Electronics for Model Railways

Part B

by Davy Dick

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In memory of Margaret

Contents

Click on the page numbers to jump to chapters

Chapter 15

An introduction to transistors, ICs and PICs

Transistors, ICs and PICs

These three semiconductors can be found in all but the simplest of household, industrial, military and medical electronic objects – and model railways.

This chapter is only an introduction to these components, as they are very wide in their scope and there is a lot of detailed information out there.   Fortunately, we can do a lot with them without having to delve too deeply into their inner workings.

This chapter only hopes to give a flavour of these semiconductors, highlighting some of their main features. All three types are fascinating, offering unlimited prospects for model railways.

Transistors

These are available in a range of shapes and sizes, using different materials and providing different functions and different power handling capabilities.

They are generally used in two ways:

- As an amplifier, to boost small audio or radio-frequency signals.
- As an electronic switch, to control LEDs, relays, etc.
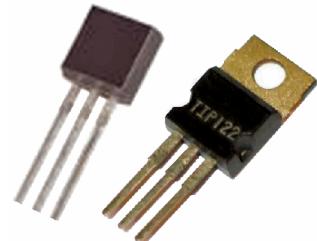
As the images show, they have three wire leads.   In most transistors, these are called the emitter, base and collector.

Although other types are used, we will examine the most common types of transistor – those known as PNP and NPN types.

The difference lies in their physical construction.
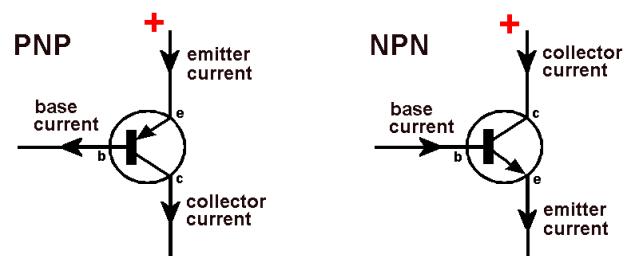
A PNP type has a layer of n-type semiconductor that is sandwiched between two layers of p-type semiconductor.

The NPN type is more common nowadays and it has a layer of p-type semiconductor that is sandwiched between two layers of n-type semiconductor.

The illustration shows the symbols for the two types. It also shows how current flows through them.

With a PNP type, the collector is taken to 0V while the emitter is taken to the positive supply.   This is the reverse for NPN types; the emitter is taken to 0V.

In both cases, the base connection can be thought of as a tap that regulates the amount of current flowing between the other two connections (another type of transistor, the FET, even calls the connections the 'source', the 'gate' and the 'drain').

The PNP transistor

> Applying a voltage across the emitter and collector produces a current flow between them.   If you now gradually increase the voltage between the base and emitter, the current flow will be reduced until it completely stops (known as *'cutoff'*).
> Conversely, decreasing the voltage across the base/emitter junction, increases the flow of current between the emitter and collector.

The NPN transistor

Applying a voltage between the emitter and collector produces no current flow. If you now gradually increase the voltage between the base and emitter, the current flow will be increased until it reaches the maximum that is possible with that transistor (see below).

Conversely, decreasing the voltage across the base/emitter junction, decreases the flow of current between the emitter and collector until it eventually stops.

Gain and saturation

There is a direct relationship between the input current and the output current of a transistor and this is called its *'gain'*.

For example, a BC547 transistor (an NPN type) has a maximum current gain of 800. So, a current of 1uA (one microamp) flowing from base to collector should result in a current flow of 800uA from collector to emitter. Similarly, a 2uA base/emitter current should result in a 1.6mA collector/emitter current and a 10uA base/emitter current should result in an 8mA collector/emitter current.

This current amplification cannot carry on indefinitely, as the BC547 can only handle a maximum current of 100mA from collector to emitter.

Once the transistor reaches the 100mA flow, any further increase in base/emitter current has no further effect on the output current. This stage is known as *'saturation'*.

The larger power transistor shown in the above picture is a TIP122 and is an NPN type with a gain of 1000 and a maximum current of 5A. So, a 1mA base/emitter current should result in a maximum of 1A collector/emitter current. As with other power transistors, its collector is bonded to a metal plate to allow a heat sink to be fitted to transfer away heat when high currents are being drawn.

Note

The arrows in the above illustration show the flow of 'conventional current' (see chapter 1) which thought that current flowed from a positive potential to a negative potential. In fact, actual current comprises a flow of electrons which is attracted to a positive potential (the opposite of the directions shown in the arrows). As long as you are aware of the distinction, you will not be puzzled when different diagrams and explanations describe current flow differently.

Further reading

That was only a brief outline of the transistor's main characteristics. If you want to know more about transistors, here are a few places to look:

www.electronics-tutorials.com/basics/transistors.htm

www.kpsec.freeuk.com/components/tran.htm

http://vsagar.com/2011/12/how-npn-transistor-works-understanding-forward-reverse-biasing-of-an-npn-transistor/

www.rason.org/Projects/transwit/transwit.htm

www.electronics-tutorials.ws/transistor/tran_4.html

Also, see Electric Circuit Basics 6 by John Matthews, in the Jan 2006 MERG Journal.
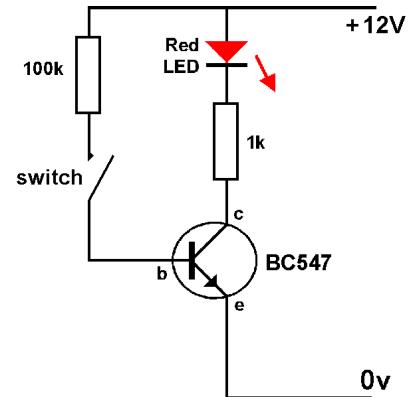
Practical examples

Here are some example circuits which might further explain how transistors work.

Single LED

This circuit uses an NPN transistor, with its emitter taken to 0V and in this configuration acts as an electronic switch. The 1k resistor limits the current through the LED (and also through the collector-emitter junction). As shown, no emitter/collector current will flow and the LED will be unlit. If we now throw the switch, conventional current flows from +12V through the 100k resistor and through the base-emitter junction. The 100k resistor is used to limit the maximum base-emitter current.
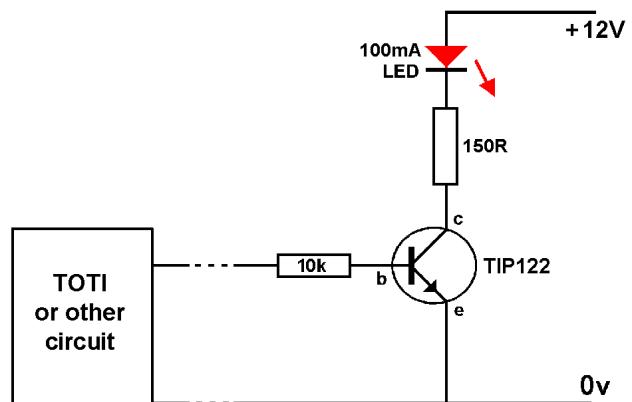
The smaller current through the base-emitter junction results in a much greater current through the collector-emitter junction and the LED will light.

This circuit is used to illuminate a much brighter 100mA LED and uses a TIP122 power NPN transistor. The 150 ohm resistor limits the maximum collector current.

The output from a TOTI (Train On Track Indicator) or other electronic module is unlikely to be able to provide the larger current requirements of this high-current LED.
This is solved by using a power transistor switch like the one shown.
In this case, the output of the other device is used to produce the TIP122's base-emitter current. Once again, the smaller base-emitter current results in a much greater collector-emitter current.

Logic probe
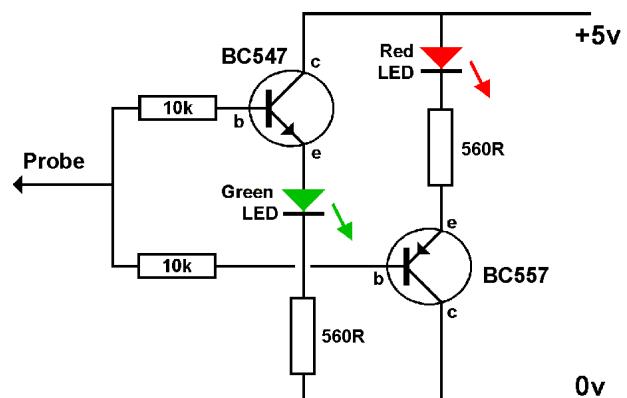
Many modellers own multimeters, which are extremely useful tools for testing and fault-finding on layouts and on electronic modules. The ability to read different voltage levels helps trace bad joints, etc.

But, when dealing with modules that work on <u>digital</u> inputs and outputs, you only want to know whether a particular point in your circuit is at +5v or at 0v.

That is where a logic tester is handy.
This circuit works by connecting it to the +5v and 0v of the module you are checking. Then you touch any point in the circuit with the probe. If +5v is on that point, a green LED lights up. If there is 0v at that point, the red LED lights up. All other voltages, or points not connected to anything, either keep the LEDs unlit or dimly lit.
The BC547 is an NPN type and current flows from its collector to emitter when its base is at
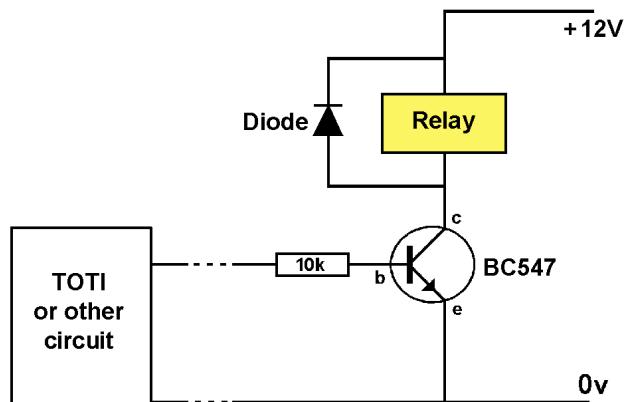
a higher voltage than its emitter.   The BC557 is a PNP and allows current to flow from its emitter to collector when its base is at a lower voltage than its emitter. That's why the red LED lights on 0V while the green LED lights on 5V.

Relay

Some relays operate with a relatively small current. Others require a transistor to act as a current amplifier to switch the relay.   You have to check the manufacturer's specifications.

In this circuit, the relay resistance is 250 ohms, therefore requiring 48mA to operate it.   The BC547 provides the required current amplification.

As mentioned in a previous chapter, the diode prevents an back EMF from damaging the transistor when the relay is switched off.

Integrated Circuits

These are often simply referred to as *'ICs'*.

As the description implies, it is a single electronic component that carries out a task that would normally require multiple individual components.   The semiconductor layers inside the chip are created in such a way that they carry out the functions of multiple transistors, diodes, capacitors, resistors, etc. - all integrated within a single small casing.

With the advent of ICs, large boards jam packed with components were replaced by much smaller, more efficient, lower current, cheaper devices.   Just how far this process has gone can be demonstrated by the 'brains' of a humble Xbox 1 computer which uses 5 billion transistors – all built in to a device the size of an After Eight mint!

A simple IC may have only 6 pins to connect to the outside world, while complex ICs may have 80 external pins.

There is a huge range of ICs and each one is designed to carry out a particular function or set of functions.   Their internal workings are pre-set at manufacture to carry out specific tasks and these cannot be altered, although their performance can often be tweaked using external components.

Examples include:
- Voltage regulators – to ensure a constant fixed supply voltage output, regardless of most input voltage fluctuations and changing current demands.
- Timers – to create timed pulses for scale time clocks, control brightness of LEDs, control servo movements, control loco motors using PWM (pulse width modulation).
- Amplifiers – to boost the level of audio or radio signals, or act as current amplifiers for switching or control purposes.
- Convertors - to convert digital values to analogue values (and vice-versa), to convert voltage levels into frequencies.

- Logic – to implement simple switching decisions (e.g. the output only changes to low when all its inputs are set to low) or more complex logic operations (e.g. using only 4 input lines to change the output level of any one of 16 output lines).
- Display drivers – to control bargraph displays, 7-segment LEDs and LCD displays.
- Remote control encoders/decoders – to control toys, televisions, garage openers, etc.
- Memory chips – to store data for later use (e.g. in digital cameras, audio players, etc.) or to store applications while being run in computers.
- Motor drivers – to handle DC motors, stepper motors and servo motors.

All of these IC chips are connected to devices or components in the outside world. Sometimes the components are connected in order to adjust performance (within the range allowed by the IC).   For example, the settings of a timing chip are set by the choice of external timing components.
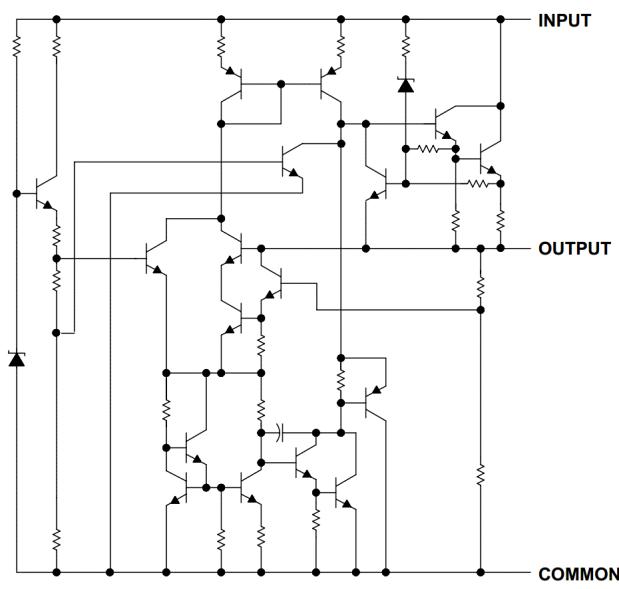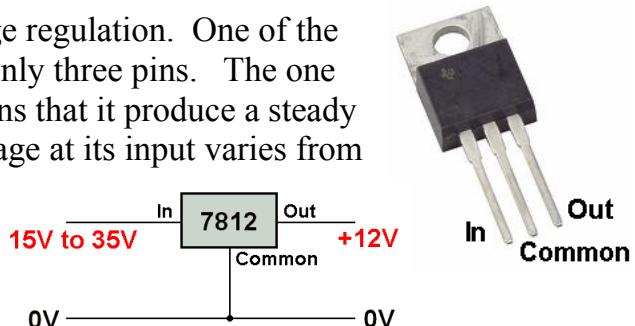
In other instances, the IC acts on external stimuli (e.g. a remote control encoder) or controls other circuits (e.g. a voltage regulator).

Practical examples

Here are some typical examples of integrated circuits.

Voltage regulators

Chapter 1 looked at power supplies and voltage regulation. One of the simplest ICs is the voltage regulator.   It has only three pins.   The one shown in the illustration is a 7812, which means that it produce a steady 12V output, at up to 1.5A, even when the voltage at its input varies from 15V DC up to 35V DC. The 7812 has an internal voltage loss of 2.5V, so needs a minimum of 14.5V DC input to ensure a smooth regulated output.

Its case, and common pin, are bonded to a metal plate to which can be bolted a heat sink. This is necessary when dropping large voltages at high currents, to prevent the IC overheating.

When used in a circuit for this purpose, it would also normally have smoothing capacitors fitted.

The circuit is reproduced to demonstrate that even a simple IC can be complex inside. The 7812 has over 40 internal 'components', including 17 transistors.

Flashing LED

This is a very well-known, well-used circuit and many variations can be found on the Internet.
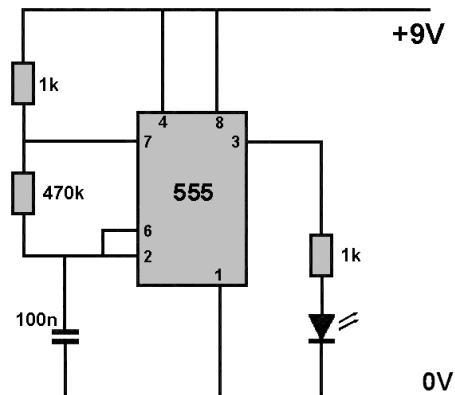
It uses a 555 timer IC. This chip can be used as a timer, an oscillator or a pulse generator (as in this circuit).

Here, the output is a continuous stream of pulses that make the LED flash.

The frequency at which the LED flashes is controlled by the charging and discharging of the capacitor

The rate of charge/discharge is determined by the values of the two resistors and the capacitor

Pin 3 goes high while the capacitor is being charged and goes low when the capacitor is being discharged.

The 555 timer chip is also used to control the delays in a shuttle – a loco that runs back and forth along a section of track.

Apart from altering the frequency of the pules, the mark/space ratio (the time the pulse stays compared to its off time) can be altered and this is used to good effect to control servo motors, dim LEDs, etc.

For more details on 555 timers, read John Matthew's article in the Winter 2006/7 Journal, or look at

http://talkingelectronics.com/projects/50%20-%20555%20Circuits/50%20-%20555%20Circuits.html
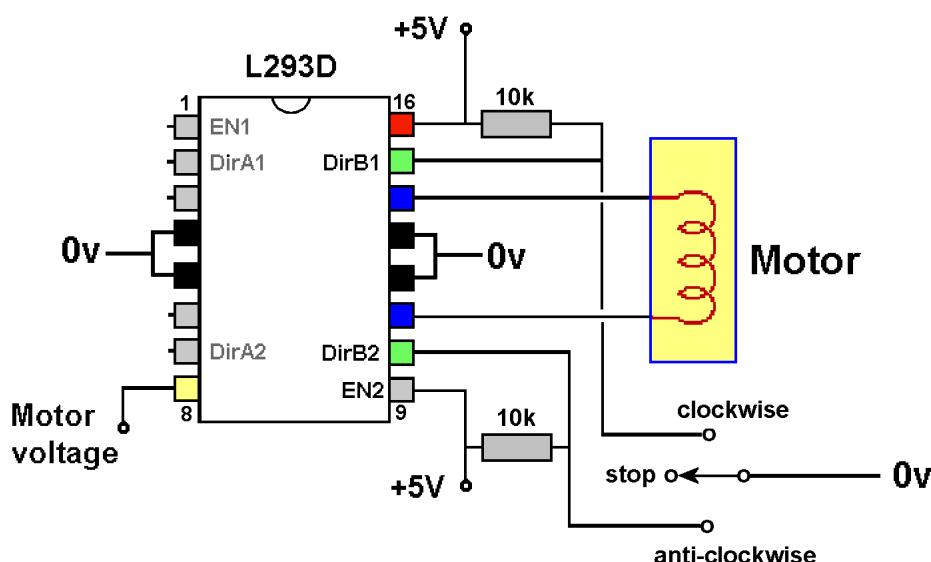
Motor control

This diagram shows an L293D, an integrated circuit described as *'Quadruple Half-H Drivers'*. They are designed to be used in pairs, where they offer bidirectional control (i.e. the outputs can be reversed – handy for DC motors)..

Pins 1,2 3, 6 and 7 on the left side comprise one set of drivers and pins 9, 10, 11, 14 and 15 make up an identical set of drivers. It is designed to control high current devices including inductive loads such as motors, stepper motors and relays.

In this circuit, it only requires few resistors to make it into an IC capable of independently controlling two motors.

Pin 16, marked in red, is taken to a +5V supply and the pins marked in black are taken to 0V.   These supply the power for the IC. The illustrations shows a single motor being controlled.

Pin 9, marked as EN2, is the 'Enable' pin for the right-hand side of the chip.   It is taken to +5V to make these drivers active (taking the pin to 0V disables these drivers).

Pins 11 and 14, marked in blue, are taken to the DC motor.   These outputs are capable of handling motor currents up to 500mA (1.2A peak), so cover most locos.

Pins 10 and 15, marked in green, control the direction of the motor. This table shows the motor logic.

Pins 15 and 10, labelled as DirB1 and DirB2, are held high to +5V by the two resistors.   The motor will not move.   Bringing either of these pins low to 0V will make the motor rotate. The three-position centre-off

DirB1	DirB2	Motor
Low	High	Clockwise
High	Low	Counter clockwise
Low	Low	Stop
High	High	Stop

switch controls the motor direction, with the centre position bringing the motor to a halt.

The power for the motor is provided at Pin 8 and can be from +4.5V to +36V – probably +12V for model railways.   Note that the power for the motor is independent of the supply to the IC, making it able to cover a wide range of motors with differing voltage requirements. If required, the input to Pin 8 can even be a PWM (Pulse Width Modulation) source. See the chapter on Loco Controllers for a description of PWM.

The pins on the left hand side of the chip perform in exactly the same way if a second motor is to be controlled.
While the above circuit uses a switch to control the motor, it can easily be controlled by logic from other circuits (train detectors, PICs, computers, CBUS modules, etc.).
contains two identical sets of driver circuits.

PICs

While very useful, integrated circuits are dedicated to a single function, or set of functions. This has led to the development of a range of *'microcontrollers'* which, like ICs, combine a lot of components into the chip, but allow the user to <u>program</u> its activities.   This opens up a whole new approach, since the same PIC chip (**P**eripheral **I**nterface **C**ontroller) can be employed to carry out many different actions depending on what program it contains.
The biggest seller of microcontrollers (with sales in billions of units) is Microchip Technology Inc, who manufacture a large range under the heading of PICs.
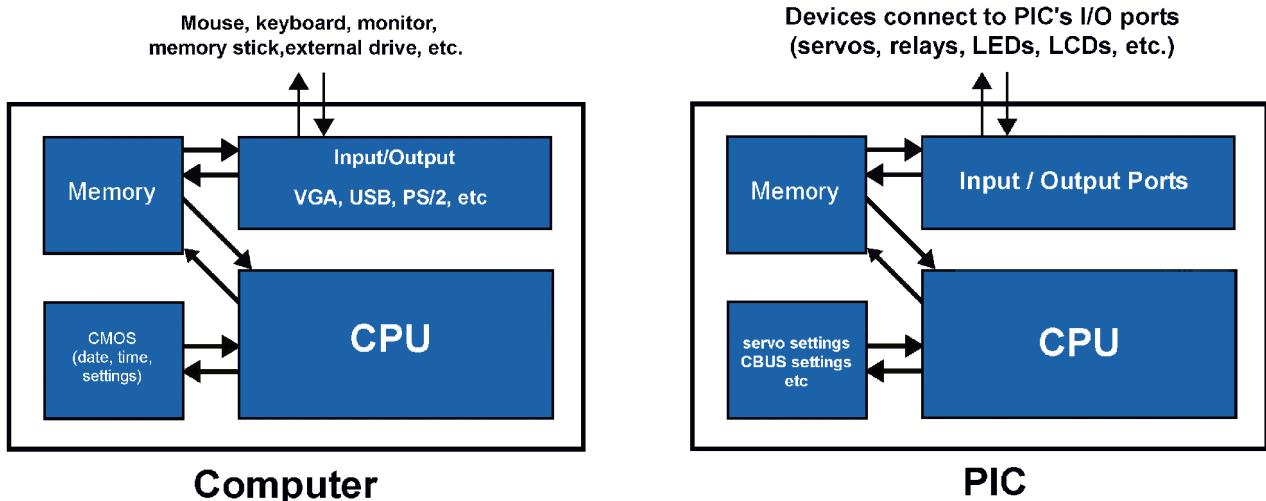
How they work

PIC microcontrollers can be regarded as similar to a computer, as shown below.

They both have a CPU, the main brains of the system; they both have a memory area to store the program being used; they both a smaller memory area to store data when the power is removed; and they both have connections to the outside world.
Naturally, the computer system is much more sophisticated. Then again, all the parts that you see on the PIC diagram are embedded inside the chip.
This arrangement makes PICs extremely flexible.
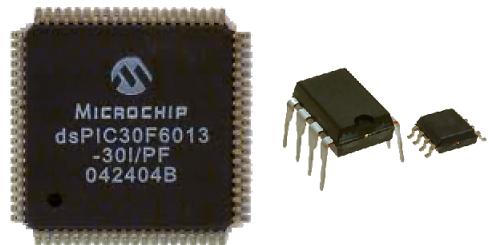
Computer   **PIC**

There are other manufacturers who make microcontrollers, including Arduino, PicAXE, AVR and Propellor.   These, and the range of PICs, share the same advantages:

- Low cost.
- Easily programmed and reprogrammed.
- Many can be programmed in situ (i.e. the chip remains in the module it is designed for).
- Large body of support through documentation, source code, user groups, etc.

PICs look very similar to ICs. Many have the same shapes, same number of pins, etc. However, they are easily distinguished by the markings on their bodies. For example, an L293D is an IC while a 12F675 is a PIC.

PICs are available in sizes from 6 pins to 144 pins, in either QFN (Quad Flat No Leads), DIL or surface mount pin formats.

Despite their size and pin differences, they have common features such as inbuilt oscillators and I/O (input output) pins to interface to external devices.

Beyond that, different PICs offer additional facilities such as:

ADC   Analogue to Digital Conversion.
               The ability to read analogue values into a pin.
               Useful for reading the voltage levels from potentiometers, heat sensors, light sensors, etc.   A circuit inside the PIC converts these analogue values into digital equivalents that the PIC can process.

DAC   Digital to Analogue Conversion.
               The ability to turn stored digital values into analogue equivalents that are sent out of a PIC's pin
               Useful for creating sound effects, playing sound samples (e.g. WAV files), etc.

PWM   Pulse Width Modulation.
               The ability to generate pwm outputs on one or more of a PIC's output pins.
               Useful for controlling motors, dimming LEDs, etc.

Timers   The ability to generate signals in regular time intervals.
               Useful for data communications, counters, etc.

Some also provide a range of interfaces with commonly used communications systems, such as CAN, USB, UART, Ethernet, etc.

Programming a PIC

This is a whole new subject and whilst the actual steps will depend on the programmer and hardware being used, a typical process is:

- Write a program on a computer, using commercial software or free software such as JAL (**J**ust **A**nother **L**anguage).
- Turn the program into the form that the PIC will understand (usually called a compiled *'hex'* file).
- Connect the computer to a 'PIC programmer'
- Connect the PIC programmer to the circuit board being used.
- Insert the PIC into the circuit board.
- Copy the hex file into the PIC.

Practical examples

Here are some typical examples of PIC microcontrollers for use with model railways.

Dual purpose flasher

Apart from the LED and its resistor, the PIC only uses two other components.

All the decision making, timing and output switching is done inside the PIC as it carries out its stored program.
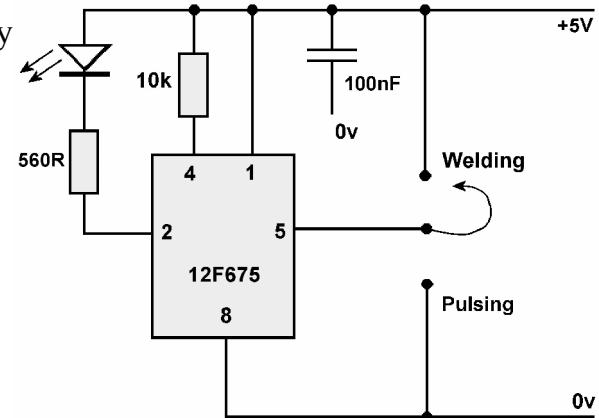
In fact, there are two separate programs stored inside the PIC and the choice of which program to run is determined by how pin 5 is wired.

Pin 5 can be wired either to +5V or 0V in this example.

When it is connected to +5V, the PIC detects that Pin 5 is at a high level and runs a welder emulation program. This produces periods of LED flashing followed by pauses. When pin 2 connects to a white or blue (or maybe both) it simulates the arcing of a welding machine.

When pin 5 is connected to 0V, the PIC runs a program that emulates the pulsating lights that you see on top of tall buildings and structures to act as aircraft warning lights. Unlike the rapid on/off output provided with the welding program, the output slowly illuminates and dims a red LED.
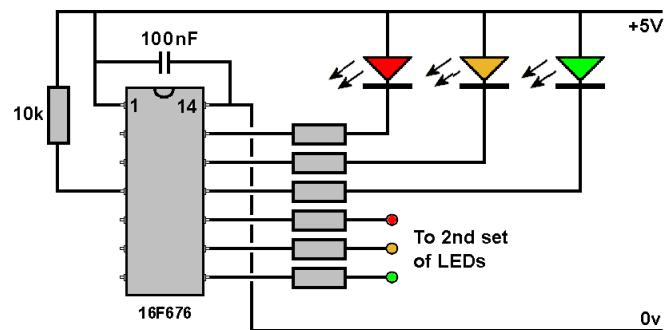
Traffic Lights

This circuit uses a larger PIC, as it needs more output pins than are available on an 8-pin PIC. Again, it uses only two components, with all the timing, sequencing and LED switching being carried out by the single program stored inside the PIC.

It uses six pins as outputs, to provide a four-way traffic lights system.

These are covered in greater detail in the chapter on *'Pocket Money Projects'*.
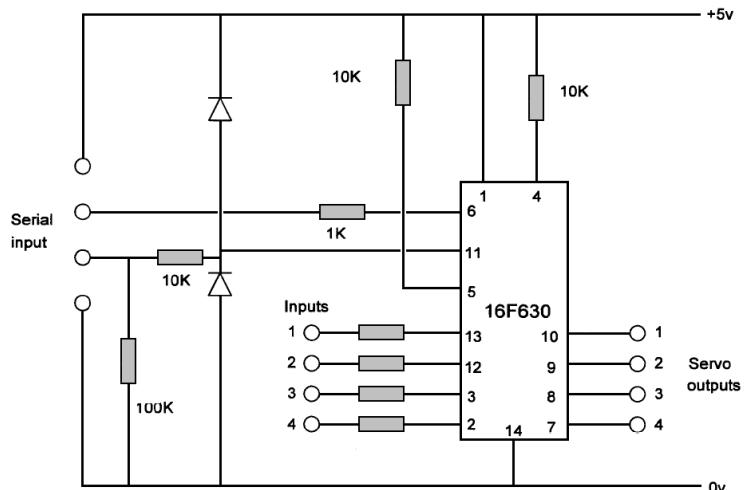
Controlling 4 Servos

Here is a simplified version of the MERG Servo4 board that is used to control four servos (used for operating points and various animations).

Its main features are:

- It has four inputs that are normally held high but can be brought down to 0V using switches, the output from a track occupancy detector, a CANBUS module, or any other 5V digital output.
- Each input, when switched between +5V and 0V, alters the corresponding servo's rotation (input 1 controls servo 1, etc.).
- The PIC can be connected to a computer, using the serial port input connection.
- The computer's software application can set the amounts of rotation (the 'endpoints') for each servo.
- The final settings can be stored in the PIC's internal memory.

This PIC, therefore, uses digital inputs, pulse width outputs and a serial interface.

For more information on PICs, just do a Google search for 'PIC tutorials' – there are more than you can read.

For information on the JAL programming language, a good starting point is this website:

http://justanotherlanguage.org/content/tutorial_book

Chapter 16

Interfacing

Interfacing

What is interfacing

We use interfaces every day.   We communicate with each other using speech, sign language and the written word.   We communicate with each other over distances using interfaces such as the telephone, radio, texting, social networks, etc.   We use interfaces such as ATMs and credit card readers.   We interface with our computers using keyboards, touch screens, mice, monitors, etc.   The computer input/output devices can use electronic interfaces such as USB, Ethernet, wifi dongles, serial ports, HDMI, SATA ports, etc.

In the model railway world, we interface with our layouts using the switches, knobs, lights, etc. on our control panels and also using our loco controller.   The electronic interfaces may use direct wiring, DCC, Cbus, Loconet, etc.

In all the above cases, interfaces enable communication between separate, usually dissimilar, things.   For example, human to computer, computer to printer, etc.

Electronic interfacing

From our point of view, interfacing has two main purposes:
- Connecting input and output devices to an electronic module.
- Connecting two electronic modules to each other.

You may have built some kits or bought some electronic modules.   That raises questions such as:
- What things can I connect as inputs to my modules (e.g. switches, track occupancy detectors, etc.)?
- What things can I connect as outputs to my modules (e.g. relays. LEDs, etc.)?
- Can I connect two modules to each other?
- Can I connect modules to each other even if they work at different voltages?
- If these things are possible, how do I do it?

This is a very wide-ranging area, as there are so many different circuits and devices but it is still possible to look at the general approaches.

Apart from DC power to the track, most circuits interconnect using digital signals, not analogue.   A module's pin is either high or low.   Many electronic circuits use a 5v power supply (or a 12v supply reduced to 5v).
So their inputs and outputs are designed to work at 5V or 0V.
However, the auxiliary power from many controllers is either 15VAC or 12V DC.
Consequently, some modules are designed to run on 12V.
This chapter looks at connecting modules and devices of various kinds, so that they interact with each other without any problems.

Connecting inputs

In model railways, the inputs to our electronic circuits will mostly be expecting to detect changing voltage levels. Sometimes the changes will be analogue and sometimes digital. With a few exceptions (e.g. CBUS, DCC decoder) the voltage levels are compared to 0V. So a 5V reading means that it is 5 volts more positive than the 0V supply line.

The task for the various input devices is to convert their changes into voltage changes at a module's input. Sometimes this will involve converting from changes in light or magnetic fields, or current, sound, temperature or pressure changes.

Switch inputs
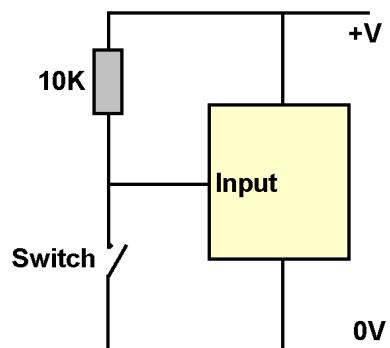
This is probably the most common interface to an electronic device.

In the example shown in the illustration, the module's input is detecting a change of voltage.

With the switch open, the input line is held by the 10K resistor to a high voltage. The resistor is known as a *'pull-up resistor'* as it pulls the input up to the supply voltage under normal conditions.

When the switch is closed, the input line is taken down to 0V. So the input switches between 0V and the supply voltage level. In many circuits, this would mean switching between 0V and +5V.

Of course, the switch could be replaced by a push-button, a microswitch or even the contacts from a relay.
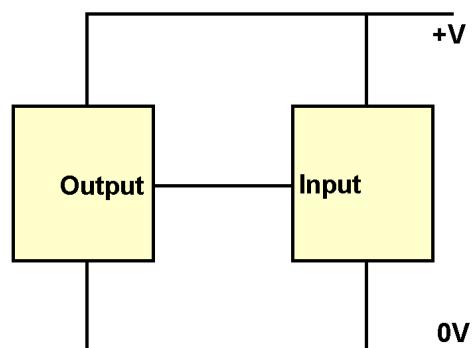
Output to Input

This illustration shows the output of one module connected directly to the input of another module. This is common in digital circuits where the first module's output switches between the supply voltage and 0V, and the input of the second module operates on the same voltage changes.

Note

Where the two modules operate on different voltages, special arrangements may be necessary to allow them to interface without problems (see later).
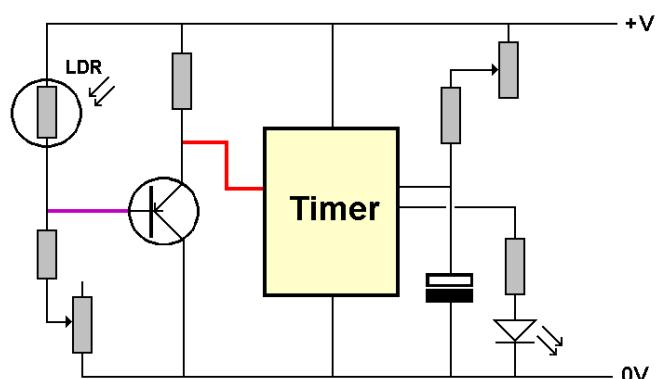
Analogue input

Some circuits require an analogue voltage as its input.

This illustration is a cut-down version of a circuit that illuminates an LED for a set period when the light at the LDR drops below a set level.

The voltage at the junction of the LDR and the resistor/variable resistor combination changes with the light level.

This analogue change of voltage is taken to the transistor – the purple line shows the transistor's analogue interface.

At a certain input voltage level, the transistor's output level will change from high to low. This change is connected to the timer's input – the red line shows the digital interface.

The variable resistor determines the voltage fed to the transistor and is used to set the level at which the module switches the LED on and off.
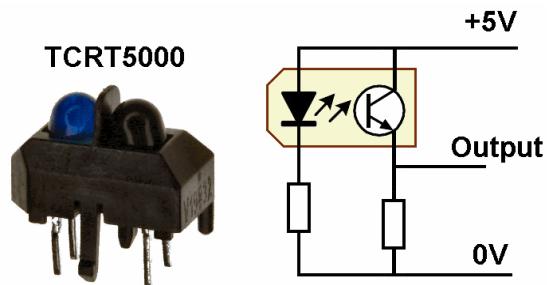
The main interface here is the one between light level and voltage.

Another light-to-voltage interface is that of the infrared detector.

The illustration shows the TCRT5000 Reflective Optical Sensor. Its use in model railways is explained in the chapter on *'Track Occupancy Detectors'*.

The output voltage is a function of the distance between itself and the object reflecting the infrared light.

The values of the two resistors are not critical , with different users having values between 100R and 1k and between 4k7 and 20K.

Magnetic inputs

In this case we are using magnetic fields to change voltage levels.

The simplest example is the reed switch which is just a switch that operates when a magnet is placed close to it (see the chapter on *'Track Occupancy Detectors'*).

It can be used in place of the switch or push button shown earlier.
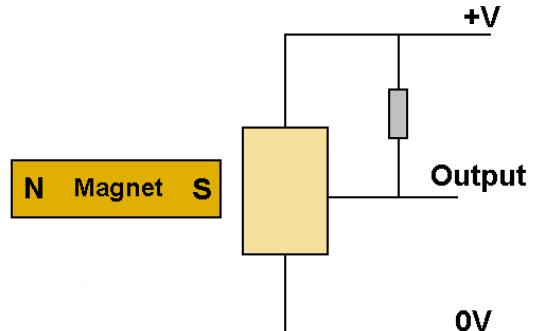
It is essentially an interface between magnetic fields and a digital voltage output (the reed switch is either made or released).

An electronic version (i.e. no physical movement) of this is the Hall Effect switch.   It produces a change of voltage at its output when a magnet is placed close to it.

Since the Hall Effect switch's output is quite small, many Hall Effect sensors also contain a built-in high gain amplifier.

They are available as either linear output (the output voltage is directly proportional to the magnetic field) or digital (the output is either high or low).

Some have *'open collector'* outputs which mean that the output has to be provided with an external load across which the voltage will develop.

Other inputs

Some devices can be directly connected to a module's input.   These include pressure pads (which act like switches) and temperature sensors.

Other devices require additional electronics to make them work.   These include current detectors, sound detectors and RFID sensors.   All the components are mounted on its own board and can be treated as an output device (see the earlier Output to Input diagram).

Connecting output devices

Your electronic modules have outputs that are designed to control and operate devices on your layout. These include control panel lights, motors, points, signals, gates, uncouplers, sound, smoke, etc.

Since these devices may operate differently and have different voltage or current demands, the module has to be able to cope with those requirements.
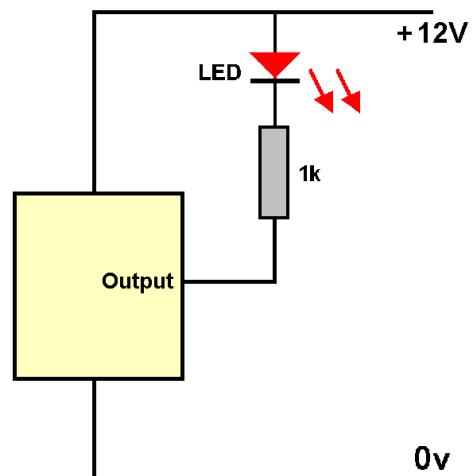
LEDs

In most cases, the current capacity of an electronic module's output is capable of switching an LED on and off - except for high-power LEDs which are looked at next.
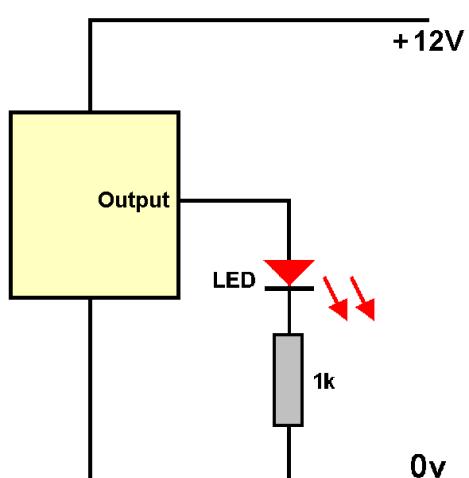
This illustration shows a LED being connected to a module using a resistor to limit the current through the LED.   The actual value of the resistor used depends on the voltage and current requirements of LED.

When the module's output goes low, there is a voltage difference between the its output and the power supply. This illuminates the LED.

When the module's output is set to high, there is a high voltage on both ends of the LED and it will not illuminate.

This circuit is an example of *'sinking output'*.   The load (LED and resistor) are provided with a high voltage from the positive supply, while the output provides a path for the current to flow to 0V. In effect, the module's output pin has *'sunk'* to the level of 0V.

This illustration shows the LED being wired to 0V. In this case, the LED will illuminate when the module's output pin goes high.

When the output is low, there is no voltage difference across the LED and it will not illuminate.

This circuit is an example of a *'sourcing output'*. One end of the LED is connected to the 0V of the supply. When activated, the module's output pin rises to the level of the +V supply.

The output pin is now the *'source'* of the current flow through the LED.

In most cases, a module will be able to work in either mode, so both of the above connections are valid.

Some components, are capable of sinking higher currents than they can source but you are unlikely to come across them.

This illustration shows a module's output being connected to two LEDs that are connected in series across the power supply, along with their dropper resistors.   The junction between them is connected to the module's output.

When the output goes low, there is a voltage difference between the output pin and the +ve supply.

The module sinks current through the green LED from the supply. The green LED illuminates.

Since both ends of the red LED are at 0V, it stays unlit.
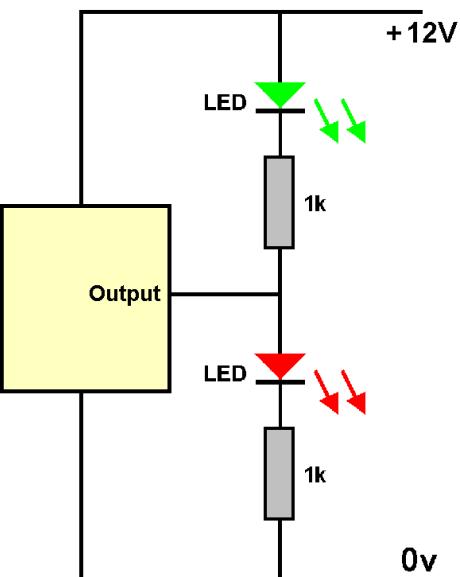
When the output goes high, there is a voltage difference between the output pin and the 0V of the supply.

The module sources current through the red LED from the supply. The red LED illuminates.

Since both ends of the green LED are at the same voltage level, it stays unlit.

This circuit is useful in a number of applications:

- Switching control panel LEDs from green to red when an error occurs.
- Indicating which way a point is set
- Changing lights for oncoming trains when it enters a section of track that is fitted with an occupancy detector.
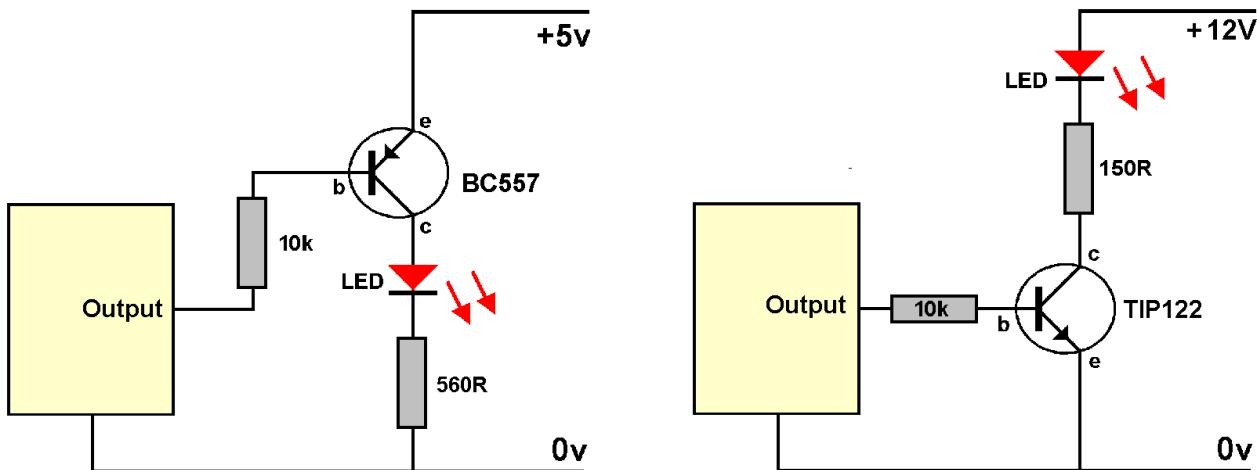
High power LEDs

As the chapter on 'Scenic Lighting' explained, LEDs specifications detail the *maximum* current that the LEDs can operate on. In practice, most can still illuminate at well below the maximum rating.

This means that normal LEDs can be connected most modules that have a digital (i.e. high or low) output.

There are occasions when you might want a module to switch a high brightness LED.

As they need a higher current than most modules can supply, you need to use a transistor as a *'driver'* to interface a low current output module to a high current component.
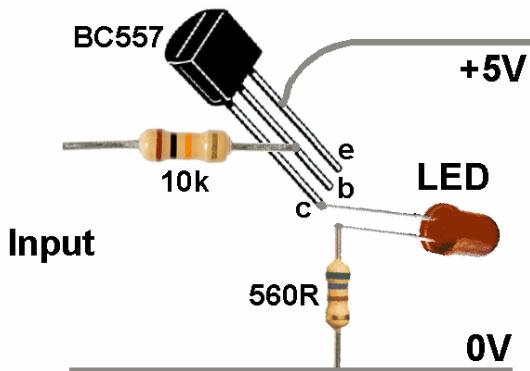
These illustrations show two such circuits.

The one on the left uses a transistor as a switch for currents up to 100mA, the maximum that the transistor can handle.

The BC557 transistor is of a type known as a *'PNP transistor'*. This means that when its base ('b' in the diagram) is brought down to 0V, it switches on. This allows current to flow through its emitter/collector pins and illuminate the LED.
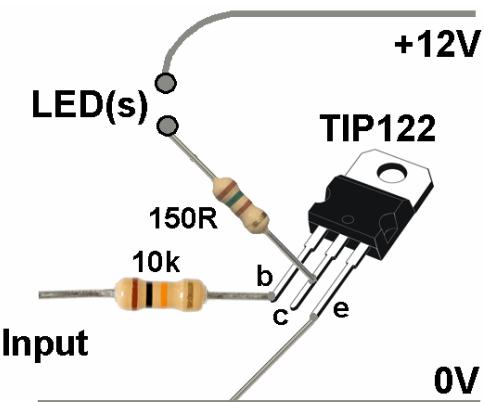
When the module's output goes high, the transistor is switched off and no current flows through the transistor. The LED is unlit.

If you intend to illuminate a very high power LED or a LED strip that contains multiple LEDs, you need to use a transistor that can handle these larger currents.

The TIP122 is a *'NPN power transistor'* which can handle up to 5A. It works in the opposite way to the BC557 circuit above. When its base ('b' in the diagram) is brought high, it switches on. This allows current to flow through its emitter/collector pins and illuminate the LED or LED strip.

The illustration shows a single high-power LED in the circuit but that could be replaced by a LED strip with the dropper resistor removed (the LED strip has its own inbuilt resistors).
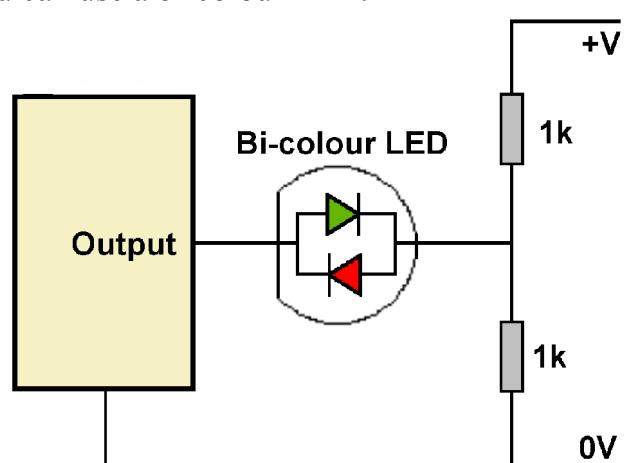
For more details on how transistors work as switches, look at:

www.rason.org/Projects/transwit/transwit.htm
www.electronics-tutorials.ws/transistor/tran_4.html

Bi-colour LEDs

An illustration on a previous page showed how to control two LEDs from a single input line. If you want to have a single LED on your control panel or on your layout and still control two colours from a single inout line, you can use a bi-colour LED.

As explained in the chapter on *'Scenic Lighting'*, a bi-colour LED is just two differently coloured LEDs built into the one casing, wired in reverse of each other. It has only two connecting leads. If you connect the power one way, the upper LED lights. If you reverse the power, the lower LED lights.

This circuit is an illustration of both sinking and sourcing currents.

If the module's output goes high, the green LED will illuminate, with the module sourcing current to the LED via the lower resistor. The red LED will remain unlit as it has a high voltage at both of its ends.

If the module's output goes low, the red LED will illuminate, with the module sinking current to the LED via the upper resistor. The green LED will remain unlit as it has a low voltage at both of its ends.
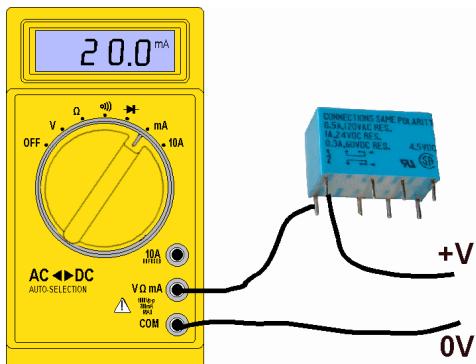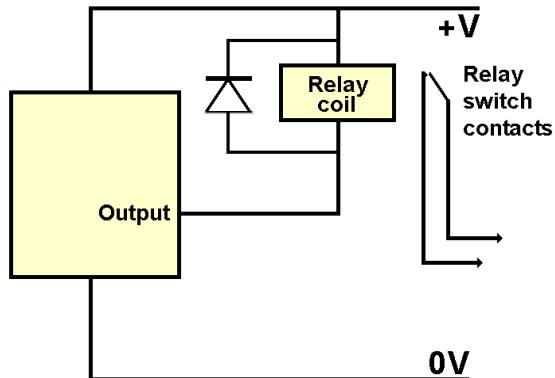
Relays

Although electronics is continually developing, many enthusiasts still feel more comfortable using relays for switching purposes.

Many relays operate on quite small currents and so can be connected directly to the digital output of most modules.

The illustration shows a single switch contact, although they are available with multiple switches and as changeover contacts.

As mentioned previously, the diode prevents any back EMF from damaging the transistor when the relay is switched off.

If there is any doubt about the above circuit, you can check what the module's current handling capacity is and compare it with that need to operate your relay. If you are lucky, you will have the relay's specification which will include its coil resistance, allowing you to calculate the expected current for the supply voltage you are using.

If you do not have this information, it is quite easy to measure the relay's current using your multimeter set on its current range. The relay inscription will usually tell you what voltage it is designed to operate on (e.g. a 5V relay or a 12V relay).
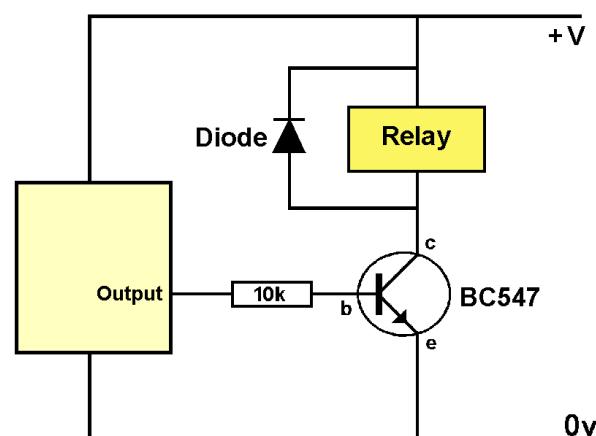
So for example, if the relay is a 12V type you would connect a 12 supply and read the current value from the multimeter.

If the value read is capable of being driven directly from the module's output, you would use the circuit at the top of this page.

If you are in any doubt, or you think you are operating too close to the module's maximum rating, you would use a transistor switch to operate the point.

Since the transistor and resistor are pretty cheap, you may want to use this circuit anyway.

This would ensure that the addition of any further circuits to the module's output would not exceed its current rating.

You can also buy *'solid state'* relays which work like normal relays but have no moving parts. They can handle large currents and are available for switching AC and DC.
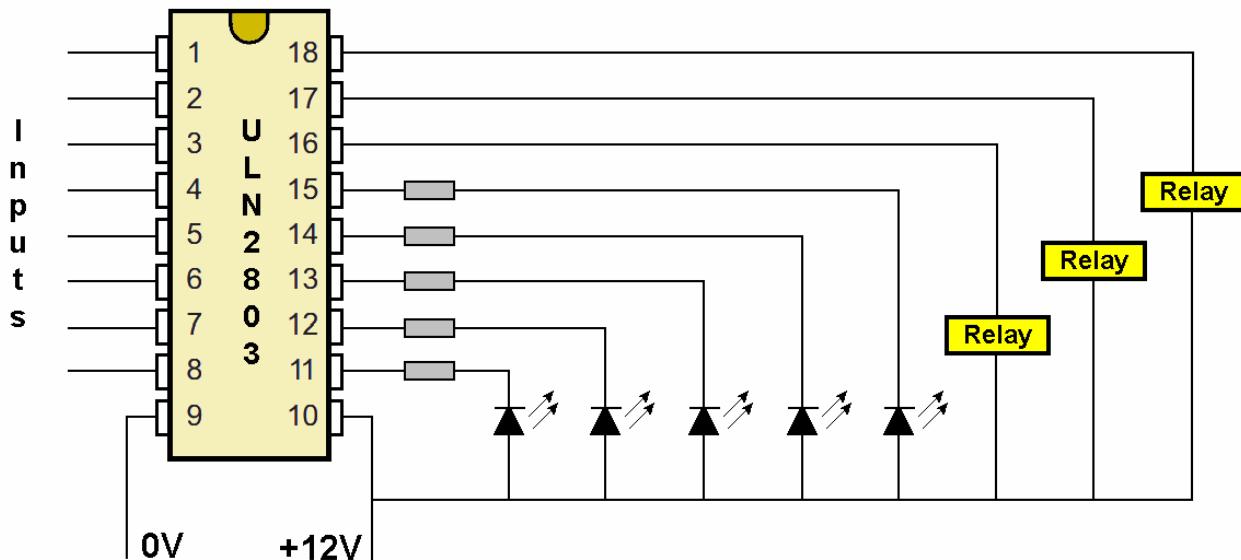
The AC types can be used for switching main appliances on and off, which is not a normal requirement in model railways. The DC types can be used for block switching, etc.

Driving multiple devices

If you only have a single high-power LED or relay to control, a transistor or power transistor is all you need.

If you have multiple LEDs, relays, etc. to control you can use a single component that has eight entirely separately operated *'drivers'* inside it.

This illustration shows five LEDs and three relays being controlled through this single device. The ULN2803 is called a *'high-voltage, high-current Darlington transistor array'*.

It has two rows of pins and pins 9 and 10 are connected to the power supply.

The other pins are arranged in pairs with the input pin facing across from the output pin.

So, pin1 is the input pin that controls output pin 18, pin 2 controls output pin 17 and so on.

The drivers have *'open collector'* outputs. which means that they require a load to be connected to their outputs to see the expected voltage changes.

The outputs are *'inverted'*, which means that each output pin is always at the opposite polarity to its corresponding input pin.

When pin1 goes high, it makes pin 18 go low.

When pin 1 goes low, it makes pin 18 go high.

The same applies to all of the drivers. So when pin 8 goes high, it makes pin 11 go low, and vice versa.

The outputs can handle up to 50V and an individual output is capable of handling up to 500mA. However, that does *not* mean that the ULN2803 can simultaneously drive all 8 outputs at 500mA, as it would overload and burn out the chip. In practice, you could drive four outputs at 300mA each, or seven outputs at just under 200mA each.

Since the inputs to the ULN2803 can handle PWM inputs, you can still drive all eight outputs at 500mA each – if you drive all inputs with a duty cycle of just under 25%.

These are only limitations if all outputs are having to simultaneously control devices with heavy current demands.

If you wanted to, you could connect inputs together, so that several outputs would operate from a single input change. For example, if you connected pins 2 and 3 together, a single input change would switch two relays on and off.

The chip has built-in back emf protection for inductive loads such as relays, so there is no

need to fit external protection diodes.

The ULN2003 device is very similar to the ULN2803. Since it only has seven sets of drivers, the chip has 16 pins compared to the 18 pins used by the ULN2803.
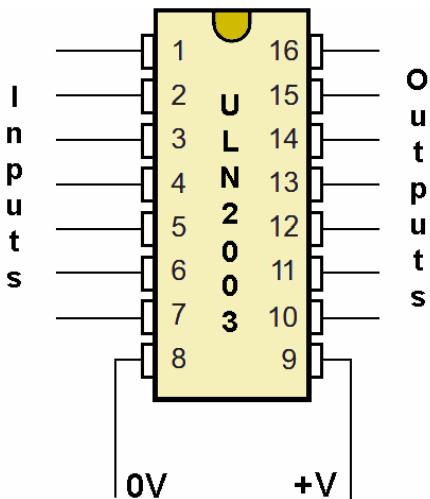
Like its larger brother, the ULN2003 has its inputs pins facing their corresponding output pins; a very hand layout when designing circuit layouts.

So, pin1 controls output pin16, etc.

Its outputs are also inverted and it has similar voltage and current handling capabilities to the ULN2803.

Although these chips have built-in back emf protection, some manufacturers recommend using additional external protection measures.

Motors

The following electronic circuits could be used for controlling your DC locos but you probably already have a loco controller.   Of course, if you are looking to automate your layout, these circuits could be very useful.

The circuits are useful for all sorts of motor-driven features that you can add to your layout. You may already have some features, such as a windmill, on your layout that would benefit from being animated.

There are different needs for motorised features.

- Some, such as a windmill, a water mill, or a screw conveyor rotate constantly in the one direction and the motor is left to run unattended. The only consideration may be reducing the voltage of the layout's power to that of the motor.
- Some, such as a Ferris wheel or a Carousel /Merry-Go-Round, also rotate in one direction but also stop from time to time.   The motor may be controlled manually or using a timer.
- Some, such as elevators/lifts, funicular railways, funfair pendulum/swinging chair rides also stop from time to time – but they also have to rotate the motor in both directions.

From some of the above examples, you will have noticed that a motor does not have to be used only to rotate things.   If the motor shaft is attached to a threaded rod, with a nut free to move up and down the rod, the nut can be attached to all sorts of features to animate them. This image shows the basic idea.
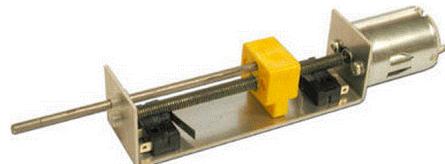
With this 14RPM motor fitted, the nut moves along at about one inch per minute. You choose the motor speed that suits your planned feature.

The rod assembly could be under the baseboard, with a pin connecting the nut to the item to be moved back and forth.   In this way, we can have barge slowly glide along a canal, as well as the elevators and funicular railways already mentioned. This technique allows to animate features horizontally, vertically or at any angle.

This image shows an implementation of this technique, complete with microswitch sensors.

Motor speeds

There are three approaches to getting the speed you want from a motor:
- Using gearing. This includes toothed gears (including built-in and external gearboxes), belts and pulleys, etc. Even with these, you may still want to tweak the final speed.
- Using a dropper. For motors with small to medium current requirements, a simple resistor can be placed in series with the motor (see below).
- Using a regulated supply. Droppers are not the most suitable for high current motors and a power supply that can be set to the required motor voltage is preferable.

Constant rotation

If you are using a 12V motor and you have a 12V supply, you simply wire the motor to the supply – the correct way round, otherwise your watermill will be pushing water upstream! Of course, you may not want to run the motor at full speed. As long as the motor is a low current type, you can add a resistor in series with the motor.

Lets consider two examples:

Case 1
You have a 12V supply and a 3V motor that you want to run at full speed.
So, you want to drop 9v across the resistor and 3V across the motor.
Calculating the resistor to drop 12V down to your 3V motor depends on knowing the current the motor takes when run under load at full speed.
Once you know the current requirements of the motor for your required speed, you can use Ohm Law to calculate a working value for the resistor.
So, for example, if you knew that your motor took 20mA at full speed, the added resistance would be R = V/I.
In our example, that would be 9/.02 = 450 ohms
470 ohms is the closest available value and could be used with no discernible effect on the motor speed.
The power dropped in the resistor can be calculated thus:
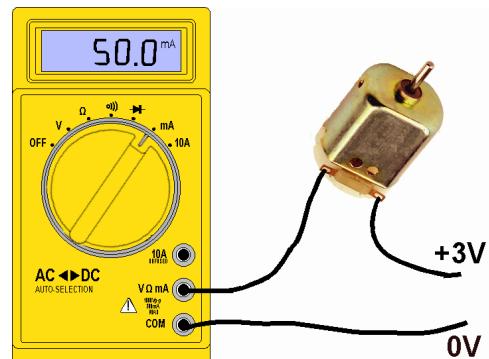
$$W = I * V$$
$$= 0.2 * 9 = 0.18W$$

So, a 470 ohms with a rating of 1/4W or preferably 1/2W could be used.

If you don't know the motor's current at 3V, place your multimeter (set to read current) in series with the motor and across a 3V supply.

Case 2
You have a 12V supply and a 12V motor that you want to run at a slower than maximum speed.
If you have a variable power supply, connect it to your motor and adjust the voltage until you get the speed you want at its working load   Read the voltage level that is used and then connect your meter in series as shown above to read the current consumed at that voltage.
You now have the voltage and current that the motor should operate at.
Subtract the motor voltage from the supply voltage to find the voltage drop required across the resistor and use Ohms Law to calculate the required resistance.

High current motors

Case 1 above looked at running a 3V motor from a 12V supply.   It took 20mA and so a relatively low wattage resistor could be used as the voltage dropper.

Consider what would happen if the the motor current was 500mA instead of 20mA. The voltage drop across the resistor would still be 9v and the power consumed by the resistor would be $W = I * V$
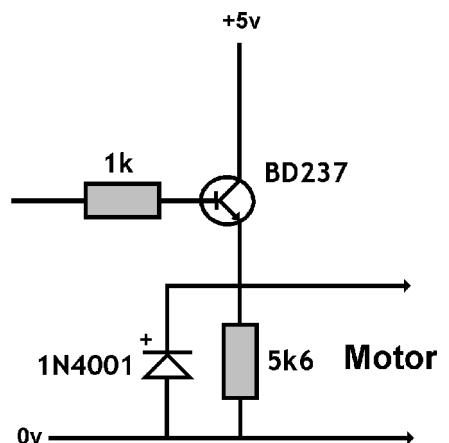
$$= 0.5 * 9 = 4.5W$$

You can buy power resistors that can handle high currents, including those that are aluminium-clad for bolting to heat sinks.

Switching the motor on an off is more of a problem, unless you are using manual switches.

You could not normally connect the motor/resistor directly to the output of a module, as they are usually not capable of switching such high currents.

You could use a relay, as described earlier – or you could use a transistor as a switch, as in this example.
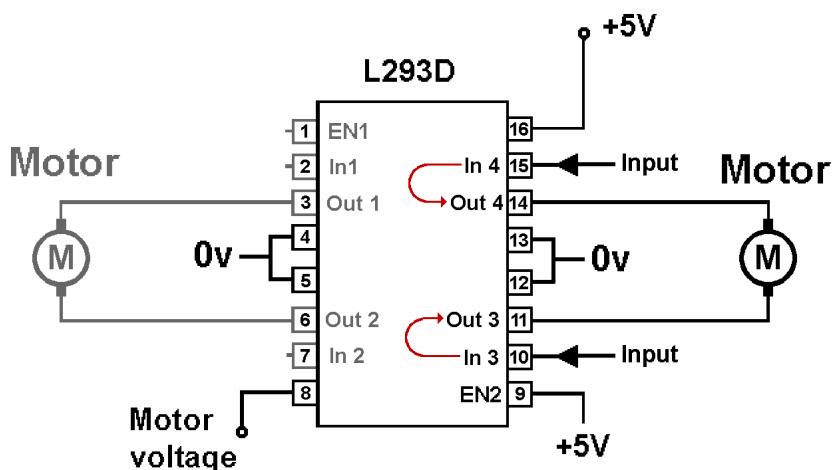
Controllable motors

To be fully controllable, a motor has to be be able to run both forward and reverse, able to be be switched on and off, and also have its speed alterable.

Electronic circuits can be designed for these tasks.   You can build a circuit using multiple transistors, etc.   However, there is no need as there are integrated circuits that combine these features in a single chip.   Indeed, some chips can handle two motors.

Two such examples are the L293D and the SN754410 *'Quad Half H-Bridge Motor Driver'* chips.

The two chips have identical pin connections and work in exactly the same way.   The only real difference is that the L293D can handle 600mA continuously, while the SN754410 can handle 1A continuously (both can handle double these currents for short periods).

The *'Quad'* in the chip title indicate that the chip contains four identical drivers, each with its own input pin and output pin. There are two such circuits on each side of the chip.

So, for example, taking pin 15 high makes output pin 14 go high, while taking pin 10 high makes output pin 11 go high.   So, the chip could be used to control four separate motors.
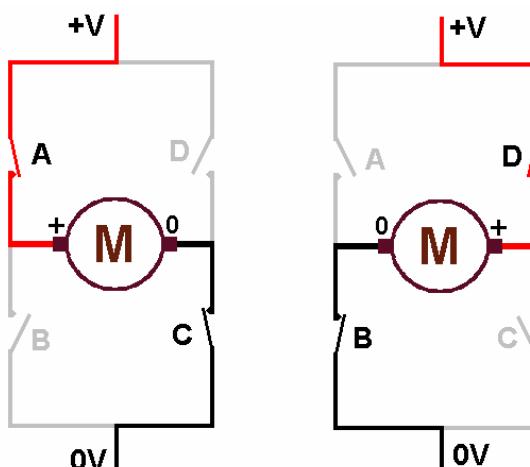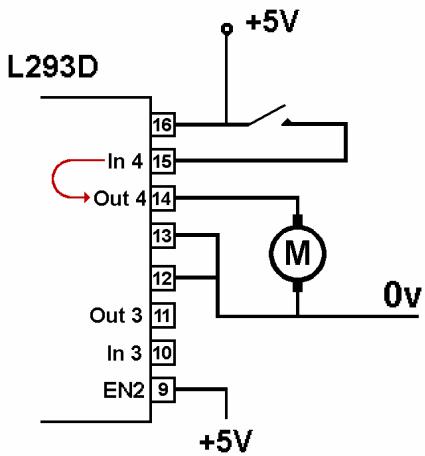
This illustration shows a single motor being operate by its own switch.   Taking pin 15 high results in the output pin 14 going high. The motor turns.

Removing the +5V from pin 15 results in pin 14 going low. The motor stops.

Although the diagram shows a switch, pin 15 could be switched by a push-button, relay contacts or from the output of another module.

Although they can be switched on and off separately, they are unable to be reversed. That is where the *'H-Bridge'* mode in the chip's title can be utilised.

This illustration shows the operation of an H-bridge circuit, using conventional switches.

When switches A and C are closed, the motor has a positive potential on its left hand connection and 0v on it other connection.   The motor will turn in one direction.

If we now open switches A and C, and close switches B and D, the voltage across the motor is reversed and the motor turns in the opposite direction.

An H-bridge can be constructed from four power transistors or even relay contacts, each carrying out the functions of the four switches in the above circuit.   Better still, the L293D (and the SN754410) can be wired to provide two separate H-bridge circuits.

If we switch pin 11 high and pin 14 low (see the L293D diagram) the motor will rotate in one direction.   Reversing the polarity of these two output pins will rotate the motor in the opposite direction.

If pins 10 and 15 are both at a supply voltage or both at zero volts, there is no potential difference across the motor and it will not rotate.

The table below summarises the options:

Pin 10	Pin 15	Result
Low	High	Rotate one direction
High	Low	Rotate other direction
High	High	Motor stopped
Low	Low	Motor stopped

If required, an input pin can be fed with a PWM signal, to achieve speed control. For example, pin 15 could be taken high, while pin 10 is fed with a PWM input.

Switching an H-bridge

As can be seen from the above table, we need two inputs to control an H-bridge circuit, allowing us to have forward, reverse and stop.

This example circuit uses a SPDT CO switch to handle the inputs. It has three positions, including a centre-off position.

When the switch is left in the middle position, neither pin has a high voltage and the motor is stopped.

Throwing the switch to the left brings pin 15 high (pin 14 goes high) and the motor rotates. Throwing the switch in the other direction, brings pin 10 high (pin 11 goes high) and the motor rotates in the opposite direction.

Although a switch is shown, it could be replaced by relay contacts, a pair of pushbuttons, or the outputs from other modules.

The other pins

- Pin 16 is connected to the +5V supply.
- Pins 4, 5, 12 and 13 are connected to the 0V of the supply.
- Pin 8 is connected to the voltage supply for the motor, which may be different from the +5V supply for the chip (e.g. it might be connected to +12V to run a 12V motor).   It supports from 4.5V to a maximum input of 36V.
- Pin 9 is the *'Enable'* pin for the right-hand drivers. This can be switched externally, where bringing it down to 0V stops the left-hand drivers from working.   If this is not needed, the pin can be permanently connected to +5V.

Notes
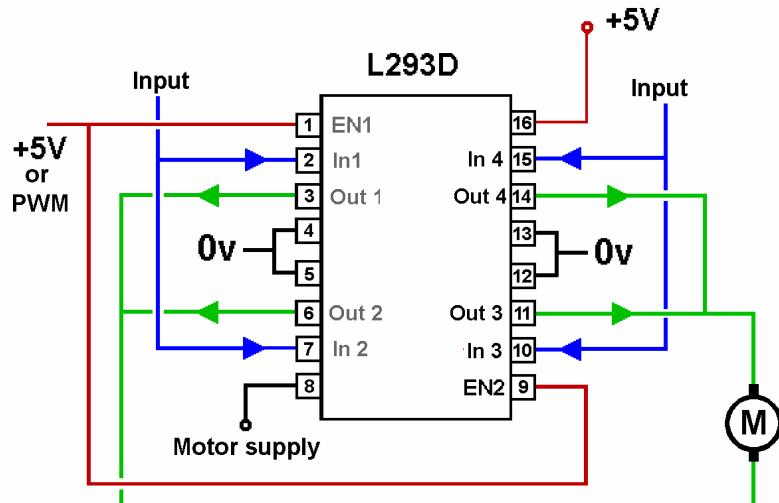
> Although the examples show the input and output pins on the right hand side of the chip, the identical sets of pins are available on the left hand side inputs and outputs. Make sure you buy the L293D and not the other variations of this chip, as the 'D' indicates that the chip contains internal clamp diodes to allow it to work with inductive loads.

If you need to switch even greater currents, you can parallel the inputs and outputs of both bridges, as shown in this illustration.   This doubles the output handling capacity of the L293D to 1.2A. The blue lines show the inputs on each side being connected together.
The green lines show the outputs of each side being connected together.
The enable pins are also connected together and taken to +5V, or to a PWM signal if required.

Sound

The chapter on *'Layout Sound'* covered how to interface various sound modules.
Which just leaves the requirement to make a general sound that can be used as feedback that an action has happened.
Examples are:
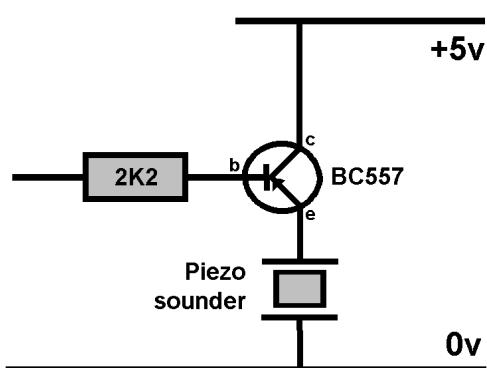
- A confirmation beep when a button is pressed.
- A warning tone for shorts, overheating, etc.
- Placing a microswitch on buffers at the end of a hidden siding.   The user slowly runs the train forward until a beep is heard, indicating that the train has reached the end of the track. The user then reverses a little to stop the tone.
- A warning when you try to run a train in to a removable section that has not be refitted properly.

You can use electromagnetic buzzers but piezo buzzers use less current and produce no unwanted electromagnetic radiation.

A piezo buzzer is a thin piece of piezoelectric ceramic bonded to a disc. When subjected to an alternating voltage, the material stretches and compresses, making the sound.

Some piezo buzzers are self driven and have their own built-in driver circuits.   A typical example will operate at 3V to 24V, with a current consumption of around 15mA at 12V.
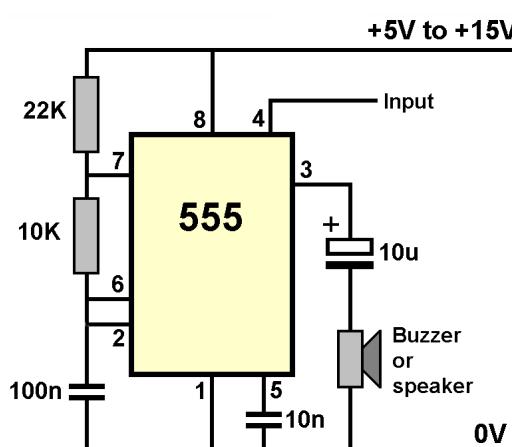
If your module's output can handle that amount of current, you can connect the buzzer directly to the output pin.
When a DC voltage is applied across it, it will emit a continuous high pitched tone.

If there is any doubt about your module's current rating, you can use a transistor as a current switch, as shown in this diagram.

The basic piezo buzzer is shown in this image.   It is not self driven and requires an external driving circuit to excite the piezoelectric material.

This circuit is a simple oscillator that can be turned on by raising its input pin 4 to the positive supply.   While pin 4 is held low, the circuit does not oscillate.
The output from pin 3 can be taken to either a piezo buzzer or to a loudspeaker.
With an 8 ohm speaker connected, the circuit draws 10mA at 5V while oscillating and 40mA at 12V.

Smoke

Smoke and steam effects can greatly add to the realism of a layout.

Smoke units are available from manufacturers such as Seuthe, Vollmer and LGB. They can be fitted into steam locos or used in the chimneys of scenic buildings such as houses, factories, pottery kilns, *'burning'* buildings, campfires, etc.

These units are available in different sizes and different voltage/current requirements but they all work on the same principle.

Their construction and use is simple.   They consist of a small metal tube that is sealed at the bottom and open at the top. There is a small heating element inside the tube, with external leads that connect to your power supply.

The tube is filled with smoke oil and heated when power is applied to the element. The oil is vaporised and rises from the tube where it condenses to produce visible smoke or steam.

Different sizes

The length and diameter of the tube determines how much oil the smoke unit can hold and a large range of sizes are available, to suit various uses.

The full Seuthe range is described here:
>   www.gaugemaster.com/seuthe.html

They recommend different units for HO, 0 and 1 gauges.

Some are designed to fit into locos that are designed to accommodate them.

Others are for you to fit in your own way.

For HO and 00 users, voltages range from 8V to 22V and current requirements ranging from 70mA to 140mA.   For O and 1 users, voltages range from 10V to 16V and current requirements of 140mA.

For buildings, voltages range from 10V to 18V and current requirements of 50mA to 60mA. The Seuthe 117, shown in this illustration, is designed to fit in the chimney of a building.

Seuthe also sell the 500 series "*Super"* Smoke Units.   These have a large reservoir tank to keep the unit topped up, allowing for much longer periods of use.

This unit is designed to fit in a boat but is suitable for large scale buildings:
>   www.harbormodels.com/site08/main_pages/smoker.htm

This website show how someone made their large scale smoke unit:
>   www.scale4x4rc.org/forums/showthread.php?t=25024

An this website shows how someone enlarge their reservoir for their loco:
>   www.newrailwaymodellers.co.uk/Forums/viewtopic.php?p=180324

Different oils

Unless you have a unit with a reservoir, you keep the oil level topped up by dripping oil into the top of the unit with a pipette. Don't refill the container while it is still hot as this will cause splatter.

The fluid used is a mixture of light oils and ammonium chloride (to quicken the vapourisation process).

Manufacturers of smoke units also sell smoke oils and Peter's Spares produce a range of perfumed oils.   Apart from producing smoke, they emit aromas such as Coal-Fired Steam, Fireplace, Diesel Power, Lumber Mill, Wood Stove, Barbecue, Coffee and Cut Grass. Check out:
>   www.peterspares.com

A Google check reveals many ways of producing your own smoke oils at much cheaper prices. Suggestions include Paraffin Oil (Mineral Oil), Witch Hazel, Lamp Oil and Propylene Glycol (as used in e-cigarettes).
This website describes using a glycerine mix with distilled water:
www.ehow.co.uk/how_7671896_make-smoke-oil-model-trains.html

As always, these alternatives should be approached with caution and at your own risk. While many enthusiasts claim great success over long periods, you should make your own tests to be satisfied that they are safe to use. For example, vapourised paraffin (as compared to burnt paraffin e.g. candle wax) can collect in your lungs and cannot be expelled.

Other issues

While smoke units can be a great asset to a layout, it is worth noting potential problems.

- When the vapour condenses, it drops back down on to the loco, or the track, or the scenery. The thin film of oil may attract dust and necessitate more frequent cleaning.
- Any oil spillages on to a loco body may eventually degrade its shell.
- The units should always be fed by a voltage within its specified range. Too high a voltage can overheat the unit and burn out its element, or melt/burn its surroundings. Too low a voltage will not sufficiently vapourise the oil and the unit will instead splatter out oil.
- It is vital that the unit never be allowed to completely run dry. This will also result in the element burning out and possible damage to its surroundings.

Fitting in Locos

Some locomotives come prepared to accommodate the installation of Seuthe steam generators, including some Marklin, Fleischmann, Roco, Lilliput, Trix and Brawa models. For these selected models, both DC and DCC, the installation is fairly simple.
For DC locos, the units leads can be wired directly across the power from the wheel pickups. So, the unit with the lowest operating voltage is best, as it will not sufficiently heat the oil until the track voltage reaches that voltage level. When the loco is stopped, there is no voltage at the element and it will cool down and not produce smoke. In other words, it cannot produce smoke while it is stationary. When the loco moves again, there will be a delay before smoke appears as the heating element takes time to come up to temperature.

DCC locos, on the other hand, have power from the track at all times, even when stationary. So, a unit in the 16V to 22V range would be most suitable. If the unit is wired directly across the wheel pickups, it will be constantly vapourising oil which is not likely to be required; it will also require much more frequent topping up.
If the unit is wired to an auxiliary pin of a DCC decoder, the smoke unit can be switched on an off as required. The unit is wired across an auxiliary pin and the blue common positive pad.

Note
It is important that you confirm the current handling of your decoder's auxiliary output can handle the current requirements of the smoke unit you purchase.

Fitting in buildings

Given the options for larger oil containers, and the simple two wire heating element, smoke units are easy to fit to layout buildings, etc.

At its simplest, you wire the heating element through a switch to your 12V supply.

You may consider wiring a timer output to the element, so that the smoke was emitted periodically.

This timer circuit provides power to the smoke unit heater element every so often, depending on the values of the resistors and large capacitor.

With the values shown, the timer's output pin goes low for around 15 seconds every 3 minutes.

This website provides a calculator, if you want different timings:

http://web.udl.es/usuaris/p7806757/555-calculadora/555%20Calculator.htm

The 555 chip handles a maximum output of 200mA.

To prevent the chip overheating, it is best to use a transistor switch. In fact, this will be essential for the units that draw more than 200mA.

The TIP126 is a PNP type power transistor.   When its base goes low, it turns on providing a supply to the smoke unit.

At exhibitions, you might consider having a detector (see chapter on detectors) that senses the presence of visitors and switches on the smoke unit.   During quiet periods, the smoke unit is switched off.
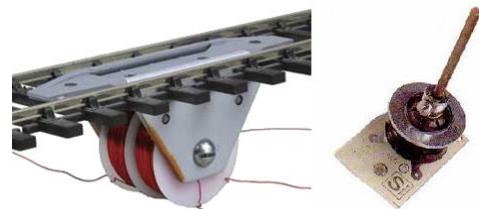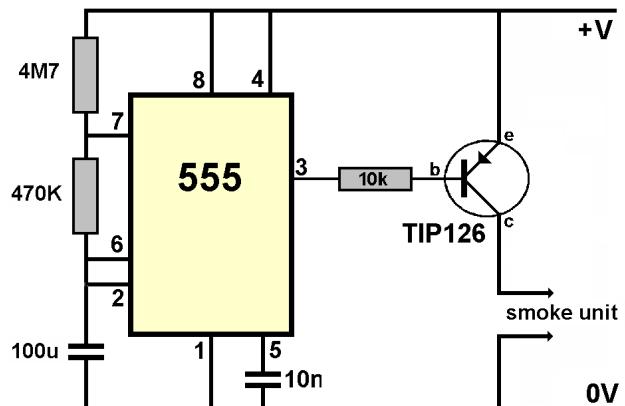
Electromagnetic uncouplers

Kadee couplings are popular amongst a section of enthusiasts.   To avoid having to manually uncouple rolling stock with hooks and sticks, Kadee brought out under-track permanent magnets.   These sit under the sleepers so that the magnetic field opens the knuckles reliably.

Although this is a great improvement on manual uncoupling, it is far from perfect.   It involves some tricky shunting of the wagons back and forth to achieve uncoupling. In addition, moving a train over the magnets may lead to accidental uncoupling of rolling stock.

For easier use, Kadee brought out their HO electromagnet uncoupler.   This is fitted under the baseboard, as shown in the picture (it also shows the Seep EM1 version).   You simply stop the train with the couplings over the electromagnet, energise the decoupler coil and pull the rest of the train away.

Kadee recommend a 16V DC supply of at least 3A to power their uncoupler. The Seep EM1 model takes 1A at 12V DC and 1.5A at 18V DC.   They can both be operated by a simple pushbutton of suitable current rating (check before you fit).   Do not use a switch as it may be left on by mistake and overheat until the coil is burn out.   Kadee recommend a maximum of two minutes continuous use, although users recommend a much shorter time.

Inverters

When connecting modules together, you cannot always guarantee a direct connection is suitable – i.e. connecting one module's output into another's input.
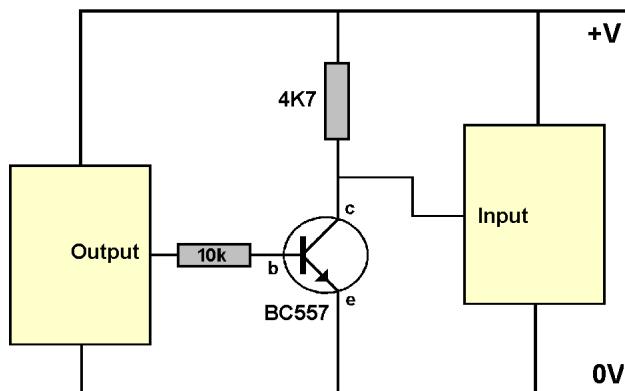
For one thing, they may be operating at different voltage levels (interfacing 12V modules to 5V modules, etc. is covered later).

A module's output may go high when activated but the other module expects a low voltage on its input.

The diagram shows how this problem is overcome.

The BC557 is wired as an *'inverter'*. This means that a positive voltage on its base brings its collector down to 0V. Conversely, 0V on its base results in a positive voltage on its collector. In other words, its output is always the opposite of its input.

In this way, two modules can be interfaced so that the correct outcome is achieved, at a cost of a few pence.

Fanning

Sometimes you want the output from a module to connect to multiple other modules and devices (e.g. the output from a track occupancy detector connecting to relays, LEDs, timers, etc.). This is know as a *'fanout'* and you have to ensure that the total current requirements of all the attached modules and devices does not exceed the available current output from the module feeding them.

Voltage incompatibilities

Earlier pages demonstrated how to drive high current devices from modules with low current outputs.
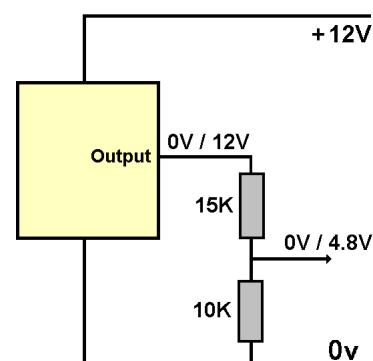
Another problem is interfacing devices that work at different voltage levels. Many digital devices work with a 5V supply and others with a 12V supply. The aim is to safely connect their inputs and outputs.

Connecting high voltage outputs to low voltage modules

This illustration shows a method of connecting a 12V output to a module that expects a 5V input.

Two resistors are connected in series across the module's output pin and 0V. Together they form a *'potential divider'*, with some of the voltage being developed across each resistor. The voltage across the lower resistor is taken to the next module.

The voltage across the lower resistor depends on the ratio of the two resistances. So, for example, if they were both 10k than a 12V across them would drop 6V across each resistor. Using the values shown, a 12V output from the module will produce 4.8V across the lower resistor. This will work in may circumstances, although the input circuit of the next module may have its own resistors.

In addition, you may want to achieve electrical isolation, specially if you want a module to interface with a high voltage devices such as mains-driven circuits.
In these cases, you can adopt the technique below.

Connecting low voltage outputs to high voltage modules

The input pin of a high voltage module may still switch with the +5V coming from a 5V module's output.   On the other hand, you may not want to risk any damage to the 5V module by connecting it to a potentially higher voltage.
One popular solution is ensure that there is no electrical connection between module outputs and inputs.   Instead, it uses light as the link between the modules, using *'optocouplers'*.

Optocouplers

An optocoupler, sometimes called an opto-isolator or a photo-coupler, is essentially an infrared LED and photo-transistor in one package.
The illustration shows the KB814 optocoupler.
It is a small four pin package, with two pins connected to a source of infrared light and two pins that connect to a photo-sensitive transistor.
When current passes through the LED, it emits infra-red light which hits the base of the photo-transistor and switches it on.   Current can now conduct between its output pins.
Many optocouplers have a single LED inside its case, but the KB814 has two that are wired opposite to each other. This allows this particular optocoupler to work with an AC input if required.
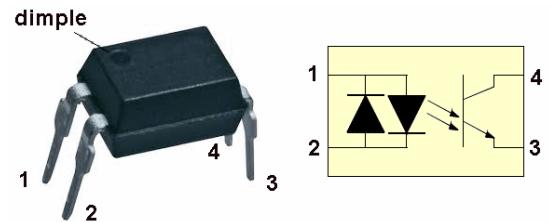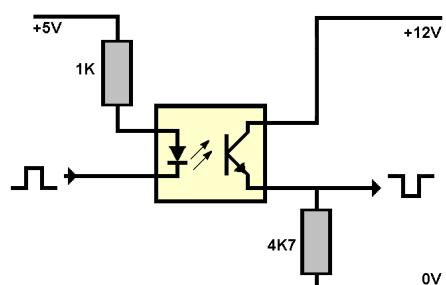
This ciruit shows the LED of an optocoupler being connected to a module that works at 5V, while the photo-transistor is connected to a module that works at 12V.
The only link between them is the infrared beam.   This provides a high degree of electrical isolation between them, 5KV for the KB814.
With the 4K7 load resistor in the emitter, the output is inverted – a high at the LED results in a low at the output.
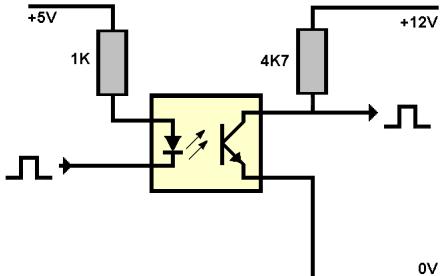
When the input to the LED is high, it will not emit light and the transistor will stay switched off.   This results in the photo-transistor's emitter going low.

When the input to the LED is low, it will emit light and the transistor will switched on, bringing the photo-transistor's emitter high.

This circuit is known as a *'level shifter'*. The input is either at 0V or +5V, while the output is either 0V or +12V.   This arrangement can be used to interface many voltage differences (e.g. 12V to 5V, 5V to 18V, etc.).

This variation on the above circuit places the load resistor in the photo-transistor's collector, to create a non-inverting output. When the LED is switched high, the LED does not emit and the photo-transistor is turned off. The output from its collector also goes high.
Taking the LED's input low, makes it emit and the output also goes low.
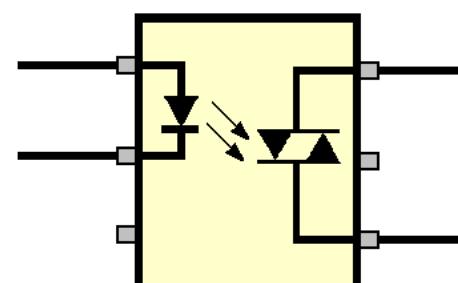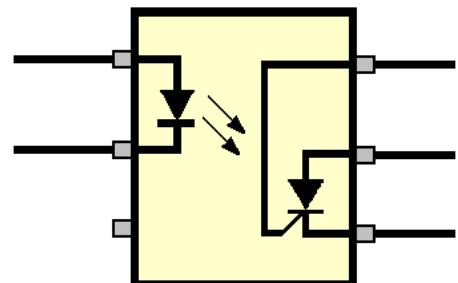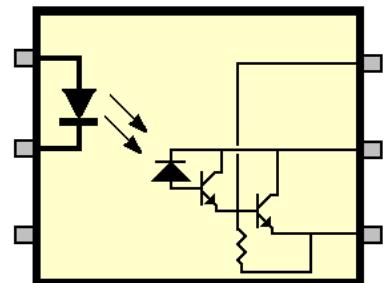
Opto-isolator types

These devices are available in the following varieties:

- DC input photo-transistor, with a single LED, such as the Sfh610-a2.   The above example circuits are of this type.
- DC or AC input photo-couplers with two LEDs, such as the KB814.   There is little use for AC inputs in model railways but it is commonly used with DC inputs.
- Photo-Darlington opto-couplers, such as the IS4N46.   The specifications for all opto-isolators include their *'transfer ratio'*. This is the ratio of the current flowing through the LED to the current flowing through the collector/emitter of the transistor. These can vary widely, from as little as 10% (e.g. 20mA through the LED results in only 2mA flowing through the transistor) up to 500% (e.g. a 20mA through the LED results in 100mA flowing through the transistor). For example the KB814 can produce a maximum transfer ratio of 300%. To achieve the highest transfer ratios, some opto-couplers have a *'Darlington Pair'* built in to them. A second transistor boosts the current from the photo-transistor to provide an increased transfer ratio.   Where even higher currents are required, further additional transistors can be connected to the output to handle higher current loads.

- Photo-SCRs, such as the H11C4.   The SCR stands for *'Silicon Controlled Rectifier'*.   When the LED is powered, the diode conducts, allowing current to pass between its anode and cathode.   It is mostly used to switch AC loads.   It can be used to switch a DC output but once the diode conducts it stays conducting even after the LED is witched off. The only way to stop the output from conducting is to cut of its power.

- Photo-TRIACs, such as the MOC3020.   TRIAC stands for *'Triode for Alternating Current'* and it can conduct current in both directions.

The photo-SCR and photo-TRIAC are included for completeness.   You are unlikely to come across them in model railway circuits, although you may find TRIACs (not photo-TRIACs) being used to operate points in some layouts.

Conclusion

All the above circuits are snippets; they are building blocks.   You have to adapt to whatever modules you are working with.

Don't forget to use the internet as a source of information about your specific modules.

specific modules already documented

For example, MERG members who want to connect CBUS units together can find details at:

http://groups.yahoo.com/group/mergcbus/files/CBUS%20Module%20Connections/

Chapter 17

Using computers

Using computers

This chapter looks at how computers can benefit your layout, what is available, and how to use it.

Most people have access to computers, generally desktops and laptops. Along with mobile phones, they are mostly used for browsing, email and social networking.

However, computers can make a major contribution to model railways. Some shy away from computers in their modelling but there are many levels at which computers can contribute to your layout. These range from finding out how to do things (e.g. lay track or build trees) up to implementing full-blown automated layouts.

Why use computers?

You don't have to install new software or change anything on your computer to get loads of extra benefits.

If your computer is connected to the Internet, you already have access to:

- Information
- Help
- Free goodies
- Most model railway and electronics retailers

If you are comfortable about purchasing/downloading software and installing it on your computer, you can have any (or all) of these:

- Train simulators.
- Track planners
- Stock inventory
- Layout control software
- Automation software

Information

A Google search for *'model railway'* returned over 41 million results! There is certainly plenty to keep you searching and reading for a long, long time. Getting more specific, a search for *'model rail turntables'* returned 760,000 results and *'laying model railway track'* returned 108.000 results

There are whole websites dedicated to bringing together model railway news, views and product reviews. Examples of such sites are:

> www.model-railways-live.co.uk/
> www.mremag.com/
> http://mrr.trains.com/

For free track layout suggestions, check out:

> www.freetrackplans.com/
> www.bandrmodelrailways.co.uk/Design%20ideas.html
> www.track-plans.net/

Help

Model railway enthusiasts are always happy to help newer members or members with specific problems.   There are websites that are dedicated to answering questions and each Forum is worth a visit.

Examples are:

www.modelrailwayforum.co.uk/
www.modelrailwayforum.com
www.newrailwaymodellers.co.uk/Forums/
www.rmweb.co.uk/community/
www.mrlforum.co.uk/
www.modeltrainforum.com/

This is one of the sections from the modelrailwayforum.co.uk website.

Model Railway Construction

Forum	Last Post	Threads	Posts
Baseboards (4 Viewing) All posts regarding baseboard construction	**BASEBOARD - another way to...** by LostockGuy Yesterday 12:17 PM	107	1,141
Track Layout & Design (18 Viewing) Help with designing your track work	**Hornby uncoupler units** by Bethony Today 01:54 PM	440	4,022
Scenery (7 Viewing) Help with layout scenics	**Platforms - Metcalf? Cutting...** by Walkingthedog Today 06:55 PM	217	1,790
Wiring & Electronics (19 Viewing) DCC (530/4278) Analogue (177/1356) Other (100/883)	**Defying the laws of physics?** by Steve M Today 06:25 PM	965	8,021
Kit Building (4 Viewing) Help with scenic kits	**Card kit pub?** by Wishmaster 19-04-2014 10:04 AM	123	1,248
The Gallery Post your model railway pictures here for others to see.	-	-	-
Members layouts (10 Viewing) Dedicated area to show the community your model railway projects	**DCC Automated N-Gauge Loft...** by RogerB Today 08:08 PM	127	3,973
Location location location (2 Viewing) Where can I keep my model railway?	**loft or shed** by andy757 15-04-2014 07:58 AM	15	164
Allan Downes - Model Buildings (2 Viewing) Here Allan will show his detailed buildings and give construction techniques to help others make their scratch built buildings.	**Scratchbuilt buildings** by allan downes 19-04-2014 09:22 PM	1	325

Other sections cover specific gauges, sales and wants, etc.

Examples of more specific Forums are:
www.hornby.com/forums/
www.merg.org.uk

Freebies and savings

Constructing buildings from pre-printed card is very popular, although some kits are now quite expensive.   To the purchase, you have to add the cost of postage, unless you buy them at an exhibition.

If you have Internet access, you can download the images and print them off yourself.   This is cheaper than paying postage and has the advantage that the buildings' images can be printed again and again.   One purchase can create multiple buildings.
Even better, a number of websites provide free downloads of building kits.
If you prefer constructing your own buildings and use brick paper, tile paper, etc., then you can also download these textures, including free versions.
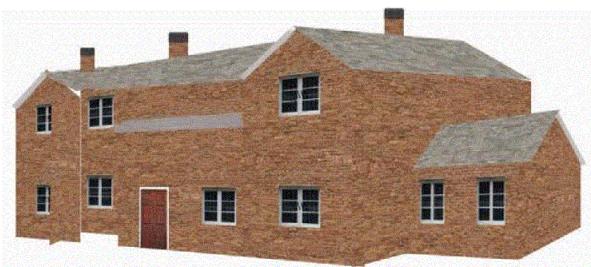
The image shows a building that was constructed from a free download from:
> www.modelrailwaybuildings.com/

Other sites worth a look are:

> www.wordsworthmodelrailway.co.uk/index.html (accepts voluntary PayPal donations)
> www.scenerybuilder.com/modelbuildingkits.html
> www.railwayscenics.com/free_downloads.php (also sells commercial card kits)

These websites mainly sell kits but have free samples.
> www.modelrailwayscenery.com/
> www.smartmodels.co.uk/
> www.modeltrainsoftware.com/brickyard.html
> www.modeltrainsoftware.com/model-builder.html

Mail order suppliers

In the past, you ordered from a limited number of catalogues and, if the items you wanted were not available locally, you had to send off cheques to the companies along with your order form.   That facility is still available, although you can now place telephone orders using your credit/debit card.
With the expansion of the Internet, even small local model railway shops and electronic suppliers are within your reach.
www.ukmodelshops.co.uk/ provides a list of many local model railway shops.

eBay

If you subscribe to eBay you can access sellers from all around the world, which is ideal for tracking spcecialist items, or for making significant savings.
You can order from UK sellers, or worldwide sellers, although be prepared to wait up to five weeks for deliveries from Hong Kong, China, etc.
A search for *'OO'* resulted in 20574 items being sold, with *'HO loco'* displaying 3125 items for sale.   Overall, 480626 items for sale were found in the *'model train'* category.
Some items are for immediate purchase, while others are on auction.

The next two pages provide a list of resources and suppliers that you can find on the Internet.   Please note that some smaller companies may come and go; its difficult to keep such a list current.

Sources of information, calculators

http://led.linear1.org/1led.wiz   - Calculates resistor need for LEDs

www.csgnetwork.com/resistcolcalc.html   - Identifies a resistor by its colour code

www.hobby-hour.com/electronics/resistorcalculator.php   ditto

http://home.cogeco.ca/~rpaisley4/CircuitIndex.html   - Loads of electronic circuits for railways

www.wiringfordcc.com   - Loads of DCC-related how-to articles

www.opendcc.de/index_e.html   - Build your own DCC modules

www.nmra.org/beginner/wiring.html   - NMRA's basics on layout wiring

www.elexp.com/t_acron.htm   - Commonly Used Acronyms explained

www.ntrakexpress.com/   - Speed and scale calculators

www.electronics2000.co.uk/data/index.php   - Technical data archive

www.talkingelectronics.com/te_interactive_index.html   - Loads of general electronic projects

www.discovercircuits.com - Loads of general electronic projects

www.electronics-lab.com   - Loads of general electronic projects

www.epanorama.net

www.microchip.com - Loads of PIC specifications, suggestions

http://www4.tpg.com.au/users/talking/index_of_chapters.html - Course on PICs

www.elecfree.com/electronic

www.bnoack.com/index.html - Information on a wide range of electronic devices

www.siliconchip.com.au

www.kpsec.freeuk.com   - The Electronics Club

General component suppliers

www.rapidonline.com

http://www.bitsbox.co.uk

http://uk.farnell.com/

http://www1.uk.conrad.com

http://cpc.farnell.com/jsp/home/homepage.jsp

www.cricklewoodelectronics.com

www.distel.co.uk

www.expotools.com/

www.fastcomponents.co.uk   - Good range of motors

www.mainlinegroup.co.uk/

www.futurlec.com

www.mindsetsonline.co.uk

www.bardwells.co.uk

www.partridgeelectronics.co.uk

www.richmondcontrols.com   - Modules for railways

www.greenweld.co.uk

www.bowood-electronics.co.uk

www.toby.co.uk   - Mainly cables and connectors

www.pw-electronics.co.uk

www.rshelectronics.co.uk

Specialist component suppliers

www.active-robots.com   - A distributor and manufacturer of robotics & electronics technology

www.avitresearch.co.uk – Suppliers of specialist adaptors and cables

www.decisioncards.com/   - Suppliers of interface cards

www.jperkinsdistribution.co.uk - Mainly aircraft but have a range of useful materials

www.keene.co.uk   - Mainly Audio/Video but selection of cables, etc.

www.ultraleds.co.uk   - Large range of LEDs

www.mecanique.co.uk   - PIC-related

www.milinst.co.uk   - PICs and robotics

www.fored.co.uk   - PIC-related

www.millhillsupplies.co.uk   - Tools

www.skpang.co.uk   - Mainly PICs but a selection of electronic components

http://robosavvy.com   - Robotics, servos, etc.

Model railway software

The previous pages covered accessing a range of support, using just your computer and your web browser. Now we will look at software that you have to install on your computer, to get the benefits of their features. In most cases, the installation is easy and all you need is some time to get familiar with the application and all its options.

Train simulators

Just a quick mention, since it is railway related software of a sort. You don't even need a layout for this, as it mainly for fun.

Most packages have pre-determined routes that you follow as the train's driver. The image shows a screenshot from the RealRailway Train Simulator.

Those that allow you to alter the trackwork, can provide the feel of a layout before committing to a real track plan.
Examples are:

      ArcRail Train Simulation (http://arcrail-train-simulation.en.softonic.com/)

      RealRailway Train Simulator   (www.railsimulator.com/)

      PC-Rail Simulations (www.pcrail.co.uk/index.php)

      Rail Simulator fro Electronic Arts (www.ea.com/uk/rail-simulator)

Although something to entertain you and the kids/grandkids, it does not make a serious contribution to your layout. The software that follows does.

Track planners

When contemplating starting a new layout, modellers take many approaches.
Some have a plan of sorts in their heads and just start laying track.
Some draw a sketch on a postcard or a sheet of paper. Some are more organised and use graph paper to judge lengths and the radius of each bend and point.

Clearly, making it up as you go along or working to a vague plan is a recipe for lots of mistakes. In fact, even the more disciplined approach of using graph paper has it drawbacks.
Firstly, as you work through the planned layout, you will likely want to alter track positions, locations of points, the radius of a curve, etc. To make the changes, you have to rub out some the existing plan and start over. This can be a laborious and frustrating process, particularly when working with flexitrack.
Sometimes the difficulty is visualising how the layout will look when it is finished.

This is where track planning software becomes useful. The time spent in installing the software and learning how it works makes planning a layout an interesting and enjoyable experience. Even better, it need not cost too much – some programs are free.
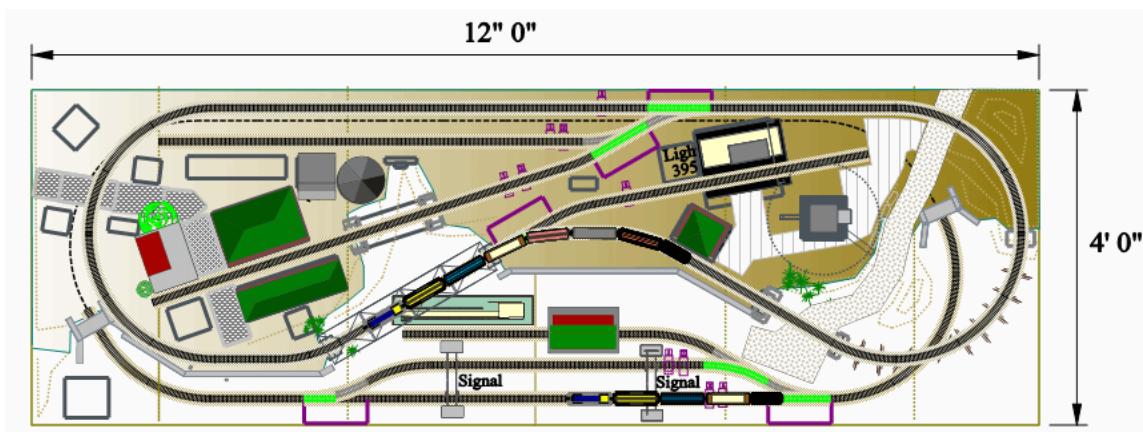
Features

Some packages have basic (although useful) facilities while others are rich in their features.
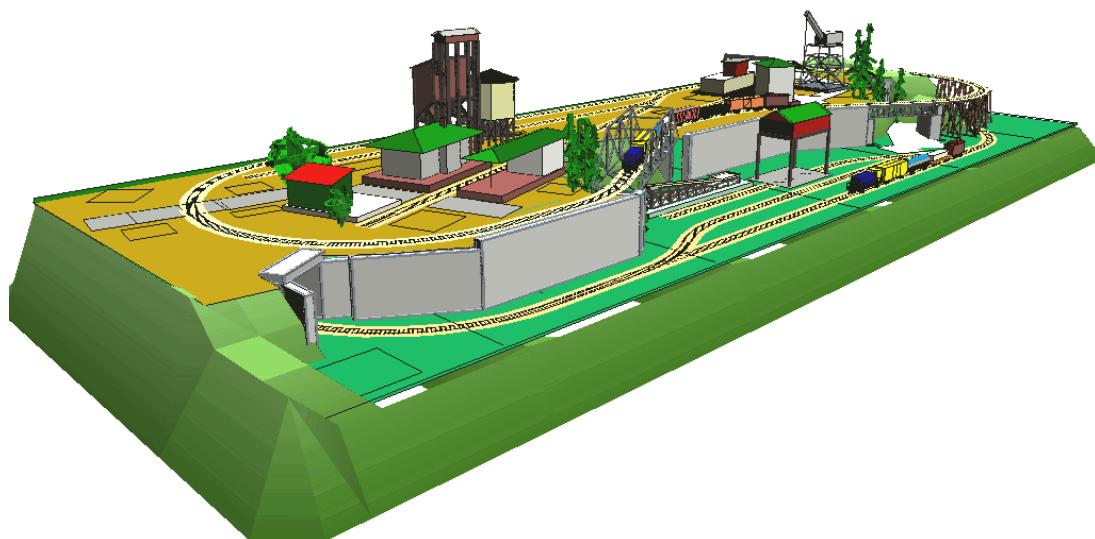
The most useful facilities could include:

- Works for any gauge.
- Works with both set track and flexitrack.
- Pre-defined track libraries for different manufacturers.
- Handles transition curves (a curve of constantly changing radius).
- Can print out layout sheets.
- Can print out track templates.
- Option to display a 3D view of the layout.
- Option to add in lineside features, trees, etc.

This illustration shows a layout that has been designed using the *'Cadrail'* package.

And this is the software displaying the same layout in 3D.

Track planning packages

Here is a look at some of the packages that are available.   Some are completely free, some are commercial but allow free use on a limited basis and some are completely commercial.

Cadrail

The images you saw on the last page were made using this package.
It is available for download from:

     www.sandiasoftware.com/
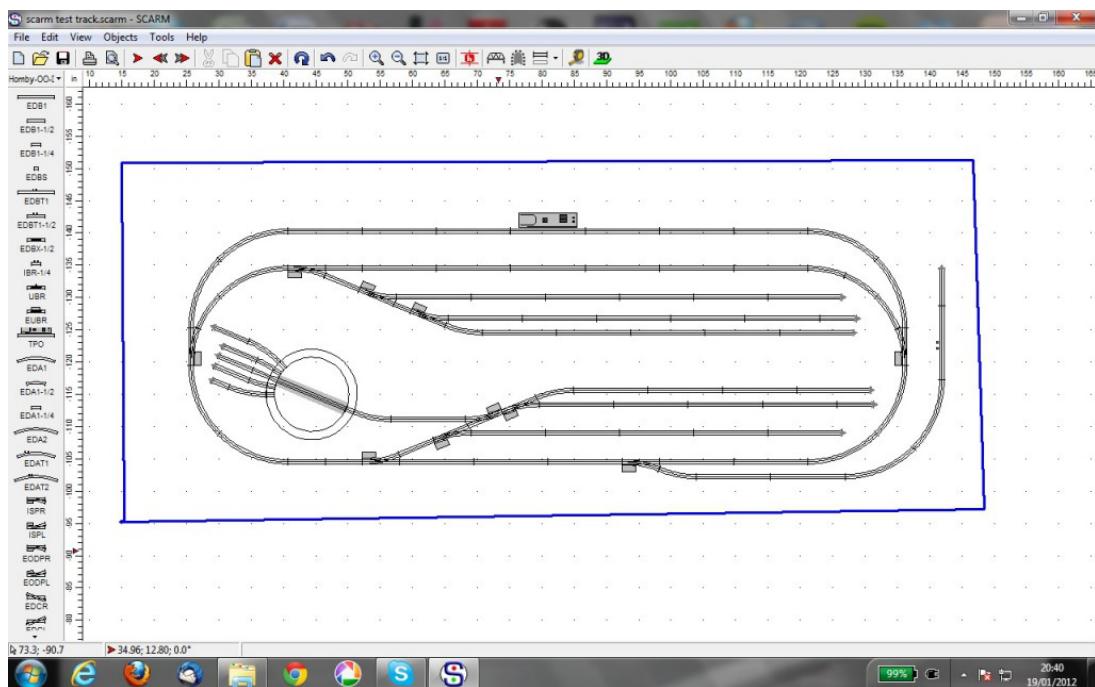
It is a commercial package but allows free use with a maximum of 60 objects.

SCARM

This stands for '*Simple Computer Aided Railway Modeller'* and is a freeware package that is available from:

     www.scarm.info/index_en.html

Here is a screenshot of the package in operation.

AnyRail

This is another commercial package that allows free use, this time a maximum of 50 objects.
It can be downloaded from:

     www.anyrail.com

Templot

Templot is intended primarily for modellers who wish to construct their own track.
It can handle slips, 3-way tandem turnouts, curved double-junctions and mixed-gauge formations. It is free to download and use, with a request for donations.
It can be downloaded from:

     www.templot.com

It has its own user Forum.

XTrkCad

This is a fairly comprehensive package with benchwork, on-screen ruler, elevations and even 'Post It' notes.
It is free and can be downloaded from:

www.xtrkcad.org

It has its own Yahoo Group with over 5,000 members.

WinRail

A commercial product that can be downloaded from:

www.winrail.com

Has useful features such a tool to design 3-rail trackwork, for combining narrow-gauge and standard gauge track systems.
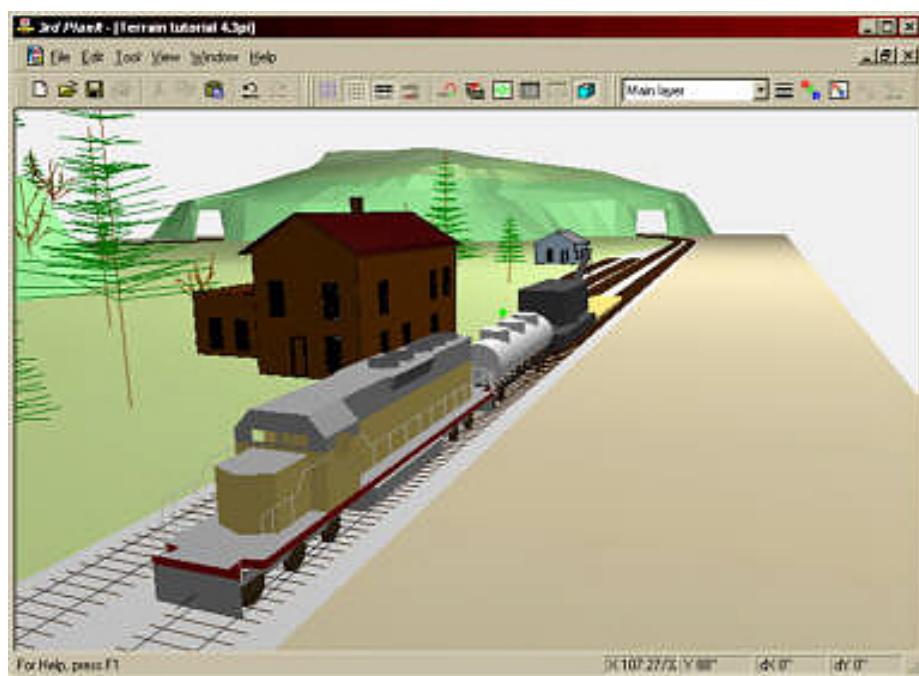
3rd PlanIt

A very well featured commercial package that can be downloaded from

www.trackplanning.com/3pi.htm

It has facilities for adding terrain including foliage and viewing in 3D.
A special feature is the ability to design your own locos and run them on the track, as shown in this screenshot.

It allows you to use the software without payment, with a restriction of no more than 100 objects and no ability to save the layout.

The Right Track

This is a freeware package that is available from:

http://the-right-track-r-software.software.informer.com/10.0/

This application provides templates not just for track but also bridges, turntables, buildings and electrical controls.

Stock inventory

It is not uncommon for railway modellers to amass countless locos and pieces of rolling stock.   When the cost of the trackwork, buildings, controls, etc. are added, the entire collection can easily be a four or even a five figure sum.

That raises the question of how to protect these items in case of fire, flood, theft, damage in transit, accidental damage, etc.

Household insurance policies don't fully cover collections of items and most will not cover layouts in garages or sheds, or garden layouts.   In addition, layouts taken to exhibitions or stored in clubrooms are not included in household insurance policies.

Luckily, a number of insurance companies offer special policies for model railways.
To maintain proper coverage, an accurate and up-to-date record of all your model railway items need to be recorded and lodged with the insurers.
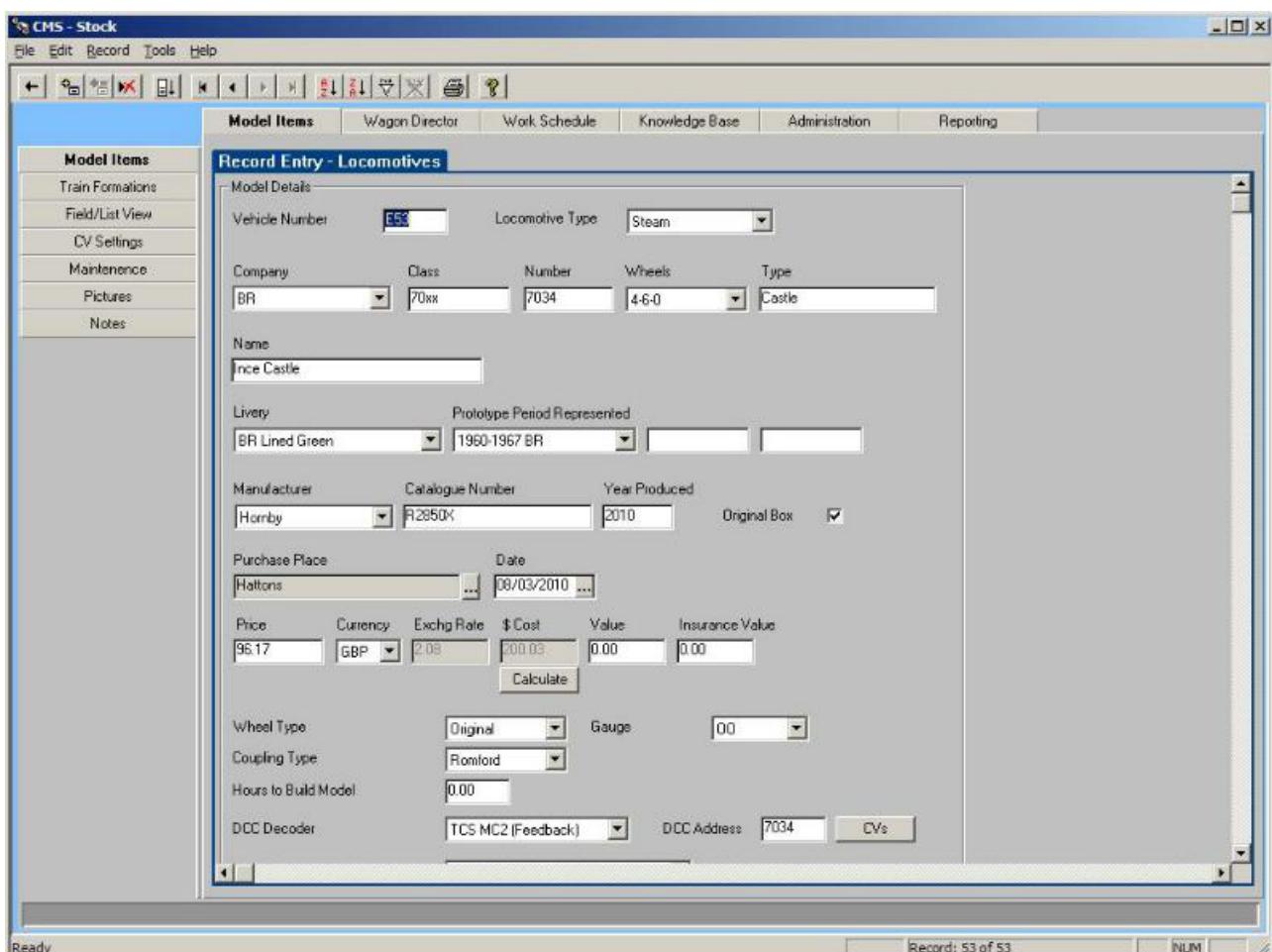
A number of stock inventory systems are available for installation on your computer.   You enter the details of each item and they are stored in the application's database.   This can be a simple set of details, while the more advanced applications allow you to store additional information including photographs, scanned documents (e.g. receipts) and videos.

CMS Stock

This is a fully-specified application that can be downloaded from:
        www.gppsoftware.com/ViewProd.aspx?P=41582C2324292128
or can be supplied on CD.

It is a commercial product but you can download a free fully-functional one month trial version.

The program stores Locomotives, Carriages and Wagons separately with no limit on the number of records.   The program is also customisable, allowing you add your own extra categories to the database.

Apart from creating a list for insurance purposes, the database can store valuable information for day-to-day use, such as servicing or maintenance schedules, exhibition dates, which locos have DCC decoders, what type of coupling is used, etc.

Track Those Trains

This program can be downloaded from
> www.bacitsystems.com/index.php?p=1_8_Track-Those-Trains

It is *'shareware'*, which means that it can be freely distributed and used for evaluation purposes.   Buying a license allows you to add unlimited records and adds printing, exporting in PDF format, a backup function, and other features.

The program also allows you to attach multiple digital images, video clips and documents.

AP Railventory
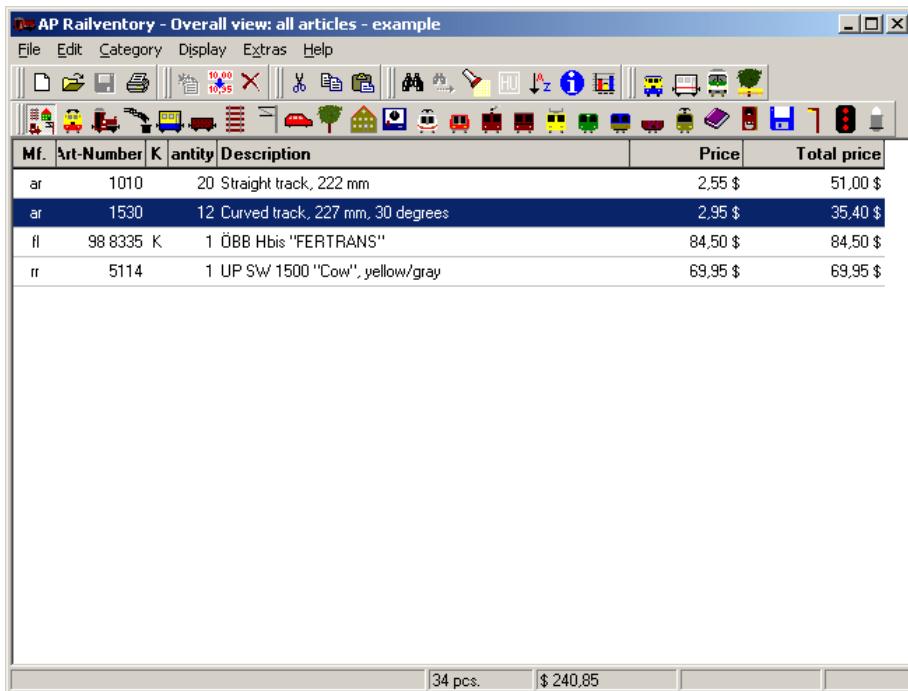
This is a commercial program although you can download a 30 day trial version that is limited to 50 items.

It is available for download only from
> www.pothe.com

The database supports 26 categories including locomotives, rolling stock, track, buildings, electronics, software and literature.   There is no limit to the number of items.

You can include two images and unlimited text for each item.

Control software

The previous pages looked at what you could achieve using only your computer, the Internet and maybe a printer.   These provide benefits that supported your model railway activities. This next section looks at using your computer to <u>control</u> what actually happens on your layout.

What is a computer controlled layout?

Computer-assisted systems can provide different levels of operating support.
There are three main operating modes:

Fully manual
> The operator is in complete charge of all loco, point and accessory operations, using a mouse or pad to interact with buttons and sliders on an on-screen control panel.   It is the responsibility of the operator to see where things are and what needs to happen next.

Partially automated
> The computer software is left to run locos on the layout's main lines, with no attention needed from the operator.   The operator is responsible for, and manually controls, locos in specific areas of the layout such as the shunting yard or fiddle yard.

Fully automated
> The operator sets up a sequence of operations and the computer handles all the layout activities, while the operator sit backs and watches.   To work, the layout needs to provide feedback to the computer, telling it when events have occurred (e.g. a train has arrived at a station).

Well-written software allows the operator to switch between these different modes, with fully automated running on some occasions (e.g. at an exhibition) and fully operator controlled at other times.   The operator can have both a normal physical control panel and also a screen-based control panel (sometimes called a 'glass panel').

Although it is possible to design automatic controls for DC systems, DCC systems have an advantage for computer control as they are already equipped with decoders in the locos.

What do you need?

The computer has to interface to the layout's electronics, so that it can control activities (locos, points, accessories) on the layout.   For this, it needs both hardware and software.

- The hardware makes the physical link between the computer and the model railway electronics (usually a DCC command station or a DCC booster).
- The software provides the user with the ability to operate locos, points, etc. using the computer monitor and an input device such as a mouse or a touch screen.
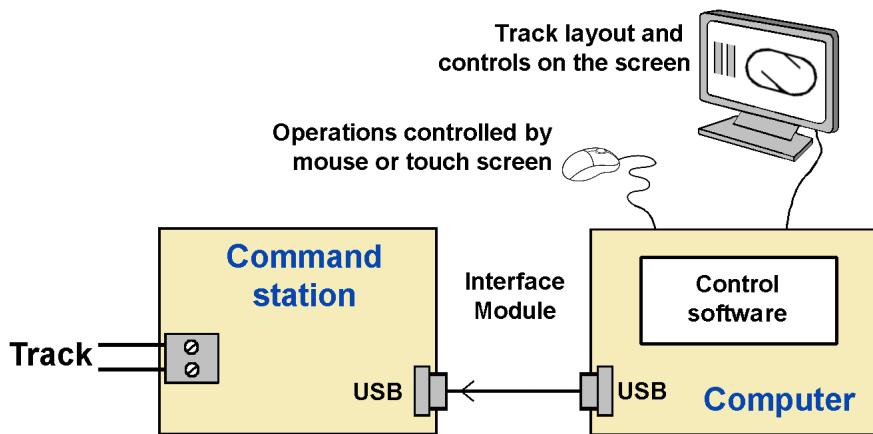
Hardware

There are two main ways that the computer can interface to your layout:

Through your existing DCC command stations

If your command station has a built-in USB port, then it can connect directly to your computer's USB port.   Examples of this type are the ESU Navigator and the Hornby Elite.

The setup is as shown in this illustration.

The command station connects to power and to the track as normal.   A USB cable is used to connect the command station to the computer.

The control software (see examples of these later) is installed in the computer.   The monitor screen layout can be as simple as a replica of a handheld control, where you click on screen buttons instead of pressing physical buttons.

Most packages allow you to go much further and create a replica of your layout on the screen.

There are no physical alterations to the computer; nothing needs to be added or tweaked; the case does not need to be opened.   The only additional tasks are those of setting up and configuring the software.
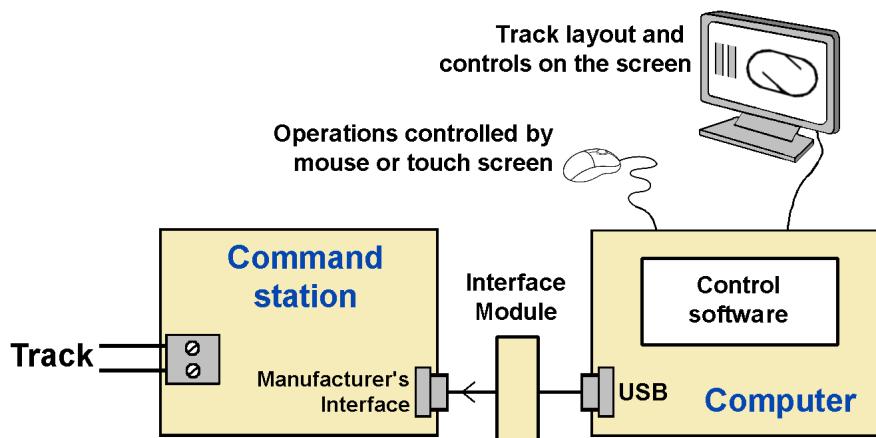
Proprietary interfaces

For their own reasons, manufactures often use their own interface methods.

To make these command stations work with a computer, you have to place an external module between the command station and the computer. This module's purpose is to translate the signals on the computer's USB port into signals that are understood by the manufacturer's own particular interface.

Examples are Digitrax using a PR3 unit or a LocoBuffer-USB unit, NCE using the NCE USB interface module, and Lenz or Atlas Commander using the Lenz LI-USB interface module.

The interface modules connect between the two ports and are usually powered from the computer's USB port.

Through an independent interface unit

The systems shown above use a command station that can be operated with or without connection to a computer, allowing you to switch between these uses.

Another approach uses units that *only* work when controlled by a computer. They do not have external knobs, buttons or sliders that you can touch and manipulate. They rely solely on the instructions they receive from your computer.

Their main advantage is their relatively cheap price compared to standard command stations.

Hornby's *'eLink'*
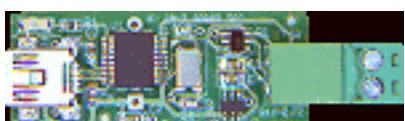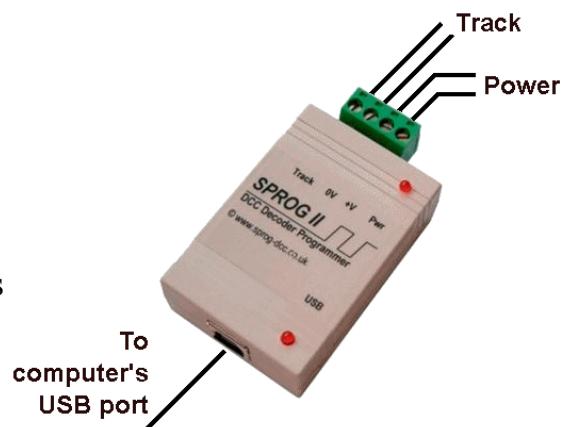
This unit combines a USB connection to a computer and a DCC booster. It has outputs for the main layout track and for a separate programming track

It is supplied with a 1A transformer, which is sufficient for many smaller layouts, but can be replaced with a 4A transformer if required.

SPROG modules

The first SPROG model was intended as a programmer for DCC decoders. The SPROG 2 is a combined USB interface and 1A DCC booster. When it was recognised that it could also be used for controlling layouts, a more powerful SPROG 3 version also became available. The SPROG3 looks similar to the one in the picture but includes a 2.5A DCC booster.

If you own a DCC booster but no command station, SPROG have introduced the *'s-Nano'* which interfaces a computer's USB port to any any DCC booster.

MERG Command Station
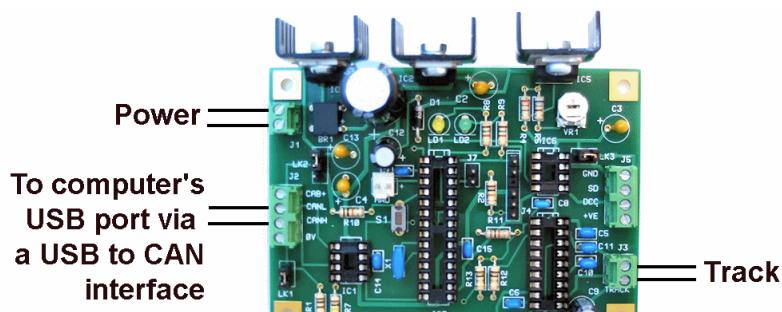
Like the others, this module connects to both power and the track.

Unlike the others, it can be connected to a handset to convert it into a conventional DCC command station.

Its interface uses a variation of the CANBUS system (CBUS), so has to use a CBUS-to-USB interface card.

The CBUS system is explained in a separate chapter.

It is supplied as a kit and its ability to work from a handset or from a computer makes this unit very versatile.

Control Software

Controlling layouts from a computer can be as simple or as complicated as you want.
This chapter cannot provide tutorials on all the software applications out there.
You need to choose the one that best suits your needs (and pocket) and be prepared to learn how to use it and get the most from its facilities.

At its simplest, the computer screen can look just like a handheld DCC controller, as shown in this illustration.

Once the program is running, you select which loco you want from the drop-down list near the bottom of the screen, click on the 'Forward' or 'Reverse' button and move the slider up and down to adjust the loco speed.

This *'Throttle'* facility is included as part of *'Decoder Pro'* .

The software is provided by the JMRI (Java Model Railroad Interface) Project group.   This is an informal open-source software group who describe their project as:

> *"a jumping-off point for hobbyists who want to control their layouts from a computer without having to create an entire system from scratch."*

The software is constantly being developed by this large group of enthusiasts who co-operate to provide free access to their two main programs.
Their website explains that
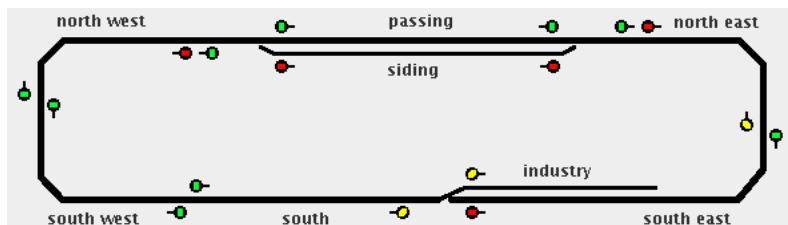
> *"JMRI can be used to automate parts of your layout, from simply controlling a crossing gate to running trains in the background".*

The Decoder Pro program is mainly used to make programming DCC decoders an easy task and this is described in the chapter on DCC. The *'Throttle'* facility is a useful addition for those who do not want to go down the road of automation.
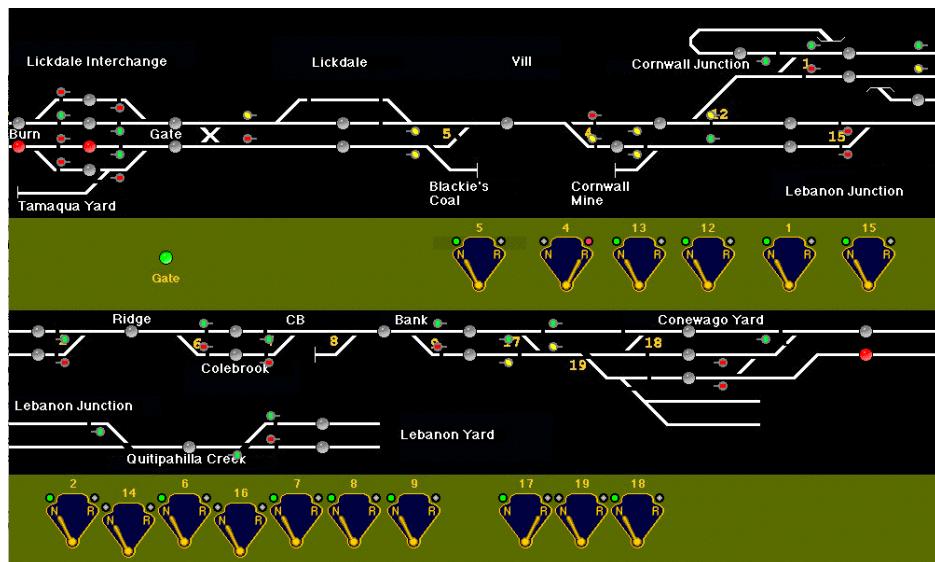
JMRI's other application is called *'PanelPro'* and it is used for handling automated or semi-automated layouts, using two methods. You can choose to use either method, or even both together.
The *'Layout Editor'* lets you draw your layout on your screen, as shown in this simple example.

Once set up, the operator can control the layout's points and signals.

The *'Panel Editor'* lets you create an on-screen representation of a normal control panel like the one shown here.

It is an alternative approach to control locos, points, etc. from the screen – or have them run automatically.
For automatic running you need feedback to the computer from sensors that tell the software when events have completed (e.g. a train has arrived at a station).   See the chapter on track occupancy detectors for information on this.

JMRI software includes the ability to use iPhones, iPods and Android phones as handheld remote throttles.
More information is available at:
        http://jmri.sourceforge.net/
The website provides a list of al the command stations and other hardware that it is able to work with.

Rocrail
This another open source project that is free to download and use.   It is also being continually developed by enthusiasts.
It provides options for you to run the layout manually from your on-screen layout, or to configure it to run automatically or semi-automatically.
As for JMRI, automatic running in Rocrail relies on feedback to the computer from sensors that tell the software when events have completed (e.g. a train has arrived at a station).   See the chapter on track occupancy detectors for information on this.
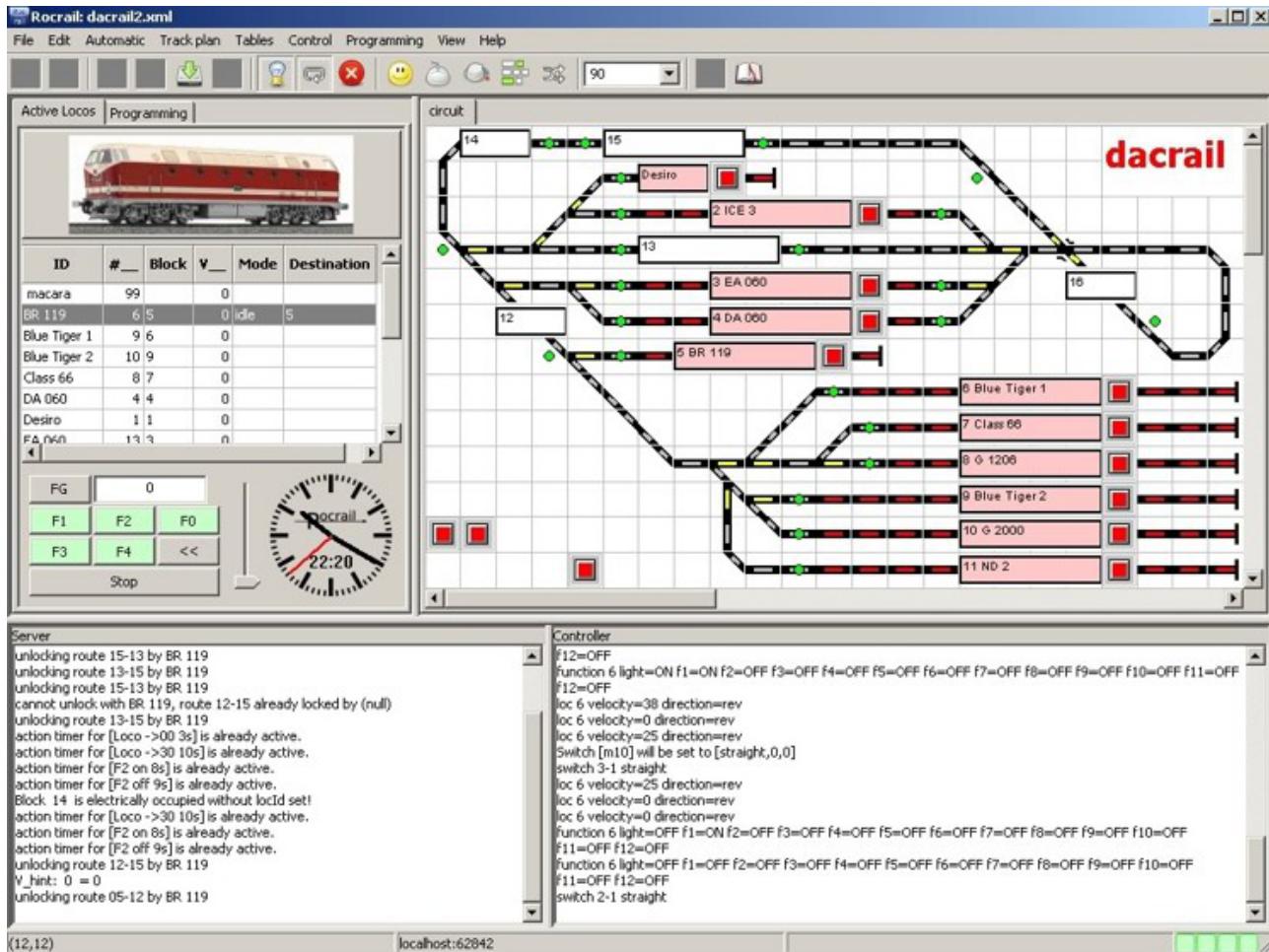
More information is available at:
        http://wiki.rocrail.net/doku.php
The website provides a list of al the command stations and other hardware that it is able to work with.
Rocrail also has its own Forum where help and advice is available.
        http://forum.rocrail.net/viewforum.php?f=95

Here is an example:

Hornby RailMaster

Hornby's RailMaster software works with the Hornby Elite DCC controller or the e-Link DCC booster.

It can be purchased on its own or bundled with e-Link.
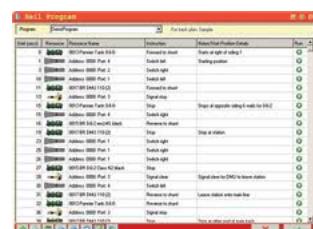
As the image shows, it uses the same approaches of drawing the layout on the screen and providing on-screen control of locos if required..   The movement of locos, points, uncouplers, etc. can be controlled either by your mouse or by using a computer with a touch screen.

The points and accessories are controlled via DCC accessory decoders.

Automation can be achieved in two ways.

The software provides a programming option where you enter a list of activities such as starting or stopping locos, operating points and setting signals. These events are entered in the order that you want them to occur and you have to enter the times at which each event will happen.   This may be a bit of a suck-it-and-see operation where you amend the timings after running the program.

The alternative is to use the software's 'recording' option, where the software creates the list of activities and includes the actual times you took to run the locos, etc.
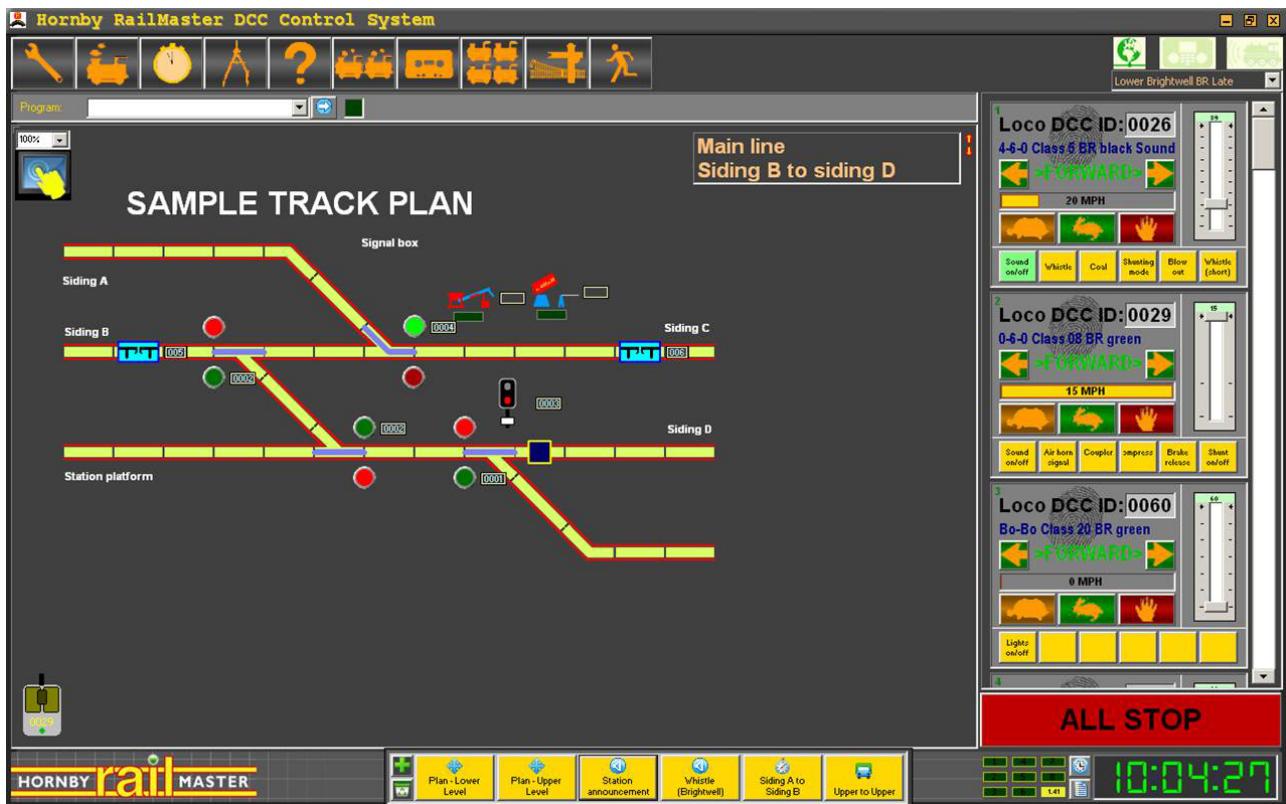
While Hornby's timed list approach is simple to create, it has the serious drawback that it cannot cope with unexpected events such as stalling or derailments.   The program

relentlessly progresses though its list of events, since it has no knowledge that a previous event failed.

JMRI and Rocrail cope with mishaps by using feedback from track detectors.   That way, it knows that a loco failed to arrive at its intended destination and won't carry on until the situation is rectified.

Hornby are aware of this shortcoming and they are likely to introduce a range of their own detector modules, possibly including RFID. At the time of writing they are awaiting patents before bringing them to the market.

Like the JMRI and Rocrail, Railmaster allows remote control of your layout using and iphone, iPad tablet, and Apple and Android devices.   The device communicates via WiFi with your computer and you have to purchase their app.

TrainController

This is another commercial product, created by Railroad & Co.

It is available in three versions, Bronze, Silver and Gold, with differing amounts of facilities and prices ranging from around £100 to around £500.   A comparison chart for the three versions can be read at:

> https://secure.freiwald.com/pages/traincontroller_bronze.htm
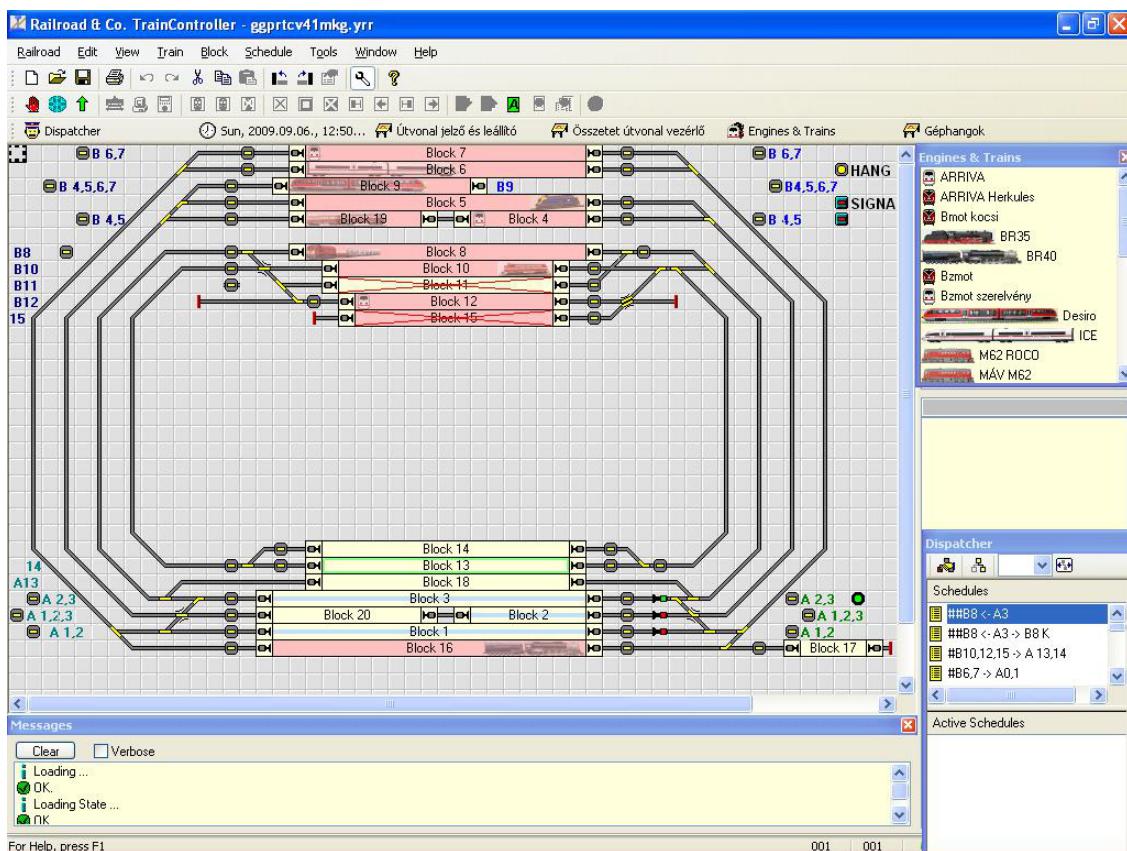
It claims to support the train detection systems of all leading manufacturers.

You can check whether the software is compatible with your hardware by looking at:
> https://secure.freiwald.com/pages/traincontroller_bronze.htm

The program has several thousand users and has its own Forum.
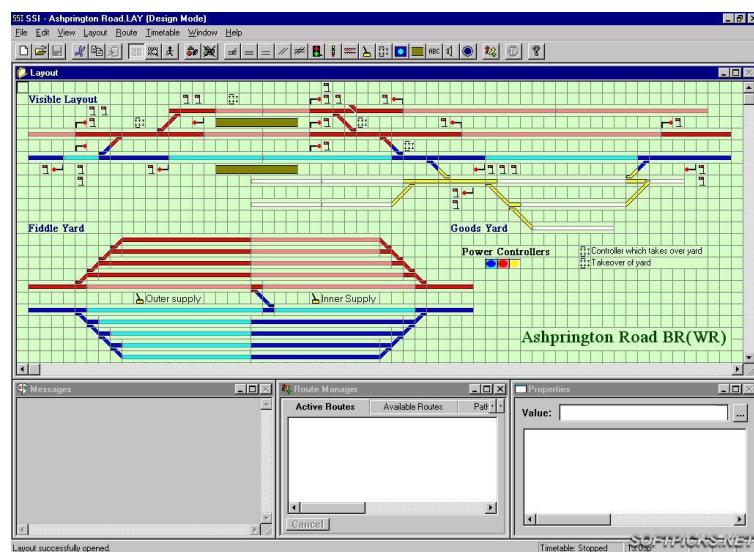
They offer a free trial download with no restrictions for the first 30 days.

SSI

SSI stands for Solid State Interlocking, since it provides full control of points and signalling and these can be interlocked.   The software provides prototypical operation and control. Routes can be defined so that a series of points and signals can be set in one operation.

A range of drivers is provided, allowing it work with various pieces of hardware (e.g. the MERG RPC, MERG CBUS, Lenz ExpressNet, Hornby Elite, and NCE DCC).

The software can be purchased from:
> www.gppsoftware.com/SSI/

You can also download a fully functional 30 day trial.

TCC
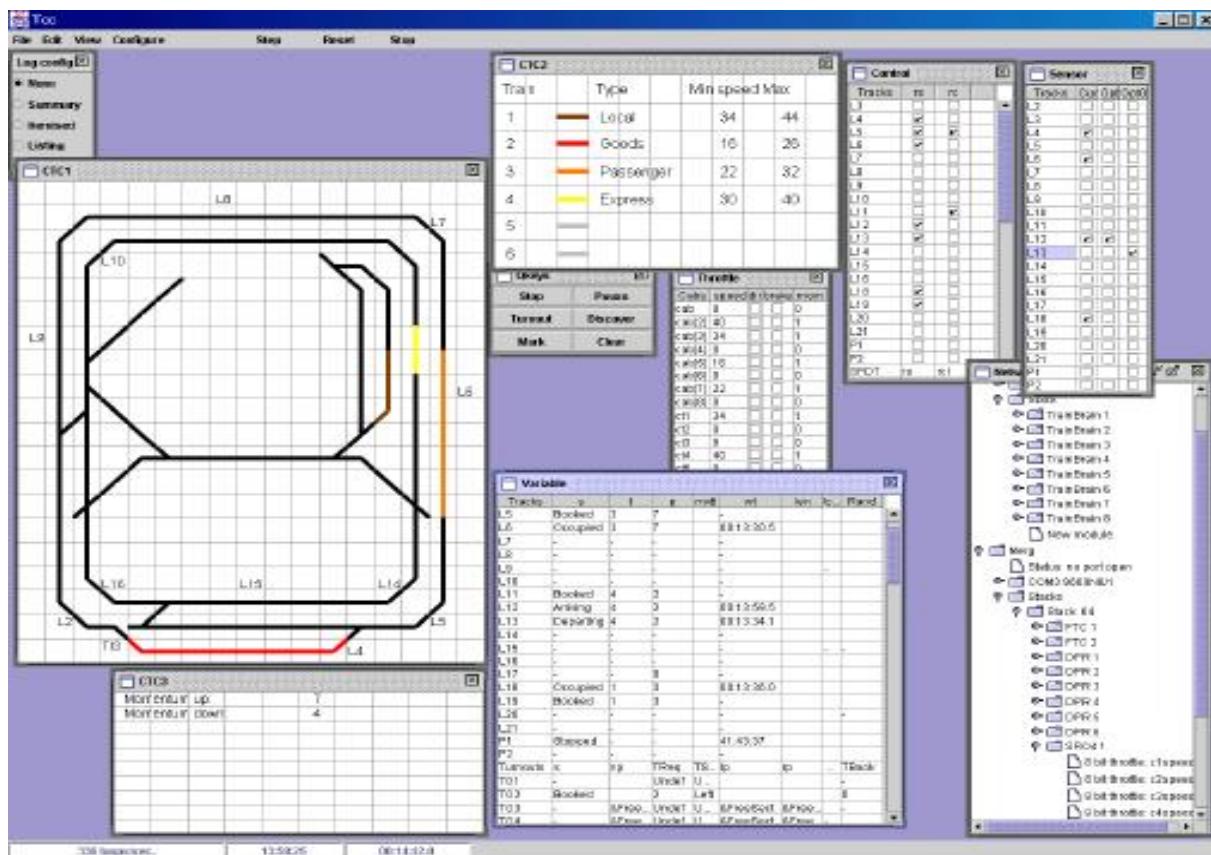
TCC (Train Control Centre) can drive three types of hardware interface module: CTI modules, RPC modules and QTU modules available from QtuTrains.

It connects to your computer's serial port, or to your USB port using a serial-to-USB adaptor.

More information is available at:

      www.qtutrains.com/SoftPane.html

In its most complex form it could be used to control signals and points with full interlocking, entry/exit route selection, automatic timetable running or fully automatic operation. To do these more complex things you have to write a configuration script.

Note

Although these programs can reduce a lot of the workload, the user will only get the best from these systems by tweaking them to their own needs.   This is achieved through writing 'scripts', small sections of computer instructions.

So, although of great help, computer-assisted layout operations still need you to learn a little about programming.

Here is a line of JMRI code, expressed in their Jython language:

      turnout.commandedState = CLOSED

which hopefully is self-explantory.

You may wish to dip your toe into this challenging and rewarding area of model railway control.   Many of the software programs are free and the only investment is some time. But when you click on a button and move the slider and watch a loco slowly move off …......

Interfaces – technical notes

First the good news

You do not need to know a lot about how computers work in order to use railway control software.   You only need to know how to install and run a computer program and connect some cables/wires.   In most cases, the software installs automatically or leads you through the steps.   Similarly, the hardware you buy will have installation notes.
How it all works can remain invisible to you if you want.

These next pages explain how serial and USB interfaces work.
It is included for two reasons:
- To satisfy the curiosity of those who like to know how things work and want to learn more.
- To help those who may be having problems with their setup.

> The approach should be - read what you need – skip what you know.

What is digital?

Almost all computer activities involve data communication of some sort. Communications can take two forms: '*Analogue*' or '*Digital*'.   This describes how the signal level changes with time (usually the voltage level changes across two wires or between two points).

Analogue

Data transmitted in analogue form has infinite potential variations. Examples include sounds recorded on a cassette tape and AM radio transmissions. In the model railway world, turning the knob on the DC controller results in voltages that can vary from zero to 12 volts or more – and every voltage level in between.

Digital

Digital signals can be in one of only a set number of possible states for each item of data. For example, computer data consists purely of ones and zeroes, with nothing in between. Either the wire carries the full voltage or no voltage. It is either high or low, ON or OFF, 1 or 0. There are no intermediate levels.   The ON, or HI, voltage level depends on the system.   It is 5 volts for many electronic devices and systems (e.g. USB, PICs, many digital logic chips, CBUS) and 12 volts and above for others (e.g. RS232 ports, DCC).
Examples of digital devices include printer cables, broadband connections, and DCC and CBUS in the model railway world.

What are bits and bytes?

Most data is stored in multiples of a 'byte' – a byte being a collection of eight data bits. At any point in time, all bits could be at zero voltage, or all at high voltage, or any combination of Highs and Lows.   This provides 256 possible different combinations and explains why a GIF image offers only 256 colours (one byte representing a screen pixel of a particular colour) or why early sound cards only produced 256 sound levels.
Its also why some decoders offer a range of 256 CVs.

A byte can also be used to store alphanumeric characters or numbers between 0 and 255.
For larger numbers, bytes are grouped into multiples and handled in multiples.
Hence, we have 32-bit, 64-bit, 128-bit or even 256-bit graphics cards and Windows 7 handling data in 64-bit chunks at a time.   CBUS uses events that are 32 bits. And not forgetting CV 2-byte long addresses.

All storage and speed measurements are stated in bytes, with a typical hard disk being 1TB or a typical broadband modem speed being 10Mbps. The upper case B denotes the value is in bytes, while the lower-case denotes bits. So, in the examples, the 1TB hard drive stores 1,099,511,627,776 bytes while the modem receives at ten million bits per second.

> Note that when measuring weights, distances, transmission speeds, etc., kilo is a magnitude of 1,000. However, in computing memory and data storage, a kilo is 1024; this is due to the binary system used in computing (1 kilo = 2x2x2x2x2x2x2x2x2x2 = 1024). Similarly, Mega is 1024x1024 not 1000x1000.
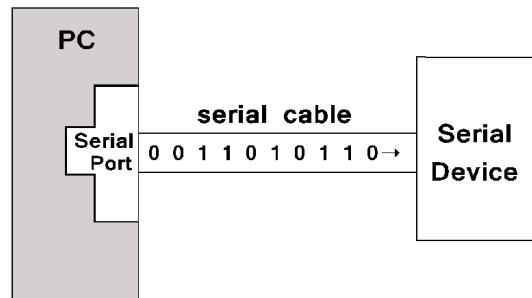
How is data moved around?

There are two ways in which data can be transmitted: '*Parallel*' or '*Serial*'.

The parallel method uses multiple data lines, to transfer multiple data bits in parallel with each other. The values on all the data lines are moved around at the same time. Within a computer, most data is moved round in parallel format on the various internal buses between the CPU and other chips. Older computers had parallel ports that were used to connect external peripherals such as a printer.

Serial

This type of communication uses a single data line, with only one data bit being transferred at a time, as shown in the diagram. On a basic level, the serial device waits for a group of eight incoming bits to arrive and assembles them into a byte for use. Similarly, a string of data from the device to the PC is built up into byte-size chunks before being used by the PC programs.
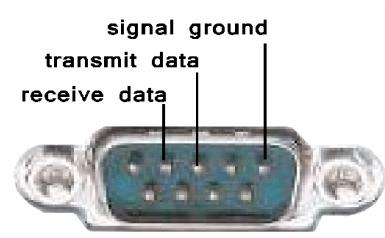
Modern computers pass data between computers and peripherals using one of a number of different serial types of connection. Serial systems are used for keyboards, mice, memory sticks, scanners, digital cameras, broadband routers and modems, local area networks, etc. Example interfaces are the serial port. USB, Firewire, external SATA ports, Bluetooth, IrDA, etc.

In model railway systems, DCC and CBUS use serial techniques.

What is a serial port?
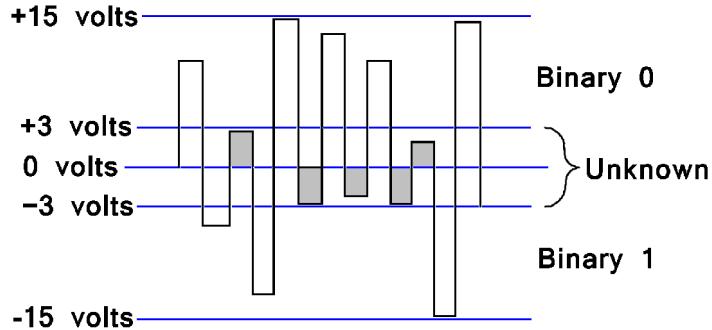
The serial port is situated at the rear of older PCs. They are generally 9-pin D-type connectors, although the specification allows for 25-pin connectors. 9-pin to 25-pin adapter or cables are available.   The connector at the rear of the PC is male (i.e. has pins) while the cable end is female (i.e. has sockets).

As the illustration shows, one of the pins ('signal ground') is used as a common return for all connections on the port.   The data signals are measured with respect to this pin.   One pin is used for transmitting data down the serial cable, while another is used to receive data that has been sent to the computer.   The other pins are used for various signalling purposes.

The RS232 standard was designed to minimise interference on the wires carrying the data signals.

To aid this, the voltages carried are higher than the normal range for digital signals carried inside the PC. The logic states inside the PC carry voltages typically no more than 5 volts. With RS232, binary 0 is represented by a voltage of +3 to +15 volts and binary 1 is represented by a voltage of -3 to -15 volts. Ideally, the signals would be +15v and -15v but by specifying a positive and a negative range, allowance is made for signal losses along the line.

Voltages between +3 volts and -3 volts cannot be converted to known values. These indeterminate values may be caused by interference spikes or may be the result of losses of signal on the line. They are shown shaded in the diagram.

Note:

The RS232 serial port uses values that swing both positive and negative of the common ground wire. Other serial systems only use data that swings positive with respect to the common ground (e.g. CBUS and USB).

Transmission Speeds

The speed of data transfer is measured in bits per second (bps). So, for example, if a device had an output running at only 1bps, you could monitor the output every second and find either a high or a low value. Of course, data is moved round at much faster rates than that. The very early modem connections ran at just 110bps, later dial-up modems run at 56kbps, while the latest USB3.1 offers a transfer rate of up to 10Gbps.

The maximum data rates for different interfaces are given in the table below.

Interface	Speed
CBUS	125kbps
Serial RS232	115kbps
USB1	12Mbps
USB 2	480Mbps
USB 3	4.8Gbps
USB 3.1	10Gbps

When you connect two devices that operate at different speeds, the data can only be transferred at the lowest data rate, as the slowest one will not be able to keep up with and understand the fastest one. For example, if you use a USB-to-serial adaptor, the USB port will be able to operate at many Mbps or even Gbps but the serial end of the adaptor can only transfer data at at a maximum rate of 115kbps.

The MERG series of CBUS modules operate at 125kbps. So, the modules communicate with each other at a data rate of 125kbps. However, if you use their CAN-to-serial adaptor (the CAN_RS) the communication between the computer and the modules is limited to 115kbps. This should not cause any problems unless a layout has a huge amount of traffic on the CBUS which could potentially result in loss of some data. This possible limitation can be overcome if a CAN_USB computer interface is used, as this will communicate with

the computer at the full CBUS speed of 125kbps.
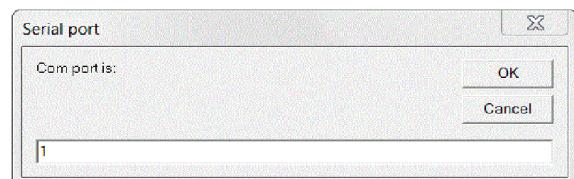
Using the serial port with a serial device

There are two steps to connecting a serial device to a computer's serial port.

- The first step is simple.   Take a serial cable and plug one end into the computer and the other end into the device!   In our realm, this might be a serial SPROG, a CAN_RS module, a Servo4 module, or a Lenz LI101F Computer Interface. Of course, the device will need to have its own power supply connected.
- The second step is to ensure that the necessary application software to control the device is installed on the computer.   This may be Decoder Pro, MERG's CAN_RS software, Servo setting programs (Servoset or AltServo), etc.

Allocating a COM port

In most cases, when the software is run, it asks which serial port is to be used with the application, with some offering an enumerated list to choose from.   The computer supports a number of different serial ports, often numbered 1 to 4 but could go higher.

The user can simply try selecting each port number in turn until the application works.   In well-written applications, entering the wrong port number simply results in an 'Invalid port number' error message. The experienced user might wish to use Window's Device Manager to examine which COM ports may already be in use.

One benefit of using a genuine serial port, compared to USB ports (or USB to serial adapters) is its robustness.   If the device temporarily loses power or the cable disconnects, the system will begin working again as soon as the power/connection is restored. Such glitches in USB-connected systems could prove more of a problem.

USB

All new computers have USB ports, with up to six external ports being common.

USB (Universal Serial Bus) is designed to connect external peripherals such as mice, keyboards, scanners, digital cameras, printers, memory sticks, hard disks, networking components, etc. to computers.

It has become the standard external connection method for Windows, Macs and Linux. USB and RS232 ports both send and receive data in serial format – but the format of each is different (in terms of speed, data format, etc.)

What does USB offer?

The advantages for model railway systems include:

- Can handle full CBUS data rates, unlike RS232.
- Never run out of interface ports, even with many devices attached.
- Overcomes lack of serial ports on many modern computers, despite some devices still using serial interfaces (e.g. Servo4, serial SPROG).   Solved with USB to serial adapters.
- Good noise immunity (see later)
- USB ports can supply some power to externally connected devices.
- Like RS232, you don't have to open the computer case to add extra devices.
- USB devices can be *'hot swapped'* - fitted and removed without rebooting or reconfiguring the computer. If a new device is plugged in while the computer is switched on, it may be configured with no need to throw DIP switches, add/remove jumpers or determine IRQ settings or I/O

addresses.

USB Speeds

The table shows the maximum data rates for different USB versions, measured in millions of bits per second. The actual data rate is usually lower, due to protocol overhead.

USB Standard	Description	Max Data Rate
USB 1.1	Low Speed	1.5Mbps
USB 1.1	Full Speed	12Mbps
USB 2	Hi Speed	480Mbps
USB 3	SuperSpeed	4.8Gbps
USB 3.1	Superspeed+	10Gbps

The early USB standard, USB 1.1, is only found in the very earliest computers with USB. Most computers have either USB 2.0 or USB 3.

The lower rate of 1.5Mbps was intended for slow devices such as keyboards and mice, while Hi Speed USB, SuperSpeed and SuperSpeed+ are designed for for quick data transfers on external drives, quick copying, and for playing video.

For our purposes, even the slowest implementation of USB has a faster maximum data rate than CBUS. So, all computers with USB ports, even old computers, should run CBUS quite happily.

USB Cables

Unlike the multi-wiring of 9/25 pin serial ports, USB 1.1 and USB 2 cables are light and flexible containing only four wires. They have two wires for power (+5 volts and ground) and a pair of wires to carry the data. There may be a fifth connection at the computer end, wired to a protective shield around the USB cable. USB 1.1 and USB 2 use a twisted pair for the data wires, to reduce noise and crosstalk. To achieve its higher data rates, USB 3.0 cables use two pairs of shielded data wires.

The maximum length of a standard USB 1.1 and 2 cable is 5.0 metres (16.4 ft).

The USB 3 standard only requires that the cable meet its electrical specification, although a cable that uses AWG26 copper wires is limited to 3m (9.8 ft).

With most electronics, the voltage readings are taken with respect to ground (e.g. 5v higher than ground). USB uses *'differential signalling'* instead. The receiving device reads the difference between the two signals wires D- and D+ and ignores the wires' voltages with respect to ground. This increases the system's noise immunity and minimises problems of unwanted electrical interference.

Can the 5m length be increased?
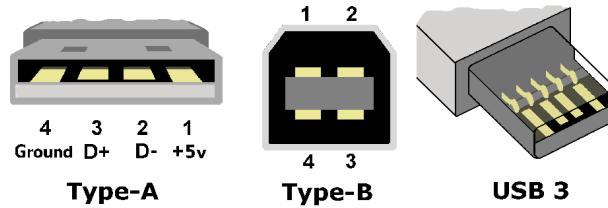
While some enthusiasts have a computer dedicated to their model railway operations, others may have their computers installed some distance from their layouts.

USB cables of 5m in length are readily available but care should be taken with *'USB Extension Cables'*. Extension cables have a plug on one end and a socket on the other and one or more can be used to increase the cable length between the computer and the controlled device. Consequently, these cables can be used to exceed the cable length restrictions for USB. However, the length restriction exists for a good reason – it encompasses the permissible round-trip time delay of USB signals. If the computer's commands are not answered by the connected USB device within the allotted time, the computer treats the command as being lost. A safe way to increase cable runs is to use hubs

(see later).

USB Connections

A variety of plug types are used on the end of USB cables and the ones most likely to be used with model railway electronics are shown in the illustration.

The USB specification describes two main categories:

Upstream

These plugs and sockets are called Type-A (sometimes just *'USB-A'*) and are always used at the controlling *'host'* end– usually the computer.

Downstream

These plugs and sockets (Type-B or USB-B) are always used at an attached device.
The image on the preceding page shows a USB-B socket in use on a CAN-USB module and the same socket can be found on the Lenz USB interface module, etc.

So, in most cases, USB cables have a Type-A plug at one end and a Type-B at the other.

The table shows the wiring for each pin in USB 1 and USB2 connectors.   The illustration shows the connections on the plugs. The wiring on the sockets are reversed, so that the +5v on the socket connects to the +5v on the plug, and so on.

Pin	Purpose	Colour	
1	+5V	Red	
2	D-	White	
3	D+	Green	
4	Ground	Black	

As the illustrations show, the connectors have power pads that are longer than the data pads. This ensures that the device is powered up before data signals are applied.

USB 3 connectors have the same four connection pads as earlier versions but have additional contacts recessed into them.

These additional contacts provide the extra data lines for the SuperSpeed signals.

Note

Smaller USB connectors are available. These are known as Micro USB and the older Mini USB and were introduced for connecting small devices such as PDAs, mobile phones and digital cameras. They are not common on model railway devices.

Are they all compatible?

All USB systems maintain backwards compatibility.   This means that older specification devices still work on newer ports.   So, a USB 2.0 device can be work with a USB 1.1 port, but only at USB 1.1 speed. A USB 3 device will connect to either older port (USB1.1 or USB2) but will only perform at the data rate of that port.

Mechanically, they will all connect although, because of its extra connections, the USB 3 plugs and port sockets are deeper than earlier types.

Power from USB?

The computer's USB ports can provide power to any low-power devices that connect to it., eliminating the need for the external device to have its own power supply.

Low-power devices (such as a mouse or a keyboard) can draw their power directly from the bus. High-power devices (such as printers and scanners) have their own power supplies and draw minimal power from the bus.
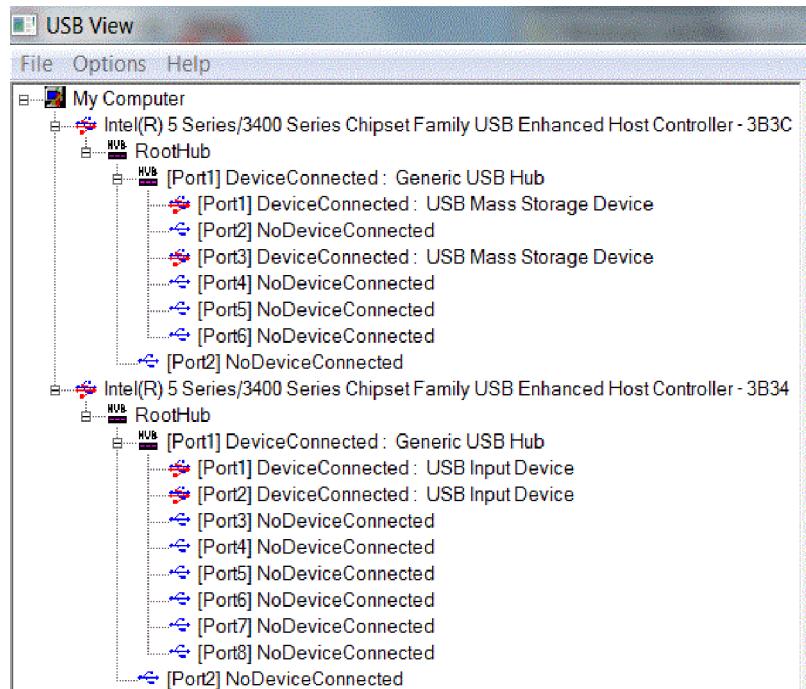
USB 1.1 and USB 2 ports are capable of providing a <u>maximum</u> of 500mA at 5v, while

USB 3 ports can provide up to 900mA. These figures are for the <u>total</u> of all devices connecting to a USB port.   If the power requirements of device, or a collection of devices, exceeds the port's limit, the computer will turn off the port.
So don't be tempted to use the USB port to power modules, relays, LEDs, desk fans, drinks warmer pads, etc.

What are USB hubs?

USB uses a master/slave implementation.   The computer host is the master controlling all bus traffic. This is achieved by having a host controller that handles a *'root hub'*.
All devices connect to the computer through a root hub.   Some computers now have two controller and two root hubs.   With all the functions (controlling power, enabling and disabling ports, etc.) being handled inside the computer, external slave I/O devices are simplified and cheaper to make.

Microsoft has a utility called USBView that can be downloaded from its website. This provides information on the hubs in use on your computer.

In the example shown, the computer has two host controllers and two root hubs.   Two of the ports are used for connecting to memory cards readers built in to the computer, while the other root hub has two input devices (USB mouse and USB keyboard in this example) attached externally.

External hubs
As computer users, we are more familiar with external hubs.
They come in a range of shapes but they all have multiple input USB ports and a single lead to connect the hub unit to one of the computer's USB ports.   A hub therefore connects a group of devices to a single connection point.

So, for example, a laptop with only two USB ports can be expanded to allow the connection of multiple USB devices (e.g. external mouse, keyboard, CAN_USB3 module and a

SPROG) all at the same time.

External hubs are of two types:

Bus-powered

Bus-powered hubs use the power supplied from the computer's USB port to supply their internal electronics.   With a permitted maximum of 500mA, a hub often uses 100mA, leaving 100mA to each of its four downstream devices.

Self-powered

Self-powered hubs have their own mains power supply and can supply 500mA to each of its downstream devices.   This allows further hubs to be connected downstream (see next).

Like USB ports, hubs are built to standard USB 1.1, 2.0 o r 3 specifications.

Devices connected to a USB 1.1 hub will only operate at USB 1.1 rates.

On an USB 2.0 controller, standards can be mixed; a connected USB 1.1 device can operate at USB1.1 speeds while a USB 2 device can operate simultaneously at USB 2 speed.

When purchasing a hub, make sure that you check their speed.
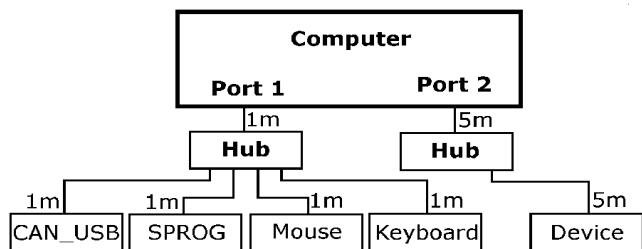
Cheaper hubs only operate at USB1.1 speeds.

Using external hubs

External hubs are employed for two reasons:

To connect multiple devices

If the handful of USB ports on a computer are insufficient, hubs allow additional devices to be connected. In fact, up to 127 devices can connect to a single USB port if hubs are used to expand the system.

The diagram shows a PC with two USB ports.   Port 1 connects directly to a hub and this has four outlets connected to typical USB devices.

If you have greater connections needs, you can replace one of the attached devices with another hub. This will provide further connection ports.   In this case, however, the original hub will have to be a powered type, as an unpowered hub would be unable to handle the anticipated extra power requirements.

In fact, USB supports a tired network of hubs cascaded up to five levels, providing for a maximum of 127 devices attached at any one time.   As expected, the port's bandwidth has to be shared between all the devices connected to it.

To overcome distance limitations

In the example, all the cables attaching devices to Port 1 are shown as short 1m lengths. Due to timing restrictions, an individual USB cable cannot be longer than 5m. In the example, Port 2, connects to a hub over a 5m cable and the hub's connection to the device is a further 5m in length.   The 10m coverage should be sufficient for most people's needs. However, the USB 2.0 specification allows up to five hubs to be connected in a long tiered daisy chain.   If 5m cables are used between each connection, the maximum distance can be extended to 30m (although why would you want to operate your layout from a computer sited almost 100ft away?).

Note

USB is marketed as being 'hot-swappable', with USB devices able be added and removed at
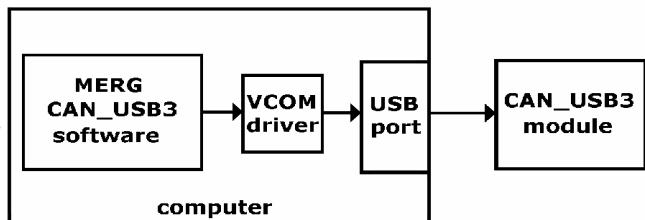
any time. This is not strictly true, otherwise Windows would not need to provide a *'Safely Remove Hardware'* facility!   The problem arises with the use of external storage devices. To prevent constant access to a hard drive, for example, software will not write data to it continually. Instead it will store some data in its cache (a chunk of memory) and only send the data in chunks.   If the user removes a drive before all its data is successfully stored, the file on the drive can be corrupted.

This is not a problem for model railway electronics which do not handle such large blocks of data to requires caching, so for example MERG's CAN_USB module can be inserted/removed without any problems.

What about Device Drivers?

There are many hardware devices that can connect to a computer and the computer has to be able to communicate with devices that have completely different methods of passing data. A device driver is a small piece of software that provides a properly functioning interface to a particular piece of computer equipment. The equipment might be external such as a printer, plotter, digital camera or monitor – or it might be an internal such as a graphics card. Take, for example, connecting a printer to a computer.   There are a huge range of printers, past and present, of different types (inkjet, laser, plotters, etc.).   Even printers using the same basic technology may provide different facilities and employ different methods to achieve the same results. and offering different facilities.   Since it is not practical to write a separate version of a word-processing package to interface to each available model of printer, the solution lies in placing a piece of conversion software between the word-processing package and the computer's printer port. This is called the 'device driver'. When the user prints a document, the material is processed by the driver software and sent to the printer in the specific format required by that particular printer model.

That explains why many products are packaged along with CDs containing their own device drivers. Microsoft Windows includes many commonly-used drivers along with its operating system.   However, unusual devices, including those for model railways, are not included in Windows and have to be installed by the user.

The illustration shows a MERG CAN_USB3 module attached to a computer's USB port. A number of applications can communicate with this module, either working as a *'sniffer'* allowing the user to view messages coming in from the module (e.g. track occupancy information) or sending messages to the module to operate devices on the CAN bus.

FTDI, the company that manufacture the UM245R USB interface module used on the CAN_USB3 module, provide an appropriate royalty-free driver (VCOM or VCP- Virtual COM Port) from their website. It is packaged as the *'Combined Driver Model'.*   This driver emulates a standard PC serial port, saving program writers from the many complications of handling USB communications.

When a user sends a message using the application software, the following things happen:
- The software writes a CAN bus message to the serial port.
- The VCOM driver intercepts this and translates it into a message for the USB port.
- The USB port sends the message to the CAN_USB3 module.
- The CAB_USB3 modules translates the message into a CAN bus message.

The original CANbus message remains the same throughout the process; it is only the way the message is packaged that changes with each step.

Although it looks a bit over-complicated, it is the easiest way to do things, as many existing applications are written for serial ports. In addition, routines for reading/writing with serial ports are provided in a number of programming languages.

Installing a device driver

There are a number of ways that a device driver can be installed

If Windows recognises the device, one of these happens:

- Windows automatically installs the specific associated driver from its own collection that was stored on the hard drive during the installation of the operating system.
- Windows automatically installs a generic driver (one that is common to many similar devices) from its collection.

In these cases, a message might pop up to inform the user that the device is successfully installed.

If Windows does not already have the driver, it gives the user three options:

- Windows will search the Internet for the driver, then install it.
- Windows will search the computer, or CD/DVD drive, looking for a folder that might have the driver stored there. If it finds it, Windows installs it.
- The user can tell Windows which folder to find the driver.

This may result the user being given the choice from a small menu of drivers and the user must select the one that exactly matches the device.

There are variations on this procedure.   Some manufacturers specify that their driver should be installed prior to installing their device.   Others place an auto-run, menu-driven installation routine on their CD.   In some cases, the computer has to be-booted after installing a driver. Windows may prompt for a re-boot, or it may be stipulated in the device's manual.

Note

Depending on the specific computer architecture, drivers can be 8-bit, 16-bit, 32-bit, or 64-bit. This corresponds directly to the architecture of the operating system for which those drivers were developed. For example, in 16-bit Windows 3.11, most drivers were 16-bit, while most drivers for 32-bit Windows XP are 32-bit. Modern 64-bit Linux and Windows versions have required hardware vendors to provide newer 64-bit drivers for their devices.

Using a USB device with a USB port

Having read all the above, there is not much to say about this.   Just plug the USB device into a USB port and, assuming that any necessary device driver is present, the device (and its controlling software) is ready to use. Examples here are memory sticks, Bluetooth and WiFi dongles, mice and keyboards – not forgetting the CAN_USB3 module.
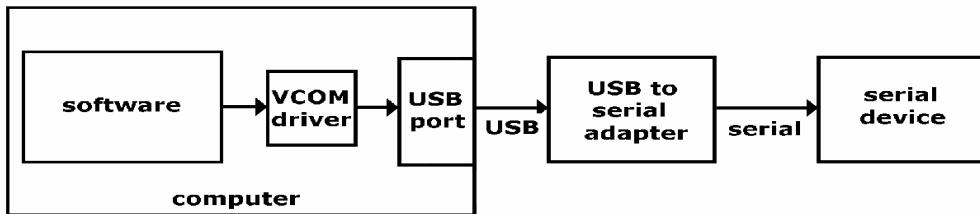
Using a serial device with a USB port

At one time, all older computers had serial ports.   While serial devices (e.g. the Servo4 and CAN_RS modules) are easily used with serial ports, they cannot be used with modern USB ports. This is solved with the use of a *'USB to serial adapter'*.   It does what it says on the tin; it is a piece of hardware (often built into a cable) with one end plugging into the computer's USB socket and the other end plugging into a serial device. The adapter's hardware

carries out the conversion between USB and serial formats.

The illustration shows the steps involved in using a serial device (e.g. Servo4 module) on a modern computer that only has USB ports.

The module's control software writes to a serial port but, since the computer has no serial ports, the drivers and adapters are used to transport the data to USB and then back to serial before connecting to a serial device.
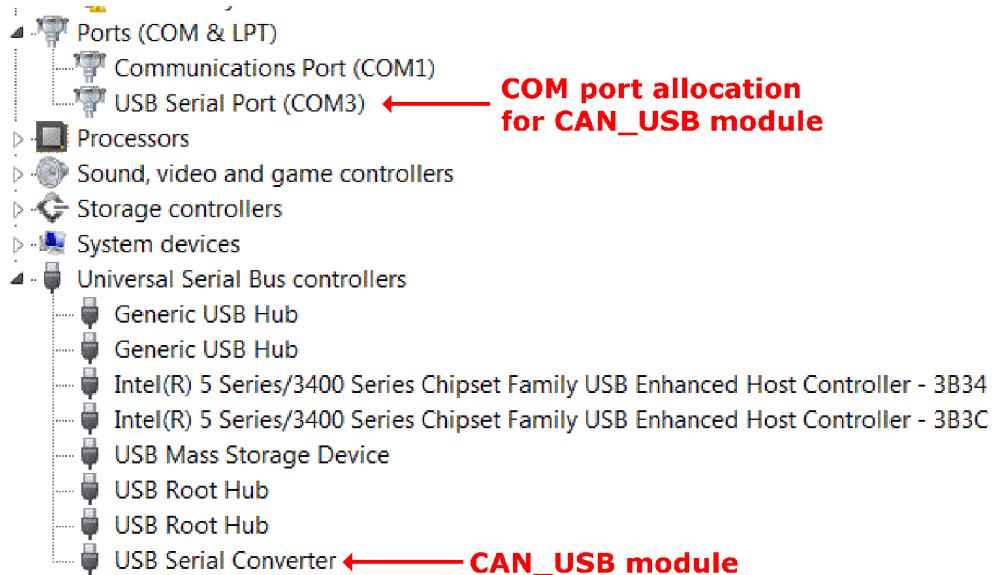
COM ports

When software is run that accesses a serial (or in our case a virtual COM port), it asks which serial port is to be used with the application.

Although we are using a USB port for the external connection, the software still has to be allocated a serial port number to associate with the virtual driver.

Once a COM port is allocated, the process shown in the above illustration is established.

The illustration below shows the entries in Device Manager after connecting a CAN_BUS module.

In this example, COM3 has been automatically allocated to the module and this value is the one to enter into any application software when prompted for the COM port number.

Note

It cannot be assumed that the COM port allocated will be the same each time the device is plugged in.   So, for example, if another device is already allocated to COM3, it will use the next available COM port. With a computer dedicated to layout control, such changes are less likely.

HyperTerminal can also be used to determine the COM port of a newly added USB device. Just check the available ports before adding the device and any new COM port added after inserting the device is listed.   Hyperterminal is not available in Windows 7 but it can be

copied across from an existing XP computer; Google for details.
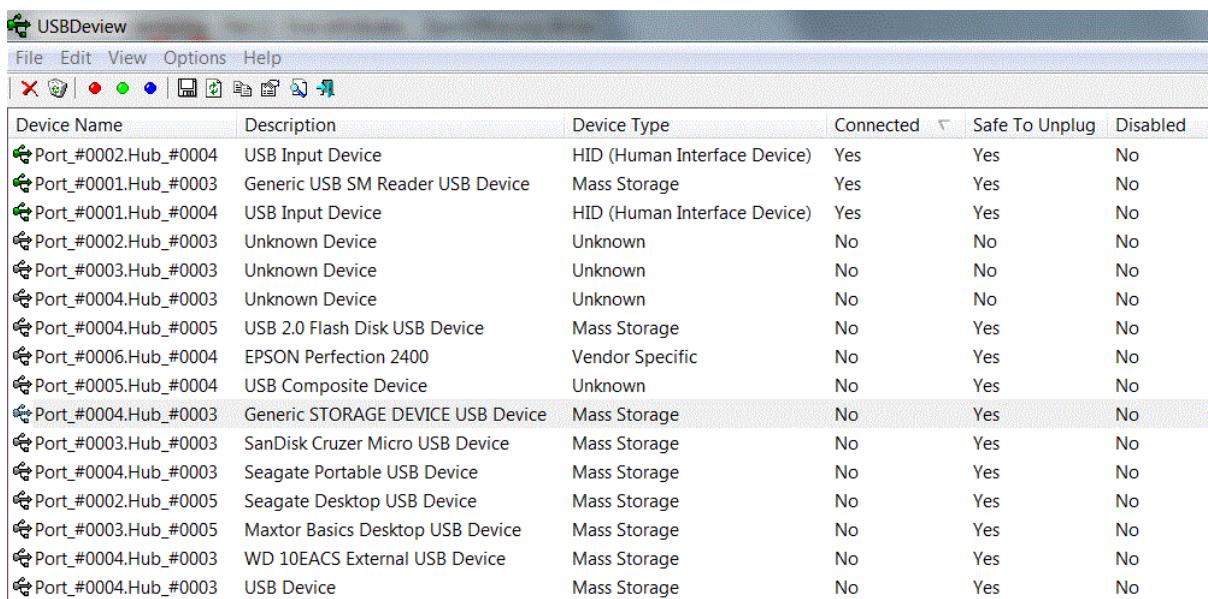
USB Problems

As mentioned before. the serial port is a robust, if slow, communication mechanism. For example, if a serially-connected device temporarily lost power or had its serial cable temporarily disconnected, the port, the software and the modules would all work as normal as soon as the cable/power was restored. This without any additional action by the user. With USB, on the other hand, the loss of power or cable disconnection affects a USB connection badly.   In both cases, the voltage from the device's pull-up resistors would be removed and the hub would detect this and disable the port. The usual remedy is to unplug and re-insert the USB cable, so that the device is detected and configured once again. As a consequence, the application software usually has to be restarted.

When a USB device is enabled, its driver software is located and loaded into memory. When that same device is unplugged, its port is freed and its driver is unloaded from memory.

However, the computer stills stores information about that device and its connection in the Windows Registry (use regedit to look under the 'Enum' key in the HKEY_LOCAL_MACHINE folder – but don't alter anything unless you know what you are doing).

The illustration shows a computer's USB enumerations, as viewed by USBDeview, a freeware utility that improves on Microsoft's USBview and on Device Manager.   While Microsoft's USBview utility only allows viewing of port information, USBDeview has options to disable and/or uninstall device allocations (when run using Administrator rights).

USBDeview

File   Edit   View   Options   Help

Device Name	Description	Device Type	Connected	Safe To Unplug	Disabled
Port_#0002.Hub_#0004	USB Input Device	HID (Human Interface Device)	Yes	Yes	No
Port_#0001.Hub_#0003	Generic USB SM Reader USB Device	Mass Storage	Yes	Yes	No
Port_#0001.Hub_#0004	USB Input Device	HID (Human Interface Device)	Yes	Yes	No
Port_#0002.Hub_#0003	Unknown Device	Unknown	No	No	No
Port_#0003.Hub_#0003	Unknown Device	Unknown	No	No	No
Port_#0004.Hub_#0003	Unknown Device	Unknown	No	No	No
Port_#0004.Hub_#0005	USB 2.0 Flash Disk USB Device	Mass Storage	No	Yes	No
Port_#0006.Hub_#0004	EPSON Perfection 2400	Vendor Specific	No	Yes	No
Port_#0005.Hub_#0004	USB Composite Device	Unknown	No	Yes	No
Port_#0004.Hub_#0003	Generic STORAGE DEVICE USB Device	Mass Storage	No	Yes	No
Port_#0003.Hub_#0003	SanDisk Cruzer Micro USB Device	Mass Storage	No	Yes	No
Port_#0004.Hub_#0003	Seagate Portable USB Device	Mass Storage	No	Yes	No
Port_#0002.Hub_#0005	Seagate Desktop USB Device	Mass Storage	No	Yes	No
Port_#0003.Hub_#0005	Maxtor Basics Desktop USB Device	Mass Storage	No	Yes	No
Port_#0004.Hub_#0003	WD 10EACS External USB Device	Mass Storage	No	Yes	No
Port_#0004.Hub_#0003	USB Device	Mass Storage	No	Yes	No

Note that only three devices are currently connected (a mouse, keyboard and memory card reader). All other entries describe devices that were previously connected to various ports. Hub #003 is actually Hub 1, Hub #004 is actually Hub 2, while Hub #005 is an external hub.

Chapter 18

Assembling a tool kit

Assembling a tool kit

You may already have a selection of tools that you use for building your layout and some of these will also be of use in working with electronics.

Those new to electronics often ask about which tools they should buy. This chapter looks at the wide range of tools that are available. Which ones you buy will depend on your needs – and your budget!

Investing in the correct tools will make life easier, safer, and also more enjoyable. Although you can sometimes get by with a minimal selection, it is best to always have the correct tool for the job. A screwdriver is for tightening and loosening screws; it should not be used as a chisel or a scaper. Similarly, don't be tempted to use the tip of your soldering iron as a lever to pull components off a board.

A minimum starter set

As a guide, everyone's toolkit should include:

- A soldering iron and solder
- A pair of pliers
- Cutters
- A selection of screwdrivers
- Wire strippers

These, and other tools, will be looked at later.

In the meantime, take care over the quality of the tools you buy. The very cheap tools and kits of tools can cause both frustration and damage. If you buy a set of screwdrivers from a discount store, you may well find that they are made of inferior materials such as white metal and will distort during use. Their lifespan will be much shorter than a quality product. Even worse, they may chew the head of the screw that you are trying to extract, requiring it to be drilled out to remove it.

You may consider buying an off-the-shelf toolkit. These usually come in their own case and, if chosen carefully, can be a good starting point. However, it is a case of 'buyer beware'. If something seems to good to be true, it usually is to good to be true. You can hardly expect to buy a 60-piece quality toolkit for a small outlay. That said, some useful toolkits can be found marketed as 'PC Repair Kits'.

Tool collections are different from all-purpose toolkits and these can be useful. Sets of Allen keys (hex keys), socket sets, etc. provide a selection of sizes at a reasonable price.

Two other assets

Apart from tools, there are two other important assets that you possess.

Pencil and Paper

Don't rely on your memory; what you remember today may not be recalled next week. So write down important details (e.g. what colours of wire are used for particular purposes, what settings you have used, what options you have chosen, simple wiring diagrams, etc.).

Plenty of time and patience

Don't rush at a job. You may be desperate to see things working but that leads to mistakes and botched results. Accept that projects may take twice as long as expected and leave time to understand, plan and properly execute what you are doing.

Safety on the bench/layout

This chapter has to begin with some words of caution when working with electricity and with hand tools.

Model railway equipment runs at relatively low voltages but that does not mean that there are no potential threats to health and safety.

A few simple precautions, and a responsible approach, will ensure that the hobby can be enjoyed without any significant risk. The main areas of concern are listed below.

Electric shock

Although the equipment runs at low voltages, the power supplies that feed it connect to the mains supply. It should go without saying that you should not open up mains power supplies unless you really know what you are doing. There is 240V AC lurking inside these units, which can be lethal.

Here are a few simple rules:

- Ensure that power supplies are safe. Check the power cable for any damage such as cracked or burnt insulation, cracked or bulging plastic casing, broken or loose plugs.
- If you are in any doubt, you can check whether any metal surfaces are live to the mains by touching it with a *'mains tester screwdriver'* as shown. If the neon inside the handle lights, the surface being touched is live. The tester can be used with no risk to the user as the handle and shaft are insulated.
- If your mains-powered unit blows a fuse, ensure that the replacement is of the same rating as the original. If a plug has a 5A fuse, do not replace it with a 13A fuse – it uses a 5A fuse for a reason. Of course, the unit that blew the fuse should be thoroughly checked before being used again.
- If your layout is in a damp environment, you may consider fitting an RCD (Residual Current Device) between your power unit(s) and the mains outlet. An RCD device monitors the current passing through it and switches the power off very quickly (30 to 50 milliseconds) if the normal current balance is upset (e.g. a leak between live and earth). Some exhibition managers prefer to have these on every layout in their show where the hall does not provide this in their wiring.

Risk of fire/burns

Although electric shock is a very serious condition, it is rarely a danger for modellers who follow some elementary precautions.

More common are the minor accidents that occur at the workbench, mainly burns and cuts. Some pieces of equipment consume very little current and produce very little heat – unless things go wrong. Other modules are designed to handle larger currents and have components that are fitted with heatsinks, a piece of metal with fins designed to dissipate the unwanted heat.

A short on a board, or other fault that results in excess current, results in excessive heat being generated. For example, if a 12V module suddenly shorts and draws 2A, the module is now dissipating 24 Watts, mostly in heat. If the unit has a thermal cut-out, things may be controlled; otherwise, you have the equivalent of a soldering iron inside your plastic box! The other danger, and probably more common, are the risks of minor to serious burns when using a soldering iron.

- If you smell burning, or see smoke, turn off the module's power immediately. If you are working in an enclosed space, you may want to open a window to dispel any possible toxic fumes.
- If you are building a module that handles large currents, fit heat sinks to the power transistors and the voltage regulator.
- Do not overload a circuit by adding extra modules beyond the supply's working capacity.
- Heat sinks can get very hot, even during normal operation. So, use caution when touching a heatsink.
- The soldering iron should stay in its stand/holder when not in use. Do not leave it resting on your workbench; that is an accident waiting to happen.
- If the soldering iron should fall from your bench, your instinct is to catch it – Don't! Let it fall then carefully pick it up by its handle.
- Take care when soldering. This is when most accidents occur. While concentrating on juggling wires, components, soldering iron and solder, it is easy to accidentally touch the soldering iron or the work being soldered.
- Use aids that support the work being soldered (see later). This prevents burns caused by touching the objects being soldered; the heat from the soldering iron conducts along the metal and the soldered joint takes a little while to cool down.
- Wherever possible, avoid soldering joints that are above you, such as under baseboards. Stray blobs of falling solder are a real danger to your face and eyes.

Risk of fumes / poisoning

Electronics components can contain toxic materials which can be released if mishandled. Some solders also fall into this category. Many users find 60/40 solder (i.e. 40% lead) much easier to work with than lead-free solder. Unfortunately, over-exposure to lead can affect the nervous system, the heart, bones, kidneys, etc. That is why lead is banned in paint, petrol, etc. 60/40 solder is still widely available and in regular use by hobbyists and is safe if handled correctly.

- Avoid the temptation to hold small components or solder in your mouth while you are working.
- After a soldering session, wash your hands before eating.
- Avoid the fumes that are generated while soldering. Work in a well-ventilated area or use a fume extractor. A cheaper alternative to an extractor is to use a 12V fan recovered from an old computer to blow away the fumes.
- Burning plastic is particularly nasty, releasing very toxic dioxin fumes. If you come across burning plastic, hold your breath, switch off power to the module, open a window and quickly leave the room
- Most printed circuit boards are made from a material called FR-4. The 'FR' indicates that it is flame retardant. However, if any components on that board overheat or catch fire, the board will give off highly toxic halogen fumes. In that event, take the same actions as listed above.
- Caution should be observed when sawing or filing boards or components, to avoid inhaling the dust; or use a fume extractor/dispenser.

Risk of cuts

As a railway modeller you have doubtless already suffered a number of cuts and the same advice applies to working with electronics.

- Use a wire stripper to remove insulation from wires (see later).
- Do not attempt to cut materials with a blunt knife. The blade is likely to skid off the work and cause damage elsewhere, including you.

- Use the correct knife for the job (see later).
- Beware cheap quality knives that may break during use.

Risk to eyes

While modellers are usually aware of the risks of burns and cuts, eye protection is often overlooked or seen as a burden.   Taking risks can result in temporary or permanent damage to the eyes.   The main risks are irritation or damage from fumes, dust or particles from sawing, grinding, filing, and solder blobs being accidentally flicked while soldering.

- For fumes, read the preceding section.
- Use safety glasses while working.
- Alternatively, view the job you are working on through an illuminated magnifier glass (you may already need this because of failing eyesight)

Risk to circuit

Apart from keeping yourself safe, you want to avoid damaging your project.
Static electricity can destroy some sensitive components and spilled fluids are the enemy of all electronic circuits.

- When working with integrated circuits that are sensitive to static, always take steps to avoid static build-up on your body.   The commonest method is to touch a bare metal area of a radiator to disperse the charge before handling chips.
- A cheap but effective approach is to use an anti-static wristband. The strap attaches to your wrist and the clip is attached to any ground connection. Do NOT make your own as the commercial band includes a high value resistance to prevent any high current flowing through its wearer.
- Regular users might want to invest in an anti-static floor mat. This prevents static from building up on the body.
- Avoid having fluids on the workbench.   A spilled coffee can wreak havoc with your electronics project – and can be dangerous if spilled over mains-powered equipment.
- The single biggest threat to a project is connecting it to power before carefully checking it over. Any mistakes can lead to the destruction of some components.
- Do not solder components while the module is still connected to a power supply.
- Use insulated tools while working on projects that are connected to power.   Sometimes you have to make adjustments on live modules and the insulation prevents accidental shorting.
- Be aware that large capacitors, like those used in capacitive discharge modules, can maintain a high voltage for some time after the power is disconnected.

Of course, there are other things that can damage a project and/or its components.   Issues such as inserting components the wrong way round, inserting the wrong component, etc. These are not strictly health and safety issues although they can be costly and can cause damage in some cases. These issues are covered in the chapter on fault finding.

The work area

An organised work bench is a major contributor to safety.

- Have a well-lit work area.
- Have an uncluttered and clean work area, with only the things you need on the bench or to hand. Remove any flammable objects, drinks, etc.
- Have the appropriate tools to hand before starting a project.
- Do not remove safety shields or other protective devices from your tools.

- Maintain your tools in good working order.
- Have a printed copy of project's circuit diagram and assembly instructions.
- Read through the instructions before you begin.   This will minimise errors and prevent expensive (and maybe dangerous) mistakes.
- If your tools need special handling, familiarise yourself with them.
- Make sure you switch your soldering iron off when not at the bench.
- What about having a First Aid Kit handy?

Finally ...

The above pages try to point out potential working hazards and how to avoid them. In practice, you may never come across many of these dangers.   However, knowledge of them and an alert mind goes a long way to having fun in a safe environment.

Electronics/Electrical tools

The tools detailed in the following pages cover most of what you will ever need.   They are not intended as a shopping list; you will find a useful home for some of them and may decide to add others to your collection as you progress.

Cutters / strippers

You will often need to cut wire to specific lengths for your projects and to trim the wires from resistors and capacitors. You should have a pair of wire cutters reserved for that job alone.   Wire cutters, often known as *'diagonal cutters'* or *'side cutters'*, are designed for that task and are a good investment.

Cutting wires with scissors or knives will result in an inferior cut and will blunt or chip these tools more quickly as a result.   The added effort in using these tools also makes their use more dangerous than the tool designed for the job.

Rail cutters

These are designed to produce a clean flush cut of the rails of 00, HO and N gauge track.   The sides of the cut ends are smooth and free from burrs and any rounded edges.   The results are quicker and superior to using a razor saw or a Dremel cutting disc.

Again, these cutters should only be used on track.   Cutting wires with rail cutters can damage the cutting edges of the tool.

Wire strippers

Removing the insulation from the end of a piece of wire to expose the copper is a regular task for modellers.   Some users cut round the insulation with a knife and prise the unwanted insulation free.   Others use wire cutters to *'nip'* the insulation before pulling the unwanted section away.   The danger is that the copper wire is nicked in the process making it vulnerable to breaking in the future.   The images show two tools that do an efficient job of removing the unwanted insulation without damaging the copper wire inside.   The blue handled strippers are adjusted with a screw to the desired setting before stripping.   The red handled version has preset blades of different gauges along its length.

Screwdrivers / nut drivers
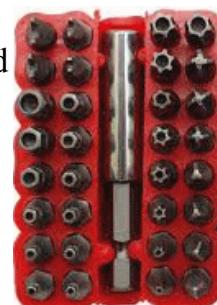
You probably have some of these already and it is useful to have different sizes of each type.

The three most common types of screw and bolt are shown in the illustration and it is best to use the correct screwdriver for each type, to avoid chewing the head of the screw or bolt.

The most common type is known as the *'Standard'*, *'Flathead'* or *'Slotted'*.

You may come across other types such as the hex, Torx, square, tri-wing and a range of tamper-free screws intended to keep the amateur from opening devices and equipment cases. The picture shows a set of these screwdriver bits that is used for handling these more unusual types.

The advantage of having separate bits is that you can use them with a ratcheting handle for quicker insertion/removal or for use in confined space where there is little room to manoeuvre.

Electric screwdrivers are available and are useful where there is a lot of screws to be fitted, such as constructing a baseboard.

Another possible purchase is a set of jeweller's screwdrivers. These miniature screwdrivers are useful for handling small screws, adjusting trimmers and working on locomotives.

They are sometimes also known as watchmaker's screwdrivers

Nut driver

You will use nuts and bolts to connect things together, such as constructing a case or panel, securing switches to panels, bolting voltage regulators to heatsinks and so on.

Do not be tempted to use pliers to tighten the nuts, as the effort is likely to result in slippage and the edges of the nuts being rounded off.

Nut drivers, also known as a nut spinners are designed for the safe tightening and loosening of nuts.

They are available as sets, as shown in the image, or as a single handle with a set of interchangeable sockets.

The smaller ones can also be used with a loco's crank-pin nuts.

Pliers

Completing the trio of indispensable items is one or more pairs of pliers.

They are used for holding small objects, bending wires, holding wires during soldering, straightening pins, tightening rail joiners, inserting/removing track pins and a host of other tasks.

The images show two pairs of needle-nose pliers, also known as long nose pliers. They are available in both straight and bent angle versions and the ones shown are fitted with springs which open the jaws when pressure on the handles are released.

Electricians and other tradesmen often use combination pliers to bend and cut wire and cable. They are larger and have flat edges on the nose and often incorporate cutting blades. They should NOT be used to tighten larger nuts – that's what a spanner is for!

Seeing what you are doing

Electronics makes use of small components and cramped tracks on printed circuit boards and stripboard.

A well lit work area is important, as is the ability to inspect your work at close quarters.

Sometimes, these two features are combined, with illuminated desk magnifiers. These are available with a heavy stand (as shown) or with a clamp to secure it to the desk. The one shown is particularly useful as it has a smaller lens built into the main lens. The main lens is used while doing general soldering and construction, allowing hands-free operation. The smaller lens has greater magnification for close inspection of the completed job, looking for dry joints, solder blobs, etc.

While a normal eyeglass like the one shown on the left is useful for close inspection it has one problem – the closer you get to the work, the more you obstruct light getting to the circuit being examined. This can be overcome by using an illuminated 'Jeweller's Loupe'. A small internal battery powers a bright LED that shines on the circuit. Combined with its magnification properties, it is a very useful inspection tool.

If you find working under a magnifier stand too restrictive, you may want to consider a headband with built-in magnifiers. This allows you to work hands-free over a larger area, if you don't mind wearing the headgear. The image shows the popular Optivisor which is available with a range of lenses of varying magnification, from 1.5X to 3.5X. The Optivisor can also be worn over a user's prescription glasses.

If you have good eyesight but want to work in the dark area under a baseboard, you can buy a headband with built in LED lamp. These are cheap and are powered from a built-in battery. These are better than a normal torch which requires to be held or strapped to a surface during your activity.

If you want to work in a darkened space, but have poorer eyesight or need to work with small parts, then you can buy a headband that combines a light with a magnification lens.

Finally, you may consider buying a small dental mirror or a mirror that it attached to a telescopic handle.
This allows you inspect awkward areas tight spaces, round corners, behind objects, etc.

Holding the work

Sometimes construction can be a really fiddly business. Trying to hold the soldering iron and solder, along with the items to be soldered makes you feel that you could benefit from having extra hands.

Thankfully, a range of tools is available to help out. They are designed to hold the items to be soldered, leaving you with only the soldering iron and solder to handle.

The most common aid is the *'Third Hand'* shown in the image. The alligator clips are attached to a heavy base and are adjustable. They hold the work in place, leaving you free to solder. Some, like the one shown, also provide a magnifying glass while others may include a solder mop and/or storage tray for the parts you are working with. Modellers also tend to use the clips to hold items that are being painted or glued.

Tweezers

The tips of most tweezers are normally open and are closed together by squeezing on their sides. This is handy for picking up and laying objects. A variation on these are the *'cross action'* or *'reverse action'* tweezers. Their sides are normally held closed and need to be squeezed to open them. This reverse action allows wires and components to be held securely while you solder them. The type with the flat grippers on the tips, as shown, can also be used while soldering LEDs to boards. If the leads between the LED and the board are gripped by the tweezers, it prevents excess heat from the soldering iron being conducted up into the LED and causing damage if soldering takes too long.

A similar tool is the *'Hemostat'*. It looks similar to a pair of scissors. The blades are replaced by the holding tips and you will notice that there are two projections close to the finger holes. When you close the jaws over, the friction between these projections locks the tips onto your wire or component.

The above tools are for holding items during soldering and construction. There are another couple of tools that are useful. The upper one in this image is a *'prong holder'*, sometimes called a *'part picker'*. When the cap on the top of the holder is pressed by your thumb, prongs pop out from the other end. The prongs are placed round an object and when you release your thumb, the jaws retract and hold the object. It is able to pick up small parts that you would find difficult to fetch with your fingers. It is also useful to place small screws in their wanted locations.

The other tool is a telescopic magnetic retriever. As the name suggests, it is ideal for recovering small screws or bolts that you have dropped into areas that are difficult to access. It is simply a telescopic rod with a magnet on one end, although some also have a light to help locate a dropped part.

Soldering tools

These tools are so important that they can be found in the chapter on soldering.

Other useful items
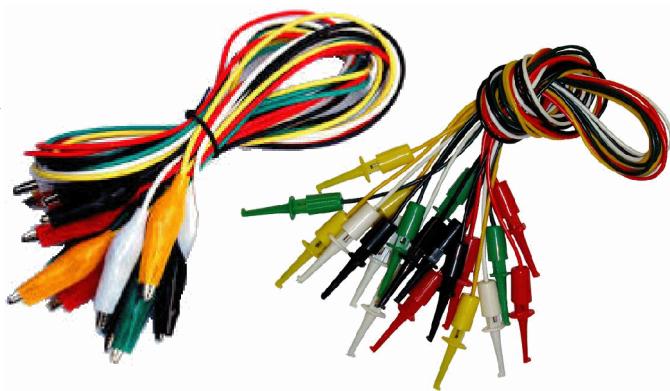
There are a number of other tools and aids that can make construction easier.

Test leads

There are many occasions when you want to make temporary connections, without the fuss of soldering and unsoldering components or wires.

The set of low voltage jumper leads shown on the left is cheap and is supplied with leads of different colours to aid recognition when a number are used on a project. They have croc clips on the ends of each lead and they clip on to component leads, tag strips, etc. If you are working with smaller components or have less room to work in, the leads on the right use mini grabber probes to make the connections.

IC Insertion/Extraction tools
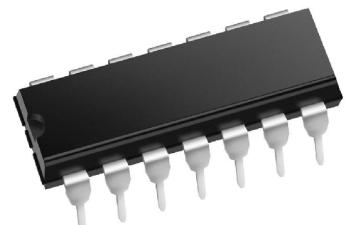
Many projects make use of integrated circuits and these have rows of pins that are pushed into an IC socket. Trying to get both rows of pins lined up to insert without bending the pins can be tricky. The more pins on the chip, the trickier it becomes.

It is also difficult to remove a chip from its socket. Levering it out with a screwdriver, for example, will often bend or break the pins.

The upper tool in the image is used to extract a chip from its holder. The prongs are clipped under the top and bottom of the chip and then the chip is pulled out vertically with a very slight rocking motion, avoiding bending the pins.

The lower tool can also be used to remove a chip from its socket by clipping it under the sides of the chip and pulling vertically. It is also used to insert a chip into a socket as the pins are held in place by the tool during insertion.

Crimping Tool

A number of modules that you will come across use *'crimp terminal'* plugs and sockets to connect the module to power or to other devices. These plugs and sockets are 'keyed' so that they cannot be inserted the wrong way round and are available in a number of sizes; the image shows a 5-way connection.

The plugs are soldered to the module's board while the sockets use a terminal housing and a set of crimp terminals (see the image).

The crimp terminals have to be connected to the wires before inserting into the terminal housing, where they click into place.
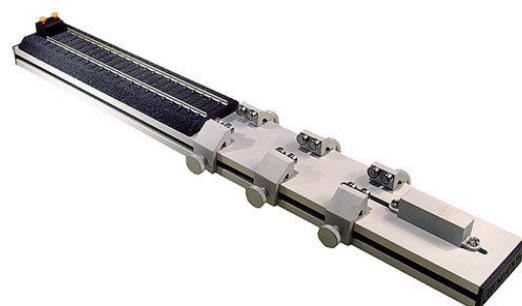
With a little practice, wires can be soldered to the crimp terminals but the professionals use a crimping tool to do the job. The bare end of a wire is inserted into the terminal and placed in the jaws of the crimping tool. Squeezing the handle results in a strong mechanical joint.

Rolling road

A rolling road is a replacement for a length of test track. If you need the loco to run for some time, the test track has to be formed as a circle. This largish board is often inconvenient, as it has to be kept close to where you are working, or you end up carrying the loco between the workbench and the test track.

The rolling road is simply a set of rotatable metal discs on which the loco's wheels sit. The discs are powered by your supply and the loco remains stationary while its wheels spin on the discs.
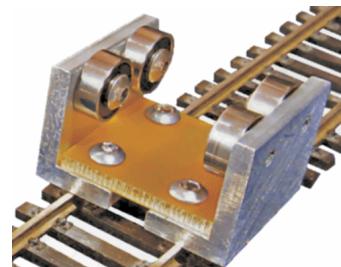
Rolling roads are ideal for:

- Running in a loco
- Warming up a loco before using it at an exhibition
- Setting a DCC decoder's CV settings
- Testing radio controlled locos

Rolling roads are available for scales from N through to gauge 1. The upper image shows the Hornby rolling road, where the rolling discs are adjustable along slides.

The lower image shows one that sits on any existing piece of track, getting its power from that track. These would be used in sets, depending on the loco's wheel configuration.

Test tools

If everything we built or designed, everything we ever wired up or connected, always worked first time, we would not need any test equipment to help us locate the faults. Since we are never that lucky, we need tools to help us. This is covered in detail in the chapter on *'Using test equipment'*.

Cleaning tools

Dirt is the enemy of model railway electronics. It interferes with successful soldering, it affects the performance of motors, it affects the efficiency of trackwork, and more.

Keeping the work area free from dust and debris is a simple task, requiring no more than a brush and/or small vacuum cleaner

For each of the other tasks, a range of cleaning tools is available.

Cleaning the board

If you are building a module you ought to clean the printed circuit board, or strip board, twice – once before soldering and once after soldering.

As explained in the chapter on soldering, surfaces to be soldered must be free from oxidation, grease, dirt, etc. The surfaces can be cleaned using either steel wool, fine grit sandpaper, or an ultra-fine abrasive pad.

A cleaning block can be used but ensure that it is not also used for cleaning track, as you can easily transfer dirt from the track on to the soldering surfaces.   Maintain separate cleaning blocks. Another tool is the fibreglass pen (supplied with refills). This cleans with little surface damage.   However, take a little care in use as small strands of fibre can break loose and these can irritate or damage your skin.

When the soldering on a circuit board is complete you may have some yellowish gunge on the surface. This is flux residue that needs to be removed.   The build up covers work areas making it difficult to check for dry joints, solder blobs, etc.   Since fluxes can contain acid, it can erode part of the copper tracks over time.

An old toothbrush is a handy tool for brushing away loose debris, while a wooden toothpick or careful prising with the tip of a screwdriver can break away stubborn buildup.

Servisol sell a cleaning solvent known as De-Flux 160 which produces a clean finish when sprayed on the affected areas. Or, use IPA (see later).

Cleaning the track

Problems of keeping the tracks clean are well known to all modellers.   The build up of surface dirt, grease or oxidisation results in poor running and the stalling of locomotives. There are two approaches to cleaning track – abrasive blocks and liquid solvents.

There are cleaning blocks, such as the PECO Rail Cleaner, designed for this purpose.   Do not use sandpaper, as this will scratch the rails and worsen future running.

If you can afford it, the Hornby R296 Track Cleaning Coach uses spring loaded abrasive pads to clean the track as it goes round your layout.   This takes some of the effort out of keeping the track clean as the loco can be set to make multiple runs round the main loops in the layout – while you do something more interesting.

A similar choice is available with solvents.   You can either clean the track manually, using a bottle of cleaner, such as Rail-Zip2 or LocoLube, and applying with a lint-free cloth (i.e. one that does does give off fluff when used).

A number of cleaning wagons are available that use solvent soaked pads to clean the track.

The Tomix 6421 Track Cleaning Wagon is a N gauge wagon that uses pads and cleaning fluid.

The image shows the CMX Track Cleaning Machine, an OO gauge wagon that offers both abrasive and solvent pads.

The Dapol B800 OO Track Cleaner is a solvent based system that has motorised cleaning heads and even a vaccuum.

For those areas that a track cleaning wagon cannot easily be used, there is always the track cleaning rubber and IPA (Isopropyl Alcohol) rubbed with a cloth.

Cleaning loco wheels

Smooth running depends not only on clean trackwork, but also on clean loco wheels and clean pickups. There are a number of methods for keeping wheels clean.

The simplest is to use a cotton bud dipped in cleaning fluid such as IPA. Turn the loco upside down (or in a loco servicing cradle if you have one), apply power to the wheels and hold the bud against the wheel to be cleaned.

If there is particularly stubborn gunge on the wheel, you can use a fibreglass brushes to clean the wheel.   Take care that no stray threads break from the brush and get into the loco mechanism.   Also, do not use this brush to also clean PCBs or stripboard, to avoid transferring contamination from the wheels to the copper tracks of the module you are building.

Only use sand paper or grit paper in extreme circumstances, when the gunge is caked and immovable by other means.   Take care, as overuse will scratch the surface of the wheels leading to more problems later.

Avoid using steel wool to clean wheels as strands are likely to break off.

Wire brushes use steel wire bristles and and are also to be avoided.
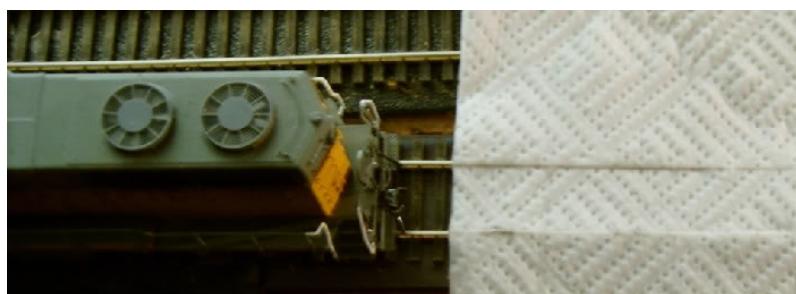
You can use a brass brush or brass pencil to clean the wheels.

This approach is adopted by the Trix HO Locomotive Wheel Cleaning Brush and by the Conrad model shown in the image.

Two rows of brass bristles are powered up and the loco is held against the rows.   As the loco motor rotates, it cleans all the wheels at the same time.

It also has an added advantage, in that the loco is never turned upside down thereby reducing the risk of material falling into the loco mechanism.

It is best to maintain wheels in good condition. Regular cleaning saves time in the long run, compared to having to tackling hardened deposits.

If you prefer not to use abrasive materials, you may consider this simple but effective way to keep wheels clean. A piece of J cloth or paper towel is placed over the track and drops of cleaning fluid such as IPA are sprinkled on the areas that are over the tracks.

One set of wheels is placed on the cleaning area while the other wheels are held on the powered track.   As the motor spins, the wheels are cleaned. Then, reverse the loco and clean the other wheels.

This, like the cleaning brush above, has the advantage that the loco is not turned upside down.

There are a couple of videos on YouTube that illustrate this process:

        www.youtube.com/watch?v=R3GzV0i_wW8
        www.youtube.com/watch?v=NOvoejG9F3A
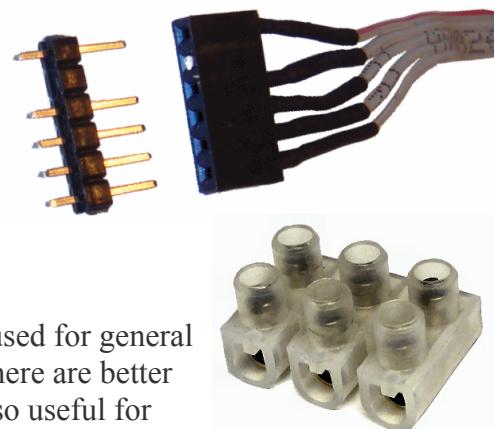
Consumables

Apart from tools, there are items that you will use either regularly or occasionally.

Your list of consumables might include:

- Hook-up wire in various colours. 7/0.2 is a popular general-purpose wire made up of seven strands of 0.2mm copper wires. Ideal for interconnecting modules, making temporary connections, or even for low current layouts (it can handle a maximum of 1.4A). Alternative, use 10/0.1 wire (ten strands of 0.1mm wire). This type can only handle a maximum of 0.5A but is thinner (0.9mm compared to 1.2mm for 7/0.2) and suitable for most low current connections.
- Kynar wire. A very thin (usually 30AWG) wire with excellent heat resistant insulation (i.e. the insulation does not instantly melt when soldering). Ideal for wiring where normal hook-up wire would be too obtrusive or space-consuming.
- A selection of heat-shrink shrink tubes of different diameters. As the name suggests, the diameter of these plastic tubes shrink when heat is applied. The image shows the result. Pieces of the tubing are cut off and slipped over a wires prior to soldering. The tubes are then slipped over the soldered joints and when the soldering iron is held close (not touching), the tubes shrink over the joints. This prevents any possibility of shorts between the pins. It also provides a level of protection from contamination and mechanical movement.
- Choc block terminal strips.
- Rolls of electrical tape in various colours. These are used for general purposes and for the temporary insulation of joints (there are better methods for the permanent connection of wires). Also useful for colour coding wires by wrapping a small strip of a particular colour round a wire (for example you could use red for +12V, orange for +5V, black for 0V, and so on).
- Cable ties. Use for the temporarily securing modules or for holding bunches of wire neatly.
- A selection of nuts, bolts and washers. Include some of the very small sizes as these are the ones you most often lose.
- A selection of screws. Many modules have mounting holes on them so that you can screw them to a board. Sometimes, these holes are small and and cannot be enlarged as it might break the nearby copper tracks. For these situations, keeping small screws in your collection pays off.
- Double Sided VHB Gel Tape. This double-sided tape has very strong bonding properties compared to some other products and is widely used in industry as a quick and permanent replacement for conventional fixings such as bolts, screws and rivets. It can bond together a variety of materials such as metal, plastic, glass, etc. Its foam layer also allows for some degree of gap filling.
- For those jobs that can't be achieved with double-sided tape, there are epoxy resins. It is supplied as two separate components and these are mixed to produce a fast acting permanent fixing.
- Isopropyl Alcohol (IPA) for those many cleaning jobs.
- Cotton buds for use with IPA.
- Solder, either 60/40 or lead-free, depending on your preference.
- Flux remover
- Solder tip cleaner.
- Containers to hold small parts.
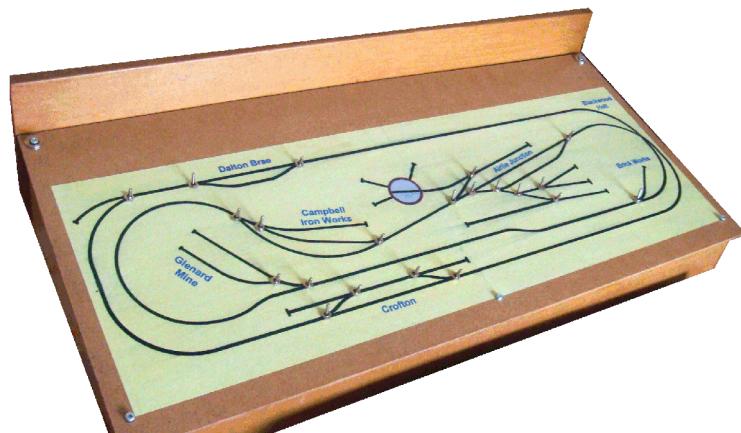
Control panels

One of the most common construction tasks for railway modellers is the building of a layout control panel to house the switches, buttons, lights and some of the electronic modules needed for controlling your layout.

The following tools help with creating a control panel.   Although not strictly electronic tools, they are included because they contribute to creating panels in addition to general layout construction.

The main tasks for these tools are sawing, cutting, drilling and fixing. Of course, many of these tools will used in other tasks such as baseboard and scenic construction.

Sawing and cutting

There is quite a range of tools for cutting and shaping materials such as wood, plastic and metal. Although you can muddle through with a simple £2 hacksaw, you might want to look at the features of the various other types of saws as they are designed for specific purposes and produce superior results.

Panel saw
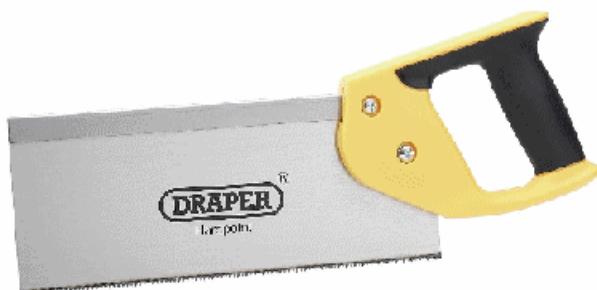
The first task is to cut a sheet of material (usually wood) to the specific dimensions of your planned control panel.   The panel saw, often referred to as a handsaw, is designed to make straight cuts in large sheets of wood.

Its tempered steel blade blade, shown in the upper image, has a fine toothed crosscut and can handle plywood and other wood sheet material.

Tenon saw

The tenon, or mitre, saw is useful for making the battens that often support a panel's box construction. As the lower image shows, the back of the saw has a steel stiffener and this prevents any flexing of the blade. The result is an accurate straight cut, making it popular for general modelling.

Hack saw

Although the hacksaw can be used to cut wood, it is mostly used for cutting plastic and metals.   The blades are replaceable and are held in tension by adjusting screws. Like other saws, whether their blades are coarse or fine cutting is determined by the number of cutting teeth per inch (tpi) along the blade.

The options are:
- 14tpi is coarse and is used for sawing soft metals such as aluminium.
- 18tpi is used for general jobs
- 24tpi is used for cutting thin steel plate (up to 5mm).
- 32tpi is a very fine blade and is used for sawing tubes and other hollows sections.

A cheap miniature version, the Junior hacksaw, is a common tool on the workbench and is mostly 32 tpi.

Razor saw

The razor saw often comes as a handle with interchangeable blades.
A saw normally cuts a slightly larger width than the width of its blade; this is known as its *'kerf'* and makes the blade less likely to jam while cutting.   The razor saw, as the name may suggest, has a very thin blade (i.e. a low kerf) and produces a very fine cut compared even to a fine hack saw.
Blades are available from 32tpi to 52tpi and are used to cut wood, plastic and soft metals.   The Ultra Thin (Superfine) and Fine blades saw through wood and plastic without any splits or ragged edges, great for balsa and thin ply.   The Medium is often used for metal cutting (e.g. an alternative to rail cutters for cutting flexi-track or cutting track breaks) while the Heavy blades are used for heavier wood cutting jobs.
Like the tenon saw, the blades have steel stiffeners to ensure a straight cut.

Improving the cut

Unless you are experienced in woodworking, you could probably benefit from having tools that help produce a clean straight cut.
The humble vice is a useful tool as it holds the work while it is being sawed, preventing it from moving and allowing both hands to be free.   It can also be used for filing, bending and soldering tasks.
However, if you need cuts to be sawn at precise angles, you can use a mitre box, as shown in the image.
It is made from wood, plastic or aluminium and has slots into which the saw blade sits, thus ensuring perfect square or angled cuts.   A mitre box is very useful for structure work and for cutting track.

Finer cuts

There are occasions when you need a more precise cut in situations where the above saws are not practical.   For example, cutting rectangular holes in control panels for mounting switches and meters, or cutting rectangular holes for windows in buildings.
For these jobs, the coping saw, fret saw and jeweller's saw can be used.
They all have a saw blade that is stretched across a C-shaped frame.   The work to be cut has a small hole drilled within the area to be removed. The blade is then disconnected at one end and the blade is passed through the hole before being reconnected to the frame.   The

saw is then able to cut any shape, subject only to the depth of the saw's frame (the throat depth). When the area is cut out, the blade is disconnected again and extracted from the piece being cut.

The differences between the types are mostly about construction and blade abilities.

A *'Coping Saw'* uses blades that are generally of set length with pins at each end that are held by the saw frame. Since the blades are smaller than hacksaw blades, they are better at sawing shapes and curves. These saws are mostly used to saw plastic and wood.

A *'Fret saw'* is like a coping saw with a deeper throat, perhaps 10" or 12" Their blades are not pinned but are clamped at each end of the saw with thumb screws. They use thinner saw blades, allowing them to cut tighter curves than a coping saw and produce more intricate results. The finer blades make them more vulnerable to snapping than coping blades. Also, many users find the larger frame more awkward to work with.

A *'Jewellers Saw'* also has its blades clamped by thumbscrews but its 'C' frame is adjustable. With the other saws, a snapped blade means a discarded blade. With the jeweller's saw, you can still use the remains of a broken blade by adjusting the frame width. Their blades are generally even thinner than those used by fret saws, resulting in even more intricate cuts and a smaller kerf.

Although capable of cutting plastic and wood, they are ideal for detailed cutting of metal (hence its name).

Jigsaw

If you are building an oddly shaped control panel, or are just needing to cut curved rising trackbed as shown in the image, the jigsaw power tool is the answer. With a little care (watch out for the exposed blade) and a little experience, curves and custom shapes are quickly cut.

Blades are available for sawing wood, laminates, metal and plastics, Don't expect too fine a cut as some blades can be as low as 10tpi or even 5tpi.

If you already own a Dremel multitool, you can buy the *'Mini Saw Attachment'* that converts it into a rip saw.

Other shaping tools

While the main shaping work is carried out by saws, there is often a need to give a final trim or shape to a job. For these, a selection of knives and files is useful.

General craft knifes, such as the X-Acto or Swann Morton ranges, have handles with removable and interchangeable blades. These include blades that designed for special tasks such as scoring, chiselling, whittling, deburring, stripping, etc.

A popular knife for the larger, although less accurate, jobs is the Stanley Knife with the retractable blade for safety when not in use.

For high precision, Swann Morton sell surgical scalpels. They are very effective but have to be handled extremely carefully as they are not called scalpels for nothing!
A useful addition for cutting panel labels, decals, etc., is a self healing cutting mat.   This supports the work and provides a clean cut.
Don't forget to replace blades if they show any signs of wear or chipping, or are leaving jagged edges on the cut material.   Apart from doing a bad job, they can lead to accidents.
Finally, there is always a place for the humble pair of scissors.

Files

The final step is often a final smoothing of edges and surfaces.
Rasp files, such as the *'Bastard File'*, are too coarse for finishing work and files with finer teeth are required.
Small sets of files, known as *'Needle Files'* are ideal for smoothing small areas of wood, plastic, metal and even glass.   As the image shows, they are available in various shapes, such as
round, half round, flat or pillar file, square, and triangle.
This provides flexibility for the user to achieve the wanted effect for a particular job.
The surface of the file is usually coated with fine tungsten or diamond grit, to provide the smaller abrasive effect required for finishing work. They may come with handles
already attached (as shown), or are expected to be used with a separate handle.
It is best to keep a separate set of files for metal and plastic/wood.
And, if you really want a superior finish, you can always carry out a bit of hand sanding with very fine grade sandpaper.

Drilling

Apart from the general uses of a drill while model making, there are specific tasks where drilling tools are useful.
- Drilling pilot holes for screws, to prevent the splitting of wood.
- Drilling holes in control panels and project boxes for switches and lights.
- Drilling holes in baseboard battens to pass wires through.

A hand drill is relatively cheap and is more controllable when extra care has to be taken to prevent damage (e.g. drilling beyond the work piece to areas underneath).
A mains-powered or cordless drill is much faster and is safe to use if handled with care.
Some rotary tools, such as the Dremel Multitool, offer extra facilities such as flexible shaft between the drill and the drill bit to allow drilling in otherwise inaccessible areas.

There are many types of drill bit, including specialist bits for drilling masonry, glass and tile.   For modellers, drill bits for wood and metal are the ones to add to the toolkit.

Twist Bits

This is the most common bit in use, for both hand drills and powered drills.

They are general purpose bits for use on wood, plastic and light metal.

There are three main categories of twist bits:

Carbon Steel	The cheapest but not suitable for metal or even hardwoods.
High Speed Steel (HSS)	Can be used to drill wood or plastic but are best used with metals, as they can handle the higher tip temperatures that are generated. These bits usually are black in colour.
Titanium Nitride (TiN)	The TiN coating makes the bit particularly suitable for drilling metal; do not use on wood. The bit has a golden colour.

Making a point

The cutting edges of a drill bit has an angle (usually 118º) and the tip of the bit is where you start drilling the hole.   In practice, it can sometimes be difficult to get the bit to stay in place, specially when you start drilling into metal.   The bit can skid along the metal, scoring the surface, or you might drill a hole that is slightly off where you intended.

A centre punch tool can prevent any movement of the drill. It has a pointed end that is held at the centre of the intended hole position.   The top of the punch is then tapped with a hammer and this makes a recessed dimple in the metal.

This indentation helps keep the bit in place during the initial drilling.

If a large hole has to be drilled, a smaller pilot hole can be drilled first. This gives extra protection against the larger bit from wandering along the metal surface.

A similar technique can be used when drilling wood, specially hardwood. Again, a smaller pilot hole can be useful to mark the exact centre point for the hole.

With softwood, the danger is that forcing a large screw into the wood might result in the wood splitting along its grain. This danger can be minimised by making a pilot hole to break up or remove some of the wood fibre.

A pilot hole can be made with a drill bit smaller than the final bit size, or with a bradawl.   A bradawl look similar to a screwdriver and is inserted into the wood and twisted to break up the fibres.

Brad Point Bits

Sometimes called spur point bits, these are for drilling through wood and some plastics

The tip of the bit has a sharp point that holds the bit in place when starting to drill the wood.

This makes positioning and drilling more accurate.

It also has two spurs at the tip and these ensure straight, parallel, clean-sided holes.

Apart from general use, they are ideal when for drilling holes for dowelling work (they are sometimes called dowel bits).

The Bullet Pilot Point bit. Is the version for drilling metal; it can also be used with wood and plastics.

Flat Wood Bits

Sometimes called Spade Bits or Paddle Bits, these are designed for drilling out large diameter holes in wood and some plastics.   They can be used for drilling holes in baseboard battens (to pass wires and cables through) or in panels (to mount some instruments).
These bits are for use with power drills that are run at high speed to prevent the bit from jamming in the wood.
The sharp tip keeps the bit on the centre of the intended hole, while the flat blades cut away the excess wood.

Countersink Bits

When using screws you want to ensure that the head does not sit above the surface of the material, otherwise it may scrape other surfaces.
If the surface part of the drilled hole is enlarged, the head of the screw can sit flush, or below, the surface of the material.
You could simply uses a drill bit of larger size than the hole to create this recessed area.
However, there are drill bits specially made for this job.

The countersink bit shown in the image can be used with either a hand drill or a power drill.

When used with a powered drill, care has to be taken to avoid accidentally drilling down to deeply.

You have more control with a hand drill and you can buy a countersink bit with its own fitted handle.

A combination bit is available that both drills and countersinks in the one operation. As the image shows, it also has a limiter to prevent you countersinking too deeply.
Unless you work a lot with the same screw size, this can be an expensive option as you would require a countersink/clearance drill for every hole size that you use.

Although commonly used with wood, countersink bits are available for metal too.

Pin Vices

When you work with very fine, small diameter, drill bits, they are very fragile and snap easily.   When used with large hand or electric drills, the size and weight of the drill threatens the stability of the drilling process, tilting the drill and snapping the bit.
To provide better control over drilling small holes, you can use a pin vice.   This is basically a small hand

drill.

You locate the drill bit in the chuck (collet) and rotate the pin vice barrel between your fingers, while holding the top of the barrel steady with your other hand.

Some provide a rotating knob at the top of the barrel so that the vice can be used more comfortably and perhaps single handedly.

As the image shows, you can buy pin vices that cover a range of bit sizes.

An alternative is to buy a pin vice with replaceable collets, so that you only need a single tool that covers a range of bit sizes.

If you are using an electric drill and find it difficult to hold small bits centrally in the chuck, you can hold the small drill bit in a pin vice and place the pin vice in the electric drill.

Finally, avoid using drill bits that have been blunted with wear.   They will take forever to drill the work, will overheat and may char the wood being drilled.   A sharp bit always drills faster and results in a cleaner hole.

Final fixing

After cutting and drilling the material, you will want to secure the pieces together.
Nails are not recommended, apart from using panel pins to hold a job while the glue dries.
A light to medium weight hammer is all that is required to drive home panel pins.
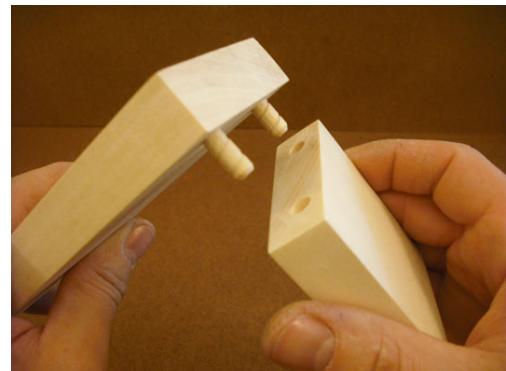
The most common way to secure wood sections to each other is with screws and screwdrivers were covered earlier.   This method allows the construction to be disassembled at any time by removing the screws (unless you have also used glue).

An alternative approach, that used in many items of office and home furniture, is to use dowels.
The two pieces of wood are drilled and wooden dowels are glued into the holes.   The large surface area of the dowel rods provides a substantial contact area for the glue and this makes the joint stronger than using screws, particularly with composite materials such as plywood.

When two pieces of wood are screwed together, they are pulled tightly together when the screw is driven home.
This does not happen with dowels, so you have to ensure that they are in close contact.

Often, a tap with a hammer suffices. Even better, use clamps to hold the pieces tight while the glue dries.

The downside with dowels is that construction takes longer than screwing, as you have to wait for the glue to dry.   The upside is a stronger joint and the joint is hidden (there are no screw heads showing).
You can buy a small starter kit as shown in the image to practice this technique.   If you are happy you can then buy a bag of dowels and use your own glue.

Glue gun

These are relatively cheap tools and you will find many uses for it once you own one. You can use the glue to secure LEDs inside buildings, hold wires in awkward places, and anywhere you want a quick fixing.

Beware though, that the glue is very hot and very sticky.

Some last words

This chapter covers more tools than you might need but does still not cover all that are available. What you buy depends on your particluar needs and preferences.

Also,the chapter has not covered the use or care of tools. That is a whole other subject. Always read the instructions for each tool you intend to use.

Chapter 19

Soldering

Soldering

Soldering is defined as the joining of two metals using a low melting temperature alloy (solder) as the filler metal.

Solder has three functions:

- It wets the metal surfaces that make up the joint.
- It flows to fill the spaces between the two parts.
- It metallurgically bonds the surfaces when it solidifies.

Although solder is a poorer conductor than the metals it connects, its very short conducting path means that it has little impact on the overall resistance of the joint.

Soldering requires three resources:

- A soldering iron (sometimes called a soldering bolt) to generate the heat required.
- Solder to bond the joint.
- A selection of tools and accessories to aid the soldering process.

Soldering Irons

Types of soldering iron

A range of soldering irons are available, with differing characteristics and advantages/ disadvantages.

Wired

Most soldering irons work at 240v and plug directly into a mains supply socket.
This ensures a constant supply current and allows for high-wattage irons to be constructed.

Another mains-powered bolt is the hot air iron. This blows out a clean source of heat and is very useful for other tasks such as drying glue, fault-finding, working with SM (surface mount) components, heat-shrinking and desoldering. A very expensive option.

Another wired iron works from a 12v supply. This is useful when working under a baseboard, attaching the iron's cable to any 12v connection that runs along under the baseboard. Also handy for working on car repairs. They are fixed wattage irons, with no facility to vary temperature.

Portable

There are two types of portable (i.e. non-wired) irons. These have the advantage that they can be used anywhere without needing to find a source of power.
The illustration shows a typical battery-powered iron. It produces 6W and runs off three AAA batteries.
The Weller BP860CEU is an 8W model that can carry out 180 solder joints on a set of four AA batteries.
They are often described as "cold soldering" as the tip heats to working temperature in only a few seconds and, when switched off, the tip is safe to touch within only a few seconds.
A 'ColdHeat' version has a tip made up of two prods that are shorted by the joint/solder and the high resulting current produces an almost instant heat. When removed from the joint, the tip cools very quickly. This iron is NOT suitable for kit building as the voltage it produces may damage electronic components.

The other form of portable iron is gas powered, as shown in the illustration, and uses normal cigarette lighter fuel. A typical gas iron will run for about 20 minutes on a butane fill. With portable irons, you gain convenience of use at the cost of regular replacement of batteries/gas and less control over temperature.

Wattage and temperature

These are different characteristics but they are closely linked.

The temperature specifies how hot the iron's tip can become, while the wattage determines how long this temperature can be maintained when applied to a joint (i.e. the heat capacity).

> Soldering is all about applying heat at the correct temperature and for the correct amount of time, for any given job.

So, using a higher wattage iron does not necessarily providing greater heat; it means it may provide heat for a longer period.

In some situations, a sustained heat is necessary - e.g. when soldering brass items together or when soldering an earth wire to a metal chassis. A low wattage iron would not be capable of maintaining a constant high temperature, as the heat would be shunted away by the large area of the job being soldered.

On the other hand, high sustained heat applied to small joints could easily result in burnt/lifted PCB tracks and burnt components.

Modellers may, therefore, have two soldering irons - a lowish wattage iron for working on circuit boards and a higher wattage iron for soldering track droppers, brass kits, etc.

Soldering irons rated at 12W / 15W /17W / 18w are generally used for assembling kits, with 25W irons used for general layout work (e.g. brass kits, track droppers, baseboard wiring).

Higher wattage irons range from 40W / 50W / 80W / 100W and are used for larger soldering jobs, such as connections to metal chassis, large terminals, earthing tags, stained glass windows.

Variable temperature irons

Different types of solder melt at different temperatures (see later). Also, desoldering 60/40 solder is normally carried out at a higher temperature than soldering.

To provide this flexibility, you can buy a *'soldering station'*.

This is a soldering iron that can have its bit temperature set by a rotatory knob or by push-buttons (as in the illustration).

A cheaper alternative is the soldering iron whose temperature is controlled via a miniature setting dial, set into the handle which is continuously variable from 200 to 450°C .

Typical operating temperatures are:

  60/40 (leaded) solder - 280°C to 320°C
  Lead-free solder - 350°C to 400°C
  Solder for white metal - 80°C
  Desoldering - 320°C to 360°C
  Sleep - 220°C

Bits

The tip of the soldering iron's bit is usually made from copper or copper alloy, to achieve the best heat transfer to the joint being soldered.
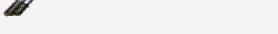
As the illustration shows, a wide range of bit sizes is available, even for average soldering irons.

The size of the tip determines the heat transference capability, while the shape of the tip determines how well the heat is transferred to the joint.

The trick is to match the tip size/shape to the nature of the work.

The smallest bit shown is ideal for working with tiny components, or in awkward places to reach.

The largest, chisel-shaped, bit is best used to transfer large amounts of heat to large surface areas.

TIP Ø MM
0.12
0.5
1.0
2.3
2.3
2.3
3.0
4.0
4.7
5.0
6.0

Solder

For many years, solder was made from an alloy of tin and lead, usually in the proportions of 60% tin and 40% lead (therefore known as '60/40 solder').

However, on July 1, 2006 the European Union Waste Electrical and Electronic Equipment Directive (WEEE) and Restriction of Hazardous Substances Directive (RoHS) banned using lead in most consumer electronics products manufactured in the EU.

60/40 solder is still OK for home/hobby use and is still manufactured.   It is widely regarded as easier to work with than lead-free solder.

The melting points of different solders are:
        60/40 solder – 188°C
        LMP (Low Melting Point) for SM – 179°C/188°C
        Low Melt (for white castings) – 70°C
        Lead-free solder - 217°C to 227ºC

Lead-free can have a matt finish, whereas leaded solder is shiny.

Solder is available in different thickness.   18swg is used for for larger joints, while 22swg is used for kit building.   Low melt solder, for use in constructing white metal loco kits, is supplied in sticks or as solid blocks.

Flux

A successful soldered joint requires that the surfaces to be soldered be perfectly clean, both before and during the soldering process.

Unfortunately, metals such as copper and tin oxidise rapidly when exposed to air, moisture or heat. It forms a nonconductive, therefore non-solderable, surface on the metal. For example, copper's normally bright shiny colour turns to a dull, orange colour.

Flux is a chemical cleaner with three jobs;
- It removes any existing oxide layer from the joint's surfaces.
- It prevents the joint's surface from oxidizing under the extreme heat of the bolt – until the solder makes the joint.
- It encourages the flow of solder into the recesses of the joint.

Most solder has several cores of flux embedded in the solder (maybe 3 or 5 cores).   When heat is applied, the flux flows out over the surfaces to be soldered, thus removing any oxides and preventing re-oxidation during the soldering process.

It is possible to buy a flux pen, shown in the illustration.   It has a 'felt' tip, similar to that used in marker pens.   When pressed, it dispenses flux and the pen can be used to apply addition flux to a particular spot. This is sometimes used when soldering thin lead-free solder, where the joint may not be getting sufficient flux.   Its use has been controversial, mainly due to constructors using water soluble flux pens which can cause long-term damage to the joint and its surrounding metal.   The "No Clean" flux pen is not water soluble and is commonly used as a safe aid for soldering with thin lead-free solder.

Note
Soldering brass kits and white metal kits use different materials and different techniques from assembling electronic modules.
A Google search will result in websites that explain theses processes.
In both cases, cored solder is not used. Instead joining surfaces have flux applied to them and the solder is applied before the flux is burnt away.
For example, ROX150 Liquid flux is used for white metal soldering and Rox145 solder is used for brass and nickel silver joints.

Soldering

Successful soldering is about how heat is transferred to the joint and how solder is applied to the joint.

Below is a suggested guide to the steps.

Clean the joint
The surfaces to be soldered must be free from oxidation, grease, dirt, etc.
While flux is great at removing oxides from the surfaces, it will not clean dirt, oil, grease, etch resist, etc.   For that you must use one of a number of cleaning methods.
The PCB connecting pads can be cleaned using either steel wool , fine grit sandpaper, a cleaning block, a fibreglass pen (supplied with refills) or an ultrafine abrasive pad.

Prepare wire/components
When you purchase a kit it is likely that the components have been purchased relatively recently and will only show minor amounts of surface deterioration. Nevertheless, the leads of the components should be cleaned before insertion into the PCB.
Strip off a little of the insulation on any wires that are to connect to the PCB and tin their ends (especially with multi-stranded wire) before soldering on to board.

Support the work
Holding components in place and rotating the board to the best angle for soldering, while holding the soldering iron and applying solder can be a frustrating experience. Ever wished you had three hands?

A number of devices can be used to support the board and hold it at the correct angle, freeing your two hands for the iron and the solder. For professional work an expensive PCB holding frame is available. , Hobbyists usually employ a small vice or a *' helping hand'* as shown in the illustration. This model has a clamps to hold the work, as well as a magnifying glass, a soldering iron holder and a pad for cleaning the iron's tip.

Best mechanical joint

Where possible, it is best to obtain a good mechanical connection between components. The illustration shows a wire being wrapped round a pin or a tag. This provides improved mechanical strength as well as improved electrical conductivity.

This is not always possible e.g. poking a resistor's leads through holes in a PCB. In such cases, it is best to insert the component's leads through their holes and then bend the wires to an angle. This has the double benefit of allowing the lead to touch the side of the copper pad on the PCB, as well as preventing the component from dropping out when the board is turned over for soldering.

Wet/tin the iron's tip

The first step in soldering is to heat the joint to be soldered. The iron's job is to transfer heat to the joint. To promote the the transference of heat, the iron's bit is 'tinned' or 'wetted' – a small amount of solder is applied to the tip. This allows the tip to have a greater contact with the surfaces of the joint and prevents oxidisation of the tip.

Apply heat to joint

Use the iron's tip to apply heat to both surfaces of the job. Try not to rely on heat applied to one surface being transferred to the other surface. This could result in a 'dry joint' (see later).

The process is   – the iron heats the surfaces
                   – the surfaces melt the solder that is placed on them.

Apply solder to heated joint

With the joint at working temperature, apply the solder to the joint. The heat from the joint melts the solder and its flux cores. Capillary action ensures that the molten flux covers the surfaces to be joined and also penetrates between the surfaces.

Apart from keeping the joint clean, the flux encourages the flow of the molten solder into every part of the joint. As soon as the joint is covered by the solder, the soldering iron should be removed from the joint.

The act of soldering a joint should only take about two seconds to complete. If it takes a lot longer, the iron may not be up to the job, the joint may be dirty, or you may be doing it wrong.

Enough is enough - applying heat for longer than necessary risks heat damage to sensitive components or copper tracks lifting away from the PCB. It may also change the physical properties (strength and hardness) of the metals being soldered in a process known as 'annealing' leading to failed joints at a later time.

Some dont's

Don't apply extra heat or extend the soldering time in an attempt to 'force' the solder to adhere to a dirty surface.

Don't drip solder on to to joint, or create a large blob of solder on the end of the tip, to carry over to the joint. That way, the flux that was designed to protect the joint

from oxidisation during soldering is burnt off prior to the solder touching the joint.
Let the joint melt the solder.
Don't use 60/40 on lead-free joints. The lead will degrade the lead-free material.

Support joint until it cools

When the soldering iron is removed from the job, the solder on the joint takes time to solidify. If the connection is disturbed during this time, it can lead to dry joints.   Resist the temptation to immediately move the board and wait until the solder has cooled before snipping off the excess wires on component leads.

Some other soldering issues

Soldering track droppers

Soldering wires to track can be difficult, as the large amount of metal in the track can quickly shunt away the heat from the area to be soldered.   Contrary to possible expectations, a high wattage iron should be used. Although this may be thought to melt the plastic, the shorter time required to make the soldered connection results in a lesser risk of melting the track.   A large amount of heat for a short time is the preferred way to solder track droppers.

Tack soldering

Here, a small temporary solder joint is used to hold component in position (e.g. one pin of an IC socket) with the joint being remade later.

Seam soldering

Used in the building of brass kits, a continuous bond is made along a seam or joint, by slowly moving the iron along the seam, heating up the soldered area as it progresses.

Health and Safety

A hot soldering iron is a dangerous implement when not given sufficient respect.   It is not unknown for hobbyists to burn tables, lamps – and themselves – while carelessly holding an iron (usually while engrossed in examining a joint, etc.).
Switch the iron off when not being used for a period, keep the iron in its holder when not in use, and keep the iron away from any flammables.
Remember too that the joint remains very hot for some time after the soldering is removed.
Try to avoid inhaling the fumes that are produced during soldering. Professional workshops have extractor fans, but you can use a small desk fan to push the fumes away from you.   If possible, work in a well-ventilated area.
Phosphoric acid fumes can be highly irritating to the nose and lungs, while inhaling Cadmium fumes (silver soldering) can cause serious lung conditions.

Tip maintenance

Although the soldering iron tip may be clean and wetted at the start of a session, it can soon end up with a tip that is dry and is dirty.
Eventually, flux residue and oxidized lead from the solder coat the tip. This gunge is often referred to as 'clag' and can contaminate joints. A black oxide scale results from using 60/40 solder.
Since only a tip that is clean, shiny and wetted successfully transfers heat, it follows that the tip needs periodic cleaning during soldering.
Different methods are compared next.

Tip cleaner

The illustration shows an example of a tip cleaner that is supplied in a small tin. The tin contains a solid disc of solder powder and some chemicals.

For badly affected irons, the tip of the iron is pushed into the cleaner and results in large quantities of smoke being produced (use in a well-ventilated room). For general use, a single wipe of the bit across the block is sufficient to clean an re-wet the tip.

Moist sponge

A very popular method is to clean the tip with a moist (not wet) sponge. The tip is wiped across the sponge to remove any oxide layer.

Most soldering iron stands and soldering stations have a built-in area for storing the sponge. This is the cheapest method but it has its drawbacks.

It is often suggested that the sponge should be used after every soldered joint but this can lead to early tip failure.

Repeated frequent wiping during a session creates large swings in tip temperature and the metal layers that make up the tip expand and contract at different rates, leading to metal fatigue.

The sponge is also often used to remove excess solder from the tip. The tip of the iron is drawn across the damp sponge and this cools the solder at a different rate from the irons' tip, helping to remove debris. However, this dumps the excess solder, burned flux residue, and other contaminants onto the sponge. Eventually, the next time you clean the tip, you may pick up as much gunge as you deposit. To overcome this, some sponges have a circle or an arc cut out of them so that the gunge can be wiped on their edges. This depositing the gunge in the hole rather than on the sponge.

Brass wool

A very useful option is the brass wool pad into which the tip is inserted and withdrawn, or wiped across a few times.

Brass is abrasive enough to remove the gunge without damaging the tip's coating, as brass is a softer metal than that of the tip.

Unlike the sponge, it does not cool down the iron's tip significantly, so soldering can carry on without waiting for the tip's temperature returning to its operating point. Great for 60/40 solder, or a badly coated lead-free tip.

Abrasives

It is possible, although not advisable, to scrape the gunge off using a file, sandpaper or steel wire brush. While they may be used in cases of extreme contamination, they should generally be avoided.

An iron's tip is generally made from a copper core with an outer iron cladding and a nickel or chrome plating. If the protective outer plating is breached, flux is able to penetrate into the copper area. Combined with the heat, this will rapidly eat away the copper core, leading to pitting and holes in the bit's surface. If you really must use extreme measures, use extra fine grade sandpaper (between 220 and 600 grit) and be careful not to rub excessively.

You may find that a fine-bristle, brass grill-brush will be sufficient and safer.

Keep tip tinned

The tip should be kept clean and shiny during the soldering session, for the reasons already explained.

It helps if you match the diameter of the solder to the tip. Using small diameter solders may not keep the tip flooded with solder while in use and cause the tip oxidize and wear faster. If, on the other hand, there is excess solder on the tip, remove the iron from the job, take it to an used section of the workbench (one with a protective cover) and give the iron a gentle tap or whip-like shake to remove the excess solder.

At the end of a soldering session, the iron should be left in a tinned state, to protect it from oxidation and corrosion when lying unused.

Other issues

- Do not use the iron's tip to push a component or use it as a lever (e.g. to prise out a component lead).
- Do not push solder against the tip, to force it to melt; wait until the tip is sufficiently hot to melt the solder naturally.
- Do not use pressure or rubbing of the bit on the joint, in an attempt to improve heat transfer.

Excessive force on the tip will cause the iron plating to crack, with reduced tip life as previously explained.

Use only the temperature that you need. Higher tip temperatures result in faster oxidation. Soldering at temperatures over 470º C will make the tip to oxidize twice as fast as soldering at 370ºC.

Desoldering

There are many occasions when you might want to desolder a wire or a component.

- A component has become faulty.
- You have wired a component in the wrong place.
- To remake a joint that you think may be suspect.
- You want to lift one lead off a component to aid in fault-finding.
- You want to recover components from a module that you no longer use.

Trying to remove the solder with only the use of the iron is often not successful, with the remaining solder running back into the joint whenever the iron is removed.
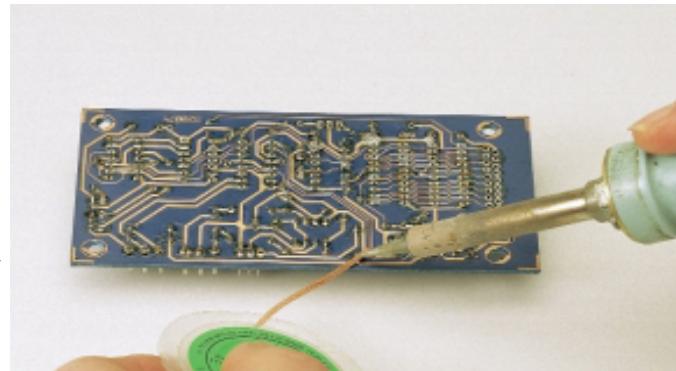
To remove large solder blobs, a desoldering pump, often called a 'solder sucker' can be used. It is a spring-loaded device that puts the spring into tension when the knob is pushed down. The iron is placed on the soldered joint to melt the solder before being quickly withdrawn and replaced by the sucker. A quick press on the button releases the spring and the solder is sucked into the body of the pump.

A very effective method for most joints is the use of a 'solder wick' or 'desoldering braid'.

The wick is made from a ribbon of braided copper wire that is impregnated with flux. The braid is placed over the soldered joint

and the soldering iron's tip is then held against the braid.
The heated braid melts the solder which wicks (seeps) into the braid.
Removing the braid lifts away the excess solder.
The impregnated section of the braid is then cut off and discarded.
A typical desoldering may use up less than 1" of the braid and, since the braid comes in 5' rolls, it will last for some.

Shopping List

If you are just about to start experimenting with soldering, the following is a list of the tools and accessories you might find useful.

Must haves
- Soldering Iron
- Soldering Iron Stand (if not supplied with the soldering iron)
- Solder
- Cutters (to trim off component leads, cut wires and wire links to length)
- Pliers
- Magnifying glass / eyeglass
- Good lighting
- Protective surface (to avoid burning the dining room table!)
- Cleaner sponge (if not supplied with the soldering iron stand)
- Brass wool

Useful accessories
- Third 'Hand' / small vice
- Wire strippers (strips insulation from wires without risking damaging the wire)
- Solder wick / desoldering braid
- Solder sucker
- Earthing strap / anti-static wrist strap with cord (if handling static-sensitive devices)
- Brass wire brush
- Tweezers
- Tip cleaner
- Flux pen
- Heatsink (to clip on to a lead if it is being soldered close to a heat-sensitive component)

Further information on some of these tools can be found in the chapter on *"Assembling a Toolkit"*

Surface Mount components
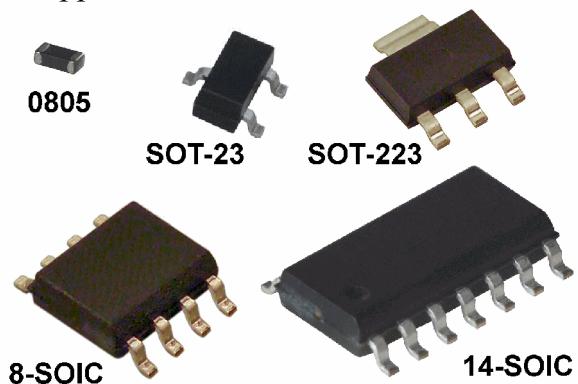
For a long time, electronic components were of the *'through-hole'* type. They have wire leads that poke through holes in circuit boards and are soldered to the copper pads underneath. These are still in widespread use but have been joined by *'surface mount'* equivalents. These are tiny devices that allow the miniaturisation of mobile phones, etc. They also make the production of commercial boards quicker and simpler to produce, being designed for robotic pick-and-place assembly of boards, rather than the manual assembly. All the common electronic components, such as ICs, resistors, capacitors, regulators, LEDs, etc. available in both through-hole and SMD types.

Surface mount devices are so small that they are measured in thousands of an inch. The most common size is the 0805, which means that it is 8 thou long by 5 thou wide (i.e. 2mm x 1.3mm). Most resistors and capacitors are supplied in this size. Other sizes are larger (1206 – 3mm x 1.5mm, 1210, 2010 and 2512) or smaller (0603 and even smaller).

The image shows some of the most common shapes for SMD components.

Passive components (i.e. resistors and capacitors) are found in the 0805 or 1206 outlines. General-purpose transistors use the SOT-23, with power transistors using the SOT-223 outline.

The 8-SOIC and 14-SOIC are the *'Small Outline Integrated Circuit'* outlines for many integrated circuits.

SMD components are so small that it is difficult to print conventional markings on them. Often, they will have no markings and have to be kept in separate plastic bags with labels. They are usually supplied on a bandolier (a 'film strip' with many sealed pockets) and should be kept there until they are ready to be mounted on your modules.

If any components have markings, they will not be ones you are accustomed to but you can look up their details at:

> http://www.marsport.org.uk/smd/codeintro.htm

For example, a resistor marked as 273 is a value of 27k, while one marked as 2702 is a 27k resistor with a 1% tolerance.

Soldering methods

As SMD components are intended for industrial and professional use, it poses extra challenges to hobbyists who have to work with much smaller components and increased risks of shorts, dry joints, burnt-out components, etc. Having said that, many hobbyists have adapted to working with surface mount technology.

They have different (sometimes contradictory) experiences, use slightly different methods and offer differing advice.

There are three main methods, depending on what you are prepared to spend.

- Hand soldering
- Hot air
- Reflow oven

Hand soldering

Like conventional soldering, it uses a soldering iron and solder, with the possible addition of other aids and materials.

Soldering iron

You might think that you would use a soldering bit with a fine point but it will not transfer heat as effectively as a bit with a flat edge.   A flat or chisel tip of at least 1mm should be used, with some users reporting great results with a tip as large as 3mm.

While a 15W iron will handle a few components, it may struggle to maintain its temperature when soldering many components, or working with large surface areas.

If you have a temperature controlled station, you will benefit from the constant heat output it provides. The temperature can be set to 315ºC to 370ºC for tin-lead solder, and 370ºC to 426ºC for lead-free solder.

A different tip is better for handling ICs and this is covered later.

Solder/Flux/Solder paste

Efficient solder flow is even more important when soldering SMD components, as prolonged application of heat from the soldering iron can damage components. Solder that contains a small amount of silver aids the flow and shortens the time needed for soldering.

From earlier, we know that flux prevents oxides from forming on surfaces, aids the distribution of heat and makes the solder flow more easily.

Normal solder has flux cores embedded in it and the flux flows when the soldering iron melts the solder.   We can use this method to solder SMD components but normal solder is far too thick for the job.   Instead, we use a fine gauge solder (26 SWG) that still manages to have cores of flux. Since the solder is so fine, there is not a lot of flux in the cores. If necessary, the user can apply extra flux to a solder pad using a flux pen or brushing on from a jar of liquid flux.

There are three types of flux in common use - water soluble flux, rosin-based flux and no-clean flux.

- Water-based flux is more 'active' (better at combatting oxides) but is mildly corrosive and also conductive, so excess flux has to be cleaned off with water.
- Rosin-based flux is less active, less corrosive and the residue is cleaned off using a cleaning solvent.
- No-clean flux has a low activation level, making it harder to achieve good results. However, its residue is non-corrosive and non-conductive, so does not require to cleaned away except to improve appearance.

Solder paste is something completely different and should not be confused with solder flux. Flux can be used along with your solder, as in normal soldering.

Solder paste is used *instead* of separate solder and flux.   It has tiny particles of solder suspended in a flux gel.   The paste is grey in colour and sticky to help hold components in place during soldering.

The two hand soldering techniques are looked at next.

Getting started

The components you are working with are tiny and the board on which they will be soldered is likely to be small too. These pose extra challenges for us.

SMD components can easily slide off the board, or even *'ping'* off in any direction and get lost forever.

It helps, therefore, to work on a flat surface that has plenty of visibility.

If you place the board on a flat work area that is covered by a large sheet of white paper (A3 or even lining paper) you improve your chances of successful construction.

Professionals use precision board holders that clamp the board to prevent movement during soldering. A budget equivalent is to stick your small board on to a larger piece of board using double-side tape or even Blu-Tack. This larger board provides stability and can be easily rotated to provide optimum access when soldering.

Other items to gather together include:

- A source of adequate light
- A magnifier (or combined lamp plus magnifier)
- A soldering iron
- The appropriate soldering bit for the method being adopted.
- Brass wool or other cleaner to maintain a clean bit.
- Tweezers
- Desolder braid
- Solder, flux or solder paste and a cocktail stick
- IPA, to clean the board before starting, during the construction where required and after completion of soldering where required.

As a rule, it is best to work with a single SMD component at a time to minimise the risks of lost components. The protective film strip should only be peeled back as far as required to uncover each component. The component can then be removed by tipping it on to the board, where it can be moved into place.

Using cored solder

The pads on the printed circuit board may or may not be pre-tinned. If the pads are tinned, ensure that they are only a thin film; any blobs should be removed with desolder braid.
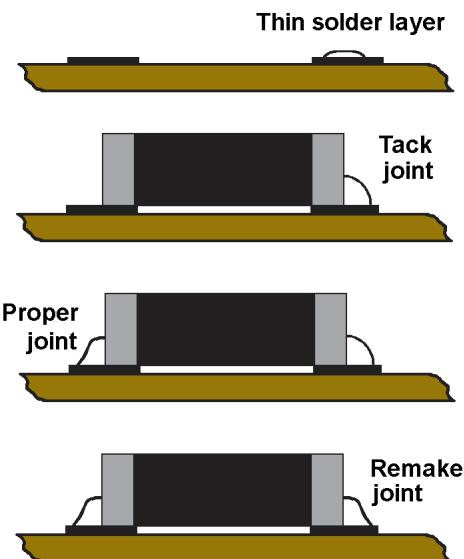
If the pads are not tinned, tin one pad only.

- Pick up the component using tweezers.
- Place the component across the pads.
- Hold the component in place.
- Quickly tack one side of the component to its pad, with as little solder as possible.
- Check that the component has not moved; melt the solder and adjust if necessary.
- Maintaining light pressure on the component, solder the other end properly.
- Return to the first end of the component and solder it properly.

Solder as quickly as possible with as little solder as possible, consistent with making a good joint.

You can watch this video on YouTube:
http://www.youtube.com/watch?v=Jpj3tiIlaik

You do not need a lot of solder to make a good joint. If a pad is pre-tinned, you may only need apply a little solder to the iron's tip and apply it to the joint, specially if you apply flux to the pads.

This is the opposite of conventional soldering where you heat the joint and then apply the solder to the heated joint. You can still manage this with fine gauge solder. Alternatively, you can melt the solder on the iron and apply it to the joint. This way, the flux will boil off before the iron reaches the joint, hence the need for additional liquid flux.

When all the components are soldered, clean off the flux residue.

Using solder paste

This method is a little simpler.

- Ensure that *both* pads are tinned with a thin layer; use desolder braid to remove any excess solder.
- Apply solder paste to each pad, using a cocktail stick or similar thin pointed object.
- Pick up the component using tweezers.
- Place the component across the pads.
- Hold the component in place.
- Place the iron's tip on one end of the component, until the paste melts and flows.
- Check that the component has not moved; melt the solder and adjust if necessary.
- After a few seconds, the joint will be cool enough to solder the other end of the component.

If your iron is too hot, the paste will sputter and minute solder balls will be sprayed out from the paste. That, and any unfused paste must be cleaned from the board.

This method can also be seen on the above YouTube video.

Soldering ICs

This can appear a very task as you have to solder multiple tags that are spaced very close to each other, with all the possible shorts that could be caused.

A number of techniques are used and they all share some basic rules:

- Before starting, make sure that all pads are tinned with a thin layer of solder. Check that there are no solder bridges between adjacent pads.
- When placing the IC on the pads; make sure the pins are centred on the pads and it is fitted the correct way round!
- Solder two pins on diagonally opposite sides of the IC. This holds the IC securely in place while soldering the remaining pins. Check and reposition if necessary before proceeding.

Some hobbyists apply flux to the pads. This method is:

- Apply flux to the pads.   There is no need to dab each pad individually, just apply to the local area.
- Place the IC on the pads, soldering diagonally opposite pins.
- Solder each remaining IC pin, one at a time, using a fine gauge solder and a very fine tipped soldering iron. Pause from time to time to prevent the IC from overheating.
    OR
- Using a soldering iron with a flat tip, rub the flat tip along the pins whilst feeding solder. Pause between each row to prevent the IC from overheating.

Some hobbyists use the 'drag soldering' method. It is similar to the above method but uses a soldering iron with a special tip with a concave cup at the end. These are available as gullwing tips, bucket tips, spoon tips, or NTGW conical tips.

This acts as a reservoir or bowl for some molten solder.

This method is:

- Apply flux to the pads. There is no need to dab each pad individually, just apply to the local area.
- Place the IC on the pads, soldering diagonally opposite pins.
- Load up the reservoir pool with solder.
- Slowly run the tip across a row of pins with its solder pool facing the pins. The solder will be drawn to the joints and, with practice, there will be little or no shorts between pins.

This method can also be seen on this YouTube video;
http://www.youtube.com/watch?v=t06malVew40

Some hobbyists apply solder paste to each pad. This method is:

- Apply solder paste to the pads. There is no need to dab each pad individually, just run a strip of the paste along each row of pins.
- Place the IC on the pads, soldering diagonally opposite pins..
- Solder each remaining IC pin, one at a time, using a very fine tipped soldering iron.
      OR
- Using a soldering iron with a flat tip, rub the flat tip along the pins.

Hot air rework station

This method does not use a soldering iron to melt the solder. Instead it directs a stream of very hot air at the joint.

This method is:

- Before starting, make sure that all pads are tinned with a layer of solder. Check that there are no solder bridges between adjacent pads.
- Apply solder paste to the pads.
- Place the component on, or close to, the pads.
- Heat the air gun to its working temperature and set the air flow to a constant gentle stream (you don't want to blow the component off the board!).
- Hold the gun over the work until the solder melts.
- Move the component into its final position.

Some users replace the solder paste with flux and rely on having sufficient solder on the pad to melt and complete the joint.

As the image shows, you can fit specially-shaped nozzles on the end of the hot air gun. A range of shapes and sizes is available, covering round shapes, DIP 8-pin upwards and QFP (Quad Flat Package) outlines. These nozzles direct the heat more efficiently at the work area, allowing an IC to be soldered in a single operation. They also prevent any unintended unsoldering of nearby components. Unlike soldering iron tips, the nozzles have a very long working life.

Note
You cannot use a normal hot air gun (the kind used for stripping paint, thawing pipes, etc.). for soldering as you cannot sufficiently control its temperature.

You can see this method near the end of this video on YouTube:
http://www.youtube.com/watch?v=Jpj3tillaik

Reflow oven

All the above methods solder one component at a time.
This method solders all the components at the same time, in a single operation.
It uses an oven with infrared heating elements.
Large versions are used industrially and the one shown in the image is smaller and used by developers and hobbyists who are willing to pay out around £200.
This method is:
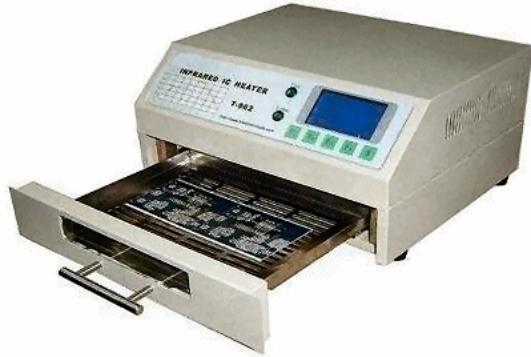
- Before starting, make sure that all pads are tinned with a layer of solder. Check that there are no solder bridges between adjacent pads.
- Degrease the board, using a cleaner such as IPA.
- Apply solder paste to the pads .
- Place the components on the pads.
- Check that all components are seated correctly.
- Place the board in the oven.
- Set the timer.
- Sit back and relax while the heat melts the solder.

This is a much simpler and less stressful process than soldering one component at a time.
The drawback is the price for someone who only builds boards occasionally.
If you are really adventurous and are confident in your abilities, you can always consider building your own reflow oven, usually from a toaster oven.
Just do a Google search for 'DIY reflow oven'.

In all cases …

Whichever method you use to solder components to boards, you should make the same final steps.

- Examine board with magnifier, looking for any problems with joints, solder bridges, components that have moved, etc.
- Remake any bad joints.
- Remove any solder bridges with desolder braid.
- Remove any flux or other residue, using a cleaner such as IPA.

Chapter 20

Test procedures

Test procedures

You build a module … You apply the power … It doesn't work   … What's wrong?

Where do you start?
What do you need?
What can you do?

Firstly, don't panic!   You are certainly not alone.   No-one gets every project to work first time.   However, we can minimise the risk by having a logical approach to fault-finding and testing.
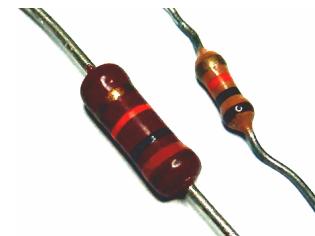
This chapter can't cover all possible faults for all kits and home-built projects found in magazines or on the Internet.. Some use ICs or PICs, some don't; some are supplied as kits with carefully selected components, others are supplied as circuit boards with members sourcing their own components; some need computer software, some don't.

This chapter should provide useful pointers, looking at the most common problems users encounter. It also looks at some equipment that should help you test your modules.

Let's start with the good news … **Its not always us**

If a module won't work, it might not be our fault, as there are other possible factors, such as:
- Faulty components. Rare, but does happen.
- Incorrect instructions.   Happens occasionally; watch out for updates and amendments.
- Ambiguous instructions.   The author knows what is meant but has taken too much for granted.
- Ambiguous components. Chip with markings rubbed off or difficult to determine.   One of these resistors has a red band while the other has an orange band- which is which?
- Bugs in the software

Now the bad news....   **Its usually us**
Not as bad as it sounds, as in the great majority of cases the problem can be identified with a visual inspection (aided by a decent magnifier).

Getting started
Many modellers initially make little distinction between construction and testing.   They build their kits and are keen to see if they work.   While understandable, it is best to take the time to carry out simple checks before plugging in the chips and switching on the power.   Although there are a variety of approaches, one of the best is:
> *"Fault-finding starts before you insert the PICs and/or ICs"*
This is for two reasons:
- Faults that might damage your components can be detected before they destroy your circuits. For example, its best to spot that you've mistakenly use a 15v regulator instead of a 5v regulator, or connected a 12v supply to a 5v connection – before your PICs or ICs are fried.
- Checking for shorts or breaks in a circuit and resistance values are not complicated by the internal resistances between pins on PICs and/or ICs, giving 'wrong' readings.

Once all the checks listed below are completed satisfactorily, any transistors can be soldered on to the PCB and ICs and/or PICs can be inserted into their holders

Keep an open mind

It's easy to jump to the conclusion that the chip must be faulty, or the program is wrong – only to find that you have soldered a component the wrong way round or forgot to wire an essential link on a board.   Rule nothing out; start with the premise that anything and everything is possible.   The chip or component might be faulty (it has happened, although rarely) or the program may have errors (this has happened too) but the vast majority of mistakes are caused by the constructor.   Fortunately, most problems are easily detected and corrected.

Knowing the symptoms

"It doesn't work" is a first observation but it pays to use all your senses to fully appreciate the problem.   Can you:

    See: Screen contents, error messages, motion, lights, even smoke!
    Hear: Points operating, motors spinning, warning beeps.
    Feel: Vibration from rotating parts, temperature of chips.
    Smell: Components overheating, dust, odour from spillages.

In addition, you can deduce:

    Times: Start-up times, shutdown times, delays in running tasks.
    Sequences: Noting the order of events (e.g. does the computer application hang before or after a particular device is used).
    Differences: Noting the performance comparisons between two identical modules running the same application or connected to the same system.

If you ask for help, others will probably ask you to describe the symptoms and saying *"it doesn't work"* is not really an answer.

Visual checks

Let's start with the obvious; the problems we can spot just by looking.   Don't skip over this section, assuming that you built the project correctly and the fault must be somewhere else.   After all, if you build the project correctly, there is a good chance that it would work.
Many faults are found solely through visual inspection.

Here are some self-checks to try.

Are all the components fitted to the board?
Compare your board to the layout in the printed instructions or the circuit diagram.   A quick first check is to look at the diagram and note the component quantities.   If, for example, the resistors are numbered from R1 to R8 and the capacitors are numbered from C1 to C7, there should be 8 resistors and 7 capacitors on your project board.

Are all components the correct values?
For example, have you swapped a 10k and a 100k resistor?   If you are unsure of the coding system for resistors, you can find them on many websites, such as:
       www.doctronics.co.uk/resistor.htm
       www.csgnetwork.com/resistcolcalc.html
To identify capacitor values from their markings:
       www.csgnetwork.com/capcccalc.html
       www.csgnetwork.com/capcodeinfo.html

Are all components wired the correct way round?
More on this later.

Are all wire links and/or jumper links in place, where they are included?

These are easily overlooked. Bear in mind that some are optional links while others are essential; read the instructions.

### Are all components soldered to the PCB pads?
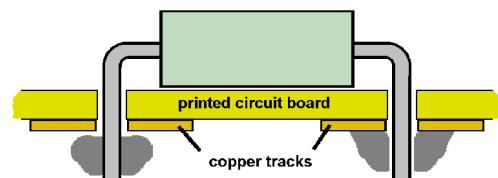
Are there any components whose wires protrude through the holes in the circuit board but have not been soldered to the track pads of the PCB?

Are there any dry joints?

Poorly soldered joints are a major source of problems. They prevent circuits from working, or cause them to function badly or intermittently.

The wire leads on the components and the copper pads on the printed circuit board should be clean and bright (free from any oxidisation) prior to soldering. The wire should be in full contact with the pad; the solder should not be used to bridge a gap.

This illustration shows the effects of dirty or oxidised joints. On the left, the solder has formed a blob on the component lead but has not made a connection with the copper pad. On the right, the solder has formed a mound on the pad but has not made a connection with the component lead.

Consider the image on the left.
It shows that the left-most pin is not making a solid connection to the track pad. The solder had adhered to the component wire but not to the pad.

Poor connections are also formed when a component is disturbed before the molten solder has been allowed to fully harden (e.g. by prematurely cutting the excess wire from a component). These are visible as the solder surface is not smooth but crystalline. Both of these image show disturbed joints

Most dry and disturbed joints are easy to spot on visual inspections. In some other cases, jiggling a component results in one end moving or even lifting from the PCB. You could also use a multimeter to confirm whether there is any break or unwanted resistance across a joint.

A suspect joint can be remade by removing as much of the solder from the joint as possible. If required, the component lead or track pad should be cleaned, before applying fresh solder. The soldering iron tip should be cleaned and wetted (a small amount of solder on the tip to aid the heating of the joint). Never apply the solder to the soldering iron tip and then transfer it to the joint. That way, the flux that was designed to protect the joint from oxidisation during soldering is burnt off prior to the solder touching the joint. Instead, apply the heat to the joint surface and apply the solder to the heated surface.

Are there any unwanted shorts between the tracks of the PCB?
This is another very common problem and is usually caused by:
- Applying excessive solder to a joint to the point that the blob flows across to a neighbouring copper track on the circuit board.
- A fine stray wisp of wire.
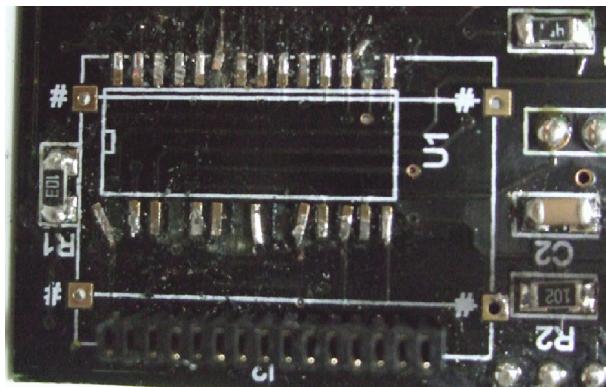
Use of a magnifier is helpful here, even if you have good eyesight.   An eyeglass magnifier or an illuminated magnifier on a stand is a worthwhile investment if you plan to construct a number of projects.

Are all the PCB tracks solid?
If you etch your own boards, 'holes' in tracks from over-exposure/over-etching a thin copper track and can lead to minute breaks in the track, or tracks that split when a board is flexed when screwed down.

Similar problems can be caused by overheating a connection during soldering, to the stage where the copper track separates from the board.   The floating thin copper track is vulnerable to cracking and breaking.

Here is an extreme example, where the excessive heat has lifted and broken many of the board's pads.

Are switches set correctly?
Applies to modules where DIP switches are used for configuring its settings.

Are all ICs correctly fitted?
Check that all ICs are pressed fully home into their holders.
Check that none of the IC's pins have been bent under instead of being inserted into the IC holder.

Are all module connections sound?
The module board may check out OK, but what about the connections to attached components – e.g. potentiometers, switches, buttons, lights, plugs, sockets, etc.

Are heatsinks fitted?
Heatsinks are commonly used on components that might overheat due to high current handling. These include voltage regulators, power transistors and some dropper resistors. These can easily be overlooked as they are not mentioned on some schematic diagrams or even in the assembly instructions.
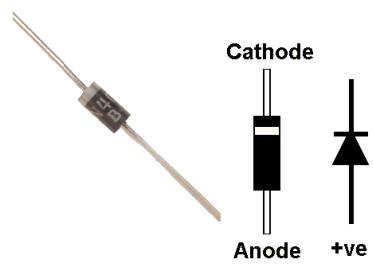
Polarities
The next step is checking that the components are fitted to the board "the right way round". Resistors and smaller value capacitors can be fitted either way round but higher value capacitors and all semiconductors have polarities that have to observed.   Fitting a semiconductor component in reverse stops the module from working correctly, and may destroy the component.

Here, as a reminder, are details of the polarities of commonly-used components.

Diode
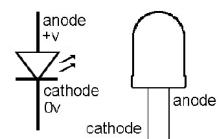
The band round a diode denotes the cathode and this is shown compared to its symbol on a schematic diagram.

Fitting a diode in reverse may not destroy it, depending on how it is used in a circuit, but may destroy another component by allowing excessive current to flow.   For example, it is common to connect a diode across a relay that is being switched by a transistor.   Fitted the correct way round, it prevents back emf (high reverse voltages caused by the collapsing magnetic field in the relay coil) from destroying the transistor. However, if fitted the wrong way round, it effectively puts the full supply voltage across the transistor.   With no load to limit it, the current through the transistor will rise from tens of milliamps to hundreds of milliamps. Not only will the relay fail to operate, but the circuits components may be damaged by the excess current flow.
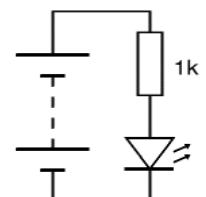
LED

The LED symbol, as shown on a wiring schematic, is displayed on the left, while the drawing on the right shows that the longest lead a LED is commonly the anode.

If you have LED with its leads cut (e.g. been removed from a board), you can't use this identification but you can use other methods.
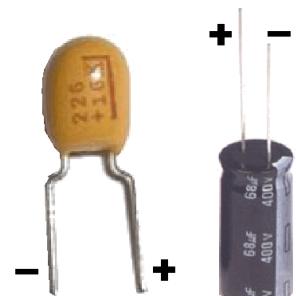
In some round LEDs, there is a flat edge on the LED bezel and this is always next to the cathode. If you don't have a flat edge, look inside the LED; the cathode is usually, but not always, the larger electrode.

If all else fails, just connect a 1k resistor to the positive terminal of a power supply (say 5V) and a wire to the negative terminal.   The LED will illuminate when the LED's anode is connected to the resistor.

High-value capacitors

Electrolytic and tantalum are 'polarised' – they have to connected the correct way round or they risk being destroyed.
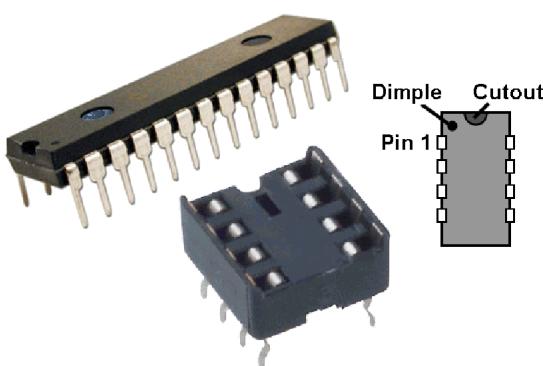
The polarities are marked on their bodies; the examples show a + symbol on one leg of a tantalum capacitor and a negative symbol on a black stripe on an electrolytic capacitor.

ICs and PICs

At one end of the body there is an arc cut into the moulding and often a 'dimple on the body.   These indicate where the pin numbering begins and ends, with pin 1 of the chip being next to the dimple, to the left of the arc.

Most I.C. holders have similar markings to indicate the 'top' and should be soldered to the PCB the right way round.   Then, when the chip is due for insertion, it is pushed into the holder with the orientation markings aligned.

I/O pins

Many modules use a ribbon cable or multiple wires to connect it to external components, or to another module.   The wires could be soldered directly to the module circuit board but is is more convenient to use plugs and sockets, as they allow easy removal and refitting.
The pins may be plain or may be the 'Molex' type that have a plastic body that ensures that the plug can only be inserted one way round. This prevents, for example, a power plug being inserted in reverse.   Of course, this assumes that you have correctly wired the plug in the first place.
Similarly, check that wires to the interconnect plugs have their wiring in the correct order and are plugged in with the correct orientation.   Using ribbon cables or a colour coding system minimises wiring errors.

Ratings

Electronic components have ratings that denote their maximum operating conditions – e.g. the amount of current that a diode can pass, or the amount of power that a PIC output pin can handle, beyond which they are likely to be destroyed.
In some cases, their specifications list both a continuous rating and a maximum rating.   For example, a 0.25W resistor could dissipate 0.5W for a limited time.   On the other hand, an integrated circuit may be instantly destroyed if it is operated beyond its maximum rating.

If you are building a project, the wattage value of power (e.g. dropper) resistors is calculated by

$$P = V \times I \qquad or \qquad P = I^2 \times R \quad or \qquad P = V^2 / R$$

where P is the power value, V is the voltage across the resistor and R is the resistor value.
Consider a 10mA LED connected to a PIC pin via a 270 ohm resistor. The 5V from the PIC is reduced to 2.5V at the LED.   The minimum wattage rating for the dropper resistor is only 2.5v x 0.01A = 0.025W. Now consider connecting a 6V 1 Amp relay to a 12v supply via a 6 ohm resistor.   Dropping 6V at 1A would dissipate a full 6 Watts in the resistor, requiring a high wattage resistor mounted on a substantial heat sink and situated away from the module's other components.
As can be seen, a resistor's wattage rating has to cope with its maximum working conditions. In practice, a wattage rating higher than that calculated is used, to provide a margin of safety.

Linked to maximum wattages, transistors and ICs also have maximum operating temperature ratings, beyond which destruction is likely.   Exceeding safe temperatures drastically reduces component life and can lead to 'thermal runaway' – increased temperature results in increased current flow, which leads to even greater temperatures, and so on, until the point of destruction is reached.
This can be avoided by ensuring that transistors and ICs:
  • are never run beyond their operating parameters.
  • are not close to, or touching, any heat sources.
  • Are fitted with their own heat sinks where appropriate.

You can use components with higher ratings than those specified; it just means that their size may be larger. For example, you can use 1N4002 (2 Amp) diodes instead of 1N4001 (1 Amp) diodes, or a 2A power supply instead of a 1A supply.   The exception is fuse ratings; never fit a fuse with a higher rating than recommended.
Don't use components that have lower ratings than specified – they were given the higher rating for a purpose.

Tolerances

A component's tolerance is the degree to which its value may vary from its stated value. So, for example, a 100k resistor with a 10% tolerance may be found to be as low as 90k or as high as 110k. You can buy resistors and capacitors with very narrow tolerances but these are rarely required in our projects; they are most used where very accurate results are required, such in timing circuits or in measuring equipment.

Note
If you are building from a kit, all the tolerance and rating values have been selected and tested and should pose no problem to constructors.

External problems

Sometimes the problem is not in the module but in the way that the module is connected and/or used.

Are you using a suitable power supply?
Does it have the required voltage and the required current rating?
The power supply should provide a stable output, one whose voltage remains constant under a variety of current requirements. Cheaper power supplies are unregulated. This means that their voltage output without a load may be higher than its quoted output, while their voltage output may drop below their quoted output when they have to supply current.

Many modules fit voltage regulators and these expect to fed by a voltage that is over 2V greater than the required voltage. So, for example, feeding a 9v supply to a 5v regulator is OK, while feeding the same regulator with a 6v power supply will produce an output that is less than 5v – often low enough to reset a PIC or alter a circuit's switching levels

What is the effect of a lower supply voltage level than that given in a schematic?
In the best case, little or nothing. However, in many cases the module's performance suffers; amplifiers produce lower voltage swings, relays fail to operate, switching levels are not reached, and so on. If a module uses a PIC, its brownout level will be reached, causing the PIC to reset. Many PICs include a built-in Brown-Out Reset (BOR) feature that resets the PIC when its supply voltage drops below an acceptable level for correct operation. Bear in mind that a PIC's supply voltage may only occasionally drop when it has to supply a burst of heavy current (e.g. when activating servo motors). This might explain how a module seems to misbehave intermittently.

What is the effect of a higher supply voltage level than that given in a schematic?
Firstly, there is the danger that semiconductor devices may be destroyed,
Then there are the problems of heat, component life and thermal runaway mentioned earlier.
Also, the triggering point for switching devices may be altered.

How can a power supply be tested?
The simplest way is to test the power supply when not connected to a circuit but with a dropper resistor across its terminals. The resistor value is chosen to draw the maximum current that the supply says it can provide. The value is determined by R= V/I, where V is declared voltage of the power supply and I is its declared current rating (bearing in mind that the nearest available value may have to used).
For example, if a module requires 100mA, a 5v power supply can be tested by placing a 47 ohm 1W resistor across it output leads. The current should be 5/47 = approx 106mA and a satisfactory power supply's voltage should still be 5V.

Any other power supply problems?

SMPS (switched-mode power supply) supplies only provide their stipulated output voltages when a sufficient current is drawn from the supply. If the minimum load current is not drawn (e.g. when testing the supply before connecting it to a module) the supply regulation does not function properly. In the case of PC power supplies, a source of high-wattage that is readily available from discarded computers and often found at car boot sales, the supply simply cuts off it there is no load.

Test a stand-alone SMPS supply by connecting a 100 ohm resistor across the terminals before taking a voltage reading.

A word of caution. The power dissipation in the resistor = 12 x 12 / 100 = 1.2W

If testing a laptop 18v supply, P = 18 x 18 /100 = 3.24W.

So, beware of the considerable heat from the resistor. Handle with care; watch your fingers!

Some users have a variable supply when building a module on the workbench. Some of these supplies may initially output a higher than the desired voltage, until regulation takes over. This poses the possibility of blowing semiconductors and/or PICs.

In general, it is best to switch on a power supply before connecting it a module that has no power regulator fitted. Fully-built modules with 5v regulators fitted are safe, as the regulators prevent any initial voltage surges.

Are you using the correct software/firmware?

Some projects are "works in progress", continually being developed and improved, removing bugs and adding features.

There may be hardware changes (e.g. the selection of a better component or a different component value), firmware changes (e.g. a new version of the code to be used to program a PIC) or software (e.g. updated versions of control programs or test utilities).

Maybe a feature you think you ought to have is unavailable because you are using a previous version of the software or the PIC code. Check their websites and use the latest versions.

Also, some modules only work when their device driver software is installed (see their documentation).

Are you using the software correctly?

Make sure you understand how to use the software, how to set it up, what it is supposed to do, what steps you need to take (and in what order), and what any error messages may mean. Some software is pretty obvious (e.g. an on-screen throttle) while others benefit from reading the manual (e.g. JMRI) or an understanding of the background technology (e.g. CBUS traffic monitors or RS232/USB sniffers).

Do you have the correct COM port setting?

Some modules may be designed to plug straight into your computers USB port. Others may only have a serial port interface, in which case a serial to USB adaptors has to be used. In this case, the software is fooled into thinking it is communicating with a specific serial port given by its COM port number. The software will prompt for which port number to use. Providing the wrong port number will either result in the program not working, or the program producing an error message. This can be complicated by different computers allocating different COM port numbers to your device. So, for example, it may attach as COM5 on your desktop but as COM3 on your laptop – and as a different port number on your friend's computer.

Is there unwanted electromagnetic interference?

These fields are caused by all mains, radio frequency and oscillatory electrical circuits. They can act at a distance and can induce unwanted voltages in anything that contains a length or coil of wire.

Sources of magnetic fields include SMPS power supplies, thermostats (e.g. fridges, central heating), car ignition circuits, fluorescent lights, radio masts and amateur radio, mobile phones, cordless phones, wireless LANS, video senders, etc.   In addition, model railway sources include electric motors, solenoids and DCC signals.   Of course, railway tracks act as great aerials!

The spurious voltages can result in unwanted operating conditions in a module and can explain why a module works on the workbench but not on layout.

Some interference sources are obvious; the layout works OK on another SMPS power supply, the problems start when the fluorescent lights are switched on, or when a cordless/mobile phone is used, etc.   Others are evident with a little observation; glitches coincide with the central heating switching off or when a particular servo or solenoid is activated.   Some interference problems are solved at source (e.g. changing a fluorescent tube or starter, fitting a suppressor or replacing a thermostat).   Other problems may be solved at layout level (e.g. re-routing cables, fitting additional RF bypass capacitors or filters, replacing a noisy servo).

Does your layout suffer thermal problems?

With many layouts sited in sheds, garages and lofts, they are subjected to extremes of temperature.

Excessive heat, and changes in temperature, can cause a great many faults.

Excessive heat, as explained earlier, can cause excessive currents in modules, and causes component lifetimes to be shortened.   Extreme heat warps plastic, causes LCDs to lose their contrast, and causes mayhem with semiconductors.

Temperature changes also produce problems.   The differing thermal coefficients (the amount of expansion and contraction) of PCB track, wire and solder can loosen the solder bond of a module's connections over time.

Temperature variations can also lead to 'thermal creep'.   IC chips move a tiny fraction of a millimetre each time the module heats up and cools down and eventually 'creep' out of their sockets.

Temperature variations also cause the layout's metal tracks to expand and contract and can lead to poor connections at track junctions

The application of heat (by a hair dryer or similar) to an area of the module board will expand any metal and hopefully expose any poor or intermittent connection. Conversely, if the problem is already present, the application of a freeze spray (available from electronic component suppliers) to selected areas will cool the area and hopefully restore normal operations, thereby showing up the problem connection.

Do you have static problems?

Static electricity discharge is really a construction issue but it might also explain a 'faulty' IC.   Static energy is most commonly generated when humidity is low and we walk across a carpet, wear nylon clothing, rub against certain materials and furnishings, etc. The static charge remains on the body remains it gradually bleeds away – or we touch an object that allows the static to be rapidly discharged as a spark.   If that object is a module board and its components then there is a danger of damage, particularly to CMOS chips.

These dangers can be minimised by the avoidance of static buildup and proper handling of devices.

Attention can be paid to the working environment, by having an antistatic floor mat or bench mat, applying antistatic agents to suspected materials, increasing the room's moisture level using a humidifier (or those little water containers than hang from your radiators), or even sometimes by opening the room's window.

Attention should also be paid to handling sensitive components, or boards on which they are mounted.   Fully-populated boards should be held by their edges, avoid touching the components, the PCB tracks or the board's edge connections.   Components that are sensitive to static damage should be kept in their packaging until they are about to be fitted to a module. The antistatic bags or conductive foam protect them until ready for use.

Lastly, make sure that you are not a carrier of static charge before handling sensitive components.

Some people rely on touching the radiator or a screw on a computer case, as both of these should be earthed.   A more reliable technique is ground yourself with a conductive antistatic wrist strap.

These are readily available and consist of a wrist band that makes contact with your skin and connects to the ground via a 1 MegOhm resistor, and a length of wire with a crocodile clip on the end.   This ensures that any high voltage charge is safely leaked away to ground. The resistor is fitted as a safety measure, to greatly limit the current should the croc clip accidentally come into contact with live mains.

Note

These measures won't repair a blown chip, but may stop you from also blowing the replacement chip.

Fault-finding equipment

If none of the above tests find the fault, test equipment can help you locate a fault. Project designers employ a range of test and development tools. For most hobbyists, a simple multimeter is a good investment and a worthwhile tool that will be used again and again.   They are available very cheaply and are accurate enough for most purposes.

A few other aids are also covered but lets start with the most commonly used tester.

The multimeter

As the name suggests, it is a meter that can make a range of measurements that help detect problems in components, in project boards and also in track wiring.   It can expose problems not found by visual inspection.   Even the most basic model will measure:

- Resistance
- Voltage
- Current

Each of these will be available in a number of ranges, as this aids reading accuracy.

For example, the voltage ranges might include 0 to 200mV, 0 to 2V, 0 to 20V and 0 to 200V. You choose the range that you expect best cover the voltage being read.

Not also, that the meter will have both AC and DC voltage and current ranges.

There are two types of multimeter:

- The analogue meter, with a needle that moves across a calibrated scale.
- The digital meter, with the readings being read off a digital display.
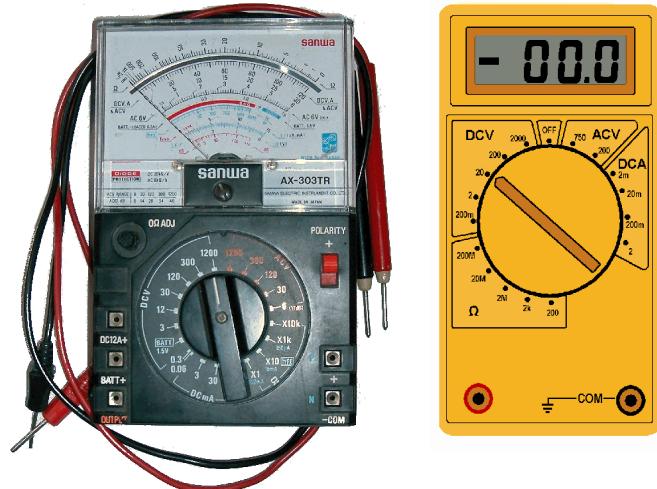
They both have different benefits.

The digital readout provides a reading with no ambiguity, subject only to the tolerances of the meter's own electronics.   If you are asking for help on a Forum, you can guarantee that you will asked for the voltage levels at various points on your circuit.
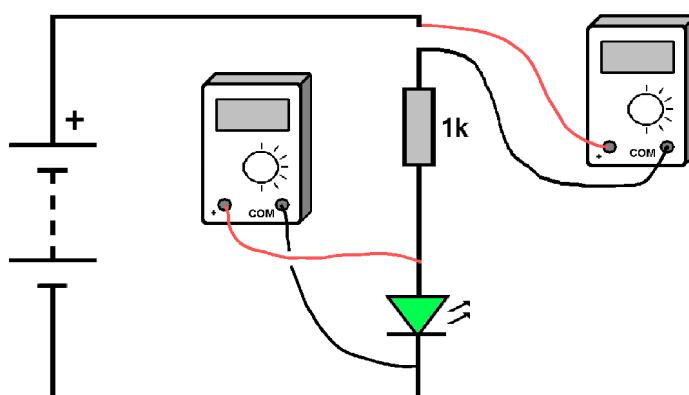
The analogue meter has advantages when reading varying levels.   The digital meter takes readings periodically and presents them to the user.   It is not easy to spot if there is a sudden quick dip in a value (e.g. a drop in voltage as a loco creates a momentary short going over a point). With an analogue meter, this would be readily detected as a quick dip in the meter reading.   Just be careful with analogue meters as you can damage the needle if you try to read a high value with the range set to a low value; the needle will shoot up to the end of its range and could be bent. Always work from higher ranges downwards, if there is any doubt. More expensive multimeters may also test diodes and transistors.

Apart from fault-finding on electronic modules, multimeters are used for a host of tests on model railways.   For example, on trackwork, it can detect broken wires, shorts at points, poor (i.e. high resistance) connections. On locos, they can detect whether all wheel pickups are working and whether there are any problems with the motor.   On controllers, they can detect whether there is the expected voltage output, whether a fuse has blown, etc.

The illustrations show typical multimeters. The sockets along the bottom are for plugging in test leads that are used to make the measurements. The black lead connects to the COM (Common) terminal and the red lead to the red terminal. The large knob chooses whether voltage, current or resistance is being measured, with each allowing a range of measurements.

This simple circuit has a battery powering an LED.   There is a dropper resistor in series with the LED to limit the current through the LED.
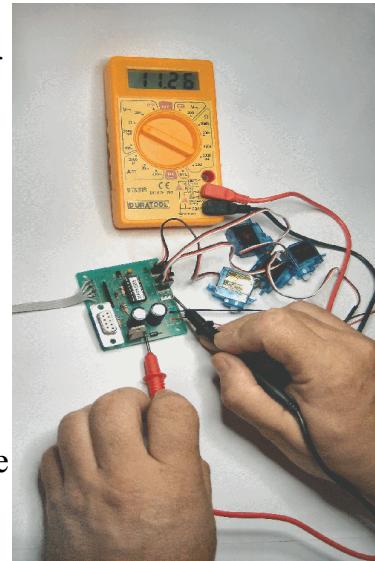
The illustration shows how to measure the voltage across the LED and also the current flowing through the LED.   Connecting the meter across the LED tells you what voltage the LED is working on.   Connecting the meter in series with the LED tells you what current is flowing through the LED.

Measuring voltage
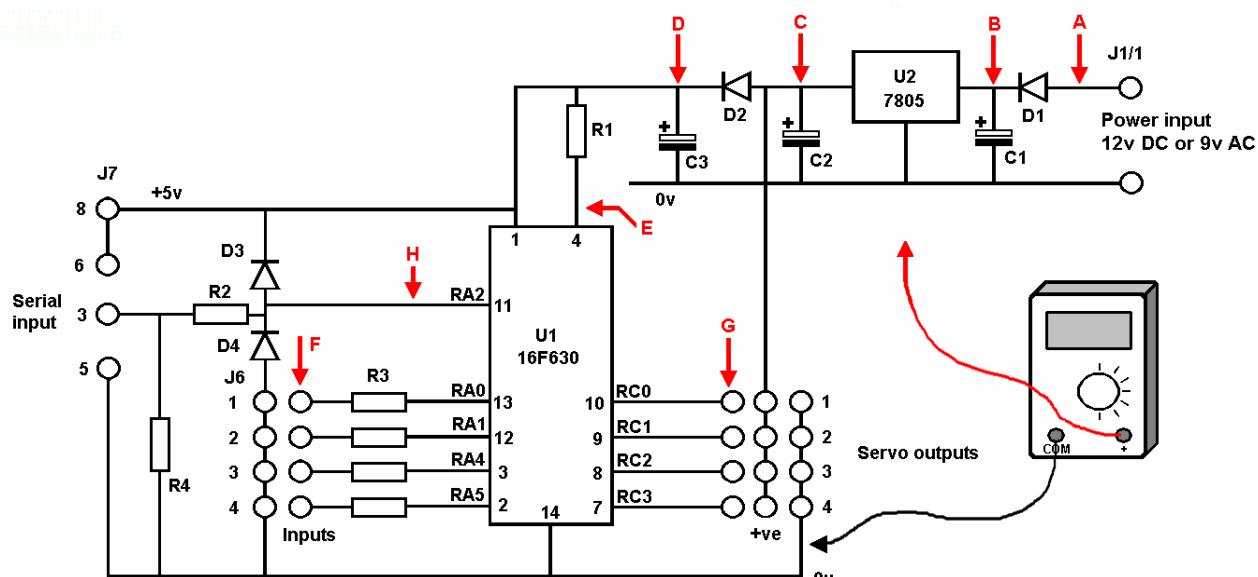
With these settings, the meter measures the voltage *across* a component, or *between* two particular points in a circuit. So, for example, if you are told that there should be a 2v drop across a resistor, the leads are touched against each side of the resistor wires, or to the parts of the copper track to which the resistor is soldered. Bear in mind that one end of the resistor will be 2v higher than the other end (e.g. it may be 5v at one end and 3v at the other end). The measurement is reading the *difference* between both ends.

In most cases, measurements are taken with respect to ground potential. So, if you are simply told that the reading at a point in the circuit should be 4v, it means with respect to ground. In these cases, the black lead is connected to ground, with the red lead touching the point to be read. In most other circuits, the ground potential is the common 0v point.

Example

Consider these possible voltage tests on a SERVO4 module.

Test point	Likely voltage reading	Purpose of test
A	12v DC or 9v AC	Confirms that the external power supply is working and is making a satisfactory connection to the module.
B	11.3v	Confirms that D1 is wired the correct way round and is working.
C	5v	Confirms that U2 is wired the correct way round and is working. Confirms that there is no abnormal load (e.g. a short circuit) across the regulator.
D	4.53v	Confirms that D2 is wired the correct way round and is working.
E	4.5v	Confirms that R1 is correctly connected.
F	Switches between 0v and 5v	Confirms that the incoming switching signal (e.g. from a switch on a control panel or from the output of another module such as a CBUS board) is working and is reaching the SERVO module input.
G	Between approx 0.17v and 0.33v	See notes
H		See notes

Notes

The difference in readings between A and B (and between C and D) is caused by the voltage drop across the diodes.

Test points G are the outputs from the PIC to the servos.   If the PIC is working properly, it sends out a stream of pulses whose pulse width varies depending on the programmed servo rotation position. The voltmeter averages out the voltage pulses, producing an average voltage that is significantly lower than the supply voltage.

Test point H is the input to the PIC from the serial input socket and is only active when a PC is programming the servo module, otherwise the voltage reading is zero. A voltage reading at point H can confirm that the PC's serial port output is arriving at the PIC, proving that the computer, the serial cable and the servo setting program are all functioning.   The voltage reading at point H should be approx 3v, dipping while the application's setting slider is moved.

Ground / Earth / 0v

The above diagram measures readings against the 0v level.

You may find some magazines or articles refer to this as 'GND' or 'ETH' level, GND being the American term for ground and ETH being the UK term for earth.   Strictly speaking these terms should only be used when that connection is taken to the actual physical ground (e.g. to a metal water pipe or a metal spike sunk into the ground.   However, the term is sometimes used for 0v level.   Most circuit diagrams refer to 0v.
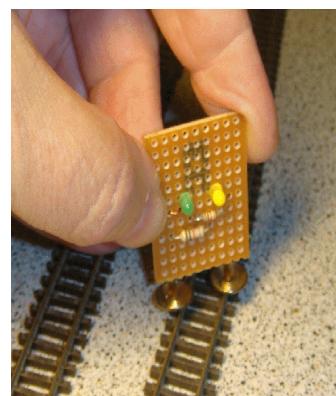
Other voltage readings

Multimeters are useful for detecting voltage drops with long cable runs.   If 12v is fed into a cable but only 10v arrives at the other end, the cable may be too thin or the drop may be caused by badly soldered joints, poor plug and socket connections, poor relay contacts, etc. The meter will expose the source of the problem.

DCC signals can be measured using the AC settings of a multimeter, with enough accuracy to determine the presence/non presence of the signal and an approximate reading of DCC signal level.

This image shows a quick and easy way to test for the presence of DCC at various points on the track.

Two studs are soldered to a piece of stripboard.   Two LEDs (with their resistors) are wired in different directions across the studs. The tester is held against the rails.   If one LED lights, you have power. If the other LED lights, you have power in the opposite direction.   If both LEDs light, your track is receiving DCC power. The tester can be moved around to test various sections of track easily and is less fuss to use than a multimeter (e.g. it can be used one-handed).

Note

While multimeters are capable of testing mains voltage, beginners should never poke around inside mains power supplies, or any other device where live mains voltages are exposed.

Dont carry out high voltage tests, specially mains voltages, unless you are fully competent. **Mains voltages can be lethal.**

Logic probe

Many of the voltage readings you make will be analogue (e.g. The voltage might be any level between 0V and 12V).

However, when you work with digital modules, you only want to know if an input or output is high or low, usually 0V or +5V.

Examples uses of a logic probe are to:

- Check the supply pins of a chip. Is it getting both the +5v and the 0v?
- Check the output from a track detector – is it changing when a loco passes?
- Check the input to a circuit that is coming from a switch – is it going from +5v to 0v, or 0v to 5v, when the switch is operated?
- Check whether the inputs and outputs of digital modules are producing the expected results.

The internal circuits in lots of electronic modules work on 5v, even when the they are connected to a 12v or other voltage supply. This project is for a very useful tool that tells you whether a point in the circuit is at +5v or at 0v.

You could ask why not just use a multimeter? You could connect the -ve lead of your meter to the 0v line of your module. Then you could tap various parts of the circuit with the other lead. If you have +5v on that point, you will get a reading. But – and here is the catch – if you do not get a reading, it does not mean that you have 0v at that point. You might just have a broken wire that is not connected to anything. To check for connections to 0v, you would have to connect the meter's +ve lead to the 5v line and then test with the other lead's probe. You would have to reverse your meter connections every time you wanted to check for +5v or 0v.

That is where a logic tester is handy. It connects to the +5v and 0v of the module you are checking. Then you touch any point in the circuit. If +5v is on that point, a green LED lights up. If there is 0v at that point, the red LED lights up. All other voltages, or points not connected to anything, either keep the LEDs unlit or dimly lit.

The image shows a commercial logic probe but it is not too difficult to build your own.

Measuring current

With these settings, the meter is placed in *series* with the part of the circuit being measured, so that the normal circuit current also flows through the meter. This might necessitate breaking into the circuit, probably by unsoldering one end of a component and lifting that end clear of the board. The diagram shows a very basic test used to measure the current flowing through an LED.

Most often you will be checking the current drawn by an entire module. Here, the multimeter is placed in series with the power lead to the module. Again, observe polarity – i.e. the red lead to the more positive side of the circuit.

Most modules consume approximately 20mA to 60mA. This does not include the current drawn by any devices (e.g. motors, solenoids, servos, etc.) connected to the module. For example, a servo control module draws about 20mA but each individual servo could draw many hundreds of milliamps.

If no current is read make some basic checks (meter switched on/set to current range/wired

in correctly, power supply switched on) before checking the module's components. If an excessive current is read, switch off immediately, before any components are destroyed. Then make the checks outlined earlier (e.g. shorts across tracks, wrong component values, components connected incorrectly, etc.).

Other uses for current readings are
Heatsink decisions
Read the voltage across and the current through a component (e.g. a voltage regulator or a dropper resistor), calculate the power dissipated in the component and select the heatsink necessary to handle it.
LED droppers
LEDs are rated to work at certain currents, with most rated at a maximum of around 25mA or 30mA. Low current LEDS can operate as low as 2mA and a 20W power LED works at over 1A. You can use an online calculator to determine the dropper resistor value. If you are not connected to the Internet, you can use the multimeter to check the resultant current from using a number of different series resistors (remember to use the highest value first).

Reading fluctuating values
Some circuit produce temporary changes in voltage/current, either intentionally or as the result of some problem. These cannot be accurately examined or measured with a digital multimeter, which is intended to read fixed values. If the value changes slowly, as in the case of gradually increasing current caused by overheating, then a digital meter can display the changes.
However, short duration spikes or voltage dips are unwanted and cause problems. For example, a burst of heavy current being drawn by a servo may drop the supply voltage and cause a PIC to reset. The duration of the voltage change may be too short to be detected by a digital multimeter. In many cases, such changes are observable on an analogue multimeter. Instead of a digital readout, they move a pointer across a marked scale. Hence many short-lasting changes are displayed as a flick of the pointer, where it would not be likely to be detected on a digital readout. Analogue multimeters are slightly more expensive than digital versions.
Rapidly changing values, such as DCC or CANBUS signals, can only be accurately examined with the use of an oscilloscope (an expensive piece of equipment and not required for general use – see later).

Measuring resistance
With these settings, the meter measures the resistance *across* a component, or *between* two particular points in a circuit.
Note that the readings must be made with the power switched off.
Like voltage readings, accurate measurements are simple when a component is tested before it is soldered to a PCB. Measurements of components once soldered are often complicated by other components that are on the board. In extreme cases, you may have to disconnect one end of the component from the PCB, to ensure that you are only reading the component on its own.
Also, remember to read the resistance with the meter's probe connected both ways round, to ensure against unexpected results (e.g. an initial suggestion of a short circuit might simply be that you are reading a diode or a transistor in its low resistance direction).

Typical problems detected by resistance measurement are:

Open circuit

No reading means no resistance to measure, indicating a break in the circuit (assuming you have switched on the meter, set it to the correct range and connected it across the correct points).

Short circuit

A very low resistance reading indicates a short inside the component or a short across the modules PCB tracks or connections.   Of course, there are occasions when you hope to see a short circuit - when testing for the continuity of a stretch of wiring, or confirming that wires have been connected to the correct pins/connectors.

High resistance

A higher reading than expected usually indicates a poor connection.   Check for a dry joint in the soldering, or poor switch and relay contacts. It could also mean that the wrong value of component has been fitted.

Intermittent connection

Fluctuating readings indicate a connection that only makes proper contact intermittently. It may be caused by badly soldered joints, poor plug and socket connections, poor relay contacts, or even a wire that is broken inside the plastic outer sheath. As explained previously, an intermittent connection may only exhibit itself in times of extreme heat or cold.

Using an oscilloscope

This is definitely not the first test tool that you will buy.   In fact, you may never need or use one, although it is widely used by professional developers and service technicians. In the hobby area, it is a valuable tool for examining signals where there is a suspected problem.

An oscilloscope creates a two-dimensional scaled graph on the screen showing how the signal voltage being monitored changes over time, as shown in this image. It can display both AC and pulsating DC waveforms.

Time is displayed along the X (horizontal) axis, from left to right, and the voltage level of the signal read at each point in time is shown on the Y (vertical) axis.
The display is usually calibrated in 10 horizontal divisions and 8 vertical divisions.
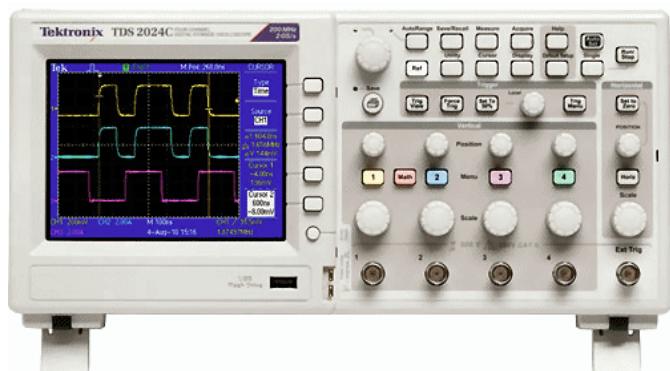
Oscilloscopes are very useful in examining and checking signals that are 'cyclic' – i.e. signals that repeats themselves.   This can commonly be found in model railway electronics.
Examples are pulse width DC controllers, servos, DCC, CBUS, etc.
Older oscilloscopes used cathode ray tubes,similar to those used in old television sets.
Most models now use an LCD screen to display their readings.
The model shown above is a professional product and these can cost thousands of pounds. They are really bench tools.
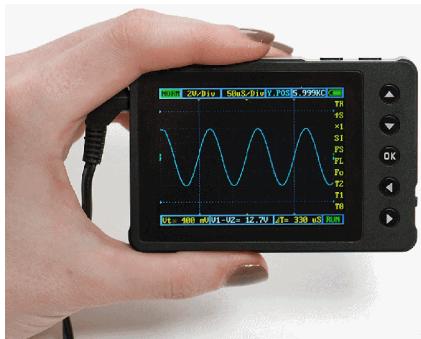
If you need to test on the move, you can buy a handheld version as shown.

Another approach is to place the electronics in a separate box and connect it to a PC or laptop. That allows the monitor to be used as a large display screen. It also reduces the cost considerably.

This image shows a PicoScope unit converting a laptop into a temporary oscilloscope.

One lead from the scope is connected to 0V and the probe is touched against the point in the circuit to be tested.

Likely tests using the oscilloscope include:
- The voltage level of the signal
- The frequency of a signal
- The repeat rate of pulses
- The time delay between events.
- Whether the signal is being distorted
- Whether the signal is suffering from interference or noise
- Whether the waveform is clean (a fast rise and fall time, no ringing)
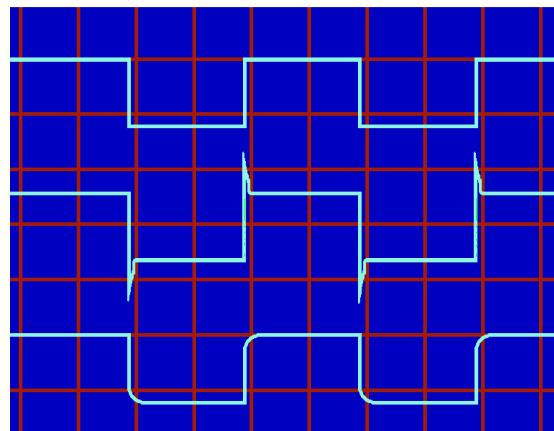
The illustration shows a square wave output being examined.

The top display shows what a clean waveform should look like.

The middle display shows the effect of 'ringing', with the value overshooting as it rises and falls.

The bottom display shows that the waveform is being rounded off.

These imperfections would produce no visible effect on a simple pulse device such as a flashing LED on a vehicle.

However, on systems that rely on efficient communications, such as DCC and CBUS, these distortions can create a significant problem. The oscilloscope can be used to reveal any such signal problems.

Some signals are entirely cyclic, such as a servo's signal stream or the PWM output from a controller. The exact same waveform is constantly transmitted for any one setting. Change the setting (e.g. increase or decrease the controller's speed) and you get another constantly repeating waveform.

Other signals contain data and these contain 0s and 1s in particular patterns to encapsulate the information being sent. Since they don't contain continual repeating ons and offs, their data rate is measured in bps (bits per second) and its multiples (Kbps, Mbps).
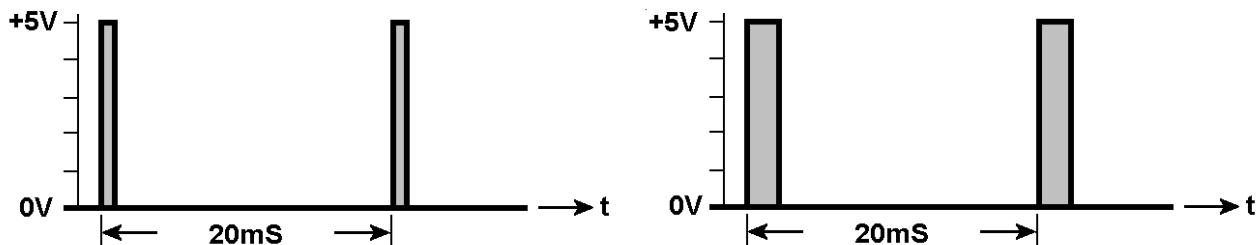
Some examples:
- Servo repeat rate is 50Hz
- PWM repeat rate can be as low as a few hundred Hz.
- DCC is approx 7KHz
- A computer's serial port operates at 115200 bps
- CBUS is 125kbps

The oscilloscope has to calibrate the X axis in units of time appropriate to the speeds being examined, otherwise you would not be able to adequately see the waveform.

The 'Horizontal Sweep' is the control that alters the speed at which the trace moves across the screen and is usually measured in seconds per division (s/div), milliseconds per division (ms/div), microseconds per division (s/div), or nanoseconds per division (ns/div).

Example
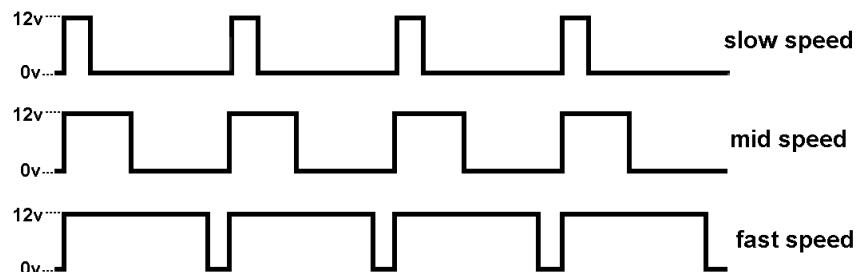
The scope's horizontal scale has 10 divisions.   Say you want to look at the signal being sent to a servo.   The pulse is sent out every 20mS, so setting the sweep speed to 10mS/div would result in the display showing what happens over a 100mS time slot.   This would let you see five servo pulses on the display.

If the sweep speed was set to 1mS/div, you would see 50 pulses on the display but the pulse widths would be so narrow that you would not be able to see the pulse width changing when the servo settings were altered.   Its a matter of matching the sweep width to the signal being examined. Oscilloscopes typically handle waveforms from as low as 1Hz up to several MHz, or if you pay a lot more they can cover several hundred GHz.

The chapter on loco controllers explained how PWM (pulse width modulation) improves the running of your loco, specially at low speeds.

The repeat rate of the waveform may be a few hundred Hz but can be lower or even many Khz.   The common feature is that the pulse width varies from being non-existent (the same as 0V) to being constantly high.

Some DC controllers have a PWM output but don't mention it in their advertisements.   You can easily check with an oscilloscope by placing its leads across the controller output and adjusting the horizontal sweep until you see waveforms like those above.

Voltage levels

In the same way as you match the horizontal scale to the waveform, the vertical axis must also be set to have the waveform fill most of the vertical screen space.   The vertical scale is measured in volts per division (V/div), millivolts per division (mV/div), etc.

If the signal being measured peaks at only 10mV, you wont see much if you have the vertical scale set to 1V/division.   Similarly, if you try to view a 5V signal with the scale set to 10mV/div, the waveform shoots off the vertical edges of the screen and you won't see the waveform details, such as ringing and rounding.
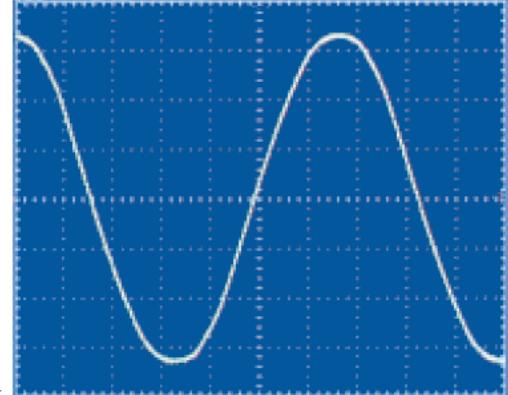
AC readings

The above examples show pulsed DC signals being examined.   The oscilloscope is also able to read AC waveforms, such as the output from a mains transformer (you can also read the mains itself if you are experienced enough and take safety precautions – if in any doubt, leave well alone!).

The illustration shows a typical display of an AC voltage.   The horizontal line along the middle of the display indicates 0V and the waveform swings above and below this value as it alternates between positive and negative peaks.

In the UK and most of the world, the mains supply is at 50Hz (mostly around 230V), with the Americas and some other countries using 60Hz (mostly around 120V).

So, if the oscilloscope was set to 10mS/div, you would see two complete cycles of 50Hz AC on the display.

If the scope was set to 50V/div, we would mostly fill the screen vertically with a standard UK mains supply waveform (from the first chapter we noted that a 240V RMS is the same as 680V peak-to-peak which is what the scope will see).

Digital storage
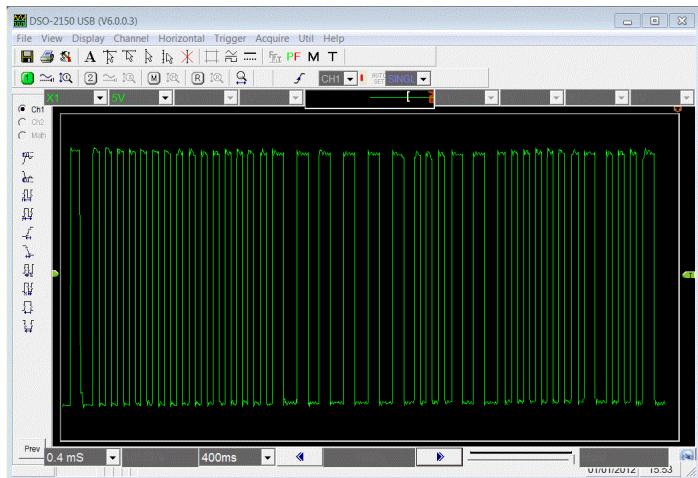
All the above waveforms were cyclic: you could rely on the pattern continually repeating itself.   However, there are other signals that don't repeat so conveniently.   For these, a *'digital storage oscilloscope'* is used.   Instead of simply reading the input and displaying the results on the screen, a DSO saves the values of each sample it reads into memory   This lets you view the results your convenience. The results can also be stored as a file or be printed out.

So, events that happen only once or only occasionally, known as *'transients'* can be detected where they would otherwise happen too quickly to be spotted.   This is handy for detecting 'brown outs', sudden short drops in the supply voltage that may reset PICs or provide false triggering. You also check whether a change of output somewhere is unexpectedly triggering an unwanted input somewhere else.

DSOs are also used to examine digital signals that are not cyclic. These signals contain data that may be constantly changing. Examples are communication systems, DCC and CBUS.

The image shows the display of a DCC signal. Although the pattern looks random, the sequence of ONs and OFFs, contain the data that will be used by the DCC decoder.

It is possible to examine this waveform and determine the exact content of the message.   It can also be used to check the integrity of the waveform, for example to see whether there is excessive ringing on the DCC bus.
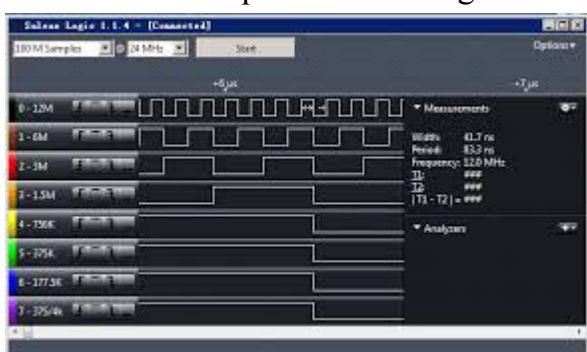

Logic analyser

Most oscilloscope have two separate independent inputs, allowing you to monitor two different signals at the same time. The more expensive models can handle four channels. As explained earlier, oscilloscopes can examine both analogue and DC pulsed inputs and so can display voltage levels, rise and fall times, noise, distortion, etc.   However, with their limited number of inputs, they cannot readily be used where there are many different digital readings to be taken simultaneously and compared.

Developers, or those faultfinding on modules with multiple input and outputs, use a *'logic analyser'* to display the status of all the inputs/outputs on a single screen simultaneously. As the name suggests, it is not designed for looking at analogue signals. It captures and displays the logical state (i.e. either high of low) of digital signals.

It has the big advantage over oscilloscopes in that it can handle a large numbers of different signals, the exact number depending on how big your budget is.   The most-powerful laboratory models can have a large display area and show up to hundreds of channels.

The picture shows a *'Saleae'* analyser with 8 channel capability.   It has 9 test hook clips, one for the common point and one for each point to be monitored. To reduce costs, it connects to your computer via USB and uses the computer and its large monitor.

Of course, you do not have to use all eight channels if you do not need them all. This image shows eight different points on a circuit being monitored. An analyser's display shows the sequence of events and the timing between events (e.g. whether the output from one part of the circuit triggered an input in another part of the circuit and, if so, if there was a delay).

Since you can look at many outputs lines in parallel, you can see the output from 8-bit or 16-bit buses, which is why this tool is popular with computer engineers.

Some models can look at a group of inputs and display their combined values in decimal or hex notation, or even in assembly code mnemonics.

Some models understand communications protocols such as RS232, I2C, SPI, CAN, etc.

Final observations

This chapter is not the definitive text on fault-finding.   There are many variations, different approaches, and much that can be added from others' experiences.   Remember, tests and their results will depend on the circuit being tested and your ability to use your equipment (you have read the manuals, haven't you?)

Hopefully, this chapter provides some useful tips for those starting off in the hobby and gives an overview of some test equipment.

Chapter 21

Pocket Money Projects

Pocket Money Projects

This chapter presents at a series of mini-projects that first appeared in issues of the MERG Journal.   They are designed as *'getting started'* kits for beginners, although they are also useful to all enthusiasts.
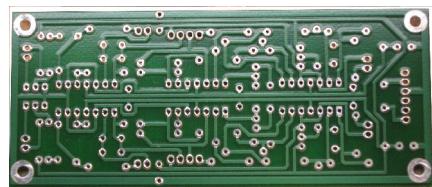
PMPs aim to meet the following requirements:

Cheap	Projects must be inexpensive, so that you can *'have a go'* without any great outlay (or any great loss if they make a mess of things!)
Easy	Kits must be simple to build. They must use the minimum number of components and avoid fiddly parts such as surface mount devices. They should require no specialist tools or computers to build and test. The components should be mounted on a piece of stripboard, as stripboard has wide copper tracks and wide gaps between tracks. This avoids producing costly printed circuit boards and makes soldering easier, minimising shorts between tracks, etc.
Useful	Kits must provide useful extensions to layouts, including some features not otherwise available.
Educative	The notes must include a section on *'How it works'* that is not too technical but helps you learn a little bit more about electronics.
Alterable	Kits will not be at the cutting edge of technology, providing every possible facility. They are fun projects with a useful item at the end. They should be capable of modification as you learn more.
Easily available	The parts should be available from all major electronics suppliers and use no specialist components, apart from the pre-programmed PIC chips that some projects use. All the projects that follow are available as complete kits of parts to MERG members.

Why stripboard

Once you have got past the stage of buying an using ready-built equipment, you might consider tackling building a kit that for your layout.
A careful read of the instructions, an evening's soldering and the kit is complete and can be tested and connected.   You don't need to worry about how it works; only what it can do for you. These kits usually come with a printed circuit board similar to the one shown here.
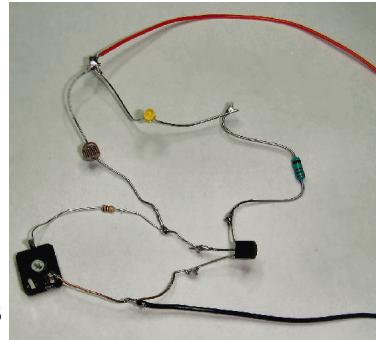
Eventually, you might think of trying to build a circuit you saw in a magazine or on the Internet – or even a simple idea that you want to try. For the great majority of projects, getting the components is easy; they can be purchased from suppliers such as Rapid, Radiospares, CPC, Bitsbox, etc, or even cheaper on eBay.   But, since they are not complete kits, there will not be a printed circuit board available.   PCBs are great; they tell you where to put your components and make life simpler for the constructor.

Without an available PCB for your, you have a number of options.

- Solder them all hanging in mid air, as in this photograph. This will work for a very small temporary test circuit but is useless for large or permanent builds.
- Design your own PCB and have it made for you. This involves learning how to use a design package. Even worse, manufacturing one board is very expensive.
- Design your own board and etch the PCB yourself. This still involves learning the design software. It also requires working with chemicals.
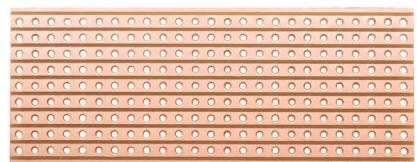
None of these are of much use to a beginner

That is where stripboard comes in.

Stripboard (originally called 'Veroboard') is designed as a prototyping board for building a one-off project. The finished project, if proven to be successful, can be put into long-term use or – if it becomes popular - PCBs might be produced for wider use.

Most stripboards use a thin sheet made from SRBP (synthetic resin-bonded paper - a paper based laminate). Higher quality versions are made from FR- 4 (a fibreglass-reinforced epoxy laminate).

As the picture shows, one side has copper tracks bonded to it. The whole board is then drilled through with holes that are spaced 0.1" (2.54mm) apart. This is designed to have the same spacing as ICs, their holders, etc..

Sizes

The most commonly used sizes by hobbyists are

25mm x 64mm - This board has 9 tracks, each track with 25 holes

64mm x 95mm - This board has 24 tracks, each track with 37 holes

The 25mm x 64mm version are used in all the Pocket Money Projects.

Vero Technologies make a large range of other sizes and details are on their website at:

www.verotl.com/veroboard

If required, the boards can easily be cut to size with a small hacksaw.

All the circuit's components are laid on the opposite side to the copper tracks, as shown in the picture.

The wires from the components are bent, then inserted through the holes and soldered on to the copper tracks on the other side.

The copper tracks are used to make the connections between the various components. If you see a picture of a project on a stripboard, it usually has the strips underneath running horizontally.

Cutting the tracks

To use the copper tracks to maximum efficiency, the lengths are often cut, to create smaller runs of connecting track.

In the case of the chip shown in the above picture, the track between the rows of chip pins would have to be cut; otherwise the pins would be shorted together.

You could cut the track with a sharp knife but that can be a messy – and dangerous – task.   If you are considering making a number of projects on stripboard, it might be worth investing in a stripboard spot face cutter, which quickly does a nice clean job of removing the unwanted copper. The cutter is placed in the desired hole in the copper track and rotated back and forth until a circular area of copper is removed. Check as you go, otherwise you might drive the cutter right through the board!

An alternative to a spot face cutter is a drill bit (3mm or 5mm). Turn the bit it by hand; an electric drill would rip a large hole in the stripboard in two seconds flat!

In either case, before moving on, check that there no remaining tiny strips of copper still bridging any of the track sections. Next, clean the copper strips prior to soldering the components.

Making links

The copper tracks are not always sufficient to connect all the components. In those cases, and it can happen often, you fit wire links between the points you want connected. You can see copper wire links in the above picture.
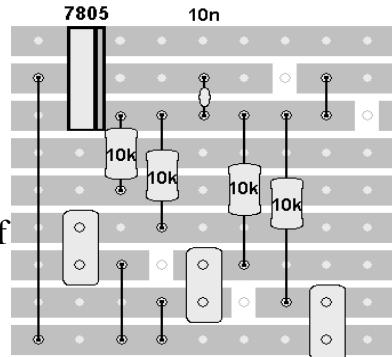
They nearly always run vertically, bridging two section of track by jumping over the tracks in between.   Any wire will do, as long it can handle the current it is expected to carry.

Positioning

Getting the components into the correct positions and through the correct holes is a tricky business, as it is very easy to make mistakes.   After all, even the smallest board has 225 holes (9 rows of 25).

Unfortunately, you can't look at both sides of the board at the same time.

To help, some diagrams show the components and the track at the same time, as in this example.   It is really showing where the components should go.   It shows the tracks underneath, as if the board was transparent, to help you cut the tracks in the correct places and position the components correctly.

Designing a layout
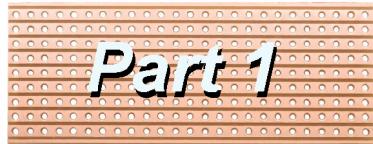
This is not often an issue for beginners, as printed layouts are usually provided. However, if you become ambitious, you would have to consider how to convert your circuit into an efficient stripboard layout.   Paper, pencil and rubber could be used but a number of software applications are available to help you. These range from StripMagic (free) to LochMaster (commercial).
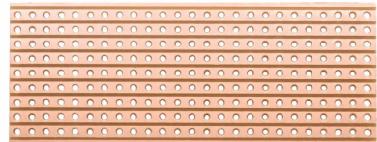
A number of possible packages are reviewed on this website.

www.printedcircuitsboards.com/software/88/veroboard-stripboard-software.html

Pocket Money Projects

Part 1

A series of small, cheap,
easy to build projects
using stripboard

*by Davy Dick* M1853

Track power indicator
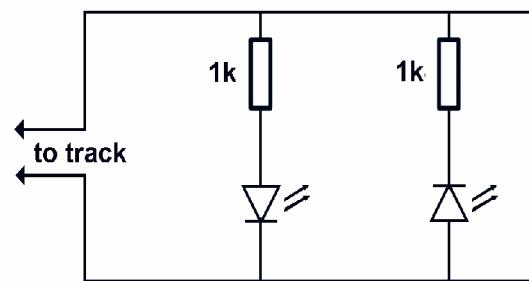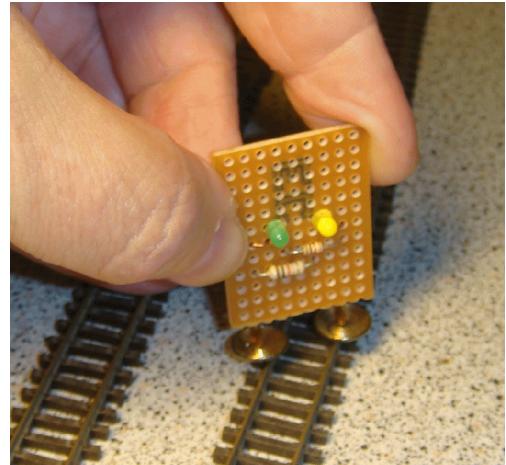
There are many occasions when you may need to
check if a particular section of track is receiving power.

- Maybe the power to a track section is switched
  by relays or switches.
- Maybe the wiring or connections to a piece of
  track is suspect.
- Maybe you want to check if you have wired a
  new piece of track with the polarity the correct
  way round.

You could always check with a multimeter but these
are inconvenient, bulky and awkward to use in tight
situations.

With our little board, you simply touch the module's
studs on to the rails.   If one LED lights, you
have power. If the other LED lights, you have
power in the opposite direction.   If both LEDs
light, your track is receiving DCC power.

Fancier commercial versions are available, some
even with digital readouts - but they are 20 times
to 100 times more expensive.
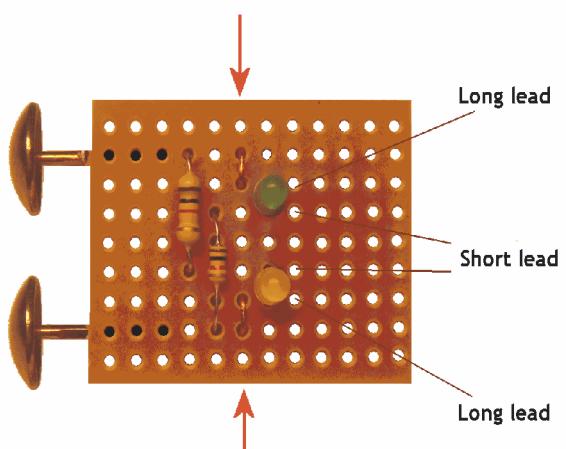
How it works

The circuit diagram is very simple.
Two LEDs (light emitting diodes) are connected
across the track when the board's studs touch
the rails.

The 1k resistors (known as *'dropper resistors'*)
are there to make sure that the high track
voltage does not result in excessive current that
would destroy the LEDs.

A LED only lights when it is connected across a
voltage in the correct direction. If wired the other
way round, it won't do any damage, but it won't
light up.

You will notice that the two LEDs are wired in different directions from each other.
So, if the track voltage is one polarity, one LED lights up. If the track voltage wired in the
opposite polarity, the other LED lights up.   That way, you can still test for track power
regardless of whether the controller is set to forward or reverse.

If you have a DCC system, your track voltage is constantly switching polarity at a very fast rate, so both LEDs will light up if DCC power is detected.

Parts list

- One piece of stripboard 25mm x 64mm   34-0500
- One RED LED   55-0150
- One Green LED   55-0105
- Two 1k resistors   62-0370 (sold in packs of 100)
- Two brass dome upholstery studs – or two short leads with clips on the end.

If you are a MERG member, this is available as a kit - PMP1 Part No: 801.

If you are in an Area Group/club, why not place a joint order and share the postage costs? The part numbers listed are for Rapid Electronics (www.rapidonline.com).   Alternatively, check out www.bitsbox.co.uk or eBay for competitive prices.

Construction

With so few components, this project does not need any cutting of the copper tracks. First clean the copper strips and the wire leads on all components. This minimises problems from dirty or oxidised surfaces during soldering.

The studs are soldered directly to the copper tracks and their position allows them to touch across either 'N' gauge and '00' gauge rails.
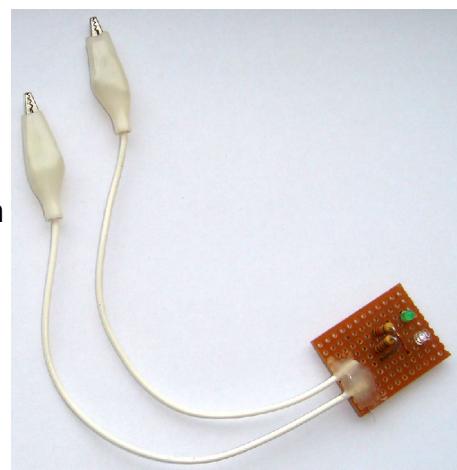
The resistors can be fitted either way round but the LEDs must be inserted as shown in the illustration. LEDS are manufactured with one of the two wires longer than the other.

Don't forget to fit the two wire links (they are pointed to by the arrows)

You may want to have the module connected to a stretch of track while you check the layout wiring, switches, connectors, etc.

An alternative to studs is to solder two short lengths of wire where the studs are connected. The two wire leads should have clips soldered to their ends. The module can then be clipped across the track while tests are carried out.
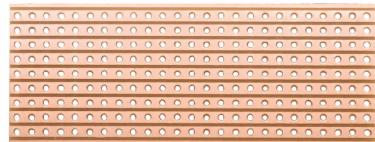
In fact, since the above project only uses half of the stripboard, why not cut the board in half and build both versions – it will only cost you £1.

Pocket Money Projects

Part 2

A series of small, cheap,
easy to build projects
using stripboard

by Davy Dick M1853

Train detector

This is basically a circuit for detecting changes in light levels
and it is has many uses in model railways.
A light sensor is positioned between track sleepers and the light
to it is blocked when a train goes over the sensor. This triggers
an output from the module (in our case lighting a LED).
Possible uses include:

- A train stops in a marshalling yard and yard lights come on.
- A light comes on in the control panel when a train reaches a required point on an obscured
  section of track.
- Control panel lights indicate which hidden sidings are occupied.
- Triggering events in other modules such as the CANAC8c.
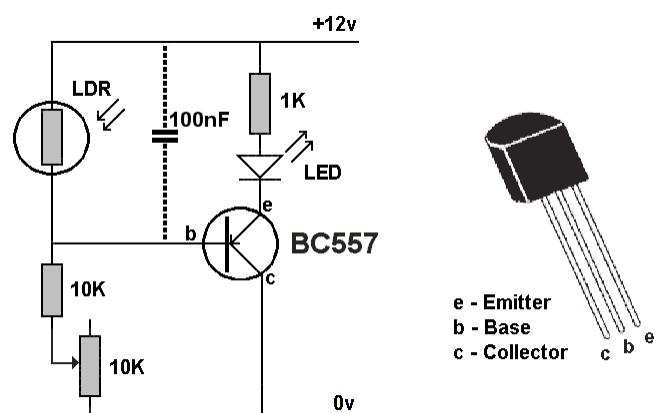
The project uses just six (or 7) components.

How it works

If you are curious about how it works,
read this section; otherwise skip to the
next section (you can always come back
and read this later).

Here is the circuit diagram for the light
detector.   It is powered from a 12v
supply since that is a common voltage on
model railways. However, it can also be
operated by a 5v supply.
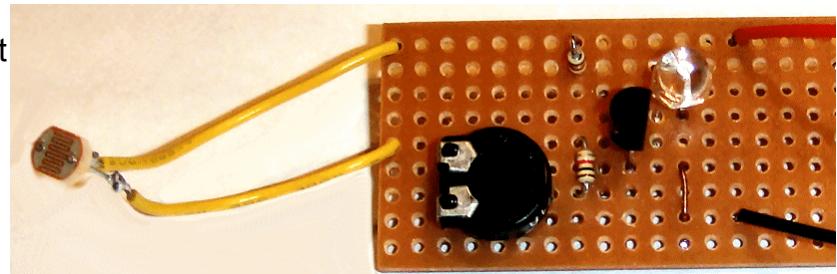
It uses a transistor to light the LED.
A transistor is a small 3-wire semiconductor device that was originally mainly used as an
audio or radio frequency amplifier, like those in an old transistor radio.
Depending on the voltage fed to them, they can also act like a switch, as in this project.
The main flow of electrical current in a transistor is through its collector and emitter wires.
That current is used to light the LED. The 1k resistor that is wired in series with the LED
protects the LED by limiting the current flowing through it.
The amount of current through the transistor depends on what happens at its 'base'
connection. It acts like a tap,
controlling the amount of current
flow.
The light sensor used in this
project is called a light
dependent resistor (LDR)
because its resistance varies
with the amount of light shining

on it.   The one shown has a resistance of between 8kohms and 24kohms when exposed to light (at 10 lux), rising to 1Mohm when in darkness.
It will have resistance values between those two extremes, as the light value alters.

There is an LDR, a 1k resistor and a 10k preset potentiometer (a small variable resistor) all in series across the 12v supply.   The base of the transistor is connected to the junction of the LDR and the 1k resistor.   The voltage at the transistor base will vary depending on the resistance of the LDR (which, in turn, varies with the amount of light shining on).
When exposed to light, the LDR has a low resistance and the voltage at the transistor base will be high.   This will turn the transistor off and the LED will be unlit.
When in darkness, the LDR has a very high resistance and this lowers the voltage at the transistor's base. This switches on the transistor and the LED lights.
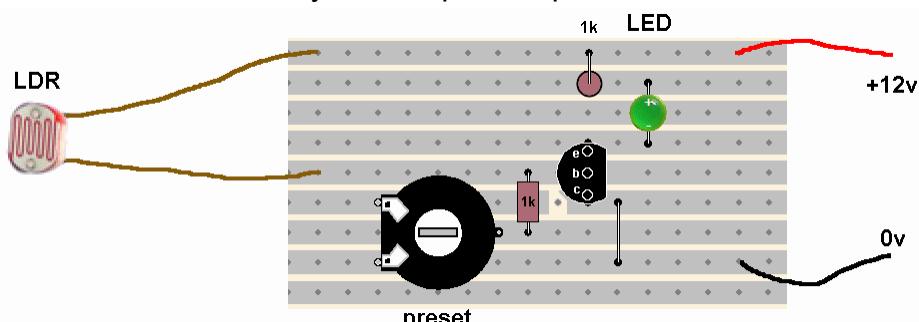
Parts List

One piece of stripboard 25mm x 64mm	34-0500
One LED (your choice of colour)	55-0150 for example
One 1k resistor (it has brown-black-red bands)	62-0370 (sold in packs of 100)
One 10k resistor	62-0394 (sold in packs of 100)
One 10k preset potentiometer	67-0466
One BC557 transistor	81-0474
One LDR light detector	58-0134
One 100nF ceramic capacitor – optional (see text)	08-0235

If you are a MERG member, this is available as a kit - PMP2 Part No: 802.

If you are in an Area Group/club, why not place a joint order and share the postage costs?
The part numbers listed are for Rapid Electronics (www.rapidonline.com).   Alternatively, check out www.bitsbox.co.uk or eBay for competitive prices.

Construction

This project is built on a piece of stripboard that has nine strips of copper on one side.
It is important to note that all the components are mounted on the _other_ side of the board (see the picture) and their leads are poked through the holes for soldering on the copper side.   This illustration show the components and the tracks at the same time.   It is really showing where the components should go.   It shows the tracks underneath, as if the board was transparent, to help you cut the tracks in the correct places and position the components correctly.
The first step is to cut a break in the track at the point shown in the illustration.
   Tip: If you are not too sure, count along the rows and columns on the component side, then poke a wire through the hole where the track is to be cut. Then turn the board over and cut where the wire pokes through.
I use a stripboard spot face cutter, but you could use a hand-turned 3mm or 5mm drill bit – or even a sharp knife if you must.
Next, check that there no remaining tiny strips of copper still bridging any of the track
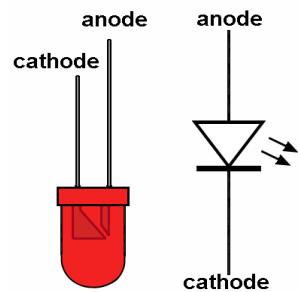
sections. Then clean the copper strips prior to soldering the components.

When inserting and soldering the components, follow these guidelines:

- The resistors can be fitted either way round.
- The preset pot has three legs. Only two are used in this circuit.
- The LED has to be fitted the right way round, with the cathode end nearest the transistor.   The cathode lead of an LED is the shortest lead (see the illustration).
- The transistor has to be fitted the right way round, with its flat end facing rightwards, as shown in the layout illustration.

Setting up

Before connecting power to the circuit, do a close visual inspection of the board, ensuring that you have no short circuits, dry joints, unsoldered connections, etc.

If you have a multimeter, you can check how much current the circuit is taking.

In darkness, the module takes a tiny 0.03mA , rising to 10mA when exposed to a bright light.

The variable resistor can be adjusted with a small screwdriver, to set the point at which you module switches the LED on and off with changes in light level.   This setting will be depend on the ambient light in your railway room and where the LDR is located.

When the correct setting is found, it is possible to remove the preset, read its value and replace it in the circuit with an ordinary resistor of the same value.

Usually, however, it is best to leave the preset on the board, as it allows for any future alterations.

In situations of very bright lighting, you may need to partially shield the LDR by placing it in a small length of tubing, although this is not normally needed.
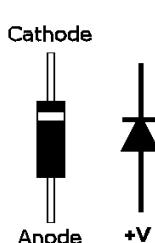
If the LDR is placed in a particularly gloomy area of the layout (e.g. in a tunnel or behind tall buildings), you may have to use an auxiliary source of lighting, such as a lamp suspended above the track.

Modifications
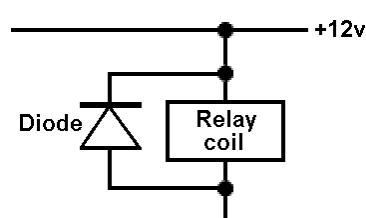
The LDR can be mounted on the stripboard if necessary, although most operators prefer it to be connected to the board by a a length of wire to allow easier placement.

Similarly, the LED can be fitted to the board, or can be fitted to a remote place (e.g. the operator's control panel, on top of a yard lamp) using wires from the board to the LED.

The circuit shows a 100nF capacitor wired across the LDR.   This is only required where the circuit is feeding into a CBUS or computerised system, to prevent any possible stray pulses from the loco's motor or the DCC signal on the track from generating unwanted pulses.
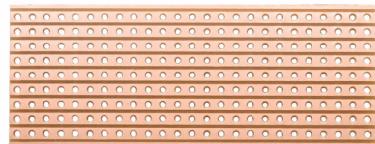
Lastly, the LED and its 1k resistor can be replaced by a 12v relay, if required.   You can connect the relay's coil either way round, although the diode (a 1N4001 type is sufficient) has to be wired the correct way round, as in these diagrams.

Pocket Money Projects

Part 3

A series of small, cheap,
easy to build projects
using stripboard

*by Davy Dick* M1853

Servo controller / tester
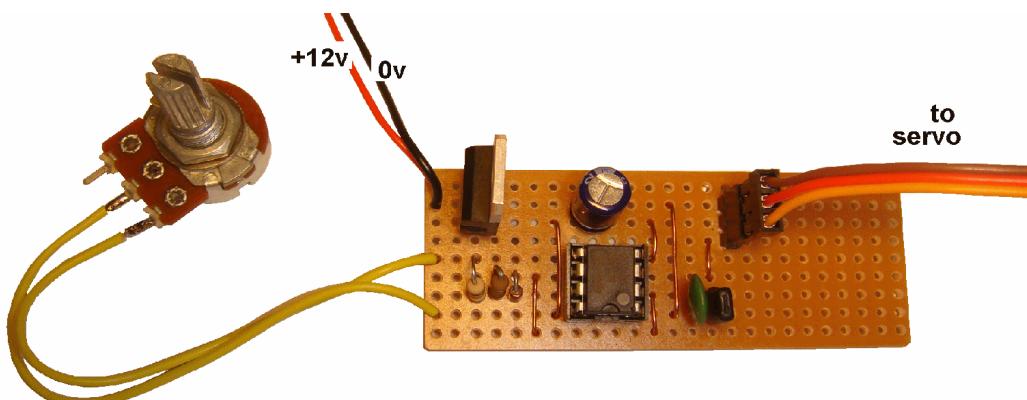
Servos have become very popular in model railways in the last few years.
They are used for operating points, signals, crossing gates and barriers, cranes, and a variety of lineside animations.
The MERG Servo4 kit is mostly used to control servos, with one kit being able to handle four separate servos.   It is designed to move a servo's arm between two fixed points and at fixed speeds set by the user.

Of course, a servo arm can be rotated to many different positions, and at different speeds each time - if a manual control is used.
That is what this project is for.

Turning the spindle of the variable resistor (called a *'potentiometer'* or *'pot'*) rotates the servo arm. You can turn the pot really slowly, or as fast as you want; the servo will respond accordingly.
For more details on how servos work read my Journal article of Autumn 2008.
The project uses nine electronic components.
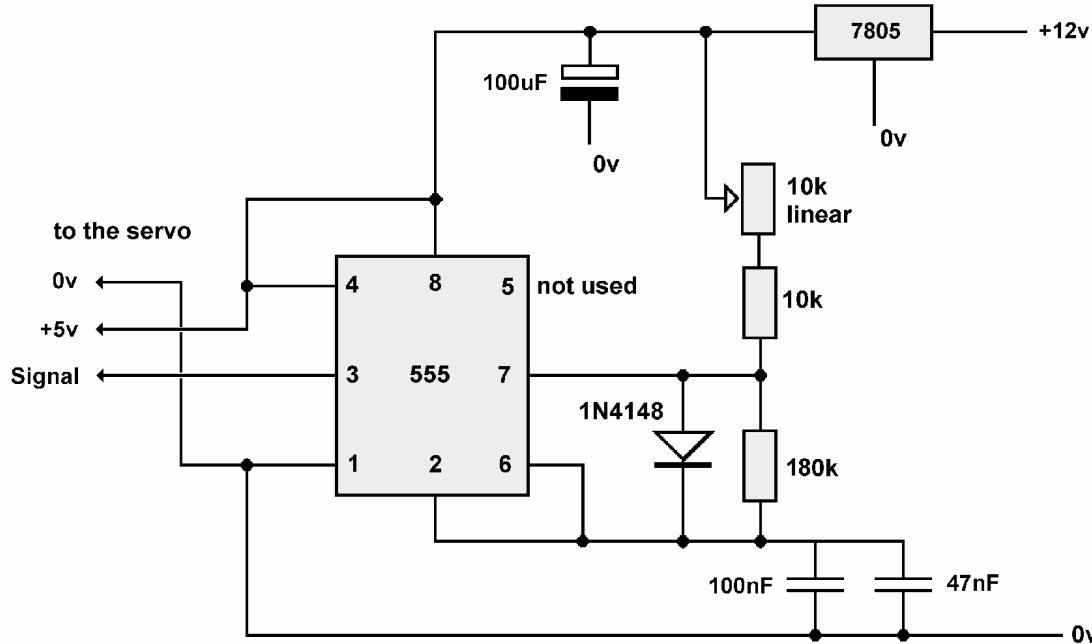
Its uses include:
- A cheap introduction to playing with servos.
- A module to test servos before fitting them on a layout.
- Manual control of aerials, radar heads, guns (great for kids).
- When you need to move to intermediate positions (e.g. a flag at half mast)
- Mounting a cam on the arm, so you can scan a hidden area of the layout.
- An asymmetric turntable for smaller gauges (the pivot point is near one end rather than the centre).
- Any manual control for occasional use.

How it works

This project uses a tried and tested circuit.   The 555 chip is a timer IC which is just what we need for this project.   Servos expect to receive regular pulses on their *'Signal'* wire (the other two wires on the servo are for our 5v power).   The width of the pulse decides what position a servo arm will move to.

If a pulse is 1mS long, the arm will move fully in one direction, while a 2mS pulse duration rotates the arm fully in the opposite direction, Any pulse width between 1mS and 2mS results in an intermediate position (e.g. a 1.5mS pulse will move the servo arm to mid position).

The 180k resistor and the 100nf and 47nf capacitors are used to control the time between pulses, while these same capacitors are used in conjunction with the two resistors and 10k pot to control the length of the pulses. So, varying the resistance of the pot controls the servo arm's rotation.

For more details on 555 timers, read John Matthew's article in the Winter 2006/7 Journal. The module is designed to work from a standard 12v DC supply and uses a 7805 voltage regulator to bring the voltage down to 5v for the chip and the servo.

Parts List

One piece of stripboard 25mm x 64mm   34-0500
One 555 timer integrated circuit   82-0338
One 7805 voltage regulator   47-3313
One 180k resistor   62-0424
One 10k resistor   62-0394
One 10k potentiometer   65-0715
One 1N4148 diode   47-3416
One 100uF electrolytic capacitor   11-0245
One 100nF
One 47nF ceramic capacitor
One length of 0.1" pitch single row header strip
One 8-pin DIL socket (the IC holder)
If you are a MERG member, this is available as a kit - PMP3 Part No: 803.
If you are in an Area Group/club, why not place a joint order and share the postage costs?
The part numbers listed are for Rapid Electronics (www.rapidonline.com).   Alternatively, check out www.bitsbox.co.uk or eBay for competitive prices.
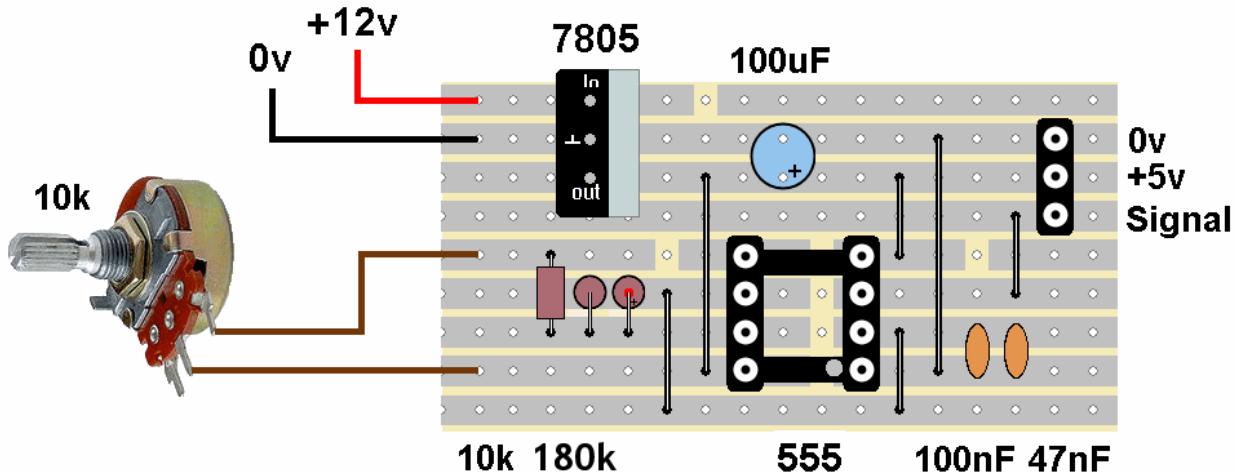
Construction

This project uses a piece of stripboard that has nine strips of copper on one side. It is important to note that all the components are mounted on the *other* side of the board (see the picture) and their leads are poked through the holes for soldering on the copper side. This illustration show the components and the tracks at the same time. It is really showing where the components should go. It shows the tracks underneath, as if the board was transparent, to help you cut the tracks in the correct places and position the components correctly.

The first step is to cut breaks in the track at the points shown in the illustration.

  Tip: If you are not too sure, count along the rows and columns on the component side, then poke a wire through the hole where the track is to be cut. Then turn the board over and cut where the wire pokes through.

I use a stripboard spot face cutter, but you could use a hand-turned 3mm or 5mm drill bit – or even a sharp knife if you must.

Next, check that there no remaining tiny strips of copper still bridging any of the track sections.

Then clean the copper strips and the wire leads on all components. This minimises problems from dirty or oxidised surfaces during soldering.

When inserting and soldering the components, follow these guidelines:

- Fit the six wire links.
- The resistors and the 100nF and the 47nF capacitors can be fitted either way round.
- The electrolytic capacitor must be fitted the correct way round (see the illustration).
- The 10k pot has three legs. Only two are used in this circuit.
- The diode has to be fitted the right way round, with the cathode end to pin 6 of the 555 chip. The cathode end has a band round it, as shown here.
- The 7805 regulator must be fitted with the metal surface pointing inwards.
- It helps if the IC holder is fitted to the board with its notch facing bottom right, as shown in the layout illustration. This reminds you to also fit the 555 chip correctly (i.e. with its notch also facing bottom right).
- The header strip is usually sold as a long row. Break or cut off a strip of three and insert the shorter ends into the stripboard.
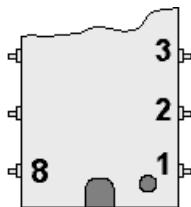
- If the module is to be used for more than occasional use, fit a heatsink to the voltage regulator (or bolt it to a piece of metal) to prevent it overheating.
- If you feel like really splashing out, buy a knob for the potentiometer.

Setting up

Before connecting power to the circuit, do a close visual inspection of the board, ensuring that you have no short circuits, dry joints, unsoldered connections, etc. Connect the power to the board and check that you get a 5V reading between pins 1 and 8 on the IC holder.   If that checks out, remove the power, insert the chip (notch to the bottom) into its holder and reconnect the power.
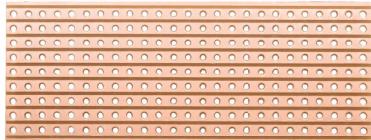
When you connect the power, the servo arm will twitch; thereafter, it will move in sympathy with the rotation of potentiometer spindle.

A series of small, cheap, easy to build projects using stripboard

by Davy Dick M1853
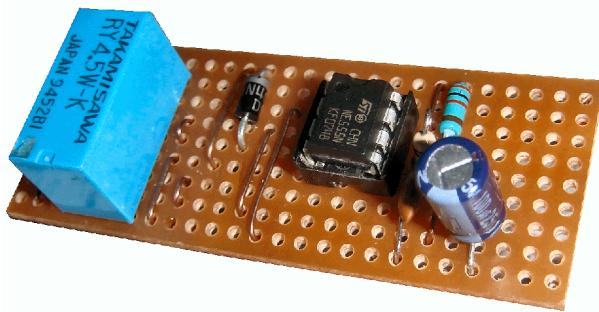
Simple shuttle

The definition of a shuttle is *"a form of transportation that travels regularly between two places".*   On our layouts, that could be a loco or maybe a tramcar.

The loco runs to the end of the track and stops for a set time. It then reverses to the other end of the track before stopping once more. This cycle repeats indefinitely.

The uses for a shuttle include:

- Emulating a tramcar service.
- Emulating a country line, with tunnels at both ends (using longish waiting times at both ends).
- Emulating an industrial shuttle – e.g. ferrying material from mines to the docks or loading bays.
- Maintaining visitor interest at exhibitions, during back operations. People have something to watch while trains are assembled behind the scenes.
- Running in or warming up a motor, using short waiting times. The loco is constantly being exercised.
- Testing a loco before placing on a layout.

Ready-built commercial modules are available, such as the Gaugemaster SS-1, or the Just for Electronics Shuttle.   These are fine for a basic shuttle, although our project carries out the same functions at a fraction of the cost.

More complex modules provide acceleration and deceleration, such as the Heathcote SA1 (although this module needs loco detectors) or the MERG Automatic Train Controller kit. As you would expect, you pay more to get these features.

Most shuttle modules are for DC working, as DCC operations require more than just reversing the voltage on the track.
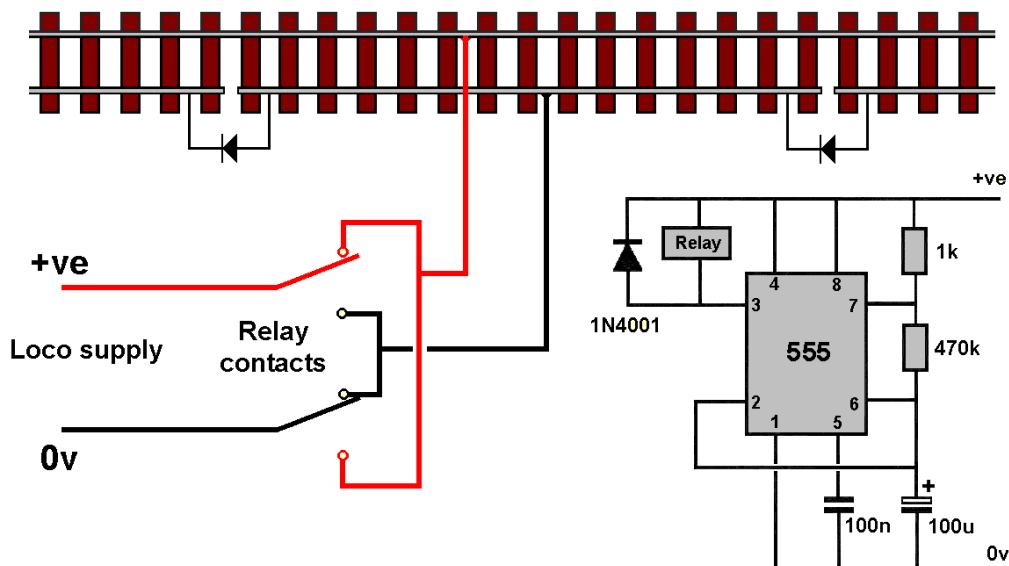
Our project uses nine electronic components.

How it works

The project uses a 555 timer chip in a tried and tested circuit.   It is used in *'astable'* mode which means that its output constantly switches between a high and low voltage.   The rate at which it changes depends on the values of the resistors and the large capacitor.

If there is a short time between switching, the output stream would be audible (you would have built an audio oscillator).   For our project, there are long on periods and long off periods.

The 555's output (pin 3) makes a relay switch on and off at regular intervals and the relay's contacts reverse the voltage on the track.

The diagram shows that the track is split into three sections, with a long middle section and a shorter section at each end.   The cuts in the track isolate the three sections from each other.   One rail is continuous the entire length of the track.

The centre section of track is constantly powered from a DC source, while the other sections have a diode wired across the gaps. Being diodes, they only allow current to pass in one direction.

The operating sequence is as follows:

- When pin 3 is high, the relay is not energised (it has a high voltage at each end of its coil).
- The relay contacts are as shown in the illustration, connecting the loco supply's positive to the upper rail and 0v to the lower middle section of rail.
- The loco moves leftwards and enters the left section until its rear wheels leave the middle section and power is lost.
- The train remains in the left section until pin3 of the 555 eventually switches low.
- The relay switches (it has a high voltage at one end and a low voltage at the other end).
- The relay contacts switch such that the positive supply is connected to the lower middle rail with 0V on the upper rail.
- The loco runs in reverse (because the diode allows the current to flow into the isolated left rail).   It reverses into the middle section and then enters the right isolated section.
- When the loco wheels leave the middle section, it stops as it has no power.
- When pin 3 eventually switches high again, the relay drops out and its contacts return to the state shown in the illustration.
- The loco moves forward again out of the right section and into the middle section to start the cycle all over again.

The 555 chip can operate on a voltage range of around 4.5V to 14V and the time delays are independent of the voltage used.

The timer circuit can be powered from a 12V DC source, in which case, the relay should a 12V type.   Alternatively, the circuit could be fed from a 5V supply, using a 5V relay.

The loco supply voltage should match that required by the loco being used.

For more details on 555 timers, read John Matthew's article in the Winter 2006/7 Journal, or look at
http://talkingelectronics.com/projects/50%20-%20555%20Circuits/50%20-%20555%20Circuits.html

Setting the timings

The circuit does not know how fast the loco is moving or how long the track section is. It is up to you to use components that provide the delays that you need. As a minimum, the delay before switching should be long enough to allow the loco to get from one end of the track to the other.

The values shown in the illustration provide a delay of just over 30 seconds. Replacing the 470k resistor with a 820k resistor gives a delay of about 1 minute, while a 2M7 resistor gives a delay of around 3 minutes.

Changing the other resistor or the capacitor also has an effect on the on and off pulse widths. There are formulae to work out the delays but you can use a simple calculator like the one at

http://web.udl.es/usuaris/p7806757/555-calculadora/555%20Calculator.htm

Parts List

One piece of stripboard 25mm x 64mm	34-0500
One 555 timer integrated circuit	82-0338
One 470k resistor	62-0434 (sold in packs of 100)
One 1k resistor	62-0370 (sold in packs of 100)
Three 1N4001 diodes	47-3420 or from the MERG Kit Locker

These diodes work up to 1A; for more power hungry locos, replace the diodes bridging the gaps with 3A diodes such as the 1N5401 (part 47-0818) or from the MERG Kit Locker.

One 100uF electrolytic capacitor	11-0245
One 100nF ceramic capacitor	08-0235
One 8-pin DIL socket (the IC holder)	22-0107 (sold in tube of 60)
One 12v relay	

(the OKO type 47W from the MERG Kit Locker is the cheapest I could find and switches up to 2A. For more power hungry locos, use the 5A relay from Rapid Electronics (part number 60-4610).

If you are a MERG member, this is available as a kit - PMP4 Part No: 804.
If you are in an Area Group/club, why not place a joint order and share the postage costs? The part numbers listed are for Rapid Electronics (www.rapidonline.com). Alternatively, check out www.bitsbox.co.uk or eBay for competitive prices.

Construction

This project uses a piece of stripboard that has nine strips of copper on one side. It is important to note that all the components are mounted on the _other_ side of the board (see the picture) and their leads are poked through the holes for soldering on the copper side. The illustration show the components and the tracks at the same time. It is really showing where the components should go. It shows the tracks underneath, as if the board was transparent, to help you cut the tracks in the correct places and position the components correctly.

The first step is to cut breaks in the track at the points shown in the illustration.
   Tip: If you are not too sure, count along the rows and columns on the component side, then poke a wire through the hole where the track is to be cut. Then turn the board over and cut where the wire pokes through.

I use a stripboard spot face cutter, but you could use a hand-turned 3mm or 5mm drill bit – or even a sharp knife if you must.

Next, check that there no remaining tiny strips of copper still bridging any of the track sections.

Then clean the copper strips and the wire leads on all components. This minimises problems from dirty or oxidised surfaces during soldering.

When inserting and soldering the components, follow these guidelines:
- Fit the twelve wire links.
- The resistors and the 100nF capacitor can be fitted either way round.
- The electrolytic capacitor must be fitted the correct way round, with the positive lead connecting to the track of pin 6 of the chip (see the illustration).
- The diodes have to be fitted the right way round. The anode end of one diode goes to pin 3 of the 555 chip. The diodes bridging the rail track gaps should be fitted as in the illustration.   The diode's cathode end has a band round it, as shown here.
- It helps if the IC holder is fitted to the board with its notch facing top left, as shown in the layout illustration.   This reminds you to also fit the 555 chip correctly (i.e. with its notch also facing top left).

Setting up
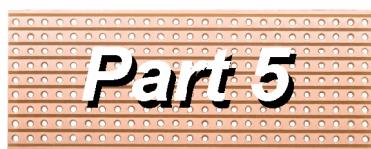
Before connecting power to the circuit, carry out a close visual inspection of the board, ensuring that you have no short circuits, dry joints, unsoldered connections, etc.

Then connect the power to the stripboard.   If it is working correctly, you will hear the relay click on and off.
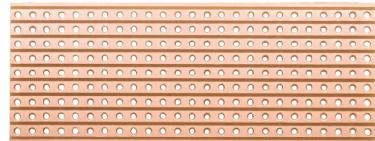
You can expect a slightly longer delay the first time it is powered up, as it charges up the large capacitor. Thereafter, the circuit should provide the correct timings. You can then connect the wires to the track and the lead from the loco controller's supply.

If you wish, to avoid tying up a separate loco controller, you could use the same 12v supply for supplying both the timer circuit and the loco.   At 12V, the loco would run too fast, unless you wired a dropper resistor in series with one of the leads the leads to the track.

Pocket Money Projects

Part 5

A series of small, cheap,
easy to build projects
using stripboard

by Davy Dick M1853

A logic probe

Many enthusiasts own multimeters, which are extremely useful tools for testing and fault-finding on layouts and on electronic modules.   The ability to read different voltage levels helps trace bad joints, etc.

But, when dealing with modules that work on <u>digital</u> inputs and outputs, you only want to know whether a particular point in your circuit is at +5v or at 0v.
These circuits act like electric switches where much of the operation only works with ONs and OFFs, sometimes also called HIGHs and LOWs.

Examples uses of a logic probe are to:
- Check the supply pins of a chip. Is it getting both the +5v and the 0v?
- Check the output from a track detector – is it changing when a loco passes?
- Check the input to a circuit that is coming from a switch – is it going from +5v to 0v, or 0v to 5v, when the switch is operated?
- Check whether the inputs and outputs of CBUS and other digital modules are producing the expected results.

The internal circuits in lots of electronic modules work on 5v, even when the they are connected to a 12v or other voltage supply.   This project is for a very useful tool that tells you whether a point in the circuit is at +5v or at 0v.

You could ask why not just use a multimeter?   You could connect the -ve lead of your meter to the 0v line of your module.   Then you could tap various parts of the circuit with the other lead. If you have +5v on that point, you will get a reading. But – and here is the catch – if you do not get a reading, it does not mean that you have 0v at that point. You might just have a broken wire that is not connected to anything.   To check for connections to 0v, you would have to connect the meter's +ve lead to the 5v line and then test with the other lead's probe.   You would have to reverse your meter connections every time you wanted to check for +5v or 0v.

That is where a logic tester is handy.   This, project, like the commercial versions, works by connecting the unit to the +5v and 0v of the module you are checking. Then you touch any point in the circuit. If +5v is on that point, a green LED lights up. If there is 0v at that point, the red LED lights up.   All other voltages, or points not connected to anything, either keep the LEDs unlit or dimly lit.

Fancier commercial versions of our little tester are available - but they are about 20 times more expensive.

How it works

Here is the circuit diagram for the logic tester.
It uses just eight components.
It is really just two almost identical sections; one to light the red LED and one to light the green LED.
It uses a transistor to light each LED.
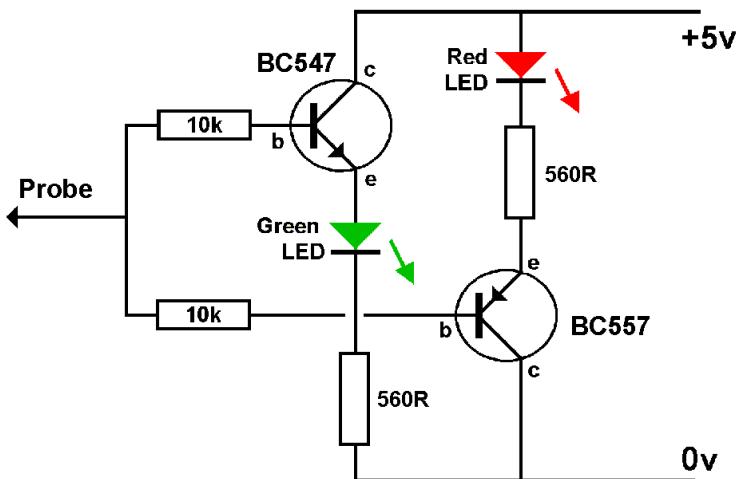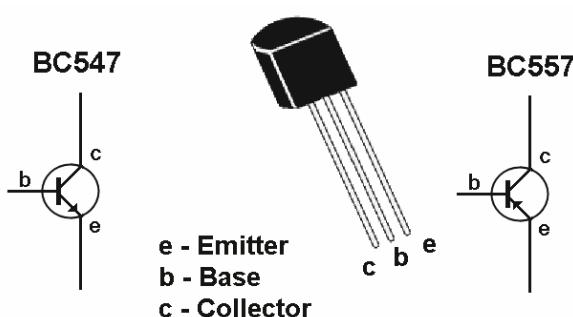
A transistor is a small semiconductor device that was originally mainly used as an amplifier, like those used in an old transistor radio.
Depending on the voltage fed to them, they can also act like a switch, as in this project.

In normal operation, a small increase in current through the transistor's base results in a larger current through its collector.   The total resistance of the LED and resistor means that there is a maximum current that can flow through the emitter/collector. When this point is reached, increasing the base current has no further effect.   The transistor is said to be in *'saturation'*. The 10k resistors limit the base current to be sufficient to switch the transistor fully saturated.

The two transistors use different semiconductor layers in their construction. This means that the BC547 allows current to flow from its collector to emitter when its base is at a higher voltage than its emitter.   The BC557 allows current to flow from its emitter to collector when its base is at a lower voltage than its emitter. That's why the red LED lights on 0V while the green LED lights on 5V.

For more details on how transistors work as switches, look at:
www.rason.org/Projects/transwit/transwit.htm
www.electronics-tutorials.ws/transistor/tran_4.html

Parts List

- One piece of stripboard 25mm x 64mm   34-0500
- One RED LED   55-0150
- One Green LED   55-0105
- Two 560 ohm resistors   62-0364 (sold in packs of 100)
- Two 10k resistors   62-0394 (sold in packs of 100)
- One BC547 transistor   81-0468
- One BC557 transistor   81-0474

If you are a MERG member, this is available as a kit - PMP5 Part No: 805.
If you are in an Area Group/club, why not place a joint order and share the postage costs?
The part numbers listed are for Rapid Electronics (www.rapidonline.com).   Alternatively, check out www.bitsbox.co.uk or eBay for competitive prices.

Construction

This project is built on a piece of stripboard that has nine strips of copper on one side.

It is important to note that all the components are mounted on the _other_ side of the board and their leads are poked through the holes for soldering on the copper side.

This illustration show the components and the tracks at the same time. It is really showing where the components should go. It shows the tracks underneath, as if the board was transparent, to help you cut the tracks in the correct places and position the components correctly.

The first step is to cut four breaks in the track at the points shown in the illustration.

> Tip: If you are not too sure, count along the rows and columns on the component side, then poke a wire through the hole where the track is to be cut. Then turn the board over and cut where the wire pokes through.

I use a stripboard spot face cutter, but you could use a hand-turned 3mm or 5mm drill bit – or even a sharp knife if you must.

Next, check that there no remaining tiny strips of copper still bridging any of the track sections.

Then clean the copper strips and the wire leads on all components. This minimises problems from dirty or oxidised surfaces during soldering.

When inserting and soldering the components, follow these guidelines:

- The 560 ohm resistors have green,blue and brown bands round them, while the 10K resistors have brown, black and orange bands round them. The resistors can be fitted either way round.

- The transistors have to be fitted the right way round, with their flat ends facing outwards, as shown in the layout illustration. They look identical apart from their markings, so make sure you fit them as shown.

- The LEDs have to be fitted the right way round, with the anode end nearest the top of the board. The anode lead of an LED is the longest lead (see the illustration).
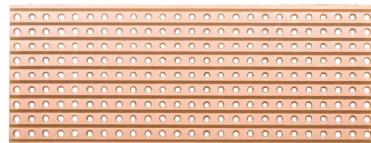
Before connecting power to the circuit, do a close visual inspection of the board, ensuring that you have no short circuits, dry joints, unsoldered connections, etc.

Connect the 5V supply to the board. The LEDs may remain unlit or be dimly lit.

Touch the probe to the +5V of the supply and the green LED should illuminate brightly.

Touch the probe to the 0v of the supply and the red LED should illuminate brightly.

Pocket Money Projects

Part 6
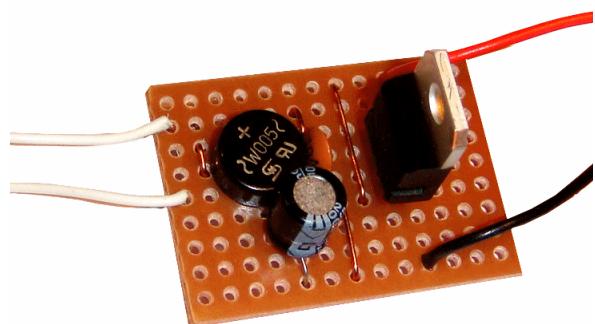
A series of small, cheap,
easy to build projects
using stripboard

by Davy Dick *M1853*
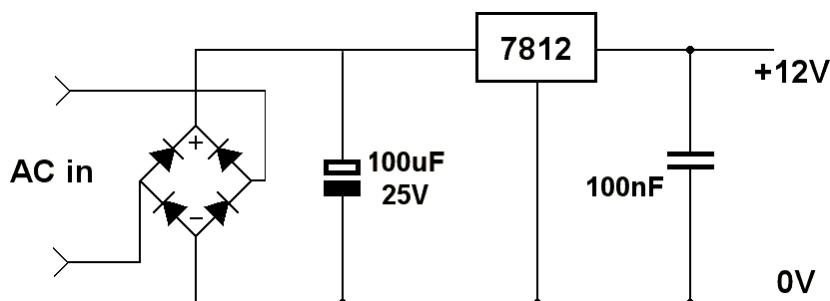
A 12V output from a 15V AC supply

Many of the Pocket Money Projects are
designed to work from a 12V DC supply.
However, a number of loco controllers provide
an auxiliary 15V AC output.
This little module converts the 15V AC into a
constant regulated 12V DC output.

How it works

Here is the circuit diagram of the 12V regulator.

An AC voltage is called an alternating current because its polarity is constantly changing.
The voltage rises from zero to a maximum value in the positive direction, before falling
back to zero again. It then rises to a maximum value in the negative direction, before
returning to zero.   It does this 50 times every second (50Hz).
The bridge rectifier ensures that its output is always positive-going.
The 100uF capacitor is used as a reservoir, to keep the voltage that feeds the 7812 at a
fairly constant level.
More information is available from:
          www.kpsec.freeuk.com/acdc.htm
The circuit can handle a maximum output current of 1.5A, although in that case you ought
to fit a heat sink to the 7812 to prevent it overheating.
The circuit does not use fuses or cutouts, but the 7812 has built-in overload protection.
The 7812 has an internal voltage loss of 2.5V, so needs a minimum of 14.5V DC input to
ensure a smooth regulated output.

Parts List
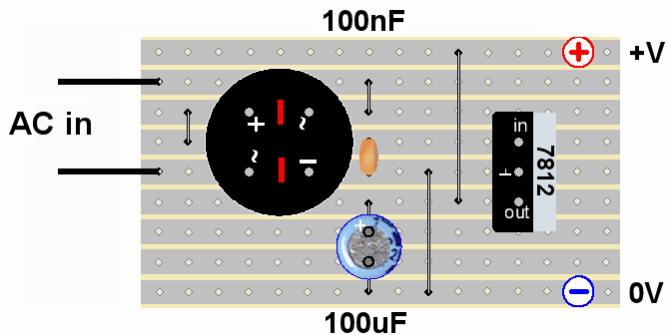
- One piece of stripboard 25mm x 64mm   34-0500
- One bridge rectifier W005, available from the Kit Locker.   47-3190
- One 7812 voltage regulator, available from the Kit Locker. 47-3315
- One 100uF electrolytic capacitor   11-0245
- One 100nF ceramic capacitor   08-0235

If you are a MERG member, this is available as a kit - PMP6 Part No: 806.

If you are in an Area Group/club, why not place a joint order and share the postage costs? The part numbers listed are for Rapid Electronics (www.rapidonline.com). Alternatively, check out www.bitsbox.co.uk or eBay for competitive prices.

Construction

This project is built on a piece of stripboard that has nine strips of copper on one side. It is important to note that all the components are mounted on the _other_ side of the board and their leads are poked through the holes for soldering on the copper side.

This illustration show the components and the tracks at the same time.   It is really showing where the components should go.   It shows the tracks underneath, as if the board was transparent, to help you cut the tracks in the correct places and position the components correctly.

The first step is to cut two breaks in the track under the bridge rectifier, at the points shown in red in the illustration.

> Tip: If you are not too sure, count along the rows and columns on the component side, then poke a wire through the hole where the track is to be cut. Then turn the board over and cut where the wire pokes through.

I use a stripboard spot face cutter, but you could use a hand-turned 3mm or 5mm drill bit – or even a sharp knife if you must.

Next, check that there no remaining tiny strips of copper still bridging any of the track sections. Then clean the copper strips and the wire leads on all components. This minimises problems from dirty or oxidised surfaces during soldering.
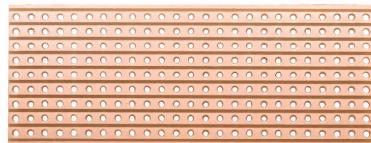
When inserting and soldering the components, follow these guidelines:
- Fit the four wire links.
- The bridge rectifier must be fitted as shown in the illustration, with its + marking in the top left corner.
- The 100nF capacitor can be fitted either way round.
- The 100uF capacitor has to have its negative lead soldered to the outer copper track. The negative end of the capacitor case usually is marked with a negative sign and/or a black stripe down its side.
- The 7812 regulator also has to be fitted the correct way round, with its metal tab facing outwards.

Pocket Money Projects

Part 7
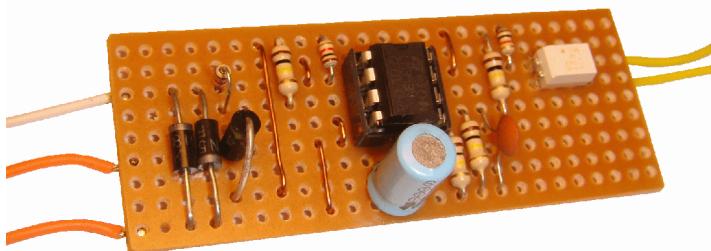
A series of small, cheap,
easy to build projects
using stripboard

by Davy Dick M1853

A DCC train detector

Part 2 of the series looked at a train detector that reacted to changes in light levels when a train passed over a point in the track. It could be used on both DC and DCC layouts but it only produced a change of output while the train blocked the light.
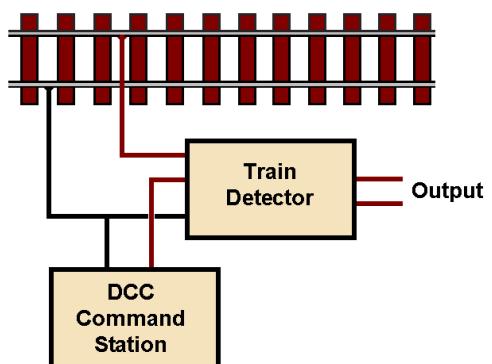
This circuit is only for DCC systems but it will maintain a changed output as long as the train remains in a section of track. Its output is normally at a high resistance but this changes to low resistance when a train sits anywhere on that track section – either moving or stationary.

Possible uses include:
- A train enters a marshalling yard and the yard lights come on.
- Control panel lights indicate which hidden sidings, or obscured sections of track, are occupied.
- Triggering events in other modules such as the Servo4 or CANACE8C.

The track section to be detected has to be isolated from the rest of the layout track, probably by using plastic rail joiners at each end. The DCC power is fed to this track section as shown in the illustration. Both leads from the command station are taken to the train detector board, with one of the leads passing through the circuit on the board before being wired to the track. This allows the circuit on the board to detect any current flowing between the command station and   a train on the track.
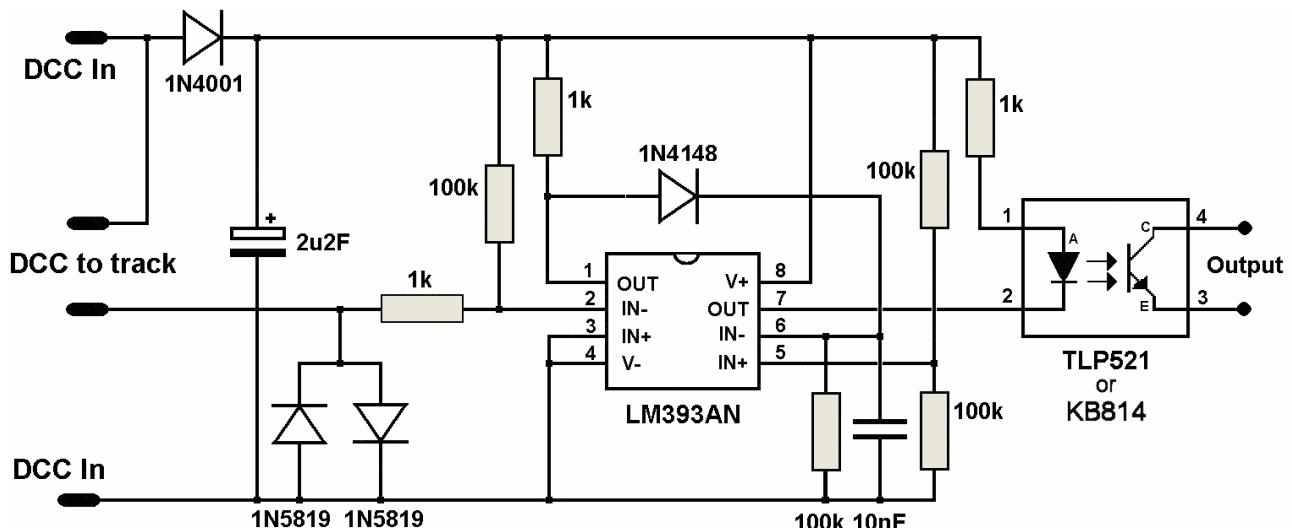
Being part 7 in the series, the circuit is a little more bit more of a challenge, but still easily fits on a piece of stripboard (see the above image).

It needs no separate power supply as its gets its power from the DCC supply.
The project uses fifteen electronic components.

How it works

Here is the circuit diagram of the DCC train detector, as designed by MERG member Trevor Stockill.

The KB814 is the more easily available alternative to the TLP521, as is the Sharp EL817 and others.

The voltage from a DCC command station alternately swings positive then negative, in what is described as *'bipolar DC'*.   The 1N4001 diode only passes the positive-going pulses which are then smoothed out by the 2.2uF (2u2F) capacitor. The voltage across this capacitor provides the DC supply for rest of the circuit.

The LM393 is a 'dual comparator' chip. This means that it contains two separate comparator circuits inside the chip. This illustration shows one of the comparators. Current is able to flow through the OUT pin when the voltage on the IN- pin is higher than the voltage on the IN+ pin.

As you can see from the above circuit diagram, the supply from the command station passes through the diodes on its way to the track. A stationary loco on that track will draw a tiny current to power its decoder, while a moving loco will draw even greater current. In both cases, the current produces a stream of voltage pulses across the diodes. These pulses are fed to pin 2 and result in the output pin 1 having a pulsed output.   The pulses are routed via the 1N4148 diode and increase the charge on the 10nF capacitor until it reaches approximately half the supply voltage. At this point the second comparator turns on and switches on the opto-isolator.
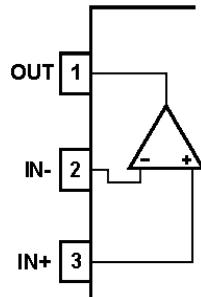
When the train leaves the track, there are no further pulses to maintain the charge on the capacitor. It then slowly discharges through the 100k resistor and its potential eventually drops below the comparator level and switches off the LED in the opto-isolator.

The values of the 10nF capacitor and the 100k resistor across it determine the switching delay.
For more details on comparators, look at:
   http://home.cogeco.ca/~rpaisley4/Comparators.html

When output pin 7 goes low, current flows through the LED in the KB814.   The light from the LED falls on a photo-transistor and its resistance drops.   The change in resistance across pins 3 and 4 is then available to switch other circuits (see later).   The KB814 isolates the train detector from other circuits, preventing potential problems from interference or voltage differences.

## Parts List
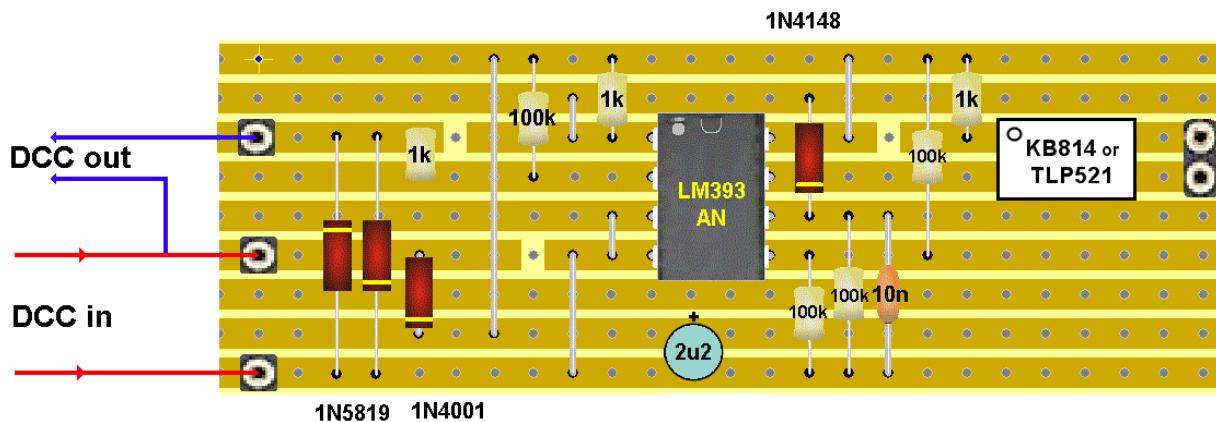
- One piece of stripboard 25mm x 64mm   34-0500
- One LM393AN chip   QU057 from bitsbox.co.uk
- One KB814 opto-isolator   58-0920 or Kit Locker
- One 1N4001 diode   47-3420 or Kit Locker
- One 1N4148 diode   or Kit Locker
- Two 1N5819 diodes   or Kit Locker
- Three 1k resistors   62-0370 (sold in packs of 100)
- Four 100k resistors   62-0418 (sold in packs of 100)
- One 2u2F electrolytic capacitor   11-0210
- One 10nF ceramic capacitor   08-0230
- One 8-pin IC holder   22-0107 (sold in tube of 60)

If you are a MERG member, this is available as a kit - PMP7 Part No: 807.

If you are in an Area Group/club, why not place a joint order and share the postage costs?
The part numbers listed are for Rapid Electronics (www.rapidonline.com). Alternatively,
check out www.bitsbox.co.uk or eBay for competitive prices.

Construction

This project is built on a piece of stripboard that has nine strips of copper on one side.
It is important to note that all the components are mounted on the *other* side of the board
and their leads are poked through the holes for soldering on the copper side.

This illustration show the components and the tracks at the same time.   It is really
showing where the components should go.   It shows the tracks underneath, as if the
board was transparent, to help you cut the tracks in the correct places and position the
components correctly.

The first step is to cut three breaks in the track at the points shown in the illustration.
Also cut track breaks between the pins on either side of the IC chip (i.e. between pins 1
and 8, between pins 2 and 7, etc.). Lastly, cut the tracks between the pins of the KB814.

  Tip: If you are not too sure, count along the rows and columns on the component side, then
    poke a wire through the hole where the track is to be cut. Then turn the board over and
    cut where the wire pokes through.

I use a stripboard spot face cutter, but you could use a hand-turned 3mm or 5mm drill bit –
or even a sharp knife if you must.

Next, check that there no remaining tiny strips of copper still bridging any of the track
sections. Then clean the copper strips prior to soldering the components.

When inserting and soldering the components, follow these guidelines:
- The 100k ohm resistors have brown, black and yellow bands round them, while the 1K
  resistors have brown, black and red bands.   The resistors can be fitted either way round.
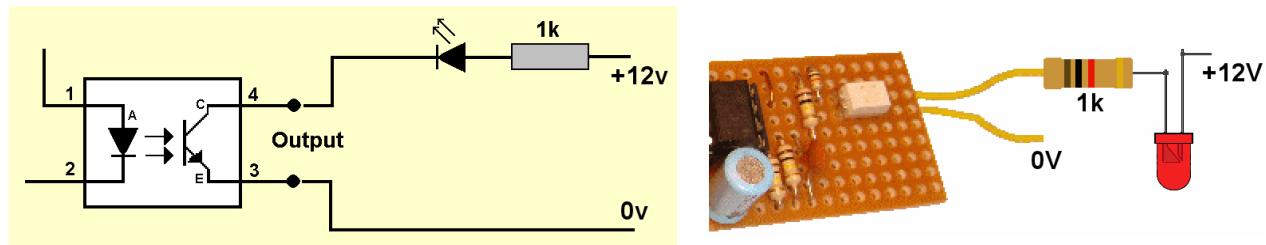
- The diodes must be fitted the correct way round (follow the illustration).
- The 10nF capacitor can be fitted either way round but the 2u2F capacitor has to have its negative lead soldered to the outer copper track; the negative end of the capacitor case usually is marked with a negative sign and/or a black stripe down its side.
- The LM393 chip also has to be fitted the correct way round. Pin 1 is on the upper left-hand side of the chip, often marked by an indentation as shown in the illustration.
- The TLP521/KB814 also has an indentation at one corner indicating where pin 1 is.

Examples of use
Here are some typical examples of how you could use the project to improve your layout.

Lighting a LED
A simple but useful facility. The output wires could be taken back to a control panel and used to illuminate a LED when a train occupied the track section.   No need to guess whether track sections that are out of sight, or a hidden sidings in a tunnel, are occupied.

Since the KB814 output is isolated from the rest of the circuit, a separate power supply is needed to provide the 12v that lights the LED.
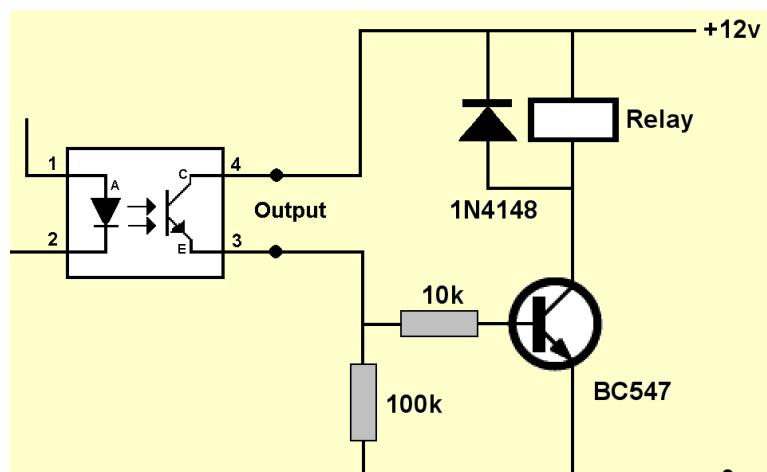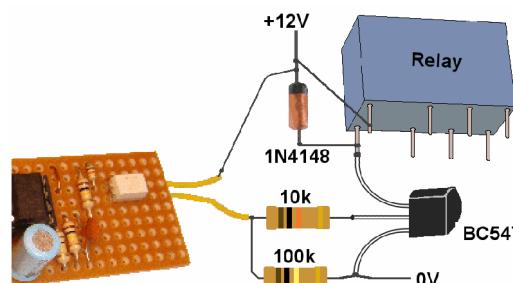
A 12v supply is shown above since most layouts already use a 12v power supply.   If you are using a 5v supply, you could reduce the value of the resistor to around 560 ohms.

This circuit is not suitable for handling for high-power LEDs since it – not enough current without a separate driver circuit.

The LED need not be placed in your control panel.   How about a factory's loading bay light coming on when the train pulls in; or station lights, or yard lamps.

Switching a relay
The maximum current that the KB814 can pass is 50mA. If you want the train detector board to switch a high-current device such as a motor, solenoid or high wattage lamp, you can use a relay to switch the higher currents.

A simple circuit is shown here using
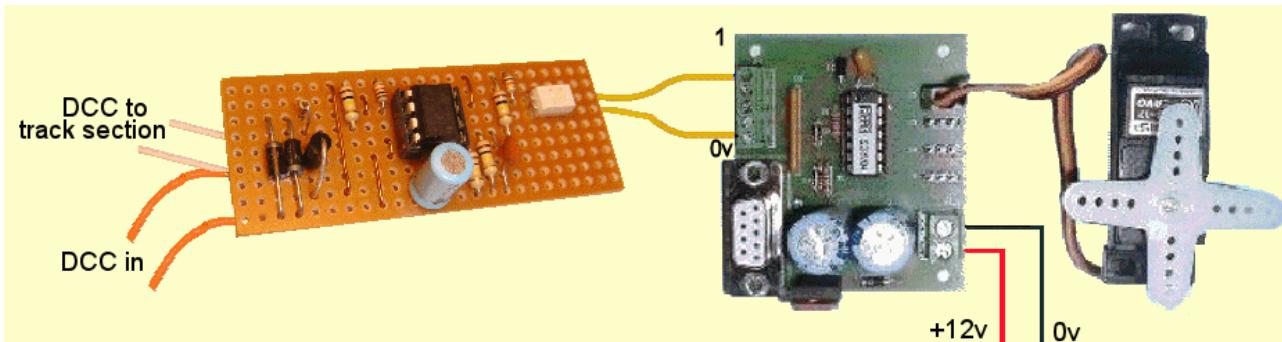
easily-obtained components (the relay and the transistor are available from the Kit Locker).   With a bit of repositioning, you could fit most of the parts on the stripboard.

The transistor can pass a maximum of 100mA which is more than sufficient for most relays, including the ones in the Kit Locker.

Operating a Servo4 channel

If the output from the train detector is fed into a Servo4, you can have activities that happen automatically as soon as a train enters the track section.
Examples might include automatic crossing gates, barrier gates, semaphore signal arms, cranes, etc.
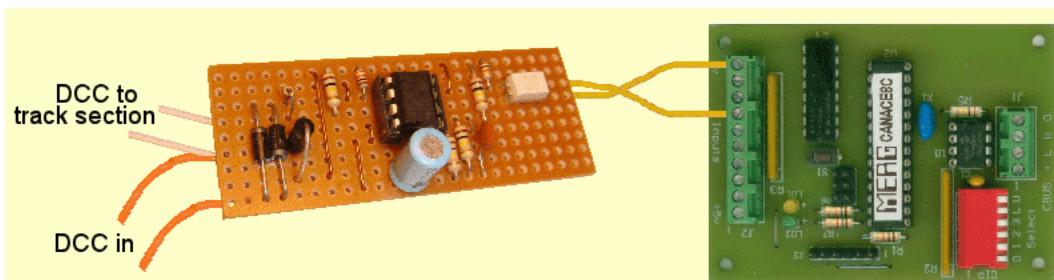
The image shows how the detector's output connects across the Servo4's 0v terminal and the input that you choose to switch (in this case input 1). As simple as that. When the track section is entered, the loco is detected, the TPL521's resistance drops and the servo moves to the new pre-set position. When the loco leaves the section, the resistance increase once more and the servo returns to its previous pre-set position.

Switching a CANACE8C channel

A very similar approach can be adopted by members who are using the CBUS system. The CANACE8C is designed to detect changes of voltage at its inputs and send appropriate messages on to its bus.

The image shows the detector's output across the CANACE8C's 0v line and input 6. The CANACE8C will send out a message when the train enters the track section and another message when the train leaves.
The messages might be picked up by a computer for automating operations, or may be picked up by another CBUS module (e.g. a CANACC8) for local action without the need for a computer.

Further enhancements

Why stop at a single detector. The circuit uses a single LM393 and a single KB814 to create one train detector module. However the KB844 is a 16-pin device that is four different optoisolators in the one package. Likewise, the LM339 is a 16-pin chip that is essentially four LM393's in the one package.
Why not design a board with these devices and have two detectors on the one board.

Pocket Money Projects

Part 8

A series of small, cheap,
easy to build projects
using stripboard
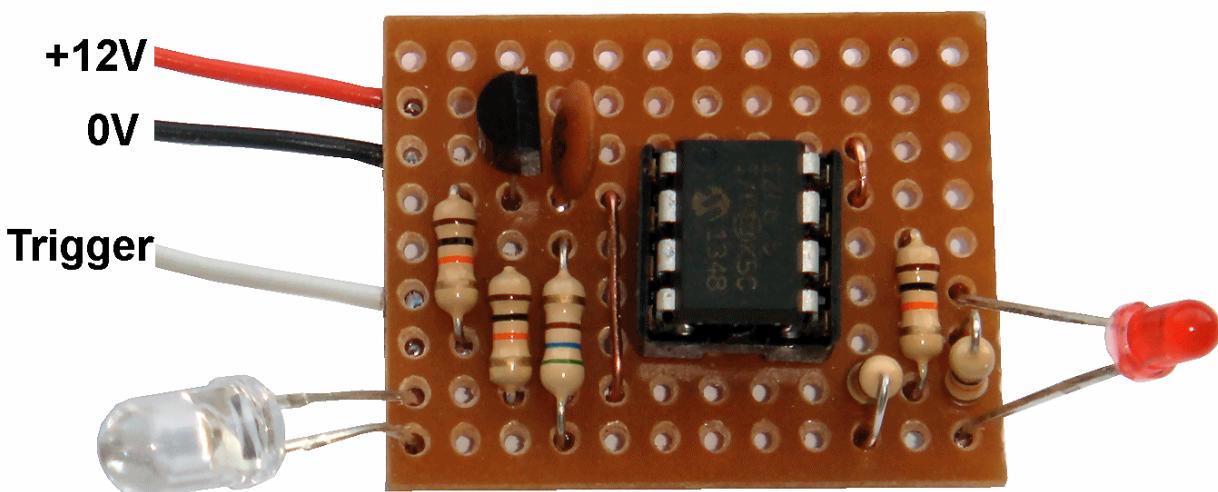
by Davy Dick M1853

Multi-purpose flasher

This easy to build project has four possible uses:
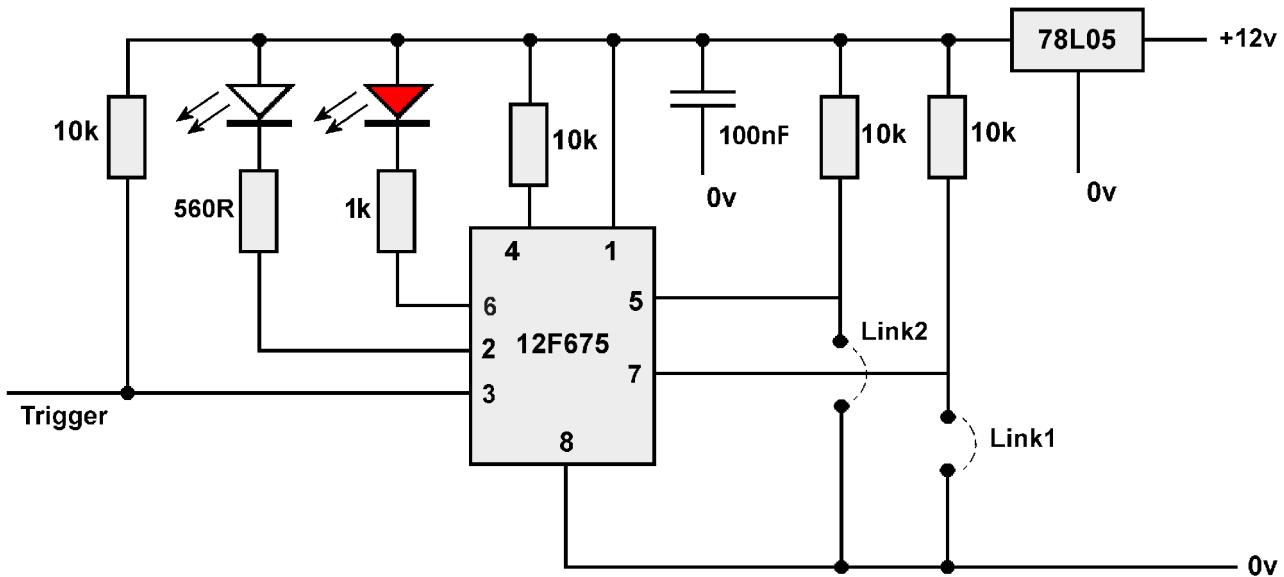
- To simulate a welding machine.   Every 15 seconds, there is a burst of flashes from a LED to give the impression of a welding operation. With a large LED, it could be situated inside an engine shed or machine shop. With a small surface mount LED, it could be used 'outdoors' on a construction site or at trackside repairs.   A red or orange LED can also be connected to this module. The LED illuminates during the flashing period then slowly dims, providing an 'afterglow' effect.   You simply position the additional LED for optimum visual effect.
- To simulate the arcing from a tram's trolley pole or an electric loco's pantograph pickup. Every 5 seconds, there is a random number of flashes from an SMD LED placed on top of the trolley pole or pantograph close to the catenary wire.
- To simulate the flickering of a fluorescent tube on startup.
- To simulate the pulsing aircraft warning lights that are fitted on tall structures (buildings, TV masts, power pylons, bridges, etc.)

Two wire links are used to select the mode of operation.

How it works

Here is the circuit diagram for the simulator.

It uses just 11 components.

All the timing, decision making, etc. are pre-programmed into the 12F675 PIC chip.

The 78L05 is a voltage regulator.   It reduces the 12V supply to the 5V used by the PIC and the LED.

The 10k resistors connected between pins 5 and 7 and +5V keeps these pins at supply voltage.   Fitting link1 brings pin 7 down to 0V, while link2 brings pin 5 down to 0V. The PIC chip senses the voltages on these pins and decides the mode in which to operate.

The options are:

No links fitted	– welder simulation
Only link 1 fitted	– pickup arcing
Only link 2 fitted	– fluorescent tube startup
Both links fitted	– pulsing warning light

When in fluorescent tube mode, pin 3 is held high by a 10K resistor and the LED does not light.   When the 'trigger' input on pin 3 is brought down to 0V, the LED sputters before remaining fully lit.   Removing the 0V from pin 3 extinguishes the LED once more.

The trigger input could come from a switch, relay contacts, CANACC8 outputs, etc.

Parts List

- One piece of stripboard 25mm x 64mm
- One 8-pin IC holder
- One white LED or red LED (see text)
- One red LED
- One 560 ohm resistor
- One 1k resistor
- Four 10k resistors
- One 100nF ceramic capacitor
- One 78L05 voltage regulator
- One pre-programmed 12F675 PIC chip

If you are a MERG member, this is available as a kit - PMP8 Part No: 808.

The output pin of the PIC can pass a maximum current of 25mA.

The 560 ohm resistor works with many LEDs, both standard and surface mount types.

> Before starting, it would be useful to read the article on using stripboard that appeared in the Autumn 2012 Journal.

Construction

This project is built on a piece of stripboard that has nine strips of copper on one side. It is important to note that all the components are mounted on the *other* side of the board and their leads are poked through the holes for soldering on the copper side.
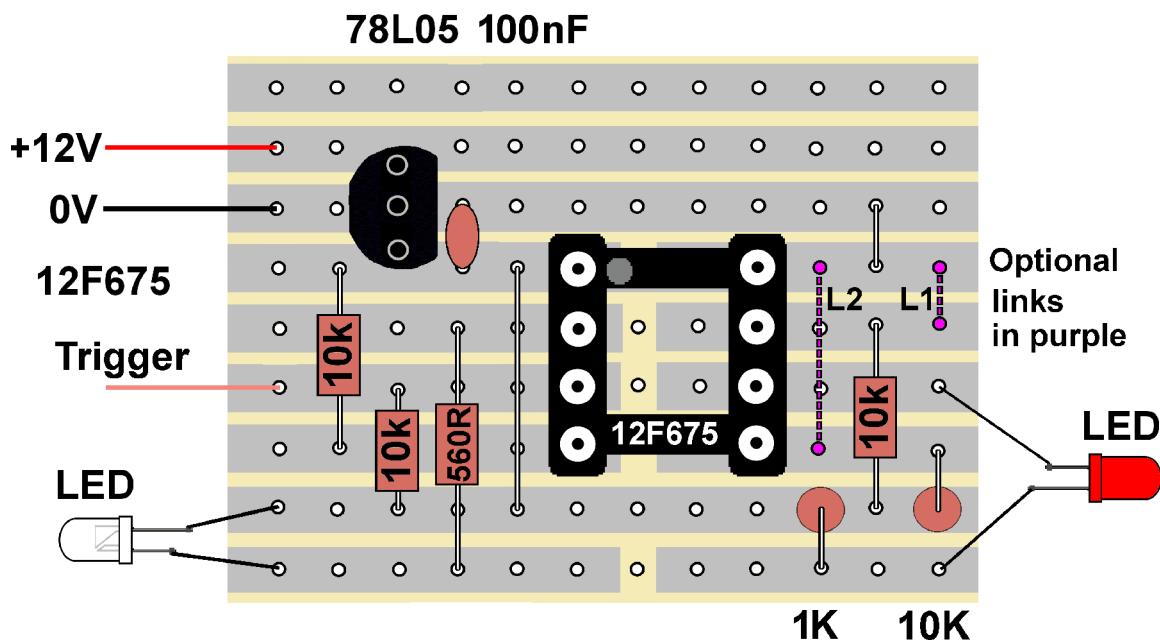
This illustration show the components and the tracks at the same time. It is really showing where the components should go. It shows the tracks underneath, as if the board was transparent, to help you cut the tracks in the correct places and position the components correctly.

The first step is to cut five breaks in the track at the points shown in the illustration.

Tip: If you are not too sure, count along the rows and columns on the component side, then poke a wire through the hole where the track is to be cut. Then turn the board over and cut where the wire pokes through.
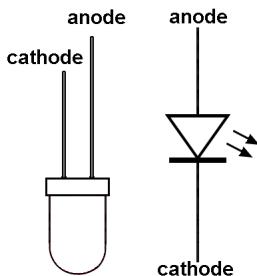
It is best to use a stripboard spot face cutter, but you could use a hand-turned 3mm or 5mm drill bit – or even a sharp knife if you must.

Next, check that there no remaining tiny strips of copper still bridging any of the track sections. Then clean the copper strips and the wire leads of the components prior to soldering the components.
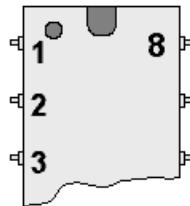

When inserting and soldering the components, you may want to follow these guidelines:

- Solder the two wire links in place (not the ones shown as purple dotted lines).
- Fit the six resistors. The 560 ohm resistor has green,blue and brown bands round it, the 10K resistors have brown, black and orange bands round them and the 1k has brown, black and red bands. The resistors can be fitted either way round.
- The capacitor can be fitted either way round.
- The LEDs have to be fitted the right way round, with the anodes (the longer leads) connected as shown in the illustration.
- The 78L05 regulator must be fitted with its flat surface pointing inwards.

- It helps if the IC holder is fitted to the board with its notch facing top left, as shown in the layout illustration.   This reminds you to also fit the PIC chip correctly (i.e. with its notch also facing top left).
- Fit link1 and/or link2 if required, depending on which mode of operation you want.

Before connecting power to the circuit, do a close visual inspection of the board, ensuring that you have no short circuits, dry joints, unsoldered connections, etc.
Connect the power and check that you read 5V between pins 1 and 8 of the chip.

Using as a welder
Fit the white LED and the red LED.   Do not fit link 1 or link 2.
The output pin of the PIC can pass a maximum current of 25mA and this is sufficient for fairly bright LEDs.

Using as pickup arcing
Fit link 1 only.   Only fit the white LED.
The LED used should be a tiny surface mount type, about the size of a grain of rice. It should be glued to the overhead pickup and wired down to the loco body (Kynar wire is specially thin).
Since the module has to fitted inside a loco or tram body, it has to find a source of power.
For large scale, you might consider running the module from a PP3 9V battery.
This is the easiest to wire but results in the LEDs arcing even when the motor is stationary.
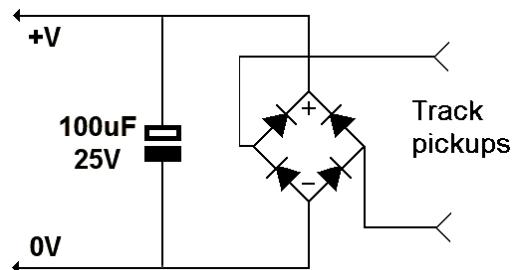
Another option is to take power from the track.
The easiest way is to connect to the motor's pickups.
The diagram shows the extra two parts required.   It uses a *'bridge rectifier'* and this produces a DC from its output, regardless of whether the motor is running forward or backwards.
The capacitor is of a large capacity, to store energy from the track and supply it to the module when there is small glitches in picking up track power.
The PIC chip expects around 5V to operate correctly, so the LED will not flash at slower speeds.

Of course, if you are using DCC, there is continual power to the track pickups and the LED will flash even at slow speeds. Unfortunately, it will also flash when the motor is stationary. However, if you have an unused output from the DCC decoder, such as a headlamp connection, this could provide a switched supply to the flasher module.

Using as a fluorescent tube startup
Only fit the white LED.   Fit link 2.
Connect the trigger pin (the yellow wire in the picture) to a switch, or other circuit, that can take the pin down to 0V. When the module is first connected to power, nothing happens until the trigger is brought to 0V.   At that point, the LED will splutter before settling to being permanently illuminated.   When the 0V is removed from the trigger pin, the LED extinguishes again.
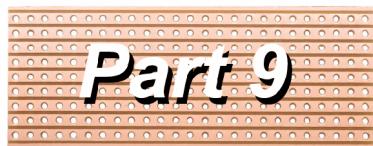
Using as a pulsing warning light
Fit both link 1 and link 2.   Fit a red LED in place of the white LED.
When the module is first connected to power, the LED will slowly increase and decrease in brightness.
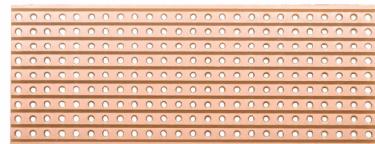
Pocket Money Projects

Part 9

A series of small, cheap, easy to build projects using stripboard
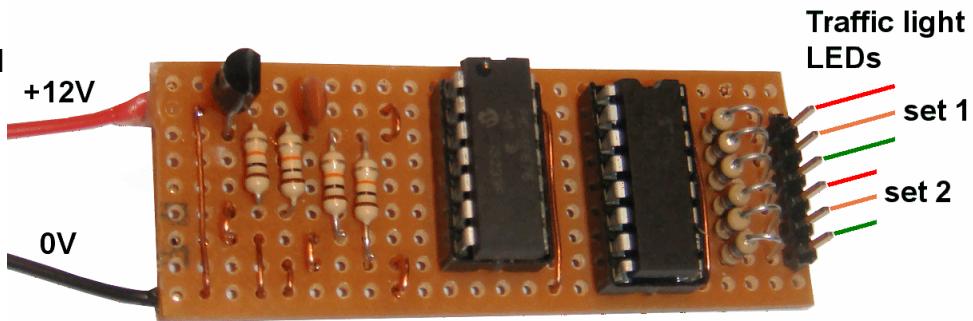
by Davy Dick M1853

4-way traffic lights

This little project simulates UK road traffic lights, producing the correct switching sequence.

It can handle four sets of lights for a full junction, or just a single set if required.

Traffic light LEDs

set 1

set 2

+12V

0V

You insert or remove the links across the board's copper tracks to set the speed at which the lights change.

The eight speeds are:

| Link 1	Link 2	Link 3	Speed
IN	IN	IN	5 secs
IN	IN	OUT	15 secs
IN	OUT	IN	30 secs
IN	OUT	OUT	60 secs
OUT	IN	IN	90 secs
OUT	IN	OUT	120 secs
OUT	OUT	IN	150 secs
OUT	OUT	OUT	180 secs
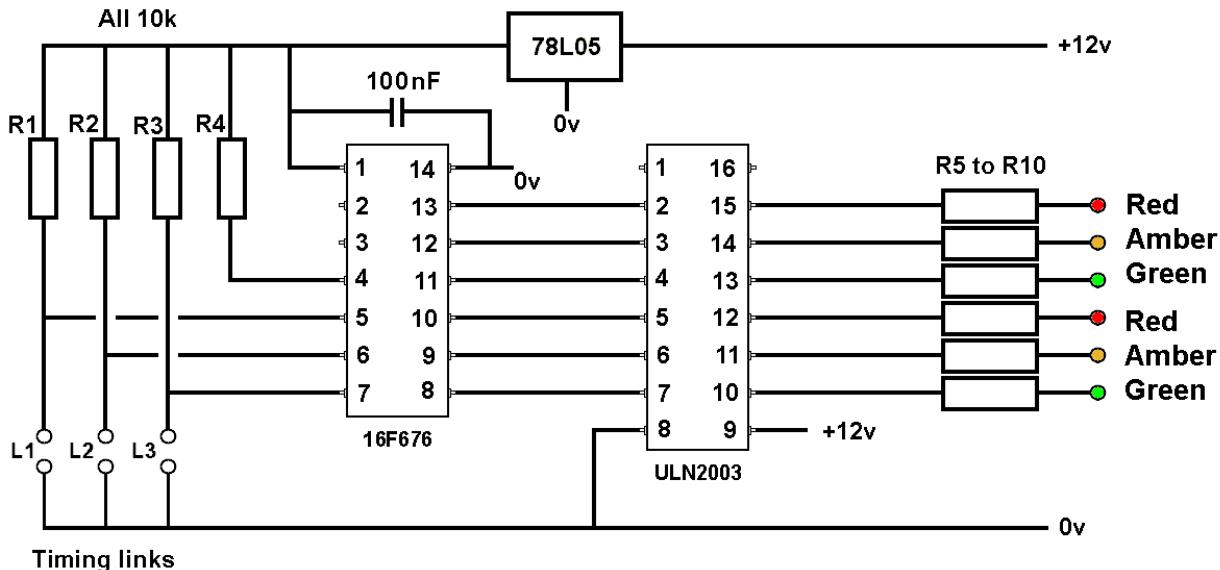
The fastest speed is really to test the module after it is built. Once you know it works, you can use the links to set the speed that best suits you.

How it works

You don't need to know how it all works to build and use it, but this brief explanation helps you understand what each component is for.

Below is the circuit diagram for the module. All the fancy timing and switching takes place inside the 16F676 PIC chip, which is pre-programmed for you.

The module is intended to work from a 12v DC supply which powers both the ULN2803 and a 7L805 voltage regulator.   The voltage regulator reduces the 12v down to 5v which is the required voltage for the 16F676 PIC chip. In fact, the traffic light module will work over a range of supply voltages from 9v to 35v but you would have to choose the resistors for the LEDs to match any higher voltages beyond 12v.

R1, R2 and R3 ensure that pins 5, 6, and 7 on the PIC chip are kept at a high voltage, unless links are wired across to 0V.   When a wire link is inserted, it pulls that pin down to 0v.   The PIC knows which timing sequence to use, based on which links are made (see table above).

R4 makes sure that the PIC's pin 4 is kept high at all times.   Pin 1 and 14 on the PIC are taken to the +5v and 0v lines respectively.   These pins connect the PIC to the 5v power supply and the capacitor is used to prevent any stray voltages from upsetting the operation of the PIC.

When the module is first powered up, it looks at which links are inserted and runs the appropriate lights timing sequence.
The PIC's pins 8, 9 and 10 are used to switch a set of green, amber and red LEDs, while pins 11, 12 and 13 switch another set of red, amber and green LEDs – but in the opposite lights phase (e.g. when one set has its green LED lit, the other will have its red LED lit).

As described so far, that would be enough to run a single set of lights, or even two sets if low current LEDs were used.
Each output pin of the PIC can handle a maximum current of 25mA and the total for all output pins is limited to 200mA.
With a 4-way lighting system, lots of LEDs will be illuminated at the same time and this can be a problem, particularly if want to use high current lamps for larger scales.
So, the circuits use a ULN2003 chip, known as a *'Darlington array'*.   It has seven separate amplifier circuits, although we only use six for this project.
Its job is boost the current handling levels of the PIC.   For example, pin 13 of the PIC connects to pin 2 of the ULN2003.   When the PIC's pin 13 switches high, it switches pin 2 of the ULN2003 chip and this lowers the voltage on its pin 15.
The ULN2003 can handle 500mA from each output.
Suggestions for connecting LEDs are discussed later.

Parts list

- One piece of stripboard 25mm x 64mm   34-0500
- One pre-programmed 16F676 PIC chip
- One ULN2003 integrated circuit   82-5036
- One 78L05 voltage regulator   47-3612
- One 14-pin IC socket   22-0108
- One 16-pin IC socket   22-0109
- Four 10k resistors   62-0394
- One 100nF ceramic capacitor   08-0235
- Red, amber and green LEDs (see text)
- Six 560 ohm resistors   62-0364

If you are a MERG member, this is available as a kit - PMP9 Part No: 809.

Preparing the stripboard

This project is built on a piece of stripboard (originally called Veroboard) that has nine strips of copper on one side.   It is important to note that all the components are mounted on the _other_ side of the board (see the picture) and their leads are poked through the holes for soldering on the copper side.

The first step is to read the various lighting options, _before_ cutting the breaks in the track at the points shown in the illustration below.

If you think you will be making other projects on stripboard, it might be worth investing in a stripboard track cutter, which does a nice clean job of removing the unwanted copper.
Otherwise, use a drill bit - but turn it by hand or you will rip a large hole in the strip board in two seconds flat!
Make sure that you cut tracks between the two rows of legs of the chips.
After you are sure that there no remaining tiny strips of copper bridging any of the cuts, clean the copper strips and the leads of the components prior to soldering.
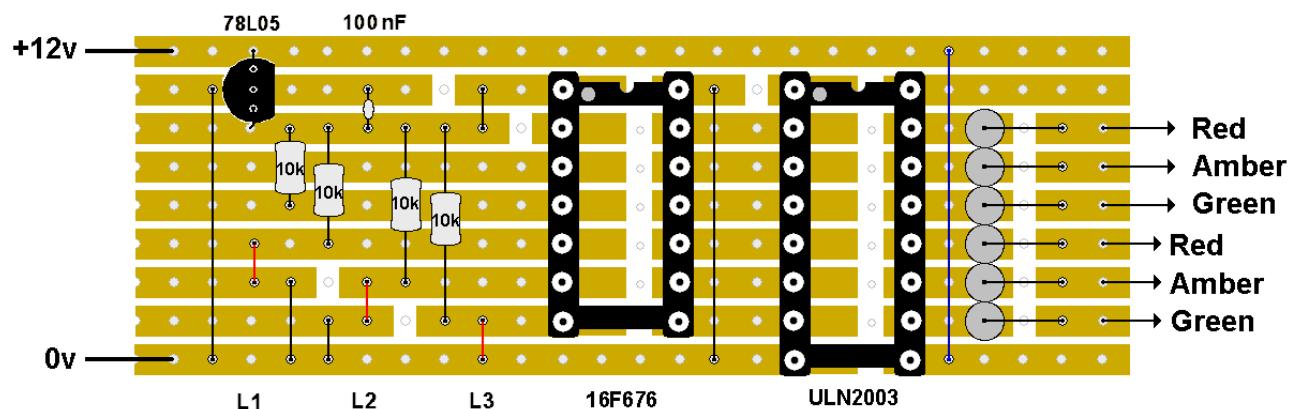
Construction

This following illustration shows where the components are situated on the stripboard.
It shows the tracks underneath, as if the board was transparent.   That helps to align components with their correct mounting holes.   If in doubt, have another look at the photograph on the first page.

It is a smallish project but you might still prefer to follow the construction in this order.
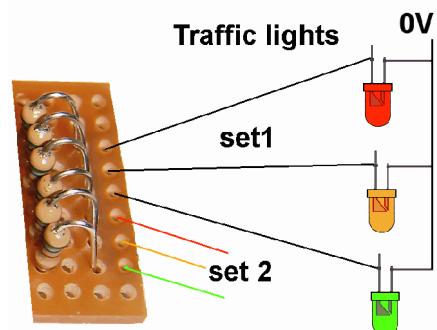
For both versions:

Cut all the breaks in the tracks, apart from those that would be under the ULN2003 IC socket.

Solder the five wire links that are shown in black in the illustration.

Solder all four 10k resistors. They can be fitted either way round.

Solder all six 560 ohm resistors. They can be fitted either way round.

Solder the 14-pin IC socket with its notch or indent towards the top as shown in the component layout.

Solder the 10nF capacitor. It can be fitted either way round.

Solder the 78L05 regulator in place, with the flat surface pointing inwards.

Solder leads to the board edges, to connect to a 12v supply.

A single, traffic light

If you only want to have a single traffic light on a layout:
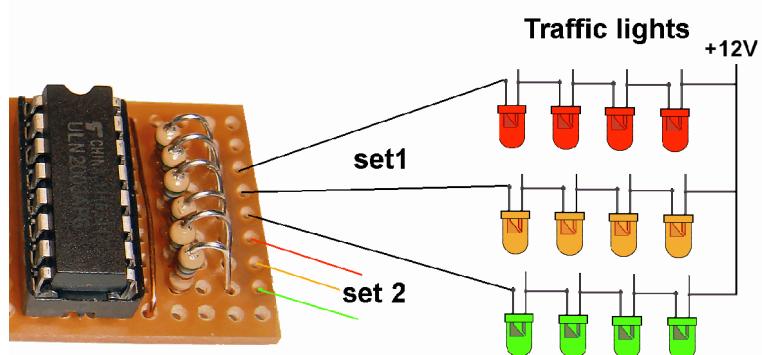
- Don't fit the ULN2003 or its IC socket.
- Don't fit the link marked in blue in the illustration.
- Wire the outputs to the LEDs as shown, with their shortest leads being connected together and making a common connection to 0v.

4-way traffic lights

If you want a full 4-way set of lights:

- Solder the 16-pin IC socket with its notch or indent towards the top as shown in the component layout.
- Cut the tracks between its pins.
- Fit the wire link marked in blue in the illustration.
- Wire each sets of coloured LEDs in series with each other – the short leads connected to the next LED's long lead (see the illustration). The LEDs are then connected together and the common connection is wired to the 12V positive supply.   Note that this is different from the single light, which is taken 0V. This is because the ULN2003 outputs are *'inverted'* (if one of its inputs is high its output is taken low – and vice versa).

Next

Before inserting the chip(s), check that all track cuts have been made and all required links are in place, check for shorts between adjacent tracks, check for dry joints and check that you have put all the components in the correct place and the correct way round.
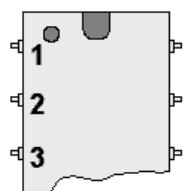
If everything is OK, connect the board to a 12v DC supply.

Using a meter, you should read 5v DC between pin 1 and pin 14 of the 16F676 IC socket (and 12V DC between pins 8 and 9 of the ULN2003 IC socket).   This proves that the 5v regulator is working.
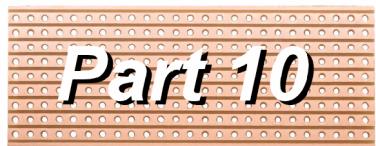
Now, disconnect the power and insert the chip(s) – make sure they are the correct way up. They have a notch or indent at one end, indicating where pin 1 is (see the example in the illustration).

Reconnect the power and the lights should start sequencing.
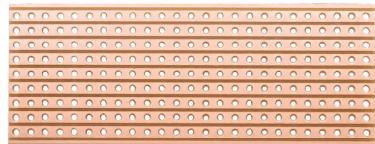
Try different combinations of the links and the time sequences should alter.

For smaller gauges, you may consider using tiny surface mount LEDs.

Pocket Money Projects

Part 10

A series of small, cheap,
easy to build projects
using stripboard
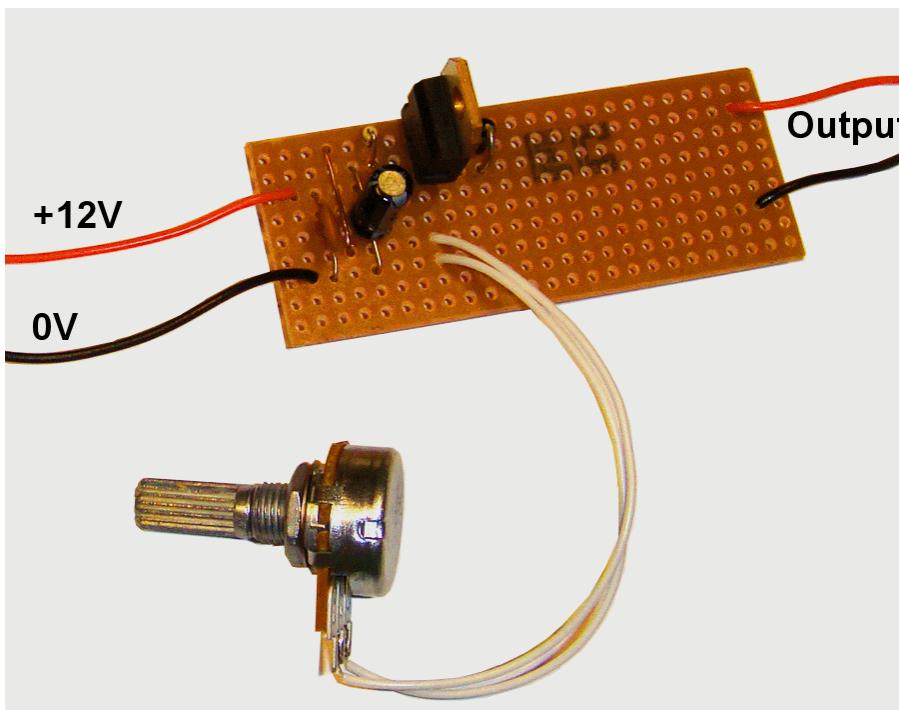
by Davy Dick M1853

A speed controller

This easy to build project has two uses:

- To provide a basic motor speed controller. (e.g. for a loco, cooling fan, etc.).
- To provide a basic variable voltage power supply for use on your workbench.
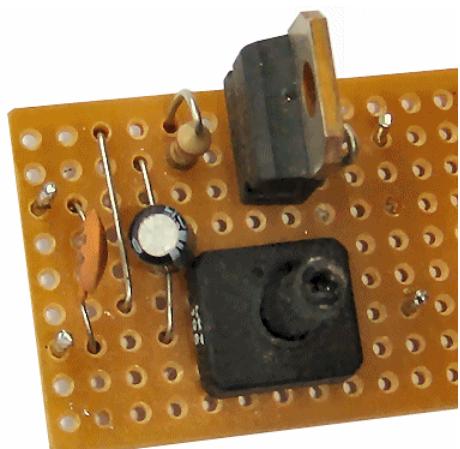
The image shows a variable resistor fitted. This allows easy control over the output voltage, using a knob.

For use with the unattended shuttle module (PMP4), the potentiometer can be replaced by a 4k7 preset
The preset is adjusted to match the speed requirements of the loco being used and the loco is then left to run by itself.
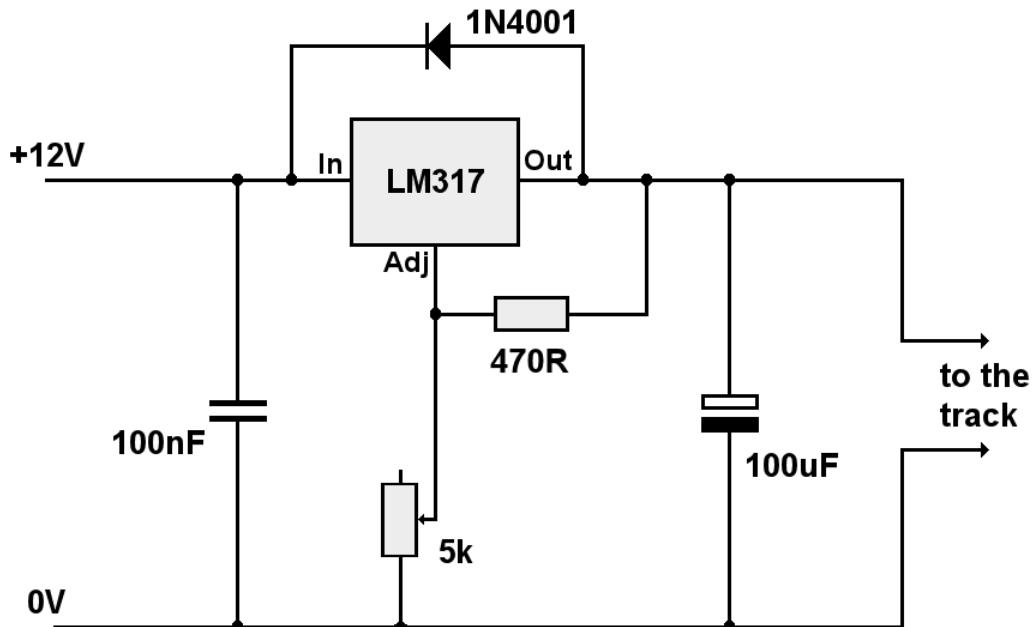
This setup can also be used if you require a fixed voltage for any other layout feature (e.g. setting the speed for a windmill or watermill).

How it works

Here is the circuit diagram for the controller.
It uses just six components.

The LM317 is a 3-pin device that can have its output set to provide output voltages from 1.2V upwards (it does not go down to 0V).   The output depends on the input fed into it and the combination of the resistor and potentiometer values that provide a voltage feedback to the chip's adjustment pin.

The chip needs to maintain a 1.25V difference between its output pin and feedback pin, which explains why a 12V input produces an output range of around 1.2V to 10.7V.

The 100uF capacitor acts as a reservoir to smooth out any small changes caused by current variations.

The diode is used to prevent possible damage to the chip that would be caused by a fully charged 100uF capacitor trying to push current back through the LM317 in the event that its input became shorted (unlikely but, for the sake of a few extra pence, worth the trouble).

Parts List

- One piece of stripboard 25mm x 64mm   34-0500
- One LM317   47-3318 or from the Kit Locker
- One 470 ohm resistor   62-0362
- One 4k7 linear potentiometer   65-0710
      (avoid logarithmic pots as they are for audio use)
  OR
- One 4k7 preset potentiometer   67-0464
- One 100nF ceramic capacitor   08-0235
- One 100uF electrolytic capacitor   11-0245
- One 1N4001 diode   47-3420 or from the Kit Locker

If you are a MERG member, this is available as a kit - PMP10 Part No: 810.

If you are in an Area Group/club, why not place a joint order and share the postage costs? The part numbers listed are for Rapid Electronics (www.rapidonline.com).   Alternatively, check out www.bitsbox.co.uk or eBay for competitive prices.

Construction

This project is built on a piece of stripboard that has nine strips of copper on one side. It is important to note that all the components are mounted on the _other_ side of the board and their leads are poked through the holes for soldering on the copper side.

This illustration show the components and the tracks at the same time.   It is really showing where the components should go.   It shows the tracks underneath, as if the board was transparent, to help you position the components correctly.

The first step is to clean the copper strips and the leads of the components prior to soldering.

When inserting and soldering the components, follow these guidelines:

- Fit the wire link.
- The 470 ohm resistor has yellow, violet and brown bands round it and can be fitted either way round.
- The 100nF capacitor can be fitted either way round.
- The 100uF electrolytic capacitor has to be fitted as shown in the illustration, with the negative lead (indicated by a band and/or negative symbols) nearest the bottom of the board.
- The diode has to be fitted the right way round, with the striped end furthest from the top of the board.
- The LM317 regulator must be fitted with its flat metal surface pointing to the right.
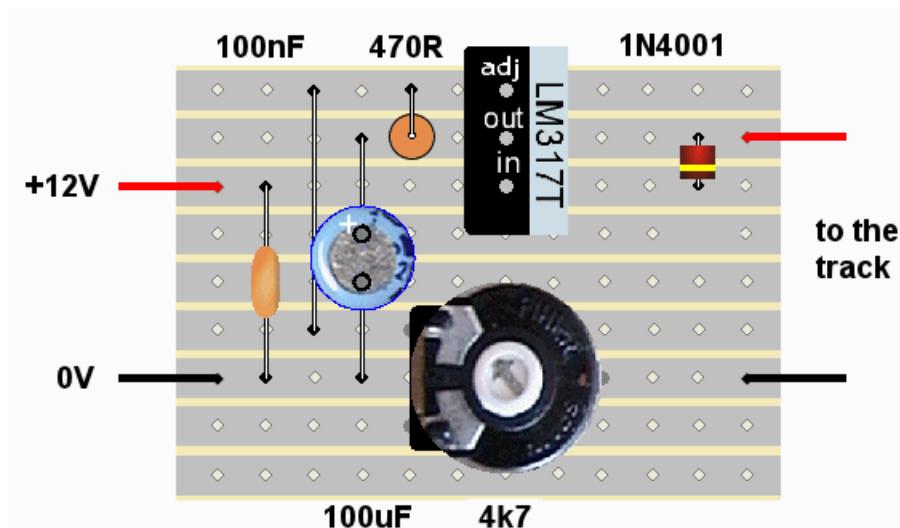
Using as a bench supply

- Wire a 4k7 potentiometer to the stripboard as shown by the blue wires.   One of the leads connects to the potentiometer's middle pin.
- Wire the output connections to a couple of terminals on your bench (on a board or fit everything inside a case).
- Connect your multimeter (on the DC voltage range) to the terminals and rotate the potentiometer until the desired voltage is read.

Using with the shuttle module

- Fit a 4k7 preset resistor as shown in the illustration.
- Wire the output of the supply to the 'Loco supply' inputs of the shuttle module.
- Adjust the preset value until the desired operating speed for the loco is reached.
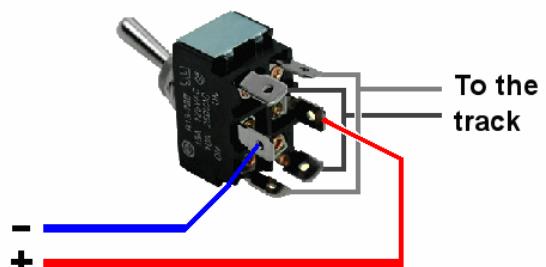
Using to control motors

- Wire the 4k7 potentiometer to the stripboard as shown by the blue wires. One of the leads connects to the potentiometer's middle pin.
- Wire the output connections to the track.

This way, the module controls a DC motor – as long as it is going in the one direction.

That is fine for a fan, windmill, etc., but If using with a railway loco, some means of reversing the direction is required.

This achieved by adding a changeover switch at the output.

This requires a double pole double throw switch to reverse the polarity and its wiring is shown in this illustration.
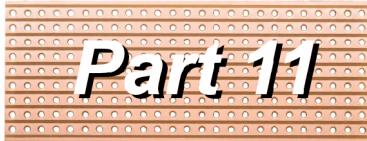
The LM317 is capable of handling currents up to 1.5A.

When such high currents are being taken, a heatsink should be bolted to the LM317 on its plain metal side. This should not be required when running a small N gauge loco.

Remember, though, that the voltage cannot be reduced to zero; there is always at least 1.2V on the output.
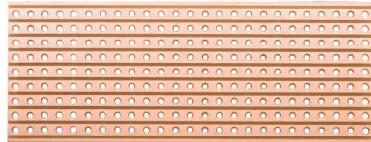
While it does not have the sophisticated features of other loco controllers (acceleration, deceleration, etc.) it is a good starter project that provides basic control at a great price.

Also, if you can't afford an expensive variable voltage supply, this will prove a low-cost alternative.

Pocket Money Projects

Part 11

A series of small, cheap, easy to build projects using stripboard

by Davy Dick M1853

LED dimmer

Many layouts now incorporate LED lighting inside buildings, in lamposts, yard lights, etc. It is also increasingly being used as a means of illuminating a layout, usually with long LED strips hidden behind pelmets.

LEDs are usually illuminated using a fixed voltage supply and a fixed value of dropper resistor (the dropper resistor prevents excessive current through the LED).
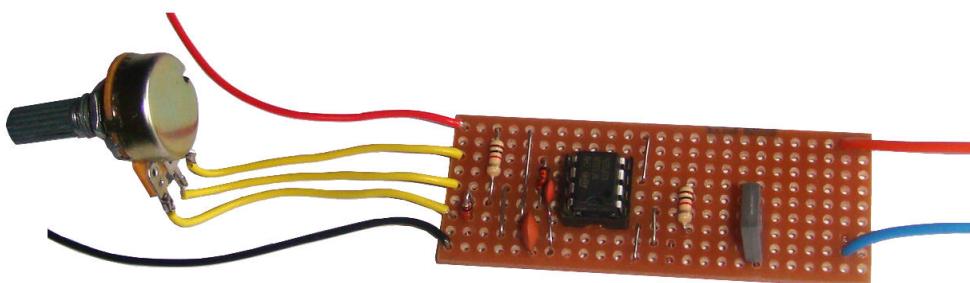
LED strips have built-in dropper resistors and are intended to be run at 12V.

These work fine but always produces the same level of illumination.

Ideally, you want to be able to handle these situations:

- On a bright day, you may want to have maximum brightness.
- Used at night, in a dark, room, you may want to lower the brightness, otherwise the lights become too overwhelming and unrealistic.
- At different public exhibitions, your layout may be situated in areas where the LED light level needs to be adjusted to match the ambient light in the room.
- Illuminating LED strips to different levels to simulate different times of day (morning, dusk, etc.) or different weather conditions (sunny, sunsets, overcast, etc.).   This effect is increased if a number of coloured LED strips are used (bright white, warm white, amber, blue).

That's where a LED dimmer is useful, as it opens up ways to bring interesting effects to a layout.

This project can be used to dim a 12V LED strip, as shown in the picture, or dim one or more individual LEDs, using a dropper resistor.

How it works

You don't need to read this section before building the circuit.   You can always come back and read it later. It's up to you.

A normal incandescent bulb works by supplying sufficient current to heat the filament to the point where it glows brightly.   If the voltage to the bulb is reduced the lamp shines less brightly.   Increasing the voltage results in a greater current and more light – until it eventually overheats and burns out the filament.
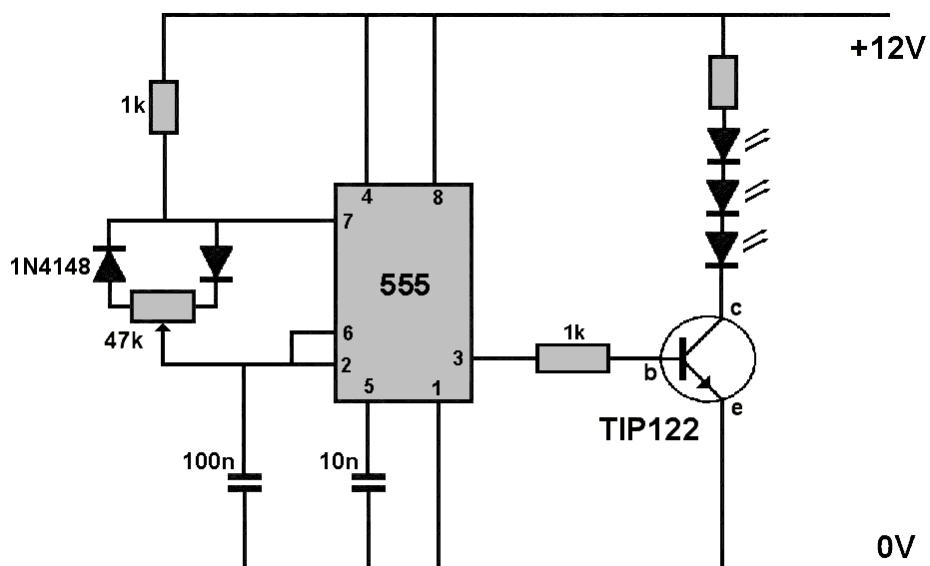
LEDs work differently. If you slowly increase the voltage across a LED, nothing would happen for some time. Eventually the LED will produce light and again will be destroyed if too much current is passed through it.   Unlike the incandescent bulb, the range over which it illuminates is small and, once it start to illuminate, current flows at an ever increasing rate for very small voltage increases. This makes altering LED brightnesses very difficult simply by using voltage changes. So, for example, you could not easily dim a LED by placing it in series with a variable resistor.

Some loco controllers use *'pulse width modulation'* as a means of controlling the current through a motor.   The same principle can be used to control LED brightness.   Firstly, the value of the series resistor is calculated for the required maximum brightness. Then power to a LED, or a string of LEDs in series, is delivered as a succession of on/off pulses. If the pulse period is long, with hardly any off time, the lamp illuminates brightly.
Conversely, if the on period is short, with long periods off, the LED will be dim.
In other words, altering the pulse width changes the LED brightness.   The rate at which the pulses repeat has to be fast enough to prevent the LED simply flashing on and off.
So, the voltage never changes; it's the duration of the pulses that determine the average current flowing through the LED.

Here is the circuit diagram for the dimmer.

It uses a 555 timer chip which runs at a fixed frequency of a few hundred Herz (i.e. the number of times its output switches between low voltage and high voltage every second). The output from the 555 chip (pin 3) is a square wave that has a variable 'duty cycle' (the time that the voltage is high compared to the time it is zero). The duty cycle can vary from 0% (never on) to 100% (always on) and is determined by the setting of the 47k potentiometer
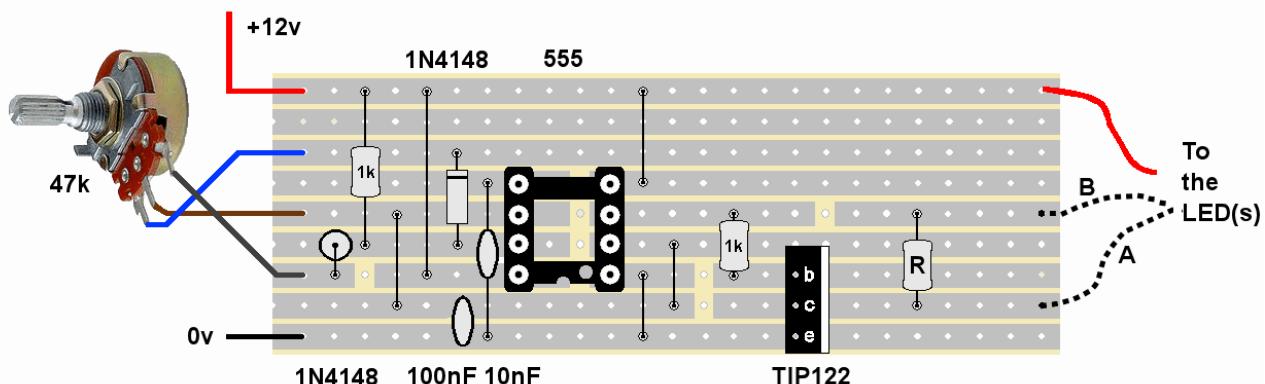
The output of the 555 is taken to a TIP122 power transistor. This transistor is able to switch higher currents than the output of the 555, allowing it to control a long string of LEDs if required.   The TIP122 is rated for a maximum of 5A.   When using high currents, a heatsink is advisable.

Parts List

- One piece of stripboard 25mm x 64mm   34-0500
- One TIP122 power transistor   available from bitsbox
- One 555 timer integrated circuit   82-0338
- Two 1k resistors   64-0370
- One 47k linear potentiometer   65-0710
    (avoid logarithmic pots as they are for audio use)
- One 100nF ceramic capacitor   08-0235
- One 10nF ceramic capacitor   08-0230
- One 8-pin DIL socket (the IC holder)   22-0107 (sold in tube of 60)
- Two 1N4148 diodes   47-3416 or from the Kit Locker

If you are a MERG member, this is available as a kit - PMP11 Part No: 811.

If you are in an Area Group/club, why not place a joint order and share the postage costs? The part numbers listed are for Rapid Electronics (www.rapidonline.com). Alternatively, check out www.bitsbox.co.uk or eBay for competitive prices.

Construction

This project is built on a piece of stripboard that has nine strips of copper on one side. It is important to note that all the components are mounted on the _other_ side of the board and their leads are poked through the holes for soldering on the copper side.
This illustration show the components and the tracks at the same time.   It is really showing where the components should go.   It shows the tracks underneath, as if the board was transparent, to help you position the components correctly.

Make sure that you cut tracks where indicated in the above illustration. Check that all eight are cut and that there no remaining tiny strips of copper bridging any of the cuts. The next step is to clean the copper strips and the leads of the components prior to soldering.

When inserting and soldering the components, follow these guidelines:
- Fit the five wire links.
- The 1k resistors have brown, black and red bands round them and can be fitted either way round.
- The 100nF and the 10nF capacitor can be fitted either way round.
- The diodes have to be fitted the right way round, with their striped ends as shown in the picture and the illustration.
- It helps if the IC holder is fitted to the board with its notch facing bottom right, as shown in the layout illustration.   This reminds you to also fit the PIC chip correctly (i.e. with its notch also facing bottom right).

- The TIP122 transistor must be fitted with its flat metal surface facing to the right.
- If you are using a 12V LED strip, connect using the 'A' lead and the red lead. The LED strip will have points along its length where wires can be soldered.   These points will be marked with plus or minus signs.   Connect the red lead to any point on the strip marked with a positive symbol (it need not be at the end of the strip).   The 'A' lead should be connected to any point on the strip marked with a minus sign.
- If you are using one or more individual LEDs, use the 'B' and red leads The value of the resistor 'R' will depend on which LEDs you use and how many LEDs you wire in series.
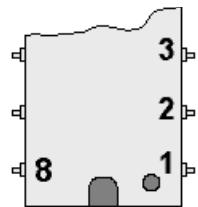
Before connecting power, carry out a close visual inspection of the board, ensuring that you have no short circuits, dry joints, unsoldered connections, etc.

Attach 12v to the module and check that your meter reads 12V between pins 1 and 4 of the IC holder.

Disconnect the power and fit the 555 chip with its notch facing downwards, placing its pin 1 to the bottom right in the holder.

Reconnect the power.   Rotating the spindle of the potentiometer should make the LED(s) brighten or darken.
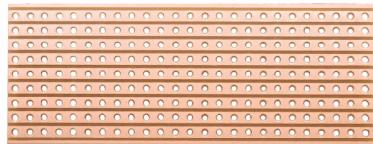
Pocket Money Projects
Part 12

A series of small, cheap,
easy to build projects
using stripboard

by Davy Dick M1853
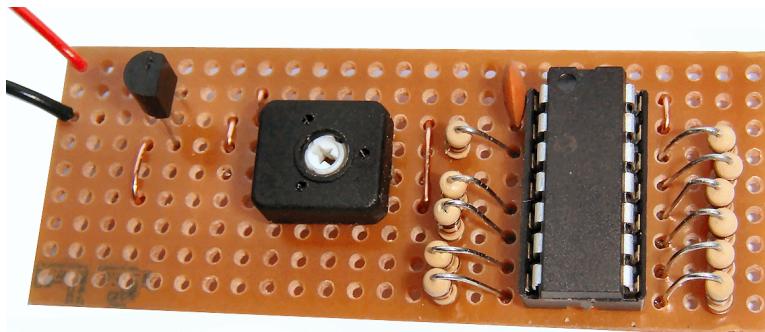
Random lights

Some railway layouts have no scenic lights whatsoever. Every building is in darkness.
Other layouts have lamps inside the buildings.   The buildings are constantly lit.
While constant lighting is better than no lighting, permanently-lit buildings are not ideal.
Of course, you can use switches to manually control building lights, or even have lights
that are triggered automatically (e.g. a station light comes on when a train enters the
station).

This project provides the ability to have 10 lights that come on and off randomly, as in real
life.   Imagine a block of flats, a row of houses, a factory, an office or a hotel where the
lights work without your intervention.

The module has a preset potentiometer that can be adjusted with a small screwdriver.
This sets the speed at which lights may be changed. For instance, you may use the
shortest delays to test that all the LEDs work.   Short delays are also useful at exhibitions,
where kids expect things to happen quickly.
At other times, you can adjust the delay to your own needs.

How it works
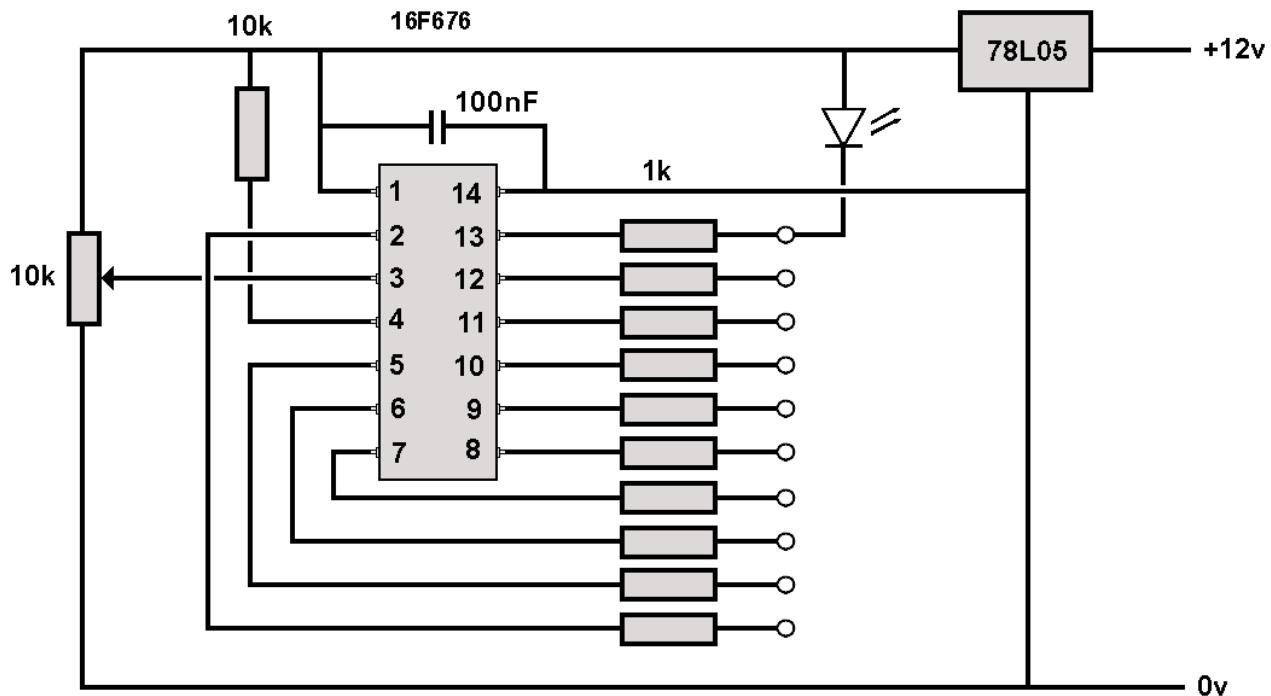
You don't need to read this section before building the circuit.   You can always come back
and read it later. It's up to you.
The circuit diagram is on the next page.   It is based on a pre-programmed PIC chip that
contains all the decision-making and controls.   A PIC is a chip that can be programmed
using special hardware and software. Don't worry, this has all been done for you.
The sequence continually repeats itself and is as follows:

- The 10k preset potentiometer sets the delay time.   Rotating the screwdriver alters the
  voltage fed into pin 3 of the PIC. The PIC reads this voltage and uses it to set the delay
  time.
- After the delay is over, the PIC chip makes a random choice between 1 and 10. This
  decides which light may be altered.
- The PIC chip then randomly decides whether that LED should be lit or unlit.   It then makes
  the output to the chosen LED high or low.

This provides a double random system.   You don't know which light will be next. You don't even know whether it will change the light, since the chip might decide to light a LED that is already lit (or vice versa).   In that situation, nothing happens and the delay before any possible change is doubled.

Each output of the PIC is taken to a 1k resistor and the outputs can be fed directly to a LED.   The output on pin 13 is shown wired to a LED, as an example.
Each output can handle a maximum current of 25mA, with the chip capable of a total of 200mA.   So, 250mA must be the combined total of all LEDs used, as there may be times when all LEDs are lit and drawing current.   This should not pose a problem as modern LEDs are very bright at low currents.   The 1k resistors limit the current to around 5mA per LED but these can be replaced with lower values if brighter LEDs are required.

If you don't want to use all 10 outputs, you can decide which pins you want to use – giving an even more random effect.
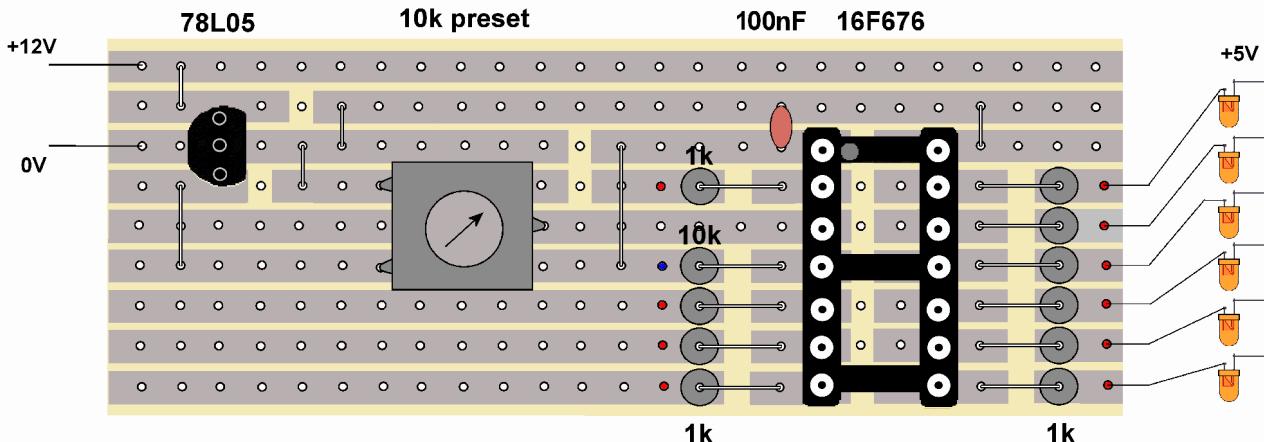
Parts List
- One piece of stripboard 25mm x 64mm   34-0500
- One pre-programmed 16F676 PIC chip
- Eleven 1k resistors   64-0370
- One 100nF ceramic capacitor   08-0235
- One 14-pin DIL socket (the IC holder)   22-0108 (sold in tube of 34)
- One 10k preset potentiometer   67-0466
- Ten LEDs (depends on what colour mix you want – e.g. white, yellow, red)

If you are a MERG member, this is available as a kit - PMP12 Part No: 812.

Construction
This project is built on a piece of stripboard that has nine strips of copper on one side.
It is important to note that all the components are mounted on the _other_ side of the board and their leads are poked through the holes for soldering on the copper side.

This illustration show the components and the tracks at the same time.   It is really showing where the components should go.   It shows the tracks underneath, as if the board was transparent, to help you position the components correctly.

Make sure that you cut tracks where indicated in the above illustration. Check that all 22 are cut and that there no remaining tiny strips of copper bridging any of the cuts.
The next step is to clean the copper strips and component leads prior to soldering.

When inserting and soldering the components, follow these guidelines:
- Fit the six wire links.
- The 1k resistors have brown, black and red bands round them and can be fitted either way round.   An alternative five-band resistor will have brown, black, black, brown and brown bands.
- The 100nF capacitor can be fitted either way round.
- It helps if the IC holder is fitted to the board with its notch facing top left, as shown in the layout illustration.   This reminds you to also fit the PIC chip correctly (i.e. with its notch also facing top left).

Setting up
Before connecting power, carry out a close visual inspection of the board, ensuring that you have no short circuits, dry joints, unsoldered connections, etc.
Then connect the power to the board where shown.   If it is working correctly, you will read 5V across pins 1 and 14 of the IC holder.   If all is OK, disconnect the power supply and solder connecting leads from the board to the LEDs. Only fit wires to the 1k resistors (the red blobs in the illustration). Connect each LED's short leg to the red blobs.   The 10k resistor is used by the PIC and should not be connected to a LED.
Lastly, fit the PIC chip (with pin 1 – the notch- top left) and reconnect the power.   The LEDs should randomly light and extinguish, at a rate set by the setting of the preset pot.

Modifications
If you want a room in a building to be extra bright, you can look for a suitable LED (with a max current of 25mA) and calculate the value of the resistor from this web site;
        http://led.linear1.org/1led.wiz
To use even higher current LEDs, you have to use transistors or a ULN2003 chip to handle the extra current.   But, that's for another day.

Pocket Money Projects

Part 13

A series of small, cheap,
easy to build projects
using stripboard

by Davy Dick M1853

## A lighthouse simulator

In fact, this project has two uses:
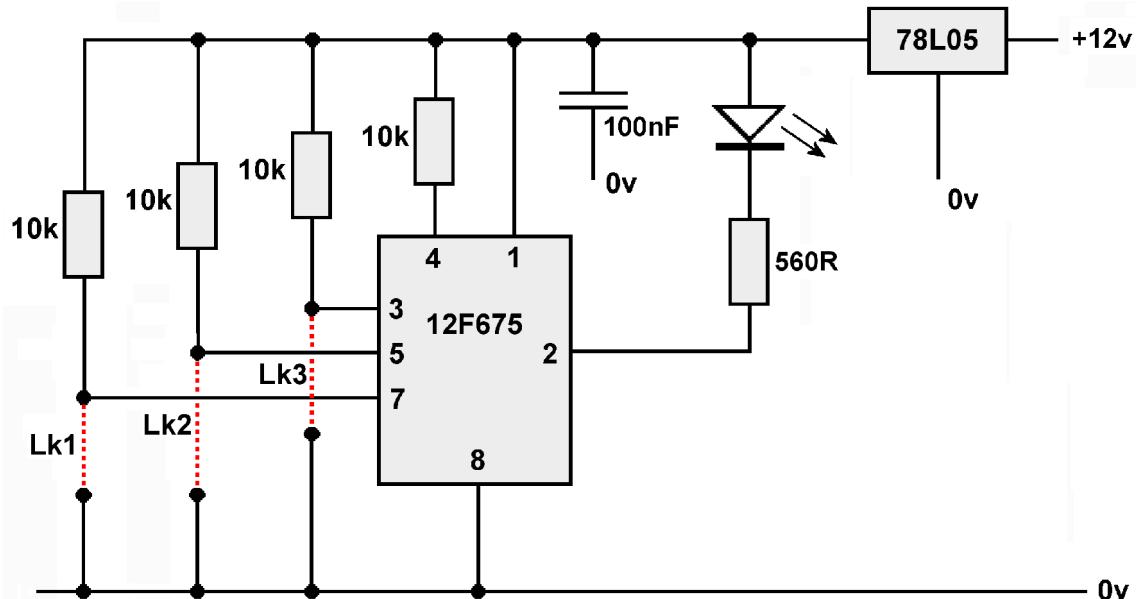
- To simulate a variety of UK lighthouses.   Seven different flashing patterns are provided, covering a total of 32 UK lighthouses.
- To simulate the aircraft warning lights that are fitted on tall structures (buildings, TV masts, power pylons, bridges, etc.)

Three links are used to select which mode of operation is displayed.

How it works

Here is the circuit diagram for the simulator.
Despite the variety of output patterns, it uses just nine components.

All the timing, decision making, etc. take place within the 12F675 PIC chip.
A PIC is a chip that can be programmed using special hardware and software.
Don't worry, this has all been done for you. (of course, it means that you can't alter the timings).   Pins 6 is unused in this circuit.
The 78L05 is a voltage regulator.   It reduces the 12V supply to the 5V used by the PIC and the LED.
Pins 3, 5 and 7 are normally held to a high voltage as they are taken to +5V via the 10k resistors.   If a link is inserted, it brings that particular pin down to 0V. Since there are three possible links, there are 8 possible permutations (see the chart later). The chip senses which links are inserted and pulses the LED on and off in the pattern chosen by the user's selection.

Parts List

- One piece of stripboard 25mm x 64mm   34-0500
- One 8-pin IC holder   22-0107 (sold in tube of 60)
- One white LED (see text)   55-1886
- One 560 ohm resistor (see text)   62-0364
- Four 10k resistors   62-0394 (sold in pack of 100)
- One 100nF ceramic capacitor   08-0235
- One pre-programmed 12F675 PIC chip
- One 78L05 voltage regulator   47-3612

The output pin of the PIC can pass a maximum current of 25mA.

The 560 ohm resistor works with many LEDs, both standard and surface mount types.

If you want to calculate the best value for your particular LED, you can use the handy calculator at:

> http://www.daycounter.com/Calculators/LED-Tutorial-Calculator.phtml
> http://led.linear1.org/1led.wiz
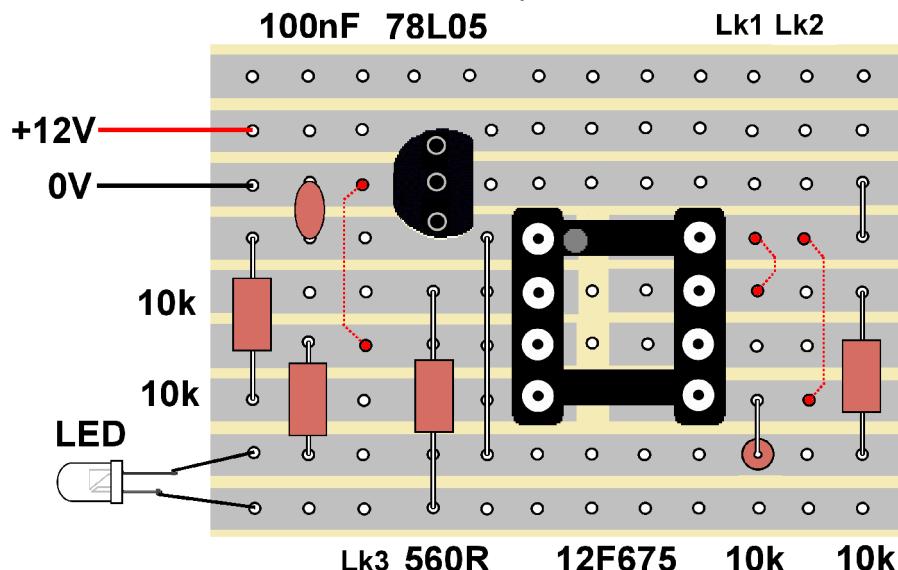
If you are a MERG member, this is available as a kit - PMP13 Part No: 813.

Construction

This project is built on a piece of stripboard that has nine strips of copper on one side.

It is important to note that all the components are mounted on the *other* side of the board and their leads are poked through the holes for soldering on the copper side.

This illustration show the components and the tracks at the same time.   It is really showing where the components should go.   It shows the tracks underneath, as if the board was transparent, to help you cut the tracks in the correct places and position the components correctly.

The first step is to cut four breaks in the track at the points shown in the illustration.


Tip: If you are not too sure, count along the rows and columns on the component side, then poke a wire through the hole where the track is to be cut. Then turn the board over and cut where the wire pokes through.

I use a stripboard spot face cutter, but you could use a hand-turned 3mm or 5mm drill bit – or even a sharp knife if you must.

Next, check that there no remaining tiny strips of copper still bridging any of the track sections. Then clean the copper strips and the leads of the components prior to soldering.

When inserting and soldering the components, you may want to follow these guidelines:

- The 560 ohm resistor has green,blue and brown bands round it, while the 10K resistors have brown, black and orange bands round it   The resistors can be fitted either way round.
- The capacitor can be fitted either way round.
- The LED has to be fitted the right way round, with the anode end nearest the top of the board.   The anode lead of an LED is the longest lead (see the illustration).
- The 78L05 regulator must be fitted with its flat surface pointing inwards.
- It helps if the IC holder is fitted to the board with its notch facing top left, as shown in the layout illustration.   This reminds you to also fit the PIC chip correctly (i.e. with its notch also facing top left).
- Fit the link wires to control the flashing sequence you require (see the chart below). These are shown as red dotted lines in the layout illustration.

Before connecting power to the circuit, do a close visual inspection of the board, ensuring that you have no short circuits, dry joints, unsoldered connections, etc.

Connect a 12V supply to the board. You should read 5V between pins 1 and 8 of the PIC. If all is OK, disconnect the power and insert the PIC chip.   Pin 1 of the chip should be at the top left of IC holder (see the illustration).
When the power is reconnected, the LED should flash with the pattern that you selected using the wire links.

The available patterns are:
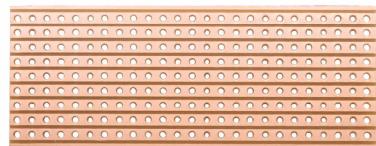
Link1	Link2	Link3	Pattern	Lighthouses
N	N	N	4 flashes every 5 secs	Flamborough, Lynmouth Foreland, Pendeen, Strumble Head
N	N	Y	2 flashes every 30 secs	Alderney, Casquets, Nab Tower
N	Y	N	2 flashes every 20 secs	Beachy Head, St Bees, Holy Isle
N	Y	Y	1 flash every 20 secs	Longstone, Mull of Galloway, Peninnis, Royal Sovereign
Y	N	N	1 flash every 15 secs	Lowestoft, Lundy North, Sark, Turnberry, Wolf Rock
Y	N	Y	1 flash every 10 secs	Anvil Point, Crammag Head, Dungeness,Point Lynas, Southwold
Y	Y	N	1 flash every 5 secs	Cromer, Little Ross, Lundy South, Monkstone, Orfordness, South Bishop, St, Catherines, Trwyn Du
Y	Y	Y	1 flash every sec	Aircraft warning lights

The lighthouse simulations should use a white LED, while a red LED is commonly used for aircraft warning lights.

Pocket Money Projects
Part 14

A series of small, cheap, easy to build projects using stripboard
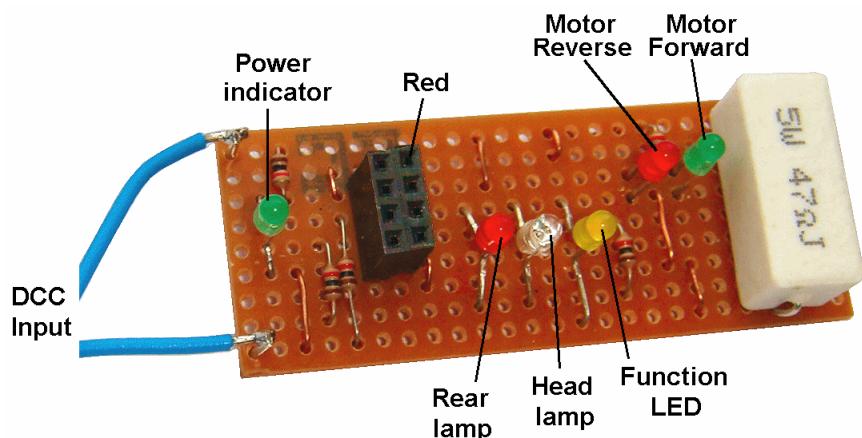
by Davy Dick *M1853*

A DCC Test Rig

This project is intended for use with DCC decoders that have 8-pin plugs at the end of their connecting leads.

The module has two uses:
- To test a newly-purchased decoder prior to fitting to a loco.
- To set up a decoder's CVs.
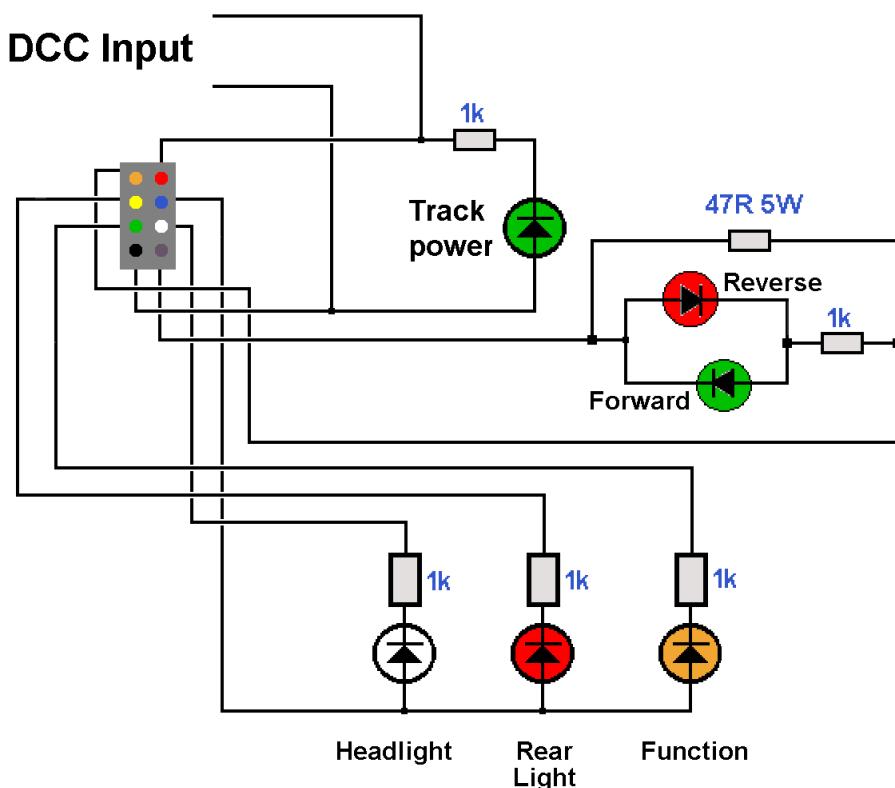
Commercial test rigs are available but are expensive. This is useful, and much cheaper, alternative.

Power indicator — Red — Motor Reverse — Motor Forward — DCC Input — Rear lamp — Head lamp — Function LED

How it works

Here is the circuit diagram for the test rig.

DCC Input — 1k — Track power — 47R 5W — Reverse — 1k — Forward — Headlight — Rear Light — Function — 1k — 1k — 1k

The DCC decoder is plugged into the module's 8-pin socket.

The module is wired to a command station's output, connecting via the socket to the red and black wires on the decoder.

When the command station is switched on, it sends out a continual waveform and that is used to illuminate the *'track power'* LED (the LED and its resistor are connected directly across the incoming DCC signal).

The command station needs to sense a load on its output to fully function. This would normally be a loco's motor.   This is replaced on the module by a high-wattage resistor.   If you have an unused motor, this could be used in place of the resistor (see later).

The orange and grey connections on the decoder normally connect to the loco's motor. In the module they connect across the 47R power resistor.

Across the 47R resistor are two LEDs. These are connected in reverse of each other, then connected across the 47R resistor, with a 1k resistor in series.   The output of the orange and grey wires is the PWM output to the motor, so increasing and decreasing the loco speed control on the command station results in one of the LEDs being made brighter and dimmer.   In the forward direction, the green LED illuminates, while the red LED illuminates when the controller is being used in the reverse direction.

Parts List

- One piece of stripboard 25mm x 64mm   34-0500
- Two green LEDs   55-0105
- Two red LEDs   55-0102
- One white LED   55-1630
- One yellow LED   55-0076
- One 47R 5W resistor   62-8234 or loco motor
- Five 1k resistors   64-0072 (sold in pack of 100)
- One 8-pin connecting block (see last para) 22-5136
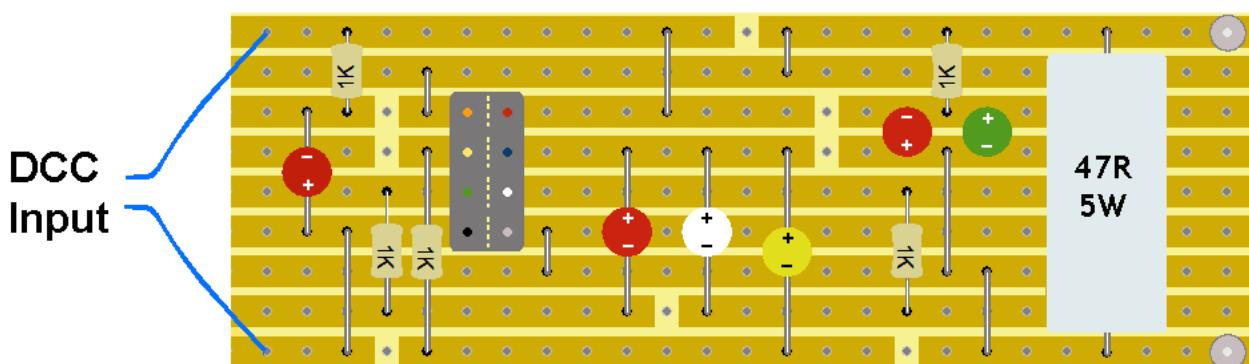
If you are a MERG member, this is available as a kit - PMP14 Part No: 814.

If you are in an Area Group/club, why not place a joint order and share the postage costs? The part numbers listed are for Rapid Electronics (www.rapidonline.com). Alternatively, check out www.bitsbox.co.uk or eBay for competitive prices.

Construction

This project is built on a piece of stripboard that has nine strips of copper on one side.

It is important to note that all the components are mounted on the *other* side of the board and their leads are poked through the holes for soldering on the copper side.

This illustration show the components and the tracks at the same time.   It is really showing where the components should go.   It shows the tracks underneath, as if the

board was transparent, to help you cut the tracks in the correct places and position the components correctly. If in doubt, consult the earlier photograph.

The first step is to cut all the breaks in the track at the points shown in the illustration.

> Tip: If you are not too sure, count along the rows and columns on the component side, then poke a wire through the hole where the track is to be cut. Then turn the board over and cut where the wire pokes through.
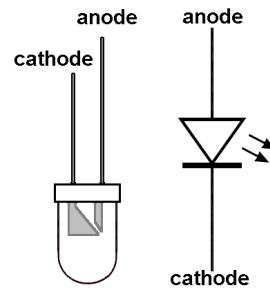
I use a stripboard spot face cutter, but you could use a hand-turned 3mm or 5mm drill bit – or even a sharp knife if you must.

The trickiest part is cutting gaps between the two rows of connecting block, to prevent the two rows from shorting to each other. This involves careful removal of the track, leaving enough for soldering the connecting block. The dotted lines indicate the cuts under the connecting block.

Next, check that there no remaining tiny strips of copper still bridging any of the track sections. Then clean the copper strips and the leads of the components prior to soldering.

When inserting and soldering the components, you may want to follow these guidelines:

- Fit the seven link wires.
- The 47ohm resistor has its value marked on its case, while the 1K resistors have brown, black and red bands round them   The resistors can be fitted either way round.
- If you expect to have long periods of running at maximum speed, it is best to solder the 47R resistor so that is not touching the stripboard.
- The LEDs have to be fitted the right way round, with the anode end, marked with a plus in the board layout, positioned as shown in the layout.   The anode lead of an LED is the longest lead (see the illustration).

Before connecting the DCC controller to the circuit, do a close visual inspection of the board, ensuring that you have no short circuits, dry joints, unsoldered connections, etc.

How to use it

The decoder is plugged into the 8-pin socket and <u>must</u> be inserted with the plug's red lead at the top right-hand corner of the socket.

Testing

- The project's two leads are taken to a DCC command station's normal output connection. The leads can be connected either way round.
- The command station can then be switched on.
- The project's power indicator LED should illuminate.
- A newly-purchased decoder is factory set to operate at address 3, so the command station would be set to address 3.
- Increasing the speed in the forward direction should make the 'Motor Forward' LED light with increasing brightness.
- Increasing the speed in the reverse direction should make the 'Motor Reverse' LED light with increasing brightness.
- The three lamp and function LEDs should be switched on and off using the functions keys on the command station. This will depend on the capabilities of the decoder being tested (read the decoder's manual).

In this way, all the main functions of the decoder can be testing prior to it being brought into use.

If the decoder being checked is not brand-new, it will probably be set to a different address

than the default of 3.

If you know its address, just change the command station's address to match the decoder's.   If you don't know the address, you can try different addresses on the command station until the direction lights illuminate.

Note

The 47R resistor is large because it has to handle the full voltage that would normally be applied to a loco's motor.

Instead of creating movement, as with a loco motor, the power is dissipated in the resistor in the form of heat.   This results in a fair amount of heat if the speed control is set to max.   Now you know why a high wattage resistor is used. So, handle with care!

Setting up

The module is also useful for setting up a DCC decoder's performance, by adjusting the decoder's CV values to set up loco address, acceleration, deceleration, and much more.

A decoder's manual provides details on what CVs are supported on the decoder (the basic ones are all identical but the more sophisticated settings are usually only available on the more expensive models – check the manual).

- The project's two leads are taken to a DCC command station.   This may be the command station's programming output connections or the standard output connections if the controller and the decoder support POM (programming on the main).
- Alternatively, connect the leads to the output of a SPROG.

Thereafter, use the hardware and/or software (e.g. Decoder Pro) that you normally use to configure decoders.

This article is not intended as a tutorial on configuring decoders; there are plenty of articles available on the Internet, or in user manuals, that describe the process.

Modifications

If you have a spare loco motor, you can replace the forward and reverse LEDs with their 1k resistor and the large 47R resistor with the motor.
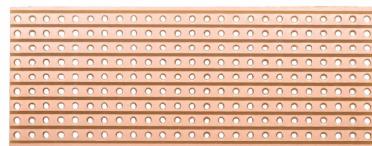
Simply omit fitting these components and wire the motor across the top and bottom tracks of the stripboard on the right-hand side (the side opposite the leads to the controller).

Finally, this project was designed for 8-pin decoders. If you use 6-pin decoders, you could redesign the layout to accommodate them instead.

Pocket Money Projects

Part 17

A series of small, cheap,
easy to build projects
using stripboard
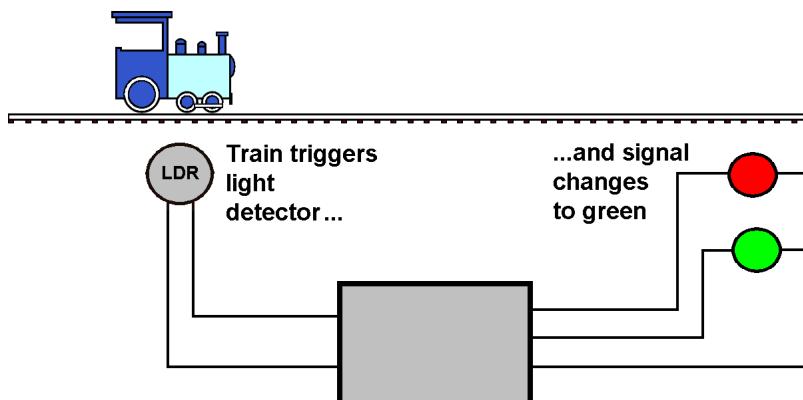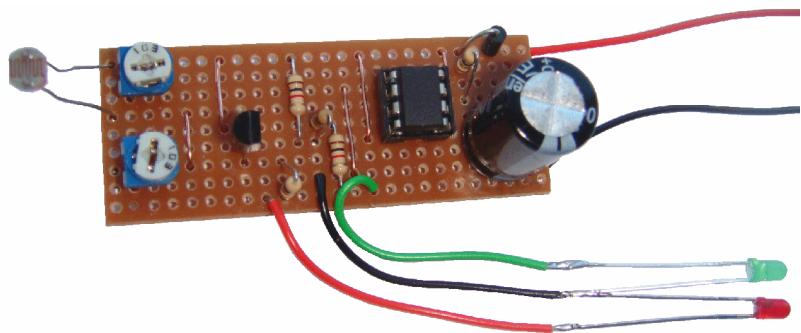
by Davy Dick *M1853*

Automatic signals

This project came about by chance.   I was approached by a MERG member from a local model railway club.   Their layout has an up line and a down line. Each line has signal lights that are currently operated by switches.   He complained that the operators usually forget to throw the switches, resulting in trains running through red lights.

He wanted something that would detect the approaching train and automatically turn the lights to green for a period until the train passed.   The delay in switching back to red should be adjustable. We already have a train detector – the PMP2.   This uses an LDR as a general purpose light detector.   It is used to detect trains in hidden sidings, automatically switch on station lights when a train is on a platform, etc.

This circuit uses the same detector circuit but blocking the light to the light-dependent resistor (LDR) triggers a timer that is added to the board. This results in a module with a single function but one that is useful and not readily available or at a reasonable price. This illustration shows the setup.

The LDR is fitted between sleepers in the track pointing upwards towards the light.
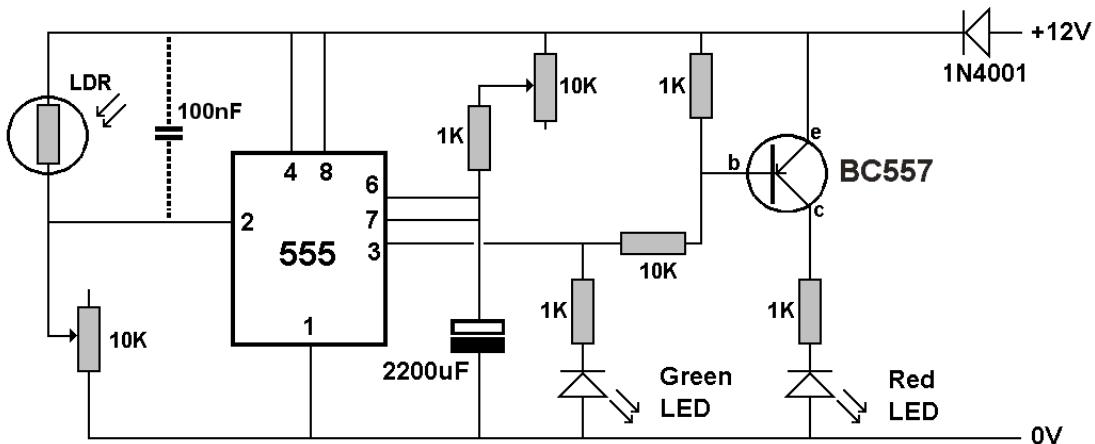
How it works

This part is included for interest. It is not essential to read this before building the project but it helps you better understand what is happening.

The detector

The LDR and a 10k preset potentiometer (a small variable resistor) are in series across the 12v supply.   The voltage at the junction where the LDR and the trimmer join will vary depending on the resistance of the LDR (which, in turn, varies with the amount of light shining on it).
When exposed to light, the LDR has a low resistance and the voltage at this junction will be high.

When the loco passes over the LDR, it blocks the light reaching the LDR.   In darkness, the LDR has a very high resistance and this lowers the voltage at the junction.
The 10k trimmer is used to adjust the sensitivity of the detector.

The timer
A low voltage on pin 2 of the 555 chip triggers the timer into operation.

The 555 timer chip is used in *'monostable'* mode which means that it has a normal stable state, with its output (pin 3) at 0V.
The output pin stays low until there is a negative-going pulse on pin2.   This results in the output pin going high for a fixed period, before returning to 0V again.
How long the output stays high is determined by the values of the resistors and capacitors connected to pins 6 and 7.
This can be calculated with the formula
    $t = 1.1 \times R \times C$
where t is time, R is total resistance in Ohms and C is Farads.
The other 10K trimmer adjusts the value of the total resistance and in this circuit produces delays between 3 seconds and 26 seconds.
If you want different time delays you can use the formula or use this handy online calculator:
    http://web.udl.es/usuaris/p7806757/555-calculadora/555%20Calculator.htm

The outputs
The output of the 555 is used to drive two LEDs, one directly and one via a transistor.
The second transistor is used an 'inverter' which means that a high voltage on its base results in a low voltage on its collector – and vice versa.
When pin 3 goes high, the green LED illuminates during the time of that pulse.
The high voltage on the transistor's base drives its collector low and the red LED extinguishes.

The 1n4001 diode ensures that incorrect connection of the 12V power will not damage the circuit.   The power has to connected the correct way round for the circuit to function.

The 555 chip can operate on a voltage range of around 4.5V to 14V and the time delays are independent of the voltage used.

For more details on 555 timers, look at
http://talkingelectronics.com/projects/50%20-%20555%20Circuits/50%20-%20555%20Circuits.html
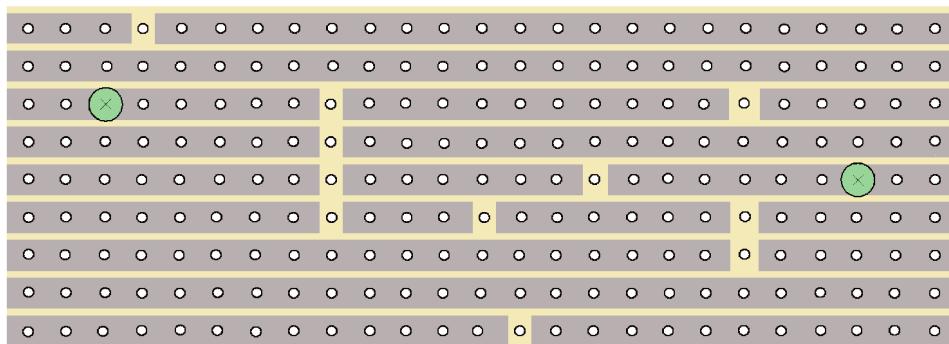
Parts List
One piece of stripboard 25mm x 64mm
One NE555 chip
One 8-pin IC holder
One BC557 transistor
One 1N4001 diode
One LDR detector
Four 1K resistors
One 10K resistor
Two 10K trimmers
One 100nF capacitor (optional)
One 2200uF 25V capacitor
One red LED and one green LED

Note: If you are a MERG member, this is available as a kit - PMP17 Part No: 817.

Construction

> Before starting, it would be useful to read the article on using stripboard that
> appeared in the Autumn 2012 Journal.

This project is built on a piece of stripboard that has nine strips of copper on one side.
First, turn the board over so that the copper strips are uppermost.
Now cut all the eleven breaks in the track at the points shown in this illustration.

If you think you will be making other projects on stripboard, it might be
worth investing in a stripboard track cutter, which does a nice clean job of
removing the unwanted copper.
Otherwise, use a 3mm or 5mm drill bit - but turn it by hand or you will rip
a large hole in the strip board in two seconds flat!
You could cut the tracks with a sharp knife if you must but that is a very
risky approach.
Make sure that you cut tracks between the two rows of legs of the chip holder.
The green circles indicate places that you might want to drill the hole out a little larger, to
provide places where the board can be screwed down.
Next, check that all the cuts have been made and there no remaining tiny strips of copper
still bridging any of the track sections. Then clean the copper strips and the leads of the
components prior to soldering. This minimises problems from dirty or oxidised surfaces
during soldering.
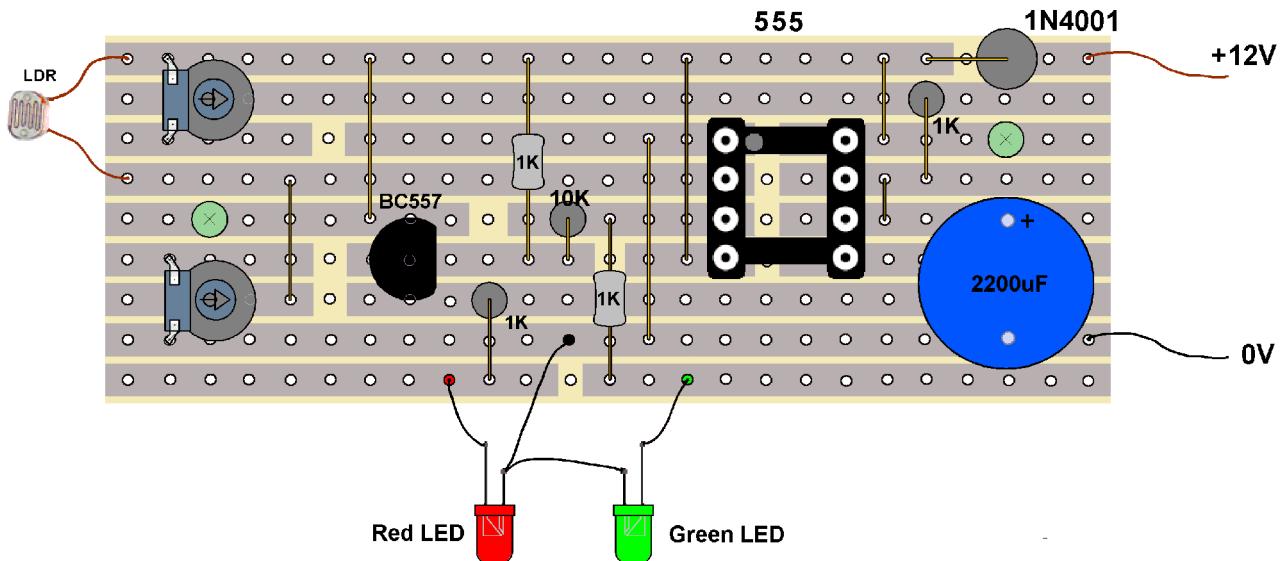
Now turn the board over to fit the components.
It is important to note that all the components are mounted on the _other_ side of the board

from the copper strips and their leads are poked through the holes for soldering on the copper side.

This illustration show the components and the tracks at the same time. It is really showing where the components should go. It shows the tracks underneath, as if the board was transparent, to help you position the components correctly. If in doubt, consult the earlier photograph.

When inserting and soldering the components, you may want to follow these guidelines:
- Fit the six link wires.
- Fit the 10K resistor. It has brown, black and orange bands painted round it. It can be fitted either way round.
- Fit the four 1K resistors. They have brown, black and red bands painted round them, The resistors can be fitted either way round.
- Fit the 8-pin IC socket, with the indent at the top.
- Fit the two 10k trimmers.
- Fit the diode vertically with the end with the white band at the top, connecting to the track that leads away from the input wire.
- Fit the transistors. Its flat surfaces should face towards the 555 chip.
- Fit the large capacitor. It has to be fitted the correct way round, with its positive lead facing upwards away from the bottom of the board.
- Connect the LDR at the points shown in the illustration.
- Connect the two LEDs as shown in the illustration. The shortest wires of the LEDs should be connected together and taken to the common point on the board. The longer leads are individually wired to the board.
- Optionally, fit the 100nF capacitor across the LDR. This is only required where the circuit is feeding into a CBUS or computerised system, to prevent any possible stray pulses from the loco's motor or the DCC signal on the track from generating unwanted pulses.

Quick checks
- All the six links in place?
- No shorts between adjacent tracks?
- No dry joints or unsoldered connections?
- All the components in the correct place and the correct way round?

Do not install the 555 chip yet.
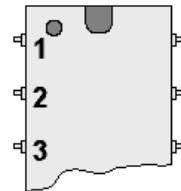
Connect a 12V DC supply to the board, at the points shown in the illustration.
Check that your meter reads approximately 12V between pins 1 and 8 of the IC holder
(there is a small voltage drop across the diode).
Place your meter leads across pins 1 and 2 of the IC holder, with the black lead to pin1.
The voltage should swing from high to low as you move your hand over the LDR.

Disconnect the power and fit the 555 chip with its notch facing upwards,
placing its pin 1 to the top left in the holder.   It will have a notch or indent
at one end, indicating where pin 1 is (see the example in the illustration)

Reconnect the power.

The red LED should illuminate.
Cover the LDR and the red LED should extinguish and the green LED should illuminate.

The trimmer at the bottom of the board sets the sensitivity of the detector and can be
adjusted with a screwdriver.
The other trimmer sets the delay time.

Modifications
The project uses two LEDs that can be built into your own signal assembly.
The board can also be used with commercial signals that have common cathode LEDs,
sometimes describes as common negative lights.
Instead of using separate LEDs, the board's output wires are soldered to the commercial
unit's wires, subject to any alterations to wiring their dropper resistors.
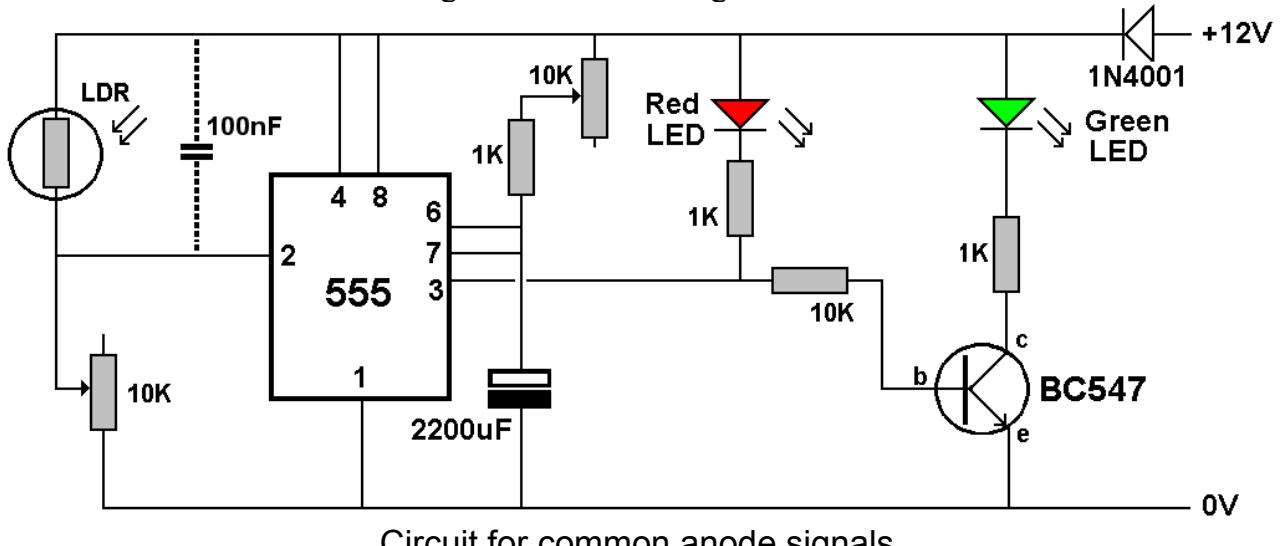
Modification for common anode signals

The above circuit was designed for home-built signals or commercial signals that have *'common cathode'* connections – i.e. the cathode of each LRD is connected to the 0V line. Examples of this type are produced by Atlas, Train-Tech and Traintronics.

Some signals, e.g. the Gaugemaster 2 Aspect signal (GM508) use *'common anode'* wiring, with the anode of each LED connected to the positive supply line.

The modified circuit for handling common anode signals is shown below.

Circuit for common anode signals

How the modified circuit works

When the train passes over the LDR, it blocks the light reaching the LDR and the output of the 555 chip changes from a low voltage to a high voltage.
This results in the red LED having a high voltage at both ends, so the red light does not illuminate. The increased voltage at the base of the BC547 transistor causes it to turn on allowing current to flow through the green LED.
After the train no longer blocks the light to the LDR, the timer will eventually switch the 555's output (pin 3) back to a low level. This illuminates the red LED and extinguishes the green LED.

Modifying the board

For common anode signals, the components on the right hand side of the stripboard remain unchanged, as do the cuts in the track (apart from an extra cut on the bottom track)
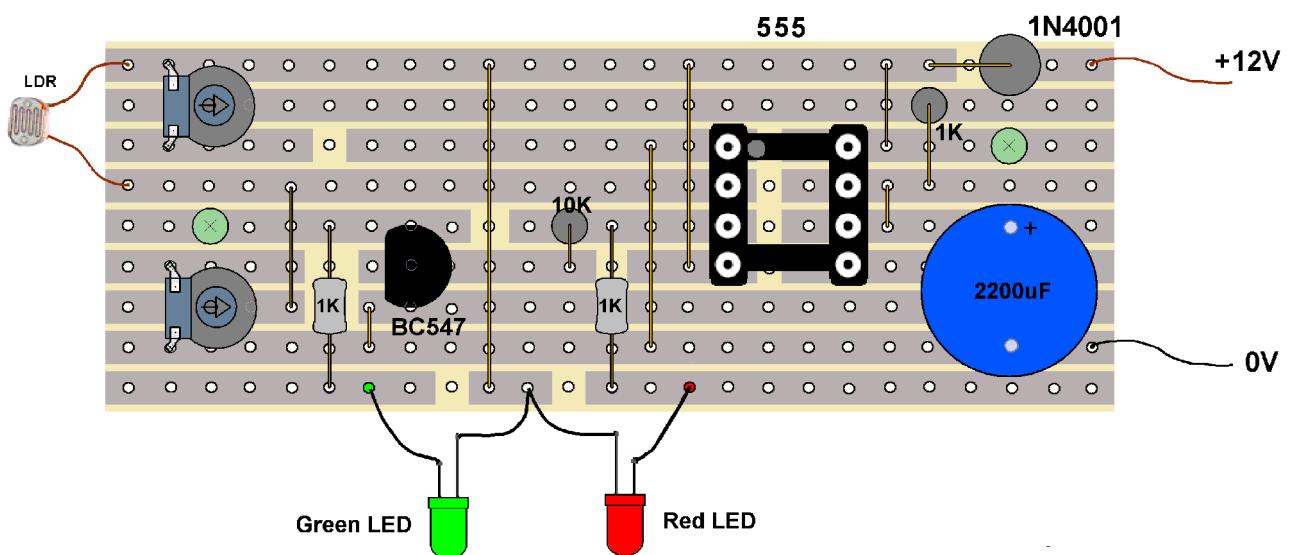
The changes are
Use a BC547 transistor instead of a BC557 transistor (note the flat surface now faces leftwards).
There is no link between the transistor's emitter (e) and the top track; the link is between the transistor's emitter and the second bottom track.
The 1K resistor between the transistor's collector (c) and the bottom track is moved further left, as in the illustration below.
There is no 1K resistor linking the transistor's middle leg (b) to the positive supply.
The red and green LED's change positions and have their anodes (the longer leads) connected to the same point on the bottom track.
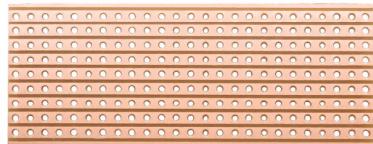
Layout for common anode signals

Pocket Money Projects

Part 18
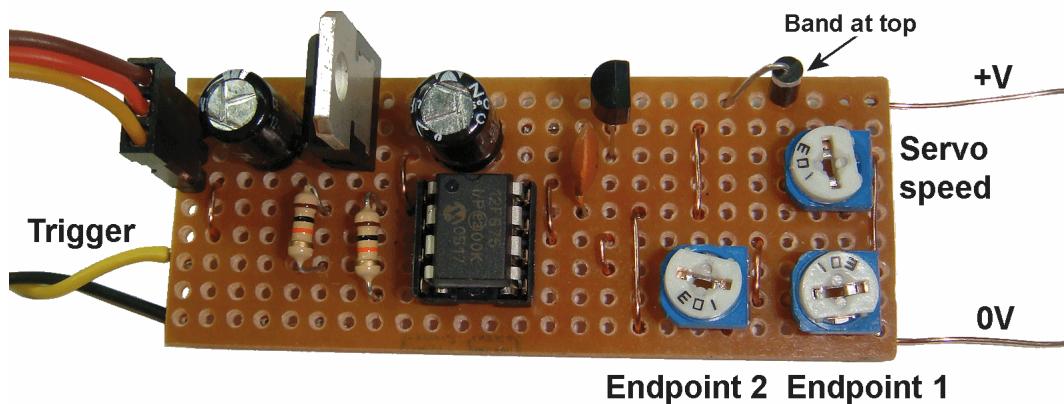
A series of small, cheap,
easy to build projects
using stripboard

by Davy Dick M1853

EzyPoints

This servo module controls your points and is set up using only a small screwdriver. It is suitable for use on DC, DCC, and CBUS systems and does not require a computer to set it up.

Servos are becoming increasingly popular as a means of operating points.   They avoid the thump-thump of solenoid actuators, which require large pulses of current and which can eventually loosen points.   Motorised point motors, such as the Tortoise, avoid these problems and produce a slow movement of the point's tie bar.   However, they are expensive and require to be manually adjusted.

Servos have the advantages of point motors (slow speed and lower current/voltage demands) but have the added advantages of cheapness and the ability to have their positions adjusted electronically.
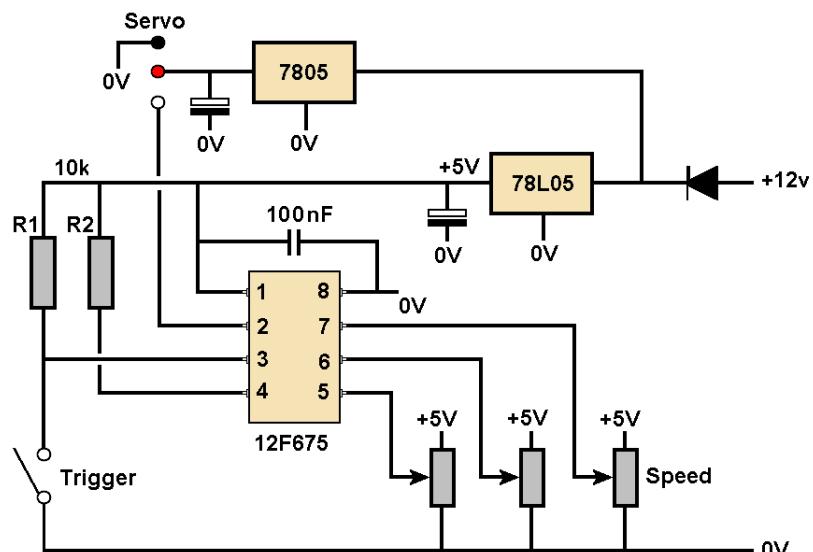
This project controls a single servo, requiring only connections to a 12V DC supply, the servo and a simple on/off switch to operate the point.

How it works

You don't need to read this section before building the module.   It is only included to explain how the module works. You can always come back and read it later. It's up to you.

The circuit uses a pre-programmed PIC chip that contains all the decision-making and controls.

The 78L05 is a voltage regulator.   It reduces the

12V supply to the +5V used by the PIC.   Another 5V regulator, the 7805, provides a separate +5V line to the servo.

There are three trimmers that are adjusted using a small screwdriver.   One sets how far the servo rotates when the switch is closed; another sets the servo position when the switch is opened – and the third sets the speed at which the servo arm turns.

When the trigger switch is closed, it takes one the PIC's pins (pin 3) down to 0V.   The chip then reads the voltage from the *'Endpoint1'* trimmer into pin 6. This voltage decides the composition of the control signal that is sent to the servo.   When the switch is released, the chip reads the voltage from the *'Endpoint 2'* trimmer into pin 5 and this results in a different signal being sent to the servo.

The voltage read into pin 7 controls the speed of the servo arm's rotation.

Parts List

- One piece of stripboard 25mm x 64mm
- One pre-programmed 12F675 PIC
- One 8-pin IC holder
- One 7805 5V 1A regulator and one 78L05 5V 100mA regulator
- Two 10k resistors
- Three 10k trimmers
- Two 100uF capacitors and one 100nF capacitor

Note: The complete set of parts is available from the Kit Locker (PMP18).

Construction

> Before starting, it would be useful to read the article on using stripboard that appeared in the Autumn 2012 Journal.
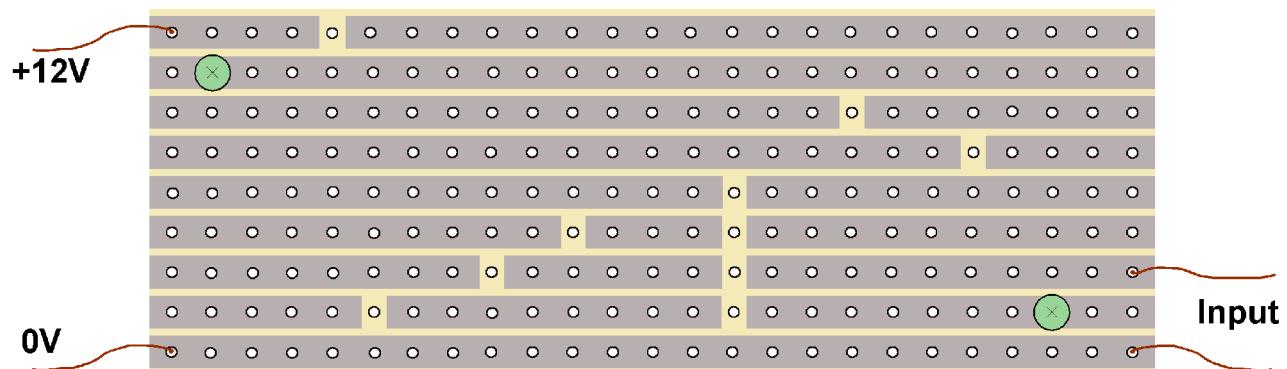
This project is built on a piece of stripboard that has nine strips of copper on one side.

First, turn the board over so that the copper strips are uppermost.

Now cut all the ten breaks in the track at the points shown in this illustration.

I use a stripboard spot face cutter, but you could use a hand-turned 3mm or 5mm drill bit – or even a sharp knife if you must.

The green circles indicate places that you might want to drill the hole out a little larger, to provide places where the board can be screwed down.

Next, check that there no remaining tiny strips of copper still bridging any of the track sections. Then clean the copper strips and the leads of the components prior to soldering. This minimises problems from dirty or oxidised surfaces during soldering.

Now turn the board over to fit the components.

It is important to note that all the components are mounted on the _other_ side of the board from the copper strips and their leads are poked through the holes for soldering on the copper side.

This illustration show the components and the tracks at the same time. It is really showing where the components should go. It shows the tracks underneath, as if the board was transparent, to help you position the components correctly. If in doubt, consult the earlier photograph.

When inserting and soldering the components, you may want to follow these guidelines:

- Fit the eight link wires.
- Fit the two 10k resistors. They have brown, black and orange bands painted round them The resistors can be fitted either way round.
- Fit the 8-pin IC socket. It helps if it is fitted to the board with its notch facing top left, as shown in the layout illustration. This reminds you to also fit the PIC chip correctly (i.e. with its notch also facing top left).
- Fit the three 10k trimmers. These components have three pins and are available in different shapes and sizes and may look slightly different from the ones shown in the photograph or illustration.
- Fit the diode vertically with the end with the white band at the top, connecting to the track that leads to the 78L05 and 7805 regulators.
- Fit the 100nF capacitor, either way round.
- Fit the 78L05 regulator, the small black device with three leads. Its flat surface should face outwards, as shown in the illustration.
- Fit the three pin connector for the servo lead.
- Fit the two 100uF capacitors with the positive leads connecting to the tracks furthest from the top of the board. The capacitors have white stripes down their sides with a minus sign on them, indicating which leads are the negative ones.
- Fit the 7805 regulator, the one with the large metal tab, with the tab facing inwards (see the photograph).
- Connect an on/off switch at the points shown in the illustration.
- Connect a 12V DC supply to the board, at the points shown in the illustration.
- Connect the servo with signal end being the furthest from the top of the board. A servo's signal wire is usually coloured white,yellow or orange, depending on the manufacturer.

Installing the servo

Before fitting the servo to your point, adjust the trimmers so that the servo arm is in mid-position when the switch is both open and closed. If necessary, remove the servo horn (the moving arm) and refit for best position. You can then install the servo knowing that it has movement available in both directions.

Modifications

Although the module is called EzyPoints, it can also be used to operate semaphore signals, crossing gates and animated trackside features. Its your choice.

It is also capable of being operated by other MERG modules.

The circuit diagram shows a switch being thrown/released to operate the module.

All the switch does is bring the chip's input pin 3 down from +5V to 0V.

So, other modules whose output switches between +5V and 0V could be used to operate EzyPoints. Just make sure that they share the same 0V connection, as all voltages are with respect to this common ground connection.

This allows, for example, the *remote* operation of points/features by connecting the outputs of a DCC Steady State decoder (Kit53) or a CBUS CANACC8 (Kit 88) to the input of the EzyPoints module.   Points/features can then be controlled from your control panel or DCC command station.

Also, it allows *local* operation of the module by connecting the outputs of the DTC8 8-channel block detector (Kit 56), the DCC Train Detector (PMP Kit 807) or the LDR Train Detector (PMP Kit 802) to the input of the EzyPoints module.   Example uses are detecting when a train is in a particular track section and station/yard lights coming on, doors opening, cranes moving, sounds being played, etc.

Chapter 22

Acronyms & Abbreviations

Acronyms & Abbreviations

Beginners are often confused by the abbreviations that they find in books and articles; the author expects the reader to know what is being talked about.

Acronym

This is formed from the initial letters of other words and pronounced as a single word. Examples are ASCII, LAN, Laser, Modem.

Abbreviation

This is a shortened form of a word and when spoken is pronounced as its longer equivalent. Examples are, Hz is pronounced as Hertz, GND as Ground, mV as milliVolts, etc.

There are many thousands of acronyms and abbreviations but here are some of the more common ones you will come across:

+ve	Positive potential
-ve	Negative potential
1-Scale	1:32 scale, 10mm to the foot, 44.45mm track
A/D	Analogue to Digital
ADC	Analogue to Digital Converter
AC	Alternating Current
ACK	Acknowledge
AMP	Ampere – measure of electrical current
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
ATC	Automatic Train Control
AUX	Auxiliary
AWG	American Wire Gauge
BEMF	Back EMF
BSI	British Standards Institution
CAD	Computer Aided Design
CAN	Controller Area Network
CCW	Counter-Clockwise
CMOS	Complementary Metal Oxide Semiconductor
CR	Carriage Return
CT	Centre-tapped – e.g. in a transformer
CV	Configuration Variable used in DCC decoders

CW	Clockwise
CDU	Capacitive Discharge Unit – usually for operating solenoids
COM	Communication – usually describing a computer's serial port
CPS	Cycles Per Second
CPU	Central Processing Unit – the 'brains' of a computer or PIC
CRO	Cathode Ray Oscilloscope
D-SUB	Series D Sub-miniature Connector
Db	Decibels - a measure of noise level
DC	Direct Current
DCC	Digital Command Control
DEMU	Diesel Electric Multiple Unit
DIL	Dual In-line Package
DIN	Deutsches Institut für Normung – speciciations for some plugs and sockets
DIP	Dual In-line Package
DMU	Diesel Multiple Unit
DPDT	Double Pole Double Throw switch
DPST	Double Pole Single Throw switch
DSO	Digital Storage Oscilloscope
DVM	Digital Voltmeter
ELCB	Earth Leakage Circuit Breaker
EM-Scale	4mm to the foot, 18.2mm track
EMC	Electromagnetic Compatibility
EMF	ElectroMotive Force
ESD	Electro Static Discharge
ETX	End of Transmission
FAQ	Frequently Asked Questions
FAST	Federation Against Software Theft – fights against software piracy
FET	Field Effect Transistor
G-Scale	1:22.5 scale, 45mm track
Gbps	Gigibits per second
GB	GigaBytes
GIF	Graphic Interchange Format – a compressed image format
GIGA	Billion (10^9)
GND	Ground

HO-Scale	3.5mm to the foot, 16.5mm track
Hz	Hertz – measurement of frequency
IC	Integrated Circuit
ICSP	In Circuit Serial Programming – interface for programming PICs.
IEEE	Institute of Electrical and Electronics Engineers
IO	Input / Output
IPA	Isopropyl Alcohol – an electronic cleaning solvent
IR	Infrared
IrDA	Infrared Data Association – specifies the protocols for IR communications
JAL	Just Another Language – used for writing programs for PICs
JPEG	Joint Photographic Experts Group - a compressed image format
HSS	High Speed Steel – as for drill bits
Kbps	Kilobits per second – measure of data transfer speed
KB	KiloByte
KHz	KiloHertz
KILO	Thousand (10^3)
LAN	Local Area Network
Laser	Light Amplification by Stimulated Emission of Radiation
LCD	Liquid-Crystal Display
LDR	Light Dependent Resistor
LED	Light Emitting Diode
LF	Line Feed
Li-ION	Lithium-ION – rechargeable battery
LMP	Low Melting Point – as with some solders
mA	milliAmp
Mbps	Megabits per second
MB	MegaByte
MCD	MillCandela – measure of luminous intensity
MEGA	Million (10^6)
Modem	Modulator/Demodulator
MP3	MPEG-1 or MPEG-2 Audio Layer III – compressed audio file
MHz	Mega Hertz
Micro	A millionth (10^-6)
MILLI	A thousandth (10^-3)

MOSFET	Metal–Oxide–Semiconductor Field-Effect Transistor
MTBF	Mean Time Between Failures – measures reliability of devices
MTTF	Mean Time To Failure
mV	MilliVolt – a thousandth of a Volt
mW	milliWatt– a thousandth of a Watt
n-Gauge	1:160 scale, 2mm to the foot, 9mm track
N/C	Normally Closed – e.g. a push-to-break button
N/O	Normally Open – e.g. a push-to-make button
Nano	A billionth (10^-9)
NiMH	Nickel-Metal Hydride, used for rechargeable cells
NMRA	National Model Railroad Association
NPN	Type of transistor
O-Scale	1:48, 7mm to the foot, 30mm track
00-Scale	1:76 scale, 4mm to the foot, 16.5mm track
009-Scale	1:76 scale, 4mm to the foot, 9mm narrow gauge track
00n3-Scale	4mm to the foot, 12mm narrow gauge track
OpAmp	Operational Amplifier
P-P	Peak to Peak
PB	Push Button
PCB	Printed Circuit Board
PIC	Peripheral Interface Controller
PICO	(10^-12)
PNP	Type of transistor
POM	Programming On the Main – technique for programming DCC decoders
POT	Potentiometer – a 3-pin variable resistor
PSU	Power Supply Unit
PVA	PolyVinyl Acetate – wood glue, white glue
PVC	Polyvinyl Chloride
PWM	Pulse width modulation
RCD	Residual Current Device – circuit breaker to prevent shocks
RF	Radio Frequency
RFID	Radio Frequency Identification
RMS	Root Mean Square
RPM	Revolutions Per Minute

RS232	Retma Standard 232 – a Serial port
RX	Receiver
S-Scale	1:64 scale, 4.7625mm to the foot, 22.42mm track
SATA	Serial ATA – a bus for computer data transfer
SCART	Syndicat des Constructeurs d'Appareils Radiorécepteurs et Téléviseurs - a 21-pin plug/socket for audio-visual equipment.
SCR	Silicon-Controlled Rectifier
SD	Secure Digital – as used in computer memory sticks
SIL	Single In-Line
SMD	Surface Mount Device
SMPS	Switched-Mode Power Supply
SMT	Surface Mount Technolgy
SPDT	Single Pole Double Throw switch
SPST	Single Pole Single Throw switch
SSR	Solid State Relay
STX	Start of Transmission
SWG	Standard Wire Gauge
TiN	Titanium Nitride – as used in drill bits
TOD	Track Occupancy Detector
TOTI	Train On Track Indicator
TPI	Teeth Per Inch – specification for saw blades
TRIAC	Triode for Alternating Current
TT-Scale	1:120 scale, 3mm to the foot, 12mm track
TTL	Transistor-Transistor Logic
TX	Transmitter
UART	Universal Asynchronous Receiver/Transmitter
USB	Universal Serial Bus
UTP	Unshielded Twisted Pair
Vcc	Positive supply
Vdd	Positive supply
Vss	Negative supply, ground
XTAL	Crystal
Z-Scale	1:200 scale, 1.385mm to the foot, 6.5mm track
ZIF	Zero Insertion Force

Appendix

The Model Electronic Railway Group

The Model Electronic Railway Group

This book is not a MERG production; as the author I retain control of its contents. Nevertheless, as an active member of this group, I know that MERG can make a valuable contribution to both club layouts and home layouts. I am very happy to introduce you to what the group has to offer.

Model railway electronics for all gauges and modellers at all stages

MERG is the leading international forum for all railway modellers interested in applying electronics to the hobby

The Group enables members to exchange ideas and information, and provides kits covering a number of interests including DC operations, DCC, Radio Frequency Identification, computer control and CBUS.

Members have a wide range of knowledge and capability, from beginners to those who work in the electronics and railway industries. MERG caters for all-comers:- beginners (which is where we all started from), semi-experienced, and professionals.

Have a look at the public area of the website:

www.merg.org.uk

MERG - Leading Model Railway Electronics since 1967

Over 2,100 members worldwide

Home	**MERG (Model Electronic Railway Group)** is an international, UK based group promoting interest in the application of electronics & computers to all aspects of railway modelling.
About MERG	
Downloads & links	
Membership benefits	Founded in 1967, the Group's aim is to actively promote and advance the use of electronic and computer technology for model railway operation, which is ideally suited to take advantage of these technologies, and the application of electronics and computers can be used to good effect to add enhanced features and realism to model railway operation. Read more here
Members Links	
Meetings & Shows	
Resources & Information	
Area Groups	
Contact Us	
Apply to join online	

Latest CBUS information:

CBUS is a comprehensive layout control system developed by MERG Members, using a CAN based layout control bus. Below are the latest documents relating to CBUS.

Developers Guide

Module Guide

Click here to read more about CBUS

ATC - Auto Shuttle

'ATC' is intended to denote 'Automatic Train Controller' - it offers basic shuttle functionality, but has built-in flexibility that allows it to be used for other purposes.

Click here to read more about ATC

MERG DCC System

Read more about MERG's DCC system

DCC Command Station   *Hand control*

MERG is a friendly and informal *'first names'* group and new members are encouraged to present their ideas, as well as share those already available .

Benefits include :

Website

The members' area provides access to a large range of resources. There is a huge amount of material on the website, that you could spend many interesting hours looking through.   The material covers all the subjects that you would come across when working with your layout's electrics and electronics.

A regular Journal

This is posted out at least four times a year to all members, containing new ideas and reports on developments.   Its contents reflect the range of abilities of its members, including simple but useful circuits, reports on what members are working on and suggestions for new devices.

Kits

MERG has a great reputation for developing and making a comprehensive range of low cost, self assembly kits available to members.
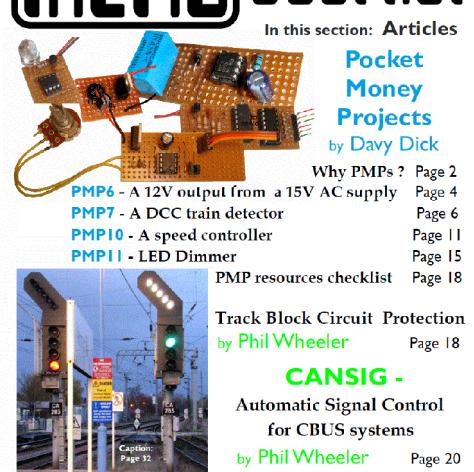
Kitlocker			
Kitlocker Home	**CBUS Kits** MERG's layout control bus system, for layout control and supervision	**DCC Kits** MERG DCC Equipment, including handsets, accessory decoders and the new CBUS-DCC system	**General Kits** General MERG kits
Product Search			
Your Orders			
QUICK ORDER			
CBUS Kits	**SMD Starter Kits** Kits you can practice on without breaking the bank	**Pocket Money Projects** PMP A selection of starter kits as featured in the Journal	**SuperBloc Kits** Analogue DC Modular Automation System
DCC Kits			
General Kits			
SMD Starter Kits			
Pocket Money Projects			
SuperBloc Kits			
PTP-Lite	**PTP-Lite** A new range of Layout Control System Modules. COMING SOON!	**RFID Kits** RFID based detection equipment kits	**RFID Components** Components for use with RFID Kits
RFID Kits			
RFID Components			
Multipacks	**Multipacks** Multipacks Multiple kit packs	**Tools**	**Accessories** Servos, brackets and CAB holders
Tools			
Accessories			
CBUS PCBs			
DCC PCBs			
General PCBs			
Clothing			
Offers			
Power Supplies			
Components			
Transistors			
Diodes			
PICs			
ICs			
Capacitors			

This includes kits for signal operations, operating points, train detection, etc.
Its range of DCC kits includes a command station, a district cutout, accessory decoders, etc.
These kits, and the range of Pocket Money Project kits described in chapter 21, can be ordered directly from the website or ordered through the post.

Assistance

MERG is renowned for the help that it gives to its members.

Its has members throughout the world and they are all able to access help and advice through the MERG internet Forum …..

….. and also through the MERG Yahoo Group.

These are used extensively by members to get help while building kits, recommendations for components and equipment, advice on wiring, and much more.

Meetings and Local Area Groups

There are national meetings of MERG members at least four times a year in London. In addition, there is an increasing number of local groups being set up to bring members together in regional areas. Currently, there are Local Area Groups in;

Aberdeen, Bristol, Cardiff, East Anglia, East Midlands, East of Scotland, Essex, Exeter, Hants & Dorset, Highlands, Kent, North East, North West, Northern Ireland, Shanghai, Somerset, South East Queensland, Thames Valley, Three Counties, West Midlands, West of Scotland, and Yorkshire.

Training

Apart from bringing members together, Local Area Groups play an important role in training and educating members.   Members get a chance to find out how things work, see modules in action and pick up new skills such as soldering.

MERG also provides tutors for the weekend courses run at Missenden Abbey, Bucks.

Technical Bulletins

The MERG website provides access to over 250 Technical Bulletins. These documents provide background reading on a large range of subjects, as shown.

Making savings

Bulk buying means that the kits and other items are sold at cost price – and much cheaper than ordering you own components.

In addition, MERG offers discounts on selected commercial products and some model railway electronics publications.

How MERG operates

MERG is entirely run by volunteers - no member receives any financial remuneration for the time and expertise that they contribute. This applies to those who provide the administrative support, those who design and assemble the kits and those who write Technical Bulletins and provide advice on the Forum.

How to join

There is a variety of ways to join and get involved with MERG.

Exhibitions

MERG has a stand at several major shows each year, as well as a number of local shows ones, usually attended by members from the Local Area Groups.

Online

The home page of the MEG website has a link to join MERG, payment being made by credit/debit card, or through your PayPal account.

By mail

You can also complete an application form and post it off with a cheque.

MERG membership application

To join MERG and take advantage of all that the group has to offer, please read the following and then print the form on the next page, fill it in and post it to the Membership Secretary.

I agree to abide by the Rules of the Group and I confirm that I am 18 years of age or over. By applying for membership of MERG I consent to the data supplied on the application form being used for the promotion of MERG's aims and for membership administration purposes. I understand that the data will be included in a Membership List that is provided to other members. Once a year the list may also be viewed on the password protected members only area of the MERG website. I understand that the Membership Secretary will hold my details on a computer. I also understand and accept that my data and that of other members may not be used for any commercial purpose. Should I not renew my subscription, my full name and membership number will be retained, for the purpose of allowing the re-allocation of the same number if I rejoin at a later date, other membership data will be deleted 24 months after last renewal.

Members are responsible for advising the Membership Secretary of any changes in their data. I also agree to indemnify MERG, its Officers and Members against any claim arising from any use or misuse of any publication, kit or other goods supplied to me by MERG.

Current Membership Rates :

The basic subscription runs for a year from the date of joining.. For new joiners, there is a one-off joining fee of £5.

- For countries in the UK it is £16. New members pay £21 in their first year only.

- For countries in the Royal Mail European area it is £18. New members pay £23 in their first year only.

- The rest of the world pays £20. New members pay £25 in their first year only.

The higher subscription rates outside the UK are to offset a proportion of the higher postage cost.

Cheques should be drawn on a UK Bank and made payable to **"MERG"**

If you have any queries, please do not hesitate to contact the membership secretary at memsec@merg.info for details before sending in the form.

Unfortunately, at present, we are unable to accept payment by credit card (except via PayPal) or to handle direct debits.

MERG Model Electronic Railway Group

123, Mudford Rd., Yeovil, Somerset, BA21 4AQ, UK

Please write clearly (in BLOCK CAPITALS) and return with remittance to the Membership Secretary at the address above.

NAME : . . . .

ADDRESS : . . . .

TOWN / CITY . . . .

COUNTY / STATE : . . . .

COUNTRY : . . . .

POST CODE / ZIP : . . . .

TEL No. : . . . .

EMAIL : . . . .

Where did you pick up this leaflet ? . . . .

I live in the UK and enclose my Cheque/PO No. . . . . for the sum of **£21** or

I live in Europe and enclose my Cheque/PO No. . . . . for the sum of **£23** or

I live outside Europe and enclose my Cheque/PONo . . . . for the sum of **£25** or

I have paid by PayPal using reference . . . .

I have read and accept the conditions overleaf

Signature . . . . .Date . . . . / . . . . / . . . . .

For MERG Administration purposes only

Date rec'd	Cheque/cash	Date entered	Banked ref	Vouchers	Mem no