Electronics for Model Railways

Chapter 18

Interfacing

By Davy Dick

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In memory of Margaret

Contents

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, Wi-Fi 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, EzyBus, 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.

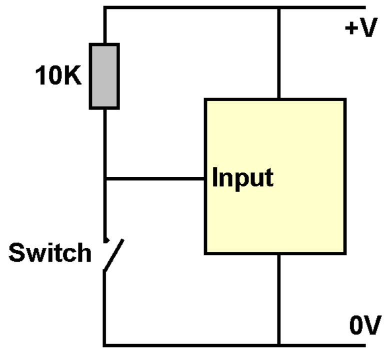
Apart from DC power to the track, most circuits interconnect using digital levels, not analogue levels. A module's pin is either high or low. Many electronic circuits use a 5v power supply (or a 12v supply reduced to 5v).
So their inputs and outputs are designed to work with values of +5V or 0V.
However, 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 detecting 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 can be set to either the supply voltage level or 0V. Of course, the switch could be replaced by a push-button, a microswitch, a reed switch or even the contacts from a relay.

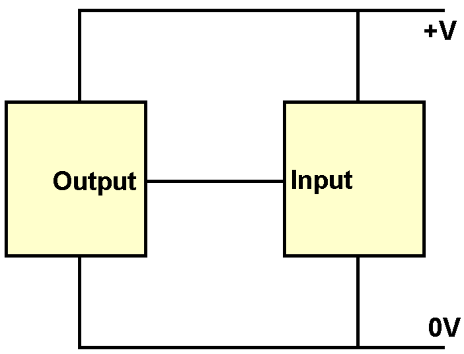


Output to Input

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.

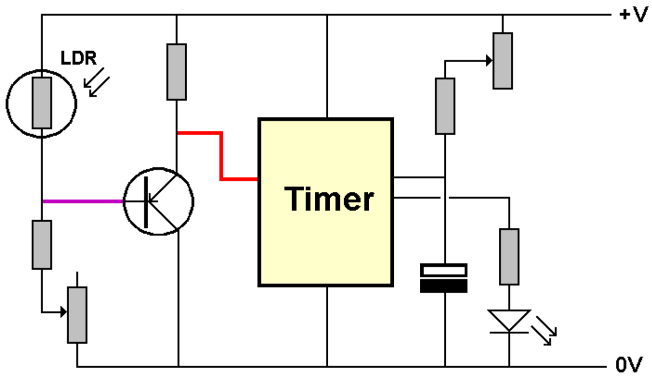
Note

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



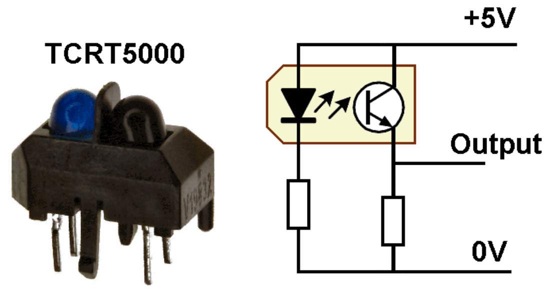
Analogue input

Some circuits require an analogue voltage as their inputs.
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.

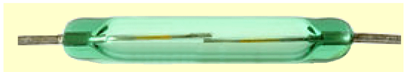
The main interface here is the one between light level and voltage.



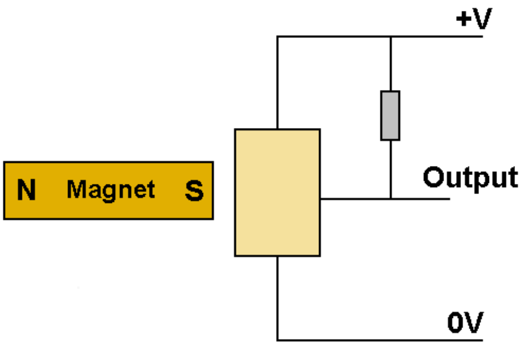
Another light-to-voltage interface is that of the infrared detector.
The illustration shows the TCRT5000 Reflective Optical Sensor. Its use in model railways is explained in the chapter on *'Track Occupancy Detectors'*.
The output voltage is a function of the distance between itself and the object reflecting 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 the 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.

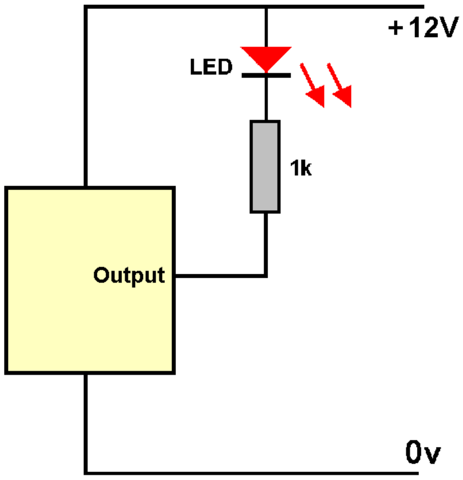
Other inputs

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).

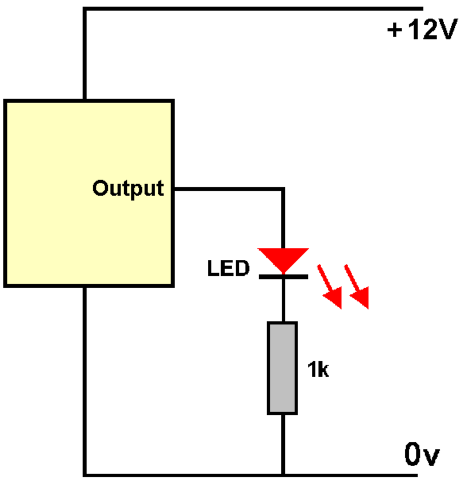
Connecting output devices

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.

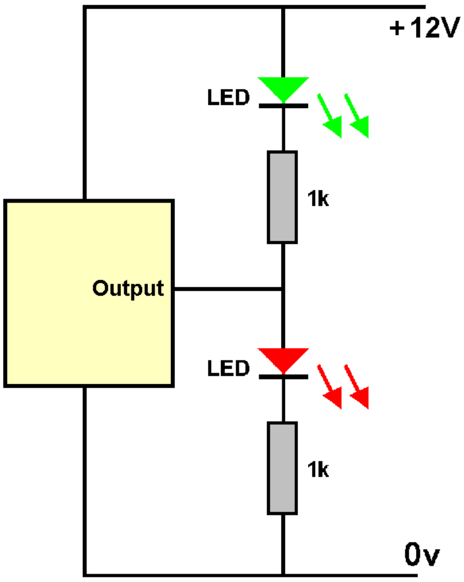


This illustration shows the LED being wired to 0V.
In this case, the LED will illuminate when the module's output pin goes high.
When the output is low, there is no voltage difference across the LED and it will not illuminate.

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.



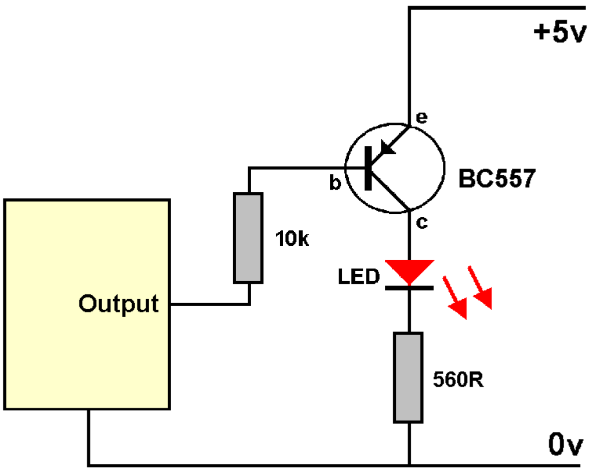
This circuit is useful in a number of applications:

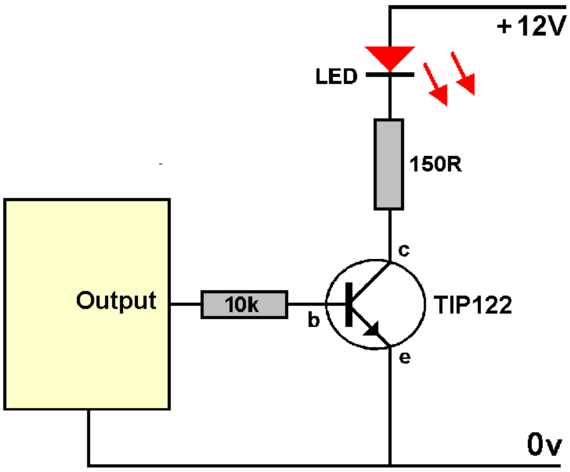
- Switching control panel LEDs from green to red when an error occurs.
- Indicating which way a point is set
- Changing lights for oncoming trains when it enters a section of track that is fitted with an occupancy detector.

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 to most modules that have a digital (i.e. high or low) output.

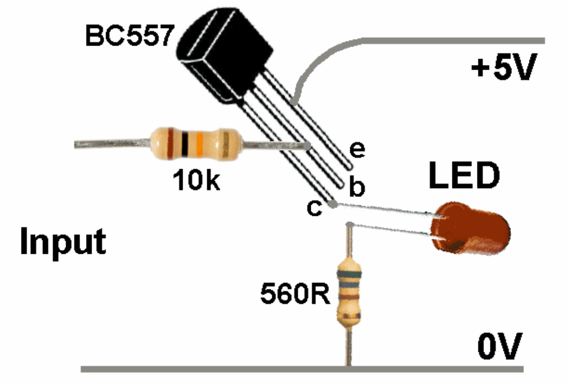
There are occasions when you might want a module to switch a high brightness LED.
As they need a higher current than most modules can supply, you need to use a transistor as a *'driver'* to interface a low current output module to a high current component.
These illustrations show two such circuits.



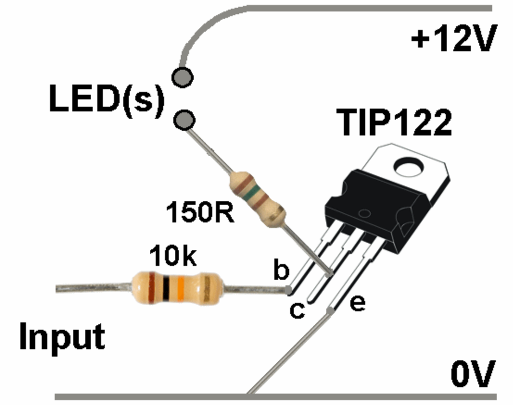


The one on the left uses a transistor as a switch for currents up to 100mA, the maximum that the transistor can handle.

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.



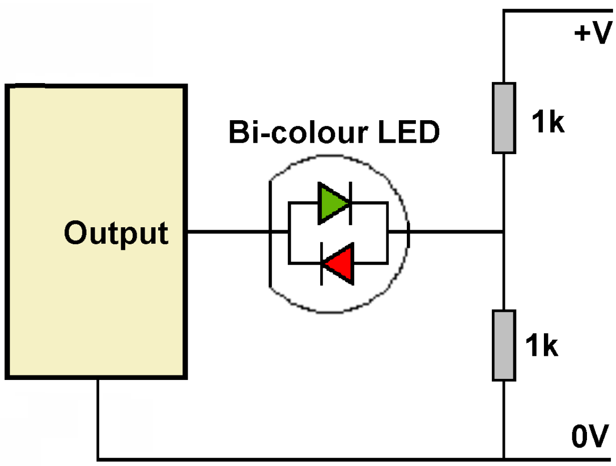
If you intend to illuminate a very high power LED or a LED strip that contains multiple LEDs, you need to use a transistor that can handle these larger currents.
The TIP122 is a *'NPN power transistor'* which can handle up to 5A. It works in the opposite way to the BC557 circuit above. When its base ('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 input 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.

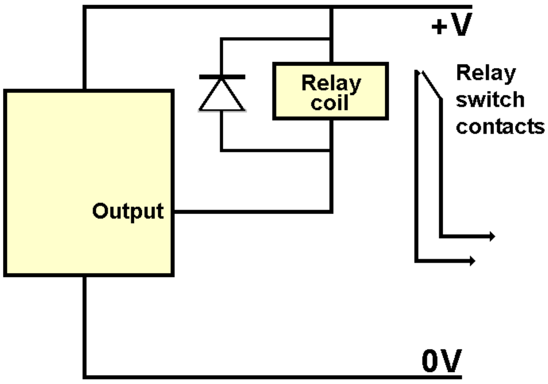


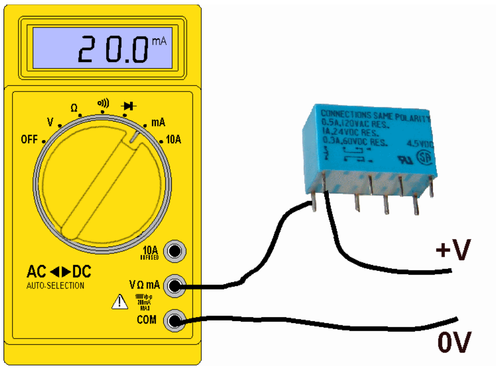
This circuit is an illustration of both sinking and sourcing currents.
If the module's output goes high, the green LED will illuminate, with the module sourcing current to the LED via the lower resistor. The red LED will remain unlit as it has a high voltage at both of its ends.
If the module's output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

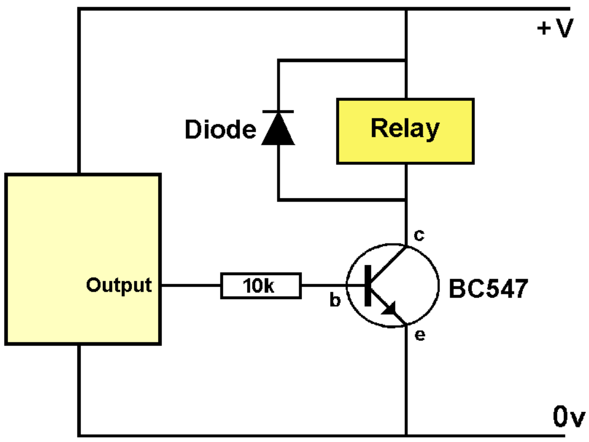
Many relays operate on quite small currents and so can be connected directly to the digital output of most modules.
The illustration shows a single switch contact, although they are available with multiple switches and as changeover contacts.
As mentioned previously, the diode prevents any back EMF from 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.
See the chapter on *'Semiconductors and ICs'* for details.

Motors

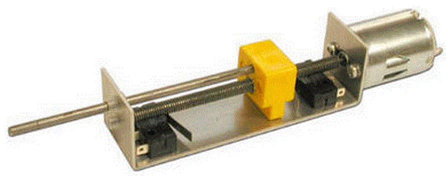
The following electronic circuits could be used for controlling your DC locos but you probably already have a loco controller. Of course, if you are looking to automate your layout, these circuits could be very useful.
The circuits are useful for all sorts of motor-driven features that you can add to 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 four 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 variable 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.
- Using a PWM (pulse width modulated) controller.

Constant speed 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:

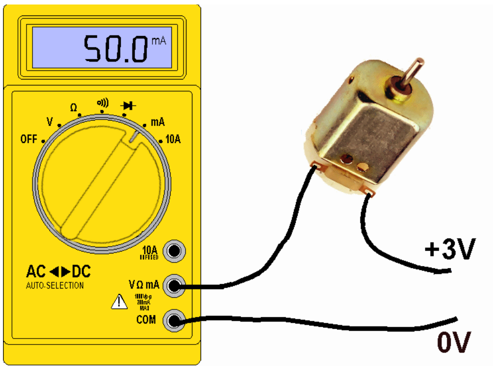
Case 1

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 ¼W or preferably ½W 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.



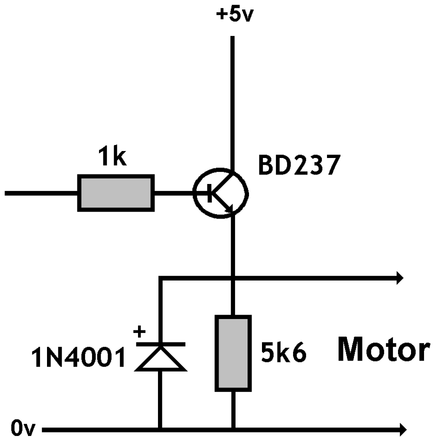
Case 2

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.

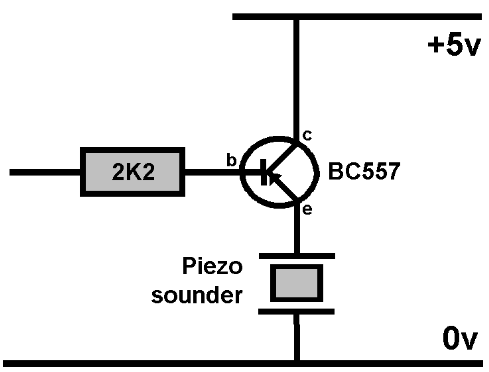
Sound

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.

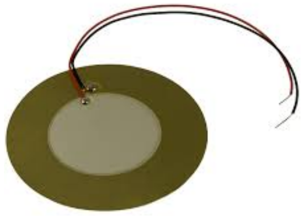
Some piezo buzzers are self driven and have their own built-in driver circuits. A typical example will operate at 3V to 24V, with a current consumption of around 15mA at 12V.

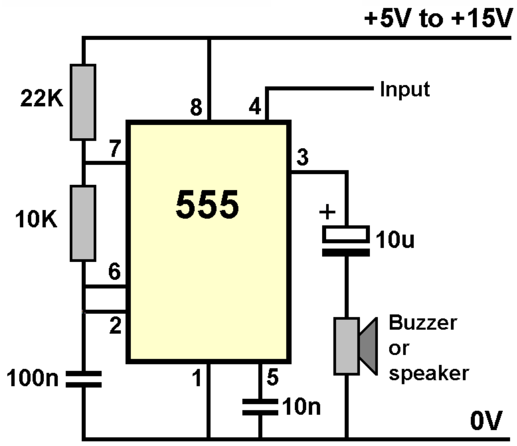


If your module's output can handle that amount of current, you can connect the buzzer directly to the output pin.
When a DC voltage is applied across it, it will emit a continuous high pitched tone.

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.

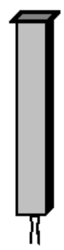
Smoke

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.
Some are designed to fit into locos that are designed to accommodate them.
Others are for you to fit in your own way.
The range is covered here:

www.osbornsmodels.com/seuthe-smoke-generators-1165-c.asp



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 own large scale smoke unit:
www.scale4x4rc.org/forums/showthread.php?t=25024

And 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.petersspares.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.

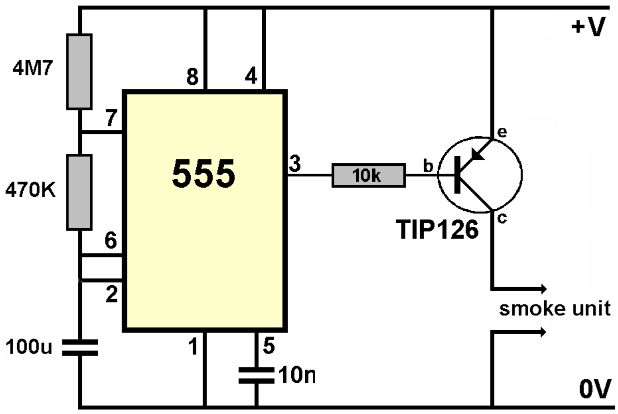
Note

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.

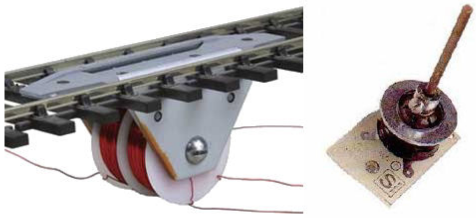


This website provides a calculator, if you want different timings:
www.ohmslawcalculator.com/555-astable-calculator
The 555 chip handles a maximum output of 200mA.
To prevent the chip overheating, it is best to use a transistor switch. In fact, this will be essential for the units that draw more than 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

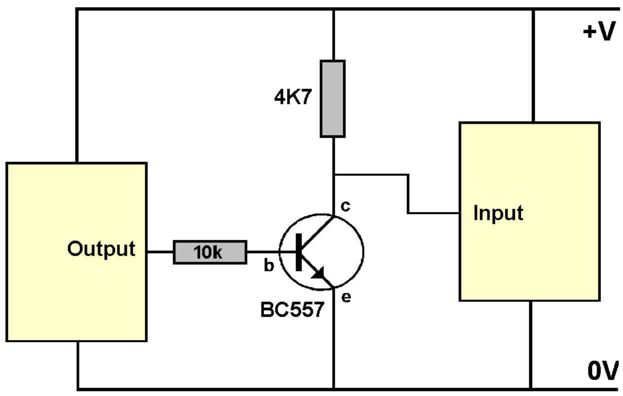
Kadee couplings are popular amongst a section of enthusiasts. To avoid having to manually uncouple rolling stock with hooks and sticks, Kadee brought out under-track permanent magnets. These sit under the sleepers so that the magnetic field opens the knuckles reliably.
Although this is a great improvement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

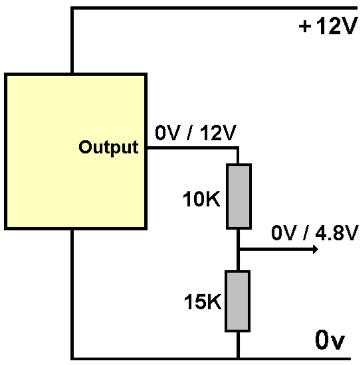
Fanning

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 dropped 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.

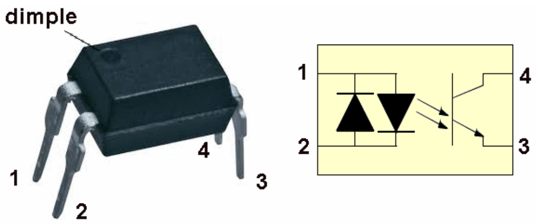
In addition, you may want to achieve electrical isolation, specially if you want a module to interface with a high voltage devices such as mains-driven circuits.
In these cases, you can adopt the technique below.

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 *'opto-couplers'*.

Opto-couplers

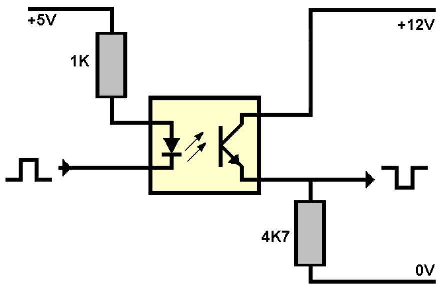
An optocoupler, sometimes called an opto-isolator or a photo-coupler, is essentially an infrared LED and photo-transistor in one package.



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.

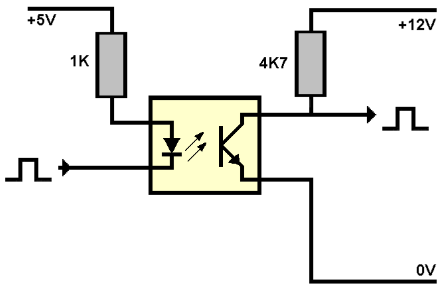


When the input to the LED is high, it will not emit light and the transistor will stay switched off. This results in the photo-transistor's emitter going low.

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.

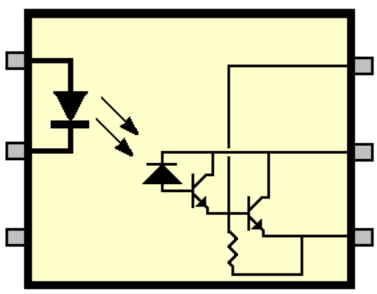


Opto-isolator types

These devices are available in the following varieties:

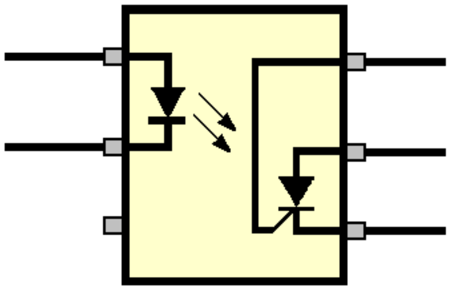
1. DC input photo-transistor, with a single LED, such as the Sfh610-a2. The above example circuits are of this type.

- 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%.

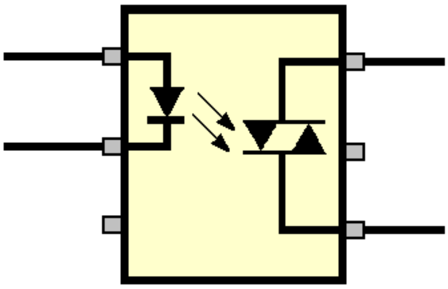


  To achieve the highest transfer ratios, some opto-couplers have a *'Darlington Pair'* built in to them. A second transistor boosts the current from the photo-transistor to provide an increased transfer ratio. Where even higher currents are required, further additional transistors can be connected to 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 switched 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.