Electronics for Model Railways

Chapter 10

Track occupancy detectors

By Davy Dick

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In memory of Margaret

Contents

Track occupancy detectors

Detecting the presence of a train has been a useful facility on many model railways, although perhaps still under-used.
This chapter looks at different methods of detecting track occupancy and compares their relative merits. The chapter covers nine different methods and MERG currently sells components or kits for six of these (using reed switches, Hall Effect switches, current detection kits, infra-red and RFID modules).
Others technologies exist, utilising radio transceivers or even GPS systems.
Track occupancy detectors are often called *'TOTIs'* – train-on-track-indicators.

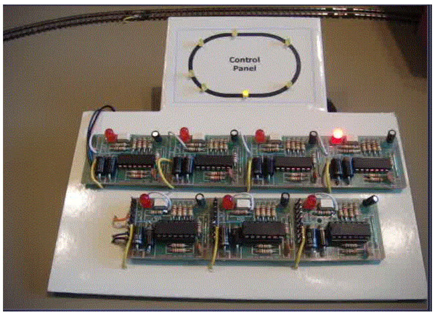
Track occupancy detectors uses

Hobbyists will have different uses for detectors, including a mix of some of those below.

Improving look/feel

- A train enters a siding and the yard light comes on.
- Track side animations.
- On-screen timetable announcements.
- On-screen train descriptions.
- Sound effects (station announcements, whistles, bells).

Improving functionality



- Feedback to mimic panel (the image shows part of an exhibition layout with TOTI modules lighting LEDS as a loco travels round a loop).
- Automatic crossing gates and barriers.
- Automatic signalling.
- Reverse loops.
- Collision prevention.

Improving control

- Detecting train lengths.
- Detecting direction of travel.
- Detecting a wagon that becomes detached from a train.
- Selective switching of points.

This list is by no means exhaustive. You can no doubt add many more possible uses, as the only limit is our imagination.
While many of these features can be implemented by all users, some require the use of computers.

Levels of detection

Not all detectors are interchangeable, as they work and operate differently.
Firstly, there is a distinction between *'spot detection'* and *'stretch detection'*.

Spot detection The detector's output is only changed when a train passes the detector. The output reverts to its original state when the train leaves the detectable area (although sometime you can add a delay before switching back). This method, therefore is momentary and relies on movement past the detector. This method is useful for triggering events (sounds, CBUS notifications, etc.)

Stretch detection	The detector's output is changed when a train sits in any part of a track section. The output only reverts back to its original state once the train (usually the loco or a specially adapted coach) vacates the entire track section. This method, therefore, does not rely on movement but on occupancy. This method is useful for stationary information (knowing a hidden siding is occupied, maintaining a signal at green while the train passes, etc.) Also, if a train has a resistor across the wheels of the last coach/wagon, if a train uncouples, the section left behind is still detected. This can prevent the next train running into it.

Another distinction is between *'Occupancy'* and *'Identification'*.

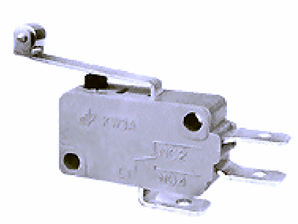
Occupancy	The operator, or computer, knows that a track section is occupied by 'something'. This is not as bad as it sounds and this method is still very useful and is the most widely used.
Identification	The operator, or computer, knows not only that a track section is occupied; the details of the train are made available (allowing for station announcements, different train whistles, selective action for point operations, etc.)

Starting at the beginning

The article looks at the different methods, starting with the simplest and ending with the most complex. Hopefully, readers at all levels will get something out of it.

So, lets start with a detector that even the newest beginner can tackle.

Microswitches



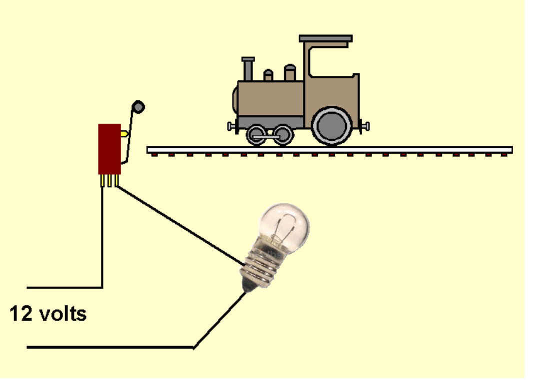
Microswitches are available in a range of sizes, current handling abilities and switch contacts arrangements.
As the image shows, all have a plunger that operates the switch. This is often supplemented by a lever that operates the plunger. As it provides greater leverage, it needs less effort to operate the switch.
Some levers are a simple strip of metal, while other have rollers (see the photo) to reduce any friction against the lever.
Some microswitches are simple ON/OFF devices and have two tags that are shorted when the lever is pressed. This simple action, known as single-pole single-throw (SPST) is similar to a push-button - the switch is designed to release again when the pressure is removed from the lever.
The microswitch shown in the image is a single-pole double throw type (SPDT). It has three tags with the lower tag shorting to one of the upper tags when the lever is pressed and shorting instead to the other tag when the lever is released.

An alternative is the 'leaf switch'. It is much smaller and need very little operating force. It is designed for low current switching and can be use for indicating point positions, when mounted close to the point's tie bar. Its main weakness is that is open to the elements.

Basic use

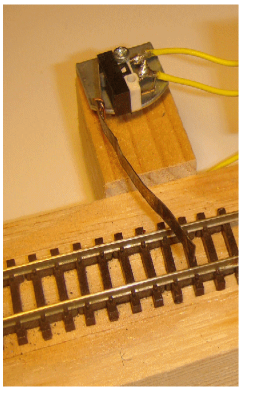
We all know that if we take a power supply and wire it across a bulb, the bulb lights. We also know that we can wire a switch in series with one of the wires, so that we can switch the lamp on and off.
Let's start from there.

The illustration shows the simplest form of train detector possible.
The lever of the microswitch protrudes from between the buffers of a siding. When the loco reaches the end of the siding, the lever is pressed and the lamp lights. So simple, so basic, yet so handy when you have hidden sidings.
The next step might be to replace the filament lamp with an LED and dropper resistor.

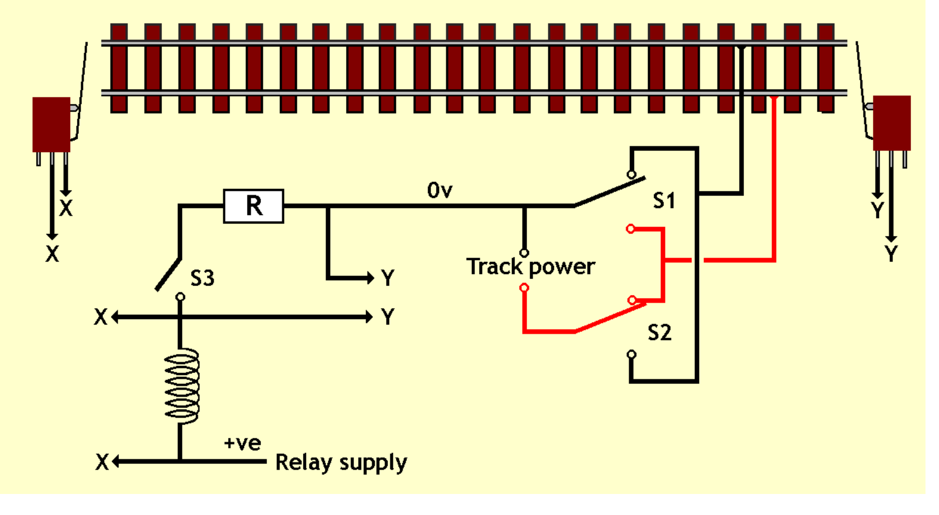


If we now use two microswitches and add in a relay and a resistor, we have a cheap alternative to a rolling road, or even a very basic DC shuttle system.

Microswitches are positioned at each end of a section of track. The image shows that I added an extension to the microswitch operating arm, using a piece of tin taken from a beans can.
The relay is a 3-pole double-throw type. Two change-over switches are used to switch the polarity of the controller power to the track, while the other is used a single switch to the relay. The relay is available from RadioSpares.



The circuit relies on the *'hysteresis effect'*. This means that the relay takes a certain current to move the switch assembly but, once activated, requires a lesser current to hold the relay switched. In my own circuit, my 12v relay needs 15mA to operates the relay contacts – but they will stay operated until the current drop below 5mA.



The value of the resistor depends on the relay's operating voltage and its internal resistance. In my case, a 220 ohm resistor was used.

The sequence of events is:

- When power is applied, the relay is not operated and the power is switched as shown in the illustration.
- The loco moves rightwards until it presses against and switches microswitch Y.
- This creates a path from the relay's +ve supply, through the relay, through microswitch Y to 0V. The relay operates.
- This results in two activities. The relay switches the two changeover contacts S1 and S2, resulting in the loco power to the track being reversed. It also switches S3, which connects the relay to 0V through resistor R.
- When the loco starts moving leftwards, microswitch Y is released but the relay remains held operated as there is sufficient current being supplied through resistor R to hold in the relay.
- When the loco reaches the end of the track, it operates microswitch X. This shorts across the relay, making it drop out (there is no short to 0V due to the presence of resistor R).
- The relay releases all the switches and the wiring reverts back to that shown in the illustration.
- The process starts all over again.

Place a loco on the track and connect the power to watch the loco traverse up and down the track at a speed determined by the controller. This allows it to warm up locos, instead of using an expensive rolling road.
It can even act as basic shuttle, although there is no pause at each end before changing direction.
Again, this is not the most sophisticated project but, given the small component count, it makes a good starter project.

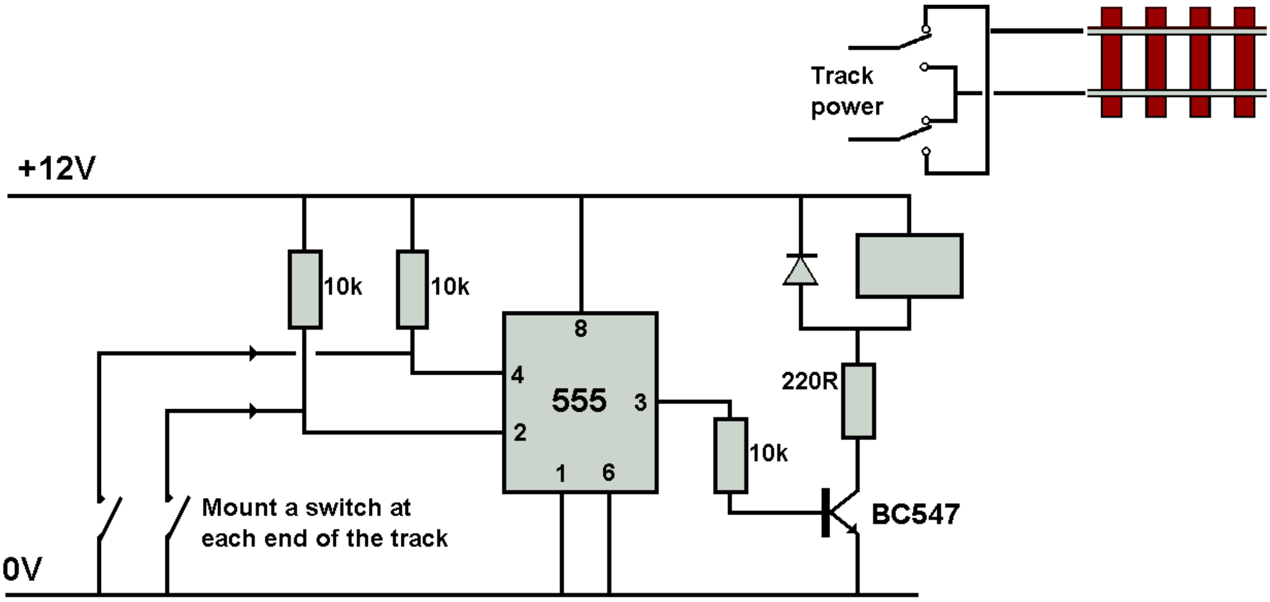
Pros:

- Cheap, easily obtained, simple. Good for beginner's projects.
- Easily fitted to an existing layout.
- No modifications to track/power/etc. are required.
- Unaffected by light
- No modifications to locos or rolling stock.

Cons:

- Limited use, due the way the detector can only be placed at the ends of track sections (although experiments have been made with the microswitch being under the baseboard with the operating lever being operated by trains passing over them).

Here is an alternative approach that uses a 555 chip in *'bistable'* mode. That means that it happily stays in either one of two possible states – i.e. with its output pin 3 or low.
A microswitch, or leaf switch, is mounted at each end of the track and one of these will bring pin 2 down to 0V when the loco pushes it. The other microswitch brings pin4 low when the loco pushes it. When pin 2 goes low, it makes pin3 goes high. Pin 4 going low makes pin 3 go low. The output from the chip is taken to a transistor that switches the relay on and off, as the loco reaches on end of the track then the other.



Reed switches

This was one of the most popular early detectors used for model railways.
Its is covered in the MERG Technical Bulletin A7/1.
Two strips of metal are held in a sealed glass tube.
When a magnet is positioned nearby, one of the strips is attracted by the magnetic field and bends; in so doing it makes contact with the other strip.

They are in common use in burglar alarm systems and a range of industrial applications such as in wind turbines, mines, and as fluid level switches. Their airtight situation makes the contacts immune from external problems such as dampness. Also, there is no danger of sparking hazards in potentially combustible areas. This means that they are made in large quantities and easily available from a range of suppliers.

The image shows part of on exhibition layout. A reed switch is embedded under the track of the siding. A loco pulls a wagon that is fitted with a magnet. When the wagon passes over the reed switch, the switch operates and lights the yard lamp (on the right); it also sends back a pulse to a PIC that controls the overall sequence. The PIC makes the train stop and activates a series of servos that opens a door, rotates a crane, moves a lorry, etc.

Pros:

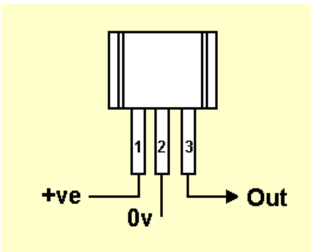
- Cheap, easily available.
- Easily fitted.
- No modifications required to locos or rolling stock.
- No modifications to track/power/etc. are required.
- Unaffected by light.
- Good for garden layouts, due to their waterproof construction.
- Can have conditional trains, with some fitted with magnets and others not. So, for example, points may only move to let goods trains enter a shunting yard; while the express train (not fitted with a magnet) cannot activate the point.

Cons:

- Each piece of rolling stock requires its own magnet.
- Only produces a momentary pulse output, so will probably require additional circuitry (such as latches or delays) in most circumstances – unless the pulse is used to send event information back to computers.

Hall effect switches

Hall Effect switches are widely used in the automobile industry and most cars have many such switches (transmission sensors, ignition sensors, gear stick position sensors, etc.). More details are available from Technical Bulletin A7/2, on the MERG website.
Like reed switches, Hall Effect devices are switched by the presence of a magnetic field. Unlike reed devices, they need power to operate.



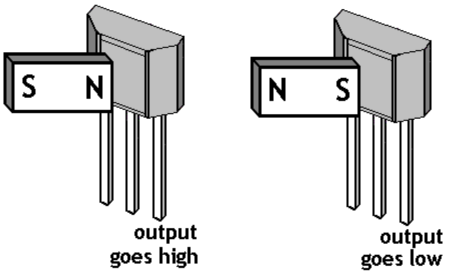
They are simple, 3-pin devices, with two of the pins connecting to a power supply (typically between 4.5V and 24V). The third pin is the output pin that changes state when the device detects the presence of a changing magnetic flux.
With output currents of 10mA upwards, their outputs can be directly connected to LEDs, via the usual voltage drop resistors. These devices are open collector, which means that they need a load between the collector and the positive supply.
These switches are available from the MERG Kit Locker.

An interesting feature of Hall Effect switches is that they can differentiate between a magnet's North and South Poles, unlike reed switches. The output changes when a North pole passes the flat side of the device, or when a South pole passes the chamfered side. So, a North pole passing the chamfered side creates no change in output. Similarly, nothing happens when a South pole passes the flat side.

Latching types

A variation on these switches is the 'latching' switch, available for about 40p each from eBay. It is still a 3-pin device but it behaves like a toggle switch (a bistable).
It needs to use both the North and South poles of a magnet to switch states. As the illustration shows, a North pole makes the output go high. However, when the magnet is removed, the output remains high (unlike the normal Hall Effect switch which reverts back to its previous state).

When a South pole now passes the switch, its output goes low – and stays low until switched again by a passing North pole.



The MERG Technical Bulletin A7/4 suggests a use for a latching switch involving putting magnets at both end of a train, The front magnet would be mounted with its North face pointing towards the Hall Effect switch, while the rear magnet mounted to present its South face. As the train passes the switch, its output goes high and stays high until the end of the train passes. Paul King cleverly shows how a normal Hall Effect switch can act like a latching type, at the expense of an extra magnet being placed behind the switch. Although requiring an extra magnet for each switch, it has the additional benefit of increasing the range over which the switch operates. Of course, this extra benefit is only available when used in latching mode.

Pros:

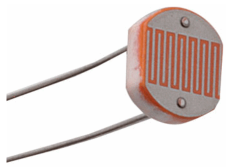
- No modifications to track/power/etc. are required.
- No modifications required to locos or rolling stock.
- Unaffected by light.
- Small component count.
- Clean ONs/OFFs (they use internal Schmitt triggers).
- Can be used as a latching sensor

Cons:

- Possible problems in positioning magnets and detector switches.
- Needs a powerful magnet, as the detector has only a small sensing distance (around 5mm).
- Only a momentary pulse output, unless using latching type.

LDRs

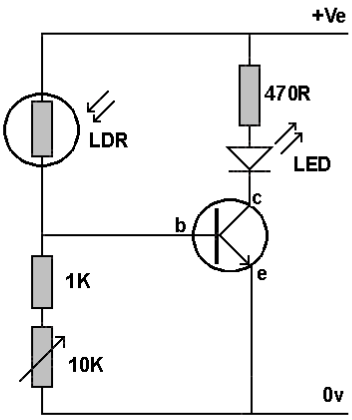
Light dependent resistors (LDRs), as you might expect from the name, are devices whose resistance changes with the amount of light that falls on them.
They are two-wire devices and can be wired either way round.
In their 'normal' state (i.e. in darkness) they have a very high value of resistance, usually measured in Millions of Ohms. As the amount of light shining on them increases, their resistance progressively lowers to a low point measured in hundred of Ohms.



This output is different from the other detectors which are either fully ON or fully OFF. The output resistance can be at any value within its range, depending on the amount of light shining on it. This characteristic could be used to improve the lighting on a layout. If the layout is operated in a subdued light, the lights inside the buildings could be dimmed a little to prevent an unrealistic glare. If the layout, however, was then operated in a brightly-lit room, the lights could be brought up to full illumination.
In most cases, though, LDRs are used to detect the presence of objects passing along the track.

LDRs are usually mounted under the track with the light sensitive area located between the sleepers.
The normal ambient light in the railway room results in the LDR having a relatively low resistance.
As the loco/wagon/coach passes over that section of track, it lowers the amount of light that reaches the LDR and the LDR resistance increases. This change of resistance is used to sense the event and trigger some activity.

The diagram shows a typical circuit diagram for boosting an LDR's output. The 1k resistor and the 10k variable resistor are used to tweak the light level at which the LED will illuminate. These can be replaced by a single resistor once the required value for a particular LDR and light surroundings is determined.
Mostly any NPN transistor will do in this circuit, including the BC547B that is available from the MERG Kit Locker.
MERG Technical Bulletin T33_25 describes another interface using a LM358 dual op-amp IC.I



If you Google for *'LDR circuit'* you will find a wide range of different circuits using different transistors and ICs.
Pros:
- Cheap.
- Works for locos or wagons/coaches.
- No modifications required to locos or rolling stock.
- No modifications to track/power/etc. are required.

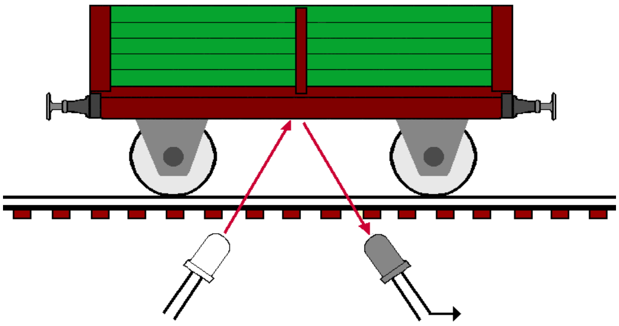
Cons:
- Sensitive to ambient light changes (e.g. at exhibitions).
- May require careful shielding to minimise unwanted switching from peripheral light changes (e.g. as you stretch across your layout).
- Only a momentary pulse output.
- Not a clean switch between on and off, unless using additional circuitry.

Infrared detectors

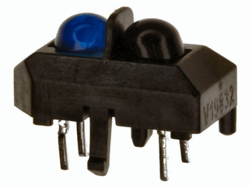
Infrared (IR) waves sit between microwaves and visible light in the electromagnetic spectrum.
Humans radiate some infrared energy and this is utilised by the motion detectors that are used in burglar alarms and automatic security lights. Almost every member will have a TV that they control with a remote that uses infrared..
In the modelling world, if we use a source of infrared emissions in conjunction with an infrared detector, we can detect the presence of locos and/or rolling stock as they pass by.

There are two methods of detection:
- The IR is bounced off the rolling stock.
- An IR beam link is broken when rolling stock passes through it.

In the first configuration, the emitter radiates the IR, which reflects off the undercarriage of any passing rolling stock. This reflected IR is detected by the IR diode, which allows current to flow and generates a voltage pulse.

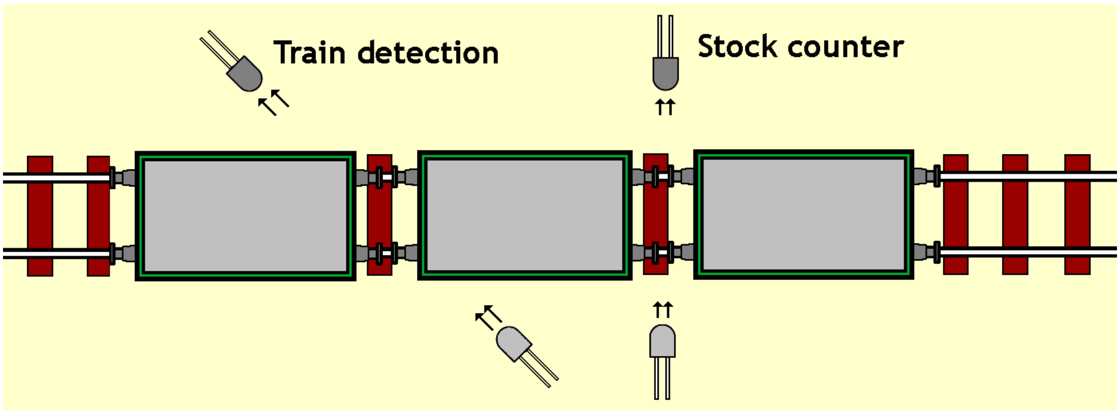


The illustration shows the radiation from an infrared transmitter bouncing off the undercarriage of a wagon and reflecting back to an infrared receiver.



The emitter and the detector diode are available as separate components. They can also be bought with both enclosed in a single case and these are ideal for mounting under the track.

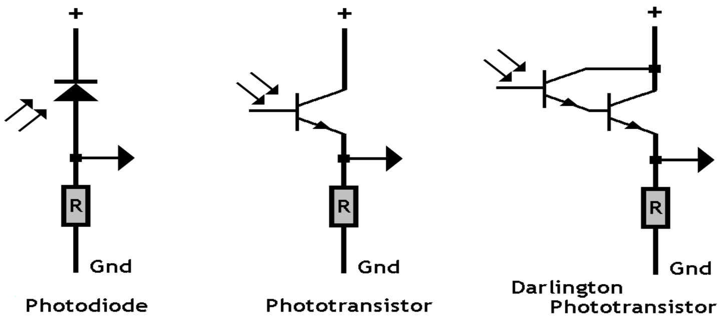
In the second configuration, we use a separate IR emitting diode and IR receiver diode. This allows us to mount the two devices above the baseboard.   They are spaced apart, such that the emitter points directly at the detector across a railway track.
The illustration shows two possible mounting methods.
On the right of the illustration, the two devices are placed directly opposite each other across the track.   In the example, there are three items passing the detector.   Since there are gaps between each item, it would result in the beam being broken three times and three output pulses being generated.   Mounted this way, it could act as a counter of how many items were in a particular train.



However, most users would prefer an output that stays set for the duration of the passing of the entire train, no matter how many items were attached.
The left hand of the illustration shows the two devices set at a diagonal across the track.
The gaps between items of rolling stock are no longer detected. This results in the output being set when the first item passes and only being reset after the last item passes.

IR detector types

The three types shown in the illustration provide different levels of sensitivity. The basic photodiode can be improved by using a phototransistor, which acts like a photodiode and amplifying transistor in one device. The Darlington phototransistor provide even greater levels of sensitivity with the extra high gain provided by the two transistors.



Mounting

Many IR phototransistor can be sensitive to light in the visible spectrum and it may be necessary to shield the detector to minimise unwanted effects from ambient room lighting. This may involve placing the detector in a lineside building or hiding it in a bush. Often, the detector is mounted inside a piece of tubing that is opaque (don't forget to seal or paint the back of the tube).

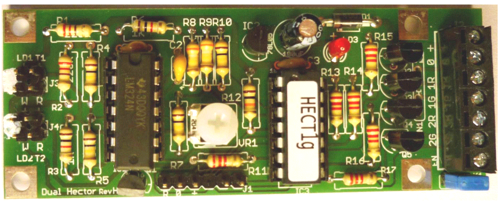
Line-of-sight mounting, particularly if the detector is shielded or at a distance, requires accurate alignment for reliable results.

Some users recommend using multiple LED emitters, to increase the usable range of the system.

Hector

The MERG Dual Hector (Kit 72a) is an infrared detector kit that houses two separate detector channels. The two channels work independently of each other.

The module requires a 9V to 12V power supply and consumes around 20-25mA, peaking to 50mA when the IR emitters are pulsed on.



The board also provides a variety of logic level outputs that can directly drive colour signal lights or interface to CBUS/EzyBus/other logic circuits. It can detect a piece of white paper at around 2”.

Pros:

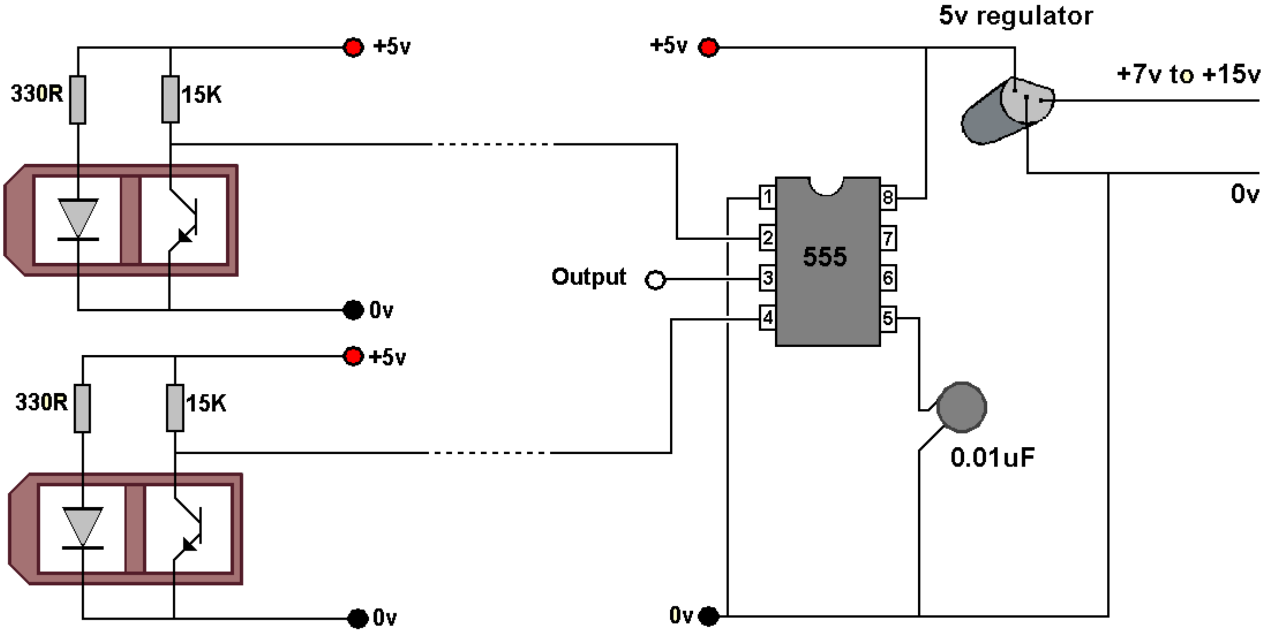
- Can be mounted under track or trackside.
- Low power requirements.
- Can detect entire trains, or act as a stock counter.
- No modifications to track/power/etc. are required.
- No modifications required to locos or rolling stock.
- Output is digital (clean ON/OFFs).

Cons:

- Can be a little affected by ambient light.
- May need shielding.
- May need careful alignment.
- Relatively expensive.

Shuttle using infrared detectors

This circuit employs the same 555 bistable chip as used in the previous shuttle circuit that used microswitches as detectors.

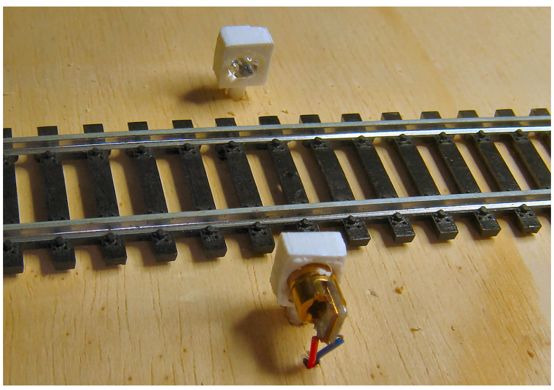


The microswitches are replaced with two infrared emitters/detectors, one at each end of the track.
When the loco moves over one of the detectors, its output goes low and the output is wired back to the 555 chip where it triggers a change of output state.
The output can be wired directly to a relay if it is a low current type, or it can be used to switch a transistor on and off.

Laser detectors

This detector works with both DC and DCC.
Unlike some others it can work in complete darkness (e.g. tunnels, hidden sidings).
It uses a laser head to emit the narrow beam and a laser detector. The laser head is the type used in many laser pointers and laser spirit levels.
The IR emitter and the IR detector are placed on your layout so that a laser beam straddles a track.
While the laser beam is interrupted, the detector module's outputs goes from +5V to 0V.
This change will remain as long as the beam is interrupted. When the interruption ceases, the pin reverts to its previous state (i.e. the output pin goes back to +5V).

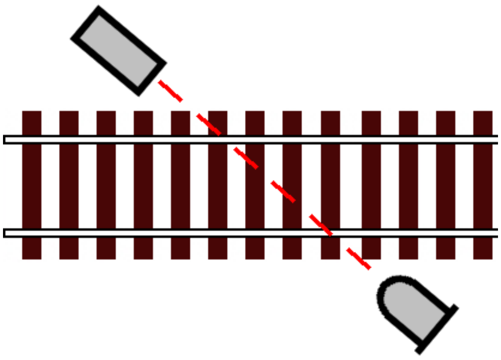
If the laser head and detector face each other across a track, as in this image, a train is detected the moment it breaks the beam.
The output will remain on until the beam is no longer broken.



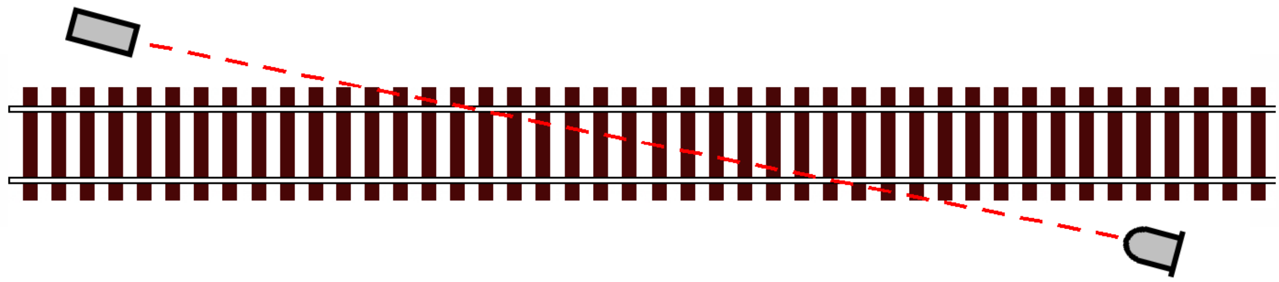
Alternatively, the laser head could be mounted above a track (e.g. in a tunnel or inside a shed) with the phototransistor embedded between the sleepers. In this case, the train would be interrupting a vertical beam.

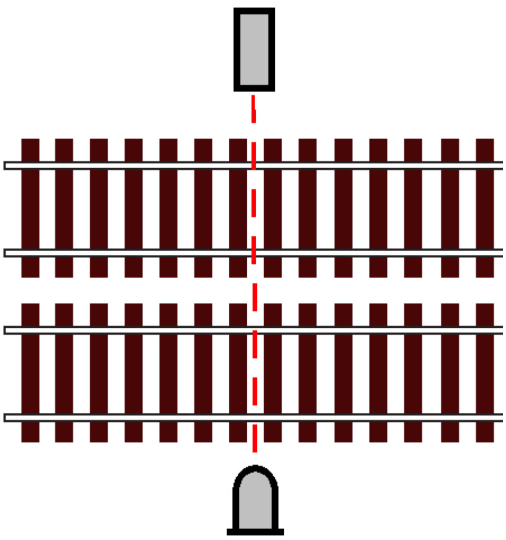
This method is useful for triggering another module that needs a simple pulsed change of state to start its activities. Take, for example, a sound player that begins playing an audio clip as soon as it is triggered – and continues to the end of the sound track regardless of the state of its input trigger. It then does not matter whether the beam is then restored, as the audio track has been successfully played.
This method is also useful for triggering events on CBUS / EzyBus modules.

If the laser head and detector are placed at an angle across a track, the beam remains broken while the entire train passes, as gaps between rolling stock are not detected. The output only resets after the last item passes (perhaps after an optional delay).
This is useful for modules that need to be kept activated (e.g. keeping crossing gates open, keeping station lights on while train is in the station, etc.).



The output reverts to its original state when the train leaves the detectable area. If the train passes the detector and stops further along the track, the section is occupied but there is no feedback.
However, if the head and detector are spaced a distance apart, the module can be used to detect the presence of a train sitting anywhere along a straight section of track.



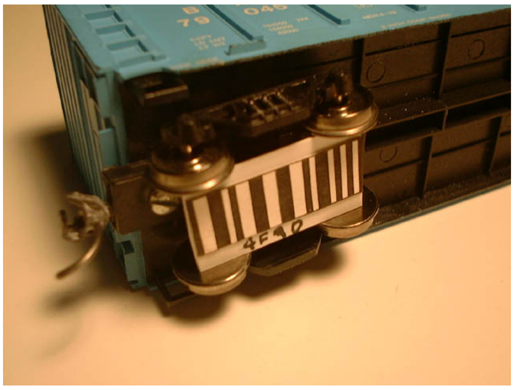


If required, the head and detector can straddle two or more tracks and will be triggered if a train comes into any of the tracks (e.g. in a fiddle yard).

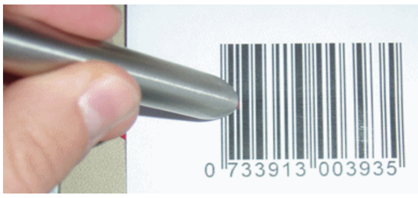
Since the module has a long range, it can be used to detect across multiple tracks. It would work equally well across many more parallel tracks.

Barcode readers

We have all watched or used barcode scanners when our groceries are swiped across a supermarket checkout. The technology is widely used and bar code labels can be found on most goods.
At its simplest, a bar code is a series of black bars on a white background, the width and spacing of the bars representing different characters. The bar code reader bounces light off the label as it passes and detects the changes in in the amount of light that is reflected back.



In the model railway world, the reflected data is more than just an indication of occupancy; it can send back detailed information on every loco, coach or wagon that has a label fitted (see the photo for an example). Free software is available that can print barcodes on to sticky labels.
However, this system is not widely used, mainly due to the complexities of integrating it into a model railway control system.
Commercial barcode readers have USB interfaces, requiring computer software to decode the barcodes and act on the data found.
Where multiple readers are to be used, as in most layouts, ways have to be found to interface them all to a computer. While not insurmountable, it requires hardware and software expertise not widely available.
Alternative options include:



- Hack a USB interfaced scanner to get at the TTL output.
- Use a home-made infrared detector as discussed earlier.
- Buy a barcode scanner wand that already has a TTL output. The image shows one sold for under £10 on eBay.

The output from these readers still has to be decoded to extract the data. This could be achieved via the computer's software or by feeding the TTL output into a PIC whose output pins would feed other logic (or a CBUS CANACE8C).
Until this system is available into a reliable kit that can be implemented by most hobbyists, it remains mostly for those who relish a challenge.
Pros:

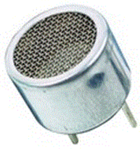
- No modifications to track/power/etc. are required.
- Returns detailed info.
- Can be used to take selective action (e.g. moving points, train whistles)
- Can be used for on-screen announcements.

Cons:

- Requires rolling stock to be labelled.
- Needs reader under every spot to be detected.
- Not easily integrated.
- Expensive option.
- Relies on keeping labels clean and unsmudged.
- The greater the detailed required, the longer the printed label. This may present problems with smaller gauges.

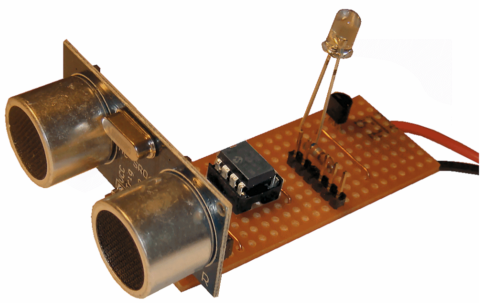
Ultrasonic detectors

Ultrasonics are acoustic frequencies (i.e. they work by vibrating air) that are higher than those audible to the human ear.
An ultrasonic detection system can therefore be thought of as a loudspeaker and a microphone, tweaked to only operate within a small range of ultrasonic frequencies.
The products marketed by Parsonics range from operating frequencies of 14.6KHz to 420KHz and can operate at distances up to 150 feet.
Ultrasonic detectors are used in car parking sensors, burglar alarms, range finding, process control, etc.
The most commonly used systems operate at around 40KHz.



The units can purchased separately, as shown in the image, and they are marked as TX (transmitter) and RX (receiver). Other transducers can be used as either transmitters or receivers (known as 'transceivers').
Like infrared systems, they can be used facing each (e.g. beam breaking) or mounted to detect reflections.

Many circuits are available for providing the 40KHz transmission and for the detection of the ultrasonic waves. They all tend to have many components.



Another option is to use the HC-SR04 module, as shown in the image. This module can be picked up for around £2.50 on eBay and consists of a PCB with both transmitter and receiver modules mounted on it, along with much of the required circuitry already mounted. Apart from the power connections, it has only two other pins. One pin, when pulsed low by a PIC, sends out a short ultrasonic burst. The other pin changes state if it detects an echo being returned (i.e. something is within its reflective range). I can adjust the PIC to switch anywhere between 1” and 24”.
If necessary, you can even check the time it took for the echo to return to calculate how far away an object is (as used by car parking sensors).

The problem with the cheaper ultrasonic receivers, apart from reduced range, is the wide angle of detection (some 15° in either direction). While this might be useful to see if there is any movement in an entire marshalling yard or group of hidden tracks/sidings, it limits its use to short distances in situations where tracks are closely laid (i.e. most layouts apart from larger gauges and garden layouts).

Pros:

- No modifications to track/power/etc. are required.
- Can operate over long distances.
- Unaffected by light.
- Low current consumption.

Cons:

- Needs additional circuitry (either lots of components or a PIC)
- Large; problems in hiding on layouts.
- Wide detection spread, particularly at longer distances.
- Not recommended for continued operation at high temperatures.
- Not recommended for continued operation at high humidity.
- Subject to vibration.

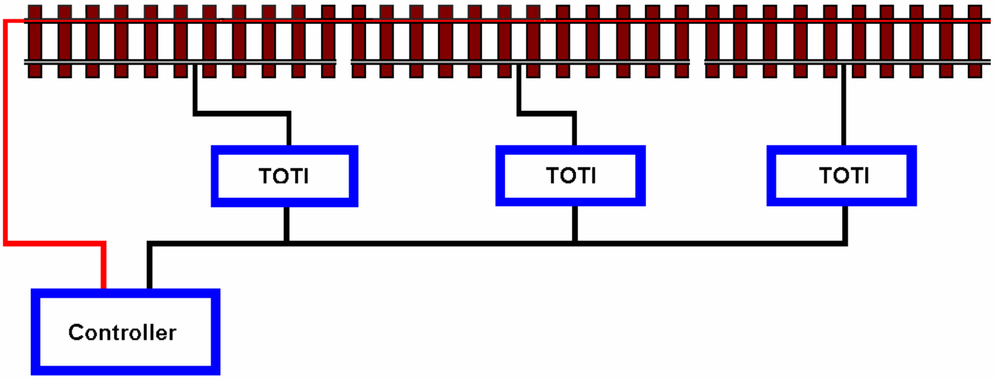
Current Detection systems

Previously discussed detection systems were *'spot detectors'* – they only triggered when a loco or wagon passed a specific point in the track. When the loco/wagon moved beyond that point, the detector reverted to its previous state (unless a delay was added to the output). This momentary or extended change in output is often sufficient to carry out a required task such as changing a signal or sending a pulse back to a computer or a PIC.

There are many occasions, however, when you want the output to stay changed as long as a section of track is occupied, only reverting back to its original state when the track is unoccupied.
Consider, for example, a hidden siding in a tunnel or in a building. The train may have passed beyond a detector but still be occupying the track. You can avoid running a train into an occupied hidden section by relying on your memory or your jottings. Better still is to have an indication that all operators can see, using lights on a control panel or on a computer screen.

On a layout, we could simply use street/yard lamps to indicate track occupancy. This same output can be sent back to computers for use in automation software.
To achieve this, the detector must activate when a train is sitting in <u>any</u> part of a track section, not just adjacent to a spot detector.

Current detectors work by sensing even a small current being drawn from a section of track, through a loco or adapted wagon/coach sitting on that section.
Since we need to detect occupancy on different sections of track, it follows that the layout has to incorporate track sections that are isolated from each other – the biggest drawback with current detectors.



The above diagram illustrates a controller feeding one of its outputs to a common rail, while the other output is fed to each individual track section by passing through a TOTI detector.

Note

> This is <u>not</u> the same as a block control system. In our example, all the sections are powered all the time.

Three types of current detectors are sold by MERG

- TOTI2 – diode drop based.
- DTC2 and DTC8 – transformer based.
- PMP7 – diode drop module for a single section.

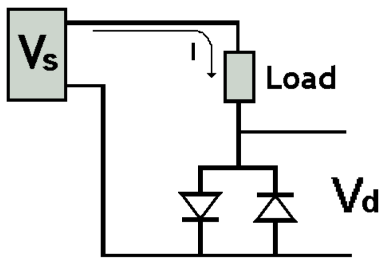
How current detectors work

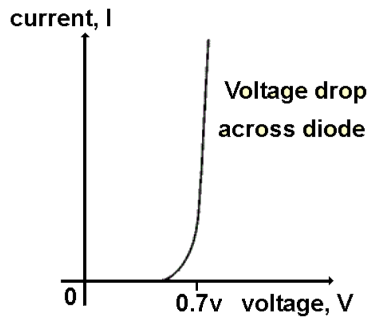
There are two methods that are widely used.

Diode Drop Detector

A diode, when a current is passed through it, develops a voltage across itself. This voltage remains almost unchanged over a range of different current levels, from small to large.

As the illustration shows, a varying voltage source Vs (e.g. a loco controller) can produce varying current draws through a load, while the voltage across the diode, Vd, remains almost constant at 0.7V.

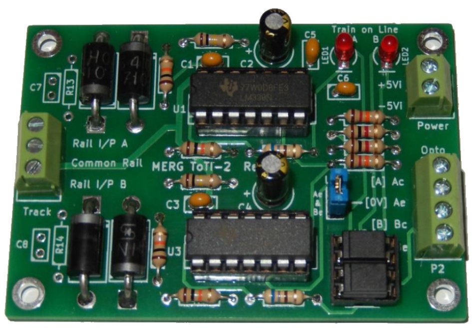




If we place two diodes in reverse parallel, then a voltage drop of +0.7V or -0.7V can be detected across them when a load is present to complete the circuit. This positive or negative voltage depends on whether the controller is moving the loco forward or in reverse.

In practice, the load is usually a loco that is sitting in a particular track section. However, a load can be rolling stock fitted with resistors on their axles, as in the image.
The loco or rolling stock does not need to be moving to be detected; it could be be stationary in a siding and still be detected.
The current required to allow this detection is so small that it will not cause the loco to move or overheat, but is still sufficient to generate a 0.7V voltage across the diode combination.

This is the MERG TOTI2 board (Kit 62) and it works with both DC and DCC systems.
The necessity to handle both positive-going and negative-going voltage means that the module needs a dual supply of +5V and -5V.

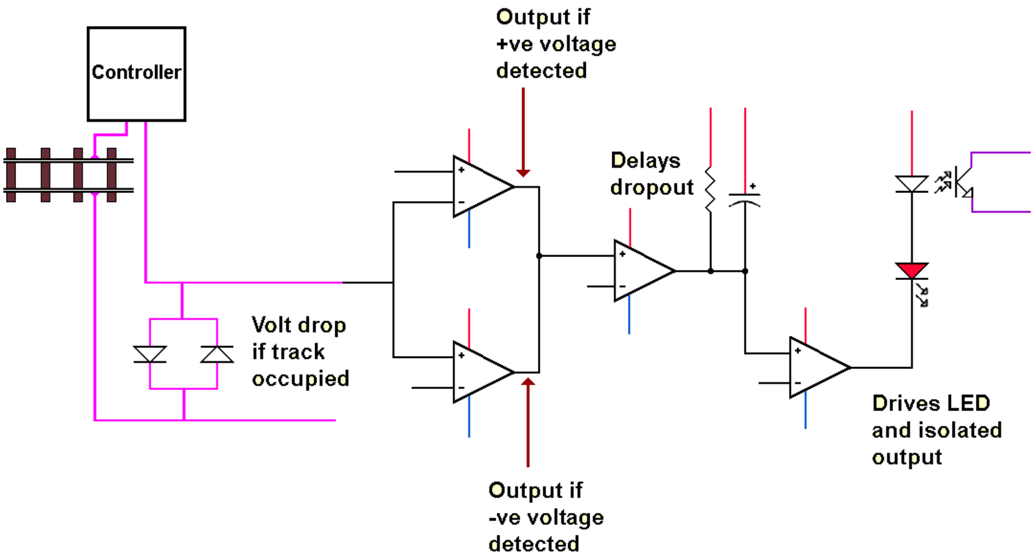


The block diagram below shows the four main stages that the MERG TOTI2 board uses to process the output from the diode combination.

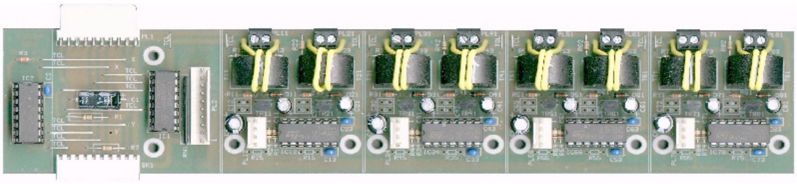
The lines shown in purple indicate the initial detection of current produced by a loco occupying the track section. The voltage developed across the diodes is passed to a chip that has four separate parts.

One part of the IC produces an output if a positive voltage across the diodes is detected, with another part producing an output if a negative voltage is detected.

The third part of the IC provides a delay before reverting back to a previous state, once a voltage drop is no longer detected, while the fourth part interfaces the module to the outside world.

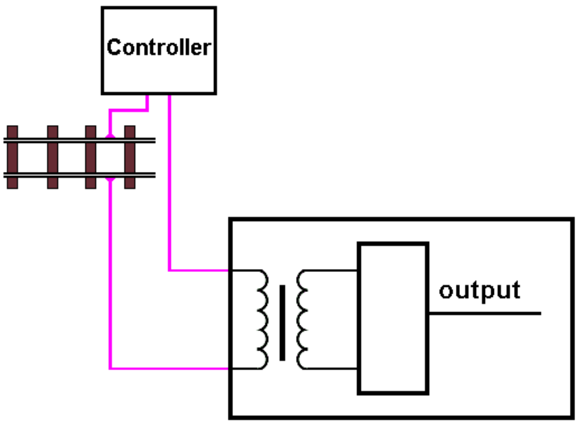


Transformer Block Detector



MERG's DTC2 and DTC8 modules also detect the flow of current but only works with DCC systems, unlike the TOTI2 module which work happily with either DC or DCC.

Again, the output from the controller passes through the detector module. This time, instead of passing through diodes, the current passes through a transformer's primary winding on the detector module. If the track is occupied, a current flows through the transformer secondary and is detected.
Unlike the diode drop version, the module's circuitry is isolated from the track circuitry and there is no voltage drop caused by its use.



Current detection systems require no additional circuitry and can interface directly to mimic panel LEDS, servos boards, CBUS modules, etc.

Pros:

- Detects any occupancy on an entire section of track.
- Does not rely on movement.
- Can detect rolling stock.
- Unaffected by light.

Cons:

- Need to create track sections.
- Requires modification to rolling stock.
- TOTI modules needs a split supply.
- TOTI modules slightly reduce the track voltage, due to the voltage drop across the diodes.

Summary of features

	Micro switch	Reed switch	Hall Effect	LDRs	Infrared	Laser	Barcode	Ultrasonic	Current detector	RFID
Cheap	Y	Y	Y	Y	n	Y	n	n	Y	n
Affected by light	n	n	n	Y	Y	n	Y	n	n	n
Must modify loco	n	Y	Y	n	n	n	Y	n	n	Y
Modify rolling stock	n	Y	Y	n	n	n	Y	n	Y	Y
Must modify track	n	n	n	n	n	n	n	n	Y	n
Computer 'essential'	n	n	n	n	n	n	Y	n	n	Y
Stretch detection	n	n	n	n	n	Y	n	n	Y	n
Identification	n	n	n	n	n	n	Y	n	n	Y
Detect stationary train	n	n	n	n	n	Y	n	n	Y	n
Good immunity	Y	Y	Y	Y	n	Y	n	Y	n	n

Notes

- Some of these characteristics are definite (e.g. either train modifications are required, or they are not).
- Others are relative to each other (e.g. an RFID reader can cost over £20, while a reed switch can cost 30p, but is £6.60 for a Hector kit cheap or expensive?).
- Others are indicative (a barcode reader may only be susceptible to ambient light under certain conditions).

The table is a quick guide only; refer to specific pages and product specifications for greater details.

Comparison of different occupancy detectors

The restrictions, or possible restrictions, are marked in grey.

	ToTi2 (part 62)	Hector (part 72A)	DTC8 (part 56)	LDR (part 802)	DCC (part 807)	Laser (part 822)
Number of channels	4	2	8	1	1	1
Works on DC?	Yes	Yes	No	Yes	No	Yes
Works on DCC?	Yes	Yes	Yes	Yes	Yes	Yes
Works on 12V?	No 1	Yes	Yes	Yes	Note 2	Yes
Spot detection?	No 3	Yes	No 3	Yes	No 3	Yes
Section detection?	Yes	No	Yes	No	Yes	Yes
Long distance?	Yes	No	Yes	No	Yes	Yes
Works in the dark?	Yes	Yes	Yes	No	Yes	Yes
Free from ambient light?	Yes	No	Yes	No	Yes	Yes
Can read multiple tracks?	No	No	No	No	No	Yes

Notes

1 - Requires a split supply
2 - Module gets its power from the DCC signal
3 - Only if you make a very short track section

Interfacing detectors

Many of the detectors simply produce a change of voltage when activated and may require additional circuitry to be usefully deployed.

Some examples of interfaces

Direct connection	Controls devices by direct wiring to them (e.g. switching a solenoid point)
Delay circuits	Introducing a pause before reverting to previous state (e.g. keeping crossing gates open while train passes)
Latched circuits	Short pulse switches an add-on's output to stay switched, until unswitched by another pulse (usually from a different detector).
Sequencers	Starts a sequence of changes on a number of different outputs, each being connected to another device (e.g. sounds, lights and animations occurring at timed intervals).
Computer	Providing control of semi/fully automated layouts via serial or USB ports.
PIC	Controlling devices by direct wiring to them (e.g. operating multiple devices, LEDs servos, etc. - including delays, latching and conditional operations).
CBUS	Providing control of semi/fully automated layouts via a CAN_SB or CANRS module.