Electronics for Model Railways

Chapter 13

Train lighting

By Davy Dick

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In memory of Margaret

Contents

Train lighting

Now that we have our stations, streets, factories, houses, etc., all lit, we can turn our attention to our rolling stock.
These lights would certainly add appeal to trains:

- Loco cab lights, headlights, Mars lights, ditch lights
- Guards van / caboose lights
- Steam loco fire box
- Coach lighting

Locos with headlights and tail lights could be a good starting point. Then, imagine the effect of a glow from the cab of a steam loco, or coaches illuminating their passengers and internal details.
This chapter looks at how this can be implemented both in DC and DCC layouts.

Of course, it is not quite as simple as scenic lighting, since the objects we want to illuminate keep moving. There are other restrictions such as avoiding excessive current draw, space restrictions, difficulty of fitting, and so on. Nevertheless, it is well worth the effort.

Choice of lights

There are three types of light that we can use for train lighting.

1.5V lamps

These are marketed as *'Grain of rice'* bulbs and are available from Rapid Electronics (part number 41-0186) or from many model railway stores such as Kytes Lights. They light at a lower voltage than LEDs but consume a higher current (15mA) compared to many LEDs. They also produce heat and have a shorter life. They are small, at only 1.4mm diameter and, being incandescent, they are non-polarised (they can be fitted either way round).
Generally, they are being sidelined in favour of LEDs. The examples used later all assume using LEDs.

Single LEDs

Single LEDs are mostly used where a single light is required, such as a loco's headlight or a train's tail light. They require a higher voltage before they illuminate – around 2V for yellow LEDs and 3V for white LEDs. They are more robust than grain of wheat bulbs, and produce usable light at currents as low as 5mA and sometimes even 2mA (well below the figures given as their maximum ratings). Surface mount LEDs as small as 1mm x 0.5mm allow lights to be fitted in even the tightest of spaces.

LED strips

LED strips are purchased as a long continuous strip or roll of LEDs, with an adhesive backing. This makes them ideal for lighting coaches with a long LED strip; it saves wiring lots of individual LEDs and the strip can have its backing strip removed and be pressed on to the coach ceiling.
You can choose which LED spacing suits your project best. The strip/roll is available with either 60 or 120 LEDs per metre length.
Although continuous, the strip consists of a chain of individual sets of three LEDs with

their own dropper resistor. Each section has its own solder pads, so you can cut off a group of three, a group of six, or whatever length you require.
You only require a single pair of wires to connect to a chain of any length.
Most LED strips rated at 12V, and the current consumption for a group of three LEDs is 20mA. They start to illuminate at 8.5V and provide adequate illumination at 9V, where they only consume 5mA per group of three LEDs. This means that a LED strip can be supplied by a 9V voltage regulator or even a PP3 battery.
If you search around, you can also find LED strip that are designed for 5V working and also for 3.3V working, although they are more expensive than the 12V strips.
At the time of writing, a 12V 300-LED 5m roll cost only a few UK pounds. This makes home-brewed lighting a much cheaper option than commercial products.

Lighting features

The circuits for train lighting should meet some, or all, of these requirements.

Constant brightness

The intensity of the light(s) should remain constant regardless of the loco's speed or load. This is easily achieved on DCC systems because the track voltage level remains unchanged at all times. With DC, the track voltage varies from 0V up to 12V or more. At the lower levels (between 0V and around 3V) there is insufficient voltage to illuminate the LEDs and special approaches need to be adopted.

Flicker-free

The track voltage that is at a sufficiently high level to power the LED(s) may still be interrupted due to dirt on the track, the wheels or the pickups, or due to crossing a point's frog. This affects both DC and DCC systems. The circuit should maintain current to the lights during any track power interruptions.

Directional lighting

The use of headlights and rear lights varies with the era, the company and the country. For example, with double-ended diesels, there may be a white light at the end moving forward and a red light at the trailing end. This is easily achieved in DC and with DCC decoders that implement directional lighting.

Variety

Locomotives, in particular, may have various lights and lighting effects. These might include a flickering glow in the firebox of steam loco, flashing ditch lights, a rotary beacon, a gyra light, single and double pulse strobe lights, Mars lights and headlight dimming.

Switchable

Constant brightness lighting is fine, but we may not always want the lights to be constantly illuminated. When coaches or wagons are out of service and sitting in a siding, we don't want them to have any working lights.
With DC, its a bit easier, as the lights will only be lit if they rolling stock is sitting in a section of track that is powered. So, with block control, removing the power from a siding, etc. automatically switches off any lights. Otherwise, other means have to be used.

With DCC, some of the lights can be switched on and off through instructions issued by the command station.
For lights that are not controlled by decoders, there is a similar problem of how to switch them on and off.

Small size

Some of the circuits use very few components and these can usually be tucked away out of sight. In other cases, particularly where onboard power storage is used, space is an issue in the smaller gauges.

Powering the lights

There are two ways to supply power to train lighting:

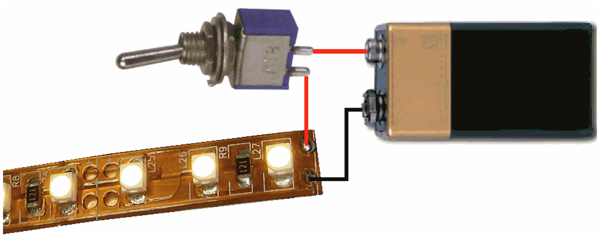
- Power on-board
- Power from the track

Power on-board

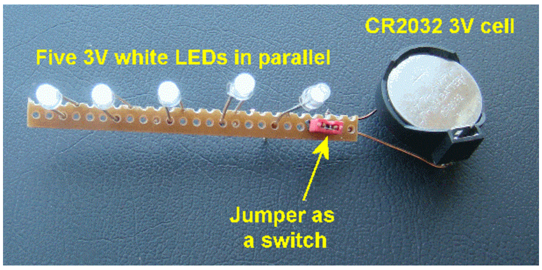
The idea of using battery power to run trains has been around for a long time and is still a common feature in cheaper 'toy' trains. Some modellers with garden railways also use battery power to run their locos. These use re-chargeable NimH battery packs.

We can install batteries in our locos and rolling stock, dedicated to powering lights.
This provides reliable, flicker-free lighting. On the other hand, batteries need replacing or recharging and are bulky.

Here is a very simple home-brew circuit comprising a PP3 9V battery, a switch and a length of LED strip. Using an alkaline battery with a capacity of 550mAh, lighting a LED strip that uses 10mA gives a theoretical 55 hours of continuous running before needing replacing (120 hours if using a lithium version).



Equally simple is using a coin cell to illuminate a set of LEDs mounted on a piece of stripboard. Although LED strips are handy, the spacing of the LEDs may not suit the coach layout. With separate LEDs, you can space the LEDs out any distance apart that you need.



This is the basis of many commercial offerings.
For example, Layouts4u's coach lighting kit comprises a LED strip (white or amber), a coin cell battery and holder and a miniature slide switch.
For more details, see:

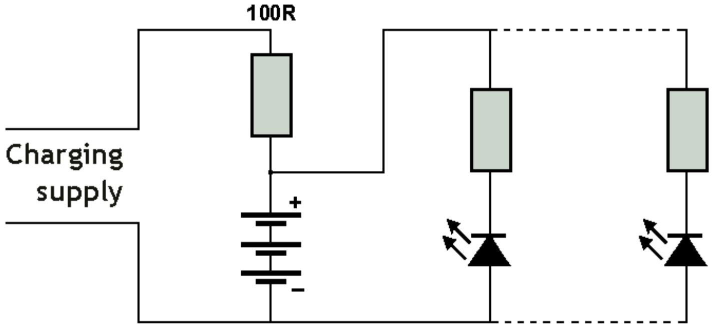
www.layouts4u.net/coachlighting.html

It uses a switch to control the lights, which can be inconvenient. The need to replace batteries is also a nuisance. This results in onboard power only being used where track-powered lights is impossible or inconvenient (e.g. with plastic tracks or unpowered tracks).

Rechargeable power

If you have the space in your coaches to store rechargeable Nickel-Metal Hydride NimH cells or supercapacitor, then you have a light source that is completely flicker-free and will illuminate your coach for hours, even when track power is removed.

NimH cells



A NimH battery could replace the alkaline batteries used earlier and provide longer life.
You would still have to put the battery in its charger then fit back into the coach.
However, if you kept the battery permanently in the coach, you could charge it from your battery charger if you made a suitable connection point on the coach.

Supercapacitors

Another approach is to use supercapacitors (also known as supercaps).
Large versions of these are to be found in renewable energy systems, uninterruptible power supplies and hybrid vehicles.
They are also available in much smaller size and capacity for use in portable equipment.
Their construction and materials result in very high storage capacitance compared to traditional electrolytic capacitors.
They can be charged or discharged in a fairly short time and can be subjected to countless thousands of charge/discharge cycles without much degradation.
They mostly operate at 2.5V, 2.7V or 5.5V.

This image is of the KR-5R5C105-R available from Farnell (have a look at their range).
It is 20mm x 5mm and with a stated 20 year design lifetime.
It is a 5.5V model with a whopping storage of 1F (one Farad).
That is 100,000 mFd, a figure hugely greater than most electrolytic capacitors.
This method is used in a barge that travels up and down a canal in the *'Uppen Doon'* layout. The barge has two interior LEDs and they stay illuminated all day at an exhibition on a single charge.

There is a very useful article by Julian Coles in the MERG Journal Vol 51 No 4 2017, where he describes supercapacitors and their use as stay-alives.

Ways to recharge

The barge has a two-pin socket hidden at the rear of cabin. A similar setup could be used with coaches.
However, it would be nice if we could recharge coaches during a running session.
How about a coach being given a charge boost every time it stopped in a station or at a signal, or in a siding?

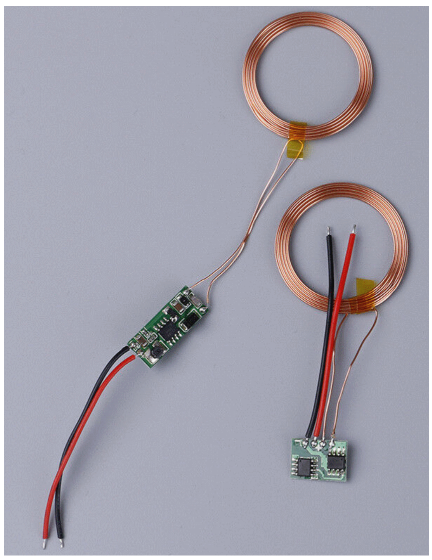
Possible methods are:

- wipers
- pogo pins
- wireless charging

Coaches could be fitted with phosphor bronze wipers that would make contact with copper strips laid at the trackside. That would be suitable for larger gauges but the wipers may not be able to maintain a good contact with lightweight coaches in smaller gauges.

In that case, a better solution would be to use pogo pins. As the image shows, these are spring-loaded test pins, made from brass or copper, with a thin nickel coating. Some have gold plating on the tip.
The barrel end is soldered to wires or boards and the sprung tip end is pressed to make temporary contact with another electrical or electronic surface. This small sized version is still capable of carrying 3A. They cost little over 1p each (don't expect gold tips for that price!). Pogo pins provide sufficient friction for good contact without being too abrasive that they cause excessive wear.

As an alternative, how about this for an experiment?
The coach's lighting circuit would connect to metal studs that replace the buffers. A coach could be parked in a siding with its buffers touching pogo pins embedded in the buffer stop. With the pogo pins wired to the power supply, the charging would take place.
If it was found that there was insufficient contact (specially with lighter smaller gauge coaches) small neodymium magnets could be used to maintain good contact between the pogo pins and the buffer studs (just make sure that you achieve a good compromise between maintaining contact while still allowing the coach to pull away easily).



Also in the experimental stage is the use of wireless charging modules.
The receiver module and its coil would be in the coach while transmitter modules and their coils would be positioned round various stopping places on the layout.
The system delivers 5V at up to 500mA but there are a few issues.

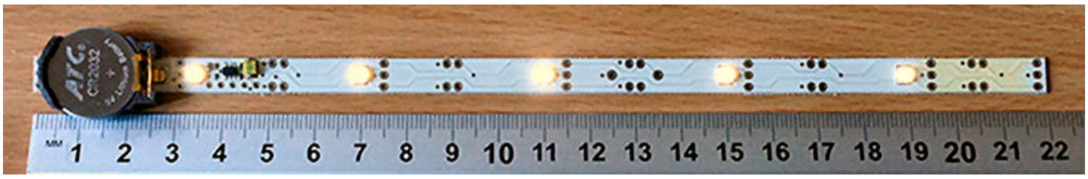
- While the receiver module is quite small (24mm x 10mm), the coil diameter is 33mm.
- The two coils cannot be too far apart from each other, otherwise the power transfer is seriously reduced.

Redesign of the coils, while maintaining both at the resonant frequency, is the main challenge.

Automatic lighting

Imagine an automatic lighting system where the coach lights only come on when the train is moving. When movement is detected, the LED lights come on and stay on during the train's journey. If the train stops at a station or at a signal, a built-in delay keeps the lights on for a couple of minutes. However, if the coach is left parked, its lights will go out after those couple of minutes. This process would be automatic, the only control being a small power 'switch' that is set at the start of a session.

The image shows a module from TrainTech that does just that.



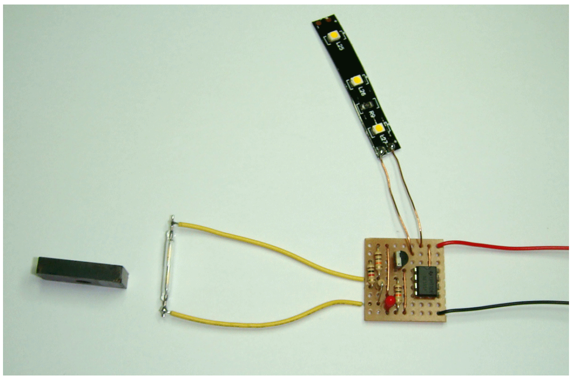
This module is useful but it relies on vibration to detect movement and is therefore prone to unwelcome triggering from unintended local vibrations.

Alternative methods

Experiments with tilt sensors (based on mercury switches or rolling metal balls), vibration sensors (based on springs or piezoelectric elements) and the ADXL335 accelerometer all proved unsatisfactory, being either too sensitive or too insensitive.
I settled on two alternative systems, one that worked but was restrictive (reed switches) and one that became a kit.

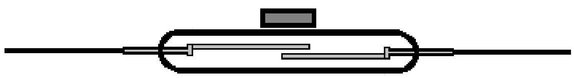
Reed switch and timer

The coach is fitted with a reed switch. When the reed passes near a magnet, it switches the timer on. When it next passes near a magnet, it switches the timer off. Magnets could be on the track, or mounted in tunnel mouths or gantries. The circuit is simple enough but is not sufficiently flexible. Coaches cannot be operated on anyone else's layout as their lights depend on magnet placement. A 'wand' (a magnet on a stick) can be waived over the coaches to switch lights but that means that the system is cumbersome and no longer automatic.



Latching reed switch

This reed switch has a magnet attached to its glass casing.
The magnet is too weak to fully pull the switch blades together. However, if you place a more powerful magnet (with the same magnetic pole) close to the reed switch, the blades make contact. After removing the main magnet, the weak magnet is strong enough to maintain the switch closed. If you later pass the main magnet close to the reed switch, in the opposite magnetic pole, the blades release contact once more.
You can buy these ready-made from layouts4u on their website:
www.layouts4u.net/coach-lighting-tail-lights/battery-coach-lighting-kits-and-tail-lights/latching-reed-switch



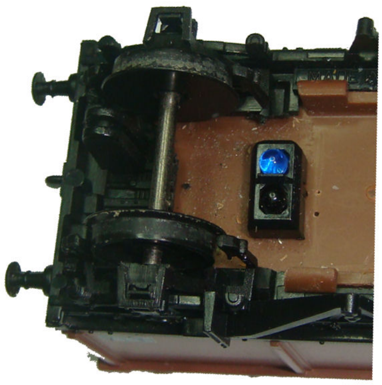
Or you can make your own and save.

These videos give you some idea of how to use them:
www.youtube.com/watch?v=U4Ze0JYAO-c
www.youtube.com/watch?v=iLimSOw4zI4&t=26s

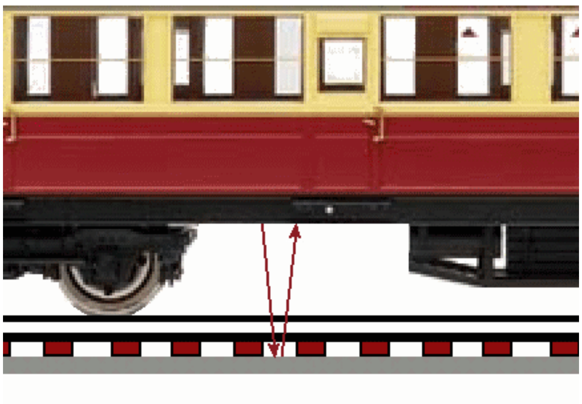
If a coach's LEDs are connected to a battery via a latched reed switch, passing a powerful magnet on a wand will switch on the LEDs; turning the wand over and moving it over the reed switch turns the LEDs off again.

Infrared and timer

Most infra-red units have a source of infra-red (IR) light and a phototransistor that is sensitive to IR. When the transmission level between them is altered that change is detected (think burglar alarms, vending machines, printers, etc.). Alternatively, the IR beam is deliberately switched off and on (think TV remote, remote control toys, etc.).



In this case, a TCRT5000 emitter/phototransistor combination is fitted on the coach's undercarriage and points down at the track.
The amount of IR detected depends on the surface that reflects the IR beam, in this case the sleepers and the ballast which will both have different reflective properties.



When the coach is stationary, the amount of light reflected will stay largely the same. This holds true whether the unit is positioned over a sleeper or over a section of ballast.
When the carriage starts to move, the amount reflected will change as it moves over sleeper-ballast-sleeper, etc. This change is detected and used to switch on the coach lighting for a period. It does not matter whether you are using wooden sleepers or concrete sleepers, light coloured ballast or oily black ballast. The circuit is not detecting actual light levels; it is looking for significant *changes* in light levels.

Power from the track

Most model railways run their locos from power picked up from the track rails.
This same power connection can be used to light loco and rolling stock.
Every loco has its own track pickups and these can also be used to provide lighting within or on the locomotive body.

Coaches and wagons do not have their own power pickups and therefore the power for lighting has to obtained in one of two ways:

- Getting power from the loco, using connectors between the loco and the first coach, between the first and second coach, and so on.
- Getting power directly into each coach or wagon by fitting it with its own track pickups.

Micro-connectors

Fitting your own pickups to coaches can be a bit of a challenge to some and they prefer to utilise the power that is already present in the loco.

The image shows a range of miniature connectors that can be used to connect between the loco and items of rolling stock. With the two-wire version, you solder the socket's two wires to the loco pickups and the socket exits from the rear of the loco. The two wires from the plug are used to wire up lighting circuits in the coach. If desired, this can be repeated to connect each coach in a train.

The downside is having to plug and unplug the connectors every time you couple or uncouple a coach from a train. If you run trains of fixed length, this is not a problem. Although very small, the connectors are nevertheless visible, particularly when used with smaller scales.

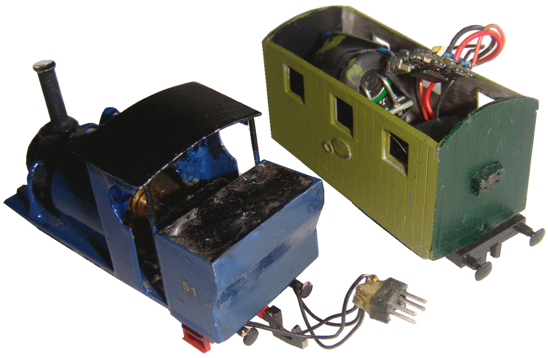
For more details, see:

www.expressmodels.co.uk/catalogue/micro-connectors
www.digitrains.co.uk/2-pin-micro-connector.html
www.dccsupplies.com/cat-387/micro-connectors.htm

Home made

The micro-connectors are relatively expensive and a home-brewed version is shown in this image. It uses PCB interconnect headers and sockets. You can just see a four-pin socket mounted on the side of the coach.

In this example, it is used to take track power from the loco's pickups into a coach which contains a DCC decoder and stay-alive capacitor, as these are too large to be hidden in the open-cab loco. The motor output from the decoder is then fed back to the loco's motor.



The header and sockets can be bought as strips and cut into the sizes needed – a 2-pin version would be less conspicuous.

For details of the connectors, see:

http://uk.farnell.com

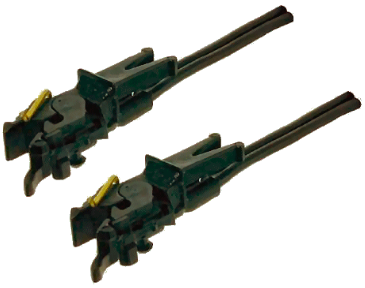
The socket is Order Code 1593458 and the header is Order Code 2356176.

Electric couplers

In an effort to hide the electrical connection, Viessmann has built connectors into its own couplers.

This image shows their 2-pole electric couplers and these are available from:

www.railroomelectronics.co.uk
www.gaugemaster.com
www.expressmodels.co.uk
www.dccsupplies.com

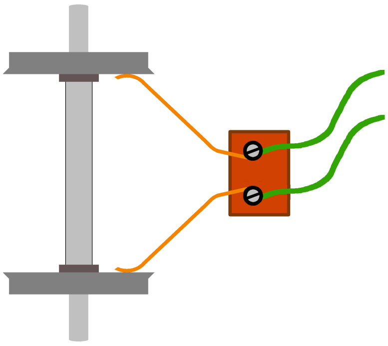


Gaugemaster also sell a four-pole version.

Unfortunately, they are fairly expensive and may not match an existing coupling/uncoupling system on a layout.

Using additional pickups

You don't have to depend on loco power and external connectors for coach lighting, if you fit your own track pick-ups to the coach or wagon you want to illuminate.
If your coach's wheels are plastic, you will have to replace them with metal wheels. These must be mounted on an axle that insulates the metal wheels from each other, to prevent a short across the track.
Often the axle is metal but the wheel at both ends are insulated from the axle. Other wheel sets have only one wheel insulated from the axle.
You can buy these ready made or can convert your own axles.

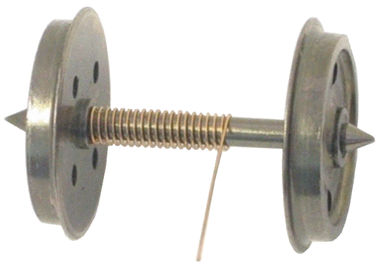


After replacing the plastic wheels, the coach's wheels are 'live' and we can pick up power from them.
The illustration shows one approach to this but enthusiasts will adopt a method that best suits their situation. In this example, two lengths of phosphor-bronze wire (maybe 28swg) are held in tension against the inner disc of the wheels. This has to be a balance between getting a reliable contact and avoiding excessive friction.

Suitable wire for this can be obtained from suppliers such as:

www.eileensemporium.com
www.wizardmodels.ltd
www.dccsupplies.com/shop/product_info.php?products_id=2023

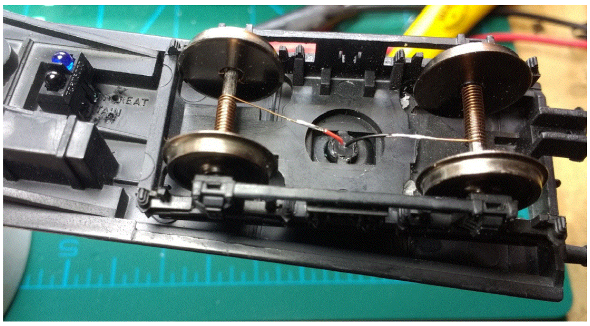
If you prefer, you can use phosphor bronze strips instead of wire.
Wipers introduce extra rolling friction and this will increase with every coach that is similarly wired.
To minimise friction, another method is to use coiled springs as shown in the image.



This relies on the metal axle being electrically connected to one of the wheels.
These are the DCCconcepts *'Flickerfree pickup springs'* and are available in N and OO/HO from

www.dccconcepts.com/?s=pickup+springs

Since there is much more surface contact between the phosphor bronze spring and the metal axle, a more reliable pickup is obtained with much reduced friction. You need less tension as there is always one part of the spring likely to be touching the axle at any one moment.
To fit the spring, you have to remove one of the wheels, slide on the coil and then refit the wheel to exact gauge. You repeat this with the other wheel set, ensuring that it is refitted to the chassis such that both springs wires are connecting to opposite track rails.

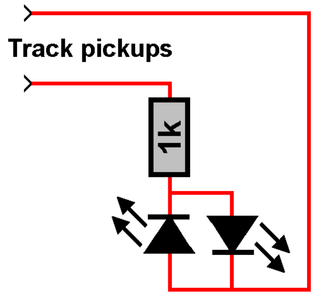


The great benefit of fitting coach pickups is that they are hidden, unlike the system of connecting plugs and sockets.
On the other hand, being separate from the loco's power, the lights will illuminate whether or not the coach is attached to a train.

Although there are similarities, there are also some differences between lighting on DC and DCC systems. Therefore, they are considered separately. In each case, the reference to track pickups includes whichever method you use to get the power from the track to the coach or wagon.

DC Track pickup

This first lighting circuit is very simple, using only three small components. The items cost pennies and will fit into small spaces.
It uses two LEDs, wired in inverse parallel with each other. This ensures that one of the LEDs will light as long as the loco is travelling in either direction.
This would be ideal to illuminate a loco's firebox using two red or amber LEDs, or simply to illuminate a cab's interior.

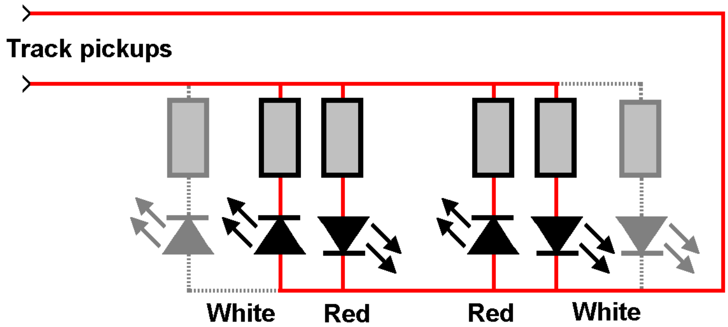


The diagram shows a 1k resistor and this can be altered to suit the LED you are using. Being very simple, it has some limitations:

- It needs around 3V and higher to illuminate
- The LEDs brightness will vary with the loco speed.
- When the train stops, the lights will go out.
- The LEDs will flicker as the power suffers temporary interruptions.

Later circuits show how to improve this.

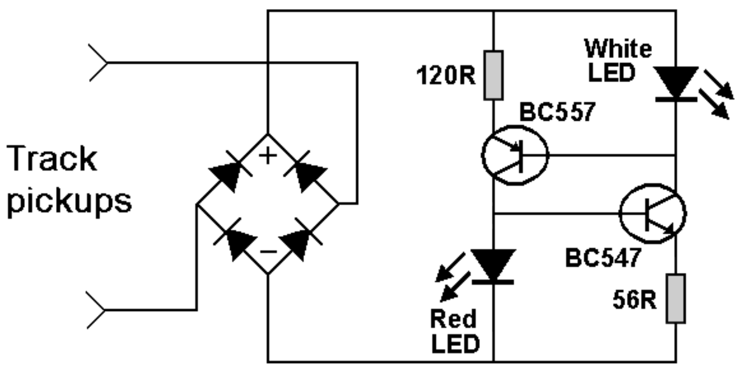
This circuit takes us a little further forward. It provides directional loco lights for double-ended diesel locos, with either one or two white lights at the end that is moving forward and a red light at the trailing end.



In this case, separate resistors are used with each LED, as the white and red LEDs will have different minimum working voltages.
When the track pickup that connects to all four/six LEDs is negative with respect to the other pickup, the red LED on the left hand side and the white LED(s) on the right hand side illuminate. When the track polarity is reversed, the other two/three LEDs illuminate.

Constant brightness lamps

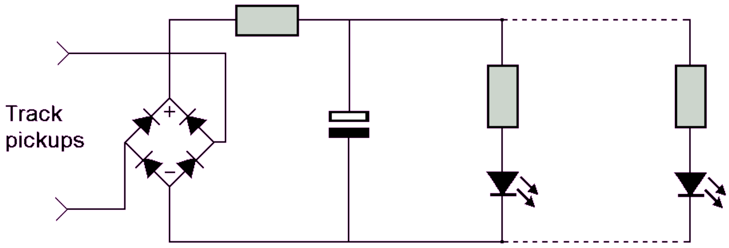
The problem of varying lamp brightness can be partially overcome with this circuit from MERG member Chris Stanforth. It ensures a constant brightness from the two LEDs, as long as the output from the bridge rectifier is between 3V and 15V. It uses a handful of cheap, easily obtained, components and the addition of the bridge rectifier ensures that the LEDs illuminate whether the loco is moving forwards or in reverse.



It also work with DCC power, where the LEDs will be lit – even when the loco is stationary.

Flicker free

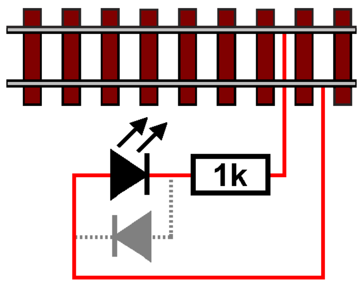
For constant illumination, LEDs rely on a constant supply of power. Any piece of dirt on the track, dirt on a wheel, a variation in rail height, a plastic frog, etc., can result in a temporary loss of power.



Here is a basic flicker-free circuit.
A large capacitor is used as a reservoir that can supply the LEDs when power from the rails goes down temporarily. The larger the capacitor the better (470uF or 2200uF if you have the space), the longer the LEDs can be kept illuminated.
The resistor is in series with the capacitor
This limits the current when you first place the coach on a powered track. The inrush could damage the capacitor. Also, if multiple coaches were on the track, the total initial current draw could be enough to trip the controller.
The value of the resistor would be relative to the value of the capacitor (e.g. 100R or 220R).

DCC track pickup

With DCC, the track is always powered.
This is a potential constant source of power for lighting – both lineside and on rolling stock.
For example, why run a long cable just to illuminate a single semaphore lamp, isolated cottage, or buffer stop lamp, when you can just tap into the nearby DCC traction bus?
This circuit connects to the track and permanently illuminates a LED. As the chapter on DCC pointed out, the track voltage polarity is constantly reversing.

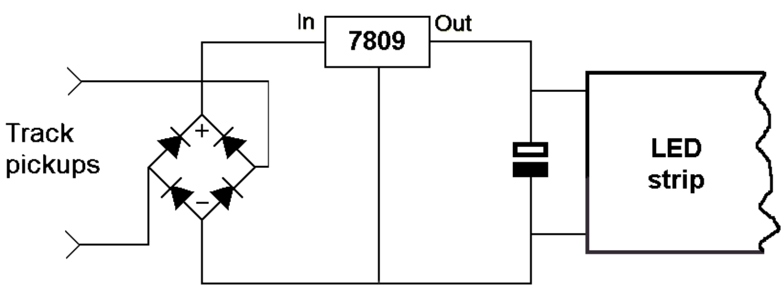


When the track that connects to the resistor is negative with respect to the other pickup, the LED will illuminate. When the track polarity is reversed, a diode (e.g. a 1N4001) may be fitted in inverse parallel across the LED. This protects the LED from any excessive reverse polarity voltages.
While useful for the occasional remote light, the DCC bus should not be used as the main power supply for all your lineside lighting – use a dedicated power supply.

This approach can be used for lighting locos and rolling stock, by using track pickups instead of direct connections. Since the LED only uses DCC power for half the time (during alternate half cycles), its light is dimmer than when fed by a DC supply.

LED strips with DCC

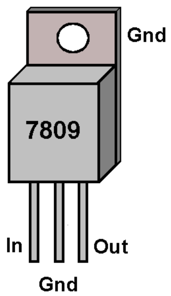
As mentioned earlier, LED strips are purchased as a long continuous strip or roll of LEDs, with an adhesive backing. The strip/roll is available with either 60 or 120 LEDs per metre length. You can choose which LED spacing suits your project best.

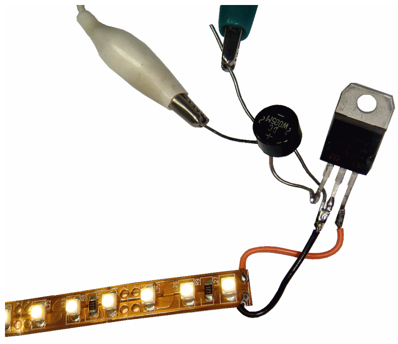


The strips are rated as working on 12V. At this voltage, the strip consumes 20mA for every group of three LEDs. In practice, most strips first illuminate at around 8.5V and provide adequate illumination at 9V, taking only 5mA per group of three LEDs.

This circuit uses only two or three components and is capable of driving a strip of up to 600 LEDs, although you will more likely be using a strip of 3,6,9, or depending on the coach size.

The DCC is fed through a bridge rectifier so that both cycles of the waveform are used. This is fed to a 7809 voltage regulator, which ensures that its output is always at 9V.





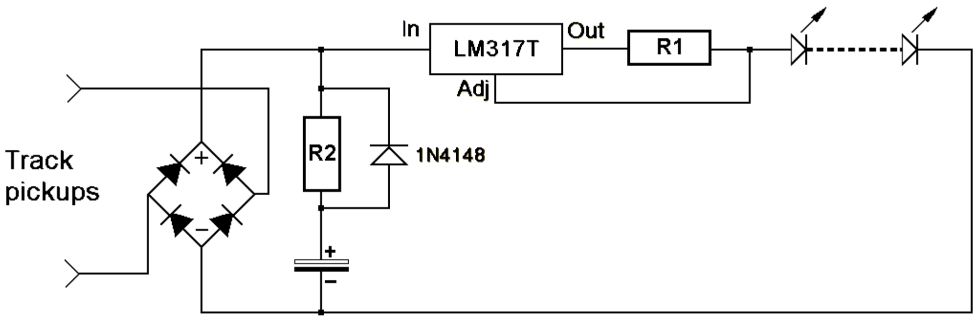
To minimise flicker, a capacitor (4700uF 16V) can be wired across the regulator's output. If your coach is large enough, you might consider connecting two of these capacitors in parallel, to provide even more stable illumination.
Here is the pin out of the regulator.
Note that the metal tab with the fixing hole is actually connected to the Ground pin, so be careful the tab does not touch other components.

Using an LM317

The LM317 is a three-pin device that can be used as a voltage regulator but can also be used as a *'constant current source'.*
Here is the Wikipedia definition of constant current source:

> *"a circuit element where the current through it is independent of the voltage across it "*

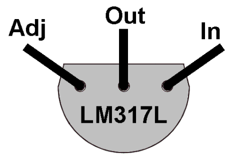
This circuit uses the LM317 as a constant current source to feed a chain of LEDs wired in series.



Since the same current flows through each LED, all the LEDs in the chain should have identical characteristics (don't mix LEDs that work on 5mA with LEDs that need 25mA).
The maximum number of LEDs in the chain depends on three factors:

- The DCC voltage from your command station.
- The voltage drop in the LM317. The output can be expected to be 3V lower than its input voltage.
- The forward voltage drop of the LEDs used. Different coloured LEDs usually have different voltage levels before they illuminate (e.g. yellow LEDs are usually 2V, while white LEDs are usually 3V)

So long as the output voltage from the LM317 is sufficient to illuminate the series of LEDs, there is no need for a series dropper resistor. A 1A 100PIV bridge rectifier is sufficient. The LM317T is a larger tabbed device (like the 7809) while the smaller LM317L is rated at 100mA, which is more than sufficient for our needs.



The value of R1 is calculated as 1.25 / current required; here are some examples:

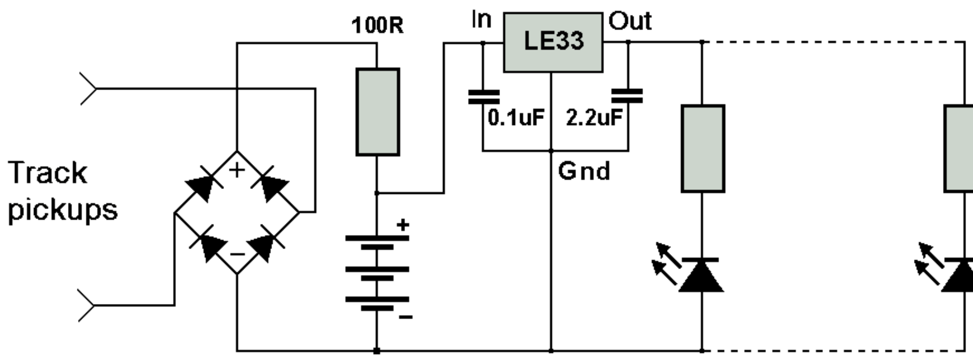
- for 10mA, the resistance is 1.25/.01 = 125 ohms
- for 20mA, R = 1.25/.02 = 75 ohms
- for 5mA R = 1.25/.005 = 250 ohms

If you prefer, you can always use this calculator:
www.reuk.co.uk/LM317-Current-Calculator.htm
After calculating, you would use the nearest resistor value. In the above examples, the most likely choices are 120 ohms, 68 ohms or 75 ohms, and 240 ohms or 270 ohms.
The current you choose to feed to the LEDs need not be their maximum rated current. For example, many 20mA rated LEDs illuminate quite brightly at 5mA.

To minimise flickering, a large value capacitor (4700uF or better) can be used. R2 is a 100 ohm ¼W resistor. When you first place this circuit across the track, there would be a surge of high current to charge the capacitor and this would trip command station overload detector – it would see it as a short. The resistor ensures that the capacitor is charged more slowly. The diode allows the current to flow unimpeded from the capacitor to the LM317. We charge the capacitor gently but discharge it quickly.

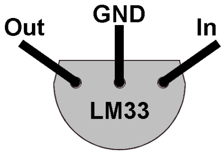
DCC storage

As before, the DCC track supply is fed through a bridge rectifier to obtain a DC supply. This is used to keep the three rechargeable batteries fully charged during normal running. The 100 ohm resistor prevents current surges during initial charging and provides trickle charging of the cells. At 1.2V per cell, the set of batteries can then supply 3.6V.



The batteries' positive connection is fed into the input of an LE33 chip. This is a 3-pin voltage regulator that provides a stable 3.3V output. With most voltage regulators a few volts are lost between their inputs and outputs. That would normally mean that an input voltage of 5V or 6V would be required to ensure a stable 3.3V output. However, the LE33 is a *'very low dropout voltage regulator'*. As the description suggests, very little voltage is lost across this regulator. So, three cells (3.6V) are sufficient and saves having to use extra batteries as would be required with a normal voltage regulator.

Here is the pin out of the regulator, viewed from underneath.
It has a maximum 100mA rating which is more than enough for our needs.
The values of the dropper resistors depends on what LEDs you use.
White LEDs operate from 3V upwards and you will probably find that they can be directly connected across the LE33 output without any dropper resistors.
Yellow LEDs will need in the region of a 100 ohm resistor, depending on the brightness you require.   You can connect as many LEDs across the LE33 output as you require, subject to the 100mA maximum current draw.   In practice, this could be 20 or more LEDs running at 3mA to 5mA.



You can use AA or AA rechargeable cells. The AA cells are larger but have a greater storage capacity.   This is measured in mAh (mA per hour), with AA cells starting from 1700mAh upwards and AAA starting from 600mAh upwards.   So, for example, a 1000mAh cell would provide up to 50 hours of light at 20mA.

An alternative is to use the battery packs for cordless phones. They are smaller (e.g. 50x32x11mm) but have less capacity (400mAh upwards).

Even smaller (e.g. 22x16x14) are backup batteries and these, although around 150mAh and 200mAH, should prove more than sufficient for most purposes.

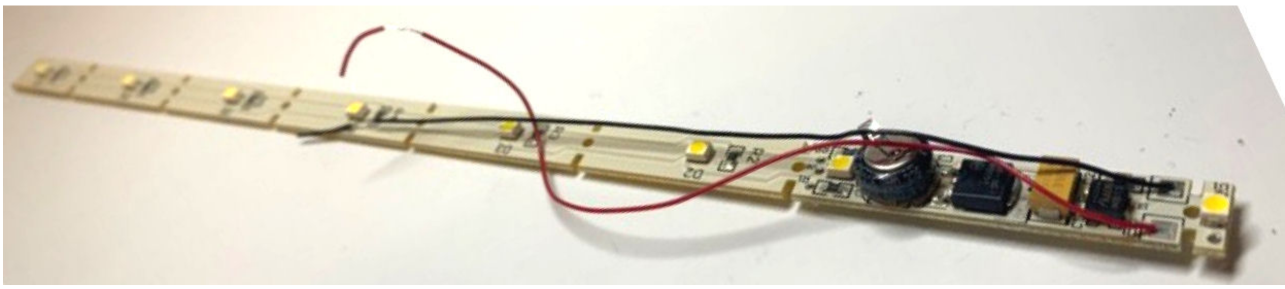
Commercial options

If you don't want to try constructing your own DIY circuits, you can always purchase commercial products.

Some are simple plug-and-play units, where the loco or coach has already been fitted with pickups and connectors. Like the Dapol 156 and Mk3 coach units, described here:
www.hattons.co.uk/526481/dapol_2a_000_042_light_bar_coach_lighting_unit_for_modern_coaches_and_multiple_units_cool_white_/stockdetail.aspx

Some are designed for specific models and the kit supplies the necessary track pickups.
www.traintrax.co.uk/11212-standard-coach-lighting-ver2-p-690.html
https://topslotsntrains.com for Kato

Some are general-purpose, leaving it you to find a source of track power, such as the Miniatronics 100-YCL-01 Yeloglo Interior Passenger Car Lighting System.
It uses a supercap to obtain up to 4 minutes flicker-free running when power is interrupted (just how dirty is your track?).



Mounting the lights

The actual steps in fitting lights will depend on your particular loco, coach or wagon. These are just some general suggestions.

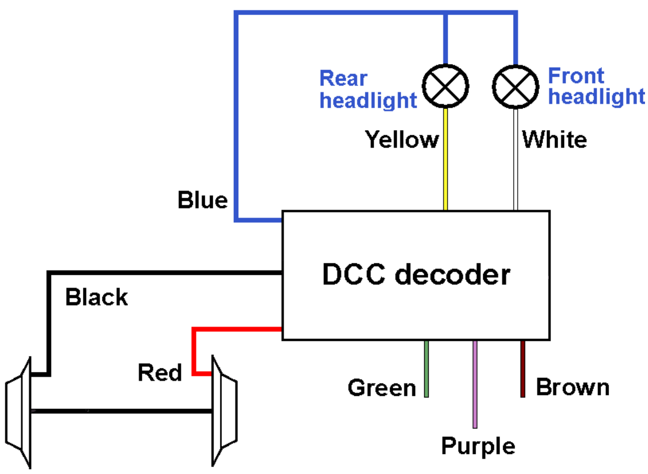
- Don't make any lights too bright, even though you can – it will not look realistic.
- Make sure that light does not escape through thin plastic walls or joints. If necessary, paint the inside of the body.
- Aluminium silver foil self adhesive tape can be stuck to the ceiling of coaches, prior to fitting LEDs, to achieve maximum even reflection.
- Sometimes it can be more effective to hide the LEDs on the coach floor and bounce the light off the ceiling.
- Consider using 30AWG Kynar wire or Litz wire to wire the LEDs and connectors, as they are very thin (specially Litz) and come in a range of colours.
- There are some situations where even Kynar or Litz wire is awkward to use, for fear of the soldering iron melting plastic or the difficulty in making connections to tiny surface mount LEDs. In these instances, consider using conductive silver paint. It is available from Rapid Electronics, Farnell, etc. It comes in a small bottle but a little goes a long way.

Using a DCC decoder

The circuits covered so far are easy and cheap to build but they all suffer from the same deficiency – easy switchability. The lights are either only lit when the train is moving – or they are often permanently lit. This is not realistic, since not all locos and coaches are constantly illuminated. Of course, we could lean over and throw switches on the locos/coaches, or we could introduce automatic light switching using reed switches, Hall Effect switches and the like. Neither of these is particularly satisfactory.

That is where using a DCC decoder offers advantages. We, as controllers, can switch lights on and off using our command station or handheld.
That involves sending specific instructions to the decoders.

The chapter on DCC included an illustration of a DCC decoder. For clarity, it only included the motor, headlight and rear light wiring.
Here it is again, stripped of the motor wiring.
As a minimum, a decoder will have two function outputs, as shown. Often, manufacturers provide additional function outputs.
In this example, the decoder provides three additional function outputs. Each of these can be connected to a light or light strip.
The blue wire is the common return wire for all function outputs. These additional outputs can be used to provide any effect you require such as a firebox glow, hazard lights, ditch lights, beacons, etc.



The output voltage of a function connection is approximately the DCC track voltage level. There is usually a current limit for each individual function output – often 100mA.

There is also a total current limit that the decoder can handle (e.g. 500mA or 1A). This can be found in your decoder specification, but you would not expect to approach this limit since LEDs consume so little current.

Programming the lights

Your DCC controller will have buttons marked as 'f0', 'f1', etc.
You want to be able to press one of these buttons, knowing that it will switch a particular decoder output. Deciding which button should switch output and then setting it up is known as *'function mapping'*.

There are three ways to do this:

- You can look up the manual for your particular decoder, work out what you want and then use your controller to program the decoder. This can be a fiddly and error-prone process.
- You can us an on-line calculator to work out the values for you. Have a look at:
  www.digitrax.com/support/cv/calculators/

  This image shows an extract from the calculator and you tick the boxes to match the function number to the wire to be switched. It then displays the values that you need to enter into the appropriate CVs in your decoder.

Throttle Function Key	Function Mapping CV#	CV Value	White 0F	Yellow 0R	Green 1	Violet 2	Brown 3
F0 (F0F)	CV33	1	☑	☐	☐	☐	☐
F0 (F0R)	CV34	2	☐	☑	☐	☐	☐
F1	CV35	4	☐	☐	☑	☐	☐
F2	CV36	8	☐	☐	☐	☑	☐
F3	CV37	16	☐	☐	☐	☐	☑

  This image shows an alteration being made such that f1 switches the violet (purple) output and f2 switches the green output.
  As you can see, the values to be entered for CV35 and CV36 have been altered as a consequence.

Throttle Function Key	Function Mapping CV#	CV Value	White 0F	Yellow 0R	Green 1	Violet 2	Brown 3
F0 (F0F)	CV33	1	☑	☐	☐	☐	☐
F0 (F0R)	CV34	2	☐	☑	☐	☐	☐
F1	CV35	8	☐	☐	☐	☑	☐
F2	CV36	4	☐	☐	☑	☐	☐
F3	CV37	16	☐	☐	☐	☐	☑

- You can use Decoder Pro. Like the above calculator, it lets you match functions to outputs. However, it is more intelligent. It only shows the white and yellow options because the decoder being programmed does not have any other function outputs.
  Even more useful, you don't have to calculate or remember any values; they are all hidden from view.

Use this sheet to determine which functions will control which outputs

Description	Output wire or operation 1 A - White	2 B - Yellow
Forward Headlight F0(F)	☑	☐
Reverse Headlight F0(R)	☐	☑
Function 1	☐	☐
Function 2	☐	☐
Function 3	☐	☐
Function 4	☐	☐
Function 5	☐	☐
Function 6	☐	☐

In addition, your decoder may have other facilities than can be set, such as directional lights, headlight dimming, flashing, flickering, etc. Read your manual, or see if Decoder Pro offers you those options.

Coach decoders

Using the decoder's function outputs gives you control over the loco's lights – both internal cab lights and externally lamps.
That still leaves coaches and wagons to be made switchable.
Of course, you could extend the wires from the function outputs into the train's coaches, using the plugs and socket previously mentioned.

Alternatively, you can fit track pickups to a coach and install a separate DCC decoder into the coach. You would simply use the function outputs for controlling the lights in the coach, ignoring the loco outputs. The decoder would have its own unique address, separate from the loco and this allows the coach to be used on a loco with no other modifications.
DCC accessory decoders can also be used in coaches. Although larger and more expensive than most DCC motor decoders, they can carry out activities that are not readily suited to loco decoders.

Using accessory decoders

The accessory decoder is really intended for use at the lineside, where it can operate points, signals, etc. Consequently, they are designed for higher currents and are on large PCBs.
These can still be used inside coaches, if you have enough room to fit them.
The big advantage of using these decoders is the larger range of outputs and/or features.

The Tam Valley LEDecoder only has three outputs but can handle a bi-colour LED and flickering effects.
For more details, see:
    www.tamvalleydepot.com/moreproducts/ledecoder.html

The ESU LokPilot Fx v4.0 has six function outputs with a maximum current of 250mA per output.
For more details, see:
    www.esu.eu/en/products/lokpilot/lokpilot-fx-v40/

If you fancy building your own, have a look at:
    http://atoomnet.net/circuits/tiny-dcc-decoder-for-leds/

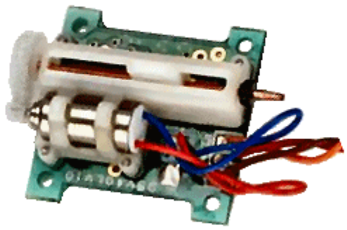
Special features

Why stop at just lights? Accessory decoders can be used to operate any animation in your coach or wagon that you can think of – space permitting.
You can now consider modelling:

- A maintenance or track-laying crane.
- A guard waving his lantern (another LED?) from the guard's van.
- On-board uncouplers.
- A moving pantograph or trolley pole.
- Sliding carriage doors.
- A remote-operated smoke or steam unit.
- And so on and so on.

We know from a previous chapter that we can animate things using servos – and some accessory decoders are able to also control servos.
Check out:
www.zimo.at/web2010/documents/MX-KleineDecoder_E.pdf
If you are working in larger scales, the commonly used servos such as the Tower Pro SG90 could be installed.

For smaller scales, the tiny Spektrum linear servos can be used. These come in standard throw, as in this image, and in long throw (just under 1”).
For more details, see:
www.spektrumrc.com/Products/ServoGuide.aspx

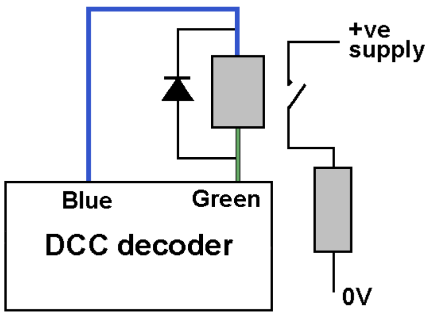


Another feature that can be controlled via DCC are the smoke units and steam units marketed by Seuthe. These are available from:
www.gaugemasterretail.com/magento/seuthe-seuthe-no100e.html
Here is the link to a YouTube video on fitting a smoke unit:
www.youtube.com/watch?v=6TKyclFoClM
There is also a lot of information on smoke units at:
www.trainweb.org/girr/tips/tips3/smoke_tips.html

Power for additional devices

The voltage level from decoder function outputs are just a little less than the DCC voltage and this is sufficient for anything we want to switch. In fact, we will have to reduce the voltage for connecting servos and LEDs.
The bigger issue is the current limit from any one function output – often a 100mA maximum. Since the Seuthe Smoke Unit uses 149mA at between 11V and 16V, and the Seuthe Steam Generator needs 130mA at between 10V and16V, we cannot drive these directly from a decoder output.
Instead, we use the decoder output to operate a transistor switch and/or a relay, which in turn supplies power to the device (see the chapter on interfacing).

This circuit gives an idea of how to interface a Seuthe smoke unit. A 12V low current relay is connected between a decoder output and the blue wire which is always positive Suitable relays are widely available, such as those from Rapid Electronics (part number 60-2410 or 60-4662), or the BT 47W/6H relay from MERG.
Don't forget to fit a protection diode, such as a 1N4148 across the relay coil.



The decoder has its own circuitry that converts the incoming DCC into a DC supply. This must **not** be used to power any high-current devices.
Use the bridge rectifier, with the voltage regulator if necessary, described earlier in this chapter.