Electronics in Model Railways

"PLAYING WITH TRAINS" is probably how most readers would describe Model Railroading, the latter being the much preferred expression. Of course, there are a lot of people who do not just "play with trains". Names such as Hornby Dublo or Triang bring back memories of bygone youth to many an adult.

Nevertheless, the hobby is not just one of running a train around a circle of track under the Christmas tree; the mature model railroader invests a great deal of effort into scale realism of operating models, structures, scenery and track. And if you tie that need for realism into the extensive growth of electronics as a hobby in the last ten years or so, you'll see why the expert on precision scale operation is keenly interested in how electronics can help this hobby.

Or, to look at it another way, there are so many variables possible in controlling several trains on a model railroad — as indeed there are in a real one — that it's not surprising that several companies have used model railroads at trade shows to demonstrate microprocessor versatility. A recent example was discussed in Byte magazine for July 1977.

Apart from computer control, which is really outside the scope of this short article, there are several uses for both digital and analogue electronics in the model train empire. Let's discuss them in stages — control, signalling, lighting and sound.

Control

Most model locomotives use 3, 5 or 6 pole dc permanent magnet motors. A few use brushless, ironless rotor motors and a very few ac motors. Power is picked up directly from the two rails, and reversal of track polarity reverses the locomotive direction except in the case of the ac motors, where an extra "kick" of ac triggers a reversing contact in the locomotive.

The Christmas train set power pack is nothing but a full wave rectifier delivering pulsating unfiltered dc to the track via a 100 ohm variable resistor as speed control. This gives very poor control at low speeds for the simple reason that stall current on a permag motor is much higher than its low speed current. Consequently there's a tendency for jackrabbit starts. Now the dyed-in-the-wool hobbyist wants precise control of low speeds because nearly all layouts have miniature freight yards — box-cars and cabooses have couplers operated by magnet remote control so the operator can make up and break down his trains. The more or less ideal speed control — or one approach anyway — looks like the circuit of Fig. 1.

This type of control has several features; the variable dc output has a pulse ripple added at lower speeds to vibrate the motor armature and reduce motor cogging and 'stiction', secondly it has a low source impedance for the motor, thirdly a delayed action can be switched in and out so that the controlled inertia of a heavy train can be simulated together with brake levers; and lastly it's short-circuit proof by virtue of heavy duty transistors and an overload trip. The last is indeed essential because short-circuits abound on the model railroad!

Though the circuit I've shown uses two darlington transistors, commercial versions are available, particularly from the USA, using op amps, SCR control or pulse width modulation. Even the renowned Heathkit has introduced a version. The most important feature is probably that superimposed pulse, for if it's too small in amplitude or too high in frequency, it is not effective; but if it goes too far in the opposite direction, the resulting buzz or rattle from the motor becomes objectionable. Anyway, you electronic fans with a dusty train set in your attic, dig it out, build a momentum-pulse-throttle and you just might pick up an extra hobby!

In terms of current rating, the power pack shown should

Model trains, like the Hornby Dublo model right, have reached a level of sophistication where they require electronics for control. Peter Thorne explains . . . .

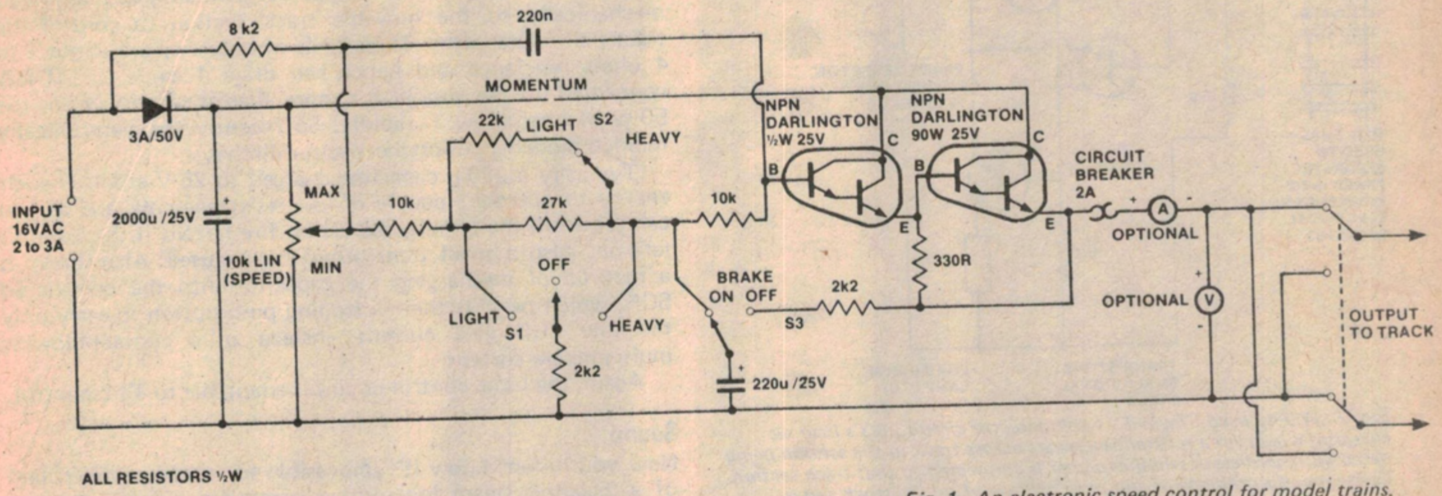


Fig. 1. An electronic speed control for model trains.

be capable of about 2.5 A at 12 V. This is adequate for any HO scale models, which scale 1:87, even with double heading locomotives. As you'd anticipate, the current requirements decrease with scale size – the second most popular scale is 1:160 (or n for Nine mm, which is the track width). Going up a size to 0 scale (1:48) many motors will need the full 2.5 amps. By the way, in case you home computer builders are thinking "why waste money on electronics for toys", some of these "toy" locomotives retail for over $1000 apiece and lately have been appreciating in value at well over 20%.

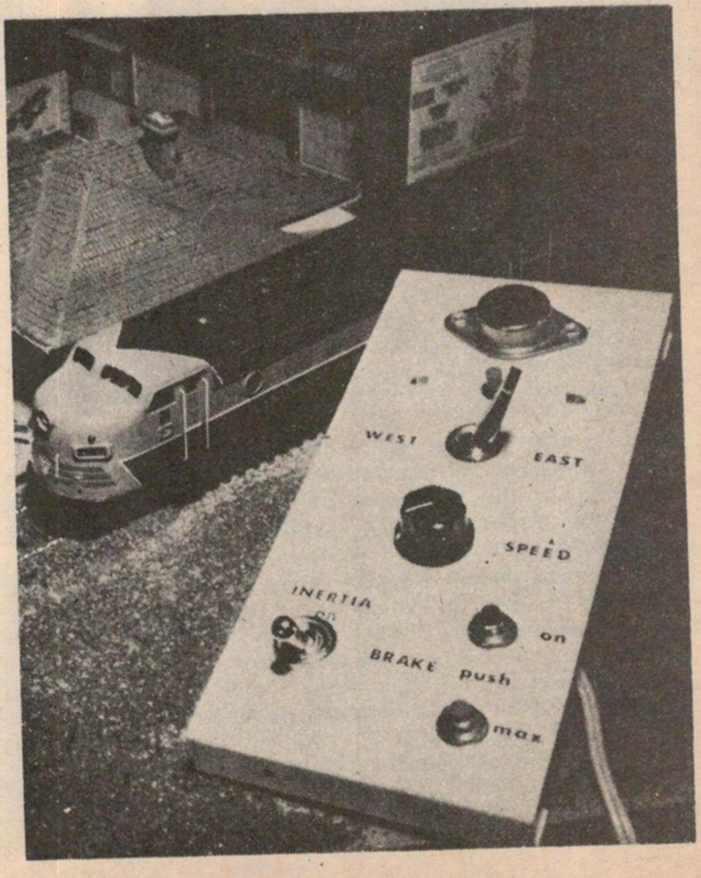
Signals

A natural for digital IC application is signalling. Model signals in two (red and green) or three aspect (red, yellow, green) with minature 12 volt, 60 milliamp lamps are readily available, Until recently, relays were widely used by modellers to operate these lamps in controlled sequence and often automatically disconnected a section of track ahead of a red signal for automatic train control. The relays used were typically low resistance coils in series with the power supply to the track. When the locomotive entered a particular track section, the relay contacts closed. All model railroads use track sections from 200 mm to 6 m long insulated from each other and switchable to alternate power packs. This facilitates the operation of multiple trains.

Complete model railroads still exist using these series relays for automatic control and signalling; but they're a maintenance nightmare for their intermittently proud owners. Up to date techniques use TTL gates driving red, yellow and green LED's for signals.

Relay driver ICs can be added to drive the small 12 V signal lamps if preferred and also to operate good solid 12 V relays for automatic stops and starts.

The interface between train and TTL is a little more



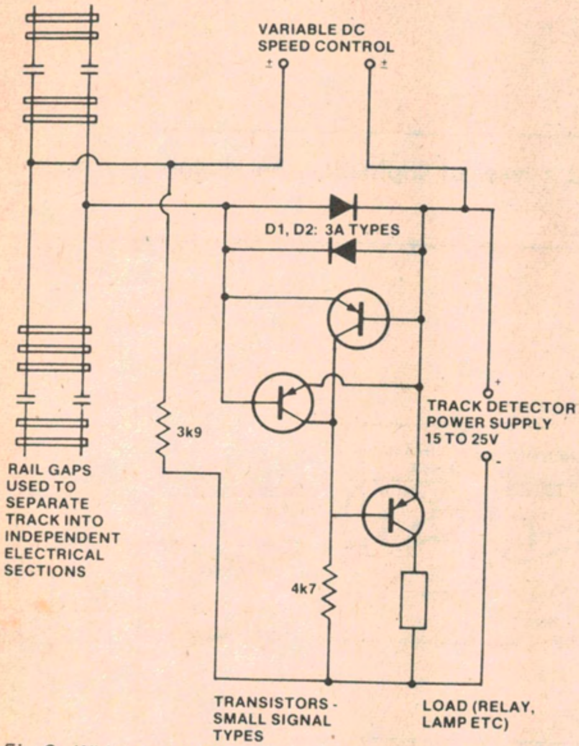


Fig. 2. Widely used "Twin T" track detector circuit. Q3's load de-energises whenever a resistance appears across track in the section being detected, regardless of whether power is connected to that track section. Consequently presence of any train or item of rolling stock can be sensed remotely.

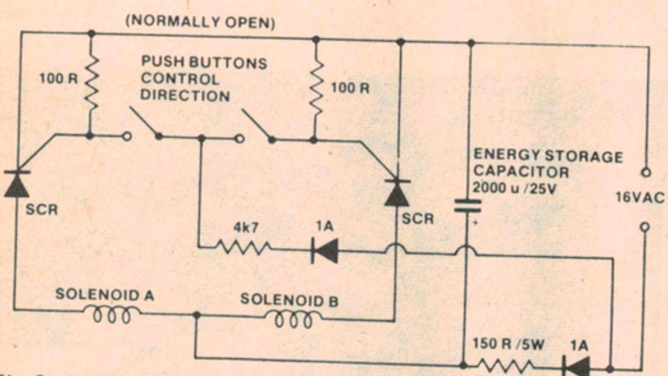


Fig. 3. Capacitor discharge system enables solenoids to be thrown with small average energy. System also prevents solenoid burnup if accidentally left powered-up. SCR switch control enables small current push buttons to switch heavy current. The SCR's automatically switch off when capacitor stored charge zeroes.

tricky; you've noticed, of course, that the track has only two rails which are required to conduct power (in either direction) to the locomotive. The requirement to detect locomotive presence led a few years back to a widely used detector circuit known as a "Twin-T".

The simple circuit is shown in Fig. 2. The circuit detects resistance between the rails as high as 50 k, but is insensitive to the connection of the power supply in the circuit, so it will respond only to the presence of a locomotive motor or any rolling stock with a 10 k to 47 k resistor wired between its wheels. Other less subtle interfaces are magnetic reed switches between the track, triggered by disc magnets under rolling stock — ideal for JK flip-flop operations, or opto-electronics, where ambient light can be interrupted by the movement of rolling stock to trigger or detrigger a light activated SCR, for example.

With a light activated system, the light source and the opto detector must be angled to the track to avoid gaps between moving rolling stock causing light modulation.

Turnout Control

Turnouts (switches, or points) control train routing. Remote control of these, on the models as on the prototype has nearly always been electric. The usual method is the use of a solenoid motor (Fig. 5). A soft iron armature can be moved into either of two high flux copper wound coils, depending on which is energised — using 16 volt ac or dc. The armature is linked mechanically to the movable track section to control the train's alternate paths. These coils of necessity are about 2 to 4 ohms resistance and hence can draw 4 amps. If left connected to the supply for more than a second or so, the 50 W of heat show — rapidly. So recently the electronically minded modeller adopted capacitor discharge.

Typically a 220 μ capacitor charged to 25 V stores enough energy to operate a couple of low resistance coils and as you can see from the circuit, there's no fire hazard if the power is left on. Also a small transformer can be used. Also shown is a method of discharging the capacitor into the coil via an SCR, which permits the controlling push button to carry only the low SCR gate current, instead of a contact-blowing multi-ampere current.

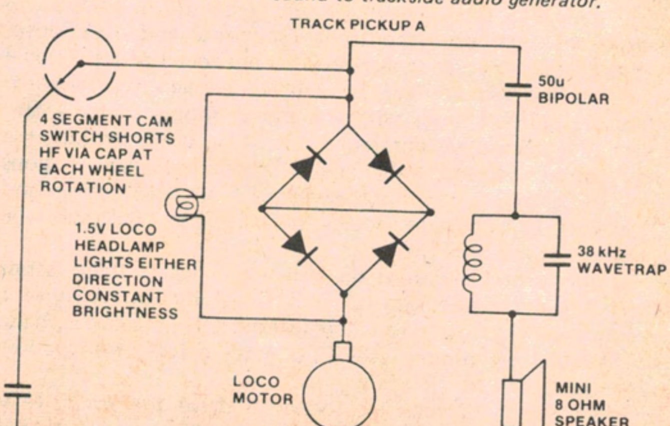
Again, the basic control circuit is adaptable to TTL control.

Sound

Now you hi-fans know it's impossible to reproduce the sound of a gigiantic steam locomotive without a 100 W amp and a four cubic foot bass reflex enclosure. Except those model railroad nuts don't believe you! Quite expensive, at about US$350, is a Pacific Fast Mail sound unit that transmits sound and motor power through just those two rails. The sound is synchronized to the piston position, that is for a two cylinder steam engine there are four "chuffs" per driver wheel revolution. Plus bell sound and the required wailing steam chime can also be sent from the trackside to be nicely reproduced in a miniature speaker located in the locomotive tender.

The PFM unit synchronizes the "chuff" sounds by transmitting a 2 V 38 kHz (approx.) signal superimposed on the dc motor voltage going to the track. The dc voltage source (a transistorized circuit, which is a simplified version of the

Fig. 4. These components, mounted in locomotive tender reproduces audio signals superimposed on dc motor voltage. Cam switch signals synchronization of "chuff" sound to trackside audio generator.



circuit shown in Fig. 1) has a low resistance choke in series with its output: this prevents the 38 kHz and the audio tones from disappearing into the speed circuitry. When the 38 kHz reaches the locomotive, it is intermittently shorted out in a capacitor (see Fig. 3). The capacitor is grounded four times per drive wheel revolution via a phosphor-bronze contact, which rubs on the inside of a drive wheel equipped with insulated quarter sections. As the 38 kHz signal shorts out, a relay operates in the track-side unit, sending out transistorized hiss to the locomotive-borne speaker. Being highly inductive, the locomotive motor bypasses neither the 38 kHz nor hiss — nor bell nor steam chime sounds, all of which are solid-state generated in the PFM box with full operator control. And even though the speaker is less than 50 mm in diameter, the sound is very effective.

Another electronic gimmick in the PFM system is the bridge rectifier of Fig. 3. There's a constant voltage drop of 1.4 V across the bridge, since it's in series with the motor — regardless of the motor/voltage polarity. Connect a miniature 1.5 V headlamp across the bridge and presto — constant brightness, regardless of motor speed.

A California-based firm — Modeltronics, produces sound systems that are completely contained in the model — also synchronized for "chuff". The supply voltage for the noise generator and miniature amplifier is derived from the track voltage much as the PFM "constant lighting section". Of course, the Modeltronics system does not offer bell or chime — yet.

LED Hazard Flashers

Pop a 3 mm red or yellow LED into the cabin roof of a model diesel, drive it from an internal LM3909 flasher integrated circuit, oscillating at 0.3 Hz, powered up from 0.5-3V, and you've duplicated real life on the "Atcheson Topeka and the Santa Fe".

Grade crossing flashers in model form are available ready made, with miniature 12 V lamps, just like signals. To flash, take an 555 IC timer, put one pair of lamps from IC output to trail, another pair from output to rail, apply 12 V, time to 20 per minute and grade flashers are in business.

Lighting

Whole passenger trains can be lit up using a supersonic generator at around 25-40 kHz. This can be fairly easily constructed using a 10 W audio power amplifier with the conventional negative feedback re-phased to positive. Connected in parallel with the train motor power, with a blocking choke between the two, constant lighting can give a superb visual effect with artificial twilight on a layout. Switch off the generator — and the lights go out. Each train group of lights uses a 220 n capacitor in series to block the otherwise additive lighting power from the dc motor voltage.

Radio Control and Carrier Control

As a purely personal observation, I feel the next and imminent step in electronics with model railroads is radio control. At least one experimental, but practical circuit has already been published. All that's needed are very low current motors powered by rechargeable NiCad batteries together with radio receiver, variable speed and direction controls, and sound generator circuit plus amplifier. Of necessity the concept requires extreme miniaturization because for HO scale (the most widely used size), the space available for everything is hardly more than 5 or 6 cubic inches. The entire receiver and motor drive circuit can easily be derived from model aircraft RC designs, particularly if the new Signetics NE544 motor/servo driver chip is employed. On-board sound — for example a diesel horn sound, can use a 556 IC in the self-oscillating mode generating two tones, each around 250 Hz, amplified by an LM380 audio chip.

Individual function control is practical using 555 tone generators in the transmitter with phase lock loop decoders in the receiver. The advantage of this type of control is that the modeller has become free of the power-to-the-rails restriction.

In summary, I hope this overview shows how another hobby can adapt techniques of electronics in order to add to the fun.

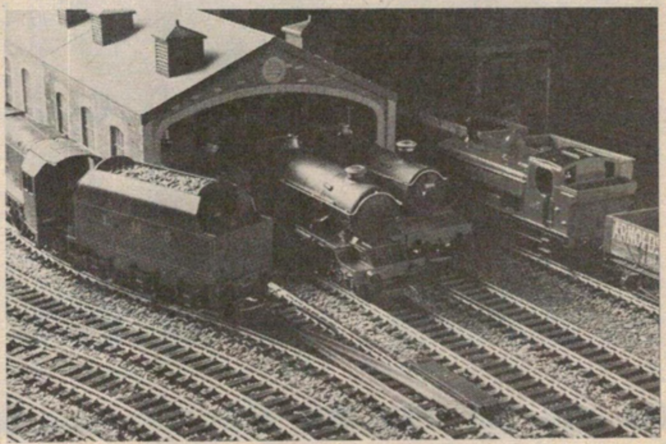


Fig. 5. Model railroad signals. Normally supplied with 12 V lamps, LEDs can be fitted.