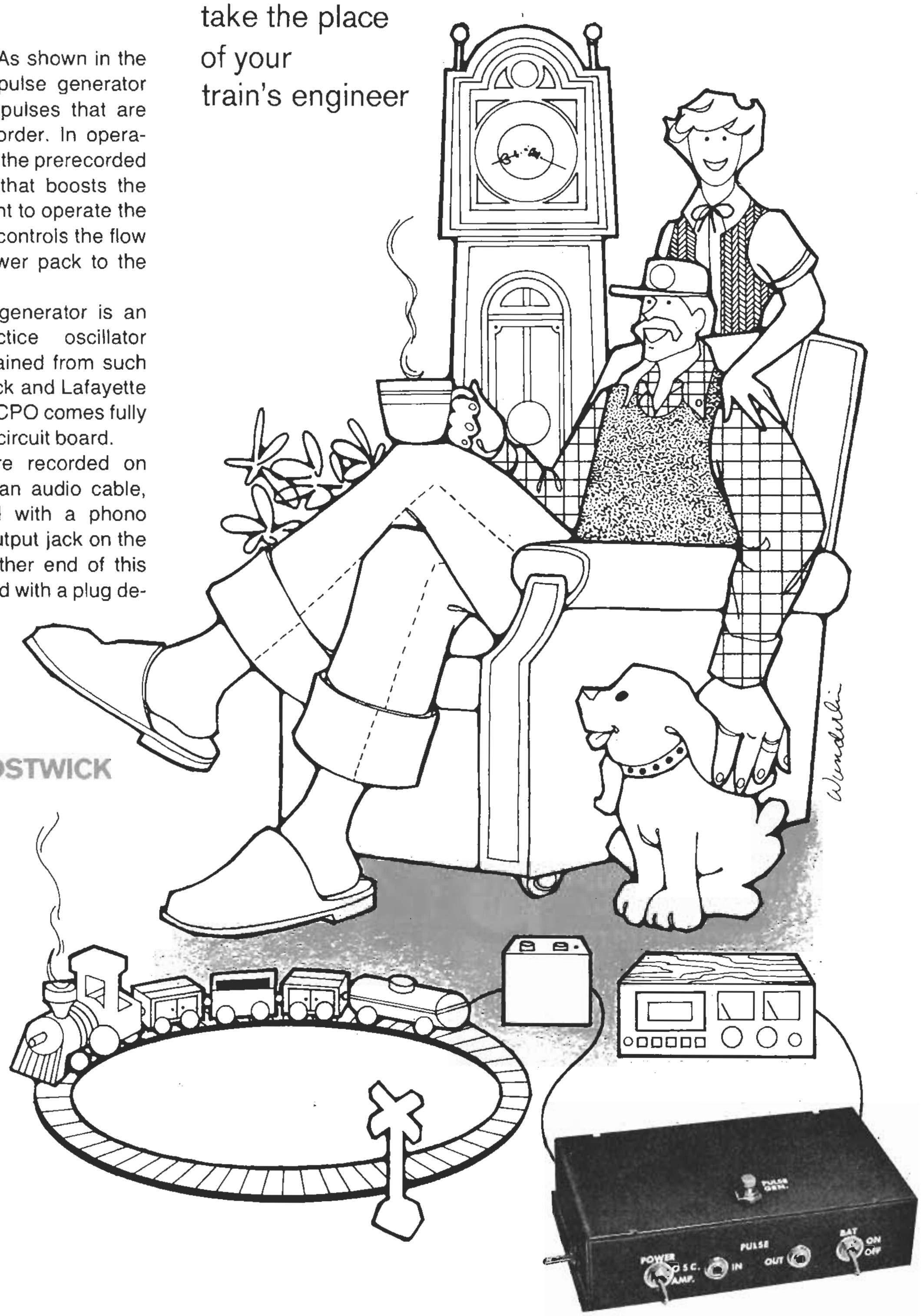
Control Your Model Railroad With Audio Tape

Let signals from a cassette tape take the place of your train's engineer



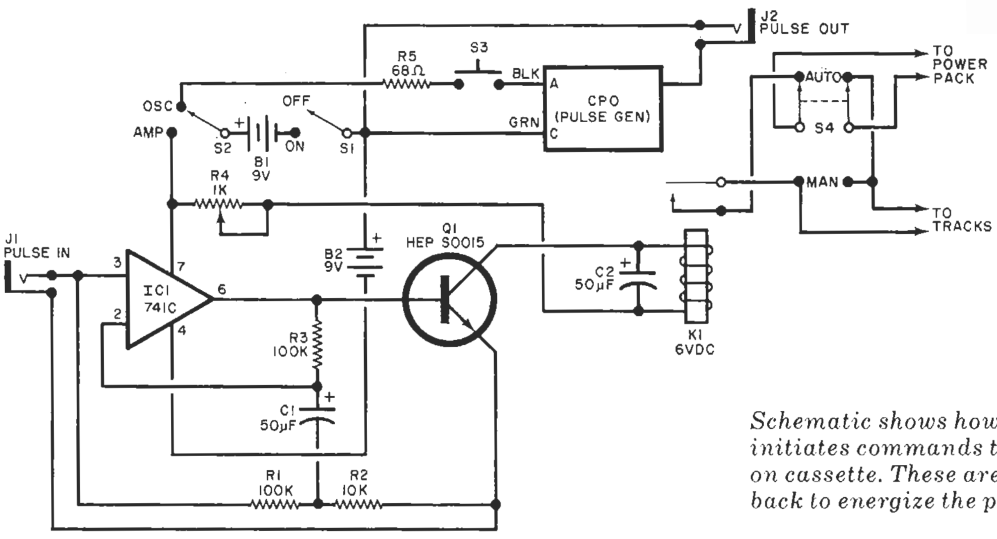
BY SPENCER BOSTWICK

IN RECENT YEARS, the cassette tape recorder has been used in a number of nonaudio applications. A good example of such use is as a mass-storage memory medium in a microcomputer system. Using a similar technique, the cassette recorder can be employed in model railroading. In the "Automatic Model-Railroad Engineer" described here, the cassette recorder serves as a storage system for timed "stop and go" commands. The approach is simple and inexpensive.

System Operation. As shown in the schematic diagram, a pulse generator initiates the command pulses that are fed into a cassette recorder. In operation, the recorder sends the prerecorded pulses to an amplifier that boosts the signal to a level sufficient to operate the relay. In turn, the relay controls the flow of current from the power pack to the model railroad's track.

The system's pulse generator is an inexpensive code-practice oscillator (CPO) that can be obtained from such suppliers as Radio Shack and Lafayette Radio Electronics. The CPO comes fully assembled on a printed circuit board.

Pulse commands are recorded on tape as follows. First, an audio cable, terminated at one end with a phono plug, connects to the output jack on the pulse generator. The other end of this cable must be terminated with a plug designed to mate with the auxiliary (AUX)



Schematic shows how pulse generator initiates commands that are recorded on cassette. These are later played back to energize the power relay.

PARTS LIST

B1,B2—9-volt battery
C1, C2—50μF, 15-volt electrolytic
IC1—741 operational amplifier
J1,J2—Miniature phone jack
K1—6-volt dc relay (Potter & Brumfield No. RS5D or similar)
Q1—HEP S0015 (Motorola) transistor
R1,R3—100,000-ohm, ¼-watt resistor
R2—10,000-ohm, ¼-watt resistor
R4—1000-ohm flat-mount pc potentiometer
R5—68-ohm, ½-watt resistor
S1,S2—Spst toggle switch
S3—Spst, normally open pushbutton switch
S4—Dpdt switch
Misc.—Printed circuit board or perforated board and solder clips for amplifier circuit; battery holders and connectors for B1 and B2 (2); code practice oscillator (Radio Shack No. 20-1155 or similar); suitable enclosure; patch cord; connectors for power pack and track (4); rubber grommets (2); spacers; machine hardware; hookup wire; solder; dry-transfer lettering kit; etc.

input jack on your cassette recorder. Then, with the recorder operating in the record mode, the pulse generator can be keyed on and off for the desired run and stop times.

Once the desired run and stop times are recorded on tape, the tape can be rewound and played back through an amplifier that energizes and deenergizes a relay. The relay's contacts open and close the output circuit from the model railroad's power pack to its track, timed according to the blank spaces and pulse trains recorded on the tape. Prerecorded programs can be as short or as long as the tape's running time.

The amplifier is built around dual high-gain operational amplifier *IC1*. The op amp drives conventional transistor amplifier *Q1* to develop enough current flow to operate relay *K1*. Two standard 9-volt batteries, *B1* and *B2*, provide power for *IC1*. One battery (*B2*) is also used to power the pulse generator (CPO) and relay *K1* through dropping resistor *R5* and potentiometer *R1*, respectively.

Construction. Both the pulse generator (CPO) and amplifier/relay circuits can be housed in a single compact box (see lead photo). Prepare the box by drilling ¼" (6.4-mm) holes as follows: four evenly spaced across the front of the box; two through the left side of the box; one through the rear of the box; and one through the top of the box. Locate the hole toward the front on the left side of the box well to the front but where it will not interfere with any other components. Also, locate the hole in the top well toward the front and midway between the front-panel center holes.

Deburr the holes and scrub the box with fine steel wool. When the box is completely dry, spray it with two or more coats of paint, allowing each coat to dry before applying the next. Allow the final coat to dry for at least eight hours. Then use a dry-transfer lettering kit to label the holes as follows: PULSE GEN. for the hole in the top; TO TRACK for the hole in the rear; MAN/AUTO for the front and POWER PACK for the rear holes in the left side; and POWER OSC/AMP, PULSE IN, PULSE OUT, and BAT ON/OFF for the holes in the front panel from left to right. (Note: Legends with slashes indicate al-

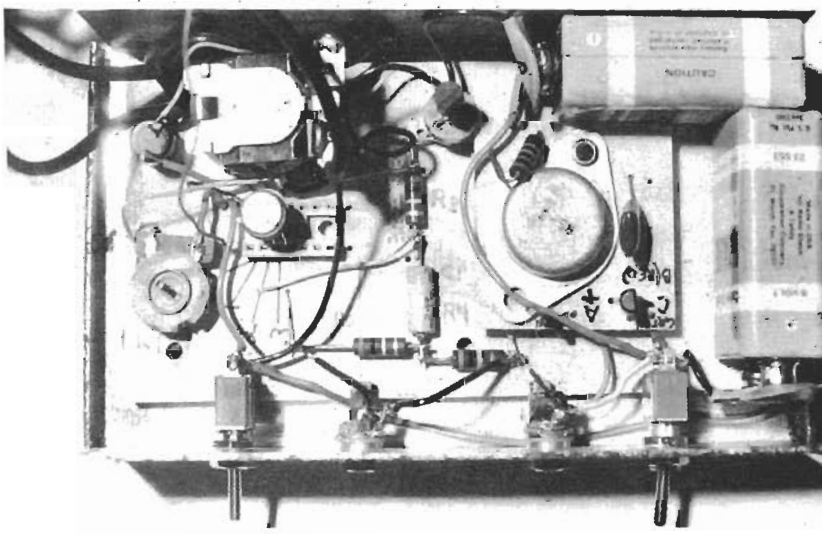


Photo shows layout and wiring of enclosure for the author's prototype Model Railroad Automatic Controller.

EVENT	PLACE	TIME	MIN. SEC.
START OF RUN	SMITH RIVER	00.00	00.00
RUN TO →	REDSTONE LIVESTOCK	00.08	00.08
HOLD	" "	00.10	00.18
RUN TO →	HENRY TOWN WATER TOWER	00.19	00.37
HOLD	" "	00.11	00.48
RUN TO →	ADOBE BRIDGE	00.12	1.00
HOLD	" "	00.11	1.11
RUN TO →	ALICE SPRINGS	00.20	1.31
HOLD	" "	00.10	1.41
RUN TO →	SMITH RIVER	00.20	2.01
END			

Typical timing chart for a train run lasting about two minutes.

ternate positions of the switch. For example: POWER OSC/AMP means that this switch applies power to the CPO in one position and to the amplifier/relay circuit in the other position, but not to both circuits simultaneously.)

Mount the switches and jacks in their respective holes. Line the TO TRACK and POWER PACK holes with rubber grommets to protect the wires that will exit the box through these holes from being cut through by bare metal. Take care to avoid damaging the lettered legends.

Using appropriate machine hardware and spacers, mount the CPO, amplifier/relay circuit, and battery holders in the box. Interconnect the various elements in the system with hookup wire and solder. Then carefully check your wiring and install the batteries.

Before you can put the Automatic Railroad Engineer into service, potentiometer *R1* must be properly adjusted. To do this, you will have to make a test tape. Connect one end of a patch cord to the PULSE OUT jack and the other end of the cord into the recorder's AUX (auxiliary) input jack. Place the recorder in the RECORD mode and turn up the volume to maximum. Now, press and hold the PULSE GEN switch for 10 seconds, release for another 10 seconds, and press and hold for a final 10 seconds. Rewind the tape to the start of the program.

Plug the patch cord into the remote-speaker output jack on the recorder and the PULSE IN jack on the Automatic Railroad Engineer and play the tape while observing the relay and with the POWER switch set to AMP. As the tape is playing, the relay's contacts should close, open, and then close again, each for a period of 10 seconds. If you do not observe this relay action, rewind the tape and play it again while adjusting *R1* for the proper response.

This completes test and adjustment. Assemble the Model Railroad Engineer's box and connect it into your model railroad system.

All Aboard. As you become familiar with the operation of the Automatic Model-Railroad Engineer, you will find that you can set up just about any combination of stop-and-go programs to suit any run, no matter how complex. Programs can be as long as you wish, up to the maximum length of time possible on a single side of a cassette tape. Now when you want a break, you can play a program cassette and sit back to drink your coffee and watch your model railroad run automatically. ◇

ELECTRONICS IN MODEL RAILWAYS

A profile of how electronics is applied to a hobby which is essentially scale modelling. By Peter J. Thorne.

"PLAYING WITH TRAINS" is probably how most readers would describe Model Railroading, the latter being the much preferred expression. Of course, there's a heck of a lot more who do just "play with trains". Names such as Hornby Dublo or Triang bring back memories of bygone youth to many an adult.

However, 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 is 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 analog 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 100ohm 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 hobbyists 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 there to anyway—looks like the circuit of Fig. 1. A simpler version shows on the lead photo. 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

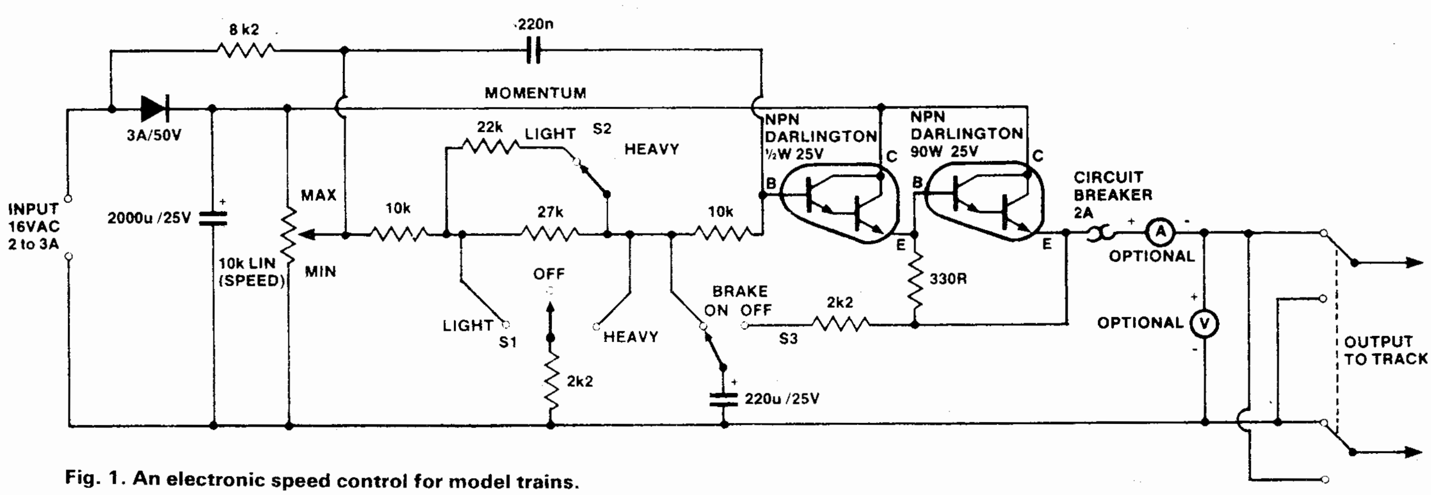


Fig. 1. An electronic speed control for model trains.

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-circuitproof 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 transisotrs, 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 be capable of about 2A5 at 12V. 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 (n for Nine mm, which is the track width) scale. Going up asize to O scale (1:48) many motors will need the full 2A5 . 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 £500 apiece and lately have been appreciating in value at well over 20%.

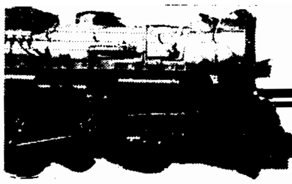
Signals

A natural for digital IC application is signaling. Model signals in two (red and green) or three aspect (red, yellow, green) with operating miniature 12V 60mA lamps are 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 2 to 20 feet 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 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".



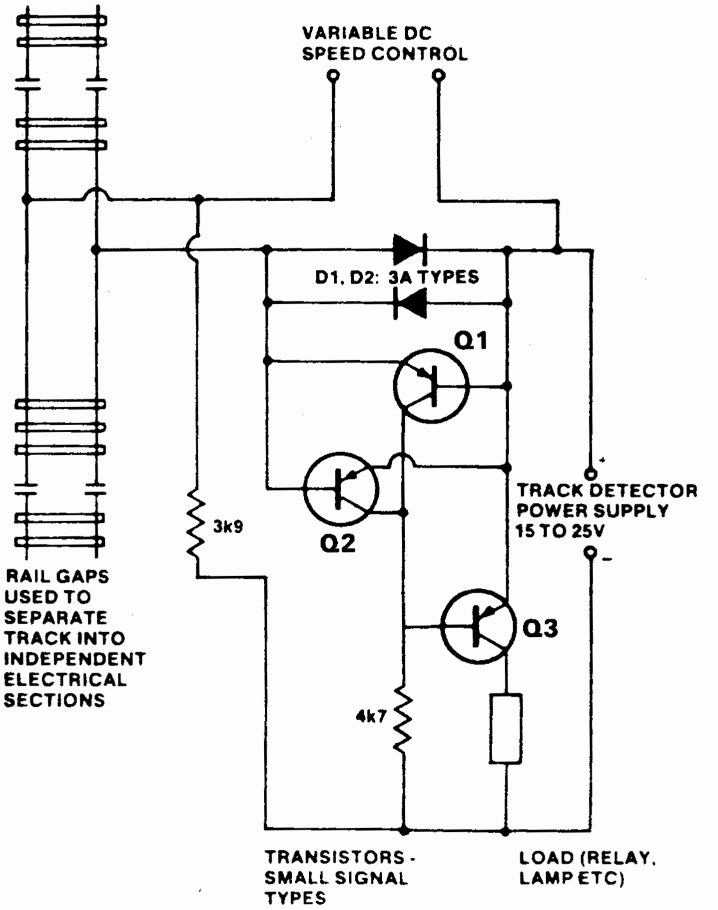


Fig. 2. Widely used "Twin T" track detector circuit. Q3's load de-energises whenever a resistance appears across track in the section being detected, regardless of whether power is connected to that track section. Consequently presence of any train or item of rolling stock can be sensed remotely.

The simple circuit is shown in Fig. 2. The circuit detects resistance between the rails as high as 50k, 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 10k to 47k 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.

All three track detection systems are, of course, suitable input interface for microprocessor control of signals . . . and track voltage, polarity, etc.

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 a 4 A. 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.

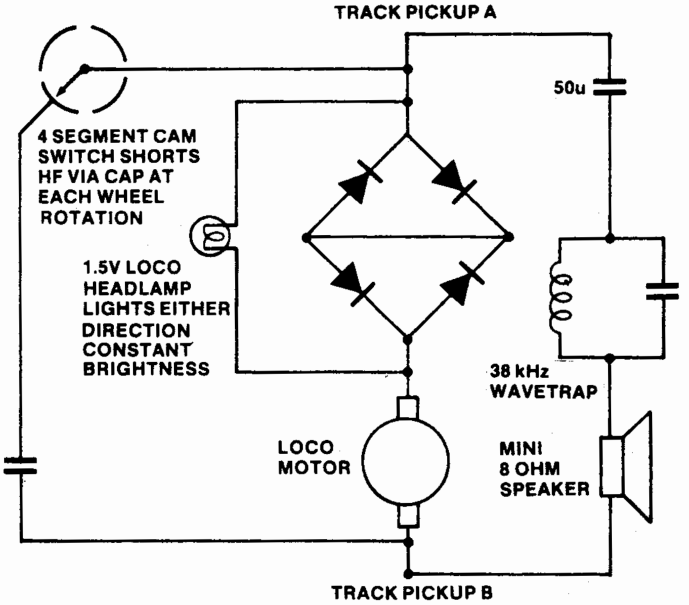


Fig. 3. These components, mounted in locomotive tender reproduces audio signals superimposed on DC motor voltage. Cam switch signals synchronization of "chuff" sound to trackside audio generator.

Typically a 220 u capacitor charged to 25 V stores enough energy to operate a couple of the 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, this basic control circuit is adaptable to TTL control.

Sound

Now you hi-fi fans know it's impossible to reproduce the sound of a gigantic steam locomotive without a 100 W amp and a 4 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.

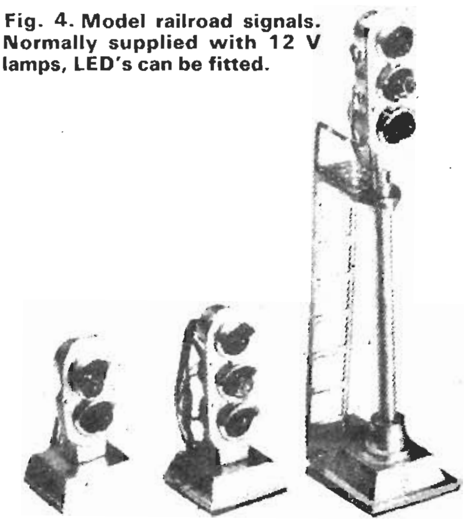


Fig. 4. Model railroad signals. Normally supplied with 12 V lamps, LED's can be fitted.

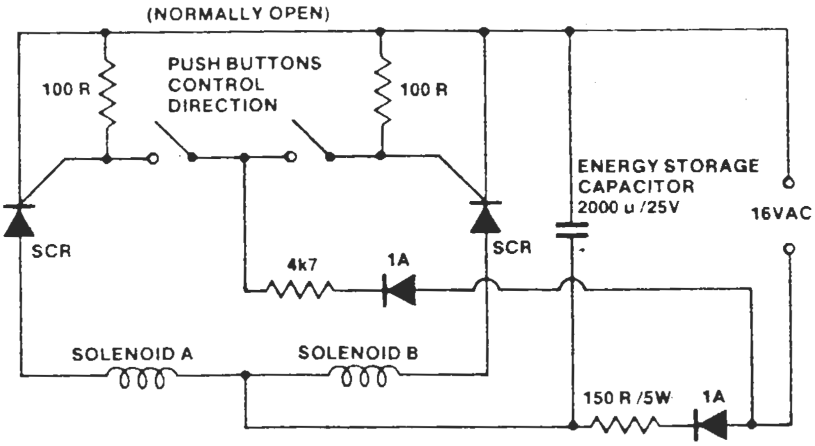


Fig. 5. Capacitor discharge system enables solenoids to be thrown with small average energy. System also prevents solenoid burnup if accidentally left powered-up. SCR switch control enables small current push buttons to switch heavy current. The SCR's automatically switch off when capacitor stored charge zeroes.

The PFM unit synchonizes 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 circit, which is a simplified version of the 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 phospor—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 2 inches 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 1V4 across the bridge, since it's in series with the motor—regardless of the motor/voltage polarity. Connect a miniature 1V5 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 3mm 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 0V5-3V, 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 on 555 IC timer, put one pair of lamps from IC output to + rail, another pair from output to-rail, apply 12 V, time at 20/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 rephased 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 220n 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. Taken to the ultimate, needed are very low current motors powered by rechargeable NiCd batteries together with the 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. Maybe I've tempted you to pop round to your nearest Model Railroad emporium. ETI