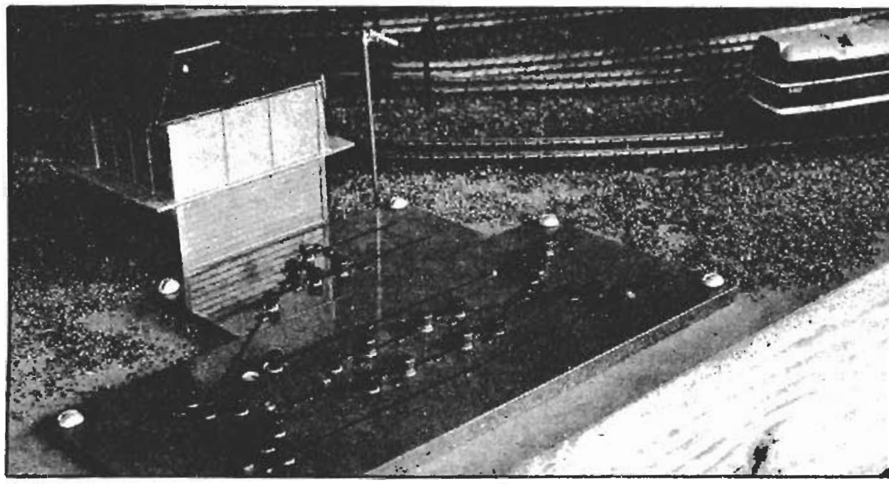
Model Railway Switch Controller

This project employs a capacitive discharge type power supply to drive the solenoid actuators in model railway turnout switchers. An add-on indicator unit can be used in conjunction with it to show which way turnouts are switched at any time.

by Jonathan Scott



Signal map. This shows a view of one of my signal maps with the switch pushbuttons and indicator LEDs installed.

THE IDEA of using a capacitive discharge supply to drive the solenoids in model railway turnout switchers is not new. Indeed, you can buy these at hobby shops for $20 or so, if you are not inclined to build one for yourself. However, this project incorporates refinements you may not have seen, along with a system of indicating the state of turnouts modelled after the fashion of the 'professional' signal box lighted map.

The capacitive discharge supplies bought 'over the counter', generally charge a capacitor of one to two thousand microfarads via a current limiting resistor from a rectifier and an AC source. This is quite adequate, but can be refined. If you charge the capacitor from a constant current source, it charges somewhat faster and one can provide an 'unready' indication while it's charging. The little extra speed one gains in charging is handy as several switches often need to be changed in a short space of time and one's fingers dance from button to button when doing so.

With either system, the current limiting arrangement protects the solenoids against burnout if the supply happens to be accidentally connected indefinitely. The simpler system almost invariably incinerates something if you get a short somewhere.

The idea behind the capacitive discharge method is simply that the switch changes in the first hundred milliseconds or so; any other power delivered is wasted. The high momentary current capability of a capacitor means that the solenoid always moves quickly. When you connect the charged capacitor to the switch solenoid, it will deliver a very high current which rapidly subsides to nothing or, at worst, the charge current which can be much less than the current required to actuate the solenoid. Thus, the solenoid remains cool even if connected (by some accident or other) indefinitely, avoiding burnout of the solenoid.

The outline of a capacitive discharge supply is shown in Figure 1, along with the outline of a 'remote point indicator', or 'remoter'.

The remoter is simply a 'memory' circuit which records which way the switch was last changed. I used a simple flip-flop for this. Two LEDs or lamps are used to indicate the switch's condition. These may be built into a signal map panel. This is basically just a line diagram of a track layout, or part thereof, with lights and switches in the symbollic positions of the actual switches on the track layout. Train signal lights are also usually included on the map along with train position sensors, if used.

There is, of course, no need to have remoters. They are purely conveniences, rather than necessary functional items. Remoters are primarily important if you wish to have a layout which is as much like the 'real' thing as possible. However, for the few dollars or so extra cost each, they add a very pleasing touch of realism.

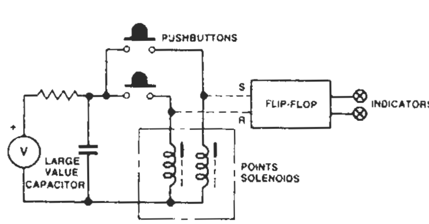


Fig. 1 The controller indicators scheme.

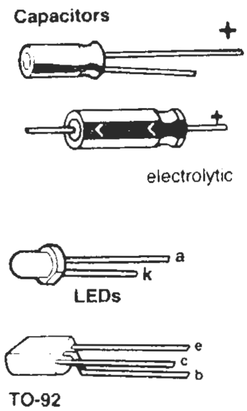
You can have any number of turnouts in your layout and you'll only need one capacitive discharge supply unit. The one described can easily drive three turnouts simultaneously if you need to operate some of them together. One remoter is needed for each set of turnouts.

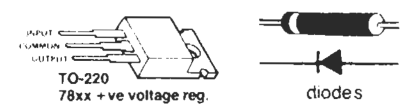
Construction

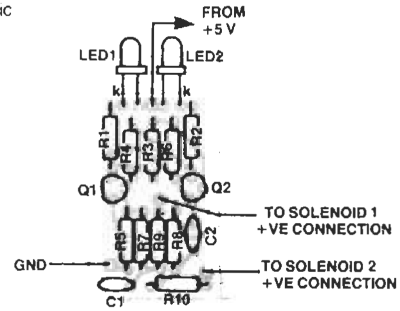
Construction is relatively brief. The only part we can really cover here is the assembly of the pc boards and with the usual exhortation "assemble the boards according to the overlays," it's nearly all over!

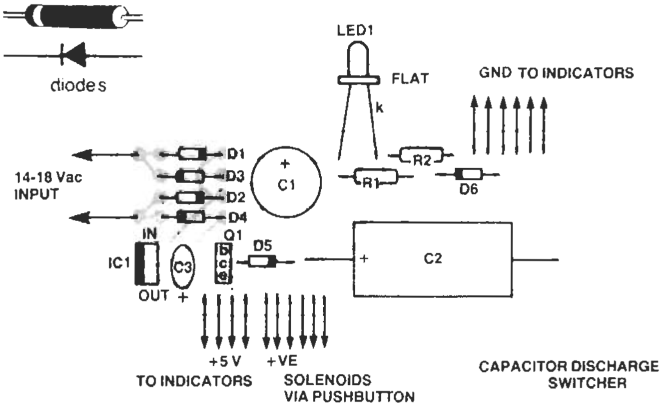
There are two pc boards: the capacitive discharge supply, and the other is for remoters. Let us take the supply board first. It is easiest to mount the diodes and resistors first, then Q1 and IC1, followed by the capacitors. Take care with the orientation of the diodes and transistors as well as C1 and C2. Note that Q1 and IC1 should have heatsinks attached. You can make these from a scrap of aluminum; each heatsink should be at least 25 sq. cm in area. They can be bolted straight to the face of each device, but don't forget to smear on thermal compound first.

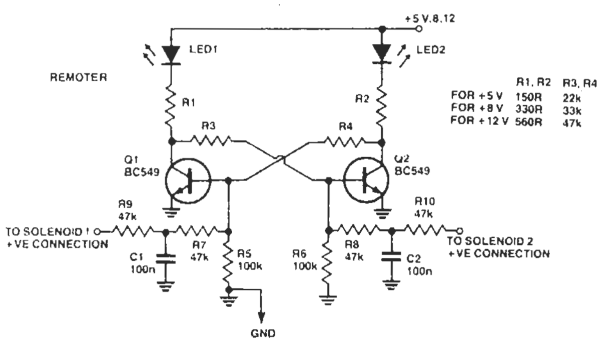
You may or may not wish to mount the 'charging' LED (LED1) off the board; such as on the front panel of your controller, for example. This is a good idea if other perople are using your layout, as it helps them allow for the necessary delay

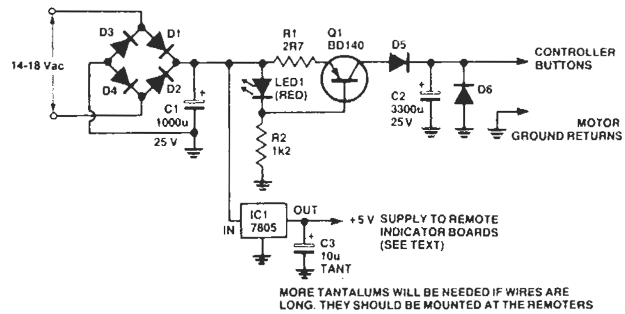












REMOTERS PARTS LIST

Resistors

R1,R2	see text, circuit
R3,R4	see text, circuit
R5,R6	100k
R7,8,9,10	47k

Capacitors

C1,C2	100n

Semiconductors

LED1	TIL220Y yellow LED
LED2	TIL220G green LED
Q1,Q2	2N3904 or equiv.

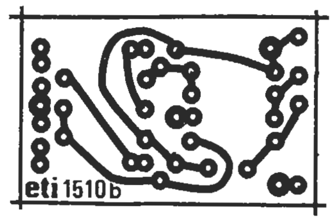
Miscellaneous

pc board; hookup wire, etc.

between switching operation of about half a second or so. Make sure you wire in LED1 the right way around.

The remoter board is quite straightforward. Best way to tackle this one is to mount the resistors and capacitors first. Then mount the two transistors making sure you get them the right way around. Finally, mount the two LEDs. Leave their leads long as the board can actually 'hang' from them. Alternatively, the LEDs may be mounted off the board and the board mounted somewhere conveniently nearby.

I secured my board to the underside of the model railway baseboard with staples from a staple gun holding down the wires to and from the units. The capacitive discharge supply was actually mounted at right angles to the baseboard. The remoters were held flat on the baseboard by stapling the wires fairly



close to the pc board. This arrangement has proved entirely satisfactory.

Trying Out

The supply board can be tried out first. Hook up the input to an AC source of between 14 and 18 volts. On switch-on, LED1 should light, then extinguish about a second later. If not, check that it's connected the right way around. If that's OK, check that you're getting about 1½ times the AC input voltage across C1 (between 20 and 25 V DC or so should appear across it). If not, switch off and check the diodes D1 to D4 are all correctly oriented. Correct any faults as you go. When you've got LED1 to light on switch-on, then check that the output of IC1 is +5 V. Measure the voltage across C2. It should be equal, or nearly so, to the voltage on Q1. If LED1 won't go out, or there's less than one volt across C2, odds are you've got D6 the wrong way round.

Temporarily hook up the supply to a switch solenoid and see that it operates as expected.

You can check out the remoter(s) by temporarily connecting it to the +5 V

SUPPLY PARTS LIST

Resistors (all ½W, 5%)

R1	2R7
R2	1k2

Capacitors

C1	1000u/25 V electro.
C2	3300u/25 V axial electro.
C3	10u/6 V tant.

Semiconductors

D1-D6	1N4001/2/3/4 etc.
LED1	TIL220R red LED or equiv.
IC1	7805
Q1	1A 50 V PNP, 2N4920 or equiv.

Miscellaneous

pc board; hookup wire, etc.

from the supply board. One or other of the LEDs will light. Say, LED2 on the remoter lights. Connect the 'SOLENOID 1' input momentarily to the positive terminal of C2 on the supply, LED1 should light and LED2 should extinguish. If not, check transistor and LED orientations. If this works, then temporarily connect the 'SOLENOID 2' input to the positive terminal of C2 and the LEDs should swap over.

When wiring in the remoters, it may be necessary to add some extra supply bypassing to prevent random toggling of the LED indicators. Add a tantalum with a value between 4u7 and 10u. You'll need one of these per extra metre of cable length if the cable is a metre long or more.

Wiring Multiple Switches

Invariably, you will want to install multiple sets of switches, some of which operate alone, some of which may need to operate together. There are two wiring options which exist and which may prove useful if you have not seen them before.

It often happens that two switches will always need to be switched together. These can be wired directly in parallel and operated by only two pushbuttons. The capacitive discharge supply described, should drive such an arrangement easily, without the need to increase the value of the discharge capacitor (C2). The 3300u capacitor specified would easily and reliably operate three parallel switches in my layout. If you need to drive more, then the capacitor's value can be increased (try 4700u). Conversely, you can decrease the capacitor's value if you find your solenoids are light ones and/or don't have parallel operated switches. Don't forget that if you increase the capacitor's value, you'll increase the charging time. If you decrease it, charging time speeds up.

Sometimes there is a need to have one set of switches 'slaved' from another, but have the first set operated independently also. This is readily achieved by the inclusion of some simple diode logic. A diode with its anode connected to one solenoid and its cathode connected to another, will leave the first turnout unaffected by the second when switched, but will ensure that when the first is switched, the second also operates. This can be implemented with ordinary silicon rectifier diodes such as EM401s, 1N4001s, etc.

The various wiring arrangements are illustrated in Figure 2.

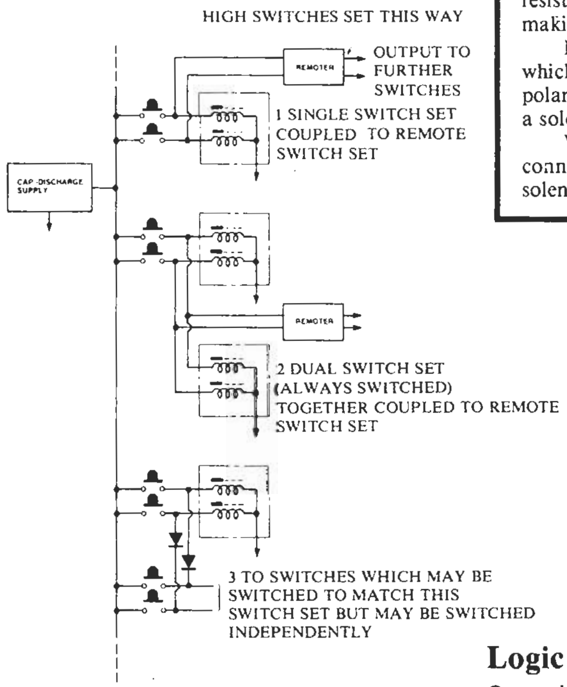


Fig. 2. Showing the three fundamental schemes for wiring switches.

Logic Output

One advantage of remoters is that they can output the state of a switch set as logic levels for feeding into a digital system or computer. Astute readers will have noticed a certain provision in these model railway projects for a computer interface. The collectors of the transistors in each remoter circuit give a 'low' voltage when the respective side is that one carrying the traffic. For a 5 V supply, the levels are TTL. This is the main reason that the remoters are run from a carefully regulated supply, apart from a desire to keep LED illumination level fairly constant. For those needing CMOS or other levels, the resistor values for 8 V and 12 V supplies are shown on the diagrams. (R1-2 and R3-4 will vary.)

Coupled with position sensing systems, the remoters can allow a simple anticrash logic system to be hardware implemented! **ETI**

HOW IT WORKS

There are two distinct parts to the project: the first is a capacitor discharge supply used to operate the switch solenoids, the second is a remote indicator unit.

The capacitor discharge supply unit charges a capacitor which is then discharged into the switch solenoid, which then operates the switches. This unit is capable of changing one switch every half second or so, and can power a larger number of switches together.

The remote indicator unit, or 'remoter', has the job of 'remembering' which way the switch set was last switched and indicates the direction with a pair of LEDs mounted as part of a signal map.

Consider the capacitor discharge unit. Diodes D1-D4 rectify the 14-18 volt AC input to provide a DC supply capacitor C1 smooths this for IC1, which regulates the voltage supply for the remoters. Up to fifteen remoters can be run off the output of IC1.

Transistor Q1 and surrounding components form a current source which charges C2 via D5. LED1 forms the voltage reference and doubles as an indicator which illuminates for the time when the capacitor is being recharged after use. Diode D5 prevents reverse biasing of the transistor when C2 is charged and C1 is below the peak input voltage value.

Using a current source for the charging element, removes the need for a large series resistor and speeds up recharging as well as making the system short-circuit proof.

Diode D6 is a "freewheel" diode which prevents possible reversing of the polarization of C2 by the flyback voltage of a solenoid.

When a button is pressed, making a connection from the output of the unit to a solenoid, C2 discharges into the coil, changing the switch. After C2 is discharged, the only current flowing through the coil is the recharge current of about 375 mA. When the button isolates the solenoid, the current is free to charge C2, which takes about a quarter of a second. When C2 reaches the input voltage, Q1 saturates, LED1 goes out, and the unit is ready to operate again.

The 375 mA charging current is insufficient to harm a solenoid if it is left connected for any reason. As the controller can withstand indefinite shorting itself, the whole system is protected against abuse and failure of switches, etc.

Each remoter consists of an R/S type flip-flop formed by two transistors. Assume initially that Q1 is on, and Q2 off. The collector current of Q1, via R1, illuminates LED1, and the saturation collector voltage of Q1 ensures that Q2 remains off.

When a solenoid is activated by the discharge of the capacitor, a large voltage spike appears across it. Suppose that the voltage across the coil appears on R10. Capacitor C2 filters out brief induced spikes, so that no signal other than the correct one can affect the circuit. When the longer duration discharge pulses appear on R10, some current reaches the base of Q2, turning it on. This turns on LED2 via R2 and removes the base drive from Q1, and it turns off. Thus LED1 goes out, and the collector voltage on Q1 keeps Q2 turned on via R3. The reverse operation occurs when a pulse appears on R9.

Transistors are used rather than an IC as they have a higher output drive, are less intolerant of supply voltages, and ICs normally have more than one flip-flop in each package and you waste the rest.