Railroad Signal Lights

The right lights for your layout, by C.K. Jones.

THE ELECTRONICS of the system consist of two circuit modules. The basic Track Module controls one set of signal lights for one section of track; it responds to the location of the train and the settings of any points, level crossings etc in that section of track. The second module is a Junction Module, required to drive the white lights of a branch line indicator and to control the Track Modules on either side of the junction.

For the signal lights, it is easy to use Light Emitting Diodes (LEDs) which, conveniently, are available in red, yellow (amber) and green. There are several methods that can be used to detect the position of a train; one of the simplest and most reliable is to use small bar magnets attached under the locomotives at axle height, and magnetically operated reed switches positioned on the track between the rails. Model points do not usually provide a signal suitable for driving the circuits but, with a little ingenuity, microswitches can be attached to the points to give suitable inputs to the modules.

The Track Module

The circuit diagram of Figure 1 is for a single Track Module; a model layout will need one of these for each set of lights. The circuit itself is quite simple (though as we shall see, the interaction of two or more modules becomes slightly more complicated!). the 'brain' of the circuit is the bistable flip-flop consisting of NAND gates IC1c and IC1d (truth tables for both NAND and NOR gates are shown in Table 1 Switches SW2 and SW3 are the magnetic reed switches which close momentarily when the locomotive passes over them.

When SW2 closes, pin 5 of IC1c is taken to 0V (logic 0 or 'low') for just a moment, so that the output at pin 6 goes high (logic 1, +5V). This high is coupled to pin 2 of IC1d and, since its pin 1 input is already helf high through R6 and R7, pin 3 goes low. This is coupled back to the other input of IC1c at pin 4, ensuring that output stays high. Thus the momentary low on pin 5 is 'latched' by the flip-flop and it will maintain this state, which indicates that there is a trian in the section controlled by the module.

When the train leaves the section of track, SW3 closes and pin 1 of IC1d goes low for a moment; this is coupled to pin 4 of IC1c and, since pin 5 in being held high through R4, R5, the output at pin 6 goes low. This is fed back to the pin 2 input, maintaining the high output on pin 3. So, the new state is latched in and this indicates to the following circuitry that the train has cleared the section.

If the flip-flop is the brain of the circuit, the quad-input NOR gate IC2 is its 'heart'. Its output at pin 8 directly drives the red signal light, LED3, and indirectly controls the other two lights. As shown in Figure 1, two of the inputs are wired directly to 0V, one to 0V via the normally closed points switch SW1, and the fourth is connected to the pin 6 output of the flip-flop. When all four inputs are low, the output will be high and the LED is

INPUTS		OUTPUT
A	B	$\overline{A \cdot B}$
0	0	1
1	0	1
0	1	1
1	1	0

NAND
OUTPUT = NOT (A AND B)

INPUTS		OUTPUT
A	B	$\overline{A+B}$
0	0	1
1	0	0
0	1	0
1	1	0

NOR
OUTPUT = NOT (A OR B)

Table 1. Truth tables for NAND and NOR gates.

biased off, with +5V on both the anode and cathode. However, when the flip-flop is triggered by a train entering the section, pin 9 of IC2 goes high, pin 8 goes low and LED3 turns on. The result is the same if SW1 is opened (indicating that the points are set against an oncoming train), since the internal circuit of the TTL gate puts a high on any open circuit input.

If the section of track monitored by a module does not contain a set of points, them terminal 2 should also be wired to 0V. The other two inputs, at module terminals 3 and 4, are available for other switch functions within a section of track, eg for level crossing indication, etc.

Keeping Track

To understand how the remainder of the circuit works, it is easier to look at the interaction between several modules, controlling two or more sections of line, and to trace the logic sequence as a train passes through. The composite circuit diagram of Figure 2 shows the internal circuit of the module controlling Section 2 of a length of line, together with the outlines and terminals of the adjacent modules. The internal circuit has been simplified by drawing the flip-flop as a block with SET

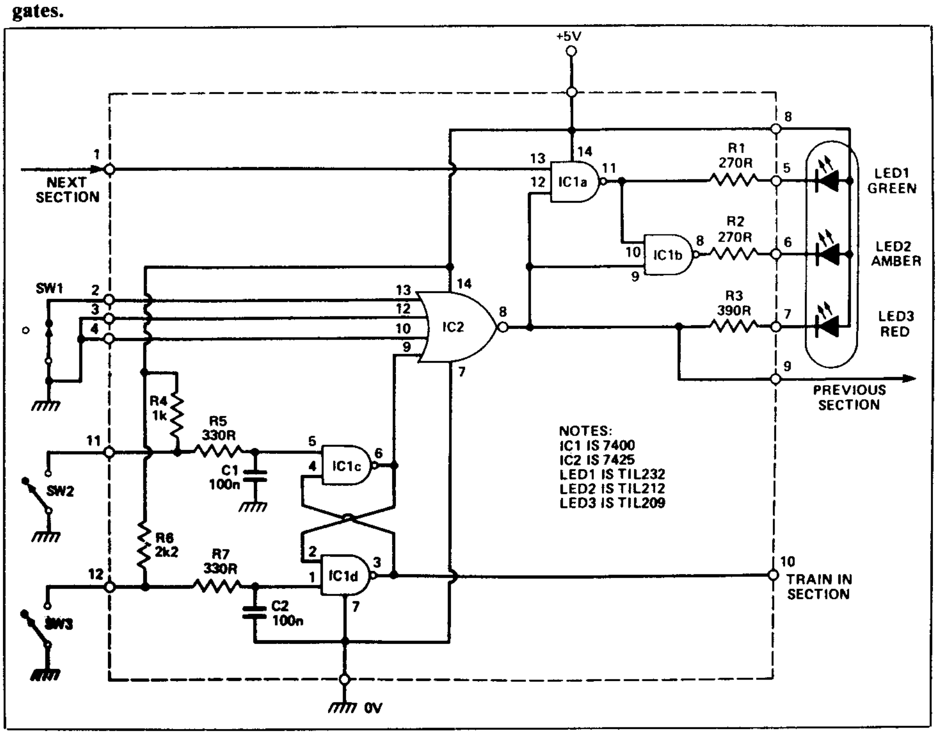


Figure 1. Circuit diagram of the Track Module

and RESET inputs, and Q and Q outputs, in standard notation; however, its operation is exactly as described earlier. The timing diagram, Figure 3, will be helpful in tracing the action of the sequential logic.

We should establish the starting conditions. After a power-on reset, all inputs to IC2 are low and the red LED is turned off. The output from Module 2 terminal 9 is a high, indicating that the section is clear. Similarly, the terminal 9 output from Module 3 is high. Therefore, the inputs to NAND gate IC1a are both high; its output will be a low and the green light, LED1, turned on. The gate IC1b has a high input from IC2 and a low from IC1a so its output will be high and the amber light, LED2, is turned off. The logic conditions are the same for Modules 1 and 3.

Junction Module

The function of the second circuit module is to control the signal lights indicating a branch leaving the main line, and to connect the Track Modules on either side of the junction, according to the setting of the points. The composite diagram, Figure 4, shows the internal circuit of a junction module and its connections to the Track Modules. It is most easily understood with the aid of the timing diagram Figure 5, which traces the logic sequence of trains passing through the junction, and with the truth tables of the NAND and NOR gates.

We can assume, at the start, that all signals are showing green, ie, all Track Modules are in their reset condition, and that the points are set for a straight-through run. The inputs and outputs of the Junction Module are as follows: the inputs to IC2d are a high (since TS1 is open) and a low (from PS1, which is closed); therefore its output is high and the branch lights are turned off.

Normally, in a straight section of track, Module 1 is reset by the train passing over TS2; in this case, however, it is reset via the Junction Module. When TS2 closes, it takes one input of IC2a low for a moment, forcing the output to go high. With both its inputs high, IC2c will go low, providing the reset pulse to terminal 12 of Modul 1 and turning off the red LED of L1.

The train now moves through Section 1 and takes the branch line, which we have called Section 3. As it does, TS3 closes, turning L3 to red and putting a low on one input of IC2b, so that its output is forced high. The other input of IC2c is being held high by PS1, via ICs 1d and 2a, therfore IC2c will go low, putting a reset pulse on terminal 12 of Module 1 and turning off its red LED. Simultaneously, terminal 9 of Module 3 has gone low; IC1c now has two low inputs (the other is held low by

PARTS LIST

Track Module

RESISTORS (All 1/4 watt 5% carbon)	
R1,2	270R
R3	390R
R4	1k
R6	2k2
R5,7	330R
CAPACITORS	
C1,2	100n C280 polyester
SEMICONDUCTORS	
IC1	7400 TTL quad 2-input NAND
IC2	7425 TTL dual 4-input NOR
LED1	TIL232 green 0.2" LED
LED2	TIL212 orange 0.2" LED
LED3	TIL209 red red 0.2" LED
MISCELLANEOUS	
SW1	SPST switch track switch-see text
SW2	SPST switch points switch-see text

PCB; signal stands (see text); wire solder etc.

Junciton Module

RESISTORS (All 1/4 watt 5% carbon)	
R1	1k
SEMICONDUCTORS	
IC1	7402 TTL quad 2-input NOR
IC2	7400 TTL quad 2-input NAND
MISCELLANEOUS	
SW1	SPST switch points switch-see text

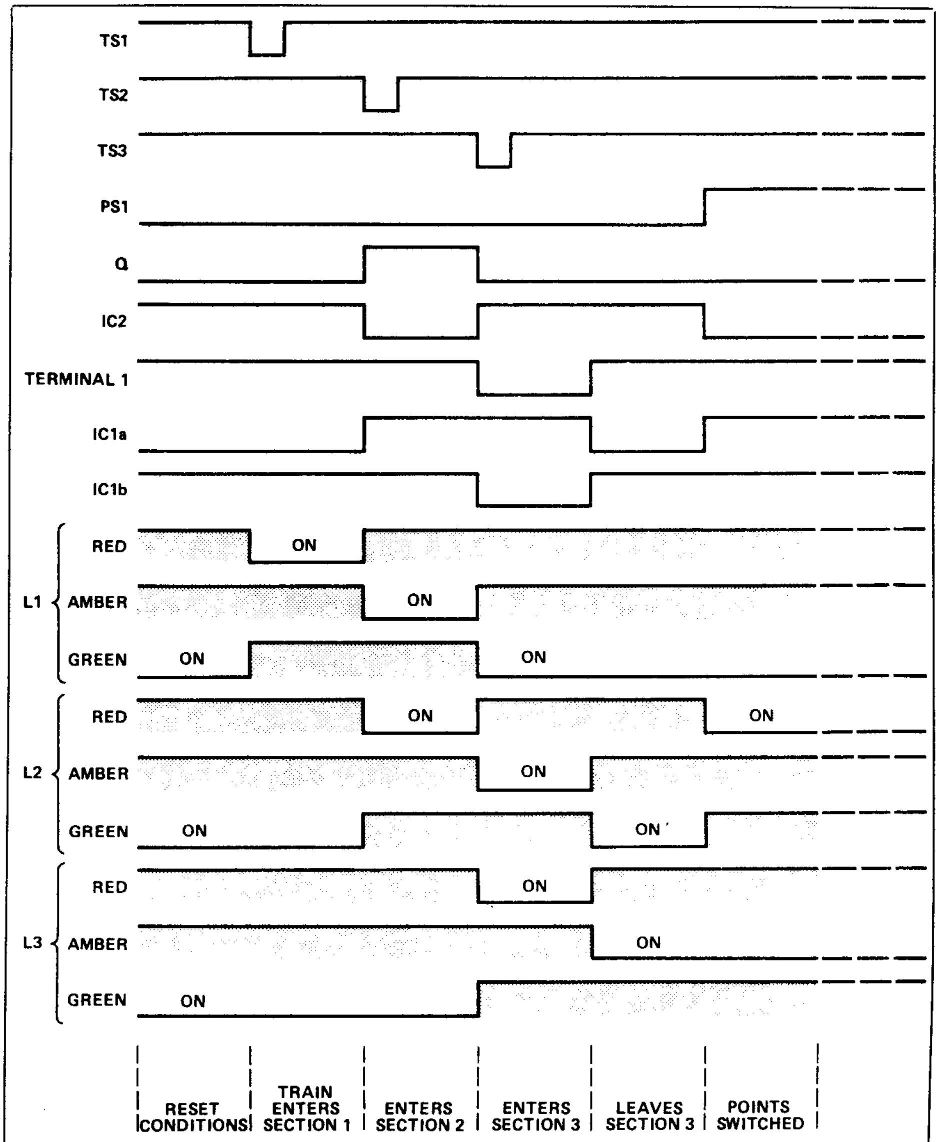


Figure 3. Timing diagram for "Keeping Track".

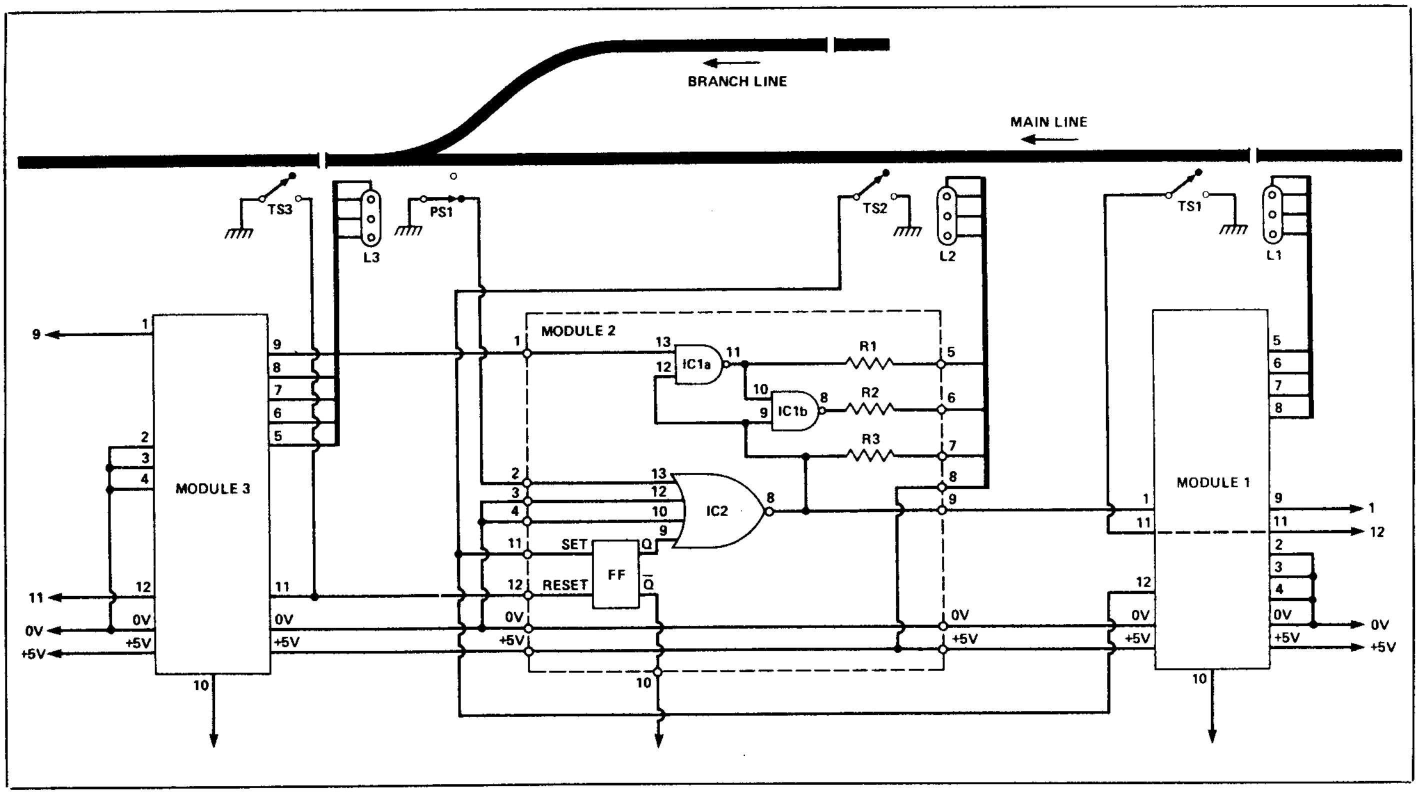


Figure 2. Combines Module circuit and track layout diagram; note that the flip-flop has been drawn here in standard 'block' form.

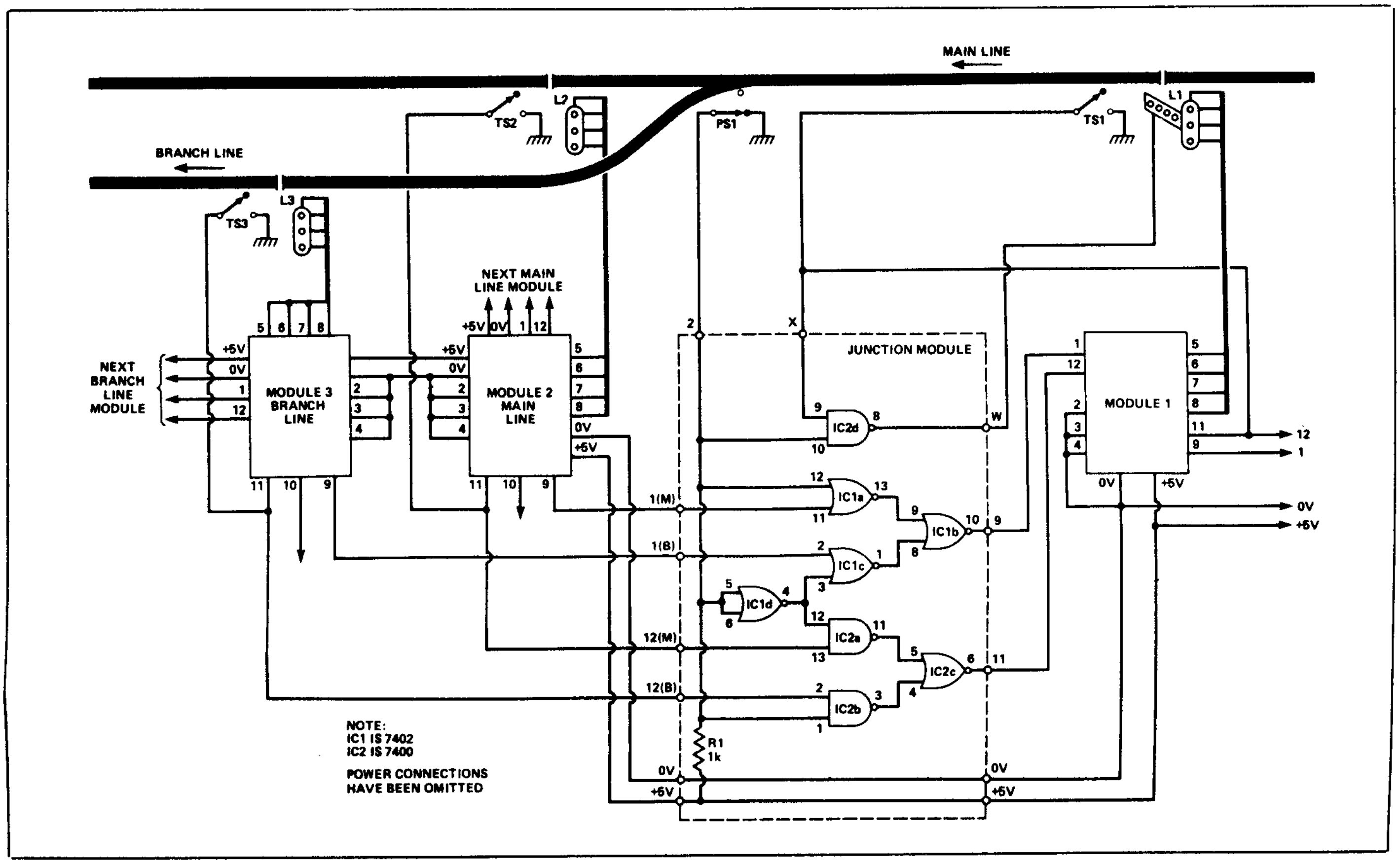


Figure 4. Combined Junction Module circuit and track layout diagram.

PS1 via IC1d), so its output goes high, forcing IC1b high and thus turning on the amber LED in L1 via Module 1.

A similar sequence of logic will set L1 to green when the train finally clears Section 3. The timing diagram, Figure 5, shows this sequence as well as that which results when the points are reset.

These circuits, although very simple by themselves, can be quite complicated in their interactions, as we have just seen! Everything depends on the timing of the various switch closures, together with the conditions which resulted from the last operation. Timing diagrams are essential for understanding circuits of this kind.

In fact, if the timing of the switch closures (which trigger the logic changes resulting in the appropriate signal lights) are not correct, the system will not produce the right results. The track switches must be positioned very carefully, at the start of each section of line, to produce the desired signals. Another small trap, which should not normally be of any bother, is that a set of points cannot be changed until the train has cleared the section controlled by the branch indicator. In other words, the points cannot be set for the branch line, in our example, until the train has cleared Section 2. Otherwise the amber light on L1 will not clear.

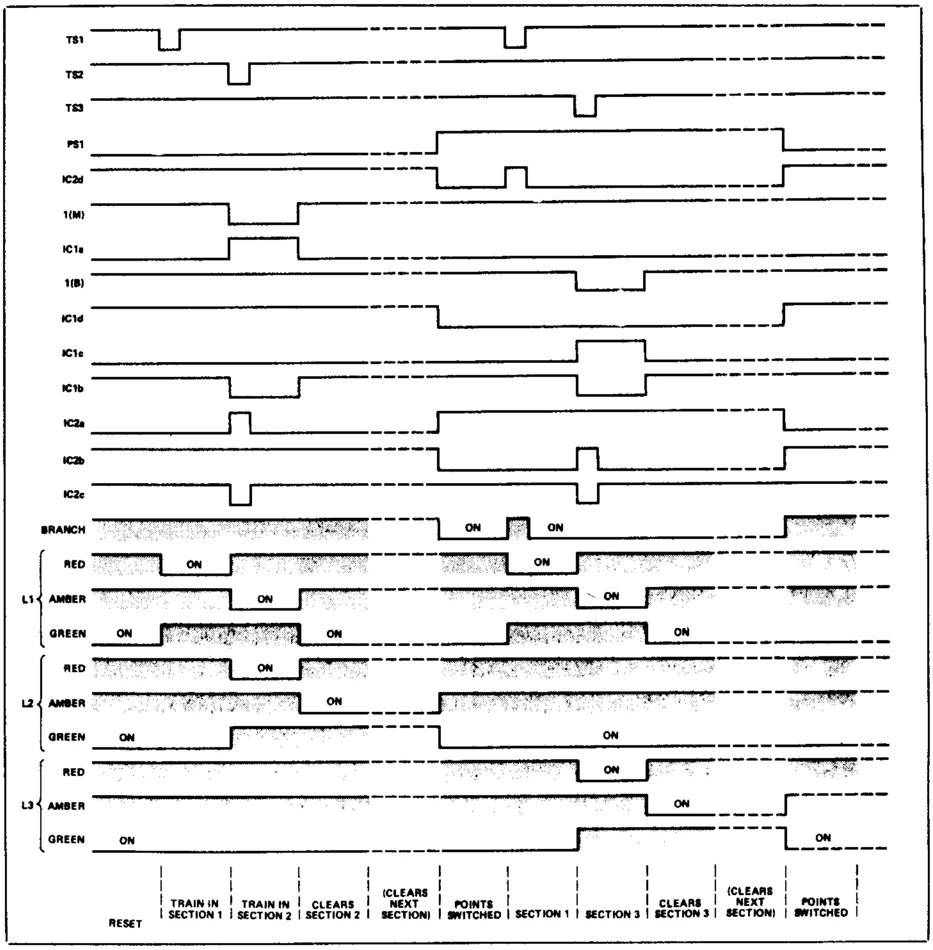
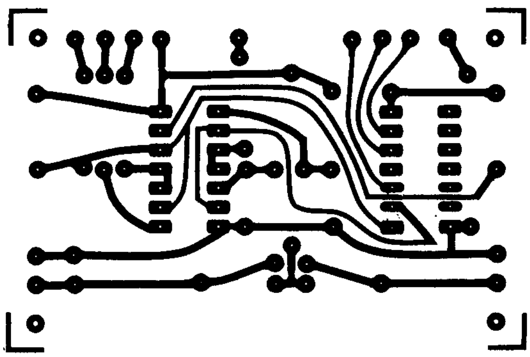


Figure 5. timing diagram for tracing the Junction Module operation.

Construction and Layout

The component overlay diagrams for a Track Module and for a Junction Module are shown in Figures 6 and 7, respectively. Full sized PCB patterns are reproduced on the PCB Printout page.

The construction is quite straighforward and should not give any difficulty. The ICs are all TTL, so no special handling procedures are needed except for normal care not to overheat them or bend the pins. The composite circuit diagrams, Figures 2 and 4, should be used as a guide to positioning the track switches and signal stands. The modules are most conveniently mounted under the track layout and connected together, as shown in Figures 2 and 4, by lengths of four-way ribbon or multicore cable. The connections to the signal lights can also be made with four-way cable.



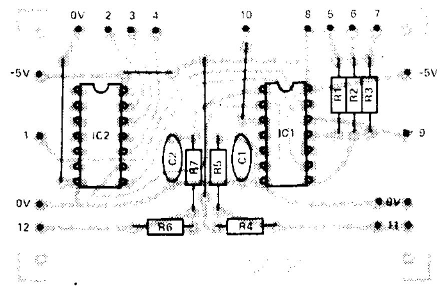


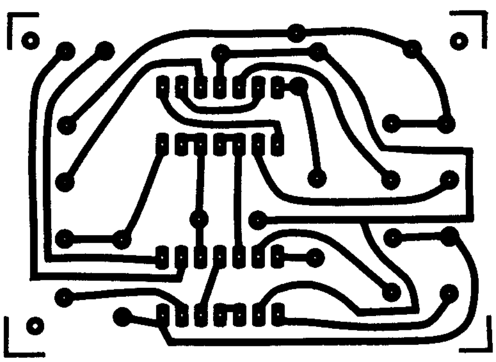
Figure 6. Component overlay for the Track Module.

Power Supply

All the circuit modules are powered from +5V, which can easily be derived using a three-terminal 5V regulator. Each module will draw approximately 50 mA, so the source must have the capability to supply this current, times as many modules are there are in the layout.

Signal Posts

As for the signal posts, we leave this up to the ingenuity of the individual instructor. They can be fashioned out of anything resembling a signal post and the LEDs should be wired using color-coded wire to avoid confusion.



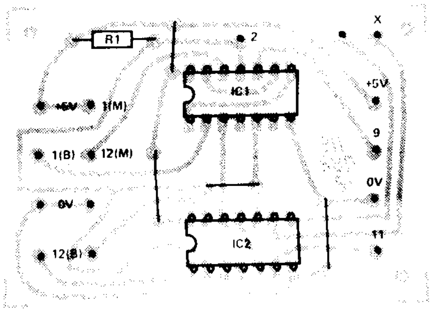


Figure 7. Component overlay for the Junction Module.

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