Special Constructional Feature

USING THE LM3914-6 L.E.D. BARGRAPH DRIVERS

RAYMOND HAIGH

Getting to grips with this versatile family of l.e.d. and bargraph driver i.c.s couldn't be easier. We include practical circuits and a multi-purpose p.c.b. set that will turn ten l.e.d.s into a robust, easily read, voltage display – and more!

WHEN something more robust, or more easily read, than a moving coil meter is needed, one of the LM3914-6 family of dot- or bargraph drivers and an l.e.d. display will usually provide a solution.

Manufactured by National Semiconductors, this "family'' of chips (three) is extremely versatile. A single resistor and ten l.e.d.s are the only extra components required to produce a basic voltmeter or signal-strength meter. Two or three more resistors enable sensitivity to be adjusted, or the range expanded until a small, but critical, voltage change fills the entire display.

INTERNAL STRUCTURE

The internal arrangement of the LM3914 i.c. is shown in Fig.1.

The Comparators

At the heart of the device is a chain of ten resistors which set the bias on ten comparators so that l.e.d.s are switched on sequentially as the input voltage rises. The LM3914, 5 and 6 are identical apart from the values of the resistors in the voltage divider chain.

In the LM3914 the resistors have equal values to produce the *linear* response required for voltmeter applications. The resistors in the LM3915 are scaled *logarithmically*, and span 0dB to 30dB in ten 3dB steps, making this version suitable for signal-strength and power meters. The resistors in the LM3916 are related in a *semi-log* fashion to simulate a VU meter.

Input Buffer

A high input impedance buffer stage minimises loading on the circuit under measurement. The stage is protected against reverse polarity inputs by a shunt connected diode, and up to 35V can be applied to input pin 5 before any damage occurs.

This can be increased to 100V by placing a 39 kilohms resistor in series with the input. Pin 5 *must* be connected to the 0V rail via a resistor of not more than 100 kilohms ohms or l.e.d. 10 will lock on.

Reference Voltage

Although the ends of the resistor chain can be connected to external reference voltages, it is generally more convenient to use the reference produced within the i.c. Typically 1·25V (it can vary from 1·2V to 1·34V), it is brought out at pins 7 and 8.

The voltage at pin 7 (Reference Out) can be increased to a maximum of 12V by connecting pin 8 (Ref. Adj.) to the 0V rail via

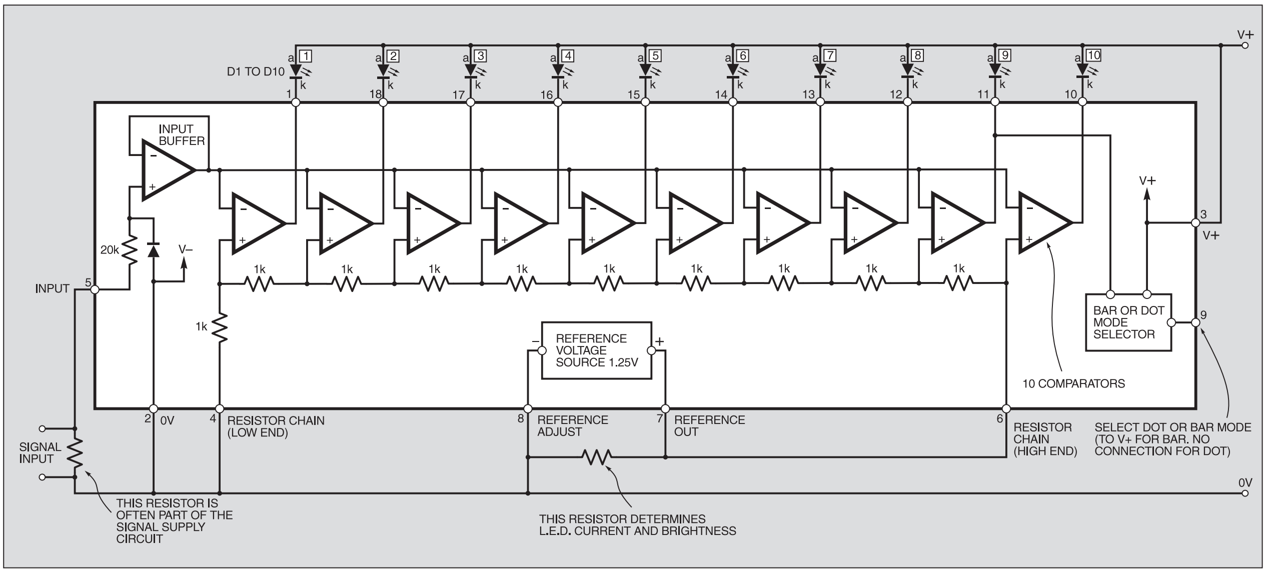


Fig.1. Block schematic diagram for the LM3914 l.e.d. bargraph driver showing the simplest external circuit. The LM3915 and LM3916 are identical except for the values of the internal resistors which determine the switching of the comparators.

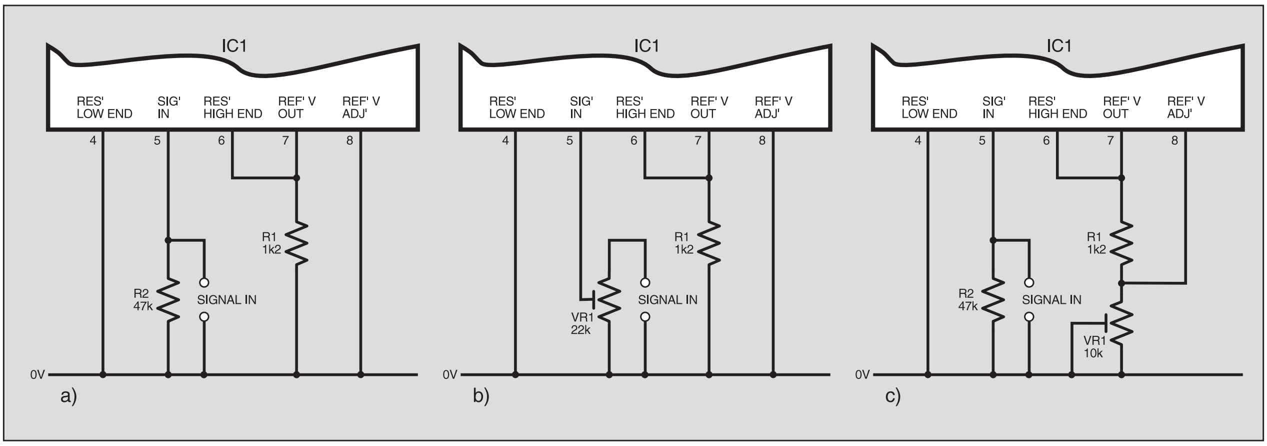


Fig.2a. Basic Sensitivity. Connecting the internal resistor chain directly across the 1·25V reference gives an input sensitivity, to l.e.d. D10 on, of 1·25V. Fig.2b. Reducing Sensitivity (Method One). Connecting the input to pin 5 via a preset potentiometer is the simplest way of reducing sensitivity. Fig.2c. Reducing Sensitivity (Method Two). Grounding pin 8 (Reference Adjust) via potentiometer VR1 increases the voltage across the internal resistor chain. This increases the input voltage required to turn l.e.d. D10 on. With a value of 10k for VR1, the sensitivity can be varied from 1·25V to more than 10V.

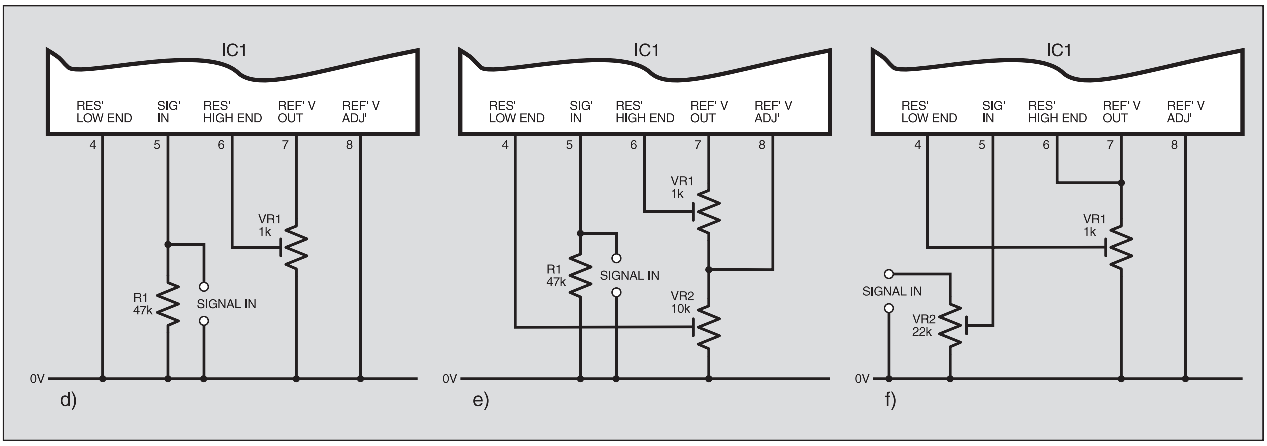


Fig.2d. Increasing Sensitivity. By connecting the "high" end of the internal resistor chain to the slider of potentiometer VR1, the input voltage to turn l.e.d. D10 on can be reduced to 0·1V or less. Fig.2e. Expanded Range (Method One). Connecting the ends of the internal resistor chain to the sliders of potentiometers VR1 and VR2 enables l.e.d. D1 and l.e.d. D10 "on" voltages to be adjusted. In this way a small, but critical, voltage change can be expanded to fill the entire display. Fig.2f. Expanded Range (Method Two). Connecting the "low" end of the internal resistor chain to the slider of VR1 enables range minimum (the input voltage required to turn l.e.d. D1 on) to be set between one tenth of range maximum and close to range maximum. Range maximum (the input voltage required to turn l.e.d. D10 on) is set by potentiometer VR2.

a resistor. The ability to increase the internal reference in this way makes it easier to set sensitivity over wider limits.

Bar or Dot Mode

A Bar or Dot mode selector is brought out to pin 9. Leaving pin 9 unconnected results in a dot display. Connecting pin 9 to pin 3 produces a bargraph.

Supply Voltage and Current

The supply voltage to the chip can be as low as 3V. It must, however, always be at least 1·5V more than the reference voltage applied to the "high'' end of the internal resistor chain. The absolute maximum supply voltage is 25V.

Standby current (all l.e.d.s off) varies from around 3mA with a 5V supply to 10mA with a 20V power supply rail.

FIXING L.E.D. CURRENT

Current flow through ***each individual l.e.d.*** is ten times the current drain on the internal reference. L.E.D. current can, therefore, be programmed by a resistor connected between pin 7 and pin 8 (see Fig.1).

If the internal resistor chain is connected across the reference source (it usually is) the current through it must be added to the current through the programming resistor. When the LM3914 is used, the total resistance of the chain is nominally 10 kilohms, and l.e.d. current can be calculated from the following formula:

$$\text{L.E.D. current} = 10\left(\frac{1{\cdot}25}{R} + \frac{1{\cdot}25}{10k}\right)$$

when R is the value of the programming resistor.

With a 1·2k programming resistor, individual l.e.d. current is:

$$10\left(\frac{1{\cdot}25}{1200} + \frac{1{\cdot}25}{10000}\right) = 11{\cdot}6\text{mA}$$

and the current in bargraph mode with all l.e.d.s on would, of course, rise to 116mA.

The reference voltage and value of the resistor chain can vary significantly between samples of the i.c., and some departure from the calculated current can be expected. The resistor chains in the LM3915 and LM3916 exceed 20 kilohms, and their contribution to l.e.d. current can usually be ignored.

SENSITIVITY AND RANGE

The input voltage required to turn l.e.d. 10 (D10) on is equal to the reference voltage applied to the "high'' end of the resistor chain. Similarly, the input required to turn l.e.d. one (D1) on is determined by the voltage applied to the "low'' end.

There are limitations. The "low'' end of the chain cannot be taken below the 0V rail, and the potential on the "high'' end cannot exceed 1·5V below the power supply voltage. The internal reference can be set no higher than 12V.

The various ways in which the sensitivity and measurement range can be adjusted are illustrated in Fig.2a to Fig.2f. A brief description of the various methods of adjusting the input sensitivity follows:

Basic Sensitivity (Fig.2a)

Connecting pin 6 to pin 7 applies the internal reference to the "high'' end of the resistor chain and the input voltage required to turn l.e.d. 10 (D10) on is, therefore, fixed at 1·25V.

The "low'' end of the chain, pin 4, is connected to the negative terminal of the reference, pin 8, via the 0V rail. The input voltage required to turn l.e.d. one (D1) on is, therefore, one-tenth of 1·25V or 125mV, and each increment of 125mV turns another l.e.d. on.

L.E.D. current is programmed by resistor R1 which is, in effect, connected across the internal reference source.

Reducing Sensitivity (Fig.2b):
Method One

Applying the input signal via potentiometer, VR1, enables the voltage for l.e.d. 10 on to be set at any level above the 1·25V internal reference. Inputs much in excess of 50V should be connected via a fixed resistor of suitable value to avoid the power rating of the potentiometer being exceeded.

Reducing Sensitivity (Fig.2c):
Method Two

The reference voltage at pin 7 can be increased by connecting pin 8 to the 0V rail via a resistor. In Fig.2c, the current flowing in resistor R1 is grounded via preset potentiometer VR1 (wired as a variable resistor), thereby increasing the voltage at pin 7 and pin 8. Applying this increased reference voltage to the "high'' end of the internal resistor chain increases the voltage required to turn l.e.d. 10 on.

The formula relating resistor values to reference voltage is:

$$\text{Reference voltage} = 1{\cdot}25\left(1 + \frac{VR1}{R1}\right) + VR1 \times \frac{80}{10^6}$$

(The above formula allows for an 80μA current flowing out of pin 8 to ground via VR1.)

By making the resistor between pin 8 and ground (0V) a 10 kilohms preset potentiometer, the reference voltage can be varied from 1·25V (VR1 at zero resistance) to 12V (VR1 near maximum).

Increasing Sensitivity (Fig.2d)

The basic sensitivity of 1·25V can be low for some applications. If preset VR1 is connected across the reference voltage and its slider (moving contact) taken to the "high'' end (pin 6) of the internal resistor chain, the input to turn l.e.d. 10 on can be varied from 1·25V down to 100mV.

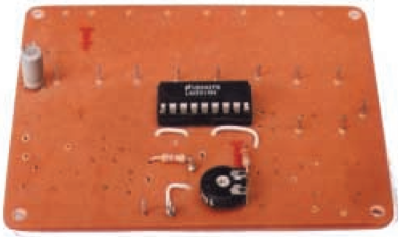
Expanding the Range (Fig.2e):
Method One

Sometimes it is desirable to expand a small, but critical, voltage range to fill the entire display. Battery condition checkers often rely on circuits of this kind.

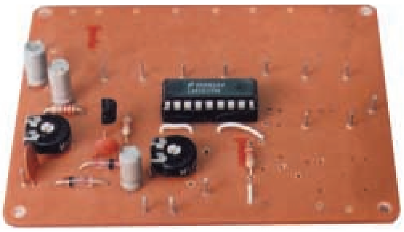
Range maximum is set just above the fully charged or "fresh'' voltage, and range minimum is set a little below the voltage at which the working of the equipment would be impaired. Different coloured l.e.d.s representing "good'', "acceptable'' and "dubious'' ensure an easily read display, and a resistor to simulate the normal load should be wired across the cell under test.

In Fig.2e, preset potentiometer VR2 increases the reference voltage at pin 7. The "low'' end of the internal resistor chain (pin 4) is connected to its slider enabling range minimum to be shifted over wide limits.

Adjustment of range maximum is facilitated by connecting the "high'' end of the chain (pin 6) to the slider of VR1.



Voltmeter with adjustable input sensitivity (1·25V to 10V) circuit board. See Fig.2c for circuit and Fig.10a for p.c.b. details.



Signal-Strength Meter (dot-mode) with amplified and rectified input. See Fig.2a for sensivity fixing, Fig.5 for input circuit and Fig.10e for p.c.b. details.

The resistance of VR2 should chosen to increase the voltage on pin 7 to a level just above range maximum. If necessary, connect fixed and variable resistors in series to produce the desired value.

Expanding the Range (Fig.2f):
Method Two

A more versatile method of expanding the range is shown in Fig.2f, where the circuit is configured for a basic sensitivity of 1·25V. Connecting the slider of preset VR1 to the "low'' end of the resistor chain enables range minimum to be set anywhere between one-tenth of range maximum and close to range maximum.

Range maximum is set at any level above 1·25V by potentiometer VR2.

ACCURACY

Accuracy is partially dependant on the switching precision of the comparators, and their performance improves as the voltage across the internal chain of resistors approaches its maximum value. For this reason, the sensitivity adjusting circuits given in Fig.2c and 2e are to be preferred when accuracy is paramount. The circuits in 2b and 2f will, however, function with power supply voltages down to 3V.

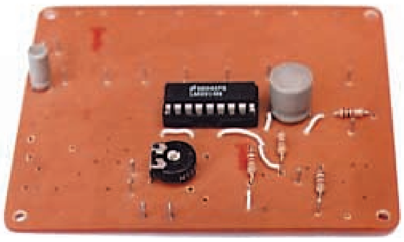
Temperature variations, over a 0°C to 70°C range, have a negligible effect, especially if the voltage across the internal resistor chain is kept high.

When considering the question of accuracy, it should always be remembered that this method of displaying voltage lacks the precision of a digital or large moving-coil meter. The l.e.d.s are switched in a series of one-tenth steps and, to avoid display ambiguity, one l.e.d. fades out whilst the next is switching on.

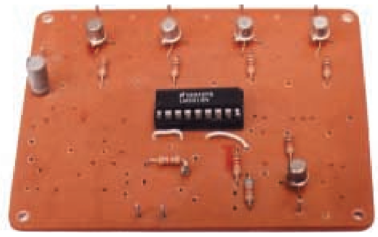
Unless, therefore, there is considerable expansion, the display inevitably represents an approximation of the voltage being measured.

DISSIPATION

The manufacturers of the devices quote an absolute maximum power dissipation of



Bargraph display with "warning" flasher. Sensitivity adjustable from 1·25V upwards. See Fig.4 for circuit and Fig.10c for board details.



Remote Relay Driver circuit board. See Fig.7 for circuit diagram and Fig.10f for board details. It is possible to control up to 10 relays, using the control board of Fig.9.

1365mW, and this figure has to be de-rated if the ambient temperature is higher than normal. When the display is configured in the bar mode, it is prudent, therefore, to check that total dissipation does not exceed, say, 600mW when *all* l.e.d.s are on.

Voltage drop across the l.e.d.s is determined by colour. It is near enough 2V for red, yellow and green l.e.d.s, and around 3·6V for white and blue.

To calculate dissipation, deduct the l.e.d. voltage drop from the supply voltage to give the voltage across the i.c., and multiply this by the total l.e.d. current plus, say, 10mA for device standing current.

With red l.e.d.s working at 10mA, and with a supply voltage of 12V:

Voltage across i.c. = 12 – 2 = 10V.
Maximum current = 10 + (10 × 10) = 110mA
Maximum dissipation = 10 × 110 = 1100mW, which is too high for safety.

Adopting dot instead of bar mode will bring dissipation within safe limits, and l.e.d. current can be reduced by increasing the value of the resistor between pin 7 and pin 8. However, for many applications using standard l.e.d.s, a current of 10mA is required to produce a bright enough display.

Dissipation can, of course, be reduced by reducing the supply voltage to the i.c., but it must always be 1·5V or more above the voltage applied to the internal resistor chain. When the supply to the i.c. has to be high for this reason, dissipation can be reduced by using a separate power supply of 3V or 5V for the l.e.d.s.

If separate supplies are inconvenient, dissipation can be kept within safe limits by placing a 470 ohm resistor in series with *each* l.e.d.. The manufacturers suggest a single resistor placed in series with the l.e.d.'s common anode lead (the l.e.d. end of this resistor should be bypassed to the 0V rail by a 10μF electrolytic capacitor). With this method there may be a perceptible reduction in brightness as the bargraph extends.

STABILITY

The circuit may become unstable if the l.e.d. connecting leads are longer than 150mm. A 10μF electrolytic capacitor connected across the power supply rails, and mounted reasonably close to pins 2 and 3, avoids this possibility.

Instability can also arise if the internal resistor chain is connected to independent reference voltages of high impedance. Bypassing pin 6 to ground via a 100nF capacitor will eliminate any problems.

L.E.D.S

The efficiency of l.e.d.s (light emitting diodes) in terms of light output for a given current varies considerably. The so-called "high brightness" l.e.d.s certainly produce a vivid display, but this is usually achieved by adopting current levels of 20mA or more.

If current economy is important, either to contain dissipation or to extend battery life, low current l.e.d.s, which are very luminous at 2mA, represent an ideal solution. The 3mm types seem brighter than their 5mm counterparts, no doubt because the light source is not obscured by so much plastic.

By using low current l.e.d.s in the dot mode with a 3V supply, and increasing the l.e.d. current programming resistor to 10 kilohms (R1 in Fig.2a), a very economical voltage display can be produced.

BARGRAPH DISPLAYS

Rectangular l.e.d.s are more appropriate for bar graphs, and separate diodes can be combined into a ten l.e.d. display. A method of doing this is illustrated in Fig.3.

The provision of a bezel avoids the difficulty of cutting a neat rectangular slot in the instrument case, and l.e.d.s of different colour can be combined. The meeting faces of the l.e.d.s must be coated with dark paint before being glued together, or light spread will be a problem.

Ten segment displays can be purchased for little more than the cost of separate l.e.d.s. This does, however, deny the constructor the opportunity to mix l.e.d.s of different colours.

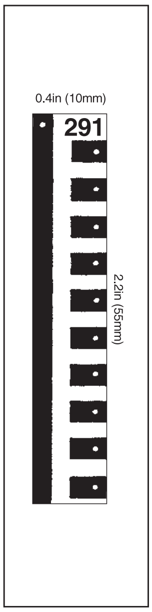


Fig.3b. Full-size L.E.D. Display foil master.

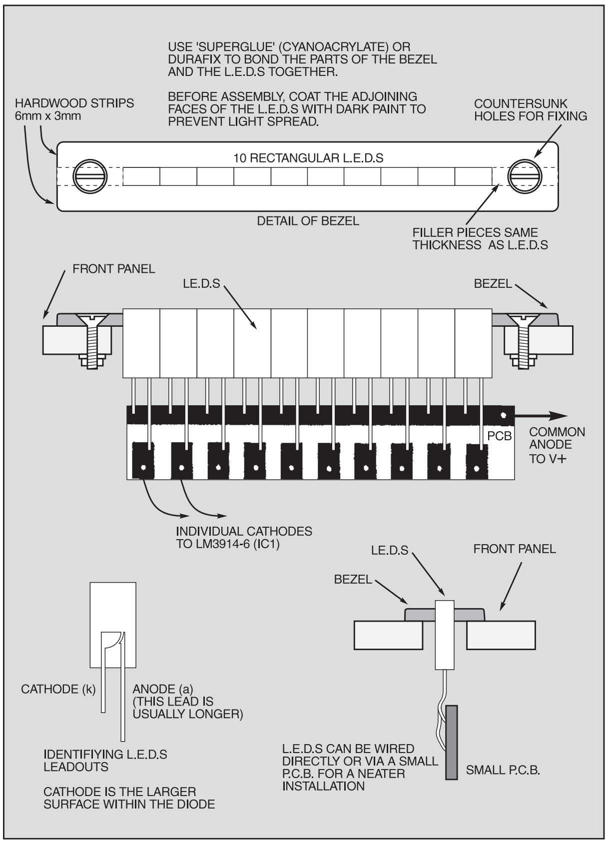


Fig.3a. Assembly details for making the l.e.d. bargraph.

"Homebrewed" bargraph display using separate l.e.d.s.

FLASHING DISPLAYS

How the entire display can be made to flash when a critical voltage level has been reached is shown in Fig.4. Bargraph mode (pin 9 to pin 3) must be adopted with this arrangement.

The display can be made to start flashing from l.e.d. 2 onwards. Simply connect resistor R2 in series with the anode (a), and take the junction of resistor R3 and capacitor C2 to the cathode (k), of the l.e.d. where flashing is to start.

SIGNAL STRENGTH METERS

Bargraph drivers are commonly used for signal strength and power meters. The LM3915, with its logarithmic response, is the natural choice for applications of this kind.

The simplest system involves the direct connection of the signal to pin 5. Remember to include a blocking capacitor if d.c. is present: a 220nF ceramic or polystyrene component is suitable.

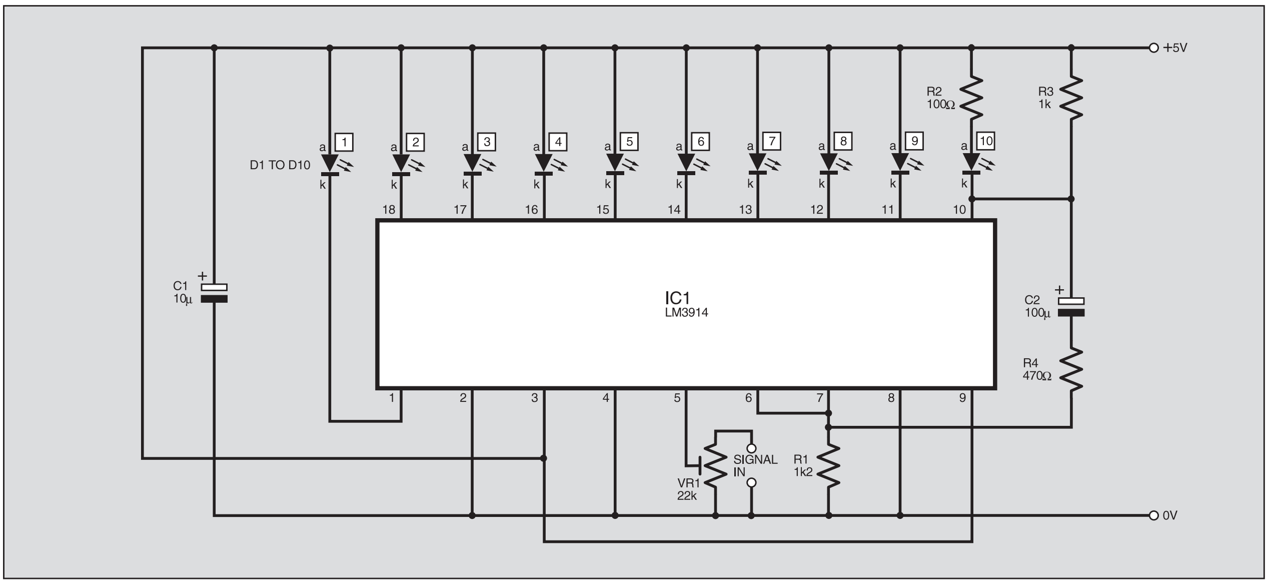


Fig.4. Circuit diagram for the Bargraph display, with alarm flasher. When D10 is activated it begins to flash.

The manufacturers recommend dot mode and a 30mA l.e.d. current when this method is adopted. If, however, the display seems patchy at high signal levels, try the bar mode and a lower l.e.d. current.

When a sensitivity greater than the basic 1·25V is required, use the circuit given in Fig.2d.

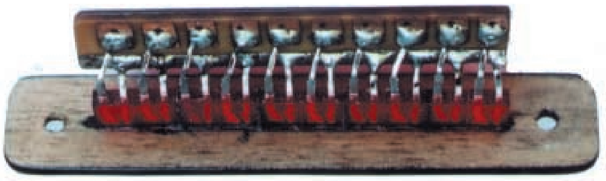
RECTIFIERS

Better results can be obtained by rectifying the signal and applying d.c. to the bargraph driver. A suitable circuit is given in Fig.5.

Transistor TR1 amplifies the signal to ensure that diodes D1 and D2 are working in their conductive region. The diodes are arranged in a voltage doubling circuit, and preset potentiometer VR1 should be set just short of signal clipping in TR1 to ensure that they are driven hard. Potentiometer VR2 is then set to deliver the required input to the i.c.

The high input impedance of the field-effect transistor, TR1, minimises loading on the signal circuit, and reservoir capacitor C5 sharpens the l.e.d. display. The amplifier and rectifier circuit can be teamed with the basic i.c. arrangement illustrated in Fig.2a, and a 12V power supply is required.

If the bargraph mode is chosen, take one or other of the measures outlined earlier to ensure that dissipation is not excessive. The stabilising capacitor across the power supply, C1, should be increased to 47µF when this circuit is used.



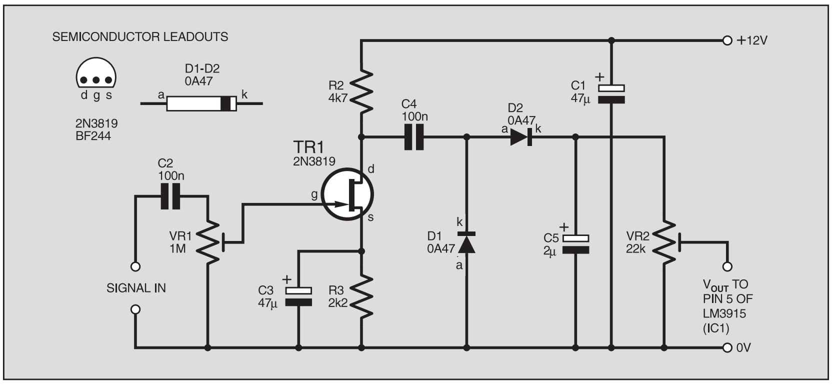


Fig.5. Amplifier and rectifier stages for the Signal Strength Meter. R1 is the l.e.d. brightness resistor, not shown here – see Fig.2a. VR2 acts as the input (pin 5) grounding resistor (R2 in Fig.2a).

POWER METERS

Signal strength meters can be adjusted to indicate power levels. The load is known (the speaker impedance quoted by the manufacturers), and the power delivered is, of course, proportional to the voltage developed across it.

How a dummy load, test meter and the bargraph driver are connected during the setting up process is shown in the circuit of Fig.6. Simply inject a signal into the amplifier, increasing it until the test meter indicates that the maximum power level has been reached, then set preset VR1 to light l.e.d. 10.

The formula relating power to voltage and load impedance is also given in Fig.6: e.g., with a 4 ohm speaker, 10 watts is being supplied when 6·3V is developed across the dummy load, 50 watts when the voltage is 14V, and 100 watts when the voltage is 20V.

The setting up signal should be below 1kHz because the accuracy of most test meters reduces at frequencies much higher than this. Provided the response of the amplifier is wide enough, 50Hz from a low voltage transformer can be applied if a signal generator is not available.

Test meters indicate the r.m.s. values of a.c. voltages, and the power meter will, therefore, display r.m.s. power levels. If peak power is to be displayed, set VR1 so that l.e.d. 10 (D10) lights when the voltage reading on the test meter is 0·707 times the value indicated by the formula in Fig.6.

REMOTE RELAY DRIVER

If switching transistors and relays are substituted for the l.e.d.s, the LM3914 can be used to control up to ten functions via a two-wire link.

The circuit diagram for a Relay Driver set-up using the LM3914 is given in Fig.7. When one of the comparators draws current, the voltage developed across base/emitter resistor, R4 to R8, makes the relevant transistor collector (c) conduct and the asssociated relay coil is energised. Diodes D1 to D5 shunt the high voltage developed across the relay coil when the transistor turns off.

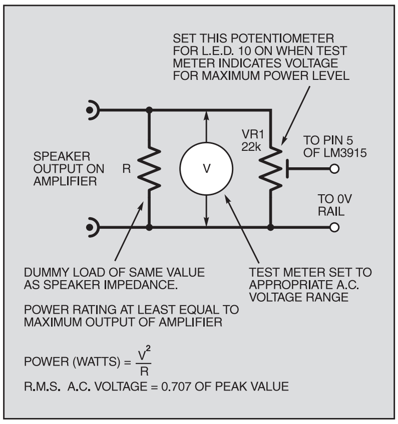


Fig.6. Setting up bargraph drivers to display peak r.m.s. power.

The combination of resistors R1 and R2 fixes the voltage across the resistor chain at 9V. This ensures a good difference between trigger levels and adjustment of the control voltages is less critical. Only

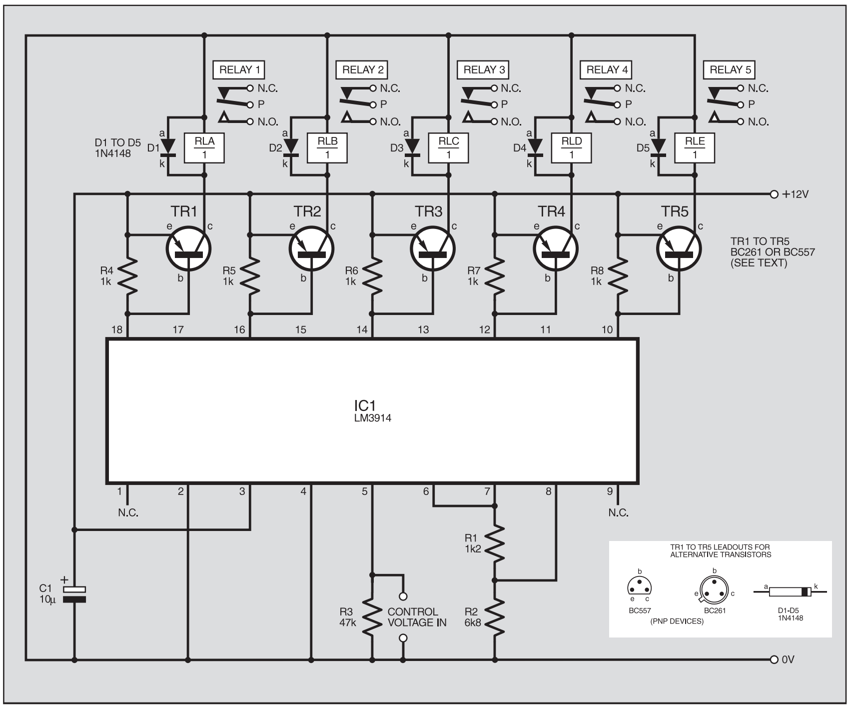


Fig.7. Circuit diagram for using the LM3914 as a relay driver. Remote control of up to ten relays, via two wires, is possible.

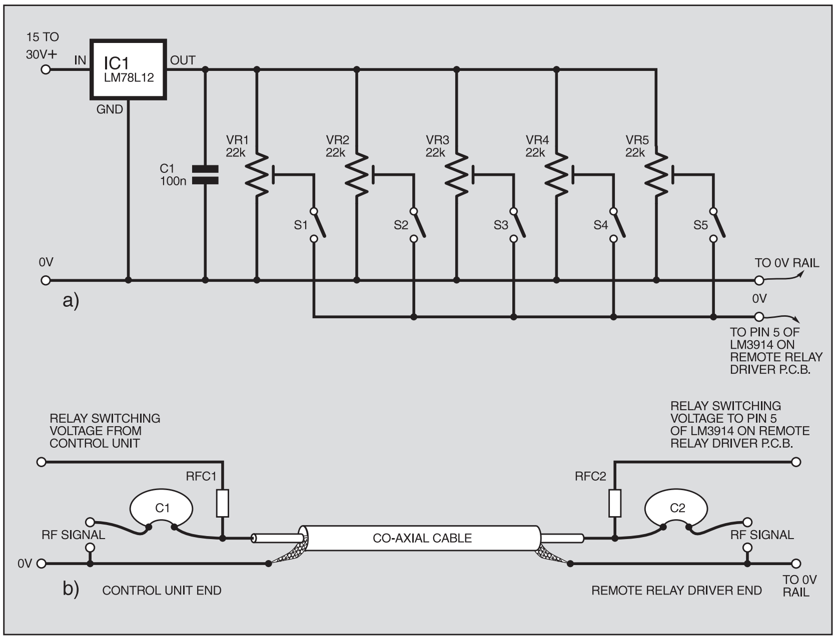
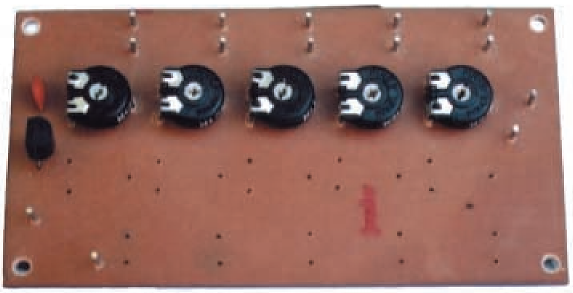


Fig.8. Control Unit and applying switching voltages via an r.f. signal cable. (a) circuit diagram and (b) cable interlink details.



Relay Control board (for 5 relays).

five relay circuits are shown, but all ten outputs from the i.c. can be used if desired.

A relay control board circuit diagram is given in Fig.8a. Control voltages are set by potentiometers VR1 to VR5 and selected by switches S1 to S5. Voltage regulator IC1 ensures that the correct voltage levels are maintained. Broad band r.f. noise developed by the i.c. is bypassed by capacitor C1.

This avoids problems when the control voltages are carried by an r.f. signal cable in the manner illustrated in Fig.8b. Here, r.f. chokes, RFC1 and RFC2, isolate the signals from the control circuitry, and blocking capacitors C1 and C2 prevent the flow of d.c. into the signal circuits.

Select the inductance of the chokes to suit the signal frequencies: e.g., 4·7mH for low and medium frequencies, and 1mH for medium and high frequencies. The capacitors can be 100nF ceramic type.

Alternatively, three-core cable can be used: one wire supplying low voltage power for the LM3914 and, say, drive motors, another the control voltages, and the third a common 0V rail.

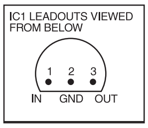
The only disadvantage to the system is that only one relay can be activated at any one time. However, with up to ten circuits available, this is no great drawback.

CIRCUIT ASSEMBLY

The full-size foil and component sides of a p.c.b. for the Relay Driver Control Board are shown in Fig.9. Although five circuits are shown, provision is made on both p.c.b.s for all ten to be installed should this be required

The components for the various circuits are best assembled on a small printed circuit board (p.c.b.). The full-size, copper foil side of a multi-purpose board, which can accommodate all of the circuits discussed, is shown in Fig.11. The various topside component layouts are illustrated in Fig.10a to Fig.10f, also see the photographs. The board (one only) is part of a set which is available from the *EPE PCB Service*, codes 289/290/291.

It is a good idea to use a holder for the LM3914/6, and solder pins, inserted at the lead out points, ease the task of off-board wiring. Use a small crocodile clip as a heat-shunt when soldering the f.e.t. (TR1) and germanium diodes (D1, D2) for the "rectified" version of the Signal Strength Meter in Fig.5. Remember to include the wire links, and always check the orientation of electrolytics and semiconductors before applying power to the board. □



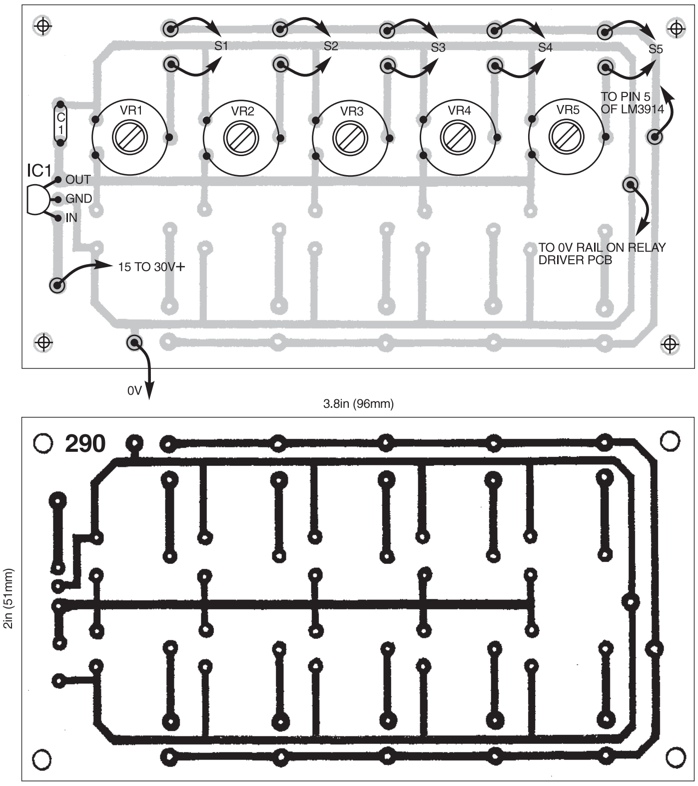


Fig.9. Relay Control p.c.b. component layout and foil master.

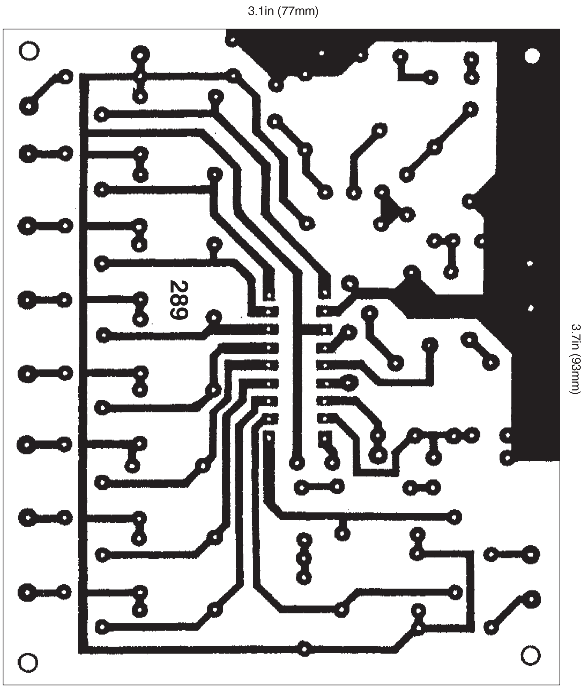


Fig.11. Full-size Multi-purpose L.E.D. Driver foil master.

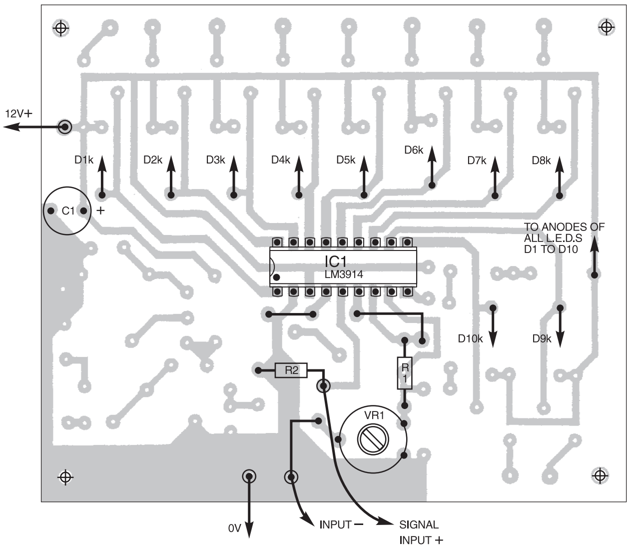


Fig.10a. Component layout for Voltmeter with adjustable input sensitivity (1·25V-10V). See Fig.2c for input circuit. C1 is a 10μF capacitor connected across the supply rails.

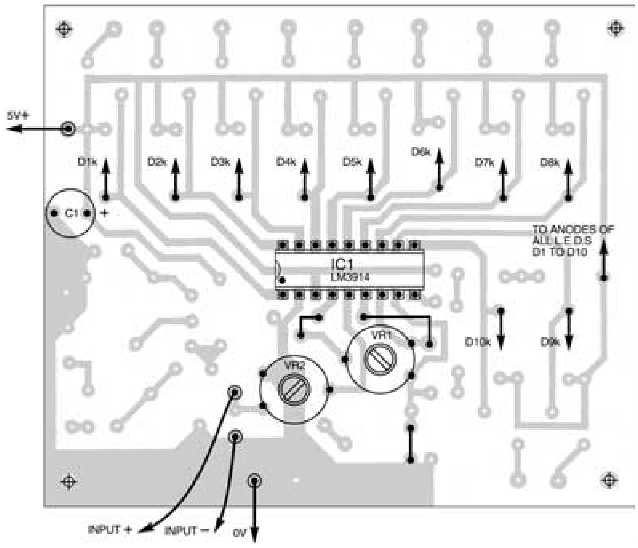


Fig.10b. Component layout for expanded range dot mode voltmeter. See Fig.2f for circuit.

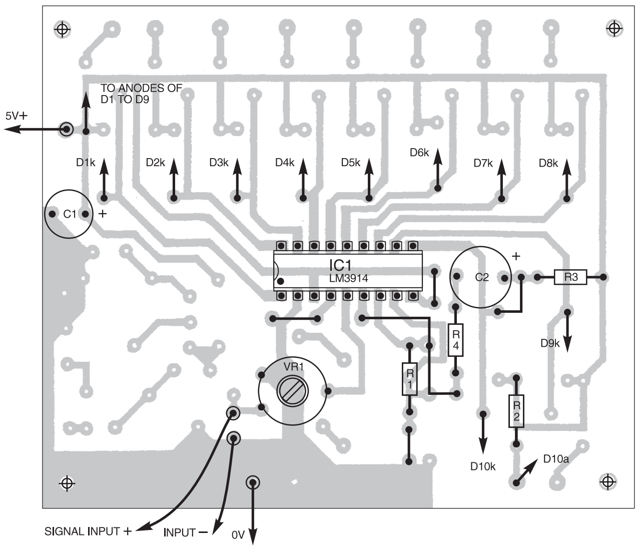


Fig.10c. Component layout for Bargraph display, with alarm flasher. Sensitivity adjustable from 1·25V upwards. See Fig.4 for circuit.

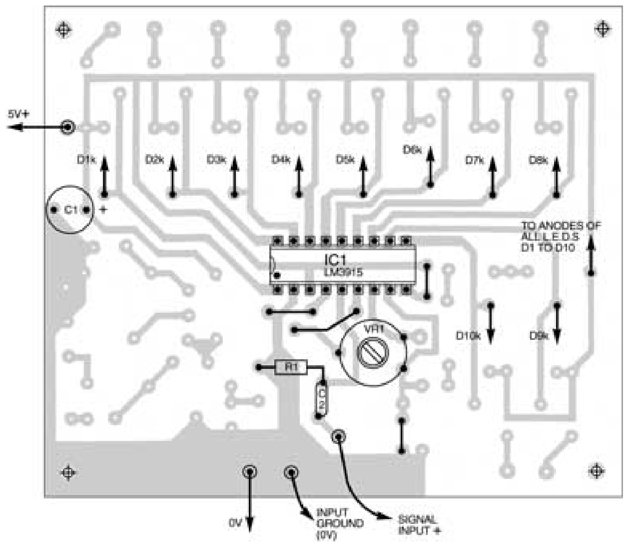


Fig.10d. Component layout for basic bar-mode Signal-Strength Meter. Input sensitivity adjustable over a 100mV to 1·25V range. See Fig.2d for circuit. C2 is a 220nF d.c. blocking capacitor at the input.

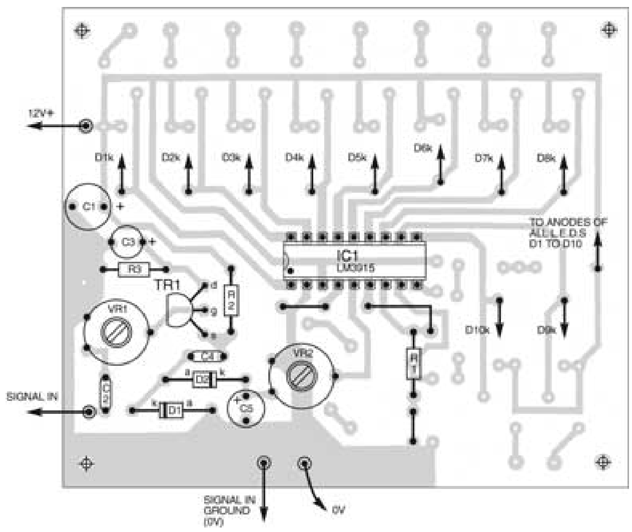


Fig.10e. Component layout for Signal-Strength Meter (dot-mode), with amplified and rectified input. See Fig.5 for input circuit. See Fig.2a for i.c. sensitivity fixing circuit.

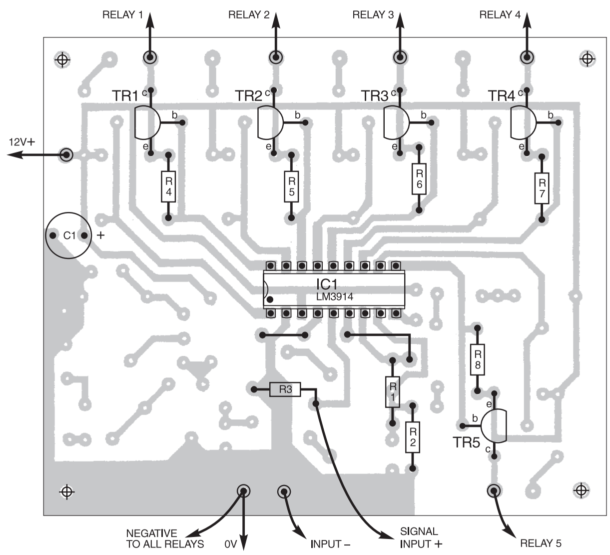


Fig.10f. Component layout for Remote Relay Driver. See Fig.7 for circuit diagram. Up to ten relays can be controlled.