THE ETI LEDSCOPE

Tony Ellis lights up your life with 140 LEDs in this simple but instructive design which acts as an oscilloscope, simple voltmeter and ohm-meter, too.

Of course, the Ledscope will not equal the performance of a cathode ray oscilloscope, but it costs considerably less, is easy to construct, portable and can display waveforms at the lower end of the frequency spectrum surprisingly well. It could also be of educational interest, as it makes clear the workings of one of the most useful pieces of test equipment, and can give valuable — and cheap — hands-on experience.

The Ledscope could be built by any moderately competent constructor and will be rugged enough for most workshop environments. Its limited frequency range is nonetheless adequate for much audio work.

Leading Lights

The display consists of four 7 x 5 packaged LED arrays which form the 140 element 'screen'. For the scope function vertical (y) position depends on a bar-graph IC (the LM3914) used in dot mode. The IC suppresses all but the leading light of a bar of LEDs. The timebase (or x-position) is provided by a 14-line decoder (the 4514) driven by a clock which sequentially pulses the array turning on each column in turn.

A dot of light may be made to appear to move along the display giving a trace which varies in height with the input voltage. Only one LED is illuminated at any one time, but persistence of vision results in us seeing a continuous curve showing the waveform of the varying input.

Higher or lower frequencies can be captured by varying the timebase clock frequency, which is divided down by the decoder circuitry. No trigger is incorporated in the circuit largely because it was felt to be unnecessary and complicating. At the kind of frequencies the Ledscope can actually handle, it is possible to very closely match clock and input frequencies to give an almost stationary waveform.

To operate with low voltages and give the scope a high input impedance, a CMOS op-amp is used for the input stage. This section is the y-amplifier. Gain is controlled by a panel-mounted potentiometer. Experiementers may wish to combine this with switched attenuation to provide a series of ranges.

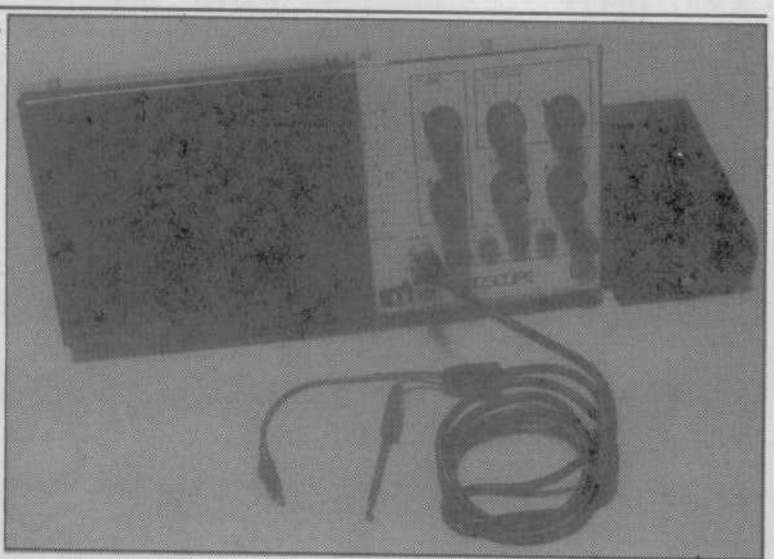
Since the bar-graph IC we're using can only accept a positive input, while the scope will be required to display AC waveforms, a second op-amp is used to add a constant voltage (a DC offset) to the output of the y-amplifier. This shifts the whole trace upwards. A zero volt trace will now appear around the centre of the display — subject to the y-shift potentiometer setting. A positive input voltage causes the upper half of the display to illuminate, and a negative input voltage turns on the lower half.

In volt-meter mode, the device acts as a simple DC meter with two ranges: 0-10V and 0-50V. Only one column of the display is activated and the bar-graph is in dot mode so that LEDs illuminate in sequence up a single column in response to applied voltage.

In ohm-meter mode, the device can be used to indicate resistance. The ohm-meter can be calibrated for different resistance ranges using the 'ohm adjust' control. Only one column of the display is activated. The bar-graph is in bar mode so that input *conductance* is directly related to the length of an illuminated column. A short-circuit should light-up all the LEDs in the column.

The 3914 can provide different LED currents and resulting display brightnesses. This is used to advantage in the Ledscope. Full current (20mA per LED) is used for the scope function to ensure a clear bright trace. Low current (7mA per LED) is used for the ohm-meter to reduce current consumption when up to 10 LEDs may be simultaneously illuminated.

The Ledscope with probe and battery box.



Construction

Provided you obey a few simple rules and take care, your circuit should work first time. Inevitably, too much haste leads to carelessness and disappointment. The main points to remember are:

- Ensure components are inserted the right way round. This is essential with semiconductors, as you will seldom get a second chance if they are inserted incorrectly. If in doubt follow our overlay diagram (Fig. 2) and use the circuit diagram for confirmation.

- Only use a miniature soldering iron of 25W or less, and remember to wipe the tip regularly with a wet sponge to remove excess solder and flux. Do not overheat components.

Begin construction by installing the wire links. Positions are indicated on the kit PCB by a white line on the legend.

Cut each of the 25-way DIL socket strips listed in the Parts List into three seven-way DIL strips, taking care to cut the eighth socket each time. Insert these in to the PCB. Make certain that all sockets are installed in the same direction, because the socket pins are off-centre which can result in a misaligned display. Next solder in place the six IC sockets — also the right way round, of course.

Solder the resistors in place (note: R4 should be laid flat), then follow with the capacitors. Next insert all diodes, making sure that the OA47 is in D1 position. Solder them and the fuse carrier and trim all surplus leads.

Finally insert the ICs and the LED arrays into their prepared sockets. Refer to Fig. 2 for the orientation of the LED arrays, but check positioning with the ICs, too.

HOW IT WORKS

IC6a (Fig. 1) forms a non-inverting amplifier with DC being fed directly and AC via capacitor C4. The gain of this stage is controlled by RV1 and ranges from unity to about 20. R10 sets the input impedance of the scope to about 1M0 since the effect of IC6a's impedance is negligible.

The display driver (IC1) requires a positive input, but the signal on pin 1 of IC6a may well be negative. The solution is to offset the input signal so that IC1 only ever receives a positive voltage.

A constant negative voltage is taken from the wiper of RV2 to the inverting input of IC6b, while the output of IC6a is taken to the non-inverting input of IC6b. With R4, 5, 6 and 7 all equal, the arithmetic of op-amp differential amplifiers shows that the output of IC6b will be (V+) − (V−), where V(+) is the voltage at the output of IC6a and V(−) is the voltage at the wiper of RV2. Since V(−) varies between −9V and 0V, the effect is of a screen-movable zero trace that will move upwards in response to a postive scope input and downwards in response to a negative one.

The constant negative voltage is provided by the voltage inverter, IC5, which produces a negative output of equal magnitude to its postive input. This output also provides the negative rail for IC6.

The timebase clock is formed by IC4a and b and the frequency is varied by means of SW2 and RV3. The clock output is sent to IC3, a dual four-bit binary counter on half of which is used. The four-bit output is fed to a 4-to-16 line decoder, IC2, which drives the horizontal axis of the screen matrix. This pulses lines 0 to 13 sequentially and resets IC3 on the 15th count when line 14 goes high. Together with IC1, this provides a simple sample against time display driver with a resolution of 10x14.

IC1 is a dot/bar display driver which drives the vertical axis of the LED 'screen'. The IC contains a voltage divider and 10 comparators that turn on in sequence as input voltage rises. The IC has constant current ouputs so no series resistors are required with the LEDs. Current output is actually determined by R1 and R2 and is switchable to give high current per LED in dot and scope mode and low current in bar mode. The mode is chosen by connecting pin 9 to pin 11 (dot) or pin 9 to the positive rail (bar).

In volt and ohm modes, the 4-to-16 line decoder is inhibited and LED column 13 (the 14th and right-most column) is fed via D2 to give a single column display.

Once you have checked that the board is okay, that everything is correctly in place and that there are no solder bridges, short circuits or breaks in the tracks, you can wire up the panel controls keeping all wires as short as possible (Fig. 2). It's a good idea to cross off

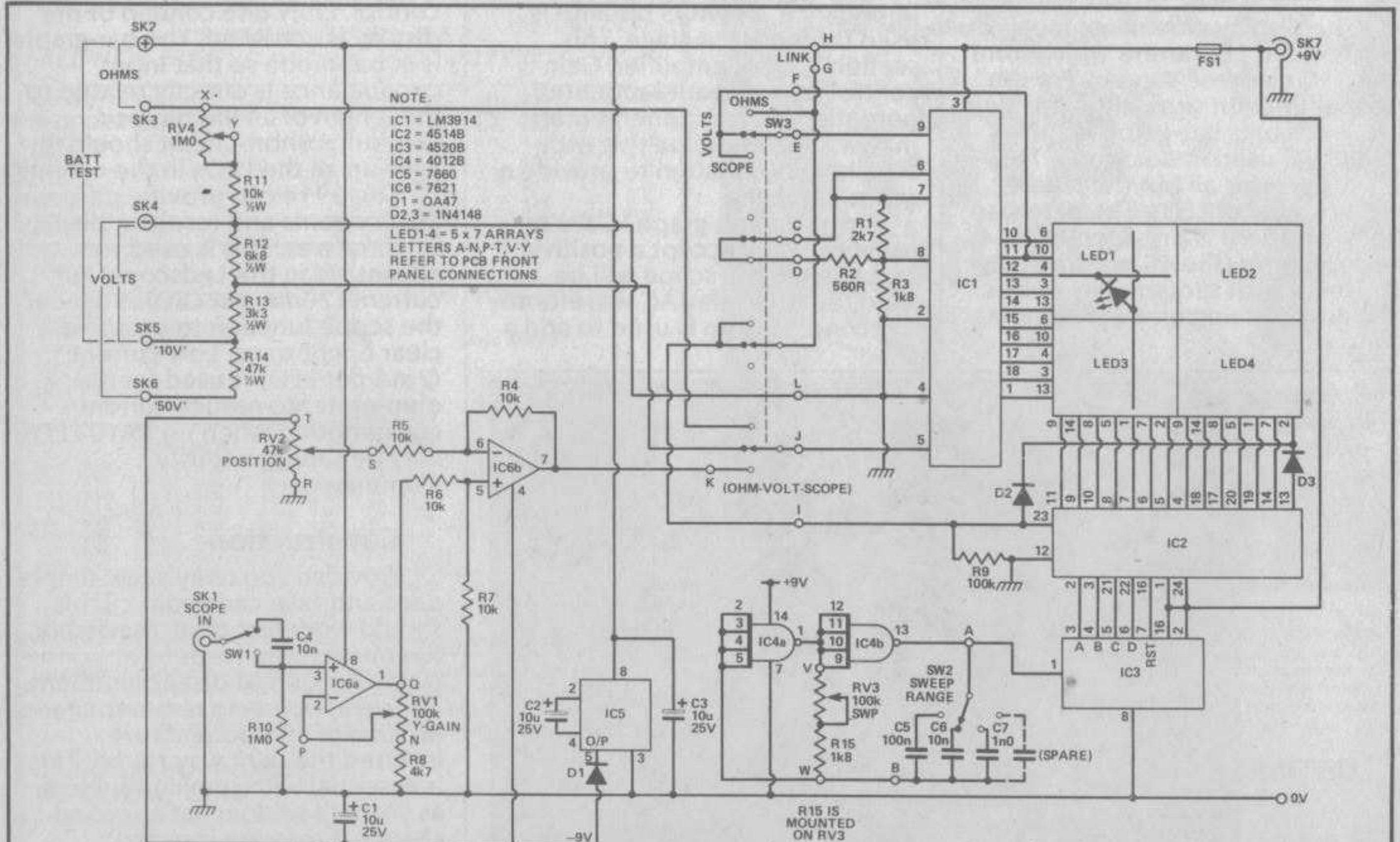


Fig. 1 Circuit diagram.

from the drawing each wire and component as it is assembled. Make sure, too, that the shield on the screened cable from the BNC input socket is soldered to the earth pad provided.

Case Construction

If you decide to build a case like that used in the prototype then you will have to drill and bend perspex. This may seem to be a simple task at first, but if you've never done it before it will require much thought and care.

Perspex can be bent once it has been heated along its bendline. This is usually done on a purpose-built perspex bending rig which the home constructor is unlikely to have access to. The solution used in making the prototype was to replace the rig with a blowlamp and an engineer's vice. Please note: GREAT CARE MUST BE TAKEN WHEN USING A BLOWLAMP TO BEND PERSPEX AND IT SHOULD NEVER BE UNDERTAKEN IN THE HOME.

PARTS LIST

RESISTORS (a ¼W 5% carbon film unless stated)

R1	2k7
R2	560R
R3, 15	1k8
R4, 5, 6, 7	10k
R8	4k7
R9	100k
R10	1M0
R11	10k ½W
R12	6k8 ½W
R13	3k3 ½W
R14	47k ½W
RV1, 3	100k lin
RV2	47k lin
RV4	1M0 lin

CAPACITORS

C1, 2, 3	10µ 25V elect.
C4, 6	10n
C5	100n
C7	1n0

SEMICONDUCTORS

IC1	LM3914
IC2	4514B
IC3	4520B
IC4	4012B
IC5	7660
IC6	7621
D1	OA47
D2, 3	1N4148
LED1, 2, 3, 4	5x7 LED array (LITON 2157 or similar)

MISCELLANEOUS

SW1 SPDT, SW2 4-way, SW3 4-pole 3-way switches; 2x8-pin, 1x14-pin, 1x16-pin, 1x18-pin, 1x24-pin DIL sockets; 3x25-way DIL socket strip; 50R BNC socket; ¼" jack socket and plug; 4mm sockets (2 red, 1 black); 4mm terminals (1 red, 1 black); FS1 250 mA fuse; chassis fuseholder; PCB; short length low capacitance and screened cable; stick-on feet; perspex; aluminium for case; materials for battery box and simple tester (see text).

Perspex is supplied with a backing paper attached. This can be used to draw your bendlines (Fig. 3 gives the necessary measurements). You will notice that the bendlines are 3/16" back from where we want the actual bends to be. This is because a 90°

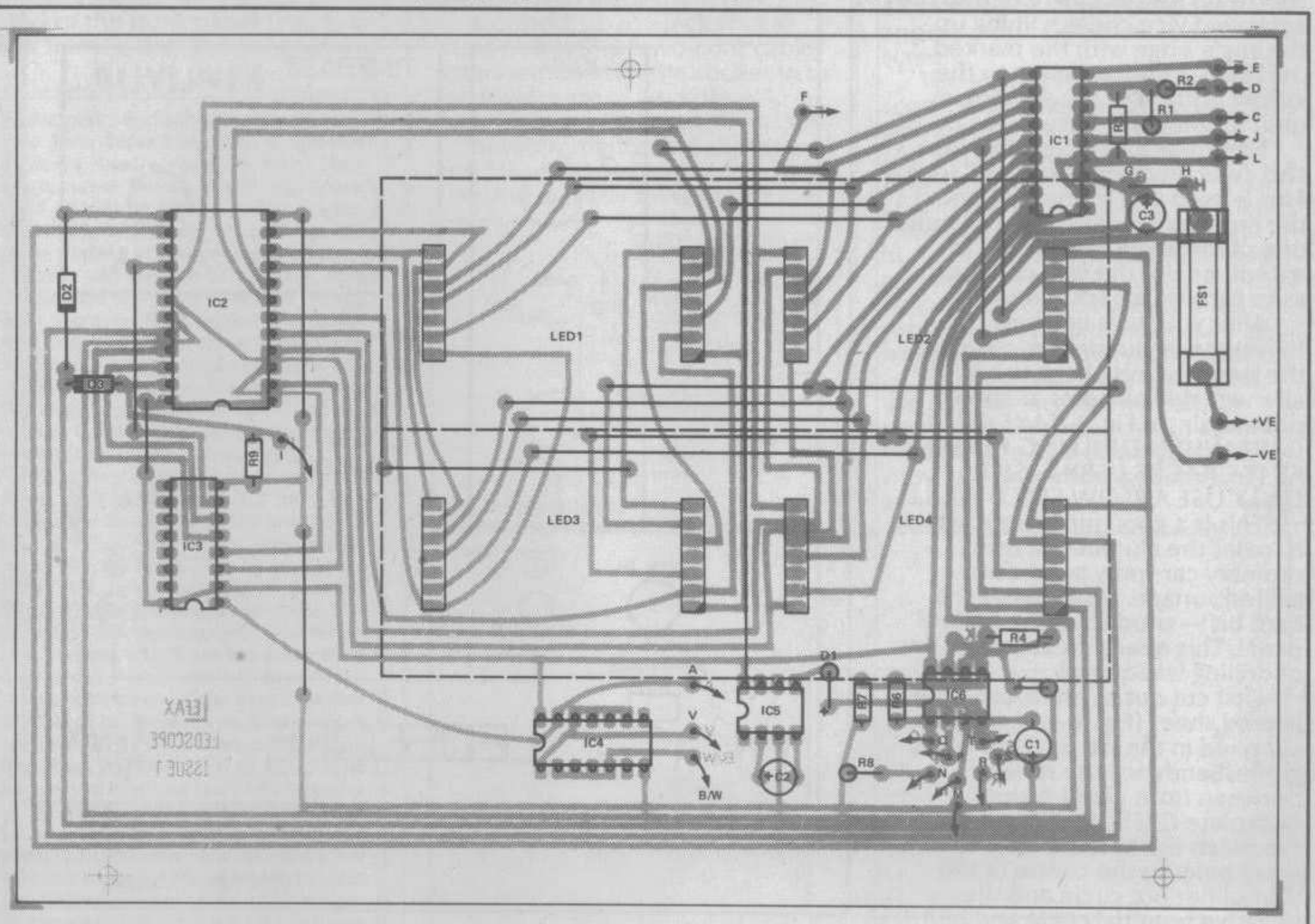


Fig. 2 Component overlay (note modification to PCB which should be incorporated in the commercial kit). The letters correspond to off-board connections (see Fig. 1).

bend in perspex takes in that much material in its curve.

Before you start the bending, get two pieces of 1" x 1" angle iron (or similar) about 12" long to extend the vice cheeks. Once these are positioned centrally, place the marked perspex into the vice and line the edge of the angle with the marked bendline. Tighten the vice and remove part of the backing paper where the bendline is (about 2" from the angle edge).

Using a low flame, run the blowtorch up and down the angle edge (don't do this too slowly or the perspex will bubble). The perspex will soften and you will be able to pull a 90° bend with your hands. Take the heat away and let the perspex cool and set. Do this with all the pieces and bends necessary.

The aluminium is much simpler to deal with. First mark out the backplates (see Fig. 3 again). Now cut off the areas shown shaded and place the aluminium (longways for backplate A and shortways for backplate B) into the extended vice cheeks, lining up the angle edge with the marked bendline. Apply pressure to the visible portion of the aluminium until a right angle forms.

Now take away the angle iron and cut a piece of wood 5 ¼" long. This is used as a former to bend the remaining edges. You will need one of the angle iron pieces to extend one of the vice cheeks so as to provide a back former.

After you have finished bending the aluminium, offer up the perspex and check the fit. If all's well drill all holes as shown, once again, in Fig. 3. TAKE GREAT CARE WHEN DRILLING PERSPEX AS IT CRACKS VERY EASILY. ONLY USE A SLOW SPEED DRILL.

This is a good juncture at which to paint the aluminium, using ordinary car spray paint on a buffed surface. Now comes the hard bit — producing the control panel. This needs great care as lots of drilling is required.

First cut out or photocopy the legend sheet (Fig. 4 — also supplied in the kit) and use it as a guide. Sandwich the sheet between front panel B and backplate C (Fig. 5). Clamp the sandwich tight. It may help to drill small holes in the centre of the y amplifier pot circle and the negative terminal circle and bolt panel, sheet and plate together with two 4BA screws and nuts.

Carefully drill all the other holes, starting with pilot holes and then increasing their diameters to correspond with the legend sheet. This must be done gradually, stepping through the drill sizes to avoid cracking the perspex. A set of round files will be useful to smooth out the holes and make minor enlargements.

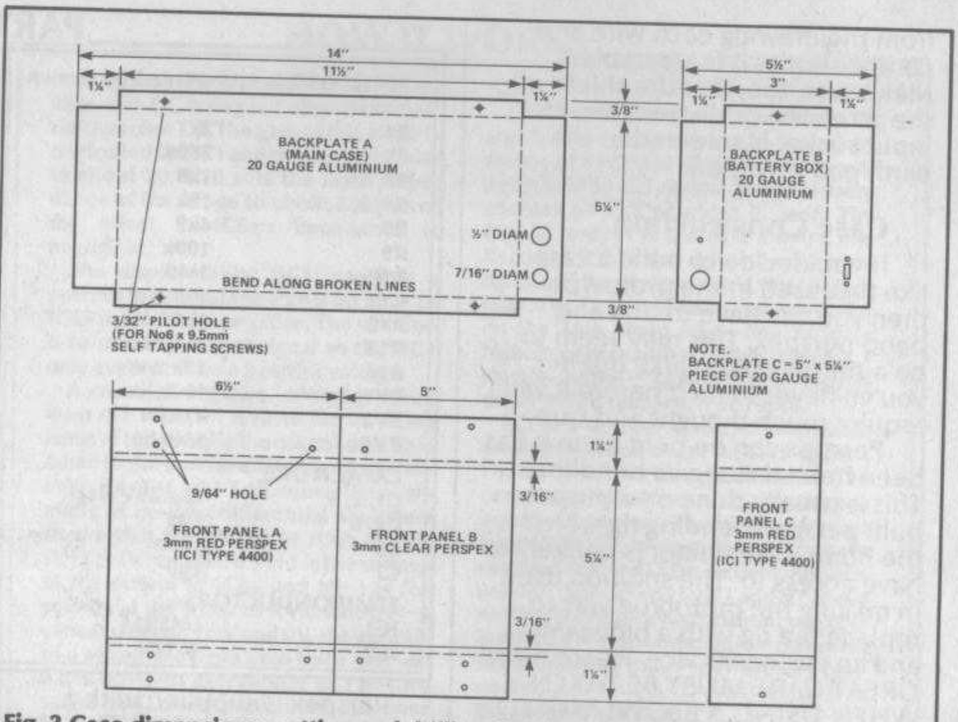


Fig. 3 Case dimensions, cutting and drilling details.

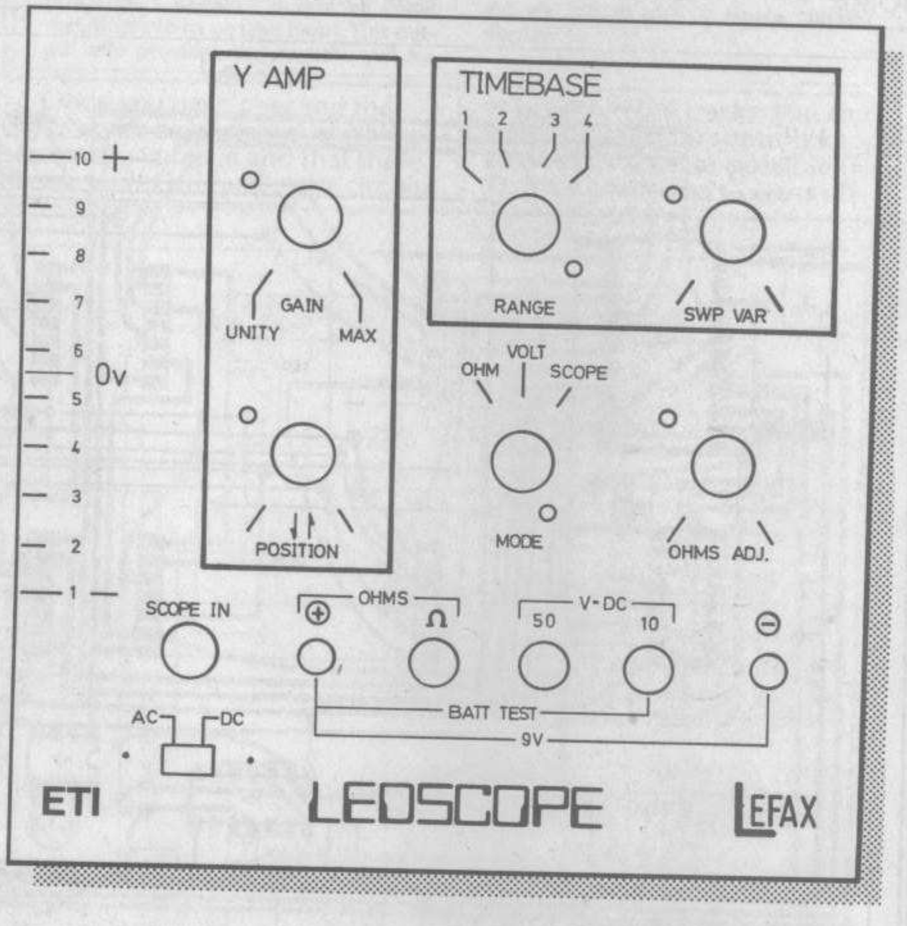


Fig. 4 Panel legend.

When the drilling is complete, install the sockets and tighten the fixing nuts. You can now remove the two 4BA screws and finish off the two remaining holes. After cutting all potentiometer and switch spindles down to ½", mount the pots, switches, terminals and BNC socket. Front panel B is now complete. Now make up the drill and ½" x ½" angle pieces shown in Fig. 5 and assemble front panels A and B as shown.

The battery box can now be assembled from the illustration in Fig. 6. The jack plug is fitted by making a locking nut out of the original plastic cover, using a junior hacksaw to remove ⅛" carefully from the screw-threaded end of the cover.

The two battery holders are glued on to a perspex plate to avoid shorting out the batteries if the holders were to come in to contact with aluminium and also to make the holders easily removable.

The assembled PCB can be fitted to the front panel (Fig. 5, view from A) and the connections made between the board and the control panel (Fig. 2). Keep all interconnecting wires as short as possible. You may have to unscrew and slightly move the PCB while you wire up the BNC socket and switch section of the controls. When wiring is complete, dress the looms to keep them tidy.

Connect up the jack socket using about 9" of two-core cable. Insert and tighten the socket in to the lower side of backplate A. Assemble the main case completely, tightening all screws, and insert the battery box jack. The unit is ready for testing.

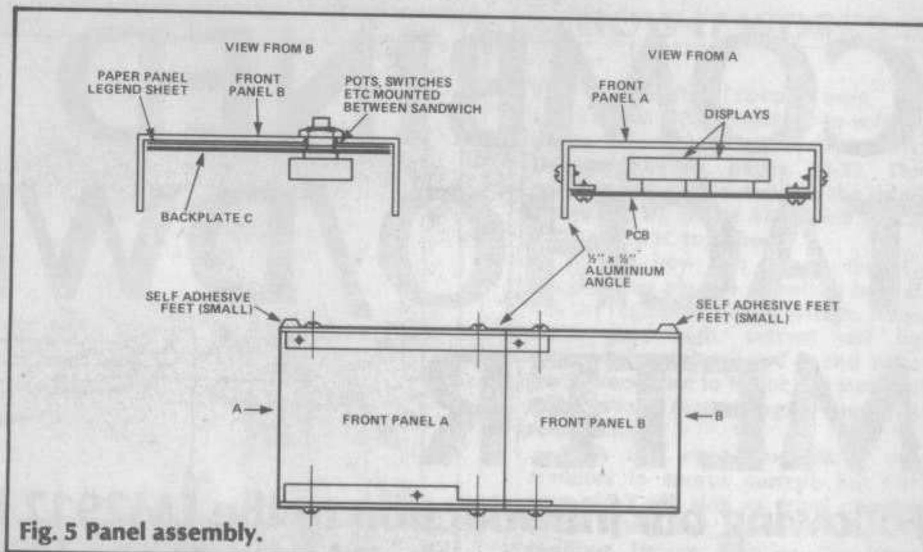


Fig. 5 Panel assembly.

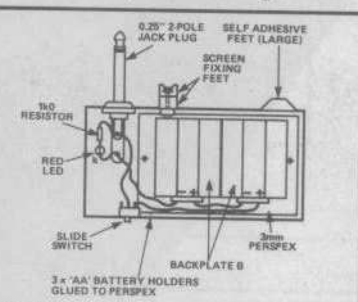


Fig. 6 Battery box.

Testing

Before switching on, turn the y position knob to halfway, the y amplifier (or gain) knob to unity, the timebase switch to '1', the knob marked 'SWP VAR' to halfway and the mode switch to 'SCOPE'. Plug in the scope lead and switch on. A trace should appear around the centre of the screen.

The easiest test is to place the scope lead close to a mains lead. NEVER CONNECT THE LEDSCOPE INPUT DIRECT TO THE MAINS — IT IS POTENTIALLY LETHAL. With the scope lead near a mains supply it should pick up hum. By adjusting y amplifier gain and the timebase ('SWP VAR'), the scope should show a clear sine wave whose amplitude should be adjustable using the y amp control.

To check the meter functions, use appropriate known voltage sources and resistances. In ohmmeter mode, the display should show the right-most column only as a bar.

ETI

BUYLINES

A kit of parts, excluding the case, is available from Lefax Ltd, Unit 6, Genesis Business Centre, Redkiln Way, Horsham, West Sussex RH13 5QH (tel: 0403 54135) at £49.95 incl. VAT plus £2.50 p&p. The biggest problem for those wishing to source their own components will be the LED arrays. You should use the type specified, which have a greater light output than other types which look the same. Maplin type FT61R will not be bright enough. You could always make your own array from 140 individual LEDs — in which case use orange types which are brighter or, if money is no object, ultra-brights.

The other components should not prove problematic. The ICL 7621 is a low-power dual op-amp, but is not critical. It is available from Electromail, Dept. 101, PO Box 33, Corby, Northants NN17 9EL (tel: 0536 204555), but the 353 or 072 should be just as usuable. The prototype case was made from aluminium and perspex which are available from high-street shops who will usually cut them to size for you. Lefax have a number of all-aluminium cases available, which are ready shaped, drilled, painted and legended. Together with an ABS plastic battery box, the cost is £14.95 inclusive of everything, if ordered with the main kit, or £14.95 plus £2.50 p&p if ordered separately. The company also sell a low cost test lead kit suitable for this project (or, indeed, for use with other meters and scopes). The price is £7.95 inclusive for which you get a scope lead with integral probe and BNC plug and a set of 4mm test leads.

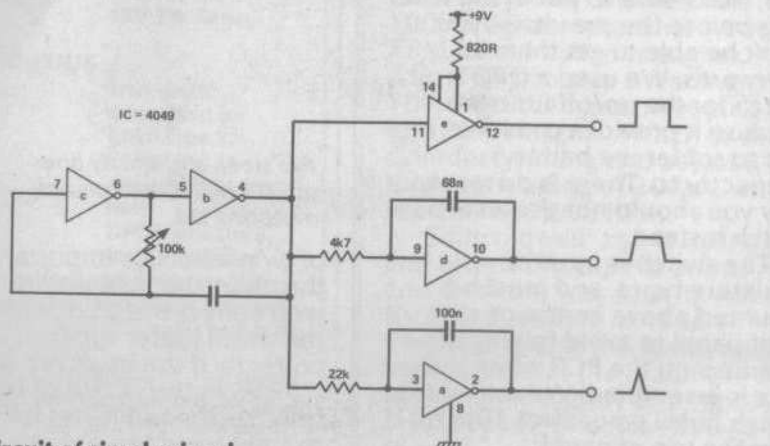


Fig. 7 Circuit of simple signal generator for testing.