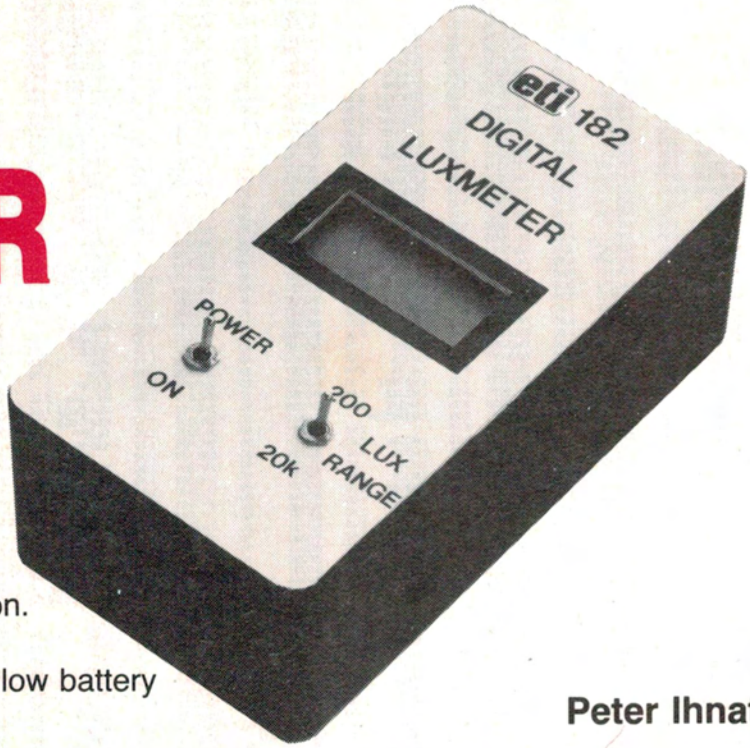
Project 182

DIGITAL LUXMETER



This instrument is a portable, battery operated device for measuring illumination. It covers light levels from below 1 lux up to 20k lux in two ranges and includes low battery indication.

Peter Ihnat

ETI, IN THE PAST, has described many instruments for measuring just about anything from heart rate through to passion (yes, we published a passion meter once long ago !!!). One quantity however which seems to have missed out is *light*.

In the last twelve months we described two devices which measure light, but not in absolute terms. They were both darkroom exposure (or light) meters. These 'measure' the amount of light in a particular area of the image produced by an enlarger by comparing the intensity with that of a value obtained when a test print was made. Unfortunately, outside the darkroom this technique is of limited use.

The current project can measure light in absolute terms, just as we measure current in amps and frequency in Hertz. This results in a versatile unit for anyone having anything to do with lighting systems. Some examples include, photographers, electricians who fit lights into classrooms, offices and factories or even the home video nut who insists on video taping under very low light levels . . . the list is endless.

Why do these people need to know the level of illumination? The answer is rather obvious in the case of photographers, movie and video camera operators. They need to ensure that the illumination of a scene or subject is sufficient to produce images with the maximum amount of detail. Poor lighting setups can only produce poor images.

In the case of classroom, factory and office lighting, there are recommended illumination levels to suit the type of work performed in each area. To give the reader an idea of illumination available from some common sources and some recommended levels, refer to Table 1. As you may notice, the eye (like the ear) has a wide dynamic range.

Description	illumination
Full moon	0.4
Candle flame at 1 m	1
Highways	20-30
Living rooms and offices	300-400
Shops, workshops and classrooms	500
Area for fitting components to pc board	800
Precision engineering workshops, drawing offices	1000
High precision work eg, repairing watches	3000
Bright summer day	100 000

Table 1. Illumination levels in lux.

One problem in the past with designing a luxmeter was that a suitable sensor was not available in this country. Only fairly recently has one of the few photodiodes which covers more than the red and infra-red regions of the spectrum become readily available in Australia. Ladies and gentlemen . . . introducing the BPW21 photodiode.

Figure 1 shows some of the photodiode's characteristics. Its peak spectral response is around 555 nm, corresponding to yellow/green light. Its spectral range is 350 to 775 nm which almost matches that of the human eye (see dotted line labelled as Vλ). For many applications this is quite adequate and makes it ideal for monitoring daylight or artificial light. One more important feature is that its short circuit current versus illumination is highly linear over a wide range (0.01 to 100k Lux) . . . truly a remarkable sensor.

Figure 2 shows the operation of the luxmeter in block diagram form. The BPW21 is connected in the standard way (reverse biased and into a short circuit) to produce a current in direct proportion to illumination. This is converted to a voltage which is fed into a voltmeter and displayed in digital form. Normally, a circuit such as this would be rather complex but the availability of the ICL7106 digital voltmeter IC reduces the parts count dramatically. Those interested in the digital voltmeter circuitry can refer to two previous ETI articles — ICL7106 data sheet ETI October 1977 and project 161 ETI August 1982.

Contruction

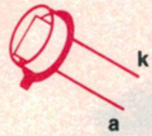
Construction should present few problems if the recommended pc board is used. The layout is not critical and other forms of construction such as Vero-board, may be employed. Use of the recommended board does result in a very compact unit and if correctly assembled will help to ensure that everything works first go.

Firstly, inspect the pc board for broken tracks or shorts — check carefully in the areas where tracks pass between IC pins. If all is OK, start by fitting the three wire links. Note that one link has a 90° bend in it.

Next, mount the resistors, capacitors and trimpots in that order — it may be necessary to bend the leads of capacitor C6 inwards slightly to fit in its correct position. The 40- ▶

Silicon photodiode with incorporated Vλ filter

BPW21



Special features:

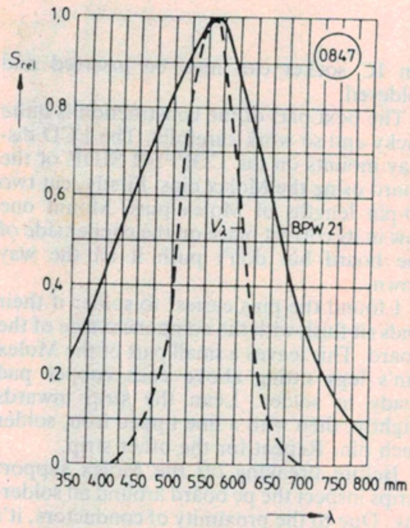
- High reliability
- No testable degradation
- Low noise
- High open-circuit voltage as photovoltaic cells
- Detector for low illuminance
- Short switching time
- High photosensitivity
- Strong logarithmic relation between V_0 or I_s and illuminance of 10^{-2} to 10^5 lx
- Wide temperature range
- Suitable in the range of visible light

Characteristics (T_{amb} = 25°C)

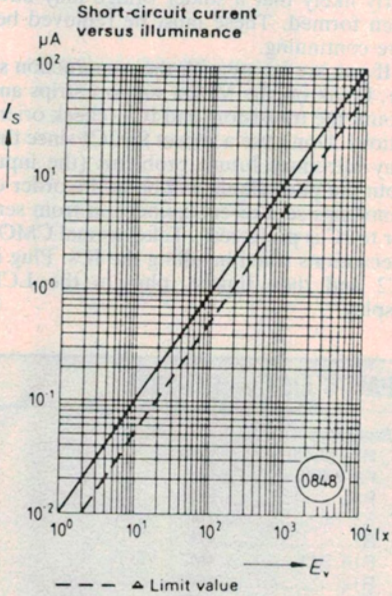
Photosensitivity (V_R = 5 V, standard light A, T = 2856 K)	S	9 (≧ 5,5)	nA/lx
Wavelength of max. photosensitivity	$\lambda_{S\,max}$	550	nm
Spectral range of photosensitivity (S = 10% of S_{max})	λ	350...775	nm
Radiant sensitive area	A	7.34	mm²
Dimension of radiant sensitive area	L x B	2.71 x 2.71	mm
Distance chip surface to case top edge	H	1.9...2.3	mm
Half angle	φ	60	degrees
Dark current (V_R = 5 V)	I_R	2 (≦ 30)	nA
(V_R = 10 mV)	I_R	8	pA
Spectral photosensitivity (λ = 550 nm)	S_λ	0.21	A/W
Quantum yield (λ = 550 nm)	η	0.47	Electrons / Photon
Open-circuit voltage (E_v = 1000 lx, standard light A, T = 2856 K)	V_0	390 (≧ 320)	mV
Short-circuit current (E_v = 1000 lx, standard light A, T = 2856 K) (Deviation of I_s linearity in the range of $3 \cdot 10^{-2}$ to 10^4 lx: max. 12%)	I_S	9 (≧ 5,5)	μA
Rise and fall time of photocurrent from 10% to 90% and from 90% to 10% of final value (R_L = 1 kΩ, V_R = 10 V, λ = 550 nm, I_P = 9 μA)	t_r, t_f	1	μs
Forward voltage (I_F = 100 mA, E_e = 0, T_{amb} = 25°C)	V_F	1.2	V
Capacitance (V_R = 0 V, f = 1 MHz, E_v = 0 lx)	C_0	750	pF
(V_R = 10 V, f = 1 MHz, E_v = 0 lx)	C_{10}	220	pF
Temperature coefficient of V_0	TC	−2.6	mV/K
Temperature coefficient of I_S	TC	0.12	%/K

Figure 1. Silicon photodiode characteristics.

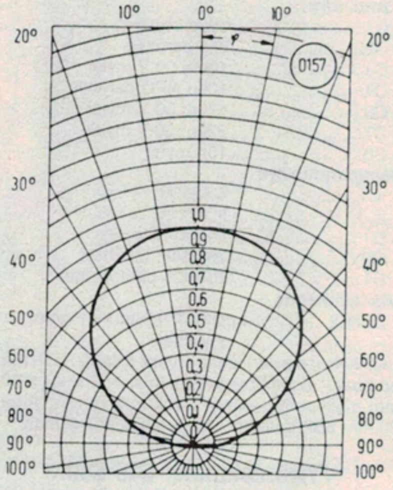
Relative spectral photosensitivity versus wavelength



Short-circuit current versus illuminance



Directional characteristic
Short-circuit current versus half angle



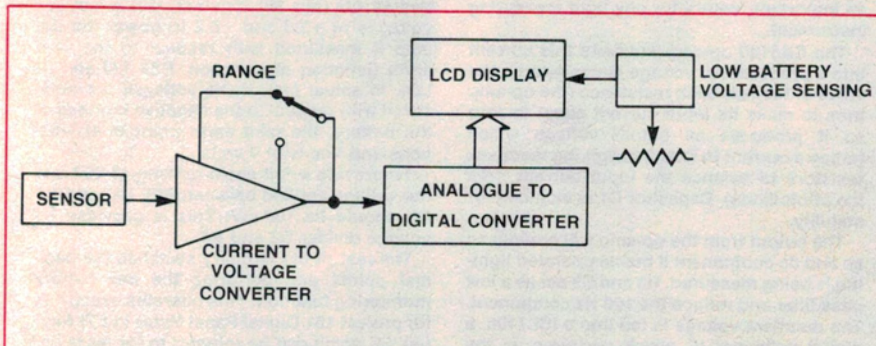


Figure 2. Block diagram.

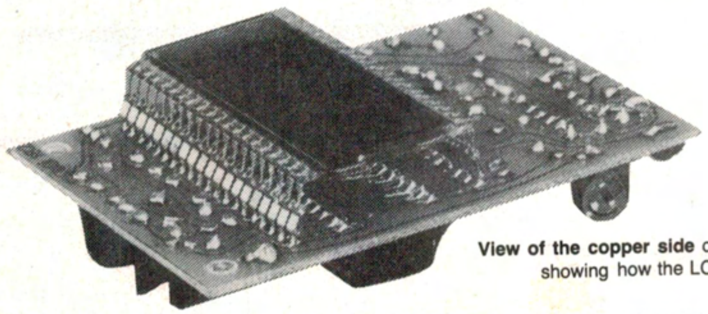
pin IC socket can now be inserted and soldered.

The next part of the construction is quite tricky and so work carefully. The LCD display mounts on the COPPER SIDE of the board using the Molex pins. Firstly, cut two 20-pin lengths of Molex pins. Mount one row in its correct place on the copper side of the board but don't push it all the way down.

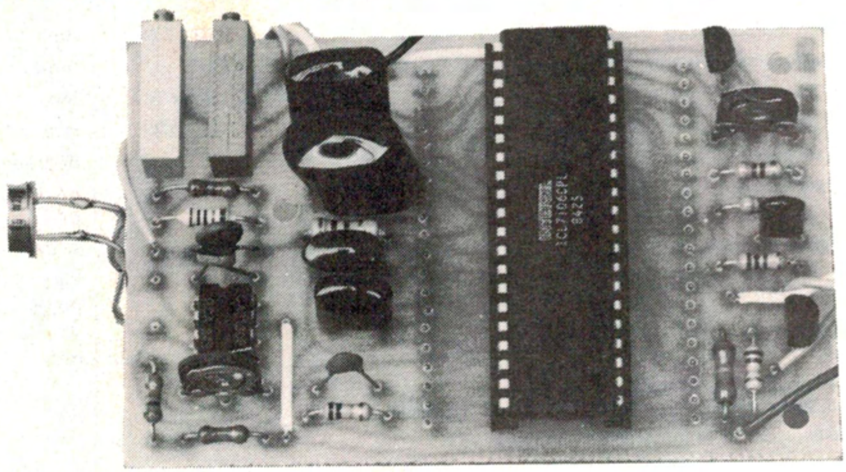
I found the pins easiest to solder if their ends sit flush with the component side of the board. This leaves a small part of the Molex pin's legs sitting above each copper pad ready to solder. Lean the strip inwards slightly, then with a fine tipped iron, solder each pin. Repeat for the other strip.

Before breaking off the Molex support strips inspect the pc board around all soldering. Due to the proximity of conductors, it's fairly likely that a solder bridge may have been formed. These must be removed before continuing.

If you are happy with the construction so far, break off the Molex support strips and mount the transistors and IC1 (check orientation). Don't use a socket for IC1 since this may introduce future problems (the input from the photodiode will be in the order of nanoamps so a direct connection from sensor to IC is preferred). Take normal CMOS precautions when handling the ICs. Plug in IC2 and then finally, plug in the LCD display. ▶



View of the copper side of the pc board showing how the LCD is mounted.



View of the component side of pc board.

PARTS LIST — ETI-182

Resistors................all 1/4W, 5%
- R1, R6, R8............100k
- R2, R4..................1k
- R3.........................27k
- R5, R9...................1M
- R7.........................47k
- R10, R11...............4M7
- R12........................680k
- RV1.......................100k ten-turn trimpot
- RV2.......................1k ten-turn trimpot
- RV3.......................100k trimpot
- RV4.......................500k trimpot

Capacitors
- C1..........................180p ceramic
- C2..........................56p ceramic
- C3, C5...................100n, 50 V mylar
- C4..........................100p NPO ceramic
- C6..........................470n, 50 V mylar
- C7..........................220n, 50 V mylar
- C8..........................10n mylar

Semiconductors
- IC1..........................CA3130
- IC2..........................ICL7106
- Q1 ....BC547, 8 or 9
- Q2 ....2N5458, MPF106
- D1...........................BPW21 photodiode.

Miscellaneous
- SW1,2 ....DPDT miniature toggle switches

LAD204(or similar) liquid crystal display; ETI-182 pc board; Scotchcal front panel; 150 x 80 x 50 mm multi-purpose box; 9 volt battery clip; three 20 mm 6BA bolts (countersunk head); 9 nuts.

Price estimate: $45-$50

HOW IT WORKS

The block diagram shown in Figure 2 gives the overall operation of the unit. Very basically, illumination is converted into a current, current into voltage and then voltage into digital readout.

Photodiode D1 produces an output current proportional to illumination. If this is fed into a short circuit, the current versus illumination characteristic becomes extremely linear, an important feature for any light measuring instrument.

The CA3130 op-amp converts this current into a proportional voltage dependent on the value of the feedback resistance (the op-amp tries to make its input current equal to zero so it produces an output voltage which forces a current to flow through the feedback resistors to balance the input current from the photodiode). Capacitor C1 is included for stability.

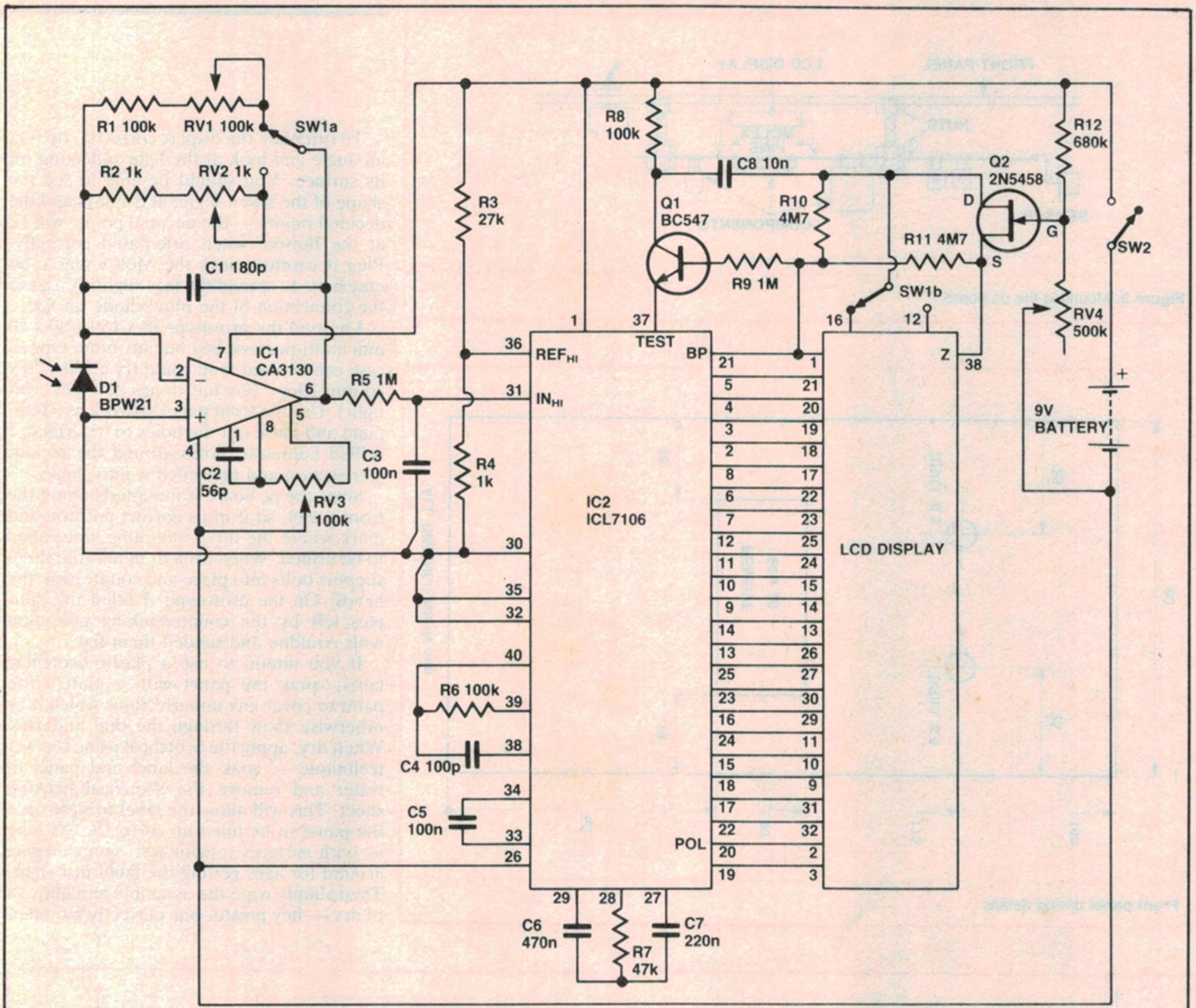
The output from the op-amp will contain an ac and dc component if mains operated lighting is being measured. R3 and C3 act as a low pass filter and reduce the 100 Hz component. The resultant voltage is fed into a ICL7106, a digital voltmeter IC which performs all the hard work of displaying its input voltage. More details of the operation of the ICL7106 can be found in the references given in the main text.

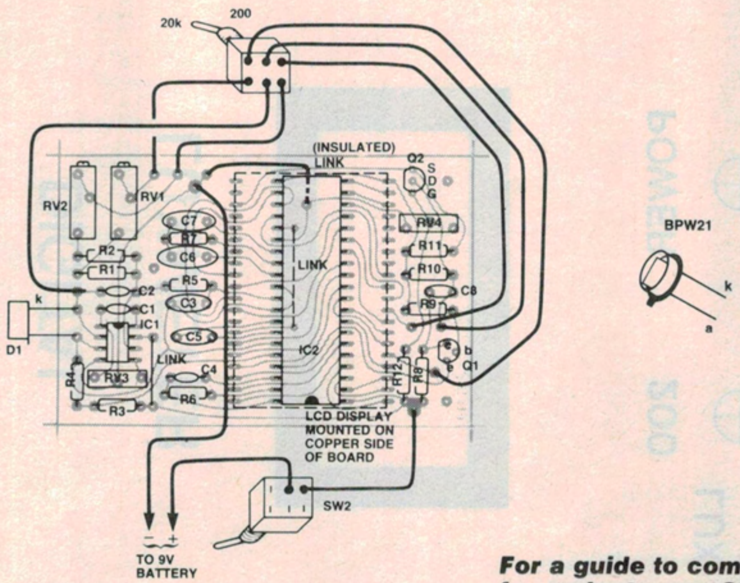
One interesting aspect of circuit operation is the method used to provide split rail voltages for the op-amp. The ICL7106 has a built in voltage reference of approximately 2.8 volts between pin 1 (Vcc) and pin 32 (common).

By connecting common, REF LO (pin 36) and IN LO (pin 30) together, this produces voltages of +2.8 and −6.2 to power the op-amp if measured with respect to the fake earth (junction of common, REF LO and IN LO). In actual fact, if the voltages are measured with respect to the negative terminal of the battery, the fake earth point is at +6.2 volts and Vcc is at 9 volts.

To provide a full scale reading of 200 mV, the voltage applied between REF HI and REF LO should be 100 mV. This is provided by voltage divider R3 and R4.

The rest of the circuitry switches the decimal points and performs the low battery monitoring function. This operates exactly as for project 161 Digital Panel Meter in ETI August '82 which can be referred to for more details.





For a guide to components and kits for projects, see SHOPAROUND this issue.

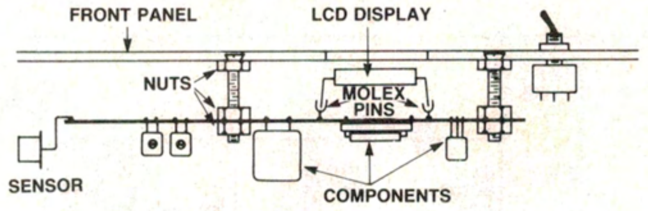
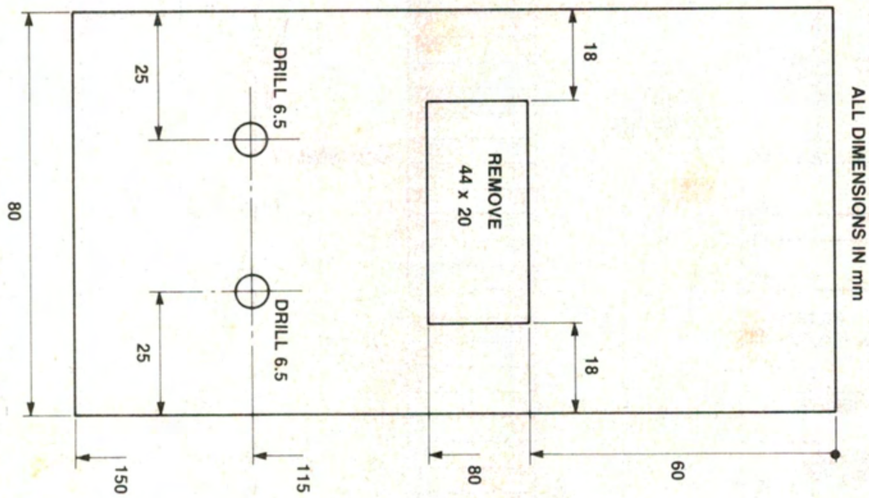


Figure 3. Mounting the pc board.



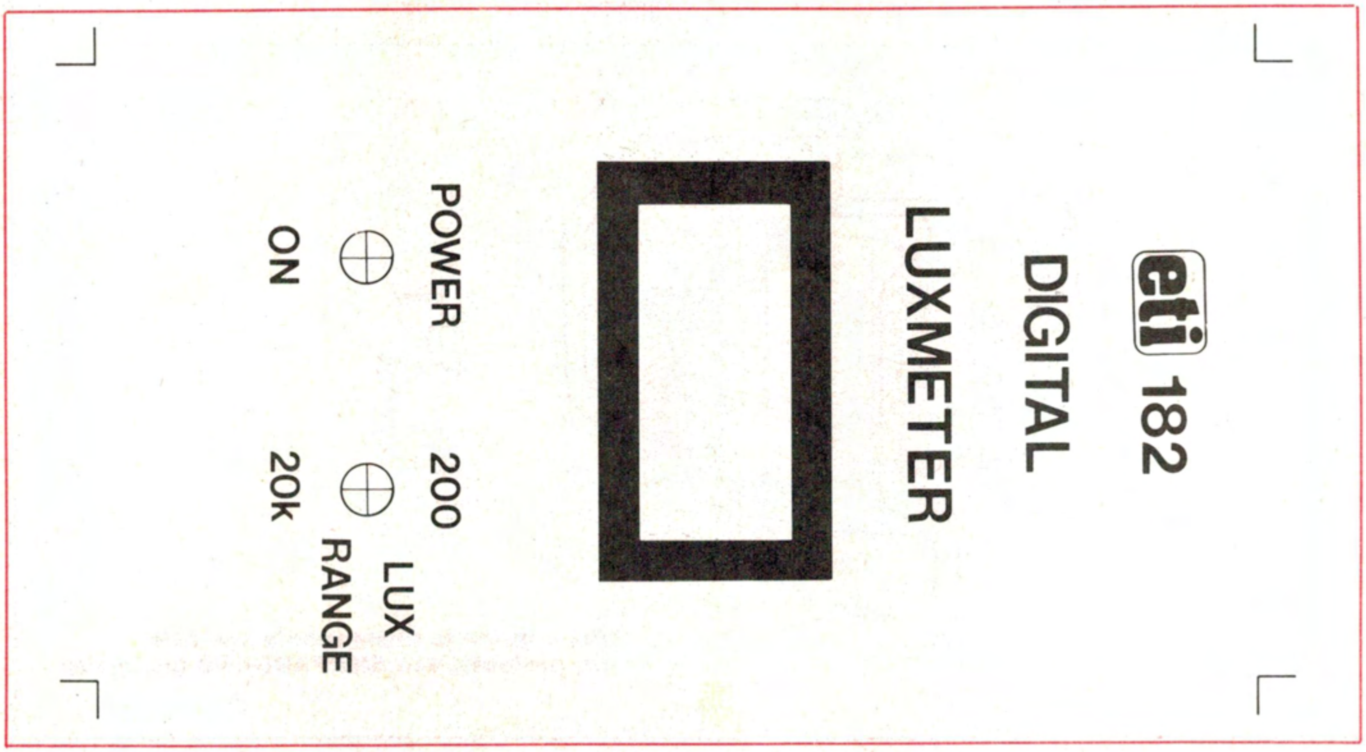
Front panel drilling details

To orientate the display correctly, tip it at an angle and look at the light reflecting off its surface. You should be able to see the shape of the seven segment displays and the decimal points — the decimal points will sit at the bottom when orientated correctly. Plug it carefully into the Molex pins (you may have to spread the legs slightly). Leave the connection of the photodiode till last.

I housed the prototype in a 150 x 80 x 50 mm multi-purpose box but any other type of case can be used (you could try a 130 x 75 x 40 mm Zippy box but things may get a bit tight). Use the front panel artwork as a template and mark out the holes to be drilled. I drilled numerous holes around the rectanglar section and then filed it into shape.

Since the pc board is mounted behind the front panel, sit it in its correct position and mark where the three mounting holes need to be drilled. When drilled, mount the three support bolts into place and countersink the heads. On the prototype, I filled the dimples left by the countersinking operation with Araldite and sanded them flat.

If you intend to use a plastic Scotchcal label, spray the panel with a matt white paint to cover any imperfections which may otherwise show through the thin material. When dry, apply the Scotchcal using the wet technique — soak the label and panel in water and remove the Scotchcal backing sheet. This will allow the label to slide over the panel to be lined up correctly. As long as both surfaces remain wet, you can play around for ages getting the label just right. Then simply wipe the assembly and allow it to dry — hey presto, one perfectly mounted ▶



label. Mounting dry Scotchcal onto dry panels only allows you one chance of getting it right — usually you miss.

Next, drill an 8 mm diameter hole in one end of the case to hold the sensor. If your particular case has internal ribs, remove those in the vicinity of the hole to allow the front window of the sensor to sit flush with the end of the case. Mount the two toggle switches and wire the unit as shown in the overlay diagram. Place another nut on each of the support bolts and fit the board into place. A final nut on each bolt will secure the board (refer to Figure 3).

Setting up

The first adjustment to be made is the offset trimmer RV3. This should be done BEFORE the photodiode is connected. Simply switch the unit on and adjust RV3 until the display shows 0. If this is not possible with your unit or if the reading on the display wanders randomly, check the orientation of semiconductors and all your soldering. It's no use continuing until this offset adjustment can be made.

If all is well, the photodiode can be attached — check orientation carefully. Use some tinned copper wire to extend the leads by about 15 mm. To set the low battery warning trimpot (RV4), run the unit from an adjustable power supply set at 9 volts. Watch the reading carefully while decreasing the voltage. When the reading starts to differ drastically from the original, set RV4 so that the LO BAT indicator just comes on. Do not exceed 9 volts on the supply leads when doing this test.

The final adjustment to be performed involves the calibration of the unit. The most accurate way of doing this is to compare the reading with that of a commercial unit. Set up a fixed light source, such as a light globe, and place the commercial light meter at a position which gives a reading of 100 lux. Place the ETI-182 at this same distance, select the 200 lux scale and adjust RV1 until the display shows 100 lux. Next, repeat the exercise with a reading of 1000 lux (by shifting the meters closer to the globe), use the 20k lux range and adjust RV2.

If you don't have access to a commercial light meter, the following not-quite-so-accurate method can be used for calibration. Set up a 100 watt light globe in an area where there are no reflecting surfaces, brightly coloured walls or mirrors. The illumination level at 300 mm from the globe will be 1000 lux and at 750 mm, 160 lux. Simply place the meter at each of these distances and set the appropriate trimpots.

The unit is now ready for use. ●