Giant Musical Bargraph

Now you can have 100 LEDs to play along with your 76 trombones. Paul Brow's bargraph display is bigger than some people's hifi - and comes in two sizes.

Many of us can remember the old needle type VU meters, prolific on hifi tape decks and some amplifiers in the 1970s. They virtually disappeared because of the high cost and the introduction of solid state LED bar graph displays. Being fascinated with the new technology, I modified an amplifier in 1977, fitting two 10-bar LED displays as power meters. As bar graph ics were not available, the 10-driver channels were made from three quad op amps and a reference ladder of resistors - a high component count for a simple display. Today, all modern tape decks, mini hifi units, equalisers and some amplifiers are fitted with a variety of bar graph displays using custom drivers ics, and displays such as LED, LCD, and fluorescent. The displays are configured most commonly as stacked bars or blocks, and all perform the same basic function of showing signal level, overall or at particular frequencies. We have also all

Figure 1: the circuit of the audio input, AGC and inverter and inverting buffer

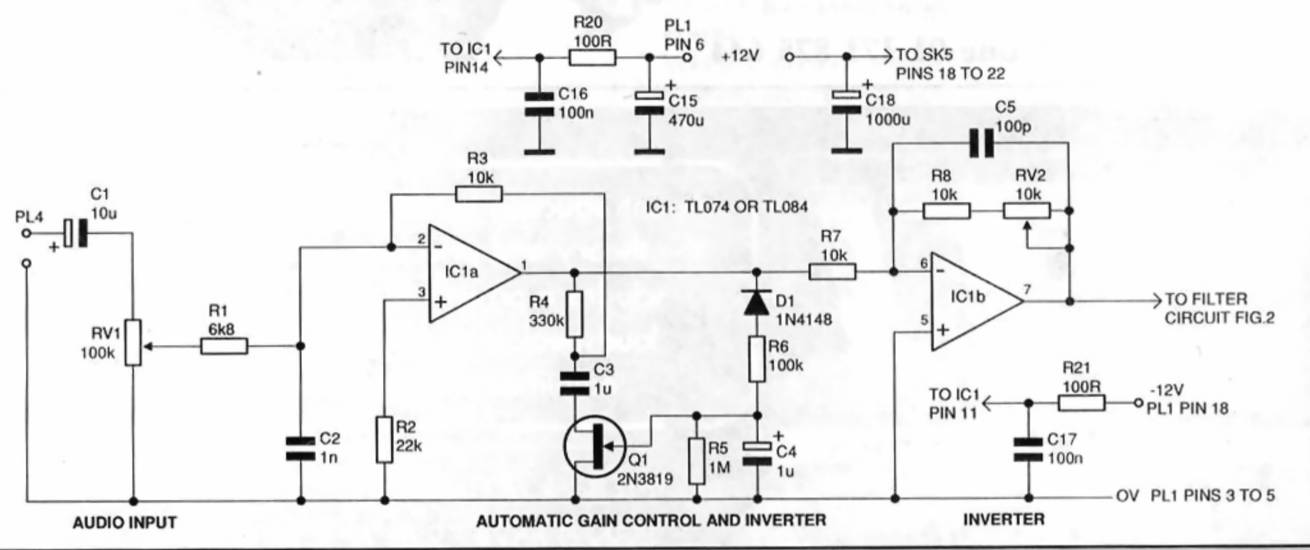


Figure 2: the circuit of the low pass filter, high pass filter and diode pump

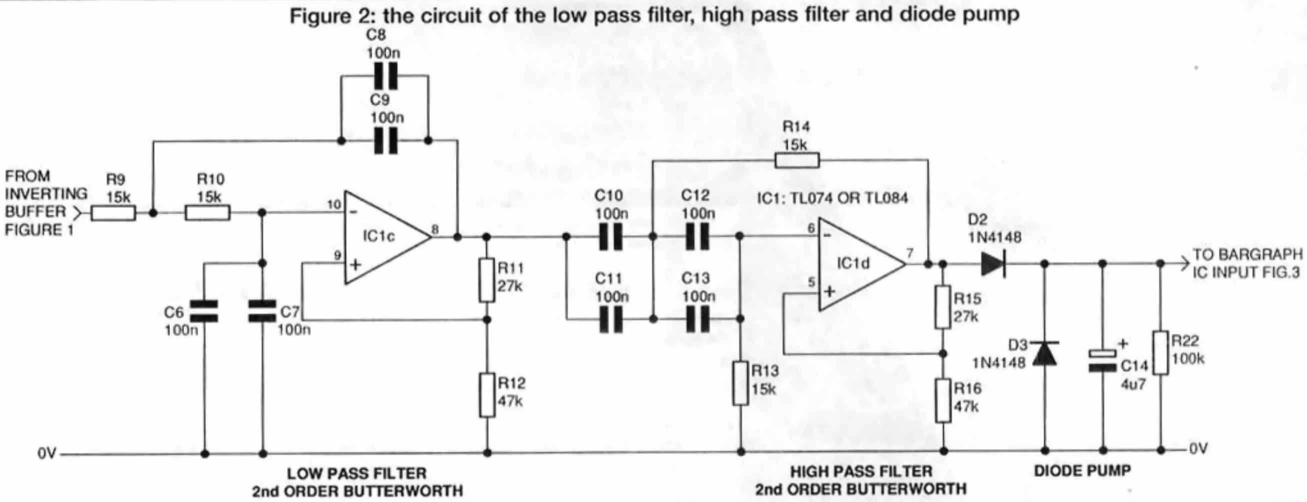


Figure 3: the circuit of the bargraph driver - basic 20mA per output version

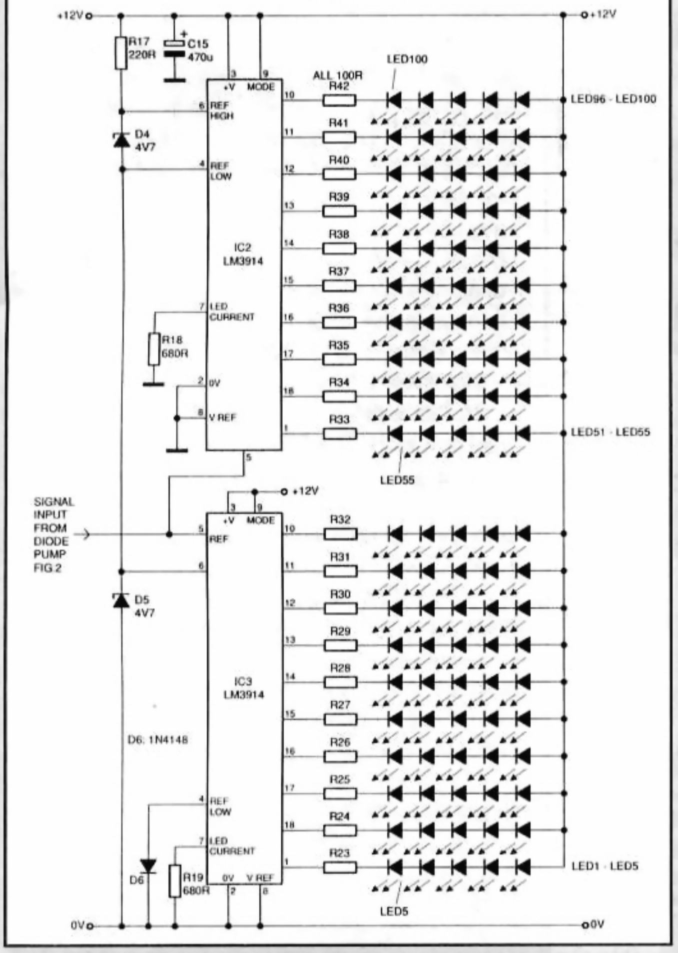


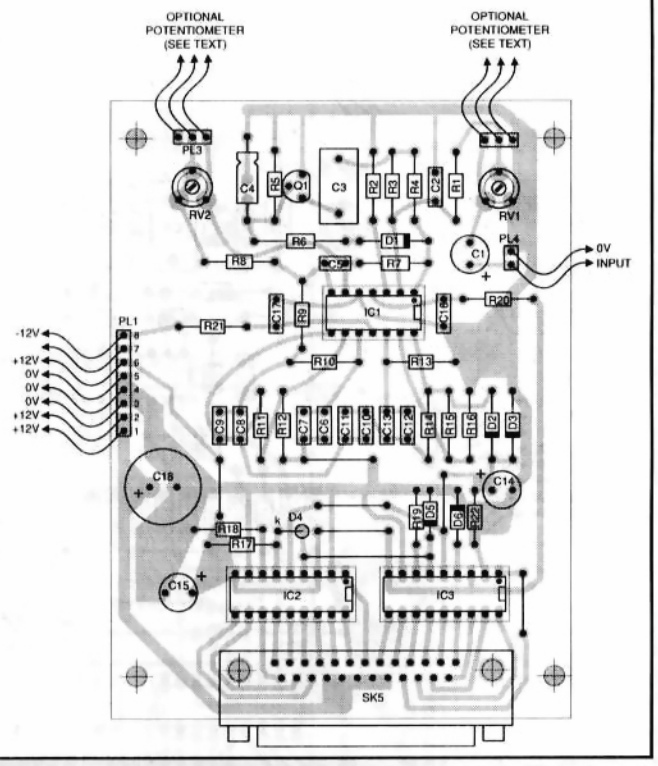
Figure 4: capacitor values for alternative frequencies

Frequency	Cx	C6, C8, C10, C12	C7, C9, C11, C13
50Hz	212n	100n	100n
100Hz	106n	100n	–
200Hz	53n	47n	4n7
500Hz	21n	22n	–
1kHz	10n	10n	–
2kHz	5n3	4n7	470p
4kHz	2n6	2n2	470p
8kHz	1n3	1n	330p
16kHz	660p	560p	100p

$$C = \frac{1}{2\pi Rf}$$

$$C\ (nF) = \frac{1,000,000}{6.28 \times 15 \times f}$$

Figure 5: the component layout of the 20mA version



seen sound to light units, so I wondered how effective a combination of these would be - hence this project, a giant sound-to-light driven LED bargraph.

Modern audio equipment uses anything from five simple LEDs to ten or twenty individual segments. The display is large and I didn't want the discrete steps to be noticeable so I decided that 20 separate bars of 5 giant 10mm LEDs would be effective. More on the display design later.

I have designed the control circuit, figures 1 to 3, to give the most pleasing and effective display. Music content can vary wildly, so displaying different types would require some control adjustment. Enter automatic gain control (AGC), which produces a fully effective display with loud or quiet music. This means, of course, that the display is no good as a true VU meter, as the combination of automatic gain control and linear display driver ics makes the actual levels meaningless.

Remember, this has been designed to be the most effective and entertaining display. I tried LOG and LOG/LIN display driver ics, but they were not effective visually. However, if you are curious (and have some expensive LOG driver ics lying around), try changing the LM3914 driver ics for LM3915, or even an LM3916, and check the result for yourself.

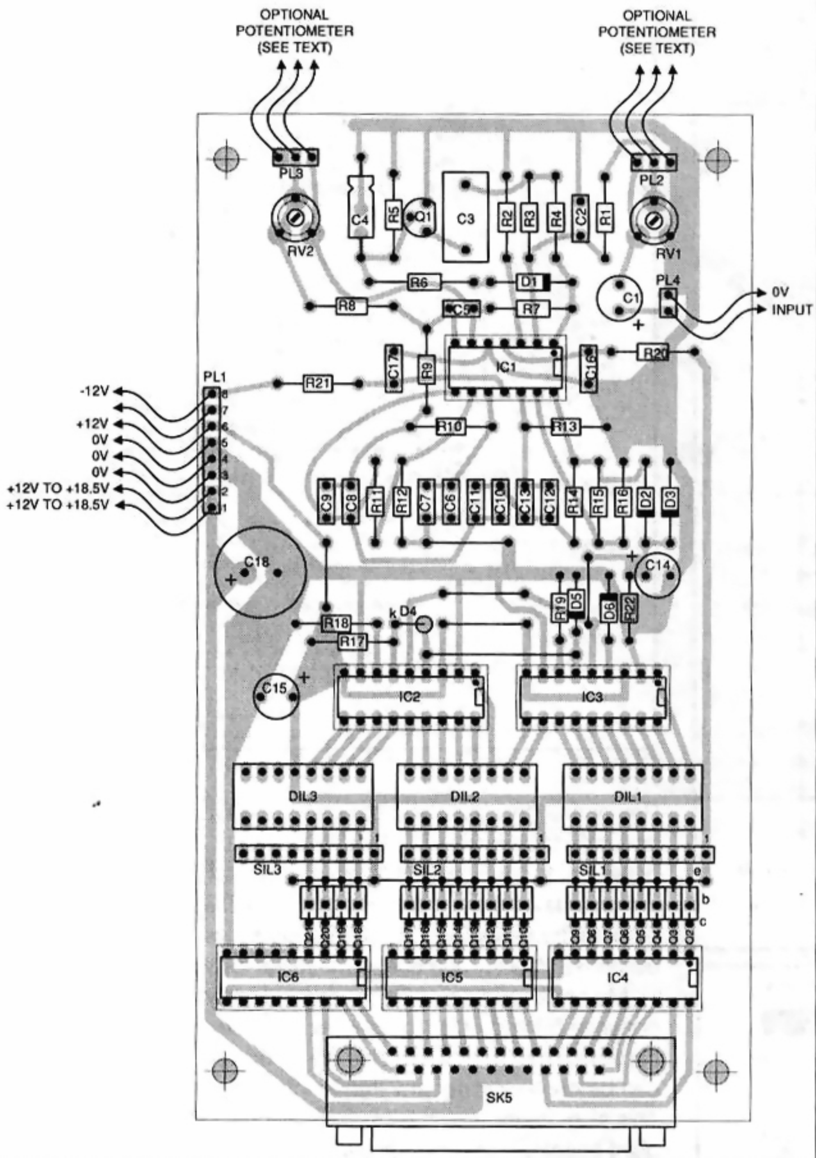
My preferred frequency range for display purposes is bass between 50 and 100Hz. However, this may not be everyone's choice so the control circuit is designed with active filters that can be configured for any frequency in the audio spectrum. This also means it is feasible for adventurous types to build a giant spectrum analyser display with seven to ten bar graph units - but we are getting carried away. Even so, figure 4 shows component values required for different frequencies.

Two versions

The circuit diagram shows two capacitors paralleled in each of the four filter capacitor locations, C6 to C13. Two capacitors can be combined to create the required value for a specific filter frequency. For 50Hz, an overall value of about 212nF is required so you could fit a 220nF capacitor in location C6 and forget about C7. Alternatively, you can fit a 100nF capacitor in location C6 and another in C7 to produce a total of 200nF, close enough for this purpose. The same applies to C8 through C13. Figure 4 shows some typical frequencies, and the overall value of capacitance that would need to result from each pair of filter capacitors. Figure 4 also gives the formula for calculating the overall filter capacitance for any frequency. The most common frequency arrangement for multiple displays like spectrum analysers is one bar for each octave. Alternatively, you could select frequencies that display bass, middle, and treble for a triple bargraph display. I leave this to the constructor's preference (and pocket depth), but you can choose various options.

I have included details of two slightly different board versions. The basic unit has a lower current drive capability,

Figure 6: the component layout of the high current version



perfectly adequate for LEDs but not for lamps or for multiple LED displays. The high current version includes transistor drivers that are rated at 500mA maximum per channel (as long as they have a suitably hefty power supply) for driving filament lamps or other custom displays of your own design.

The main project concentrates on the 20mA per channel version, driving 100 large LEDs. The parts list shows the additional parts required for the high current version. PCB layouts have been included for both versions.

The circuit

IC1 performs the automatic gain control and filtering. The audio signal, taken from the record output socket on an amplifier, for example, is input through DC blocking capacitor C1 to potential divider VR1. This allows input level matching, which is then normally left alone. C2 is a simple first order high frequency filter to eliminate possible interference. IC1a combined with Q1 forms an automatic gain control whose output is maintained at 1.5V to 2.8V over a much wider range of input signal levels, typically 10mV to 500mV. C3 and C4 set the auto gain time constant such that it still responds to the changes in the audio while being able to amplify small signals dramatically.

Effectively Q1 behaves like a voltage controlled resistor in the op amp negative feedback loop. The FET's resistance is low (high gain) for small audio signals and its resistance is high (low gain) for large audio signal levels. The auto gain amplifier output then, via R7, drives an inverting buffer amplifier formed by IC1b. The buffer has variable gain for set-up purposes but only from unity gain to times two. The gain can increased if necessary by making VR2 47K or even 100K. C5 is a simple high frequency filter to limit high frequency interference. The inverting buffer then drives the active filters.

IC1c forms a second order Butterworth response low pass filter and IC1d forms a complementary high pass filter at the same frequency which overall forms a narrow band pass filter, with a response curve as shown in figure 14. The default values for C6 to C13 of 100nF create a 50Hz narrow band pass filter with steep roll offs either side of 12dB per octave. R11 and R12 set the filter gain (similarly R15 and R16), hence the Butterworth response. After all the frequencies except those around 50Hz have been rejected, the resulting signal is rectified and converted into a pulsating DC level formed by the diode pump arrangement of D2, D3, C14 and R22. C14 and R22 set the display decay time constant, that is, they increase the value of C14 for a slower decay.

The diode pump then drives the two linear bar graph ics. These are cascade arranged such that IC3 forms the lowest ten bar segments and IC2 forms the upper ten segments. The zener diodes D4 and D5 form voltage references for the IC internal resistor divider chains, where the junction of D4/D5 is the HI reference for IC3 and also the LO reference for IC2. This creates a seamless transition where the signal level crosses from one driver ic to the other. The LO reference of IC3 is set slightly above 0V at 0.6V with D6 to prevent the bar graph

Figure 7: side view of the PCB build

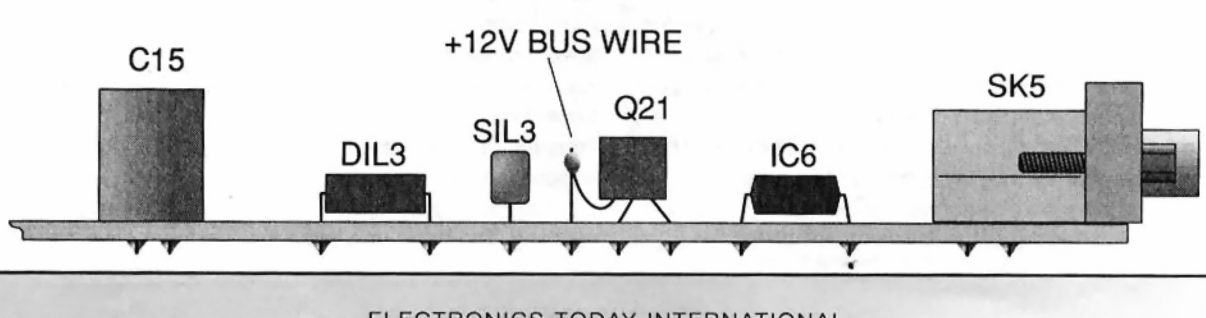


Figure 8: dimensions for the case cut-out for the D connector

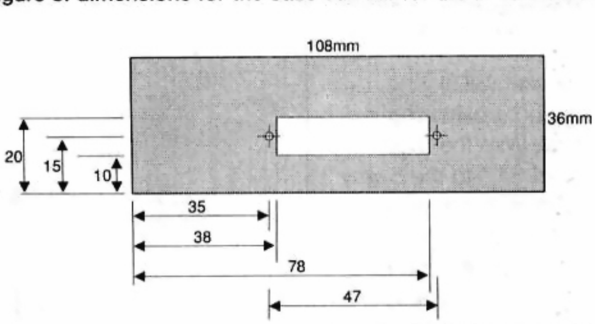
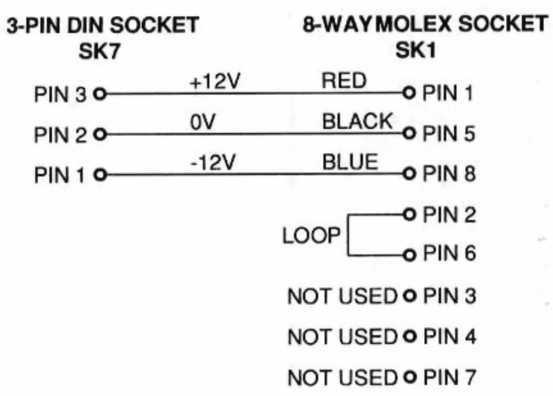


Figure 9: cable wiring chart



responding to system noise such as hiss or rumble. Both ics respond to about 4.4V making a total of about 8.8V required from the diode pump to illuminate all LED segments. R18 and R19 set the drive current maximum to about 20mA per output and R17 provides the bias current for the zener diodes. Current limit resistors R23 to R42 are not strictly necessary but provide protection in fault conditions, incorrect wiring or during testing.

In the high current version, the bar graph drivers IC2 and IC3 drive Darlington transistor arrays. SIL and DIL resistor packs are used to simplify the design (see figure 15). Q2 to Q21 convert the negative going signal to positive going to drive the transistor arrays IC4 and IC5. These are then capable of driving more LEDs or filament lamps.

Construction

The low current version is cheaper to build. Experimenters should build the high current version just in case. The main board is very straightforward. Insert all the physically smaller components first: wire links, resistors, ic sockets, SIL resistors, transistors, and then all the odd shaped components like capacitors, potentiometers and connectors. Fit the 25-way D connector last, but make sure that your PCB is trimmed such that the edge does not protrude beyond the edge of the D connector, as the connector barrel needs to stick out of the plastic case.

The 3 way Molex pin connectors and pre-set potentiometers are designed to be mutually exclusive. Fit the pre-set potentiometers VR1 and VR2 and omit the 3 way Molex pins if on board adjustment is required. Fit the 3 way Molex pins, omit the pre-set potentiometers and connect standard potentiometers to the Molex connectors if external adjustment is required. As regular adjustment is not required, I drilled two 4mm holes in the case top to gain access to the pre-set potentiometers for occasional adjustment.

Note the ZTX500s!

The majority of the additional components for the high current version fit according to the component overlay but the ZTX500 transistors Q2 to Q21 warrant a special mention. The ZTX500 was chosen because its physical size makes it easy to stack in a line to suit the spacing of the driver ics. This would have been perfect if the transistor pin out had been Base Emitter Collector to suit the way it

Figure 11: the display PCB spacer fitting

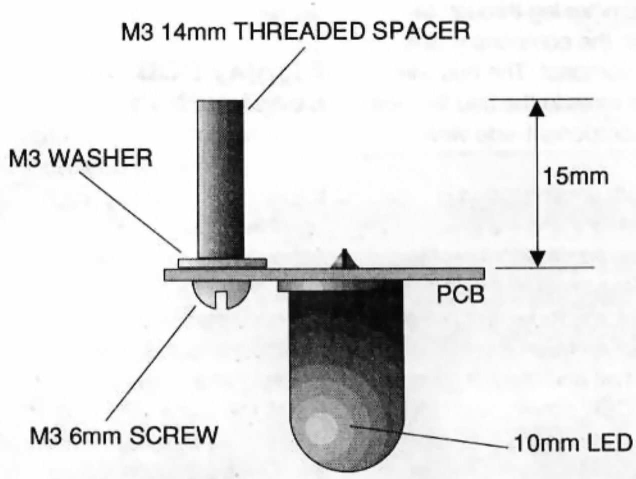


Figure 10: LED display component layout. FIVE identical modules as shown are required - increase the part numbers for four more PCBs.

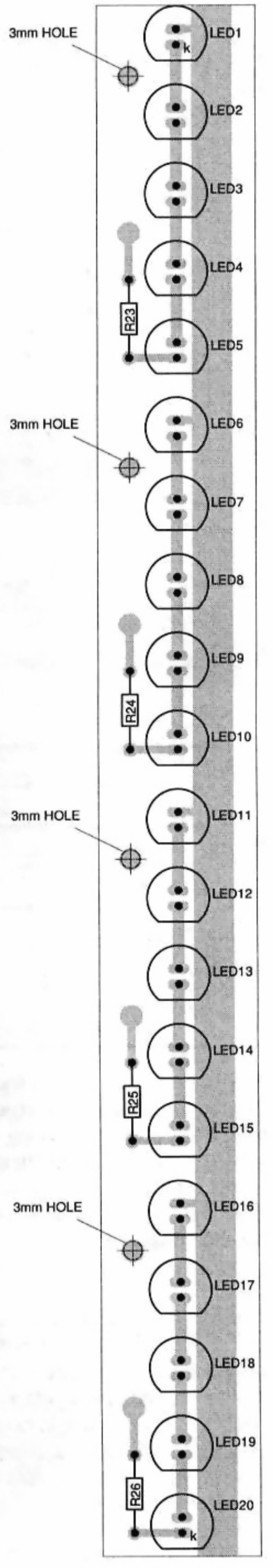
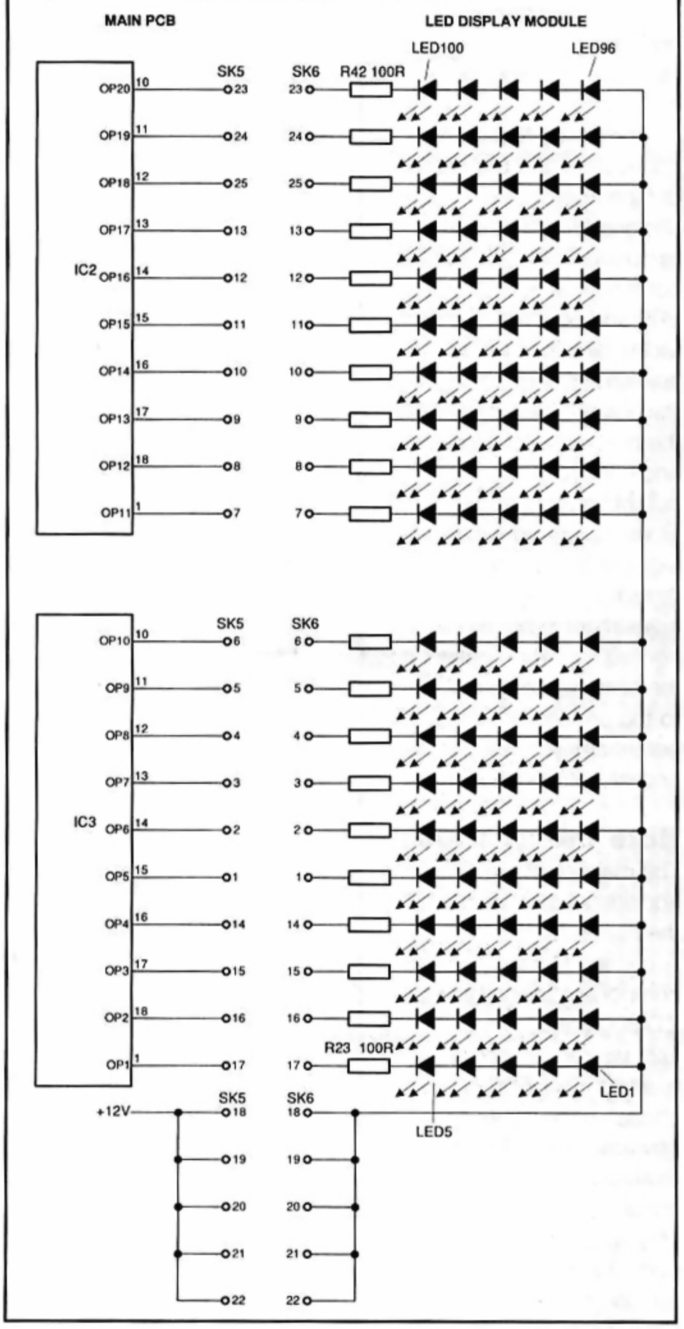


Figure 12: the output socket pin configuration



is connected but I could not find a commonly available transistor with the package style and pin out. The ZTX500 is Emitter Base Collector causing component layout problems. This was overcome by not fitting the Emitter leg through the PCB but connecting it to a bus wire on the component side instead. This keeps the layout design compact. The bus wire is really a long wire link with two support wires in the middle. See the component overlay, figure 6 and component side view, figure 7.

The Maplin case specified will fit both versions, and is easy to drill and file. The main difficulty is determining the exact position for the D connector cutout (see figure 8). When the cutout has been formed, attach the plastic end to the D connector - you will have to countersink the mounting holes slightly so that the UNC spacers do not protrude too far. Test fit this and the PCB to the case lower half and mark through the PCB holes. Drill and fit M3 12mm CSK screws with double nuts to act as 4mm PCB spacers. The other case end cap needs a 3 pin DIN socket (SK7) and a single chassis mount phono socket (SK8) mounting but positioning is not critical. Wire the 3 pin DIN socket SK7 to the 8 way Molex socket as shown in figure 9. Wire the phono socket with about 160mm of screened wire to a 2 way Molex socket (SK4). Make sure the cable screen connects to PL4 0V pin as shown on the component overlay in figure 5 or figure 6.

The construction of the bar graph display requires some accurate drilling but is more or less straight forward. Obtain a length of white electrical plastic trunking 38mm by 24mm by 1.5m. Remove the trunking top and place to one side - this will actually be used as the bottom of the display. Mark 100 hole positions all exactly 0.5 inch apart, centrally along the length of the trunking U section. Start approximately 120mm from one end. Sorry about the mixed measurement units, but the LED spacing is determined by the PCB imperial design grid. Carefully drill 100 holes of 10mm diameter. I used a bench mounted sheet metal punch, giving excellent results but slow drilling and careful de-burring is perfectly acceptable. At one end of the trunking make a cut out to accept a 25 way chassis mounting D connector. The trunking is now ready to accept the five identical display PCBs.

Display PCB construction

It is extremely difficult to etch a PCB 1.2 metres long! So the display is actually made up of five separate PCBs. Although the component numbers are listed as though it is one giant board, the five boards are all identically assembled and the resistors are all the same value. Insert R23 to R42 and then fit the 100 LEDs flat to the board.

Figure 13: the LED display wiring (part only shown) - connect wiring on copper side

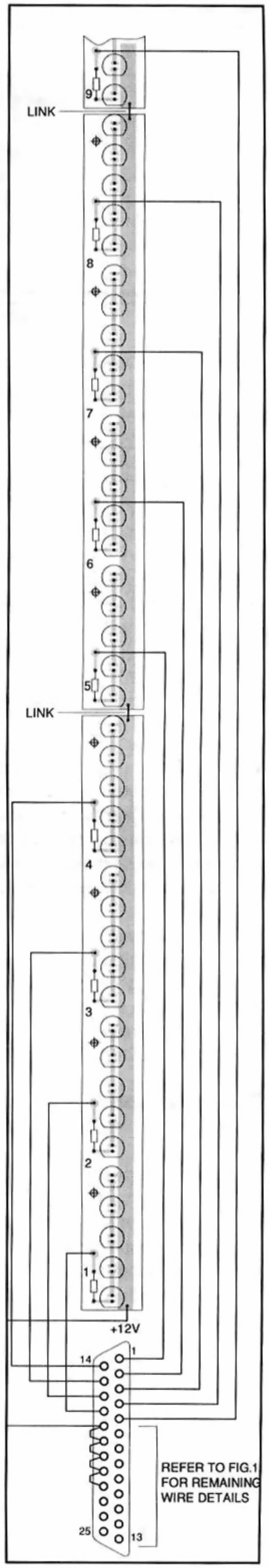


Figure 14: filter response at 1 kHz

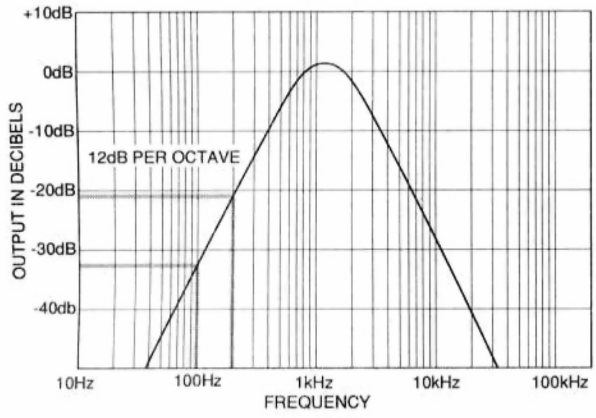
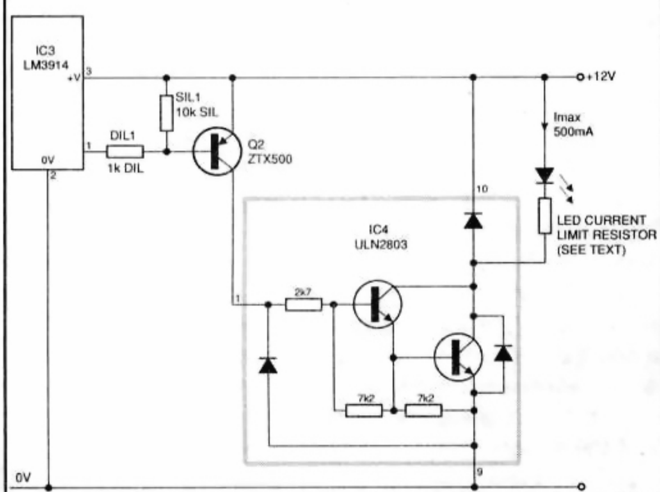


Figure 15: alternative high current driver circuit (see text) - example of one 500mA output



The board of the 20mA version of the Bargraph

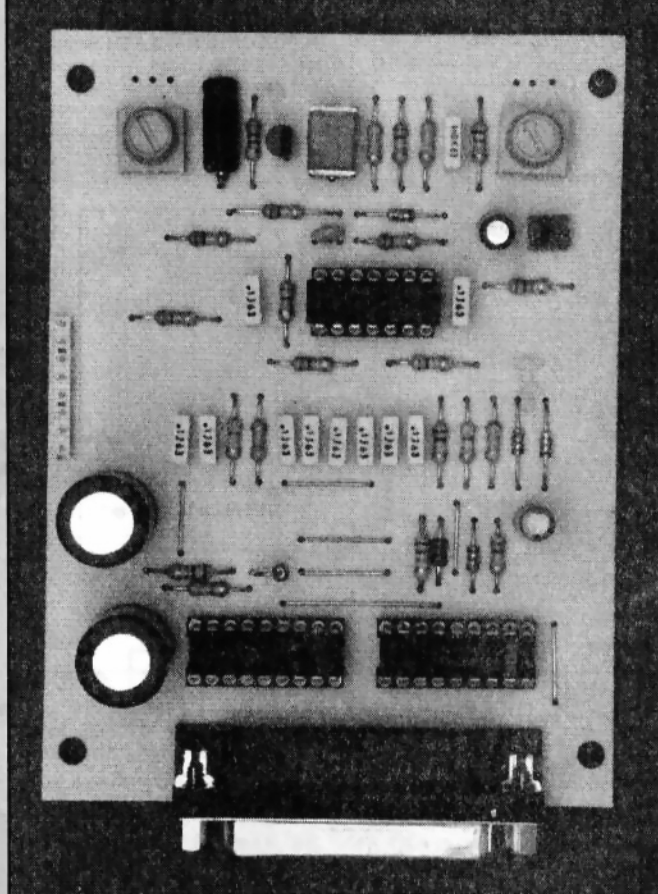
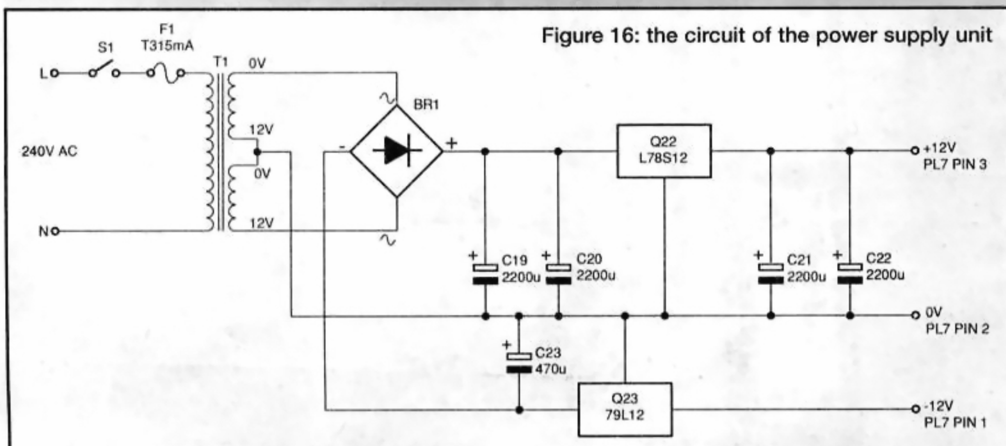
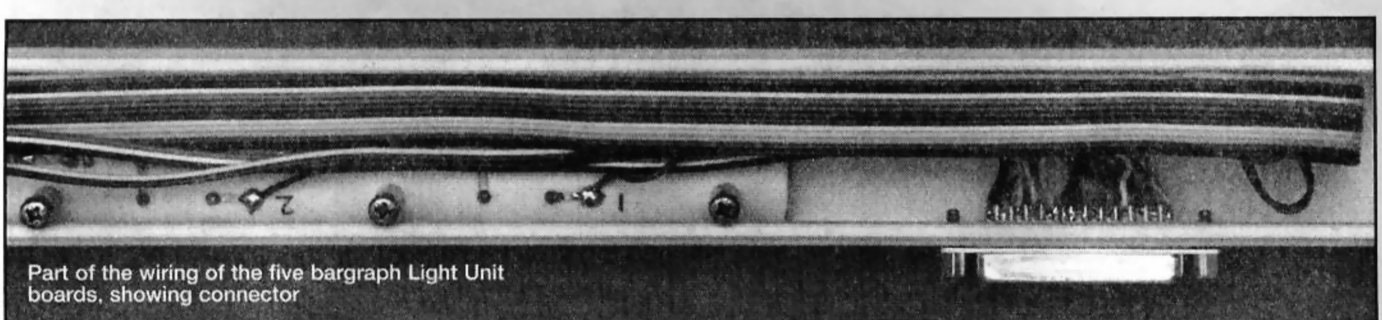


Figure 16: the circuit of the power supply unit



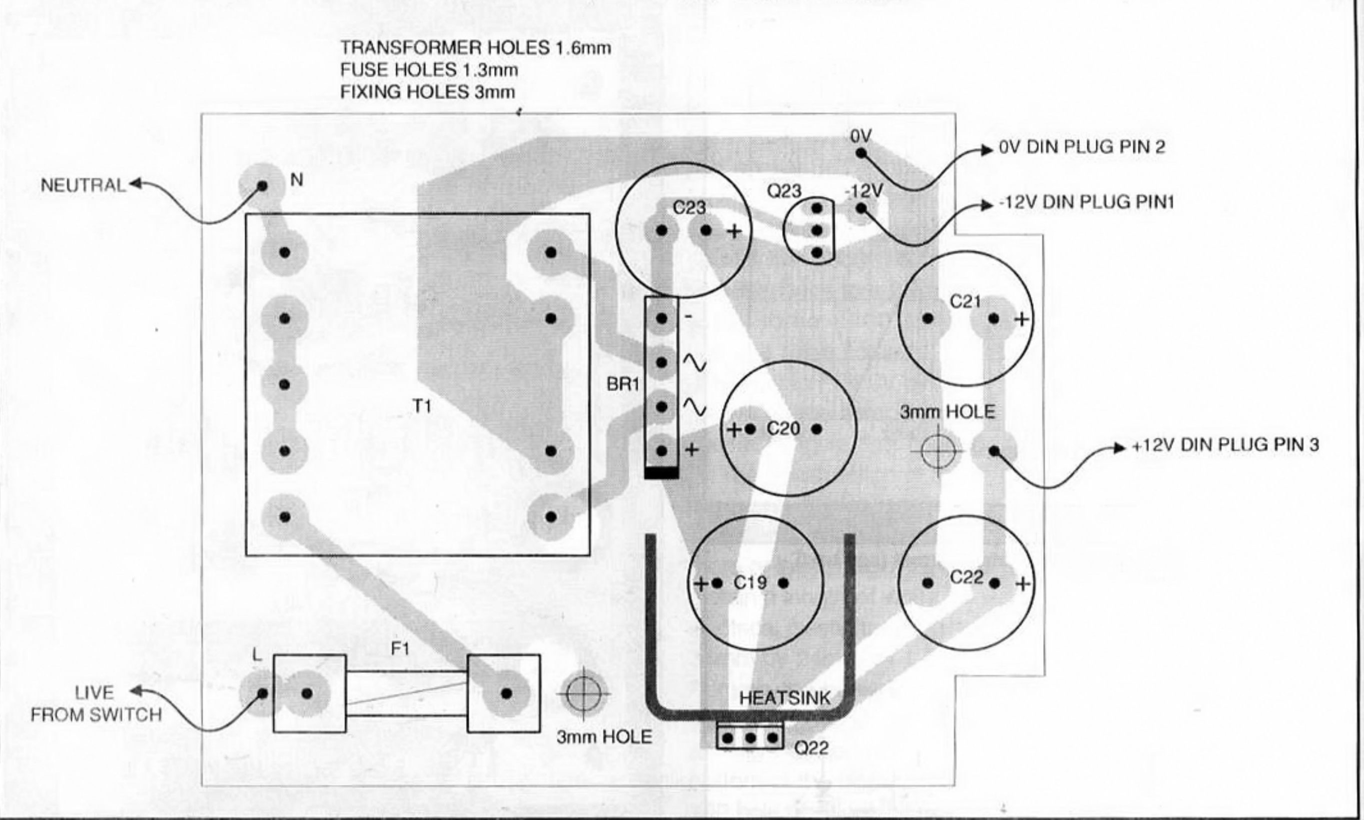
Ensure that the cathode leads all face the same direction as shown in figure 10. A 15mm spacer must then be fitted on the copper track side into the four holes per board - the spacer rests against the trunking lid (now display back) to prevent the LEDs being pushed inside the trunking. The 15mm spacers can be formed by using Maplin 14mm M3 threaded spacers and adding two or three washers (figure 11). Maplin sell insulated spacers with brass inserts of exactly 15mm but they are much more expensive (25p each) than the 11p 4mm type.

Insert the assembled display PCBs into the drilled trunking and then solder an 18 SWG tinned copper wire link from one board to another onto the wide +12V track (see photograph). Fit the 25 way D connector and then hard wire each pin connection to the



Part of the wiring of the five bargraph Light Unit boards, showing connector

Figure 17: the power supply component layout



display PCBs according to figure 12 and figure 13. I used rainbow ribbon cable to keep the wiring together. Carefully enclose all the wires and clip the 'lid' onto the trunking. You can test each segment by temporarily connecting a 12V supply, +12V to the pin 20 of SK6 and then touch the 0V supply to the appropriate D connector pin to illuminate a segment.

R23 to R42 are fitted as current limit protection so do not apply a supply voltage directly to the LEDs as this will destroy them.

Set-up and testing

If everything has been inserted into the main PCB the correct way round, of the correct value, and your soldering is of reasonable quality, then it should work first time. Connect the bargraph display to the main board using a 25-way fully connected male to male D connector lead. Make sure the lead is the type where pin 1 connects to pin 1, and similarly for all the remaining pins. It is less hassle (and cheaper) to

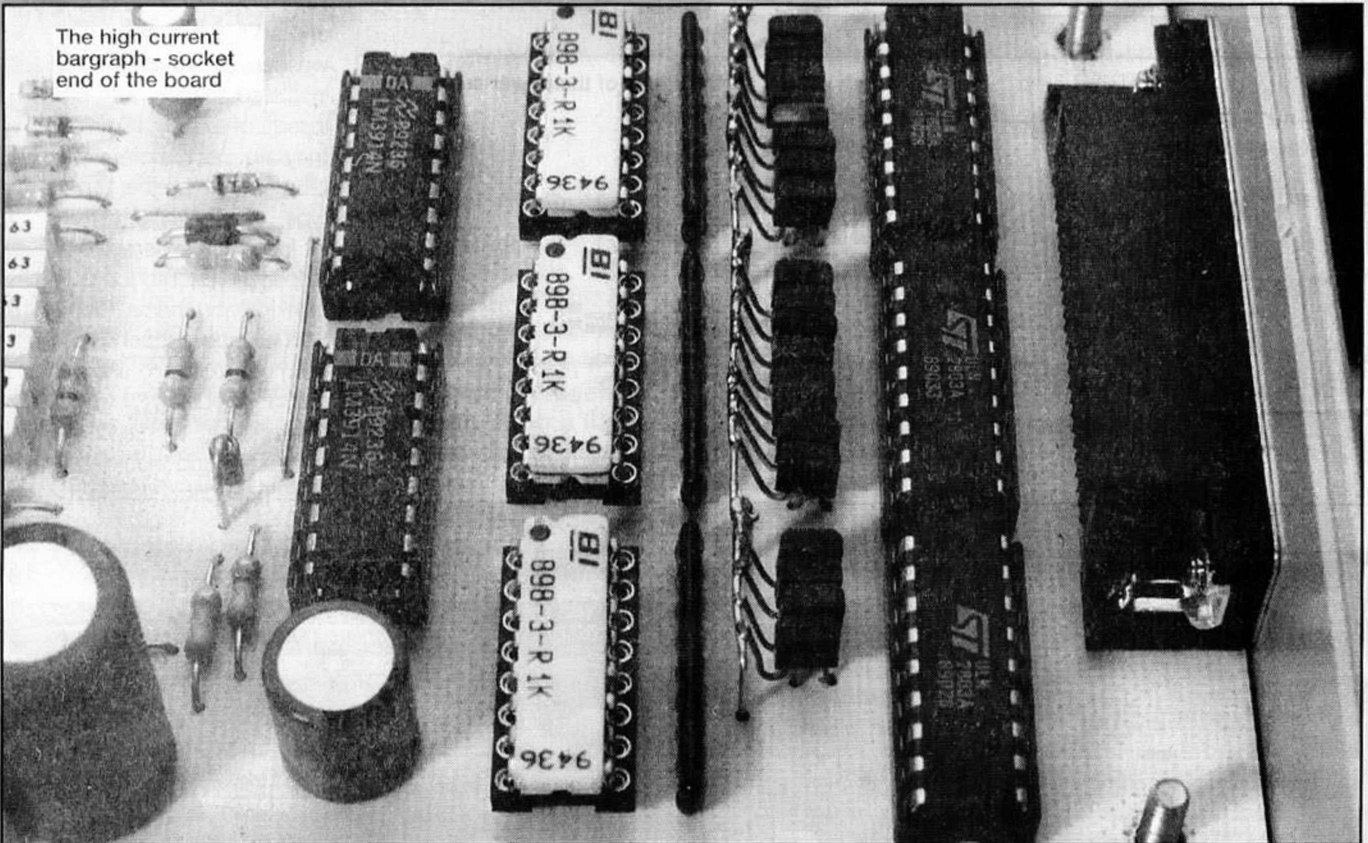

The high current bargraph - socket end of the board

Figure 18a: mounting a switch in the PSU box

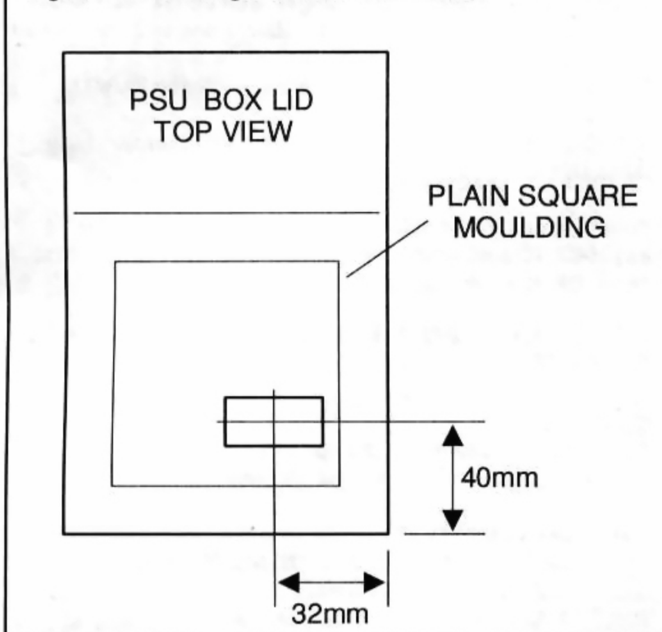
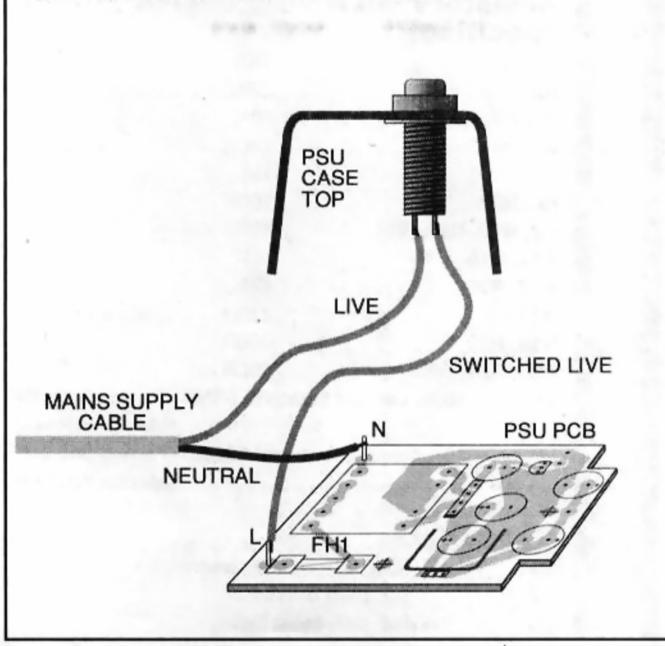


Figure 18b: the PSU mains switch wiring



buy a lead rather than make it yourself. The Rapid Electronics lead specified in the parts list is only £5.40. Connect the audio input to any standard line output, for example, a tape deck output or amplifier record output. You might need to make a phono Y splitter cable (okay as the loading is minimal), if you use an occupied record output from a hifi amplifier.

Although not designed as such, you can drive the bar graph circuit direct from speaker outputs, but to do this you must fit a 100K resistor in series in the signal input line. Due to the varying listening levels with speakers, regular adjustment of VR1 will be required.

Set VR1 fully off (anticlockwise) and VR2 to about mid point. Now gradually increase VR1, with a typical music signal, until the display is pulsating to your taste. The best effect is where the display pulsates from about 30% to 90%. Adjust VR2 for more gain if the signal level is too low. You can view the LED display directly or use the reflected light to good effect. The LED light output is very bright so the display looks impressive when hidden from direct viewing so that the light output is reflected off a nearby surface. If someone does build a giant multi-frequency spectrum analyser version, drop me a line or send me a video - it will be great to see one in action.

Power supply for the basic version

The power supply for the low current version is shown in figure 16. This will also be suitable for the high current version if you use the display as detailed, but you will need to add a high current supply (which I have left for you to design) to PL4 pins 1 and 2 if driving filament lamps, and break the loop going from PL4 pins 2 and 6.

The PSU circuit

The power supply, as shown in figure 16, is a standard split rail design but with quite high value capacitors. 240V AC mains is transformed down to two 12V AC secondaries. These are arranged to provided a centre tapped supply and then full wave rectified by BR1. C19 to C23 are reservoir capacitors. The +17V and -17V smoothed DC from BR1, C19, C20 and C23 is regulated to plus and minus 12V by Q22 and Q23 respectively. C21 and C22 provide additional reservoirs for the +12V supply.

Should you find that the -12V regulator (the 79L12) oscillates, you can add a 10uF capacitor to its out put, but this should not normally be necessary.

Power supply construction

Q22 can be a standard 1A 7812 regulator but the 2A 78S12 performed better on test. C19 to C22 should not be physically larger than 17mm diameter or 30mm high due to the fairly limited space. Following figure 17, firstly, solder the five Veropins, BR1, Q23, and fuse holder into the PCB. Then insert and solder C19 to C23 flat to the PCB. Attach Q22 to the heatsink with an M3 6mm screw and nut (an insulator is not required) and solder the assembly into the PCB with the heatsink flat to the board. If you have a hot glue gun handy, drop a few blobs of glue around the heatsink to secure it to the board. Finally, fit and solder the mains transformer T1 flat to the board, and attach the appropriate cables to the Veropins.

If the specified case and parts are used. no earth connection is required as the unit will be double insulated, so only 2-core mains cable will be needed. The integral On/Off switch is optional but if fitted, ensure it is fitted as shown in figure 18 due to space restriction and to avoid contact with other components. Use heat shrink or rubber sleeving on the switch connections and fit the plastic fuse cover to avoid mishaps with mains voltages. Please use cable grommets and don't knot the cable to prevent it being pulled - use a proper clamp or tight plastic cable tie. Only two of the three case mounting points are used and I added a 20mm square self adhesive foot, cut in half, fitted under the PCB (directly under the transformer) for added support. Use number 4 by 10mm self tap screws to secure the board to the case. The 12V DC supply cable used was actually a length of three core 3A mains cable attached to a 3 pin DIN plug. Ensure that pin 1 connects to -12V, pin 2 to 0V and pin 3 to +12V to conform with the component overlay and circuit diagrams. The usual care should be exercised when building and testing mains operated circuitry - ideally by using a mains isolating transformer while the power supply unit is open.

PARTS LIST for the Giant Bargragh Light Show

Resistors (all 0.25W unless specified)

R1	6K8
R2	22K
R3, R7, R8	10K
R4	330K
R5	1M
R6, R22	100K
R9, R10, R13, R14	15K
R11, R15	27K
R12, R16	47K
R17	220R
R18, R19	680R
R20, R21, R23-R42	100R

VR1 100K cermet Spectrol 63MT (Farnell 347-358) (Maplin WR44X)
VR2 10K cermet Spectrol 63MT (Farnell 347-322) (Maplin WR42V)

Capacitors

C1	10uF 63V radial electrolytic
C2	1nF mini polyester
C3	1uF polyester layer
C4	1uF 25V axial electrolytic
C5	100pF ceramic
C6,C7,C8,C9,C10,C11,C12,C13	See text (filter capacitors, select according to frequency)
C16, C17	100nF mini polyester
C14	4u7 25V radial electrolytic
C15	470uF 25V radial electrolytic
C18	1000uF 16V radial electrolytic

Semiconductors

IC1	TLO74 or TLO84 quad op amp
IC2, IC3	LM3914 bar graph
Q1	2N3819
D1-D3, D6	1N4148
D4, D5	BZY88C4V7 zener
LED1 - LED100	Bright red 10mm LED (Maplin UK53H) (Rapid 55-0330 or 55-0340)

Miscellaneous

PL1	8 way Molex pin wafer (Rapid 22-0975)
PL2, PL3	3 way Molex pin wafer (Rapid 22-0955)
PL4	2 way Molex pin wafer (Rapid 22-0950)
PL5 to PL6	25 way D type male to male lead (Maplin DD25C) (Rapid 19-0592)
SK1	8 way Molex pin housing (Rapid 22-0930)
SK2, SK3	3 way Molex pin housing (Rapid 22-0910)
SK4	2 way Molex pin housing (Rapid 22-0905)
SK5	25 way PCB mounting D type female (Maplin FG27E) (Rapid 15-0185)
SK6	25 way chassis mount D type female (Maplin YQ49D) (Rapid 15-0160)
SK7	3 pin DIN chassis mount socket
SK8	Single chassis mounting phono socket (Rapid 20-0215)

Molex crimp pins for SK1 to SK4 (13) (Rapid 22-1097)
14 pin DIL IC socket (1)
18 pin DIL IC socket (2)
Printed circuit board 20mA version
DB4 Case (Maplin BN54J)
White trunking 38mm x 24mm x 1.5m (DIY or electrical retailers)
M3 screws, nuts and 15mm spacers

Additional parts for high current version

SIL1, SIL2, SIL3	10K 8 resistors one end commoned (Maplin RA30H) (Rapid 63-0230)
DIL1, DIL2, DIL3	1K 8 resistors (Maplin DL86T) (Rapid 63-0645)
IC4, IC5, IC6	ULN2803 transistor array
Q2 to Q21	ZTX500

Printed circuit board 500mA version
16 pin DIL IC socket (3)
18 pin DIL IC socket (3)

PARTS LIST FOR THE BARGRAPH POWER SUPPLY

Capacitors

C19, C20, C21, C22	2200uF 25V radial electrolytic
C23	470uF 25V radial electrolytic

Semiconductors

BR1	SKB2/02L5A (Rapid SKBP02) (RS 261-491)
Q22	L78S12CV (Maplin UJ56L)
Q23	79L12 (Maplin WQ86T) (Rapid 79L12)

Miscellaneous

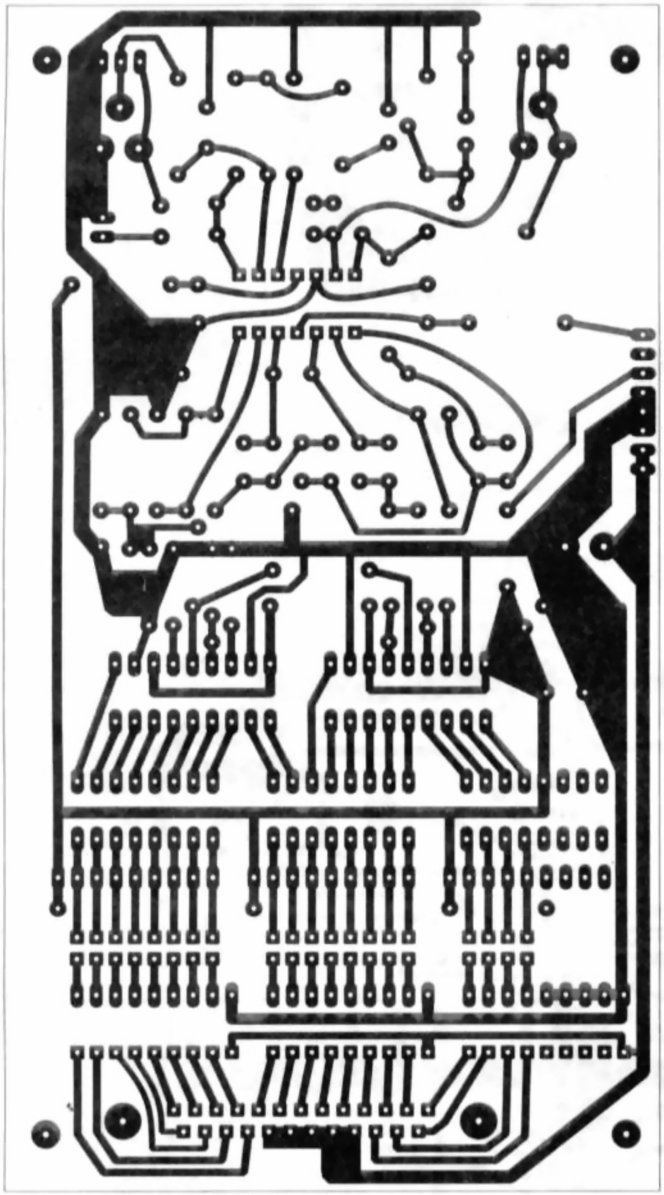
F1	T315mA 20mm fuse
T1	PCB mounting transformer 12V-0V-12V 1A (Maplin DM13P)
PL7	3 pin DIN plug

20mm PCB mounting fuse holder (Maplin DA61R) (Rapid 26-0165)
Clear fuse holder cover (Maplin DA62S) (Rapid 26-0170)
Redpoint TV40 heatsink for Q22 (Maplin FG55K) (Rapid 36-0250)
PSU case (Maplin YU32K)
Cable grommet (2) (Maplin JM16S)
Power supply PCB
1mm single sided Veropin (5)
2 core cable 16/0.2mm 3A
3 core cable 13/0.2mm 2.5A
Push button latching mains switch (Maplin FG46A)
Mains plug

All the components should be easily obtainable at Maplin or Rapid Electronics. The author can supply any parts except the printed circuit boards. For prices send a stamped addressed envelope to ETI Bar Graph, 21 Crossgates Avenue, Leeds, West Yorkshire, LS15 7QF. Sorry - no phone calls or callers please. PCB master laser film prints, directly for use with UV light and photosensitive board, are also available from the author at £1 each pattern.

Component suppliers

Maplin Electronics, Rayleigh, Essex, SS6 8LU.
Rapid Electronics Ltd, Heckworth Close, Severalls Industrial Estate, Colchester, Essex, CO4 4TB.
Farnell Electronic Components, Canal Road, Leeds, LS12 2TU.
RS Components (Electromail), Corby, Northants.



GIANT BARGRAPH

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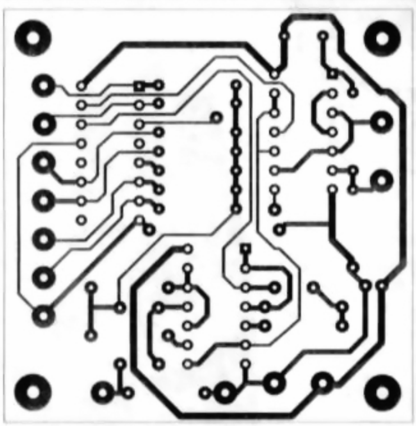

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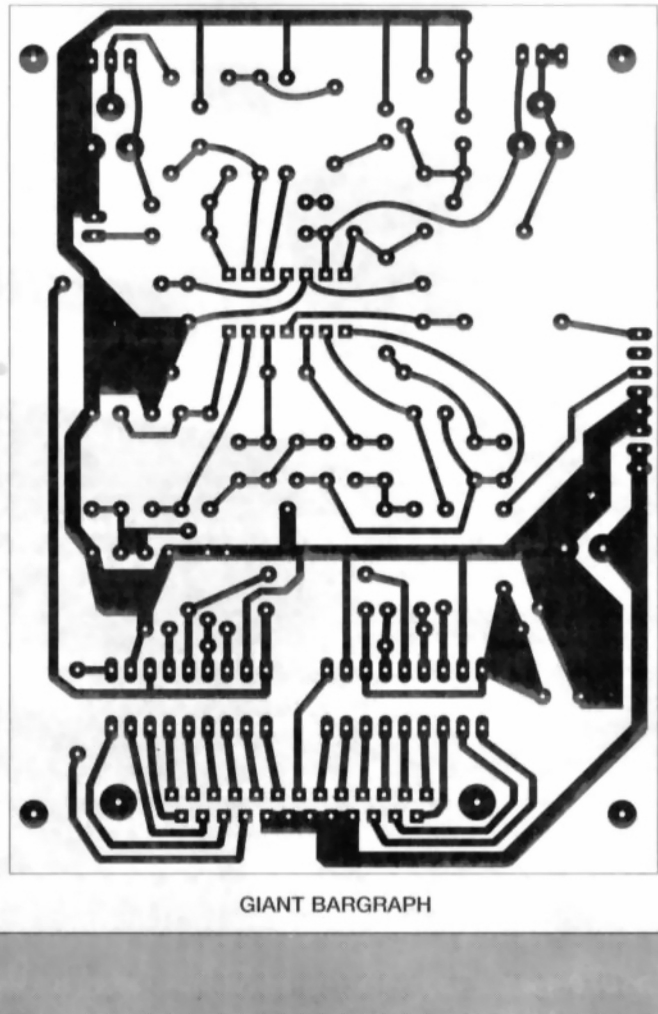
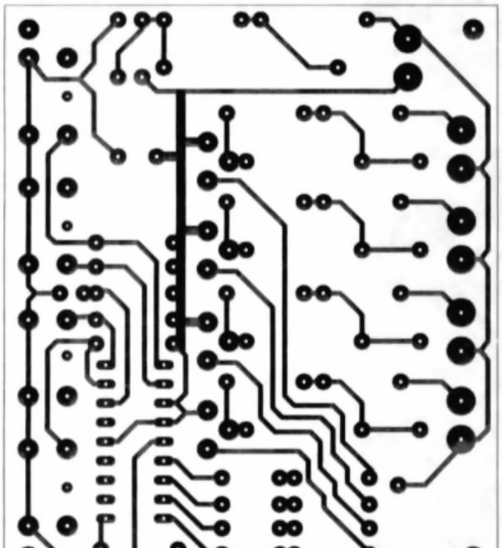


GIANT BARGRAPH



CHRISTMAS LIGHT CHAIN