# Digital Delay Line



by **POWERTRAN**

# DIGITAL DELAY EFFECTS UNIT

*by Tim Orr*

★ **Digital encoding for studio quality results**
★ **Time delays from 0.625ms to 1.6 seconds**
★ **Produces all the popular time delay effects:**
★ **Phasing** ★ **Flanging** ★ **ADT and chorus**
★ **Echo (including 'freeze' for infinite repeats)**
★ **Time domain vibrato, etc.**

RECORDED ON CASSETTE NO. 6

**M**any musical effects such as echo boxes, flanging pedals etc. use a time delay as part of their circuitry. The cheaper units, aimed at the stage musician, offer only one or two effects per box; in addition, they use analogue delay components whose sound quality deteriorates considerably as the delay increases. High quality delay units for studio applications, in contrast, use digital techniques offering theoretically unlimited delay times; however, they are very expensive, often with four figure price tags.

Now, the E&MM Digital Delay Effects Unit offers you the best of both worlds; it gives all the time delay effects, with digital quality, all for the price of a high quality analogue unit but with much superior specifications). the most popular effects are shown in Figure 1, along with the various ways of producing them. The E&MM Delay is shown in block diagram form in Figure 2, and by manipulating its variables all the effects in Figure 1 may be obtained. These are introduced here; the project will be concluded next month, with full circuit and construction details.

## Phasing

Phasing is produced by mixing an audio signal with a delayed version of itself. The frequency response this produces is known as a comb filter. Feedback is sometimes used to make the frequency response more peaky, which in turn produces a more noticeable colouration of the sound. By slowly modulating the time delay, the notches in the comb filter expand and contract, producing an interesting musical effect. Phasing effect pedals use a phase shift filter rather than a time delay line, although the effect is the same. Phasing is characterised by having very few notches within the audio band, typically 2 to 5. This is equivalent to time delays between 0.2ms and 0.5ms.

## Flanging

Phasing and flanging are often confused, which is not surprising as the two effects are produced in a similar way. To obtain a flanging
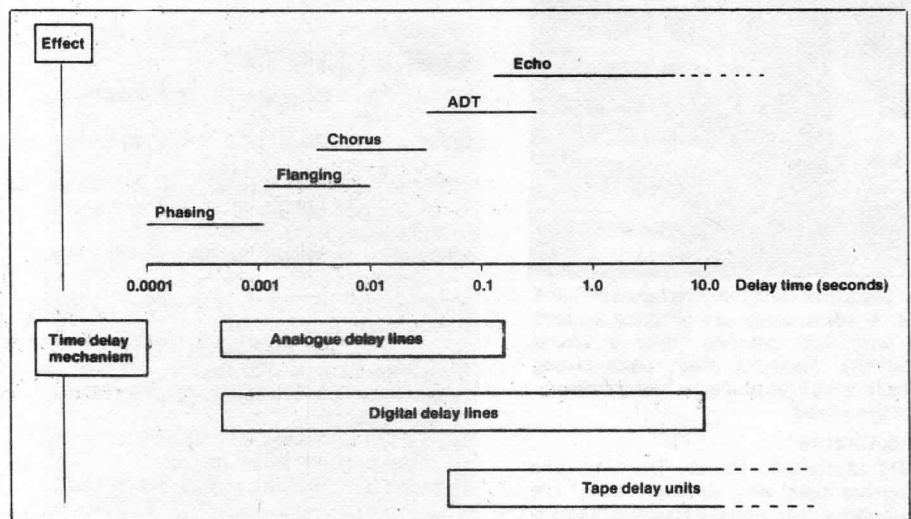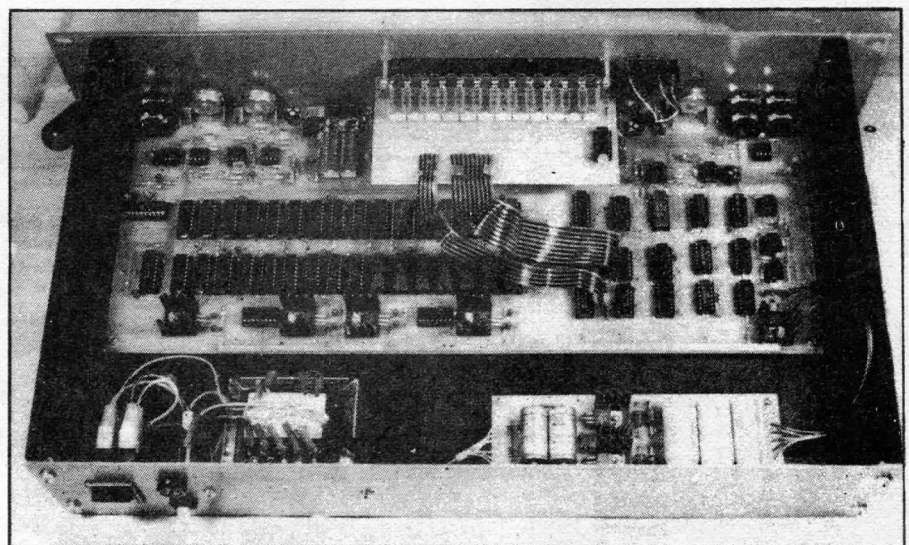




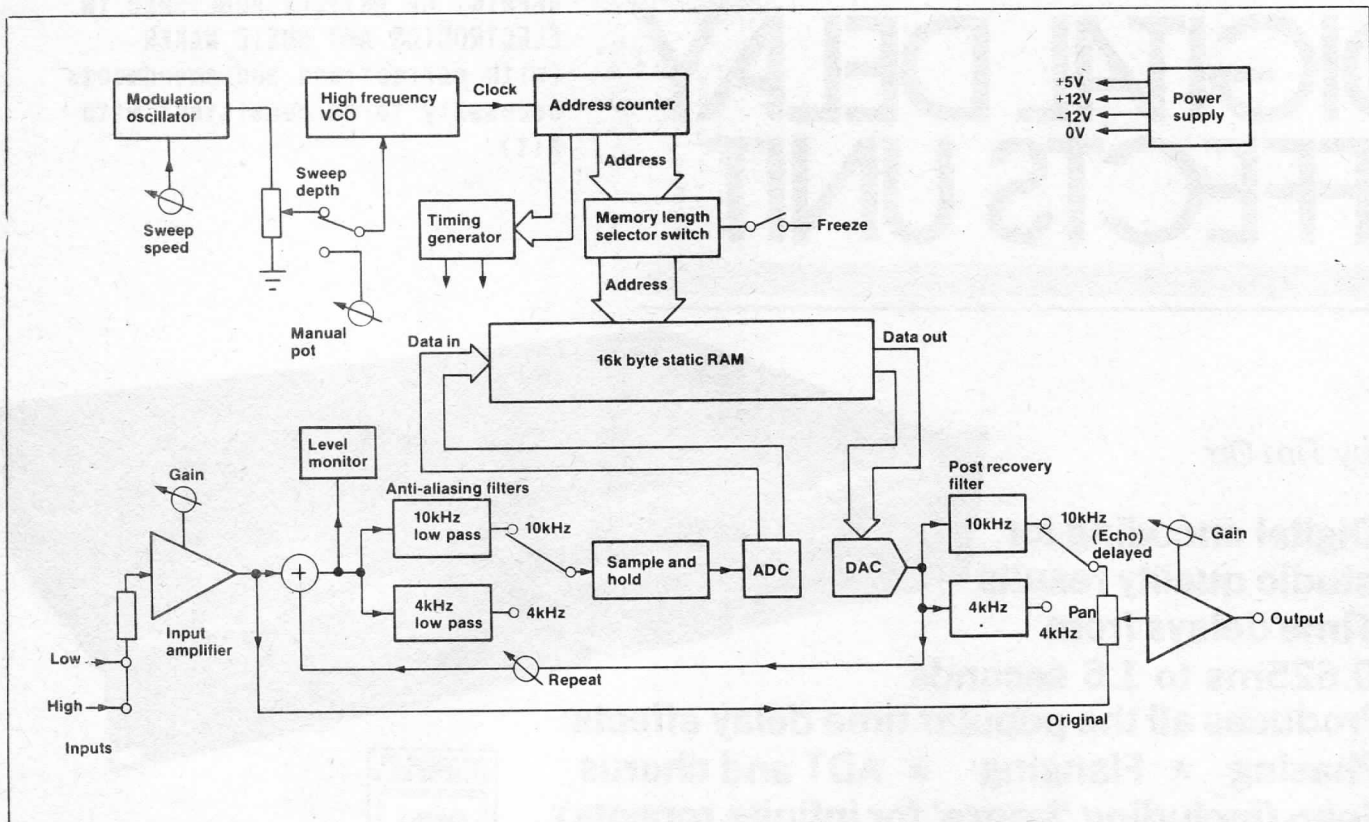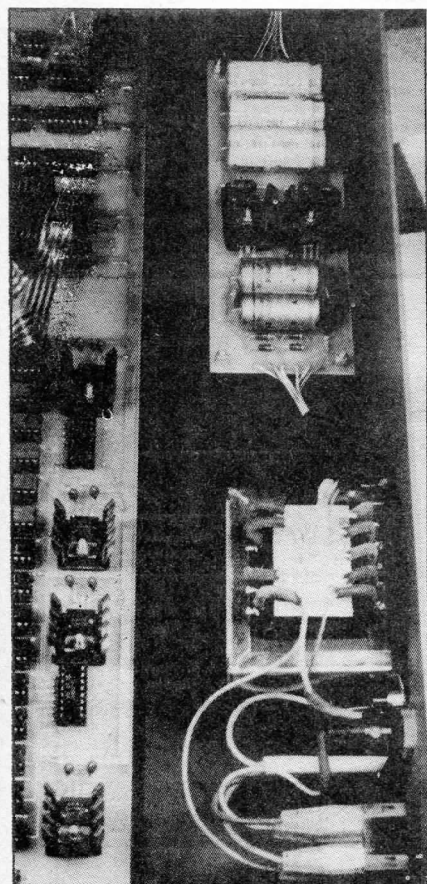**Figure 1.** Effects obtainable with time delays.

Figure 2.    Block diagram of the digital delay line.

effect use a time delay varying between 1 and 10ms. A 10ms delay will produce a comb filter with 100 notches (over a 10kHz bandwidth). Flanging often uses strong feedback which produces a heavy colouration of the sound.

### ADT & Chorus

ADT (Automatic Double Tracking) and chorus are both very similar effects. The chorus effect uses a time delay that is slowly
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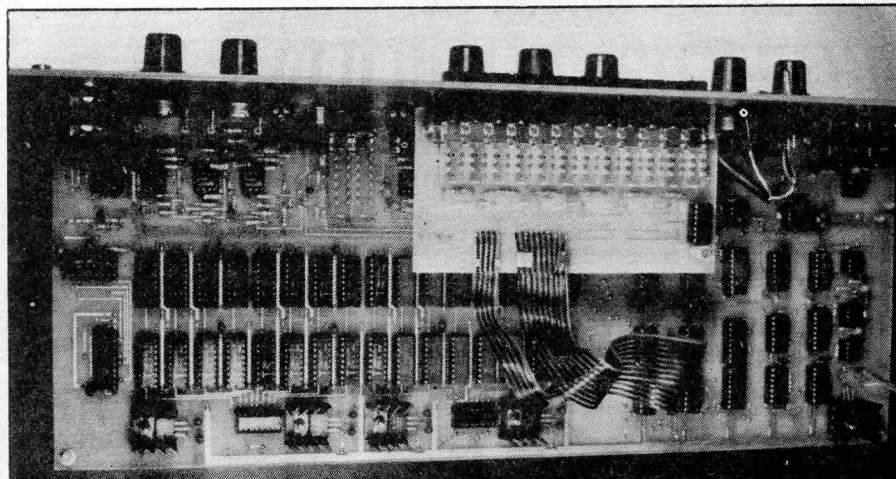
modulated, and the original and the delayed signal are mixed together producing a 'spacey' effect. ADT uses a longer time delay to simulate a very short echo, short enough to give the impression of two sound sources.

### SPECIFICATIONS

Size: 2 unit (3.45") high, 19" rack mounting, 10" deep.
Delay time: 0.625ms to 0.64s at 10kHz bandwidth.
1.6ms to 1.6s at 4kHz bandwidth. Both time delays can be halved using the manual control pot.
Modulation oscillator: Triangle sweep; rate, 0.025Hz to 17Hz.
Memory size: 16K bytes, 128K bits.
Input impedance: Low 1k5
                         High 28k5
Output impedance: 220 ohms.
Output level: +3dBm, with 30dBs of available attenuation.
Typical signal to noise ratio: 75dB (this is not signal to quantisation noise).
Overload LED: Turns on 6dB before clipping.

### Echo

Time delays greater than 30 or 40ms become noticeable as distinct echoes. Time delays of around one second are very useful for building up melodies with several repeats. Also, it is possible to freeze the sound in the digital memory and have it continuously recirculate without degeneration. This repeating sound may then be used as a sequencer-like backing, or transposed using the delay time controls.

### Vibrato

Vibrato can be produced on any time delay setting, but best results are obtained on the 40ms delay with 10kHz bandwidth. A modulation speed of 3 to 7Hz with a small modulation depth should do it.    **E&MM**

The E&MM Digital Delay Line is obtainable as a complete kit of parts from Powertran Electronics, Portway Industrial Estate, Andover, Hants SP10 3WW.

# DIGITAL DELAY EFFECTS UNIT

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*Part 2 concludes the project with full constructional details.*

## Circuit Description

The complete circuit of the unit is shown in Figures 3 and 4, and operation may be clearer if the block diagram (Figure 2, published last month) is studied at the same time.

The input signal is amplified by the input amplifier IC21, to bring the signal up to a suitable operating level. Next the signal is filtered by two low pass filters, one of which has a 4kHz cut-off, and the other a 10kHz cut-off. The 4kHz or 10kHz operation is selected by S16. These are known as anti-aliasing filters; aliasing is an effect that sounds like ring modulation and is caused by harmonics of the input signal interacting with the analogue to digital conversion. If these harmonics are greater in frequency than ½ of the conversion frequency, then side bands will be generated that will fall within the audio spectrum: to prevent this from happening, the input signal is low-pass filtered to remove these high frequency harmonics.

The signal is then fed into the ADC (analogue to digital converter). This section continuously samples the analogue waveform, and measures the instantaneous amplitude which it describes with an 8-bit digital word. This word is then stored in the digital memory. In order to convert the analogue waveform into a digital word it must be 'frozen' long enough to allow the ADC to perform the measurement. The freezing is done with a sample and hold device, IC10. The 'lumpy' output of the sample and hold unit (TP8, see Figure 8) still represents the input signal; if it were low-pass filtered then the original waveform would be recovered, as in fact it is when it is reconstructed by the digital to analogue converter (DAC) after the selected time delay (TP10, Figure 8).

The ADC consists of three main sections, a comparator IC14, a successive approximation register (SAR) IC17, and a DAC IC13.

Their purpose in life is to measure the input voltage and to describe it with an 8-bit digital word. The SAR produces a binary code which it sends to the DAC; this generates an output voltage which the comparator compares with the input signal. The result of the comparison determines whether the MSB of the digital word is a 1 or a 0. The SAR then tests the next bit of the code, and then the next, until all 8 bits have been determined; the conversion is then complete. The 8-bit word causes the DAC to produce a voltage equal in magnitude to the input signal, therefore the word is a measurement of the input sample.

The DAC is in fact a companding DAC, and not a linear one; it can be operated in both compression and expansion modes. In the ADC (IC13) it compresses the signal, and in the DAC (IC33) it expands the signal thus giving an overall linear transfer function. The performance of the DAC and ADC can be described in several ways. First, the dynamic range: this is the ratio between the largest signal that the system can handle and the smallest. The dynamic range is 72dB which is quite good.

The signal to noise ratio is the ratio between the largest signal that the system can handle, and the output noise with no input signal. This may be better than 72dB, but it is not that important, because the system only generates digital noise (quantisation noise) when it is converting signals. The noise only appears when a signal output is being generated; this noise is related to the
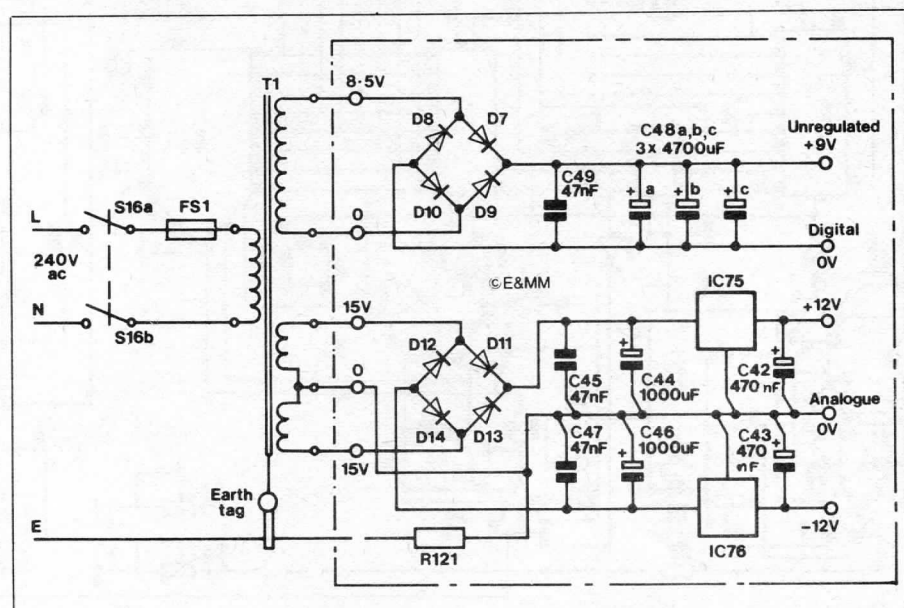


**Figure 3a. Circuit diagram of PSU.**

**Figure 3. Main circuit of the Digital Delay Effects Unit.**
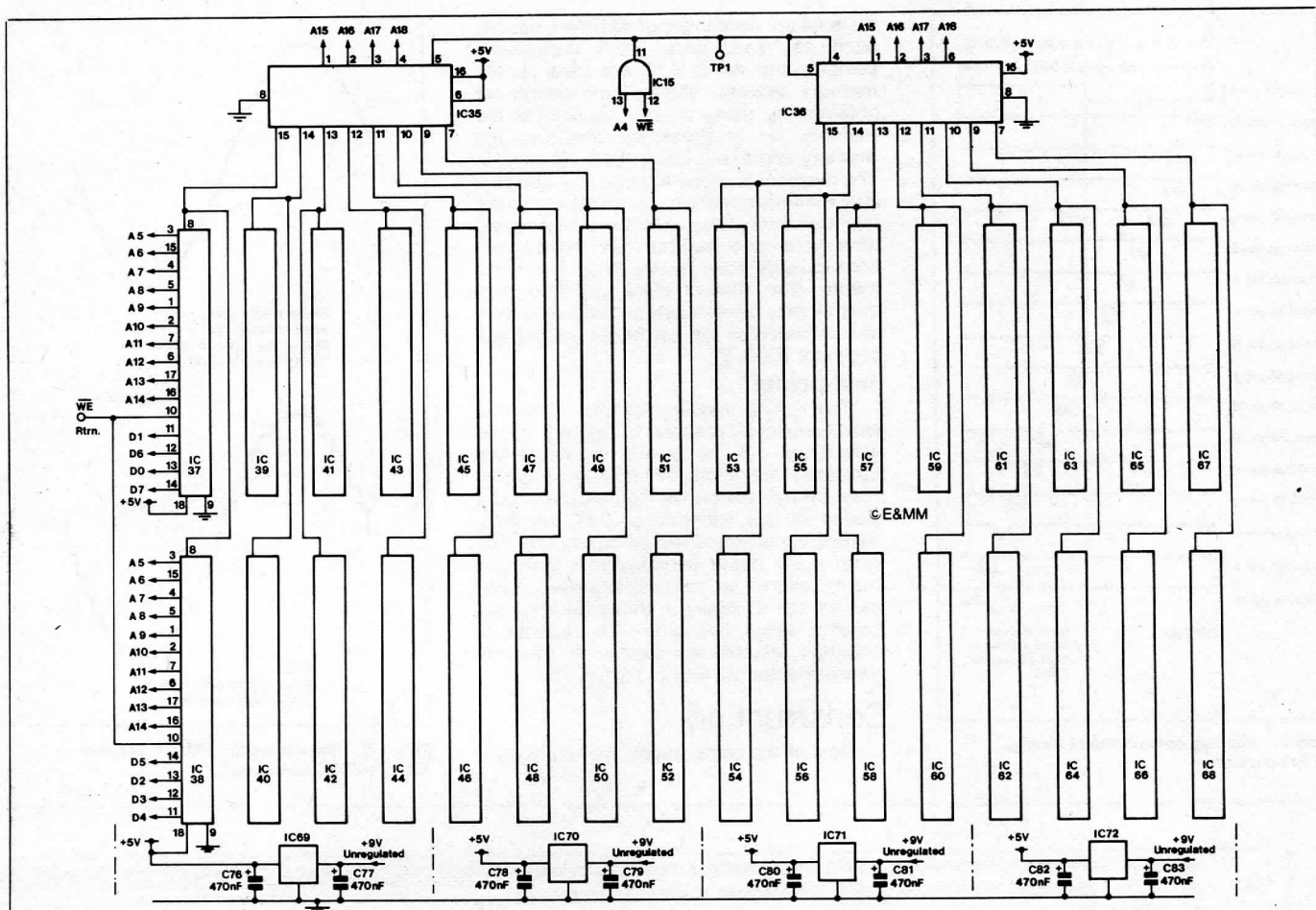E&MM

DDL A4

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**Figure 4. Circuit of the memory section.**

amplitude and spectrum of the input signal.

Now consider the signal to quantisation noise ratio. If the delay line is processing speech, then the quantisation noise is hardly noticeable; the noise is masked by the rapidly changing information in the speech. If the input signal is high in frequency compared to the selected bandwidth, then again the quantisation noise is lost, this time having been removed by the output filters. However, if the input signal is a low frequency pure tone then quantisation noise can be heard sizzling away in the background! This problem is overcome by giving the input signal a treble lift from 600Hz up to 6kHz (R3 and C3 give pre-emphasis) and by providing a treble cut at those same frequencies on the output signal (R86 and C31 give de-emphasis). The overall frequency response is flat, and the quantisation noise is selectively filtered out. The energy spectrum of most natural sounds falls off with increasing frequency, and so the pre-emphasis does not produce any signal overload problems.

The memory is 16K bytes long, being constructed from 2114L static RAMs (4 bits by 1K). The read/write cycle is as follows: the memory address is set up, and data is read from that memory location by being clocked into a latch (IC34) that drives the DAC (IC33). Next, data is written into the same memory location, the data being obtained from the ADC. The address is then incremented by one bit. If the full memory length were being used, then the address would have to count in a full circle (16K) to retrieve the data that had just been entered.

The output data is converted to an analogue voltage by the DAC (IC33). This voltage is quantised into steps, and it needs
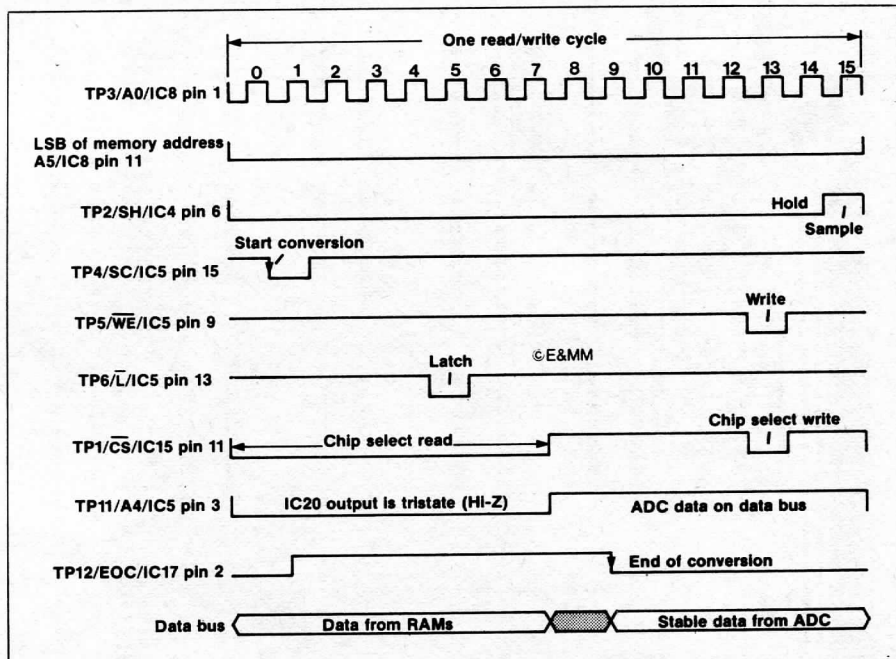
filtering to remove the unwanted harmonics that constitute these steps. Again a 4kHz and a 10kHz low pass filter (IC28, 29, 30, 31) are used.

The master clock for the system is generated by a high frequency voltage controlled oscillator, IC1, 2 and 3. IC2 and 3 form a standard Schmitt trigger/integrator oscillator, the frequency of which is controlled by the current into pin 5 of IC3. IC1 is used as a buffer to drive the subsequent TTL stage.

IC8, 12 and 16 are binary dividers which generate the memory addresses A0 to A18.
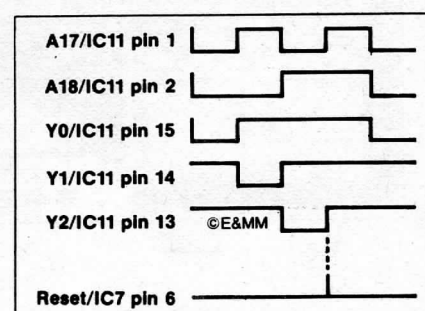


**Figure 5. Timing diagram for one read/write cycle.**



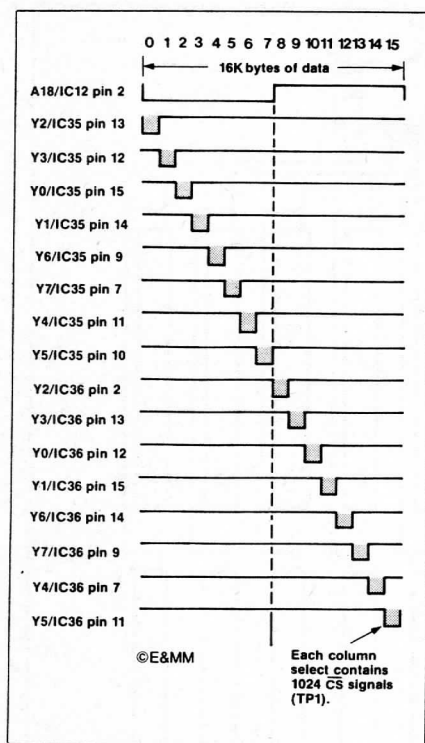**Figure 6. Memory reset timing, shown with ¾ memory selected.**

Figure 7. Memory column select timing, with full memory.

A0 to A4 are used to generate timing signals, such as read, write, start conversion, sample, and A5 to A18 are used as the memory address. Shorter time delays are obtained by using smaller sections of the memory, by progressively disabling the memory addresses using IC15, 18 and 19. The memory is sectioned into four quarters (see memory options in parts list) and so the top four time delay selections have equal time increments, but the lower eight selections provide time delays in octave increments. The master clock oscillator frequency may be manually controlled by RV3, or modulated by the low frequency triangle oscillator IC26, 27.

## Test points

The timing diagram for one conversion read/write cycle is shown in Figure 5. All the waveforms will be clearly visible at the indicated test points (TP1-12). The memory reset timing is shown in Figure 6. A18 has a period of 1.6 seconds or 0.64 seconds, depending on the selected bandwidth. The reset pulse has a period of less than one micro-second, so don't be surprised if you cannot see it! Figure 7 shows the memory column select decoding. The number of columns selected will depend on the time delay selected by SW12, 13, 14, 15.

## Construction

Most of the components, including con-



TP7.
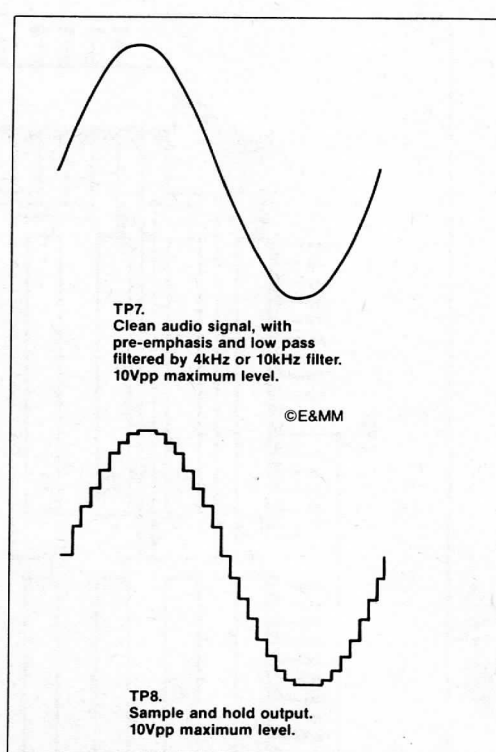Clean audio signal, with pre-emphasis and low pass filtered by 4kHz or 10kHz filter. 10Vpp maximum level.

©E&MM

TP8.
Sample and hold output. 10Vpp maximum level.

Figure 8. Waveforms for TP7-10, showing ADC and DAC operation.
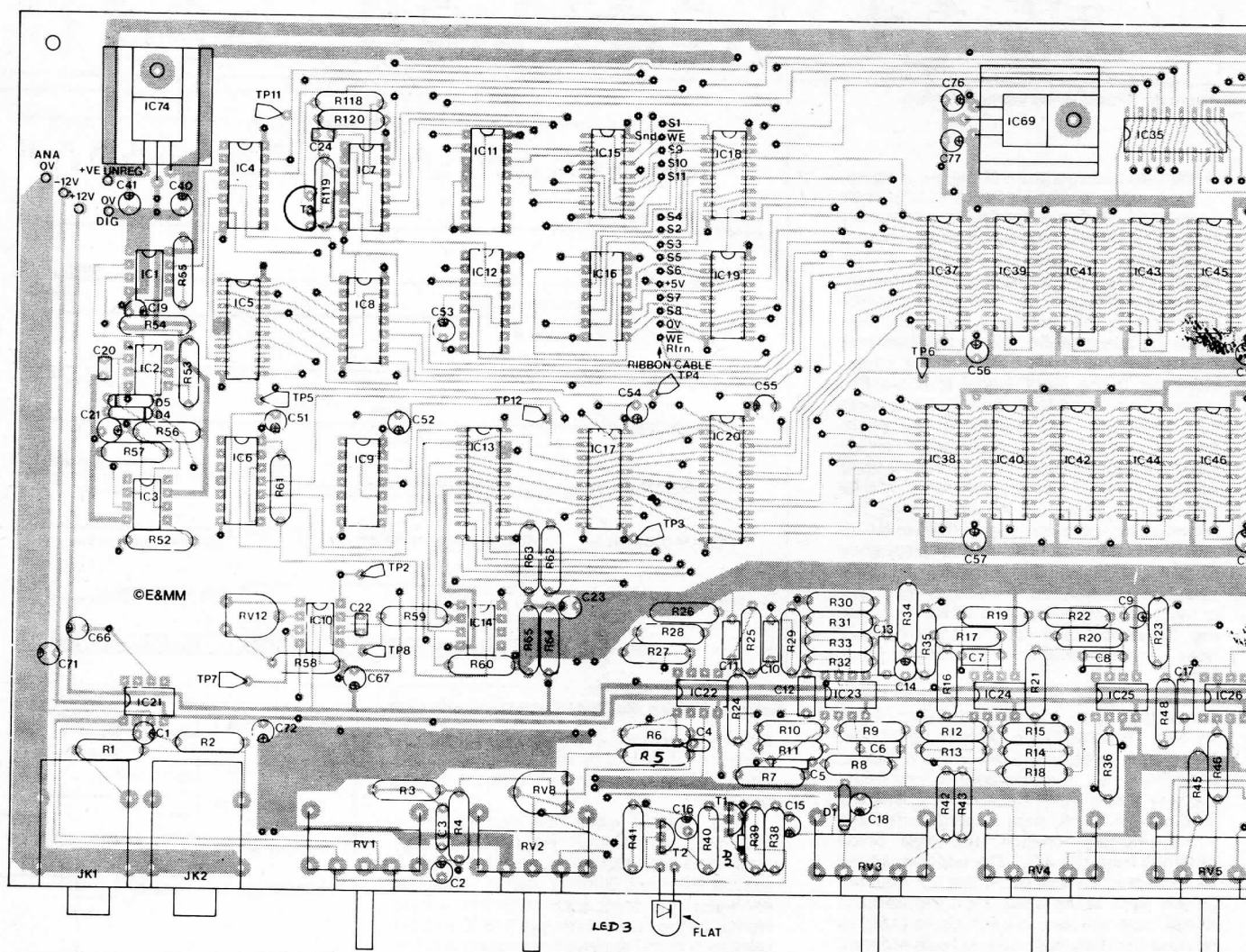


Figure 9. Component layout for the main PCB.

**TP9.**
DAC output same as TP8
but delayed in time.
3.5Vpp maximum level.

©E&MM

**TP10.**
Filtered audio output with
pre-emphasis removed.
3.0Vpp maximum level.
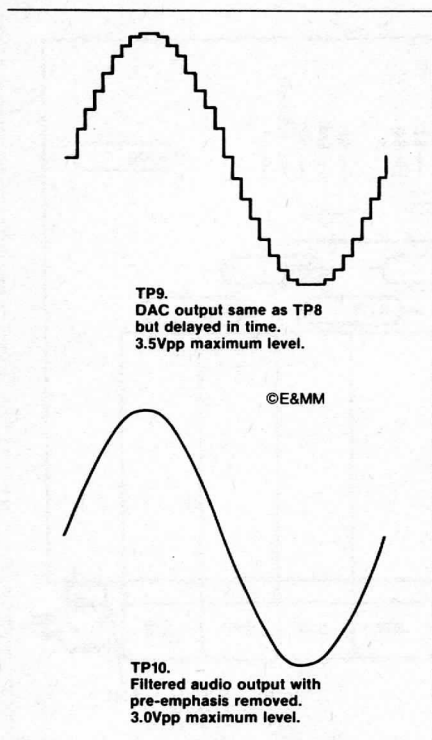
trols, are mounted on one large double sided PCB, whilst two smaller single sided boards carry the time delay selector switches and the power supply components (with the exception of the transformer). Powertran's PCBs will not carry a printed component legend, but all the component positions are identified in Figures 9, 10 and 11 and construction should be straightforward.

Sockets are recommended for the ICs, and again, these are provided in the kit. As always, take special care with the soldering, and check for dry joints, solder splashes and correct component orientation before switching on.

There is very little wiring to be done. The switch board is linked to the main board with two lengths of ribbon cable, as shown on the component overlays; the PSU board and transformer wiring is shown in Figure 12. The connections to the freeze switch and footswitch socket are on the switch board diagram.

If required, the delay unit may be built with ¼, ½ or ¾ memory to begin with, and this is simply a matter of omitting some of the components: the parts list gives details.

Once all the soldering is done, do not insert any ICs except those in the power supply. Power up and test the regulated supply rails (the unregulated rail voltages only refer to a fully loaded power supply). Insert the ICs, in lots of 10, and then power up and check the regulated supply rails. Do this until all the ICs are inserted. Don't forget to turn off the power when you are putting them in! Having completed a successful power up you can now test the unit.

Connect a signal and check all is functional. If not, then check to see if all the TP waveforms are being generated correctly. Also look at all 19 address lines. If you experience a regular repeating fault in the memory section then you may have a non-functional area of memory. Check out the address lines, the data bus and the column decoding. If these are all OK then it is probable that a memory chip is faulty. This can be located by a process of substitution. Finally, set up the presets as follows:

1) Set up the unit for a long echo, and set REPEAT to maximum. Adjust RV8 so that repeats continue for a long time, but not so that they grow in amplitude.

2) Measure the voltage on the positive end of D1; it should be +4.7V. Monitor IC27 pin 1, and adjust RV9 so that the triangle waveform is offset so that its bottom point is at +4.7V. If you don't have a 'scope, a voltmeter may be used, but turn down the
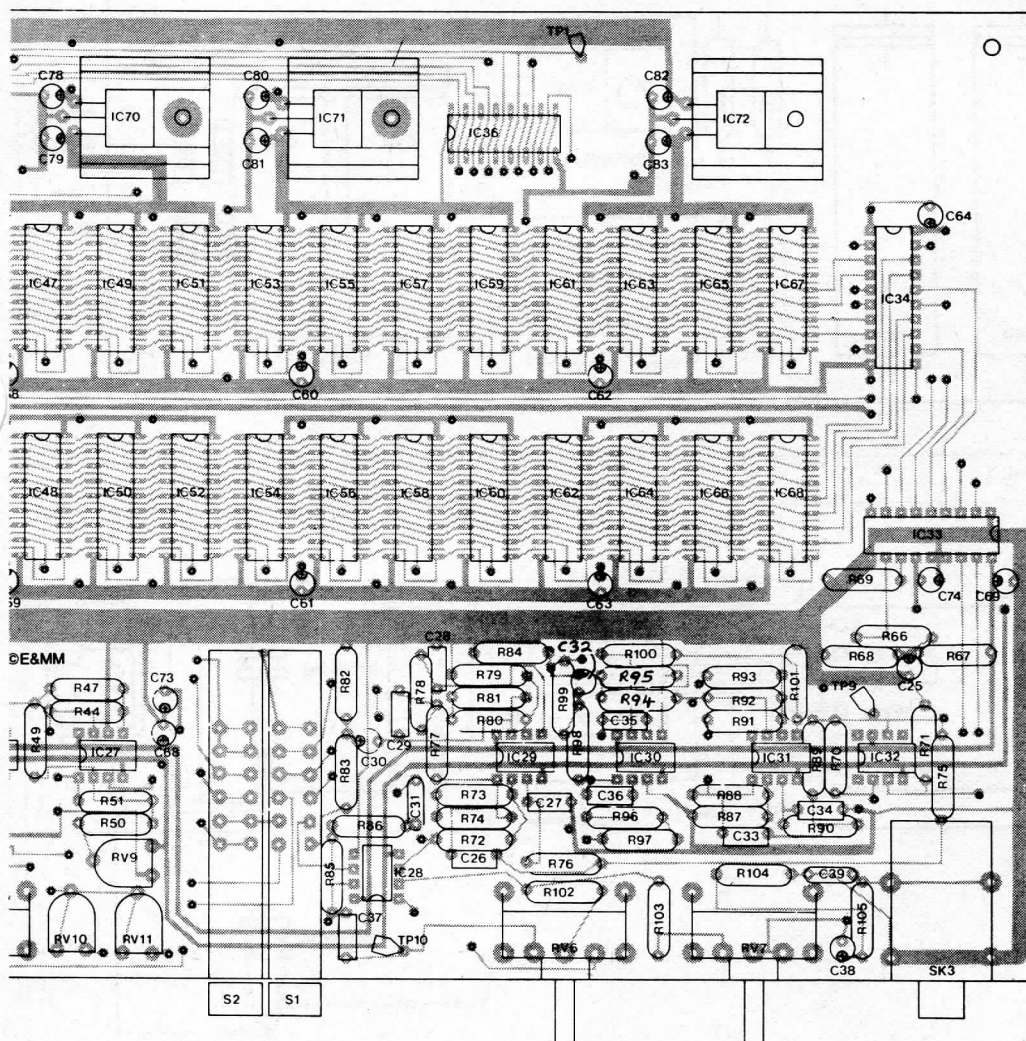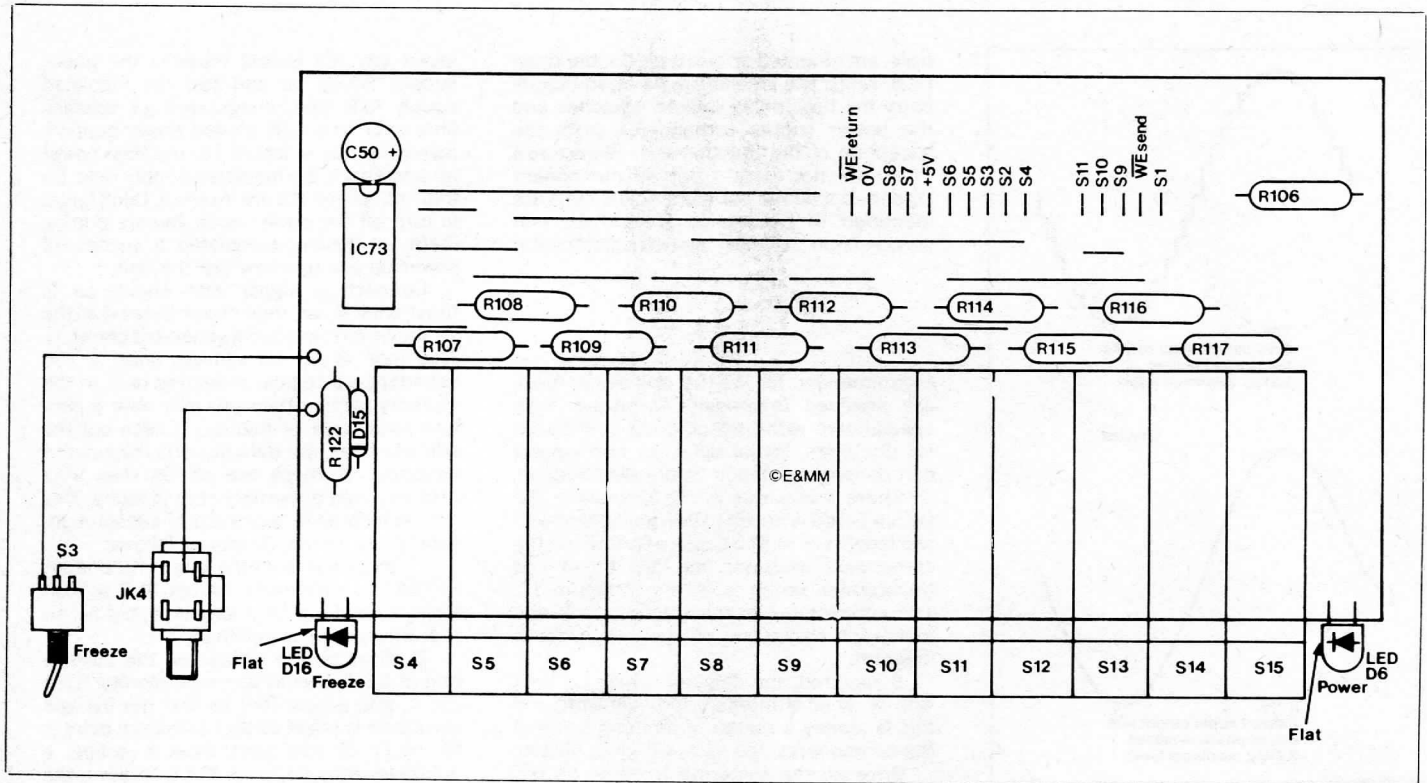
Figure 10. Component layout for the switch PCB.
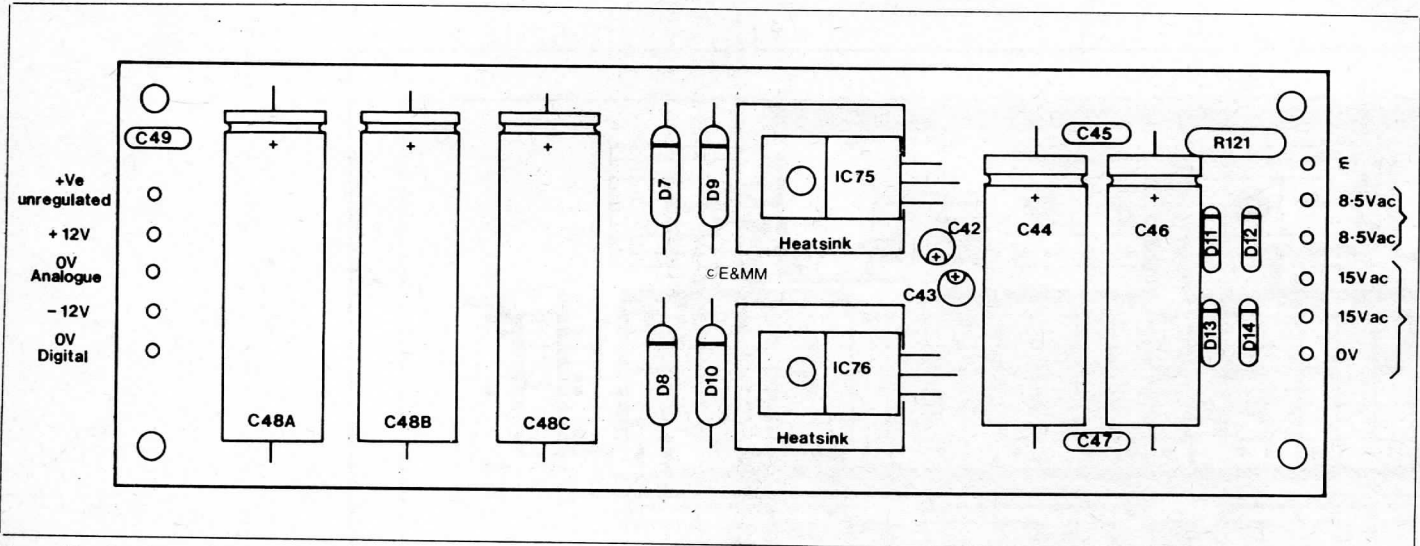


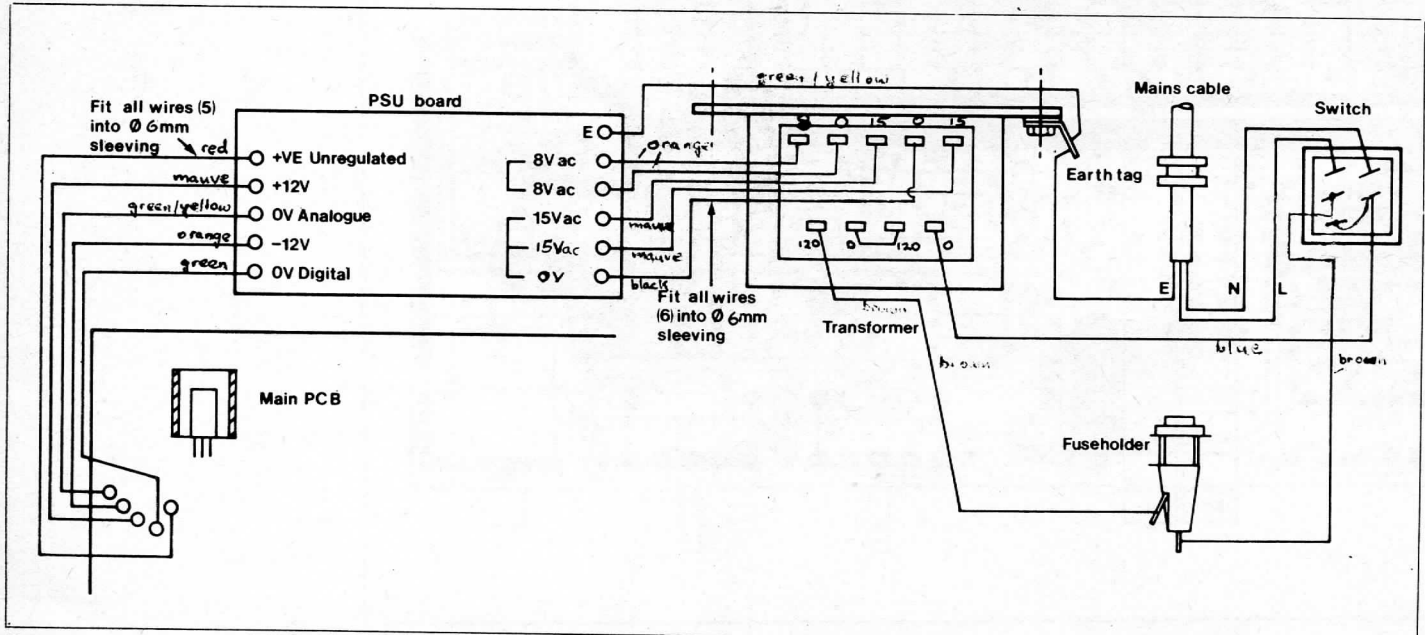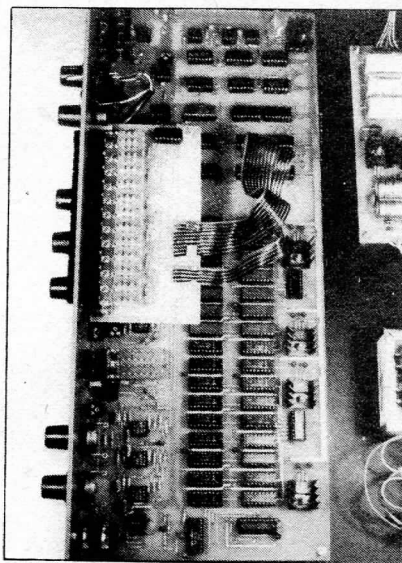Figure 11. Component layout for the PSU board.



Figure 12. Wiring to the PSU board and transformer.

sweep speed to avoid misleading readings.

3) Turn the time delay pot anti-clockwise, and select manual control of time delay. Select 10kHz bandwidth, and measure the frequency at test point 3 (TP3). Adjust RV10 so that the frequency is about 400 kHz. Now select 4kHz bandwidth, and adjust RV11 so that the frequency is about 160kHz. These frequencies can be set without instruments by entering a short signal, freezing it and setting the pre-sets so that the delay times on the longest setting are 0.64 secs and 1.6 secs (time 10 repeats, i.e. 6.4 secs and 16 secs).

4) The sample and hold offset adjustment RV12 only produces a small DC shift, which when compared to the 10Vp-p audio signal level at this point is not significant. However, if the ADC is dithering between two quantised states (and hence producing 1 LSB of dithering noise) then the DC offset can be used to shift the analogue voltage by just enough to prevent this. Listen to the delayed output, and adjust RV12 for minimum noise. Find the best pre-set position by manually adjusting the delay time. The delay effects unit is now ready for use. **E&MM**



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# DIGITAL DELAY UNIT PARTS LIST

**Resistors — 5% ½W carbon unless specified**

| | | |
|---|---|---|
| R1,10,88 | 27k | 3 off |
| R2,11,33,81,103 | 1k5 | 5 off |
| R3,48 | 1k0 | 2 off |
| R4,12-14,18, 22,24,25,29, 30,53,65,68, 75-78,91-93, 98,101,118 | 10k | 23 off |
| R5,52,64,67,121 | 4k7 | 5 off |
| R6,58 | 22k | 2 off |
| R7,8,35,83,89,90 | 13k | 6 off |
| R9,26,31,72, 79,87 | 39k | 6 off |
| R15,46,61,100 | 100k | 4 off |
| R16,19,94,96 | 6k8 | 4 off |
| R17,20,45,95,97, 107-117 | 1k2 | 16 off |
| R21,38,99 | 33k | 3 off |
| R23,32,34,49,80, 82,84,102,104 | 47k | 9 off |
| R27,36,73,85 | 5k6 | 4 off |
| R28,56,57,74 | 270R | 4 off |
| R39,51 | 12k | 2 off |
| R40,62,69 | 18k | 3 off |
| R41 | 1k8 | |
| R42,43 | 680R | 2 off |
| R44 | 1M0 | |
| R47 | 680k | |
| R50,63,66 | 15k | 3 off |
| R54 | 10R | |
| R55,106 | 470R | 2 off |
| R59,60 | 2k7 1% | 2 off |
| R70,71 | 1k0 1% | 2 off |
| R86 | 560R | |
| R105,122 | 220R | 2 off |
| R119 | 2k2 | |
| R120 | 2k7 | |
| RV1,5 | 470k log pot PCB mounting | 2 off |
| RV2 | 10k reverse log pot PCB mounting | |
| RV3 | 1k lin pot PCB mounting | |
| RV4 | 10k lin pot PCB mounting | |
| RV6 | 47k lin pot (with central 'click') PCB mounting | |
| RV7 | 47k log pot PCB mounting | |
| RV8 | 22k min horiz preset | |
| RV9,10 | 10k min horiz preset | 2 off |
| RV11 | 47k min horiz preset | |
| RV12 | 2k2 min horiz preset | |

**Capacitors**

| | | |
|---|---|---|
| C1,2,9,14,18,19, 21,30,32 | 4u7 15V tantalum | 9 off |
| C3 | 27nF polycarb | |
| C4,20 | 470pF ceramic | 2 off |
| C5-8,33-36 | 4n7 polycarb | 8 off |
| C10-13,26-29 | 1n5 polycarb | 8 off |
| C15,23,25,40-43, 51-64,76-83 | 470nF 15V tantalum | 30 off |
| C16 | 220nF 25V tantalum | |
| C17,37 | 220nF polycarb | 2 off |
| C22 | 1n0 ceramic | |
| C24 | 220pF ceramic | |
| C31 | 47nF polycarb | |
| C38,66-69,71-74 | 10uF 15V tantalum | 9 off |
| C39 | 22nF polycarb | |
| C44,46 | 1000uF 25V electrolytic | 2 off |
| C45,47,49 | 47nF ceramic | 3 off |
| C48a,b,48c | 4700uF 16V electrolytic | 3 off |
| C50 | 100uF 10V electrolytic | |

**Semiconductors**

| | | |
|---|---|---|
| TR1,3 | BC182L | |
| TR2 | BC212L | 2 off |
| D1 | 4V7 zener | |
| D2,4,5,15 | 1N4148 | 4 off |
| D3,16 | Red LED | 2 off |
| D6 | Green LED | |
| D7-10 | 1N5402 | 4 off |
| D11-14 | 1N4002 | 4 off |
| IC1,14 | LM311 | 2 off |
| IC2,3 | CA3080 | 2 off |
| IC4 | 74LS04 | |
| IC5,11,35,36 | 74LS138 | 4 off (see below) |
| IC6 | 74LS86 | |
| IC7 | 74LS27 | |
| IC8,16 | 74LS393 | 2 off |
| IC9 | 74LS74 | |
| IC10 | LF398 | |
| IC12 | 74LS193 | |
| IC13,33 | DAC76 | 2 off |
| IC15,18,19 | 74LS08 | 3 off |
| IC17 | AM2502 | |
| IC20 | 74LS244 | |
| IC21-25,28-31 | RC4558 | 9 off |
| IC26,32 | TL081 | 2 off |
| IC27 | 1458 | |
| IC34 | 74LS374 | |
| IC37-68 | 2114L | 32 off (see below) |
| IC69-72,74 | 7805 | 5 off (see below) |
| IC73 | 74LS32 | |
| IC75 | 7812 | |
| IC76 | 7912 | |

For ¾ memory omit IC61-68,72
For ½ memory omit IC53-68,71,72,36
For ¼ memory omit IC45-68,70,71,72,36

**Miscellaneous**

| | | |
|---|---|---|
| JK1-4 | ¼" mono jack socket, switched | 4 off |
| S1,2 | 4P2W latching push switch | 2 off |
| S3 | SPST mini toggle switch | |
| S4-15 | 12 x 4 P2W interdependant switch bank | |
| S16 | DP mains rocker switch | |
| T1 | Transformer 15-0-15V, 8.5V | |
| | T0220 heatsink | 7 off — omit 1 for each ¼ memory not fitted |
| | 8 pin DIL socket | 17 off |
| | 14 pin DIL socket | 10 off |
| | 16 pin DIL socket | 6 off — omit 1 for ½ or ¼ memory |
| | 18 pin DIL socket | 34 off — omit 8 for each ¼ memory not fitted |
| | 20 pin DIL socket | 2 off |

3 PCBs -- main, switch and PSU
Knobs — 7 off
Case and hardware
Mains lead, plug and grommet
10-way ribbon cable — 8" length
5-way ribbon cable — 8" length

missing part nos. R57, C65, C70, C75

## General notes on kit construction

### Identifying parts

Before assembling any part of the kit, familiarize yourself with the components. Clear yourself plenty of space in a spare room and sort out the parts according to the check list but do not mix up the packs. Read all the parts and put them in order.

### Resistor Colour code



1' st BAND  2' nd BAND  MULTIPLIEk

— 1' st RING
— MULIPLIER SPOT
— 2' nd RING
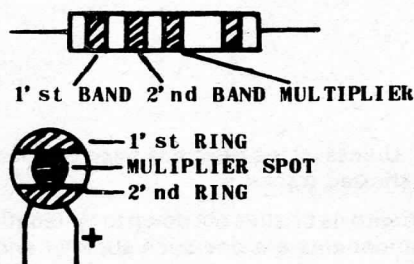
| Colour | 1st & 2nd band/ring | Multiplying factor |
|--------|--------------------|--------------------|
| Brown | 1 | 10 |
| Red | 2 | 100 |
| Orange | 3 | 1000 |
| Yellow | 4 | 10000 |
| Green | 5 | 100000 |
| Blue | 6 | |
| Mauve | 7 | |
| Grey | 8 | |
| White | 9 | |
| Black | 0 | 1 |
| Gold | | 1/10 |

example:   $390K$ = orange white yellow ($39 \times 10000 = 390000$ ohms)
Note:     K = kilohm (1000 ohms)  M = megohms (1000000 ohms)

rather than writing 5.6K for 5600 ohms usually 5K6 is written as it avoids the risk of missing the dot and reading 56K

Capacitors:  these may be marked as pico farads (P or pF or nothing at all) nano farad (n or nF) or micro farads (µF or µ or mF)

$$1pF = 10^{-12} \text{ farad} = 10^{-6}\mu F = 10^{-3}n$$
$$1nF = 10^{-9} \text{ farad} = 10^{-3}\mu F = 0.001\mu F = 1000pF$$
$$1\mu F = 10^{-6} \text{ farad} = 1000n$$

Some capacitors are colour coded. The bead tantalum types are coded in uF the striped polycarbonate types are coded in pF

### Soldering

Soldering is really very easy but strangely if a constructor runs into problems with his kit it is the soldering which is nearly always at fault. To solder well it is best to understand the principles of soldering.
Solder is an alloy (of tin and lead) which is electrically conductive and has a fairly low melting point (about 190°C) making it suitable for joining together pieces of metal (except aluminium) both mechanically and electrically without causing heat damage. Solder supplied for electronic construction is in the form of wire which has small cavities containing 'flux' which is a chemical which when hot and freshly melted will remove from the pieces being joined the oxide layer and other dirt which otherwise would prevent the solder wetting the surfaces – if the solder does not wet the surfaces the joint will be unsound both mechanically and electrically – you then have a 'dry' joint.
To solder well the iron must be clean – wipe the tip on a damp sponge whenever it has a lot of black rubbish (burnt flux) on it. WARNING some beginners books talk of filing the bit or rubbing it on abrasive paper – good modern irons have iron plated bits which will be ruined by this procedure. To solder a component into a circuit board, insert its leads and bend them slightly to hold the component in place. We do not recommend flatenning the leads onto the board (except for the very thin leads of polystyrene capacitors – the ones which look like rolled up Sellotape) because doing that makes removal much more difficult if you later find you have fitted it into the wrong space. Next trim the leads to about 2mm from the board. Now comes the easy bit which so often goes wrong.

Some constructors cover the iron with melted solder and attempt to transfer this to the joint. Apart from the risk of solder spreading across the tracks, solder carried on the iron no longer has active flux to clean the joint which is necessary for the solder to be able to wet the components.

The way to make solder work for you is to touch the solder onto leads and tracks which are hot enough to melt the solder and release active flux onto the joint, so place the tip of the soldering iron onto the circuit board track touching the component lead at the same time, wait about a second then place the solder where the track, lead and soldering iron tip meet. The solder will then flow around the joint. Make sure the lead is surrounded by solder then remove the solder and iron. Now look at the joint and you will see that you DO *NOT* HAVE A BLOB OF SOLDER around the lead – you will see solder smoothly tapering off in thickness as it spreads away from the joint.

### Soldering wires to component tags

On some components to which wires are attached there are holes in their tags. To solder a wire to these wrap the wire (insulation stripped off the last ¼" first) through the hole so as to hold the wire in place then heat tag and lead simultaneously and apply solder to where the lead, tag and iron meet and do not remove the iron and solder until the joint is smoothly covered which may take a few seconds with thick tags or thick wire.

## Soldering wires to pins on PCB's

This calls for a different technique as it is not normal to make a mechanical joint before soldering. Holding a wire, a soldering iron and solder in place simultaneously requires 50% more hands than most people are born with so instead of attempting that, it is usual to pre-coat the pin and lead with solder and then join them with heat. This pre-coating is called 'tinning' – heat the bared wire with the iron and apply solder to where the wire and iron meet until the wire is coated – next repeat this for the pin. Hold the wire against the pin (pliers or tweezers help in some difficult to reach places), with the solder resting on the table, with the end bent up so it can be touched with the iron without burning the table melt a *SMALL* amount of solder onto the iron (this is the ONLY time loading the iron is permissible) and as fast as possible apply the iron to the joint and remove as soon as solder is seen to have joined the wire to the pin but do not yet remove your grip on the wire. As solder cools it passes through a semi molten stage (eutectic) when visually it may appear solid but is in fact very weak and if the joint is disturbed at this stage it will be permanently weakened and likely to fail later.

## Cleaning of the circuit board

The importance of cleaning the track side of circuit boards cannot be overstressed. Unless all the resin has been cleaned from the joints it is very easy to miss spotting an unsoldered joint, a dry joint or shorted tracks.

To remove the flux brush the soldered joints with a stiff brush (a ½" wide paint brush with its bristles cut down to ½" length is ideal) and a suitable solvent. Proprietary board cleaners are available – RS Components are one such supplier and this can be obtained from many component dealers, however, cheaper alternatives are also available. Acetone can be purchased readily as solvent/brush cleaner for polyester resins from Strand Glass Co. the fibre glass specialist. Snopake thinners are available from stationery suppliers (Snopake is the white correcting fluid used by typists). Nail polish remover also gives reasonable results and Boots own brand is good value.

When cleaning, keep the solvent off the component side of the board as it could remove the markings of the components and possibly damage them (particularly likely with polystyrene capacitors). Solvent could flow through any spare holes on to the component side of the board so these should be soldered over before cleaning. Check the board when dry under a bright light (in our laboratory we use a 6' fluorescent fitting mounted 22" above the test bench) look very closely (a magnifying glass helps) at each joint and also all regions where tracks are close to each other. Sometimes very thin whisps of solder fall across a pair of tracks and these have to be looked for very closely. Even with very careful soldering a surprising number of faults can be revealed by this examination.