electronics today INTERNATIONAL

AUGUST 1978

45p

LCD DIGITAL MULTIMETER

NEED SOME SCOPE?

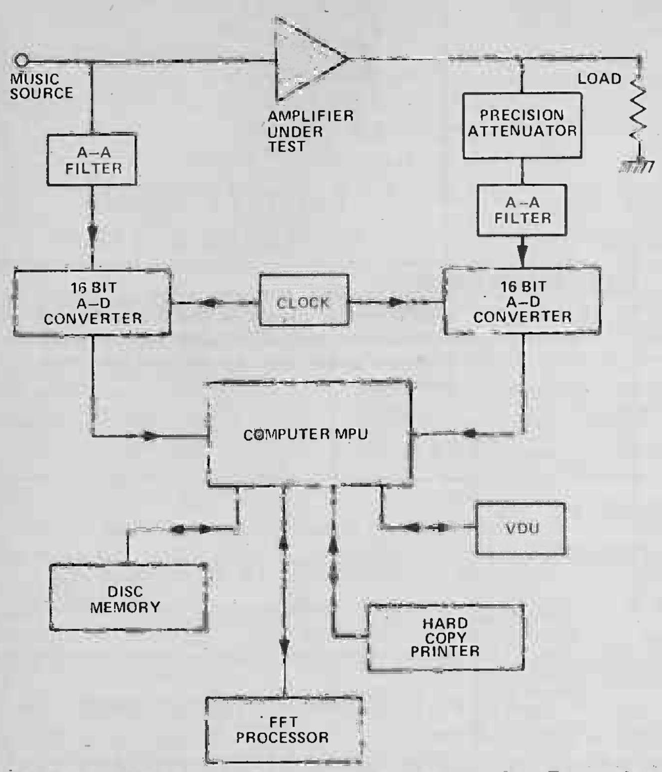
SPECIAL OFFER INSIDE......

Lab Power Supply

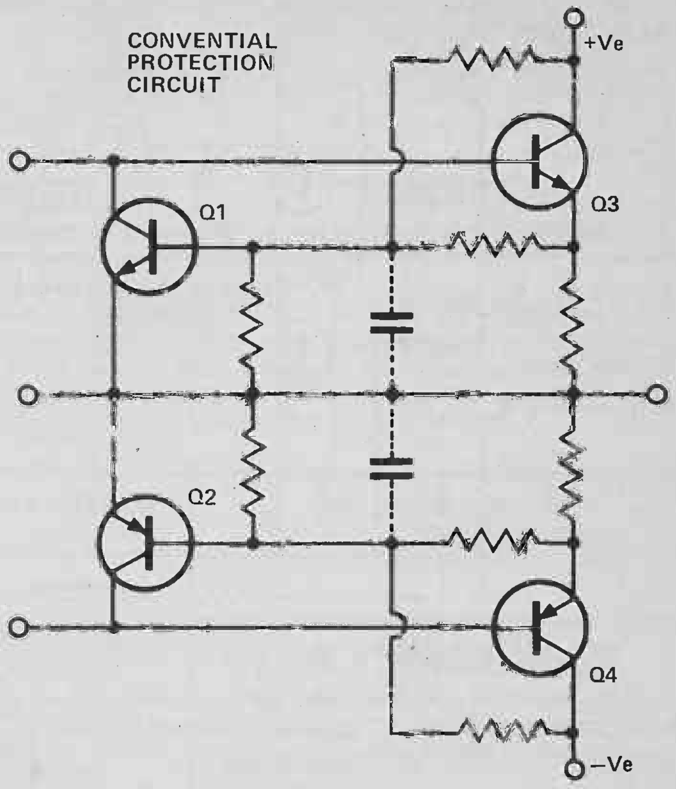
Motoring Electronics

Designing Super-fi Amps

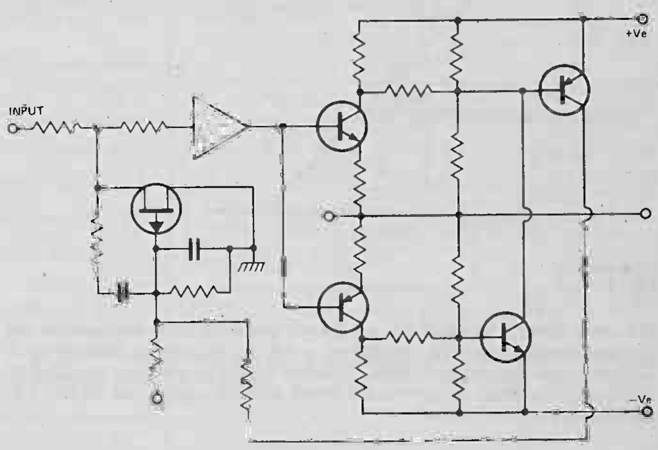
...NEWS....PROJECTS....MICROPROCESSORS....AUDIO...



Analog Engineerings Transient Intermodulation Distortion Measurement System, used in Britain by Mission Electronics.



A study of the circuit of a conventional V-I protection circuit will show that as the protection transistors turn-on they become a 'non-linear resistor' across the bases of output transistors Q3 and Q4 and as such create unpleasant distortion. One solution tried by some companies was to slug the bases of Q1 and Q2 with a capacitor to provide a time-delay to prevent the protection operating except during a sustained short-circuit.



In this protection circuit the FET starts to turn-on when full-power is delivered into a 2 Ohm load. The main advantage over a conventional protection circuit is that the limiting is "soft" (i.e. very gradual) and thus audibly acceptable and secondly that the distortion is much lower — and still only about 0.1% at limiting.

signals can be described in a form that is useful to the engineer and related to the structure of the music signal at that instant. Unfortunately this test show that, as yet, no perfect amplifier exists — each type of amplifier circuit produces its own particular types of "transient error."

Out of The Rut

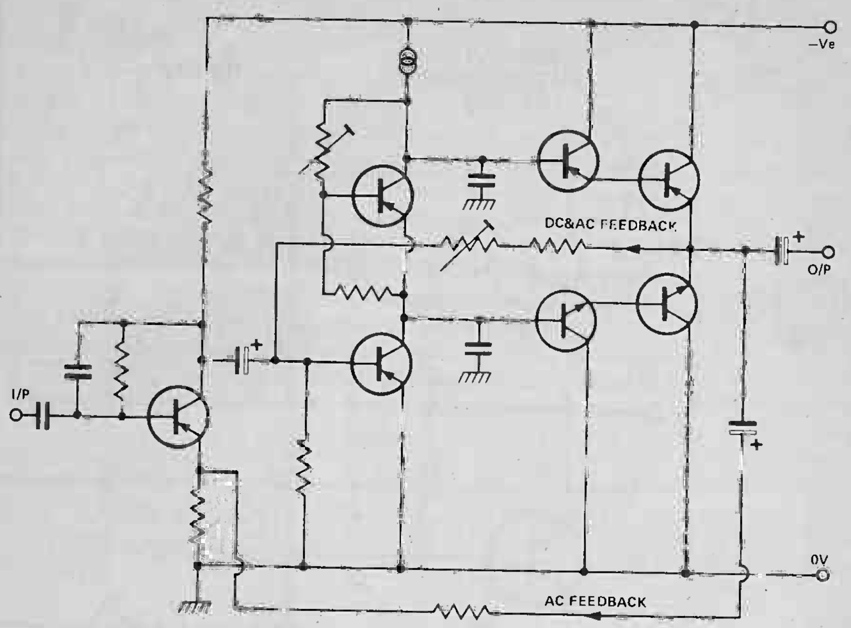
A few years ago power-amplifier design had settled into a satisfying rut. In the U.K., the Quad 303 and the Cambridge P-Series had achieved very satisfactory performance figures and they were generally considered to be good amplifiers. In the U.S.A. the Crown DC300 hac achieved an almost theoretically perfect specification and was hailed as "State of the Art."

However, the first crack to appear was caused by new loudspeaker designs. Some had very demanding impedance curves which in some cases presented a 2 Ohm load to the amplifier. Such a low value of load (almost a short circuit to some minds!) operated protection circuits in many amplifiers, limiting the current to protect the output transistors.

The operation of these caused a very unpleasant "clipping" sound in some cases and even strange "clicks" and "bangs" in other cases. Thus alerted it became apparent to some designers that conventional protection circuits were turning partly-on quite frequently in the course of a piece of music and so giving a sort of premature clipping action.

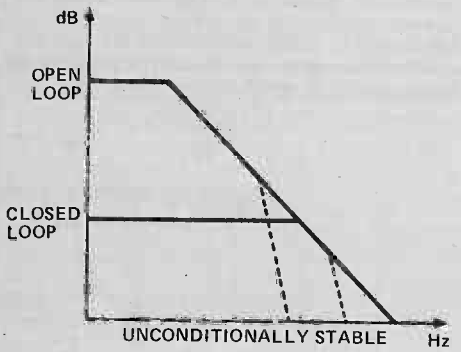
Without any doubt the best results are achieved when the output stage is devoid of any protection AT ALL. The output stage should be designed to deliver all the current a load demands without limiting. Consider the reproduction of a bass drum. If the amplifier starts to limit the start of the "thump" the sound pressure will collapse and the bass-drum will appear to have no body and thus sound unrealistic.

The output-stage should ideally be able to sink the full energy of the power-supply until its regulation causes the current to limit progressively. So in a good amplifier design the output-stage and the power-supply must be designed as a single item and not as separate circuits. Several amplifiers *are* designed like this. The Lecson AP3 Mk II, the BGW models 500 and 750, and the Mission Power Amplifier. The Lecson AP3/11 can, for instance, deliver nearly 20 Amps to the load before the mains fuse blows and the BGW model 750 even more.

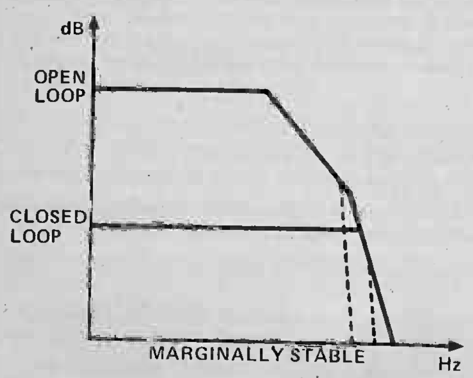


Circuit diagram showing a typical circuit which would prove to be prone to DC instability when in use. Note that separate paths exist for AC and DC feed-back.

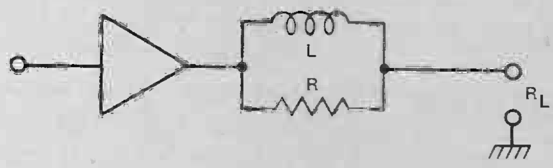
If the amplifier now has to drive a capacitive load eg. electrostatic speakers, or complex crossover networks; another pole is added at the output eg: —



Above: Effect of adding an extra pole at the output of an unconditionally stable amplifier, such as might be added by a complex crossover network. Below: Same condition applied to marginally stable type. Phase shift now borders on 180°, i.e. oscillation.



In the case of the inconditionally stable amplifier the only ill-effect will be some "ringing" in the closed loop step response — but in the case of the marginally stable amplifier it may go completely unstable. The most popular "belt and braces" solution to this problem is to fit a resistor-inductor network at the output to "cancel-out" the effect of the capacitive loading, thus:



Ever wondered what this circuit in the output of an amplifier is for? Wonder no more — it's to aid the output stage in handling a capacitive loading by partially cancelling the effect.

It is interesting to note that some marginally stable amplifiers omit those components as, in the practise, most speaker cables have sufficient resistance and inductance. However, some of the new "Super-Cables" (Litz and Lucas, etc) have a very low resistance and almost no inductance but some capacitance — and their use with certain amplifiers has caused instability, with the amplifier (or speakers) eventually blowing-up!

ETI

Next month Stan Curtis goes on to consider the effects of phase and bandwidth (amongst other odd things) upon amplifier performance and asks what do we want from an amplifier? — The answer may surprise you all!

LCD DIGITAL MULTIMETER

A Digital Multimeter is, in our opinion, a must in any well equipped electronics workshop and A. S. Webb BSc, of Watford Electronics, has designed just such a meter that can be built for less than half the cost of an equivalent commercial unit.

PSST! — WANT A DMM that has five DC and five AC ranges of both voltage and current as well as six resistance and four capacitance ranges at a price that is far less than any equivalent commercial unit? You'll have to build it yourself of course—but then that's half the fun and if you follow the construction information exactly and make use of the calibration service we have arranged, your meter should perform accurately and reliably for many years.

The basis of the DMM is the Intersil 7106 digital panel meter IC (featured in October/March '77) which has excellent linearity and auto zero facilities and directly drives the 3½ digit Liquid Crystal Display. The low current consumption of this device enables the unit to be battery powered and hence completely floating from the circuit under test.

This project is aimed at the more experienced constructor due to the fairly high component density and reasonably intricate switch wiring, and should not be attempted unless a soldering iron bit of less than ⅛in and small pliers and cutters are available.

Handling Of Components

The usual precautions must be observed when handling the MOS devices used in this project, but it may not be realised that other components are liable to damage through mal-treatment. The 1% precision resistors should be handled with respect, their wires bent with pliers and soldered in as quickly as possible, since excessive heat may permanently alter their resistance values and the switch wafers should be handled with care prior to ▶

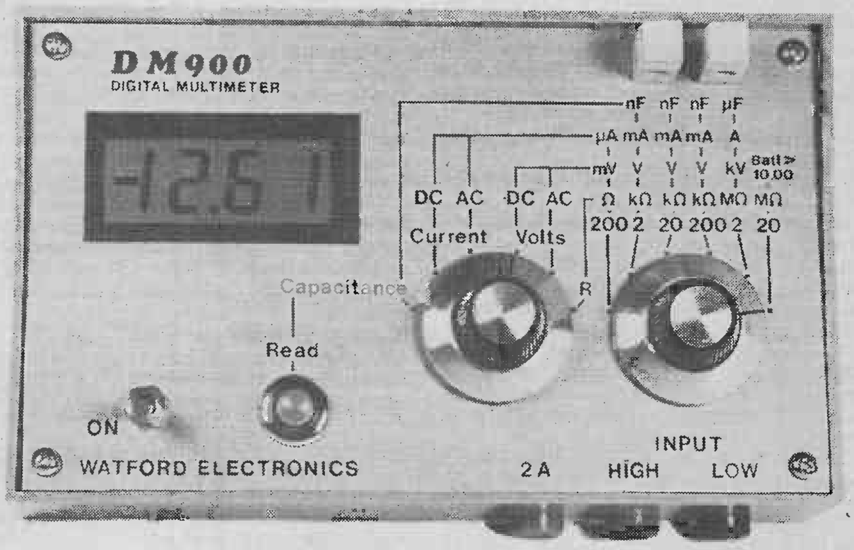


Fig. 1. View of the final unit. Note, in order to ensure that the input sockets do not foul the PCB yet allow the probes to be inserted, the sockets should be mounted 10mm from the bottom of the case.

SPECIFICATION

Input Impedance	10M
Display	3½ digit LCD
DC & AC volts	200 mV to 1 000 V in 5 ranges, resolution to 0.1 mV
DC & AC current	200 uA to 2 A in 5 ranges, resolution to 0.1 uA. Max. voltage drop 200 mV. RMS reading on sine waves only.
Resistance	200R to 20M in 6 ranges, resolution to OR1.
Capacitance	2n0 to 2u0 in 4 ranges, resolution to 10p
Accuracy	1% ± 1 digit (on prototype)
Overrange Indication	1 in MSD, other digits blank
Polarity Indication	
Autozero	
Display Test	
Input Protection	
Power Consumption	5mA average, single 9 V supply

HOW IT WORKS

DISPLAY DRIVES
The segments of the LCD display are directly driven by the ICL7106 (pins 2-19 and 22-25) in conjunction with pin 21 (backplane drive). Liquid Crystal Displays will become damaged if a DC voltage is continuously applied to them and must be driven with an AC signal. To turn on a segment a wave form of equal amplitude but 180 degrees out of phase with the square wave backplane drive must be applied to that segment.

The 7106 generates the appropriate segment drives for all digits internally, but the drive signals for the decimal points and polarity indication segments are generated by external circuitry.

The decimal point drives are provided by the components around IC2C,D and IC3D. These are two input exclusive OR gates driven by the backplane square wave and by voltages from the range switch.

Consideration of the truth table of an exclusive OR gate will show that with the backplane square wave applied to one input we can produce an output from the gate that is the inverse of this signal (segment on) by taking the other input to the gate high.

SW2D activates the appropriate decimal point.

Polarity indication is provided by the circuitry around IC3A,B and C.

The signal at pin 20 of IC1 can be used to drive the minus segment directly, that is its output is a square wave out of phase with the backplane drive when a negative signal is applied to the 7106, in phase when the input is positive.

However, in this circuit we provide a + sign for positive inputs (formed from - and-: segments) and a - sign for negative inputs. As the output from pin 20 drives the colon it is, usually, necessary to invert it in IC3B.

Outputs from the AC and capacitance stages are negative and in this case IC3D takes care of blanking the polarity display.

The resistance range is arranged to show only the colon.

The control inputs of the decimal point gates and the wiper of SW1G are connected to IC1 pin 37. This pin is normally held at a voltage 5V below V+. By taking this pin to +V supply all segments of the display will be "turned on". This display test, enabled by shorting the two pins on the PCB, should only be activated for a few seconds as prolonged operation will drastically reduce display life.

A stable source of reference voltage is required at many points in the DMM circuit. The 7106 provides just such a voltage, PIN 32 (common) being maintained at a voltage 2.8 V below the positive rail.

This reference voltage, as well as being used elsewhere in the circuit, provides the basic reference voltage for the 7106's input circuitry. The 7106 is calibrated to a 200mV full scale — to accomplish this 100mV potential difference must be set up between Ref Hi and Ref Lo (pins 36 and 35 respectively).

This voltage is derived from the potential divider formed by RV1 and R26.

C9 and R27 set up the 7016's internal oscillator frequency while C7, 8 and R25 are concerned with the auto zero and polarity circuits.

Having dealt with the components intimately associated with IC1 we now move on to deal with the rest of the DMM circuit.

DC Voltage & Current Ranges.

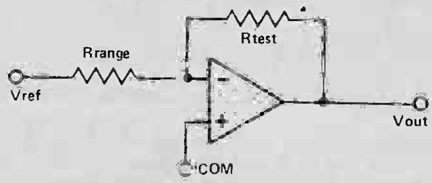
SW1 is the function switch and when set to DC volts, the five DC voltage ranges are selected by SW2B, which is connected to the input alternator. The input resistance is always more than 10M, and exact division is achieved by using precision 1% resistors throughout the chain. The voltage selected by the wiper is fed via SW1F and a 1M resistor to pin 31. This resistor and a capacitor to ground serve to filter any noise, and also to limit the current fed into the input should an overload voltage be applied. With SW1 set to DC current ranges, the input current is passed through one of the five current measuring resistors. The maximum voltage across one of these is 200 mV at full scale. The 2 A range is connected by a third socket on the front of the case, since a few milli ohms of switch contact resistance would produce a significant error. The unit is protected from excessive currents by a 2 A fuse in the common line.

AC Voltage + Current Ranges

On AC voltage ranges, a 10n capacitor is switched in series with the input line to remove any DC component present. The signal is fed through the attenuator as before and then via SW1E to the AC convertor. Similarly AC currents are fed via SW1E to the AC convertor. This is a precision rectifier IC4 using a TL081 J-FET input op amp, so that there are no problems with input bias current. The gain of the circuit is set by RV2 and the negative component sampled by the 10M resistor and filtered by 100n capacitor C4. The resulting voltage may be RV2 to be equal to the RMS value of a sine wave to the input of the DMM, and is then fed via SW1F to IC1.

Resistance Ranges

A simplified circuit is shown here, the op amp IC6 is another TL081 and will try to maintain the voltage at its input at common voltage.



Hence the output voltage must be:

$$V\,out = R\,Test^1 \cdot \frac{V\,Ref^1}{R\,Range}$$

and is proportional to the resistor being measured (R Test^1).

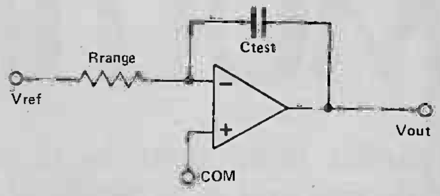
V Ref^1 is derived from a potential divider between +Ve and common, and is set by RV3. IC5 is a voltage follower, and is fed via SW1D to the bottom of the resistor chain in the attenuator. SW2A selects the range in reverse order to the voltage ranges, and its wiper is connected to the input socket by SW1A and to the input of IC6 by SW1C and another R-C network for filtering and protection. The output of IC6 is boosted by an emitter follower Q1, since the current on the 200 ohms range is quite high, and then fed to the other end of R Test^1 via SW1B. The offset voltage of the op-amp is zeroed by RV4, but a small offset from zero exists on the 200 ohm range because of the switch contact and the fuse resistances. The voltage output proportional to R Test is attenuated by about ten times and fed to IC1 via SW1F.

BATTERY TEST

The unused position of SW2 on the DC voltage range is fed from a potential divider between common and the battery negative (OV) rail so a voltage governed by, though not proportional to the battery voltage is fed to IC1. The resistor values are arranged to give a reading of 10.00 when the battery voltage has dropped to 7 volts, but at other voltages the readings are meaningless due to the 2.8V reference voltage.

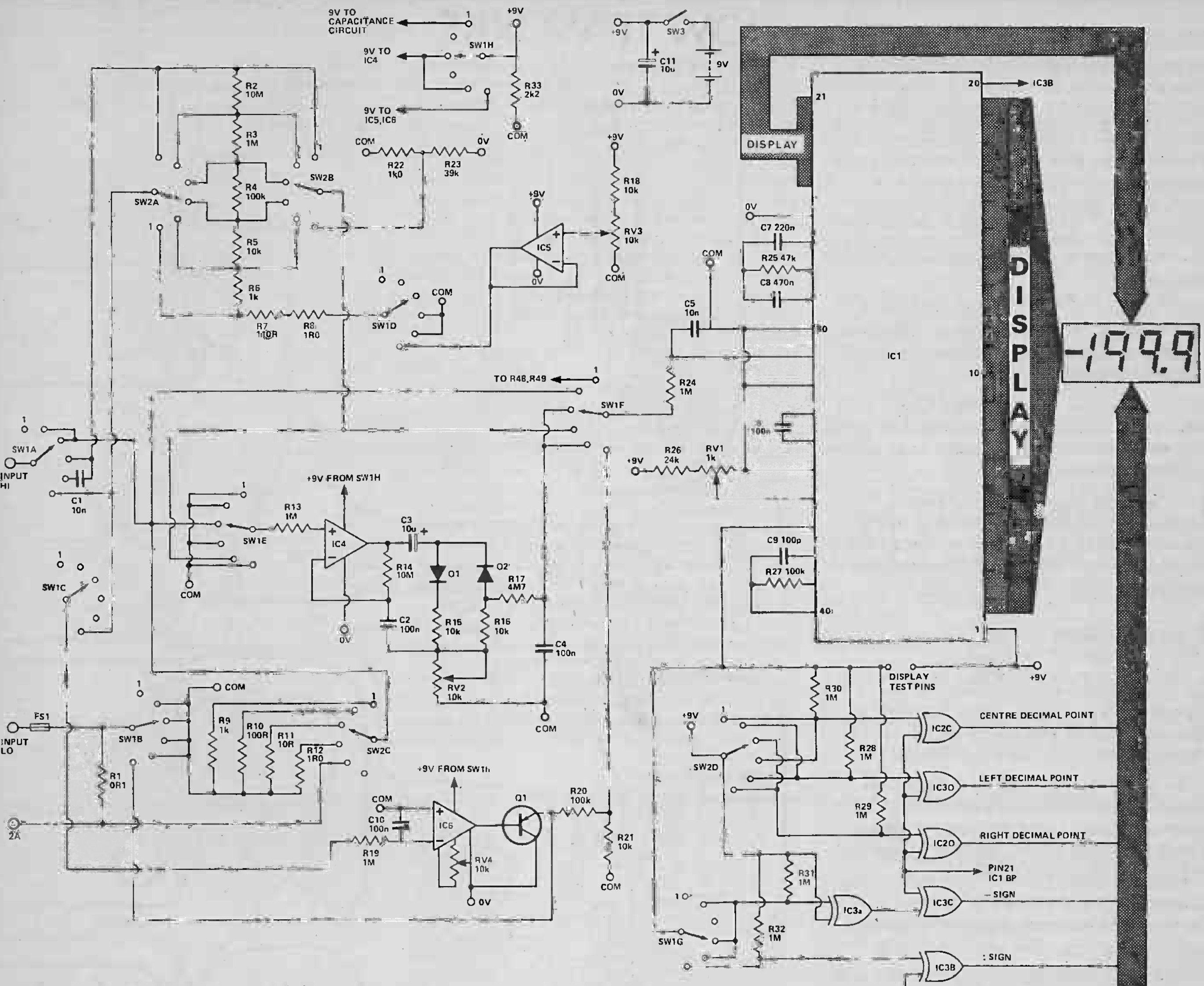
Capacitance Ranges

Using a simplified circuit, if V Ref^1 is joined to V Out^1, then V Out^1 will equal the common voltage since the op-amp is acting purely as a voltage follower. Hence C test is



fully discharged. If V ref^1 is now suddenly taken to a positive voltage, the output will begin to ramp negative at a rate determined by R Range^1 and C Test^1, and for a given R Range^1 the time taken to reach a given negative voltage is determined by and is proportional to C Test^1. In practice, a quad J-FET op amp type TL084 is used for IC9. The first stage IC9A is the integrator just described and in the rest state with Q2 off, the output and input are joined by the range resistor selected by SW2E. IC7 is a hex C MOS invertor which produces the timing control signals. IC7A and B form a monostable, triggered by pressing the READ button SW4. Having connected C Test but before pressing SW4, the op-amp will have discharged C Test^1 as above. IC8 is a CMOS analogue switch type 4016, which in the rest state has both stages OFF. IC9D is another integrator which due to the very high input impedence of the TL084 and low leakages of the 4016 will hold any voltage on C17 for many seconds. When the button is pressed, the output of IC7B goes low, unaffecting IC7 D and E but making the output of IC7C go high, thus turning on IC8B shorting the capacitor and making the op amp output equal to common voltage. At the end of the monostable period, C17 will be fully discharged and IC7B output goes high, in turn turning off IC8B. Simultaneously IC7D and E are triggered by the positive edge and IC7D output goes low, turning on Q2 and hence connecting the range resistor to the positive rail, causing IC9A output to start ramping negative. IC7E drives IC7F output high, and causes IC9B output (which was previously at the +Ve rail) to go negative from the common rail an amount determined by the two resistors R45 and R46. This voltage is an exact multiplication of the common to +Ve voltage, and is fed to the inverting input of IC9C, a comparator. Since the non-inverting input is fed from IC9A output which is still ramping negative, the output of IC9C switches positive, turning IC8A on and hence connecting the input of IC9D to the +Ve rail via a resistance. Hence IC9D output will also start to ramp negative. Remember this has all happened within microseconds of the end of the monostable period.

After a while, IC9A output will go more negative than IC8A and isolates the input of IC9D completely. The voltage on IC9D output is proportional to the value of C Test, and will only be discharged by leakage. This voltage is fed via an attenuator to SW1F and then to IC1. Since IC9 is a quad op amp, no provision is made for offset nulling, so a negative current is fed into the attenuator to counteract any offset. Calibration is achieved by adjusting the current fed into IC9D input during the measuring period by RV5.



BUYLINES

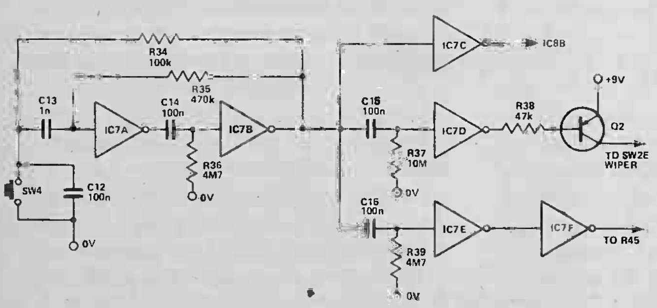
Watford Electronics, 33 Cardiff Road, Watford, can supply a complete kit of parts for this project. The kit, which includes predrilled case and punched and screened front panel, will be sold at a special introductory price of £49.95 plus 8% VAT and £1 p&p and ins. Test Leads are available for an additional £1.50.

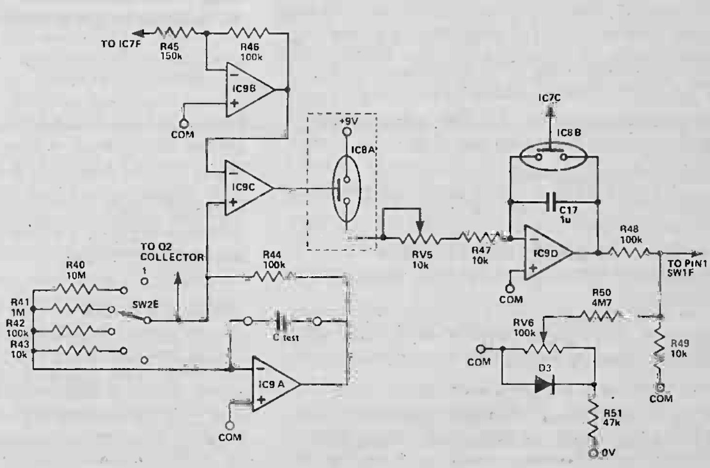
Watford are also to offer a calibration service. This service will apply to **working** units only and will cost £5.75 all inc.

Fig. 2. Full circuit diagram of the DMM excluding the capacitance measuring circuitry. R1 and FS1 are not mounted on the main PCB. Note that although a protection network is incorporated, it is wise to ensure that a high range is selected before the meter is applied to the circuit under test.

▶

Fig. 3. Below, left and right, circuit diagrams of the capacitance section, a patent has been applied for in respect of this design.





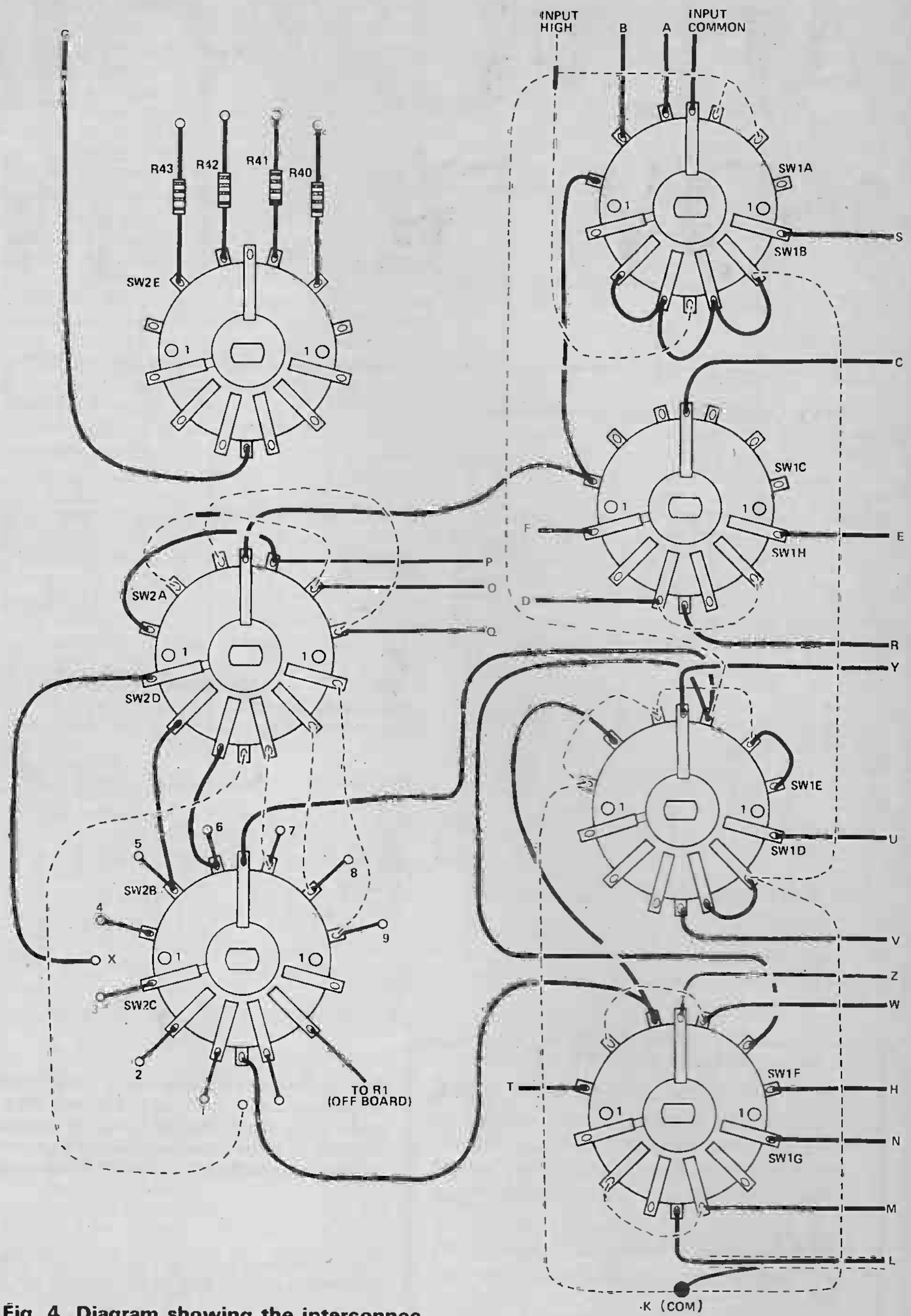


Fig. 4. Diagram showing the interconnections between the wafers of SW1 and 2.

assembly and the wipers only rotated to position 1 if necessary since it is possible to bend fixed contacts without noticing, the damage not being discovered until testing of the DMM takes place. To replace a damaged wafer after assembly is complete is an extremely difficult operation.

The most delicate part by far is the display itself. This should be examined carefully for defects in the glass and then kept in its cardboard wrapper until ready for use. It must be pressed into its socket with extreme care, and easing the soldercon pins with a piece of tinned copper wire before insertion is recommended.

Note the LCD display should not be subject to temperatures greater than about 60° C and should not be exposed to strong sunlight for any period of time.

Construction

If it is hoped that a DMM will result with a similar specification to the prototype, the parts list must be followed closely, as must these instructions. The use of a double sided board makes construction a less onerous task than would have been the case with a single sided design. However, to avoid the considerable expense of plated through holes connections from one side of the board to the other are made with copper wire or, better still, with pins designed for this purpose.

The resistors should be fitted to the PCB first, noting that there are three types specified, carbon film for non critical applications, metal oxide for long term stability and the 1% components. Interchanging of these would cause loss of accuracy. The capacitors and transistors may be fitted next, together with the pots and IC sockets. The use of these is strongly recommended. Do not fit the soldercon pins for the display yet, since subsequent handling of the PCB will almost certainly cause damage to them. Fit the vero pins, noting that the two for the capacitance socket wiring are inserted from the opposite side of the board.

The switches may now be prepared. The knob shafts should be cut down to 9mm in length, and then turned fully anti-clockwise to the end stop (viewed from the front). Next the nut and washer are removed and the ring to fix the number of positions set to the six hole. Rotate the shaft five positions clockwise to check that there are only six positions in all, then rotate back to the original position and replace the nut and crinkle washer. Repeat with the other switch assembly.

Prior to removing the studding carefully pull out the wafer drive shaft and cut to a length of 30mm, remove any burrs and reinsert. Next unscrew the 8BA nuts from the four lengths of studding, and cut these to a length of 37mm each. Fit a nut to one end of each piece of studding, putting the remaining washers and nuts aside for use later. Beware—the centre of the assembly will push out very easily in this state causing a loss of springs, balls and temper.

Place the switch operating mechanism on the non component side of the PCB with the number '2' on the casting nearest to the display location and pass two studs through the switch and PCB. It is possible to fit the wafers in any of four positions,

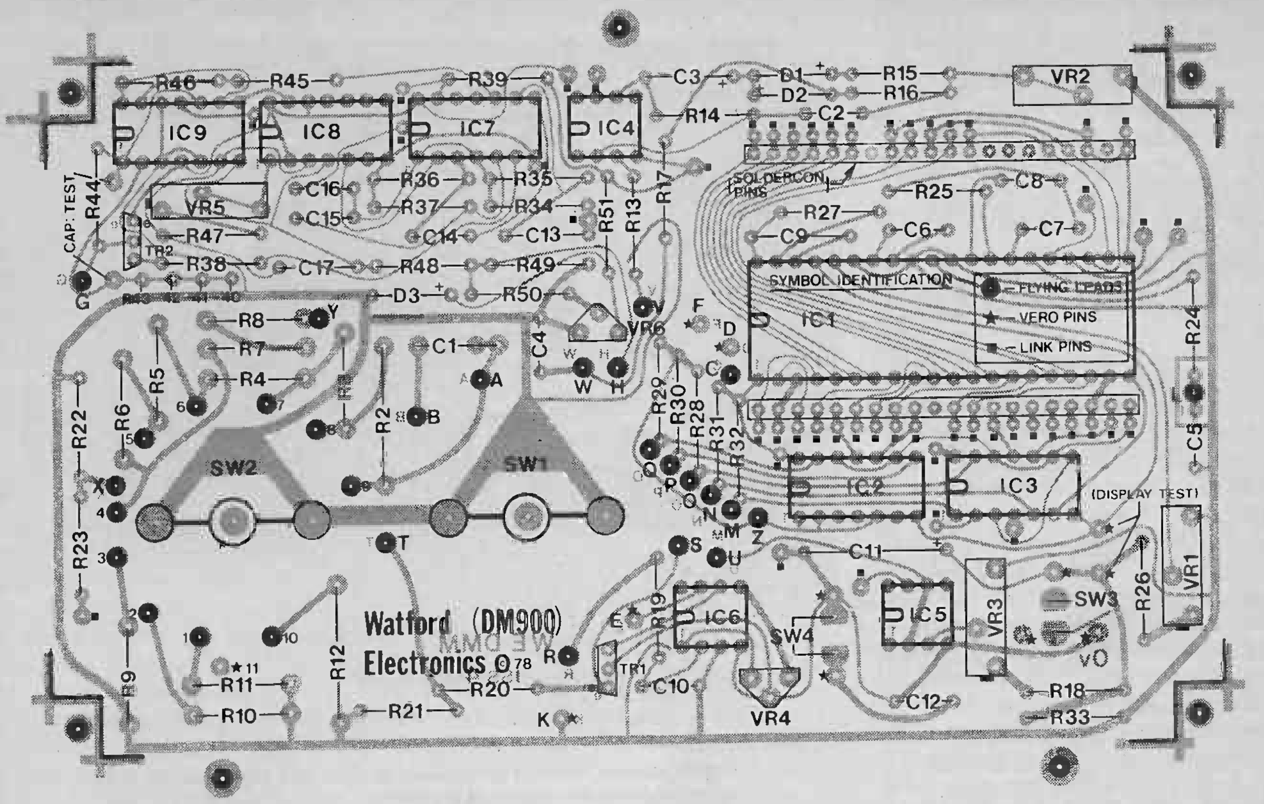


Fig. 5. Component overlay for the DMM circuit board, points marked ■ are through board links and points marked ★ are terminal pins. Only one side of the pattern is shown for clarity.

PARTS LIST

RESISTORS (* 1% Hi-stab, † ¼W MO 2%, other ⅛W 5%)

*R1	OR1
*R2, 40	10M
*R3, 41	1MO
*R4, 42	100k
*R5, 43	10k
*R6,9	1kO
*R7	110R
R8	1RO
*R10	100R
*R11	10R
*R12	1RO
R13, 19, 24, 28 29, 30, 31, 32	1MO
R14, 37	10M
R15	10k
†R16,18,21,47,49	10k
R17,36,39,50	4M7
†R20,48	100k
R22	1kO
R23	39k
†R25	47k
†R26	24k
R27,34,44,46	100k
R33	2k2
R35	470k
R38,51	47k
R45	150k

POTENTIOMETERS

multi turn ¾in cermet

RV1	1kO
RV2,3,5	10k

min. vert.

RV4	10k
RV6	100k

CAPACITORS

C1	10n 2kV disc ceramic
C2,4,6,10 12,14,15,16	100n 100 V polycarbonate
C3,11	10u 16V electrolytic
C5	10n 100 V polycarbonate
C7	220n 100 V polycarbonate
C8	470n 100 V polycarbonate
C9	100p polystyrene
C13	1n0 polystyrene
C17	1u0 100 V polycarbonate

SEMICONDUCTORS

IC1	ICL7106
IC2,3	CD4070B
IC4,6	TL081
IC5	741
IC7	CD4069B
IC8	CD4016B
IC9	TL084
Q1, 2	BC214L
D1,2,3	1N914

SWITCHES

SW1	8 pole 6 way
SW2	5 pole 6 way
SW3	miniature toggle.
SW4	push button

MISCELLANEOUS

3½ Digit LCD display, PCB, IC sockets, 2A 20mm fuse plus chassis mounting holder, battery connector, case (type NJSF 1), display filter, 4mm sockets, knobs, wire, 50 link pins, 12 connecting pins, handle, screened cable.

only one of which is correct. Place the wafers on the bench with the visible wiper contact away from you, ensure the wiper tongue on the centre ring is to the left and that the flats in the centre hole lie parallel to a line joining the fixing holes. Hold the PCB component side uppermost while supporting the switch and studs and with IC1 to the right, slide the wafer over the studs and drive shaft. SW2 (the left hand switch) has three wafers and SW1 has four wafers. Fig. 7 will clarify this. With the wafers in position, the fibre washers and nuts may be fitted and tightened. The switches should now be tested with an ohmeter before proceeding to ensure no damage has been done during assembly.

The switches are now wired, using tinned copper wire and silicone rubber sleeving, since using PVC insulated wire would promote the possibility of melting due to the close proximity of the switch contacts, and with up to 1KV around this is highly undesirable. An exploded view of the switch wiring is shown in Fig. 4, and this should be studied very closely.

The switches should be wired starting at the wafers nearest the PCB ▶

and working upwards. The end of the tinned copper wire should be soldered to the first tab, a length of silicone rubber sleeving cut to the exact distance between the tags to be joined and slid over the wire, and finally the other end soldered. The signal input to IC1 is brought from the switch by a screened lead, with the braid soldered to the 'common' pin adjacent to the relevant switch tag, and cut off and sleeved at the other end.

As stated above tracks on opposite sides of the board are joined by tinned copper wire or special pins which are inserted and then broken off short before soldering. The holes next to the display socket must be joined before the soldercon pins are fitted, since soldering close to them on the wrong side of thePCB can cause wicking of solder into the socket making it unusable. Having fitted these, the display socket pins may be fitted in the normal manner.

Having checked the board for assembly and wiring errors, the IC's may be inserted, being especially careful with IC1 which requires quite a high insertion force. Finally poke a piece of 20 SWG wire into each pin of the display socket to ease them and then fit the display. There is normally no indication of which pin is number 1, but by holding it at an angle to the light and looking for an outline of the digits, the correct way up may be found.

The unit is now ready for testing.

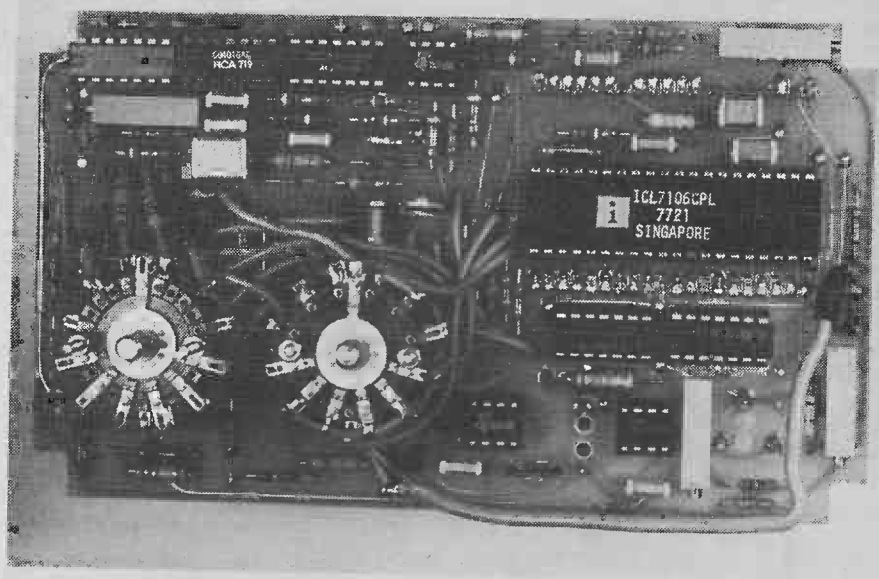
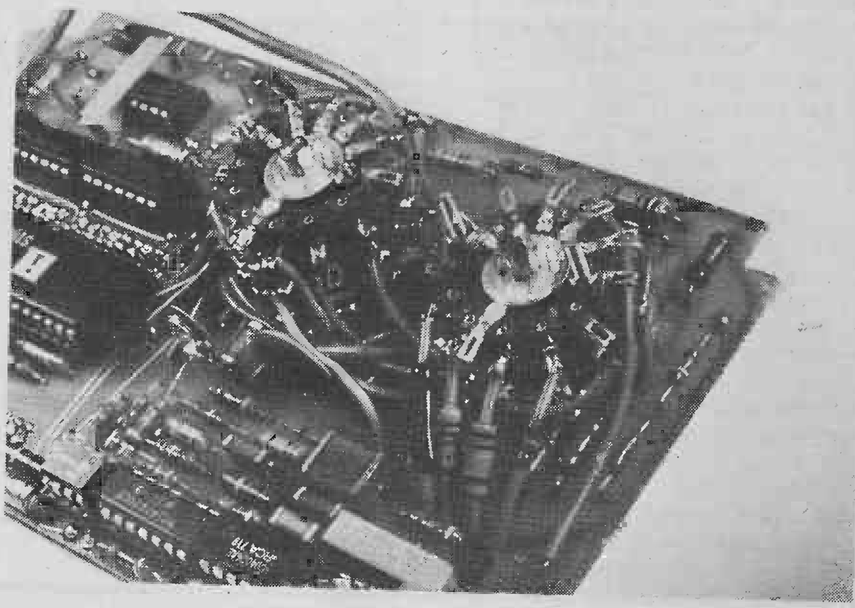


Fig. 6. Above, view of completed circuit, and Fig. 7 below, view of wiring around the range switches.



Testing and calibration

Connect up a 9 V battery and select the DC voltage range with 20V FSD. The current consumption should be about 5mA, and the display should read 0.00, with the plus and minus signs alternating. Check the voltage between the common and positive rails, which should be 2.8V± 0.4. No measurements should be attempted with the DMM until calibration is complete as these will be meaningless. The accuracy of the whole instrument depends upon the setting of RV1 so this must be set first. It may be adjusted by comparison with a meter of known accuracy or by using a Weston standard cell (1.0186 volts), and it is likely that advertisers will be offering a calibration service. Which ever method is chosen, two wires are attached to SW1A and B wipers, positive and negative respectively and connected to the test circuit. Seledt the correct DC range and adjust RV1 until the correct reading is obtained. If 1% resistors have been used where specified, changing to the next range should give a reading of exactly one tenth, and the next one hundredth, allowing for the plus or minus one digit accuracy. Calibration should ideally be done on the 200 mV range since this does not involve the attenuator, but this is not normally very easy. As many ranges as possible should be checked to ensure overall accuracy. The DC current ranges may be checked also, and should agree to a high accuracy — but remember the 2A range resistor is not yet connected.

The AC voltage ranges may also be calibrated by a comparison method, preferably starting with a low voltage transformer or a signal generator. The frequency response should be good over the audio spectrum, but this has not been measured accurately. As before, the potentiometer, RV2 this time, is adjusted until the desired reading is obtained. When switching down ranges, the response will probably fall off at reading of 10 or so due to the rectifier, so the instrument should not be used at such low readings. The mains voltage may be checked with care, and mind fingers on the switches. There should be no polarity indication on AC ranges, but the colon may occasionally flash with no input since the minus sign is blanked.

The ohms ranges should be calibrated with a standard 1% resistor, and possibly those in the capacitance circuit may be left out for this purpose. First switch to the 20k range, when the colon to indicate resistance range will be seen and only the left hand 1 and decimal point to indicate overrange, i.e. infinite resistance. This overrange is the same on all ranges incidentally. Shorting the input leads together should give a low reading which may be reduced to 0.00 by adjusting RV4. Now insert the 10K–1% resistor and adjust VR3 to read 10.00, switching ranges should read 1.00 and .10. Check with the other resistors that calibration is correct. On the 200R range a small offset from zero will be observed, this being due to the switch wiring and contacts, and should not exceed 0.5R it should be taken into account when measuring low resistances however.

In order to calibrate the capacitance range, it is essential to have an accurate capacitor of value between 1n and 10n. This will probably be a polystyrene or silvered mica type. Switch to the 2n capacitance range and short the two read button pins. The reading should be unstable for a second or two and then settle to a low reading. Now connect the test capacitor across the two pins for the capacitance test sockets. Shorting the read pins should now give a much higher reading and by adjusting RV5 and again shorting the pins the reading should be adjusted to the value of the capacitor under test. (If it is more than 2n, obviously the 10n range will be used). Now switch up a range and short the pins when a reading of one tenth of the previous one should be achieved by adjusting RV6 and a reading of one hundredth on the next range.

Re-check the setting of RV5 which may have altered slightly and then re-check RV6. This has set the capacitance ranges for best linearity, but due to stray capacitance, significant on the lowest range, an offset reading of three or four will be shown without a test capacitor. This is purely an offset, and capacitance readings down to 10pF or so can be made ignoring this offset.

All ranges should be checked as rigorously as possible to catch any faults before the unit is used in earnest. The battery condition may be checked by switching to DC volts and the fully clockwise position of SW1. The resistor network has been arranged to give a reading of 10.00 at 7 volts, below which the instrument will malfunction and the battery should be replaced.

Final assembly

To protect the display, a piece of clear perspex or Darvic approx. 65 x 40mm and no more than 1.5 mm thick is required. This is stuck to the reverse side of the front panel with Evostick or similar adhesive. Mount the push button with its pins orientated to line up with the holes in the PCB. Similarly mount the on-off switch with only a single lockwasher behind the panel. Fit the two capacitance terminals and line up the solder tags with the vero pins on the reverse of the PCB. Offer the board up to the front panel and with only a lockwasher on each rotary switch, the panel and board should be parallel to each other, with the display just clear of the perspex and central in the window. Now fit the switch nuts and knobs, and wire the toggle and push switches and capacitance terminals to their respective pins. Solder the battery connector leads to the pins adjacent to the on off switch, and three wires to the wipers of SW1A and B and the 2 amp position of SW2C. Mount the three 4mm sockets in the front of the box and connect the OR1 ohm resistor and fuse holder as shown on the diagram, then finally connect the wires from SW1 and 2. The battery may be held in position with a simple aluminium bracket. It is also possible to adapt certain types of battery holder to take six batteries of the HP7 size. Finally screw in the front panel and your digital multimeter is ready for use. Make up a couple of leads using very flexible wire and use probes which will stand the voltages and currents to be measured. ETI

ELECTRONICS IN MOTORING

It is only a matter of time before the 'smart' car comes along – cars have been relatively simple hydromechanical machines without the intelligence that a powerful electronic system could provide . . . . but that simple era is about to end.

THE ELECTRONIC REVOLUTION in the car industry is with us — the level of electronic sophistication in production cars is increasing at a surprising rate, bringing with it improved performance and high reliability.

In the past the electrical system in cars was a well known area for failure, wouldn't complex electronics be even more failure prone?

At first sight it seemed that failures would be inevitable. Cars offered an environment far more hostile to computers than the air-conditioned and dehumidified chambers they had been used to. Temperatures under the bonnet range from —40° C to 140° C. Salt spray, dust and vibration are constant menaces. And the car has a power supply ''which, by computer industry standards, has limited capacity, minimal regulation, and is quite noisy,'' as a General Motors' engineering report put it. The odds against success seemed heavy at first.

Gradually techniques were worked out that promised success. Manufacturing methods became exacting — and expensive. When building the 'Lean Burn' electronics package, said Chrysler's Huntsville general manager, Arthur E. Douyard, ''We actually try to make the unit fail during assembly. We expose it to 185-degree temperatures three times, including a final period up to 10 hours. We also pass-fail the unit by computer five times. Finally, we audit ten per cent of the units we ship to grade our quality control standards.''

The ten-hour test figure was not casually arrived at. ''Any malfunction with an electronic device should show up quickly — usually within the first ten hours,'' says Sidney L. Terry, vice president for public responsibility and consumer affairs of Chrysler. ''After that the electronic components should never wear out. Chrysler engineers estimate that for every pound the industry has invested in electronic voltage regulators, the customer has saved nine pounds in replacement costs, and that customers have saved four pounds for every pound we have invested in electronic ignition.''

This is a good record — for relatively simple devices. For more complex systems, serviceability suited to the auto repair shop will have to be worked out. ''Repair of computer-type equipment will of necessity be at the module replacement level to be practical,'' the SAE was told by Frank P. Caiati and James F. Thompson of GM's Engineering Staff. ''Isolation to a failed module will be the technological challenge. It is very necessary that a high percentage of module failures be self-indicating,'' so the usual vagaries of trial-by-replacement troubleshooting could be avoided.

''The MSI and LSI semiconductor technology of today lends itself to modularity,'' Ciati and Thompson added. Like car radios, the first complex electronic system used in a production car — the Bendix fuel injection for 1957 — used valves. Soon thereafter the valve was replaced by the transistor, much smaller and less power-hungry, while back in the semiconductor labs, the age of the integrated circuit was being ushered in.

''In 1959,'' explains Chrysler's Terry, ''a commer- ▶

electronics today INTERNATIONAL

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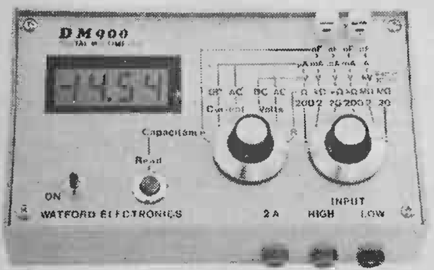
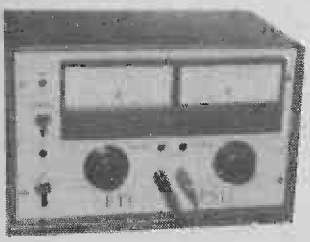
Help a leaf today p.61



High capacity p.23



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cially available chip contained only one component of a circuit. By 1964, the number of components per chip was up to ten. By 1970, the number of components was up to about 1000, and by 1976, up to 82,000. At the same time, the cost per unit dropped sharply."

The electronics industry soon discovered that the most efficient way to use those 80,000 components was to organise them into a computer-like general purpose logic chip — the microprocessor. With that much power available in a very small package, the car industry had to pay attention to microprocessors. "These new LSI microprocessor chips, as used in calculators, started the industry looking at applications in which their added cost could be handled," says Donald E. Colvill, staff engineer for electronic engine controls of GM's Delco Electronics Division. "To an engineer," he adds, "a computer is always attractive from a technology standpoint."

It was one thing to decide to use this know-how of the semi-conductor industry, and quite another to decide exactly how to use it. There are two main types of computer, analogue and digital, and each has its strengths and limitations. The car industry started with analogue computers, but it is moving rapidly and irrevocably towards digital computers today.

The analogue computer was initially the most popular because it is simpler and well suited to doing many of the jobs that the car system requires. As its name hints, it works through the setting up of an electronic circuit that is analogous to the conditions in the mechanism that it's controlling. In an analogue computer, multiplication by a constant, for example, would be done by an amplifier of fixed, pre-set, gain. Analogue circuitry 'mimics' the motions of the machine and/or the mathematical equations that describe what it does. Analogue computers can be quite versatile, but for use in cars they're usually tailored in design to suit just the job they have to do.

Analogue Circuitry

Analogue circuits started strong in cars and are still doing many important jobs in them. The Bosch and Bendix electronic fuel injection systems use analogue computers, for example. Analogue designs were chosen because they're fairly easy to change and adjust during vehicle development and during the evolution of the fuel injection system. For similar reasons Chrysler chose an analogue computer to control its Lean Burn spark-adjustment system. First launched in the 1976 model year, this functioned with 99.9% reliability on the initial field of 60,000 cars. Now in 1978 it's available on all Chrysler's eight-cylinder engine families.

Analogue circuitry also does the computing in the black boxes used in the closed-loop Lambda-sensing controls that make the so-called three-way catalysts work in the cars now on the US roads. Such systems were first marketed by Volvo and Saab at the end of 1976, using Robert Bosch electronics. Now for 1978 Ford's Pintos and Bobcats with automatic transmissions for the California market have such closed-loop or feedback controls. Both Motorola and Ford's own plant supply their analogue electronics. GM's Delco Electronics Division makes analogue controls for the similar air/fuel ratio control being fitted to some Buick, Oldsmobile and Pontiac subcompact models, also for the California market. Ford uses Bosch exhaust pipe sensors, while GM's come from the AC Spark Plug Division.

Two 1978 GM models have new spark control systems that also have analogue computer circuitry. One is Delco Electronics' Electronic Spark Control, which is called the Turbo Control Centre by its user, Buick, which employs it on its turbo-supercharged V-6 engines in the Regal and LeSabre sports coupés. This ingenious device uses a Delco Remy vibration sensor mounted on top of the inlet manifold to tell when the engine is detonating. Electronic filters on the sensor's output pass the high vibration peaks in the range of five to seven kilohertz that GM considers to be the signature of pinking or detonation. Analogue circuitry in the Electronic Spark Control modifies the spark dwell, and thus the spark timing, by a signal it sends to a special electronic module in the High Energy Ignition. Working every other crank revolution, it can retard the spark up to 20 degrees in two-degree increments until the detonation stops. It is designed to cope with extreme conditions in the running of the

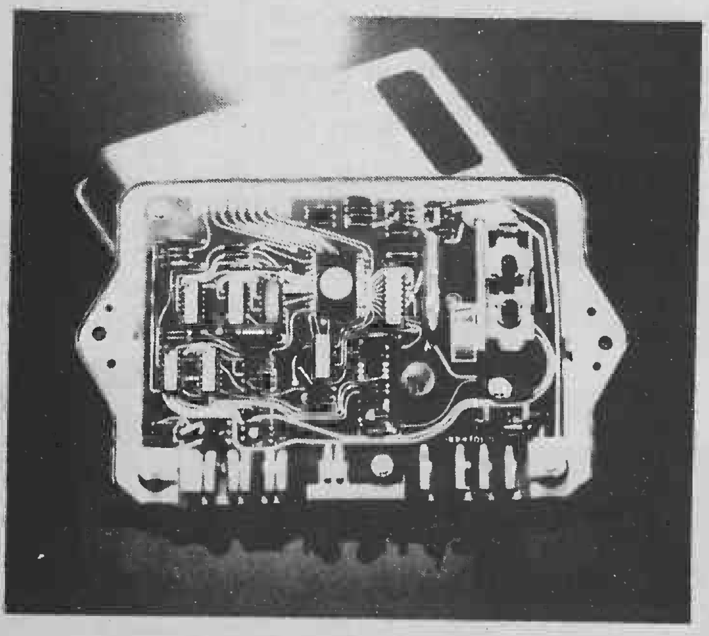
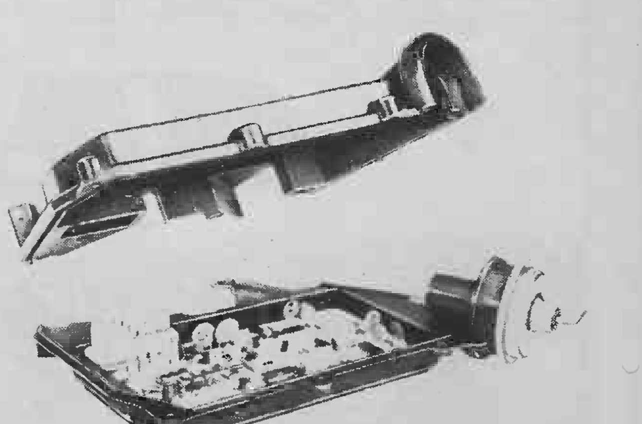


Fig. 1. Left, a Delco Remy module, part of an electronic controller for the GN 3-way catalyst system.
Fig. 2. Below, the spark control computer, part of the Chrysler Lean Burn System.



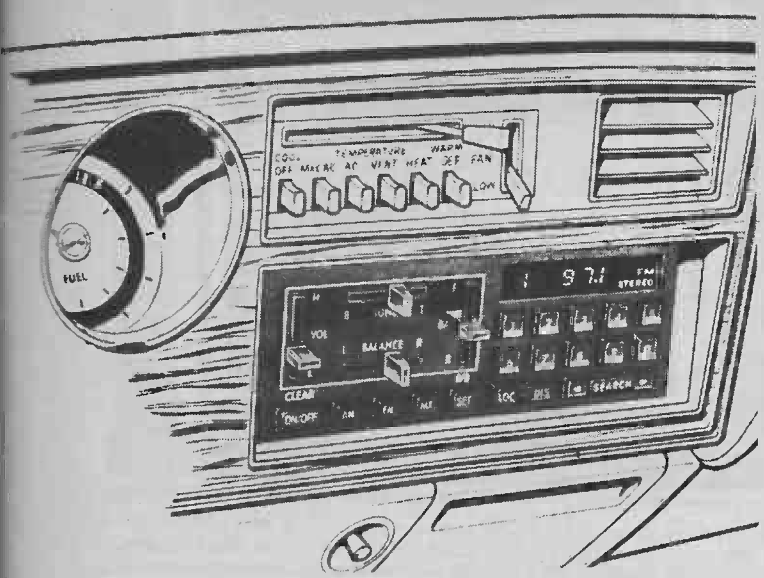


Fig. 3. Microprocessor control circuitry allows Chryslers new AM/FM Stereo Search radio to recall ten stations from its internal memory. A LED display shows the frequency and number of the selected station.

sensitive supercharged engine, such as a very heavy load on a very hot day.

This spark control system is a closed-loop device, the first of its kind to be placed in volume production. Delco Electronics' other new spark controller is an open-loop design, the Electronic Spark Selector used on 1978 Cadillac Sevilles (except for the diesels, of course). This has sensors that tell it engine speed, manifold vacuum, coolant temperature and the engine cranking condition. From these, an analogue computer advances or retards the whole spark curve to suit the running conditions. During engine warmup, for example, it retards the spark so the catalyst will reach working temperatures more quickly. Like the detonation sensor, this too allows the engine to be run with a great spark advance under most conditions, favourably affecting mileage. Cadillac expects an overall improvement of about one mile per gallon from its use. And the Electronic Spark Selector is built to "fail soft". Should it stop working, the engine simply keeps running with the last spark curve it was using before the failure.

Both Cadillac and Buick offer yet another engineering feature that combines analogue-type electronics with a simple logic chip. The new GM application is in the Automatic Level Control for the rear suspension, developed jointly by Delco Electronics and Delco Products. It uses an Optron diode sensor to measure the distance from the axle to the frame, and then through the analogue and logic circuits, it adds or subtracts compressed air (from a 150 psi supply) in the special shock absorbers to bring the rear of the car to the correct level.

Number Crunching

With all these applications, analogue computation is well established in the electronic systems of today's cars. But it has a strong and promising competitor: digital computation. It reaches similar ends in a different way. While the analogue system is computing by making comparisons between different voltage and/or current levels, the digital system is carrying out the various calculations mathematically, just as you would on a scratch pad or calculator. You might say that digital computation is to analogue as a desk calculator is to a

▶

Fig. 4. The Aston Martin Lagonda, below, has the drivers seat computer controlled through servomotors. The seat can be pre-programmed with two sets of adjustments (for husband and wife drivers).

slide rule. Actual physical relationships play a part in the analogue circuit's findings, while the digital computer gets its results by doggedly doing the actual math — very quickly.

While the digital device gives results that are inherently accurate, the electronic components of the analogue device must be "trimmed", during assembly and testing, to make sure that the complete circuit gives the right answers. This seems to show an edge for the digital device, but that's not necessarily so. Many of the inputs to digital computers will begin as analogue signals, such as a varying voltage from a temperature or throttle position sensor, and will need to be converted into digital language that the computer can understand. Such an analogue-to-digital converter will also need to be trimmed, or calibrated, for accuracy. And digital-to-analogue converter will also need to be trimmed, or calibrated, for accuracy. And digital-to-analogue converters for the computer's output will also be needed so it may perform automotive tasks.

Until recently it was simply unthinkable to fit a digital computer into a production car, because it was too big, too expensive, or both. Now, with the arrival of the microprocessor that limitation is beginning to be removed. A digital computer needs a central processing unit (CPU) to do the work. It also needs a fixed or permanent memory (known as ROM for read-only memory) of substantial size to tell it what to do and when to do it, and in addition to that a temporary memory, or RAM (random-access memory), in which it can store data it needs for continuing its calculations. All this can now be etched on one or more small LSI chips, forming a microcomputer.

Small and powerful though it may be, such a microprocessor doesn't come cheaply. It costs tens of thousands of dollars just to tool up to make the special masks needed to etch them in production. Also, to avoid needless waste they must be tailored as closely as possible to the applications for which they're needed. A nervous period of courting between the motor and semi-conductor industries is now ending, as each better understands the needs of the other, and microprocessor uses are increasing rapidly. From one in 1977 the number of applications has jumped to five in 1978, and there'll be many more in 1979, after the technique proves its value and reliability.

MISAR Sparks It Off

The beachhead for microprocessors in cars was established in the '77 model year by Oldsmobile and Delco-Remy with their MISAR spark control system used in Toronto. Standing for Microprocessed Sensing and Automatic Regulation, MISAR senses crankshaft rotation, manifold vacuum and coolant temperature, and from these decides which of more than 200 ignition advance points on a "map" of possibilities suits the engine best at that instant. These points are stored in a ROM with a capacity of 1024 ten-bit data words. Two LSI chips are at the heart of the Rockwell CPU that computes which point will be used at any moment. It completes the 335-odd instructions its program requires in about 12 milliseconds giving a fresh spark timing at that interval. MISAR works by switching the HEI distributor's own electronic module on and off.

Three other microprocessors are used to do jobs that are less vital to the running of the car. One is another Chrysler Huntsville development, an advanced solid-state search-tune radio. It has a ten-digit keyboard that

Fig. 5. Fifth among the digital microprocessors in the 1978 cars is the miles-to-empty system used, as an option, in the Lincoln Continental Mark V. Its LSI chip carries the equivalent of 3600 transistors on a surface less than a quarter-inch square. Picking up indications of car speed and fuel tank level, it calculates the distance travelled, fuel used and the resulting miles per gallon. Then it multiplies fuel mileage by the amount of fuel left in the tank to get the miles-to-empty reading shown on the dash.

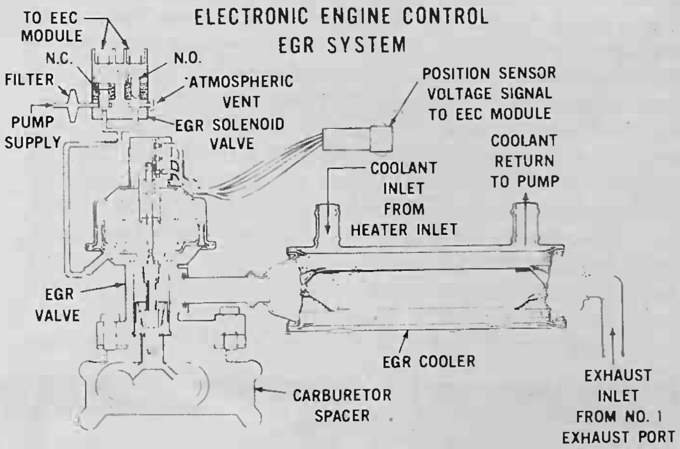
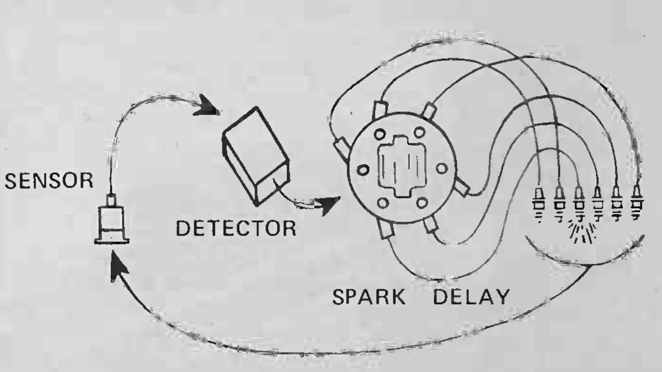


Fig. 6. Above, diagram of the Electronic Engine control system featured in the 1978 Lincoln Versaille.

Fig. 7. Below, diagram of the Delco Electronic Spark Control as used on the Buick turbo-charged V-6 engines.



can be used to choose stations directly by their frequency, or from the radio's computer memory by a push of a single button. Automatic searching for other stations, at two sensitivity levels, can be initiated by a foot switch. The frequency chosen is shown by a light-emitting diode display. This "thinking" AM/FM stereo radio is offered in such top-line models as the Dodge Diplomat and Magnum and the Chrysler LeBaron, Cordoba, Newport and New Yorker Brougham.

The fourth microprocessor available in the '78 models is an option on the 1978-1/2 Cadillac Sevilles, those without diesel engines. It's at the heart of a system called Tripmaster, which uses a large LED display made by AC Spark Plugs in place of the conventional speedometer and introduces LED displays for the fuel level and, at the right of the dash, for engine speed, coolant temperature or time of day — whichever the driver selects by pushing a button. A small panel holds a dozen pushbuttons for selecting operating modes or entering data into Tripmaster.

Its CPU, a Motorola 6800 microprocessor, allows the Tripmaster to do many navigational tasks. It can handle time, distance and average speed calculations, and it can relate them to the rate of fuel consumption and the amount of fuel left in the tank. Drawing information from the electronic fuel injection, it can read out the instantaneous fuel mileage and the average mileage for the journey. Its present ROM capacity of 4000 eight-bit words is enough to let the Tripmaster handle these jobs, and it be expanded by several multiples in the future, using the same CPU, to permit it to take over all engine functions and many other control tasks in the car.

Looking Forward

This is a promising array of digitally-controlled auto systems. Many more are waiting on the sidelines. We can expect, for example, that most and perhaps all of the present analogue car computers will be converted to digital operation in the course of the next several years. Speaking to the SAE about electronic fuel injection in 1976, Jerome G. Rivard, then of Bendix and now with Ford, said that "In the interests of cost reduction and higher production volume, the current hybrid analogue design will undoubtedly be replaced ultimately by a design based on digital EFI controller to be in production for the 1979 model year and to be in wide use in 1980. United Technology's Essex Group has also built and tested a digital injection computer, while Chrysler will use such a controller with its forthcoming Electronic Fuel Metering system. Its key microprocessor suppliers are expected to be the RCA Corp. and Texas Instruments.

The systems on the 1978 cars are the exploratory first wave for the mass invasion of microprocessors that's coming on the 1981 models. To meet the tougher emissions and economy standards then, the tiny LSI chips will take over control of all main engine variables: spark timing, EGR valve flow, choke control on carburetted cars, fuel preparation and fuel/air mixture control. The Motorola 6800 microprocessor, used already in Tripmaster, will be the key CPU for General Motors and, apparently, for Ford as well.

Those responsible for developing these new systems make no secret of the fact that the central brain, the CPU, has raced far ahead, in design, of the sensors and actuators that are the eyes and muscles of the brain. These are still relatively primitive, and all too susceptible to inaccuracy or failure under automotive operating conditions. Also many of them produce analogue outputs instead of the digital data that the microprocessor would prefer to receive. This is the area in which the mechanical and electronics engineers will have to cooperate most genially if good results are to be achieved. ETI

HOME COMPUTER

Tandy have recently introduced the Radio Shack TRS-80 computer system to this country. Phil Cornes, Gary Evans, Graham Wideman and Mark Czerwinski have been putting the machine (pity it wasn't time sharing) through its paces.

THE NAME TANDY will be familiar to many of you. Of American parentage the company have over the past few years opened up a large number of retail outlets in this country dealing mainly with audio equipment and in most cases, components. Those of you who frequent the larger Tandy stores may well have noted the appearance of a home computer, as Tandy's TRS-80 home computer system has been on demonstration in many since March. So what is the TRS-80 and how does it compare with similar systems?

What You Get

The TRS-80 system comprises of four separate units. The first, a standard 'Realistic' CTR 41 portable mains/battery cassette recorder, is used for long term storage of programs, information and data files.

The second is a video display unit which provides up to 16 lines of 64 alpha numeric characters. Each of these 1024 character locations can be further sub-divided into a 2 x 3 matrix giving an overall 128 x 48 matrix. The 6144 resulting positions on the screen can be individually lit or dimmed as required, from within a program, to produce all manner of continuous or interrupted graphics.

Thirdly we have the power supply unit, which gives a 17 volt AC output, used to power the last item of hardware, the CPU, memory and keyboard package.

The CPU is a Z80, the memory comprises of level 1 BASIC in 4K ROM, 4K of dynamic RAM for program storage and 1K static RAM for the video display. Also included are the voltage regulators, the cassette and video interfaces and the integral standard 'QWERTY' keyboard. Also supplied are a 232 page instruction manual and two cassettes, one blank for retaining your first efforts in programming the other with two games programs — Blackjack and Backgammon. In addition all leads required to connect the four units together and to the mains are provided.

Initial set-up is quite easy — simply put all four units on the same table and plug them all together. All three connections to the keyboard/CPU unit are made via five-pin DIN plugs and **ARE** interchangeable. The ▶

sockets are labelled and we are assured that swapping leads will not cause any damage. Plugging into the cassette recorder is less obvious since two of the plugs can be interchanged with no identification other than being of different colours.

Having said all this though, after setting up the system a couple of times one will be familiar with all these points and in practice we don't see many problems with these connections.

First Impressions

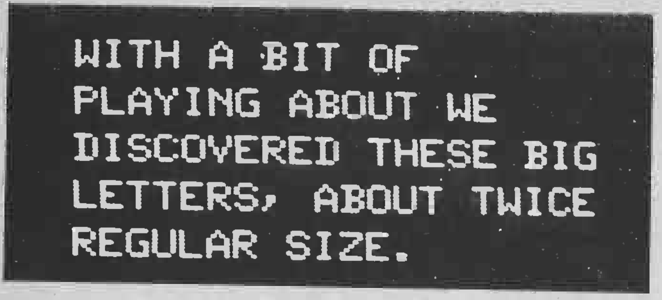
Switching the system on requires the pushing of two on/off switches. The first is on the front of the video display and the second is on the back of the microcomputer itself adjacent to the plug and socket which connect the power to the main unit. With this done it takes only three or four seconds for

READY

> –

to appear in the top left corner of the screen. The > symbol is presented to inform you that the system is in the state in which it can accept entries from the keyboard, the symbol itself is called a 'prompt'. The — is called the cursor and is presented to show you where the next character input will be displayed. A quick flick through the manual revealed on page 225, the listing of what appeared to be a very useful program, a combined function and RAM test which it is claimed "Puts the TRS-80 through its paces — All of them" and having looked through the program we could well believe it.

The program starts off by using every statement and function that level 1 BASIC is capable of with checks in the program to make sure that all is as it should be and with error messages printed for a failure. The program then goes on to write numbers into all empty RAM locations, reading them back to check that they were written correctly and finally it displays a sort of simple test card that can be used to check the alignment and centering of the picture on the screen. Care should be taken when typing this program in as there an error in the manual which has to be corrected as you enter the program. (There is a slip of paper included with the manual which corrects the few printing errors that have crept in). It is well worth dumping this program onto tape (see below) as if you are anything like us it takes about half an hour to put it in (using the well tried and trusted single finger poke and hope method).



The TRS-80 passed the test, this was the point at which we considered the system to be well and truly commissioned. The command CSAVE is the one used to dump programs to tape but the one you'll most likely want at first is CLOAD, the magic word for loading one of the programs included with the machine. Having amused ourselves with these for an hour or four we can take a look at the hardware and software in more detail.

Looking at the total system, there are advantages and disadvantages to having four separate units. The main "pro" is the flexibility of being able to move the keyboard, video monitor and cassette recorder to suit your convenience (and making it easier for Tandy to provide machines for different markets), although longer leads would have helped on some units. It might have been better, however, to combine the cassette record and power supply with keyboard thus reducing the packages to two.

Not For Hard Types

The keyboard itself, while not of "professional" quality is more than adequate being a full QWERTY typewriter style design. One point to watch is that the keyboard will not accept a new key entry until the previous key has been fully released. Even an inexperienced typist, when entering often encountered groups of letters (eg. key words) will notch up speeds that will lead to displays such as RN, LST etc. Level II BASIC (see later) will remove this problem.

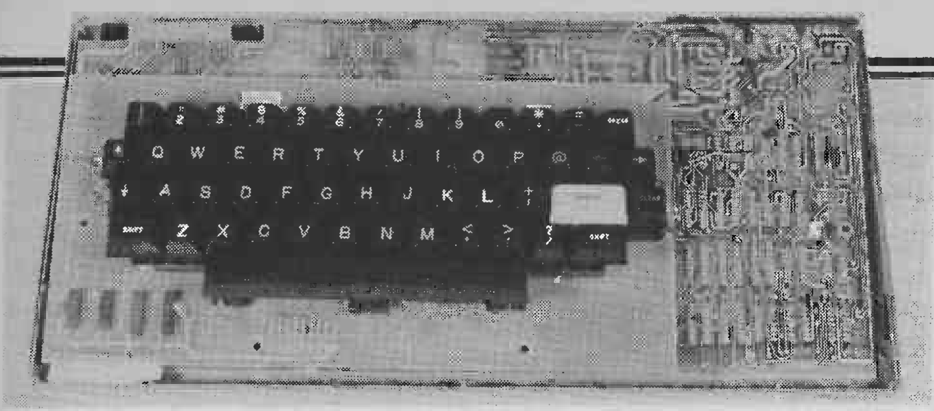
As mentioned above, the keyboard case also includes the CPU, memory and other assorted circuitry.

We don't feel that this system would be much fun for hardware enthusiasts. It's difficult to manage when taken apart, the keyboard and main board are attached to an easy to break flexible cable with no plug. No I/O ports are on board, which rules out simple add-ons, such as switching devices on and off, hooking up a speaker, and other popular experiments and applications. The back connector brings out the address, data and control buses. Thus a separate box with interface adapter could be added. Also on this connector are the keyboard lines, which would presumably facilitate adding more keyboards (possible numeric pad) in parallel with the existing one. The keyboard interface is done not with a Peripheral Interface chip as might be expected, but with ordinary buffers and latches, a cheap but less flexible system.

To summarize, this product does not appear to be aimed at the serious hardware person. Add-ons are difficult, although Radio Shack is coming out with an I/O unit. In addition, an S-100 interface is in the works, according to Radio Shack literature. The TRS-80 must then be best suited to software type, keyboard plus video and printer applications.

Data may be recorded on cassettes by means of the built in cassette interface which converts the data to a series of audio tones. Thus, any reasonable quality cassette recorder will do the trick. The cassette itself should also be fairly good since any tape "drop-outs" mean lost data. Tandy will supply five minute-per-side cassettes for this purpose although we have used C60s with no problems.

The recorder supplied with the TRS-80 (the CTR-41) has connections from the keyboard to the "AUX" input, "EAR" output, and also the remote on/off jack. Thus, when recording or playing cassettes, the operator (you) pushes the desired keys on the recorder and the TRS-80 switches the recorder on and off at appropriate times. You also need to set the volume level when playing back tapes. When recording, a dummy plastic plug must be stuck in the MIC jack to deactivate the built-in condenser microphone. The CTR-41 features a tape counter, very handy for finding your programs.



The interior of the TRS-80 reveals two PCBs, one of which carries the keyboard while the other deals with the rest of the TRS-80's circuitry. The flexible connector that joins the two boards can be seen bottom left while the expansion bus is at top left.

One dislike about the cassette system was the fact that the TRS-80 maintains control of the cassette machine at all times as long as the remote plug is left in you have to keep removing the plug to fast forward or rewind a tape to the desired position (This could easily be overcome by fitting a simple on/off switch in the main unit to short the remote jack and thereby provide a computer control/manual override switch).

Video Display

Designed specifically for the TRS-80 the video monitor accepts the signal from the keyboard unit and displays it on a 12 inch CRT. The video signal is fairly standard with 0V for sync level, 0.6V for black level with peak white at 2V. Impedance is 750R. The circuitry is isolated from the rest of the system by an opto isolator.

Power Supply

Nothing much to say about this, it converts the mains to a 17V AC unsmoothed output.

The Manual

This item is almost as invaluable as the Z80 MPU itself even if you've known BASIC all your life. It starts off by assuming you have never seen a computer before and it takes you easily and clearly through everything that you could ever want to know about BASIC and its implementation on this machine, starting with switching the machine on and ending with how to set up data files.

One thing we particularly liked about the manual was the trouble Tandy have taken to make sure that some of the sample programs don't work so that they can then go on to fully explain the error messages that the TRS-80 can give and how to interpret them and then go on from this to learn how to correct (de-bug) your own programs.

Another very useful section of the manual is an appendix which gives the listings of 11 subroutines to enable the TRS-80 to perform all the scientific and trig. functions that the interpreter can not do directly. These routines are numbered and arranged in such a way that they fit easily into any program you are writing that needs them while at the same time requiring only half a dozen lines of program each so they don't take up too much program memory.

Software

As a home computer system, the TRS 80 is probably the least hardware oriented we have seen. There are two points which support his thinking: you can't get at the internal hardware without voiding the warranty and there is no hardware interface capability other than to the display and the cassette recorder.

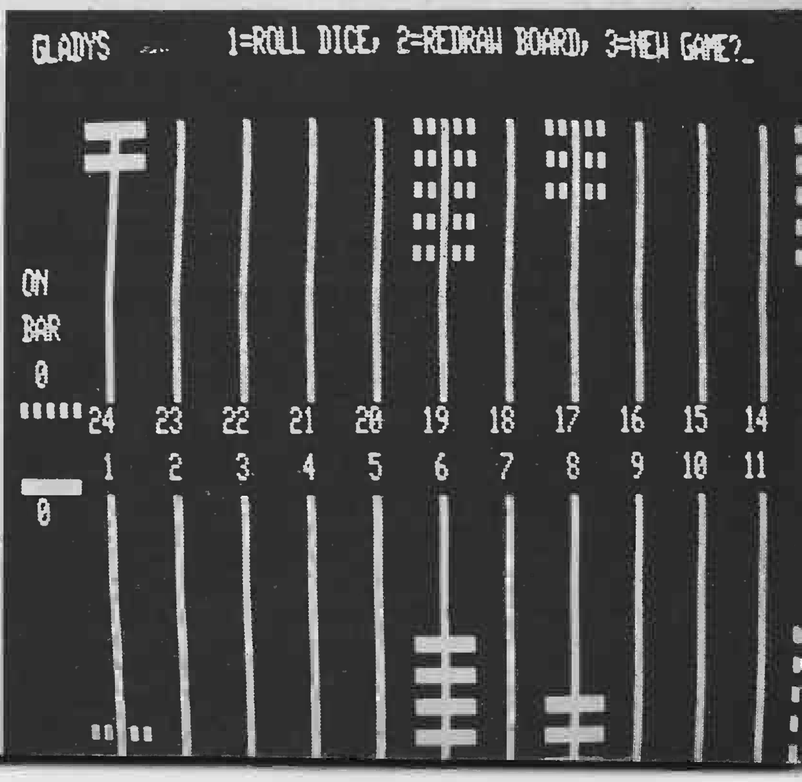
In the market at which the TRS-80 is aimed however the potential customer will be influenced by what he sees (ie packaging) and by what he can be led to believe about it (by advertising, by friends, by using the system, and even by reading electronics magazines). That customer's attention will be focused on the keyboard and display not on the internals. It won't matter to him that a Z-80 incorporates efficient machine language instructions for data searching and moving or that it's a microprocessor that can run at a 2MHz clock rate. He will be more interested in what it can do as opposed to how it does it (he's buying capability, fun and perhaps even status, not speed).

A Look At What You Get On The Soft Side

The TRS 80 comes with "Radio Shack Level 1 BASIC" in 4K ROM. Level 1 claims to support "standard BASIC statements". But whose standard? It seems to be Tandy's since some important capabilities are missing (for example: exponentiation and array dimensioning). All calculations are performed in floating point with 5 or 6 decimal place accuracy. Twenty-six numeric variables are available (A to Z) along with one numeric array variable. Two 16-character string variables can also be used. Actually, these are more properly called "string things", since they cannot be compared, manipulated, indexed or used in any but the most mundane ways. You can input and output using them, but that's all folks.

▶

The display produced by the TRS-80's version of backgammon makes use of the (limited) graphics capability of the machine. However, as can be seen, a quite acceptable display can be produced by the system.



Cassettes can be used to handle programs (CSAVE and CLOAD commands) or data (PRINT# and INPUT# statements). Since whatever you have in memory will be wiped out if you cut off the power (intentionally or otherwise), having a cassette recorder to store your information permanently is invaluable. And it makes entering of other people's programs (such as the Backgammon and Blackjack games supplied by Tandy) especially convenient.

Speaking of which, the Backgammon game makes extensive use of the TRS 80's rather limited graphics capability: there are virtually no special graphics characters — you've got to construct whatever image you have in mind by turning on some points on the display (48 points vertically by 128 points horizontal). This can be tedious. Mind you, in the low cost home computer system field this is not unusual. To compensate you can write sub-routines which draw vertical and horizontal lines, draw patterns, fill them in etc.

You And Your Program

Immediately after powering up your display and keyboard, the following will appear:

READY

At this point you can:

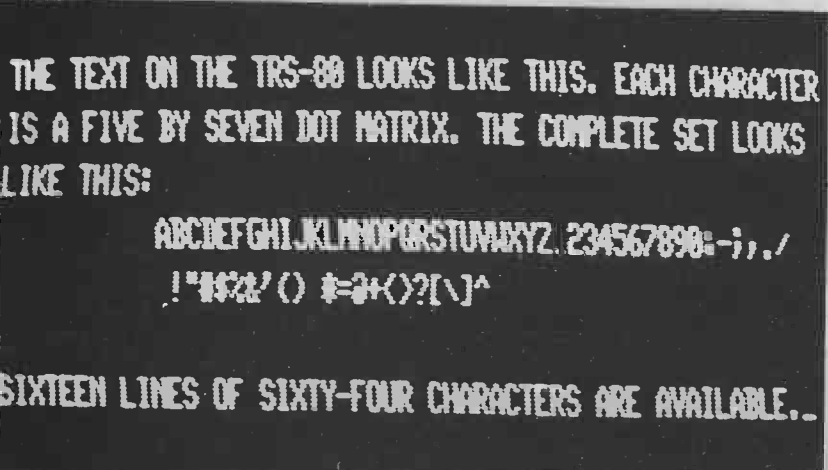
1) do simple calculator type computations (immediate execution)
2) bring in a program from tape.
3) type NEW and enter a program

Program statements are preceded by line numbers to distinguish them from immediate execution statements and keep them in order. A LIST command is available to display the program. Unfortunately the cursor control keys cannot be used to edit this display, so if you want to change a line in a program, you must retype the entire line.

Output which would otherwise stream by while your program is executing can be frozen by depressing any key. Unfortunately, if you interrupt the program itself, you cannot modify the variables it is using and then return to the point of interruption. So your only alternative is to rerun the program and in many cases, that's a nuisance.

As for error messages, they are confined to: WHAT? HOW? or SORRY (along with an indication of where the problem is). These terse messages are not unexpected when you consider that the interpreter was written to fit into 4K of ROM. In a tradeoff of readability against the amount of program code you can fit into the standard 4K of RAM, Level 1 has a "shorthand dialect". For example: G.=GO TO, N.=NEXT, and P.=PRINT. However, REA. seems to be a shortform of dubious value for READ (probably done for consistemcy).

The TRS-80 character set is shown below, note that some minor variations between this set and those on current production machines may be noted. In addition to these characters, the screen is divided into 6144 cells each of which may be lit or dimmed to form graphic characters.



Make It Fit

The overriding philosophy controlling the design of this interpreter seems to have been "make it fit". It's hard to believe that a 4K interpreter is anything but "stripped down" after you've used this one and it is somewhat unrealistic (no pun intended) for Radio Shack to claim, as they have in their sales literature, that "applications of the TRS 80 are limited only by the imagination and ability to write programs". Try something quite unimaginative like sorting a list of names. Good luck! You'll need it.

Level II

From the sketchy details available on Level II BASIC, an interpreter written by Microsoft, the statements and functions to be available would appear to make this version of BASIC at least as powerful as PET's including many editing features. In fact we would go so far as to say that Level II is the most significant upgrade for the TRS-80. We wonder how logical it is to sell a home computer with such a limited BASIC and then offer the upgrade as an option. Will this turn people off computing, or will most of them jump for BASIC II anyway?

Level II BASIC will cost you £79 when it apears in July. We also understand that a Level II machine is to cost £79 more than a Level I model. This combined with the £229 pounds Tandy are asking for converting a 4K system to 16K seems to indicate that in these areas at any rate expanding your system with Tandy's help will prove expensive. As far as the RAM goes, however, you could buy the devices yourself, conversion involves taking the 4Kx1 devices from their sockets and replacing them with 16Kx1 chips. Change a few jumpers and your machine is now a 16K model. Cost — about £100.

Other hardware items are planned but there are no firm dates or UK prices fixed yet though we do have some US prices from which we can make an educated + or — 10% guess.

1. SCREEN PRINTER reproduces anything displayed on the screen including graphics at 2200 chars./sec (price about £480)
2. LINE PRINTER 110 chars./sec,5x7 dot matrix commercial standard impact printer (price about £1000)
3. MINI DISK of which the TRS-80 can operate 4. 80K bytes per disc. 125K bytes per sec transfer rate. ½ sec average access time (price each about £400)

We were not as impressed with the TRS-80 as some of the other machines in this price bracket we have looked at. Lack of hardware access, and software which is primitive, combined to make it a less attractive product to anybody with even a little experience in home (or for that matter any) computers.

The Level II BASIC would make the machine a far more attractive proposition than at present and even with the additional £79, still an attractive choice on the grounds of cost.

The end result is that if you're in the market for a machine like this you should look very carefully at what you need and what you can get for the money.

During the review it was discovered that it was possible to get 32 characters to the line from the display (fat letters) by recording a string onto tape as a data file and then CLOADing this as a program. Sometimes using this method you lose some of the facilities of the TRS-80 and have to remove the power to restore them. (This is a standard facility of level 2 BASIC by the way).

Anyone for a users club?

ETI

MUSIC SYNTHESIZER
PART 2 — CONSTRUCTION

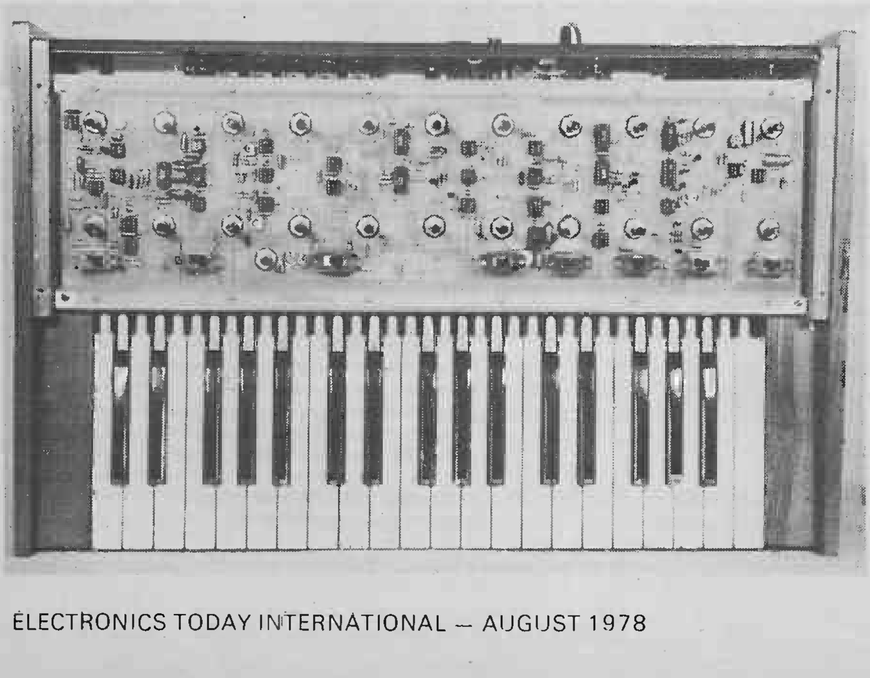
In this concluding part of the article we cover the assembly procedure for this compact design.

DESPITE the high complexity of this project, its construction should pose no *electronic* problems to the competent hobbyist. As with any synthesiser however, fitting the keyboard and its associated mechanics will prove the most onerous task.

Getting Board

Since you have to start somewhere, the PCBs are the obvious place. There are five boards all together; power supply, keyboard contact mounting (X3) and main synthesiser. The keyboard we will deal with later.

Above: the finished article all set to be played. This prototype was assembled using the Powertran Electronics kit, which includes the woodwork. Below: an internal view showing the alignment of PCB and keyboard. Note very carefully the relation of the two as there is not much space to spare. As you can see from this photo, we used IC sockets on all devices as it makes things so much easier if anything untoward should occur.



Assembly of the PSU board is very straightforward, but take care fitting the heatsinks to Q1 and Q3. Wire up the board to the transformer, and check that you can obtain the correct voltages at the output. Adjust RV1 until +12V is obtained on the red output wire.

Set to as close +12V as you can possibly measure. Check that an accurate —12V is present on the blue output wire. The power supply is now complete.

Main Line

For the main assembly we're going to assume that you're using the Powertran board. Fitting the components to this is straightforward with the exception of the switches and pots.

In order to line up the switches with the front panel and pots, it is necessary to space these from the board — the kit contains suitable spacers for this purpose. Non-kit types have to work out the height of their front panels from the board and act accordingly. The switch toggles must come level with the pot spindles, when cut to take the control knobs.

In either event glue the spacer to the board — use some powerful adhesive such as Super-Glue etc.

Cut the pot spindles before you fix them to the PCB: it's just too big to handle and too expensive to crack. The terminals should be top soldered onto the board, as should the chiripins used to mate up with the connector. Take care the solder does not run down the pins, else the plug may not fit at all.

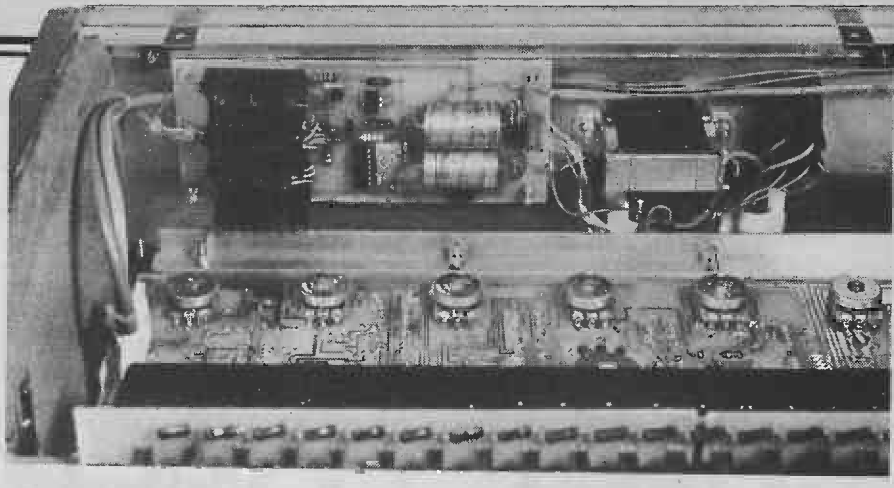
Use insulated wire to link the dual gang pot RV30 and the waveform switch to the board. The PCB cannot be mounted into place until the alignment procedures have been carried out, so there is no excuse for not checking the assembly very carefully indeed, especially the IC orientation and soldering quality. This is a BIG board which means there is more space to be careless:—check it!

Powerfull Mount

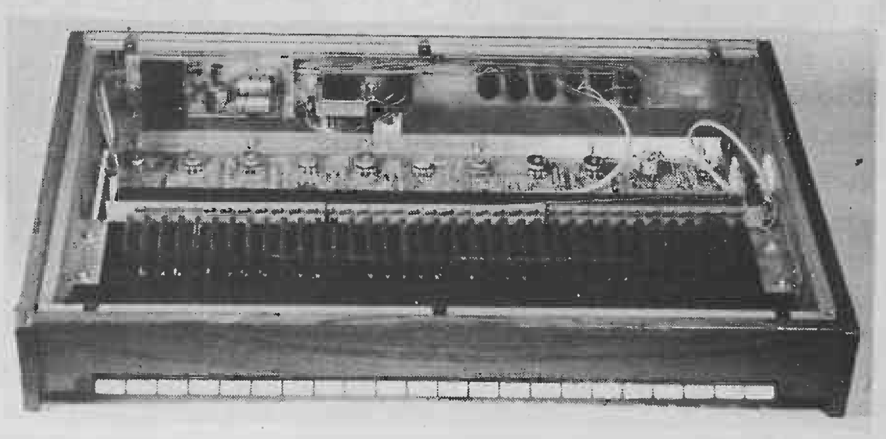
Following the rear panel wiring diagram, fit the hardware onto the case, taking care to mount the transformer as low down—away from the main PCB—as possible. This will lessen the chance of hum being induced into the circuit.

Insulate the mains wiring wherever possible, and take careful note of the earth wiring arrangements—lest the demon hum return to plague thee! Anything with mains voltage on should have a rubber sleeve over it.

The photograph shows the arrangement of PSU and transformer on the back panel.



Above: close up of the PSU board mounting within the case. Positioning the transformer is important to reduce the risk of hum. Mount this as low down, away from the board, as possible. In the foreground the resistor chain for the keyboard can be seen. Below: overall view of the machine, to give an idea of what goes where in the box. Note the three Chiri connectors which fit onto the PCB on the end of these wires snaking across the photo. The black area to the front is the line of keyboard contact blocks.

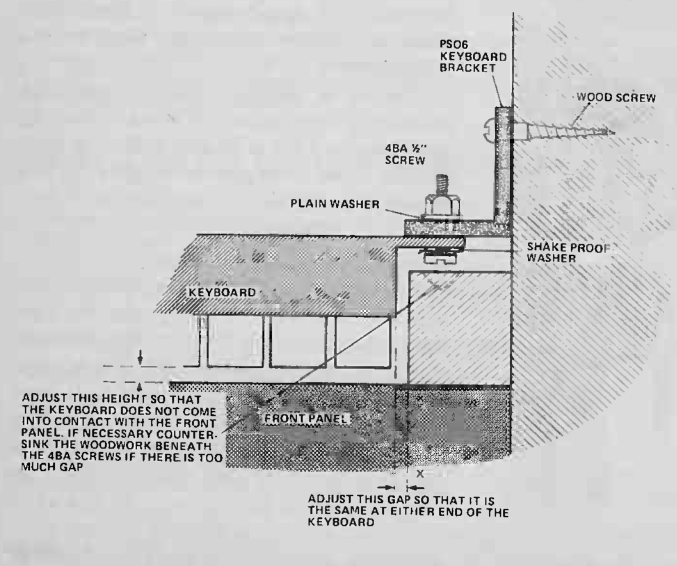


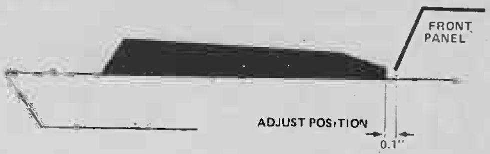
Keyed Up?

Now for the tricky bit. The keyboard. This has to be mounted in the casing first. For this the front panel should be in position. Fix the brackets to the ends of the keyboard assembly, and lower it into place. Follow the diagram below to adjust the spacing at either end of the keyboard. If the gap is more than 0.1", the woodwork underneath the fixing screws will need countersinking.

Set the gap between the black notes and the front panel as shown.

Once the alignment is correct, screw the brackets into the woodwork.





On the left is the diagram you'll need to line up the keyboard assembly with the casing and front panel. Follow this as carefully as you can, as if the keys are not in the right places, the contact blocks will not line up with the plungers, and the keys themselves will probably foul the front panel. Above is shown the alignment of keys and panel.

news digest. . . . . . .

light to sound units

Phillips have demonstrated a new digital sound system, incorporating a solid-state laser mounted in a semi-conventional pickup arm. The system uses a 110mm disc with a playing time of one hour per side, the audio is digitally encoded to provide very high fi. Phillips have christened the system 'Compact Disk', and hope to have it ready for the consumer market in the early 1980s. RCA have also been experimenting with a similar, but incompatible, system as an offshoot of their video disc developments.

A bit nearer to the present is the Sony digital recording system. This is an add on to their U-matic or Betamax video recorders, which encodes the audio as a signal on the videotape. Quality is said to be orders of magnitude better than conventional recording systems. Price is expected to be around the £700 range available from late summer.

strike detector

An ultra-simple method of determining the force in lightning strikes has been developed at NASA. All it consists of is a 4 foot length of magnetic tape inside a plastic tube! An 9kHz tone is prerecorded on the tape, and the tube mounted perpendicular to an exposed conductor — such as a guy wire. When lightning strikes a magnetic field is produced, which erases part of the signal. The amount of erasure is proportional to the field strength and hence the current in the lightning strike. To find out how strong the strike was, or indeed if there has been any strike, you simply paly the tape. Current as high as 17 000 Amps has been measured on a single guy wire with the device. Why is it that all the best ideas are so simple?

mars bars and chips

Mars Money Systems (relation) are starting to take delivery of a new device from AMI Microsystems. The fiendishly clever hunk of silicon is a dedicated one bit (bite?) MPU with onboard PROM, it is to be used in vending machines for coin acceptance and change giving. It not only counts how much you feed into the machine, it also works out the correct change and gives you it (if there is not enough money in the change chute it returns all your money).

Coin sensing is done with 3 coil like inductors, embedded in the wall of the coin path, frequency shifts are produced as the coins roll past—and the IC compares them with reference data stored in the PROM. The one bit brain can check far more precisely than any mechanical system, and the PROM can be pre-peed for any currency in use in a particular country. AMI Microsystems, 3800 Homestead Road, Santa Clara, CA 95051, US of A.

alas, poor capek

It seems that we made an omission in the recent Robot issue, as the following from Mr D. B. Pitt points out . . . In analysing the word 'Robot' we forgot to mention Capek, equivalent to analysing the word 'chortle' without Lewis Carroll.

Robot represents the first two syllables of the Czech word for worker, and, allowing for slight vowel shifts, the rule applies to all the other Slavonic languages.

The word officially entered the English language in April 1923 with the first presentation of the play R.U.R. (Rossom's Universal Robots) by Karel Capek, the famous Czech playwright, at the St. Martin's Theatre, London. The translator, Mr P. Selver, wisely left the word robot unchanged from the original Czech.

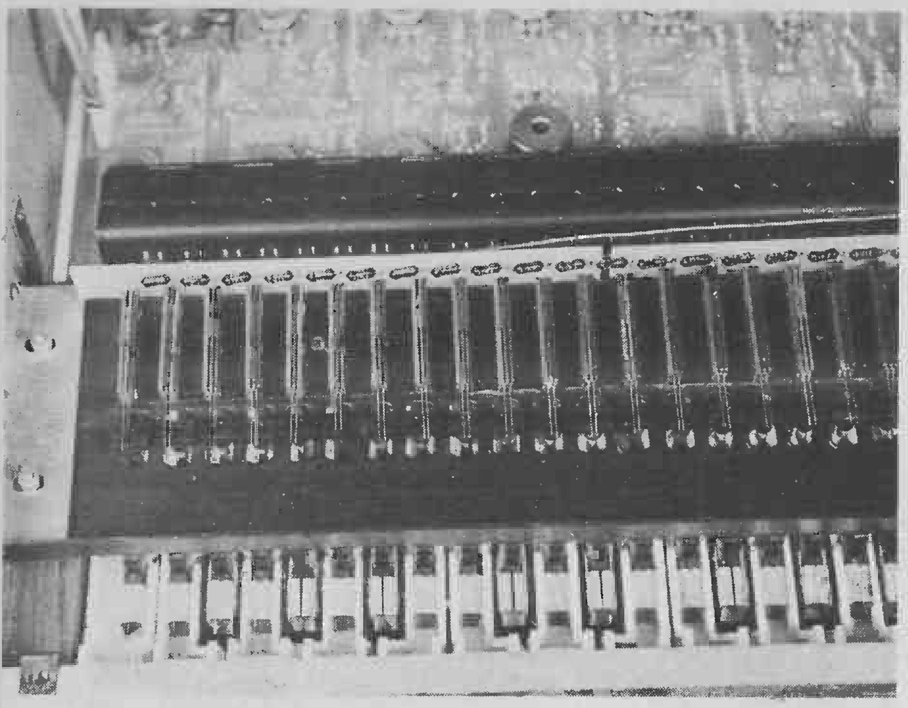
In practice, the word was already current in certain circles before that date, as the fame of Capek's political satire had preceded it, thanks to the popular press, which was quick to seize on the sensational aspects of the play's theme, a world taken over by a revolt of man-made factory workers.

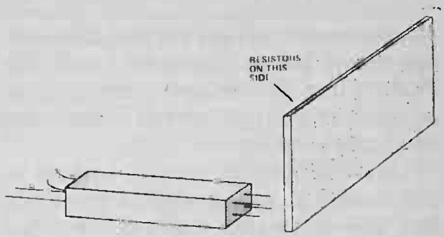
boris challenges challenger

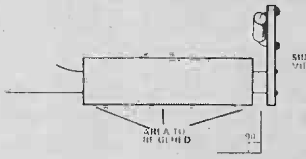
Up until recently the computer chess field was dominated by the manufacturers of the Chess Challenger — Fidelity Electronics of Chicago. After the tremendous success of the original model came the improved 3 level version, now they have introduced a 10 level version with lots of new features. The response time varies from 5 seconds on the beginners level, to a 24 hour response (suggested only for postal games!), because you may not notice when the computer makes a move it makes a couple of beeps when it has.

Now another company has entered the chess arena, with a machine called Boris, and they claim that Boris is the King of the computer chess world. Manufactured by a company called Chafitz in Rockville, Boris can even play with itself (and not go blind!). Other nice features include an 8 digit alpha-numeric display and completely variable response time, the alpha capability is used to display pieces as pictures and also for messages (illegal move, good move, etc) — the response time can be set from 1 second up to 99 hours, so you can program it/him to very specific skill levels.

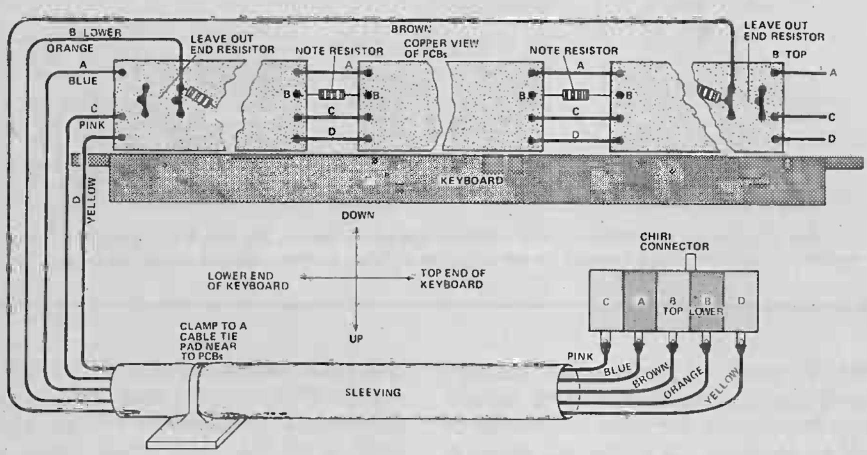
Price of the Challenger 10 is expected to be in the region of £200; Boris will probably be about the same. Neither machine is expected to be available in the U.K. until 1979.

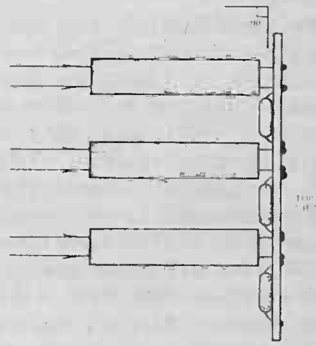






Contact blocks and resistors and where to put 'em. Follow the drawing above to fit the block to the PCB, and then line up the angle as shown below. On the lower left is the keyboard wiring diagram which shows the connecting together of the boards and the placing of the two spare resistors. The photograph shows what it all looks alike when you've finished.





Onto the contacts. Fit and solder the 27R4 resistors to the three PCBs as shown on the diagram above. One will be full with 12 resistors and the other two have eleven each, one missing at the right end on one PCB, and one missing at the left end of the other. (There are two resistors left over at this stage.)

Close Contacts Of The Key Kind

Solder in the contact assemblies, but make very sure that right angles exist between the block and the PCB. This is important. Graph paper may help in lining up.

Leave out a contact block where the resistors are omitted the diagram may help.

All three PCBs are wired together as shown in the keyboard wiring diagram taking care to place the 'gaps' correctly. Get the spacing correct by lining up the contact blocks with the keyboard plungers. Note the positioning of those two spare resistors.

Sand down one side of the contact strip, and lay some contact adhesive all over it, and the same with the soldered-in contact blocks. Make very sure that before you affix the strip onto the blocks that you have lined it up properly, as once the glue gets hold you've had it.

The contact blocks are very delicate, so handle them carefully, and don't touch the wires with your fingers. If you do you'll leave a deposit behind which may well cause malfunction. When satisfied that the assembly is O.K. position it over the plungers, and screw it down to the metalwork. Check that every plunger operates a contact, and that both contacts in each block operate when the key is depressed.

Keyboard completed — wasn't that bad after all (was it?)

The contact assembly for the keyboard should be the last thing you fit into place before wiring up all the boards as per the interconnection and wiring diagrams. With this in place fit the base plate.

Alignment is best carried out with the front panel removed, and the PCBs fixed in. Before commencing alignment though, check everything very carefully.

When attaching the front panel to the machine, check that it does not foul the keyboard, and that the gap between it and the woodwork is the same at either end.

Alignment

This will be dealt with in sections. To aid setting up and alignment procedures, test point waveforms are given for important nodes throughout the design.

VCO Alignment

There are several pitch controls for the VCO. All control voltages are injected via large resistors and are thus suitaby attenuated. The pitch bend pot uses a couple of diodes to produce a dead zone in the middle of its motion. This control voltage is then fed in via a 180k resistor and mixed with all the other control voltages.

Pitch Spread

The keyboard sample and hold produces 830mV/octave. This has to be attenuated to 18mV to produce octaves. To do this, a resistor of 46k is required. R31 and RV3 constitutes a variable resistor (39k2 to 49k2) that should enable the keyboard pitch spread to be aligned.

Turn RV6, 7, 8, 9 fully anticlockwise. Put the transpose switch in its central position. Set RV5, 4 to their central position. Play the top note on the keyboard and measure its frequency, using a scope or a frequency meter, or maybe if you are a musician just listen to it! Now play a note one octave below it and adjust RV3 until the interval is one octave below it and adjust RV3 until the internal is one octave. Recheck the top note and then try the tracking for two or three octaves down, making any necessary adjustments to RV3. Note that the top note on the keyboard is not affected by RV3 adjustments. Now put the transpose switch to + 2 octaves and adjust RV12 for a 2 octave increase. Then switch to —2 octaves and adjust RV13 for a 2 octave decrease.

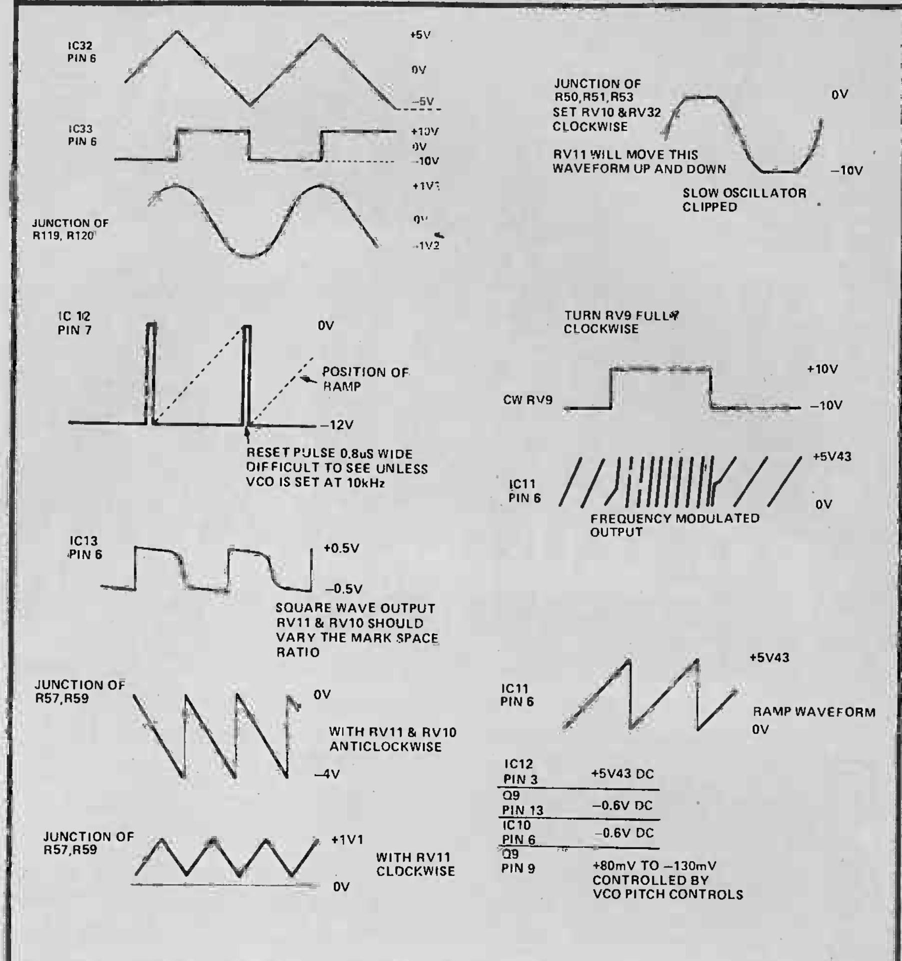
VCO Shape Modulation

IC14, 13, 15 is the VCO shape modulation circuitry. IC14 is a half wave rectifier, and is used to sum together the manual shape voltage (RV14), and the sine wave voltage from the slow oscillator. The output from this circuit is limited to a range of 0 V to about —10 V. As the manual shape pot is rotated clockwise the waveform at the junction of R57, R59 will change from a ramp into a triangle, this being due to the full wave rectification. With RV14 fully clockwise and RV15 anticlockwise adjust RV15 so that the waveform is a symmetrical triangle.

The last shape generator is a fast comparator. The ramp waveform plus the modulation voltage are fed into the comparator input. The modulation voltage shifts the DC level of the ramp and in doing so the comparator levels change resulting in a varying markspace ratio output, IC15 pin 6. The diodes limit the voltage excursion to about ± 0.5 V.

Set the VCO to + 2 octaves, tune the keyboard high and play the highest note. Now set RV10 anticlockwise, RV14 clockwise and monitor the squarewave output, IC13 pin 6. Adjust RV11 until a very thin pulse is generated. Rotate RV14 anticlockwise and the markspace ratio will revert to 1 to 1. Now set RV14 to 5 on the dial and slowly rotate RV15. The markspace ratio will be modulated at the speed of the slow oscillator.

There may be some problems with control breakthrough in the VCA but this can be minimised with a preset adjustment, RV22. Turn the VCO and noise levels to 0. Make sure that the filter is not oscillating. Put the ADSR on a fast repeat with fast attack and decay and no sustain level. Set the BY-PASS switch to ADSR and look at the synthesiser output. There will probably be some control break through caused by the ADSR, which will sound like a series of thumps. By adjusting RV22 a minimum in the thump level will be found. Just like the 3080s in the VCF, best performance can be obtained by carefully selecting IC22.



Above: test point waveforms and voltage measurements for the VCO circuit of the synthesiser. Readings should be taken with as high an impedance meter as possible.

PARTS LIST

RESISTORS (all ¼W 5% unless stated).

R1, 18, 55, 58, 120, 127	4k7	
R2, 8, 43	10k	(0.5%)
R3, 49, 133	12k	
R4, 7	3R3	
R5, 37, 38	6k8	(1%)
R6, 83, 96	1k0	
R9	4k75	(1%)
R10, 80, 81	680R	
R11, 78, 61	27k	
R12, 16, 22, 23, 70	39k	
R13, 84	100R	
R14, 27, 48, 60, 69, 136	220k	
R15	1k5	
R17, 28, 29	10M	
R19, 51, 56, 64, 75, 77, 79, 89, 90, 93-95, 97, 101, 103-108, 122, 128, 137	100k	
R20	470k	
R21, 57, 102, 114, 119, 132	22k	
R24, 30, 47, 86, 118, 121, 126, 131, 134	47k	
R25, 36, 59, 85, 87, 88, 91, 109, 113 115-117	10k	
R26, 35, 39, 82, 92, 98, 100, 135	1M0	
R31, 65	39k2	(1%)
R32	680k	
R33, 66	130R	
R34	870R	(RTC)
R39	1M	(0.5%)
R40, 62, 138	56k	(2%)
R41	470R	
R42, 74	15k	
R44	12k1	(1%)
R45	2k7	
R46	309k	(0.5%)
R50, 130	150k	
R52	120k	
R53, 54	7k5	
R63, 71	390R	
R67	820R	(RTC)
R68	15k	
R72, 73, 110	2k2	
R99	3k9	
R111	390k	
R112, 123	82k	
R124	330R	
R125	8k2	
R129	68k	
Keyboard chain (37 off)	27R4	(0.5%)

POTENTIOMETERS

RV1, 3	10k	cermet
RV2, 23-27	1M	log
RV4, 5, 15, 21	100k	lin
RV6-10, 14, 17, 18, 28, 29	10k	lin
RV11 22, 28	100k	lin preset
RV12, 13	50k	cermet
RV16, 32	100k	log
RV19, 33	10k	log
RV20	10k	lin preset
RV30, 31	10k	lin (ganged)

CAPACITORS

C1, 2, 10, 18, 26, 27, 29, 30, 32, 34 43, 45	100n	polyester
C3, 4	1000u	25V electrolytic
C5, 7, 8, 37	2u2	25V tantalum
C6	330p	polystrene
C9	1u0	25V electrolytic
C11, 14, 15, 17	22n	polyester
C12, 19-21, 35, 36, 31, 48	10n	polyester
C13	330n	polystyrene
C16, 28, 33, 46	1n0	polystyrene
C22, 44	3n3	polystyrene
C23	22p	ceramic
C24	5p0	ceramic
C25, 41, 42, 47	1u0	25V tantalum
C39, 40	100u	25V electrolytic

SEMICONDUCTORS

IC1	uA 723C	
IC2, 3-5, 7, 8, 10, 14, 15, 18, 21, 29, 31-33	741	
IC6, 9, 11, 17, 20, 30	CA 3140	
IC12	LM311	
IC13	748	
IC16, 19, 22	CA3080	
IC25, 26	CD 4001	
IC27, 28	CD 4016	
IC34	CD 4030	
IC35	CD 4006	
Q1	TIP 29A	
Q2	BC 213	
Q3	TIP 30A	
Q4, 5	BF 244C	
Q6, 13, 15, 20-22	BC 182	
Q7, 9, 10, 12	CA 3046	(2 off)
Q8	2N 4859	
Q11, 14, 16-19	BC 212	
D1-37	1N 4148	
ZD1	4V7	400mW
ZD2, 4	5V6	400mW
ZD3	3V3	400mW
BR1	RS 261 772	(1A at 400V)

SWITCHES

SW1	DPDT 250V AC
SW2, 3, 6, 8, 9	single pole slide changeover
SW4	1 pole (2 way) rotary
SW5,7,10	double pole slide changeover

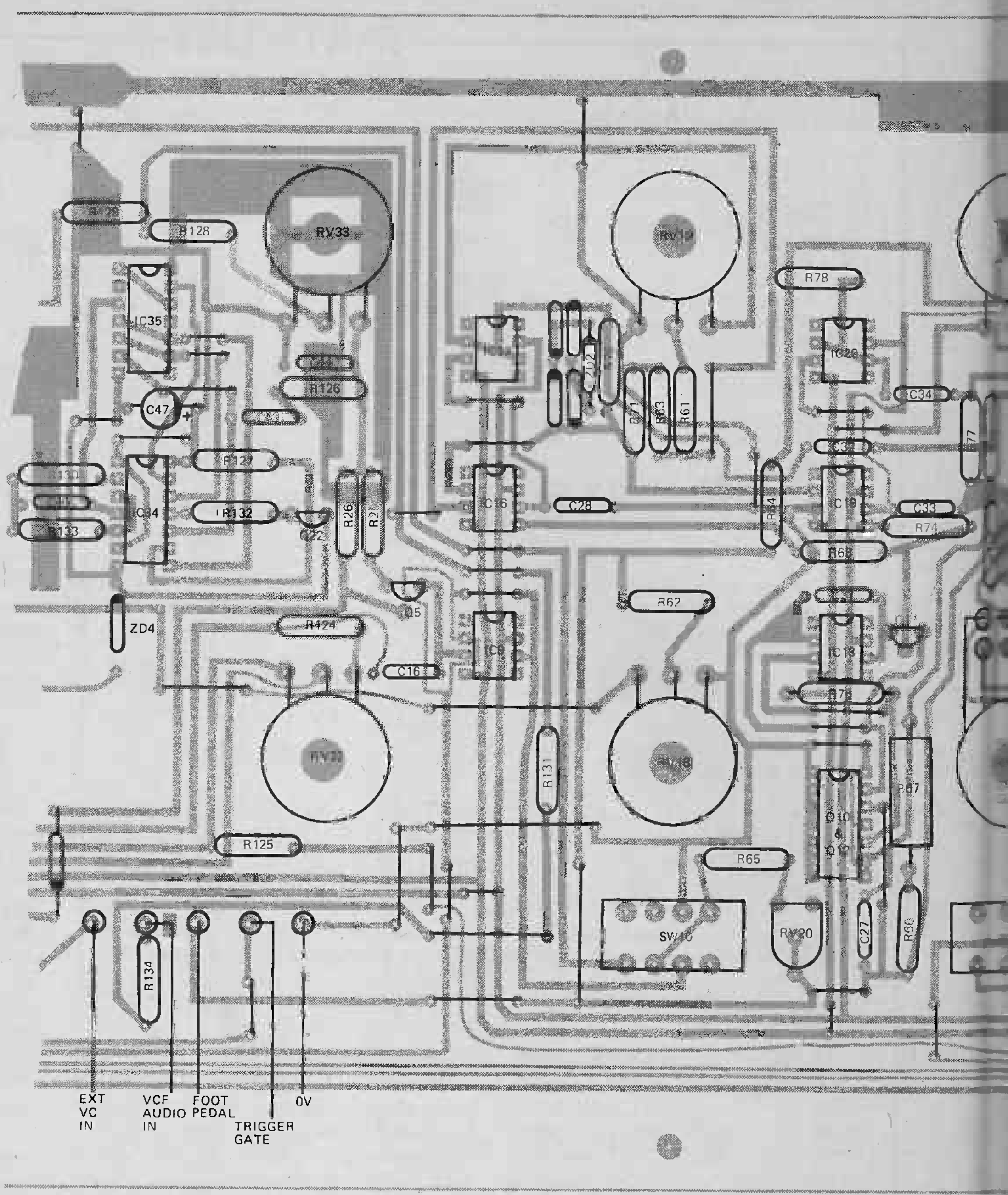
MISCELLANEOUS

Five ¼" mono jack sockets, one ¼" stereo jack socket (all panel mounting), 37 note keyboard with contact blocks, woodwork and case to suit, PCBs, three core mains lead, knobs to suit, 0A5 fuse with holder, 240V to 15-0-15V at 200mA transformer, three five-pin Chiri connectors, eight spacing blocks for switches, one foot pedal unit with cable (optional), grommets.

VCF Alignment

The VCF pitch spread should be set up as follows. Turn off RV16 and RV33. Switch the filter 'CONTROL' to KB, the 'RESONANCE' to 'OSC' and the 'AD SWEEP' to 0. Play the top note on the keyboard and adjust the 'FREQUENCY' pot to give a 1kHz sinewave output. Now play a note, one octave below the top note and adjust the present RV20 for a one octave decrease. Check the lower octaves making any necessary adjustments to RV20.

Turn the Resonance pot anticlockwise until the filter stops oscillating. Turn up the VCO level and insert a ramp waveform at a frequency of about 100Hz. Now switch the VCF 'Control' to RANDOM. The tone of the filtered signal should now vary randomly.



Main overlay for the Transcendent 2000 synthesiser design. As you may notice only a little over half the board is shown here. The other half you'll find over the page.

The reason for this is simply that with a PCB of this size our pages are too small to hold the diagram and still have it readable.

Foil patterns are not shown here, and the PCB is available from Powertran — see BUYLINES for details.

The two sets of contacts shown are mated with the Chiri connectors from the back panel wiring. Make sure the pins are straight, and that no solder has run down from the board, or the plug will not fit properly.

On the lower right is shown the PSU board overlay. Note that Q3 and Q1 require to be heatsinked for correct operation.

Both the boards should be checked very carefully during assembly, and make sure you use the switch spacers on the main PCB. Cut the pot spindles *before* mounting them.

Problems?

Any problems in the VCF circuitry are likely to emanate from IC16 or IC19. If there are any large input offset voltages or current mirror imbalances or output leakage currents, then these will degrade the VCF performance. What will probably occur is that there will be a large DC offset voltage on the outputs that varies as the resonant frequency varies. This may cause severe signal dipping at certain frequencies and will only be cured by replacing the errant 3080.

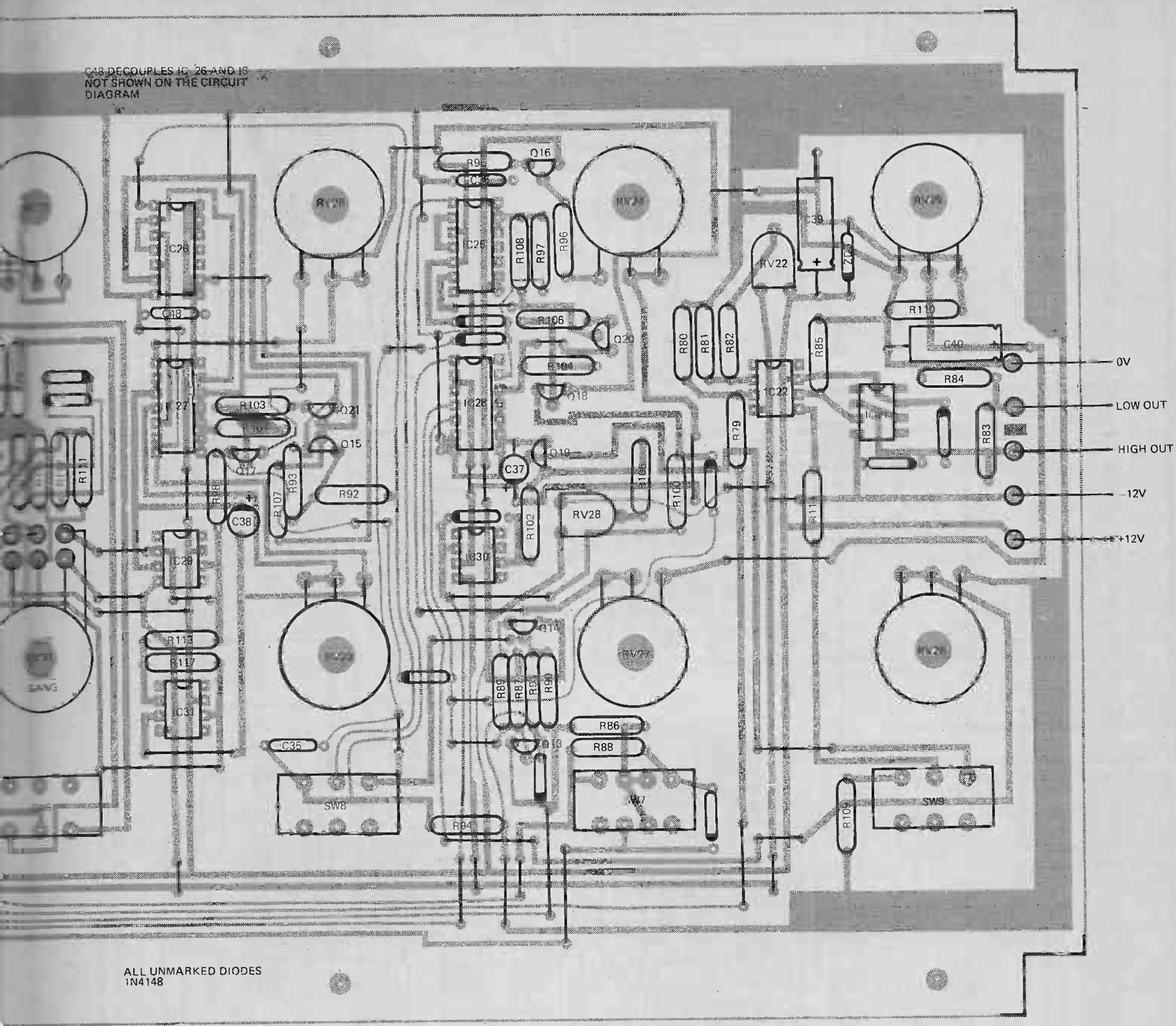
The filter has two outputs, a bandpass and a lowpass. The signal volume will generally be less from the bandpass output because this output attenuates all but the harmonics that lie close to its own resonant frequency, whereas the lowpass output has a flat response area which extends from somewhere just below resonance down towards low frequencies, and harmonics in this region are not affected.

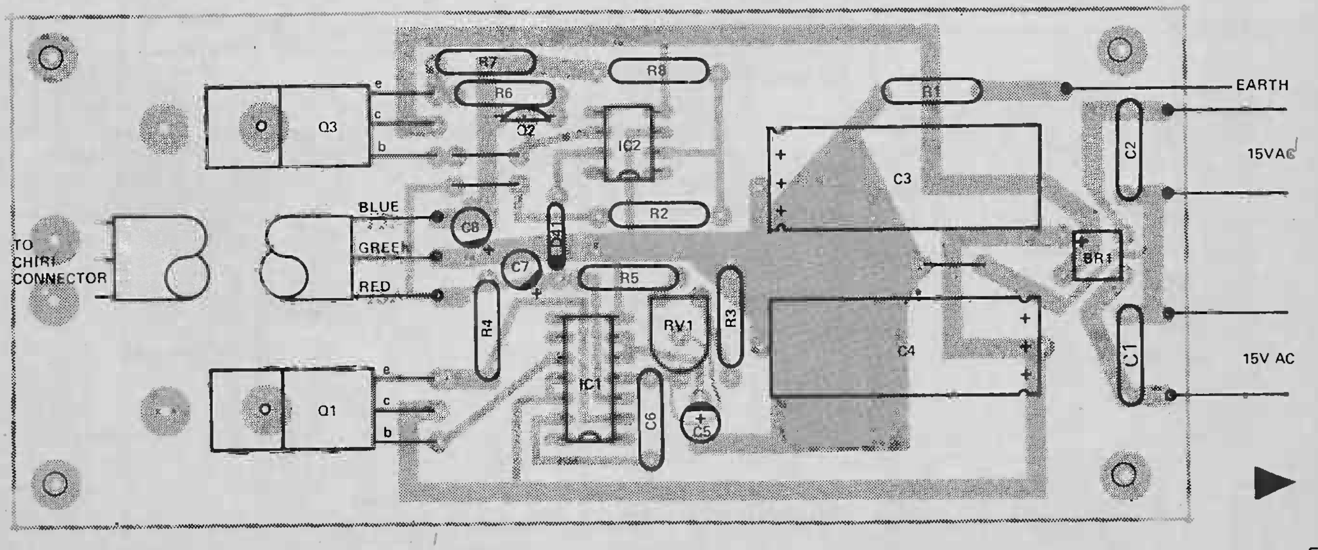
Sweeping Statement

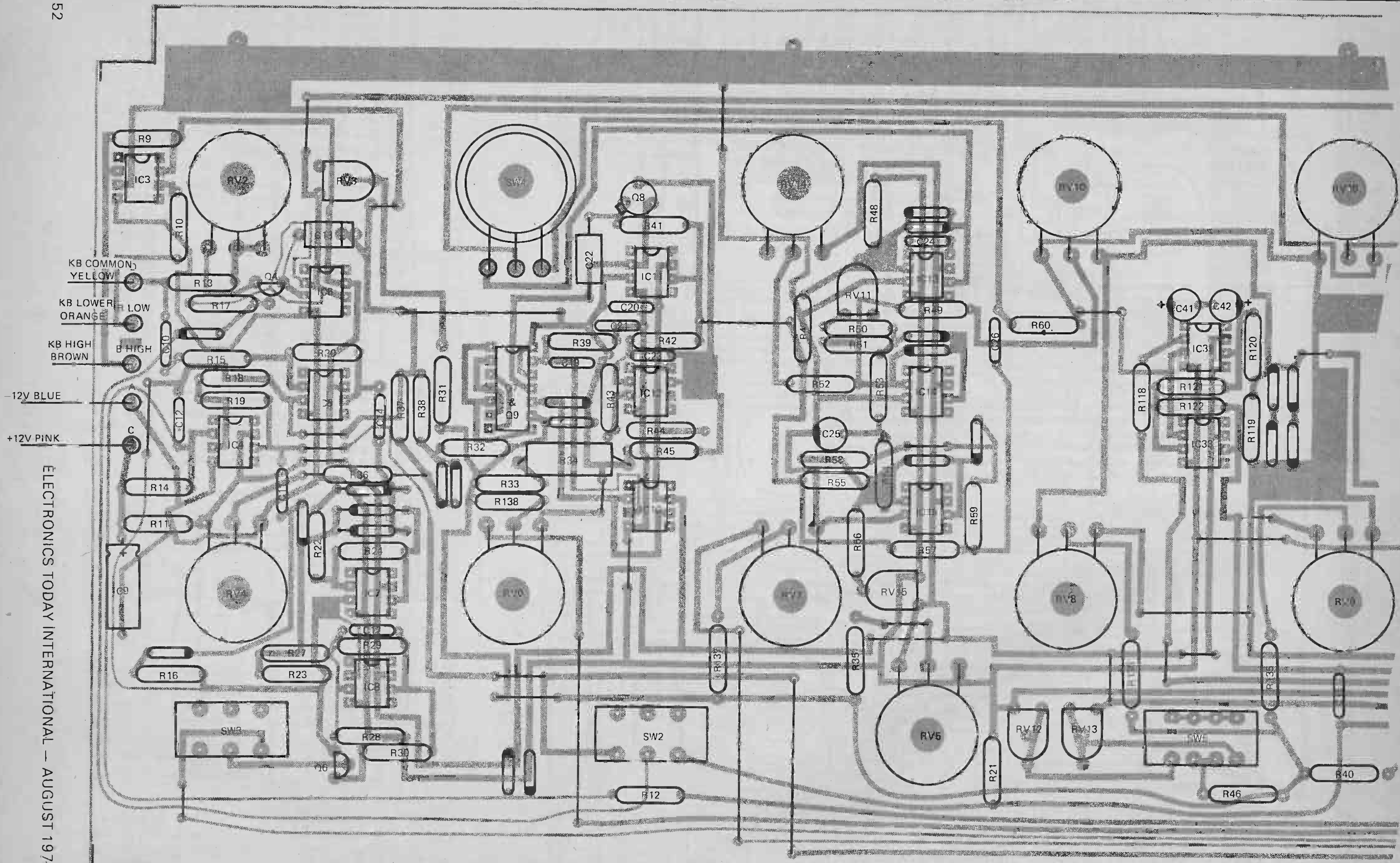
The 'synthesiser sound' is generated by sweeping the VCF resonant frequency with an AD waveform. This sweep voltage is variable in both depth and direction. The sweep pot is a dual pot; on one of its tracks there is an AD waveform at one end and the inverse at the other. Thus the wiper will pan from a sweep going upwards to one going downwards. Two diodes provide a dead zone in the middle so that a pot position of No Sweep can be easily found. The second track on the AD sweep pot is used to provide a compensating DC level shift so that the frequency pot doesn't need to be retuned when the AD sweep depth is altered.

ADSR Alignment

Set up the VCO and VCF so that a ramp waveform at 500 Hz is presented to the VCA. Turn the RELEASE pot fully clockwise and put the BYPASS switch in the ADSR position. Listen to the VCA output


C48 DECOUPLES IC 26 AND 19
NOT SHOWN ON THE CIRCUIT
DIAGRAM
0V
LOW OUT
HIGH OUT
-12V
+12V
ALL UNMARKED DIODES
1N4148


TO
CHIRP
CONNECTOR
BLUE
GREEN
RED
EARTH
15VAC
15V AC



Above: the other half of the synthesiser PCB Connections is made to the pins in the upper left-hand corner by the keyboard wiring Chiri connector.

and adjust RV28 so that the signal only just disappears. Now you can play the keyboard and experiment with different sounding envelopes.

This completes the alignment procedures for the design, and the front panel can now be fitted over the main PCB and the control knobs added.

Take care with the panel and keyboard positioning. See the diagrams where applicable.

Program Sheets

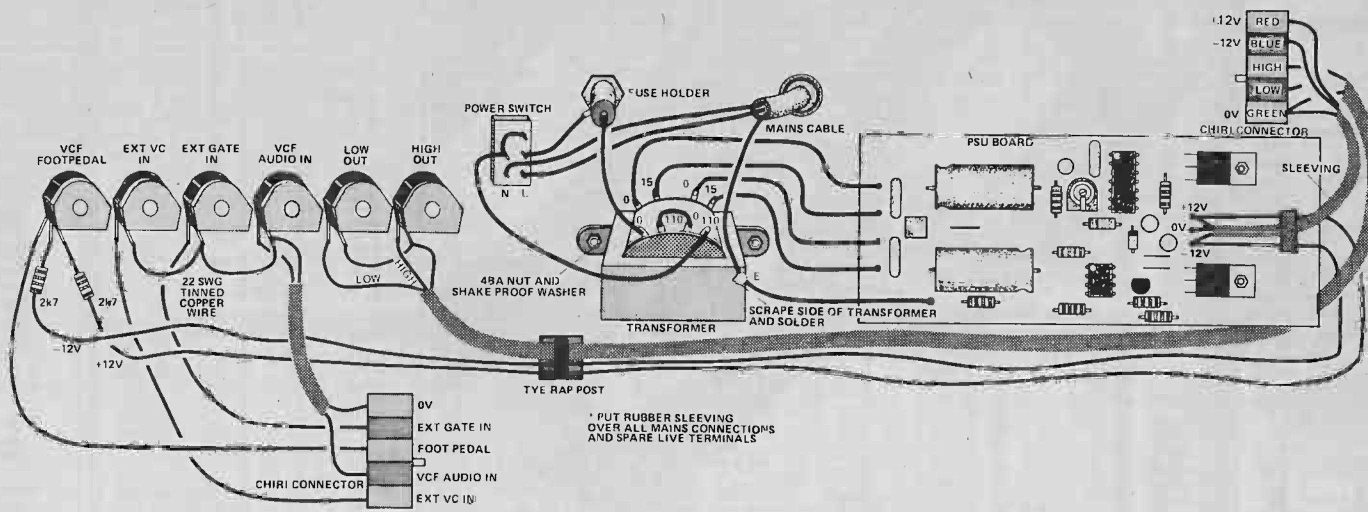
Once your machine is up and running, you will find that if you use it frequently, some method of recording various settings would be useful. This gives the ability to return to a particular sound very quickly and can be particularly useful in stage work.

As an aid to usage ETI is making available Program Sheets for the Transcendent 2000. These allow *all* control settings to be recorded for any configuration, and each sheet will record three completely independent sound settings. These cost 50p for six, including postage, from our 25-27 Oxford Street address. Mark the envelope "2000 Program Sheets".

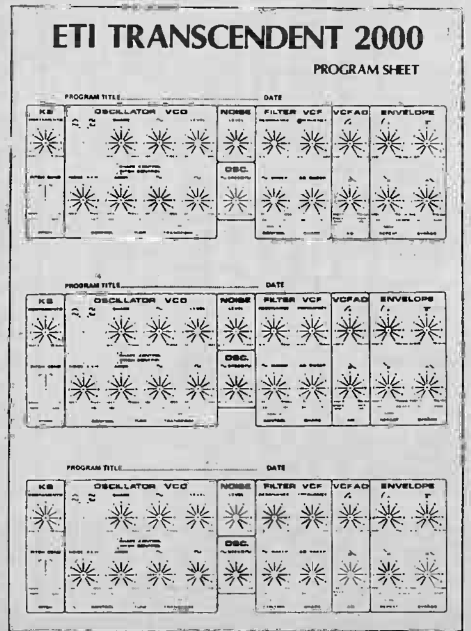
Clearing Points

Play testing since last month's article has shown that the synthesiser works better if: (numbers referred to circuit diagrams and overlay) C17 is changed in value to 4n7, as this increases the NPD sensitivity and C9 is removed entirely from the circuit, this preventing 'clicking' which sometimes arose upon operation of the keyboard.

Two minor gremlins to be laid to rest. Last month we gave (on the circuit) the circuit reference for the Transpose switch as SW3. It should be SW5. Also the undesignated KB/Noise switch is in fact SW10. ETI



Above: back panel wiring diagram. The connectors attach to the main PCB as shown on the overlay. The mains switch supplied with the kit contains a neon and the wiring takes account of this. If you use a different type of switch, the wiring will be different. Below: an example of the program sheets for the Transcendent 2000. These are used by simply marking on the settings for each control.



BUYLINES

A complete set of parts for this project, including all woodwork, metalwork, nuts and bolts, PCBs and components will be available from Powertran Electronics.

The machine used to illustrate this article was assembled using this kit, and constructional details will be based upon it. Kits will **only** be available from Powertran, as will the PCB. Because the design is based upon a single board construction, we cannot offer advice to people wishing to modify the synthesiser to a 'modular' form.

The price of the complete kit, including keyboard, will be £186.50 + VAT. However, if you're quick and put in your order before July 30th you can take advantage of an introductory offer at an even lower price of £172 + VAT.

Powertran Electronics, Portway Industrial Estate, Andover, Hants.

data sheet

7208 COUNTER/DECODER/DRIVER

INTERSIL

The ICM 7208 is available ex stock from Rapid Recall Ltd, 9 Betterton Street, Drury Lane, London, WC2.

Features:

- Useful for:
  a. Unit counter
  b. Frequency counter
  c. Period counter
- Low operating power dissipation < 10mW
- Low quiescent power dissipation < 5mW
- Counts and displays 7 decades
- Wide operating supply voltage range
  $2V \leqslant |V_{DD} - V_{SS}| \leqslant 6V$
- Drives directly 7 decade multiplexed common cathode LED display
- Internal store capability
- Internal inhibit to counter input
- Test speedup point
- All terminals protected against static discharge

Description

The ICM 7208 is a fully integrated seven decade counter-decoder-driver and is manufactured using the Intersil low voltage metal gate C-MOS process. As such it has applications as either a unit, frequency or period counter. For unit counter applications the only additional components are a 7 digit common cathode display, 3 resistors and a capacitor to generate the miltiplex frequency reference, and the control switches.

Specifically the ICM 7208 provides the following on chip functions: a 7 decade counter, multiplexer, 7 segment decoder, digit & segment drivers, plus additional logic for display blanking reset, input inhibit, and display on/off.

The ICM 7208 is intended to operate over a supply voltage of 2 to 6 volts as a medium speed counter or over a more restricted voltage range for high frequency applications.

As frequency counter it is recommended that the ICM 7208 be used in conjunction with the ICM 7207 Oscillator Controller which provides a stable HF oscillator, and output signal gating.

Testing Procedures

The ICM 7208 is provided with three input terminals: 7,23,27 which may be used to accelerate testing. The least two significant decade counters may be tested by applying an input to the 'COUNTER INPUT' terminal 12. 'TEST POINT' terminal 23 provides an input which bypasses the 2 least significant decade counter. Similarly terminals 7 and 27 permit rapid counter advancing at two points further along the string of decade counters.

Counter Input Definition

The internal counters of the ICM 7208 index on the negative edge of the input signal at terminal #12.

Format Of Signal

The noise immunity of the Signal Input Terminal is approximately 1/3 the supply voltage. Consequently, the input signal should be at least 50% of the supply in peak to peak amplitude and preferably equal to the supply. **NOTE: The amplitude of the input signal should not exceed the supply; otherwise, damage**

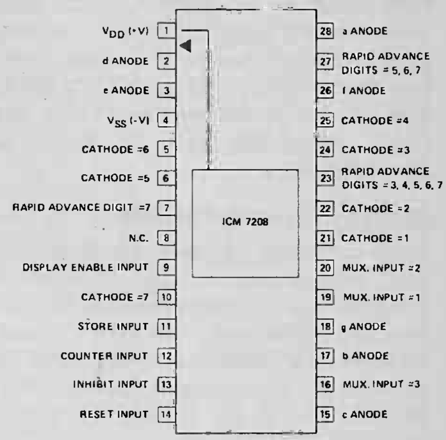


Fig. 1. Pinout.

Fig. 2. Absolute maximum ratings.

Power Dissipation (Note 1)	1 watt
Supply voltage $\|V_{DD} - V_{SS}\|$ (Note 2)	6 V
Output digit drive current (Note 3)	150 mA
Output segment drive current	30 mA
Input voltage range (any input terminal)	Not to exceed the supply voltage
Operating temperature range	-20°C to +70°C
Storage temperature range	-55°C to +125°C

*Absolute maximum rating define parameter limits that if exceeded may permanently damage the device.

Fig. 3. Typical operating characteristics.

($V_{DD} - V_{SS}$ = 5V, T_A = 25°C, TEST CIRCUIT, display off, unless otherwise specified)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Quiescent Curent	I_{DD1}	All controls plus terminal 20 connected to V_{DD}. No multiplex oscillator		30	100	µA
Quiescent Current	I_{DD2}	All control inputs plus terminal 20 connected to V_{DD} except store which is connected to V_{SS}.		70	150	µA
Operating Supply Current	I_{DDS}	All inputs connected to V_{DD}, RC multiplexer osc operating f_{in} - 25KHz		210	500	µA
Operating Supply Current		f_{in} = 2MHz			700	µA
Supply Voltage Range	V_{DD}	f_{in} 2MHz	3.5		5.5	V
Digit Driver On Resistance	R_D			4	12	ohm
Digit Driver Leakage Current	I_D				500	µA
Segment Driver On Resistance	R_S			40		ohm
Segment Driver Leakage Current	I_S				500	µA
Pullup Resistance of Reset or Store Inputs	Rp		100	400		Kohms
Counter Input Resistance	R_{IN}	Terminal 12 either at V_{DD} or V_{SS} potentials			100	Kohms
Counter Input Hysteresis Voltage	V_{HIN}			25	50	mV

NOTE 1 This value of power dissipation refers to that of the package and will not be obtained under normal operating conditions.

NOTE 2 The supply voltage must be applied before or at the same time as any input voltage. This poses no problems with a single power supply system. If a multiple power supply system is used, it is mandatory that the supply for the ICM 7208 is not switched on after the other supplies otherwise the device may be permanently damaged.

NOTE 3 The output digit drive current must be limited to 150 mA or less under steady state conditions. (Short term transients up to 250 mA will not damage the device.) Therefore, depending upon the LED display and the supply voltage to be used it may be necessary to include additional segment series resistors to limit the digit currents.

may be done to the circuit.

The optimum input signal is a 50% duty cycle square wave equal in amplitude to the supply. However, as long as the rate of change of voltage is not less than approximately 10^{-4} V/μsec at 50% of the power supply voltage, the input waveshape can be inusoidal, triangular, etc.

Display Considerations

Any common cathode multiplexable LED display may be used. However, if the peak digit currents exceeds 150 mA for any prolonged time, it is recommended that resistors be included in series with the segment outputs (terminals 2, 3, 15, 17, 18, 26, 28) to limit current to 150 mA.

The ICM 7208 is specified with 500 μA of possible digit leakage current. With certain new LED displays that are extremely efficient at low currents, it may be necessary to include resistors between the cathode outputs and the positive supply V_{DD} to bleed off this leakage current.

Display Multiplex Rate

The multiplex frequency reference is divided by eight to generate an 8 bit sequencer. Thus the display multiplex rate is one eighth of the multiplex frequency reference.

The ICM 7208 has approximately 0.5 μs overlap between output drive signals. Therefore, if the multiplex rate is very fast, digit ghosting will occur. The ghosting determines the upper limit for the multiplex frequency reference. At very low multiplex rates flicker becomes visible.

It is recommended that the display miltiplex rate be within the range of 50 Hz to 200 Hz which corresponds to 400 Hz to 1600 Hz for the reference frequency.

Control Input Definitions

INPUT	TMNL	VLTG	FUNCTION
1. Display	9	V_{DD}	Display on
		V_{SS}	Display off
2. Store	11	V_{DD}	Counter Inform. Stored
		V_{SS}	Counter Inform. Transferring
3. Inhibit	13	V_{DD}	Input to Counter Blocked
		V_{SS}	Normal Opertn.
4. Reset	14	V_{DD}	Normal Opertn.
		V_{SS}	Counters Reset

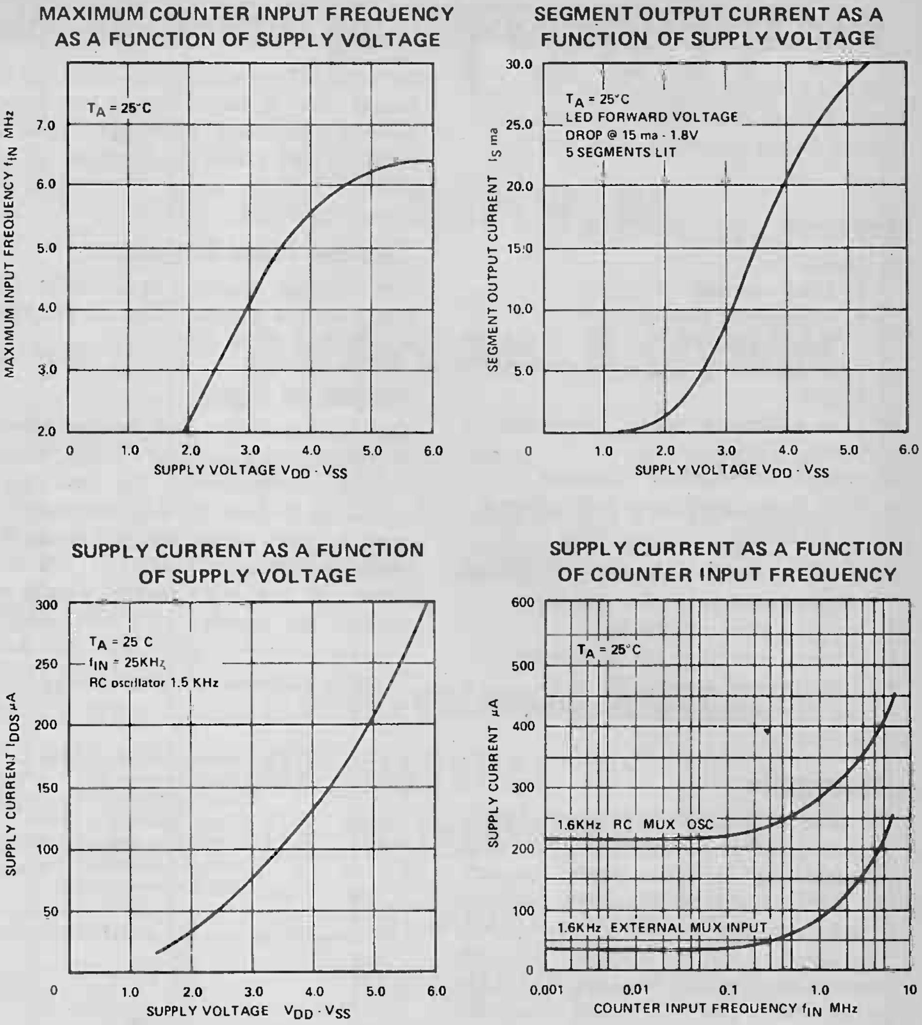


Fig. 4. Typical performance charactieristics

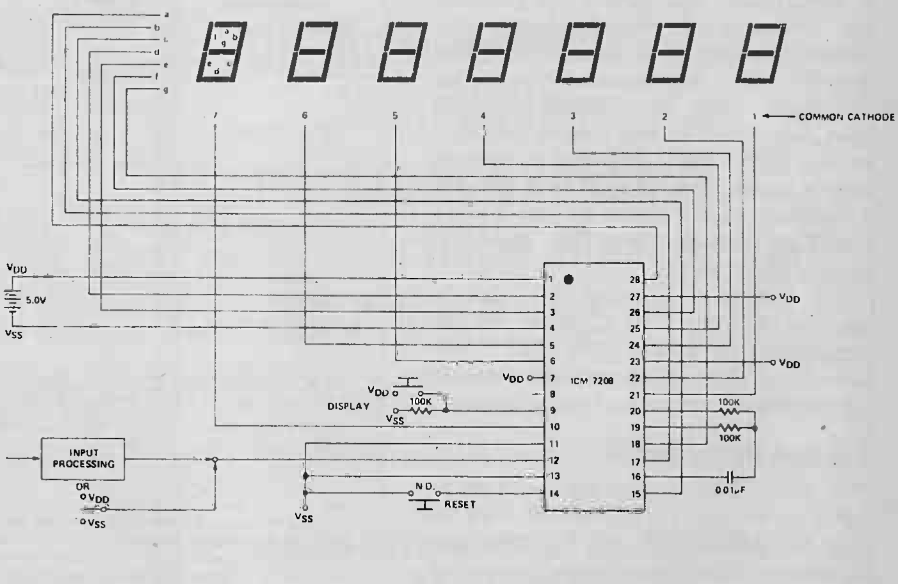


Fig. 5. Unit counter schematic.

ETI

ETIWET PLANT WATERER

If your plants suffer from a drink problem let our ETI WET look after them when you are away, ensuring that they get their daily dose of life giving liquid.

WATER, WATER, EVERYWHERE and not a drop to drink runs an old poem, well plants need to quench their thirst as well as humans — and during holiday time most are left to wilt. In the interests of flower power we decided to produce a unit that would refresh the plants that owners could not reach, hence the ETI WET.

The unit consists of a sensor, timer and electric water pump. The sensor is embedded in the soil and when dry the electronics operate the water pump for a preset time — thus infusing the plant with thirst quenching water. When the plant has drunk its fill and the sensor is dry again the cycle repeats. In this way you can soak up the sun in the knowledge that your prize plant is getting its fair share at home.

Construction And Calibration

The electronics are mounted on the PCB, using a socket for the IC. We used a plastic card filing box for the case and a 5 litre container to hold the water supply. Make sure you drill an extra small hole in the cap of the water container — so that air can replace water when the pump operates.

We used a small 6V pump (see buy lines) but other pumps can be used. For example a pet shop can probably supply small pumps (used in fish tanks) and pumps are available from most car accessory shops (used for windscreen water). If the pump you use needs 12V the battery will need changing — the electronics will work at this higher voltage.

Head on view of the completed prototype, the LED can be left out if you want extended battery life.

The moisture control and water flow control need careful setting — to ensure that the plant gets enough water, but not too much. When first switched on the ETI WET will pump water for the time set by the water flow control — use this water to wet the soil around the plant, with the probe in position.

With a properly watered plant, adjust the moisture control until the ETI WET feeds more water — then reduce the setting. ▶

news . . . . . . digest

sub ton kit

R E W Audio Visual have been given exclusive distribution rights on a new kit for budding rock & roll stars in the U.K. Called Prokit 62, it is a 6 into 2 audio mixer with features not normally found on mixers in the sub £100 range (at £99.95 it just creeps into this bracket). Each input channel has bass and treble equalisation, pan control, echo and cue busses, with choice of line or mike inputs. Distortion is claimed to be less than 0.1% and noise is said to be less than —65dBm. The unit needs an external power supply to feed it with the + and —15V at 50mA it lives on (not supplied).

Construction time is estimated to be a couple of evenings, and a 32 page manual is supplied with each kit. Further details from R E W Limited, 10/12 High Street, Colliers Wood, London SW19 2BE.

odds & ends

★ A. Marshall (London) Ltd., are moving their mail-order department from their Cricklewood Broadway premises. The new address for main offices, industrial sales, central stores and mail-order will be: Kingsgate House, Kingsgate Place, London N.W.6. The telephone number will change to 01-624 0805/6/6/8, the old premises at 40 Cricklewood Broadway have been refitted as a new branch.

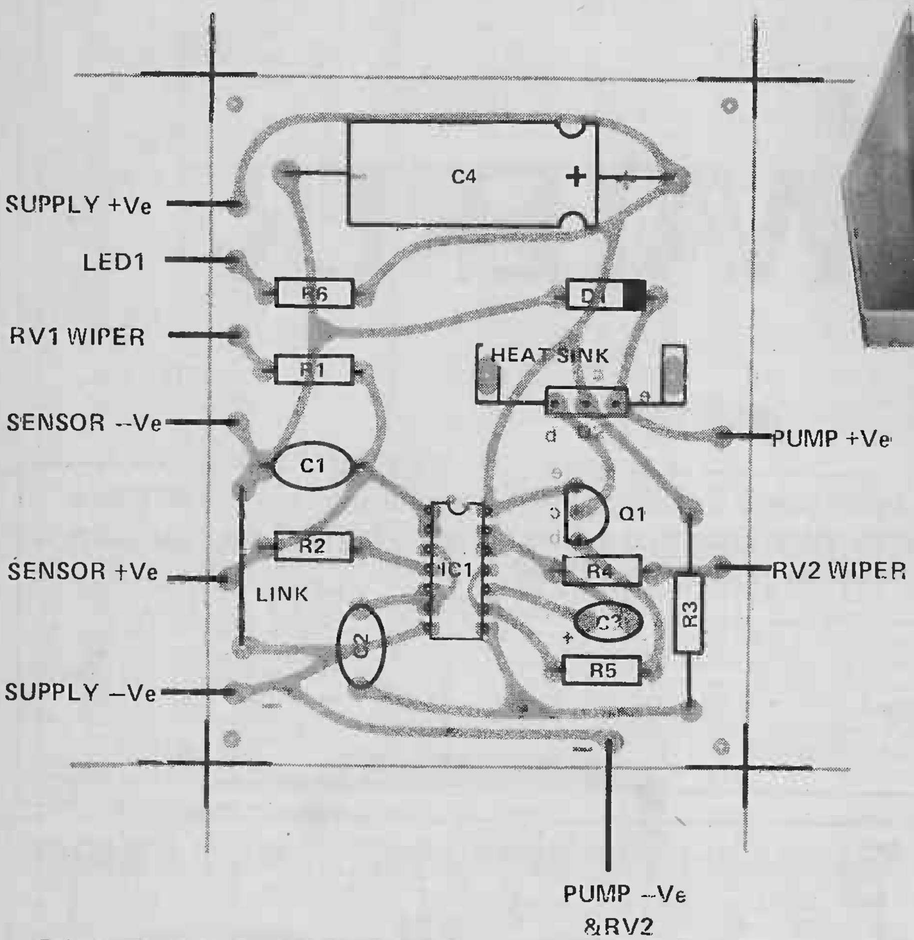
★ A Single hand ASCII keyboard, called 'Writehander', has been developed in the States. In use you place 4 fingers on switches representing the lower 4 ASCII bits and the thumb selects the remaining 3 bits, the machine looks like a hedgehog and is said to be both cheap and fast.

★ The National Enterprise Board is in the process of funding a new electronics company. Capital of £30-£50 million is to be used in the attempt to bring VLSI technology to the U.K., typical products would be 64K memories. The brains behind the scheme include British and American engineers in the States and at home.

★ Visual indication of FM station, automatically, is made possible with a new system developed by Phillips and the Dutch Broadcasting Corporation. A display indicates the result of decoding a signal superimposed on the transmitted signal, the signal is different for each station. Phillips are hoping for international agreement and cooperation to get the system off the ground (into the air).

★ The more you cram onto a silicon chip the more pins needed on the package. Up until now manufacturers of MSI and LSI have used modifications of the standard DIL, making it longer and/or wider. Problems produced by this approach include parasitic capacitance, which seriously limits the operating speed, and density of circuitry on PCBs. JEDEC, the organisation that registers all standard packages and specifications, are considering the details on a proposed new standard square package to be used in high density/speed applications.

On the left is an internal shot of our prototype, notice how we used screws to give extra 'bite' to the epoxy holding the tube connections on the front panel. Below is the overlay for the PCB.

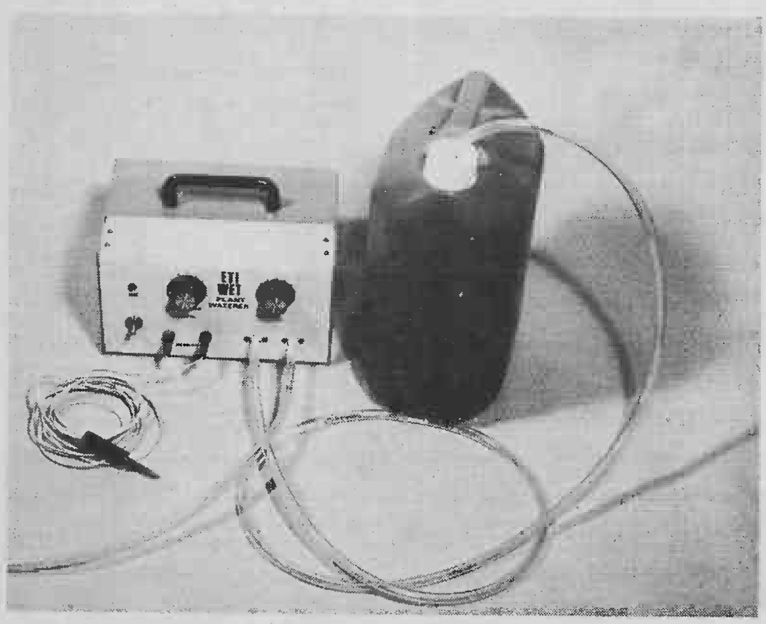


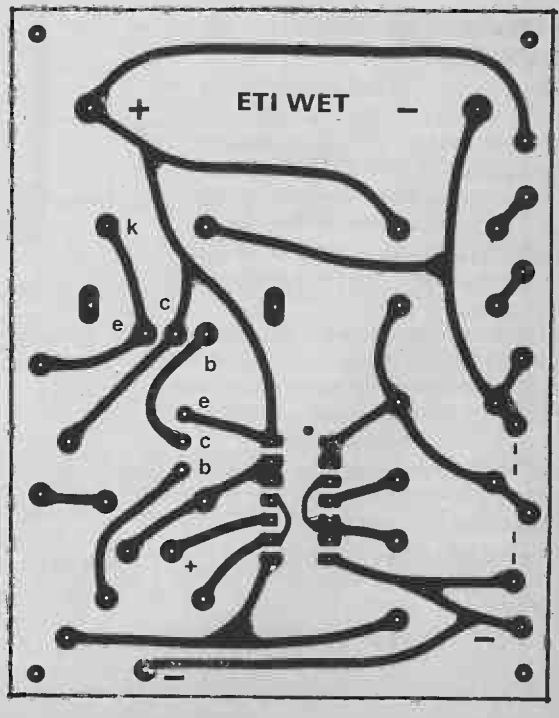
PARTS LIST

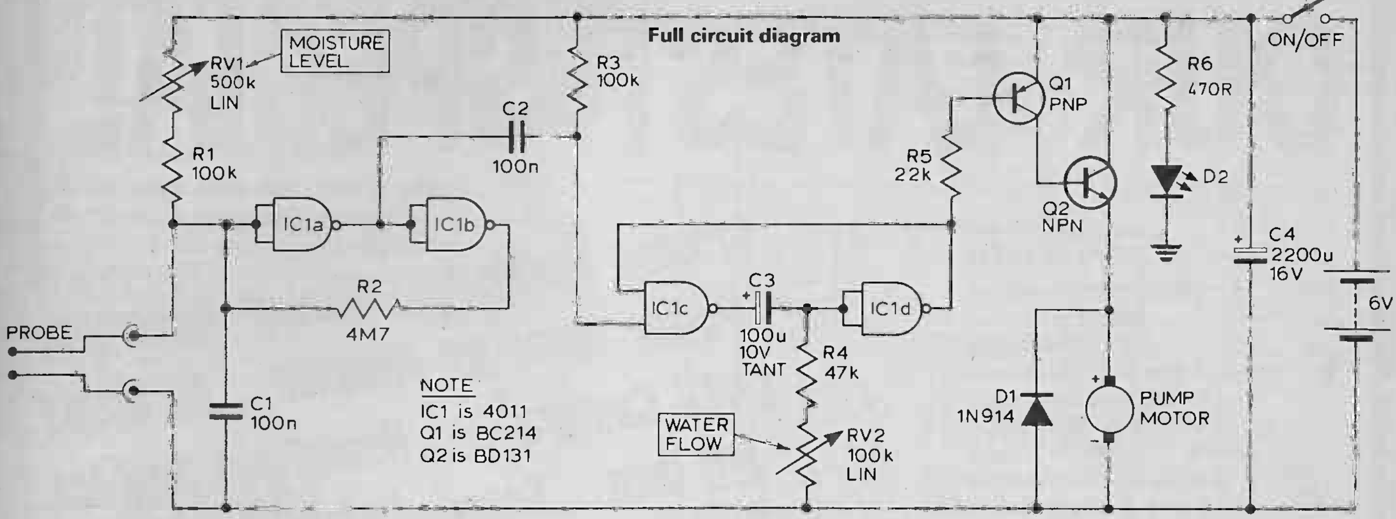
RESISTORS (all ¼w 5%)	
R1, 3	100k
R2	4M7
R4	47k
R5	22k
R6	470R
POTENTIOMETERS	
RV1	500k linear
RV2	100k linear
CAPACITORS	
C1, 2	100n polycarbonate
C3	100u 10V tantalum
C4	2200u 16V electrolytic
SEMICONDUCTORS	
IC1	CD4011
Q1	BC214L
Q2	BD131
D1	1N914
D2	TIL209

MISCELLANEOUS
Toggle switch, Battery (PJ996), Box to suit, PCB, water pump, tubing, water container, etc.

Below is the complete system, the probe used was made from a jack plug. On the right is the PCB shown full size (70mm by 90mm).







BUYLINES

The electronic parts for this project should present few problems. Sources for tubing and the connectors include chemical equipment suppliers and your local home brewing shops. The pump we used came from Proops Bros. Ltd, The Hyde Industrial Estate, Edgeware Road, Hendon, London NW9 6JS and costs £2.30 inclusive of VAT and postage.

HOW IT WORKS

The circuit is composed of three main sections: Level sensitive Schmitt trigger, variable time monostable and output driver. The level sensitive Schmitt is formed from ICIa and ICIb with the probe and R1, RV1 forming a potential divider on its input. When the resistance across the probe increases beyond a set value (ie the soil dries), the Schmitt is triggered. C2 feeds a negative going pulse to the monostable when the Schmitt triggers and R2 acts as feedback, to ensure a fast switching action.

The monostable (IC1c and IC1d) time period is determined by the values of C3 and R4, RV2. When triggered by the Schmitt the monostable turns on Q1, Q2 which drive the water pump. The monostable will only trigger with negative going input pulses, and therefore unless the probe has been shorted (by water) the Schmitt cannot retrigger the monostable. This acts as a fail safe to prevent the plant from drowning!

V·FETS FOR EVERYONE PART 2

In the second half of this article, reprinted from our Canadian edition, the practicalities of VFET circuitry are explained.

In general these devices may use any of the types of output circuits in general use with valves and bi-polars, including transformer coupled (Fig. 12) where the benefits of the absence of charge carrier storage become apparent in the absence of severe ringing at the crossover point, conventional series output such as in Fig. 1 which is a straightforward transformation from a bi-polar circuit (1), and single-ended output with current source, also transposed from an excellent bi-polar circuit (2) (Fig. 2).

Bias and Drive

These series of devices are *n*-channel, enhancement type MOSFETS, and may be biased and driven using methods appropriate to signal types and bi-polars. The drain is made positive with respect to the source and the gate enables conduction by being forward biased with respect to the source, that is to say it is biased in a positive direction. Unlike bi-polars, however, they are voltage, rather than current controlled, and circuit values are selected to provide the required voltage. Any current drawn is by the bias network itself.

Three bias methods are shown; Fig. 3 shows bias supplied from a fixed bias supply. It is the simplest possible method, allows extremely high input impedances, since *Rg* may be almost any very high value desired, and its stability is limited only by the stability of the bias supply.

The design shown in Fig. 4 has the advantage of requiring no extra supply voltage since it is taken from *Vdd*. Disadvantages are those of impedance and stability. Input impedance consists of the parallel combination of R1 and R2 (disregarding input capacitance of the MOSFET and the very low input leakage). There are practical limits as to how high this combination can become; if for example, we have a 60 volt supply and require 6 volts bias, we might have some difficulty obtaining higher values than 9 megohms and one megohms for R1 and R2.

Higher values become more difficult to obtain, stability becomes less reliable, internal inductance and distributed capacitance become problems, and overcoming these difficulties usually costs money. In addition, if *Vdd* is subject to variation, then bias varies. In a class AB amplifier this could be quite

We have just received a note from Siliconix giving the following changes in type number — VMP-11 becomes 2N6656; VMP-1:2N6657; VMP-12:2N6658; VUP-21:2N6659; VMP-2:2N6660; VMP-22:2N6661.

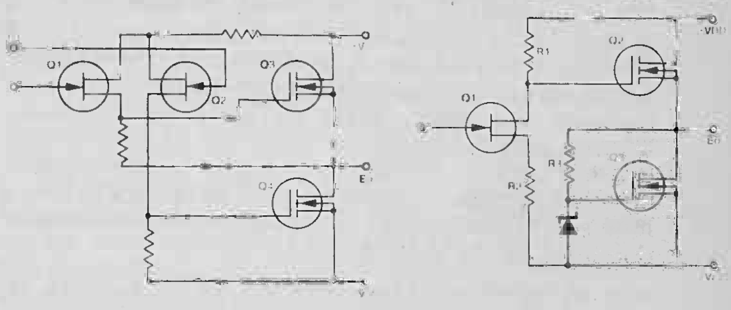


Fig. 1. Series output arrangement and Fig. 2 single-ended output with current source.

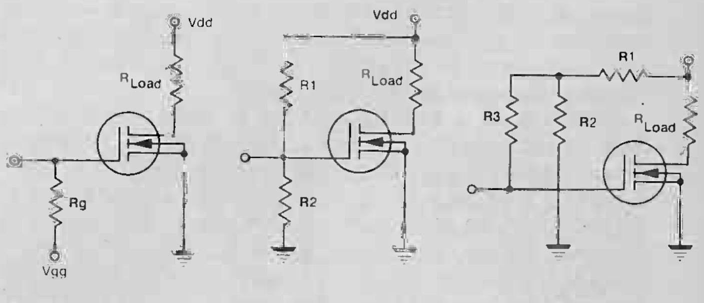


Fig. 3. High-impedance separate bias supply, Fig. 4 moderate impedance supply and Fig. 5 high-impedance common supply.

serious, since *Vdd* varies considerably with output level; at high levels, *Vdd* can be expected to drop, causing a reduction in bias.

While this may reduce the danger of over-driving the device, it will be forced to operate in its non-linear region which may result in unacceptable performance characteristics unless taken into consideration in the overall circuit design (e.g. choice of feedback values). It does provide some degree of overload protection, and with correct choice of values can ▶

provide for class AB operation at low levels, shifting to class B at high levels. With these considerations in mind, and/or where moderate impedances are required, it offers a low cost, simple, and reasonably reliable method of establishing the operating point.

The method used in Fig. 5 is similar except that with the addition of R3 higher input impedances are possible. Its configuration is similar to a noiseless biasing system frequently used in low-level bi-polar amplifiers and integrated circuits (e.g. National LM381A) but its function is somewhat different. Resistors R1 and R2 form a voltage divider as in Fig. 4 but their junction now forms a fixed bias source as in Fig. 3. Resistor R3 can be quite high since no current flows. Meanwhile, since the parallel combination of R1 and R2 are effectively in series with R3 they can be reduced to more manageable values. Alternatively R2 can be replaced by a zener diode for stability comparable to Fig. 3.

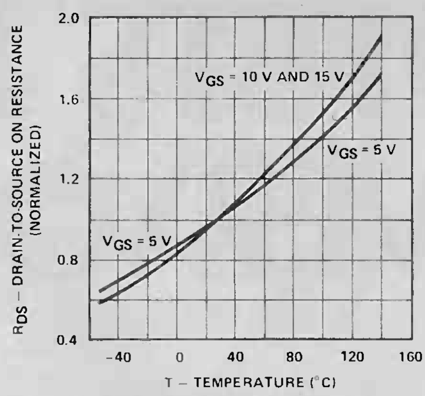


Fig. 6. Drain to source resistance against temperature (Siliconix).

Input Protection

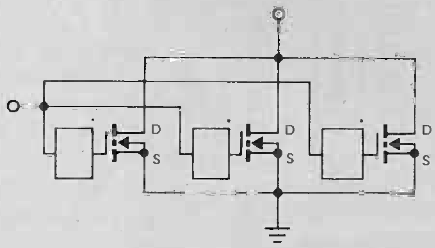
Unlike most signal MOSFETS, the gate of each of these devices, with the exception of the VMP 4, is protected with an internal 15 volt, 10mA zener diode. Most signal MOSFETS, as well as the VMP 4 are unprotected, or where extremely high impedances are not required, are protected by back to back zeners. I have no information as to why this different technique is used, but it is obvious that a negative signal swing on the gate will result in forward current through the zener. If the device is to be driven beyond cutoff, the driver must be capable of delivering current during its negative swing. Alternatively a constant current source can be used, a series limiting resistor or a driver biased to the same class of operation as the V-MOSFET.

A constant current source (we'll examine an example of its use a little later) will limit current drive to the value of the constant current diode used; a series resistance will drop the drive voltage as the diode draws current. In both cases, diode current must be limited to 10mA maximum. Higher currents will damage the protective. Higher currents will damage the protective zener diode.

However, if a class B output is used, conduction only occurs during positive half-cycles. Therefore, drive signal is not required during negative half-cycles. If a source or emitter follower driver stage is biased so as to pass no negative drive, the problem does not occur. However, great care must be exercised in the design of such a stage to ensure that drive does not disappear before the output device is cut off.

This is not too difficult with a class B or near class B stage; if the output device is operated at zero bias, then a small amount of bias on the driver will ensure conduction during slightly more than 180 degrees. Class AB operation is a little more tricky. If conduction is to occur for 270 degrees, for example, the driver should conduct for slightly more than this period.

Two types of drive circuits familiar to designers of bi-polar circuits are the Darlington and Super beta, commonly used together to provide a quasi-complementary circuit. Both circuits are current amplifiers designed to provide a compound device with very high *h*fe and provide base current to the output device. However, similar circuits can be used



*TO PREVENT SPURIOUS OSCILLATIONS, A 500 Ω - 1K Ω RESISTOR OR FERRITE BEAD (FOR HIGHER SPEED) SHOULD BE CONNECTED IN SERIES WITH EACH GATE.

Fig. 7. Basic circuit for parallel operation.

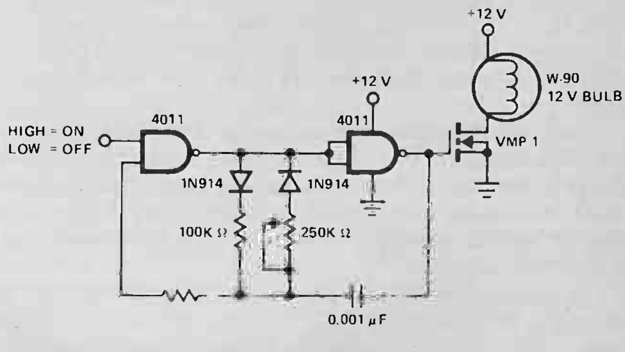


Fig. 8. Circuit of a high-efficiency light dimmer.

with these devices to provide phase inversion in a series output stage.

Thermal Considerations

As described earlier these devices exhibit a negative temperature coefficient with respect to current, so that as temperature rises, current is reduced, thus providing a self-inhibiting action which provides some protection against overload. However, this is not an unconditional effect. Fig. 6 show the

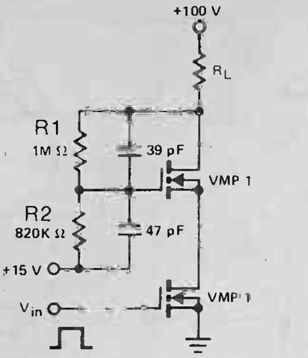


Fig. 9. Diagram for series operation.

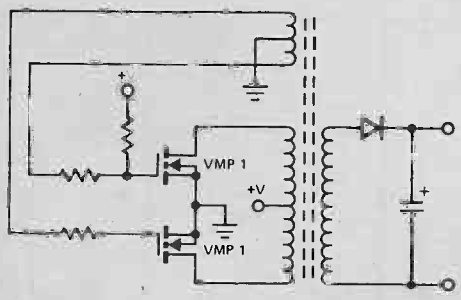


Fig. 10. A DC to DC converter (Siliconix).

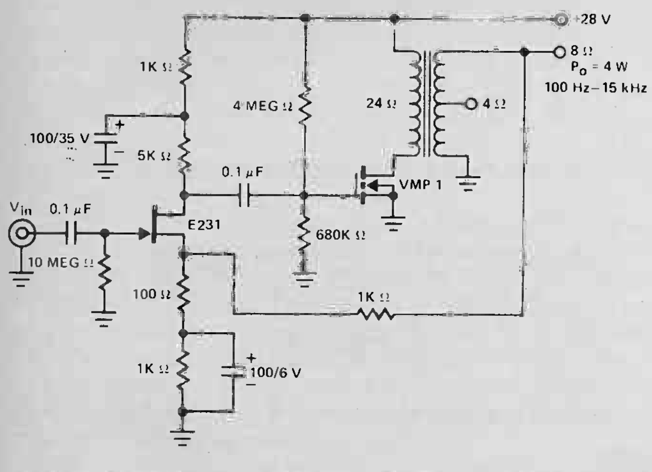


Fig. 11. Simple single-ended transformer-coupled audio power amplifier (Siliconix).

relationship between *R*DS (on) and temperature (3), based on a worst case temperature coefficient of 0.7 per cent per degree C.

Suppose that the device when on passes a current of 1 amp which causes it to heat up. The on resistance increases (which is why current drops), increasing the voltage drop across the device and the device dissipation. Now, if adequate heat sinking is used there is no real problem but if it isn't, the on resistance and junction temperature will rise to the point where extra charge carriers are generated, thus stabilizing *R*DS(on). That's great, except for the fact that this doesn't occur until the maximum safe junction temperature of 150 degrees has been exceeded.

You'll remember that we said earlier that the device was free of thermal runaway problems because of its negative temperature coefficient, but it isn't free of thermal destruction problems, and in any case, excessive temperatures will reduce output conductance. Heat-sinking requirements are, therefore, similar to those of bi-polars. The calculations of thermal operating conditions are beyond the scope of this article, but interested readers are referred to the Siliconix literature listed in the references, (4).

Extending The Ratings

The current handling capacity and therefore total dissipation capability may be easily increased by simply connecting several devices in parallel (Fig. 7). No ballast resistors are needed to ensure proper current sharing since if one device draws more current than another it simply gets a little warmer which causes it to draw less (assuming adequate heat sinking, of course). The only major precaution needed is to keep lead inductance in the gate and source connections to a minimum to prevent parasitic oscillations, unless the devices are driven from a low impedance source.

It may be advisable to insert "stoppers" – small resistors (100 to 1000 ohms) in series with each gate, wired directly to the socket, or ferrite beads mounted on the leads close to the socket terminals. An additional plus when paralleling several devices is that the gm is multiplied by the number of devices used. Mutual conductance gm is specified as the ratio of a large change in current to a small change in control voltage. If, for example, a change of 0.4 volts on the gate produces a change of 0.1 amp through one device, connecting two devices in parallel will give us an output swing of 0.2 amps, but it will still require only the original 0.4 volts gate swing. Since voltage gain A = gm x RL, if gm is increased, A is increased.

In real use, of course, the internal resistance of two devices in parallel is less than of one, the optimum load is less, so in amplifier applications, the net amplification A is the same. But notice that the drive requirements have not changed. With bi-polars current would have to be supplied to each base, thus increasing the output requirements of the drivers. Indeed, with many high-power amplifiers using multiple output devices the drivers are also power devices.

We can also extend the voltage ratings by series operation of two or more devices; Fig. 9 shows the technique. Resistors R1 and R2 bias Q2 on while C1 and C2 ensure fast switching. Input control signal is inserted between gate and source of Q1. Ordinarily the bottom of the divider chain is at ground potential for signal frequencies, so that circuit is really a cascode.

Maximum current and gm are the same as for one device. ▶

Some Practical Applications

An efficient light dimmer circuit as proposed by Siliconix is shown in Fig. 8. The 4011 acts as a pulse width modulated oscillator whose duty cycle is determined by the ratio of R1 to R2, with R2 adjusted to control the brightness of the bulb. Of special interest here is the fact that with its fast switching time, the VMP1 is especially suited to pulse width modulation at power levels and suggests it as being suitable for use in switching, or class D linear amplifiers.

A DC to DC converter is outlined in Fig. 10. The VMP1s form an oscillator with positive feedback provided by the additional coil in the gate circuits. In operation the upper V-MOSFET is biased on, and the lower V-MOSFET is off. When power is applied the upper device conducts causing current to flow from Vdd through the upper half of the transformer primary and the upper V-MOSFET to ground. The induced current flow through the feedback coil develops a voltage such as to shift the bias in the upper device off (if the winding is connected with the correct polarity) and the lower device on. This causes current flow from Vdd through the lower half of the transformer primary and the lower V-MOSFET to ground.

The secondary circuit consists of a single rectifier and filter. The resistor in the upper gate prevents shorting out of gate bias, and the one in the lower gate keeps both sides balanced. In addition, each resistor limits current through the protective diodes. These are expensive devices for such an application, but the high reliability, the reduced RF radiation (due to reduced switching transients) and the circuit simplicity easily make up for the cost. The very high circuit impedance allows for running frequency to be set by the self resonance of the transformer.

A single ended and push-pull transformer coupled amplifier for audio applications are shown in Figs. 11 and 12. Both designs utilise the biasing system described in Fig. 4. A load-line drawn on the output characteristic will show the optimum load to be 24 ohms. In Fig. 11 gate drive is supplied by a single junction FET, and voltage feedback is taken from the output transformer secondary and series fed to the source of the input device. Distortion is under 2 per cent at full output (try to get *that* with a single ended valve or bi-polar) and could probably be reduced even further by adopting a source follower output stage.

A push-pull version of Fig. 11 is shown in Fig. 12 using a differential input to provide phase splitting, drive, and a feedback point. Although the transformer winding ratio implies the use of a low impedance loudspeaker, a step-up ratio could be used for direct coupling to an electrostatic speaker, a balanced transmission line (both with some modification of the feedback circuit) an unbalanced transmission line, or a 70 volt speaker distribution line.

Notice in both circuits, and in the biasing circuits shown that no source resistors have been used, either for local feedback or for bias setting. In valve and bi-polar circuits it's a useful technique, and with bi-polars can be used to stabilize bias and control thermal runaway by using the increased current flow to increase the voltage drop, thus reducing base-emitter voltage. However, if used with these devices, it will actually impair the self-limiting action of its negative temperature co-efficient. If temperature rises due to high current, current flow is reduced. This would reduce the voltage drop across a source resistor, lowering the source voltage and increasing the gate-to-source voltage, causing an *increase* in current flow. The circuit would work great while it lasted — which wouldn't be for long.

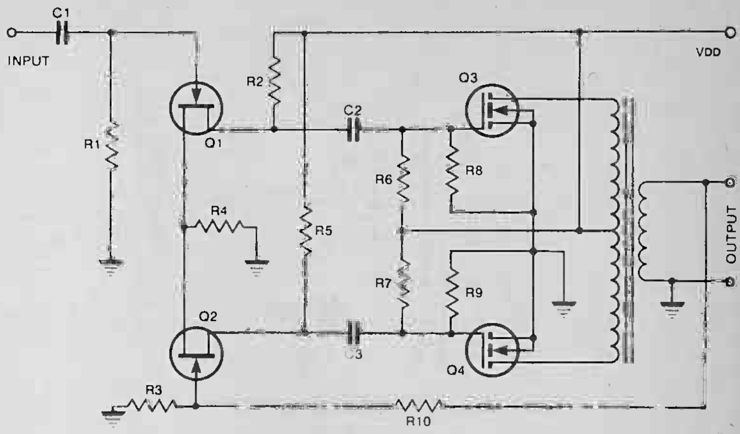


Fig. 12. Transformer-coupled output.

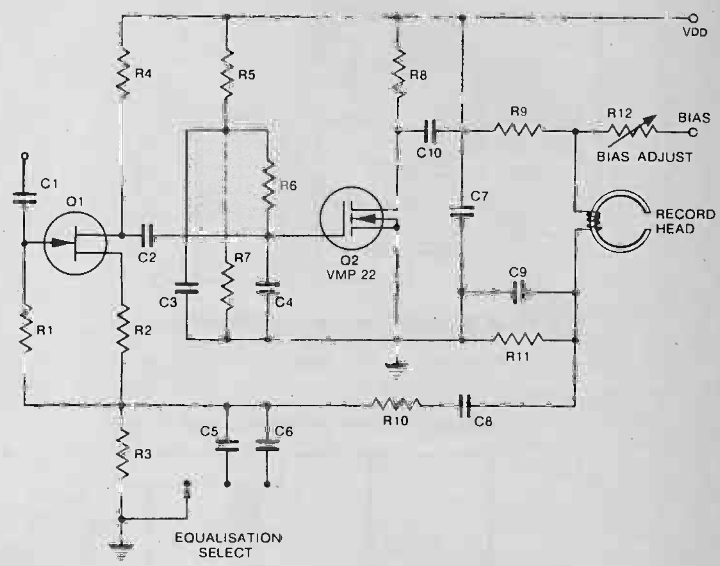


Fig. 13. Tape recording amplifier.

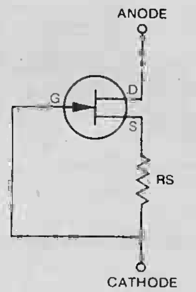


Fig. 14. A FET as a constant-current source.

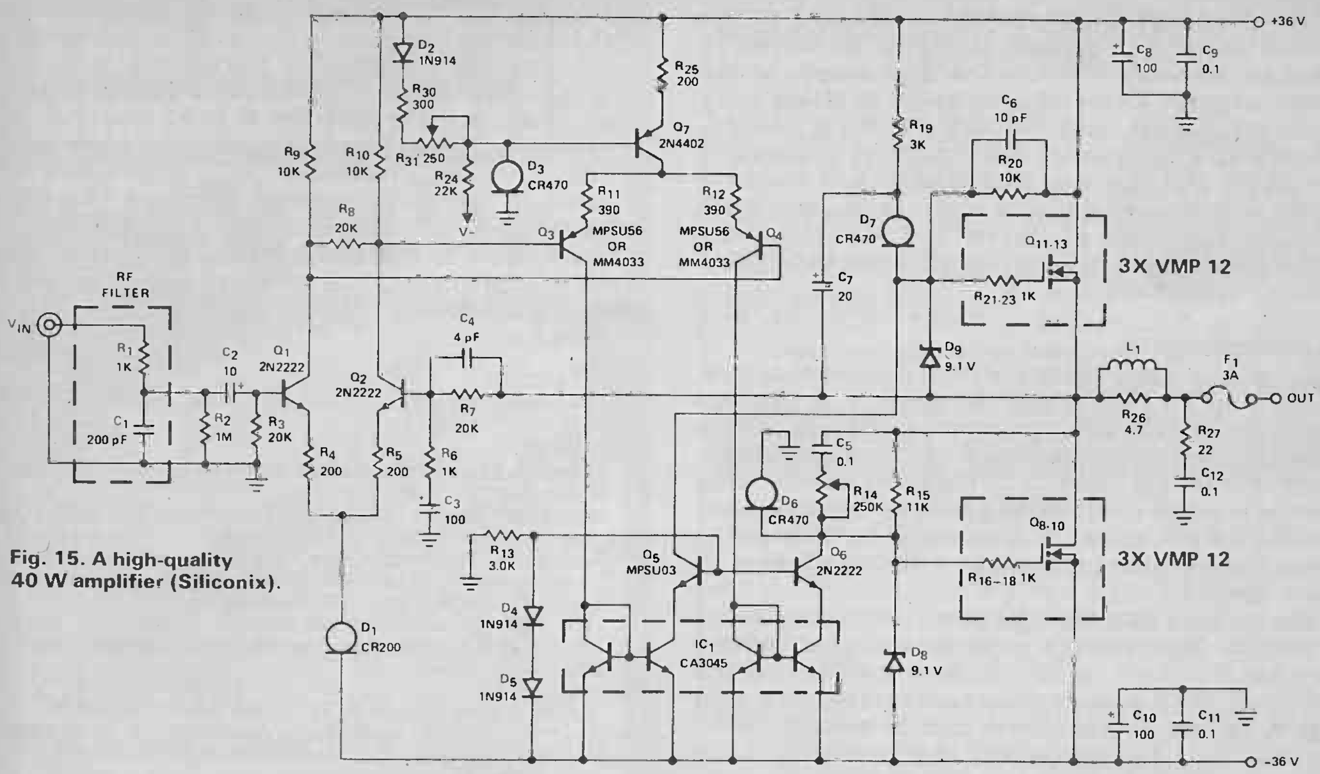


Fig. 15. A high-quality 40 W amplifier (Siliconix).

Power Amp

In Fig. 15 we have a high quality power amplifier designed by Lee Shaeffer of Siliconix Inc. (5) and described in their application notes. Output current capability is increased by using three VMP12s in parallel; providing for 6 amp current, 75 Watt dissipation and optimizing the load at 8 ohms. Q11-13 operate as a source follower, while Q8-10 form a quasi source follower. This is accomplished by applying local feedback from drain to gate via R14, R15, and driving the gate by a modified current source. This consists of a cascode circuit with a constant current diode as the load.

For the benefit of those not familiar with these devices, a constant current diode is really a FET connected internally as shown in Fig. 14. Since current in a FET is controlled essentially by the gate-to-source voltage, changes in load or in applied drain to source voltage have negligible effect since gate-to-source voltage is held constant. This is a current analogue to the zener diode and is described in detail in Siliconix literature (6).

The design is push-pull from input to output, thanks to differential circuitry throughout, prior to the drivers. Open loop distortion is low, bandwidth wide, allowing satisfactory performance with only 22dB of feedback.

Complete construction plans including PCB layout are available from Siliconix (7). A word of caution, however. Readers accustomed to construction articles in which the writer does everything but hold your soldering iron will find these plans rather sketchy. They consist of a spec sheet, schematic, board and parts layout, two paragraphs of construction suggestions, initial adjustments, and a parts list. Parts, generally, are specified as to value and rating, and that's it. These plans are excellent, but they assume some knowledge and experience on the part of the constructor. Regular 'eti constructors' should have little difficulty.

Finally, how about something elegant for its simplicity, such as the Tapered Current Voltage Limited battery charger shown in Fig. 16. This is especially useful with Ni-Cad batteries which are intended for stand-by use and are permanently on charge, such as

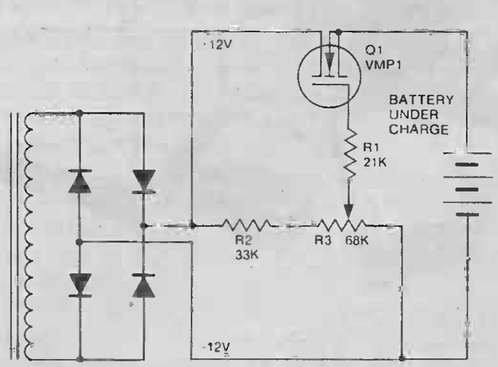


Fig. 16. Tapered-current voltage-limited battery charger.

electronic clocks. Overnight shut-downs of a few hours are occasionally but irregularly experienced. You know what this can do to clocks. Especially alarm clocks which are supposed to make noises, turn on radios, start the coffee at a pre-set time in the morning so you can go to work. Battery operation is not too satisfactory if the readout is on continuously, and Ni-Cads should not be on permanent floating charge.

With this little device current is supplied to the battery via the VMP-1. Gate voltage is set at a value equal to the desired end of charge voltage. As the battery charges its voltage increases, reducing gate-to-source voltage, thus reducing charging current. When the battery reaches full charge its voltage and that of the source equals gate voltage, and charge is terminated. If a load is placed across the battery it will draw current, and as the battery voltage drops slightly below gate voltage, charging at a trickle rate occurs – automatic.

Experimentation

The various applications shown are intended as suggestions for further experimentation on the part of the reader. They are mainly designed to illustrate various characteristics of the device under consideration, and are not necessarily representative of commercial practice or of finished designs. In some cases this may be just as well. But we would be delighted to hear of any readers' experience with any of these or other circuits.

The author's own feeling is that V-MOS constitutes a genuine breakthrough in semi-conductor technology, as important as the silicon transistor and the FET itself. We'll be seeing more of these devices, with higher ratings (a 10A 200V unit is already under development) and specialized characteristics. They are said already to be in use commercially as magnetic core drivers.

Digital enthusiasts may be somewhat impatient with the strong emphasis on audio applications in this piece but other literature has placed great emphasis on digital applications, with little attention paid to linear techniques beyond the 40 watt amplifier described here. The serious reader in all areas is referred to the references at the end.

Further literature may be obtained from the manufacturer, Siliconix Inc., 2201 Laurelwood Rd., Santa Clara, CA 95054, California. They have been most helpful in providing information for the preparation of this article.

Have fun.

ETI

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7. Ref. 5.
8. Bascom H. King: "Power FETs" *Audio*, Feb. 1975, p. 42.
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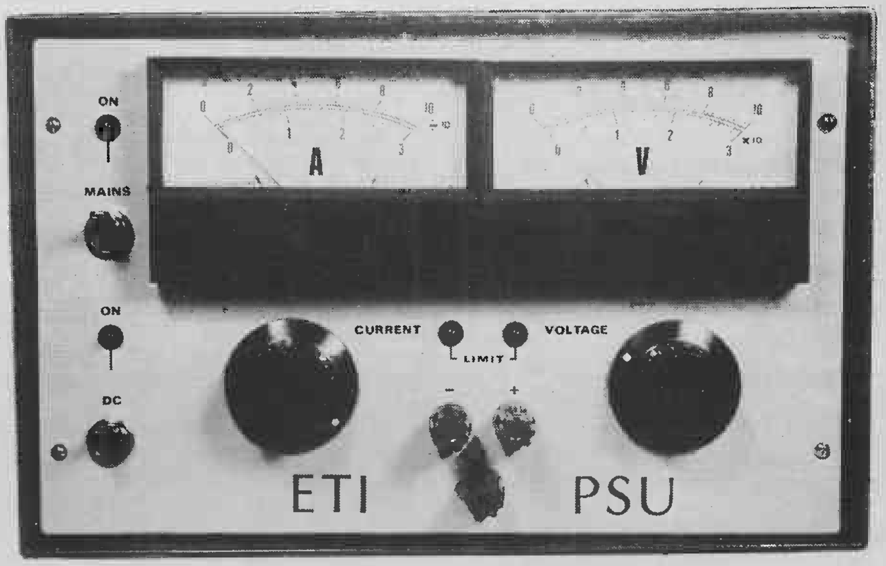
ALL PURPOSE POWER SUPPLY

The ETI project team presents a high performance Power Supply Unit based on an encapsulated regulator block.

THOSE OF YOU who threw up various parts of your anatomy at the sight of yet another power supply design probably fall into two groups. One will use batteries, will always have used batteries and won't see why they shouldn't continue to use batteries ad infinitum. There will be others who have a power supply — be it ever so humble — and are fed up with four-part articles describing the construction of same.

What is this fetish with PSUs?



Cell Your Batteries

We appeal to those of you in the first category to give batteries the old heave ho if only on financial grounds — batteries really are a very expensive way of buying power. They also come in fixed voltages and any current limiting attributes are limited to dying a death at the first sign of the short circuits that are bound to occur in even the most ordered of development work.

Supply And Demand

To those of you who fall into our second group we ask you to take a look at your present Power Supply. Is it up to the job? Does it have variable current limiting (0-1 A)? Can it provide an adjustable output of up to 30 volts? Does it have a couple of LEDS to indicate its mode of operation (voltage/current)? Can you isolate the DC output? Does it provide for remote voltage sensing?

Needless to say our design meets all these criteria.

Meg A Mania

The unit is easy to build as it is based on an encapsulated Power Supply Module. The module itself takes care of nearly all the work but in its naked form can only provide a 100m A output, Q1, acting as a series pass element, means that up to 1 A output can be provided.

The photographs show that we did not use a PCB for this project but mounted components directly to the PSU module or on a small strip of tag board.

Construction

Construction should be self-explanatory if the circuit diagram is followed through, about the only point to watch is the gauge of wire used in the current carrying sections of the design, make sure it's of adequate rating. Also make sure that the sense wires are taken to a point as near to the output sockets as near to the output sockets as possible. A switch jack socket inserted in the sense leads will provide a remote voltage sense option.

The meters are an optional extra, but we felt that these added that extra touch of professionalism to the device.

ETI ▶

BUYLINES

THE regulator module is available from Doram Electronics for £13.05.

The case used in the prototype was an Alson type 23 (10½ x 6½ x 6½). Alson are at 5/7 Long Street, London.

The other components should be generally available.

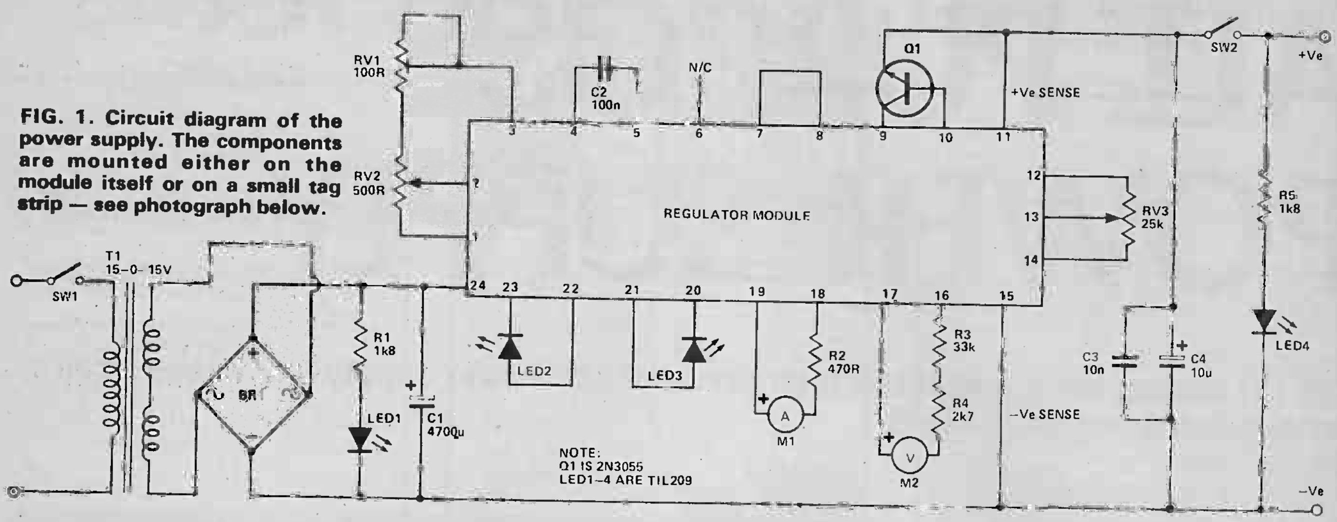


FIG. 1. Circuit diagram of the power supply. The components are mounted either on the module itself or on a small tag strip — see photograph below.

PARTS LIST

RESISTORS (all 5% ¼W unless * 2% MO).

R1, 5	1k8
R2*	470R
R3*	33k
R4*	2k7

POTENTIOMETERS

RV1	100R preset
RV2	500R
RV3	25k

CAPACITORS

C1	4700u 50V electrolytic
C2	100n 250V polyester
C3	10n 250V polyester
C4	10u 50V electrolytic

SEMICONDUCTORS

Q1	2N 3055
LED1-4	TIL 209
BR1	2A 50V

TRANSFORMER

T1	15-0-15 1.5A

SWITCHES

SW1, 2	Single pole on off

MISCELLANEOUS
1-30V, 100mA regulator module, tag strip, 100uA meters, case

HOW IT WORKS

THE AC mains is stepped down to 30 volts by transformer T1. This AC signal is rectified and smoothed by BR1 and C1. LED1 indicates the unit is on.

The regulator module provides all the control functions associated with a Power Supply.

RV1 and RV2 set the current limit, RV1 setting the maximum output current. RV3 sets the output voltage.

The basic module can provide outputs of up to 100mA only, Q1 increase the module's output capability to 1A.

LEDs 2 and 3 indicate which mode of operation the supply is in (LED2 is current mode, LED3 is voltage).

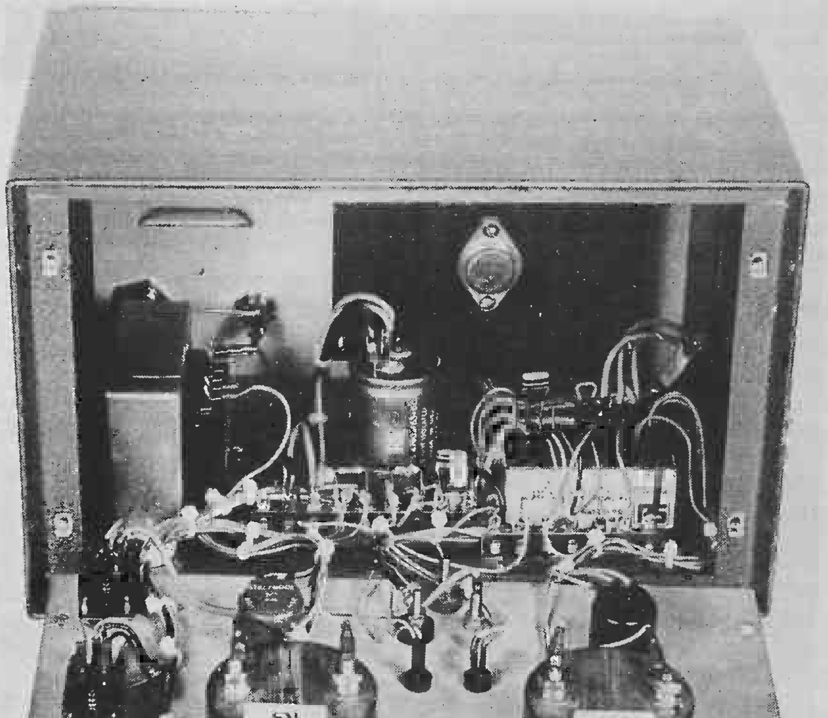
The resistors in series with the meters should be selected to ensure that the meters are calibrated, the values given are for our prototype and may need slight alteration.

C2 is included to improve the stability of the design.

The output from the module is further smoothed by C3, C4.

SW2 is the DC isolation switch and LED4 indicates that a DC output is present at the unit's output terminals.

The photograph, right, shows clearly the method of construction adopted in our prototype. Ensure that the wires carrying high currents are of adequate rating.



. . . news digest. .

solid state speech

If the latest goodie from Texas Instruments is as successful as we think it will be, the next generation will speak with an American accent! Called "Speak & Spell' it is a box that talks to the kids (with a 'standard' American accent), and theoretically helps them pronounce new words correctly — it also compares how the kids spell the word with the correct (American) spelling, and indicates whether they gave the right answer.

The 200 words in the machine were selected by educators for the 7 to 12 year old, further sets of words are to be made available as plug-in modules. In its main mode of operation it selects a word at random and 'speaks' it. The user then types in their version of how it is spelt, and the machine either says well done, or please try again (or noises to that effect). After 10 words the 'Speak & Spell' talks and displays a score. Various other modes of operation are also available, including a version of 'Hangman'.

Heart & Throat of the machine is a 128K ROM, the word library is stored as a series of sound values—representing the various word characteristics. Priced at 50 dollars in the States, it will be available from July onwards, although no date has been given for U.K. release. Methinks the ETI office culd use one usfulli. Texas Instruments Inc., Consumer relations, P.O. Box 53, Lubbock, Texas 79408.

national phoenix

National Semiconductor have recently opened the first plant in the world to process 4 inch silicon wafers. The production facility has been built on the ashes of their previous factory in Greenock, which burnt down a year ago. The builders estimated that it would take between 2 and 2½ years to rebuild, National were determined to do it in 12 months and succeeded. The advantage of 4 inch over the more normal 3 inch wafer is simple — they get a lot more usable ICs in the same time.

A touch of humour was added when Peter Sprague, a director of National and also of Aston Martin, failed to arrive in a brand new Aston Martin Lagonda (yours for £32,000). The sophisticated electronics in the car were not functioning, or as he remarked to some reporters "The *©£&()" + electronics don't work", the *©£&()" + electronics are made by a company that has just built a rather large factory in Scotland.

audiophile.....

Ron Harris examines a top of the range offering from Goldring Products — a new version of the G900SE — and asks whether or not this is the .....

BEST OF BRITISH?

GOLDRING ARE ONE of the best known names in the hi-fi industry. Most of us have at some time or other undoubtedly possessed one of their G800 series cartridges, sometimes without realising it! (Checked the end of that package deal arm recently?)

In the lower price ranges the company has been more than able to hold its own against all comers, but the higher strata have seemed beyond their reach of late. Last year they launched the G900SE, which sold at a ridiculous £25 or thereabouts, and produced an excellent sound quality. The unit never received the acclaim it deserved.

One can't help feeling that had one of the American cantilever giants produced the G900, we would be hearing about it still. Goldring, however, had themselves some financial difficulties to overcome — which they now seem to have risen above — and this could not have helped.

This month sees the release of the 900E, a lower priced cartridge, and a Mk 2 of the G900SE itself. It is this we concern ourselves with here.

Time To Mark Two?

Basically the unit is a low mass moving magnet design of high compliance, intended for use only in arms of low inertia. The cartridges weigh only 4g, and the reduction in mass over its predecessor has been achieved by what Goldring describe as "formerless winding" of the coils within the body.

More important still though, tip mass is also low at 0.32mg. A tie wire is fitted to dampen stylus movement(?) and also to act as a leakage path for static on the record surface. Quite a bit of innovation going on here, and it was to prove interesting to discover what effect, if any, this was going to have on the sound of this new Goldring.

Sound Results

As can be seen from the test results, technically the unit acquitted itself well with good separation, well balanced outputs and a good smooth frequency response. The rising (extreme) top end response may well be engineered to suit the unit to CD-4 usage. In stereo mode the resonance should not prove a problem.

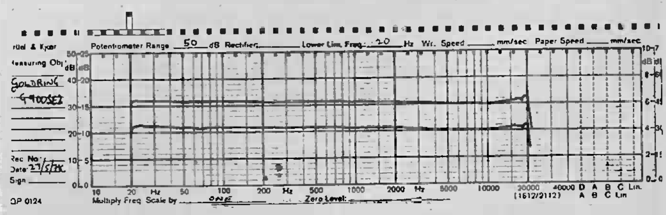
The sample was fitted into an SME Series III for test purposes, and initially the mounting method raised suspicions as to its rigidity. These proved to be unfounded, however — but it still *looks* wrong!

With a mass of only 4g, the Goldring would pose no problems to arms capable of doing it justice.

Off The Beaten Track?

Once balanced out, and with no damping applied to the arm, tracking checks were undertaken using the ubiquitous HFS 75 and several of our own torture tracks. At Goldring's stated 1g, all bands except the highest level were handled with confidence. Band C could just be tracked at around 1.1g, but only just. No improvement was apparent with increase in excess of this and so we left the tracking weight at 1.1g throughout the listening tests. ▶

SPECIFICATION



Above: frequency response plot for our sample of the G900SE. Upper trace is the left channel, and the lower the right.

Below: Specification and test results for the same sample of the Goldring cartridge.

Frequency Response:	20Hz to 20kHz ±2dB	see graph
Playing Weight Range:	0.75 to 1.5 grams	best at 1.1g
Tip Mass:	0.32mg	—
Channel Separation:	25dB	30dB (L on R 1kHz)
Output at 5cm/sec, 1kHz:	4.5mV	L—5.4mV; R—5.2mV
Weight:	4 grams	—
Inductance (1kHz):	570mH	—
(10kHz):	540mH	—

Test conditions — tracking force 1.1g, load 47k, 150p.

This result, while not as good as the best that say a V15 can manage, is still very commendable and a great deal better than the moving coil devices available at present. No change was observed in tracking ability with damping applied to the arm.

Resulting Sound

With all the test completed - and no gremlins apparent - down to listening. Initially we simply wired it up, switched it on and got on with it! First impressions were of a smooth sound with no obvious vices and a well controlled bass extension. Slight recession of extreme treble perhaps.

Over an extended listening period however we came to appreciate just how good this new Goldring can be. It has depth and it has an open quality which puts you in with the music, without ever being bright or hard.

Comparisons were made between the G900 and several other top-flight devices, including an Ultimo 20A, Sonus Blue and the new Entré moving coil unit. These showed without doubt that the G900SE is a match for any of them! At this level of fidelity it comes down more than ever to a case of personal taste. On a subjective level the Goldring was preferred to the Ultimo for its smoother presentation, although the 20A did have greater depth. The Sonus likewise came out second best, for no other reason than that the G900SE sounded better! The bass was tighter and the mid-range less aggressive.

Battle With The Coil

The most interesting comparison was between the Entré and the G900 however. The latter has many of the qualities so beloved by the devotees of the moving coil, but just fails to match the best of them in terms of delicacy of presentation. The Entré did provide a greater sense of detail throughout the frequency spectrum, but its bass response was never as well defined, and the Goldring tracks better. You pays your money and you takes your choice. . . .

What A Load Of . . .

Our main reservation concerns the specified loading for the cartridge.

This is 47k and 150p, and this was the figure the cartridge was tested at. However most amplifier and pickup lead combinations will exceed this, usually providing around 200p-250p. This could have an effect on the top end response of the cartridge, especially if the capacitance offered is higher than the upper specified limit of 200p.

We varied the load the cartridge saw to gain an idea of its performance on this parameter, and only when we reached about 350p could we honestly say a subjective difference was present, this manifesting itself most clearly on cymbals.

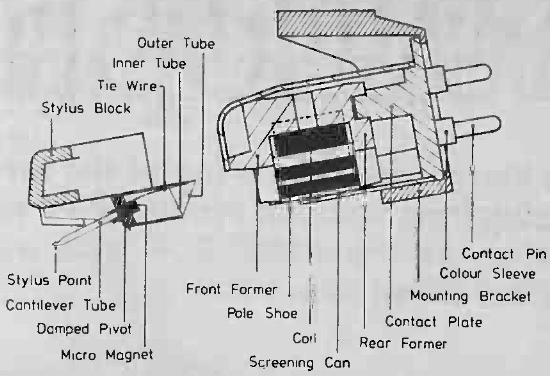
In practise then anything between 100p and 300p should be fine. It is interesting to note that Shure specify a load of 450p for the V15 III, and the fact that this is rarely met may account in some measure for the "bright" reputation that unit has made for itself, since lower values will act to boost hf response.

Impact And All That

Overall then the sound of the Goldring can be described as smooth, detailed with plenty of depth and good extension into the bass. It will undoubtedly come as a surprise to many devotees of the "bright-is-beautiful" school, but extended listening will pay even them dividends. The sound perhaps lacks an immediate nature a little *too* much, but again that is for you to decide. Impact it has — but only when the music does!!

It is good to see a British manufacturer produce a product of this quality, and be able to retail it at a price less than esoteric. At its expected cost of around £50 the G900SE disposes of similarly priced opposition with a disdaining waggle of the cantilever, and indeed takes its place with the very best moving magnet designs of the day.

ETI



What goes where inside the Goldring G900SE2. The tie wire is claimed to control stylus movement in the 'unwanted modes' — whatever they are — and to provide a leakage path for surface static. In practice the G900SE did prove highly insensitive to surface noise, whether this was due to the little wire . . .

microfile.......

Gary Evans has been going round in circles this month in search of more MPU news items.

THIS WORLD IS full of vicious things, circles and dogs spring immediately to mind. I've had experience of both, the latter in the bundle of fluff that's the nearest I get to a pet and of the former, it seems, in everything I do. At any rate it's an example of the former that I'd like to dwell upon for a moment.

The situation concerns anyone considering the development of a microprocessor based control system. As a first step in any such development program, our likely lad will look around at the various development systems, that most of the major manufacturers produce, to help potential micro users to get to grips with their particular processor.

When It's All Assembled

Having chosen one of the various kits he can now get down to the real business of developing the control algorithms and, finally, the machine code that will drive the completed implementation of his system. That's if all goes well. Many of the basic development kits come supplied with a monitor that can only be described as rudimentary, allowing only a simple memory examine/modify type instructions. The development of any routine over a few hundred bytes with such a system has been know to drive many a hardened engineer to throw down his soldering iron and go for some knitting needles.

Fear not we say to our, by now, disheartened fellow, for we can provide you with an assembler. From now on you will not have to wrestle with machine code, but can deal with mnemonics which at least makes the task of coding much easier, and if you're lucky your assembler will also take care of a few labels in our program. At this point though, our man hears of a marvellous thing called an interpreter, whereby he can program his system in a high level language that is, by all accounts, far easier to pick up than either machine or assembly code. As time is money and personnel with experience in machine/assembly programming are difficult to come by, the choice seems to lie with a BASIC INTERPRETER. We know the final system will operate slower than a machine language program, but it will be fast enough for most applications.

All is well, the final program is soon written and debugged and the time has come to dump the object code into the PROM that will reside in the final hardware configuration. It's here that we observe the beginnings of our vicious circle (you were starting to wonder weren't you).

Things Looking Up?

The crunch comes when we realise that an interpreter does not in fact produce any object code, instead, looking at a string of stored instructions line by line, it consults a lookup table within the interpreter which then directs the micro to another area of the interpreter's ROM where the routines to carry out the required instructors are located. It is important to note that this takes place on a line by line basis and at no stage is anything that remotely resembles an object code generated. Thus our poor chap has his BASIC program ready to go, but to run it on any system he will require not only to dump the program itself to ROM but also the entire BASIC interpreter. To add insult to injury, most BASICs require a fair sized stack which will also have to be provided.

So attractive as it may seem in terms of development time an interpreter supporting a high level language is no way to undertake software development in most control systems applications. So it's back to the assembler, or, if you feel like withdrawing from life for a while, machine code.

Heard The One About . . . .

Now for a few quick news items

A new addition to the ranks of places offering micro systems, along with the advice necessary to help chose between the many products around, is the Byte Shop at 426/428 Cranbrook Road, Gants Hill, Ilford, Essex. IG2 6HW. Sounds like an offshoot of the American Byte Shop chain, a franchise operation that has been going in the States for some time now. A SAE to the Byte Shop at the above address should get you details of their product range.

This issue of ETI goes to press on the eve of the DIY Computer show and a report of this event, which follows the successful show held last year, will appear in next month's Microfile. I do hear however that another computer magazine is to be launched at the show. The title I've heard is Practical Computing, but by the time you read this the thing may be on the news stands. I look forward to reading the first issue with interest.

Chip Off The Old . . . .

You may recall my mentioning the 8048 single chip MPU from Intel a while back. Well no sooner was that in print than a new product information sheet landed on my desk describing the latest addition to the Intel stable. The 8022 is a derivative of the 8048 being a single chip MPU, but with the important plus of having two on board A-D converters. Add to this an eight bit input port with variable threshold (just right for decoding touch keyboards) and the usual complement of 28 I/O lines and onboard memory and you have a product that should find its way into more products than I care to think of over the next year or so.

Why Did The Chicken . . . .

Last month I mentioned a company called PETSOFT that has begun to market software for the PET home computer. The company tell me they have had quite a number of inquiries since then with the interesting fact being that most of you have wanted more information on the various games packages offered —you lot must have a lot of time on your hands as I never get the chance to play games on our machine—honest. Before leaving the subject of PETSOFT and going on to name another company that is to offer much the same service. I must just mention a recent addition to the PETSOFT range. This program is a recipe title that goes under the name of Colonel Evans Kentucky Fried Chicken — a roast by any other name.

In case you missed PETSOFT's address last month they are at 316 Fulham Road, London.

That other company I mentioned is General Software at 16 Sommerford Avenue, Crewe, CW2 8NE. Initially this company is to deal in TRS80 software and a SAE to them at the above address will secure a list of the titles at present in their range.

And Now For Something . . . .

Many of you who have ordered either MK 14 or NASCOM kits have told me of the long waits you have had between placing your order and receiving your goods. I am assured by both companys concerned that the supply problems that, in both cases, have been responsible for the delays have now been sorted out and that the kits are now being dispatched without delay. As a result of this I have at last managed to sort out reviews of these interesting products and one or other of these should appear in the next issue of ETI.

Many A Slipped (disk) Twixt . . . .

The floppy disk untit for the PET computer will appear in Britain but not it seems before the end of the year. Meanwhile the men at Commodore are being inundated with requests for just such a unit and Commodore have asked me to say that if any of you feel able to tackle a PET-floppy interface, they would be only too glad to provide you with all the necessary information.

In One Ear, Out The . . .

I get many enquiries regarding the adaption of TV to accept video signals. With many of the sets on the market this can prove a tricky task but D. Reddington has written to tell me of a £69 Sanyo receiver that could not be simpler to adapt.

With three screws and a phono plug removed and the back comes off, two more screws and the circuitry slides out, and here's the best bit, there is a link wire joining the video stage's input to the sets RF stages. Remove this and replace by a switch and conversion is complete.

As a bonus there is a similar link in the sound stage.

One For The . . . . .

I live in a place that is a desert in the oasis of life and I'd like to move (this has got nothing to do with MPU's in case you hadn't guessed) so if any of you within the GLF (Greater London Frontiers) know of a room/flat that's going spare please let me know here at ETI. ETI

electronics tomorrow......

by John Miller-Kirkpatrick

Fig. 2. The Visitronic module, with prism, two lenses and linear IC chips.

AS YOU SWELTER in the sun this Summer (?) think forward to Christmas 1978 and the never ending task of trying to think of new and original presents for Aunt Mavis and Uncle Eric. If you think that you have problems spare a thought for the manufacturers of gimic presents who have the problem this year of what form to present an electronic goody. Should they come up with a super calculator which calculates, tells the time and date in all 24 time zones, checks your pulse and biorhythm, etc. etc, — bit old hat really! What about a new gadget for the kitchen which slices cucumber, carrots, potatoes, picks up crumbs and nails and checks your pulse and biorhythm?

Auto-focus for cameras and . . .?

Electronic cameras have been with us for some years with automatic light sensors, shutter timers, etc. The latest development is a self-focusing device which is now being fitted to some cameras, the device is from Honeywell and goes under the name of Visitronic. The type of rangefinder or auto-focusser fitted to some cameras at present is based on two mirrors, one fixed and one

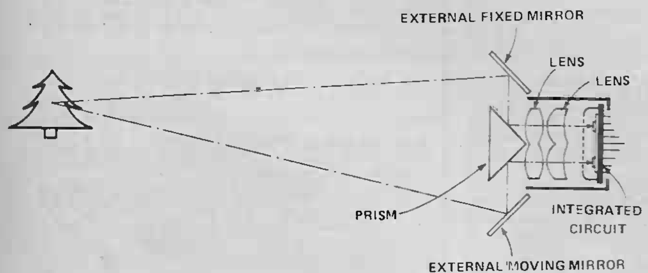


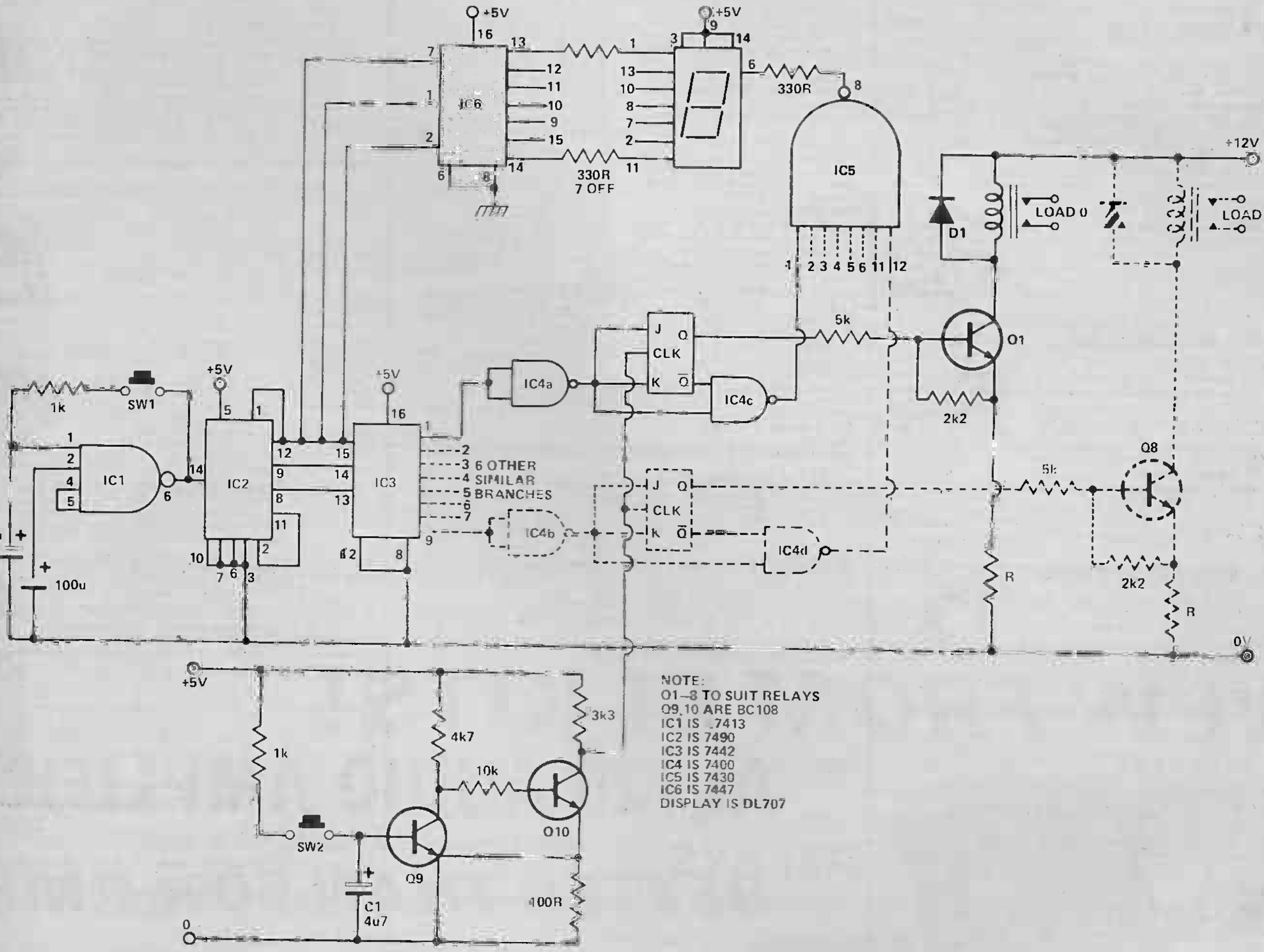
Fig. 1. External arrangement of mirrors for the Visitronic.

moveable, which reflect the images onto the viewfinder. Adjusting the focus screw moves one of the mirrors until the images relfected from the two mirrors become a single image and at this point the image is assumed to be in focus. A similar system is used in the Visitronic except that the images are reflected onto the surface of an IC with two photosensor arrays, one at each end of the IC. As the mirror is moved the images presented at the two photo arrays are compared and a signal is produced which is relative to the comparative matches in the two arrays with a peak at the best match. The movement of the mirror is linked to the focussing ring of the camera and thus is capable of continuously adjusting the focus of the camera so that it is centred on the most obvious subject in view. The speed at which this happens is fast enough to operate during the time that the shutter is open for a still camera and thus is capable of 'instant' focus for cine or TV cameras.

The whole unit is packaged in a TO-8 can with a sophisticated plastic over which also incorporates two plastic lenses and a prism to transmit the light from the external mirrors onto the photo arrays, the mirrors, mirror motor, and controls are not included. The actual chip measures 100 x 250 mils and contains sensors, amplifiers, voltage regulator, reference voltage, peak detector and output driver. The photosensor arrays are each broken down into four parrallel sensors on each side of the chip, the use of four sensors in each array increases the sensitivity of the device and allow for more accurate calculation of the best image match.

Eye Technology

Applications of the Visitronic are not limited to use in cameras. Your average run of the mill Robot uses light or ultrasonics to find its way around obstacles, it might now be possible to use one or more Visitronic devices to give the Robot something approaching the concept of an eye. With an MPU backing up the Visitronic it may be possible to differentiate between similar objects of different sizes, different textures or colours. This might well be a beginning to the answer to one Robot problem which has always fascinated me — unless you know different. If you show a young child a picture of a male lion standing under a tree the child has no difficulty in relating this to your own small tabby kitten and will not mistake it for a dog. The Robot can be persuaded to recognise the picture of the lion and can inform you that it is the picture of the lion, and can inform you that it is the picture you have told it is called lion on any sbusequent showing of the picture. If your kitten wanders into the viewing range of the Robot it will not recognise it at all unless the kitten decides to strike up a pose similar to that of the lion under the nearest hat stand. Is the problem of recognising a pattern from a different angle, size, colour, etc really that difficult?



Electronic Switch

S. Yacu

This circuit provides remote switching of up to eight loads, and uses only two switches for selection. One switch is used to select the load to be controlled, the second controls whether the load is energised or not. If the state of one of the loads needs to be changed, SW1 is depressed until the number of the load appears on the 7-segment display. The decimal point then indicates whether or not the load is energised. To change the state of the load, SW2 is depressed (pressing SW2 again will change the loads state again).

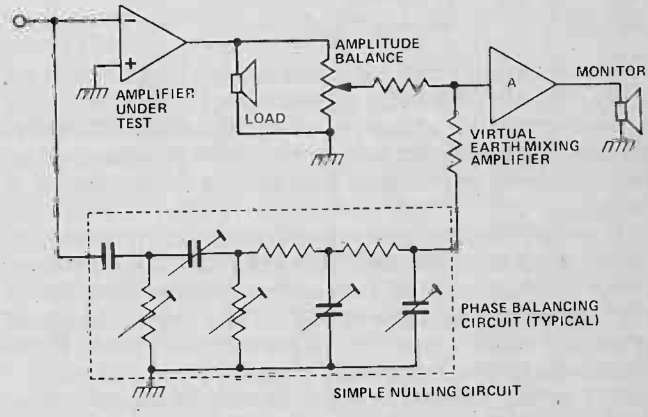
The circuit is based on a 7442 1 of 8 multiplexer and a 7490 binary counter. When SW1 is closed, the Schmitt trigger IC1 will oscillate and clock the 4-bit counter. This drives the 7-segment decoder and the 1 of 8 multiplexer. The outputs from the multiplexer are inverted and fed to the J-K flip-flops. When SW2 is pressed and released, a pulse will occur at the collector of Q10. The pulse will clock the selected flip-flop and activate or deactivate the relevant relay driver transistor (Q1-8).

Tech-Tips is an ideas forum and is not aimed at the beginner. We regret we cannot answer queries on these items.
ETI is prepared to consider circuits or ideas submitted by readers for this page. All items used will be paid for. Drawings should be as clear as possible and the text should preferably be typed. Circuits must not be subject to copyright. Items for consideration should be sent to ETI TECH-TIPS, Electronics Today International, 25-27 Oxford St., London W1R 1RF.

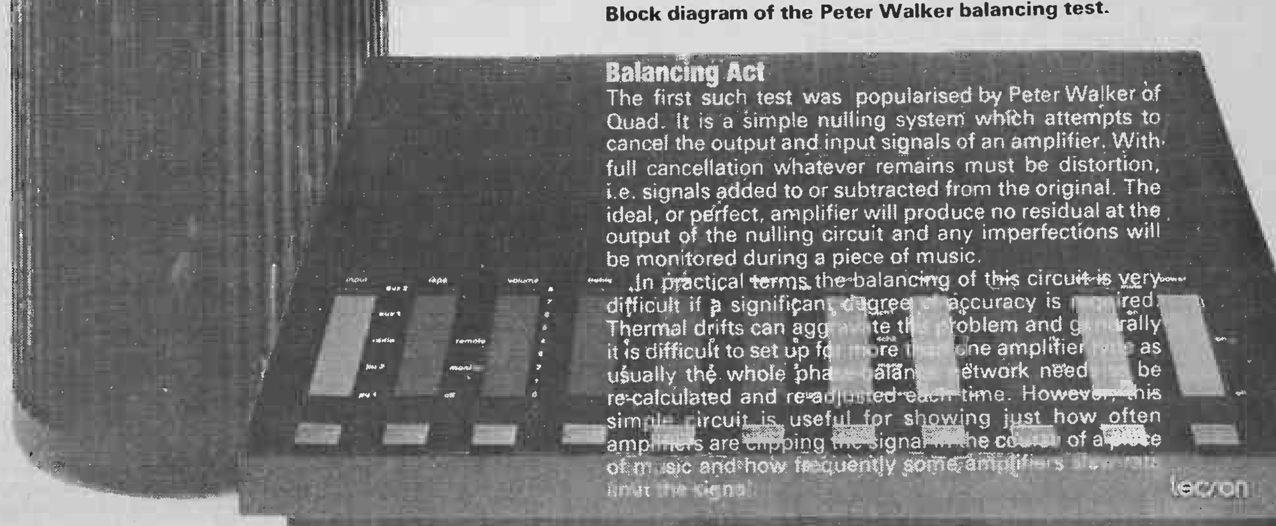
DESIGNING HIGH(EST)~FI AMPS

Audio amplifier design has come a long long way since its move into semiconductors. Stan Curtis, who has been responsible for such excellent examples of the art as the Cambridge Audio and Lecson, explains here the black arts of super-fi designing.

CAREFUL LISTENING TESTS have shown that while an amplifier that measures badly is *unlikely* to sound good one that measures well *cannot* be guaranteed to sound good. Thus it is apparent that the traditional measurements of power distortion and frequency response need supplementing by new and more powerful laboratory tests. Such tests should more closely relate to the conditions prevailing when the amplifier is driving realistic loads and using music signals rather than sine-waves, which of course represent only one special case.



Block diagram of the Peter Walker balancing test.



Balancing Act

The first such test was popularised by Peter Walker of Quad. It is a simple nulling system which attempts to cancel the output and input signals of an amplifier. With full cancellation whatever remains must be distortion, i.e. signals added to or subtracted from the original. The ideal, or perfect, amplifier will produce no residual at the output of the nulling circuit and any imperfections will be monitored during a piece of music.

In practical terms the balancing of this circuit is very difficult if a significant degree of accuracy is required. Thermal drifts can aggravate the problem and generally it is difficult to set up for more than one amplifier as usually the whole phase balancing network needs to be re-calculated and re-adjusted each time. However, this simple circuit is useful for showing just how often amplifiers are clipping the signal in the course of a piece of music and how frequently some amplifiers [illegible] limit the signal.

However, with such high current capability it is essential that the amplifiers have speaker muting to prevent switch-on "thumps" (or more accurately, earthquakes) and DC offset protection to protect the loudspeakers from the effects of 20 Amps of pure DC!

Offsetting Long Tails!

DC offset has been a major problem with many DC coupled amplifiers (i.e. those having no output capacitor). The offset voltage measured across the output terminals should not be any more than $\pm$ 50 mV. Once this voltage starts to rise the loudspeaker is subjected to a DC bias which moves the coil out of the central position. This in turn causes the coil to heat up and the power-handling capability of the loudspeaker to be restricted.

Eventually (and often sooner) the loudspeaker will blow. Many amplifiers have an offset voltage that is acceptable when the amplifier is first switched on but which starts to increase as the amplifier heats up. Such amplifiers are subject to thermal drift and this drift is normally due to a component mismatch in the circuit. The conventional amplifier, with a long-tailed pair at the input, is "theoretically" free of thermal drift as these will be automatically compensated for by the DC feedback.

However, this is on the assumption that the first two transistors (or FETs), forming the long-tailed pair, are perfectly matched.

The input offset voltage (upon which the output offset voltage is dependent) is related to the base-emitter voltage V_{BE} of each transistor.

$$\text{e.g. } V_{OS} = V_{BE1} - V_{BE2}$$

This difference can be made almost insignificant by using a dual-transistor or a monolithic integrated-circuit differential stage where matching is provided by the simultaneous adjacent fabrication of the two transistors. With discrete transistors, however, a close match is unlikely.

Similarly unbalanced output loading or mismatch of the collector resistors also increases the offset voltage. These mismatches also worsen the linearity (and hence the distortion) of this stage. Thus well designed amplifiers usually use 1% tolerance resistors in these positions and adopt balanced circuitry throughout.

The offset voltage is considerably reduced by the application of local DC feedback that occurs when emitter resistors are fitted. In this case;

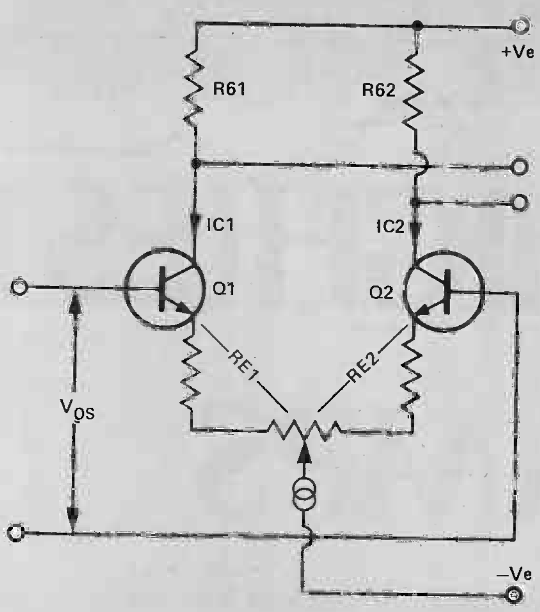
$$V_{OS} = V_{BE1} - V_{BE2} + I_{E1} R_{e1} - I_{E2} R_{e2}$$

and so by adjusting the balance between R_{e1} and R_{e2} with a trimpot a balance can be achieved.

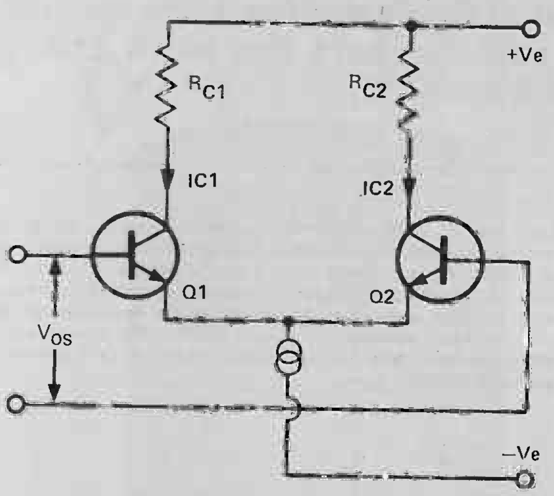
Emitting Resistance

Note that $R_e = R_E + r_e$ is the total external emitter resistance and r_e is the transistor dynamic emitter resistance. Thus it can be seen that in the earlier typical example of a stage without emitter resistors, an inbalance of r_e and r_e will cause a worsening of the offset voltage. More importantly it can reduce the common mode rejection of the stage. In this case the common mode is the HT lines with their ripple to appear at the output of the amplifier.

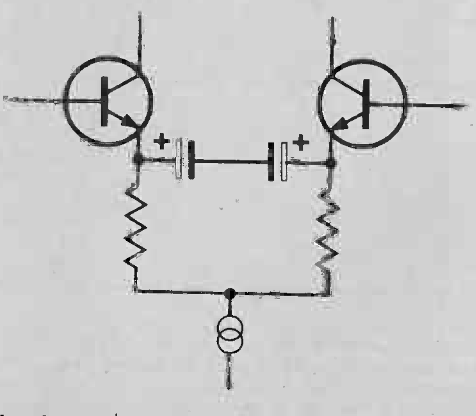
Of course the presence of emitter resistors also lowers the AC gain of the stage. For reasons to be discussed later this is not such a bad thing but in some amplifiers, for



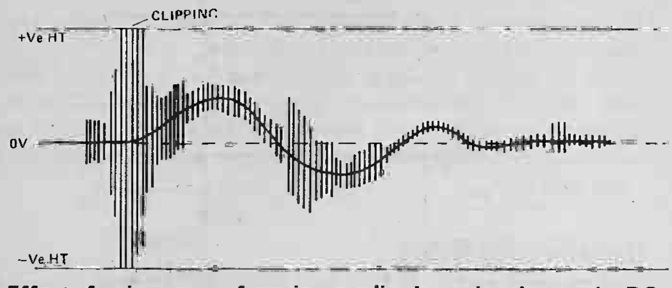
Differential pair with variable emitter resistances balanced by variation of the potentiometer.



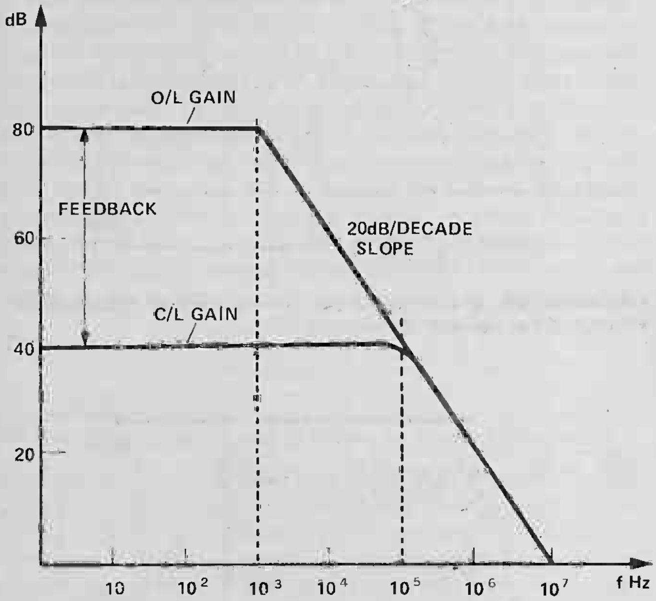
In this circuit the input offset voltage is related to the base-emitter voltage of this transistor.



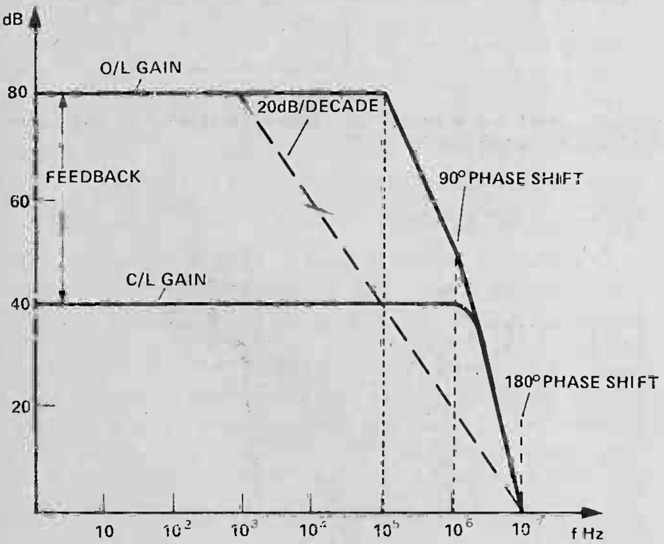
Recovering lost gain by use of bypass capacitors across the emitter resistances.



Effect of a sine wave of varying amplitude as signal upon the DC offset voltage at the output.



In the case shown in the diagram (unconditional stability) the open-ioop response of the amplifier is stabilised by rolling it off at a slow 20 dB/decade slope with a single pole at 1 KHz. This amplifier would be stable with any amount of resistive feedback. However it will be seen that at higher audio frequencies the amount of feedback available reduces and so the distortion of the amplifier will increase. For this reason many amplifiers are of the "marginally stable" type.



In this case the amplifier has a fast roll-off which allows an improved closed loop performance at higher frequencies but without careful compensation they are not stable under all conditions of feedback. Once the phase shift reaches 180° the amplifier will become unstable so it can be seen that our example is only marginally stable.

example the GAS Ampzilla. This gain can be recovered by using bypass capacitors.

Clip-on Off Set

Another situation where abnormal DC offset voltages occur is following a clipping overload of the amplifier. When many amplifiers are driven into clipping, the DC voltage of output rises towards one of the HT lines and then when the signal comes out of clipping the amplifier takes a finite time (often several seconds) to recover with the output DC voltage often oscillating between a positive and negative voltage before finally settling back to its nominal zero. Of course, when the amplifier is driven into clipping the normal negative feedback system ceases to control the amplifier.

Thus the DC instability is indicative of poor low frequency stability in the amplifier. Some of the worst (but not all) amplifiers in this respect, have separate AC and DC feedback loops and so have big eletrolytic capacitors (decoupling the AC loop) which take time to charge and discharge.

The old Cambridge P100 amplifier had this problem and the effect on the reproduction of a loud bass note can be imagined to be as waffley and uncontrolled as it is. Regrettably many amplifiers still suffer from this problem.

Quite often some amplifiers go unstable without their owners becoming aware of the problem. Sometimes the oscillation may be moderate in level and at a very high frequency; the only symptom being that the amplifier seems to run hotter and next-door's electric drill causes more TV interference than before!

Compensation Phase

To know why some amplifiers are potentially unstable it is necessary to understand the principles of phase compensation. Much of the low distortion characteristics of amplifiers are achieved through negative feedback. If the phase shift around the feedback loop reaches 360° at any frequency at which the loop gain (i.e. the overall amplifier gain) is unity the result is a self-sustaining oscillation at that frequency.

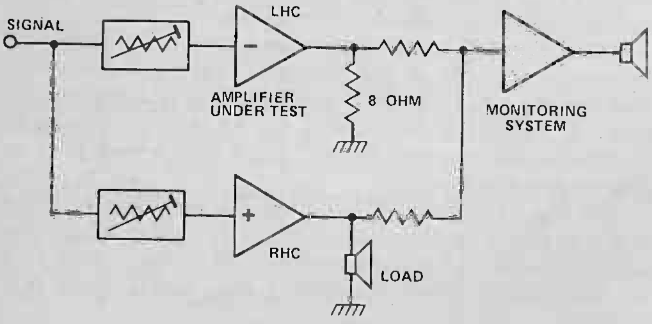
The phase-inversion to provide negative feedback produces a stabilizing 180° (eg. "out of phase") phase shift, but an additional 180° can be developed in the amplifier.

The phase shift developed through an amplifier is the combined phase shift of its several stages, and it usually develops 180° at higher frequencies. To ensure frequency stability under feedback conditions, phase compensation *reduces* the amplifier gain at those frequencies for which phase shift is high and it reduces high frequency phase shift by accepting a greater phase shift at low frequencies. This is accomplished by adding response poles and zeros in the form of resistor-capacitor networks (real or inherent in the transistors) in the amplifier circuitry.

Equally important, to the owner of an expensive pair of loudspeakers, is the problem of high-frequency instability. These days very few high quality amplifiers are so unstable that they break into oscillation. However, quite a few respected units are on the edge of instability and so can potentially become unstable following a shift in operating conditions or of output loading. ▶

Sum Theory

The author used another technique at Cambridge Audio to investigate the changes in amplifier performance that are dependent upon the loudspeaker load. The two channels of a stereo amplifier are driven in mono but one channel is converted to become non-inverting. The outputs of both channels are summed and the resulting signal is monitored. Theoretically both channels should transmit the signal in the same way and (for a given circuit design) any distortion, time aberrations etc. should be the same for both channels. It is often quite possible to balance the two channels (driving 8 Ohm resistive loads) so that the residual is inaudible. However when one 8 Ohm load is replaced by a real



Using one channel as an inverting amplifier to monitor distortion produced by the design.

"live" loudspeaker the residual betrays problems caused by the new load. In a refined form the test works well and it did reveal two interesting things;

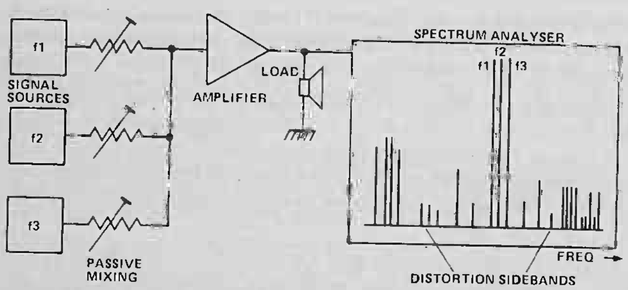
i) the two channels of the average amplifiers are rarely identical

ii) some amplifiers work better in the inverting mode than in the non-inverting.

These tests serve best to indicate imperfections without generating much data to help the designer. Two simple but useful tests do generate an awful lot of usable data. The first is an HF Intermodulation Test.

IM High

The conventional IM test uses an LF (50 Hz) and an HF (7 kHz) tone in a 4 to 1 ratio and then measures the sum-total of the sideband (e.g. distortion) components. This is of little practical value unless the amplifier is particularly non-linear.



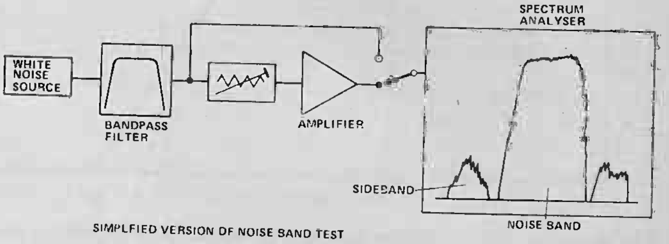
Intermodulation distortion testing using three frequencies.

The HF IM test uses two tones of, say, 15 000 Hz and 15 100 Hz and the resulting side-bands are viewed on a spectrum analyser. The frequencies can be altered to suit whatever simulation that is desired, e.g. two sopranos trying to sing the same note.

By repeating the tests at different levels it can be seen that many amplifiers have a performance which varies appreciably with signal level, and the test results correlate very well in identifying amplifiers with an aggressive "top end."

Dynamically Noisy

The second test is similar but attempts to measure the amplifiers' performance under more varying, "dynamic" conditions. A white noise source has a harmonic and amplitude structure which is variable and random and thus provides a better simulation of a music signal than does a sine-wave. The noise signal is passed through a bandpass filter to define its frequency response. The bandwidth and centre-frequency can be altered to suit the investigation as can the overall operating level. The output of the amplifier is fed to a spectrum analyser where the out of band components can be studied. Again this test is very useful for studying the effects of different loudspeaker loads but more significantly for subjecting the amplifier to random momentory "clipping" overloads.



Noiseband testing with a spectrum analyser, the sidebands produced by the amp are clearly visible.

A Channel and A Log

Possibly the most complex type of testing in use is a form of input and output signal comparison used by Analog Engineering Associates in the U.S.A. and, in a simplified form, by Mission Electronics in the U.K. AEA have developed a Transient Distortion measurement system that uses music as a test signal to evaluate circuit performance under dynamic conditions. This system consists of a dual channel analogue to digital convertor which is designed to have a resolution of 1 part in 65 536 or 0.0015%.

One channel of this is used to sample the input music signal whilst the second channel samples the output signal via a precision attenuator. The digitally encoded output of the convertors is fed to a computer memory system for later analysis. Instead of trying to compensate for the amplifiers phase and frequency response with a passive circuit (as in the earlier simple nulling circuit) a frequency sweep is made through the amplifier to generate a "transfer function" which the computer can use to correct the data during the subsequent error analysis.

Once a series of measurements have been made in the course of playing a passage of music the resultant data can be subjected to a series of Fourier and Coherence analytical calculations. Put simply, this means that any difference between the input and output