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JULY 1978

45p

Single Board SYNTHESISER

BUILD A

STEREO 10W AMP £8-45!

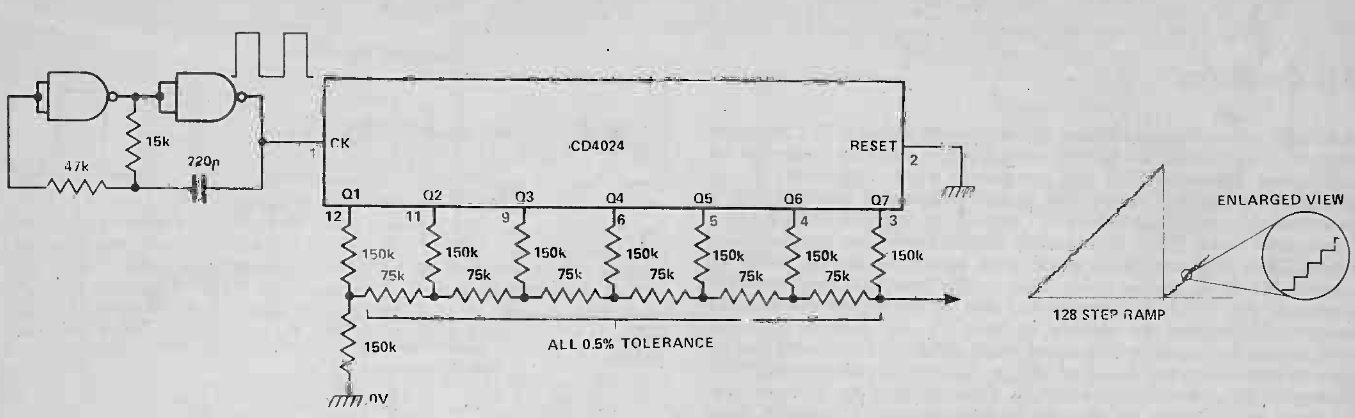
VFETS For All

Oscillator Design

Brains & Computers

Temperature Meter

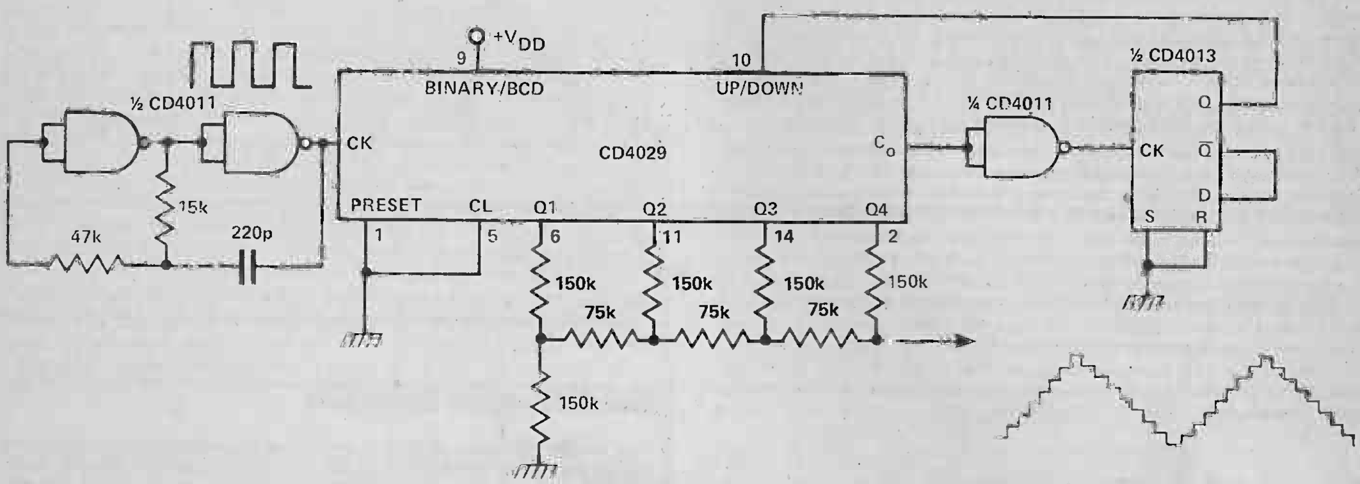
. . . NEWS . . . . PROJECTS . . . . MICROPROCESSORS . . . . AUDIO . . .



R-2R Staircase Generator

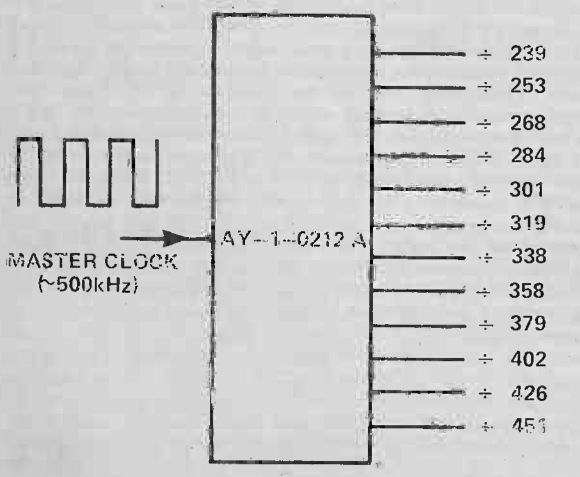
Waveforms can be constructed by building them up out of separate elements. In this case a linear ramp waveform is generated out of 128 steps. The CD4024 is a seven stage binary counter. It is being driven from a CMOS clock oscillator similar to that already described.

The Q1 to 7 outputs divide this clock frequency by 2,4,8,16,32,64 and 128 respectively and the divided outputs are then fed into an R,2R ladder network. This is in fact a Digital to Analogue Converter (DAC) and as the counter is merely counting up, then the converter will generate a linearly rising waveform made out of 128 steps. When the counter overflows, the ramp waveform resets and the process repeats itself.



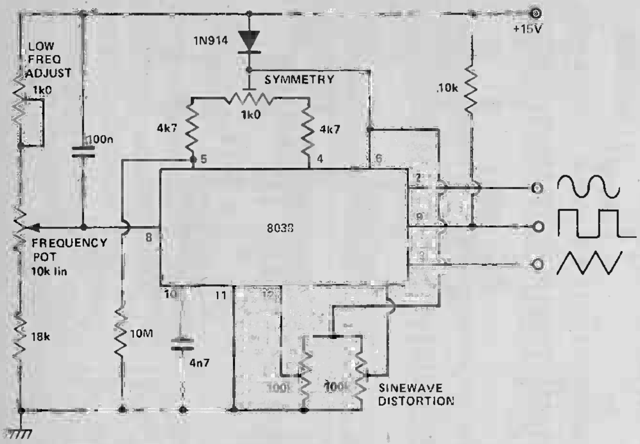
R-2R Triangle Generator

This circuit is similar to the previous except an up down counter is included. A clock signal is applied to the 4029 counter. When it has counted 16 clocks a Carry signal is generated. This clocks a D type flip-flop (4013), which changes state and reverses the up down mode of the 4029. Thus the circuit counts up, down, up, etc. The counting is converted via an R,2R ladder into an analogue output, a triangle waveform made up out of several steps.



Master Tone Generator

If you have ever made an electric organ, piano or string machine you would have had to produce the top twelve notes for the top octave by some means or other. More expensive organs might use 12 master oscillators which would be tuned to the top twelve semitones on the keyboard. This gives a nice free phase quality to the sound. The notes in the octaves below are made by using binary dividers and filtering. Very expensive organs would use an oscillator per note. This allows every note to be individually tuned and produces a very good sound quality. However, there is an easy way of producing the semitones and this is with a master tone generator chip. This is a pre-programmed divider having one input and twelve or thirteen outputs. A high frequency master clock is put into the chip which is divided by numbers ranging from 239 to 451. These divisions produce the semitone outputs. Thus, by using one master oscillator and one master tone generator a lot of the work of making an organ is removed. It is possible to produce more accurate intervals using 12 oscillators, but the speed and efficiency of the chip usually wins in the lower price end of the market.

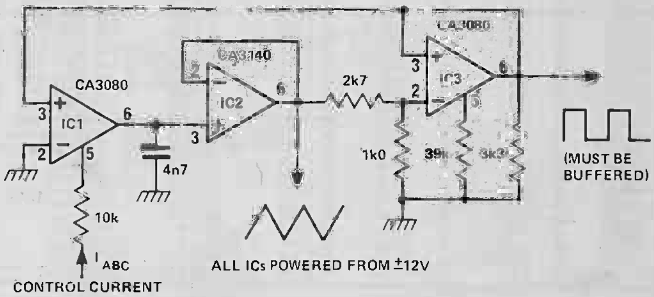


8038 Function Generator

There are several ICs available which perform some sort of oscillator function. One such is the Intersil 8038 which is a VCO with sine, triangle and squarewave outputs. The basic oscillator is a triangle squarewave device with a function generator to produce the sinewave. The frequency is voltage controllable but is not a linear function. The triangle symmetry and hence sinewave distortion are adjustable with a preset but change when the frequency is altered. Operation up to 1MHz is possible.

Triangle Squarewave ICO Using CA3080's

This circuit is very similar to that of the simple triangle/square oscillator, except that the operating frequency is controlled by a current IABC. (ICO stands for current controlled oscillator, as opposed to VCO, voltage controlled oscillator). Using this circuit, a sweep range of 10,000 to 1 is possible (for IABC 500µA to 50nA). The CA3080 is a two quadrant multiplier and the CA3140 is a MOS FET op-amp. IC1 is used as an integrator. IC2 is a high input impedance voltafe follower and IC3 is a Schmitt trigger. The CA3080 has a current output which in the case of IC1 is used to charge up a capacitor. The voltage on this capacitor is buffered by the CA3140 and fed into the Schmitt IC3. The CA3080 (IC3) forms a very fast Schmitt trigger but as it has a current output, it cannot be loaded in any way without effecting the operating frequency. The output of the Schmitt is used to make the entegrator inverting or non-inverting. Thus the operation is as follows. The integrator ramps upward until the positive hysteresis level is reached. The Schmitt flips over, the integrator then ramps downwards until the negative hysteresis level is reached. The Schmitt flips back and the process is

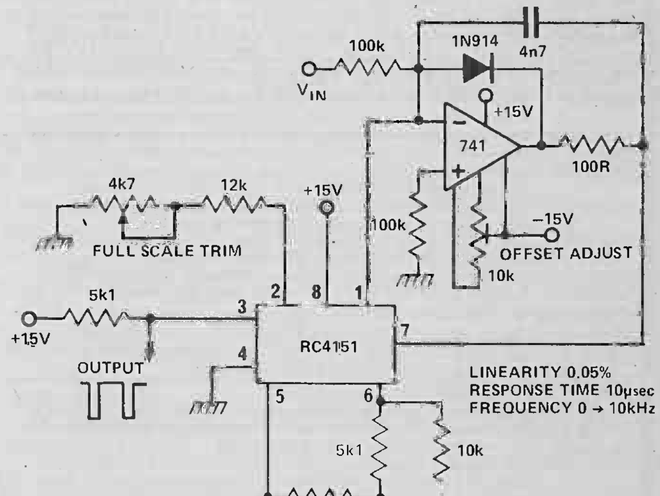


repeated. The ramp rate is determined by the size of the current IABC is linearly proportional to the oscillation frequency. At very low currents the triangle waveform may become very asymmetrical. This is due to current mirror mismatches inside IC1 and this device may have to be specially selected for continuous symmetry.

Precision Voltage Controlled Oscillator

The RC 4151 is a precision voltage to frequency converter. It generates a pulse train output which is linearly proportional to the input voltage. The linearity for the circuit shown is 0.05%. The IC compares the input voltage with an internally generated one. It dumps controlled pulses of charge into a Parallel RC network and compares this generated voltage with the input. If the input is greater it puts more pulses of charge into the RC network until the two are balanced. To get a larger sustained voltage in the RC network the frequency of the pulses must be increased. Thus the frequency of the pulses generated is made to be proportional to the input voltage.

The output is a pulse waveform and is intended to drive some sort of counting system, the chip being used as simple analogue to digital converter. It can also be used as a frequency to voltage converter. A maximum frequency of 10kHz has to be observed.



ETI

TEMPERATURE METER

A simple yet accurate temperature meter based on the LCD panel meter published in our March issue.

THE RELIABILITY of electronic circuits in the days of valves was, to say the least, poor by today's standards. The introduction of transistors and integrated circuits increased reliability dramatically. One of the main reasons for this is the reduction of power dissipation and the resultant lowering of temperature. Devices and circuits are now designed to minimise power dissipation as this allows a higher component density while increasing reliability. However, some circuits by their nature must dissipate high power and the semiconductor devices used must be kept within their temperature limits.

This temperature meter will allow transistor temperatures to be measured and the appropriate heatsink chosen. It is just as useful outside the electronic scene measuring liquid or gas temperature especially where the readout needs to be physically separate from the sensor.

Use and Accuracy

The accuracy of the unit depends on the calibration; provided it has been calibrated around the temperature at which it will be used, accuracy of 0.1 degree should be possible. We could not accurately check linearity but it appeared to be within 1° from 0° to 100°C.

However, other errors will affect this reading. If measuring the surface temperature i.e. a heatsink temperature, there will be a temperature gradient between the surface and the junction of the diode. Silicon grease should be used to minimise the surface-to-surface temperature difference. Also when measuring small objects, e.g. a TO-18 transistor, the probe will actually cool the device slightly. At high temperatures these effects could give an error of up to 5% (the reading is always less than the true value). If the probe is in a fluid (eg water) or air this problem does not occur.

Construction

Assemble the panel meter as previously described but omitting the zener diodes and R6 and R7. The value of R1 has also been changed. The decimal point drive should be connected to the righthand decimal point. The additional components can be assembled on a tag strip as shown.

We mounted our unit on a tag strip as shown in the photo. While we have not given any details, knocking up a case should be no problem. For a power supply we used eight penlight Nicad cells giving a 10 V supply. If dry batteries are used six penlight cells are recommended although a 216-type 9 V transistor battery will give about 300 hours of operation.

The sensor should be mounted in a probe as shown in Fig. 1 if other than air temperature will be measured. This provides the electrical insulation needed for working in liquids etc. It should be noted however that the quick dry epoxies are not normally good near or above 100°C and if higher temperatures than this are expected one of the slow dry epoxies should be used.

Calibration

To calibrate this unit two accurately known temperatures are required, one of which is preferably zero degrees and the second in the area ▶

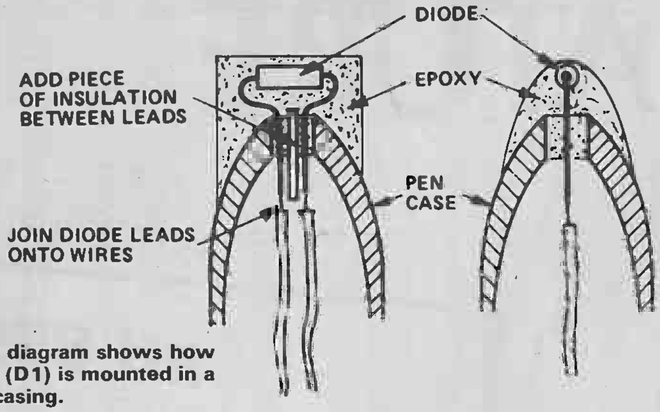


Fig.1. This diagram shows how the sensor (D1) is mounted in a ball-point casing.

HOW IT WORKS

While the voltage across a silicon diode is nominally about 600 mV it is dependent upon the ambient temperature and current in the device. The temperature coefficient is negative, i.e. the voltage falls with increasing temperature but fortunately is linear in the region of interest. The actual value varies with current and from device to device, but is typically —2.2 mV/° at 250μA.

By measuring the voltage across the diode with a suitable offset voltage to balance the voltage at zero degrees an accurate temperature meter results. The digital panel meter described in October has a stable reference voltage avaliable (between pins 1 and 32) of about 2.9 V; with the 10k resistor R11 this provides a constant current for D1 (the sensor). The offset voltage is also derived from this reference voltage by R12, RV2 and RV3. The panel meter is used as a differential voltmeter and measures the potential difference between the offset voltage and the diode. We have used two trimpots in series in the offset adjustment to give better resolution. If desired a 10-turn trimpot can be used (2k2). Adjustment of the three potentiometers allows the meter to be calibrated in either °C or °F with the upper limit of 199.9°F due to the panel meter over-ranging.

The power supply is simply a 9 V battery, and so the zener diodes and dropping resistors described in the panel meter article should be omitted.

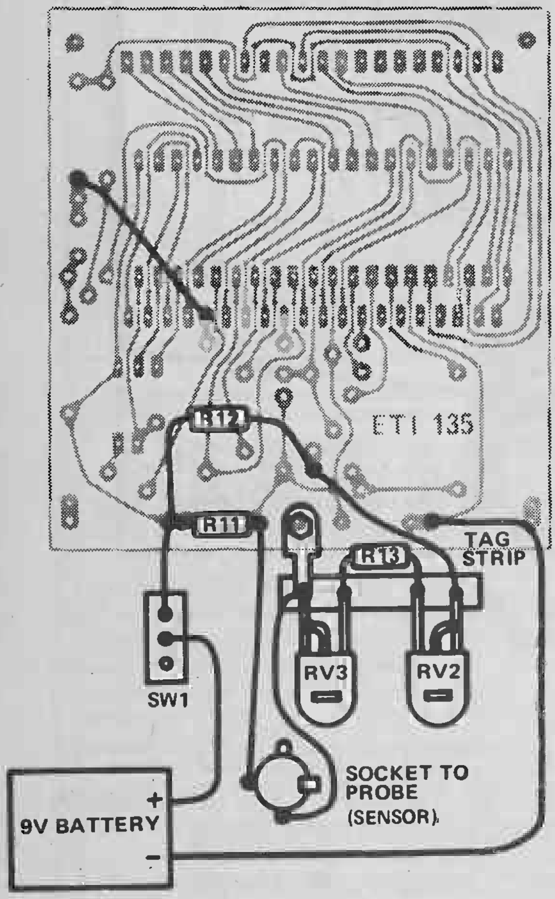
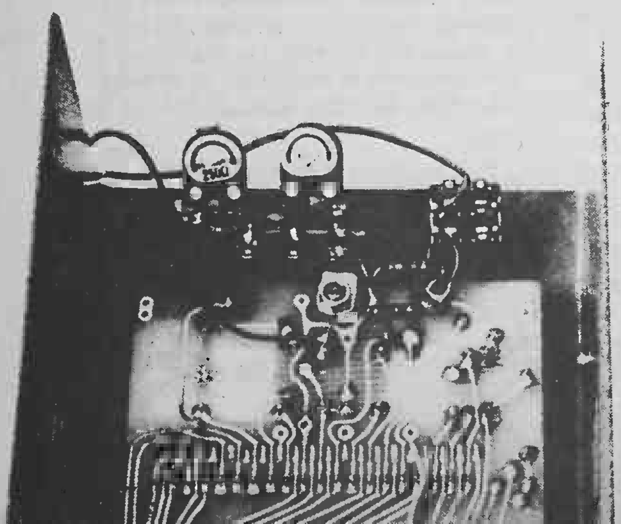


Fig.2. The external components associated with the panel meter to form the thermometer. For full details of the panel meter (foil pattern etc.) see the March 78 issue of ETI.

BUYLINES

The original LCD meter was based on the Intersil evaluation kit but since then a number of advertisers have put together kits for our project. Such a kit is probably the best place to start although the ICL7106 and suitable displays, the only components likely to prove difficult to find, are now available from most of the larger mail order firms advertising in ETI.



The photograph (left) shows the external components, detailed in Fig.2, in position.

PARTS LIST

RESISTORS	
R1, 11	10k
R2	47k
R3, 9	100k
R4	not used
R5	1M
R6, 7	not used
R8, 10	4M7
R12	27k
R13	5k6
POTENTIOMETERS	
RV1	1k 10 turn trim
RV2	2k preset
RV3	200R preset
CAPACITORS	
C1	100n polyester
C2	470n polyester
C3	220n polyester
C4	100p ceramic
C5, 6	10n polyester
SEMICONDUCTORS	
IC1	ICL7106
Q1	BC549
D1	1N914

MISCELLANEOUS
PCB as LCD Panel Meter (March 78 *ETI*), tag strip, LCD display, socket for display, box, switch and 9 V battery.

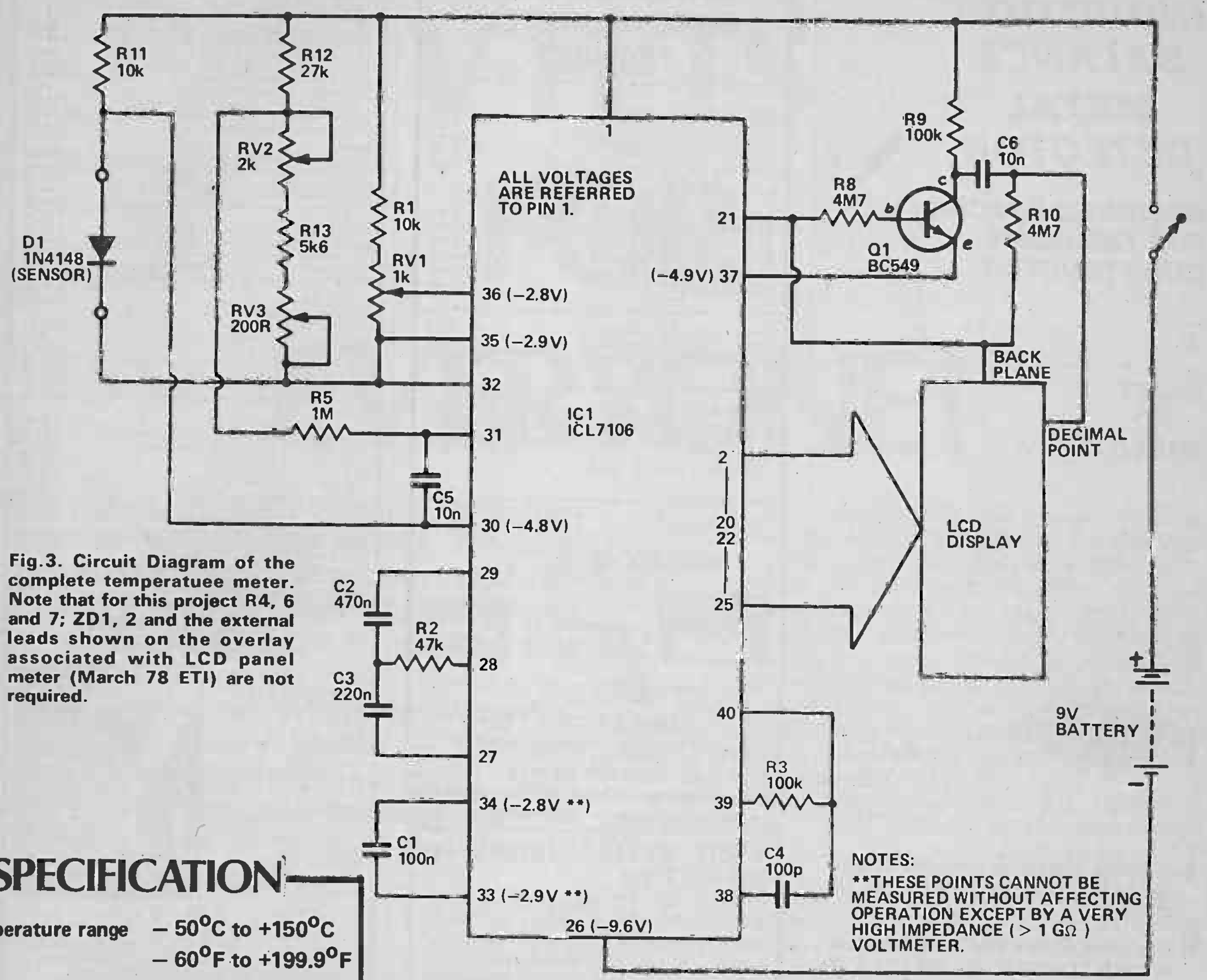


Fig.3. Circuit Diagram of the complete temperatuee meter. Note that for this project R4, 6 and 7; ZD1, 2 and the external leads shown on the overlay associated with LCD panel meter (March 78 ETI) are not required.

SPECIFICATION

Temperature range	– 50°C to +150°C – 60°F to +199.9°F
Resolution	0.1°C or F
Sensor	silicon diode
Power consumption	1.5mA @ 9 V dc

where the meter will normally be used and highest accuracy is required. For a general-purpose unit 100° C is suitable. The easiest way of obtaining these references is by heating or cooling a container of distilled water. However temperature gradients can cause problems, especially at zero degrees.

One method of obtaining water at exactly zero degrees is to use a test tube of distilled water in a flask of iced water and allowing it to cool to near zero. Now by adding salt to the iced water its temperature can be lowered to below zero. If you are very careful, the test tube water will also drop below zero without freezing (you should be able to get to about –2° C). However, the slightest disturbance at this temperature will instantly cause some of the water to freeze and the remaining water to rise to exactly zero, providing an ideal reference.

For a hot reference the boiling point of distilled water is very close to 100° C especially if the container has a solid base and is evenly heated e.g. on an electric hotplate.

The actual calibration is done as follows:

1. In the 0° C reference adjust RV2 and RV3 until the unit reads zero.
2. In the hot reference adjust RV1 to give the correct reading.

This should be all the adjustment required.

If zero degrees is not available, e.g. if setting up for ° F, the following method can be used:

1. In the cold reference use RV2 and RV3 to adjust reading to zero.

2. In the hot reference use RV1 to adjust the reading to indicate the temperature difference between the two standards. If freezing and boiling points are used, this will be 180° F.

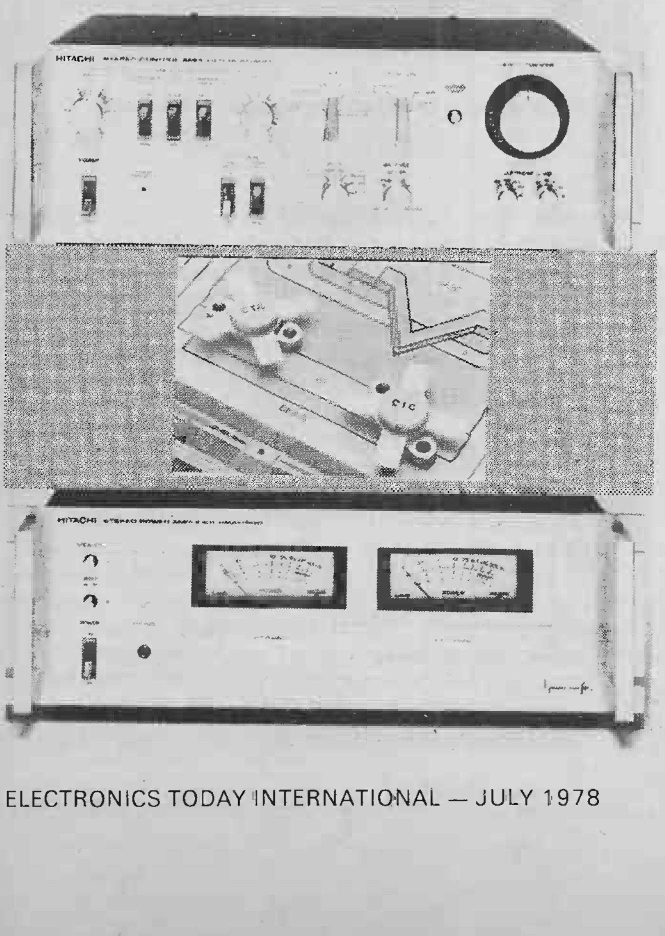
3. Now, back in the cold bath, adjust RV2 and RV3 to give the correct reading.

No further adjustment should be required. ETI

V-FETS FOR EVERYONE!

This article, by Wally Parsons, first appeared in our Canadian edition. We think that V-FETs represent a large step forward in power amplifier technology and so we have reprinted it, starting this month.

The first part of 'V-FETs for Everyone' covers the theory behind V-FETs and what their specifications mean. Next month, part two will describe how V-FETs are used at present and how to design V-FET circuitry.



SINCE THE SEMI-CONDUCTOR is precisely that, a battery across the ends of a *p*-type or an *n*-type bar will cause current to flow through the material, just as it does through a vacuum tube. If a *p*-type material is joined to the surface of an *n*-type bar, located between the battery terminals, a *pn* junction is formed, and if this junction is reverse biased, a space charge or field is produced of opposite polarity which will inhibit current flow, just as the control grid inhibits current flow in vacuum tube. Changing this reverse voltage causes a large current change, and therefore amplification results.

A simple FET (J-FET) is shown in Fig. 1. With a given drain — source voltage, maximum current flows under zero gate voltage conditions and at some reverse levels, no current will flow. Also, as in the vacuum tube, load characteristics are not reflected to the input circuit, because current is not controlled by carrier injection as in bipolars, but by voltage levels.

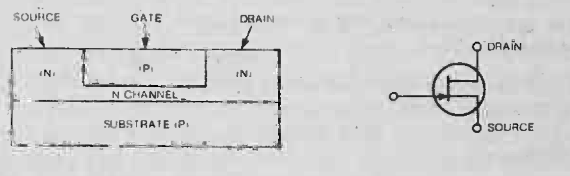


Fig 1: N-channel JFET construction and symbol

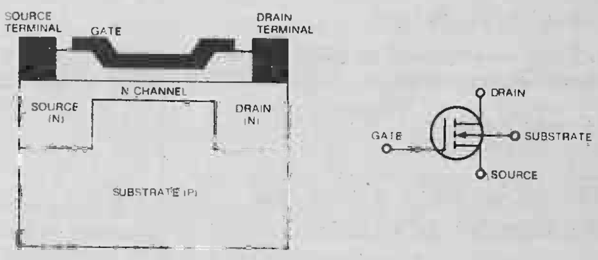


Fig 2: N-channel depletion horizontal MOSFET construction and symbol

A variation is the *M*etal *O*xide *S*emi-conductor *F*ield *E*ffect *T*ransistor. (MOSFET) (Fig. 2) a far more versatile device whose technology is virtually the cornerstone of modern computer technology, ▶

although it has had less use to date in linear applications such as audio amplification.

MOSFETS come in two basic types. In both types the gate consists of a metal electrode separated from the channel by a thin oxide layer. In the depletion type current flow is controlled by the electrostatic field of the gate when biased. Voltage relationships are the same as for the J-FET, except that when the J-FET is forward biased current will flow through the junction (after all, it *is* a *pn* junction). This does not contribute to amplification, and may even destroy the device. When a depletion MOSFET is so biased it may result in increased current flow and, provided current, dissipation, and breakdown ratings are suitable, the device may be driven on both sides of the zero volts point as with vacuum tubes. Unlike vacuum tubes under these conditions, the gate draws no cirrent and therefore does not require the driver to deliver power.

The enhancement type MOSFET shown in Fig. 3, is more widely used. The source and drain are separated by a substrate of opposite material, and under zero gate volts no current flows. However, when sufficient forward bias is applied to the gate the region under the gate changes to its opposite type (e.g. *p*-type becomes *n*-type) and provides a conductive channel between drain and source. Carrier level and conduction are controlled by the magnitude of gate voltage. Although J-FETS, and especially MOSFETS, have certainly delivered on their original promise, in one area they are particularly conspicuous by their absence, and that is in the area of power. Unfortunately, the channel depth available for conduction is limited by the practical limits on gate voltage. The lower current density has been the primary limitation due to the horizontal current flow.

VMOS

Recent years have seen the introduction and commercial use of Vertical Channel J-FETS, notably by Sony and Yamaha (Fig. 4). The vertical channel permits a very high width-length ratio, permitting a decreased inherent channel resistance and high current density. Unfortunately it exhibits the same disadvantages as the small signal J-FET, plus, in available devices, a very high input capacitance, ranging from 700pf to around 3000pf, limiting high frequency response. In addition, since they must be biased into the off condition, bias must be applied *before* supply voltage and removed after the supply if it is to be operated anywhere near its maximum ratings. This problem doesn't exist with vacuum tubes because of heater warm-up time, although some "instant-on" circuits impose heavy turn-on surges.

This necessitates a complex power supply, and indeed Yamaha, for example, uses more devices in the supply than it does in its amplifier circuits. However, the construction does make possible the design of complementary types and Nippon Electric and Sony both have high power devices available. Unfortunately, neither company seems anxious to make detailed information available, so there is little to disclose here beyond the fact that they are said to have characteristics similar to those of triode tubes.

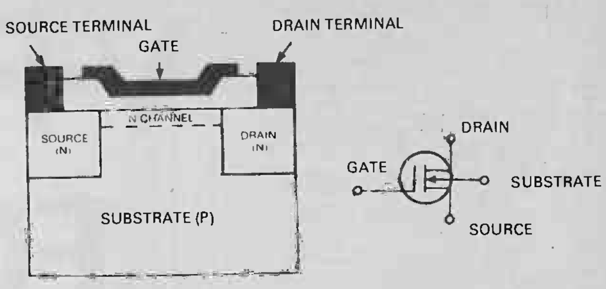


Fig 3: N-channel enhancement horizontal MOSFET construction and symbol

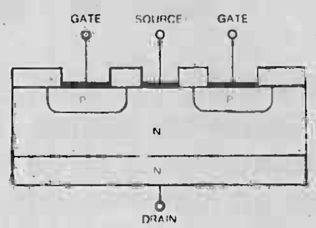


Fig 4: Vertical junction FET construction

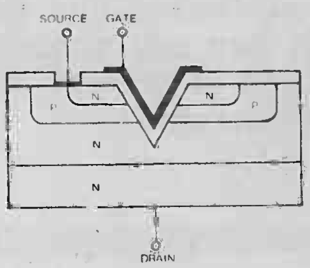


Fig 5: Vertical MOSFET construction (Siliconix)

However, the Vertical MOSFETS by Siliconix are readily available, at reasonable prices, and the manufacturer most generous in providing data. The following information is extracted from their application note AN76-3, Design Aid DA 76-1, plus device data sheets.

The Device

Notice in Fig. 5 that the substrate and body are opposite type materials separated by an epi layer (similar to high speed bi-polars). The purpose of this structure is to absorb the depletion region from the drain-body junction thus increasing the drain-source breakdown voltage. An alternative would have involved an unacceptable trade-off between increasing the substrate-body depth to increase breakdown voltage but increasing current path resistance and lengthening the channel. In addition, feedback capacitance is reduced by having the gate overlap n-epi material instead of *n*+.

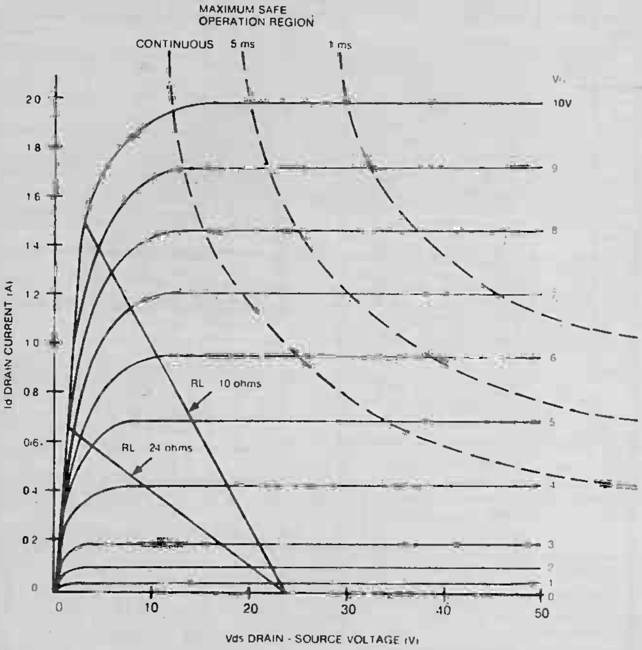


Fig 6: Output characteristics VMP1

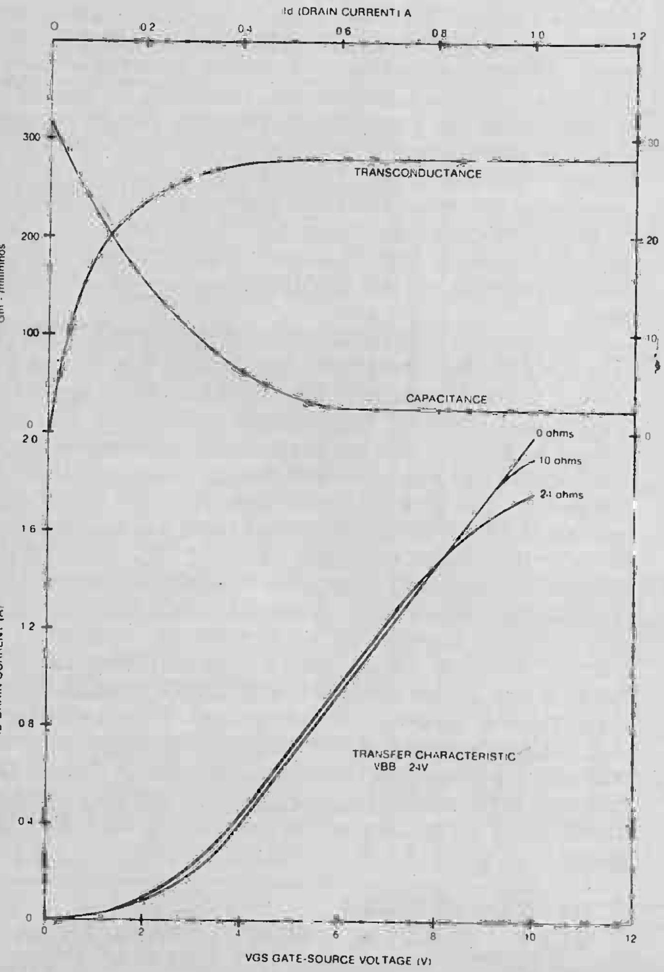


Fig 7: Other VMP1 characteristics

In manufacture, the substrate-drain and epi layer are grown, then the *p*-body and *n*+ source diffused into the epi layer, in a similar manner as the base and emitter of a diffusion type transistor. A V groove is etched through the device and into the epi layer, an oxide layer grown, then etched away to provide for the source contact and an aluminium gate deposited. It is apparent that this type of device allows current flow in one direction only; this is not always so with a similar type of horizontal FET, where source and drain may be identical in structure and of the same material. Therefore, no reverse current flows (we hope!) when used in switching applications, as was also the case with vacuum tubes.

In-circuit operation is refreshingly simple: Supply voltage is applied between source and drain, with the drain positive with respect to the source, under which conditions no current flows, and the device is off. This is an enhancement type device and is turned on by taking the gate positive with respect to the source and body. The electric field induces an *n* channel on both surfaces of the body facing the gate, and allows electrons to flow from the negative source through the induced channel and epi and through the substrate drain. The magnitude of current flow is controlled almost entirely by the gate voltage, as seen in the family of curves (Fig. 6 and 7) with no change; resulting from supply voltage changes above 10V.

Advantages

The vertical structure results in several advantages over horizontal MOSFETS.

1) Since diffusion depths are controllable to close tolerances, channel length, which is determined by diffusion depth, is precisely controlled. Thus, width/length ratio of the channel, which determines current density, can be made quite large. For example, the VMP1 channel length is about 1.5 us, as against a minimum of 5 us in horizontal MOSFETS, due to the lower degree of control of the shadow masking and etching techniques used in such devices.

2) In effect, two parallel devices are formed, with a channel on either side of the V groove, thus doubling current density.

3) Drain metal runs are not required when the substrate forms the drain contact, resulting in reduced chip area, and thus reduced saturation resistance.

4) High current density results in low chip capacitance. Also, unlike horizontal MOSFETS, there is no need to provide extra drain gate overlap to allow for shadow mask inaccuracies, so feedback capacitance is minimized.

In comparison with bi-polars, especially power devices, the advantages are even more impressive.

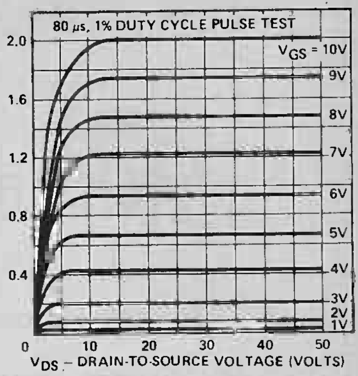
1) Input impedance is very high, comparable to vacuum tubes, since it is a voltage controlled device, with no base circuit drawing current from the driver stage. A 7 V swing at the gate, at virtually O A, represents almost O.W of power, but can produce a swing of 1.8 A in output current. This represents considerable power gain and will interface directly with high impedance voltage drivers.

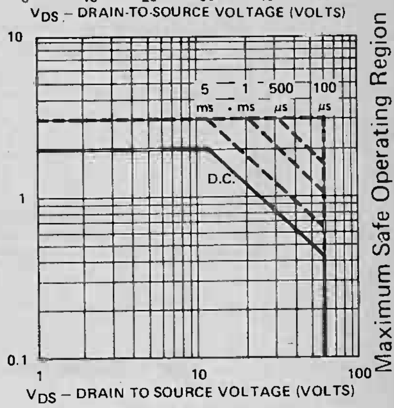
2) No minority carrier storage time, no injection, extraction, recombination of carriers, resulting in very fast switching and no switching transient in

No.		Symbol	Characteristics	VMP 11 Min	VMP 11 Typ	VMP 11 Max	VMP 1 Min	VMP 1 Typ	VMP 1 Max	VMP 12 Min	VMP 12 Typ	VMP 12 Max	Unit	Test Conditions
1	STATIC	BV_{DSS}	Drain-Source Breakdown	35			60			90			V	$V_{GS} = 0; I_D = 100\ \mu A$
2		$V_{GS(th)}$	Gate Threshold Voltage	0.8		2.0	0.8		2.0	0.8		2.0		$V_{GS} = V_{DS}; I_D = 1$ mA
3		I_{GSS}	Gate-Body Leakage			0.5			0.5			0.5	μA	$V_{GS} = 15$ V; $V_{DS} = 0$
4		$I_{D(off)}$	Drain Cutoff Current			0.5			0.5			0.5		$V_{GS} = 0; V_{DS} = 24$ V
5		$I_{D(on)}$	Drain ON Current*	1	2.0		1	2.0		1	2.0		A	$V_{DS} = 24$ V; $V_{GS} = 10$ V
6		$I_{D(on)}$	Drain ON Current*	0.5			0.5			0.3				$V_{DS} = 24$ V; $V_{GS} = 5$ V
7	SWITCH	$r_{DS(on)}$	Drain-Source ON Resistance*		2.0	2.5		3.0	3.5		3.7	4.5	Ω	$V_{GS} = 5$ V; $I_D = 0.1$ A
8					2.4	3.0		3.3	4.0		4.6	5.5		$V_{GS} = 5$ V; $I_D = 0.3$ A
9					1.2	1.5		1.9	2.5		2.6	3.2		$V_{GS} = 10$ V; $I_D = 0.5$ A
10					1.4	1.8		2.2	3.0		3.4	4.0		$V_{GS} = 10$ V; $I_D = 1$ A
11	DYNAMIC	g_m	Forward Transconductance*	200	270		200	270		170			m℧	$V_{DS} = 24$ V; $I_D = 0.5$ A
12		C_{iss}	Input Capacitance		48			48			48		pF	$V_{GS} = 0; V_{DS} = 24$ V, f = 1 MHz
13		C_{rss}	Reverse Transfer Capacitance		7			7			7			
14		C_{oss}	Common Source Output Capacitance		33			33			33			
15		t_{ON}	Turn ON Time**		4	10		4	10		4	10	ns	See Switching Time Test Circuit
16		t_{OFF}	Turn OFF Time**		4	10		4	10		4	10		

*Pulse Test **Sample Test
Pulse Test Pulse Width = 80 μsec, Duty Cycle = 1%

VMC





Figs 8, 9 & 10: Electrical characteristics of the VMP devices from Silconix, a freely available VFET.

class B and AB amplifiers. Switching time for a VMP1 is 4 ns for 1 A, easily 10-200 times faster than bipolars, and even rivalling many vacuum tubes.

3) No secondary breakdown, and no thermal runaway. VMOS devices exhibit a negative temperature coefficient with respect to current, since there is no carrier recombination activity to be speeded up with temperature. Thus, as current increases so does temperature, but the temperature rise reduces current flow. It is still possible to destroy the device by exceeding its maximum ratings, but a brief near-overload does not result in an uncontrollable runaway condition. Usually, simple fusing and/or thermistor protection is sufficient for maximum safety, and even this may be unnecessary with conservative design. Absence of secondary breakdown means that full dissipation can be realized even at higher supply voltages. In this respect they resemble vacuum tubes.

Available Devices

Seven devices representing three families are available. Types VMP-1, VMP-11, and VMP-12 are 2 A, 25 W dissipation devices intended for switching and amplifier use and differ only in voltage rating (60 V, 35 V, 90 V, respectively). Types VMP-2, VMP-21, VMP-22, are 1.5 A, 4 W devices rated at 60 V, 35 V, 90 V respectively, and are intended mainly for high speed switching, but would also be useful for low power amplifiers and as linear drivers for bi-polars, where the latter offer advantages. And finally, type VMP-4, 1.6 A, 35 W, specifically intended for VHF amplifier use. All except VMP-4 devices feature gate protection to withstand static discharges and over-voltages, and all are currently available except the VMP-4. All are *n*-channel. One hesitates to pass premature judgement, but if the millenium hasn't arrived yet, at least it might just be on the way.

Conditions

V-MOS Power FETs like signal MOSFETS, may be used in a variety of circuit arrangements to perform many different functions. However, no matter what the circuit, certain conditions, common to all applications, must be provided. These are supply power, loading, drive signal, and establishment of appropriate operating points. These are conditions necessary for amplification and since *all* active devices function as amplifiers, no matter what the total circuit function, the in-circuit performance of any device depends on the establishment of these conditions.

The electrical characteristics of the VMP1, VMP11, and VMP12, are shown in Fig. 8, and Fig. 9 and 10 shows them in graphic form.Since these are unidirectional devices, the source and drain are not interchangeable, and as they are *n*-channel devices conduction can occur only if the drain is positive with respect to the source, and high enough to ensure operation in the linear region, as with a vacuum tube, bi-polar transistor, or signal FET.

Like the vacuum tube, the absence of secondary breakdown allows realization of the full dissipation at any voltage supply up to maximum voltage and current ratings. Thus, where two different designs require the same dissipation but different voltage/load current, no derating is required. This is shown in the "safe operating area" curves. The only bi-polar transistor possessing this characteristic is the single-diffused type, which is also the least suitable for any application requiring wide bandwidth and/or high speed.

TO BE CONTINUED
NEXT MONTH SOME PRACTICAL CIRCUITS, AND HOW TO DESIGN YOUR OWN

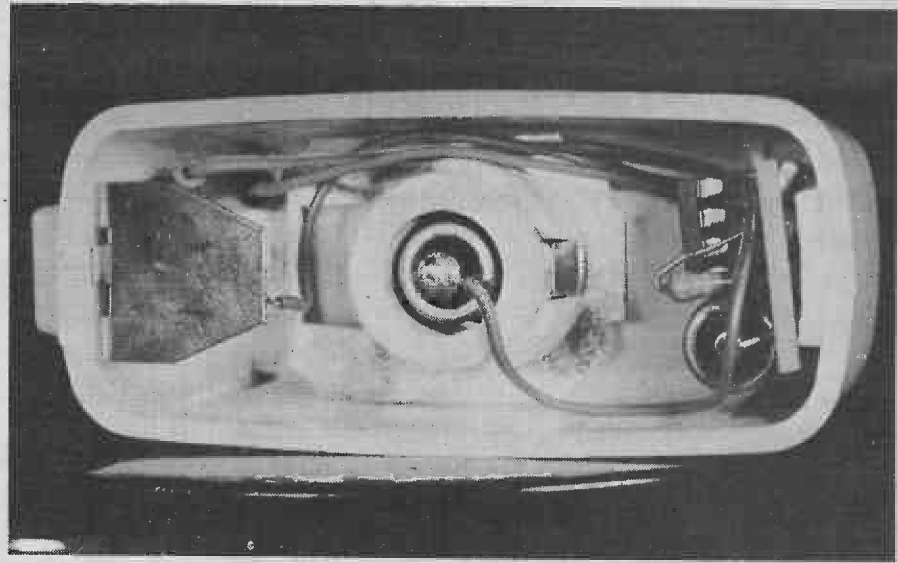
TORCH FINDER

A simple circuit which will help you find your torch in an emergency.

HAVE YOU EVER groped for the light of your life in the dark? Bow before you get any ideas about the type of project this is let's say that the light we refer to is your torch and in the dark this worthy can indeed save life and limb.

However, when the lights go out suddenly, it's often impossible to locate the torch because it's dark but you wouldn't be looking for the torch if it weren't dark . . . If this seems like a vicious circle it's here that ETI can help with our torch finder

The torch finder is designed to flash a LED that should be fitted within the body of the torch. The circuit consumes a minute amount of power and so can be left operational at all times. Using a high efficiency green LED means that inspite of the low power demanded by the circuit, the light output is quite adequate to locate the torch, quickly, in the dark.



Construction

Our photographs show how our circuit was fitted to the 'flat' torch we chose for the project.

With so few components construction of the PCB is straightforward, pay attention to the orientation of C1 and IC1.

Tuck the circuit out of the way within the torch, drill a hole to accommodate the LED and epoxy the device in place.

Insert the batteries and start hoping for a power cut so that the device can be put to the test. ETI

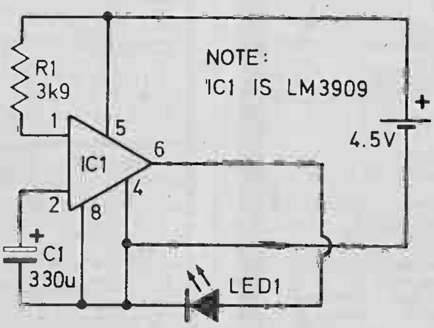


Fig. 1. Circuit diagram of the Torch Finder.

HOW IT WORKS

With only four components it's obvious that most of the action takes place within IC1. This is an LM 3909, a device specifically designed to flash LEDs.

In operation the IC will supply current to the LED, via an internal 12R current limit resistor, for only 1% of the time.

For the rest of the time the LM3909 draws only about 50μA while the capacitor C1 charges up via an internal network of resistors.

When the voltage on C1 reaches a preset level (this point can be modified by a resistor between pin 1 and supply), the LM3909 will supply a high current pulse to the LED; C1 is discharged.

For further details of the LM3909 consult the National Semiconductors data sheet on the device or the ETI data sheet in the September 76 issue.

BUYLINES

The most important aspect of this project is the torch. We used a flat type but any torch providing the 4.5 volts required by the torch finder could be used.

The rest of the components should be available from many local shops.

PARTS LIST

RESISTOR (¼w 5%)
R1 3k9

CAPACITOR
C1 330u 4 V Electrolytic

SEMICONDUCTORS
IC1 LM3909
LED1 Minature green type

MISCELLANEOUS
PCB as pattern, torch to suit

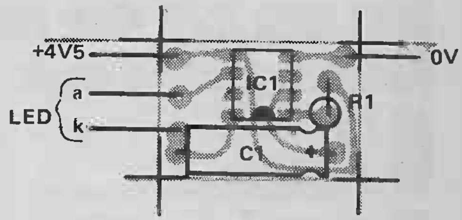
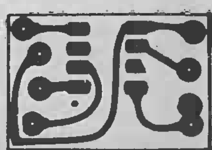


Fig. 2. Component overlay of the Torch Finder.



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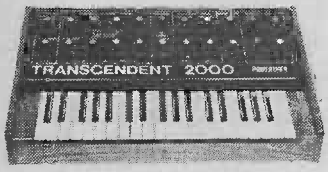

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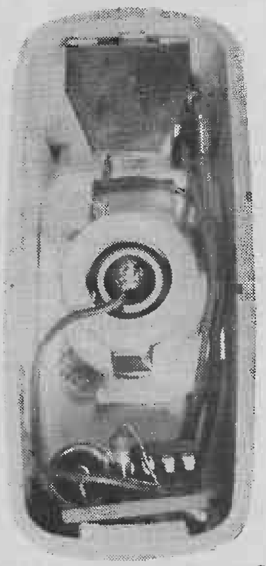

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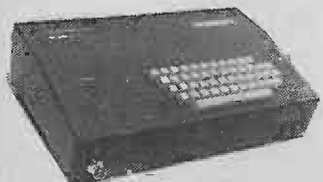

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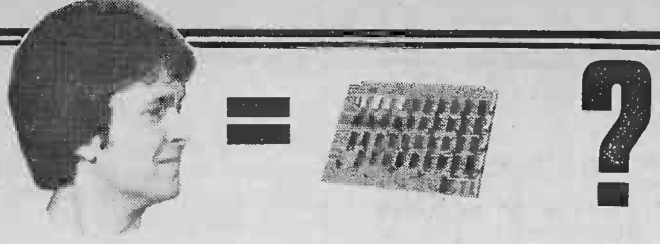


BRAINS AND COMPUTERS

BY S. McCLELLAND

Man is just a machine, or is he? Is his brain the ultimate mechanism or could it be improved by bio-engineering techniques? How can we develop artificial intelligence to match the abilities of our own brains and what do we have to learn from it?

EVEN IF THE HUMAN BRAIN is regarded as being a digital computer it must be considered to be far more complex than anything man can devise — or is likely to devise in the foreseeable future. In a volume of tissue far less than that of a football it packs some 10^{10} (that's 10 000 000 000) active elements, the nerve cells. In computer terms, its capacity to store information must run onto the 10 thousand megabit range *at least*.

Its organisation matches its abilities — on average in a normal human being it's been estimated that 1 nerve cell dies every 10 seconds throughout our lives. It is never replaced, for brain cells alone in the body cannot reproduce, and yet we never notice the loss since the brain is so well organised that many of its circuits are redundant and can be replaced by alternative channels should they fail — this has been the case even after serious injuries have been inflicted on the brain.

How much power does all this require? It's enough to make an engineer cringe — a meagre few watts!

What about the brain's higher capabilities — such as its capacity for inventiveness or 'original' thought? What was special about Mozart's brain circuits that enabled him to start composing music before he was 5 years old, or in Leonardo da Vinci's case, to design flying machines 500 years ahead of his time?

Sadly as yet we have no idea since so little is known about the brain!

Inputs and Outputs

All this uncertainty has not stopped a growing number of systems engineers and scientists from looking at the brain's organisation and operation (possibly with the idea of wanting to copy techniques in future systems!).

We can certainly find some aspects of central nervous system operation in common with computers. Both systems have of course what might be loosely termed 'input' and 'ouput' peripherals, for example. In the case of the brain the inputs are from the senses of the body, not only the primary ones of sight, hearing, smell and taste but also from many thousand of receptors near the surface of the body for various parameters such as temperatures and pressure.

Its outputs go to activate all the muscles in the body. This flow of information demands an enormous number of nerve fibres to convey it — up to a million nerve fibres are estimated to be associated with each major limb alone.

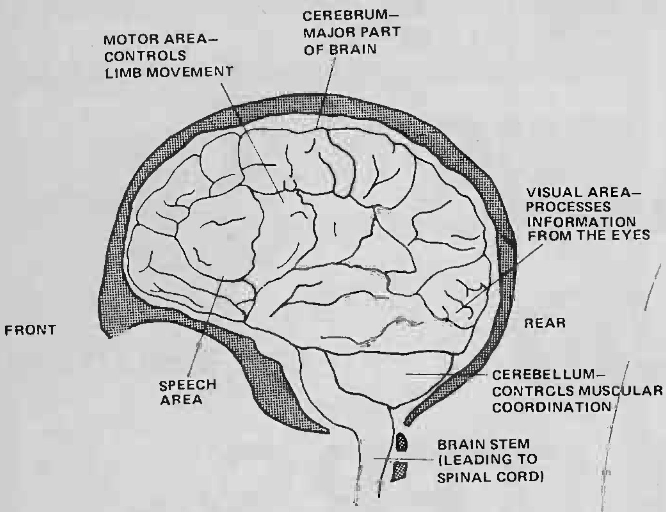
All of this of course prompts the question: "How does this information transfer take place?" To understand this we have to look at the most basic component of the whole system — the nerve cell itself.

Neurons

If we could remove a typical nerve cell from our bodies and look at it under a high power microscope, it would look something like Fig 1. Remember, this cell is probably only a few micrometres in diameter so what we're about to describe is a microscopic system-within-a-system.

The cell picks up signals from the other cells in its vicinity and these are fed down to the main part of the cell (containing the nucleus) and propogated along the long transmitter branch (axon) to the next cell.

It's along the inside of these long membranous



This is what your CPU looks like with the cover off. Note the I/O bus at the bottom (not S-100). The power supply connections have been omitted for clarity. The case is of a sturdy polymeric material and the main PCB fits it nicely.

branches that the electric impulses (or action potentials) are transmitted by the nerve.

The axon is no mere passive wire, however. If it was, the signals would soon be drastically attenuated by the leakage of the membrane to the outside after a very short travel. The cell membrance instead acts as its own signal booster to maintain the impulse at constant amplitude (about 100 mV) at any point on the axon. The action potential is either there or it isn't — there is no in-between state. A digital system? Perhaps. In fact, it's the frequency at which the action potentials are signalled that carries the information. We can now see why so many nerve fibres are needed to carry information. Each cell — and probably many others for the sake of redundancy — carries one 'bit' of information. The importance of this information depends on the frequency it is being signalled and it is likely that a high frequency signal establishes a higher priority than a lower frequency signal in a particular context — rather like signalling an 'interrupt' in a computer system.

Simple as it is, a frequency-dependent system carries its own problems. The sense organs must make amplitude-to-frequency code conversions for transmission down the fibre and at the other end, the brain must find a way of coping with a frequency-dependent signal.

A secondary point is that all the nerve cells concerned with a particular function or sub-function work in parallel. The advantages of parallel processing are fairly evident. It's faster than serial and has a higher signal-to-noise ratio (even if it does need more channels).

So we can visualise action potentials — small spikes of voltage — being flicked up and down all the nerve fibres in the body at varying frequency, but not nearly as fast as electrical impulses through cables. However, even in this, nature squeezes all the performance it can out of the human nervous system. Each nerve cell is wrapped in several layers of fatty tissue with 'nicks' or 'breaks' in the fat at intervals along the axon. The effect of these 'breaks' or 'nodes of Ranvier' as they are known is to increase the speed of transmission of the action potentials down the nerve axon to about 100 metres per second.

Delaying Tactics and Logic Gates

If neurons propagate the action potentials, then its the junctions between neurons (synapses) that route them. It's the synapses which work out if the incoming signals are of the right type and frequency to trigger the following cell to produce an action potential. From the point of view of the system, the synapses are the delay lines, one-way valves, triggers and gates all rolled into one.

It takes an electron microscope to even *see* the synapse regions and even then they don't look very special — they're merely bulbous terminations where nerve cells meet each other. Except that they don't meet each other — they're always separated by the absolutely microscopic distance of about 200 Å — so the action potential never gets across even the gap, let alone down the other side.

What actually crosses the gap is not the electric signal itself but very small quantities of hormones which are released from the transmitter bulb. The hormone crosses to the receptor membrane where (by a process that's not fully understood) it causes the generation of another action potential. Even across so small a gap the chemical transmission takes a finite time and is susceptible to interference by foreign chemicals (drug addicts please note — your synapse may be switched off!).

Some synapses, instead of generating an action potential in the receptor membrane actually inhibit it from doing so — so we've found the on-off switches for the nervous system. Can we identify Boolean logic gating arrangements in the nervous system? It's possible to speculate in those terms and certainly the basic mechanisms seem to be there, but unfortunately not enough is known about even simple neuron groups to permit an answer to this question.

Don't Believe Your Eyes!

The nervous system can do some very sophisticated things to the input signals it receives by way of data processing. It can, for example, selectivity inhibit the triggering of neurons that carry no useful information in favour of ones that do.

This so-called 'lateral inhibition' not only cleans up potentially noisy channels by making them more 'contrasty' but in some animals is known to help the eye resolve very efficiently the boundaries between dark and light edges in an image. It probably occurs in the human nervous system as well where it is thought to give rise to some of the more common optical illusions as a by-product.

So much processing sophistication backing up the senses means that the brain can work on far less sensory information than it usually gets. For example, the brain really only requires a few per cent of the data it receives from the eyes in order to form a valid judgement as to the nature of the image. The same applies to the ear — speech has to be very badly distorted before the brain cannot recognise it. There is obviously a very close and complex interaction between the senses and the memory, which is continually generating possible 'best-fit' models to match the latest information received. Each model is discarded until the brain is satisfied with the result.

Our senses show a fantastic sensitivity to the world around us — we *can* hear a pin drop in a quiet room. More staggering still, the vibration amplitude of the ear drum which the minimum audible sound creates is less than *the diameter of one hydrogen atom . . .!*

Down Memory Lane

Digital computers have clearly-defined memory locations which are usually addressed under the control of a clocked pointer in the system. The human brain on the other hand seems to have no all-powerful organ of memory — attempts to find one have so far proved inconclusive. Rather, memory is a property of the system as a whole.

Secondly, data storage on a computer tape or disc is permanent until deliberately erased but information flow through the brain is far more dynamic and its retention more selective. Information floods into our brains from our senses at every living moment. Seen in this light it is neither desirable nor even possible to store it all. 'Store only the information that is important' the brain says to itself — but what is counted as being important?

Basically, we pick out the information about the *changes* in our environment, because it's the changes in it which may be threatening our immediate survival.

On a motivated level, we can store items deliberately. We remember by repetition (e.g. a telephone number). Most importantly we store information which is associated with something which has caused us great pain or pleasure in the past. How do we recall information once stored? It's clear that association plays a critical role. After all, we store not isolated events but connected ones — 'trains of thought' if you like. The memories are recalled when the right key of stimulus is provided. This stimulus may well be a piece of information associated with the group.

For example, the question "What do you remember about November 22nd 1963?" would probably elicit a blank rely from most people until (as various commentators have pointed out) that they are told its the day when the President John F. Kennedy was assassinated. Many people can recall where they were or what they were doing — it's a memory that persists over 14 years because it is associated with such a traumatic incident.

In this way we can visualise the human memory almost as 'conglomerates' of memories — pieces of information tied together in some fashion only requiring the right input trigger to push it all out.

Some very intriguing hypothesis about how the memory operates have been suggested. One exciting and topical suggestion is that it records information as a hologram records 3-D images in laser light. A particular part of the image is not localised to a particular part of the hologram — in fact even a fragment of the hologram can theoretically recreate the entire image, a property which makes it very similar to the brain.

We must wait for more basic information on the brain to confirm or disprove this.

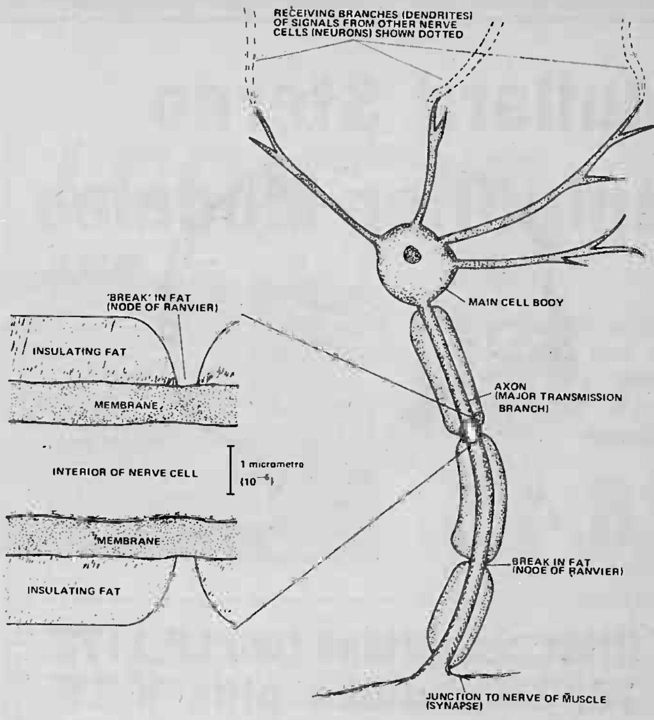


Figure 1: What a nerve! A typical nerve cell examined.

Tuning into Brain Waves

We can get some idea of what all this electrical activity is like by strapping electrodes — connected to a sensitive amplifier and chart recorder — to the skull.

We will obtain a rather confusing output of signals — referred to as an *electroencephalogram* or EEG. The EEG is usually a very weak signal — a few tens of uV amplitude at a range of frequencies mostly under 30 Hz, although higher frequency components are present.

The most well-known component of the EEG is the α-wave. Present in about 90% of all individuals, this signal (with a frequency between 8 Hz and 13 Hz) is at its most active when the subject is relaxed and his eyes closed. It disappears as soon as the subject opens his eyes or starts to concentrate on something like mental arithmetic.

What does it mean? Basically, we don't know. Nor do we know where or how it's generated, although its source (there may be more than one) *seems* to be located to the upper rear of the brain. Correspondingly little is known about the other EEG components.

Although the EEG doesn't give a great deal of information about the working of the brain (indeed we'll probably have to wait until further studies of the brain explain the EEG!), it has found great use in diagnosis of brain disorders such as epilepsy. But could the EEG have a more fundamental significance than that? My own pure piece of speculation — for what it's worth — is that it's the brain's clock, although it's too low in frequency to cope with many of the fast muscular actions of the body. Even so the 'ticking' of a brain might have a biological significance similar to a digital system's 'clock frequency'!

FURTHER READING: For those who would like to read more fully about the brain, Professor Steven Rose's book "The Conscious Brain" (Penguin paperback edition £1.25) offers a very readable account. ETI

MUSIC SYNTHESIZER

Designed for ETI by Tim Orr, late of EMS and father of some of their range, our new Transcendent 2000 is a new concept in DIY synthesizers — a single board design! Apart from the PSU all the circuitry is contained on one easily assembled PCB. Ideal as on-stage machine, the 2000 has plenty to offer the experimenter as well.

THE SYSTEM BLOCK DIAGRAM is show in Fig 1. The system is pre-patched, but is capable of generating a vast variety of different effects by virtue of its 9 switch functions, 22 pots and 6 input jacks.

The VCO is the primary sound source. It produces either a ramp or a square waveform. A ramp waveform has both odd and even harmonics, the square wave has only the odd ones.

However, the VCO has a shape modulation circuit which can turn the ramp into a triangle or the square wave into a thin pulse. Thus, a wide range of harmonic structures is available. Also, this shape modulation can be controlled by a sine wave produced by the slow oscillator. By dynamically modulating the shape of this waveform, it is possible to greatly enrich the sound quality of the VCO. (For instance, if the mark space ratio of the squarewave is modulated at about 1HZ, the output can sound like two VCO's.)

Pitch It Well

The pitch of the VCO can be controlled by several sources. A 'pitchbend' pot enables notes to be bent up or down by about ½ an octave. A dead band in the centre of the motion enables the turning to be restored. An external input socket with a sensivitivy of 1V/octave allows a sequencer to be connected.

A manual tuning pot, (screwdriver adjustment), is provided so that the synthesiser may be tuned to the pitch of other instruments. Vibrato may be added, the speed being that of the slow oscillator. The squarewave also from this oscillator can be used to produce 'two tone' effects.

The VCO pitch can be controlled by the ADSR envelope or by random pitches generated by the noise sample and hold circuit. All these controls can produce a wide variety of interesting sounds but the machine really comes alive when it is controlled by the keyboard. This keyboard is a 3 octave, (37 note), C to C device.

It is monophonic, that is it only plays one note at a time, this being the highest note selected. It generates two outputs, a pitch signal and a gate voltage. The gate controls the AD and ADSR sections, the pitch, the VCO and the VCF.

The pitch voltage is a transitional piece of information which has to be remembered in an analogue memory, a sample and hold device. The droop rate of this S & H is about 15 minutes per semitone. This is quite good.

Gliding In

A portamento circuit has also been included into the sample and hold so that glides, as opposed to abrupt changes, between notes can be produced. A transponse switch, ± 2 octaves operates on the VCO. This gives an effective keyboard control range on the VCO of 7 octaves. The keyboard S & H can be controlled by either the keyboard gate or by a pulse from the slow oscillator. This latter mode of operation makes the VCO pitch move in a series of exponentially decreasing steps between the notes played on the keyboard.

Noisy Output

The output of the VCO is mixed with a noise signal and an external audio signal and fed into the VCF. This is a voltage controlled state variable filter, with both bandpass and lowpass outputs. The resonance is manually controllable from a Q of 1 to infinity, (self oscillation).

The resonant frequency may be controlled by either a manual pot, a sweep voltage from the slow oscillator, an external footpedal control, the keyboard voltage or a random voltage or an attack decay envelope.

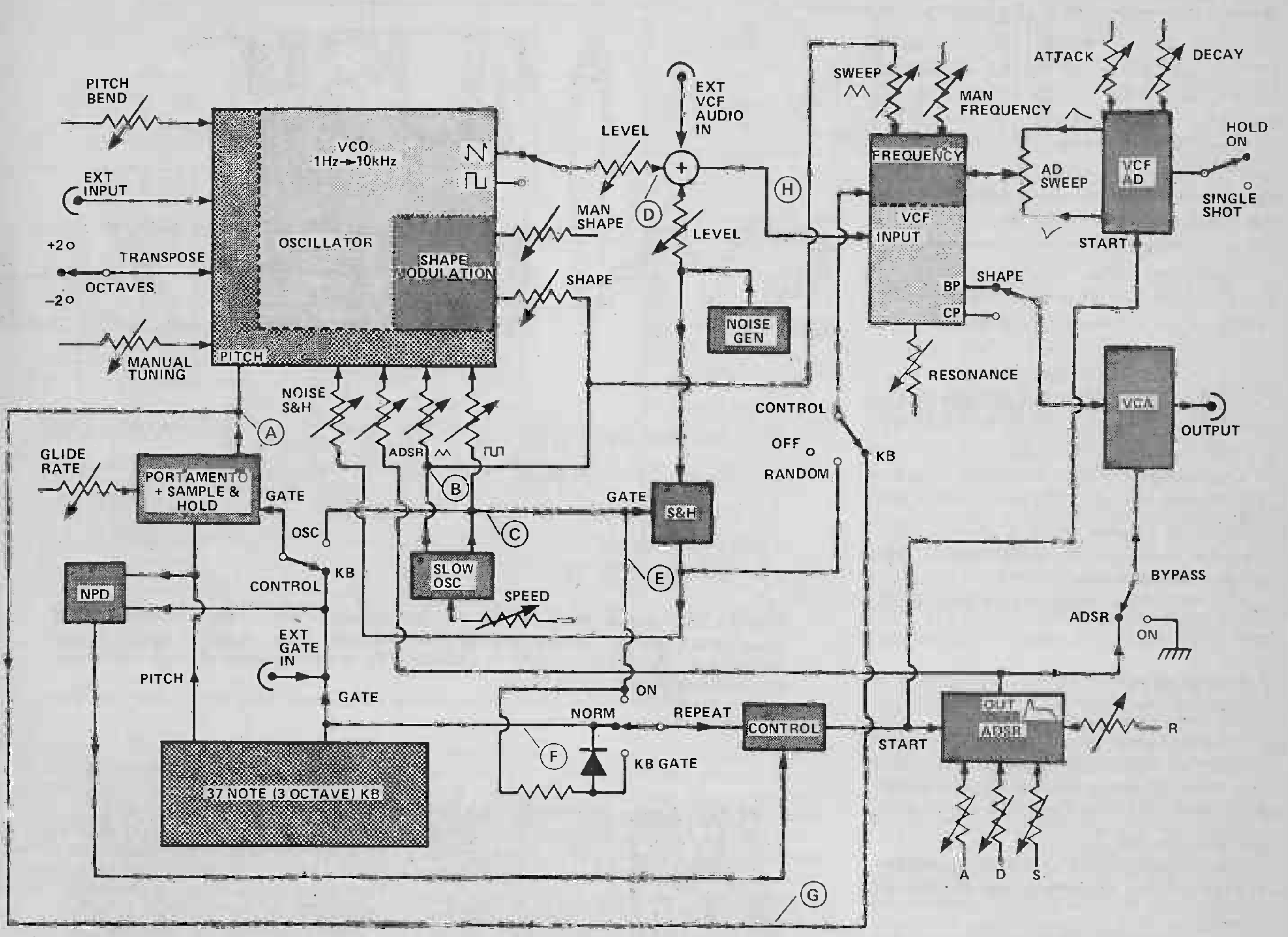


Fig 1. Block diagram for the Transcendent 2000 synthesiser. Each of the separate circuit blocks is described in detail in the appropriate section. The letters in circles correspond to the points where we broke up the circuit to make it easier to understand. These references are also given on each of the block circuits where appropriate. So if you wish to stick the whole thing together you can do so. All the components which make up this block diagram are assembled on a single PCB.

There are very few musical instruments that have any sort of dynamic filtering. The Attack/Decay envelope can be used to produce a rising or falling frequency sweep in the VCF, and by varying the AD time constants, a wide variety of sounds may be generated.

The output of the VCF passes through a voltage controlled amplifier to the output socket. This can be on all the time, or it can be controlled by an ADSR envelope. This in turn amplitude modulates the VCF signal so that the output has the envelope of the ADSR voltage.

Sustaining Interest

The ADSR is a waveform generator, and is initiated by the arrival of a gate voltage. When this arrives it generates a rising RC exponential waveform with a time constant determined by the Attack pot.

When it reaches a predetermined level it then begins a RC decay towards a sustain voltage. The 'decay' rate is controlled by the 'Decay' pot and the sustain level is set by the 'Sustain' pot.

It sits there until the gate voltage is removed, (when the keyboard is released), whereupon it decays towards ground with a release time constant, this being determined by the 'Release' pot.

If at any time the gate is removed the ADSR goes into its release mode. Time constants of 5 mS to 2 S and sustain levels of full on to completely off are obtainable.

On Key

The ADSR can be started by the keyboard, or it can be continuously repeated by the slow oscillator, or it can be repeated by the slow oscillator gated by the keyboard, as can the Attack Decay, (AD), circuit.

This has two modes of operation: single shot, whereby it attacks to a predetermined level and then decays on its own to ground, or HOLD ON, whereby it only decays upon the removal of the gate signal. Sometimes when playing pieces, it may be necessary to release a key before a new note can be generated. If the piece is particularly fast then errors, in the form of missing notes can occur. However, a device called the New Pitch Detector (NPD), can help eliminate this. When a new pitch is detected, it generates an additional gate signal which is used to reset both the AD and the ADSR.

Repeating?

Both the AD and ADSR circuits can be controlled by the REPEAT function. This is a single piece of electronics to enable repeating envelopes to be

PSU

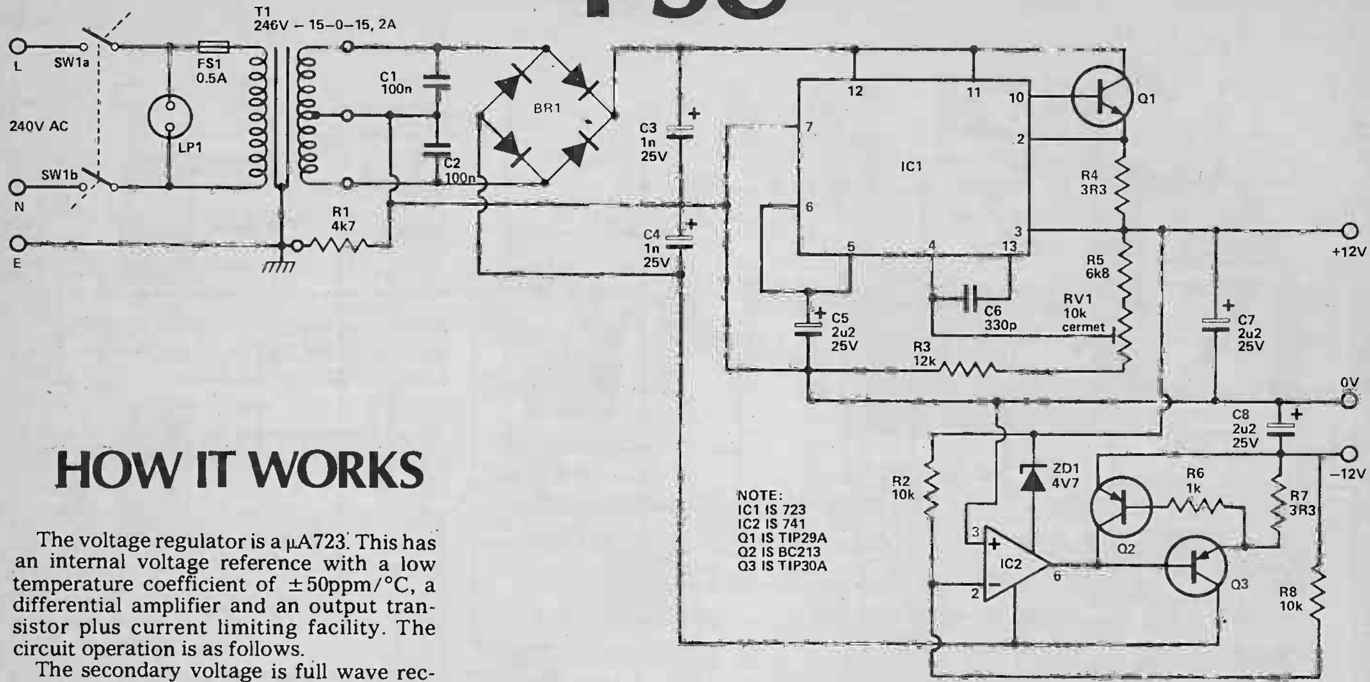


Fig. 2. The circuit diagram for the synthesiser PSU. This is capable of supplying a higher current than is really needed here, in order that it is not 'stretched'. A stable supply is essential in a synthesiser design with any pretensions to quality at all.

The components for this are made up onto their own PCB, and will not appear on the main overlay.

HOW IT WORKS

The voltage regulator is a µA723. This has an internal voltage reference with a low temperature coefficient of ±50ppm/°C, a differential amplifier and an output transistor plus current limiting facility. The circuit operation is as follows.

The secondary voltage is full wave rectified and smoothed by C3 and C4. This provides positive and negative unregulated rails.

IC1 is the voltage regulator. A reference voltage of about +7V5 is fed into the noninverting terminal, pin 5.

An external power transistor Q1 is used to regulate the positive supply rail so that IC1 remains cool. Short circuit current limiting at 200 mA is provided by R4. Either or both output rails may be shorted out without damage.

Negative feedback to the inverting terminal pin 4, IC1 sets the output voltage. C5 reduces noise on the supply, C7 reduces the impedence at high frequencies. RV1 sets the output voltage and this should be set to +12V000! (or as near as you can measure) VR1 is a cermet preset, which has a low temperature coefficient.

The negative rail tracks the positive rail. The power is handled by Q3, the current limiting by Q2 and the feedback by IC2. Resistors R2, 8 determine the negative rail voltage. As they are both 10k, 0.5% tolerance, the negative rail should be the same magnitude as the positive rail to within 0.5%.

A very stable power supply is needed for a synthesiser. A small power supply voltage variance can produce alarming effects on the oscillator pitch. Also, if the machine gets hot inside, the oscillator will drift in pitch. The current drain per rail is only 80 mA and the heat dissipated by Q1 and Q2 is 0.9 watt each. This will not cause any heating problems.

On load the unregulated rail is 23 V (at 250 VAC input), and so the mains can drop to about 190 VAC before PSU drop out occurs. The unregulated ripple is 500mVpp and so the output will be less than 0.5mVpp.

When there is no load on the power supply, a small high frequency sawtooth can be seen on the —12 V output, but this goes away completely when loaded.

generated. The outputs from this circuit then drive the AD and ADSR. With the repeat switch in the ON position, the slow oscillator square wave output continuously gates the AD and ADSR.

In the NORM position, the Keyboard gate is the control. In the KB GATE position, the slow oscillator is only allowed through when the keyboard is pressed. Using the REPEAT function it is possible to simulate a fast plucking 'banjo' effect.

A DeeEssAhh?

The ADSR is similar in operation to the AD circuit except that it has two more parameters to play with.

Upon receipt of the keyboard gate the waveform attacks until it reaches a predetermined level. Then it decays to a level known as the sustain level, which is manually controllable. When the keyboard gate is removed, the release mode occurs. The A, D, R are all time constants, the S is a level. Whenever the keyboard gate is removed the device goes into its release mode.

This type of envelope is particularly useful and versatile. With the sustain level at 10, there is no DECAY phase and so an ATTACK, HOLD ON, RELEASE envelope is generated. When the sustain is set at 4, there is an attack and a decay to the sustain level, which is held as long as the keyboard is held down and then a release. Using this setting it is possible to simulate a piano sound, by using a fast attack moderately slow decay and a faster release.

The faster release simulates the damping of the strings as the piano keyboard is released. When the sustain level is set at 0, then the unit becomes an attack decay envelope which can be used to produce short sharp plucked sounds. To get a new envelope it is necessary to get a new keyboard gate signal. This either means lifting your finger off of one note before pressing the next, or a new gate can be automatically generated by switching to the NPD mode.

Moving On

The pre-patched nature of the design is intended to suit stage and other performance applications. The resulting sound from the synthesiser can be quickly and easily modified once the function of the controls aand their effect has been mastered. Take a look at the diagram on page 44 for starters.

Another helpful aid to using a synthesiser is a 'program sheet'—simply a way of recording clearly but instantly a particular set of control settings to allow you to reproduce that sound again at a later date. Such sheets will be available for the Transcendent 2000—details next month. ▶

VCO

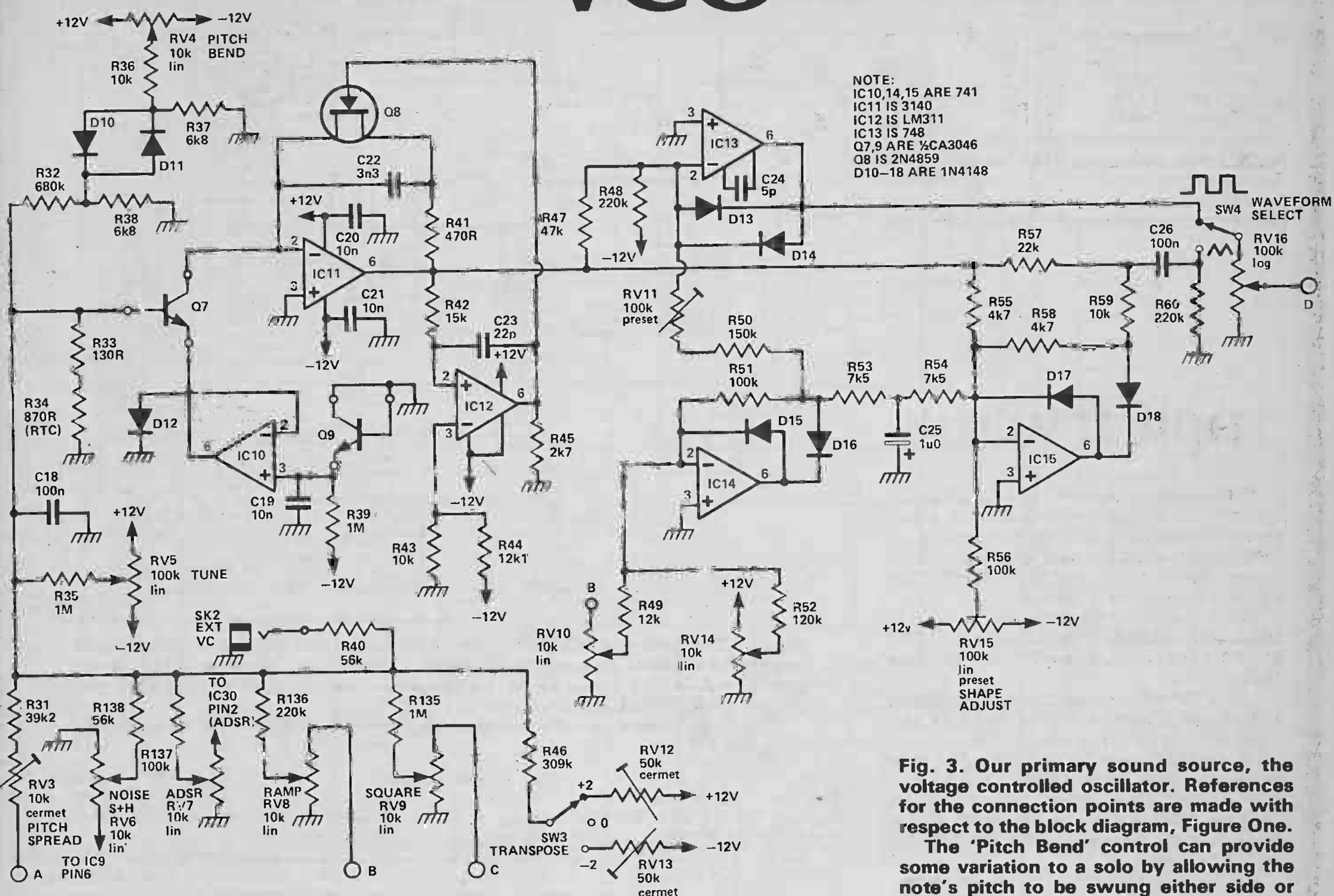


Fig. 3. Our primary sound source, the voltage controlled oscillator. References for the connection points are made with respect to the block diagram, Figure One.
The 'Pitch Bend' control can provide some variation to a solo by allowing the note's pitch to be swung either side or correct during playing.

HOW IT WORKS

The VCO is a logarithmic relaxation oscillator generating a ramp waveform. This waveform is then modified to give a square wave or a triangle wave output. The oscillator section is IC10, Q9, IC11, IC12 and Q8.

The voltage coming out of IC11 pin 6 is fed into IC12. This is an LM311, a fast voltage comparator. A voltage of +5V43 is set up on its inverting input, (pin 3) and the ramp from IC11 is fed into its non-inverting input, (pin 2). When the ramp voltage exceeds +5V43, the comparator's output, (which was at —12 V) leaps up to 0 V.

This voltage turns on the FET switch Q8 which shorts out C22 and discharges it to almost 0 V. Q8 has a very low ON resistance and hence the discharge time is relatively short, about 800 nS.

However, once the discharging has started, you would expect the comparator output to drop back to —12 V. Well it would do if it wasn't for the monostable built around it, (C23, R42). This monostable makes Q8 turn on for a fixed period of time, sufficient for the discharge process to be completed.

Note that the power supply to IC11 is locally decoupled to help protect the VCO from pitch jitter caused by fluctuating power supplies. The reset period causes the VCO to go flat at high frequencies.

As the frequency of the VCO increases then so does the C22 charging current. But this current has to flow through R41. This makes the voltage of the ramp, (IC11 pin 6) increase in size as the ramp speed is increased. This in turn means that the ramp is reset prematurely and so the pitch of the VCO will tend to go sharp at high frequencies.

If we get the size of this tendency to sharpness correct, then it can be used to cancel out the reset tendency to flatness. The overall effect will be to maintain the tuning of the keyboard up to a frequency which it could not do without R41.

The current that drives the VCO is sunk by the transistor Q7. This is used to produce the logarithmic law necessary to convert the linear voltage intervals from the keyboard into musical intervals which are logarithmically spaced. A V_{be} increase of about 18 mV will cause the collector current to double, (the VCO goes up an octave), so therefore the voltage per semitone is about IV5. This is a very small voltage indeed.

IC10 is a voltage follower and merely buffers the bias voltage to the emitter of Q7. Should IC10 go berserk, during the power up say, it might try to reverse bias the emitter of Q7 and cause it to zener. This process would corrupt the logarithmic characteristic of the transistor and so destroy its ability to produce musical intervals. D12 prevents this zenering. Q7 has to be run at relatively low currents for two reasons.

Firstly, the log law goes flat at high currents, (1 mA). This is due to the effect of the intrinsic emitter bulk resistor in the transistor. The effective voltage drop across this bulk resistor is subtracted from the V_{be} voltage and so the net effect is less collector current than was expected. Therefore to get a good musical performance, the collector current must be kept as low as possible.

Secondly, large currents will cause self-heating, which will make the VCO pitch drift, although in this circuit the collector voltage is a virtual earth and so the power dissipation is relatively small anyway.

Even though the second transistor compensates for the temperature change V_{be} problems there is another temperature effect to be dealt with. The pitch spread, that is the number of millivolts per octave, is temperature dependent. To compensate for this effect, the resistor pair R33, 34 must have a temperature coefficient, (TC) of +3400ppm/°C. There is no element with this coefficient, although an alloy could be concocted to produce it.

However, it just so happens that copper has a TC of +3900ppm/°C. Therefore a 870R copper wire wound resistor in series with a 130R metal oxide resistor looks like a 1k resistor with a +3400ppm/°C TC. There is an American company, (Tel Labs) that makes a Q81 resistor, 1k 1% made just for the job and this could be used instead of R33, 34, that is if you can obtain them.

This resistor with the special TC is mounted close to the transistor pair so as to be at the same temperature. Some manufacturers actually glue the resistor to the transistor for best thermal contact.

ADSR & VCF AD

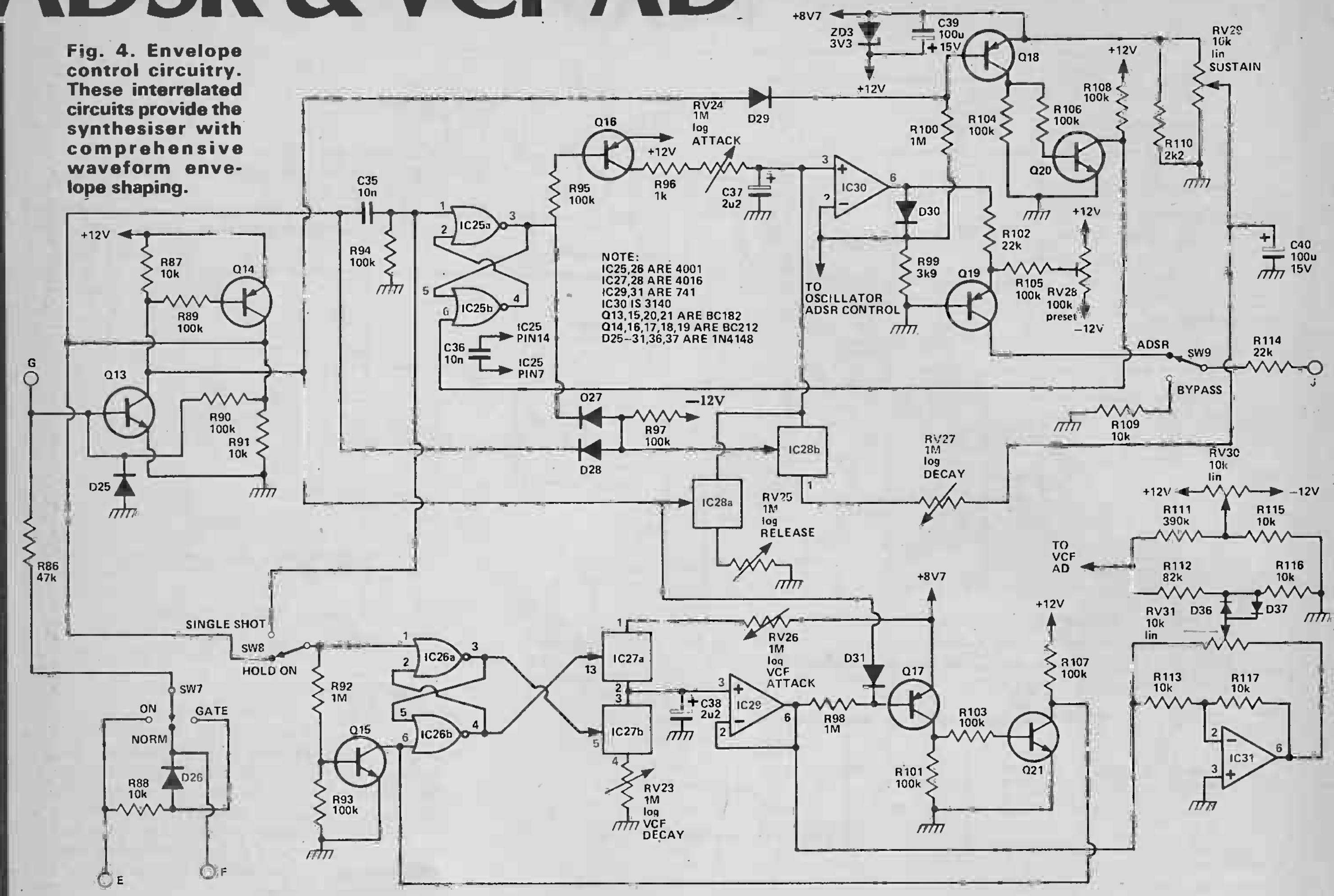


Fig. 4. Envelope control circuitry. These interrelated circuits provide the synthesiser with comprehensive waveform envelope shaping.

HOW IT WORKS

AD generator:

The AD waveform is made up out of two simple CR charge and discharge curves, Q15, Q17, Q21, and IC26, 27, 29, 31 form the generator circuit. The AD is started by the arrival of a positive voltage at IC26 pin 1. This is a SET, RESET flip flop made out of two 2 input NOR gates. A high at pin 1 sets pin 3 low and pin 4 high. These two outputs drive two analogue transmission gates, IC27. A high at the control input (13 and 5) will open the gate, a low will close it. Only one gate is ON at any one time. The event sequence is as follows: IC26 pin 1 goes high, IC26 pin 4 goes high, IC26 pin 3 goes low. C38 is charged up via IC27 pin 1, 2, 13 and RV26 towards a positive (+8V7) reference voltage. RV26 determines the charging up time (ATTACK).

The voltage on C38 is buffered by IC29, a voltage follower. Assuming that the AD generator is in its HOLD ON mode then the capacitor C38 will be charged up towards +8V7 until the gate input is removed.

When this happens the flip flop will change state and the capacitor C38 will be discharged towards 0 V via the other analogue gate and RV23.

The setting of RV23 will determine the discharge time (DECAY). The purpose of Q15 is to generate the HOLD ON by disabling the SINGLE SHOT circuitry, Q17, Q21. Imagine the voltage on C38 is +2 V and charging up. Q17 and Q21 will be turned ON. When the voltage on C38 reaches +8V1, Q17 and Q21 will start to turn OFF. The voltage at Q21 collector, which is the RESET control of the flip flop, will try to rise positively (previously it was at 0 V), but it is prevented from doing so by Q15. Only when the gate input is removed can the flip flop be reset and the decay occur.

When the single shot mode is selected only a positive going pulse is delivered to IC26 pin 1, and so Q15 cannot disable the reset. The waveform charges up to +8 V, resets the flip flop and then discharges. If however the keyboard gate is removed before the attack phase has been completed, the circuit is kicked into its decay mode by diode D31 which resets the flip flop. This means that no matter what mode the circuit is in, it always reverts to its decay mode when the keyboard is released (also true for the ADSR).

The AD waveform is inverted by IC31 and these complementary signals are fed to the AD sweep pot RV30. This waveform is only used to sweep the VCF and does not control anything else. Fast ATTACKS and DECAYS are of the order of 4 mS time constant and slow settings are approximately 2 S.

ADSR:

The circuit is very similar to that of the AD generator. IC25 is a SET RESET flip flop. IC28 and Q16 control the ATTACK, DECAY, RELEASE time constants by enabling the three control pots. A keyboard gate voltage generates a positive going pulse IC25 pin 1, causing IC25 pin 3 to go low. This then turns on Q16 and thus C37 is charged up via RV24, the attack pot. IC30 is a high input impedance voltage follower, which controls the output VCA but which is also linked to Q18 via R100.

When C37 has charged up to 8 V, Q18 begins to turn off and in doing so, turns off Q20. The collector goes high and RESETS the flip flop. Q16 is thus turned off and the analogue transmission gate IC28 pin 1, 2, 13 is turned on via D27.

Now C37 is connected via the decay pot to the sustain voltage, the wiper of RV29 and so it will discharge to that voltage and remain there until the keyboard gate is removed. When this happens the IC28 pin 1, 2, 13 transmission gate is turned off via D28, and IC28 pin 3, 4, 5 is turned on. Now C37 is discharged towards 0 V via the release pot. Also, when the keyboard gate is removed, a RESET is generated by the diode D29, so that the flip flop is ready for another cycle.

The ADSR voltage is used to control the VCO pitch and the signal level at the synthesizer's output. The ADSR is converted into a current by Q19, D30, R102, R99 and is used to drive a CA3080 acting as VCA. The OFF level of this circuit is adjusted using RV28.

The attack, decay, release time constants are variable over a range of 5 mS to 2 S. The sustain QUIET position should provide at least 40 dB attenuation.

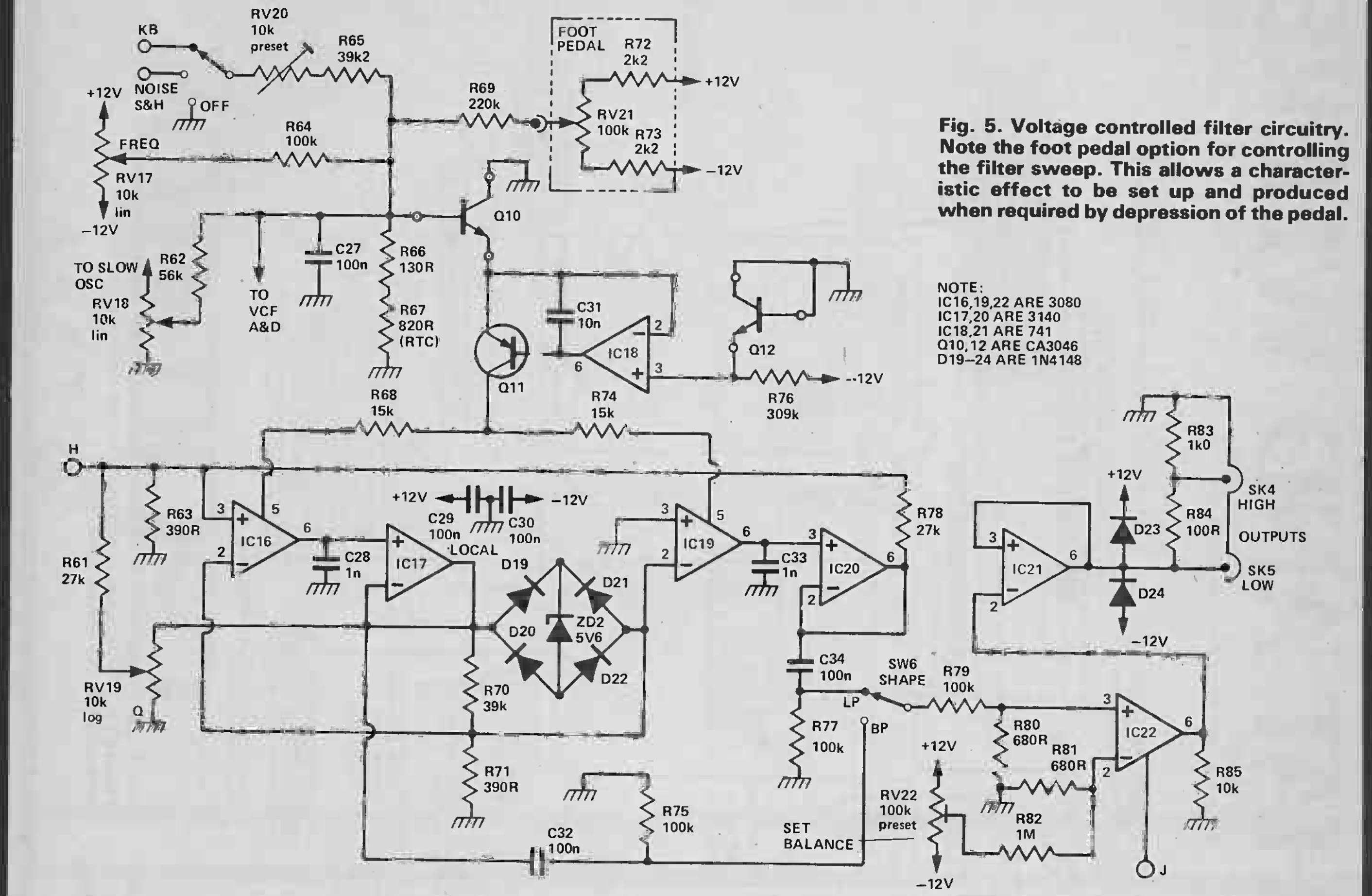


Fig. 5. Voltage controlled filter circuitry. Note the foot pedal option for controlling the filter sweep. This allows a characteristic effect to be set up and produced when required by depression of the pedal.

HOW IT WORKS

Voltage Controlled Filter

The VCF is a voltage controlled state variable filter. This particular design generates both low pass and bandpass outputs. It has the same voltage response as the VCO, i.e. it is logarithmic, as opposed to linear. A CA3046 transistor array converts the control voltage into a log current using very similar circuitry to that which was employed in the VCO to minimise temperature effects.

The control current needs to be sourced to the VCF, in fact to pin 5 of IC16 and IC19 which are both at about —11V4. This is accomplished with Q11 and IC18. The current that comes out of the logging transistor flows into the emitter of Q11 and about 99% of it comes out of the collector, the other 1% flows out of base. As long as the h_{fe} doesn't vary too drastically as a function of the collector current, then this source of error will not be greatly significant.

The tracking accuracy of the VCF is much less of a problem than for the VCO. VCF tracking errors will only result in a slight change in tone, not pitch.

IC18 maintains Q12 at a fixed bias voltage of approximately —0V62. The control current that comes out if Q11 collector splits equally down R68, 74 and into IC16, 19 respectively. These devices are CA3080's, a two quadrant multiplier which is used as a variable gain cell to tune the filter resonance.

In fact they are gain controlled integrators, where C28, 33 are the timing capacitors. The outputs are current outputs and are therefore high impedance. IC17, 20 are very high input impedance voltage followers and they unload the outputs of the integrators. IC16, 17, 19, 20, 23 is in fact an analogue model of a second order differential equation, (i.e. a tuned circuit or a mechanical resonator).

The loop gain, which is controlled by IC16, 19, is linearly proportional to the resonant frequency, therefore by varying the current into IC16, IC19 the resonant frequency of the model is controlled. Note that there is both negative and positive feedback around IC16, IC19. The negative feedback is fixed but the positive feedback is variable via the resonance pot RV19.

As more positive feedback is applied the model becomes more resonant, the Q factor increases. Too much feedback and the circuit will oscillate. In fact stable, low distortion sinewave oscillations can be produced by turning the resonance pot fully clockwise. The diode bridge amplitude limits the signal excursions and will thus stabilise the signal level when the VCF is in its oscillator mode.

The VCF can therefore be used as a low distortion oscillator or as a filter. However, the signal level in the oscillator mode is much louder, (about 10 dB) than in the filter mode.

VCA

The CA3080 is used as a two quadrant multiplier. That is the gain of the device is controlled by the current flowing into pin 5 As this current has the same contour as that of the ADSR, then any signal flowing through the VCA will have its amplitude modulated with the ADSR contour. The output is buffered by a voltage follower providing a high level output (typically OdBm) and a low level output (typically —20dBm). By putting a fixed DC current in, a constant output level is produced (BY-PASS ON), unaffected by the ADSR.

WHAT DOES WHAT AND WHERE

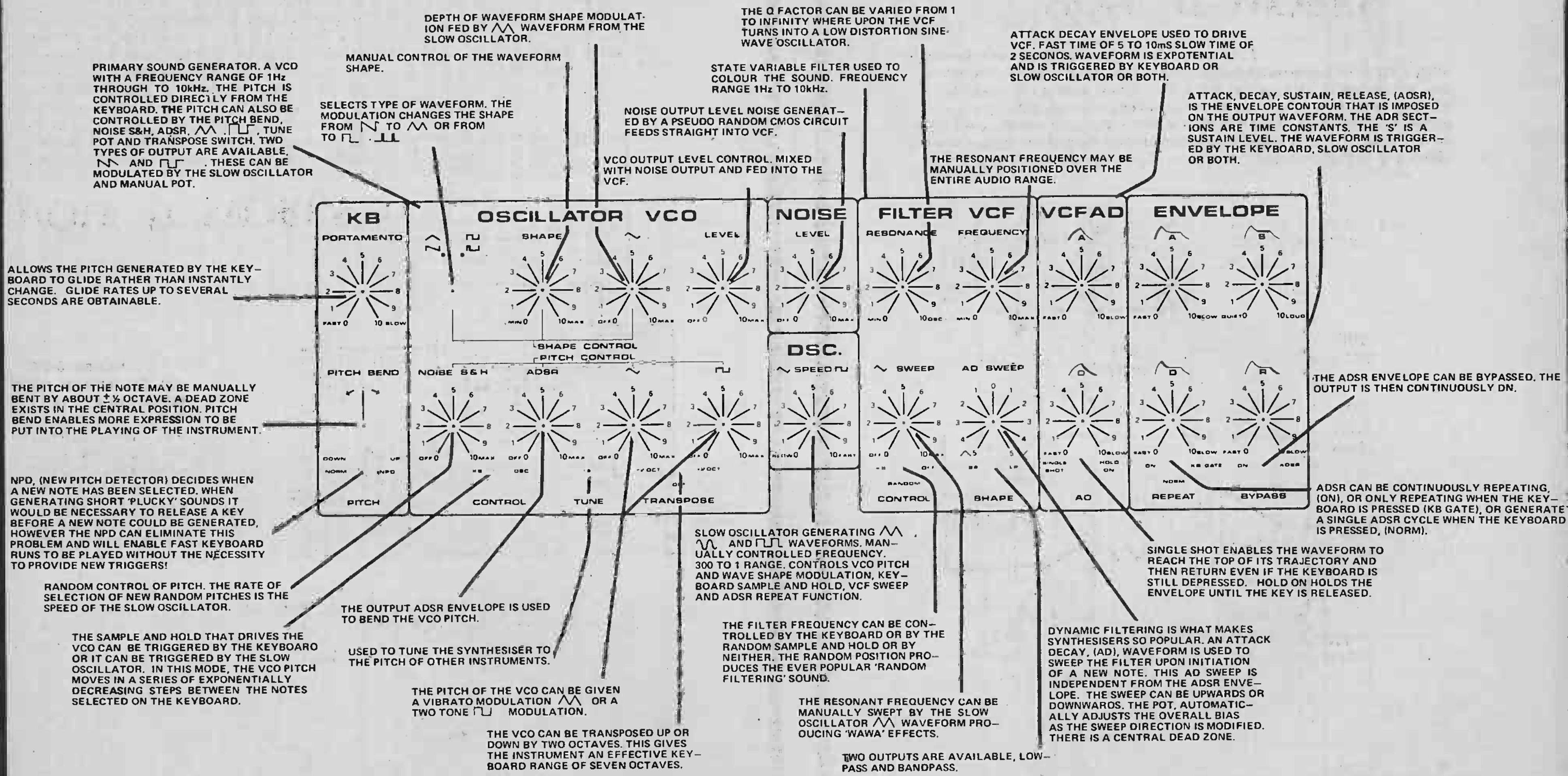
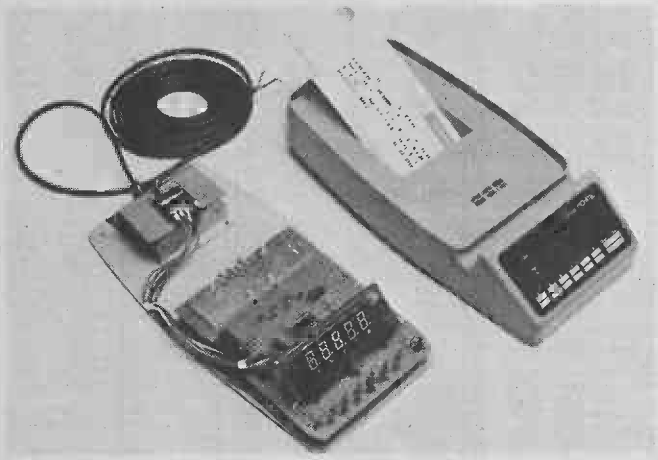


Fig. 6. The front panel layout and what to do with it. This drawing should show the newcomer to sound synthesis what to expect from the various circuit blocks, and give the expert an idea of the versatility of the Transcendent 2000 design. The keyboard, a 37 note unit, is not shown, but reference is made to its control effects where appropriate.

news digest. . . . . .

at the third stroke

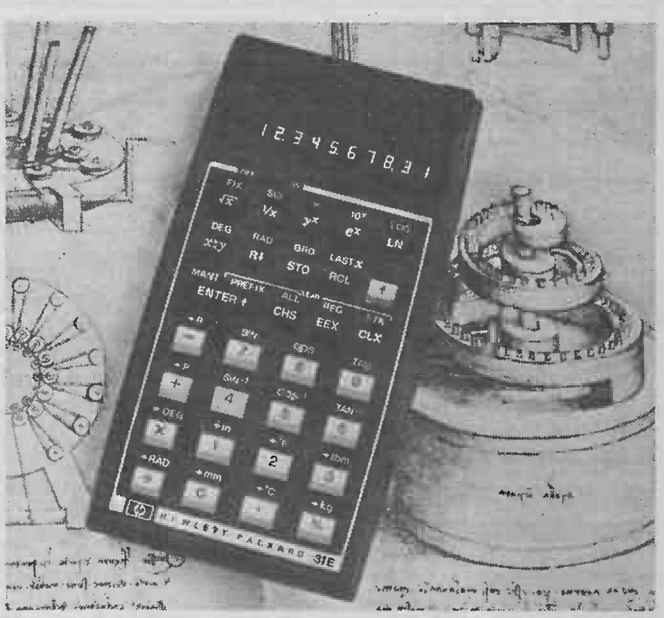


The cost will be . . . wouldn't it be nice if the telephone told you how much money you were spending. Devoted readers will remember the ETI STD timer published in Nov 76, well a firm called Monitel has latched onto a similar idea — and produced a neat unit to sit under the phone and provide the call cost, at a glance. Heart of the unit is a Rockwell MPU from their PPS4/1 range, the standard UK model uses a MM75 which has 600 bytes of ROM and 48 bits of RAM. The international model uses a MM77 with 1 300 bytes of ROM and 96 bits of RAM.

In use the unit calculates the cost, accounting for day of the week, time of day, how far you're calling and the current VAT rate. Any variations in the PO charges are fed into RAM via a punched card supplied by the manufacturers, for a nominal sum. The international model can cope with the overseas tariffs, or UK if you feed it a different card. To operate the unit you first touch the appropriate tariff switch (local, medium or long distance on the standard model), then as soon as you are connected touch the start/stop — when finished touch it again. Cost of call is displayed continuously as you talk, can be quite frightening seeing all that money disappear!

When not in use as a charge calculator it is a digital clock, power from any 13A socket is all that is needed — no extra PO fees are incurred as it is totally isolated from the PO system. Seven colours are available to match all PO standard units. Price for the standard model is about £29, the international model will be about £39. Both should be available from most large chain stores W. H. Smith, Rymans etc. Monitel Limited, Berechurch Road, Colchester, Essex.

triplets from hp



Hewlett-Packard have just announced a new set of cheap (well relatively) scientific button boxes. The HP-31E is the baby of the litter, and is the lowest priced to ever have emerged from HP at £39 inclusive. As with all their calculators it uses Reverse Polish Notation, so called because it was thought to be as easy as Polish to learn — only backwards? Seriously though RPN is a very easy way to use calculators when performing scientific calculations, once you learn it you like it. Anyway RPN commercial over, the 31E is aimed at the budding scientific student and features include — 4 addressable registers, rectangular to polar co-ordinates, inches to millimetres, pounds to kilograms, degrees and radians plus all the usual math and trig functions.

The 32E has all the features of the 31E, plus an extra 11 registers. Other features include hyperbolic functions, hours to hours — minutes and seconds, US gallons to litres and a whole bunch of statistical functions such as linear regression and x, y estimates. All this for £53 inclusive.

A 49 line fully-merged keystroke memory programmable completes the trio, it goes by the name 33E. Keycodes are displayed and 3 levels of subroutine are allowed, it also has maths, trig, log and statistical functions (of course, you say, it's HP after all!). Price for this beauty is £67. All of them come with detailed manuals, and the 33E has an applications book as well.

Further details from Hewlett-Packard Limited, King Street Lane, Winnersh, Wokingham, Berkshire RG11 5AR.

whoops

In the CCD Phaser R31 and R32 were transposed on the overlay diagram. The ICs were missed out of the Stars and Dots parts list — they are on the circuit diagram, also in this project the gremlins got at the IC labels on the overlay — IC5 should be marked IC1, and add 1 to the marked number of the other ICs ie IC2 becomes IC3 etc.

Lastly in the Chipmonk the pot values were missed off the parts list RV1 is a 100 k log type, RV2 a 10k preset and RV3 a 120k preset.

In case you missed our previous announcement we have a recorded message service for errors and other information on 01-434 1781. This service is available outside normal office hours only.

problem solved

Lasers were once called the solution without a problem. Now they have lots of problems, the latest one to suffer from the fate of laser solution is that of aerial mapping. The US Geological Survey is using pulsed lasers and silicon photodiodes, with extremely accurate interval timers and delay/discrimination electronics, to produce a ground profile as an aircraft flies over it. A gallium arsenide laser, with a pulse duration of 10 nanoseconds, is bounced off the ground and detected when it gets back to the aircraft. As long as the aircraft flies on a level path the distance to ground can be measured. With accurate position fixing and several runs, a 3 dimensional map can be produced. The technique is suited to computer analysis, unlike aerial photography or manual surveying.

NOISE GENERATOR

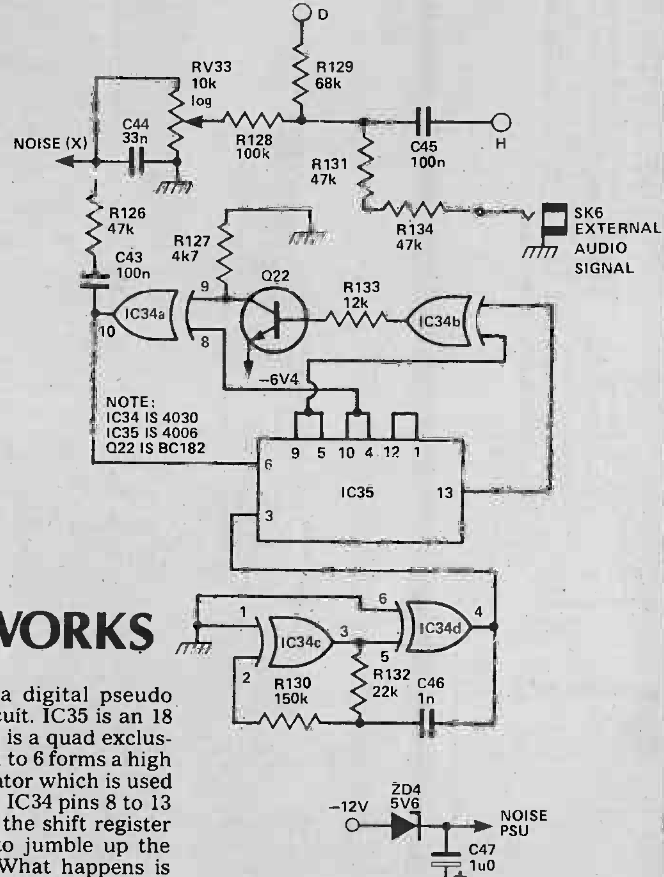


Fig. 7. The digital noise circuit is locally decoupled by C47, and the supply rail stabilised by ZD4 as shown right. The external audio signal should be about 1V for best results.

HOW IT WORKS

The noise generator is a digital pseudo random shift register circuit. IC35 is an 18 bit shift register and IC34 is a quad exclusive OR device. IC34, pins 1 to 6 forms a high frequency (30 kHz) oscillator which is used to clock the shift register. IC34 pins 8 to 13 provide feedback around the shift register and are so arranged as to jumble up the data that is circulating. What happens is that a continuous repeating sequence of 'O's and 1's flows around the register but the sequence is so very long that it only repeats about once every second. This repetition is inaudible. However the output has the characteristics of a noise source with a fairly flat spectrum.

The noise output is mixed into the audio input of the filter (RV33) and is also taken to the Random sample and hold. The noise is the signal that is sampled and the gate is generated by the slow oscillator. The output is a sampled DC signal of random voltage, the sampling rate being that of the slow oscillator. This random voltage can be used to control the frequency of the VCO and VCF.

SLOW OSCILLATOR

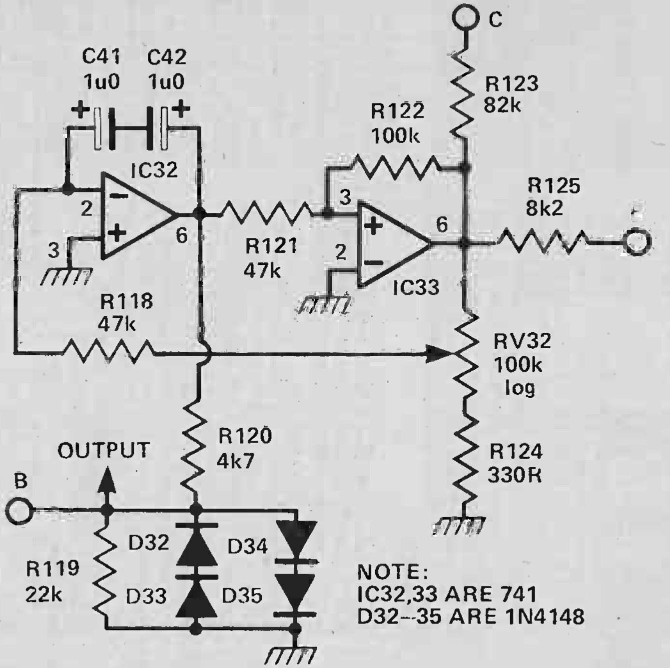


Fig. 8. Full circuit diagram for the slow oscillator block. Although very simple on paper, this circuit has a great deal of influence on the performance of the machine as a whole. The range is about 300 to 1, and the oscillator exercises control over the voltage controlled oscillator pitch, the VCO waveform modulation, the keyboard sample and hold function, the voltage controlled filter sweep rate and the ADSR repeat facility.

HOW IT WORKS

IC32 and IC33 form a triangle square wave oscillator. IC32 is an integrator the output of which ramps up and down between the hysterysis thresholds set by the schmitt trigger IC33. The square wave output of IC33 is fed back to the integrator via RV32 which determines the oscillator frequency, providing a range of 0.06 Hz to 20 Hz (300 to 1). The triangle is bent by D32-35 to form a sinewave which is used as a frequency shape modulator for the VCO. The squarewave output is used to perform a repeat function with the AD and ADSR circuits. Also it is used to frequency modulate the VCO and to provide sampling pulses, for the two sample and hold circuits.

HOW IT WORKS

The keyboard generates two outputs. A pitch output and a gate voltage. This is then fed via R14, C12 (reduces contact bounce), to a schmitt trigger IC4. When a key is pressed the output of IC4 goes high, when it is released it goes low. This gate voltage is used to operate the keyboard sample and hold and the AD and ADSR units.

The keyboard voltage is generated by passing a constant current through a precision resistor chain. Thus a series of precise voltages is set up along the chain which can be picked off by the keyboard contacts. The constant current is generated by IC3, R9. R9 puts 2.526 mA into the node at IC3 pin 2. This then adjusts its output so that almost exactly 2.526 mA flows down the resistor chain.

When a key is pressed, a voltage appears which tells the synthesiser which key has been pressed. If more than one key is pressed, then the voltage is (2.526x27.4 x N) mV where N is the number of resistors between the top note pressed and IC3 pin 2.

Thus the keyboard always generates the voltage of the highest note selected, and this is fed via R13, RV2, Q4 to C13 where it is stored. Q4 is a FET switch which has an on resistance of a few hundred ohms and a Pinch off resistance of a few hundred megohms.

It is turned on and off by the keyboard gate voltage. The sequence of operation is as follows.

The keyboard is pressed. A pitch voltage is selected. A gate voltage is produced. Q4 is turned on and C13 is charged up to that voltage via R13 RV2. The keyboard is released, the gate voltage dies, Q4 is turned off, and the voltage on C13 remains where it is. IC6 is a very high input impedance (1000 M), voltage follower, and so buffers the voltage on C13 to the rest of the electronics.

A PCB guard ring surrounds C13 so that surface leakage droop rate was about 0.1 mV/S which means that it would take 6922 seconds to drift one semitone or 8305 seconds for an octave.

The measured droop rate was about 0.1 mV/S which means that it would take 692 seconds to drift one semitone or 8305 seconds for an octave.

Portamento effects are obtained by varying RV2, anticlockwise the charging time of C13 is about 0.2 mS, when clockwise this becomes 330 mS, and the effect is to produce a slewing between notes.

If the keyboard contacts are badly out of alignment, a pitch change at the start of notes can be produced. If the first contact to close is the gate pair then this might cause a problem. The sequence of events is as follows:

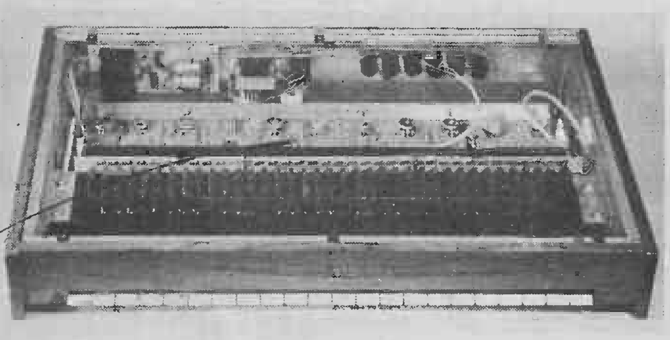
The gate contacts close. An envelope with the VCO at the previous pitch is produced. Then 10 or 20 mS. later the pitch contact is made and the sample and hold, and hence the VCO jumps to the correct pitch. The result is a pitch 'hiccup' at the start of some notes. If this is noticeable on any notes then the gate contact should be carefully bent so that it doesn't make contact before the pitch contact.

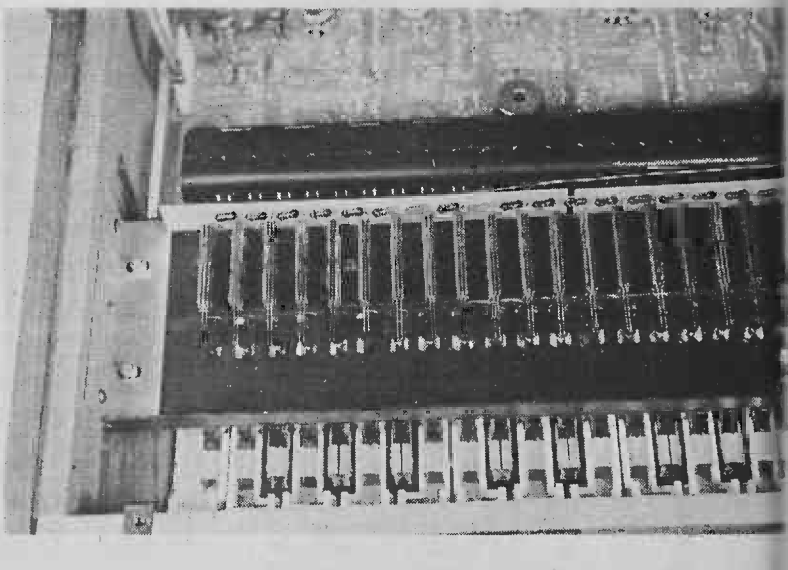
New Pitch Detector Circuit

This circuit decides whether or not a new higher note has been played, even though the gate output signal (IC4 pin 6), has remained high all the time. IC5 is a high gain amplifier which looks at the voltage on the pitch contacts. If the pitch changes, the AC component of this change will be amplified by IC5.

If the output goes positive, a pulse is produced which passes through C14, D7 and ends up across R23. If the output of IC5 goes negative, the pulse goes through C14, D6, is inverted by IC7 and passes through D9 into R23, again as a positive pulse. This pulse then drives IC8 which is a schmitt trigger. Its output is normally low, and the arrival of the pulse makes it go high for a short while and then returns to its low state. Thus an ascending or descending scale of notes will cause a series of short pulses (at IC8, pin 6) to be generated, one per new note. When the last note held down is removed there is no pulse produced. When the same note is repressed, the pitch not actually being any different, a pulse is generated (this is what is wanted) via C11 from IC4 pin 6. This route only generates pulses on +ve edges, that is the start of a new gate voltage. The pulse output from IC8 is used to turn Q6 on and off. This in turn is used to momentarily turn off the AD and ADSR circuits. Thus the NPD can be used to provide a retrigger of the AD and ADSR circuits.

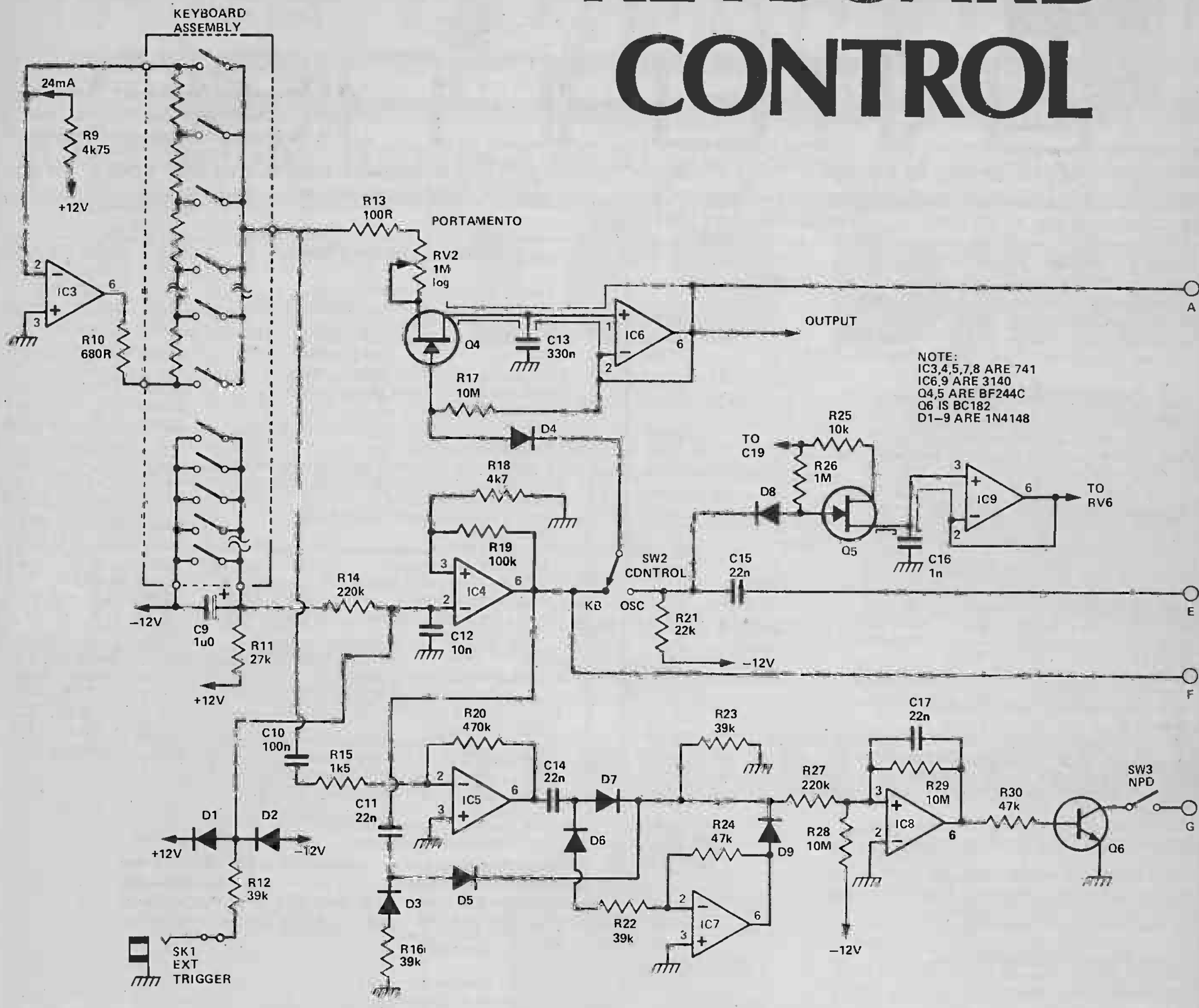
Fig. 9. On the right is shown the circuitry associated with the keyboard functions. Note the resistor chain for the keyboard is mounted remotely to the main PCB and fits into the contact block mounting board. The Ext Trigger input allows a sequencer to be wired to the synthesiser.





Above and right: a denuded synthesiser. Next month we go on to give full construction details of the design, but as you can see from the photos, it really couldn't be easier. The photo on the right shows the keyboard contact block mountings in close-up. This is perhaps the trickiest part of any synthesiser to build yourself, but as you can see ours is very straightforward.

KEYBOARD CONTROL



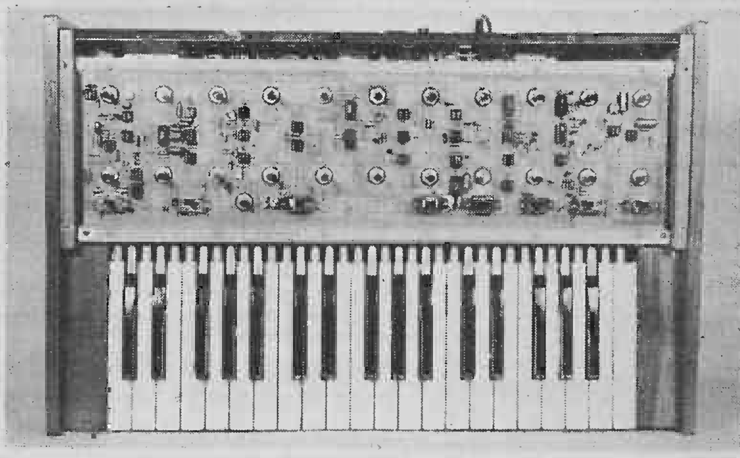
BUYLINES

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 anintroductory offer at an even lower price of £172 + VAT.

Powertran Electronics, Portway Industrial Estate, Andover, Hants,



Above: the lid removed to show the main PCB. It is worth noticing that all the controls and switches mount directly onto this, drastically reducing the interwiring necessary

Next month we conclude the article with all the constructional details of the Transcendent 2000 synthesiser, including keyboard fixing and alignment procedures.

DATA SHEET SPECIAL

THE ELECTRONICS PRESS is full of articles high-lighting the latest advances in memory technology, and we must plead guilty to this ourselves; it's quite fascinating. But we discovered that a lot of hobbyists who are using memories don't have access to good information on the devices available, and are consequently running into problems while trying to get their systems up and running.

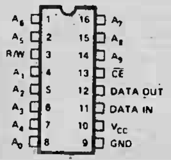
Here we attempt to give some real nitty-gritty down-to-earth useful information on memories. The data sheets are not complete by any means, but we hope they contain the most important information.

Bear in mind that distributors deal (in the main) with commercial organisations, and cannot possibly afford to supply hobbyists with heaps of expensive books, brochures and data sheets. If you request information from a manufacturer or distributor, please make life easy for them by enclosing a large stamped addressed envelope and payment, if any is required.

2102 STATIC RAM — NATIONAL

The 2102 is, without doubt, the commonest RAM in use today. It is a static 1024-bit (1K x 1) memory and is exceptionally easy to use, as many hobbyists will testify.

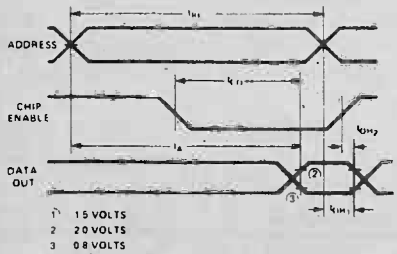
PIN CONFIGURATION



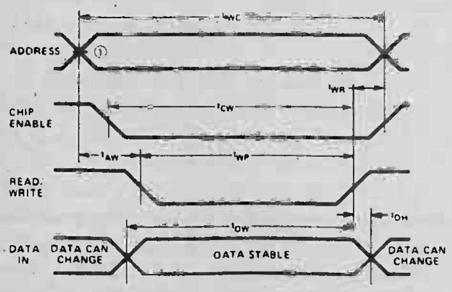
PIN NAMES

D_{IN}	DATA INPUT
A_0 A_9	ADDRESS INPUTS
R/W	READ/WRITE INPUT
$\overline{CE}$	CHIP ENABLE
D_{OUT}	DATA OUTPUT
V_{CC}	POWER (+5V)

READ CYCLE



WRITE CYCLE



A. C. Characteristics T_A = 0°C to 70°C, V_{CC} = 5V ±5% unless otherwise specified

READ CYCLE

Symbol	Parameter	2102A-2, 2102AL-2 Limits (ns) Min.	Max.	2102A, 2102AL Limits (ns) Min.	Max.	2102A-4, 2102AL-4 Limits (ns) Min.	Max.
t_{RC}	Read Cycle	250		350		450	
t_A	Access Time		250		350		450
t_{CO}	Chip Enable to Output Time		130		180		230
t_{OH1}	Previous Read Data Valid with Respect to Address	40		40		40	
t_{OH2}	Previous Read Data Valid with Respect to Chip Enable	0		0		0	

WRITE CYCLE

Symbol	Parameter	2102A-2, 2102AL-2	2102A, 2102AL	2102A-4, 2102AL-4
t_{WC}	Write Cycle	250	350	450
t_{AW}	Address to Write Setup Time	20	20	20
t_{WP}	Write Pulse Width	180	250	300
t_{WR}	Write Recovery Time	0	0	0
t_{DW}	Data Setup Time	180	250	300
t_{DH}	Data Hold Time	0	0	0
t_{CW}	Chip Enable to Write Setup Time	180	250	300

D. C. and Operating Characteristics

T_A = 0°C to 70°C, V_{CC} = 5V ±5% unless otherwise specified.

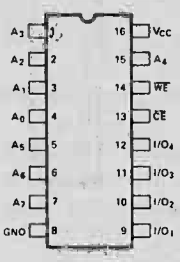
Symbol	Parameter	2102A, 2102A-4 2102AL, 2102AL-4 Limits Min.	Typ.[1]	Max.	2102A-2, 2102AL-2 Limits Min.	Typ.[1]	Max.
I_{LI}	Input Load Current		1	10		1	10
I_{LOH}	Output Leakage Current		1	5		1	5
I_{LOL}	Output Leakage Current		-1	-10		-1	-10
I_{CC}	Power Supply Current		33	Note 2		45	65
V_{IL}	Input Low Voltage	-0.5		0.8	-0.5		0.8
V_{IH}	Input High Voltage	2.0		V_{CC}	2.0		V_{CC}
V_{OL}	Output Low Voltage			0.4			0.4
V_{OH}	Output High Voltage	2.4			2.4		

Notes: 1. Typical values are for T_A = 25°C and nominal supply voltage
2. The maximum I_{CC} value is 55mA for the 2102A and 2102A-4, and 33mA for the 2102AL and 2102AL-4.

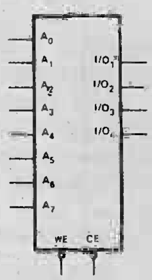
POPULAR MEMORIES

The 2112 is a 256 x 4 bit TTL-compatible static RAM which is very popular in small systems where two 2112s will provide 256 bytes of memory. Memory expansion in 256 byte increments is easy until you reach 1 K, where 8 2102s could have done the job slightly more easily. The 2112 is made by Intel, National Semiconductor and many other semiconductor manufacturers.

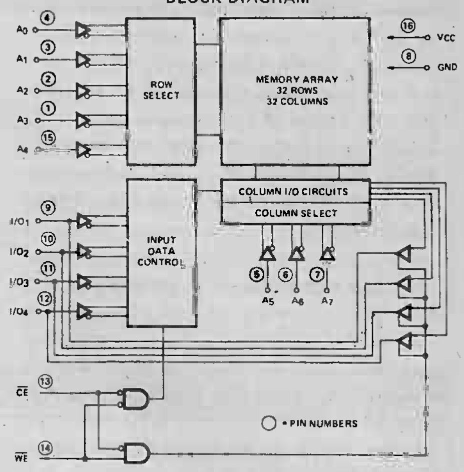
PIN CONFIGURATION



LOGIC SYMBOL



BLOCK DIAGRAM



PIN NAMES

A_0-A_7	ADDRESS INPUTS
$\overline{WE}$	WRITE ENABLE
$\overline{CE}$	CHIP ENABLE INPUT
I/O_1-I/O_4	DATA INPUT/OUTPUT
V_{CC}	POWER (+5V)

ABSOLUTE MAXIMUM RATINGS

Ambient Temperature Under Bias . . . . . -10°C to 80°C

Storage Temperature . . . . -65°C to +150°C

Voltage On Any Pin With Respect to Ground . . . . -0.5V to +7V

Power Dissipation . . . . 1 Watt

D.C. AND OPERATING CHARACTERISTICS

T_A = 0°C to 70°C, V_{CC} = 5V ±5% unless otherwise specified.

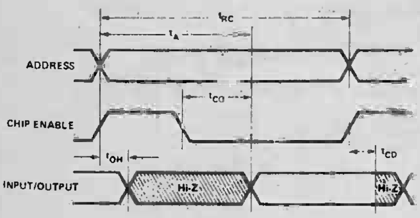
Symbol	Parameter	Min.	Typ.[1]	Max.	Unit	Test Conditions
I_{LI}	Input Current		1	10	μA	V_{IN} = 0 to 5.25V
I_{LOH}	I/O Leakage Current		1	10	μA	Output Disabled, $V_{I/O}$=4.0V
I_{LOL}	I/O Leakage Current		-1	-10	μA	Output Disabled, $V_{I/O}$=0.45V
I_{CC1}	Power Supply Current 2112A, 2112A-4		35	55	mA	V_{IN} = 5.25V, $I_{I/O}$ = 0mA
	2112A-2		45	65		T_A = 25°C
I_{CC2}	Power Supply Current 2112A, 2112A-4			60	mA	V_{IN} = 5.25V, $I_{I/O}$ = 0mA
	2112A-2			70		T_A = 0°C
V_{IL}	Input "Low" Voltage	-0.5		0.8	V	
V_{IH}	Input "High" Voltage	2.0		V_{CC}	V	
V_{OL}	Output "Low" Voltage			+0.45	V	I_{OL} = 2.0 mA
V_{OH}	Output "High" Voltage 2112A, 2112A-2	2.4			V	I_{OH} = -200μA
	2112A-4	2.4			V	I_{OH} = -150μA

CAPACITANCE[2] T_A = 25°C, f = 1 MHz

Symbol	Test	Limits (pF) Typ.[1]	Max.
C_{IN}	Input Capacitance (All Input Pins) V_{IN} = 0V	4	8
$C_{I/O}$	I/O Capacitance $V_{I/O}$ = 0V	10	15

NOTES:
1. Typical values are for T_A = 25°C and nominal supply voltage.

READ CYCLE WAVEFORMS



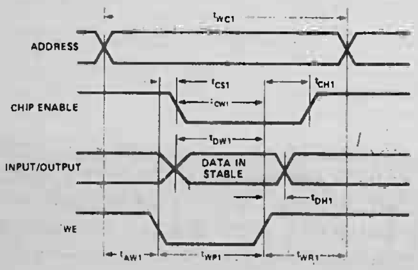
A.C. CHARACTERISTICS FOR 2112A

READ CYCLE T_A = 0°C to 70°C, V_{CC} = 5V ±5% unless otherwise specified.

Symbol	Parameter	Min.	Typ.[1]	Max.	Unit	Test Conditions
t_{RC}	Read Cycle	350			ns	t_r, t_f = 20ns
t_A	Access Time			350	ns	Input Levels = 0.8V or 2.0V
t_{CO}	Chip Enable To Output Time			240	ns	Timing Reference = 1.5V
t_{CD}	Chip Enable To Output Disable Time	0		200	ns	Load = 1 TTL Gate
t_{OH}	Previous Read Data Valid After Change of Address	40			ns	and C_L = 100pF.

WRITE CYCLE WAVEFORMS

WRITE CYCLE #1



NOTE: 1. Typical values are for T_A = 25°C and nominal supply voltage.

WRITE CYCLE #1 T_A = 0°C to 70°C, V_{CC} = 5V ±5%

Symbol	Parameter	Min.	Typ.[1]	Max.	Unit	Test Conditions
t_{WC1}	Write Cycle	270			ns	t_r, t_f = 20ns
t_{AW1}	Address To Write Setup Time	20			ns	Input Levels = 0.8V or 2.0V
t_{DW1}	Write Setup Time	250			ns	Timing Reference = 1.5V
t_{WP1}	Write Pulse Width	250			ns	Load = 1 TTL Gate
t_{CS1}	Chip Enable Setup Time	0			ns	and C_L = 100pF.
t_{CH1}	Chip Enable Hold Time	0			ns	
t_{WR1}	Write Recovery Time	0			ns	
t_{DH1}	Data Hold Time	0			ns	
t_{CW1}	Chip Enable to Write Setup Time	250			ns	

2107 DYNAMIC RAM

WHEREAS STATIC RAMS basically consist of flip-flops and will retain data for as long as power is applied, with dynamic RAMs, life wasn't meant to be easy. The basic storage element in a dynamic RAM is a capacitor which is subject to leakage and requires data to be read from a cell, amplified and written back again in order to avoid total decay of the data.

Because the memory cell in a dynamic RAM is one transistor and a cpacitor as against the six transistors of the static type, the density of dynamic RAMs is around four times higher. Thus, we now have 16 K dynamics, and 64 K types are rumoured to exist in research labs around the world!

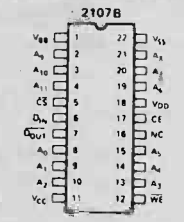
The innards of dynamic RAMs, like statics, are organised into rows and columns, 64 rows x 64 columns for a 4 K RAM, to be precise. All the cells in a single row are refreshed at the same time, and so to fully refresh a 4 K RAM, one need only cycle through all combinations of the low-order six address bits within 2 ms.

The first problem with these chips is that they are not fully TTL-compatible as is the 2102, for example. The chip enable input of the 2107B requires a high-level signal of at least 11 V to operate, but this can easily be got from a special driver chip, the Intel 3245, which also provides some selection logic.

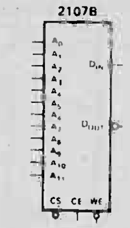
Given a 3245 and a handful of external logic, it looks as though the 2107B would be a good choice for hobbyists using the Z-80. The 2107 does not require address strobing, and consequently could run directly off the data bus, with the Z-80 supplying the refresh logic (the Z-80 has an internal refresh counter which is output while the processor decodes instructions).

If you are designing your own memory system, and your processor is not a Z-80, you will have to decide on one of three refresh schemes: Asynchronous, which insists on refresh occurring, even if this interrupts the processor; Synchronous, which runs 'in phase' with the processor, supplying refresh at times when the processor is not accessing memory; and Semi-synchronous, which is a combination of these schemes. Your decision will be dependent upon the circuit complexity, processor speed and overhead, and a number of other considerations.

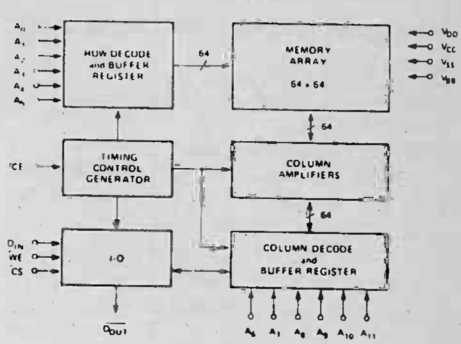
PIN CONFIGURATION



LOGIC SYMBOL



BLOCK DIAGRAM

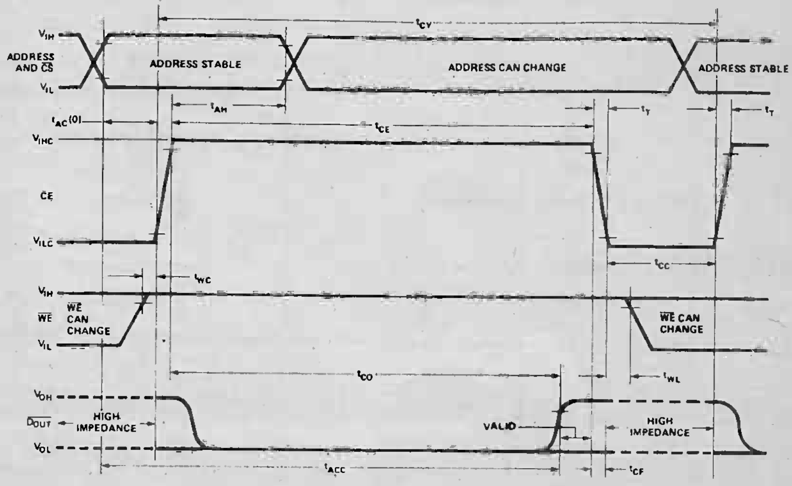


PIN NAMES

A_0-A_{11}	ADDRESS INPUTS*	V_{BB}	POWER (-5V)
CE	CHIP ENABLE	V_{CC}	POWER (+5V)
$\overline{CS}$	CHIP SELECT	V_{DD}	POWER (+12V)
D_{IN}	DATA INPUT	V_{SS}	GROUND
$\overline{D}_{OUT}$	DATA OUTPUT	$\overline{WE}$	WRITE ENABLE
NC	NOT CONNECTED		

*Refresh Address A_0-A_5.

Read and Refresh Cycle [1]



D.C. and Operating Characteristics

T_A = 0°C to 70°C, V_{DD} = +12V ±5%, V_{CC} = +5V ±10%, V_{BB} [1] = –5V ±5%, V_{SS} = 0V, unless otherwise noted.

Symbol	Parameter	Limits Min.	Typ.[2]	Max.	Unit	Conditions
V_{IL}	Input Low Voltage	-1.0		0.6	V	t_T = 20ns, V_{ILC} = -1.0V
V_{IH}	Input High Voltage	2.4		V_{CC}+1	V	t_T = 20ns
V_{ILC}	CE Input Low Voltage	-1.0		+1.0	V	
V_{IHC}	CE Input High Voltage	V_{DD}-1		V_{DD}+1	V	
V_{OL}	Output Low Voltage	0.0		0.45	V	I_{OL} = 2.0mA
V_{OH}	Output High Voltage	2.4		V_{CC}	V	I_{OH} = -2.0mA

Absolute Maximum Ratings*

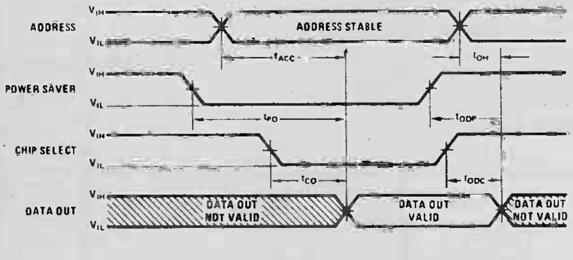
Temperature Under Bias . . . . . 0°C to 70°C
Storage Temperature . . . . . -65°C to +150°C
All Input or Output Voltages with Respect to the most Negative Supply Voltage, V_{BB} . . . . . +25V to -0.3V
Supply Voltages V_{DD}, V_{CC}, and V_{SS} with Respect to V_{BB} . . . . . +20V to -0.3V
Power Dissipation 1.25W

The second problem you will face in using dynamic RAMs is getting your memory system to work. It is a good idea to have some static RAM in the system so that the processor can be checked out without having to worry too much about the memory. Once this is done, attention can be turned to the dynamic memories. In general, dynamic memory is a good choice for expanding your memory size, but not for starting a system.

The MM5204 is a 4096-bit static Read Only Memory which is electrically programmable and uses silicon gate technology to achieve bipolar compatibility. The device is a non-volatile memory organised as 512 words by 8 bits per word. Programming of the memory is accomplished by storing a charge in a cell location by applying a –50 V pulse. A logic input, "Power Saver," is provided which gives a 5:1 decrease in power when the memory is not being accessed.

absolute maximum ratings

All Input or Output Voltages with Respect to V_{BB} Except During Programming	+0.3V to –20V
Power Dissipation	750 mW
Operating Temperature Range	0°C to +70°C



Note: All times measured with respect to 1.5V level with t_R and t_F ≤ 20 ns.

FIGURE 1. Read Operation

Erasing

The MM5204Q (The Q suffix indicates the chip has a quartz window and is UV erasable. The other 5204s are not erasable.) may be erased by exposure to short-wave ultraviolet light of 254 nm wavelength. The recommended dosage of ultraviolet light exposure is 6 W sec/cm^2, but there is no absolute rule for erasing time or distance from the source. When erasing a worst case time required should be found and any chips then erased for three times this period.

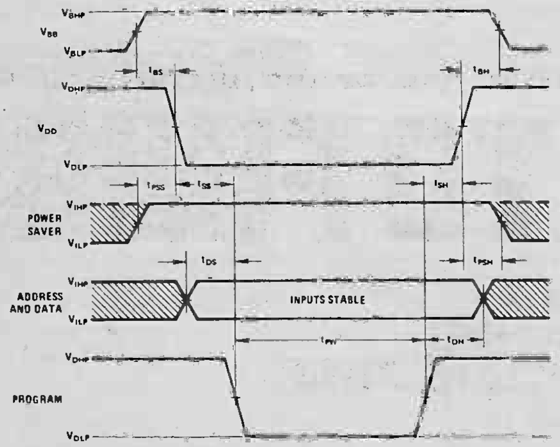
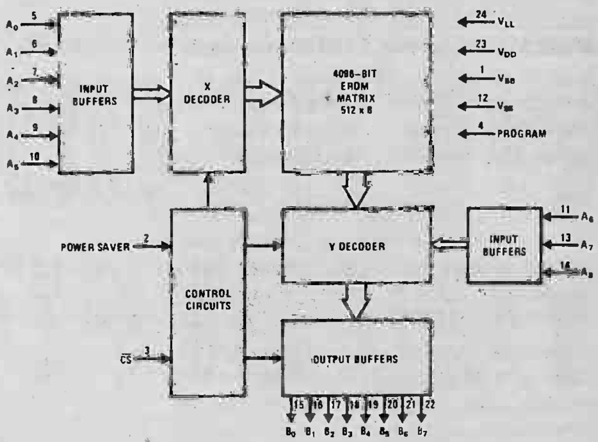


FIGURE 2. Write Operation

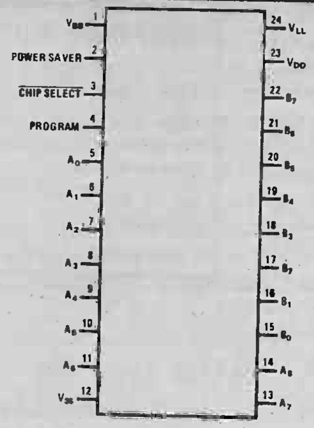
block and connection diagrams



electrical characteristics

T_A within operating temperature range, V_{LL} = 0V, V_{BB} = PROGRAM = V_{SS}, MM4204: V_{SS} = 5.0V ±10%, V_{DD} = –12V ±10%, MM5204: V_{SS} = 5.0V ±5%, V_{DD} = –12V ±5%, unless otherwise noted.

PARAMETER		CONDITIONS	MIN	MAX	UNITS
V_{IL}	Input Low Voltage		V_{SS}–14	V_{SS}–4.2	V
V_{IH}	Input High Voltage		V_{SS}–1.5	V_{SS}+0.3	V
I_{LI}	Input Current	V_{IN} = 0V		1.0	μA
V_{OL}	Output Low Voltage	I_{OL} = 1.6 mA	V_{LL}	0.4	V
V_{OH}	Output High Voltage	I_{OH} = –0.8 mA	2.4	V_{SS}	V
I_{LO}	Output Leakage Current	V_{OUT} = 0V, $\overline{CS}$ = V_{IH}		1.0	μA
	Access Time	MM5204 T_A = 0°C, $\overline{CS}$ = V_{IH}, Power Saver = V_{IL}	0.75	1.0	μs



Programming.

The MM5204 is normally supplied in the unprogrammed state. All 4096-bits at logic "0" state. In the program mode the device effectively becomes a RAM with the 512 word locations selected by address inputs A0-A8. Data inputs are B0-B7 and the write operation is controlled by pulsing the program input to –50 V. Since the EROM is initially supplied with all "0s" a V_{IHP} on any of the data input lines will leave the stored "0s" undisturbed and a V_{ILP} on any date input B0-B7 will write a logic "1" into that location. The program cycle should be repeated until the data reads true, then over programmed five times that number of cycles (denoted X + 5X programming)

programming electrical characteristics

	PARAMETER	CONDITIONS	MIN	MAX	UNITS
I_{LD}	Data Input Load Current	V_{IN} = –18V		–10	mA
I_{ALD}	Address Input Load Current	V_{IN} = –50V		–10	mA
I_{LP}	Program Load Current	V_{IN} = –50V		–10	mA
I_{LBB}	V_{BB} Load Current			50	mA
I_{LDD}	V_{DD} Load Current	V_{DD} = PROGRAM = –50V		–200	mA
V_{IHP}	Address Data and Power Saver Input High Voltage		–2.0	0.3	V
V_{ILP}	Address Input Low Voltage		–50	–11	V
	Data Input Low Voltage		–18	–11	V
V_{DHP}	V_{DD} and Program High Voltage		–2.0	0.5	V
V_{DLP}	V_{DD} and Program Low Voltage		–50	–48	V
V_{BLP}	V_{BB} Low Voltage		0	0.4	V
V_{BHP}	V_{BB} High Voltage		11.4	12.6	V
V_{DD}	Pulse Duty Cycle			25	%
t_{PW}	Program Pulse Width		0.5	5.0	ms
t_{DS}	Data and Address Set-Up Time		40		μs
t_{DH}	Data and Address Hold Time		0		μs
t_{SS}	Pulsed V_{DD} Set-Up Time		40	100	μs
t_{SH}	Pulsed V_{DD} Hold Time		1.0		μs
t_{BS}	Pulsed V_{BB} Set-Up Time		1.0		μs
t_{BH}	Pulsed V_{BB} Hold Time		1.0		μs
t_{PSS}	Power Saver Set-Up Time		1.0		μs
t_{PSH}	Power Saver Hold Time		1.0		μs
t_R, t_F	V_{DD}, Program, Address and Data Rise and Fall Time			1.0	μs

microfile.......

Gary Evans, fresh from a lesson in petting, reports on the world of micros and personal computers.

A HECTIC MONTH this, as the words you are now reading were penned in between the frantic, on my part anyway, preparations for our Petting for Beginners Seminar. A report on the event appears elsewhere in this issue but I think the two days can be summed up in a very few words — a good and informative time was had by all.

Informative not only in terms of the days lectures but because delegates talked to each other — very un-English — and found much in common. I was impressed with the high level of knowledge of most delegates and even those who knew very little of personal computing in the morning, could hold their own in discussions before the end of the day.

Petting For Softies

It was at the Saturday event that I talked to Julian Allason of William Hamilton and Allen. The company have in the past specialised in introducing advanced electronic consumer products into this country. They were one of the first to market car stereo systems and VCR equipment. They see Personal Computers as such as product but recognise that the potential is far greater than those products they have dealt with before.

The company have set up a new division which they have named PETSOFT. This section of the group will concern itself with the market that is beginning to appear as more and more people want support for their home computers.

It is interesting to note that the current efforts of the firm are directed toward building a base of good, well tried software.

At present their range includes alien attack which is — guess what — a space war game and Dr. Sinister's Personality Test.

The latter package will ask the user some fifty questions and provide a readout of personality in terms of introvert/extrovert, stable/unstable, aggression, intelligence, attractiveness (micro, micro on the wall, who's the fairest of them all). This package sounds like fun and I'm not going to tell you what the machine said about me.

The range of programs will be extended to cover small business applications in the near future — VAT, stock control, etc.

If you have any programs which you feel would find a ready market, and/or ideas for programs PETSOFT would like to hear from you — they would publish any suitable material on a royalty basis. As with their own programs, all submitted programs would be subjected to an extensive debugging operation.

At present all material is designed to run on the PET computer and will be sold in the form of cassettes recorded to the PET standard. Future plans include programs for the TRS-80 and, presumably, any other system that finds a mass market.

The cassettes will sell for between £2.50 (for small programs) to £10 (for the larger packages). This price reflects the high volume, low cost approach to software marketing that, I think, is the only effective way to circumvent software pirating.

Talking of pirating, the firm will have no objection to a few friends copying programs for each other but will pursue, in an alien attack mode, anybody selling their material.

A SAE to the firm at the address below will bring you a catalogue with details of all their programs.

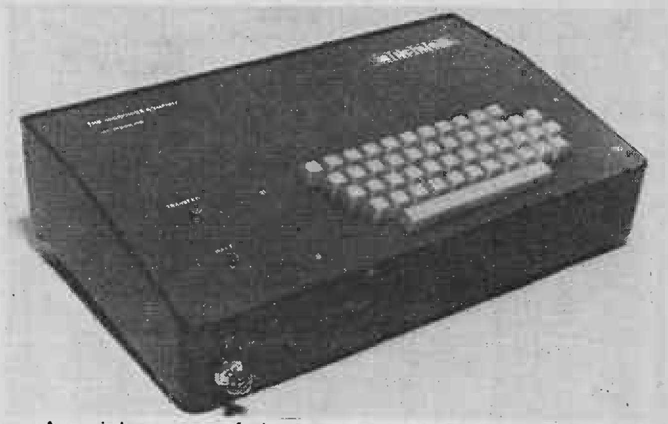
PETSOFT
318 Fulham Road, SW10

Texas Soon

At present the number of personal computer systems on the mass market is not that large — all that will change.

General Instruments are to market a board with CPU, RAM, BASIC in ROM, etc. very soon. Texas are also to enter the market. Details are scarce but we hear of a US launch in June with the system being based on the 9940. This is a 40 pin package version of their (Texas) 16 bit MPU, with, we hear, a 7K (16 bit 7K remember) resident BASIC. The machine will be interesting to see. ITT are to market the Apple system under their own name. The machines will be built here and, while initially exactly as Apple, ITT may improve things.

News now of a price reduction in a system that I have mentioned in Microfile before. The MICROS machine from Micronics is now to sell for £399 assembled and £360 in kit form (it was £550 — quite a drop).



A quick recap of the system (pictured) might be in order. Z80 based, the machine provides a 1K monitor, 2K of RAM, a 47 key keyboard, serial I/O, two parallel output parts and an output — at UHF, to allow a domestic TV set to display the machines output.

If to you that sounds like a description of the NASCOM 1 you're right. The main outward difference between the systems seems to be that the MICROS is cased and includes a PSU. The only way to make a detailed comparison of the two machines is to get them side by side and take a close look at them. My editor, God, the companies involved (in that order) willing, I shall try to do just that.

Full details of the Micros and of an impact printer for about £150 that the company hope to launch can be obtained, SAE please from

The Micronics Company
1 Station Road
Twickenham
Middlesex

$= £?

There have been quite a few comments over the past few weeks about the comparatively, high cost of many computer systems that are appearing on the British market. The general rule for American imports seems to be to take the American price and swop the dollar sign for a pound symbol, saves printing costs maybe.

It has been pointed out that on the higher priced of systems it would be possible to fly over to the states, nice one Fred, buy a system from one of the American computer stores and return to this country for the same price as purchasing the system here. You get a day or so in New York as a bonus. Sounds good doesn't it. But think again!

Many systems are not the most robust of creatures and after your, and their, travels may require attention. What happens when your machine breaks down—the UK organization is not likely to be too interested in servicing a machine brought over from the States. After all it costs a fair amount of money to set up a marketing organization together with service centres and it is this, in some part, that accounts for the higher UK price.

There is no doubt that many people are making a profit which may, politely, be called excessive: not offering much support or help to their customers and are in the personal computer business for a quick profit. Others, however are here to stay and have invested in setting up an organization that will not leave owners to fend for themselves when the going gets tough.

So, by all means compare US prices with the UK going rate but also look at the backup offered by the UK distributor/agent.

Let the buyer beware especially if he buys from the States.

CSF VDU

It probably will not be news to most of you that Thompson CSF have introduced a CRT controller chip into this country (details from Marshall's of Edgware Rd.). This chip will take care of a lot of the timing and control signals required by any VDU. Just hang a crystal, 2513, RAM and about five TTL chips around the device and you have a VDU.

I've been playing around with the thing for the past few weeks and found it to be very easy to use and capable of producing a very good display. I mention the device because you may be interested, not a lot maybe, but maybe a little, in my prototyping method.

Being brought up as I was on a diet of that product that refreshes the bits and veroboard, I find it difficult to come to terms with the new prototype methods, wire wrap—wiring pen etc. However with ICs of forty and even sixty-four legs things can get difficult. I've found a way that combines the old and new which has speeded up my design work. I use DIP vero board to mount the components but to wire the devices together, which take most of the time (cutting wires to length, stripping etc) I use prestripped, standard length wire wrap wire.

Don't bother to cut wires to length—this is where the time is saved. The final result does not look too good, but you've cut the time taken to set up and running in half.

Kit Bits

I am interested in gathering information on the problems, or potential problems involved in building and testing the various kits that are on the market at the moment. If you have built up a kit please send me your reports, good or bad, so that I can put together a review of these various products.

news.... ....digest

nota bene

AN 'electronic notebook' is now available on the UK market. Made by Toshiba, it is claimed to be the first alphanumeric pocket calculator available.

Called the LC836MN, it has 30 independent, large-capacity memories each able to hold a 6-digit alphabetic and 8-digit numeric input. Use of an extra memory can expand retention to 6 alpha plus 15 numeric.

Alpha-numeric entries are made by depressing the LETTER key, followed by the appropriate letter keys, which are also number/function keys; depressing a further master key allows entry of figures. Automatic review of the 30 memories is provided. Accidental erasure is virtually impossible; and memory is retained for the duration of battery life, some 9000 (12 months) continuous operational hours. Suggested retail price is £59.95 plus VAT.

eye eye

What have we here? National Panasonic's new lithium cell is about the size of a 5p piece, but has enough power to run an electronic watch for between 5 and 10 years. It weighs just over 3 grams, and is only 2.5 mm thin, National Panasonic say that it will operate at temperatures as low as —20°C. Its name is the BR2325 and because it is lithium has a voltage of 2V8, so less of them are needed to power most things (most cells have a 1V5 to 1V3 range). Some lithium cells are prone to emitting nasty gas and sulphur compounds, but this one is said to be completely stable. National Panasonic, Bath Road, Slough, Berks.

UFO DETECTOR

Making no claims as to the efficacy of the device, we present a circuit that will provide an indication of the magnetic disturbances which much UFO literature associates with UFO activity.

EVERY YEAR MANY thousands of people see objects in the sky which they cannot explain in terms of their previous experience. In this sense the existence of unidentified flying objects (UFOs) is not a matter for debate — people see flying things they cannot identify, thus, by definition, these things are unidentified flying objects.

The vast majority of sightings are caused by various objects or phenomena perceived in an unusual manner — cloud formations, meteors, satellites, planets, an unusually bright star, temperature inversions, etc. There are also a substantial number of hoax devices. Most people are satisfied if presented with a rational explanation for what they have seen, but a minority are not — they are 'conspiracy theorists' who deny totally the principle of occam's razor. Faced with 99 probable explanations for an unusual happening — and just one explanation which complies with a previously accepted set of concepts — they will inevitably choose the odd one out.

Klass Encounters

No explanation or proof will convince the dedicated conspiracy theorist to think otherwise — a classic example of this is the often repeated story that the results of the USA Department of Air Force UFO investigation 'project blue book' have been suppressed. This is not really true. The blue book project files were declassified in 1970, and the USA department of Air Force Office of Information state that the files are available to all bona-fide researchers and media representatives.

The conspiracy theory was well summed up by Salvador Freixedo at the UFO conference in Acapulco (April 1977). "The basic appeal of Ufology (for the masses) is that it is a belief system rather than a field of scientific investigation". A further large number of classic cases quoted by Ufologists has been well and truly debunked by Philip Klass (a technical journalist working with Aviation Week and Space Technology magazine).

Of The Financial Kind

Klass's book (UFOs explained') thoroughly demolishes the most classic cases and provides evidence which casts major doubt on those few remaining. Consider for example the often quoted 'UFO landing' in Socorro, New Mexico in 1964. It now turns out that the 'landing' was set up as a publicity stunt by the local mayor, who just happened to own that bit of land where the UFO 'landed'.

It is perhaps significant that no serious challenger has ever taken up the USA's National Equirer's offer to pay one million US dollars for proof that UFOs are unnatural phenomena emanating from outer space.

A small minority of ufologists should however be taken more seriously. These are dedicated people who investigate reported sightings as thoroughly as they are able. Unfortunately most of their investigations tend to be 'unscientific' in the sense that they lack the rigorous discipline which truly scientific investigation demands. Nevertheless, it is to the movement's great credit that they realise their investigational limitations and are currently doing their best to check out as thoroughly as they can a number of previously accepted classic sightings. In fact magazines such as the authoritative US official publication 'UFO' currently feature exposes of previously 'proven' situations. In the light of this recent background, ETI was extremely interested to learn of a UFO magnetic anomaly detector recently developed by one of our contributors.

The basis of this device is that many UFO sightings are claimed to have coincided with major magnetic disturbances. In many reported situations, electrical equipment is claimed to have ceased to operate whilst the UFO was in the vicinity.

Thus, claim some ufologists, it may well be possible to sense the approach of a UFO by detecting abnormal perturbations of the earth's magnetic field. The unit described here has been designed by Mr F C Gillespie who has considerable expertise in this field.

Flux Be With You

UFO literature indicates that magnetic disturbances associated with some UFO activity are of such a magnitude that they should be detectable by relatively simple equipment. Naturally the more sensitive the equipment the further away a disturbance could be detected — however, an upper practical limit for sensitivity is set in most areas by the generally high level of background noise associated with civilisation — and which, ironically, is often postulated as attracting UFOs to this planet.

It is not at all difficult to detect the magnetic disturbance caused by a ▶

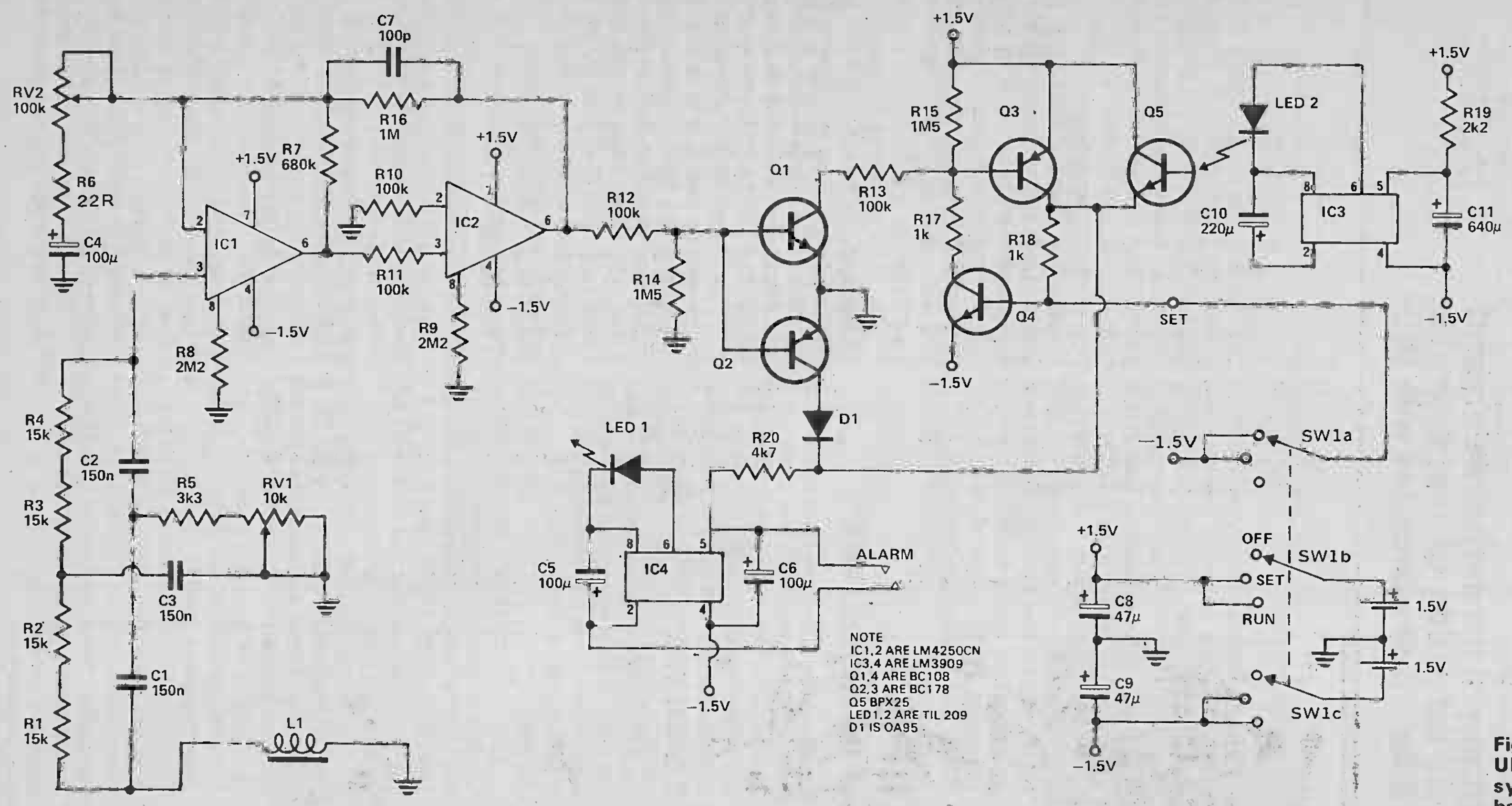


Fig. 1. Full circuit diagram of the UFO detector. Two detecting systems are provided, one based on a compass system and the other on coil L1.

HOW IT WORKS

There is anecdotal evidence that the magnetic disturbances associated with UFOs may be transient in nature or may build up and decay over a period of time or may also be of an oscillatory nature. For this reason the magnetic anomally detector has two detecting systems capable of responding to all three types of disturbance.

The simpler of the two systems responds to minor movements of a very sensitive compass. The compass needle is set up so that when undisturbed it blocks the passage of light from a flashing LED, the light output from which would otherwise fall on a sensitive phototransistor. The phototransistor output is then amplified, latched and passed to a second flasher circuit which in turn can trigger alarms.

A second and more complex circuit monitors a solenoid (L1) across which a voltage would be generated if it were subjected to a changing magnetic field. A twin-T notch filter is incorporated in this circuit to null out ambient 50 Hz.

Any voltage output resulting from a changing magnetic field around L1 is passed to the two-stage amplifier formed by IC1 and IC2. 50 Hz background noise is greatly attenuated by the twin-T notch filter formed by the components between L1 and the amplifier. The frequency of the notch is adjustable by RV1.

The gain of the amolifier IC1/IC2 is varied by RV2. Output signals from the amplifier are passed to Q1/Q2/Q3/Q4 which form two latching circuits (each functioning depending on the polarity of the output signal).

The output of the latching circuitry is then passed to IC4. This is a National LM3909 LED flasher. This causes the alarm LED to flash at about 3 Hz. An external alarm output is also provided.

The compass circuitry is quite straightforward. IC3 is used to extend battery life. Any output from the phototransistor Q5 triggers the latching mechanism thus initiating the alarm sequence.

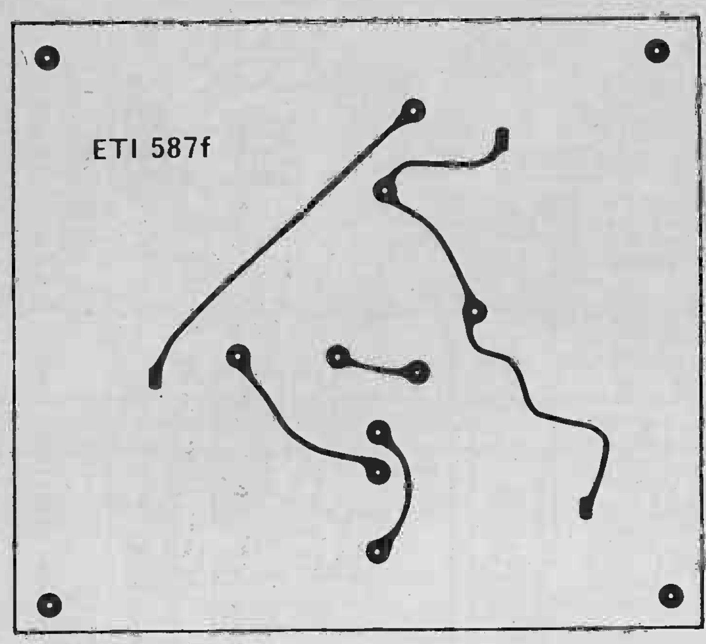


Fig. 2. Foil pattern for topside of UFO PCB.

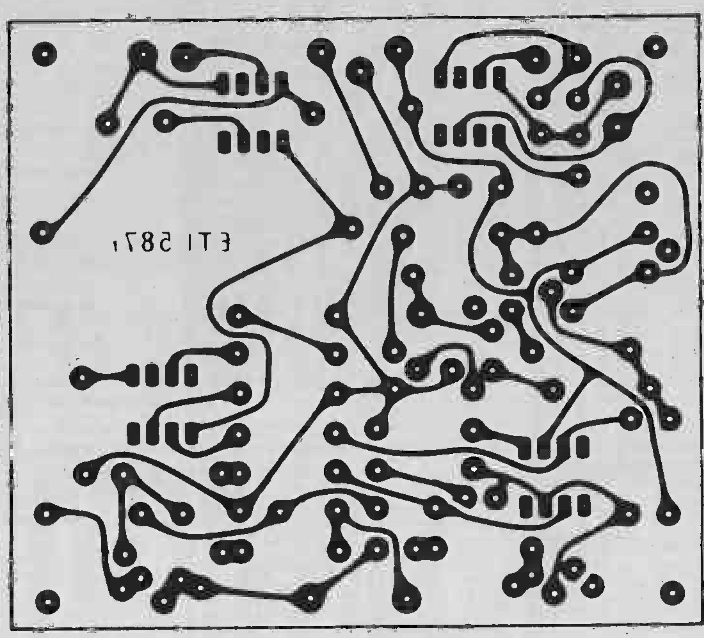


Fig. 3. Underside foil pattern.

light switched on 20m away — or a car 100 or more metres distant, but one can rarely find a sufficiently magnetic-noise-free environment in which to set up an instrument of such sensitivity. The detector described here has adjustable sensitivity and in all but the very 'quietest' of areas the sensitivity can be set so that the noise just fails to trigger it. It is only in very rare and remote locations that the detector itself is the limiting factor.

Construction

The unit has been designed in such a way that either or both detecting circuits may be used, or indeed, duplicated if required. Circuit construction is relatively straightforward, especially if the printed circuit board is used. The solenoid is the actuating coil from a Post Office type 3000 relay (5k). Many people will have such a device in their junk boxes — otherwise it can be obtained from shops handling post office surplus bits and pieces. The solenoid is located external to the unit and connected to it by a screened cable.

The block holding the LED and phototransistor associated with the compass mechanism is a little tricky to make. It may be built up from pieces of wood or plastic — or if you have the facilities it may be milled out of a block of brass or other non-magnetic material. The main requirements are that the LED and phototransistor must be very rigidly located and that the compass needle should just — but only just — block the light from the LED. The simplest way to make this section is to rebuild an old compass. We suggest that you build the unit in sections checking out each section as it is completed.

No matter how you build the device it is absolutely essential to make sure that the compass assembly is mounted very rigidly — if there is any freedom of movement random mechanical disturbances will be registered as alarms.

Setting Up

The compass circuitry is quite straightforward. Provided it has been made correctly the phototransistor

PARTS LIST

RESISTORS (all ¼ W 5%)

R1-R4	15k
R5	3k3
R6	22R
R7	680k
R8, 9	2M2
R10-R13	100k
R14, R15	1M5
R16	1M
R17, 18	1k
R19	2k2
R20	4k7

POTENTIOMETERS

RV1	10k	Trimpot
RV2	100k	Trimpot

CAPACITORS

C1-C3	150n	polyester
C4-C6	100u	3V6 Tantalum
C7	100p	polyester
C8, 9	47u	6V3 Tantalum
C10	220u	10V Electrolytic
C11	640u	16V Electrolytic

SEMICONDUCTORS

IC1, 2 LM4250CN Op-Amp
IC3, 4 LM3909 Flasher
Q1, 4 BC108
Q2, 3 BC178
Q4, Q5 BPX25
D1 OA95, or similar germanium diode
LED 1, 2 Red LED with mounting clip

MISCELLANEOUS

L1 Solenoid (eg PO 3000 relay coil)
S1 3p 3w switch
Compass (40mm max. needle length)
Connectors
PCB as pattern
Knob, Case, Batteries and holder, cable.

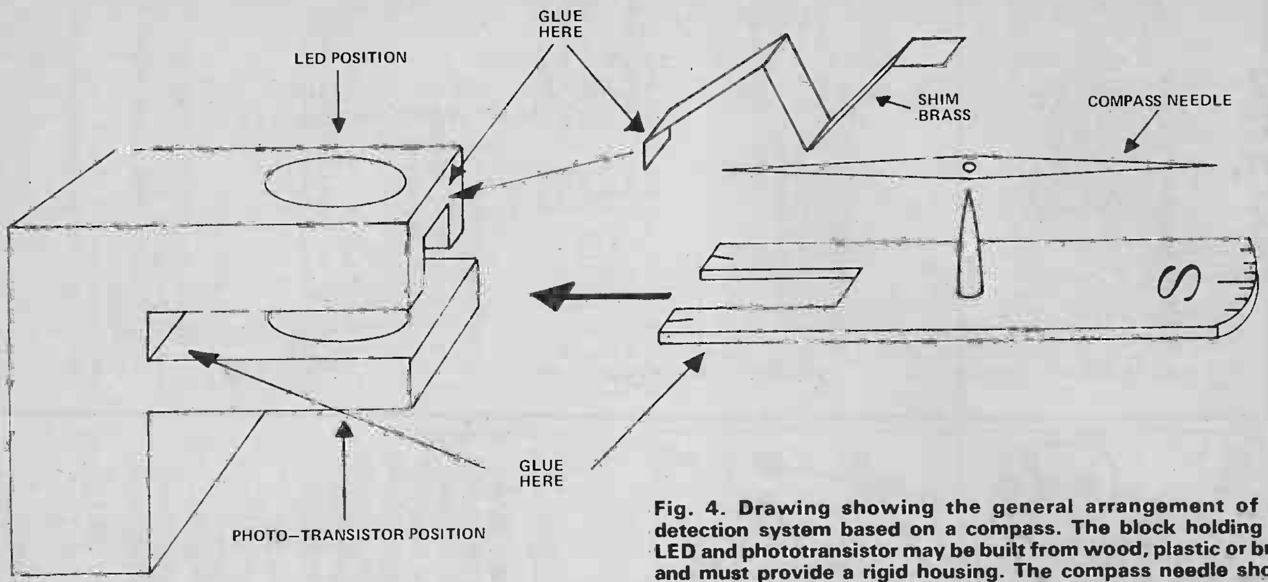


Fig. 4. Drawing showing the general arrangement of the detection system based on a compass. The block holding the LED and phototransistor may be built from wood, plastic or brass and must provide a rigid housing. The compass needle should just block the light from the LED in the quiescent state.

should be blocked by the compass needle when the complete detector assembly has been aligned precisely along the magnetic north/south line. Bringing a magnet or iron bar near the assembly should cause the needle to move slightly, thus allowing light to pass from the LED to the phototransistor, triggering Q3 and Q4, actuating the alarm.

The solenoid circuit is slightly more complex in that the twin-T rejection filter must be adjusted to optimise 50 Hz rejection. This may be done by observing the output from IC2 on a 'scope while adjusting RV1 for maximum rejection. If a 'scope is not available, then RV1 must be adjusted so that the circuit is not triggered by 50 Hz — increasing circuit gain via RV2 until the optimum setting is obtained. There is no need to inject 50 Hz into the circuit whilst setting up — in most places there's more around than you'll need.

Once the initial adjustments are made there will be little need to change anything except the sensitivity (gain) control RV2. This should be adjusted so that the unit is just short of triggering under normal conditions. Local thunderstorms may occasionally trigger the unit but this is inevitable unless you use the unit on low sensitivities. Well, there it is — the device will detect magnetic anomalies. Whether it will consistently detect UFO's is another matter — we were unable to obtain a DIN standard UFO for calibration purposes. Until we do, we refrain from making any claims as to the efficacy of this device. ETI

BUYLINES

The electronic parts should not be too difficult to obtain, indeed a number of our advertisers now offer complete kits of parts for our projects.

If you incorporate the compass based detection system, the pieces for this may prove more illusive, but a raid through your junk box or a surplus component store should produce the goods.

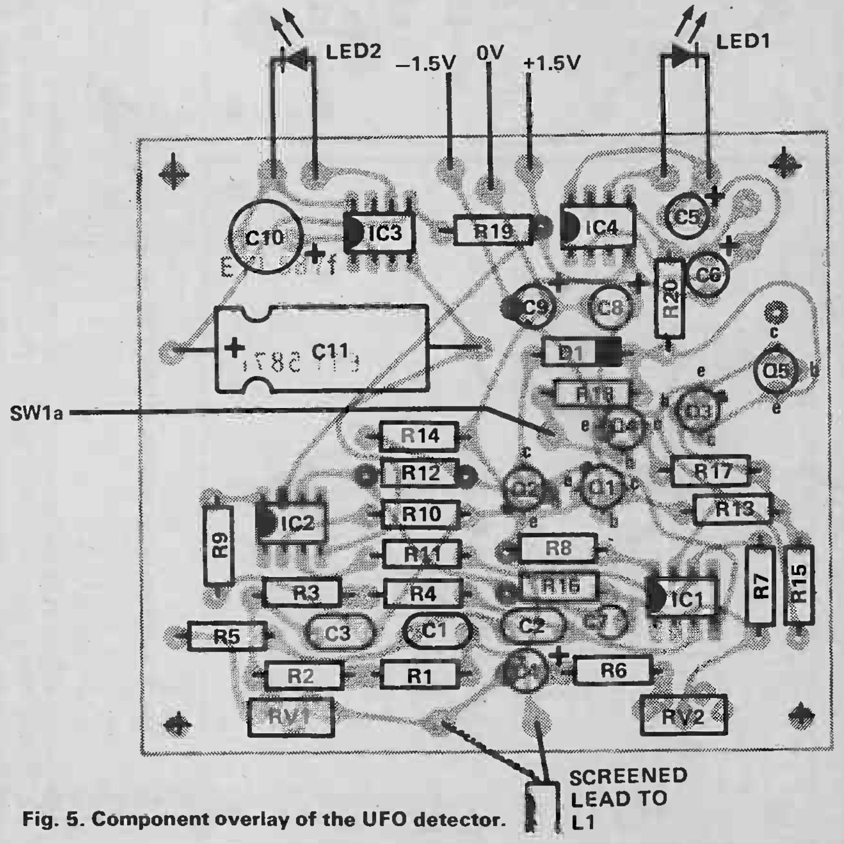


Fig. 5. Component overlay of the UFO detector.

THE RACE FOR THE BOMB

The sweeping advances towards the practical use of radioactive elements came at a time of acute political tension

IN MARCH 1939, Hitler's troops were marching in to Prague and occupying the "protectorate of Bohemia and Moravia." It was not unnoticed that Czechoslovakia was the major source of pitchblende in Europe. This was the same ore from which Pierre and Marie Curie had extracted uranium and radium many years earlier. On September 1 Hitler's troops entered Poland, and World War II had begun.

During that first *Blitzkreig* a group of eminent physicists met at the Kaiser Wilhelm Institute of Physics. Present were Hahn, Geiger, Bothe, Heisenberg, von Weiszaker. They met to consider the practical applications of atomic energy. However, a substantial number of others such as Lise Meitner, Otto Frisch, Enrico Fermi and Albert Einstein had fled the Nazi Axis and were now serving the "other side."

The German war ministry was alarmed by the news from America. Leading physicists were said to have been working with the armed forces for months, preparing for the military use of atomic energy.

Meanwhile in the USA, less was being done than the Germans imagined, but this changed and one of the greatest avalanches of research the world had seen was soon underway. ▶

When Niels Bohr had reported the news from Europe, Enrico Fermi, by then a professor of Columbia University, began lobbying for increased nuclear research, and an attack on the problems of developing the atomic bomb. His campaign against the fatal dangers of delay was unheeded till he gained the support of Albert Einstein.

Relatively supported

In July, Bohr and Einstein eventually reached the President, warning that war was imminent (the USA was still then a non-combatant) and that *"the Nazis will construct an atom bomb and will not hesitate to use it."* Bohr and Einstein thus became the driving forces in atomic research. President Roosevelt realised what was at stake, and he appointed an advisory commission of physicists and forces representatives. Their momentous decision was to make an atomic bomb. The first grant in 1940 was a mere $6,000 but by November a further $40,000 had been advanced, the sums increased like a landslide until by 1945 the sum of two billion dollars had been spent. Adjusted to present-day values this represents about ten billion dollars.

The problem facing both the Germans and the Americans was the same, natural uranium will not make a bomb. The isotope uranium-235 undergoes nuclear fission, while the major isotope, uranium-238, is a hindrance.

Uranium-235 is only 0.7% of natural uranium, and it must be separated out and concentrated. This is extremely difficult, and expensive, since it must be done using physical means, as the two isotopes have identical chemical properties. However, it is a direct method of making a bomb. When sufficient pure uranium-235 has been separated out, a bomb can be made. Two sub-critical masses of uranium-235 are brought together extremely rapidly, and an uncontrolled chain-reaction results in explosion.

No detonator was required, as once a "critical mass" is reached, the material goes off spontaneously, to release the energy equivalent of 20,000 tonnes of TNT.

Meanwhile back at the fiord

Meanwhile the Germans had occupied Norway, thus ensuring themselves a supply of heavy water from the Norsk hydro-plant at Rjukan in the mountains, where hydro-electric power was plentiful and cheap. With the ready supply of pitchblende from Czechoslovakia and heavy water from Norway everything was in favour of German success in constructing a nuclear reactor.

While German scientists did have some success in building a reactor, which could have led to development of nuclear weapons, they appeared to *avoid* the acquisition of the technology to do this.

On June 6, 1942, a group of scientists met in the great hall of Harnack House in Berlin, also present were the men behind the German war machine, including their chief, Albert Speer.

They reported some progress towards harnessing nuclear energy in an atomic pile, but did not give a positive report on the possibilities of developing nuclear weapons as initial efforts to separate out uranium-235 had failed, and it would take an enormous expenditure to find a way to do it. In addition, they did not have any expertise in particle accelerators, and were therefore not able to research many of the fundamental processes of nuclear physics.

Since the economy was already hard-pressed by the war, the decision was taken to scrap ideas of producing an atomic bomb.

United we explode

On the other side of the Atlantic, the American research project developed quickly. At the commencement of the war some twelve particle accelerators of varying power were either in operation or in various stages of construction. These were the experimental tools that enabled the scientists to understand the mechanisms of transmutations and nuclear reactions. Using such as the Berkeley cyclotron, American scientists MacMillan and Seaborg bombarded ordinary uranium with high energy deuterons and succeeded in producing new elements. Among these were minute quantities of neptunium and plutonium.

The discovery of plutonium-239 in 1941 added a new dimension. Like uranium-235 it is fissile. That is, it will undergo nuclear fission, can take part in a chain reaction, and if purified can be used in an atomic bomb. instead of uranium.

Of particular importance is the fact that it is produced in significant amounts in a nuclear reactor, or atomic pile, using natural uranium (often enriched in uranium-235). The plutonium then can be separated from the uranium fuel using chemical methods, since plutonium has different chemical properties from uranium. (This separation is much easier than concentrating uranium-235 out of natural uranium.)

There were then three ways of releasing atomic energy. The direct way is to separate uranium-235 from natural uranium, and use it in a bomb. Second, natural uranium, possibly enriched in fissile materials, is used in an atomic pile in controlled energy release, and simultaneous production of plutonium. Third, the plutonium from the reactor fuel can be separated and used in a bomb. The Americans pushed ahead with all three aspects. They were co-ordinated under the name "Manhattan Project."

The direct method needed uranium-235. Ernest Lawrence, inventor of the cyclotron, had an idea. In a mass spectrograph, charged atoms (ions) were separated according to their mass. This was done by sending them through a magnetic field. The atoms were deflected variably according to their weight by the field.

Lawrence of Berkeley

Lawrence had at his disposal the then most powerful magnetic fields on earth, generated by the 940mm electromagnet of the Berkeley cyclotron.

His research group converted the cyclotron using the giant magnet as the basic component into a kind of gargantuan mass spectrograph. They called the new apparatus the "calutron" (California University Cyclotron).

By the end of 1941 this machine was capable of separating one microgram of U235 per hour. Whilst this was nowhere near the many kilograms that were required it was not a futile enterprise. It provided the basis of future technology for separating uranium-235 on a larger scale.

The indirect method, of manufacturing a bomb with plutonium produced in an atomic pile, also had enormous problems. There was then no operating pile, and a chemical plant had to be built to separate the fissile material from the uranium fuel by the time the atomic piles were ready to deliver it.

To make a chemical plant, the chemistry of plutonium would have to be known. At this time it had not yet been produced in observable quantities. A measurable quantity was needed urgently.

Accelerating matters

Every available accelerator was brought into service and hundreds of kilograms of uranium were bombarded with neutrons for months until about a milligram of plutonium was made and separated. On this tiny amount, chemists used ultra-micro techniques to study its chemistry and design a method for separating it from uranium. By the time the atomic reactors were able to deliver large quantities of uranium fuel containing plutonium, a huge chemical plant was ready to extract it.

Meanwhile, Fermi and Allison had continued their constructions of experimental piles in Chicago. On the ninth attempt a multiplication factor of 1.0007 was achieved, signifying a self-sustaining chain reaction.

Fermi now concentrated on manufacturing a pile in which a chain reaction could be sustained and controlled. To prevent the system going out of control, a series of cadmium rods were inserted into the graphite/uranium pellet structure. The purpose of the rods was to absorb as many neutrons as possible, thus inhibiting their action when necessary. A sustained reaction was achieved in December 1942. Power was kept to a mere half watt whilst measurements were taken. This was increased to 200 watts ten days later. Outputs of one megawatt were being produced two years later.

The bomb could be made.

Development of the bomb was placed at Los Alamos some 50 km from Santa Fe, the state capital of New Mexico. To this place came physicists from all over the United States and other Allied countries, assembled by the eminent physicist Robert Oppenheimer.

Put to use

The first atomic bomb was exploded from a tower at Alamagordo in the New Mexican desert at 5.30am on July 16, 1945, at the height of a thunderstorm, and its successful result presented US President Truman with a very difficult decision, whether to defeat Japan by orthodox means — with estimated Allied casualties of 300,000 or whether to use the atomic bomb against Japan's civilian population and by such overwhelming evidence of power force Japan to surrender . . . . .

Three weeks after the first test, the city of Hiroshima was destroyed with a uranium-235 atomic bomb. ETI

electronics tomorrow......

by John Miller-Kirkpatrick

I AM IN THE ENVIOUS position of knowing someone who knows someone who knows a director of a company which is going to have a viewdata terminal (notice the lower case v as the Post Office now want us to call their viewdata service 'PRESTEL'). As an example of the average electronic engineer who is interested in viewdata and Teletext I am somewhat overjoyed to be in this position as there is now a very slight chance that one day I might be able to talk to someone who has used viewdata and thus knows something about it. I avidly read every scrap of information which is published on viewdata and at present I think I could sum up this as follows. Viewdata has the following characteristics —

1. Output is to a 40 x 24 VDU based on a commercial television set using the Teletext display format, control characters and graphics capabilities.
2. User input is designed to operate from a simple keyboard and thus all user entries are to be in the form of a choice number to a set of options displayed on the screen.
3. Communication is to be via Post Office telephone links using a PO approved MODEM (rentable from the PO at ridiculous rates).
4. Communication is to a large computer installation which is hidden away in a remote part of the country on an exchange which is a local charge call to only a very small number of people — many of whom will have not yet heard of viewdata.
5. Use of the service is for information exchange in a format which is presumably similar in format to a magazine with articles, information and advertisers all available at the push (or a dozen or so pushes) of a button.

I think that accurately summarises my knowledge of viewdata and I would think that it is possibly more than a lot of electronic engineers know—let alone the majority of the public. Let us look at the potential of a system such as a good telephone network and a few microprocessors can provide.

MPUs Make Connection

Automatic dialling is very simple to achieve for even a complete beginner. Dialling a number is achieved by picking up the receiver and then using the dial to activate a circuit breaker a preset number of times by twisting the dial to a required position and then releasing it. These two actions are handled by simple contact switches which in a simple example could be replaced by relays and could thus be driven by electronic counters or microprocessors. A simple SC/MP circuit such as SCRUMPI 2 or the MK14 could handle automatic dialling of about 200 subscriber numbers with only 768 bytes of RAM and could also be persuaded to decode the tones for ringing, engaged, unavailable or the more usual '??????' lack of tone altogether and thus redial or take other appropriate action. Total cost of building your own device would be about £80, in commercial quantities the device could cost under £10.

With an automatic dialler we could program our viewdata terminal to search several viewdata libraries on different telephone numbers to find the first available service. At this stage we will also let our microprocessor handle the required keyboard entries, for example, assume you know that the latest information on the price of bananas at the supermarket is available by dialling each of your local supermarket's viewdata systems and then answering 6 questions in the following form:

```
FREDS CORNER DELI

DO YOU REQUIRE?—

PRICES              1
AVAILABILITY        2
DELIVERY            3
PERSONAL SERVICE    9
REPLY? 1
```

```
FRED'S CORNER DELI

PRICES OF?

GROCERIES           1
VEGETABLES          2
FRUITS              3
MEATS               4
BAKERIES            5
REPLY? 3
```

```
FRED'S CORNER DELI

FRUIT PRICES?

PER KILO            1
PER BUNCH           2
PER BAG             3
PER BOX             4
PER JAR/BOTTLE      5
REPLY? 2
```

```
FRED'S CORNER DELI

FRUITS

APPLES              1
APRICOTS            2
BANANAS             3
BREADFRUIT          4
MORE                5
REPLY? 3
```

FRED'S CORNER DELI

PRICES OF
BUNCHES OF
BANANAS:

£00.47
THANK YOU FOR YOUR
ENQUIRY, WOULD YOU
LIKE TO ORDER?
YES 1
NO 2

Thus by dialling the local supermarket or delicatessen and then **always** entering the keyboard entries for 1, 3, 2, 3 and you will be presented with the required price on line 4 of the display (ie immediately after the third carriage return/line feed). So now we have a unit with a commercial price of about £25 which can order groceries on the basis of price/availability/delivery.

We have assumed that the unit can read the data on the screen which is no great technical feat but does not seem to be included as a viewdata feature. Can the output be other than a Teletext compatible unit (printer, RAM, Floppy) or is viewdata limited to the 40 x 24 VDU format?

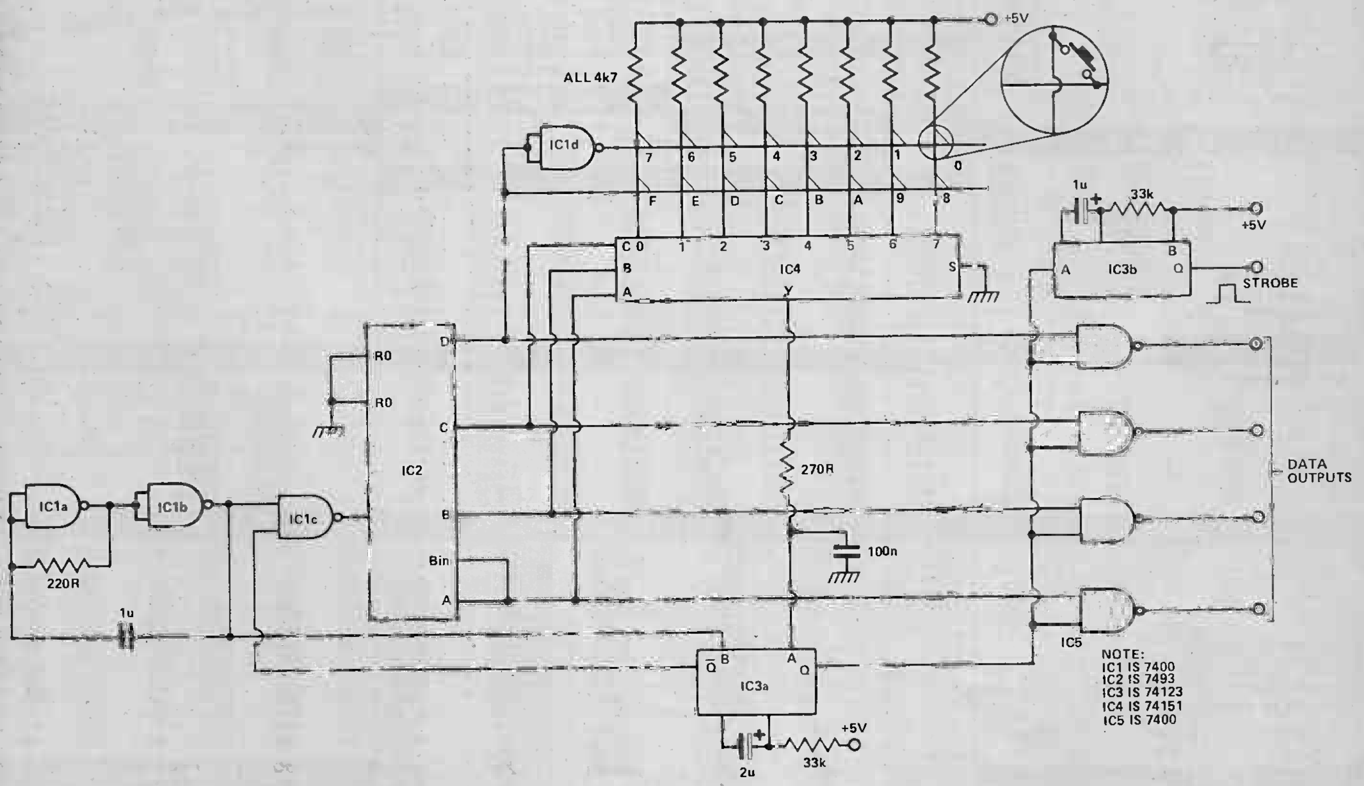
We have also assumed that "Fred's Corner Deli" has its own viewdata computer which appears to be a feature of viewdata but also appears to require large and expensive equipment. Surely any MPU system capable of handling Fred's bought and sales, invoicing, stock control and ordering (about £5,000 worth) would also be capable of communicating with something as simple as a viewdata terminal. In fact, why can't your home computer system control viewdata enquiries in and out?. Let your computer answer your phone after four or five rings and test for a viewdata or vocal caller (a viewdata caller would be recognisable with a tone). The computer can then either take a taped message for a vocal caller or start interrogating a viewdata caller and give out appropriate messages to friends (who know your password codes) or strangers. There is thus even the facility for Fred's Corner Deli to call your computer and leave a viewdata format message as your invoice, statement or this week's special offers.

All the above is a perfectly feasible proposition with today's technology, the amateur constructor could build a viewdata computer for under £500. Note that the word used is 'could', because you are in theory not allowed to—BY LAW. It is illegal to 'Permanently' connect unauthorised equipment to the Post Office Telephone or Telecommunications circuits, it is also illegal to 'steal' electricity by making unauthorised or unrecorded use of Post Office electricity. It would also be very difficult to build a viewdata computer because of the lack of specifications published. There are ways round the problem of interfacing 'Permanently' to the telephone line, one is the use of a PO MODEM at about £300 per year rental (plus installation), another is . . . . . . well the magazine would not be allowed to publish circuits but ask yourself whether the plug and socket system offered by the PO (Plan 4A?) means that the telephone unit is "Permanently' connected or not?

I don't like to get politics into a column such as this but how can our internal telecommunications industry and services grow to fruition if the cost and complexity of installation of a system such as viewdata is left in the hands of a monopoly protected by the law of the land?

ETI

tech tips



Hexadecimal Keyboard

C. N. Harrison

Programming a microprocessor can be a time consuming business if instructions are entered in binary using rows of toggle switches. A far more convenient method is to enter the code in hexadecimal notation using an appropriate keyboard. A suitable keyboard should be fully debounced, provide a strobe whenever a key is struck and use standard power supplies. The following circuit provides all these features.

The eight by two matrix of keys are scanned sequentially by the 74151 data selector, IC3 and the D output of the 7493 four bit counter, IC2. If no keys are pressed the Y output of IC3 is always logic 1 since all eight inputs are pulled high by the 4k7 resistors. When a key is pressed the Y output remains high until the counter reaches the inverse of the required 4 bit data. The appropriate input of IC3 is then pulled low and the Y output changes to logic 0. This triggers monostable IC4a which disables the clock input to the counter, enables the data outputs via IC5 and triggers IC4b to provide a data strobe. While the key is closed IC4a is retriggered by the clock so that the data remains stable on the output lines until the key is released.

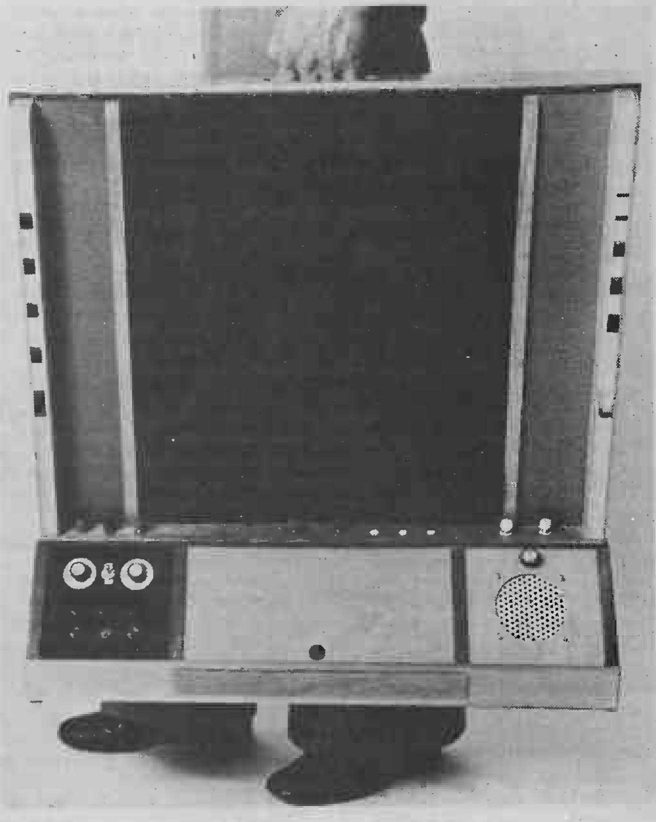
If latched data outputs are required IC5 can be replaced by a 7475 quad latch clocked from the output of IC4b. The data would be available at the Q outputs of the latch.

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.

. . . news

have bench, will travel

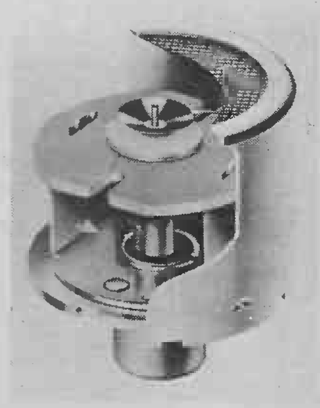


Nice idea from Home Radio is this portable workbench, instead of running riot on the kitchen table you can pack up and move your work bench when finished. Rather than try and make something with everything, they have just given it a 0-20V at 1A power supply plus a loudspeaker and mains outlet — so you can customise it to your own particular needs (built in cigar lighter etc).

Tools and soldering iron can be kept in the sides or lockable compartment and the whole thing comes for £45 (unwired) or £54 (Wired) plus 8% VAT and £2.50 carriage. A vice is also available for £5.50 plus 8%. Full details from Home Radio, London Road, Mitcham, Surrey.

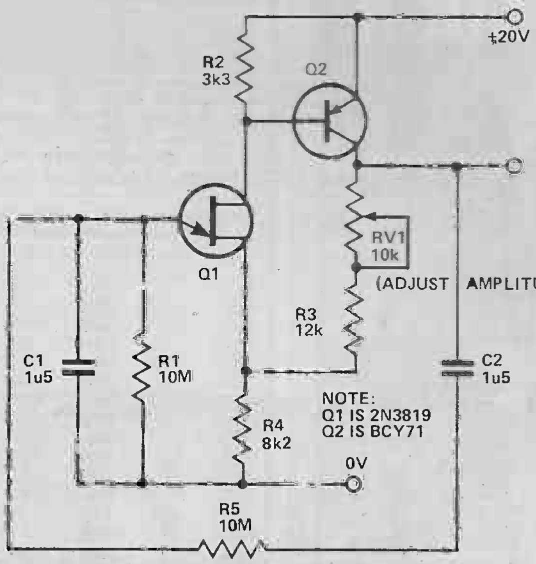
silent sound

Impectron Limited are now stocking Matsushita (try saying that after a liquid lunch) Ultrasonic Transducers. Three versions are available, the FR CRO1 range operates at 40 kHz (with a bandwidth of 3½ kHz) and is available in different sizes and with alternative mounting methods. Next is the FR CRO2 which has a bandwidth of at least 11 kHz, and is designed for multi-channel remote control applications. A totally sealed model completes the line-up, with a bandwidth of only 2 kHz, called logically enough the FR CRO3. Further information from Impectron Limited, 23-31 King Street, London W3 9LH.



VLF Sine Generator

G. Loveday

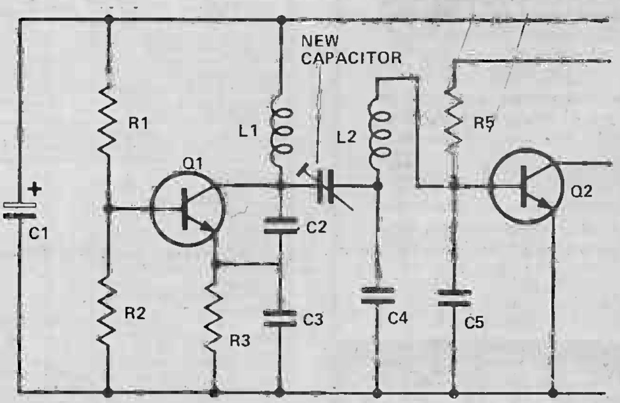


Generating very low frequency sine waves (i.e. less than 0.1 Hz) presents several problems. Timing capacitors usually have to be large valve electrolytics, any amplifier used must be D.C. coupled, and the amplifier's input impedance must be very high. One standard method is to first generate low frequency square waves, and then to shape these into an approximation of a sine wave by the use of several non linear devices, such as diodes. The circuit shown in Fig. 1 is a relatively simple approach based on the familiar wien bridge. An n-channel FET and a pnp transistor are arranged in a DC coupled circuit and the voltage gain is determined by the negative feedback R3 and R4. The gain need only be about three, thus if the bias required by the FET is 3V the output level will be approximately half the supply voltage.

Since R1 can be a high value resistor the value of the capacitor is only 1u5 for sine wave outputs of 0.01 Hz. This capacitor is available in polycarbonate. The amplitude of the output can be adjusted by RV1 to give low harmonic distortion and to be about 10V peak to peak. As expected, with this wien bridge circuit, frequency stability is good with changes in both supply voltage and temperature.

Balance Circuit For ETI Metal Locator

C. Bray



This modification is an improvement to the ETI IB metal locator Mark 2, as published in the February 1978 issue of ETI. The first two stages of the circuit showing have been redrawn showing the modifications, the additional trimmer capacitor is a Wingrove and Rogers type S60 multiturn tubular 2-25p, although any similar type giving smooth control between 1 and 8p will do. The function of the trimmer is to balance out coupling between the search head coils L1, L2.

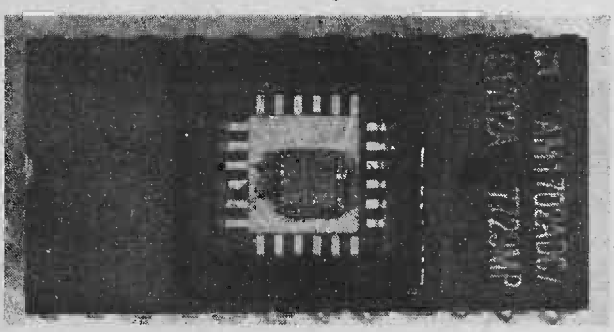
In practice, the trimmer is set to approximately 3pf and the search head coils adjusted as in the original article.

Before a search is started, the trimmer should be adjusted for minimum meter reading, with gain control RV1 set as high as possible. This should be done in free air, but if it is found that lowering the head to the ground produces a slight change, this effect can also be trimmed out.

Even if the coils are mounted very substantially, and should not move, the degree of imbalance that occurs over quite short periods of time is surprisingly high and makes the fitting of this device well worthwhile.

digest. .

wanted, probably dead



Advanced Micro Devices have been circulating this photograph of 'counterfeit' 1702A EPROMs. Some sharp operator has been emptying their dustbins and re-marking rejects — naturally he then sells them as genuine AI devices ("Just a bit cheap 'cos the lorry was moving when they fell off guv"). AMD have nicknamed the duff devices 'IIGOs' (information in, garbage out). If the 7 has a slightly curved downstroke then it's an IIGO, and if you bought it then you're an IIGiOt.

thanx

WHEN we included a reader survey in ETI we expected a good response, but the response was in fact amazing, more than 3 000 of you replied. From the analysis it seems that if you are a 27.9 year old male with an income of £4 375 and let .93 people read your copy of ETI — then you are Mr Average ETI. Most of you think ETI is also better than a year ago, thank you. Sorry we could not reward everybody but 60 people have been sent an ETI T-shirt and car stickers — thanks again to all who replied.

deaf teletext

The IBA and BBC are independently helping research into the possibilities of using Teletext for subtitles for the deaf. The BBC is working with Leicester Polytechnic on the possibilities of using a computer to process the output from a Palantype shorthand machine (used a lot in courtrooms) speed is expected to be up to 200 words per minute.

The IBA and ITCA (Independent Television Companies Association) are supporting Southampton University in a 3 year project, expected to cost £50 000. The aims are of a more general nature than those at Leicester, and are to establish the optimum forms of subtitling — with a full study of the human factors involved.

gossip, gossip

Quite a lot of the time we overhear snippets that fall into the plain old fashioned gossip category, some is too good not to publish. Some of the very large semiconductor users are not as ethical as they would have people believe. When a company develops a super-dooper new IC, after lots of research and investment, they usually give a few potential volume users samples to evaluate. Well it seems that some of the potential users were shipping the samples to the Far East, where some firms will slice any IC apart and use electron microscopes to produce a set of masks for the IC. They charge about £25 000 and have a turn-round time of 10 days, very cheap compared to possibly a year and a million pounds to design and develop from scratch.

So now the manufacturers that have had imitations flattering their product (sometimes even before it was on the market) are giving out samples on a sale or return (intact of course) basis — oh yes the sale price is usually about £300 000.

Now that Commodore and Tandy have dived into the personal computer lake, we keep hearing that amongst others I*M and T* are in the late stages of putting together their own personal systems — not to mention N*C and various others from the land of the rising sun. Going to be a lot of swimmers in the next year!

DESIGNING OSCILLATORS

One of the problems in electronics is stopping amplifiers from oscillating, another problem is getting oscillators to oscillate . . . Tim Orr explains.

AN OSCILLATOR IS BASICALLY an amplifier with positive feedback applied around it. The feedback must be AC coupled otherwise a DC latch up condition would occur. Having got some sort of oscillation, one of two things can happen. The oscillation can build up in amplitude until clipping occurs due to the power supply voltage levels. At this point a stable, but truncated waveform will be generated. Alternatively if the gain of the amplifier is too low the oscillation will die away. To produce a pure sinusoidal oscillation thelevel of the signal in the system must be accurately controlled. There must be some amplitude limiting or automatic gain control such that when the peak signal level tries to exceed a reference voltage, the amplifiers gain is reduced. This is in fact what limiting does. To maintain stable oscilation, the overall gain of the system must be exactly unity. Any less and the oscillations will never start. If the gain is more than unity, the oscillations will occur, but amplitude limiting will cause gross distortion.

A very common method for stabilising the oscillations, which is often used in Wein bridge oscillators, is to employ a very sensitive thermistor as an AGC. However, the thermal time constant of this component often produces an annoying amplitude bounce which occurs when changing to a new frequency.

Other methods are diode limiters (which tend to cuase large amounts of distortion) and FET AGC circuits. The latter method can be used to generate super low distortion sinusoids by allowing the system gain to stabilise over tens of seconds.

The oscillation frequency is mainly determined by the feedback around the amplifier. By making the feedback a reactive network, the phase of the feedback will vary as a function of frequency. Oscillations can only occur when the feedback is positive and thus the phase response of the feedback will determine the frequency of oscillation, assuming that the overall gain at this frequency is at least unity. By varying the phase response of the feedback, the oscillation frequency may be altered.

An oscillator should be thought of as being a circuit which continuously generates a waveform, no matter what the shape of the waveform. There are very many circuit techniques for generating these signals which range from relaxation oscillators to piece wise approximations using square waves. Some of these methods will now be illustrated.

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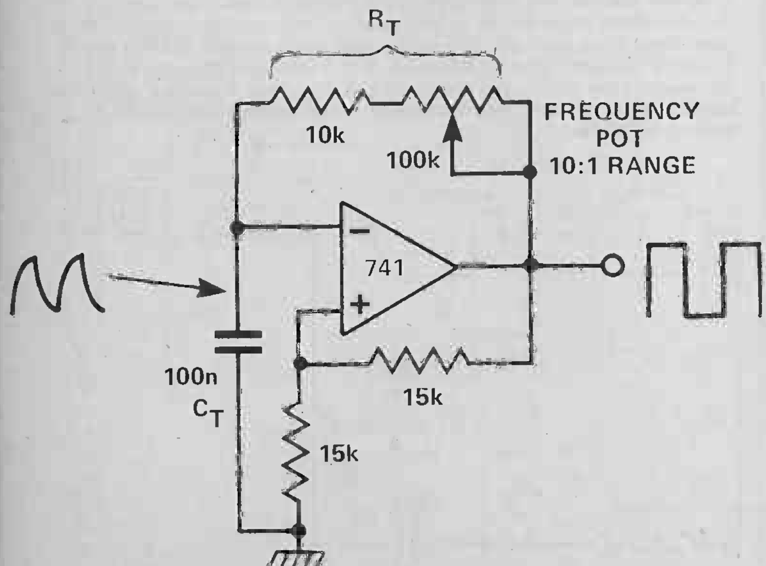
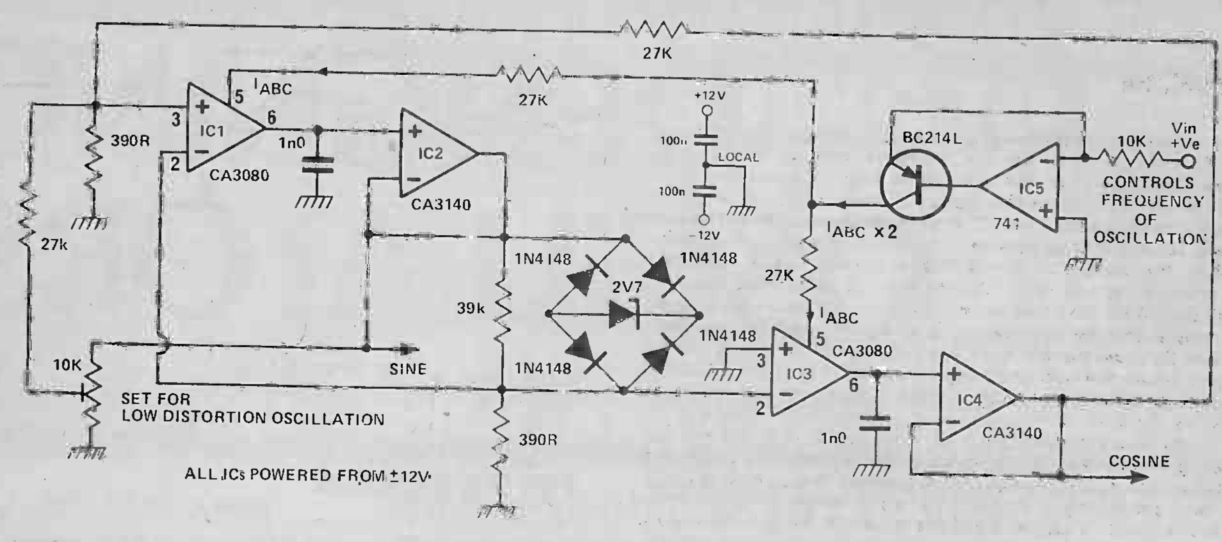


Manually Controlled Oscillator

In this circuit there are two feedback paths around an op-amp. One is positive DC feedback which forms a Schmitt trigger, the other is a CR timing network. Imagine that the output voltage is +10V. The voltage at the non-inverting terminal is +15V. The voltage at the inverting terminal is a rising voltage with a time constant of $C_T R_T$. When this voltage exceeds +5V, the op amp's output will go low and the Schmitt trigger action will make it snap into its negative state. Now the output is —10V and the voltage at the inverting terminal falls with the same time constant as before. By changing this time constant with a variable resistor a variable frequency oscillation may be produced.



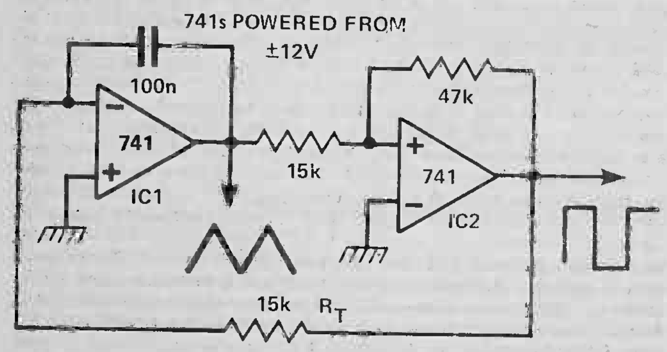
Dual Integrator Quadrature VCO

This is a sinusoidal oscillator which uses frequency dependent feedback and zener diode amplitude limiting. IC1,2,3&4 form a dual integrator circuit which is an analogue model of a second order differential equation! There is some positive feedback around IC1,2 which is analogous to having a zero damping factor in the equation. This means that the oscillations will build up. The positive feedback is controlled by the 10k preset. IC1,3 are integrators and IC2 and IC4 are voltage followers with high input impedance. The phase shift produced by an integrator is 90° so there is no overall feedback around the lop (IC1 is non-inverting, IC2 inverts). Thus we have all the conditions for oscillation, and in fact oscillations will occur when the preset is adjusted to give the correct phase shift around the IC1,2 stage. Amplitude limiting is produced by the 2V7 zener inside the diode bridge. By placing it inside the bridge the same diode is used for both positive and negative signals and the limiting is symmetrical. The integrators are two quadrant multipliers (CA3080s), so the gain of the loop can be controlled by the current I_{ABC}. In the solution of this second order differential equation, the gain of the loop is proportional to the resonant frequency. Thus, by varying I_{ABC} or rather by varying V_{IN}, the frequency of oscillation may be altered.

As the integrators produce a 90° phase shift, the two sinusoid outputs are in phase quadrature, i.e. one is a sinewave, the other a cosine wave. The cosine output is lower in distortion than the sinewave, because the amplitude limiting (and hence the distortion) is produced at the IC1,2 stage.

The second stage (IC3,4), acts as a filter and hence produces a purer sinusoid. Using this circuit a 1000 to 1 continuous frequency sweep can be obtained. However, the inaccuracies in the CA3080's will cause some amplitude variations and it may be necessary to set the positive feedback a bit high (and hence attract more distortion), to maintain stable amplitude limiting over the sweep range. This circuit is an oscillating filter and if you turn down the positive feedback and inject a small signal through a 100k resistor into IC1 pin 3, a bandpass and low pass response is obtained from the sine and cosine outputs respectively.

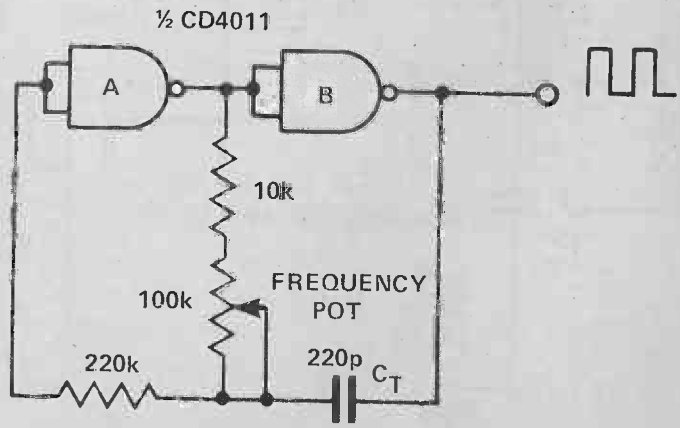
Simple Triangle Square Wave Oscillator



This circuit generates simultaneously a triangle and a square waveform. The triangle could be 'bent' by a diode function generator to produce a sinewave. The circuit is always self starting and has no latch up problems. IC1 is an integrator with a slew rate determined by C_T and R_T and IC2 is a Schmitt trigger. The output of IC1 ramps up and down between the hsteresis levels of the Schmitt, the output of which drives the integrator. By making R_T variable it is possible to alter the operating frequency over a 100 to 1 range. Three resistors, one capacitor and a dual op amp is all that is needed to make a versatile triangle squarewave oscillator with a possible frequency range of 0.1Hz to 100kHz.

CMOS Oscillator

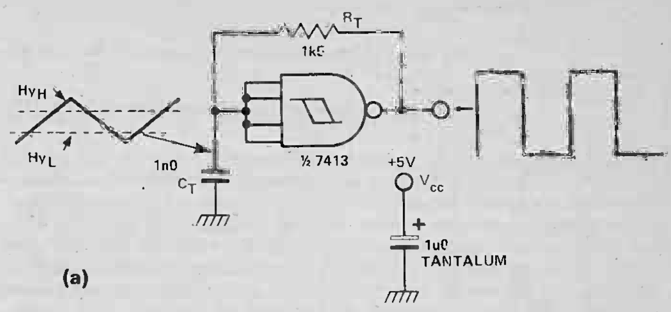
Two CMOS gates can be used to produce a simple oscillator. Imagine that output B is high. Then the input to A is also high due to it being coupled via the capacitor C_T to output B. Thus output A is low, input B is low and output B is high, which is as we would expect. However, capacitor C_T is being discharged via the 100k pot and 10k resistor to a logic 0. When this voltage reaches the crossover point for A, output A goes high, and thus output B goes low. Now the capacitor is charged up to a logic 1. Thus the process repeats itself. Varying the 100k pot changes the discharge rate of C_T and hence the frequency. A square wave output is generated. The maximum frequency using CMOS is limited to 2MHz.



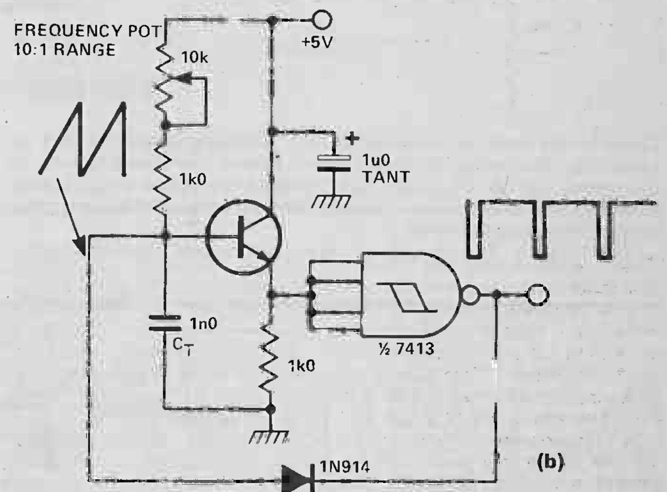
TTL Oscillator

A simple relaxation oscillator can be made using a TTL Schmitt trigger. The circuit 'a' is the most simple version that can be produced. Imagine that the output is high. Capacitor C_T is charged up via R_T. when the upper hysteresis level (Hyh) is reached, the output goes low. CT is now discharged until the low hysteresis level (Hyl) is reached whereupon the output goes high. Thus the oscillator generates a square wave, with an uneven mark to space ratio, due to the input current requirements of the 7413. The frequency can be set at any value up to several megahertz by varying C_T and R_T. C_T can be an electrolytic but R_T must not be more than about 1k5 or it will not be able to pull down the Schmitt trigger inputs. (If you use a CMOS Schmitt this does not apply). The output is a nice fast squarewave capable of directly driving several TTL loads. One problem to be encountered is frequency jitter. When the input is very near to a hysteresis level, noise in the system may cause the oscillator to prematurely trigger, thus making that period slightly shorter and producing a noise induced frequency jitter. Also using two Schmitt triggers from the same IC is sure to cause interaction and thus jitter. To reduce power supply noise effects the IC should be decoupled with a 1uF tantulum capacitor actually at the V_{cc} and GND pins of the package.

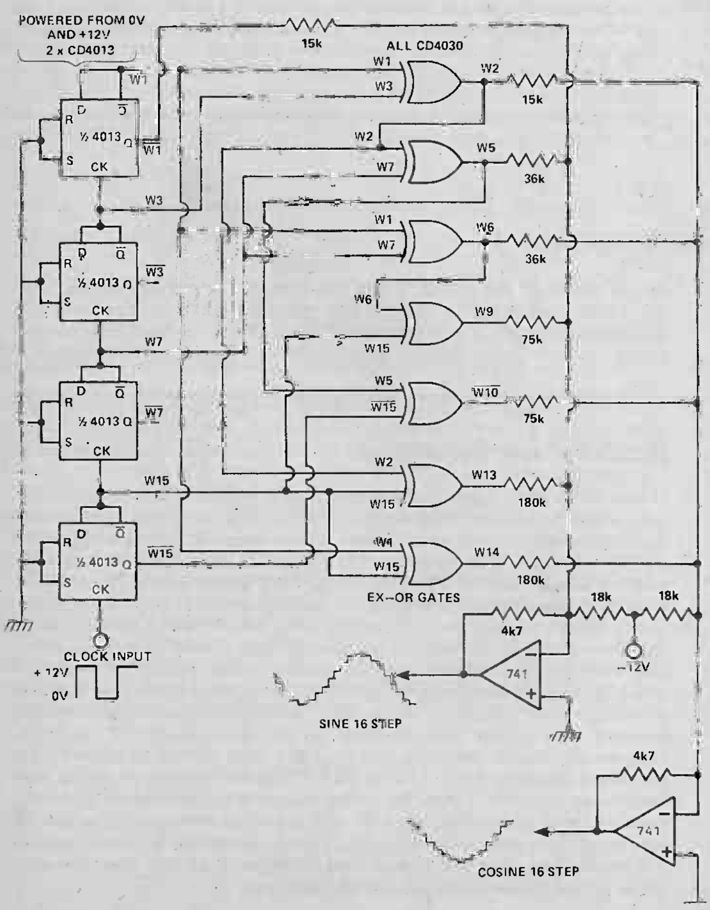
Diagram 'b' shows the same oscillator, but with a 10 to 1 manual control of frequency. The timing capacitor is charged up by the 10k pot and the 1k resistor. This voltage is then buffered by the emitter follower and fed to the Schmitt trigger. When the upper hysteresis level is reached the output of the Schmitt goes low and the capacitor is rapidly discharged via the diode until the lower level is reached. The process then repeats itself. As the discharge period is so fast, it can be as short as a few hundred nano seconds, the period can be thought of as being determined by the charging time, which is controlled by the 10k pot.



(a)



(b)



Walsh Function Generator

The mathematician, Fourier, said that any repeating waveform could be made up out of harmonic components. These components are sinusoids which are integrally related to the fundamental period of the waveform in question. This is a convenient conceptual approach, but as a way of practically synthesising waveforms it is not on. You would have to generate a whole series of harmonically related sinewaves which might prove a little difficult. However, a man called Walsh said that you could do the same thing as Fourier, but with square waves. So, instead of using sinusoidal Fourier sets, we can use square wave Walsh functions to synthesise waveforms. There are various techniques for calculating the Walsh function co-efficients for generating particular waveforms but these are beyond the scope of an article such as this. The diagram shows the circuit for generating a sine and cosine waveforms using 16 steps. Walsh functions are orthogonal functions, just as sine and cosine are orthogonal, and so the generation of these two waveforms is relatively simple using this technique. The 4013 dividers and the exclusive OR gates generate the Walsh functions, which in turn are converted into analogue waveforms by use of the correctly weighted resistor networks. Note that you only need 4 resistors to generate a 16 step sinewave approximation.

The resultant outputs can be easily filtered by fixed or tracking filters to produce pure sinusoids. The output frequency is 1/16th of the input clock frequency. The clock can be stopped and the outputs will remain fixed, try that with analogue techniques!

▶