ELECTRONICS TODAY

electronics today international

APRIL 1976

TECH-TIPS & DATA SHEET INDEX

30p

SOUTH AFRICA 60c
CANADA $1

Convert your calculator to a STOPWATCH

SPECIAL OFFER CMOS & TTL SEE PAGE 39

MICROPROCESSORS - how the chip works

CA3130—extra data

NOISE GENERATOR

AUDIO MILLIVOLTMETER

5V POWER SUPPY

SPACE ENVIRONMENT

NEWS . . . CONSTRUCTION . . . DEVELOPMENTS . . . AUDIO

electronics today international

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Special Offer

Our cover this month shows the calculator/stopwatch, featured on p10, in action at the ETI 'Yard of Ale' contest, held by courtesy of the landlord of the Victory in Pinner.

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READERS' QUERIES. These can only be answered if they relate to recent articles published in the magazine. Rarely can we supply information in addition to that published. Written queries must be accompanied by a stamped addressed envelope, and telephone queries must be brief, not before 4pm and can only be answered subject to the availability of technical staff.

BACK NUMBERS. Back numbers of many issues are available for 40p each, plus 15p postage.)

SUBSCRIPTIONS. Great Britain £5.00 per annum. Overseas £5.50.

READER SERVICES. See page 82 for details of all ETI Reader Services and other information.

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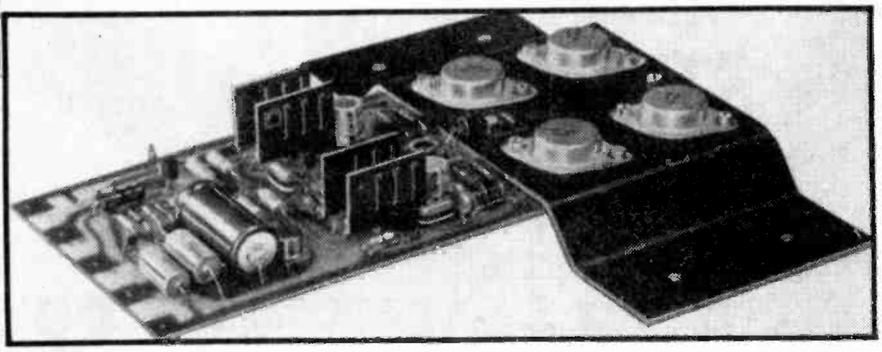
news digest

NO STRINGS (GUITAR?) POWER



Designated the AL250, a new 125W rms amplifier rose to our notice recently from Bi-Pak Semiconductors, 63a High Street, Ware, Herts. Retailing at under £16 the amplifier has a very good specification, (see below) that would suit it perfectly for use as a guitar amplifier, assuming a suitable pre-amp.

The unit is protected against short-circuit and low loading of the output, and should be, therefore, fairly rugged in use. Bi-Pak state on their sheet that the unit is suitable for 'background' music. Background at 125W rms? Amen to that! Details from Bi-Pak.

SPECIFICATION

Output Power (4Ω load)	125Wrms
Sensitivity (for 100W at 1kHz)	450mV
Input Impedance (at 100kHz)	33kΩ
T.H.D. 50W into 4Ω	0.1%
50W into 8Ω	0.06%
Signal to Noise Ratio (at ½ power)	>80dB
Power Bandwidth (−3dB)	20Hz-25kHz
Damping Factor (8Ω load, at 1kHz)	65
Size	190 x 205 x 40mm.

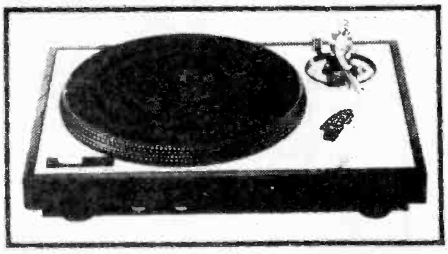
SINGLE CHIP LOW COST TEMPERATURE CONTROLLER

The new National Semiconductor LM3911 IC will control temperature over the −25°C to +85°C range better than 1/10°C stability. Included on the chip is the calibrated temperature sensor, voltage reference and op-amp. All that is needed for the complete control system are set-point resistors and a power control device. The sensor is calibrated directly in degrees Kelvin at 10mV/°K and initial accuracy is ±10°K, but can be improved externally. Applications for the LM3911 range from home thermostats to precision temperature baths. The low cost makes it attractive to use as fire alarms or overtemperature detectors in electronic circuitry. For example, an LM3911 could be included in MOS memories to speed clock rate as temperature increased.

NAVY WIRED FOR VISION

Muirhead Ltd, have recently delivered wire photo equipment to the Navy. Photo transmitters are located on board ships in areas where incidents may occur and photographs taken are then sent back to a receiver located in Whitehall. In this way Government officials have photographic information available to support verbal reports of the incident. This equipment was in regular use recently on board the Naval Frigates supporting British trawlers in the Cod War.

NEW LUX TURNTABLE



Aimed at the very top of the market the PD282 is the first venture into turntables for the Lux Corporation. The device is direct drive with a unique bearing system. No further details are available at present, but watch for it, as it is due to be released here very shortly. (For a while SME had the only one in the country.) The price will be very high; the PD282 sells in France for 1664Fr (£168). Distributor: Howland West Ltd., 3–5 Eden Grove, London N7 8EQ.

TANDY LISTS

We have just received the new Tandy catalogue, listing their ranges of hi-fi and electronic components. Whilst the hi-fi ranges offer only questionable value for their price, the catalogue does include some hard-to-obtain components e.g. strobe tubes. The prices are high, but if you can't find it elsewhere, try Tandy.

FAIRCHILD TO ENTER TV GAMES MARKET

Fairchild's Consumer Division are planning to launch a wide variety of TV games in the US during the latter part of 1976.

The basic unit providing three games is expected to retail for about $ 100 in the US but Fairchild have recognised that one quickly tires of a limited choice of games, so the unit will have a slot into which 'cassettes' can be inserted to increase greatly the game choice. Each cassette will enable 3 extra games to be played. These include sophisticated race track and war games. Cassettes are expected to retail for $ 15.

Plans to market the units in the UK have not been finalised but it is hoped to launch the range in Britain during 1977.

APOLLO–SOYUZ PULSAR

Not, as you would think, the ETI clock taking to space, but the first extra-galatic pulsar star. It was discovered by the Apollo spacecraft during the link-up last year. Lying in the Lesser Magellanic Cloud it forms a binary pair with a blue giant, circling it every 3.89 days. Designated SMC-X1 the star is ten times as powerful as any in our own galaxy.

HOWS DAT!

Maplin Electronic Services produce a regular news sheet as a catalogue supplement and frequenctly liven this up with cartoons. Main 'feature' of the February 1976 is the ETI Dynamic Noise Filter covered in the February and March issues; Maplin are doing a kit for this.

We were especially taken with the accompanying cartoon done for them by Sid Parker of the Southend Evening Echo and reproduce it below by kind permission of the artist and Maplin.

"I AM FINDIN' DIS DE BEST WAY O' GEDDIN' RID O' DE WHITE NOISE"

75 WAS BAD YEAR FOR SEMICONDUCTOR COMPANIES

Last year was a bleak one for the US semiconductor industry according to an analysis by the Chase Manhattan Bank. This had been widely predicted but only now are the facts coming out.

In the US, the sales of consumer electronic products was 20% down: audio equipment was down a staggering 30%: Microwave ovens were one of the few products which inproved.

The falling sales of consumer products led to a 20% drop in semiconductor sales but in the last months of 1975 a distinct improvement was under way. Traditionally the trends in the US are followed about six months later in Europe and Japan. If this follows on this occasion we can expect an improvement elsewhere in the world within a few months.

Digital watches 'took off' last year, cushioning the blow to some companies: sales topped 3 million units in 1975.

NATIONAL CALCULATOR IC

National Semiconductor offer a new, low-cost six digit floating decimal calculator circuit, MM5777. The device uses a metal-gate P-channel MOS process – a tried and tested process that gives low end-production cost.

To assemble a complete four-function, six-digit calculator the company offer:-

NSA 1161	LED display stick
DS 8977	Digit driver
MM 5777	Calculator chip

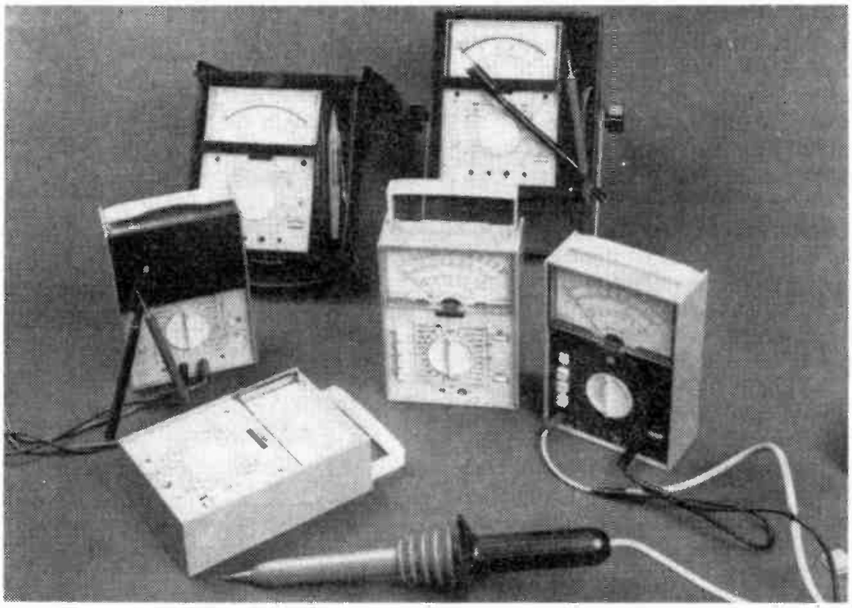
9V Battery and keyboard to choice

The MM5777 is a 24-pin, Epoxy-B DIL package, and gives leading and trailing zero suppression to conserve battery power. It operates with algebraic notation, and features floating point input and output and chain operations.

SCHOOL FOR TEACHERS

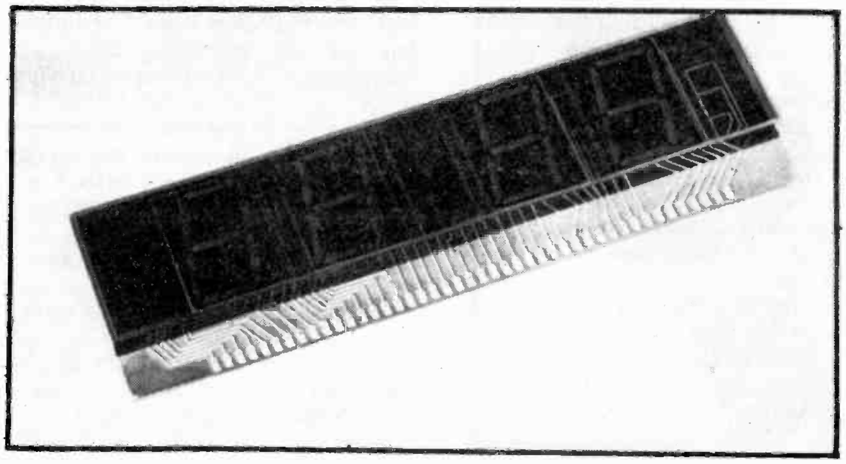
Essex University will be holding its Electronics Summer School for teachers during the week July 12–16. This year three courses will be run simultaneously, Linear Circuit Design, Digital Circuit Design and Small Computer Systems. This is a new course which should be of interest to mathematics teachers as well as those interested in electronics: Further information from R. J. Mack at the Department of Electrical Engineering Science, University of Essex, telephone Colchester (0206) 44144, extension 2408 or 2299.

BOUNCING METERS



Western Instruments have released a new VOM series, one major feature of which is their 'invunerability'. All five models in the 660 series are drop-proof and feature a custom rugged self-shielded taut-band mechanism, diode-protected meter movement, temperature compensation, pluggable circuit board assemblies, external fuse replacement, and can be recalibrated without removing from their case. They are warranted, in writing,to operate after being dropped a height of five feet. (So if you're a small clumsy engineer – your troubles are over!). Details from Electroplan Ltd, P.O. Box 19, Orchard Road, Royston, Herts. SG8 5HH.

CLOCK UP AN INCH



Two new multiple-digit, PCB mounted numeric LED displays have been introduced by Litronix. Each incorporate four 7-segment numeric LED display mounted on a PCB within a red filter. A digit height of the 4520A is ½in., and of the 4120A, 1in. – the largest numeric LED display currently available.

Design principally for applications in 12-hour or 24-hour electronic digital clocks, the displays include colons for a.m., p.m. and Alarm Set indication, and feature excellent character definition at viewing distances in excess of 60ft.

Typical electrical characteristics of the DL-4520A are: forward voltage of 1.8V (at 20mA per segment); luminous intensity of 1.0 mcd; the DL-4120A has a typical forward voltage of 3.6V (at 20mA); luminous intensity of 2.0 mcd.

Production prices are anticipated to be £4.80 for the DL-4520A, and £5.50 for the DL-4120A, in quantity.

news digest

FAIRCHILD WATCHES

The Savoy Hotel recently lent its hallowed halls to the launching of yet another range of digital watches. The culprits on this occasion are the Fairchild Corporation. Two different lines are being introduced to the UK at present (although a third is apparently possible in the future). The more expensive of these will carry the Fairchild name, for distribution throygh 'fine jewellers' only, with discounting a forbidden practise. The other is marketed under the Timeband name, and is intended for the mass market, with prices ranging from £19.95 up to £32.95. Prices for the more expensive Fairchild line run from £44 to just below £100. All watches employ the same circuit module, and use LED display. Price differences are accounted for by styling, bracelet and case.

A great deal of work has obviosly been expended on the ladies ranges, and here Fairchild have a head start on the rest of the market. The mens models, however, seem little different to the vast majority of those already on sale in the "UK marketplace" (Fairchilds phrase). Circuitry is also along standard lines and uses a 32kHz oscillator to derive the timing pulses.

The watches are five function, and are operated by a single pushbutton.

One point perhaps worth noting is that batteries are not user replaceable and return to the retailer is advised. An obvious question is how happy are the 'mass market' retailers going to be about carrying out this time consuming operation? Perhaps all digital watch manufacturers should consider this aspect more closely in the future. Availability at present is zero, but immediate shipments are being arranged by the company.

NEW CBM SCIENTIFIC

CBM introduce Greenline SR1800 scientific calculator at £29.95 including VAT, with the optional extra of a rechargeable cassette and mains adaptor/charger which come together as a rechareable kit for an additional £6.00. This give gives 3-way power with disposable battery, mains and

rechargeable cassette. The machine uses algebraic logic and is fully guaranteed for 1 year. A 12-digit green display gives 8-digit mantissa and 2-digit exponent plus signs. The functions of the calculator are:

Accuracy	Calculates to 10 digits while displaying 8 in the mantissa.
EE EE↓ EE↑	Exponent entry and exponent shifts.
Memories	Two independent memories plus summation key to memory 1.
Parenthesis	Single level bracket facility.
TRIG Functions	Sin, Cos, Tan, Sin^{-1}, cos^{-1}, tan^{-1}.
LOG Functions	Ln, e^x, log, 10^x.
Powers	$\sqrt{x}$, x^2, $\sqrt[x]{y}$, y^x.
Conversions	Polar to rectangular coordinates, degrees to radians.
Statistical	Mean and standard deviation.
Other Functions	π, change sign, 1/x, $x \leftrightarrow y$.

DANGER: 90 FUNCTION CALCULATOR ESCAPES FROM CBM!

Also from CBM comes a new scientific with an awe-inspiring 90 functions. The beast is called an SR4190R and can be bought for £59.90, but at your own risk; no responsibility will be taken for people contracting 'button mania' from the animal. We are so intrigued by the SR4190R that we have arranged to review it more fully in the next issue.

TEXAS RECALCULATE

Texas Instruments announce price reductions to six of their electronic calculators. Models affected are as follows:

Model	New Price	Old Price
TI 1200	£ 8.95	£ 10.95
TI 1250	£ 9.95	£ 13.95
TI 1500	£14.95	£ 19.95
TI 5050	£94.95	£109.95
SR 50A	£44.95	£ 59.95
SR 51A	£64.95	£ 89.95

Prices include VAT.

TWA USES COMPUTER TO SAVE FUEL

Computer-assisted flight planning and related techniques helped Trans World Airlines save more than 70 million gallons of expensive jet fuel in 1975. Flight operations use an IBM System/370 Model 168 to calculate flight plans in order to pinpoint the lowest cost route. The powerful system constructs nearly 1,000 flight plans daily for TWA's world-wide operations plus countless alternative plans.

The computer calculates three possible plans: Federal Aviation Administration (FAA) approved; free search and minimum cost. Free search means that the system examines every possible route from origin to destination for the best route. In some cases the best route may be longer (because of bad weather) but is chosen to provide a smooth ride.

A flight dispatcher creates a plan by entering information into the computer via a visual display terminal. Information includes payload, fuel requirements, allowable takeoff weight, flight time, distance and various altitudes and weather data. Stored in the computer's memory is information on factors such as aircraft performance and route.

A dispatcher can request the system to search up to five altitudes for the best one. The system figures the best routing on the first altitude, then the next and so on. Using information from the dispatcher, the Model 168 simulates each altitude/route combination. Fuel consumption, flight time and cost is developed for comparison by the dispatcher who recommends an optimum plan to the flight captain for his concurrence.

CALCULATOR STOPWATCH

ETI project 534

An inexpensive calculator modified to provide one-hundredth of a second timing.

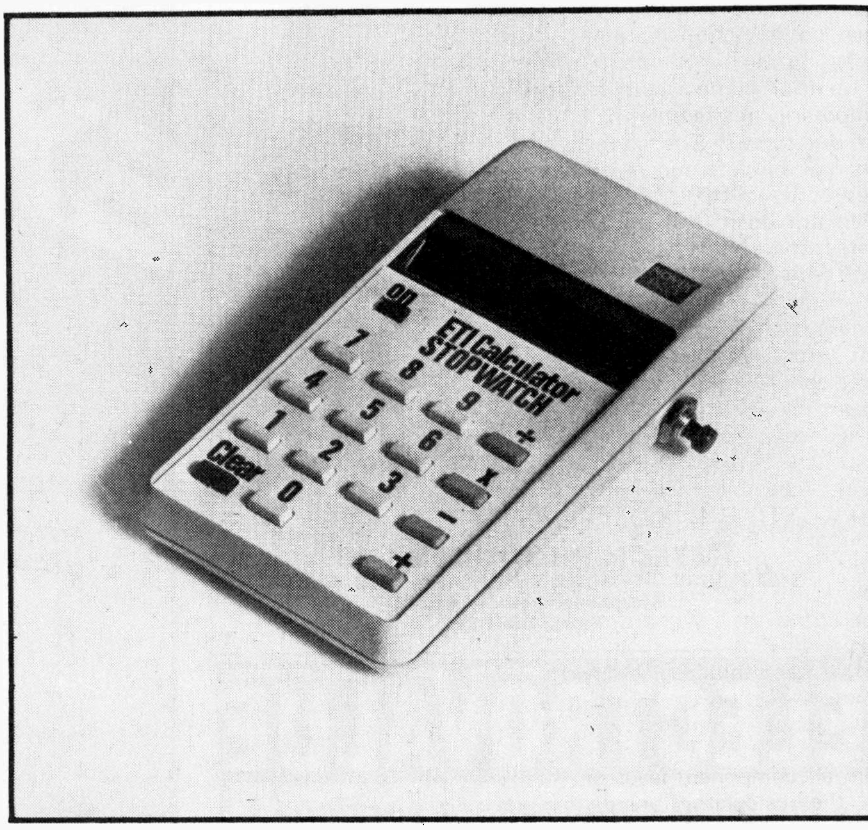
FOUR-FUNCTION calculators are now available for as little as £5.00. At those prices, it is cheaper to buy a calculator and throw away the parts that you don't need, than it is to buy a keyboard, display, or calculator chip separately.

Having this in mind we were very interested to receive an application note from National Semiconductor which detailed how to modify one of their calculators for use as a stopwatch. We therefore decided to develop this idea to a full project for a calculator/stopwatch which provides timing with one-hundredth of a second resolution for a cost as low as £10.00 (including the calculator).

The NOVUS 650 calculator is a simple four-function machine which has a fixed decimal point between the second and third (RH) digits. The calculator does not have floating point, and only works in whole numbers, the decimal point being an indicator only. These features however, whilst detracting from the usefulness of the machine as a calculator, make it ideal for modification, without difficulty, for use as a stopwatch.

Stopwatch operation is made possible by the fact that if '1' is entered into the calculator and the '+' key is continually pressed, the calculator will add '1' to the number displayed each time the '+' key is pressed. Thus, as a stopwatch, the '+' key must be 'pressed' electronically 100 times per second. (If a floating-point calculator were to be used, 0.01 would have to be added each time the key was pressed and this of course is much more difficult to do).

The 100 Hz timebase, required for the key-pressing function, needs to be supplied by means of a crystal and a divider chain or, by some other simple but stable oscillator such as a PUT. For most applications the PUT (programmable unijunction transistor) is quite accurate enough and this, coupled with the fact that the crystal and its dividers are bulky and relatively expensive, led to us choosing the PUT oscillator.



The additional electronics for the stopwatch is all mounted on a separate printed-circuit board which is a very tight fit in the calculator. Soldering to the pins of the calculator IC is also required and unless you have previous constructional experience, especially with soldering, do not attempt this project.

CONSTRUCTION

Due to the unusual nature of this project the constructional procedure given is much more detailed than usual. The constructor is well advised to follow the following steps carefully.

(a) Dissassemble the calculator by removing the battery and the four screws that hold the case together.

(b) Remove the external power socket and disconnect the leads from it to printed-circuit board. Take note

SPECIFICATION

Maximum Reading	9999.99 sec (2 hours 46 mins 39.99 secs)
Resolution	0.01 secs
Accuracy (typ)	± 0.2%

Mode — accumulating type, single button start/stop, separate button for clear.

Calculator.

Six digits, four functions, reverse Polish fixed point.

of the position of these leads as they must be replaced later.

(c) The new pushbutton for the stopwatch must now be mounted into the back cover. The photograph shows the approximate location of this button. Note that the web of plastic, between the battery compartment and the calculator housing, must be cut away on the right-hand side so that the push button may be fitted. To determine the correct position; temporarily reassemble the calculator, without screws. The correct location can now be determined as the button goes between the display board, the calculator board and the battery (yes there is space!)

(d) Due to the curved case of the calculator we did not use the normal mounting method for the push button, but just drilled and filed a hole just large enough to allow the push button to cut its own thread in the plastic. It may also be necessary, however, to epoxy the button into position.

(e) Assemble the printed-circuit board, ETI 534, as shown in the component overlay. The components must be positioned as shown, as the board fits between the calculator board and the keyboard and space is very limited

(f) Attach thin insulated wires to the points shown on the overlay and leave them about 75 mm long.

(g) To obtain a little more space, trim all component leads on the back of the calculator board, including those of the calculator IC, as close to the board as possible. Now cut the printed-circuit track on both sides of pin 1 of the MM5736 calculator IC (pin 1 is the pin next to the ● mark) Using a single strand of flexible wire rejoin the tracks on both sides of pin 1, leaving pin 1 isolated.

(h) Position the control board, ETI 534, alongside the calculator board (see photo). Due to space limitations the wires from the control board have to be soldered directly onto the pins of the calculator ICs.

(j) Check very carefully the point to which each wire must be connected, cut it to length (not too long), and solder it directly to the specified pin. The ICs are numbered anticlockwise from the '●' mark.

(k) Reconnect the power wiring from the external socket.

(l) Connect the push-button switch.

(m) Check the calculator before final assembly as follows:-

Connect the battery and switch on.

Clear the display and check all keys and calculator functions.

Clear the display

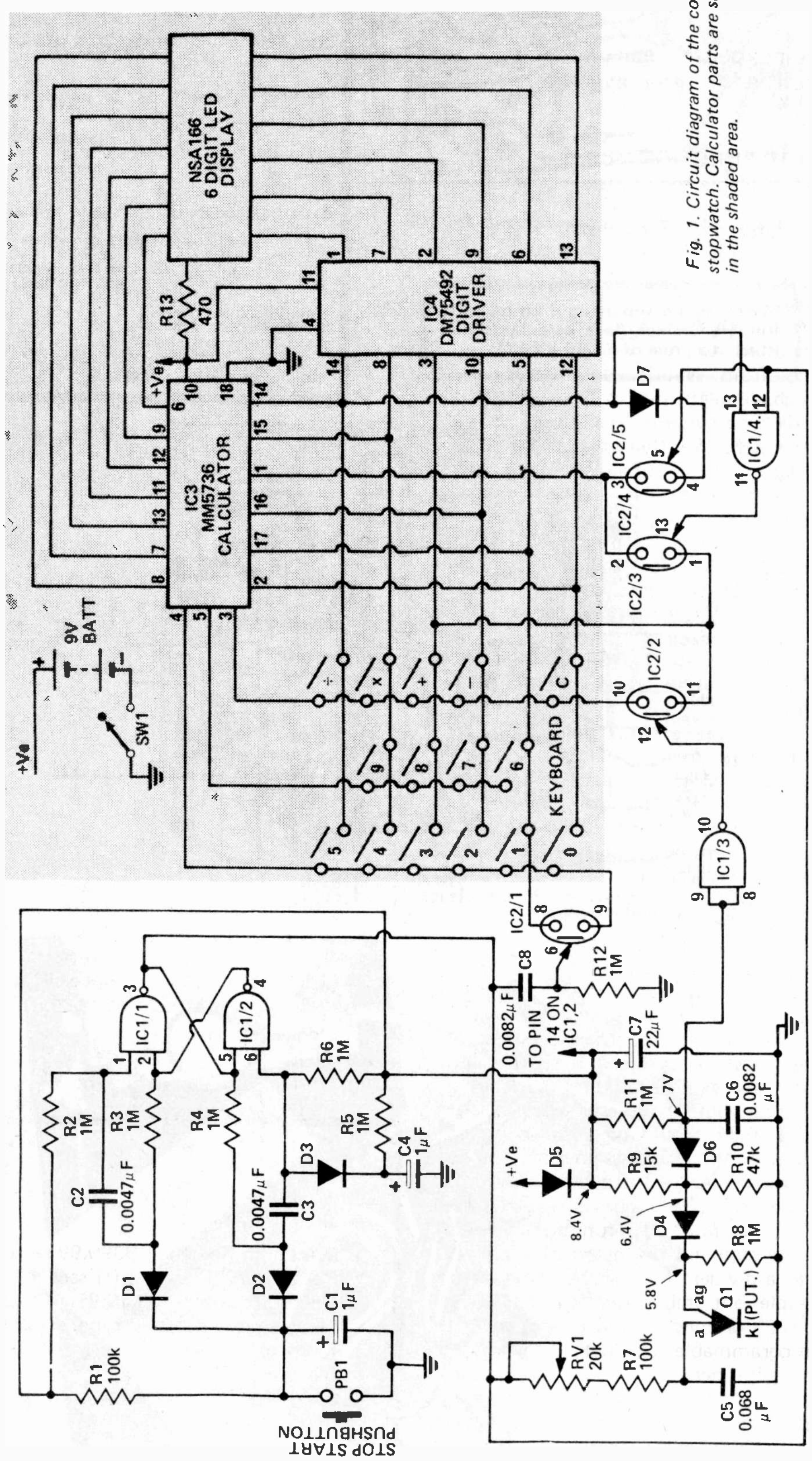


Fig. 1. Circuit diagram of the complete stopwatch. Calculator parts are shown in the shaded area.

CALCULATOR STOPWATCH

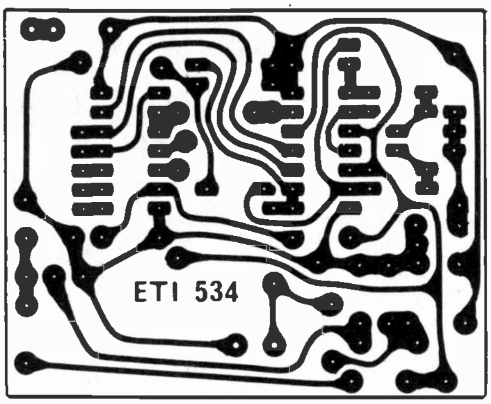


Fig. 2. Printed circuit board layout. Full size 64 x 52mm.

Marshalls are supplying a kit of parts for this project (less calculator and PCB) at a price of £2.50+VAT.

PARTS LIST — ETI 534

R9 Resistor 15 k ¼ W 5%
R10 " 47 k " "
R1,7 " 100 k " "
R2,3,4,5 " 1M " "
R6,8,11,12 " 1M " "
R13* part of calculator

RV1 Trim potentiometer 20 k 20 Turn type 84 (Morganite)

C2,3 Capacitor 0.0047 μF polyester
C6,8 " 0.0082 μF "
C5 " 0.068 μF "
C1,4 " 1 μF Tag tantalum
C7 " 22 μF 16 V Tag tantalum

D1-D7 Diode IN914 BA318 or similar

Q1 Transistor 2N6027 or similar

IC1 Integrated Circuit 4011 (CMOS)
IC2 " " 4016 (CMOS)

Small push button
PC Board ETI 534
Calculator NOVUS 650

PCB from Ramar at 68p inc.

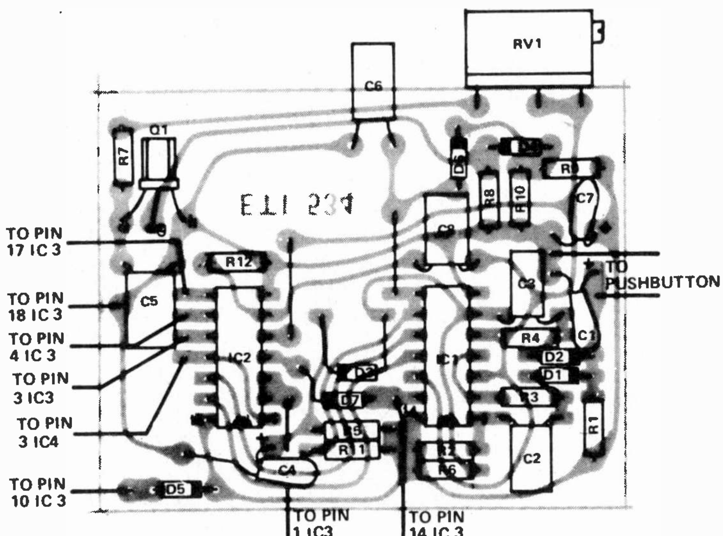


Fig. 3. Component overlay.

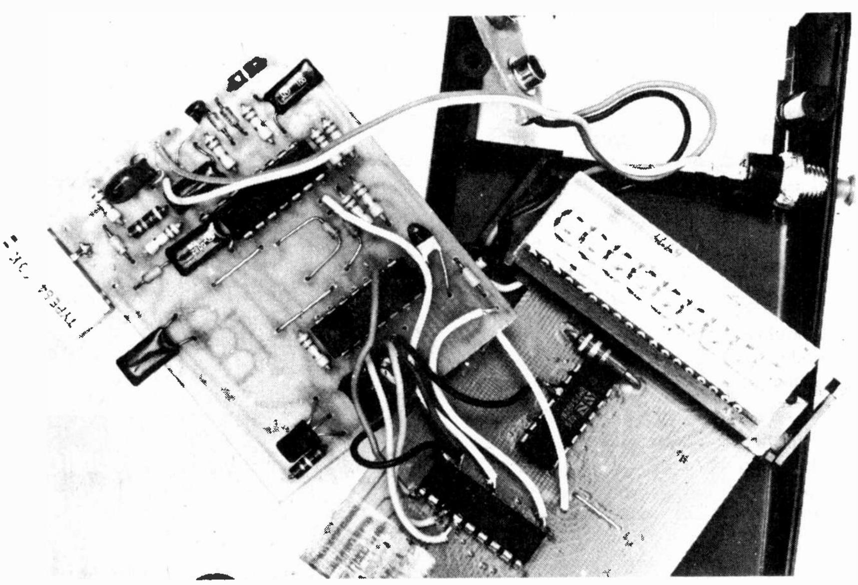


Fig. 4. The calculator as modified and before final assembly.

Press the push button once. The calculator should now count up by ones at 100 times per second.

(n) If a frequency counter or an oscilloscope is available connect to the junction of R11 and C6 and adjust for 100 Hz. If an oscilloscope is used sync the cro from the mains and beat the 100 Hz against that.

(p) Fold the control board on top of the calculator board making sure that none of the leads is on top of any of the ICs thus preventing the board from going right down.

(q) Cut a small hole in the side of the case to allow access to RV1.

(r) Assemble the calculator completely again making sure that the leads do not foul anything and that the calculator fits together without needing to be forced.

(s) Check the accuracy of the stopwatch by timing, over a long period, using a known accurate source (eg telephone time service) and make successive adjustments of RV1 to give correct results.

USING THE STOPWATCH

The conventional stopwatch has a single button which starts, stops, and resets, the timing. The ETI stopwatch, on the other hand, uses the side button for start/stop and the existing CE/C key for reset.

This configuration allows the stopwatch to be used for applications where accumulative timing is required. For example where three separate runs must be timed for a total time, the stopwatch is not reset between runs but merely started and stopped for each run.

A further advantage is that timing may be commenced from a reading preset by the keyboard. This is done by first clearing the display and then entering the starting time in one-hundredths of a second. If the '+' button is now pressed before starting, the stopwatch will count up from the entered time, whereas if the '–' button is pressed the stopwatch will count down from the previously entered time to zero.

When using the stopwatch be careful to hold it in such a way that accidental pressing of keys is avoided, as spurious keyboard entries will result in an erroneous reading.

As a service to readers having difficulties obtaining the Novus 650 calculator used as our stopwatch, we have decided to supply direct. The price is £5.00 inc. and orders should be sent to ETI Novus 650 Sales, 36 Ebury Street, London SW1W 0LW. Please allow 21 days for delivery.

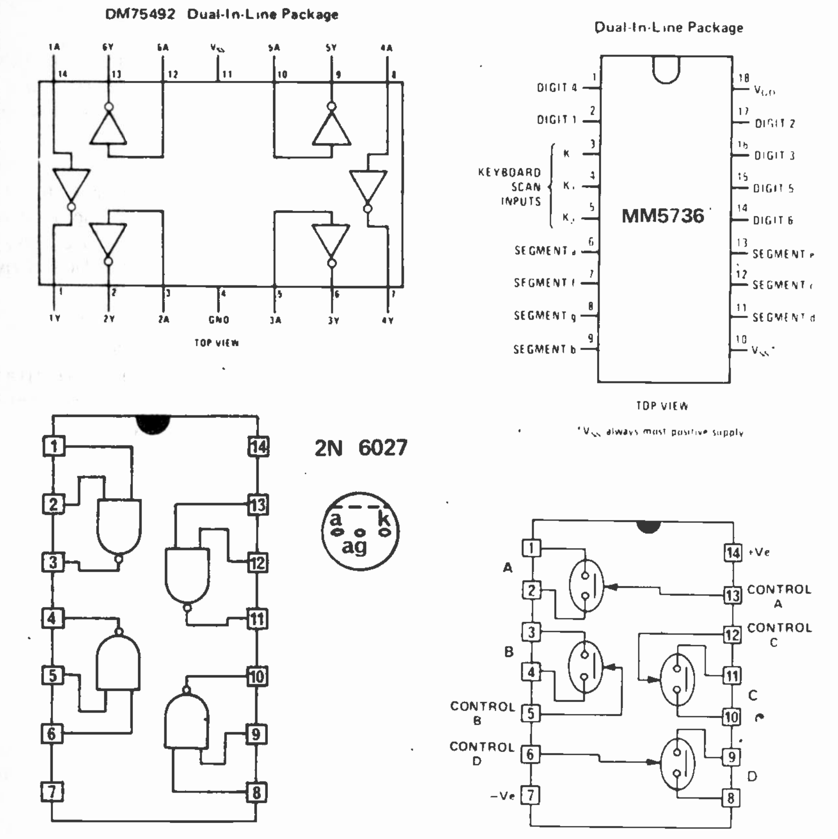


Fig. 5. Component connections.

HOW IT WORKS.

With the standard calculator the keyboard controls a three-line by six-line matrix, that is, a calculator key when pressed joins one of three pins, of IC3, to one of six other pins. This gives a maximum of 18 possible combinations of which only 15 are used. The 6 lines are both input and output of the IC, that is they drive the display via IC4 as well as passing keyboard commands to the calculator.

The stopwatch is controlled by an additional push button, which in effect stops and starts the calculator, whilst reset is performed by the front-panel 'clear' key. The push button operates a flip flop formed by IC1/1 and IC1/2. The capacitors around the flip flop change it from a normal RS type to a toggle type. Diode D3, capacitor C4 and resistor R5 set the flip flop into the stop condition on initial switch on. The output of IC1/1 is at zero volts in the 'stop' state and at +9 volts in the 'run' state.

When the output of IC 1/1 goes high capacitor C8, together with R12, provides a 10 ms pulse to the control input of IC 2/1. This is an analogue switch across the '1' key. Thus the closure of this switch is equivalent to pressing the '1' key. When the switch closes capacitor C5 begins to charge via R7. When it reaches about 6 volts (set by R9/R10) the PUT switches on, and C5 is discharged rapidly to a low voltage, the PUT turns off, allowing C5 to recharge. This action takes at place at 100 Hz. The diode D4 is used for temperature compensation. When the PUT fires, terminal 'ag' drops to a low voltage which discharges C6 via D4 and D6. And, although the PUT is on for only a short time, diode D6 isolates C6 allowing it to charge slowly (5 ms) via R11.

The pulse from the PUT is squared by IC 1/3 and is then used to control IC 2/2, which is across the '+' key. The pulse thus causes one to be added to the displayed number 100 times per second.

To operate the calculator, at the rate of 100 pulses per second, it is necessary to disable the calculator debounce circuitry. This is done by IC 2/3, IC 2/4, IC 1/4 and D7. The debounce is disabled only in the 'run' mode, and is still functional in normal calculator operation.

Diode D5 and capacitor C7 decouple the control circuitry from the calculator, as the high peak currents drawn can result in a two-volt ripple, on the nine-volt supply, which otherwise would upset the timing.

LYNX ELECTRONICS (LONDON) LTD

Transistors

Type	Price
AC126	15p
AC127	16p
AC128	13p
AC128K	25p
AC141	18p
AC141K	28p
AC142	18p
AC142K	28p
AC176	16p
AC176K	25p
AC187	18p
AC187K	25p
AC188	18p
AC188K	25p
AD140	50p
AD142	50p
AD143	46p
AD149	45p
AD161	35p
AD162	35p
AL102	95p
AL103	93p
AF114	20p
AF115	20p
AF116	20p
AF117	20p
AF118	50p
AF139	33p
AF239	37p
BC107	14p
BC107B	16p
BC108	13p
BC109	14p
BC109C	16p
BC117	19p*
BC125	18p*
BC126	20p*
BC141	28p
BC142	23p
BC143	23p
BC144	30p
BC147	9p*
BC148	9p*
BC149	9p*
BC152	25p*
BC153	18p*
BC157	9p*
BC158	9p*
BC159	9p*
BC160	32p
BC161	38p
BC168B	9p*
BC182	11p*
BC182L	11p*
BC183	10p*
BC183L	10p*
BC184	11p*
BC184L	11p*
BC207B	12p*
BC212	11p*
BC212L	11p*
BC213	12p*
BC213L	12p*
BC214	14p*
BC214L	14p*
BC237	16p*
BC238	16p*
BC300	34p
BC301	32p
BC323	60p
BC327	18p*
BC328	16p*
BC337	17p*
BC338	17p*
BCY70	12p
BCY71	18p
BCY72	12p
BD115	55p
BD131	36p
BD132	40p
BD135	36p
BD136	39p
BD137	40p
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BD181	86p
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BD232	60p*
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BDY62	55p
BF178	28p
BF179	30p
BF194	10p*
BF195	10p*
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BF197	12p*
BF224J	18p*
BF244	17p*
BF257	30p
BF258	35p
BF337	32p
BFW60	17p*
BFX29	26p
BFX30	30p
BFX84	23p
BFX85	25p
BFX88	20p
BFY50	20p
BFY51	18p
BFY52	19p
BFY64	35p
BFY90	65p
BR100	20p
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IN4007	10p*
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2N706	10p
2N929	14p
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2N1132	16p
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2N1305	20p
2N1711	18p
2N2102	44p
2N2369	14p
2N2369A	14p
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100 V	0·60	0·60	0·70	0·70	0·78	0·78	0·83	0·83	1·01	1·01
200 V	0·64	0·64	0·75	0·75	0·87	0·87	0·87	0·87	1·17	1·17
400 V	0·77	0·78	0·80	0·83	0·97	1·01	1·13	1·19	1·70	1·74
600 V	0·96	0·99	0·87	1·01	1·21	1·26	1·42	1·50	2·11	2·17

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MORE DATA ON THE CA3130

The following article provides greater detail of a device first featured in ETI Data Sheet November 1975, and lists several applications for the amplifier not covered therein.

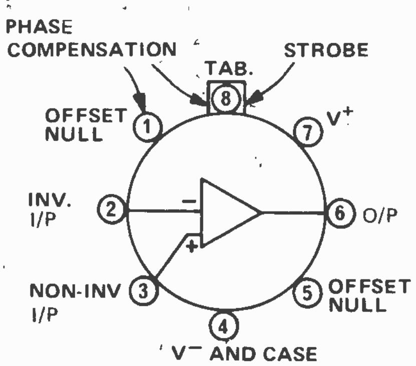


Fig. 1. Functional diagram of the CA3130.

The CA3130 series of operational amplifiers combines the advantages of both CMOS and bipolar transistors on a single monolithic chip. A specification and description of package options available were given briefly in the Data Sheet referred to above. These will not be repeated here, and the circuits for voltage regulator, pulse generator and function generator given there were sufficiently clear to make their inclusion here also superflous. Instead we shall consider in detail the circuit of the device, and give several further very interesting applications.

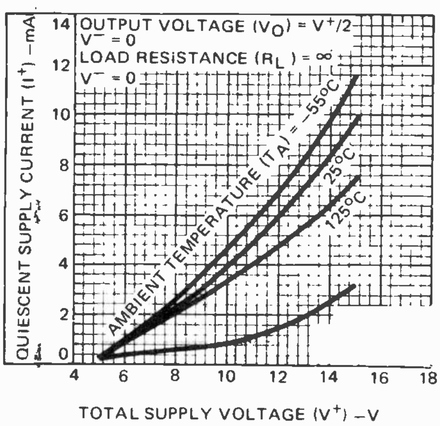


Fig. 2. Supply current against total supply voltage.

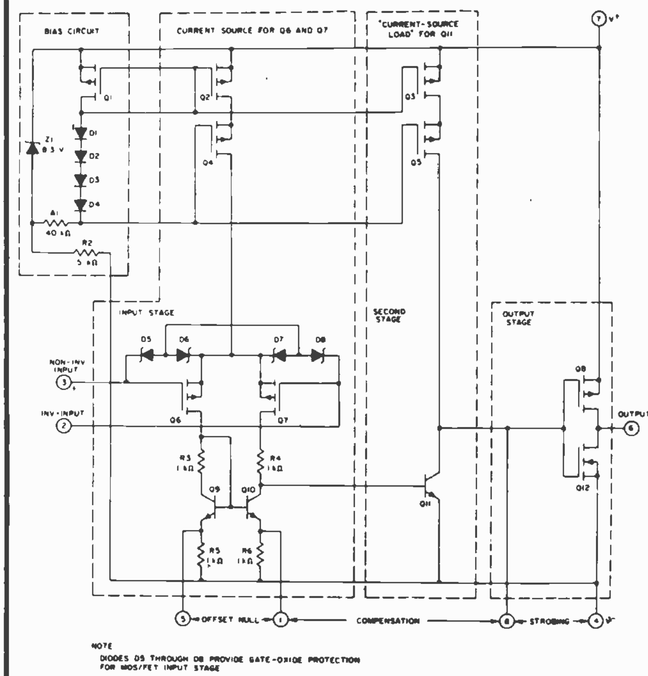


Fig. 3. Schematic diagram of the CA3130.

CIRCUIT DESCRIPTION

The output circuit consists of a complementary-symmetry MOS (COS/MOS) transistor pair, capable of swinging the output voltage to within millivolts of either supply voltage terminal (at very high values of load impedance).

The CA3130 Series circuits operate at supply voltages ranging from 5 to 16 volts, or ±2.5 to ±8 volts when using split supplies. They can be phase compensated with a single external capacitor, and have terminals for adjustment of offset voltage for applications requiring offset-null capability. Terminal provisions are also made to permit strobing of the output stage.

The input terminals may be operated down to 0.5V below the negative supply rail, and the output can be swung very close to either supply rail in many applications. Consequently, the CA3130 Series circuits are ideal for single supply operation. Three Class A amplifier stages, having the individual gain capability and current consumption shown in Fig. 3, provide the total gain of the CA3130. A biasing circuit provides two potentials for common use in the first and second stages. Term. 8 can be used both for phase compensation and to strobe the output stage into quiescence. When Term. 8 is tied to the negative supply rail (Term. 4) by mechanical or electrical means, the output potential at Term. 6 essentially rises to the positive supply rail potential at Term. 7. This condition of essentially zero current drain in the output stage under the strobed "OFF" condition can only be achieved when the ohmic load resistance presented to the amplifier is very high (e.g. when the amplifier output is used to drive COS/MOS digital circuits in comparator applications).

THE CA3130 OPERATIONAL AMPLIFIER

INPUT-OFFSET-VOLTAGE (V_{IO})

It is well known that the characteristics of a MOS/FET device can change slightly when a dc gate-source bias potential is applied to the device for extended time periods. The magnitude of the change is increased at high temperatures. Users of the CA3130 should be alert to the possible impacts of this effect if the application of the device involves extended operation at high temperatures with a significant differential dc bias voltage applied across Terms. 2 and 3.

OFFSET NULLING

Offset-voltage nulling is usually accomplished with a 100,000-ohm potentiometer connected across Terms. 1 and 5 and with the potentiometer slider arm connected to Term. 4. A fine offset-null adjustment usually can be effected with the slider arm positioned in the mid-point of the potentiometer's total range.

HANDLING

The CA3130 uses MOS field-effect transistors in the input circuit. Because MOS/FET's have extremely high input resistances, they are susceptible to damage when exposed to extremely high static electrical charges. To minimize the possibilities of damaging the input stage transistors, Q6 and Q7, the CA3130 utilizes a protective diode network in the input stage. Nevertheless, it is good practice that precautions be observed during handling, testing and actual operation of the CA3130 devices to minimize possible damage (see ETI November 74 Handling CMOS).

WIDEBAND NOISE

For low-noise performance the CA3130 is most advantageous in applications wherein the source resistance of the input signal is 1 megohm or more. In this case, the total input-referred noise voltage is typically only 23 μV when a test-circuit amplifier is operated at a total supply voltage of 15 volts. This value of total input-referred noise remains essentially constant, even though the value of source resistance is raised by an order of magnitude. This characteristic is due to the fact that reactance of the input capacitance becomes a significant factor in shunting the source resistance. It should be noted, however, that for values of source resistance very much greater than 1 megohm, the total noise voltage generated can be dominated by the thermal noise contributions of both the feedback and source resistors.

VOLTAGE FOLLOWERS

Operational amplifiers with very high input resistances, like the CA3130, are particularly suited to service as voltage followers. Fig. 4 shows the circuit of a classical voltage follower, using the CA3130 in a split-supply configuration. The digital-to-analog converter (DAC) circuit, described in the following section, illustrates the practical use of the CA3130 in a single-supply voltage-follower application.

PEAK DETECTORS

Peak-detector circuits are easily implemented with the CA3130, as illustrated in Fig. 5. It should be noted that with large-signal inputs, the bandwidth of the peak-negative circuit is much less than that of the peak-positive circuit. The second stage of the CA3130 limits the bandwidth in this case.

Negative-going output-signal excursion requires a positive going signal excursion at the collector of transistor Q11, which is loaded by the intrinsic capacitance of the associated circuitry in this mode. On the other hand, during a negative-going signal excursion at the collector of Q11, the transistor functions in an active "pull-down" mode so that the intrinsic capacitance can be discharged more expeditiously.

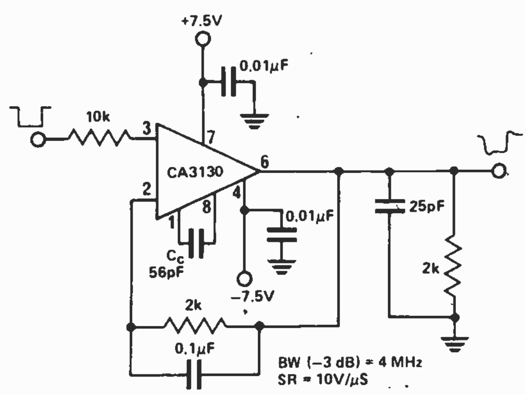
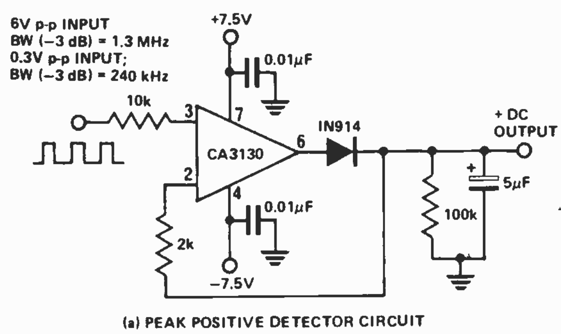


Fig. 4. Voltage follower circuit with split supply of plus and minus 7.5 volts. This circuit allows low impedance loads to be driven from a high impedance source.



(a) PEAK POSITIVE DETECTOR CIRCUIT

Fig. 5. Peak positive detector circuit. Detectors such as this are ideal for building accurate ac voltmeters.

9-BIT COS/MOS DAC

The circuit of a 9-bit Digital to Analog Converter (DAC) is shown in Fig. 6. This system combines the concepts of multiple-switch COS/MOS IC's, a low-cost ladder network of discrete metal-oxide film resistors, a CA3130 op-amp connected as a follower, and an inexpensive monolithic regulator in a simple single power-supply arrangement. An additional feature of the DAC is that it is readily interfaced with COS/MOS input logic, e.g. 10-volt logic levels are used in the circuit of Fig. 6.

The circuit uses an R/2R voltage-ladder network, with the output potential obtained directly by terminating the ladder arms at either the positive or the negative power-supply terminal. Each CD4007A contains three "inverters", each "inverter" functioning as a single-pole double-throw switch to terminate an arm of the R/2R network at either the positive or negative power-supply terminal. The resistor ladder is an assemply of one per cent tollerance metal-oxide film resistors. The five arms requiring the highest accuracy are assembled with series and parallel combinations of 806,000-ohm resistors from the same manufacturing lot.

A single 15-volt supply provides a positive bus for the CA3130 follower amplifier and feeds the CA3085 voltage regulator. A "scale-adjust" function is provided by the regulator output control, set to a nominal 10-volt level in this system. The line-voltage regulation (approximately 0.2%) permits a 9-bit accuracy to be maintained with variations of several volts in the supply. The flexibility afforded by the COS/MOS building blocks simplifies the design of DAC systems tailored to particular needs.

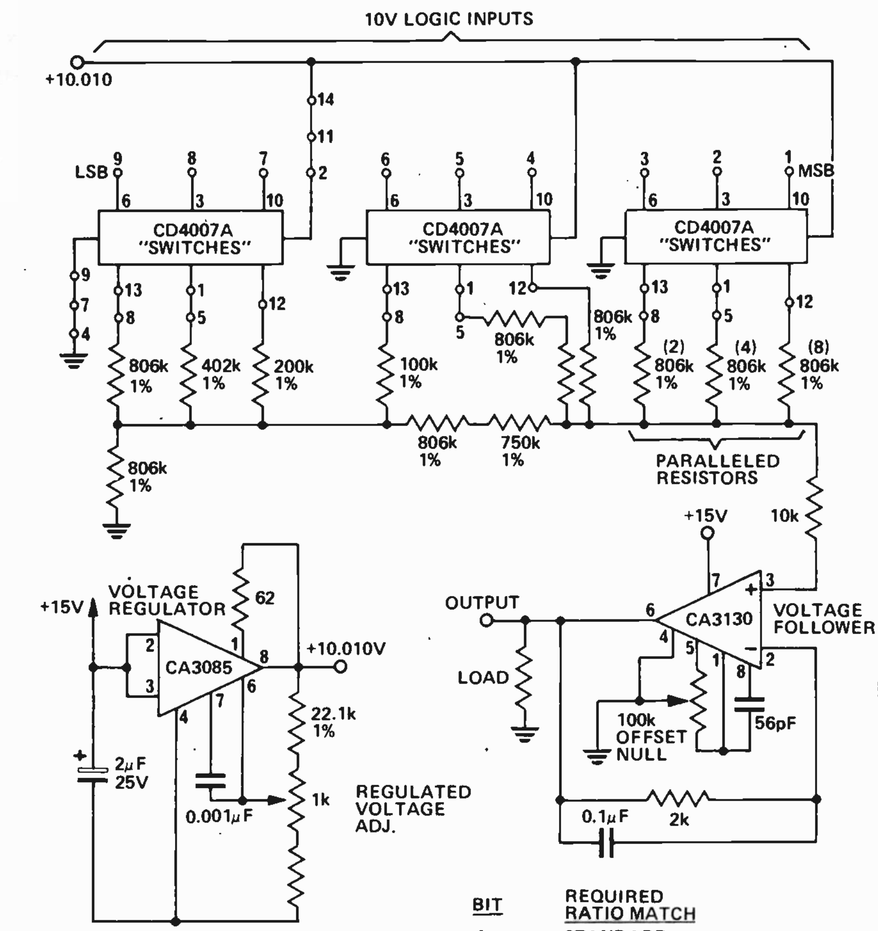


Fig. 6. Nine-bit digital-to-analogue converter uses CMOS digital switches and the CA3130.

BIT	REQUIRED RATIO MATCH
1	STANDARD
2	±0.1%
3	±0.2%
4	±0.4%
5	±0.8%
6-9	±1% ABS

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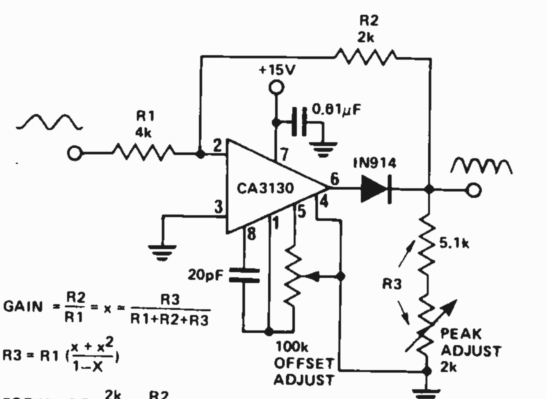
SINGLE-SUPPLY, ABSOLUTE-VALUE, IDEAL FULL-WAVE RECTIFIER

An absolute-value circuit, using the CA3130 is shown in Fig. 7. During positive excursions, the input signal is fed through the feedback network directly to the output. Simultaneously, the positive excursion of the input signal also drives the output terminal (No.6) of the inverting amplifier negative such that the 1N914 diode effectively disconnects the amplifier from the signal path. During a negative-going excursion of the input signal, the CA3130 functions as a normal inverting amplifier with a gain equal to −R2/R1. When the equality of the two equations shown in Fig. 12, is satisfied, the full-wave output is symmetrical.

Fig. 7. An absolute value full-wave detector provides the average of the input waveform. This is useful for converting dc meters. eg digital voltmeters to read the average of the ac input signal.



$$\text{GAIN} = \frac{R2}{R1} = x = \frac{R3}{R1+R2+R3}$$

$$R3 = R1\left(\frac{x+x^2}{1-x}\right)$$

$$\text{FOR } X = 0.5 : \frac{2k}{4k} = \frac{R2}{R1}$$

$$R3 = 4k\left(\frac{0.75}{0.5}\right) = 6k$$

20V p-p INPUT : BW (−3 dB) = 230 kHz, DC OUTPUT (AVG) = 3.2V
1V p-p INPUT : BW (−3 dB) = 130 kHz, DC OUTPUT (AVG) = 160mV

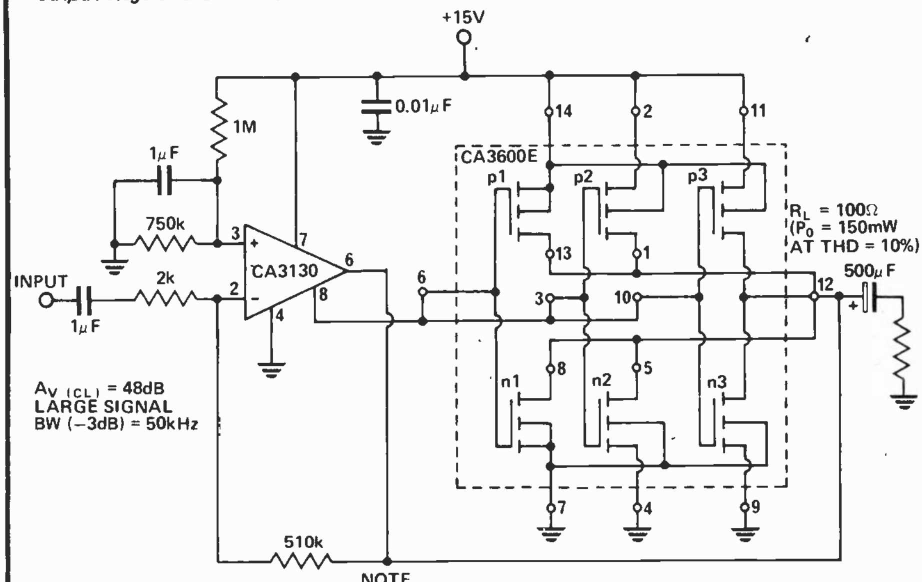
THE CA3130 OPERATIONAL AMPLIFIER

OPERATION WITH OUTPUT-STAGE POWER-BOOSTER

The current-sourcing and sinking capability of the CA3130 output stage is easily supplemented to provide power-boost capability. In the circuit of Fig. 8, three COS/MOS transistor-pairs in a single CA3600E IC array are shown parallel connected with the output stage in the CA3130. In the Class A mode of CA3600E shown, a typical device consumes 20 mA of supply current at 15V operation. This arrangement boosts the current-handling capability of the CA3130 output stage by about 2.5.

The amplifier circuit in Fig. 24 employs feedback to establish a closed-loop gain of 48 dB. The typical large-signal bandwidth (−3 dB) is 50 kHz. ●

Fig. 8. A CMOS transistor array may be connected as a power booster for the output stage of a CA3130.



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2N918	0.32
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2N1303	0.19
2N1304	0.26
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2N1307	0.30
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2N2368	0.17
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2N2369	0.22
2N2646	0.55
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2N2904	0.40
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2N2905	0.47
2N2905A	0.50
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2N3055	0.75

2N3390	0.45
2N3391	0.28
2N3391A	0.29
2N3392	0.15
2N3393	0.15
2N3394	0.15
2N3402	0.18
2N3403	0.19
2N3414	0.20
2N3415	0.24
2N3416	0.21
2N3417	0.29
2N3440	0.59
2N3441	0.97
2N3442	1.40
2N3638	0.15
2N3638A	0.15
2N3639	0.27
2N3641	0.17
2N3702	0.11
2N3703	0.12
2N3704	0.15
2N3705	0.15
2N3706	0.15
2N3707	0.18
2N3708	0.14
2N3709	0.15
2N3710	0.15
2N3711	0.15
2N3712	1.20
2N3713	1.20
2N3714	1.38
2N3715	1.50
2N3716	1.80
2N3771	2.20
2N3772	1.80
2N3773	2.65
2N3779	3.15
2N3790	2.40
2N3791	2.35
2N3792	2.60
2N3794	0.10
2N3810	0.37
2N3820	0.29
2N3823	1.58
2N3904	0.19
2N3906	0.19
2N4036	0.67
2N4037	0.42
2N4058	0.18
2N4059	0.15
2N4060	0.15
2N4061	0.15
2N4062	0.15
2N4126	0.21
2N4289	0.34
2N4919	0.95
2N4920	1.10
2N4921	0.83
2N4922	0.83
2N4923	1.00
2N5190	0.92
2N5191	0.96
2N5192	1.24
2N5195	1.46
2N5245	0.29
2N5294	0.48

2N5295	0.48
2N5296	0.48
2N5298	0.50
2N5457	0.29
2N5458	0.26
2N5459	0.29
2N5492	0.58
2N5494	0.58
2N5496	0.61
2N6027	0.45
2N5777	0.45
3N128	0.73
3N139	1.42
3N140	1.00
3N141	0.81
3N200	2.49
40361	0.40
40362	0.45
40363	0.88
40389	0.46
40394	0.56
40395	0.65
40406	0.44
40407	0.35
40408	0.35
40409	0.52
40410	0.52
40411	2.25
40594	0.74
40595	0.84
40601	0.67
40602	0.61
40603	0.58
40604	0.56
40636	1.10
40669	1.00
40673	0.73
AC126	0.20
AC127	0.40
AC128	0.35
AC151V	0.27
AC152V	0.49
AC153	0.35
AC153K	0.40
AC154	0.25
AC176	0.41
AC176K	0.40
AC187K	0.35
AC188K	0.40
ACY18	0.24
ACY19	0.27
ACY20	0.22
ACY21	0.26
ACY28	0.20
ACY30	0.58
AD142	0.57
AD143	0.68
AD149V	0.74
AD150	0.63
AD162	0.69
AD161	0.64
AD162	0.69
AF106	0.40
AF109R	0.40
AF114	0.35

AF115	0.35
AF116	0.35
AF117	0.35
AF118	0.35
AF124	0.30
AF125	0.30
AF126	0.28
AF127	0.28
AF139	0.65
AF186	0.46
AF200	0.65
AF239	0.65
AF240	0.90
AF279	0.70
AF280	0.79
AL102	1.00
AL103	1.00
BC107	0.14
BC108	0.14
BC109	0.14
BC113	0.15
BC115	0.17
BC116	0.17
BC116A	0.18
BC117	0.21
BC118	0.14
BC119	0.29
BC121	0.35
BC125	0.16
BC126	0.23
BC132	0.30
BC134	0.13
BC135	0.13
BC136	0.17
BC137	0.17
BC140	0.68
BC141	0.88
BC142	0.23
BC143	0.25
BC147	0.14
BC148	0.09
BC149	0.15
BC153	0.18
BC154	0.18
BC157	0.16
BC158	0.16
BC160	0.78
BC167B	0.15
BC168B	0.15
BC168C	0.15
BC169B	0.15
BC169C	0.15
BC170	0.15
BC171	0.16
BC172	0.12
BC177	0.19
BC178	0.18
BC179	0.21
BC182	0.12
BC182L	0.12
BC183	0.12
BC183L	0.12
BC184	0.13
BC184L	0.13
BC186	0.25
BC187	0.27

BC207	0.27
BC208	0.11
BC212K	0.16
BC212L	0.16
BC214L	0.18
BC237	0.16
BC238	0.15
BC239	0.15
BC251	0.25
BC253	0.25
BC257	0.15
BC258	0.16
BC259	0.17
BC261	0.25
BC262	0.25
BC263	0.25
BC300	0.38
BC301	0.34
BC303	0.54
BC307	0.17
BC308A	0.15
BC309C	0.20
BC317	0.12
BC318	0.12
BC337	0.20
BC338	0.20
BCY30	0.80
BCY31	0.85
BCY32	1.15
BCY33	0.85
BCY34	0.79
BCY38	1.00
BCY39	1.50
BCY40	0.97
BCY42	0.28
BCY58	0.30
BCY59	0.32
BCY70	0.17
BCY71	0.22
BCY72	0.15
BD115	0.75
BD116	0.75
BD121	1.00
BD123	0.82
BD124	0.67
BD131	0.40
BD132	0.50
BD135	0.21
BD136	0.22
BD137	0.24
BD138	0.26
BD139	0.71
BD140	0.87
BD529	0.80
BD530	0.80
BFR39	[illegible]
BFR79	0.24
BDY20	1.05
BF115	0.29
BF117	0.55
BF121	0.35
BF123	0.35
BF125	0.35
BF152	0.20
BF153	0.25
BF154	0.16
BF159	0.27

BF160	0.23
BF163	0.32
BF166	0.40
BF167	0.25
BF173	0.27
BF177	0.29
BF178	0.35
BF179	0.43
BF180	0.35
BF181	0.36
BF182	0.35
BF183	0.55
BF184	0.30
BF185	0.30
BF194	0.12
BF195	0.12
BF196	0.13
BF197	0.15
BF198	0.18
BF200	0.40
BF225J	0.23
BF244	0.21
BF245	0.45
BF246	0.58
BF247	0.65
BF254	0.19
BF255	0.19
BF257	0.47
BF258	0.53
BF259	0.55
BFR39	0.24
BFR79	0.24
BFS21A	2.30
BFS28	1.04
BFS61	0.27
BFS98	0.25
BFX29	0.30
BFX30	0.34
BFX84	0.30
BFX85	0.35
BFX87	0.28
BFX88	0.30
BFX89	0.90
BFY50	0.23
BFY51	0.23
BFY52	0.21
BFY53	0.18
BFY90	0.75
BRY39	0.38
BSX20	0.28
BSX21	0.30
BU104	2.00
BU105	2.25
C106D	0.65
CA3180A	0.85
CA3020A	1.80
CA3028A	0.79
CA3035	1.37
CA3052	1.62
CA3046	0.70
CA3048	2.11
CA3089E	1.96
CA3090Q	4.23
LM301A	0.48
LM308	1.17

LM309K	1.88
LM5TI	1.50
LM380	0.98
LM381	2.07
LM702C	0.75
LM709T099	0.48
8DIL	0.38
14DIL	0.40
LM710	0.47
LM3900	0.61
LM723C	0.66
LM741T099	0.40
8DIL	0.40
14DIL	0.38
LM747	1.00
LM7488DIL	0.44
LM7805	1.88
14DIL	0.73
LM7805	2.50
LM7812	1.99
LM7815	1.99
LM7824	1.99
MC1303	1.50
MC1310	2.50
MC13300P	0.90
MC1351P	0.80
MC1352P	0.80
MC1466	3.50
MC1469	2.75
ME0402	0.20
ME0404	0.13
ME0412	0.18
ME4102	0.11
ME4104	0.11
MJ480	0.95
MJ481	1.20
MJ490	1.05
MJ491	1.45
MJ2955	1.00
MJE340	0.48
MJE370	0.65
MJE371	0.75
MJE520	0.60
MJE521	0.70
MJE2955	1.20
MJE3055	0.75
MP8111	0.32
MP8112	0.40
MP8113	0.47
MPF102	0.30
MPSA05	0.25
MPSA06	0.31
MPSA12	0.35
MPSA55	0.25
MPSA56	0.31
MPSU05	0.65
MPSU06	0.58
MPSU55	0.63
MPSU56	0.80
NE555V	0.70
NE556	1.30
NE560	4.48
NE561	4.48
NE565A	4.48
OC23	1.35
OC28	1.48

OC35	1.16
OC42	0.50
OC45	0.32
OC71	0.17
OC72	0.25
OC81	0.25
OC83	0.24
ORP12	0.55
R53	1.80
SL414A	1.80
SL610C	1.70
SL611C	1.70
SL612C	1.70
SL620C	2.60
SL621C	2.60
SL623	4.59
SL640C	3.10
SL641C	3.10
SN76003N	2.92
SN76013N	1.95
SN76023N	1.60
SN76033N	2.92
ST2	0.20
TAA300	1.84
TAA263	1.20
TAA350	1.96
TAA550	0.32
TAA611C	2.18
TAA621	2.03
TAA661B	1.03
TBA641B	2.25
TBA651	1.69
TBA810	0.98
TBA820	0.80
TBA920	1.79
TIL209	0.30
TIP29A	0.49
TIP30A	0.58
TIP31A	0.62
TIP32A	0.74
TIP33A	1.01
TIP34A	1.51
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TIP36A	3.70
TIP41A	0.79
TIP42A	0.90
TIP29c	0.80
TIP30c	0.85
TIP31c	1.00
TIP32c	1.25
TIP33c	1.45
TIP34c	2.60
TIP41c	1.40
TIP42c	1.60
TIP49	0.70
TIP53	0.53
TIP2955	0.98
TIP3055	0.50
TIS43	0.28
ZTX300	0.13
ZTX301	0.13
ZTX302	0.20
ZTX500	0.15
ZTX501	0.13
ZTX502	0.18
ZTX530	0.23

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LP 1183/2	4.32
LP 1184/2	7.18
FM/IF AMPLIFIER	
LP 1185	5.56
FM TUNER	
LP 1186	6.88
LP 1400	7.22

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CD4002	.18	CD4020	.98	CD4044	.77
CD4006	.99	CD4021	.88	CD4045	1.30
CD4007	.18	CD4022	.85	CD4046	1.20
CD4008	.82	CD4023	.18	CD4047	.95
CD4009	.52	CD4024	.72	CD4049	.45
CD4010	.52	CD4025	.19	CD4050	.45
CD4011	.18	CD4027	.43	CD4510	1.25
CD4012	.18	CD4028	.83	CD4511	1.94
CD4013	.45	CD4029	1.06	CD4516	1.25
CD4014	.89	CD4030	.52	CD4518	1.87
CD4015	.89	CD4031	1.98	CD4520	1.87
CD4016	.45	CD4037	.88		
CD4017	.88	CD4041	.70		

Veroboard

	Copper		Plain	
	0.1	0.15	0.1	0.15
	£ p	£ p	£ p	£ p
2.5x3¾in	36	26	—	17
2.5x5in	40	39	—	19
3¾x3¾in	40	39	—	—
3¾x5in	45	47	—	32
3¾x17in	1.61	1.26	1.00	1.92
PINSx36	30	30		
x200	1.16	1.16		

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SN7401	0.16	SN7411	0.20	SN7437	0.28	SN7453	0.16	SN7482	0.65	SN7496	0.68	SN74153	0.68	SN74175	0.70
SN7401AN	0.29	SN7412	0.22	SN7438	0.28	SN7454	0.16	SN7483	0.82	SN74100	1.10	SN74154	1.20	SN74176	1.14
SN7402	0.16	SN7413	0.28	SN7440	0.16	SN7460	0.16	SN7484	0.95	SN74107	0.30	SN74155	0.78	SN74180	1.10
SN7403	0.16	SN7416	0.28	SN7441AN	0.68	SN7470	0.29	SN7485	1.00	SN74118	0.85	SN74157	0.76	SN74181	1.95
SN7404	0.19	SN7417	0.28	SN7442	0.65	SN7472	0.21	SN7486	0.29	SN74119	1.75	SN74160	0.88	SN74190	1.86
SN7405	0.19	SN7420	0.16	SN7445	0.78	SN7473	0.31	SN7490	0.42	SN74121	0.32	SN74161	0.88	SN74191	1.86
SN7406	0.36	SN7423	0.23	SN7446	0.84	SN7474	0.31	SN7491	0.75	SN74122	0.42	SN74162	0.88	SN74192	1.15
SN7407	0.36	SN7425	0.23	SN7447	0.80	SN7475	0.45	SN7492	0.45	SN74123	0.65	SN74163	0.88	SN74193	1.15
SN7408	0.19	SN7427	0.23	SN7448	0.90	SN7476	0.30	SN7493	0.45	SN74141	0.75	SN74164	1.60	SN74196	1.60
SN7409	0.18	SN7430	0.15	SN7450	0.16	SN7480	0.42	SN7494	0.75	SN74145	0.72	SN74165	1.60	SN74197	1.58
										SN74150	1.20	SN74167	3.30	SN74198	1.80
														SN74199	1.80

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AUDIO NOISE GENERATOR

ETI project 441

Simple circuit generates both white and pink noise.

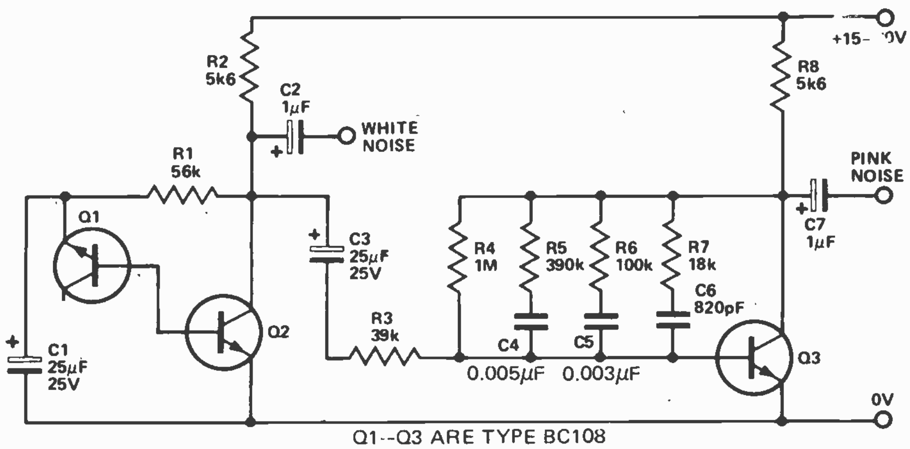
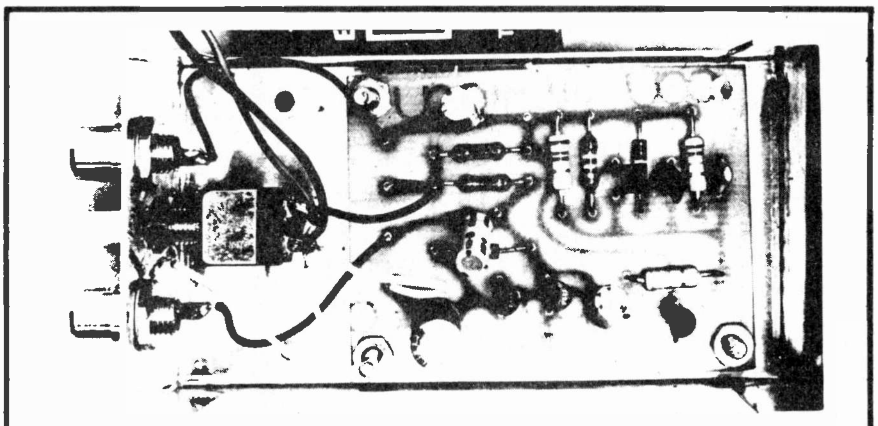


Fig. 1. Circuit diagram of the noise generator.

PARTS LIST — ETI 441

R1	Resistor	56k	½W	5%	
R2	"	5k6	½W	5%	
R3	"	39k	½W	5%	
R4	"	1M	½W	5%	
R5	"	390k	½W	5%	
R6	"	100k	½W	5%	
R7	"	18k	½W	5%	
R8	"	5k6	½W	5%	
C1	Capacitor	25μF	25V	electrolytic	
C2	"	1μF	25V	electrolytic	
C3	"	25μF	25V	electrolytic	
C4	"	0.005μF		polyester	
C5	"	0.003μF		polyester	
C6	"	820pF		ceramic	
C7	"	1μF	25V	electrolytic	

Q1-Q3 Transistor BC548, BC108 or similar
PC board ETI 441
CASE
BATTERIES
OUTPUT SOCKETS
North America: Use any NPN transistor with a gain of 100 or more (such as the Radio Shack RS2013s)



NOISE is generally an undesirable phenomena that degrades the performance of many measurement and instrumentation systems. It therefore seems strange that anyone should want to generate noise, but this is often the case.

Noise generators are often used to inject noise into radio-frequency amplifiers in order to evaluate their small signal performance. They are also used to test audio systems, and as random signal sources for wind-like effects in electronic music.

There are two commonly used noise source characteristics, 'pink' and 'white'. White noise is so called because it has equal noise energy in equal bandwidths over the total frequency range of interest. Thus, for example, a white noise source would have equal energy in the band 100 to 200 Hz to that in the band 5000 to 5100 Hz.

If white noise is filtered or modified in any way it is referred to as coloured noise or, often more specifically, as 'pink' or 'grey' noise. The term pink noise should be restricted to the noise characteristic that has equal energy per percentage change in bandwidth. For example with true pink noise the energy between 100 Hz and 200 Hz should equal that between 5000 Hz and 10 000 Hz (100% change in both cases).

Pink noise therefore appears to have more bass content than does white noise, and it appears to the ear to have a more uniform output level in audio testing. To change white noise to pink noise a filter is required that reduces the output level by 3 dB per octave (10 dB per decade) as the frequency is increased. The ETI 441 Noise Generator is designed to provide both white and pink noise as required.

HOW IT WORKS – ETI 441

In the days when vacuum tubes were in common use the most commonly used form of noise generator was a vacuum-tube diode operated in the current saturation mode. Nowadays noise generators may be very complex indeed. Highly complex digital generators which produce psuedo-random digital noise may cost many thousands of pounds An example of a simpler type of digital noise source may be found in our synthesizer design (see International Music Synthesizer 4600 ETI March 1974). However for audio work of a general nature the most commonly used, and the simplest, method is to use a zener diode as a noise generator.

Transistor Q1 is in fact used as a zener diode. The normal base-emitter junction is reverse-biased and goes into zener break-down at about 7 to 8 volts. The zener noise current from Q1 flows into the base of Q2 such that an output of about 150 millivolts of white noise is available.

The 'zener', besides being the noise source, also biases Q2 correctly, and the noise output of Q2 is fed directly to the White Noise output.

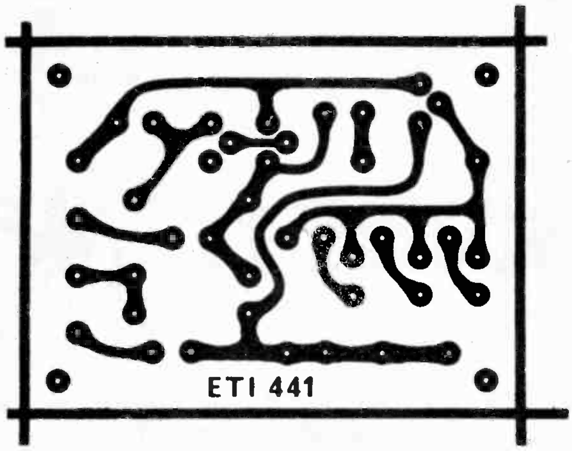
To convert the white noise to pink a filter is required which provides a 3 dB cut per octave as the frequency increases. A conventional RC network is not suitable as a single RC stage gives a cut of 6 dB per octave. Hence a special network of Rs and Cs is required in order to approximate the 3 dB-per-octave slope required. Since such a filter attenuates the noise considerably an amplifier is used to restore the output level. Transistor Q3 is this amplifier and the pink noise filter is connected as a feedback network between collector and base in order to obtain the required characteristic by controlling the gain-versus-frequency of the transistor. The output of transistor Q3 is thus the pink-noise required and is fed to the relevant output socket.

CONSTRUCTION

Construction is relatively simple and almost any of the common methods, such as Veroboard or Matrix board, may be used if desired. For neatness and ease of assembly it is hard to beat a proper printed-circuit board and for this reason we have provided details of a suitable board.

Almost any type of NPN transistor will do for the generator provided that the one used for Q3 has a gain of 100 or more.

For use as a separate instrument in general experimentation the unit will need to be powered by a pair of nine-volt batteries. However if the unit is to be built into some other piece of equipment, as is often the case, any supply within the equipment which has an output of between 15 and 30 volts dc will be suitable. ●



Printed circuit layout. Full size 67 x 49 mm.

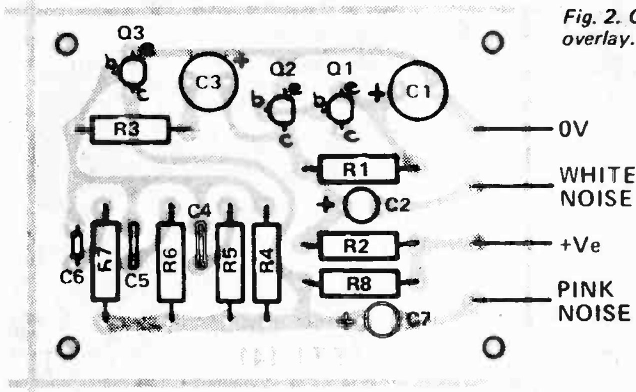
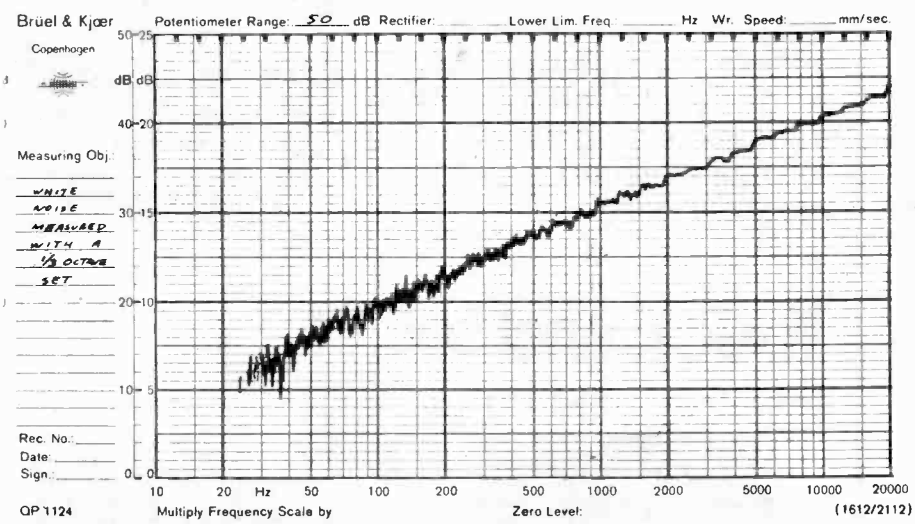
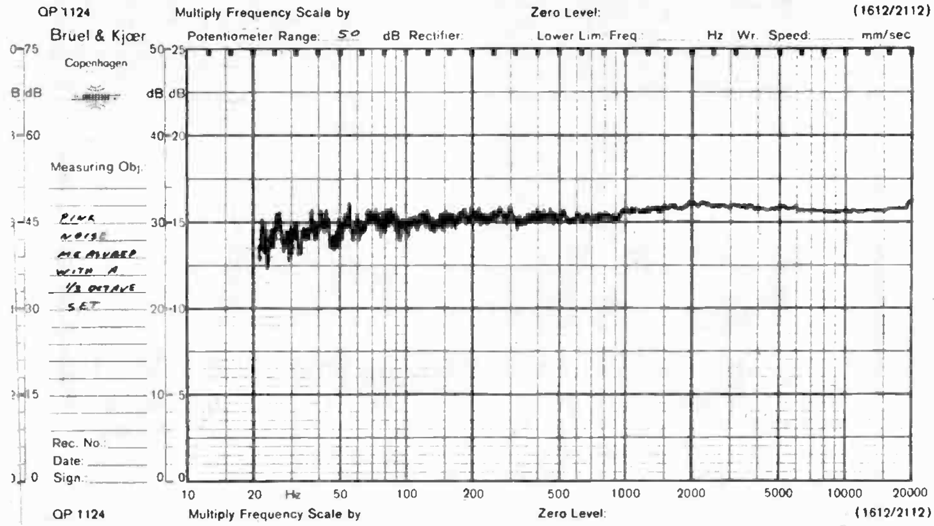
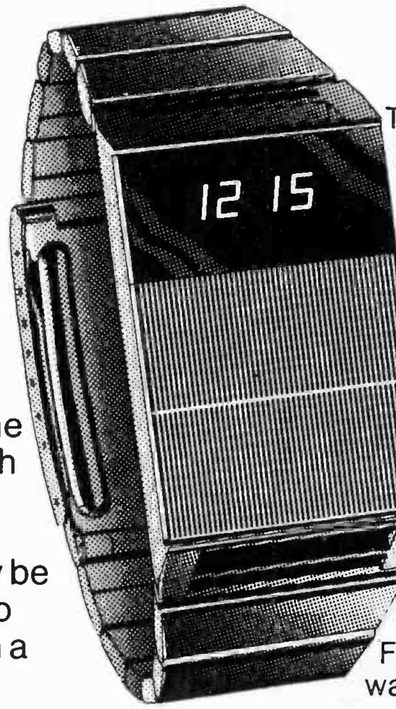


Fig. 2. Component overlay.





The Black Watch kit £14.95!



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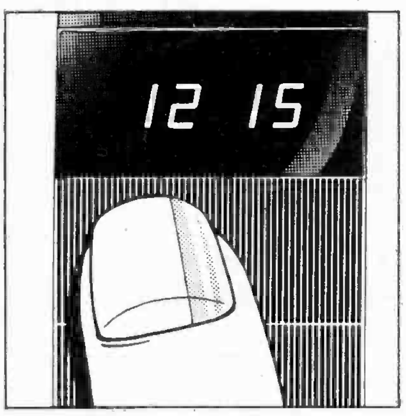
★ **Guaranteed.** A correctly-assembled watch is guaranteed for a year. It works as soon as you put the batteries in. On a built watch we guarantee an accuracy within a second a day–but building it yourself you may be able to adjust the trimmer to achieve an accuracy within a second a week.

The Black Watch by Sinclair is unique. Controlled by a quartz crystal, and powered by two hearing aid batteries, it uses bright red LEDs to show hours and minutes, and minutes and seconds. And it's styled in the cool prestige Sinclair fashion: no knobs, no buttons, no flash.

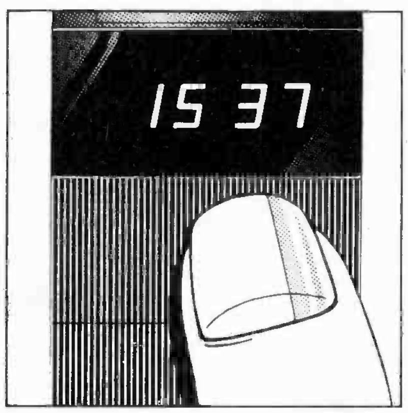
The Black Watch kit is unique, too. It's rational – Sinclair have reduced the separate components to just four–and it's simple: anybody who can use a soldering iron can assemble a Black Watch without difficulty. From opening the kit to wearing the watch is a couple of hours' work.

Touch and tell

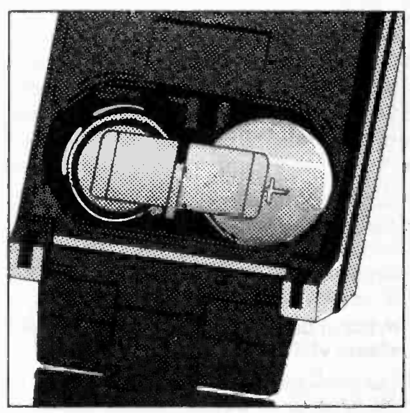
Press here for hours and minutes...



here for minutes and seconds.



Batteries easily replaced at home.



The specialist features of the Black Watch

Smooth, chunky, matt-black case, with black strap. (Black stainless-steel bracelet available as extra–see order form.)

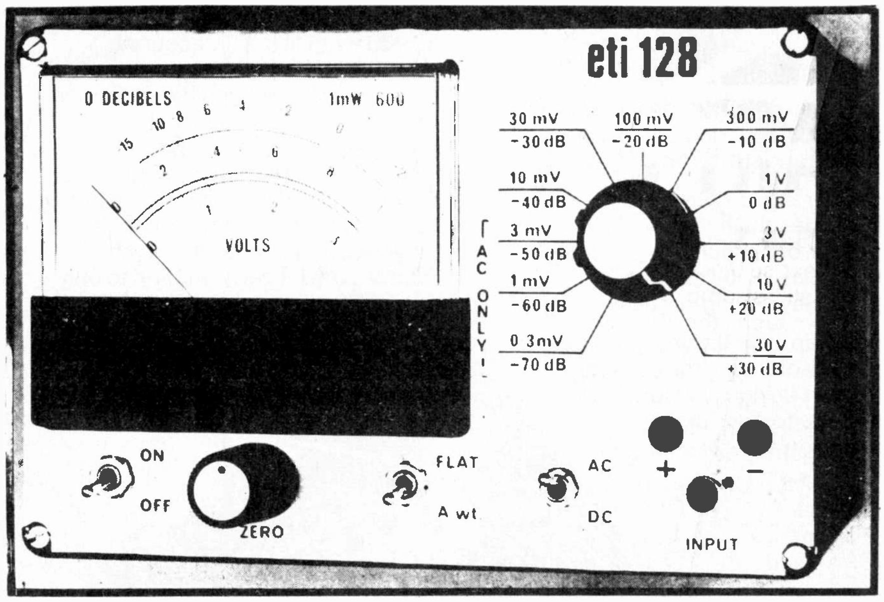
Large, bright, red display–easily read at night. Touch-and-see case–no unprofessional buttons.

Runs on two hearing-aid batteries (supplied). Easily re-set using special button–no expensive jeweller's service.

AUDIO MILLIVOLTMETER

Sensitive instrument for 'A' weighted audio noise and signal measurements.

eti project 128



AN ACCURATE and sensitive ac voltmeter is needed for many audio equipment measurements.

Whilst for example, maximum power output is readily measurable with a conventional multimeter, more complex instrumentation is required for measuring noise output (a measurement required when checking signal/noise ratio).

Even signal levels as high as 100 mV, typical output of most pre-amplifiers, are not readily measured with accuracy on a conventional multimeter.

The ETI 128 Millivoltmeter is specifically designed for such measurements whilst also being useful as a general purpose ac/dc voltmeter. The lowest range, of 300 microvolts FSD, allows measurements to 80 dB below one volt, whilst other ranges allow measurements up to 30 volts ac or dc. These ranges cover most of the measurement requirements of audio work.

When measuring noise levels account must be taken of the non-linear characteristics of the ear. For this reason a network has been incorporated which tailors the meter response-versus-frequency to match the subjective response of the ear. Such a network is known as an 'A weighting network' and its use provides a measurement which is realistically related to what is heard. When measurements are made using this network the results must be quoted as being 'A weighted'. Typically this is done by quoting dBA rather than just plain dB.

CONSTRUCTION

The meter is a highly sensitive instrument and for this reason the constructional method given should be followed closely if noise and hum pickup are to be minimized.

A diecast box is used to house the meter as this provides excellent shielding against external signals. The meter used in the prototype measured 100 x 82mm but required to be rescaled. Any similar meter may be used as long as it has 100 microamp sensitivity.

The ac/dc and Flat/'A' weight switches are four-pole types although only the outer two poles are used. The centre two poles are earthed in order to reduce the capacitance between the two outer poles. Such precautions are necessary to prevent any possibility of instability on the most sensitive ranges. The metal bracket which supports the printed-circuit board also acts as a shield between the meter circuitry and the input stages.

Commence construction by assembling components to the printed-circuit board, making absolutely sure that all are mounted in the correct position and with the correct polarity. This should be carefully done – once the meter is fully assembled, it is very difficult to change components.

Assemble the front panel, fitting all switches with the exception of SW3, LEDs, potentiometer, input socket, meter, and the shield. The shield passes between the centre two contacts of the 'A'-weighted switch.

Solder a tinned copper lead to each of the 12 contacts on the rear wafer of switch SW3 (about 25 mm long). Feed these wires through the holes provided in the printed-circuit board (1b to 11b and Wb) making sure that the wiper contact on the switch goes to Wb and that the other wires are inserted in sequence. Do not solder as yet.

Assemble the printed-circuit board onto the shield and the rotary switch to the front panel. We used a 3 mm

SPECIFICATION

RANGES	
dc (FSD)	10, 30, 100, 300 mV, 1, 3, 30 V. auto-polarity, LED indication.
ac (FSD)	0.3, 1, 3, 10, 30, 100, 300 mV, 1, 3, 10, 30 V 0 dB = 1 mW into 600 ohms (0.775 V) weighting curves, ac only, flat, 'A' weight
ACCURACY	± 3% nominal
MINIMUM READING	
Open circuit	–76 dB
Terminated 47 k	–85 dB
POWER SUPPLY	
Voltage	+6 and –6 volt (batteries)
Current	approximately 12.5 mA
Battery life	approx 100 hours (8 x 1015 cells)

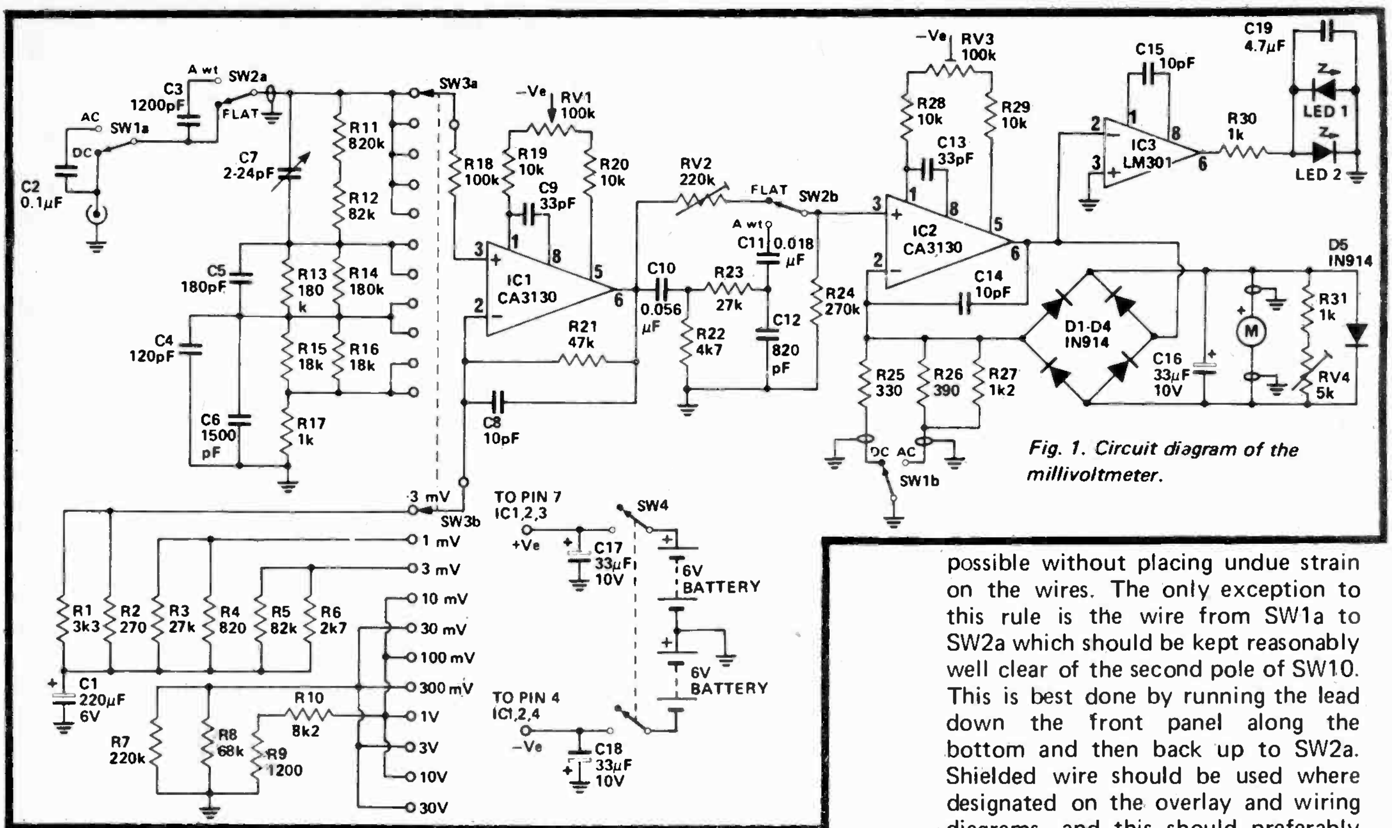


Fig. 1. Circuit diagram of the millivoltmeter.

stack of washers to space the switch back from the front panel so the control knob would sit down closer to the front panel. Remove any slack in the tinned-copper wires, connecting the switch to the printed-circuit board and then solder them to the board. Now remove the printed-circuit board and switch assembly from the front panel. The switch will now be rigidly held onto the board, and the front wafer can now be wired to the board via further tinned-copper links. Make sure that none of these wires is touching.

Add leads to the printed-circuit in the locations shown on the overlay and reassemble the board and switch assembly to the front panel. The components on the front may now be connected to the board by these leads which should be kept as short as possible without placing undue strain on the wires. The only exception to this rule is the wire from SW1a to SW2a which should be kept reasonably well clear of the second pole of SW10. This is best done by running the lead down the front panel along the bottom and then back up to SW2a. Shielded wire should be used where designated on the overlay and wiring diagrams, and this should preferably be of the low capacitance variety.

The LEDs are connected in parallel but in anti-phase, the actual polarities may be determined later if necessary during the calibration procedure.

CALIBRATION

Before commencing calibration, check that the meter performs as it should on all ranges by applying known voltages and checking that a

HOW IT WORKS – ETI 128

The millivoltmeter may be separated into several sections in order to simplify the explanation of its mode of operation. These are:–

(a) Input attenuator.
(b) Input amplifier.
(c) 'A'-weight network.
(d) Meter drive circuitry.
(e) Polarity detector.

The input attenuator consists of resistors R11 to 17 and capacitors C4 to 7, and gives division ratios of 1, 10, 100 and 1000. The capacitors are required to ensure that the division remains accurate at high frequencies.

The input amplifier is a CA3130 operational amplifier where the gain is selected by SW3b. Gains of 190, 60, 19, 6 and 1.9 are available which together with the input divider ratios provide the 11 ranges required. The high gain ranges of 190, 60 and 19 are ac coupled, as the temperature stability of the CA3130 will not allow voltages of less than 10 mV dc to be used. The output of this amplifier is 60 mV when the meter is indicating full scale on any range. A potentiometer, RV1, is provided to adjust the offset voltage on the CA3130 and thus acts as a zero-set control. Since the offset voltage is affected by temperature this control is available externally.

When measuring noise in audio systems a weighting network is often used to give a measurement which is related to the non-linear response of the ear. The most commonly used weighting is known as 'A' weight and this facility is built into the meter. The 'A' weight curve is produced by a network that has a three-pole, high-pass filter and a single-pole, low-pass filter. The main section of this filter is formed by C10, C11, C12 and R22, 23, and R24 (two poles). The third pole is due to C3 and the one megohm combined resistance of R11 to R17. This later section prevents saturation of the input amplifier at low frequencies. Since this filter introduces some loss at 1 kHz, RV2 is incorporated to provide the same loss in the 'flat' mode.

The second IC acts as a meter amplifier. Th input signal is rectified by the diode bridge D1 to D4 whilst the amplifier effectively compensates for the diode drops. A preset for offset adjustment, RV3, is provided for this IC. Calibration is performed by adjustment of the shunting resistance, R31 and RV4, across the meter. Due to the full-wave action of the rectifier the meter when on the dc ranges reads uni-directionally regardless of dc polarity. The output of IC2 will however will either be at over one volt positive or one volt negative (voltage drops across the diodes) depending on whether the input voltage is positive or negative. This is compared by IC3 against zero volts and, depending on polarity, either LED 1 or LED 2 will be illuminated. With an ac input both LEDs will be on. These LEDs are therefore the polarity indicators. Capacitor C19 removes any high frequency components which could be coupled into the input, as the LEDs are located next to the input socket.

Due to the difference between the average and the RMS values of a sine-wave a slight change in gain is necessary in the ac mode and, this change is made by SW1b.

AUDIO MILLIVOLTMETER

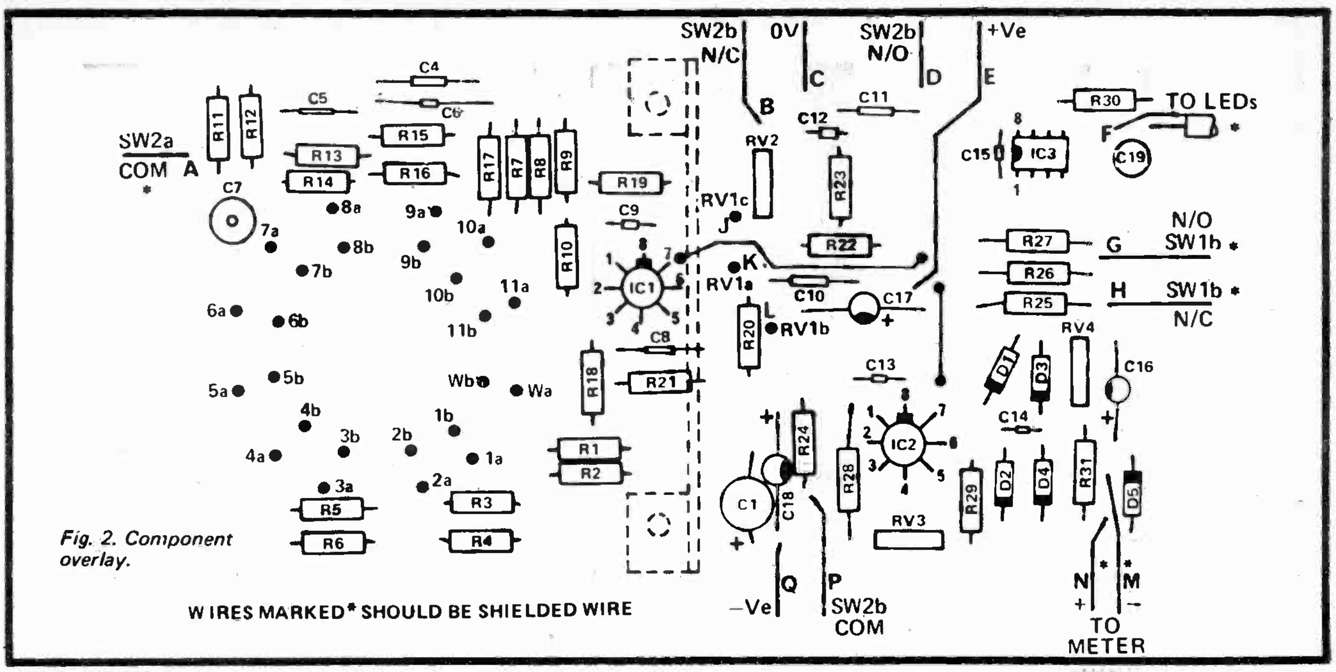


Fig. 2. Component overlay.

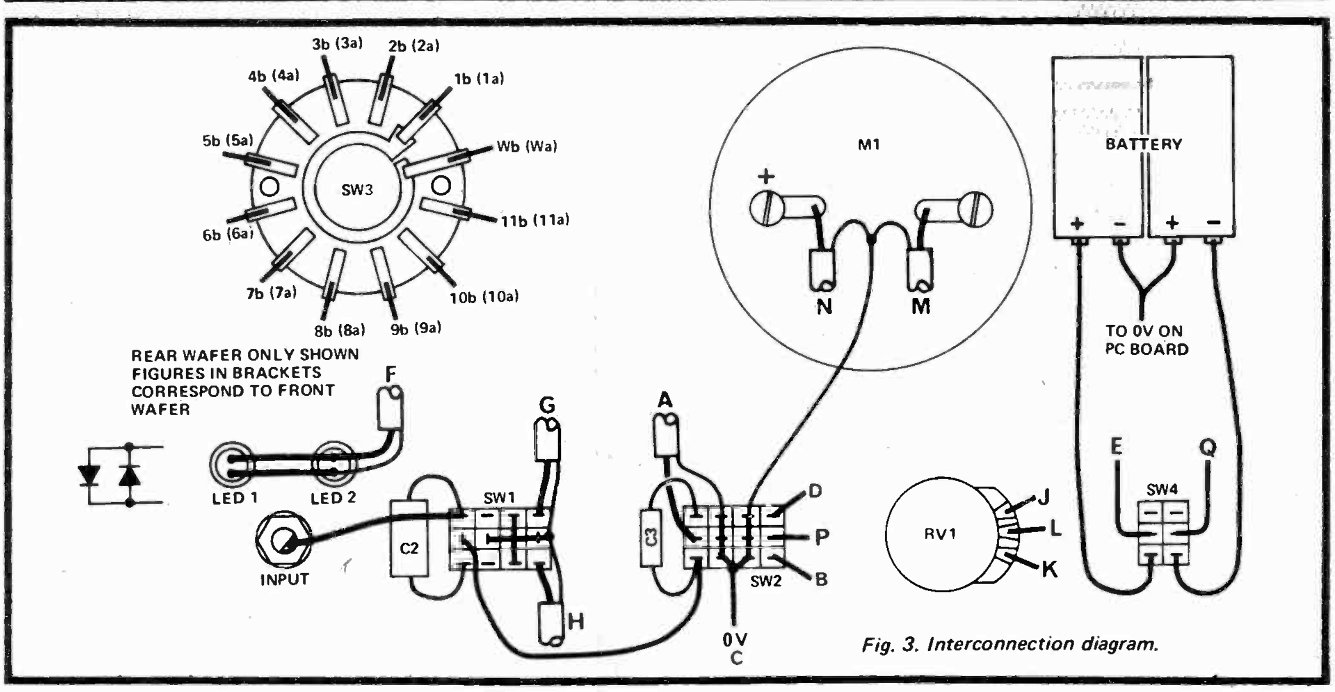


Fig. 3. Interconnection diagram.

PARTS LIST — ETI 128

R2	Resistor	270 ohm	2%	1/4W
R25	"	330 ohm	2%	1/4W
R26	"	390 ohm	2%	1/4W
R4	"	820 ohm	2%	1/4W
R17	"	1k	2%	1/4W
R6	"	2k7	2%	1/4W
R10	"	8k2	2%	1/4W
R15,16	"	18k	2%	1/4W
R21	"	47k	2%	1/4W
R8	"	68k	2%	1/4W
R13,R14	"	180k	2%	1/4W
R11	"	820k	2%	1/4W
R30,31	Resistor	1k	5%	1/4W
R9,27	"	1k2	5%	1/4W
R1	"	3k3	5%	1/4W
R22	"	4k7	5%	1/4W
R19,20	"	10k	5%	1/4W
R25,29	"	10k	5%	1/4W
R3,23	"	27k	5%	1/4W
R5,12	"	82k	5%	1/4W
R18	"	100k	5%	1/4W
R7	"	220k	5%	1/4W
R24	"	270k	5%	1/4W
RV1	Potentiometer	100k lin rotary		
RV2	"	220k preset		
RV3	"	100k "		
RV4	"	5k "		
C7	Capacitor	2-24 pF beehive trimmer 2222 808 00006		

C8,14,15	"	10 pF	Ceramic
C9,13	"	33 pF	Ceramic
C4	"	120 pF	Ceramic
C5	"	180 pF	Ceramic
C12	"	820 pF	Ceramic
C3	"	1200 pF	polyester
C6	"	1500 pF	polyester
C11	"	0.018µF	polyester
C10	"	0.056µF	polyester
C2	"	0.1µF	polyester
C19	"	4.7µF	non polarised electrolytic
C16,17,18	"	33µF	10V electrolytic
C1	"	220µF	6V electrolytic
IC1,2	Integrated Circuit		CA3130
IC3	"	"	LM301
D1-D5	Diode	IN914, BA318 or similar	
LED 1,2	TIL209 or similar with panel mounting		
SW1,2	Toggle switch 4 pole 2 positions		
SW3	Rotary switch 2 pole 11 positions		
SW4	Toggle switch 2 pole 2 positions		
M1	Meter	100µA FSD * see text	

PC Board ETI 128
Die cast Box
Two knobs
One phono socket
Eight 1½V batteries
Shield to Fig. 7

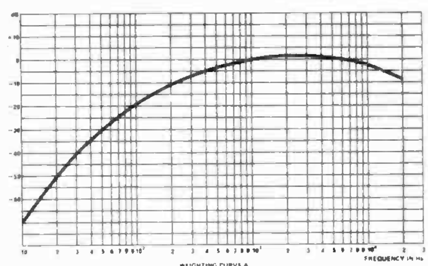


Fig. 4. Curve of 'A' weight response.

deflection of roughly corresponding magnitude is obtained. Also check that the 'A'-weighted switch appears to work as it should.

1. Short the input, select the 3 mV range and switch on.

2. Allow about 5 minutes for the instrument to stabilize thermally and

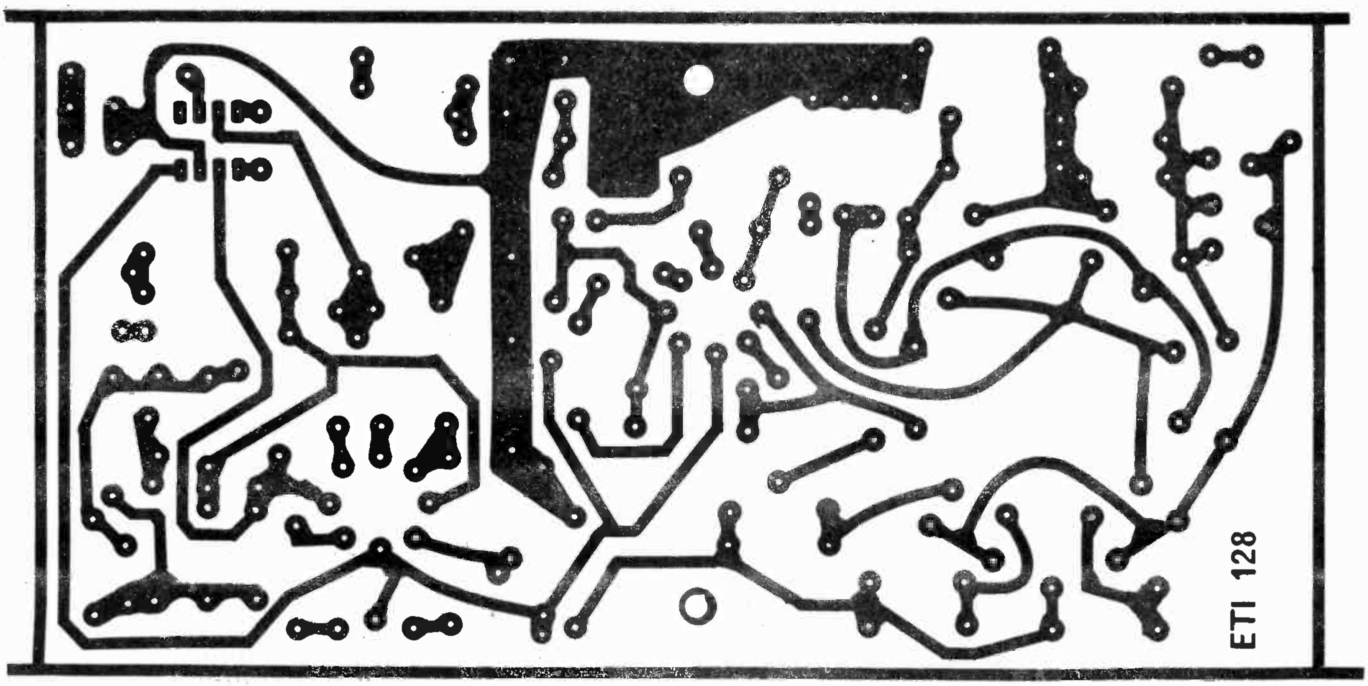
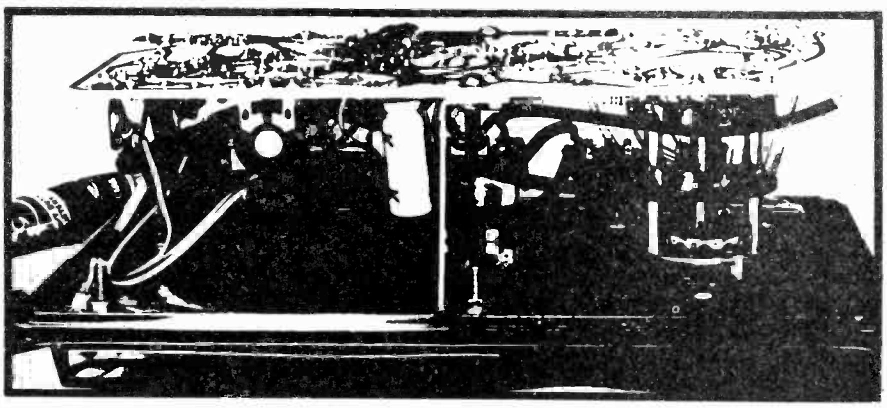


Fig. 5. Printed circuit layout. Full size 170 x 87 mm.



This internal view of the meter shows on the right, how the range switch is wired to the printed-circuit board. Note also the shield.

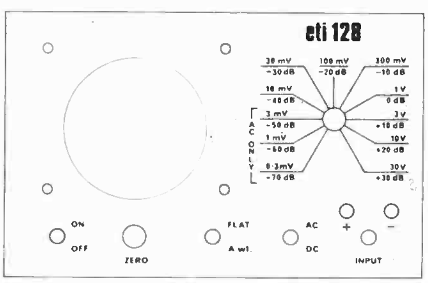


Fig. 6. Front panel artwork.

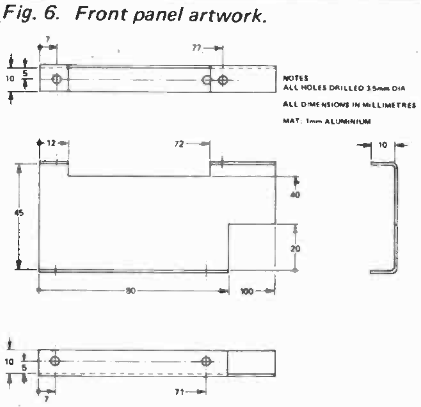
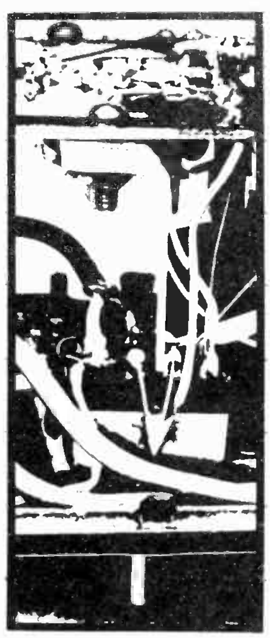


Fig. 7. Details of shield-support bracket.



Note how the shield passes between the earthed, centre contacts of the 'A' weight switch.

then adjust RV3 to zero the meter.

3. Select the 10 mV range, dc, and 'flat', and adjust the front panel control RV1 to zero the meter.

4. Remove the short from the input, select the 300 mV range and apply an input having a frequency of less than 500 Hz and a level which gives a convenient indication, eg 0 dB. Change the frequency to somewhere between 10 kHz and 50 kHz making sure that the input level is the same in both cases, and adjust capacitor C7 so that the meter reads the same in both cases.

5. Apply an ac input signal and switch between ac and dc. The reading on ac should be about 10% higher than on dc. If it is 10% lower the leads to switch SW1b should be reversed.

6. In the ac mode select 'A'-weight and apply a 1 kHz signal of sufficient level to obtain a 0 dB indication on the 1 volt range. Vary the frequency over the whole audio range and check that the response as shown in Fig. 4 is obtained.

7. Go back to 1 kHz and check that zero dB is indicated in the 'A'-weight mode. Now select 'flat' and adjust RV2 to obtain the same reading.

8. Apply an accurately known voltage with the instrument set to the flat and ac modes and adjust RV4 to give the correct reading.

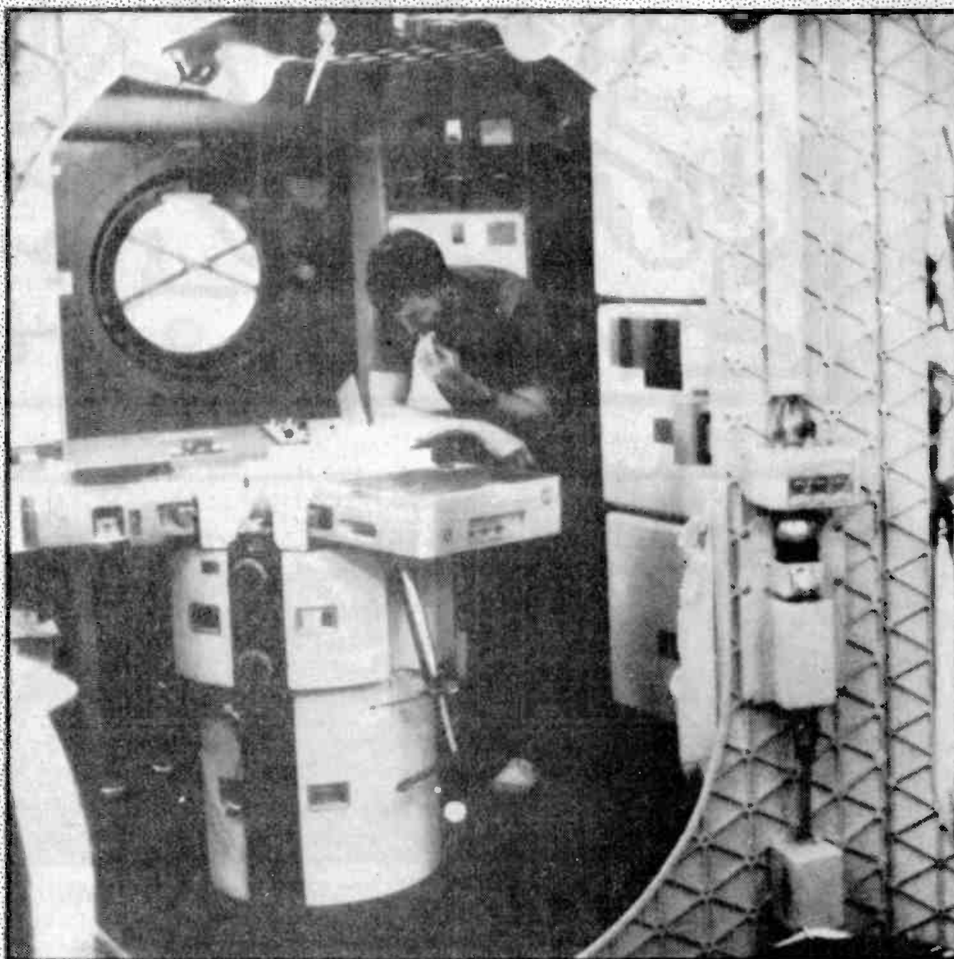
9. Apply a dc input of known polarity and check that the correct LED illuminates. If not, reverse the leads to the LEDs.

This completes the calibration and the instrument should now give accurate readings on all ranges and at all frequencies within the specified range. ●

BRUCE SIBLEY CONSIDERS

SPACECRAFT

The capsule has to provide the astronaut with a comfortable biosphere despite the hostile conditions found in space.



HOME FROM HOME

Spacecraft are essentially minute versions of our own planet. Not only must they provide air, water, food, light, similar climate, and protection but they must also provide a means of disposing of our waste products.

SPACE TEMPERATURE PROBLEMS

Probably one of the most interesting effects met in space concerns the control of temperature within the craft. A surface exposed to empty sunless space would soon freeze, whereas the opposite side facing directly towards the sun would cook.

Without the sun the temperature of objects in interplanetory space would theoretically fall to absolute zero, — 273° Centigrade or 0° Kelvin. Providing it carries no internal heating of its own any

ABOVE: Skylab crewmen Kerwin and Weitz train for their mission in a mockup of the space station at Houston. To the left is the wardroom; to the right is the waste management area. A forward compartment contains additional experiments and storage.

LEFT: Tom Stafford and Aleksey Leonov train together for the recent Apollo-Soyuz mission. The module was to permit the crews access to each others craft.

RIGHT: An Apollo module in lunar orbit. The RCS can be clearly seen to the left of the main motor.

FAR RIGHT: Part of Skylab is reflected in the helmet of Jack Lousma as he works outside the craft. Two members of the crew were employed in replacing a damaged heat shield.

ENVIRONMENT

object will stabilise close to this temperature.

COMPLICATIONS

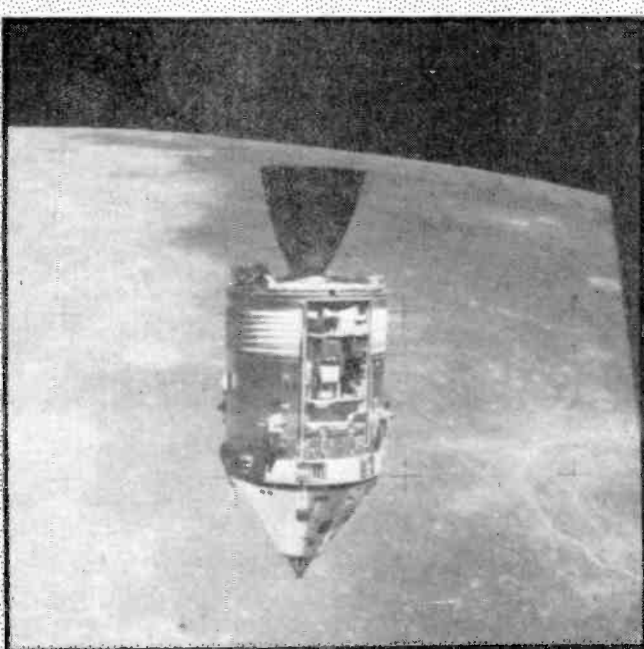
Had this been the entire problem facing American space science, life would have been relatively simple. Heaters and thermal shields could have been installed in the spacecraft to ensure that a living temperature was maintained for ship and crew. Needless to say, this is not the whole story. The solar thermal radiation, having travelled 90 million miles, delivers the equivalent of 1400 Watts per square metre in the vicinity of the earth.

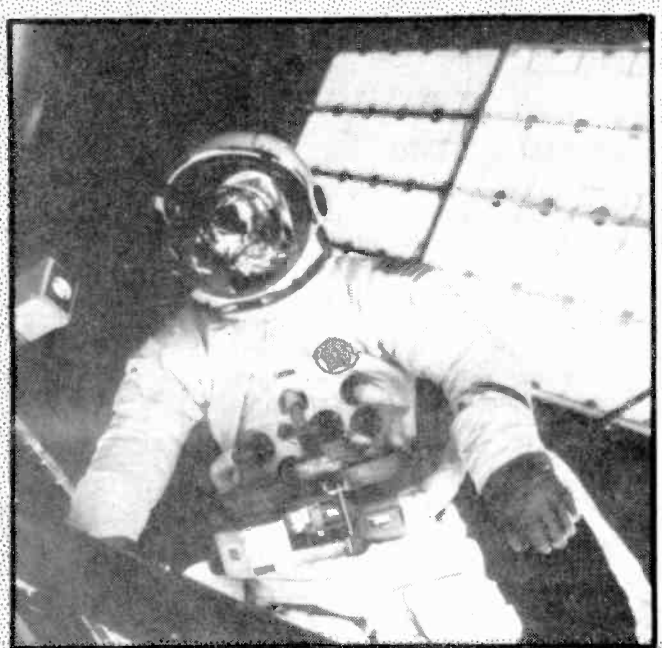
Our temperature problem is hence that one side of a metal spacecraft will be heated to a temperature of perhaps 160°C whilst its opposite side reaches a temperature of −160°C, resulting in a large temperature gradient. Such a difference of temperature across the extremities of the same material could result in the destruction of the whole structure.

In addition to the threat of solar heating there are other serious sources of infra-red radiation. The first of these is the rocket motors. Present day spacecraft employ one major engine at the rear of the space vehicle and several smaller engines, reaction control system engines (RCS), which look like clusters of miniature trumpets. RCS engines are located all over the hull of the space vehicle and are used in mid-course manoeuvers and docking. They fire the exhaust in several directions to orient the craft; thus there is a good chance that some of the hot exhaust gases will "dust" parts of the spacecraft or communications equipment. Such impacts could send the temperature soaring to 800°C in a matter of seconds.

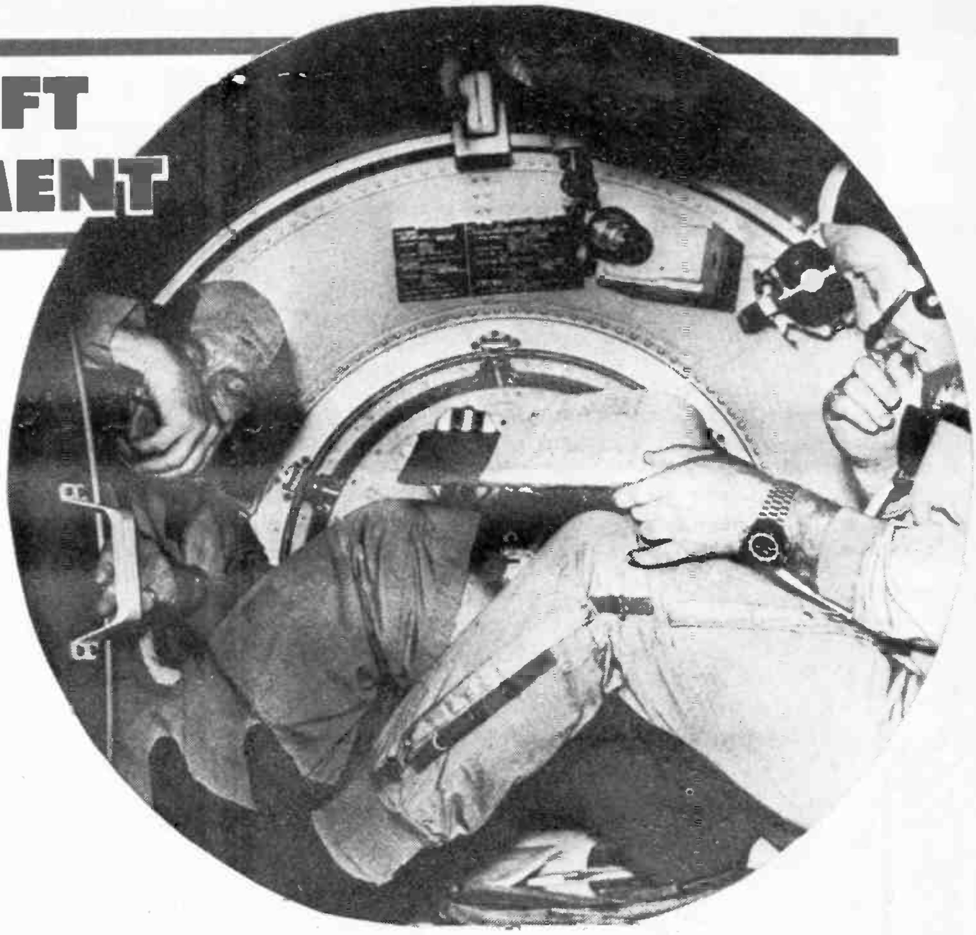
HOT BODIES

The other source of thermal radiation is the planets. The inner planets — Mercury, Mars, Venus, and Earth/Moon — whilst by no means as hot as the sun, are nevertheless hotter than surrounding space. Broadly, these interplanetary bodies are in thermal equilibrium with each other and with the smaller bodies that exist within the system. Each planet exchanges solar radiation between itself and its nearest neighbours — including spacecraft and satellites. In fact, two types of heat radiation are emitted by planetary bodies. The first is known as the 'albedo' and is the re-radiation of solar energy, the





SPACECRAFT ENVIRONMENT



second is due to the planet's own heating system, its molten core. In the case of the moon, only the albedo is present. About 12% more heat will be generated by this process and all astronauts operating on the lunar surface will encounter this.

THE ABSORBING TRUTH

Not all materials absorb heat equally. A white car for instance remains much cooler than a black one when left in the sun all day. The reason for this is that thermal radiation is confined to a spectrum of 0.8-3.0 Microns and white paint absorbs very little energy at these wavelengths (it is reflected). We 'see' at wavelengths far shorter than those which correspond to 'heat'.

MATERIAL CHOICE

Numerous substances exhibit differential absorptive and reflective behaviour to radiation of different wavelengths. So we can manufacture filters and protective coatings to weaken or reflect unwanted thermal radiation. These protective coatings help control the external and internal temperature of the spacecraft and spacesuits.

SURGICAL COATING

These coatings are usually in the form of extremely thin films, yet they have considerable effect. Great care has to be taken assembling equipment to ensure that these films are not damaged (one often sees photographs of people assembling equipment dressed like surgeons performing an operation). Every speck of dust represents a hazard.

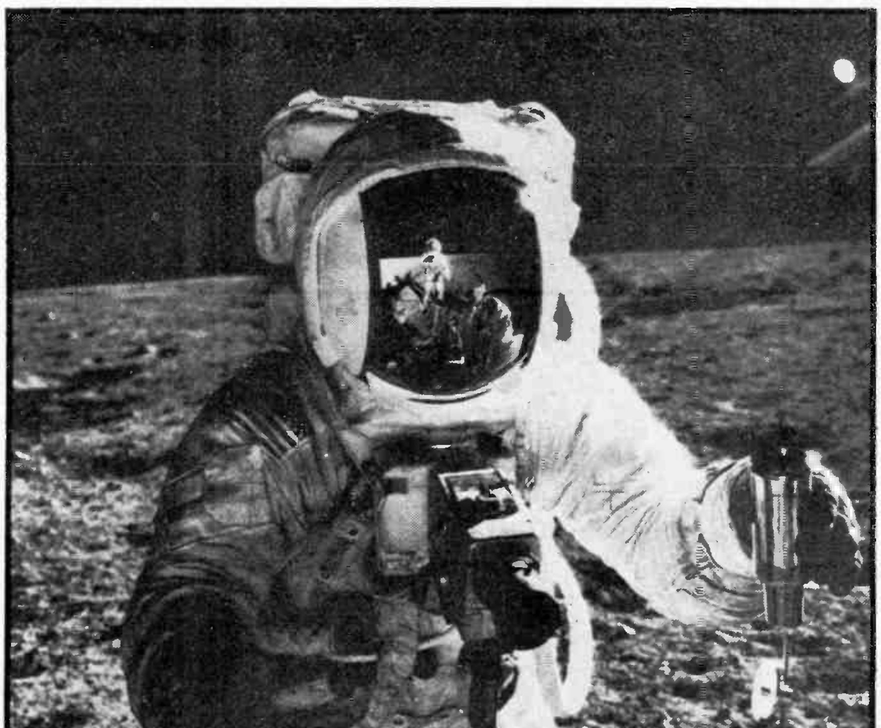
PROBLEMS WITH ULTRA VIOLET

We are all familiar with the effects of the sun's ultra-violet light radiation; the paint on a door or

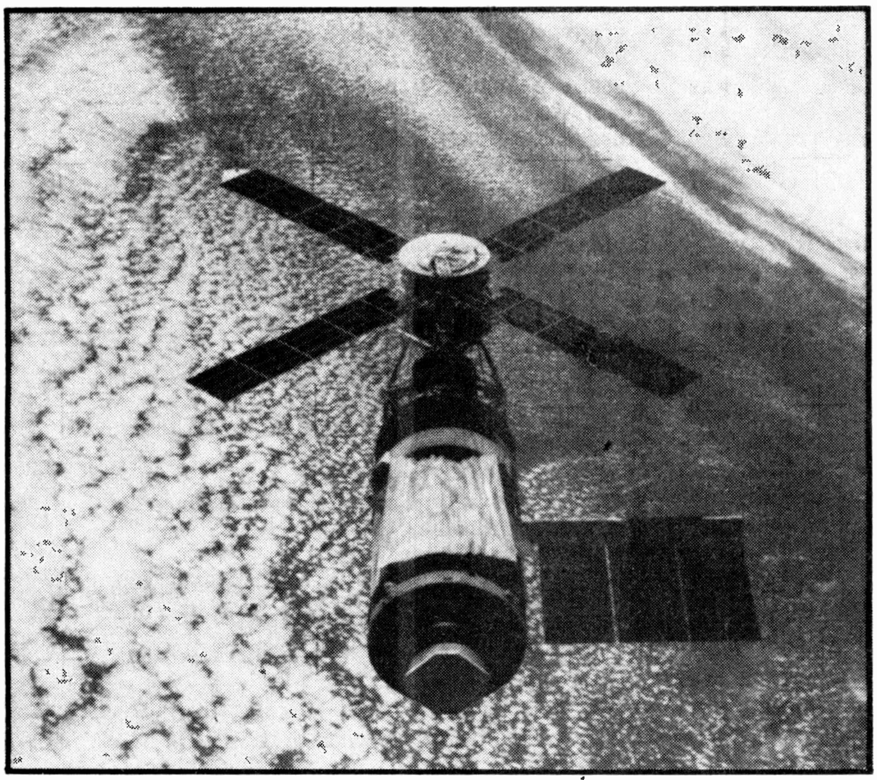
ABOVE: The link-up mission module is checked out by Lenov and Slayton in the manned spacecraft center.

BELOW: The spacesuit is the astronauts miniature craft. It provides him protection whilst outside the capsule.

RIGHT: Skylab photographed from the astronauts as they pull away. Atop the near end is the emergency solar shield deployed by the second crew. A solar power panel matching the one at right foreground was lost during the launching. At the far end is the Apollo telescope mount with its paddle-wheel power panels.



window frame discolours after being exposed to several months of direct sunlight. Our bodies become 'tanned' if we stay in the sun. Above the earth's protective atmosphere the intensity of this UV light is much greater and the discolouration process is speeded up. Fortunately, substances called 'Ferrocenes' (organic,metallic compounds) offer great resistance to UV radiation. At the same time they permit the thermal coatings beneath them to continue reflecting the thermal energy incident upon them. A series of layered protective coatings is thus formed, the layers of which function at different portions of the electromagnetic spectrum. Without ferrocenes and other similar substances, the sun's UV radiation would quickly degrade the thermal coatings.



EXHAUSTING PROBLEMS

As mentioned earlier, the exhaust gases emitted from RCS engines can greatly raise the temperature of parts of the craft in a few seconds. It is essential, therefore, to avoid placing important communications equipment — antennae, radar, altimeters, radiation probes, etc. in the path of exhaust plumes. Several techniques are employed to prevent overheating of any equipment placed outside the protective skin of the craft. Each section of an antenna, for example, is thermally insulated from the next minimising heat conduction.

The materials themselves, mainly metallic in nature, are chosen for their high temperature characteristics. Caught in a sudden surge of heat radiation their molecular structure remains intact and does not deform, an essential characteristic when using precision microwave antennas. Extra thicknesses of ferrocene coatings are also used, and have been found entirely adequate in all but the most severe exposure to rocket exhaust.

METEORS

Throughout interplanetary space there exist millions upon billions of fragments of planetary debris, called meteors, or micro-meteorites. The size of these fragments can vary between the size of a grain of sand to that of a football or a small island. Any spacecraft unfortunate enough to encounter the smallest of these fragments encounters a severe hazard. If large numbers were encountered all at the same moment the experience becomes somewhat akin to passing through a sand blasting machine. Larger meteors will wreck the spacecraft with a single direct hit. However, astronomical data already collected by deep space probes, together with earlier information built up from earth based observations, suggests that the likelihood of such collisions occurring is extremely small indeed. There are, however, regions with a very high population of these fragments, such as the Asteroid Belt between Mars and Jupiter, and until space vehicles are built as large as skyscrapers (like Star Trek's Enterprise) there will be obvious danger for any vessel probing out into space through these regions.

THE DANGERS OF 'NOTHING'

The gas pressure in space is less than 10^{-12}mm of mercury. This vacuum, the solar thermal influence, together introduce some rather bizarre problems.

Sublimation of materials is analogous to evaporation of a liquid. The metals zinc and cadium, commonly used in electronic systems, will sublime at the rate of 1 millimetre per year in the vacuum of space. Little imagination is required to see what could happen to wiring, and switch contacts, etc., when metals re-deposit themselves across a supposedly open circuit. Thus the electronic systems utilised in spacecraft must employ metals that do not sublime readily. In addition Electronic circuits are usually pressure sealded as a module, using inert gases.

OVER-ATTRACTION

A further aspect of vacuum and solar heat is 'cold welding'. Metallic surfaces devoid of grease and gas films can very easily weld together by mere impact under the correct conditions. A switch contact could become permanently closed, or a relay fused. The designers must therefore select materials which do not easily succumb to the effect. Coatings or films can assist with this problem, but generally it is overcome by the choice of materials.

It is obvious then that explorers in space have many different hazards and dangers to overcome. The fact that so many space missions have been successful is a great tribute to American scientists.

Photographs supplied by NASA. ●

TECHNICAL BOOKS FROM ETI

Since the ETI Book Service started about nine months ago, it has achieved enormous popularity with readers. The books included in the list are selected for their likely appeal to ETI readers. The list includes many 'standard' works as well as the latest titles.

This month we are listing about three times the normal number to introduce readers to some less well-known titles and specialist books.

It is our policy to quote an all-inclusive price in every case, there is nothing else to pay.

AUDIO/HI-FI

AUDIO ON WHEELS — £6.50
V. Capel
Installing and operating "in-car entertainment" equipment currently available

AUDIO TECHNICIANS BENCH MANUAL — £3.45
J. Earl
Deals with test instruments, tuner tests, disc playing equipment

ELECTRONIC MUSICAL INSTRUMENTS — £2.15
N. Crowhurst
From basic simple amplification to total music generation

EXPERIMENTING WITH ELECTRONIC MUSIC — £1.85
R. Brown
Everything is in this single volume for today's generation of music buffs

HI-FI LOUDSPEAKERS AND ENCLOSURES — £7.30
A. D. Cohen
Explains advances in stereo sound including three element stereo and all in one enclosure

MODERN RECORDING TECHNIQUES — £6.20
R. Runstein
Explains equipment, controls and techniques in the modern studio

SERVICING ELECTRONIC ORGANS — £2.15
M. Applebaum
Informs on the various electronic circuits, how to locate and correct defects

PUBLIC ADDRESS HANDBOOK — £3.50
V. Capel
Basic principles, microphones planning reliability, fault finding

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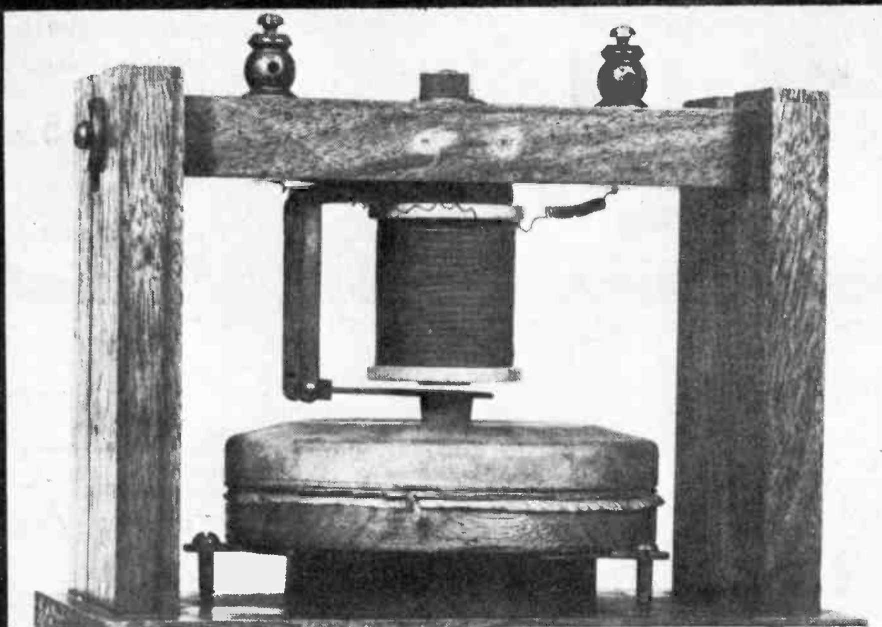
TELEPHONES



'COME HERE, WATSON, I WANT YOU'

These words were sent, and received, on the telephone shown above, on 10th March 1876

The telephone was made by Alexander Graham Bell and the world's first telephone message was sent by him to his assistant, Thomas Watson, in Boston, Mass., a hundred years ago.

Twenty-seven years earlier a telephone, believed to be the first, was built in Havana by Antonio Meucci of Florence. This instrument was never patented or demonstrated publicly.

The first publicly demonstrated phone was built in 1860 by Johan Philipp Reis near Frankfurt. It was made from a violin case, a barrel bung and a sausage skin. Listeners claimed to be able to recognise music but messages were unintelligible.

TELEPHONE BOXES

The first public call-box was opened in New Haven, Conn. on 1st June 1880. Payment was to an attendant. Regular callers could buy a key to enable calls when the attendant was off duty.

The first coin-operated telephone was installed in Hartford, Conn, in 1889. It was not until 1906 that the Post Office opened their first coin-box telephone at the Ludgate Circus P.O.

Prepayment phone boxes were not introduced until 1925.

The first outdoor kiosks in Britain were erected in 1908. Most of the kiosks were made of wood, but in dockland areas they were made of galvanised iron to withstand the agression of dockers who lose their money.

In 1912 the Postmaster General approved the provision of doodling pads to discourage callers from defacing walls. These were abandoned during the first World War.

The first standard kiosk design was introduced in 1921 — a concrete frame with red wooden door and metal glazing bars.

ETI's DIRECTORY

BRITISH TELEPHONE

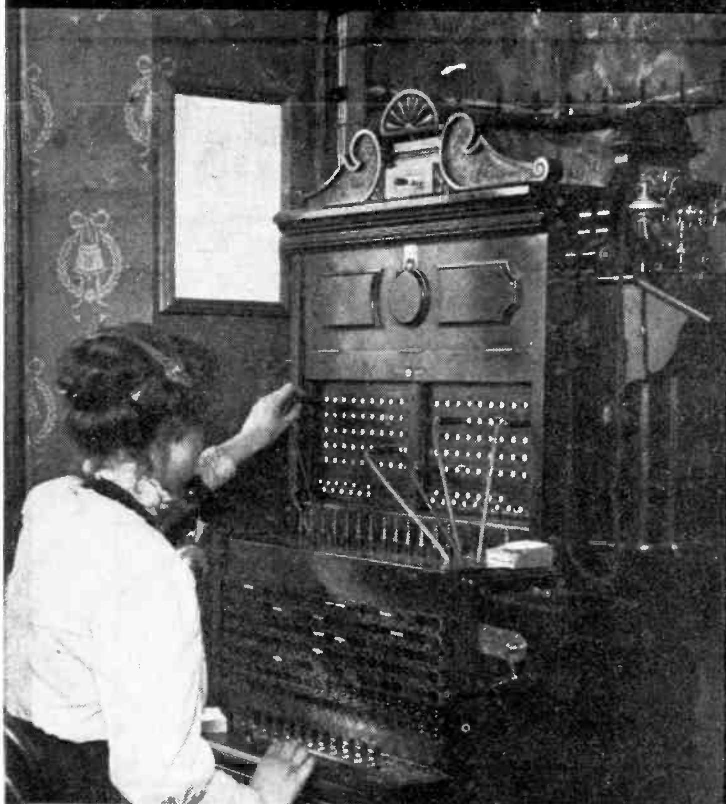
1879 First telephone exchange in England was opened in London, by the Telephone Company Ltd.
1896 National Telephone Company's trunk service was taken over by the Post Office.
1912 All National Telephone Company exchanges had been taken over by the Post Office.
1915 Archangel submarine telegraph cable was laid.
1925 Prepayment coin-collecting boxes were introduced.
1927 London — New York radiotelephone service commenced.
1929 Hand micro-telephone was introduced (combined transmitter and receiver in one hand-set).
1932 "Telex", "Printergram" and private telegraph services were introduced.
1937 First submarine coaxial telephone cable opened to Holland carrying 16 channels. "999" service introduced in London.
1943 First submerged repeater laid in the Irish Sea.
1949 London-Birmingham television radio relay link opened.
1951 Telephone Act passed, enabling the Postermaster-General to fix retail charges by Statutory Regulation.
1956 Opening of the Transatlantic Telephone Cable.
1958 First subscriber Trunk Dialling installation opened at Bristol.
1962 First telecommunications satellite (Telstar) launched. Experimental electronic exchange opened at Highgate Wood.
1963 International Subscriber Dialling (ISD) introduced, from London to Paris.
1964 Datel services introduced. First Crossbar exchange opened to public service.
1965 London Post Office Tower opened.
1968 Inauguration of first pulse code modulation (PCM) switching centre.
1973 World's first experimental International Confravision link-up between London and Sydney.
1975 ISD extended to 26 countries. Post Office's new Research Centre opened at Martlesham Heath, Suffolk at a cost of £11½ million.

THE FUTURE

Next month's ETI will feature an article on VIEWDATA. In this system subscribers will be able to call up information from a central computer using their telephone line.

Other developments being researched by the Post Office include sending signals down glass fibres. The capacity is fantastic — half a million phone calls can be transmitted down a "cable" of glass fibres!

THE WORLD'S FIRST INTELLIGIBLE PHONE MESSAGE WAS SENT 100 YEARS AGO



TELEPHONE EXCHANGES

The first telephone exchange was advertised in October 1877 by Isaac Smith, for the New England Telephone Company. Within a month he had 17 subscribers. The first in Britain was the Glasgow Medical Telephone Exchange built in 1879. Unlimited calls where allowed for a fee of £12.

The photo above shows a lady operator in an Edwardian telephone exchange.

The first automatic exchange was patented in 1889 by Almon B. Strowger, a Kansas City undertaker. Strowger had previously been losing custom when the wife of a rival undertaker became an operator of the manual exchange.

The first Strowger exchange was opened 1892 in the US; the first in Britain opened in London in 1892. The early telephones did not have dials — the subscriber has to tap out the number on 3 keys (hundreds, tens and units).

TELE-PHONE DIAL

The first telephone dials were used in 1896. Projecting vanes divided the sectors of the dial — the use of holes was a later development. Today the push-button dial is common and soon it will be standard.

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SN									CD								
7400	.16	.11	7451	.16	.11	74190	2.30	1.70	4000AE	.18	.12	4028	.83	.60	LM741 8DIL*	.40	.28
7401	.16	.11	7453	.16	.11	74193	1.15	.85	4001AE	.18	.12	4035	1.40	.90	LM748 8DIL*	.60	.39
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7403	.16	.11	7474	.31	.18				4006	.99	.73				~~NE555V~~	~~.60~~	~~.40~~
7404	.19	.12	7490	.42	.24				4007	.18	.12				2N3055	.65	.45
7410	.16	.11	7492	.45	.24				4008	.82	.63				MJ2955	1.00	.75
7413	.28	.16	7493	.45	.24				~~4009~~	~~.52~~	~~.35~~				~~MJE2955~~	~~1.20~~	~~.90~~
7416	.28	.16	7496	.68	.44				4011	.18	.12				MJE3055	.75	[illegible]
7420	.16	.11	74107	.30	.24				~~4012~~	~~.18~~	~~.12~~				~~BD135/6 Pr*~~	~~1.00~~	.75
7423	.23	.14	74121	.32	.20				~~4013~~	~~.45~~	~~.34~~				BD139/40 Pr*	1.58	[illegible]
7430	.16	.11	74150	1.20	.61				4016	.45	.34				~~BDY56~~	~~1.50~~	.98
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7442	.65	.45	74154	1.20	.70				4019	.52	.38						
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READERS ARE ADVISED TO KEEP A RECORD OF THEIR ORDERS.

18

eti microfile

MICROBIOLOGY

IN WHICH IS DISCUSSED the internal operation (biology?) of the microprocessor. Last month we discussed the general organisation of a microcomputer; this month we shall focus on the heart of this unit — the microprocessor. We shall start by reviewing a few basic concepts — incidentally a good introductory course if you haven't done much digital work is Cambridge Learning Enterprises' 'Design of Digital Systems', which is advertised elsewhere in this issue. By the time you complete Vol 6, microprocessors won't give you any trouble!

NUMBER SYSTEMS

In everyday life, people count in tens, which is fairly logical when you consider that you have 10 fingers. However, if fate had decreed that the human race should have only eight fingers, it is very probable that we should be counting in eights, and it is doubtful that we should ever find this to be a disadvantage. Now, a digital computer has no fingers and in fact the only change of state it can 'perceive' is the presence or absence of a voltage. (See 'Electronics — It's Easy' for a refresher.)

Consequently, it is convenient to represent these two states as a '0' and '1' respectively. This counting to the base two is known as binary arithmetic and is the system that virtually all digital computers use. Just as the digits in a decimal number represent varying powers of ten, e.g. 365 is $3x10^2 + 6x10^1 + 5x10^0$, so in a binary number the digits represent powers of two. For example, the binary number 11010_{two} equals $1x2^4 + 1x2^3 + 0x2^2 + 1x2^1 + 0x2^0$ i.e. 16+8+2 which is 26_{ten}. The decimal number 39_{ten} can simply be converted to binary by various methods — the simplest to use for such a low number is to find the highest power of two which can be subtracted from it and then attempt to subtract descending powers from it. In this case the highest power of two which can be subtracted from 39 is the fifth ($2^5=32$) leaving 7 remainder.

We write down a one as the first figure of our result. The next lowest power is the fourth ($2^4=16$) which cannot be subtracted from 7, so we write down a nought. Two to the third, which is 8, cannot be subtracted from 7 either, so we write another nought, but 2 squared or 4 can be taken away, to leave 3, subtracting 2 leaves 1 and taking away 1 leaves zero, so we can write the final three ones to give our final answer of 100111_{two}. There are well-defined methods for converting binary to decimal and vice versa,

LISTEN! – WITH A DEDICATED MPU DOING THE COMPOSING AND ANOTHER THE PLAYING. . . .WHO NEEDS MIKE OLDFIELD?

but it is not proposed to go into these here as they have been dealt with so often elsewhere, including 'Design of Digital Systems'.

Now, as we've said already, most microprocessors have an eight *bit (BInary digiT)* word length, and so it can be seen that the lowest number that can be represented is 00000000_{two} and the highest is 11111111_{two}, or 0_{ten} and 255_{ten}, respectively. Negative numbers can be represented in either of two ways, by making the first bit indicate the sign of the number or

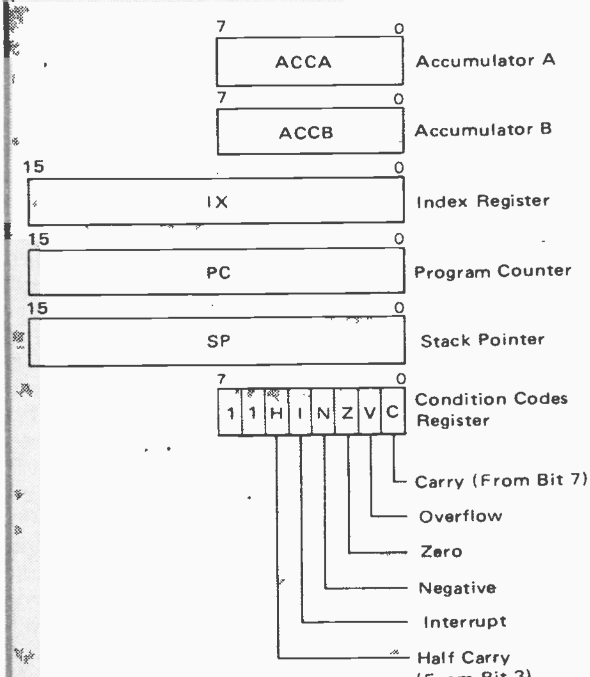

Fig. 1. MPU Registers.

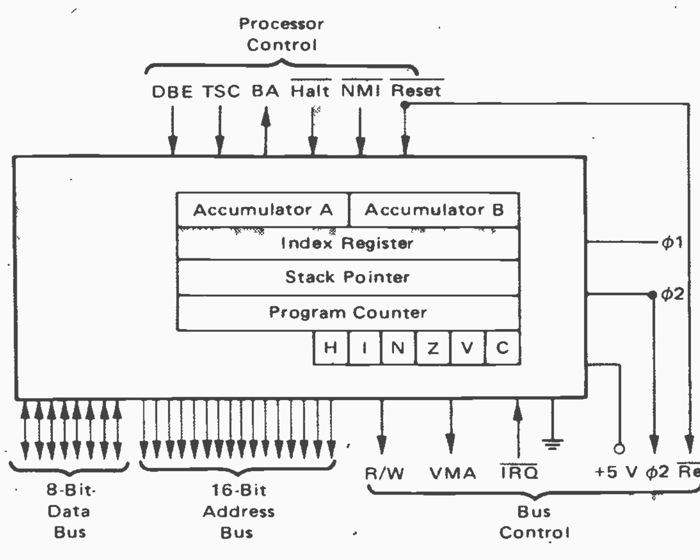

Fig. 2. Control lines.

microfile

by taking the two's complement. Once again, we do not propose to go into this in any detail as it has been adequately covered elsewhere.

Writing out binary numbers in full takes up a lot of space and the numbers are difficult to memorise; consequently a number system called *hexadecimal* is used to simplify matters. In hex the numbers 0 to 9 are numbered conventionally and 10 to 15 are numbered A to F. This is particularly convenient as 15 equals 1111, the highest four-bit binary number; and hence an eight-bit number can be represented by two hex digits as follows:

0000=0	1000=8
0001=1	1001=9
0010=2	1010=A
0011=3	1011=B
0100=4	1100=C
0101=5	1101=D
0110=6	1110=E
0111=7	1111=F

Hence, the eight-bit number 10010101 would be represented as 95. For a 16-bit number, as will be found on the address bus, the same system applies except that 4 hex digits will be required — e.g. 1110010110111101 is E5BD in hex.

To simplify the handling of decimal numbers in computers still further, yet another system exists, known as *Binary Coded Decimal* (BCD). In this system each decimal digit is directly converted into a four-bit binary number. To take an example 49 would become 01001001 as shown:

4	9
0100	1001

Equally simply, BCD numbers can be converted to decimal by taking 4 bits at a time and converting each group separately to a single decimal digit, e.g. 01101000 becomes 68.

Some expertise in handling these number systems is virtually a necessity if you want to program computers of any kind. In order to get the "feel" of them we suggest that you read up a bit and then try a few exercises in binary addition, etc.

You will soon discover, for instance, that if you try to add together two BCD numbers as if they were straight binary, you just

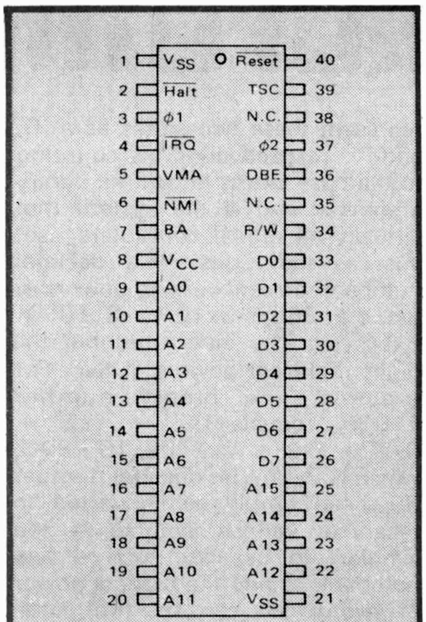

Fig. 3. Pin Layout

don't get a correct answer. There are ways round this, however, as you'll discover later. We've also treated all these systems as though they represent only numbers, however they also represent the instructions that the MPU uses as a program. For instance, the hex code 8B will cause the M6800 microprocessor to add a number from memory to one of its accumulators, or hex 97 would instruct it to store the contents of an accumulator in memory. There are 197 different instructions (72 basic types) which the MPU uses — we'll cover many of these in depth when we discuss programming.

WHAT'S INSIDE?

The M6800 MPU is a 40 pin DIL integrated circuit which contains roughly ten thousand components. The NMOS technology used permits a very high gate density and generally speaking makes the whole thing possible. There are one or two bipolar microprocessors about, such as the Am2901, but these are generally 4-bit devices which have been arranged so that they can be parallelled up to permit longer word lengths (this is known as bit-slice architecture).

If you part with around £27 of your cash to buy a 6800 micro you are getting around 3000 logic gates which is pretty cheap, if you ignore the fact that they won't do anything without quite a lot of other hardware, not to mention *software* (programs) However, at the projected end-of-'76 price of under £8 this must be value for money and if by 1980 the price drops to the expected £1 mark you just won't buy CMOS or TTL for most projects!

Obviously, circuitry on the actual lump of silicon is extremely complex — the only sections the programmer can actually get at are the six registers which are connected to the data and address busses, and via certain pins he can 'get at' some parts of the logic to handle interrupts and data transfers etc. Most of the logic is inaccessible: for example the arithmetic circuitry around the accumulators is 'transparent'; instruct the MPU to add and it will do so, automatically and there is no way that the function can be modified. Fortunately, one would almost never wish to alter the way in which the MPU operates. It is completely a 'general purpose' chip and instructions are built into it to handle everything you could reasonably wish.

The six registers mentioned above are the most important part of the MPU. They are.

1 *Accumulator A (ACCA).* One of the two 8-bit working registers of the MPU.
2 *Accumulator B (ACCB).* The other 8-bit working register.
3 (The *Condition Codes Register (CCR)* which contains various bits of information about the contents of the accumulators. It is an 8-bit register, but only 6-bits are actually used.
4 (The *Program Counter (PC)* is a 16-bit register which usually gives the address of the instruction the MPU is currently executing.
5 The *Stack Pointer (SP)* is used in setting up areas of memory for storage of intermediate results and also in handling interrupts. Also 16-bit in length.
6 The *Index Register (IX)* is used in special addressing modes to let the MPU jump around in memory to subroutines etc. Again, this is a 16-bit register.

By means of various instructions one can shift data into, and out of, the accumulators and memory, alter data, add numbers, and test results of operations. At this point, the CCR becomes of importance. It contains six bits, HINZV & C, as shown in fig 1. H is a Half-carry bit which is set when a carry is generated from bit 3 of the accumulator and is of special relevance in BCD calculations. The I bit is an Interrupt mask bit, which is set if the MPU is to ignore interrupt requests from other devices. (Sorry about continually mentioning interrupts without explaining them, but this stuff has to be covered first.). N is a Negative bit and is set if the esult of a calculation is negative. Z similarly, is set when the result is zero. V is set if the result overflows from the register as a result of calculation involving the 2's complement representation of negative numbers. C is a carry bit which is set if the result has greater than 8 bits.

The Stack Pointer and Index Register can be loaded, incremented, decremented, and stored by similar instructions. The Program Counter is altered by other instructions such as JSR (Jump to Subroutine). All of these instructions will be considered in detail when we discuss programming.

PIN CONNECTIONS

Fig. 2 shows the signals which let the MPU communicate with the other parts of the microcomputer system. The 8-Bit *Data Bus* is bi-directional, that is the MPU can either send data out on the bus or it can input data from other devices. The reception of data from memory is termed reading, whilst transmission of data for storage is called writing. The MPU will normally indicate to the other devices just what it is doing by putting the Read/Write (R/W) line low when it is writing and high when it is reading. The MPU will also put out on the Address Bus, the address of the memory location it is reading or writing to or from. However, some ambiguities could arise when the MPU is changing the address being output on the bus, and so another signal, *Valid Memory Address, (VMA)* is used which only goes high when the Address Bus has stabilised and read/write operations can take place.

The *Interrupt Request signal (IRQ)* is used by peripheral equipment to signal to the MPU to stop whatever it is doing in order to perform a more urgent task. When the IRQ line goes *low*, the micro will complete the current instruction, store away the Current contents of the registers at a location given by the stack pointer, and then go to an interrupt service program. When it has finished executing this program, it will reload its registers and start again from where it left off. If the Interrupt Mask bit of the CCR is set, however, it will ignore an interrupt request, unless the *Non-Maskable Interrupt* line is pulled low. as this bypasses the 1 bit of the CCR and the MPU *has* to respond to this request. This ability of the micro to be interrupted is phenomenally important, as it all happens so quickly the MPU seems to be doing two things at once.

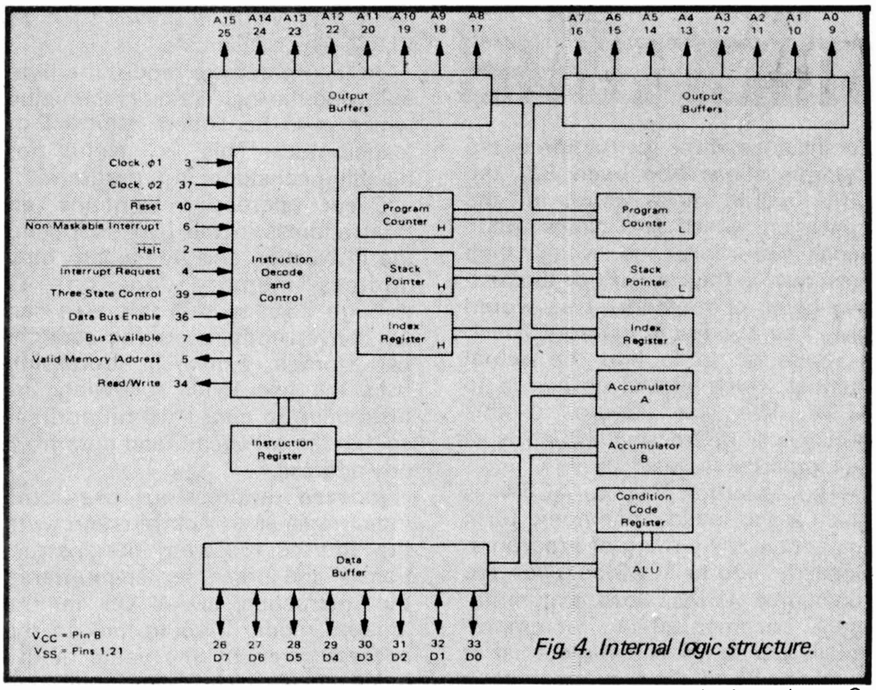

Fig. 4. Internal logic structure.

For example, the MPU can execute a program, while simultaneously inputting data from a teleprinter keyboard. The micro can execute an instruction in a couple of microseconds, while a teleprinter can input a character every 100 milliseconds for example, so that it does not make sense for the micro to hang around spending most of its time waiting for a character to be input. Instead it can be executing a program until an interrupt stops it to input the character and store it, when it can return to the main program again until it is once more interrupted.

Data Bus Enable (DBE) and *Three-State Control (TSC)* are both inputs which cause the MPU to go into a high-impedance state and, effectively, disconnect itself from the busses so that other devices can use them *without* affecting the MPU. The *Halt* instruction also forces the MPU into its three-state mode. *Bus Available (BA)* will go high when this happens to indicate that the MPU has stopped and the address bus is available.

Reset is used when the MPU is started up. A positive going edge on this input will cause the MPU to execute a special restart sequence which will initialize outputs and prevent the entire system from going randomly haywire.

φ.1 and φ2 are the two phases of the systems clock, which can operate at up to 1MHz, at which speed it can execute the shortest instruction in 2μS. φ1 and φ2 are non-overlapping square wave complements and are the only inputs to the MPU that are not at standard TTL levels. All data transfers take place during the μ2 clock cycle, and so this signal can usually be used to drive DBE and also to enable memories and interfaces.

The final two inputs to the MPU chip are the earth connection and the +5V supply.

THE INSTRUCTION SET

We have discussed how certain pins are used to control the MPU, but of course the essential basic concept of the microprocessor is that its operation is, for the most part dictated by patterns of 0's and 1's on the data bus. There are 197 such patterns, which are variations on a basic set of 72 instructions. For instance, the binary pattern 10001011 (or hex 8B) will cause the MPU to perform an addition in the following manner: If, while executing a program, the MPU increments the Program Counter to read out the next program step and then reads in the code 8B, which means in human terms 'Add the following number to what is already in ACCA', it will increment the PC so that it can read in the contents of the next location in memory and add that number to the contents of ACCA. Thus the complete instruction takes up 2 *bytes* (eight-bit words) of memory and takes 2 clock cycles to execute. Each clock cycle has two halves — during φ1 the address bus is being changed, and the internal logic of the MPU is in operation while φ2 is used to read/write data while everything is (hopefully!) stable.

All of the instructions are executed in a basically similar manner.

microfile

For instance, if the instruction in the example above had been BB, the MPU would have read in the instruction, which is a similar additional instruction, and would then have read in the contents of the next two bytes of memory. This would give it an address in memory which it would go to to find the actual number which should be added to ACCA. We shall return to this principle of *addressing*, which is of key importance, later.

The operation 'add to ACCA' is given a shortened, mnemonic form to assist in the writing of programs. Similarly 'add to ACCB' is given the mnemonic ADDB, 'load accumulator A' becomes LDAA, 'increment' is INC and so on. A complete list of operations and their mnemonics is is given in Table 1. Before discussing them in detail, we shall divert briefly to look at addressing modes.

ADDRESSING MODES

"We've already looked briefly at two different types of ADD instruction, (i) *immediate* mode, where the value to be used follows the instruction in the body of the program, and (ii) the *extended* mode, where the two bytes following the instruction give an address where the MPU can find the value to be used. In fact, there are 5 different addressing modes, or 6 if you include the case where no address or value is given, such as CLRA, which clears ACCA.

In the immediate mode, the byte following the instruction is the value which is to be added, subtracted, loaded etc. This is useful for handling constants in a program.

Direct addressing contains an 8-bit address in the byte following the instruction and hence can only address memory locations 0 through 255, so that this area can be conveniently used for scratch-pad storage. *Extended* addressing uses the two bytes following the instruction to give a 16-bit address so that the MPU can read data from any address.

Indexed addressing uses the index register in combination with the address following the instruction. If the processor encountered the instruction LDAA 05 in the indexed mode it would look in the address given by the value of the index register plus 05 and then load the contents of this location into ACCA. The indexed addressing mode is particularly useful for jumping about in a program since instructions such as LDX, INX, DEX provide ways of altering the index register value.

The *relative* mode is used only with branch instructions and enable the processor to branch ± 127 locations relative to the present value of the Program Counter. These instructions are particularly useful in setting up loops and iterative processes, as well as subroutines.

Detailed information on the instruction set and addressing modes is contained in the M6800 Systems Reference and Data Sheets, and is far too detailed to go into in any great depth here. However we have made arrangements for a data pack to be made available to our readers for 50p to cover postage and packaging from **Cramer Electronics, 16 Uxbridge Road, Ealing, London W5 2BP.** This will include the Systems Reference & Data Sheets, EXORciser Data Sheets, and assorted information including a wall chart giving pricing information.

In the next Microfile we shall look at the other components which make up the memory and input/output parts of the microcomputer.

If you do not wish to cut out the coupon, please print your name and address clearly on a piece of paper so that it can be used as a label to send you the information.

To: Cramer Electronics Ltd., 16 Uxbridge Rd., Ealing, LONDON W5 2BP.
Please send me an M6800 information pack. I enclose Cheque/P.O. for 50p. to cover postage and packing.

NAME . . . .

ADDRESS . . . .

. . . .

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ABA	Add Accumulators	CLR	Clear	PUL	Pull Data
ADC	Add with Carry	CLV	Clear Overflow	ROL	Rotate Left
ADD	Add	CMP	Compare	ROR	Rotate Right
AND	Logical And	COM	Complement	RTI	Return from Interrupt
ASL	Arithmetic Shift Left	CPX	Compare Index Register	RTS	Return from Subroutine
ASR	Arithmetic Shift Right	DAA	Decimal Adjust	SBA	Subtract Accumulators
BCC	Branch if Carry Clear	DEC	Decrement	SBC	Subtract with Carry
BCS	Branch if Carry Set	DES	Decrement Stack Pointer	SEC	Set Carry
BEQ	Branch if Equal to Zero	DEX	Decrement Index Register	SEI	Set Interrupt Mask
BGE	Branch if Greater or Equal Zero	EOR	Exclusive OR	SEV	Set Overflow
BGT	Branch if Greater than Zero	INC	Increment	STA	Store Accumulator
BHI	Branch if Higher	INS	Increment Stack Pointer	STS	Store Stack Register
BIT	Bit Test	INX	Increment Index Register	STX	Store Index Register
BLE	Branch if Less or Equal	JMP	Jump	SUB	Subtract
BLS	Branch if Lower or Same	JSR	Jump to Subroutine	SWI	Software Interrupt
BLT	Branch if Less than Zero	LDA	Load Accumulator	TAB	Transfer Accumulators
BMI	Branch if Minus	LDS	Load Stack Pointer	TAP	Transfer Accumulators to Condition Code Reg.
BNE	Branch if Not Equal to Zero	LDX	Load Index Register	TBA	Transfer Accumulators
BPL	Branch if Plus	LSR	Logical Shift Right	TPA	Transfer Condition Code Reg. to Accumulator
BRA	Branch Always	NEG	Negate	TST	Test
BSR	Branch to Subroutine	NOP	No Operation	TSX	Transfer Stack Pointer to Index Register
BVC	Branch If Overflow Clear	ORA	Inclusive OR Accumulator	TXS	Transfer Index Register to Stack Pointer
BVS	Branch if Overflow Set	PSH	Push Data	WAI	Wait for Interrupt
CBA	Compare Accumulators				
CLC	Clear Carry				
CLI	Clear Interrupt Mask				

Table 1. M6800 Instruction set

DESIGN IDEA: M6800 SINGLE INSTRUCTION CAPABILITY

The evaluation kit MEK6800D1 comprises an MPU, some RAM, ROM, I/O ports and a terminal interface. The ROM (MCM6830-L7) contains an 'Executive' program called MIKbug which enables users to load and run their programs but does not have any built-in single-step facility. This circuit (fig.) makes use of the 6800's interrupt routines by generating a non-maskable interrupt after the first cycle of each instruction. In response to the interrupt, the MPU completes the current instruction and stores the contents of the MPU registers on the stack. The MPU then jumps, via the interrupt vector, to the start of an interrupt service routine in MIKbug. This loads the index register with the address of the first instruction of the user's program. This address was previously stored by the user at a predetermined location.

The MPU then goes to the first instruction of the user's interrupt routine and executes it. This routine could, for example, print out the contents of the stack, which now holds the MPU internal register contents applicable to the user's program.

The final instruction in the user's interrupt routine (RTI) will hand back control to MIKbug. When the system is instructed to execute the next instruction, the MPU's registers will be loaded from the stack and the sequences will repeat.

HARDWARE OPERATION

The circuit relies on the fact that the RTI instruction executed just before the next step of the user's program is stored at a known address in MIKbug. A comparator, comprising four MC7242 ICs, is connected to the 6800 address bus to recognise when the address of the RTI instruction is on the bus. The output of the comparator is ANDed with the VMA and $\phi 2$ signals.

When the RTI instruction address is detected, flip-flop A is set and the MC14526 counter, which has been preset to 11, begins counting down $\phi 1$ clock pulses. When it reaches zero, flip-flop B is set, the NMI line is taken low (hence true) and the MC14040 counter is enabled. When the 14040 has counted 32 $\phi 2$ clock pulses, flip-flops A and B are reset and the interrupt pulse is terminated.

The 11 and 32 cycle delays ensure that the interrupt pulse occurs at the right time and is of the necessary length.

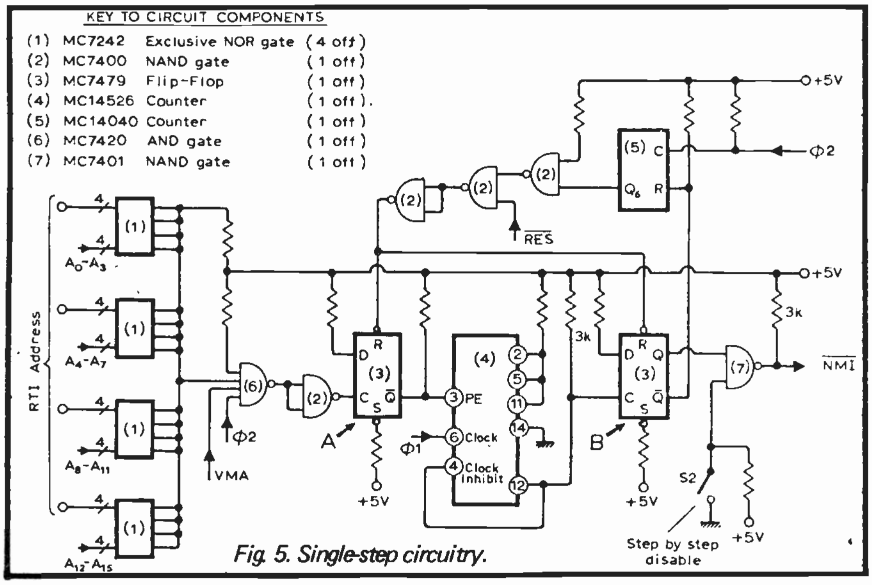


Fig. 5. Single-step circuitry.

The evaluation kit has an MCM6810 128 byte RAM, situated at the base address A000 (hex), which is used by the MIKbug program. However, locations from A04A to A07F in this RAM are not normally used and can be employed for the user's interrupt program (see below).

The STS SP instruction is only necessary when the program under test uses the stack pointer. If not, the MIKbug stack print routine can be stored directly in memory locations A006 and A007.

When the 'print contents of stack' routine at address E11F in MIKbug has been executed, a jump is made to the MIKbug control program. This means that the user can press the 'G' key to execute the next instruction in his program, or he can use any of the other facilities offered by MIKbug.

The interrupt service routine can be written to suit the needs of the user and may include printing out the contents of memory locations that might be changed by the user's program.

Design by Marc Bonzon, senior applications engineer, Microprocessor Systems Engineering, Motorola Geneva

Memory Address	Machine Code	Mnemonic	Comment
A006	A0		Address of user's
A007	4A		interrupt routine
A04A	BF	STS SP	Save user's stack
A04B	A0		pointer.
A04C	08		
A04D	7E	JMP PRINT	Jump to MIKbug
A04E	E1		'print contents of
A04F	1F		stack' routine.

NEWS AND PRODUCTS

Software for the AMI S6800 microprocessor family is now available from the CSS network, which has computing facilities available in London, Paris and Bonn. This software includes the S6800 Assembler, Relocating Loader and Microprocessor Simulator, for use in microprocessor software development.

The AMI Assembler is compatible with the Motorola assembly language and offers a number of additional features including relocatable object code, macros, conditional assembly and local labels.

The Relocatable Loader and Microprocessor simulator offer a wide range of file management and program debugging facilities.

Also from AMI is a new 512 by 8 bit UV-erasable PROM which is speed compatible with the S6800 microprocessor family. Reprogramming is effected by first erasing the existing bit pattern by exposing the chip to an ultraviolet light source through the transparent lid for around ten minutes. A new pattern can then be programmed byconnecting a –55V source on a single program pin, and standard TTL levels on all additional pins. Less than 1 minute is required to program the full 4096 bits. The S6834 also features 3-state outputs and a typical access time of 500nS. This chip is expected to find wide applications in ROM program debugging, and various applications where mask-programmed ROMs cannot be justified.

AMI Microsystems Ltd., 108A Commercial Road, Swindon, Wilts.

microfile

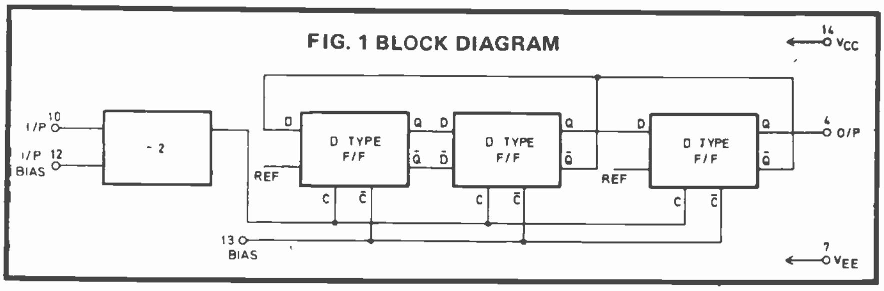
ETI DATA SHEET

SP8505 ECL ÷10 COUNTER — PLESSEY

The SP8505 is a high-performance ECL ÷10 counter. With sinewave input, the counter is specified over a 40MHz to 250MHz range, using a square wave input, the lower frequency limit for the device is extended down to DC.

It is expected to find application in frequency synthesisers and low cost counters and timers.

FIG. 1 BLOCK DIAGRAM



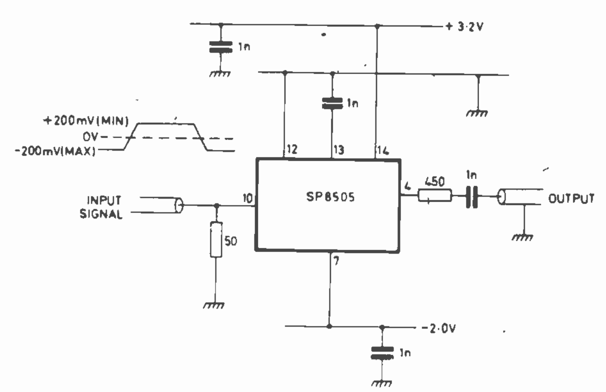


Fig. 2. Direct-coupled input signal.

ELECTRICAL CHARACTERISTICS

Max. input frequency	— 450MHz
Min. sinewave input frequency	— 20MHz
Min. squarewave input slew rate	— 30V/μs
Output voltage swing	— 750mV (typ)
Output levels high	— 750mV (typ)
low	— 1500mV (typ)
Power supply drain	— 70mA (typ)

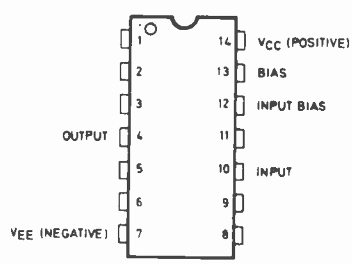


Fig. 3. Pin connections (top view).

ABSOLUTE MAXIMUM RATINGS

Power supply voltage, $|V_{CC} - V_{EE}|$	8V
Input voltage, $V_{IN\,DC}$	Not greater than supply
Input voltage, $V_{IN\,AC}$	2.5V p-p
Output current, I_{OUT}	15mA
Operating junction temperature	+150°C
Storage temperature	–55°C to +150°C

OPERATING NOTES

It is recommended that a positive ground plane is used to prevent damage to the circuit if the output emitter follower is inadvertently short-circuited to ground. The signal source is normally coupled capacitively to the input, but DC coupling can be used with suitable arrangement of the power supplies or biasing of the input.

The dynamic range of the device can be improved by decoupling the internal bias chain to ground; suitable decoupling points are brought out on pins 12 and 13. A low inductance capacitor should be used.

With a sinusoidal input of below 20MHz, the circuit tends to self-oscillate because the slew rate of the input is not high enough. The device will operate down to DC with a square wave input, however, provided that the square wave has a slew rate greater than 100V/μs.

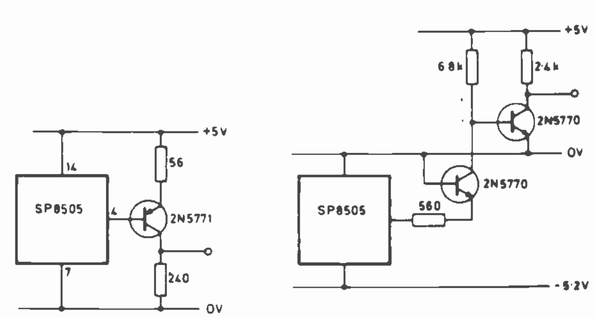


Fig. 4. SP8505 interface to TTL.

The TBA 570 is a monolithic integrated circuit for use in A.M. and A.M./F.M. receivers. It incorporates signal detector, I.F. amplifier, mixer, local oscillator and a.g.c. for A.M. limiter, complete i.f. amplifier and front-end bias stabilization for F.M. and a driver and preamplifier for audio.

It is adapted to operate in conjunction with hybrid I.F. block filters and it can be fitted with a tuning indicator.

The TBA 570 is able to drive output stages up to 3W with A.C. 187/188 transistors or 5W with AD 161/162. It can also be used in complete tuner kits, the 500mV a.f. output satisfying DIN 45 500 hi-fi standard.

The data given here is for a complete a.m./f.m. portable receiver (including short wave) driven from a 6V supply and having a 1W audio output. Voltage swing at pin 11 (a.f. driver) is about 5.5V. A swing of 18V is allowable however for mains and car-radio applications.

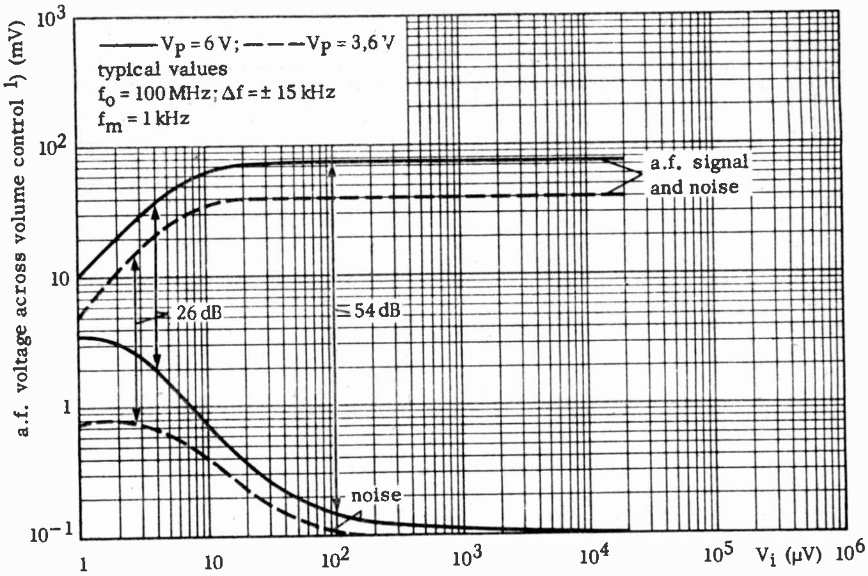


Fig. 1. Typical S/N curves at FM reception.

MAXIMUM RATINGS

Voltages with respect to pins 9 and 16	
Pins No. 1 and 7 voltage	18 V
Pin No. 4 voltage	8 V
Pin No. 8 voltage	8 V
Pin No. 3 voltage	3 V
Pin No. 5 voltage	4 V
Pin No. 14 voltage	1 V
Pin No. 11 voltage	18 V
Currents (Tolerated minimum: 0 mA)	
Pins No. 2, 6, 12, 13, 15 current	80 μA
Pin No. 10 current	5 mA
Pin No. 11 current	50 mA

Total quiescent current except TR31 collector current, f.m. front-end and discrete output stages; Vp = 6 V		10, 5 mA
Vp = 9 V		14, 0 mA
Total power dissipation at pin 8 (excluding TR31) at Vp = 9 V; $V_{8\text{-}16}$ = 7, 8 V		100 mW
Applicable supply voltage range of receiver		6 to 18 V
Base bias voltage for f.m. front-end		1, 2 V
Saturation voltage of TR31 at I_C = 50 mA; I_B = 2, 5 mA	V sat	1, 0 V
Collector breakdown voltage of TR31 (pin 11) at I_C = 25 mA; R_{BE} = 7 kΩ		18 V
D.C. current gain of driver stage TR31 at I_C = 50 mA	hfe	25

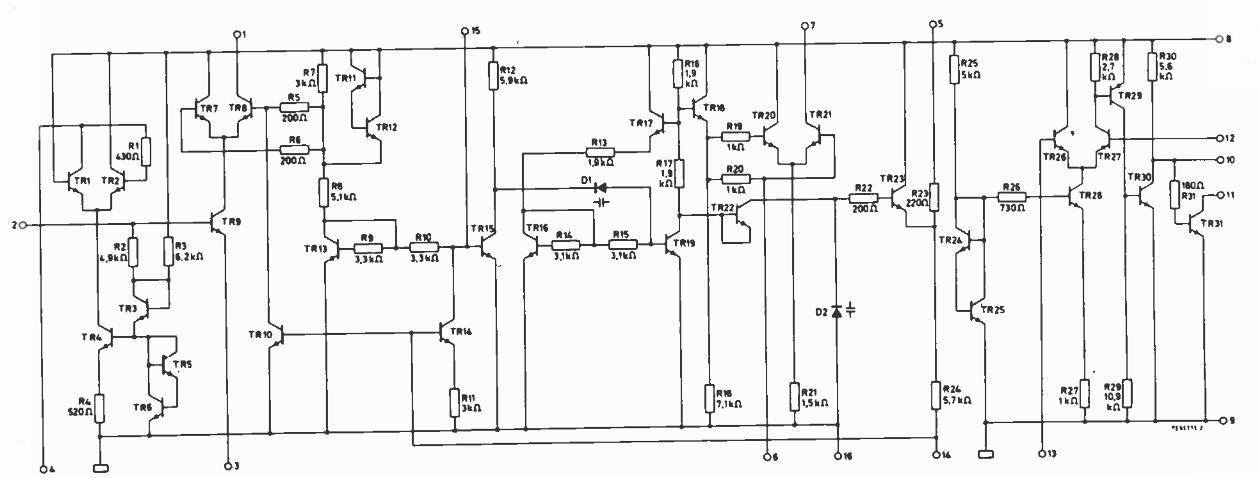
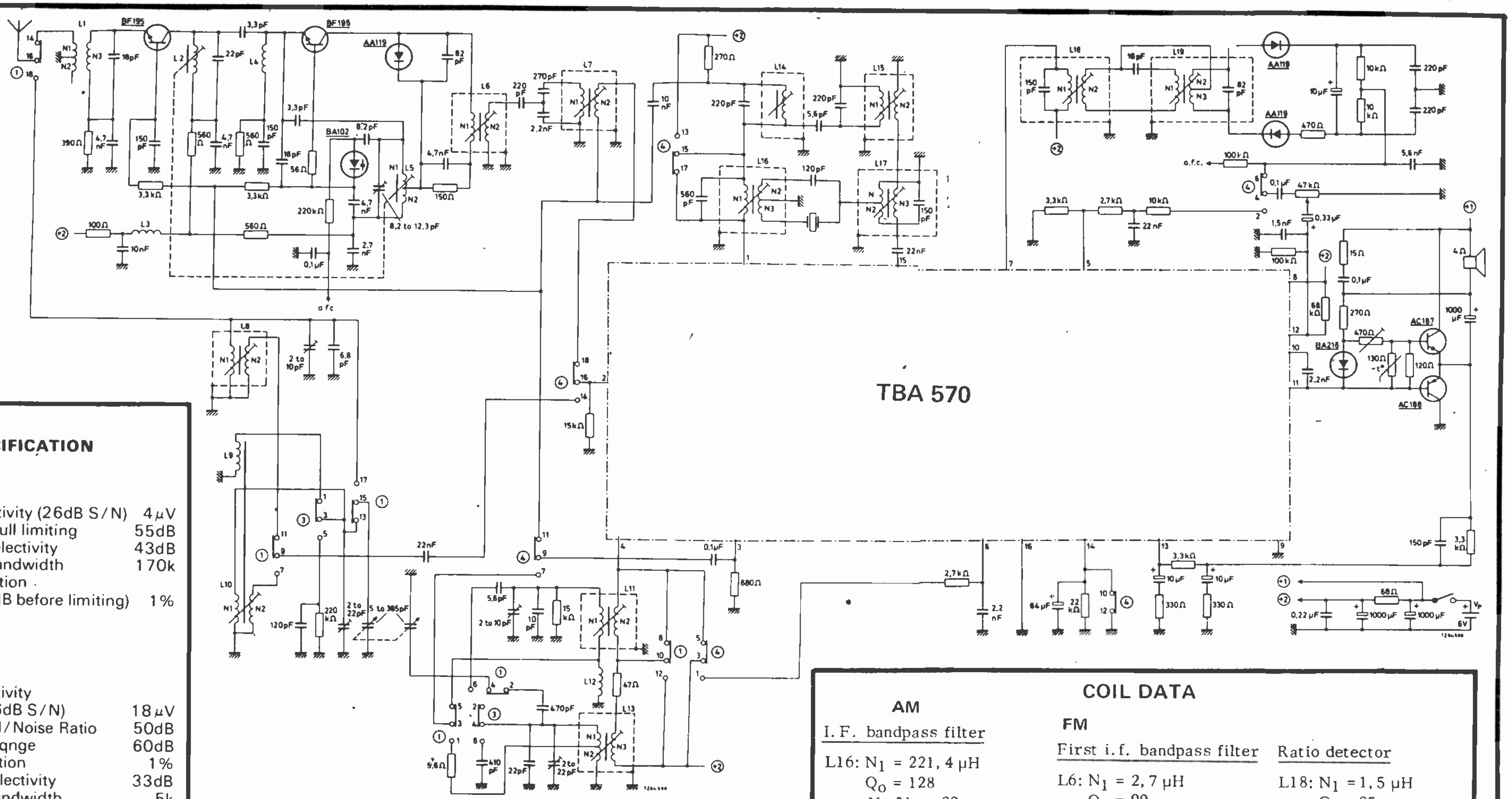


Fig. 2. Circuit diagram TBA 570.



SPECIFICATION

FM

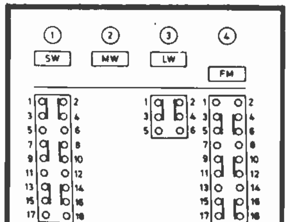
Sensitivity (26dB S/N)	4µV
S/N full limiting	55dB
I.F. selectivity	43dB
I.F. bandwidth	170k
Distortion (3dB before limiting)	1%

AM

Sensitivity (26dB S/N)	18µV
Signal/Noise Ratio	50dB
AGC rqnge	60dB
Distortion	1%
I.F. selectivity	33dB
I.F. bandwidth	5k

Audio

(4Ω speaker)	
Power output (clipping point)	1W
Distortion (clipping point)	0.5%
Noise output	20nW
Frequency response	60—15kHz (±3dB)



Swiches in FM-position

Ceramic resonator:
2422 540 00201

COIL DATA

AM

I. F. bandpass filter

L16: N_1 = 221, 4 µH
Q_o = 128
N_1/N_2 = 20
N_2/N_3 = 1, 2
$|Z_T|$ = 2, 8 kΩ

Second i. f. bandpass filter

L14: N_1 = 1 µH
Q_o = 100
$kQ_{L14-L15}$ = 1, 2

L15: N_1 = 1 µH
Q_o = 100
N_1/N_2 = 3

FM

First i. f. bandpass filter

L6: N_1 = 2, 7 µH
Q_o = 90
kQ_{L6-L7} = 1, 2
N_1/N_2 = 10

L7: N_1 = 1 µH
Q_o = 100
N_1/N_2 = 4, 5

Ratio detector

L18: N_1 = 1, 5 µH
Q_o = 95
$kQ_{L18-L19}$ = 0, 7
N_1/N_2 = 2

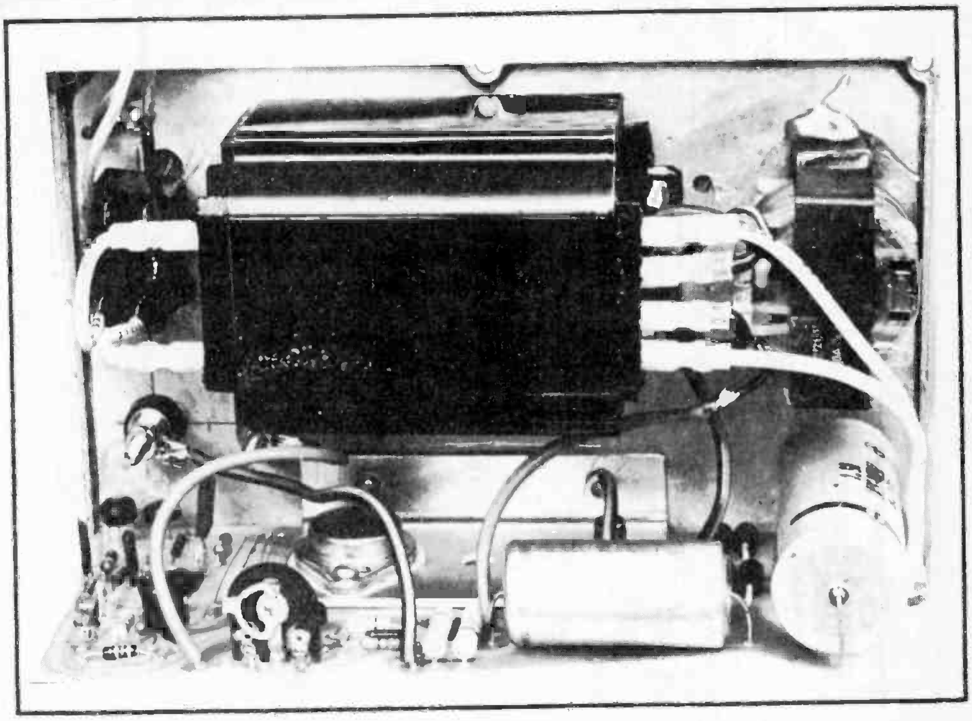
L19: $N_2 + N_3$ = 2, 7 µH
Q_o = 110
$N_2 + N_3/N_1$ = 5, 3
$N_2 = N_3$

L17: N_1 = 827 µH
Q_o = 136
N_2/N_1 = 36
$N_2 + N_1/N_3$ = 22, 4

Fig. 3. Complete AM/FM receiver using TBA 570.

SWITCHING REGULATOR SUPPLY

eti project



Drive those TTL circuits with this 5 volt 10 amp (max) supply.

WHILST the introduction of CMOS has lowered the power requirements of digital equipment using it, many large scale systems, because of cost and availability, are still designed around TTL logic. For such systems a five-volt supply having a capability of up to 10 amps is often required.

The choice of power supply for a system depends very much on the output requirements. In very low power applications a shunt regulator consisting of a series resistor and a zener may be entirely adequate. For medium power systems however a series-pass transistor regulator is normally used.

Whilst the series pass regulator is very good with regards to ripple and regulation the specification of the transformer is critical if the supply efficiency is to be above 50%. In a larger system this can be a very important factor.

With a switching regulator the requirements on the transformer are greatly relaxed and an efficiency of 70% or more can readily be obtained with mains-input variations of from 160 to 260 volts.

A fourth type is the switch-mode supply where the mains voltage is first rectified and filtered. The rectified mains then drives a high-frequency inverter which employs a ferrite transformer. Regulation is obtained by controlling the inverter and by this means very high efficiencies may be obtained. Nearly all the components in such a system work at mains voltage and hence for safety reasons this approach was not used in our project.

CONSTRUCTION

All components, with the exception of the transformer and the choke are best mounted on a printed-circuit board such as the one specified. The choke should be wound as detailed in Table 2 with four layers close wound of 16 swg wire. Due to the dc current in the choke an air gap is necessary to avoid saturation. The easiest method of adjusting this gap for best performance is to run the supply at the maximum current required and adjust the gap by inserting that thickness of insulation between the cores which gives minimum ripple voltage. We found that a 3 mm gap was required at 10 amps for a ripple of 50 mV peak-to-peak.

The prototype was mounted in a ▶

TABLE 1

Comparison of typical series and switching regulators

	SERIES	SWITCHING
Output Voltage	5 V	5 V
Output Current	10 A	10 A
Efficiency		
240 V in	50%	70%
260 V in	40%	70%
Ripple Voltage	< 5 mV p-p	50 mV p-p
Regulation 0-10 A	< 0.05 V	0.3 V
Input Voltage	240 ± 10%	160 to 260 V
Transformer Secondary	8.5 V @ 12 A	20 to 30 V @ 80 VA
Diodes Required	10 A	3 A
Filter Capacitor	33 000 μF	2 200 μF
Short Circuit Current	15 A	15 A

die-cast box which acted as the heatsink as well as a shield to prevent the radiation of RFI generated by the switching action of the supply. If another form of box is used a heatsink must be added to the transistor-diode bracket for cooling.

An external LC filter will reduce the ripple even further if required. For example a series choke of 20 turns of 1.6 mm wire on a 10 mm ferrite rod and a parallel combination of 1000 μF electrolytic and 0.47 polyester capacitors external to the box will provide considerable extra ripple attenuation.

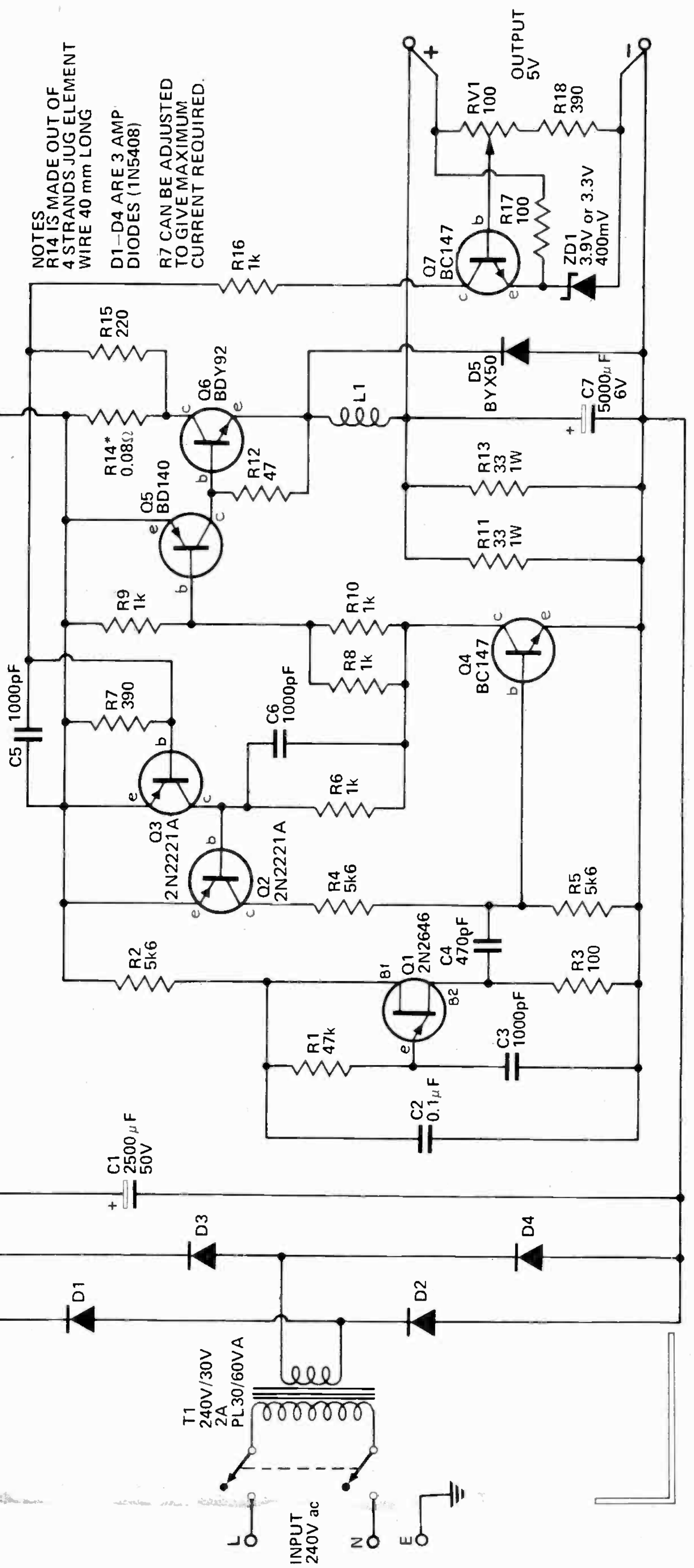


Fig. 1. Circuit diagram of the regulator.

PARTS LIST – ETI 119

R14	Resistor	0.08 Ω *		
R11,13	"	33 Ω	1W	5%
R12	"	47 Ω	½W	5%
R3,17	"	100 Ω	½W	5%
R15	"	220 Ω	½W	5%
R7,18	"	390 Ω	½W	5%
R6,8,9	"	1k	½W	5%
R10,16	"	1 k	½W	5%
R2,4,5	"	5k6	½W	5%
R1	"	47 k	½W	5%

RV1 Trim Potentiometer 100 Ω

C4	Capacitor	470 pF ceramic
C3,5,6	"	0.001 μF polyester
C2	"	0.1 μF polyester
C1	"	2500 μF 50 V electro
C7	"	5000 μF 6V electro

D1-D4 Diode 3 Amp 100V IN5408 or similar
D5 " BYX50-200

ZD1 Zener Diode 3.3 V or 3.9 V 400 mV

Q1	Transistor	2N2646 or similar
Q2,3	"	2N2221A or similar
Q4,7	"	BC147 or similar
Q5	"	BD140 or similar
Q6	"	BDY92 or similar

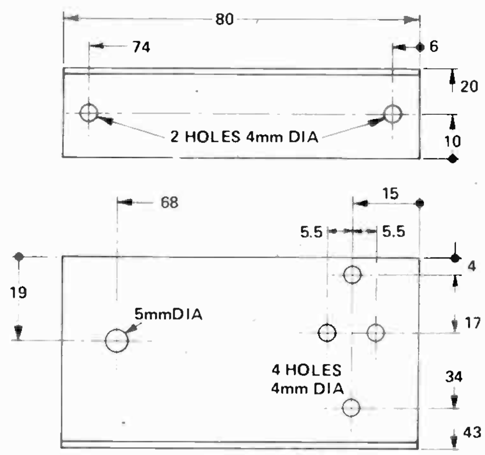
L1 choke see Table 2

T1 Transformer 20V — 30V @ 60VA (7.5 Amp output) 75VA (10 Amp output)

SW1 Toggle switch 2 pole 240 V rated.

Heatsink bracket to Fig.3
Diecast Box 6357p
PC Board ETI 119
Insulation kit for Q6 and D5
* R14 is made out of 4 strands of electric fire element each 40mm long.

A complete kit of transistors and diodes for this project is available from Marshalls of Cricklewood for £7.75 including VAT and P & P.

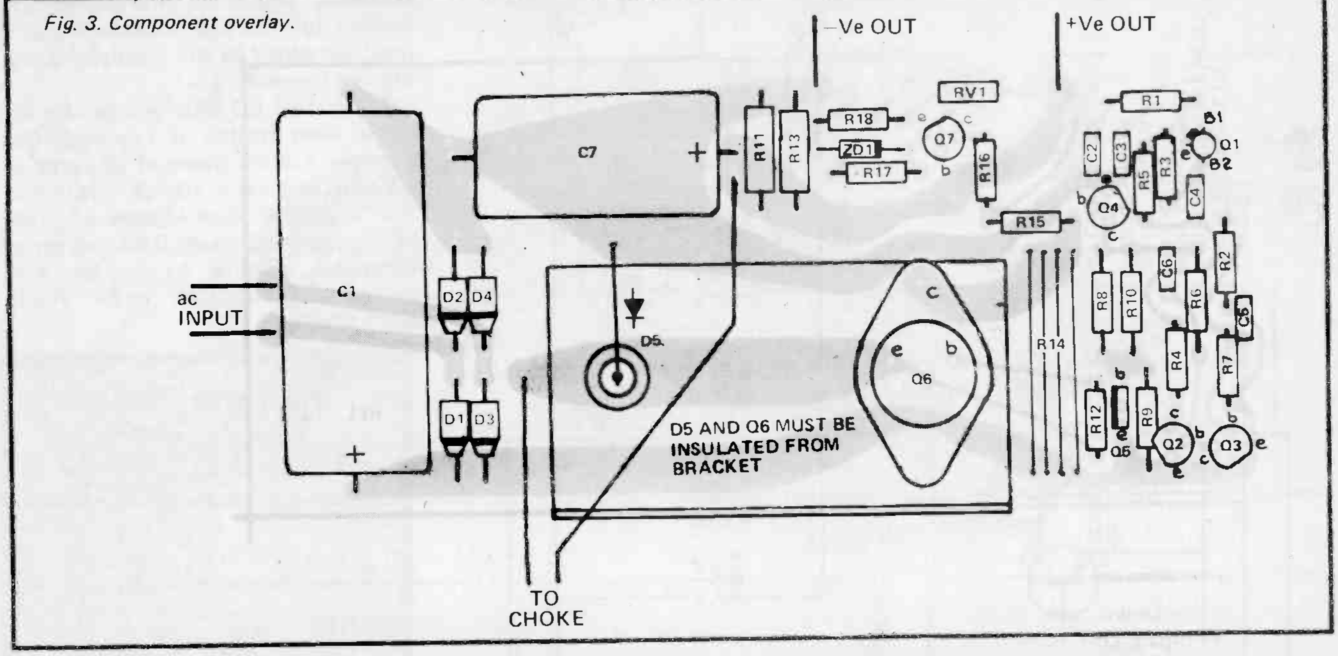


MATERIAL 1.6mm ALUM
ALL DIMENSIONS IN MILLIMETRES

Fig. 2. Transistor/diode mounting bracket.

SWITCHING REGULATOR SUPPLY

Fig. 3. Component overlay.



HOW IT WORKS – ETI 119

IN a conventional series regulator power supply the resistance of a series transistor is controlled in order to maintain the correct output voltage. The series transistor dissipates considerable power and therefore at very high load currents series regulators are quite inefficient. In the switching regulator a series transistor is still used but does not operate in its linear range. Instead it switches ON and OFF at high speed such that the load is alternately connected and disconnected to a supply voltage that is higher than that required across the load. By controlling the ratio of ON to OFF time we effectively control the average voltage as seen by the load. For example if it is on for 25% of the time the average output voltage will be 25% of the input. Thus by controlling the ON/OFF ratio the output voltage may be stabilized whilst dissipation in the series transistor is very greatly reduced.

However since most loads do not like their supply to be in the form of a square wave an LC filter is used before the load to pass only the dc component.

Referring to the main circuit diagram we see that transistors Q5 and Q6 are used as the series switch. L1 and C7 form the output filter. Due to the inductance of the choke a flywheel diode is required, not only to protect the transistor, but to provide proper operation. When the switch is on, the load current flows through the transistor, the choke, and into the capacitor and the load (Fig. A). When the switch is opened the load current must continue to flow through the choke and this is done via the flywheel diode D5 (see Fig. B). The current through the choke will thus rise during the on period and fall during the off period. The current never falls to zero except at very low load currents and the average is the same as the load current.

The operating frequency is set by the UJT Q1 which runs about 20 kHz; the higher the operating frequency the lower the ripple voltage on the output. However as the operating frequency goes up so also do switching losses in both transistor Q6 and diode D5. The 20 kHz was chosen as a compromise. It is high enough not to be audible but low enough to keep these losses to a minimum.

When the UJT fires the pulse generated is coupled into the base of Q4 by C4 turning Q1 on. This, inturn, turns on Q2 and the switch Q5/6. When Q2 turns on Q4 also turns on and both latch on. If the current through Q6 rises above about 12 to 14 amps Q3 will turn on robbing current from the base of Q2 allowing both it and Q4 to turn off. This also turns off the output switch Q5/6. This is the current protection circuitry.

A voltage proportional to the output is provided by RV1 to Q7 for comparison to the voltage of ZD1. If Q7 is turned on sufficiently it will also turn on Q3 thus unlatching Q2/4 and turning off the output switch. Once the supply has stabilised this action will control the on time of the switch in each cycle of the 20 kHz, such that the output voltage is maintained at a voltage as set by RV1 in a smooth and even manner.

We used a 240 V to 30 V 2 A transformer, which is adequate for supply currents of up to 7.5 amps, however any transformer having an output of 20 to 30 volts and a power rating of 60 VA would do. If up to 10 amps output is required then a transformer with a rating of 75 to 80 VA would be required.

It is also possible to supply the regulator from a dc supply of 10 to 40 volts. If the voltage available is less than 20 volts R2 should be replaced by a link to ensure that the UJT operates correctly.

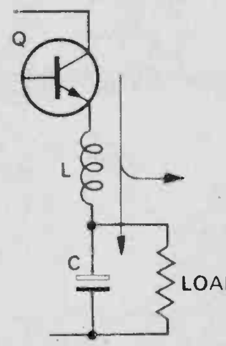


Fig. A. Current paths with switching transistor on.

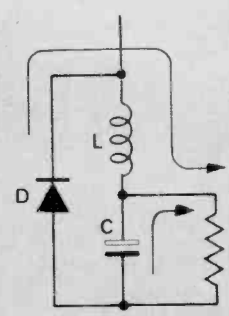


Fig. B. Current paths with switching transistor off.

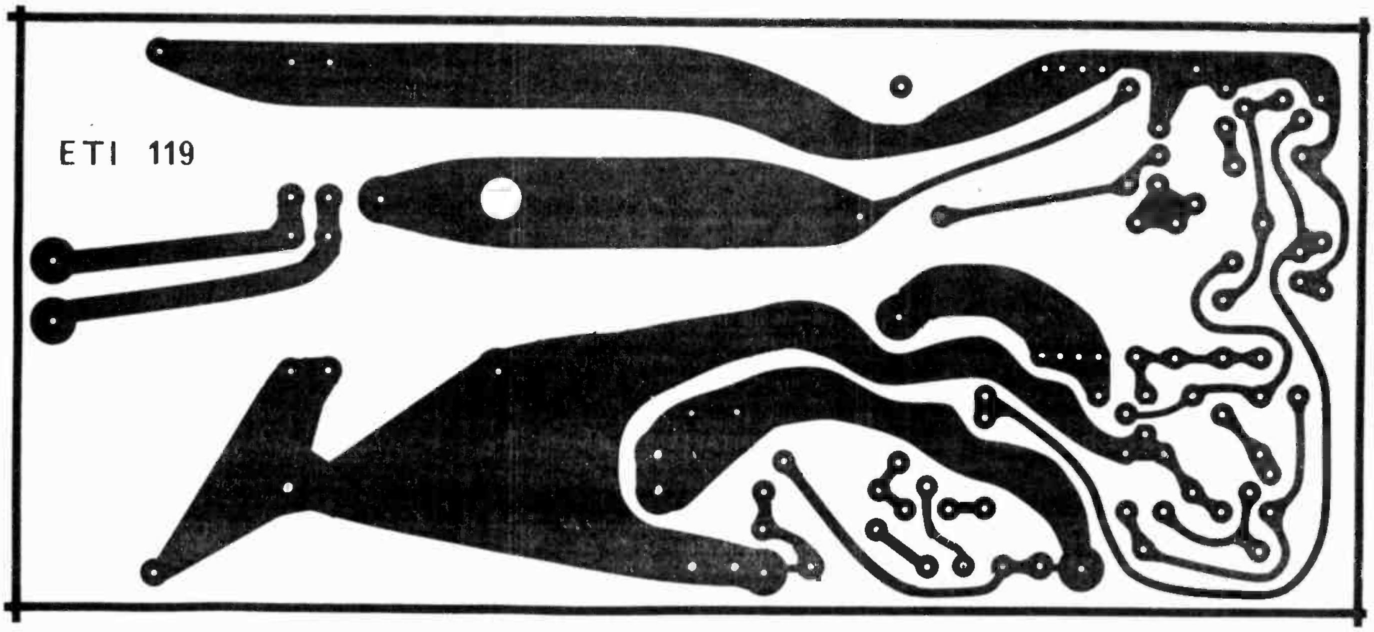


Fig. 4. Printed circuit-board layout. Full size. 178 x 78 mm.

TABLE 2 Choke winding details.

CORE	Philips E core 4322-020-34720 two required
FORMER	Philips 4322-021-31830 or 4312-021-23622 one required

Four layers close wound of 1.6 mm wire core gap 3 mm (see text).

CHOKE COMPONENTS

We have, as yet, been unable to find a source of supply to the amateur of the choke core and former. However the value of this component is not critical and is, in any case, the subject of experimentation in the adjustment of the airgap. We would therefore suggest that, although we haven't tried this, the laminations and former of a 6.3V ac heater transformer may be of suitable dimensions. It may be, in fact, that the secondary of a heavy-duty heater transformer may serve without modification, although we recommend that a 1k resistor be connected across the primary to prevent the effects of a build-up of induced voltage. Please note that this is a matter for experimentation.

[CMOS]

PART THREE

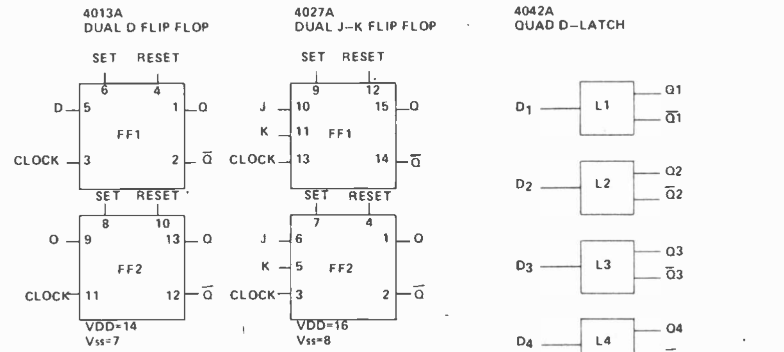
FLIP-FLOPS

Our next subject is flip-flops — and we shall assume that the reader is familiar with the working of these devices and so the discussion will begin with the pinout diagrams in fig. 1. The first two are standard dual edge triggered devices with "D" and "J-K" type data inputs respectively. No doubt it is known that the "D" variety will divide the input frequency by two if "Q" is connected to "D" whereas the "J-K" type toggle, as this behaviour is called, when both "J" and "K" are held high. The set and reset inputs operate asynchronously (ie. independently of the clock) forcing the device into the "Q" = 1 and "Q" = 0 states respectively. These inputs operate when taken high in contrast to most TTL because TTL inputs rest high when disconnected whereas CMOS inputs must never be allowed to "float" anyway. Both the 4013A and the 4027A will operate up to about 8MHz.

The last device in fig. 1 (the 4042A) is a quad data latch of the sort often used for temporary storage of BCD digits in applications like frequency meter displays. If the polarity input is held low then the "Q" output follows the "D" input in each latch when the clock is also low but on the rising edge of the clock pulse the outputs are isolated and retain the data present at that moment. When the polarity input is high all this works the other way round. The clock inputs to all these devices should have rise times of 5µs or less (at V_{DD} = 10V).

Flip-flops on their own have uses in control circuitry and counters. If you wish to produce a counter to count through an odd sequence (a Gray code for example) it is advisable to find out about Karnaugh maps and associated techniques which aid the design process considerably. The standard form for such counters is a sequence of flip-flops whose inputs are derived from the outputs of the others by a few simple logic gates. As far as simple binary is concerned, the required set-up is shown in fig. 2. but we shall have a lot more to say on the subject of counters in general later.

The other main application of flip-flops is in shift registers. A shift register is a sequence of flip-flops so interconnected (see Fig. 3) that on a clock pulse the content of each device is transferred to the next one down the line. The register so formed is referred to as a static device because, unlike some MOS devices available, data is not lost if it is not shifted for some length of time. One modification to the basic device is to provide inputs and outputs to individual flip-flops in the chain and in this form, shift registers have many applications in serial to parallel and parallel to serial data conversion. This though is another subject which must wait until a little later in our discussions.



4013A:

BEFORE CLOCK PULSE		AFTER	
CLK	"D"	Q	$\overline{Q}$
_⎍	0	0	1
_⎍	1	1	0

4027A:

BEFORE CLOCK PULSE			AFTER	
CLK	J	K	Q	$\overline{Q}$
_⎍	0	0	•	•
_⎍	0	1	0	1
_⎍	1	0	1	0
_⎍	1	1	†	†

• NO CHANGE
† CHANGES STATE

4042A:

CLOCK = 5
POLARITY = 6
VDD = 16 Vss = 8

CLOCK	POLARITY	Q
0	0	D
_⎍	0	LATCH
1	1	D
_⎍	1	LATCH

CLOCK IS COMMON TO ALL LATCHES

Fig. 1. Three common flip-flop devices.

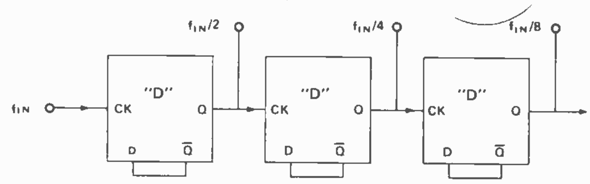


Fig. 2. Basic binary counting chain used for frequency division.

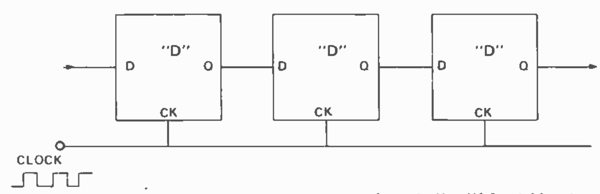


Fig. 3. Principle of shift register. The content of each "cell' is shifted one place to the right on the rising edge of the clock pulse.

CMOS

COUNTERS

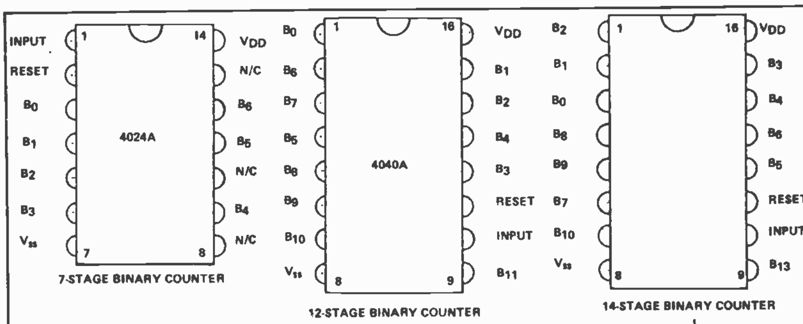


Fig. 4. Three CMOS binary counters.

Our main subject this month is counters. It might well be true to say that the range available (compared to TTL) reflects the advances which have been made in other branches of electronics, particularly display technology. BCD counters are conspicuous by their absence as they have generally been replaced by seven segment decoded counters. One disadvantage is a need in many cases for external drivers for LED displays but this will be eliminated when Liquid Crystal technology is more advanced and, hopefully, cheaper.

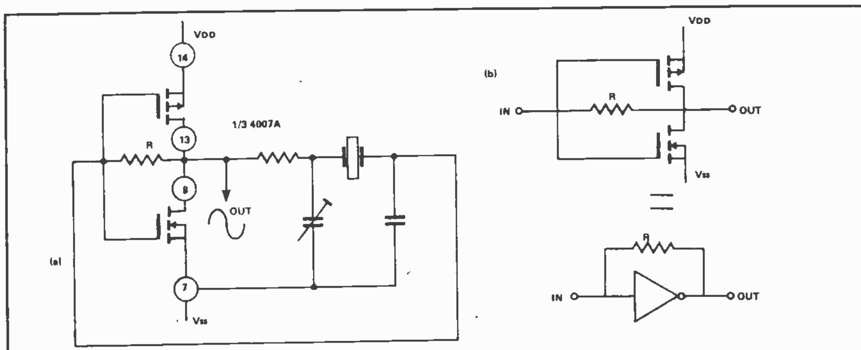


Fig. 5. (a) Basic crystal oscillator using CMOS for the active components.
(b) Simple analogue amplifier using a CMOS inverter.

BINARY COUNTERS

As usual we will start with the less glamorous devices in the range which, in the present instance, are the straight-forward binary counters. First we should mention the general operating conditions required for all CMOS counters. The clock input rise and fall times should be less than 5μS and the operating frequency limit is about 2.5MHz at V_{DD} = 5V rising to 5MHz at 10V. As far as the problem of drive current is concerned, it is advisable to consult the full data sheets for the device in question but it is reasonable to assume that no trouble is likely to be experienced if the requirement is less than 0.25mA with a 5V supply or 0.5mA with 10V.

Fig. 4 gives the pinout diagrams for CMOS seven, twelve and fourteen stage binary counters. The outputs are labelled B, with B_0 the most significant bit (i.e. giving greatest frequency division). It will be noted that three of the less significant bits are not available as outputs on the 4020A and this limits its usefullness in "divide by N" applications as we shall see later. The greatest division of the input frequency is 128 for the 4020A, 4096 for the 4040A and 16384 for the 4020A. In all cases the counters step on the negative transition of the clock pulse and the reset input sends all stages to logical zero independently of the clock when it is taken high. There is also a twenty-one stage counter (the 4045A) which produces two out-of-phase pulses at separate outputs for every 2097152 input pulses. It

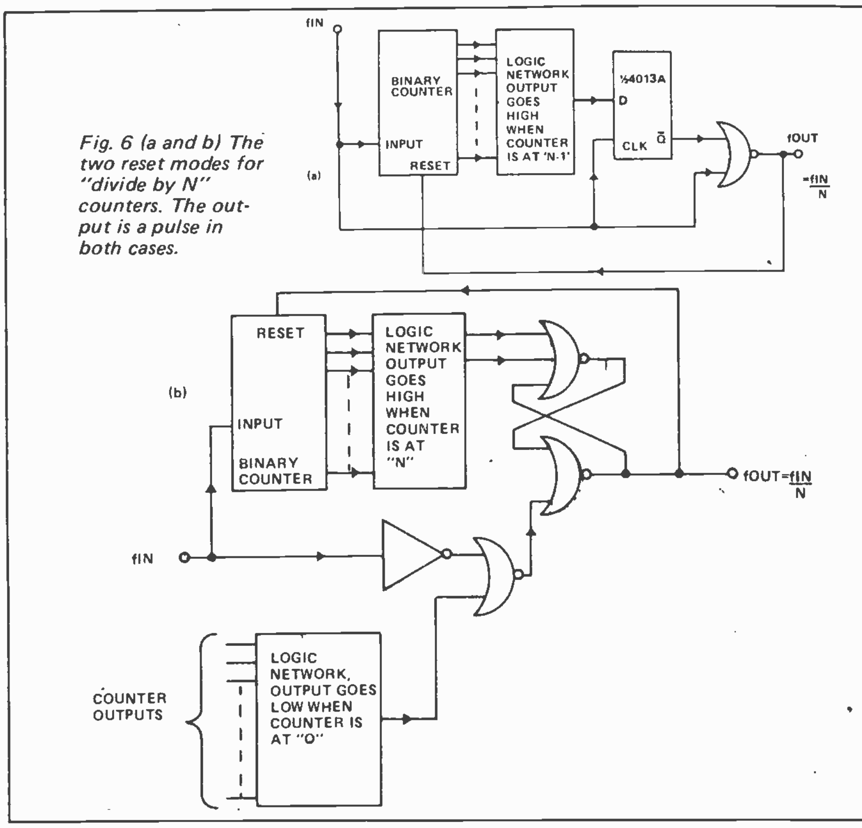


Fig. 6 (a and b) The two reset modes for "divide by N" counters. The output is a pulse in both cases.

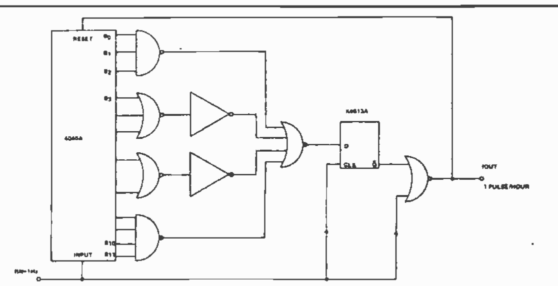


Fig. 7. A divide by 3600 counter using the first reset mode.

is intended for producing one second pulses from 2.097152 MHz crystals for driving clock circuitry and similar applications. Anyone interested in using this device should obtain data from a manufacturer.

While we are on the subject of huge frequency division chains perhaps we should consider crystal oscillators very briefly. Fig. 5(a) shows one common set-up and it is worth noting that the configuration in Fig. 5(b) is the standard way of, producing a simple analogue amplifier from a CMOS inverter.

DIVIDE BY N COUNTERS

There are times when it is required to divide a signal by other than some power of two and by using a 4024A or 4040A we may divide by any number from 2 to 128 and 4096 respectively, although extra components are required. Fig. 6 shows two ways of achieving this end. The circuit in (a) has the binary counter feeding a system of logic gates, the output of which goes high when the counter reaches N-1 (where N is the number the input frequency is to be divided by). This happens on the falling edge of the clock pulse because the counters are negative-edge triggered. On the next rising edge the flip-flop Q output goes low and when the clock goes low again the output goes high, generating a pulse of length equal to one half of the clock period which resets the counter. It is interesting to draw a timing diagram for this circuit and prove it works. It should be noted that although the actual output is a positive going pulse, a similar pulse of twice its length (i.e. one clock period) is available at the Q output of the 4013. A divide by 3600 counter which will provide one pulse an hour from a 1 Hz input is shown in Fig. 7 as an example of the technique.

The second mode has the advantage that the "N" count and not the "N—1" count is detected, but two logic networks are required; one to decide when the counter has reached "N" and another to identify the "all zeroes" state and reset the output. It is also a disadvantage in some applications that the counter spends a brief period in the "N" state. It is again interesting to draw a timing diagram and it is worth noting the cross-coupled NOR gates used as an R-S flip-flop. As an example a divide by twenty four counter is shown in Fig. 8 to produce one pulse per day from the one per hour output of Fig 7. The circuit dissipation of both the counters would be very low (less than 1mW) at this low operating frequency and the only note of caution to be sounded is that the counter and flip-flop should not both be triggered from the same edge of the clock pulse (i.e. one should be positive and the other negative edge-triggered).

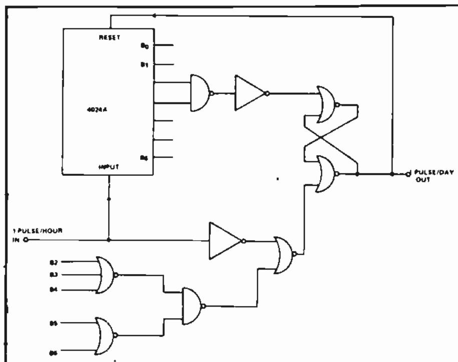


Fig. 8. A divide by 24 counter using reset mode two. Note the simplicity that may be achieved in the logic networks — one NAND gate serves to identify "24".

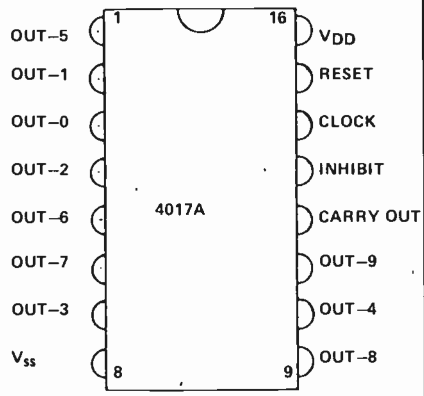


Fig. 9. Pin-out diagram of the 4017A decimally decoded decade counter.

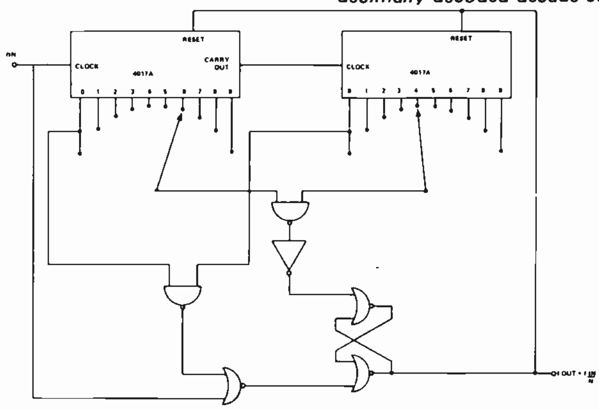


Fig. 10. A switch programmable divide by N counter for N = 2 to 99. Extension to higher N is obvious.

A DECIMAL-DECODED DECADE COUNTER

All the old hands at TTL will doubtless be familiar with the 7490 decade counter and 74141 decimal decoder driver. The 4017A combines the count and decode functions in a single package but has the disadvantage of low output drive capability. Buffering the outputs with 4049A inverters will raise the available output to about five or ten milliamps at supply voltages of five and ten volts respectively. The pin diagram is given in Fig. 9 and the counter advances one on the positive clock transition provided that the inhibit is held low. The reset operates asynchronously when taken high as usual. "Carry-out" may be used to clock the next stage in a multi-stage counter. This device has fairly obvious applications in controlling switches in multiplexing equipment as one and only one output is high at any one time. It is fairly clear also that we may extend the techniques of divide by N counters to cover these devices with the added bonus of them being switch programmable. Fig 10 shows this idea realised using reset mode two because of the ease of switching for N rather than N-1. This circuit has lost an inverter compared with Fig. 6b, this being the change necessary to adapt the circuit for counters and flip-flops which operate on the same clock transition. The sequence of counters could clearly be extended to any desired length and it is an interesting thought that seven of these counters (4017As) and the attendant gates could, when fed with a 1 Hz input, generate pulses at any interval from two seconds to over three months! On a more practical note, used in a phase locked loop circuit a most versatile digital frequency synthesiser would result. Remember however that the output is a pulse and it would need squaring (one more flip-flop) before most phase comparators would accept it.

SEVEN SEGMENT DECODED COUNTERS

We mentioned earlier that CMOS IC design reflected the changes in display technology. Two particular examples of this phenomenon are the 4026A and 4033A decade

CMOS

counters with seven-segment outputs. The pin-out diagrams for these devices are shown in Fig 11 and, as one might guess, the counters are identical with the exception that the 4026A has a display enable function for use in multiplexing digits and an ungated C-segment output, whereas the 4033A has ripple blanking and a "lamp-test" facility. We shall consider the use of these special facilities when we have discussed the features common to both. The devices are positive edge triggered and advance only when the clock enable is low. The reset operates when taken high as usual and the segment outputs go high when they are active. Just as in the 4017A the signal at the "carry out" terminal may be used to clock the next stage in multi-decode applications.

In the same way as we have considered for other counters, the seven segment outputs may be identified by logic gates and the counters made to divide by any number. Fig. 12 gives the information necessary and it should be noted that the "N-1 and flip-flop" method is used because the other method does not count through zero. If anyone wants to strike a blow for freedom against LSI we have covered most of the devices necessary for designing a CMOS digital clock. Now we will have to consider the interfacing of displays with our seven segment counters. LEDs like the MAN-3 which have a low current will interface directly with the outputs of the 4026A or 4033A and give a tolerable brightness with the available drive current (about 5mA), provided that V_{DD} is more than 9V. If we drop the voltage down to between 4 and 9V then NPN transistors should be inserted as shown in Fig. 13a and if the supply drops even lower, the addition of inverting buffers is recommended. The seven transistors needed are generally the components of a single IC. The attention of the reader is drawn to the discussion on current limiting resistors to follow.

MULTIPLEXING

Life is never as simple as we might want and there are *two* reasons for complicating the circuitry by using digit multiplexing

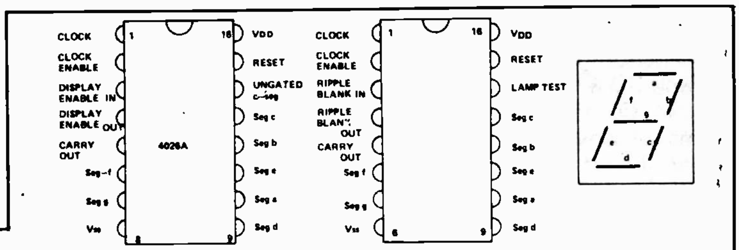


Fig. 11. Pin-out diagram for the 4026A and 4033A seven segment decoded decade counters. The labelling of the segments is also shown.

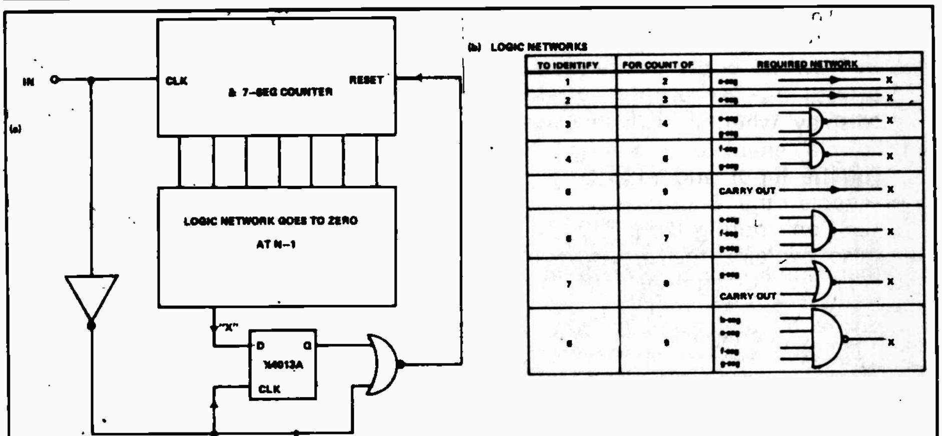


Fig. 12(a) How to produce direct seven segment divide by N counters, (b) logic networks to identify each digit. The extension to a multi-decade version is simple.

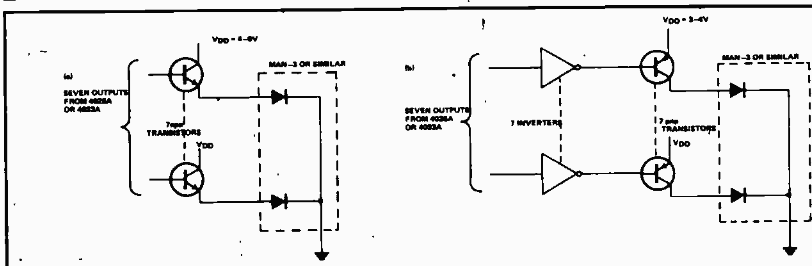


Fig. 13. Driving MAN-3 type displays (a) at intermediate supply voltages and, (b) at low voltage.

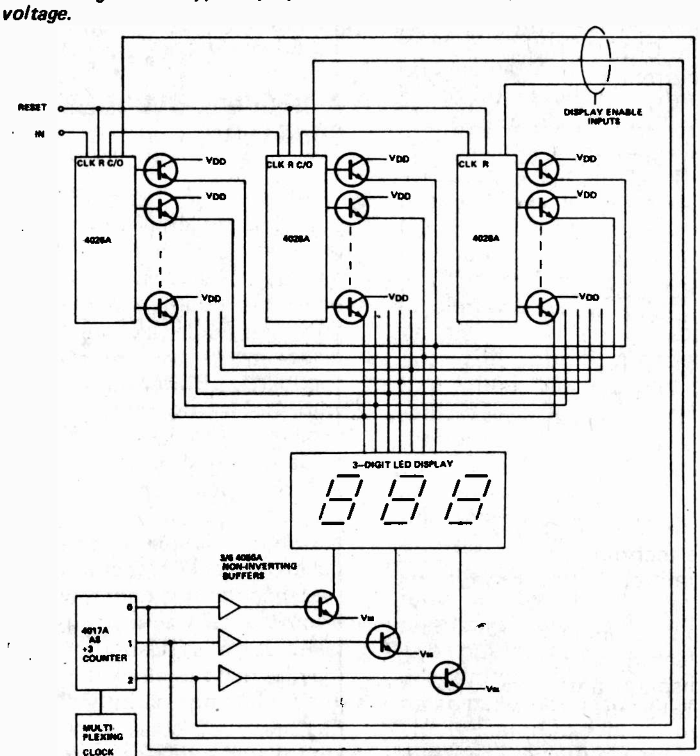


Fig. 14. A three decade counter for a 3-digit multiplexed display. Extra buffering of the digit lines may be necessary for some displays.

(i.e. each digit is displayed for a fixed period, usually between about 10 and 30% of the time). These are that to do so is more efficient in terms of power consumption and secondly that most multi-digit displays reduce the number of lead-outs (by giving just one set of seven segment drive lines for the complete display and one digit drive line for each digit).

This is the reason why the 4026A has a display enable input which, although the counter continues to function, cuts off the display when it is held low. The display enable output gives a replica of the input and may be used to enable other counters which are to be "on" during the same period. It also explains the presence of the "ungated C-segment" output which is used for producing some divide by "N" configurations which operate when the display is disabled. The basic arrangement of a three decade counter is shown in Fig. 14 and attention is drawn to the note that additional buffering may be necessary on the digit lines. It is also worth noting the use of a 4017 divide by three counter (using the flip-flop reset mode) to control the display.

Other sorts of displays which are often used are higher current LEDs such as the MAN-1 which is, in contrast to the MAN-3, a common anode device. This means it must be driven by inverting buffers as shown in Fig. 15a. We have been relying here on the output current limit of the CMOS chip to limit the forward current in the LEDs. Particularly when transistor drivers are employed it may be necessary to add current limiting resistors in the segment lines. The calculation of the value is simple given the required segment current and voltage drops (see Fig. 15(b)). In multiplexed displays the limiting resistors should, of course, be put in the common segment lines and it is worth noting that a considerable saving in resistors in non-mutliplexed displays may be achieved by putting a single resistor in the common line to each digit. The pay off is that the display brightness varies with the digit. Fig. 15(c) shows the technique for interfacing with "Numitron" and similar displays.

The ripple blanking facility is for blanking leading and trailing zeroes in the display and it works as follows. Take the ripple blanking input (RBI) of the most significant 4033A on the integer side of the display low. Then take the ripple blanking output (RBO) of the IC and connect it to the RBI of the next counter and so on until the position of the assumed decimal point is reached. Follow exactly the same procedure from the least significant counter in the fractional part of the display backwards to the decimal point (see Fig. 16(a)). Of course, if the assumed decimal point is at one end of the display then half the procedure would be unnecessary. If non-significant zeroes in the places either side of the decimal point are to be displayed (so that 7 and .6 appear as 7.0 and 0.6) then the RBI's of the two counters concerned should be taken to V_{DD} (as in Fig. 13(b)). Finally on these two ICs, the lamp-test facility on the 4033A just forces all segment outputs high when it is taken high.

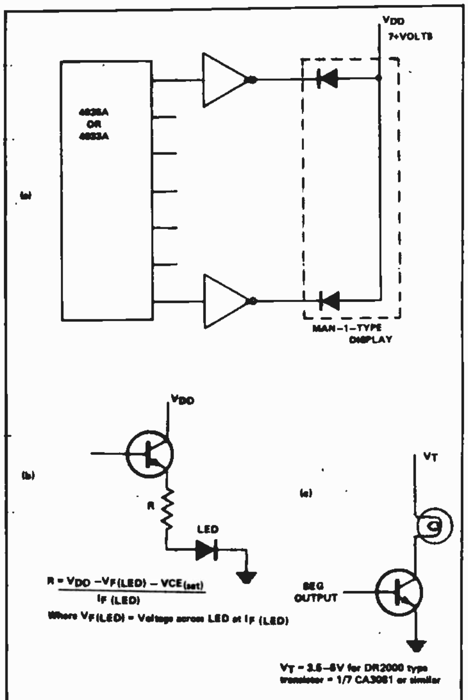


Fig. 15. Driving others displays:- (a) MAN-1 type (b) example of calculation of limiting resistor (c) Numitron type incandescent display.

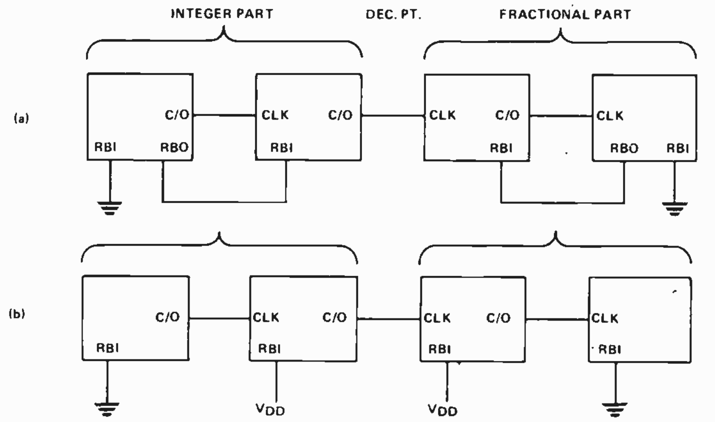


Fig. 16. Four digit counters using the 4033A with non-significant zero supression (a) in all positions (b) in first and last position only.

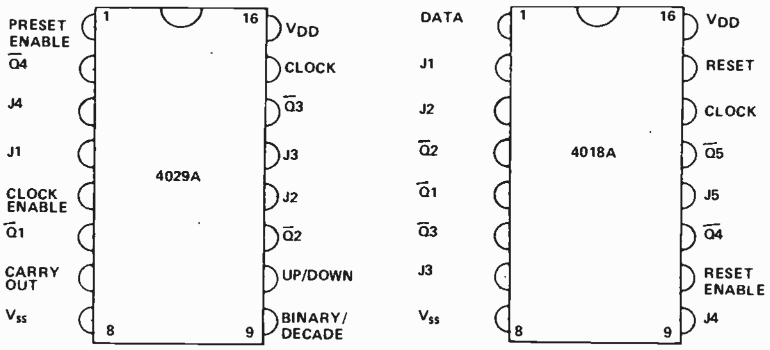
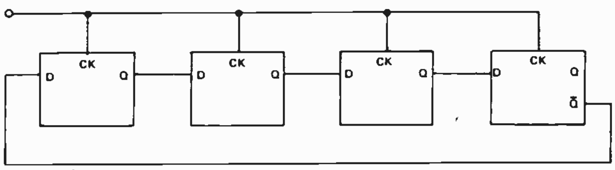


Fig. 17. Pinouts of the 4029A and 4018A.



Q_1	Q_2	Q_3	Q_4
0	0	0	0
1	0	0	0
1	1	0	0
1	1	1	0
1	1	1	1
0	1	1	1
0	0	1	1
0	0	0	1

Fig. 18. Circuit diagram and counting sequence for a four stage Johnson or "twisted ring" counter.

CMOS

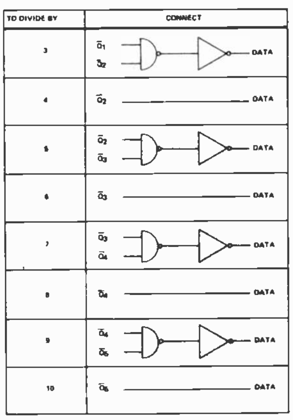
THE 4029A AND 4081A

We shall conclude our discussion of counters by looking briefly at two more devices. The 4029A is a general purpose counter which, at the price that a 7490 was a year or two ago, has most of the features of the more exotic TTL devices. Briefly, the device is positive edge triggered and advances when the clock and preset enables are both low. Furthermore it counts in binary when the Binary/decade input is high and BCD otherwise, a high signal at the up/down input persuades it to count up and a low input forces it to count down. As though this were not enough, when the preset enable input is high, the Q counter outputs are forced to follow the J ("Jam") inputs. The suffix "4" in both cases indicates the most significant digit. The pinout diagram is given in Fig. 17 along with that for the 4018A presettable divide by N counter.

There are two basic ways of producing counters. Firstly there is the chain of flip-flops each of which halves frequency produced by the one before it. This was the principle behind the binary counters, which we considered at the beginning of this month's discussion, and also of the 4029A. The second method is known as a Johnson counter and it is basically a shift register consisting of a chain of flip-flops (see p59) with the Q output of the last counter connected back to the data input. A little patience and a pencil and paper will soon show that such a counter will divide the input frequency by 2N where N is the number of stages. The counting sequence for a four stage counter is shown in Fig. 18 and the reader will notice that if the counter starts with contents not in the counting sequence (e.g. 1010) then the contents are always nonstandard thereafter. Thus some special gating is required. The simplified internal diagram of the 4018A in Fig. 19 is not complete. Also the Jam inputs and preset enable (which work in the same way as in the 4029A) together with the reset (which zeros all stages (Q1 — Q5 = 1) have been omitted for clarity. Fig. 20 shows the way to connect the 4018A to divide by all numbers from three to ten. Just as an example of how versatile this device is one application will be considered in a totally different field from counting. By disregarding the clock the Jam inputs and inverted data outputs ($\bar{Q}$) can be used as a five data latch for temporary storage, the outputs being updated to the inputs while the present enable is high. Next month we will conclude the series by considering several different subjects.

Continued next month

Fig. 20. Connection of the 4018A as a divide by "N" counter Input to clock, output waveform from DATA input is symmetric when N is even, almost so when N is odd.



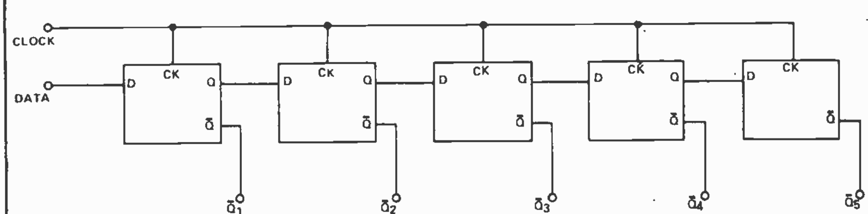


Fig. 19. Simplified internal diagram of the 4018A.

ELECTRONICS PART 26 —it's easy!

More complex logic

The exclusive OR gate is more complex than the other gates discussed last month because it contains more than one basic gate — it is a small logic system in itself. Fig. 1 shows how two inverters, two AND gates and one OR gate can be interconnected to achieve the exclusive OR requirement.

A second example is given by considering a function

$$Z=\overline{(A.B)+(C.D.E)+(F.G.H.)+(I.J.)}$$

The problem might be to realise a logic network that performs this logical task — imagine trying to describe it in words! Brackets are used to ensure that sub-connections are made in the correct way; as in linear algebra operations in brackets are dealt with first as individual units.

The first step in realising the network is to form the dot AND functions of Z. We need two two-input AND gates and two three-input AND gates. (It matters not if a gate has more inputs than needed — the unused terminal is ignored). The outputs of these four AND gates are then fed into the inputs of a four input OR gate so that the function under the negation bar is achieved. At this point we could select an OR gate followed by an INVERTER or make use of a NOR gate direct.

When drawn as a system of interconnected schematic blocks it appears as in Fig. 2a. Also given in Fig. 2b is how a 14 pin dual-in line IC would appear that performs this function.

As a third example the exercise is to devise a logic network that will add (in binary system) two binary inputs producing the binary sum output plus a carry output. This function, called the half-adder, forms the basis of digital computation with binary numbers.

Back in Part 5 the concept of the binary number system was introduced showing that the counting base is 2 instead of the more commonly encountered 10 of the decimal system. At any digit position in the binary number, the value can be only 0 or 1 so addition of two binary numbers gives a value at each digit position that alternates as 0 1 0 1, etc., as counting progresses. When 0 and 0 are added we obtain 0; when 0 and 1 are added we get 1. When 1 and 1 are added we cannot have 2 in a binary system so it returns to 0 with a carry of 1 going to the next higher digit position. Fig. 14 illustrates this idea — try adding the two numbers! A half-adder does this operation for one digit position. The truth table for the half-adder is, therefore, as given in Fig. 4a.

The sum column shows we need an exclusive -OR to provide the sum value — hence its importance in computer design. A carry is to occur when both A and B appear so an AND gate is needed. From these we can develop one form of the half-adder system —

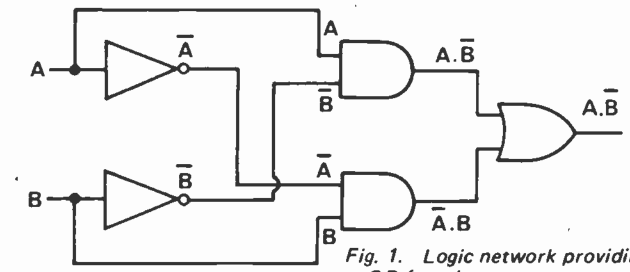
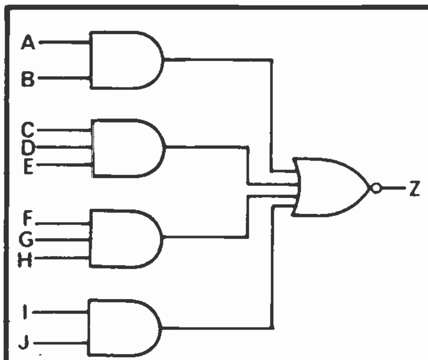


Fig. 1. Logic network providing exclusive — OR function.



$Z = \overline{(A.B) + (C.D.E) + (F.G.H) + (I.J)}$

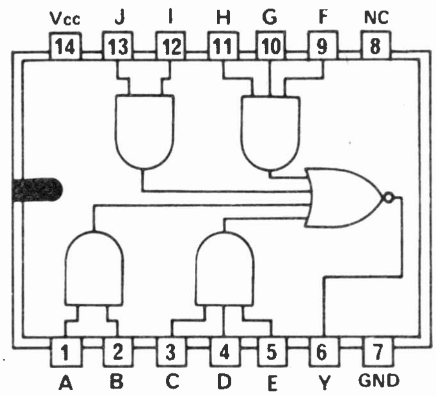


Fig. 2. (a) Logic network for function $Z = \overline{(A.B) + (C.D.E) + (F.G.H) + (I.J)}$ (b) same logic packaged in IC flatpack.

Fig. 2(b).

A		1	0	1	1	0	0	1
B		0	1	0	1	1	1	0
Z	1	0	0	0	0	1	1	1

MOST SIGNIFICANT DIGIT M.S.D

LEAST SIGNIFICANT DIGIT

CARRY OF 1 TO NEXT HIGHEST DIGIT

Fig. 3. Addition of two binary numbers proceeds with a carry as for decimal arithmetic but with only two states 0, 1 in each digit.

represents the logic configuration of Fig. 16b. This minimal form requires two less gates (provided a three input AND gate is available).

ELECTRONICS -it's easy!

given in Fig. 4b. Note how the complexity is growing. Such a circuit requires around 30 or more passive and active components and hundreds of such circuits are needed in a digital computing circuit. A version of the same circuit only constructed using NAND gates is given in Fig. 4c. Note that NAND gates 1 and 2 have both inputs tied together, they therefore perform the NOT function. Try your Boolean on this as follows – .

SOME LAWS OF BOOLEAN ALGEBRA

When devising systems of logic the situation soon arises which calls for knowledge of the rules for manipulating Boolean expressions. Possible reasons for this may be that a limited range of logic functions are available, so conversion of an expression is needed, or that a large expression may not be in its simplest state. Reduction to its non-redundant state means use of less elements.

A number of axioms (truths based on experience) exist for relationships between Boolean statements. There is little point in dwelling on their individual proofs and historical development – for that see the reading list. The following relationships are summarized to assist when needed:

de Morgan's rule 1 : $\overline{A} + \overline{B} = \overline{A.B}$

de Morgan's rule 2 : $\overline{A}.\overline{B} = \overline{A + B}$

Commutative laws : $A + B = B + A$
$A.B = B.A$

Associative laws : $A.(B.C) = (A.B).C = A.B.C$
$A + (B + C) = (A + B) + C = A + B + C$

Distributive laws : $A.(B + C) = A.B + A.C$
$A.C + A.D + B.C + B.D – (A + B) . (D + D)$

This is as for linear algebra but with extra cases:–

$A + B.C = (A + B) . (A + C)$
and $(A + B) . (A + C) . (A + D) = A + B.C.D$

Absorption laws : $A + (A.B) = A$
$A. (A + B) = A$

Double negation : not $\overline{A} = A$

Universe class laws : $A + 1 = 1$
$A.1 = A$

Null class laws : $A + 0 = A$
$A.0 = 0$

Complementation laws : $A + \overline{A} = 1$
$A.\overline{A} = 0$

Tautology laws : $A + A = A$
$A. A = A$

Expansion laws : $(A + B) . (A + B) = A + B$
$(A.B) + (A.B) = A.B$

MINIMIZATION

To save components the network first realised by inspection from a valid truth table may well not be in its simplest or so-called minimal form. In simpler cases, application of the above Boolean algebra laws by a well-practiced person can often come up with simplifications.

Beware, however, of applying linear algebra rules of factoring. It is quite wrong to cancel or subtract equal terms in both sides of a Boolean equation.

Unfortunately, no direct way is known with which to arrive at a minimal network by a routinely declared simple procedure. The nearest we can get to this is by means of a Karnaugh mapping procedure which we do not discuss in this course as few readers will be required to be expert in this facet of digital electronics.

An example will show how a simple system can be minimized by inspection. Consider the expression Z = (A + B) . (A + C) . (A + D). This is readily seen to be the logic network given in Fig. 16a. From the distributive laws given above this can be rewritten as Z = A + B.C.D which

THE VENN DIAGRAM

In the early days of logical algebra development, John Venn developed a system of overlapping circle diagrams as an alternative way with which to express the concepts contained in the truth table. Venn's diagrams consist of overlapping circles contained in a rectangular box. Each circle represents one of the required number of independent input variables – A, B, C, etc. If the output variable Z is a 1 (assuming that is the convention chosen) the appropriate area of the circles is shaded. The rules are that inside a complete circle its variable is not negated, outside it is negated. Overlapping area of common circles represents their AND combination., The examples given in Fig. 17 illustrate the use of Venn diagrams in various simple logic situations. The concept extends to as many circles, that is, inputs as are needed.

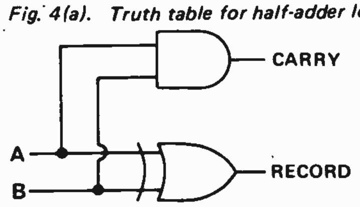
LIMITS OF BOOLEAN

There are a number of limits to the use of Boolean algebra. In the logic combination we have considered so far, there has been no mention of time

INPUTS		OUTPUTS	
A	B	CARRY	RECORD
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0
		AND CONDITION	EXCLUSIVE-OR-CONDITION

(a) TRUTH TABLE OF HALF-ADDER

Fig. 4(a). Truth table for half-adder logic.



(b) IMPLEMENTATION OF HALF-ADDER

Fig. 4(b). One form of half-adder logic network.

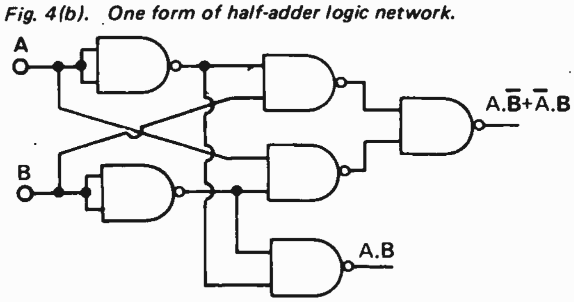


Fig. 4(c). The half adder using NAND gates only.

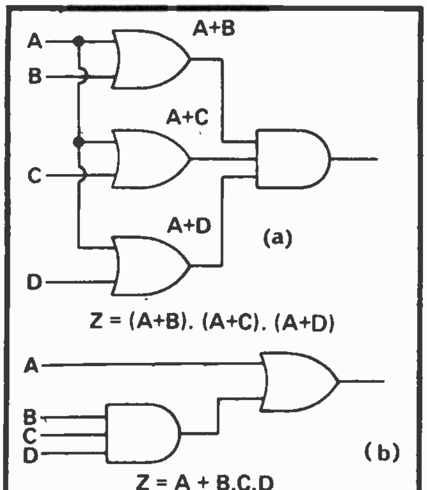


Fig. 5. Logic network realising Z = (A + B). (A + C). (A + D)
(b) Simplified network.

or of any feedback around the circuit. In practical systems, time delays always occur and, further, other elements such as counters, multivibrators and memory devices are generally present whose state depends, not only on the logical inputs at any given time but, on what has happened previously! Boolean algebra is unable to deal with such situations.

In addition, if a function is minimized by means of Boolean it does not follow that the derived circuit is the cheapest possible. The minimized circuit may call for 3-input

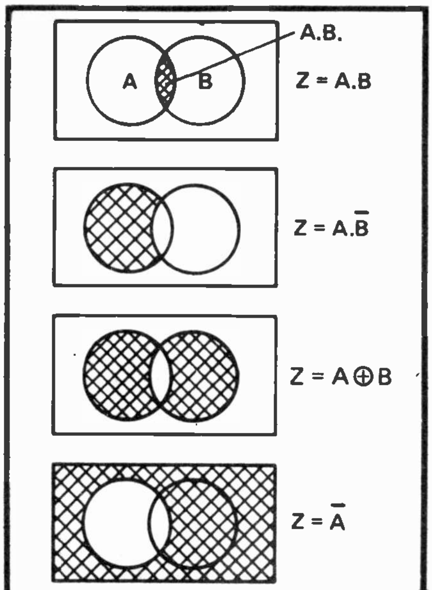


Fig. 6. Venn diagrams represent logic states in topological form. Some people find these easier to use than truth-tables.

AND gates, say, but it could well be cheaper to use the more readily available NAND gates — even if more gates are required to achieve the same function.

Thus it can be seen that Boolean algebra is far from an infallible means of arriving at the cheapest possible solution. In fact it may not give any solution at all! Engineering skill and ingenuity are still the most important

FURTHER READING

Most books on digital computer design include a chapter on Boolean algebra and binary arithmetic.

"Electronic Computers — Made Simple", H. Jacobowitz and L. Basford, W.H. Allen, London, 1967.

"Electronic Instrumentation Fundamentals" A.P. Malvino — McGraw-Hill, 1967.

"Numbers" R. Froom, Electronics Today International, Oct. 1973; p. 62--65

For the historical development of computers and other data processing equipment see

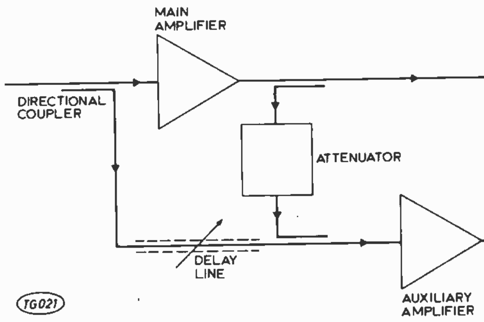
"A Computer Perspective" C and R Eames, Harvard University Press, Massachusetts, 1973.

factors in efficient logic design. It is of value however, and does give a good insight into the function of straightforward gate circuits.

In the next part we will look at practical circuitry of logic gates and introduce several other basic digital circuit building blocks. We will then be ready to discuss digital systems in some degree of depth.

FEED IT FORWARD

IAN SINCLAIR



INVENTED BEFORE FEEDBACK, THE PRINCIPLE OF FEEDFORWARD CORRECTION HAS MUCH TO OFFER MODERN DESIGNERS.

IN 1924, Black, working at Bell Telephone Laboratories, discovered the principle of *feedforward.* In 1929, he discovered feedback, which was destined to become one of the many developments of that most remarkable research institute to sweep the electronics world. The 'sweeping' took some time; probably no more than a handful of professionals had heard of the principles of feedback in the thirties, and it was the intensive development of electronics during the war which spread the news around a bit. It did, however, become the hottest property in amplifier design in the early 1950s, and appears in all but the humblest of books on electronics.

Feedforward was rather less fortunate, and but for the work of Seidal, also at Bell Telephone, in the late sixties, would have become as obscure as the "talking flame" method of modulating a spark transmitter. As so often happens, however, old ideas take on a new significance when new requirements appear, and feedforward may very well be due for a rather belated appearance in everyday electronics.

A LOOK BACK AT FEEDBACK

Let's refresh our memories about feedback. In a feedback circuit, a fraction of the output of an amplifier is fed back to the input and compared with the input signal at the input. The difference between input signal and the feedback signal is then passed through the amplifier again in such a phase as to act as a correcting signal, if the feedback is negative. Since positive feedback is seldom used in amplifiers deliberately, we shall stay with negative feedback. For example, if a positive going spike appears in the output, and is not present in the input, negative feedback will ensure that this is fed to the input in a polarity which will cause a negative going spike at the output, thus cancelling out the distortion of the signal. The amount of cancellation would be complete only if the amplifier had infinitely large gain, but can be made great enough for very satisfactory results.

Negative feedback of this kind has some advantages but also some disadvantages. On the plus side there is a very considerable reduction in distortion caused inside the amplifier, coupled with a reduction in gain and an increase in bandwidth. Any changes in the characteristics of the transistors or other devices used cause very small changes in the characteristics of the amplifier. The amplifier, however, may suffer from stability problems, caused by the phase of the feedback varying with frequency. The problem region may be outside the normal bandwidth of the amplifier, so that an amplifier has to be designed for a much greater bandwidth than is used. In addition, the amplifier, which is stable with a resistive or inductive load may be unstable with a capacitive load.

A SEPARATE AMPLIFIER

Feedforward, by contrast, samples a fraction of the signal at the output and compares it with a sample of the signal fed forward from the input. The difference is then amplified in a *separate* amplifier, and added to the output in such a phase as to correct for errors. The separate amplifier is the clue to the long time this technique has been ignored; in the days of valve or transistor amplifiers this made the technique uneconomic. The use of ICs puts rather a different complexion on it, since two amplifiers can be put on one chip almost as cheaply as one.

Oddly enough, the technique was not revived because of the easy availability of ICs, but because of distortion and noise in microwave amplifiers using travelling-wave tubes.

In any microwave tube amplifying a signal which may be in the region of 10GHz (10000MHz), the delay time of the signal — the time which it takes to pass from the input of the amplifier to the output — is several cycles, perhaps about 50. In such amplifiers, feedback cannot be used because it is not possible to make the feedback appear 50Hz *earlier* than the signal which causes it! Feedforward can, however, be used by taking the input signal and splitting it so that one part goes into an amplifier and another part is delayed and compared to the output. The difference is then amplified in another microwave amplifier and added in antiphase to the output. Figure 1 shows the type of circuit used. The coupling methods used must permit signal flow in one direction only, and some allowance must be made for the time delay caused by each coupling, amplifying, or mixing stage.

For such an amplifier, this is the only possible method of distortion reduction, and it has several other advantages over negative feedback.

There is, for example, no reduction in gain apart from that caused by the couplings and mixers, yet an increase in bandwidth is possible if the auxiliary amplifier has a greater bandwidth than the main amplifier. This is because the reduction of gain at the edge of the band acts as a distortion of signal and is compensated by the auxiliary amplifier just as any other distortion is compensated, assuming the auxiliary amplifier is able to cope. The delay in the amplifier is easily compensated for by time delays in the coupling to the auxiliary amplifier, and the distortion of the main amplifier may be reduced to as low a factor as desired by making the auxiliary amplifier better. The whole arrangement is stable under all conditions, and at all frequencies, and there is no need to worry about what the amplifiers are doing outside the band of interest.

DRAWBACKS

All of these advantages make this a circuit technique well worth looking at for other applications . . . . there has to be a snag somewhere! It lies in the auxiliary amplifier, which decides how good the main amplifier will be. Unlike the case of negative feedback, this is not a closed loop circuit, and changes in the auxiliary amplifier are not compensated for in the circuit, unless the auxiliary amplifier is itself a *feedback* amplifier. If the gain of the main amplifier is to be controlled to within 3db or so over a given bandwidth, then the gain of the auxiliary amplifier has to be controlled to a small fraction of this, the fraction being roughly the stepdown ratio at the output which enables us to compare it with the input. It is this requirement for the auxiliary amplifier which has kept feedforward from becoming better known.

AREAS OF APPLICATION

Having established these principles, however, we are left with a fascinating field for experiments, a challenge for those who say that there is nothing left for the amateur to discover. Lets toss around some ideas.

For one, we can easily make voltage amplifiers of high gain, good linearity, stability, and low noise. We can, if we like use feedback in their construction. We can also make rather cheap and nasty power amplifiers churning out many watts at high gain. Combine the two in a feedforward circuit, and we could have a good high power, high gain amplifier, stable under all conditions in which the auxiliary amplifier was stable. The output of the auxiliary amplifier need not be very high, since it exists only to correct the distortion of the main amplifier. Might this technique enable us to say goodbye to crossover distortion at low power levels?

Taking another field altogether, consider timebases. It is easy to generate a linear sawtooth of a few volts, more difficult to generate one of amplitude close to the amplitude of the power supply available, or to preserve the linearity in an inductive load. Why not generate a small amplitude linear timebase and use it as the reference in a feedforward amplifier to correct another timebase?

On another trail now, the distortion of an amplifier to which feedforward is applied is easily measured, it is simply the correction signal at the output of the feed-forward stage. All in all, there seem to be possibilities for this old idea now in the field of wideband amplifiers, transmitter modulation, crosstalk reduction, control of signal strength and goodness knows what else. We may be seeing some feedforward circuits in ETI before long! ●

ELECTRONICS TOMORROW

by John Miller-Kirkpatrick

There is a saying that goes something like 'It all comes to he who waits,' well, the waiting is over at last, a chip manufacturer has come out with the true electronic time switch. The AY-5-1230 from General Instruments is a four digit clock chip based on the successful AY-5-1200 series with the addition features of having an alarm output which can be programmed to switch on at a given time and also switch off at another given time. The outputs from the chip will drive a multiplexed fluorescent display, such as the Futaba 5-LT-01, or LEDs via interface circuitry or a TV display chip if the optional BCD outputs are used in place of the seven segment outputs. The chip was designed to drive the AY-5-8300 series of TV display chips and is intended to allow automatic turn-on and turn-off of the TV at predetermined times. If no off-time has been set then the switch output will automatically turn off 10 minutes after turning on; this is a safety aspect to ensure that the TV set is not automatically turned on and left on.

Apart from the application it was designed for, this chip has numerous other obvious applications such as central heating controller, tape recorder switching, anti-burglar lights etc. The turn-on/turn-off sequence can be optionally operated once or cycled to repeat in each 24 hour period; the output can be altered by a simple push-button or the timing can be cancelled for a complete period with another switch — all without the necessity of altering the time of day or the two alarm times. There are three outputs from the chip for controlling switching, the first is the switch output, which is intended to drive a relay or SCR (sinks 30mA), the other two outputs are intended to act as status indicators to show that an on time and/or off time has been set and will thus become active at the appropriate time.

A very well designed little chip with tons of applications, you could parallel two or even more chips if you wanted to switch the same or different circuits several times during a 24-hour period, as the display outputs can be wired in parallel and individually switched on you could wire up several chips to operate the same display.

AND NOW AND/OR

Some months ago (and also above) I mentioned the AY-5-8300 series of TV display chips and commented that they are possibly the most versatile of the range of TV display chips now on the market. They will accept time input from chips other than the AY-5-1200 series, eg the CT7002 (or HCM7002 as it is now known). GI have now announced the 8320 chip which gives the option of time and/or channel number display; whereas the 8300 is channel only and the 8310 is time or channel. As the channel number system is not used in the UK the multiplexed inputs from which the channel number is generated could display temperature, humidity, etc, or could be used in TV studio systems to identify the source of the video displayed on each monitor. I have only one comment to make to GI and that concerns the number of digits displayed in the time mode. GI only produce four-digit clock chips and thus have not considered it necessary to provide for six-digit display on the 8300 series, National make six-digit clock chips but have designed their MM5841 to accept input only from their MM5318 chip. I know that GI, Mostek and National are competitors but wouldn't it make more sense to design a chip that can interface with your own or your competitors chips? Can we hope to see an AY-5-8330 or MM5842 which will accept multiplexed input from most of the chips on the market. possibly also with optional input of seven segment or BCD inputs?

IT'S CHEAPER TO GO THE OTHER WAY

Having just mentioned optional input of seven-segment or BCD it occurred to me that the immortal 7447 decoder has been with us for some time now at prices of about £1.00 each; several decoders to work the other way have been produced but not very well publicised, thus making them expensive

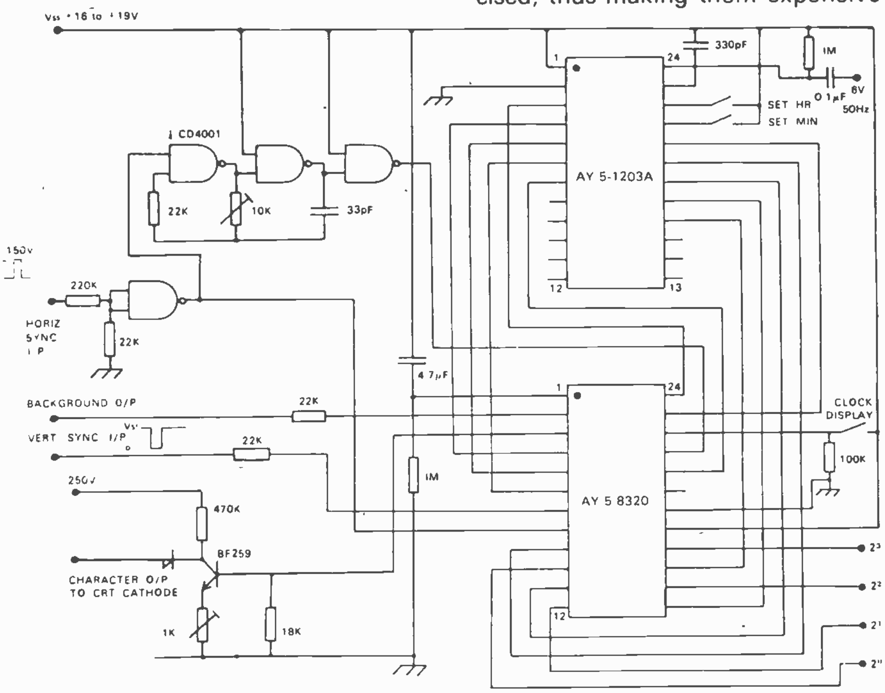


Fig. 1. The AY-5-8320 interfaces with the 1203 or 1230 clock chips.

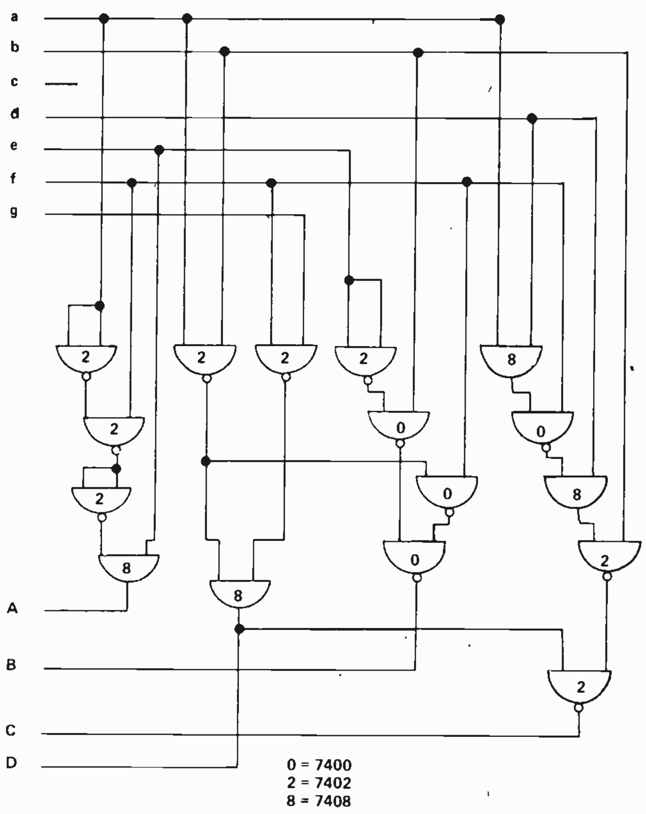


Fig. 2. Seven Segment to BCD converter.

and making them difficult to obtain. In applications where cost is a more important factor than space and power you might be interested in the circuit below for converting seven-segment to BCD. It works with numbers 0-9 including tailed sixes and nines but not tailed sevens or representations of numbers greater than 9. The inputs required are those produced by 7447s; some clock chips and the 7448 decoder have inverted signals and these would require a set of invert gates before the seven-segment to BCD decoder circuit. As CT7002s were not available for about a year I designed this circuit to work from 7001s where a BCD input was required. it is in fact cheaper than a 7447 decoder. If anybody has any similar circuits that use fewer chips or which will accept tailed sevens and/or the characters produced by 7447s for numbers above nine then I would be interested to hear from them.

	a	b	c	d	e	f	g	A	B	C	D	
0	0	0	0	0	0	0	1	0	0	0	0	0
1	1	0	0	1	1	1	[illegible]	1	0	0	0	1
2	0	0	1	0	0	1	0	0	1	0	0	2
3	0	0	0	0	1	1	0	1	1	0	0	3
4	1	0	0	1	1	0	0	0	0	1	0	4
5	0	1	0	0	1	0	0	1	0	1	0	5
6	1	1	0	0	0	0	0	0	1	1	0	6
6	0	1	0	0	0	0	0	0	1	1	0	6
7	0	0	0	1	1	1	1	1	1	1	0	7
7	0	0	0	1	1	0	1	1	0	1	0	5
8	0	0	0	0	0	0	0	0	0	0	1	8
9	0	0	0	1	[illegible]	0	0	1	0	0	1	9
9	0	0	0	0	1	0	0	1	0	0	1	9

TRUTH TABLE

MORE NEW CHIPS AND WHAT TO DO WITH THEM

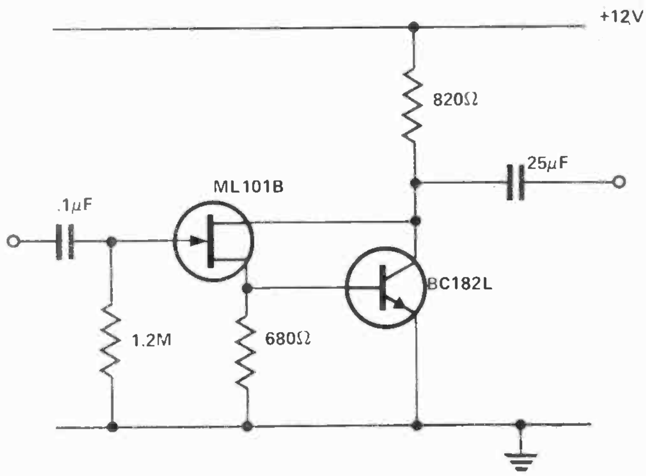
The MK50396 and MK50397 from the Mostek stable are now available. If you remember these are the hours/minutes/seconds and Minutes/Seconds/.99 versions of the MK50395 multi-purpose counter chip. This family has the features of six decades of count and display with presetting of counter and comparator registers, display latch, equal and zero outputs, BCD inputs and BCD and seven-segment outputs. Recently I have used these chips in several applications which have been very varied and have come up with some fascinating tricks that they will do. If you do not want to use BCD switches or TTL to load the counter or comparator then you can use the chip itself. One application uses the MK50396 as an up/down counter of minutes and seconds; the counter is always started from zero and counts up until an external action takes place. This action causes the counter to latch the display and also to transfer the BCD output into the comparator register. the display is then de-latched (the counter has been going all of the time) until a second action causes the counter to stop. A second sequence is then timed from zero and compared to the first by simply comparing the first signal from the sequence with the comparator equal output from the chip. If the first sequence was faster than the second then the equal will occur before the outside signal and vice-versa. If the second sequence was faster than the first then this could cause the comparator to load a new time for comparison. After a sequence of these events the comparator would contain the fastest time for the group as any that were slower would not affect the comparator and any that were faster would have recalibrated the comparator. This system could be used as a stopwatch in race meetings where competitors would know if they had beaten the record by finishing before hearing a bell. In the original application no digital readout was needed as we only need to know the fastest sequence and not the actual time of that sequence, the cost of the system was less than £20, if a digital readout was required then it would add about £10 to the cost.

Another application required time of day to be loaded into the MK50396 at regular intervals and this to be used in conjunction with the comparator this time with another external time. The application was to check the accuracy of quartz and mains clocks by regularly checking the variance from a known good source — a quartz-driven MM5318. Approximately once per hour a button was pushed by the operator; this caused the time to be loaded from the master 5318 and all of the 5318s under test into the 50396 and 50397 comparator registers. All of the 50397s now started counting at 100Hz until the counter was equal to the comparator. This caused the equal signal to change state and this in turn stopped the count and held the data in the counter. Any counter which had not stopped within one minute was assumed to have been counting in the wrong direction (ie clock was gaining not losing) and a flip-flop was reset to cause down counting at the next test. The whole system was then checked manually at leisure and the fast or slow difference of each clock under test was read out and the clock adjusted accordingly — it hasn't been built yet but it proves that you can do a lot more with some of these LSI chips when you start putting them piggy-back style. Look into the 50395 series they are almost up to microprocessor standard in complexity and ability.

Data:
GI chips: General Instrument Microelectronics, 57-61 Mortimer St, London W1N 7TD.
Mostek: Mostek (UK) Ltd, 240 Upper St, London N1.
GI and Mostek chips are available from Bywood Electronics, 68 Ebberns Rd, Hemel Hempstead.

tech-tips

A HIGH IMPEDANCE BUFFER AMPLIFIER



This circuit has a voltage gain of just less than unity, but its power gain is very large indeed. It makes an ideal preamplifier for a high impedance source signal. The input impedance is about 800k with the FET specified, but if a FET without a built in gate protection diode is used, the input impedance will be largely controlled by the gate resistor. The circuit has a small signal output impedance of about 10 ohms and is capable of delivering about 7mA p-p into a capacitively-coupled 25 ohm load. The low-frequency breakpoint is about 240Hz, the upper breakpoint is in excess of 1MHz.

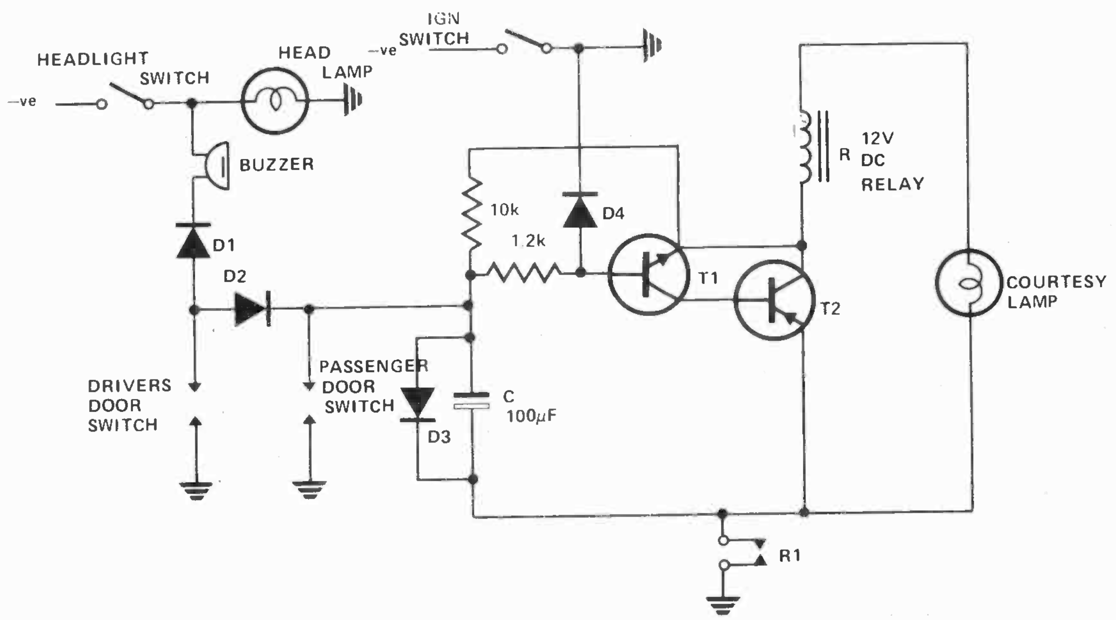
The principle of operation is simple. The circuit employs a FET front end to obtain the high input impedance, but the transconductance of the FET is too low to be useful on its own, and so it is boosted by the output transistor, the BC182L.

COURTESY LIGHT EXTENDER AND HEADLAMP REMINDER (+VE EARTH)

With the ignition switched off, an earth from the passenger or drivers door causes C to discharge, the relay to operate and the courtesy lamp to light. The relay is operated through transistor T2 which is biased on by T1. T1 and T2 remain on once the door is shut until C is recharged, hence giving approximately 15 seconds delay before the courtesy lamp extinguishes. Operation of the ignition inhibits the delay switch by biasing T1 off. i.e. courtesy lamp only alight when door open. D2 and D3 must be capable of carrying full courtesy lamp current.

The headlight reminder operates only when the headlights are left on and the drivers door is operated, thereby allowing departure of passengers without disturbance.

For –ve earth diode polarities and capacitor C should be reversed and transistor types changed.



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tech-tips

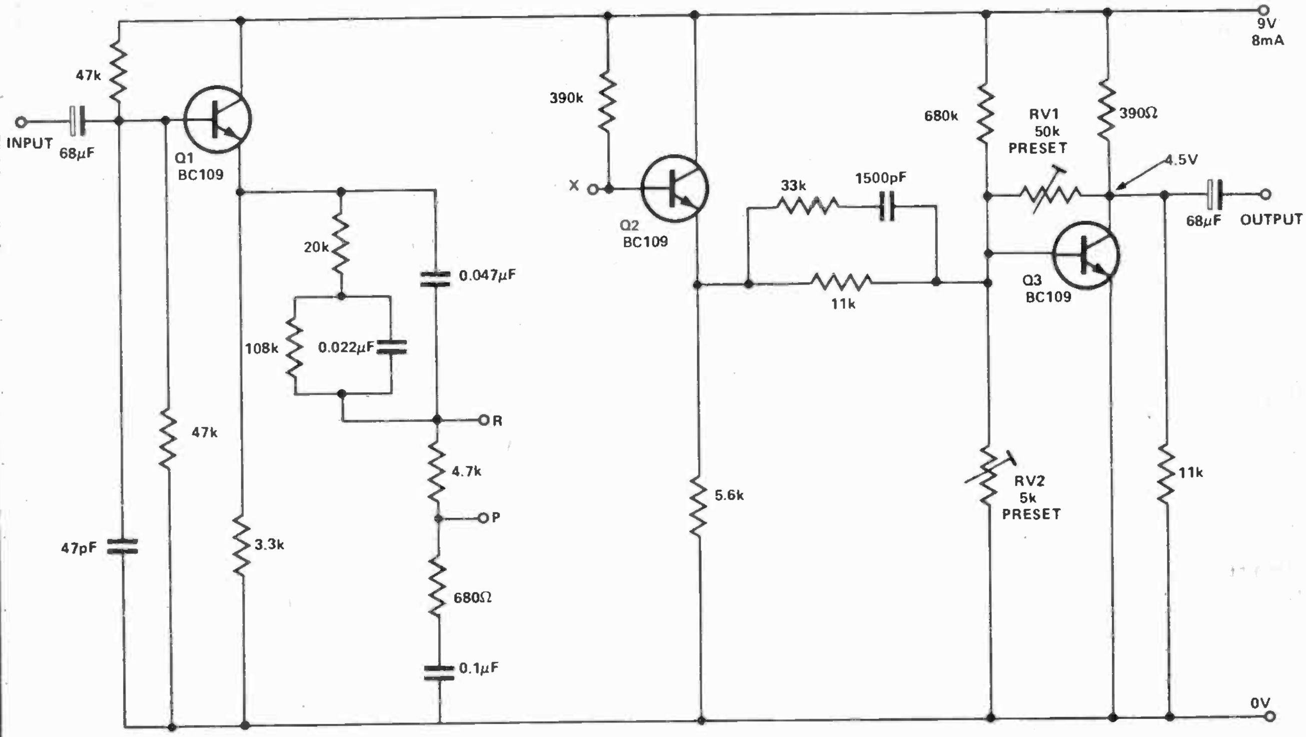
TAPE HISS REDUCTION CIRCUIT

The circuit in Fig. 1. is used to either boost or cut frequencies. When making a recording, point X is wired to point R so that treble signals are boosted by 10dB, and then during playback, point X is wired to point P so that the signal from the tape, including the hiss, has the treble cut by an equivalent amount. The circuit values are such that the overall frequency response, from record through playback, is flat over the range 20Hz–20kHz. Thus the output signal after playback is identical with the input signal before recording, but the hiss is cut by 10dB.

RV1 sets the gain of the circuit to be unity at low frequencies (<500Hz); RV2 is adjusted so that the collector voltage of Q3 is half the positive rail voltage. When this is set, the circuit will function without apparent distortion with an input voltage of up to 1.5V r.m.s.

If monitoring during record is not required, the same circuit may be used for record and playback, with X switched between P and R as necessary. If monitoring during record is required, two circuits are needed, one with X wired to R and the other with X wired to P.

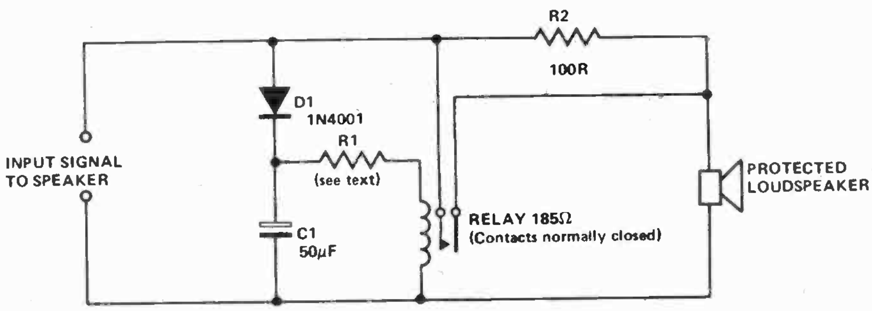
For stereo, two circuits are required.



LOUDSPEAKER PROTECTION UNIT

The following circuit will protect loudspeakers against overload if the correct components are used.

Operation of the circuit is quite simple, Diode D1 rectifies the signal across the speaker, which developes a fluctuating DC voltage across C1. When this voltage exceeds a certain level, the relay contacts open, which disconnects the lodspeaker and if required puts a resistor across the signal. In the case of valve amplifiers it is usually necessary to keep a load on the output when there is an input signal present, therefore R2 will have to be included in the design. With most types of transistor amplifiers today, the resistor R2 may be omitted.



R1 is adjusted to give adequate protection at whatever power is being used. Resistor R1 value should be selected according to the power at which the speaker will need to be limited and of course the impedance of the speaker. In my case the resistor R1 was made 220R but this may be too low for very high power applic- ations.

tech-tips

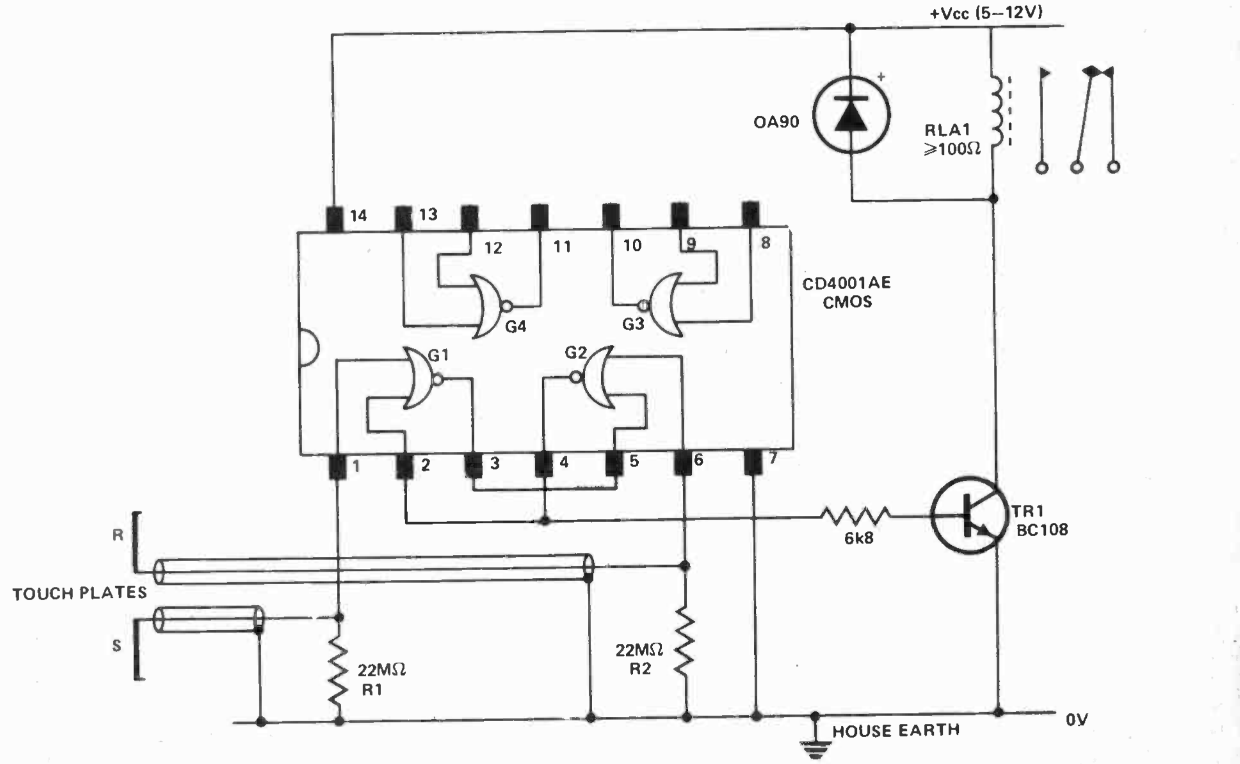
Tech-Tips is an ideas forum and is not aimed at the beginner. We regret we cannot answer queries on these items.

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, 36 Ebury Street, London SW1W 0LW.

TOUCH FLIPFLOP

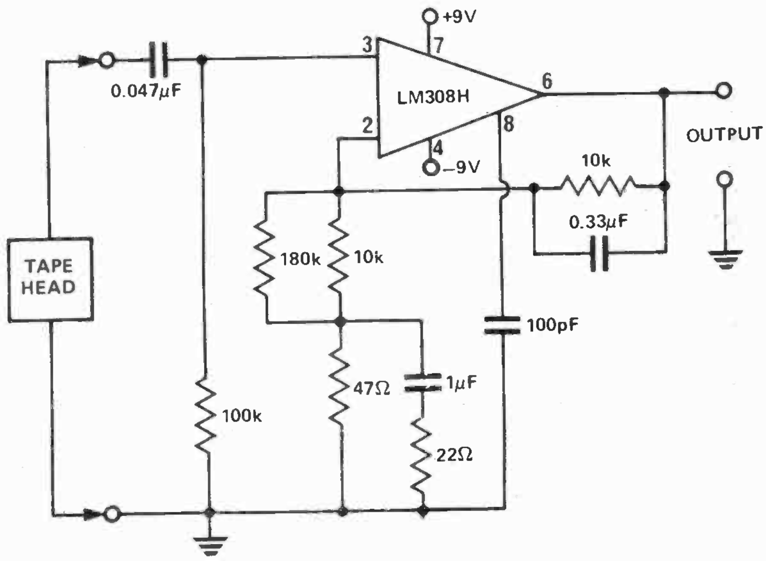
CMOS IC's have many advantages over TTL, one being the high input impedances. In Fig. 1, two NOR gates are cross coupled to form a flipflop. If plate S is touched ambient noise casuses an alternating voltage to appear at G1 input. During the first positive cycle G1 output goes negative setting the flipflop and turning RLA1 on. It remains on until the R plate is touched. R1 and R2 must not be omitted since they discharge any potentials remaining on the plates after they have been touched, thus allowing the flipflop to have its state changed rapidly. R1 and R2 also prevent any static charges building up, thud damaging the IC, while the supply is disconnected. 22Mohm resistors are difficult to get so two 10Mohm resistors in series may be used.

The unit may be left on continually as a milliameter indicates no current flow at all in the off position. If RLA1 is omitted TR1 collector becomes a TTL output with a high fan out. Connect the inputs of G3 and G4 to ground if they are not to be used. The touch plates can be placed several feet from the IC provided screened cable is used for them.



IC TAPE-HEAD PRE-AMP

This circuit is suitable for a tape speed of 3.75 inches/sec. and provides a rising gain at low frequencies (about 40 dB below 100 Hz) a minimum gain of about 15 dB around 2-3 kHz and a 6 dB boost (to about 21 dB) above 10 kHz for reasonable compensation. A low noise op-amp is used.



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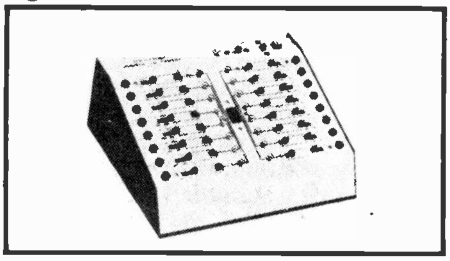
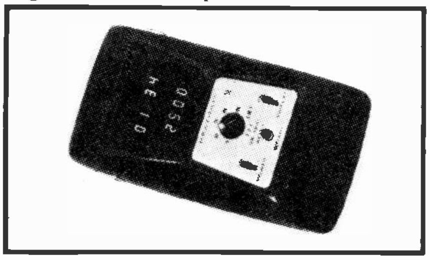


Digital electronic stop watch.



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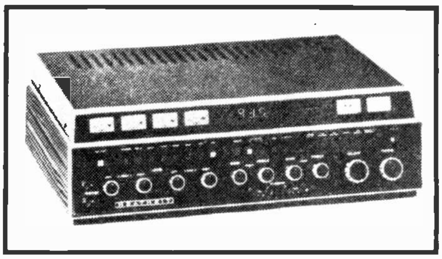

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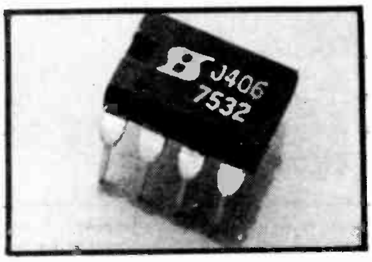
Continued from page 8

SCIENTIFIC ANALYSIS ON THE POCKET CALCULATOR
by Jon M. Smith, Wiley-Interscience

Virtually all of our readers own pocket calculators and many of them are professional engineers and scientists. It is for these readers that we have introduced this book to ETI Book Service. It is aimed at the engineer/scientists who has to perform sophisticated numerical analysis on any calculator from the Novus 650 to an HP-65. The author in fact stresses how much analysis can be performed on a simple, 4 function machine, and gives routines for calculating sin x, cos x etc. (Personally, I think it's easier to look up the tables, but if can't find them it's nice to know you're not completely stuck.) The book scores a big plus on the following points: It is authoritative, comprehensive, and forces the reader to *think* about what he is doing. The contents range from elementary tabularanalysis of data, through such topics as Bessel Functions, Fresnel Integrals, Fourier Analysis, Numerical Integration methods, Linear Systems Simulation, Approximation by Chebysher and Rational Polynomials and Statistics, with a very good final section on the Programmable Calculator. As can be seen, this is not a book for the mathematical novice, nor is it light reading. Equally well. it is perhaps a little awkward to use for quick reference. Overall, however, this is THE book for calculator users who would like a bit of intellectual exercise which will pay off in giving them an order of magnitude increase in value of their machines.

MINI–FETS

The Siliconix J401/406 and J410/412 series of monolithic n-channel dual-JFETs are presented in 8-pin Mini DIP package. The J410/J412 are for general applications while the J401 to



J406 offer a high performance for Op Amp front ends. The J401 features CMRR >95dB; offset 5mV (max) and drift 10μV/^{o}C (max): Details from Siliconix Ltd, 30A High Street, Thatcham, Newbury, Berks RG13 4JG.

SWEEPING RADAR DEVELOPMENT

Ferranti have designed and built a radar system which fits inside the rotor blades of a helicopter, and utilises these as the aerial. This enables a very narrow beam to be produced, giving a very high resolution picture. This means, amongst other things, that the helicopters will be safer to fly in poor visibility conditions, and survivors in heavy seas can be detected with vitual certaintly. Flight trials begin early this year.

HP CALCULATOR BONUS

HP-45 OWNERS who are feeling a bit peeved following the introduction of the HP-25 calculator by Hewlett Packard can take heart from the fact that the HP-45 can be used as a stopwatch and 12 hour clock.

It's a little bit tricky, but becomes easy with practice. To trigger the beast into 'stopwatch mode' you press RCL and then *simultaneously* press the keys R↓, STO and CHS. The display will then appear as four pairs of zeros representing hours, minutes, seconds and hundredths (from left to right).

Pressing CHS will stop and start the timer, EEX will blank out the hundredths, and CLX will reset the display. The unit can be switched back to 'calculator mode' in two ways: pressing ENTER↑ clears the display, while pressing the decimal point key will reformat the display to H.MMSS$\frac{1}{100}\,\frac{1}{100}$ in either FIX4 or FIX6 (depending on whether hundredths were displays).

Time splits may be stored by pressing the desired register number while the timer is running; pressing these keys while it is stopped will recall a time to the display. Pressing 0 accesses the LASTx register and recalls the time at which the timer was stopped. Times may be entered as above and the calculator switched to 'stopwatch mode' to use the times as starting values.

Now here's the catch: it's wildly inaccurate, since the clock rate is not crystal controlled However, as the chip is the same (we believe!) as in the HP-55 this problem could be overcome by the few daring people who may be willing to rummage around inside it. We apologise to HP for ever having mentioned this, as we understand that they prefer not to know about it!

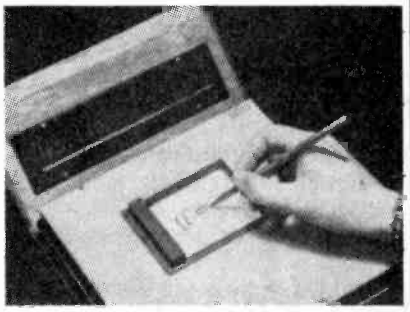
KEEP AN EYE ON THE PUPILS

After almost 10 years of work Honeywell scientists have produced a device that promises to become an important teaching tool.

The development – called a remote Oculometer – focusses a beam of infra-red light on a subject's eyes, and a special TV camera records the minute changes made by the eyes' movements. This information is fed to a signal processor, which calculates the eye movements and makes it possible to produce a television picture on which a black dot shows the exact movements the subject's eyes make while looking at a scene.

It is believed that the Oculometer can play a major role in the field of learning disabilities. Scientists are working to enable a paralysed person to use his eye movements to activate typewriter keys.

FREEHAND WITH COMPUTERS



A device called CHIT (CHeap Input Terminal), invented by National Physics Laboratory, makes it easier and cheaper to have computing complexes recognise handwriting. When linked to character recognition system, it is possible to doodle into computers, and have them understand it! This means that ordinary pencils/pens can be used, and places like banks and shops can now have a viable signature verification system.

Chit operates from two resistive strips at right angles, spaced by a small air gap. As a pen moves across the tablet, the pressure causes the two strips to meet. A current is passed through them, and the voltage developed is an analogue representation of the pen position. Switching between strips, to sample the voltage developed, gives x and y outputs. This is done very rapidly, and the output fed to the computer in binary form.

National Research Development Corporation, Kingsgate House, 66–74 Victoria Street, London SW1E 6SL.

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BC107/8/9	9p	BF173	24p	2N3055	50p
*BC114	12p	BF178	26p	2N3702/3704	11p
*BC147/8/9	10p	BF184	22p	*TIP30A	52p
*BC153/154	12p	*BF194/195*	12p	TIP31A	55p
*BC157/8/9	12p	*BF196/197*	12p	TIP32A	64p
BC177	18p	BF200	27p	TIP3055	55p
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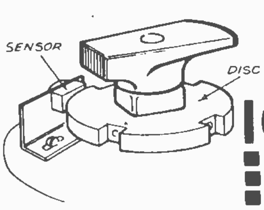

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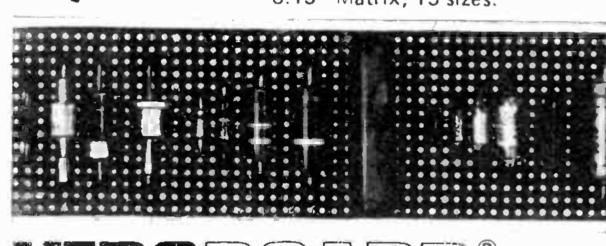

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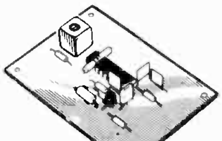

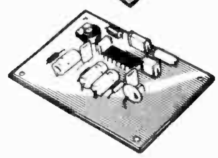

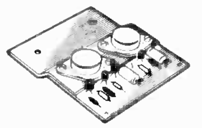

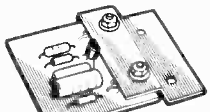

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