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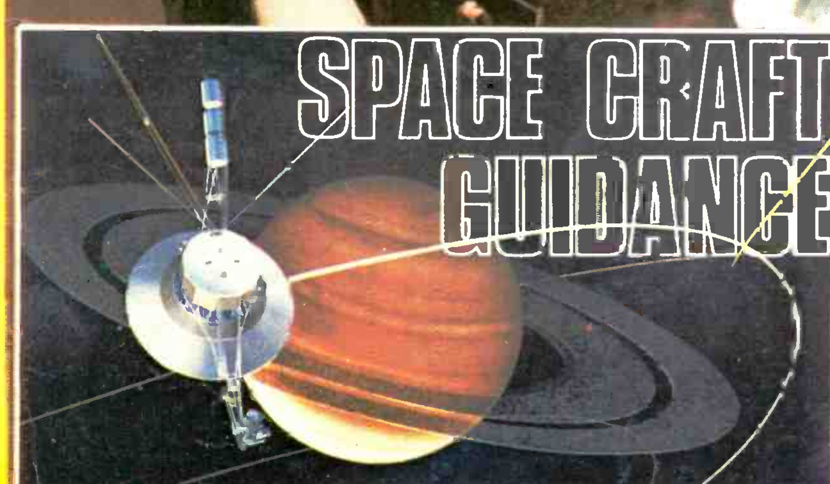
555 offer

(see page 35)

EARLY TAPE RECORDERS



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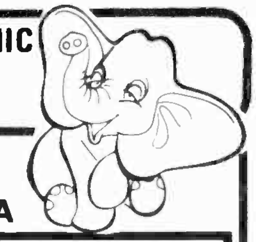

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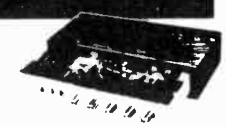

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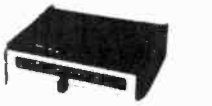

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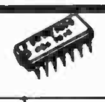

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BC149	0.10	OC36	0.60	2N3614	0.66
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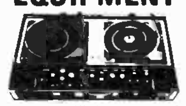

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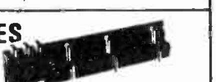

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Two 555 Linear Timer ICs for special price of £1 to our readers

Cover: The world's first magnetic tape made by BASF on a 1930's AEG tape recorder. Inset: An unmanned Mariner Spacecraft passing Saturn (planned for later this decade).

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DRX1 Crystal set 31p DRR2 Dual range 45p

COIL FORMERS & CORES
NORMAN ¼" Cores & Formers 8p
⅜" Cores & Formers 10p

SWITCHES
DP/DT Toggle 36p SP/ST Toggle 30p

FUSES
1¼" and 20mm. 100mA, 200mA, 250mA, 500mA, 1A, 1·5A, 2A
QUICK-BLOW 5p ea.

EARPHONES
Crystal 2·5mm plug 42p
Crystal 3·5mm plug 42p
8 ohms 2·5mm plug 22p
8 ohms 3·5mm plug 22p

DYNAMIC MICROPHONES
B1223. 200 ohms plus on/off switch and 2·5mm and 3·5mm plugs £1·85

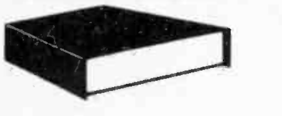
3-WAY STEREO HEAD-PHONE JUNCTION BOX
H1012 £1·87

2-WAY CROSSOVER NETWORK
K4007. 80 ohms Imp. Insertion loss 3dB £1·21

CAR STEREO SPEAKERS
(Angled) £3·85 per pair.

BI-PAK
CATALOGUE AND LISTS
Send S.A.E. and 10p.

INSTRUMENT CASES



(Black Vinyl covered)

No.	Length		Width		Height	Price
BV1	8"	×	5½"	×	2"	£1·35
BV2	11"	×	6"	×	3"	£1·75

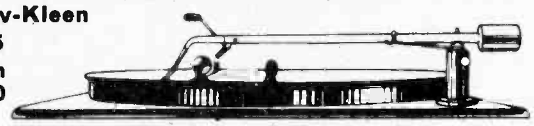
ALUMINIUM BOXES

BA1	5¼"	×	2¼"	×	1½"	49p
BA2	4"	×	4"	×	1½"	49p
BA3	4"	×	2¼"	×	1½"	49p
BA4	5¼"	×	4"	×	1½"	58p
BA5	4"	×	2½"	×	2"	49p
BA6	3"	×	2"	×	1"	42p
BA7	7"	×	5"	×	2½"	85p
BA8	8"	×	6"	×	3"	£1·10
BA9	6"	×	4"	×	2"	70p

P & P 15p on each box

BIB HI-FI ACCESSORIES

De Luxe Groov-Kleen Model 42 £1·95
Chrome Finish Model 60 £1·50



Ref. B Stylus & Turntable Cleaning Kit 34p
Ref. 36A. Record/Stylus Cleaning Kit 33p
Ref. 43. Record Care Kit £2·42
Ref. 31. Cassette Head Cleaner 58p
Ref. 32. Tape editing Kit £1·68
Model 9. Wire Stripper/Cutter 83p
Ref. 46. Spirit level 62p
Ref. P. Hi-Fi Cleaner 31p
Ref. 32A. Stylus Balance £1·87
Ref. J. Tape Head Cleaning Kit 62p
Ref. 56. Hi-Fi Stereo Hints & Tips 42p
Ref. 45. Auto changer groove cleaner £1·08

ANTEX SOLDERING IRONS
X25. 25 watt £2·05
CCN 240. 15 watt £2·48
Model G. 18 watt £2·26
SK2. Soldering Kit £3·25
STANDS: ST3, Suitable for all models £1
SOLDER: 18SWG Multicore 7oz £1·61
22SWG 7oz £1·61. 18SWG 22ft 51p
22SWG Tube 33p

ANTEX BITS and ELEMENTS

Bits No.		
102	For model CN240 3/32"	42p
104	For model CN240 3/16"	42p
1100	For model CCN240 3/32"	42p
1101	For model CCN240 3/8"	42p
1102	For model CCN240 ¼"	42p
1020	For model G240 3/32"	42p
1021	For model G240 1/8"	42p
1022	For model G240 3/16"	42p
50	For model X25 3/32"	48p
51	For model X25 1/8"	48p
52	For model X25 3/16"	48p

ELEMENTS
ECN 240 £1·30 ECCN 240 £1·32
EG 240 £1·07 EX 25 £1·16

ANTEX HEAT SINKS 10p

V.A.T. included in all prices. Please add 10p P. & P. (U.K. only). Overseas orders—please add extra for postage.

NEW COMPONENT PAK BARGAINS

Pack No.	Qty.	Description	Price
C1	200	Resistors mixed values approx. count by weight	0·54
C2	150	Capacitors mixed values approx. count by weight	0·54
C3	50	Precision Resistors 1%, 2% mixed values	0·54
C4	75	⅛th W Resistors mixed preferred values	0·54
C5	5	Pieces assorted Ferrite Rods	0·54
C6	2	Tuning Gangs, MW/LW VHF	0·54
C7	1	Pack Wire 50 metres assorted colours	0·54
C 8	10	Reed Switches	0·54
C 9	3	Micro Switches	0·54
C10	15	Assorted Pots & Pre-Sets	0·54
C11	5	Jack Sockets 3 × 3·5m 2 × Standard Switch Type	0·54
C12	30	Paper Condensers preferred types mixed values	0·54
C13	20	Electrolytics Trans. types	0·54
C14	1	Pack assorted Hardware—Nuts/Bolts, Grommets etc.	0·54
C15	5	Mains Slide Switches	0·54
C16	20	Assorted Tag strips & Panels	0·54
C17	10	Assorted Control Knobs	0·54
C18	4	Rotary Wave Change Switches	0·54
C19	2	Relays 6—24V Operating	0·54
C20	1	packs sheet of Copper Laminate 20 sq. ins	0·54

PLUGS AND SOCKETS

PLUGS

PS 1	D.I.N. 2 Pin (Speaker)	0·11
PS 2	D.I.N. 3 Pin	0·12
PS 3	D.I.N. 4 Pin	0·15
PS 4	D.I.N. 5 Pin 180°	0·16
PS 5	D.I.N. 5 Pin 240°	0·16
PS 6	D.I.N. 6 Pin	0·17
PS 7	S.I.N. 7 Pin	0·18
PS 8	Jack 2·5mm Screened	0·18
PS 9	Jack 3·5mm Plastic	0·12
PS 10	Jack 3·5mm Screened	0·18
PS 11	Jack ¼" Plastic	0·15
PS 12	Jack ¼" Screened	0·22
PS 13	Jack Stereo Screened	0·36
PS 14	Phono	0·10
PS 15	Car Aerial	0·22
PS 16	Co-Axial	0·15

INLINE SOCKETS

PS 21	D.I.N. 2 Pin (Speaker)	0·14
PS 22	D.I.N. 3 Pin	0·20
PS 23	D.I.N. 5 Pin 180°	0·20
PS 24	D.I.N. 5 Pin 240°	0·20
PS 25	Jack 2·5mm Plastic	0·16
PS 26	Jack 3·5mm Plastic	0·16
PS 27	Jack ¼" Plastic	0·30
PS 28	Jack ¼" Screened	0·35
PS 29	Jack Stereo Plastic	0·30
PS 30	Jack Stereo Screened	0·38
PS 31	Phono Screened	0·18
PS 32	Car Aerial	0·22
PS 33	Co-Axial	0·22

SOCKETS

PS 35	D.I.N. 2 Pin (Speaker)	0·08
PS 36	D.I.N. 3 Pin	0·11
PS 37	D.I.N. 5 Pin 180°	0·11
PS 38	D.I.N. 5 Pin 240°	0·11
PS 39	Jack 2·5mm Switched	0·12
PS 40	Jack 3·5mm Switched	0·12
PS 41	Jack ¼" Switched	0·20
PS 42	Jack Stereo Switched	0·30
PS 43	Phono Single	0·08
PS 44	Phono Double	0·10
PS 46	Co-Axial Surface	0·10
PS 47	Co-Axial Flush	0·20

LEADS
LS 1 Speaker lead 2 pin D.I.N. plug to open ends approx. 3 metres long (coded) 0·20

CABLES

CP 1	Single Lapped Screen	0·07
CP 2	Twin Common Screen	0·11
CP 3	Stereo Screened	0·12
CP 4	Four Core Common Screen	0·23
CP 5	Four Core Individually Screened	0·30
CP 6	Microphone Fully Braided Cable	0·10
CP 7	Three Core Mains Cable	0·09
CP 8	Twin Oval Mains Cable	0·07
CP 9	Speaker Cable	0·05
CP 10	Low Loss Co-Axial	0·18

CARBON POTENTIOMETERS
Log and Lin
4·7K, 10K, 22K, 47K, 100K, 220K, 470K, 1M, 2M

VC 1	Single less Switch	0·15
VC 2	Single D.P. Switch	0·28
VC 3	Tandem Less Switch	0·46
VC 4	1K Lin Less Switch	0·15
VC 5	100K Log anti-Log	0·46

HORIZONTAL CARBON PRESETS
0·1 watt 0·06 each
100, 220, 470, 1K, 2·2K, 4·7K, 10K, 22K, 4K7, 100K, 220K, 470K, 1M, 2M, 4·7M

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13⅞" × 8" × 5½" £2·70
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240v. Primary. Secondary voltages available from selected tappings 4v, 7v, 8v, 10v, 14v, 15v, 17v, 19v, 21v, 25v, 31v, 33v, 40, 50 and 25v-0-25v.

Type	Amps.	Price	P & P
MT50/½	½	£1·93	30p
MT50/1	1	£2·42	35p
MT50/2	2	£3·30	40p

CARTRIDGES
ACOS

GP91-1SC 200mV at 1·2cm/sec	£1·35
GP93-1 280mV at 1cm/sec	£1·85
GP96-1 100mV at 1cm/sec	£2·80

TTC

J-2005 Crystal/Hi Output	£1·05
J-2010C ,, ,, ,, Compatible	£1·20
J-2006S Stereo/Hi Output	£1·75
J-2105 Ceramic/Med Output	£1·95
J-2203 Magnetic 5mV/5cm/sec, including stylus	£4·95
J-2203S Replacement stylus for above	£3·00
AT-55 Audio-technica magnetic cartridge 4mV/5cm/sec	£3·30

CARBON FILM RESISTORS
The E12 Range of Carbon Film Resistors, 1/8th watt available in PAKS of 50 pieces, assorted into the following groups:—

R1	50 Mixed 100 ohms–820 ohms	50p
R2	50 Mixed 1K ohms–8·2K ohms	50p
R3	50 Mixed 10K ohms–82K ohms	50p
R4	50 Mixed 100K ohms–1 Meg. ohms	50p

THESE ARE UNBEATABLE PRICES—JUST 1p EACH INCL. V.A.T.

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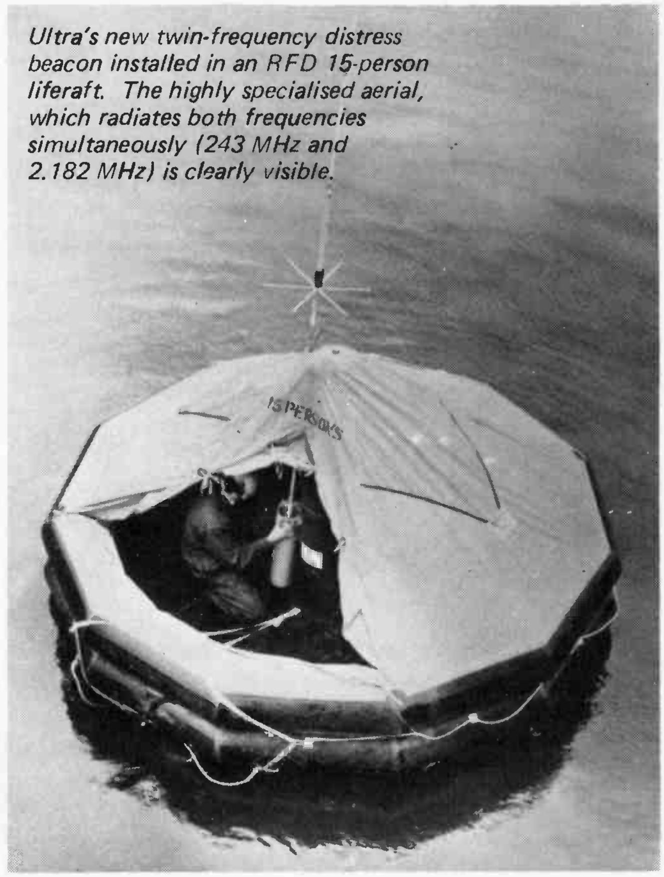
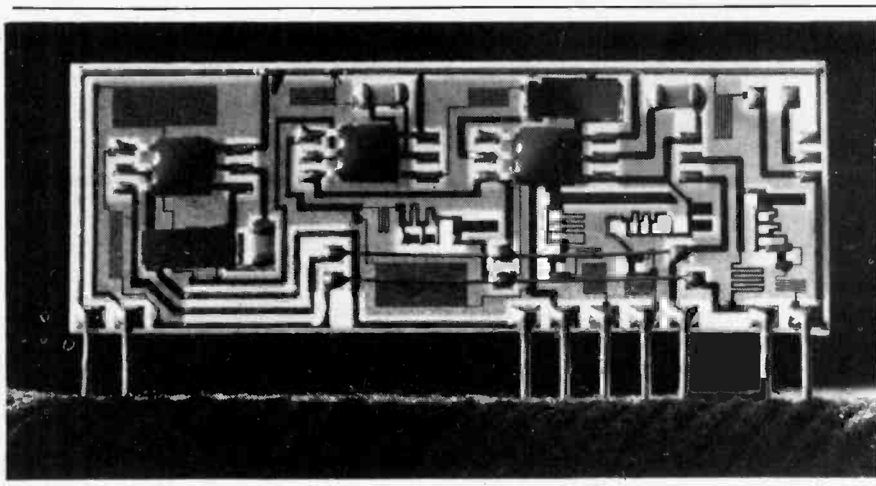
HP55



Ultra's new twin-frequency distress beacon installed in an RFD 15-person liferaft. The highly specialised aerial, which radiates both frequencies simultaneously (243 MHz and 2.182 MHz) is clearly visible.

Hewlett-Packard's latest calculator is a programmable scientific pocket model, which has an integrated digital timer which operates for a 100 hours with an accuracy to within 0.01%. As well as recording an overall time, it can store up to ten intermediate elapsed time intervals or 'splits'. These 'splits' can be recalled and used for calculations such as the mean and standard deviation of elapsed time intervals.

In addition, the new nine-ounce calculator is programmable, has 86 functions and 20 addressable memories. It is priced at £210 + VAT and is designed for scientists. Hewlett-Packard Ltd., King Street Lane, Winnersh, Wokingham, Berks, RG11 5AR.



ACTIVE RC FILTERS

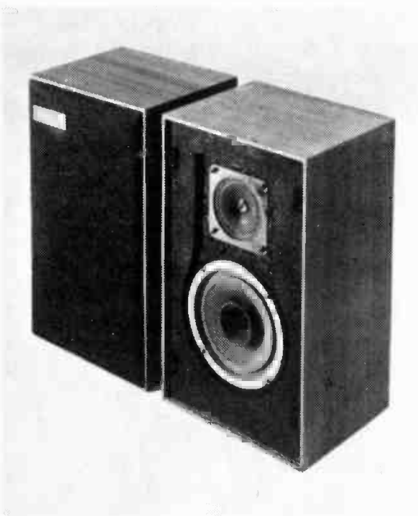
Siemens recently introduced active RC filters for the af range up to approximately 20kHz. These coilless components are marketed in tantalum thin-film technique and are hybridized with operational amplifiers in miniature housings. The desired filter parameters, such as frequency, Q-factor and gain, are set by laser trimming of specific resistors with tolerances better than 1%.

Active RC networks in hybrid layer technique have recently been discussed as technical and economical alternatives to conventional LC networks. The advantages of the coilless filters are their low space requirements and weight, the high accuracy and stability of the filter parameters as well as the additional possibility of building still other types of filter, e.g. switchable and tunable ones.

Siemens has chosen the technique using tantalum nitride resistors and beta-tantalum capacitors because this combination permits an almost ideal temperature compensation (T_K ($T_K = 40.10^{-6}/K$) which is all-important for the RC product determining frequency and stability. (This means that the frequency does not change by more than 0.2% for temperature changes of 50°C).

Filters of 100Hz to 1kHz can be made with a Q-factor of 100 and filters of up to 10kHz with a Q-factor of 50. For higher frequencies of up to approximately 50kHz other methods of synthesis are required.

The new RC filters provide high-pass, low-pass and band-pass characteristics. By suitably combining several of these modules, it is possible to produce higher-order filters of the Butterworth or Bessel, Tschebycheff or Cauer design. Various types of operational amplifiers can be used.



XL15

4522

NEW LOUDSPEAKERS

Two new ranges of loudspeakers have been announced by Marsden Hall International. The "Annexe" range is intended for use in home audio systems of up to 20W per channel. Above we show the XL15 bookshelf speaker which copes with 15W and costs £51.50 (inc. VAT) per pair. Like the XL10 and the XL20 these are two-way 40Hz-20kHz units in teak or walnut. The XL10 (10W) costs £44.50 and the XL20 will rush you £63 (inc. VAT), per pair.

For those who want 3-way speakers for a 30Hz-20kHz response MHI have two models in the "Symphony" range. Above is the 4522 free standing monitor which eats up 50W and costs you £172.50 (a pair, inc. VAT). The 3522 is a 35W version for £141.50. Speakers from both ranges can have one of 27 different fronts — black fabric or filter foam in almost any colour.

CALCULATOR PRICES EVEN LOWER

Sinclair, Europe's biggest calculator manufacturers, have made up to 35% reductions on their prices. The basic Cambridge goes for £13.99, the Scientific for £21.55 and the kits for £9.95 and £14.95 respectively (kits only available from Sinclair, London Road, St. Ives, Hunts, PE1 4HJ); all prices include VAT. The Cambridge Memory costs £19.39.

FIELD EFFECT LC DISPLAYS

Siemens incorporate the field effect principle in their new liquid crystal displays with low operating voltages.

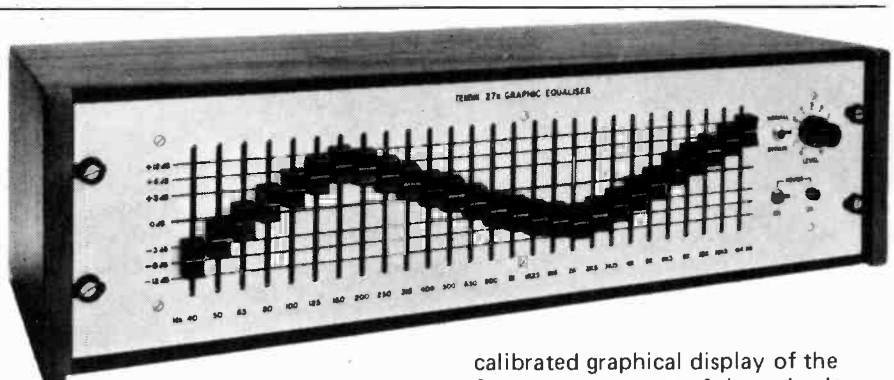
All the liquid crystal displays in field effect technology have dark symbols on a light background and are suitable for reflection operation, all with high contrast ratios, low operating voltage and low power draw. Such features allow the displays to be driven by CMOS and other ICs.

SHORTER SOLDERING IRON

A series of pencil irons, known as the Stiron 47K and the Stiron 63K are being manufactured in Sweden and assembled in the U.K. These irons are somewhat shorter than conventional types, to give operators greater control during use. This is possible because of the patented PTFE mounted heat shield.

Other features include stainless steel bit chambers and element bobbins. Bit seizure, it is claimed, has been completely eliminated. The irons are available in 20, 25, 30 and 40 watt ratings, and from 24 to 240 volts, and a wide range of pre-tinned iron plated bits is available. Tele-Production Tools Ltd., 28b Hamlet Court Road, Westcliff-on-Sea, Essex.

Two smiling ETI readers receiving their prizes won in our Heathkit competition. Presenting Mr. Harris of Newport (2nd Left) with a 5-function engine analyser is Mr. Smith, M.D. of Heathkit's U.K. operation. Halvor Moorshead, Editor of ETI (right) is seen handing over a digital clock to C. J. Pennycuick of Bristol. Mr. Shaw, winner of the silver prize, chose 9520 speakers.



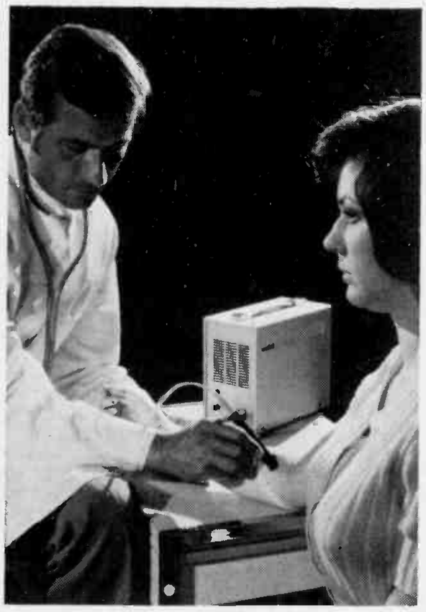
27 BAND GRAPHIC EQUALISER

The 27s is a new 27-band graphic equaliser from the new range by TEKNIK. It comprises three over-lapping LCR filters per octave arranged for boosting or cutting each band of audio frequencies by up to 12db by means of continuously variable low-noise slider controls which give a calibrated graphical display of the frequency response of the unit. It features a noise level of better than -89dbm and a THD of less than 0.01% and is available as a 19 inch rack-mount unit or fitted in a portable case. The 27s costs £350 plus VAT. Two other new models are the 11s and the dual 11s. From Klark-Teknik Limited, Summerfield, Kidderminster, DY11 7RE.

news digest

ULTRASOUND REVEALS CIRCULATORY DISORDERS

Medical statistics reveal that circulatory disorders are on the increase. To help patients, physicians and insurance companies detect vascular diseases as soon as possible Siemens has developed a new non-invasive ultrasonic unit designed to provide acoustic information on the blood flow in veins and arteries.



This ultrasonic blood vessel indicator utilises the Doppler effect. The ultrasonic waves emitted by the transmitter are reflected by the blood streaming through the vessels, but the waves are changed in their frequency according to the flow speed before getting back to the receiver. The different frequency can be made audible by a loudspeaker or the signals can be visually displayed as an ultrasonic tone pattern on an oscilloscope. The frequency shift varies proportionally with the flow speed, high frequencies representing high flow speeds and low frequencies low speeds. Thus stenotic disorders or functional incompetence of the venous valves are diagnosed rapidly and non-invasively. The unit is small and easy to operate. The built-in loudspeaker makes possible an "on-the-spot diagnosis". The ultrasonic transmitter and receiver are housed in the cigar-shaped pick-up probe which is applied with slight pressure to the skin above the vessel to be examined.

EQUIPMENT FOR P.O. COAST STATION

In view of the International Telecommunications Union calling for 'world-wide single-sideband telephony working' the Post Office specified SSB equipment for the new installation at their coast station at Ilfracombe. This station provides ship-to-shore radiotelephone and teleprinter communication for offshore oil rigs throughout the British sector of the Celtic Sea.

Four H1060 1kW transmitters - one for telephony, one for telegraphy, and two for standby, - have been ordered from Marconi. Operating on designated frequencies in the range of 1.6MHz to 3.8MHz, the installation will provide a radiotelephone and facsimile service to the oil rigs. This will be shared by customers on a party-line basis. The teleprinter link provided will give one teleprinter channel each for up to 15 customers, each channel being used exclusively by a given-rig and its particular shore office in the U.K. The H1060 is an SSB/ISB transmitter designed for use in situations where simple operation and easy maintenance are important.

The receivers for the station come from Eddystone. Four EC964/7E high stability single channel SSB receivers have been ordered, again operating on designated frequencies in the range 1.6MHz to 3.8MHz. A number of these are currently in operation on North Sea oil-rigs.

To allow up to 16 teleprinter channels to be multiplexed on to a single audio channel of 1KHz bandwidth. Marconi have used lots of ICs in their H5030 Series of Voice Frequency Telegraph Equipment. This forms the Telegraph Channelling equipment.

For matching the characteristics of a two-wire telephone line to the four wire radio circuit, and to remove the risk of instability from imperfectly matched line impedance, two H5511 Radio Telephone Channels (Marconi) are to be installed.

Also to be used at the station is the Marconi Autospec II radiotelegraph error correctling system. Fifteen Autospec terminals will enable oil rigs to use teleprinters to transmit technical and commercial data with high accuracy. Using its special error correction code, Autospec permits reliable radio communication to be achieved in all but the worst conditions of fading and interference.

ELECTRONIC MULTIMETER

This 38-range electronic multimeter designed for professional engineers is called the Dino.

It's basic sensitivity is 200kΩ/V, dc and 20kΩ/, ac. The dc current ranges extend from 5μA to 5A, the voltage ranges from 100mV to 1.5kV, and the resistance ranges allow identification from 0.2Ω to 1kMΩ. A.C. ranges extend from 5mA to 5A and 5V to 1.5kV. Range switching is achieved using a five-position rotary switch in conjunction with separate range sockets for each selection.

A second version of the instrument is available with an additional internal universal signal injector. The USI version provides a modulated r.f. output rich in harmonics up to uhf.

Another optional extra is a 30kV probe to complete the TV servicing facility. The price is £33.85 (inc. VAT) from Chinaglia (UK) Ltd., 19, Mulberry Walk, London SW3 6DZ.

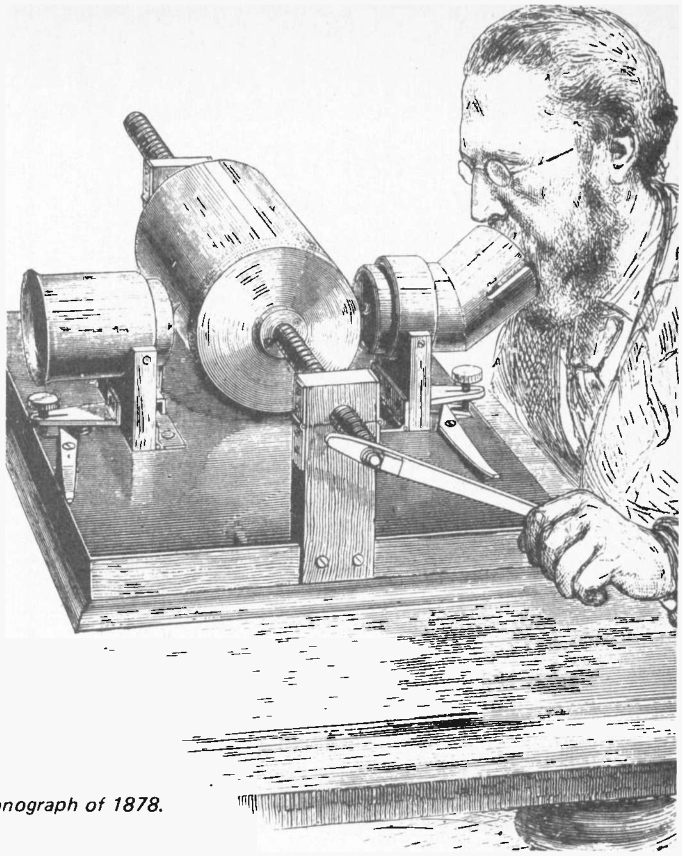
SLOTTED OPTICAL LIMIT SWITCH

A new solid state optical limit switch for object sensing has been announced by Monsanto (10 Victoria Street, London SW1H ONQ). It can serve as an optical sensor of moving objects, such as film and tape, and as a limit switch for moving mechanical objects. The unit, the MCT8, incorporates an LED infrared emitter and a phototransistor optical sensor in a single package. In this way, the absence or presence of that object can be sensed by the state of the photo-transistor. The unit is available in two models, the MCT8, with an output current of 250μA with a 20mA input current, and the MCT81 with an output current of 100μA at 20mA input.

The units feature fast switching speeds (6 μsec turn-on time and 4 μsec turn-off time), and high sensitivity to permit direct interfacing with TTL logic. The detector portion of the switch is recessed and thus provides a very high signal-to-noise ratio in ambient light conditions. Additional advantages of the units include precise mechanical alignment due to multiple slot reference surfaces, complete absence of lensing, heat sinking capability, high moisture resistance, immunity to thermal shock, and temperature stability.

Continued on page 70.

History of Tape Recording



The tinfoil phonograph of 1878.

AT THE CLOSE of the 19th Century, a Dane, Valdemar Poulsen, devised and constructed a 'Talking Machine' with which sounds could be recorded and subsequently reproduced using magnetic techniques. The machine, which Poulsen called the *Telegraphone,* was exhibited at the Paris Exposition of 1900 and caused a sensation: nothing like it had been seen before and little imagination was required to visualise its tremendous potential.

The *Telegraphone* was, however, by no means the first 'Talking Machine' nor was Poulsen even the first to propose the use of magnetic recording and reproduction techniques. And, for that matter, Poulsen's machine was far from being the end of the story; nearly half a century was to elapse before the full potential of magnetic recording was at all near to realisation.

In this field, as in others, a represensative picture of the actual course of events can be obtained by consideration of the published specifications of old Patents.

In 1856, Leon Scott, a French typographer, invented a sound recording device known as the *Phonautograph.* This device consisted of a large horn having a flexible membrane stretched across its smaller end, and a pig's bristle fastened to the membrane. The idea was that sounds picked up by the horn caused the membrane and hence the pig's bristle to vibrate, and these vibrations could be recorded, in the form of a wavy line, on a smoke blackened paper cylinder rotated in contact with the bristle. This gave a clear visual recording (or 'autograph') of the sounds, but there was no way of converting this back into sounds again.

Leon Scott's idea was taken a stage further in 1877 by Edison as can be seen from his British Patent No. 2909 of 1877. In this Patent, Edison was primarily concerned with the construction and use of a 'contact' type microphone with which sound-induced vibrations of a diaphragm could be converted into electric currents, but he also mentioned that sounds could be converted into vibrations of a stylus attached to a diaphragm and that these vibrations could be recorded and subsequently played back. He suggested five possible recording and reproduction techniques: 1) A knife edge recording stylus makes indentations in a v-shaped ridge previously pressed out of a sheet of paper. The indented ridge is played back by moving it against a play-back stylus connected to a diaphragm so that the diaphragm is caused to vibrate and reproduce the recorded sounds.

2) A self-feeding pen draws a line on a moving strip and sound-induced vibrations of a diaphragm vary the feed of ink to the pen and hence the thickness of the ink line. During play back, the ink line exerts a varying frictional force or drag on a play-back stylus which causes the stylus and an attached diaphragm to vibrate.

3) A burnishing point acts on a paper strip to produce a track of varying smoothness which is played back like manner to the ink line.

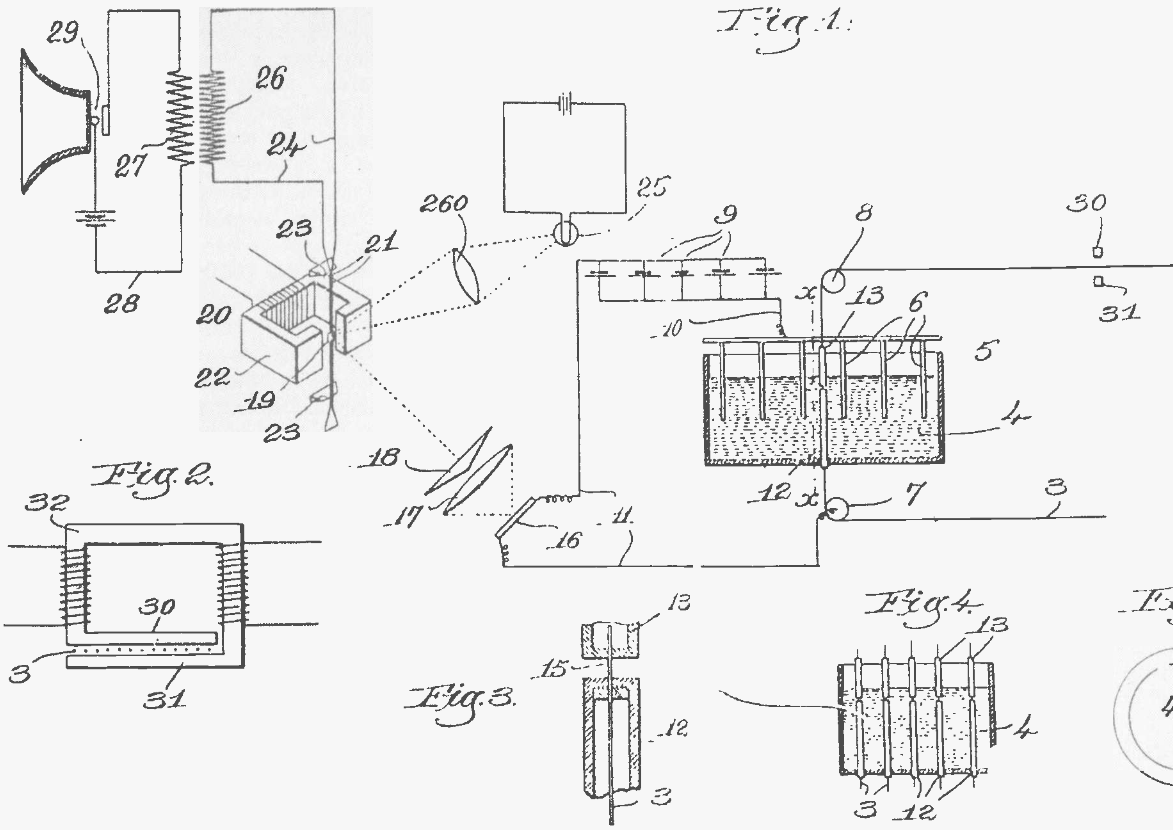
4) A thread is embedded in a paper strip by passing the strip and thread between rollers. The thread is deflected sideways, whilst it is being embedded, by sound-induced vibrations, so as to give a wavy 'track' which can be played back with a stylus and diaphragm.

5) A recording stylus forms indentations in the grooves of a tin-foil covered helically grooved cyclinder. For reproduction purposes, the cylinder is rotated with a play-back stylus in engagement with the indented groove. It is, of course, this last method which Edison adopted and used as the basis for his *Phonograph,* which is described in Patent No. 1644 of 1878.

This historic Patent for the *Phonograph* in fact went much further than merely describing the original tin-foil machine; as we shall see, it also described a number of ideas which could be said to anticipate many important developments later introduced by others in the field of both phonographic and magnetic recording techniques.

Edison's original tin foil *Phonograph* attracted a great deal of popular interest but it had many deficiencies and was really little more than a wonderful toy of no practical value. Various inventors, however, quickly set to work to improve on the basic concept.

In Patent No. 1644 of 1878, Edison had already suggested the use of wax. Wax cylinders, a much more practical proposition than tin-foil, were developed by Bell and Tainter and marketed for use with their machine, the *Graphophone,*



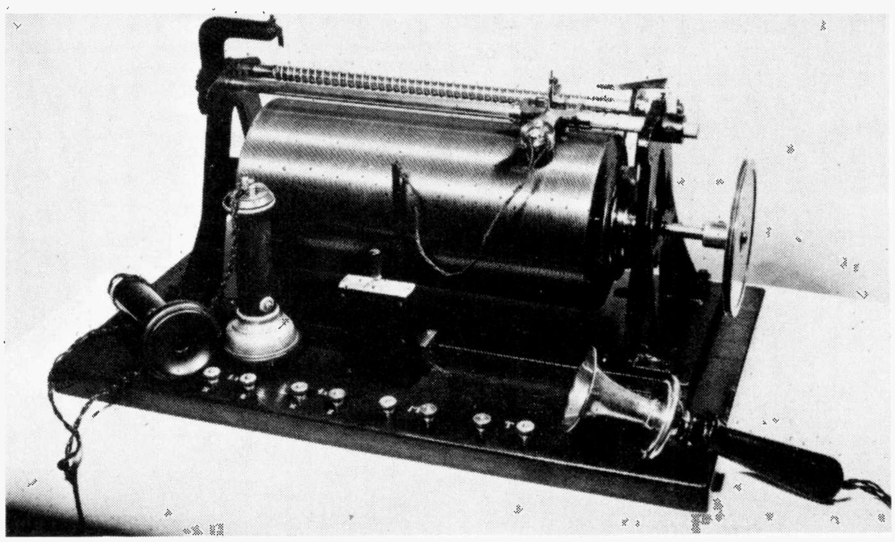
British Patent No.22962 of 1908. A magnetic recording system with which recorded sounds vary the electrolytic deposition of magnetic material on a wire.

which quickly became a serious competitor to the *Phonograph.*

GRAMOPHONE

Again referring to Patent No. 1644 of 1878, Edison had by no means restricted himself to consideration of cylinders and amongst a range of other possible forms of recording media he proposed the use of a disc with a spiral groove on each side. The idea of using a disc was taken up by Berliner, as can be seen from his Patent No. 15232 of 1887. Berliner's discs, unlike the cylinders, had "sinuous grooves", that is, sounds were recorded by sideways deflection of the groove rather than by varying its depth. Discs recorded in this manner were better suited to mass production and Berliner's disc playing machine, which he called the *Gramophone,* ultimately, of course, replaced the *Phonograph.*

Whilst cylinders and discs were the main forms of recording media actually used, other forms were also proposed. Edison, for example, in his Patent No. 1644 of 1878 suggested using tapes, either in the form of endless bands or as a continuous length wound on spools, on which sounds could be recorded in the form of indentations with a vibrating stylus. Patent No. 20306 of 1890 also refers to the use of tape wound from one spool to another, the tape having a suitable facing on which a vibrated stylus can impress recordings. In Patent No. 10357 of 1891 a tape made up of a paper or silk backing-ribbon supporting a layer of wax covered with tin foil, is described. Patent No. 2690 of 1893 relates to the use of a tape made from a soft alloy such as lead and tin, tin and aluminium or bismuth and aluminium; and Patent No. 4685 of 1893 is concerned with the manufacture of a tape by coating a paper strip with black lead then depositing electrolytically a tin or tin alloy on this. And, still the subject of phonographic tape recording, Patent No. 7624 of 1899 describes a multi-track recording technique.



The first magnetic recorder invented in 1900 by Valdemar Poulsen.

Also proposed was a phonographic recording medium in the form of a spherical segment (Patent No. 5889 of 1901) and, in a less serious vein, a chocolate or sugar disc (Patent No. 1992 of 1903)!

At the same time, inventors were also directing their efforts towards devising alternative methods of recording and reproducing sounds.

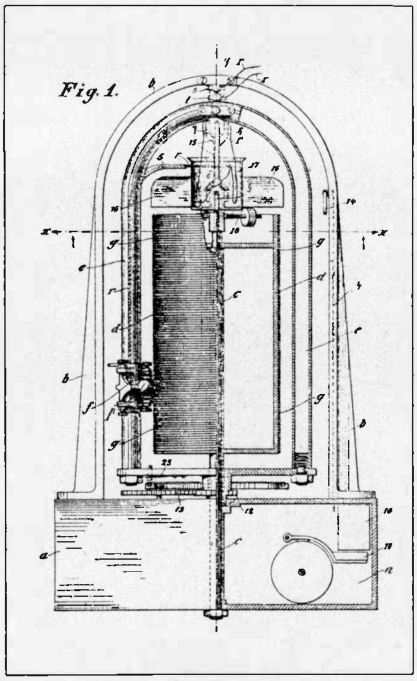
Thus, for example, Patent No. 7926 of 1884 describes an arrangement with which a plumbago pencil marks a helical line on a rotating paper cylinder. Picked up sounds cause the pencil to vibrate and vary the intensity of the marked line and play-back is achieved by running the line between two conductors connected to a telephone receiver and a battery. The line provides a varying resistance link between the conductors.

In Patent No. 6062 of 1886 a photographic sound recording technique is described. A photographic film is exposed to a light source through a glass plate on which a jet of coloured water is directed. Sound vibrations disturb the jet and correspondingly vary the light transmission through the plate. Patent No. 19901 of 1902 also relates to a photographic method. In this case a microphone actuates an electromagnet so as to vibrate a mirror which reflects a light beam onto a film. The 'record' is played back by moving the developed film between a light source and a selenium cell; the illumination of the cell varies and a correspondingly varying electrical output is produced.

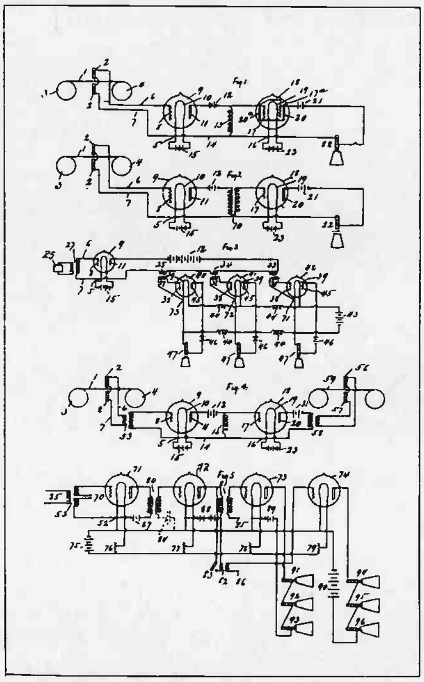
Another proposal involved the recording of sounds by varying the stretching of a wire rendered ductile by heat (Patent No. 145804 of 1919). The resulting variable thickness wire is played back with a mechanical or pneumatic transducer.

Patent No. 153300 (1919) describes a capacitance method: a recorded disc or band of varying thickness is passed between two plates so as to vary their capacitance. And in Patent No. 535328 (1939) an electrostatic system is described in which sounds are recorded as a pattern of electrostatic charges on a tape coated with metallic particles.

A Dutchman, Wilhelm Hedick described a number of interesting recording techniques in his Patent No. 569 of 1888. The techniques involve the deposition of particles on a tape under the influence of sound vibrations. In one form, deposition is achieved by charging a vibrated gas jet with material from a sublimating chamber and moving the tape over the jet so as to cause the material to condense out on the tape in a pattern determined by the vibrations. The material may be such as to give a coating of varying electrical resistance, varying smoothness, varying thickness or varying thermal properties, an appropriate transducer being used for reproduction purposes. In an alternative form of his invention, Hedick suggested coating a tape with magnetic particles by exposing the tape to a jet of magnetic dust at the same time as it passed over the pole of an electromagnet whilst "vibrating or intermittent electric currents circulate in the bobbin of the electromagnet". This causes the dust to collect on the tape in a characteristic pattern and it is then stuck in position with resin, wax or varnish. Play-back is achieved by passing the tape over the pole of a play-back electromagnet so that electric currents are induced in its coil.



British Patent No.8761 of 1899. Poulsen's original magnetic wire recorder.



British Patent No.2059 of 1914. de Forest's use of the 'audion' or triode valve to amplify tape recorder play back volume.

In 1888 therefore, ten years before Poulsen devised the 'first' magnetic recording machine, we have, in Hedick's Patent, a full description of a magnetic tape recording system, and indeed a system using tapes from paper coated with magnetic particles - tapes which were hailed as a major breakthrough when they were re-invented in the 1920s.

And Hedick was not the only person before Poulsen to consider magnetic systems. Predictably, the first seems to have been Edison in his Patent No. 1644 of 1878. The system described by Edison uses a soft iron grooved record and a play-back needle connected to a diaphragm. The needle is magnetised by attachment to one pole of a horse-shoe magnet and is slightly spaced from the groove in the record. As 'hills' and 'dales' in the groove pass the needle they cause the needle and hence the diaphragm to vibrate. A similar idea is described in Patent No. 6047 of 1886, in this case the record being a soft iron grooved disc which runs between the arms of a horse-shoe magnet and the needle being arranged in one pole of the magnet within a coil rather than on a diaphragm.

All of these early magnetic systems do in fact differ in one important respect from modern practice: recording is carried out by varying the physical distribution of the magnetic material rather than by varying the magnetisation of it. In Hedick's system the magnetic material is deposited unevenly on the tape and in Edison's system the soft iron record is cut away by varying amounts in the groove. And this concept of magnetic recording by varying the amounts of magnetic material was also considered by many later inventors. Patent No. 22962 of 1908, for example, describes a magnetic recording process which involves the deposition of a varying thickness coating of magnetic material on a wire electrolytically. Voice vibrations vary the intensity of a light beam which causes the electrical resistance of a selenium cell illuminated by the light beam to vary, and this in turn varies the current passing through an electroplating bath. In Patent No. 491037 (1937), an arrangement is described in which a ribbon is coated with magnetic particles directed on to the ribbon from a jet and the jet is vibrated by picked-up sounds.

Before Poulsen, at least one person had however had visions of a magnetic recording system involving varying the magnetisation of a magnetic material. This was Oberlin Smith who wrote an article entitled "Some possible form of Phonograph" in an American publication, Electrical World, in 1888.

Continued on page 15.

History of Tape Recording

Continued from page 12.

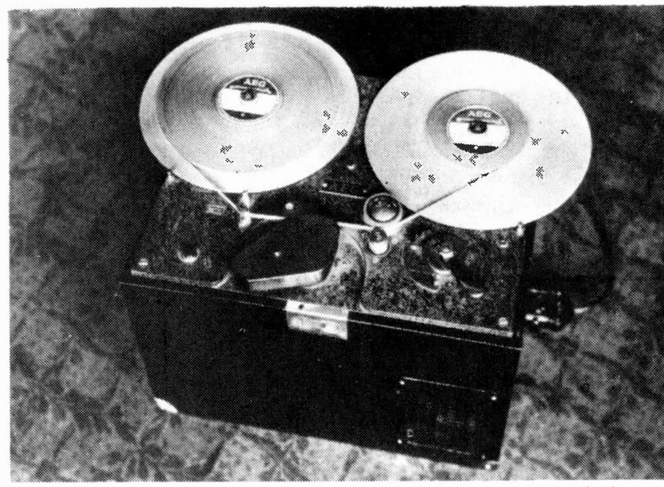
Mr. Smith visualised a "machine for spinning metallic dust into a cotton cord" on which sounds could then be recorded magnetically. But Mr. Smith's visions were only visions and no practical machine embodying his ideas was constructed, until, that is, the year 1898 when Valdemar Poulsen tried out his first *Telegraphone.*

Poulsen's machine is described in Patent No. 8961 of 1899 which is entitled "Method and apparatus for effecting the storing up of speech or signals by magnetically influencing magnetisable bodies". In his Patent Poulsen described the use of an "electromagnet acting on or being acted on by a magnetisable wire or strip". In one form, a steel wire is wrapped around a fixed drum and a record/play-back head is rotated around the drum following the path of the wire. In another form, a steel tape is wound from one spool to another past a fixed head, one spool being driven and the other braked to hold the tape taut.

This was the birth of the modern tape recorder; but there was still a long way to go. The original *Telegraphone* was expensive and awkward, the recording quality was extremely poor and play-back volume was very low.

A major problem with the *Telegraphone* lay in the nature of the recording medium itself. Ultimately it became possible to achieve good quality recordings with steel tapes and wires but there were many practical problems. Steel tapes and wires were expensive and they tended to twist and were difficult to hold in position whilst being driven at the necessary high speeds. Patent Nos. 319680 (1929) and 513729 (1938) indicate practical problems of an even more down to earth nature. The former relates to a head specially constructed to permit passage of welded or riveted joins in steel tapes, and the latter describes a method of cleaning tapes - to remove rust!

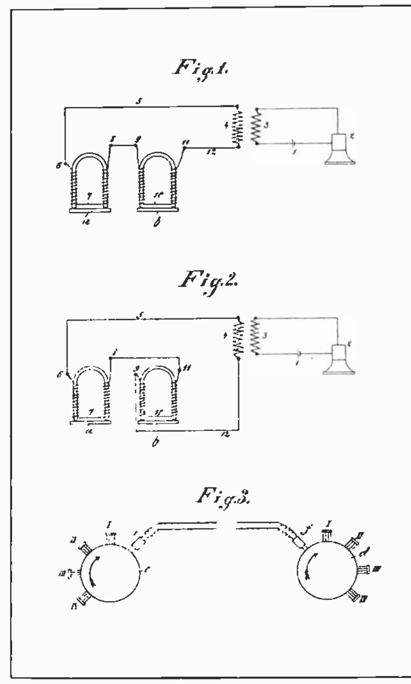
Attempts were made to improve on the recording medium. In Patent No. 23738 of 1901, for example, Pedersen, Poulsen's associate, described a method of forming recording tapes by electrolytic deposition of one or more magnetic materials such as iron, nickel, cobalt, chromium and manganese either alone or together with a diamagnetic material such as copper or aluminium. It was however not until the 1920s that really important advances were made.



The first BASF tape on AEG's "Magnetophon" recorder in 1935.

In 1927, in America, J. A. O'Neill developed a paper tape coated with magnetic particles by deposition from a liquid medium. In Patent No. 324099 (1928) a tape was proposed made from a base ribbon or film of celluloid with a track of embedded steel filings. The same Patent also describes a tape made from a textile ribbon impregnated with metal particles and refers to the possibility of recording on parallel tracks. In Patent No. 333154 (1929) Pfleumer, who was an important influence on the German tape recording industry, described a tape made of metallic powder stuck onto a backing strip by means of an organic binder mixed with the powder. Patent No. 51164 (1937), also in the name of Pfleumer, describes a cathode evaporation technique for providing a paper tape with a metallic coating; and in Patent No. 355669 (1930) there is described the use of a magnetic field to align particles before bonding them to a paper tape.

By the 1930s a German firm, Allgemaine Electricitas Gesellschaft (AEG) were marketing a tape recorder, the *Magnetophon,* using Pfleumer's coated tapes. This however by no means marked the end of solid metal tapes: steel tape systems, particularly those originating from the German Telegraphie Patent Syndikat organised by Dr. Kurt Stille, were still serious contenders, and alloy tapes were also becoming important. In Patent No. 489261 (1937), AEG themselves suggested a tape made from an alloy 25% iron, 30% nickel and 45% copper. It was however only a matter of time before metal tapes were ousted by the superior oxide tapes. Yet another German firm, I. G. Farbenindustrie, gave a lead in this respect. In their Patent No. 466023 (1935), for example, they described an oxide tape made from powered iron oxide applied in the form of an emulsion to a film of cellulose acetate. In Patent No. 594474 (1945), an iron/cobalt double oxide on cellulose acetate tape is described.



British Patent No.888 of 1900. Pedersen's use of a magnetic recording system to transmit several telephone messages simultaneously over the same wire.

Another significant disadvantage of the original *Telegraphone* was that the play-back volume was very low and the machine was really only suitable for use with headphones. With the *Phonograph,* the vigorous vibrations of the play-back stylus were capable of producing a reasonable level of sound through a horn 'loudspeaker'. There were also proposals, by Short (Patent No. 22768 of 1898) and Sir Charles Parsons (Patent No.

10468 of 1903) to use the stylus vibrations to operate a control valve interposed between a source of compressed air and an acoustic horn to give a form of pneumatic amplification, the resulting machine being known as the *Auxetophone.* Predictably Edison had already considered this idea and described it in his Patent No. 1644 of 1878.

It was clear that, to be at all competitive, the *Telegraphone* needed a suitable form of amplification, and this was ultimately provided by de Forest, as can be seen from his Patent No. 2059 of 1914. De Forest invented the triode valve, or *audion* as he called it, and although his original intention was to produce an improved detector of radio waves he soon found that the valve had great value as a means of amplification of weak electrical signals. De Forest's use of the valve to amplify the output of the *Telegraphone,* as described in his 1914 Patent, was one of the first instances of use of the *audion* as an amplifier.

The tools of electronics were also required for another very important purpose. Initially, magnetic recording machines operated in a very simple manner. An electromagnet was positioned alongside the wire or tape, a fluctuating d.c. current was passed through the coil of the electromagnet directly from the microphone or via an amplifier for recording purposes, and a steady d.c. current was passed through the electromagnet coil for erase purposes. The results of this were, by present day standards and also by contemporary phonographic standards, poor to say the least. Background noise, limited frequency range, lack of uniformity of recorded signal strength, were all characteristic features of early magnetic recordings. One reason for this lay in the typical non-uniform response of the magnetic material to the varying magnetic field produced by the current variations originating directly from the microphone or via the amplifier. To obtain a more uniform response it was necessary to operate within a different range of current variation and Poulsen quickly realised this. Accordingly in his Patent No. 541 of 1903 he suggested "A continuous polarising current may be led through the writing magnet to improve the quality of the record. Such current should be opposite in direction from that which is used for erasure".

The use of d.c. bias, as proposed by Poulsen, gave rise to significant improvement in quality, but this particular problem was still far from solved and remained unsolved for many years. In fact, it was not until more than 20 years later that the idea of using a.c. bias was suggested. Carlson and Carpenter, working in the U.S. Naval Research Laboratory, were responsible for this innovation (described in U.S. Patent No. 1640881 of 1927) which enabled standards of quality to be very greatly improved.

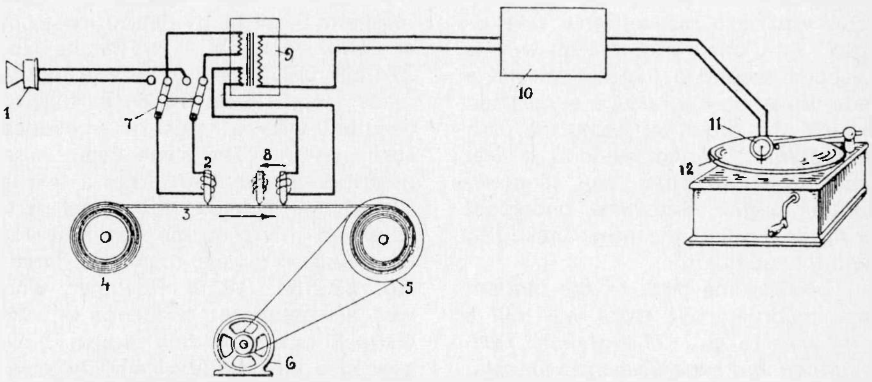
Carlson and Carpenter's work was however well before its time and many more years went by before the importance of a.c. bias became widely appreciated. Indeed, references to the use of a.c. bias do not begin to appear in British Patents until the 1940s. Patent No. 535927 (1940) in the name of Electrical Research Products Inc., for example, describes the use of an a.c. bias "of a higher frequency than that used for erase purposes and lower intensity". And in Patent No. 596796 (1944) in the name of Armour Research Foundation (of the Illinois Institute of Technology) an arrangement of side-by-side erase and playback/record heads were proposed, a high frequency alternating current being passed through the erase head during recording for bias purposes. Also in the name of Armour Research Foundation, Patent No. 617773 (1944) suggested the use of a 16kc/s bias signal. In the early 1940s much work was done on a.c. bias by Marvin Camras at the Armour Research Foundation and this resulted in the development of efficient recording machines which were used by the U.S. troops during World War II. On the domestic scene probably the first commercial use of a.c. bias was in a stereophonic recording machine displayed at the New York World Fair in 1939. The German *Magnetophon* was also found to operate better when using a.c. bias and apparently this was discovered by accident in 1940 when a faulty recording amplifier broke into oscillation.

Other electronic ideas proposed during the 1930s and 1940s for improving quality include: Patent No. 624638 (1946) which relates to FM recording using a 15 to 20kc/s carrier; Patent No. 636017 (1948) relating to a system of negative feedback of distorted signals; and 456573 (1936) which describes an erase circuit which is triggered during recording pauses so as to reduce background noise during silent periods.

Until quite late in the development of magnetic recording, the recording process was carried out with the magnetic flux running crosswise to the wire or tape, and the recording head was, like Poulsen's original recording head, simply a metal core in a coil pressing against the recording medium. Patent No. 596796 (Armour Research Foundation, 1944), already mentioned, for example, describes the use of a head having a pole piece with a V-shaped groove in one end which is pressed against a recording wire. For better quality at lower speeds a system involving recording along the length of the wire of tape was required.

Various suggestions for longitudinal recording were made, as, for example, Patent No. 354618 (1930) in which Stille's Telegraphie Patent Syndikat described an arrangement of two recording poles positioned on opposite sides of a recording wire and slightly staggered so as to give a recording flux along the length of the wire. And in Patent No. 429987 (1934), a modern-style recording head is described in the form of a ring with a narrow gap filled with a shim of insulating material.

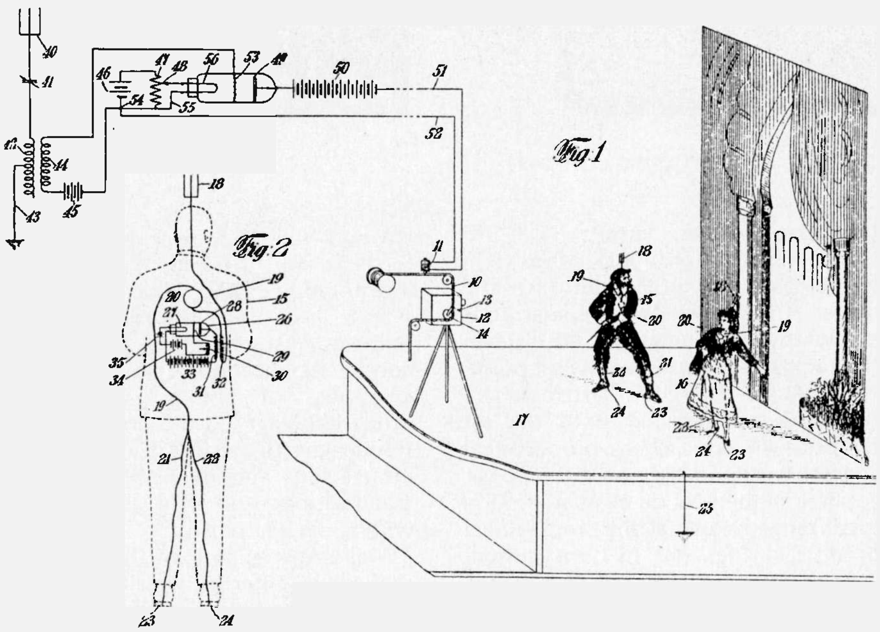
Present day development of recording/play-back heads and associated parts has reached the stage where multi-track cassette recorders are commonplace. In fact, however, neither the idea of multi-track recording nor the idea of using cassettes are particularly new. Patent No. 586390 (1943), for example, describes an aeroplane flight recorder using a broad tape and mulitple side-by-side heads. And, so far as cassettes are concerned, Patent No. 236237 (1924) relates to a cassette with a recording wire running between side-by-side spools, Patent No. 609766 (1946) describes a wire



British Patent No.328721 (1929). Recording phonographic records from a magnetic tape master. A second playback head is provided to give an echo effect.

sette which includes the record/ y-back head as well as the spools and wire, and Patent No. 612689 (1946) describes a wire cassette with the spools one on top of the other.

Initially, the big problem was that of producing a magnetic recorder which was competitive in terms of quality with phonographic machines. But once this problem had been overcome, magnetic recorders came into their own due to their important advantages in other respects. Ironically one very important use of magnetic recording machines, arising out of the great ease with which magnetic recordings can be altered by erasing, over-recording and so on, became that of making 'masters' in the manufacture of phonographic records. This technique is described, for example, in Kurt Stille's Patent No. 328721 (1929). This Patent and also Stille's



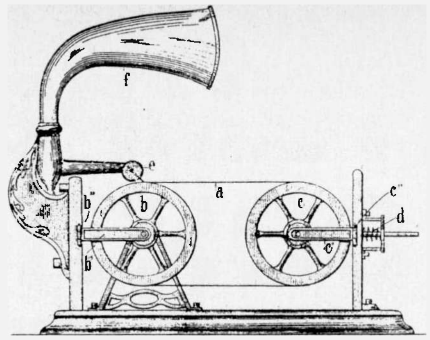
British Patent No.107167 (1917). Magnetic recording techniques used in cinematography. Each actor has a microphone and portable transmitter. The transmitters have rather prominent aerials and are earthed via connections on the actors feet and a conductive stage.

earlier Patent No. 325699 (1929) describe another important use of magnetic recorders: the production of an artificial echo using two spaced playback heads.

Suggestions for the use of magnetic recorders were by no means restricted to the entertainments industry and indeed Poulsen's original telegraphone Patent describes the recording of telephone messages and the play-back of prerecorded messages using a magnetic recorder linked to a telephone answering mechanism. Pedersen's Patent No. 888 of 1900 also relates to the use of magnetic recording techniques in telephone systems. In this Patent an arrangement is described with which a number of telephone messages can be transmitted simultaneously along a single wire. At one end, messages are recorded on a spinning magnetic disc with separate heads spaced around the edge of the disc. The messages are read off using a single play-back head and the disc is then erased. The play-back head is connected to the line wire and at the other end the interlaced sequential signals are decoded with a similar arrangement of a spinning disc with a single record and mulitple play-back heads.

Despite these proposals, there was still however a long way to go to catch up with the range of uses which had been suggested for the *phonograph.* These suggested uses included talking dolls and other toys, speaking clocks, speak-your-weight machines, and so on. Patent No. 2856 of 1900 describes a combined cigar cutter and *phonograph*, the *phonograph* playing a pre-recorded advertising message whenever the cigar cutter is operated. Patent No. 2857 of 1900 describes a *phonograph* connected up to a door so as to play a message when the door is opened. And Patent No. 18637 of 1900 relates to a juke box using phonographic cylinders. Fertile Victorian and Edwardian minds knew no bounds when it came to thinking of uses for the *phonograph.* And also when it came to concealing its use: Patent No. 10697 of 1906 describes a *phonograph* concealed in an artificial potted plant, acoustic horns being disguised as leaves!

The field of use for both phonographic and magnetic recording techniques which was probably of most interest to inventors was that of 'talking pictures'. The idea of synchronising sound with vision was



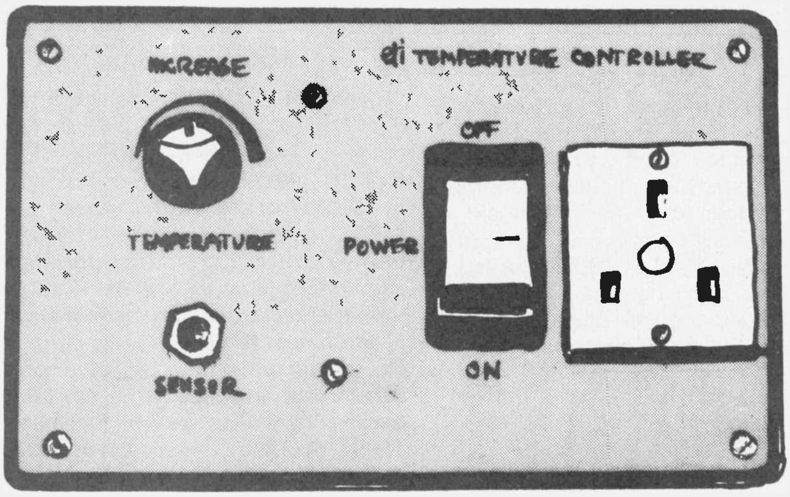
British Patent No.21789 of 1907. An early phonographic tape recorder.

thought of at an early stage in the development of moving picture technology. Patent No. 15709 of 1892, for example describes the combination of a *phonograph* with a screen projected *zoetrope* (an early form of moving picture device using drawings); and Patent No. 13143 of 1898 describes the use of a *phonograph* with a *Kinetoscope* (Edison's early form of cinematograph). The use of a sound strip along the side of a cinematograph film is described in Patent No. 18057 of 1906, the record/play-back technique used being of a photographic nature. In Patent No. 12260 of 1914, the idea of using a magnetic recording strip along the side of the film appears, the strip in this case being a steel band, and Patent No. 342755 (1929) describes a magnetic recording strip from magnetic granules. In the 1930s however these methods were ousted by a system, as is described for example in Patent No. 403164 (1932) in the name of J. A. Miller, which involves the production of a variable transparency track along the side of a film by cutting away variable amounts of an opaque layer with a recording 'chisel'. The recording is played back with a light source and photoelectric cell.

The development of magnetic recording technology took a long time to get going. Poulsen constructed his first working wire recorder in the 19th century but it was not until World War II that magnetic recording machines were really taken seriously. Now, of course, high quality tape recorders are readily available and magnetic recording techniques are used in a wide range of applications. In 1965, for example, pictures were transmitted back from Mars via tape recording equipment.

Whilst many practical developments in the field of magnetic recording are of very recent origin, it is well worth bearing in mind old Patents, such as Patent No. 288680, which show that whilst the practical developments may well be new the ideas are often not. This old Patent, dating from 1929, describes a video tape recording system with which sound signals and also television video signals can be recorded on the same tape. ●

TEMPERATURE CONTROLLERS



Three temperature controls — phase control, zero crossing (on/off), zero crossing proportional.

MANY scientific experiments depend upon the maintenance of a stable temperature — often, as with pathological specimens, over long periods of time.

Even the cheapest of useable laboratory ovens and water baths must therefore incorporate a controller capable of maintaining temperatures constant to better than 1°C — in fact many will better this by a factor of at least two.

Other applications of temperature controllers include processing of colour film on an industrial scale where large quantities of water must be held to close temperature limits, maintaining air temperature constant in chicken hatching or even just controlling a room heater in the home.

The accuracy required and the heating power necessary will depend very much on the application, and thus there is no such thing as a universal temperature controller. In this article we describe three different temperature controllers which will cover the majority of applications. They are all designed primarily for use with a thermistor as the sensor and all may be constructed on the one basic printed circuit board. They have been specifically designed to operate with an isolated thermistor thus simplifying installation and minimizing risk of shock.

CONTROL METHODS

Temperature controllers may be of two basic types, simple ON/OFF control and proportional control. In the simple ON/OFF controller the heater is ON when the temperature is below the set point, and OFF when the temperature is above the set point.

Unlike the ON/OFF system where full power is applied until the set temperature is reached, proportional control continuously varies the power applied to the heating element (over a small range known as the proportional band see Fig. 1) by an amount depending upon the deviation of the actual temperature from the required temperature.

Solid state controllers — apart from having either ON/OFF or proportional control — may be categorized as using either phase control, or zero-voltage switching techniques.

PHASE CONTROL

Phase control is a technique used to control the average power input to a load by varying the time during which current is allowed to flow in each half cycle of mains supply. This is possible by using a triac (or back to back SCRs) between the load and the mains supply. A triac may be triggered into conduction by a pulse on its gate at any time during the half cycle, and then remains conducting for the remainder of the half cycle. Thus by controlling the time at which the trigger pulse occurs, with respect to the commencement of the half cycle, we may set the power input to the load at any desired level. This is illustrated in Fig. 2.

This type of control, although inherently suitable for proportional control applications, generates large amounts of radio interference, primarily at low and medium frequencies (up to 3 MHz). It seriously affects long and medium wave radio transmissions and may also interfere with audio equipment.

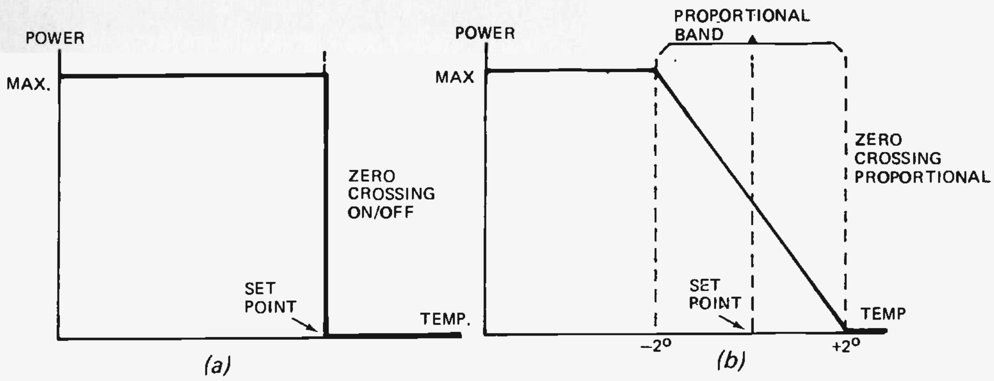
Whilst the extent of RFI may be reduced by filtering, the size of chokes required for large loads — such as heating systems — becomes excessive.

Phase control also introduces another problem — that of bad power factor. This is difficult to compensate for as the power factor changes with control setting. Some supply authorities object to this quite strongly, and others ban phase control completely.

The use of phase control should therefore be restricted to light-load applications requiring only a few hundred watts, even though potentially it is the best control system of all.

ZERO VOLTAGE SWITCHING

Zero voltage switching overcomes most of the problems inherent in phase control systems. The technique differs from phase control in that the supply is switched to the load *only* as the ac waveform passes through zero, eliminating RFI.



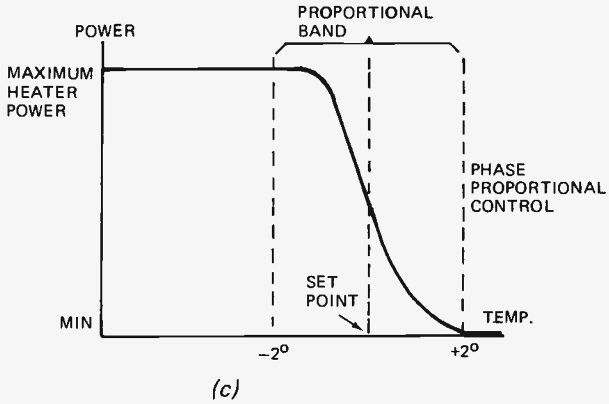


Fig. 1a. In straight on/off control the heater is ON when the load is below the set point temperature and OFF when it is above.
1b. In zero-crossing proportional control the heater power is varied linearly over a small temperature range known as the proportional band.
1c. In phase-proportional control the same proportional band is used but the control curve follows a cosine law. (Power proportional to phase angle of firing point).

In straight ON/OFF zero crossing control the power is switched "ON" when the temperature is below the desired set point and "OFF" when the temperature reaches the set point. Whilst very accurate control is possible with this method, the size of heater must be carefully selected to suit the thermal inertia of the system. Too large a heater will produce large overshoots hence this system should be used only where the load has large thermal inertia, or where the heater is selected to provide only 25% or so more heat (at full output) than is dissipated by the system through losses. In such a system the heater will switch on and off at a fairly rapid rate allowing bursts of complete half cycles to flow. The ON/OFF switching always occurs at the zero crossing point.

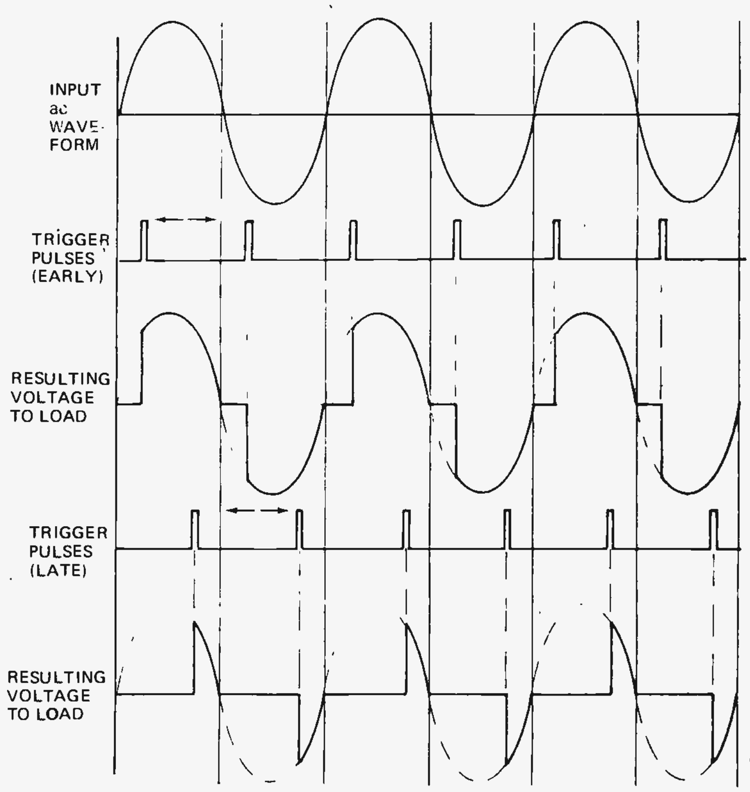


Fig. 2. In phase control the time relationship of the trigger pulse is varied to control the amount of power delivered in each half cycle.

In zero-crossing proportional control the control system varies the amount of power delivered within a set time period, eg 1 or 10 seconds, by sweeping the control voltage over a small range. Using this method the average power delivered by the heater is smoothly varied within the proportional band.

Again the zero-crossing mode ensures that little RFI is generated. The method relaxes the requirement for selection of the heater to a considerable extent but accuracy is not necessarily as good as with straight ON-OFF control.

CONSTRUCTION

Construction of the controllers will vary considerably depending on the application. We built a phase control unit into a box as shown in the photograph. However it may be more practical, where a particular device (oven etc) is to be controlled, to build the electronics into the controlled system.

Most, if not all, of the ICs manufactured for phase or zero-crossing control have the thermistor at mains potential and the thermistor must therefore be insulated in some manner for most applications, this is often quite difficult to do — especially for home constructors, consequently the ETI controller circuits have been designed such that the thermistor is completely isolated from the mains. It is only necessary to protect it with a sheath etc, when used for monitoring such things as liquids.

The triac itself should be mounted on a heatsink. In our prototype we mounted the triac on the front panel. Remember however that the triac must be carefully insulated electrically from the heatsink, and the heatsink triac assembly should be mounted in a cool place.

Pulse transformer T2 may be constructed as per the winding details in Table 4. It is essential that adequate insulation be provided over the ferrite rod (some ferrites are conductive) and between the primary and secondary windings.

Choke L1 is only required in the phase-control circuit and this too must be carefully insulated.

Where a box is used to house the assembly care must be taken to earth all exposed metal surfaces including screws. The mains earth should be secured under a single screw provided for this specific purpose. In our case the mains earth was made direct to the front panel.

Finally take care with the polarization of components on the printed circuit board. Also ensure that reference is made to the *correct* overlay for the type of controller used.

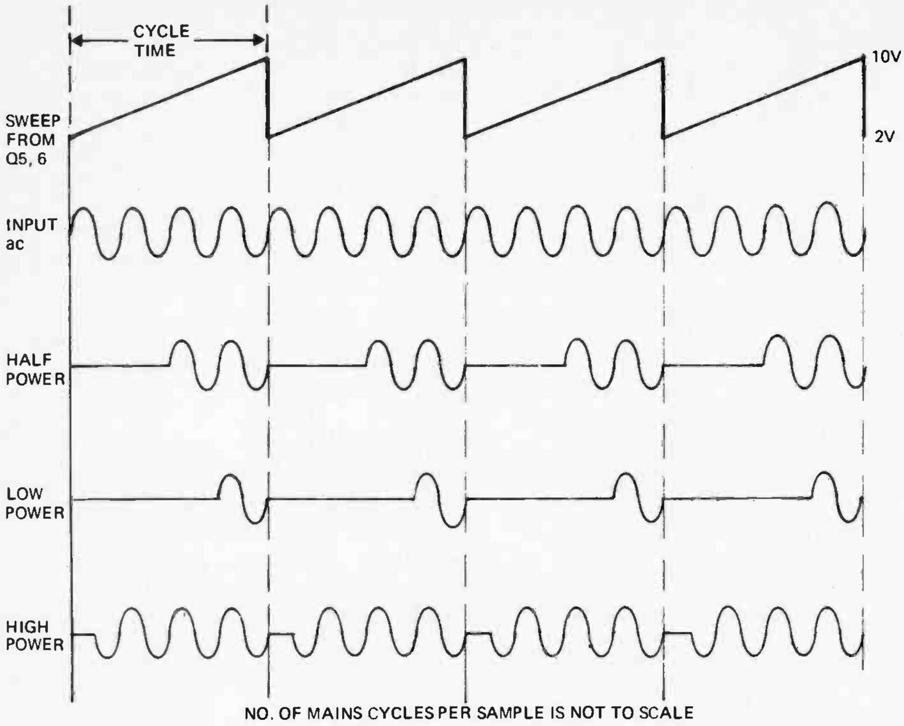


Fig. 3. The sweep voltage (a) is used to obtain a fixed cycle time. When the load has reached a temperature within the proportional band, the controller will vary the number of complete, half cycles within the time period in order to maintain the correct temperature. Note that in a typical system the cycle time may contain 50-500 cycles of mains, not four as shown.

TEMPERATURE CONTROLLERS

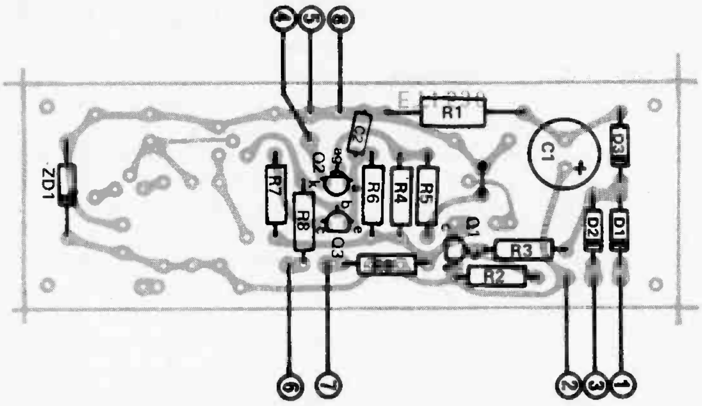


Fig. 5. Component overlay for the zero-crossing controllers. Note that for ON/OFF control some components are not fitted (refer Fig. 4).

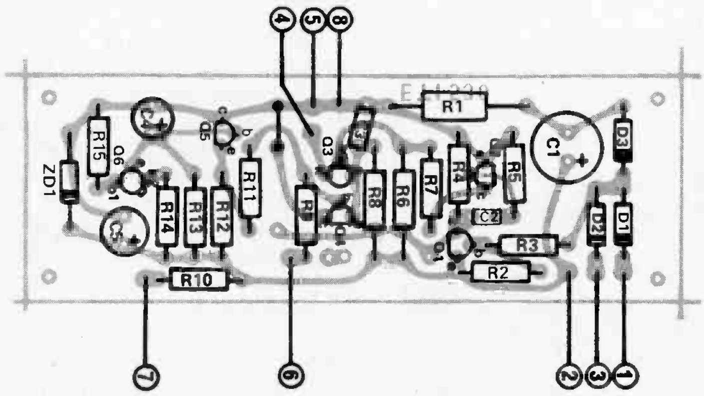


Fig. 6. Component overlay for the phase-proportional controller.

HOW IT WORKS

THERE are three different methods of control.

(a) Zero crossing control.

(b) Zero crossing proportional control.

(c) Phase control.

All three methods use the same power supply and synchronization method, that is the circuitry to the left of Q1. Up to this point only, component numbers are identical for all circuits.

Transformer T1, together with diodes D1 and D2 provide a full-wave rectified 100 Hz that is negative going with respect to terminal 2 of the transformer. This charges C1 via isolating diode D3 to about 21 volts peak (typically 20 volts when loaded). From this supply resistor R1 together with zener diode ZD1 generate a stabilized 15 volts supply for the triggering circuit.

The negative going 100 Hz waveform at the junction of D2 and D3 is applied to divider network R3 and R2. Thus Q1 will be turned on whilst ever its base is 0.6 volts negative with respect to its emitter. Hence at the collector of Q1 a narrow negative going pulse will be generated every 10 milliseconds that is centred around the zero-crossing point of the mains waveform.

ZERO CROSSING CONTROL

The synchronization pulse from Q1 is passed via C1 to the base of Q2. The positive going edge of the pulse turns Q2 on producing a negative going pulse at the collector of Q2. Thus at the junction of R6 and R7 there will be a pulse which drops from 15 to 7.5 volts just after each zero crossing. This pulse is passed to the gate of the programmable unijunction transistor Q3 (PUT). The PUT has the characteristic that it will fire only when the anode is more positive than the gate. Thus the anode must be higher than 7.5 volts if the PUT is to fire. Capacitor C3 is charged via R8 but transistor Q4 does not allow C3 to charge beyond the voltage at the base of Q4 plus 0.6 volts. If C3 does not reach 7.5 volts, therefore, the PUT cannot fire and the heater will be off.

Thermistor TH1 is chosen such that, at the working temperature, its resistance is equal to the combined value of R10 plus RV1 (set at mid point). If the temperature falls the resistance of TH1 will rise and the voltage at Q4 base will rise, and, if the temperature increases the resistance of TH1 drops and the voltage at Q4 base drops. That is the thermistor has a negative temperature coefficient.

Thus the voltage to which C3 is allowed to charge (as clamped by Q4) is dependant on temperature. When the temperature falls below the set more and this voltage at the anode of the PUT will allow the pulse at the gate of the PUT to fire it discharging C3 through the pulse transformer T2 thus in turn firing the triac. The triac continues to fire on each half cycle until the temperature rises above the set point.

Thus the heater will be on when the temperature is below the set point and off when the temperature is above the set point. Additionally switching occurs very close to the zero crossing point of the mains ensuring that little RFI is generated.

ZERO CROSSING PROPORTIONAL CONTROL

In the zero-crossing proportional mode unijunction transistor Q6 produces a sawtooth waveform with a period depending on the value of C4. With 100μF this period will be approximately 10 seconds and with 10μF approximately 1 second. This waveform is buffered by Q5 and then passed via R11 to the base of Q4. The effect of this voltage is to sweep the voltage to which C3 is clamped over a time period selected by C4 and over an amplitude (proportional band) determined by R11. Thus the temperature of TH1 will determine at what point in each sweep the triac turns on. Hence the triac turns on for a number of half cycles in each sweep, that is, for a *time* in each sweep inversely proportional to the temperature sensed by TH1. Switching still occurs at the zero-crossing point and RFI is therefore minimal.

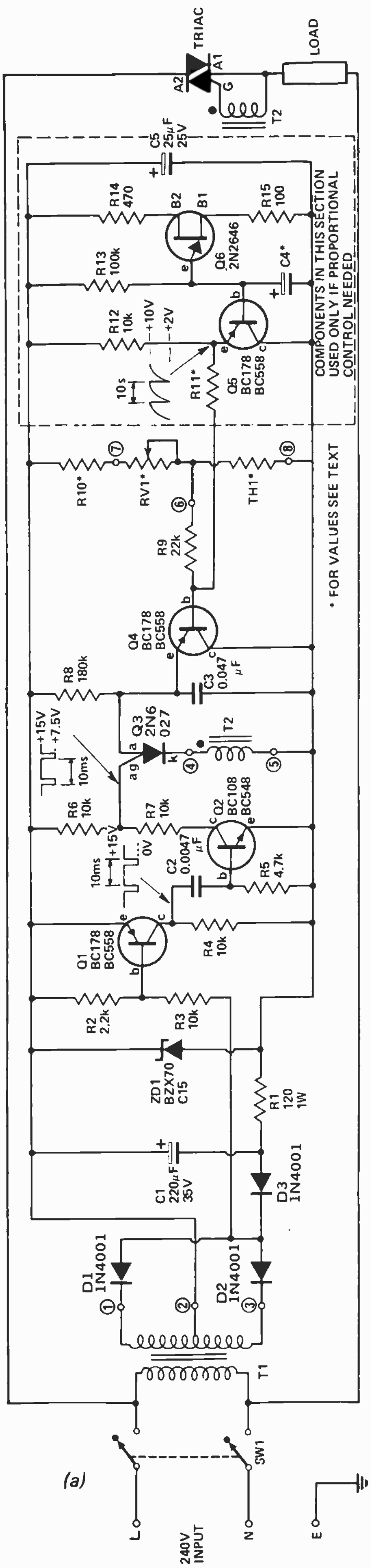
PHASE CONTROL

In the phase control circuit Q1 will turn off for a short period centred around the zero crossing point of the input ac waveform. Thus the voltage at the junction of R4 and R5 will fall to zero at the crossing point and then rise to 7.5 volts for the remainder of the half cycle. Additionally the pulse at the collector of Q1 is fed to the entire timing circuit (including the thermistor) and synchronises firing to the mains.

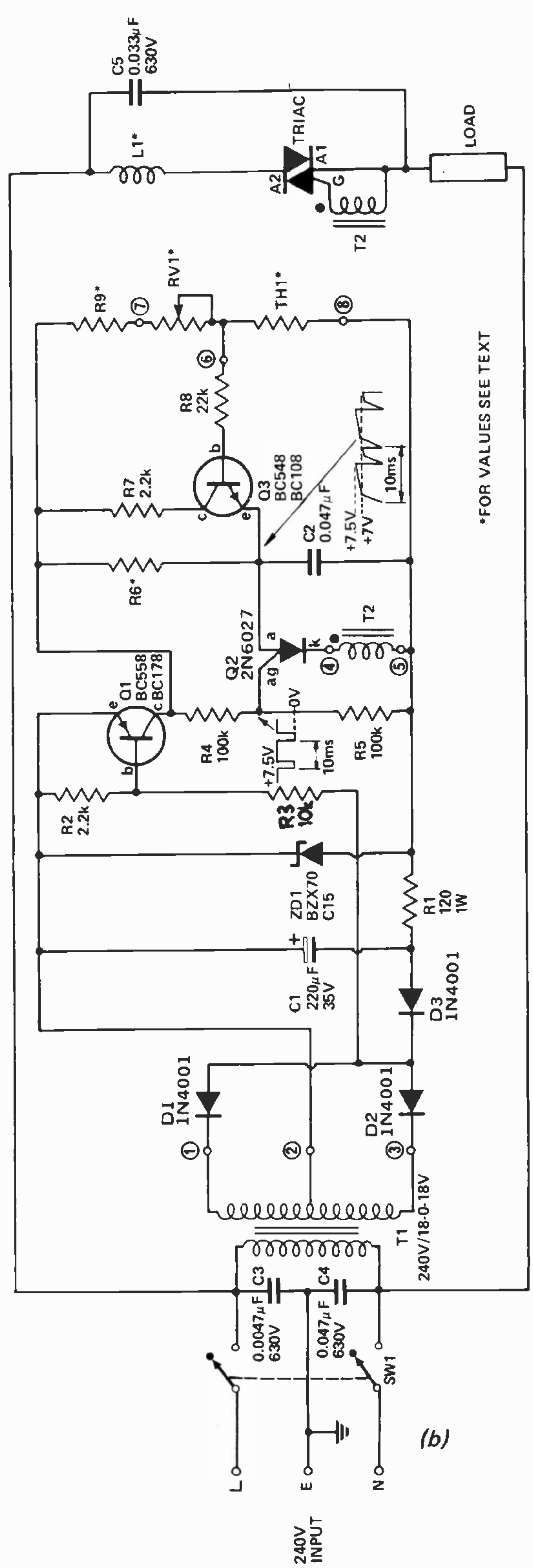
Capacitor C2 will charge rapidly via Q3 and R7 until the voltage at Q3 emitter reaches 0.6 volts less than that at its base. Capacitor C2 will continue to charge thereafter at a slower rate determined now by R6 (1 to 10 megohm) until such time as the voltage at the anode of the PUT exceeds that on the gate. When this occurs the PUT will fire discharging C2 through the pulse transformer and gating the triac on as before.

Thus the triac will be switched on for a period within each half cycle and this period will be inversely proportional to the temperature sensed by TH1.

This last mode of operation generates radio interference and capacitors C3, C4 and C5 and choke L1 are 'incorporated in the circuit to minimize this'.



(a)



(b)

Fig. 4a. Circuit diagram of the zero crossing controllers. Those components within the dotted box are fitted if proportional control is wanted.
4b. Circuit diagram of the phase-proportional controller.

THE RESISTANCE of a thermistor at any temperature may be calculated from the formula

$$R = Ae^{\beta/T} \quad \ldots\ldots\ldots\ldots 1$$

where A = a constant
e = base of Napierian logs (2.718)
β = slope factor
T = temperature deg K.

and from the above resistance versus temperature change.

$$\Delta R = A\,(e^{\beta/T_1} - e^{\beta/T_2}) \ldots\ldots\ldots 2$$

The values of R6 (phase control circuit) and R11 (zero crossing proportional) must be selected to obtain the desired proportional band. These values will depend upon the characteristics of the thermistor used and may be calculated as follows.

Firstly the thermistor should be selected to have a value between 4.7 k and 100 k at the desired working temperature. This value may be found by use of the graphs, if available, or calculated using equation 1 and the data provided for the particular thermistor.

Resistor R9 (or R10) should be chosen to equal 0.9 of the resistance of the thermistor at the maximum working temperature and R9 + RV1 should equal 1.1 times the resistance of the thermistor at the minimum working temperature.

Having selected a thermistor it is then necessary to determine the resistance change over the desired proportional band.

For example assume we select the 330 k 0.6 watt standard rod type to operate at a working temperature of 70°C and a proportional band of ±2°C.

Then from equation 2.

$$\Delta R_{TH} = 0.25\,(2.718^{\frac{4200}{341}} - 2.718^{\frac{4200}{345}})$$

$$= 7432$$

From equation 1

$$R_{TH} = 0.25\,(2.718^{\frac{4200}{343}})$$

$$= 51979 \text{ ohms}$$

Now we must determine the voltage change at point 6 as follows.

$$\Delta V = \frac{\Delta R_{TH}}{R_{TH}} \times 7.5$$

$$= \frac{7432}{51979} \times 7.5$$

$$= 1.07 \text{ volts}$$

For the phase control circuit we may now calculate R6 from:–

$$R6 = \frac{1.5 \times 10^6}{\Delta V}$$

$$= \frac{1.5 \times 10^6}{1.07}$$

$$= 1.4 \text{ M say } 1.5 \text{ Meg}$$

For the zero crossing circuit we may calculate R11 from:–

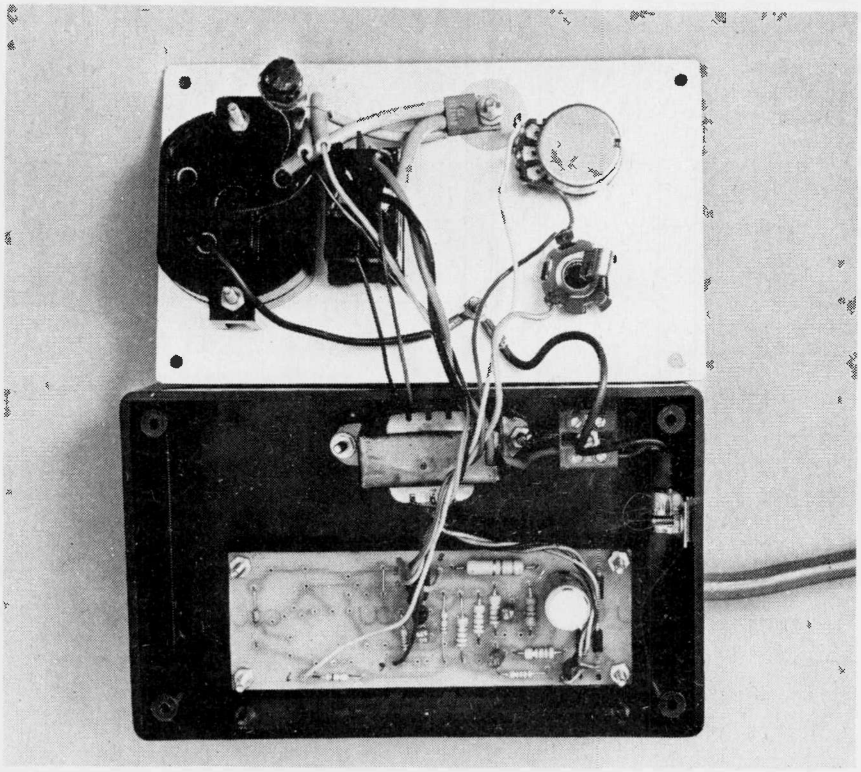
$$R11 = \frac{8 \times (\frac{R_{TH}}{2} + 22\text{ k})}{\Delta V}$$

where R_{TH} and ΔV are as determined above.

$$\text{Thus } R11 = \frac{8\,(25989 + 22{,}000)}{1.07}$$

$$= 358{,}800 \text{ ohms}$$

say 330 k



Internal construction of a typical controller. Note that board is assembled as phase-control version, triac is insulated by mica washer and mounting bush from front panel. Note also pulse transformer is epoxied to front panel at top left.

The thermistor used in the above example has the following spec:

A = 0.25

B = 4200

To convert °C to °K add 273°.

WINDING DETAILS TABLE 4

Pulse Transformer

Former 25mm of 8.0mm or 9.6mm diameter ferrite rod.

Primary 30 turns, single layer close wound of 0.25mm enamelled copper.

Secondary 30 turns, single layer close wound of 0.25mm enamelled copper.

Insulation between primary and secondary and over core – 4 layers of cellulose tape.

Bring out leads for primary and secondary at opposite ends of transformer.

Choke L1

Former 50mm of 8.0mm or 9.6mm diameter ferrite rod.

60 turns single layer close wound of 0.63mm enamelled copper.

Insulate former and over winding with plastic insulation tape.

PARTS LIST – ETI 530 A

Zero Crossing (ON/OFF)

R1	Resistor	120	1 watt	5%
R2	"	2.2k	½ watt	5%
R3,4,6,7	"	10k	½ watt	5%
R5	"	4.7k	½ watt	5%
R8	"	180k	½ watt	5%
R9	"	22k	½ watt	5%

C1 Capacitor 220 μF 35 volt electrolytic
C2 Capacitor 0.0047μF polyester
C3 Capacitor 0.047 μF polyester

D1,2,3 Diode 1N4001 or similar

ZD1 Zener Diode BZX70C15 or similar.

Q1,4 Transistor BC178, BC558 or similar
Q2 " BC108, BC548 or similar
Q3 " 2N6027 (PUT)
TRIAC SC146D or similar

T1 Transformer 240/18-0-18 volt

T2 Pulse transformer see text.

SW1 Switch DPST 240 volt ac 10 amp.

R10,RV1, TH1 are selected as detailed in text. Suitable box, heat sink for triacs, outlet socket, nuts, bolts, power cord and plug. Printed circuit board and 4 off 8mm spacers.

PARTS LIST – ETI 530 B

Zero Crossing (proportional)

All parts for ETI 530 A plus the following.

R11 selected as per text.

R12	Resistor	10 k	½ watt	5%
R13	"	100 k	½ watt	5%
R14	"	470	½ watt	5%
R15	"	100	½ watt	5%

C4 Capacitor selected as per text.
C5 " 25 μF 25 volt electrolytic

Q5 Transistor BC178, BC558 or similar
Q6 Transistor 2N2646 (unijunction)

PARTS LIST ETI 530 C

Phase Control

R1	Resistor	120	1 watt	5%
R2,7	"	2.2k	½ watt	5%
R3	"	10k	½ watt	5%
R4,5	"	100k	½ watt	5%
R8	"	22k	½ watt	5%

C1 Capacitor 220μF 35 volt electrolytic
C2 " 0.047μF polyester
C3,4 " 0.0047μF 630 volt polyester
C5 " 0.033μF 630 volt polyester

D1,2,3 Diode 1N4001 or similar
ZD1 Zener Diode BZX70C15 or similar
Q1 Transistor BC178, BC558 or similar
Q3 " BC108, BC548
Q2 " 2N6027 (PUT)
TRIAC SC146D or similar
T1 Transformer 240/18-0-18 volt
T2 Pulse Transformer see text.
L1 Choke (see text)
SW1 Switch DPST 240 volt 2 amp

R6, R9, TH1 and RV1 selected as detailed in text. Suitable box, heat sink for triac outlet socket, nuts, bolts, power cord and plug. Printed circuit board and 4 off 8mm spacers.

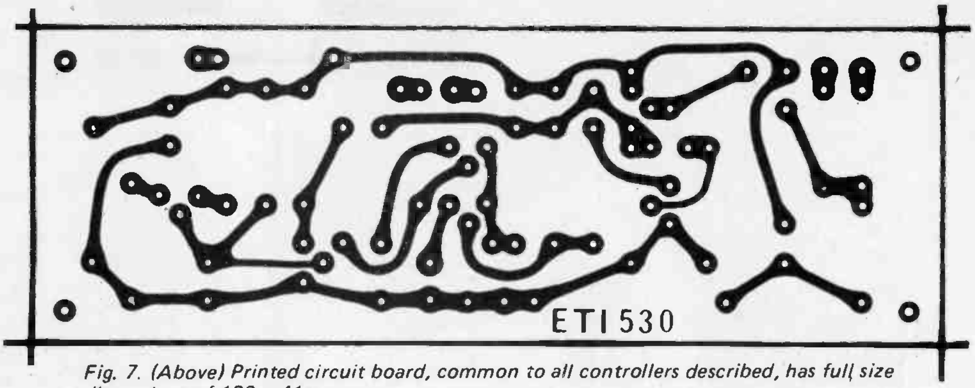


Fig. 7. (Above) Printed circuit board, common to all controllers described, has full size dimensions of 120 x 41mm.

GETTING A SUITABLE THERMISTOR

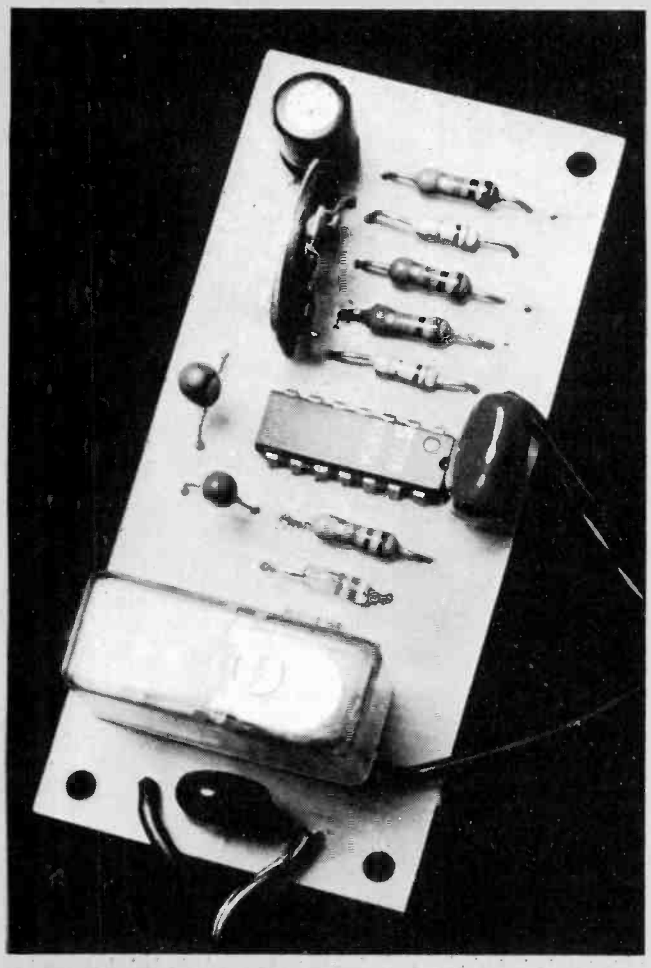
There are three main types — rod, disc and bead thermistors. The bead types are low power devices best suited for control circuits. However the disc and rod types are cheaper and easier to obtain. Brimistors are broad tolerance rod thermistors usually used in temperature compensation circuits.

Essentially one needs a thermistor with a negative temperature coefficient and a resistance between 4.7k and 100k at the working temperature. When buying the component be sure to get a data sheet. Some suppliers give the constant 'A' but this can be calculated from the resistance value at a specified temperature.

Looking through the catalogues you will find Electrovalue and Marshalls do the Mullard range VA1066s, VA1055s and VA1056s (with respective specs: B = 3250, 3550 and 3925; and R at 25°C of 4.7k, 15k and 47k). These are rod types and cost around 16p-20p. Electrovalue also cover a Siemens range coded K164. At 25°C you can choose from 4.7k, 10k, 22k, 47k and 100k types (with βs of 3930, 4050, 4200, 4450 and 4600).

For about five times the price you can buy glass-encased bead thermistors. ITT make a suitable range. This includes a device for high temperature control, the GL16, it has a resistance of 1M at 20°C dropping to 30k at 100°C. This can be bought from Doram.

eti PROJECT 313 CAR ALARM



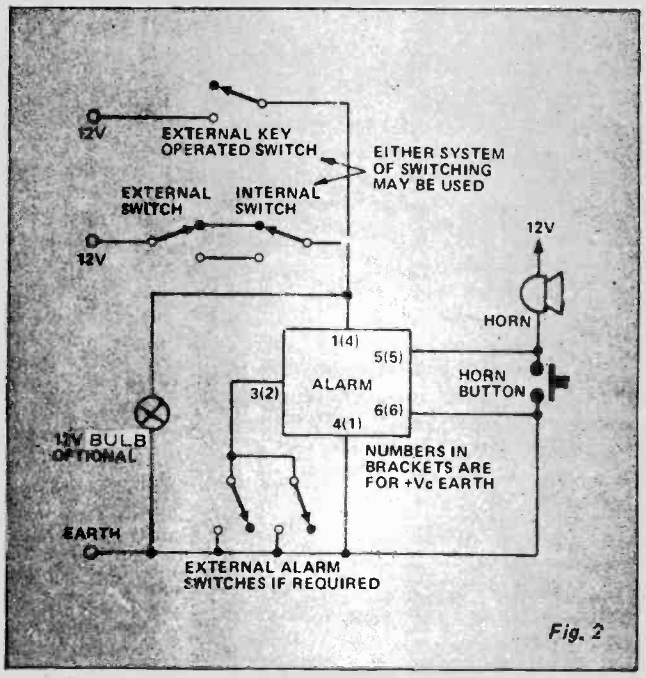


Fig. 2

Protect your car with this simple but effective circuit.

ONE OF LIFE'S more devastating experiences is to walk out of your house in the morning and find that your car has disappeared!

But this need not happen to you, for an effective alarm system, as described here, may be quite easily constructed and installed at low cost.

The ETI 313 car alarm uses one single IC and a minimum of other components. It will, when actuated, blow the horn at one second intervals, and will continue to do so until deactivated by means of a key switch etc.

The alarm is triggered by any drop in the battery supply voltage caused by an increase in loading on the vehicle's electrical system. Thus, if a door is opened, the interior light will be activated and the increase in electrical load will trigger the alarm.

This operating principle simplifies installation, for practically all vehicles have courtesy lights activated by switches on at least two of the doors — and it is a fairly easy task to install further switches on the other doors if required.

Both the boot and under bonnet areas may be protected in a similar manner — indeed many vehicles have lights already fitted in these areas, if not, it is a simple matter to fit them into the circuit such that they come on when the boot lid etc is opened.

These lights are of course very useful apart from their alarm function, but remember — they must operate at all times, not just when the ignition is on.

The alarm is sensitive enough to be activated by anyone pressing the brake pedal — or even by opening the glove box (where a lamp is fitted of course).

The unit is designed for use with cars having 12 volt electrical systems. It may be used with either positive or negative earth systems without modification.

In addition to the power sensing alarm mode other precautions may be

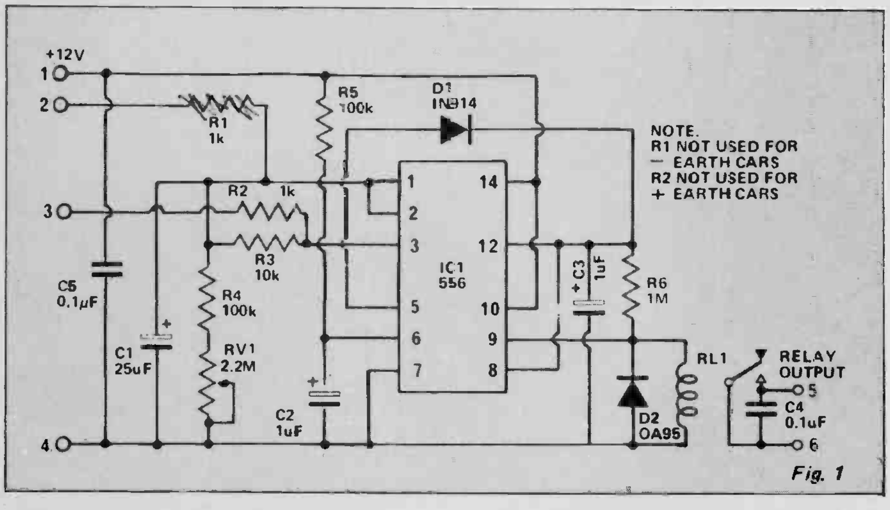


Fig. 1

taken by adding further alarm microswitches. For example microswitches may be fitted to the suspension such that if anyone tries to lift the car, in order to tow it away, the alarm will go off. If such switches are used they should be connected between terminal 2 or 3 of the alarm (see Fig 1 and 2), depending on whether the vehicle has a positive or negative earth system, and earth.

CONSTRUCTION

Construction of the alarm is extremely simple and anyone capable of using a soldering iron should not have any difficulty. All components, including the relay, are mounted on a small PC board as shown in the component overlay diagram.

Note the polarity of electrolytic capacitors, the IC and diodes. In particular make sure that the germanium diode D2 is mounted in the correct position and with the correct orientation. When soldering use a small, light-weight iron and preferably small gauge solder. Solder quickly and cleanly. Only apply the iron for sufficient time to cause the solder to flow around the joint. These precautions will ensure that components are not damaged by excessive heat. The unit should then be mounted in a small plastic, or metal, box.

Two different switching systems may be used to enable the alarm. Use either an external key switch mounted in a convenient, but not obviously seen location, or a two way system of concealed switches – one inside and one outside. The switch inside is used to enable the alarm (after opening the door) and the external one to disable the alarm before entering the car. This latter system has the advantage that anyone watching will not see where the external disable switch is located. ●

HOW IT WORKS

When a load, especially an incandescent lamp, is switched onto a battery the battery voltage will drop instantaneously and then return to normal. The amplitude and duration of this negative going spike in the supply is dependant on the size of the lamp used but is of sufficient amplitude, even with small bulbs, to trigger an alarm circuit.

The NE556 IC contains two NE555 timer ICs in a single case. One of the timer sections is used to detect the supply spike and to gate on the second timer which produces a one Hz output to the relay and horn.

Each timer section contains two comparators, a LOW comparator set at 1/3 supply and a HIGH comparator set at 2/3 supply. These comparators set a flip-flop which provides an output.

When the power is first applied, the voltage at pin 6 (input to the low comparator) is initially low for about half a second whilst C2 charges via R5. This sets the output of the flip-flop to a high state where it will remain regardless of further excursion in the voltage at pin 6.

The only way that the output may be set low again is for the input to the high comparator (pin 2) to be taken past its threshold. This threshold voltage is available at pin 3, and by using a voltage divider (R3, R4 and RV1) a slightly lower voltage is derived from it. This is used as a reference level to the HIGH comparator input (pin 2) Capacitor C1 is used to bypass any fast transients which may appear at the input (pin 2).

If the supply falls, the voltage on pin 3 will also fall. If it falls below the voltage at pin 2, the output will fall again to a low state and will stay there. The capacitor C1 will also be discharged via pin 1.

The second half of the IC is connected as a free-running multivibrator having a frequency determined by R6 and C3, of about 1 Hz. If the output of the first stage is high, the diode D1 will force the multivibrator to lock into the low state. When the output of the first stage goes low the multivibrator is freed to oscillate.

This one hertz output switches a relay which in turn controls the horn, or any other suitable device. The diodes across the relay prevent reverse voltages being generated which could damage the IC. This must be a germanium type for correct operation.

PARTS LIST – ETI 313

R1,2	Resistor	1k ½watt 10%
R3	"	10k ½watt 10%
R4,5	"	100k ½watt 10%
R6	"	1M ½watt 10%
RV1	Potentiometer	2.2 meg
C1	Capacitor	25µF 25 volt electrolytic
C2,3	"	1µF 25 volt electrolytic
C4,5	"	0.1µF polyester
IC1	Integrated Circuit	NE556
D1	Diode	IN914 or similar
D2	Diode	OA95 (must be germanium)
RL2	Relay	12V 100–470 ohm coil, 6A min. contacts.
PC board ETI 313		
SW1	Switch	SPST key operated
SW2,3	"	SPDT toggle (see text)
metal or plastic box to suit.		

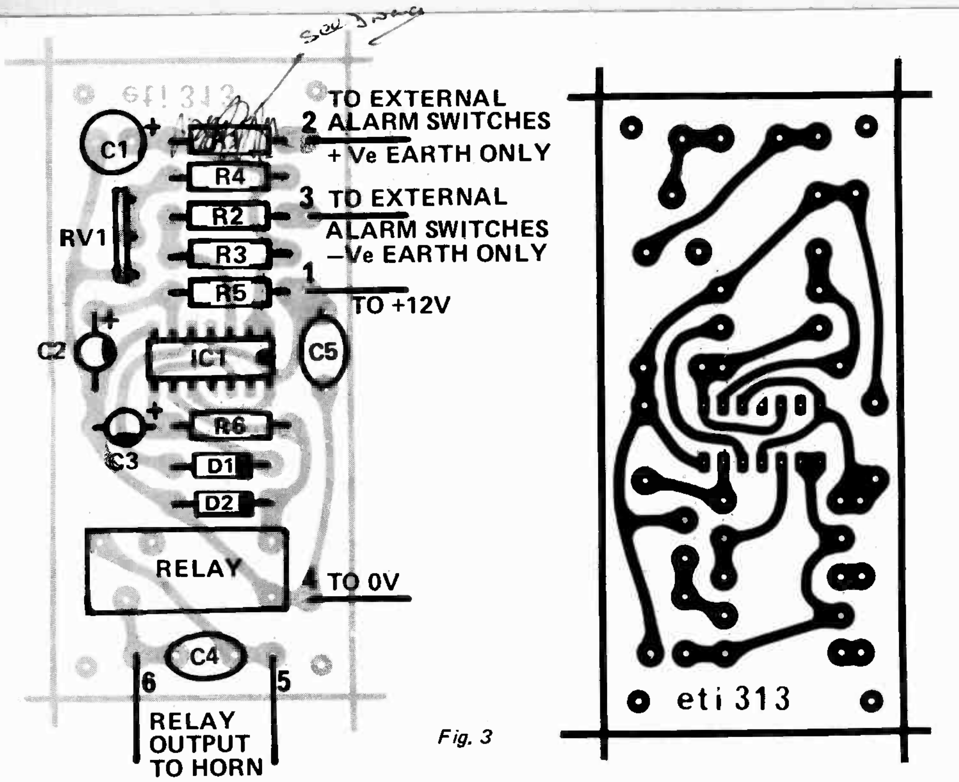


Fig. 3

This PCB will probably have to be altered to suit the particular relay used. (Electrovalue do a 12V 110Ω relay but this will not fit the PCB as shown).

SIMPLE STEREO AMPLIFIER

Ideal beginner's amplifier suits simple record players.

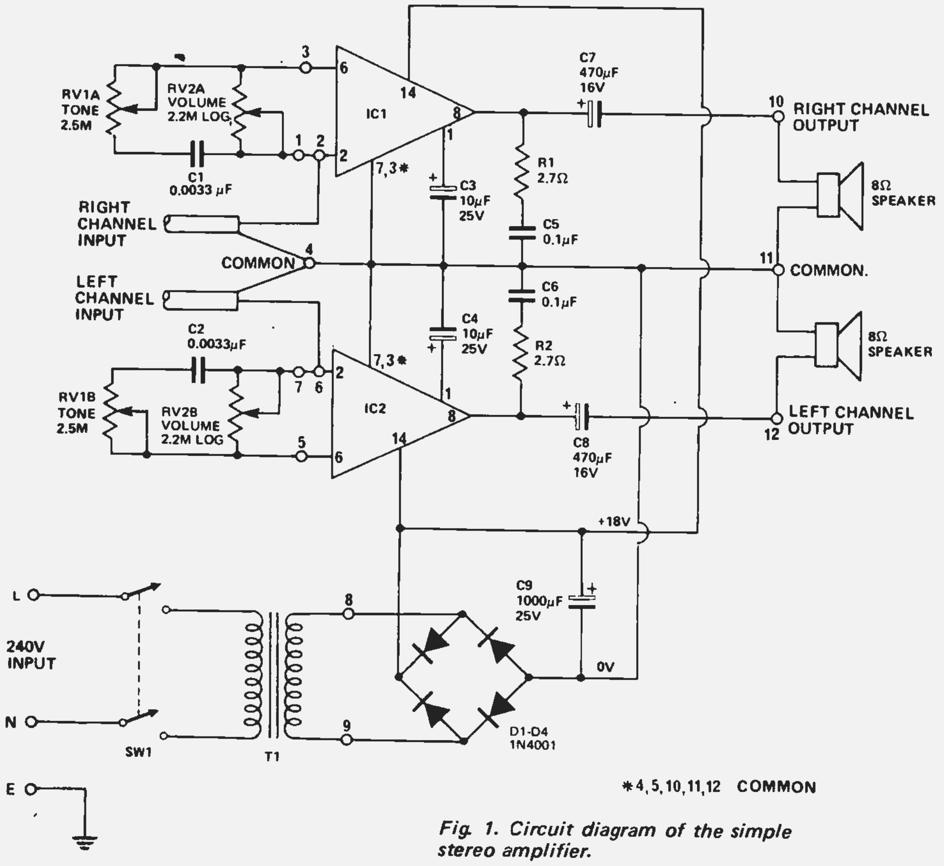


Fig. 1. Circuit diagram of the simple stereo amplifier.

THIS SIMPLE stereo amplifier uses two LM380 IC's and a minimum of external components, it can easily be assembled in only one or two evenings. It is designed to match the *crystal* cartridges found on most simple record players and gives surprisingly good results.

CONSTRUCTION

Check the orientation of the ICs on the PC board with the aid of the component overlay and solder them in position first of all. Next cut four heatsinks from shim copper or tinplate as illustrated in Fig. 3 (a rolled out tin can will do to make these).

Tin the tabs of the heatsinks and solder one to the centre three pins on either side of each IC.

Next mount the four diodes and the electrolytic capacitors, again checking orientation, as these devices are polarity conscious. Use shielded leads for the connections to the pickup cartridge and twisted pairs to the potentiometers.

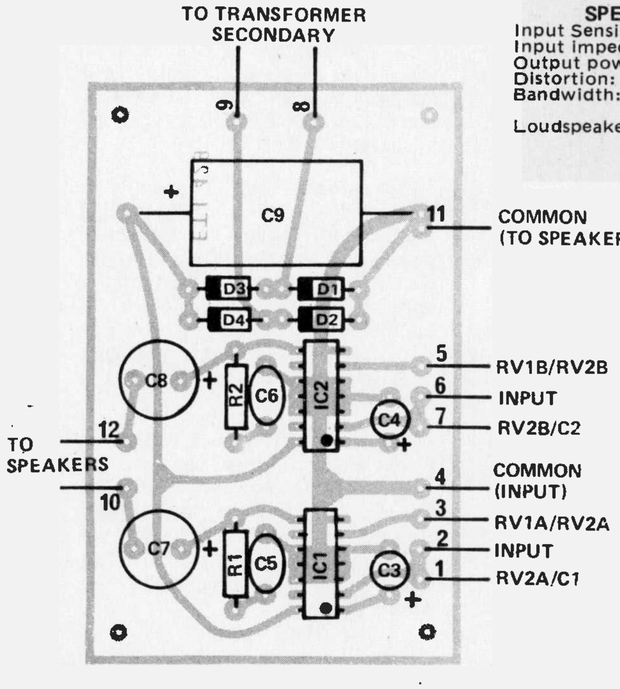
Mounting position is not critical — a general rule of thumb is to keep input circuitry away from strong ac fields such as found close to power transformers and motors. Keep all leads reasonably short and away from moving parts likely to foul them. Additionally keep the power transformer well away from the pickup arm and its signal leads.

If you mount the volume and tone controls as we have, on a wood base board, solder an earth wire to the cases of the pots. This will stop the amplifier buzzing every time you adjust the controls.

For a description of circuit operation, refer to article in our December 1974 issue. ●

SPECIFICATIONS ETI 429

Input Sensitivity:	200mV
Input impedance:	150k
Output power:	2.5W RMS/channel
Distortion:	0.2%
Bandwidth:	100kHz (tone control flat)
Loudspeaker impedance:	8 ohm or 15 ohm



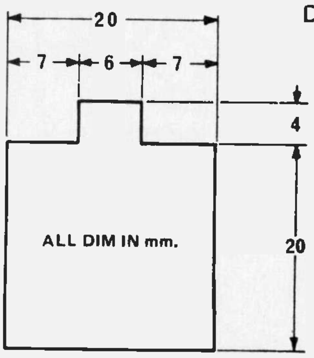


Fig. 3. Dimensions for the IC heatsinks. One is soldered to each side of the IC — to pins 3, 4, 5 and 10, 11, 12.

GETTING THE COMPONENTS

I.Cs. These were the subject of a recent ETI offer but they are easily available from advertisers in this mag.
Pots. Any values in the range 1M-3M will do. We found that Electrovalue catalogued both log and lin pots in 2.2M dual types.
Mains Transformers. The IC will operate with supply voltages up to 22V max., so transformers with up to 15V ac rating will be o.k. There is a 13V 500mA type in the Doram catalogue coded (196—202).
PCBs. See ads of Ramar and TEC.

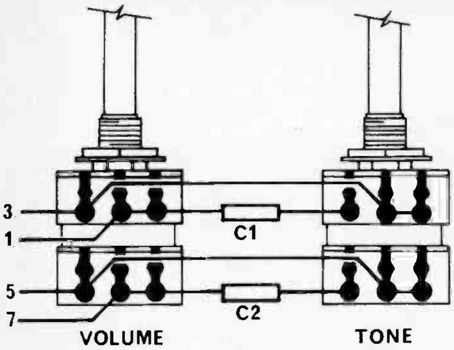


Fig. 4. Wiring to the volume and tone potentiometers.

PARTS LIST ETI 429

R1,R2	Resistor	2.7Ω ½W, 10%
C1,C2	Capacitor	0.0033μF, mylar
C3,C4	"	10μF, 25V electrolytic
C5,C6	"	0.1μF, mylar
C7,C8	"	470μF, 16V electrolytic
C9	"	1000μF, 25V electrolytic
D1,2,3,4	Diode	1N4001
RV1	Potentiometer	2.2M LIN Dual
RV2	"	2.2M LOG Dual
T1	Transformer	240V—12/15V, 500mA
SW1	Switch	DPST 2A 240V
PCB		

Three core mains flex and plug, speakers (8-15 ohm), hookup wire, knobs, 3 way mains terminal strip.

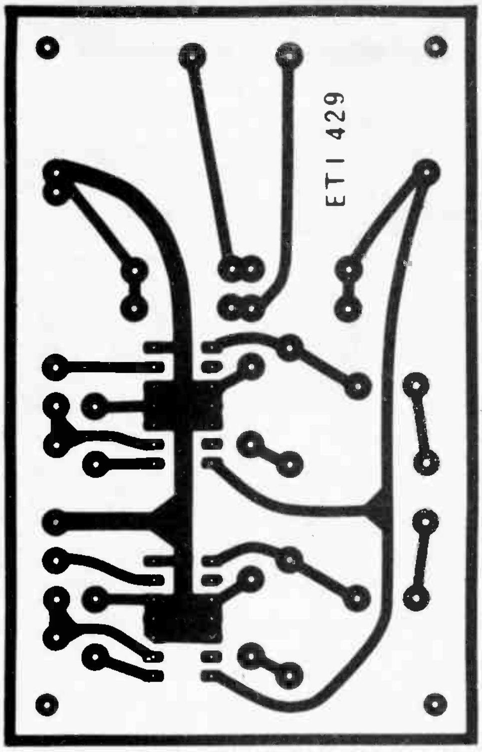
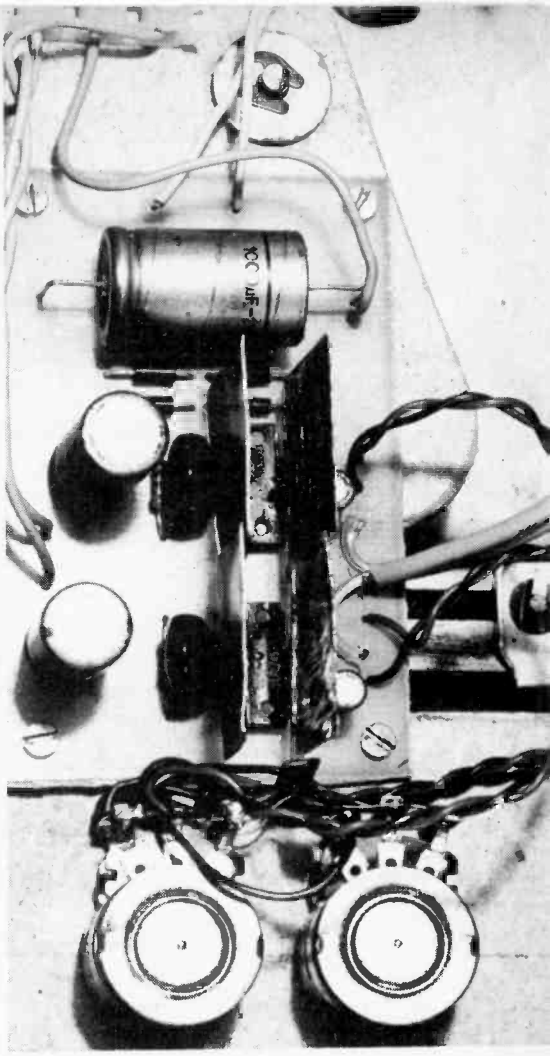


Fig. 5. Printed circuit board. Full size 97 x 61mm.



The completed amplifier fitted below a conventional record player. Transformer (not shown) is mounted well clear of signal leads.

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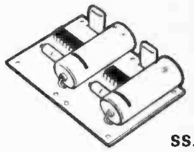

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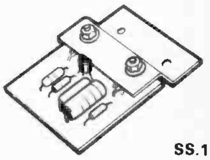

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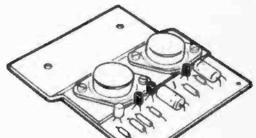

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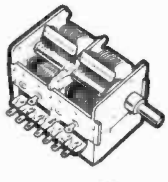

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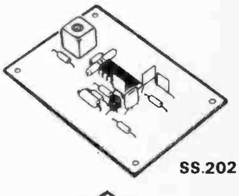

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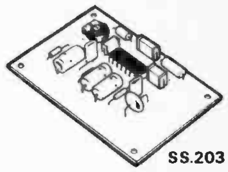

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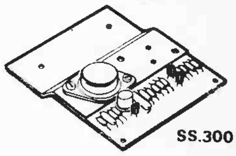

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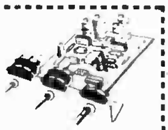

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USING THE LM3900N

THE LM3900N QUAD AMPLIFIER

ONE OF THE MOST noticeable trends in modern electronics is for more and more components to be packed into smaller and smaller spaces. One example of this trend is the fairly new LM3900 device which is manufactured by the National Semiconductor Company. It contains four separate internally compensated amplifiers in a single 14 pin dual-in-line encapsulation.

All four amplifiers are fabricated on a single silicon chip. Each amplifier contains seven transistors, a diode and a capacitor, whilst other internal components are used in the bias and power supplies.

One might expect that new devices of this type would be quite expensive, but the LM3900 is available at only £0.57 each in small quantities and is even cheaper in quantities of over 25 devices.

CONNECTIONS

The connections of the four separate amplifiers are shown in Fig.1. Each amplifier has a non-inverting input (marked +), an inverting input (marked —) and an output connection.

In addition, there is a single common positive supply connection and a common ground connection (negative supply line) for the whole device.

INTERNAL CIRCUIT

Conventional high gain amplifiers employ a differential input stage to provide inverting and non-inverting inputs, but a rather different approach is employed in the LM3900N. A 'current mirror' is employed in the non-inverting input circuit, the current 'reflected' in this mirror being subtracted from that which enters the inverting input.

This type of amplifier therefore acts as a differential stage by amplifying the difference between two *currents* rather than the difference between two voltages (as in a conventional amplifier).

The type of amplifier used in the LM3900N may be referred to as a 'Norton' amplifier, since Norton is the name of the person who developed a theorem relating the *current* flowing in a circuit to the equivalent current generator and shunt impedance.

Further details of the circuitry employed in these interesting amplifiers are given in the report by T.M. Frederiksen, W.M. Howard and R.S. Sleeth entitled "The LM3900N — A New Current-Differencing Quad of ± Input Amplifiers"; this is available from National Semiconductor (U.K.) Ltd., The Precinct, Broxbourne, Herts. under the number An-72.

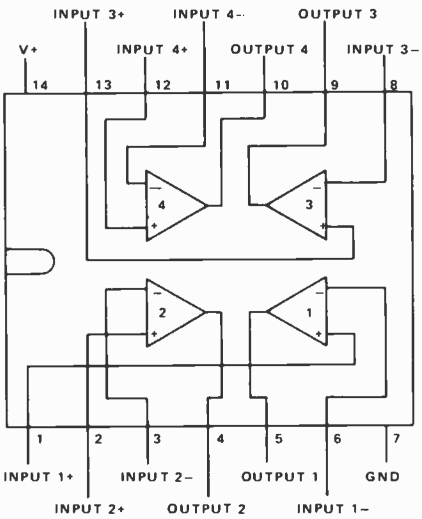
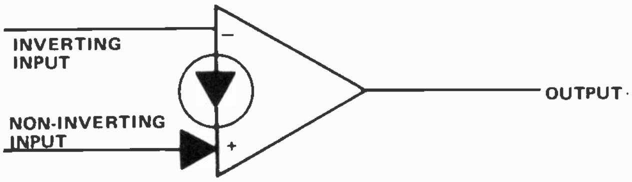


Fig. 1. The connections of the LM3900N.

Fig. 2. The symbol for one of the Norton amplifiers of the LM3900N.



SYMBOL

The symbol recommended for each of the four Norton amplifier stages in the device is shown in Fig.2. This symbol distinguishes this type of amplifier from the standard operational amplifier symbol and avoids confusion in circuits.

The symbol of Fig.2 contains an indication that there is a current source between the inverting and non-inverting inputs and implies that the amplifier uses a current mode of operation. In addition, the circuit symbol indicates that current is removed from the inverting input, whilst the arrow on the non-inverting input shows that this functions as a current input.

PERFORMANCE

The LM3900N has the advantage that it can operate from a single supply voltage over the range of 4 to 36 V. Most conventional operational amplifiers require supplies symmetrical with respect to ground (typically ±15 V); the LM3900N can be used with such supply lines if desired.

The maximum peak to peak output amplitude of an LM3900N amplifier is only 1 V less than the supply voltage employed. The current consumed from the power supply is typically 6.2 mA (maximum 10 mA).

The typical voltage gain of each amplifier is 2800 or nearly 70 dB. The minimum gain of any amplifier is 1200. The variation of this gain with

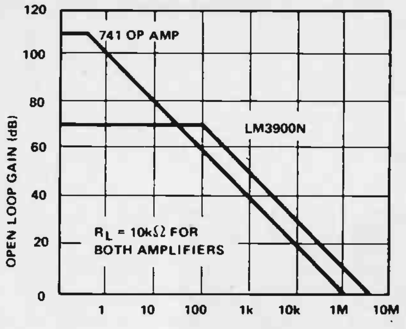


Fig. 3. Comparison of the gain of the LM3900N with that of a 741 amplifier at various frequencies.

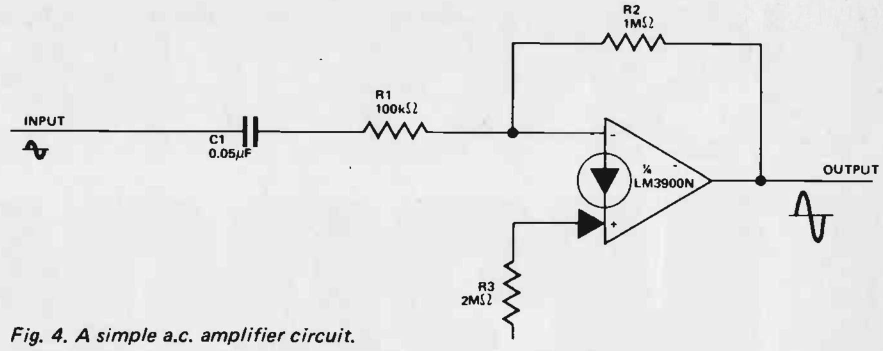


Fig. 4. A simple a.c. amplifier circuit.

frequency is compared with that of the well known type 741 operational amplifier in Fig.3. It can be seen that the LM3900N amplifiers provide about 10 dB more gain at all frequencies above 1 kHz.

APPLICATIONS

The Norton amplifiers used in the LM3900N device entail the use of somewhat different circuit design techniques than those used with conventional operational amplifiers.

The inverting input of the LM3900N amplifiers must be supplied with a steady biasing current. The current to the non-inverting input modulates that to the inverting input. The fact that current can pass between the input terminals leads to some unusual applications.

Both inputs of each of the amplifiers in the LM3900N are clamped by diodes so as to keep their potentials almost constant at one diode voltage drop (about 0.5 V) above the ground potential of pin 7. External input voltages must therefore be converted to input currents by placing series resistors in each input circuit.

USE AS AN AC AMPLIFIER

The LM3900N forms useful ac amplifiers, since its output can be biased to any desired steady voltage within the range of the output voltage swing. The ac gain is independent of the biasing level and the single power supply required greatly simplifies circuit design.

A simple ac amplifier circuit is shown in Fig.4. The gain is approximately equal to R_2/R_1 or 10 with the circuit values shown. the means potential at the output is half the supply voltage. The value of R_3 should be twice that of R_2, since the current passing through of these resistors is then the same. The positive supply and ground connections are not shown in Fig.4 for simplicity, but R_3 should be returned to the same positive supply line as that used to feed pin 14.

The circuit of Fig.4 provides a phase inverted output. Any ripple on the

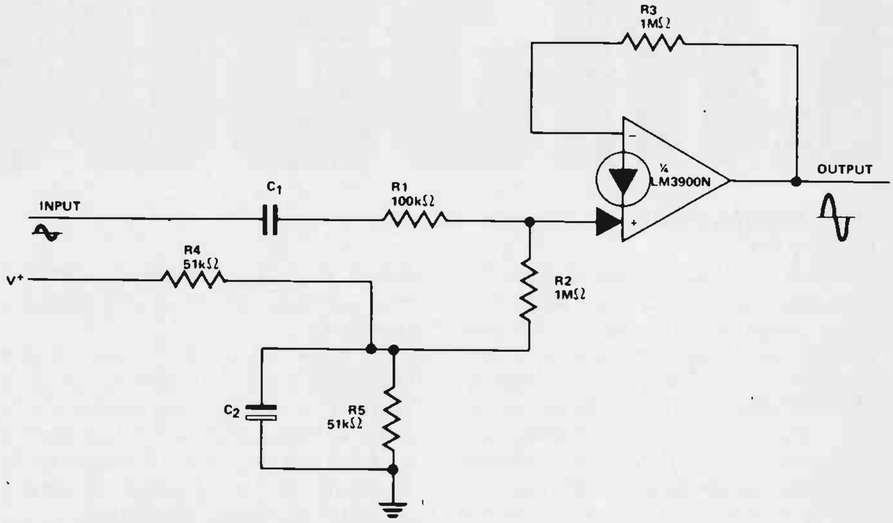


Fig. 5. A simple non-inverting a.c. amplifier.

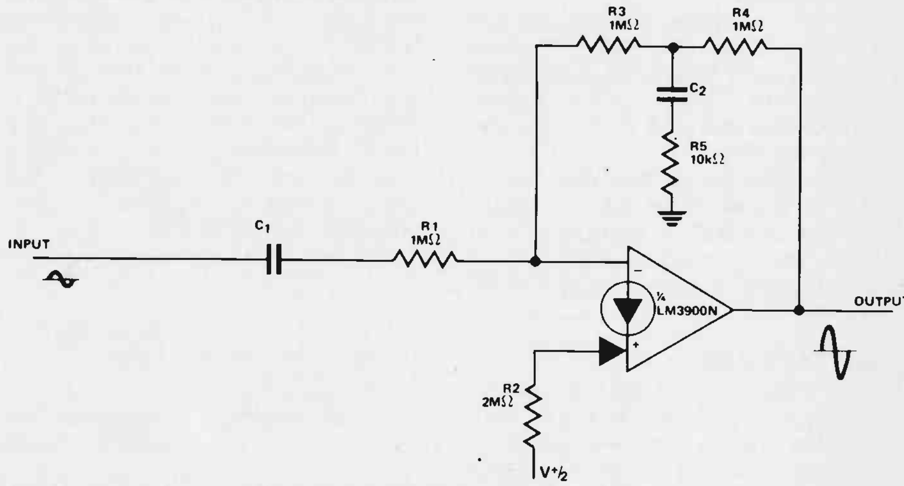


Fig. 6. An amplifier which has a high gain and a high input impedance.

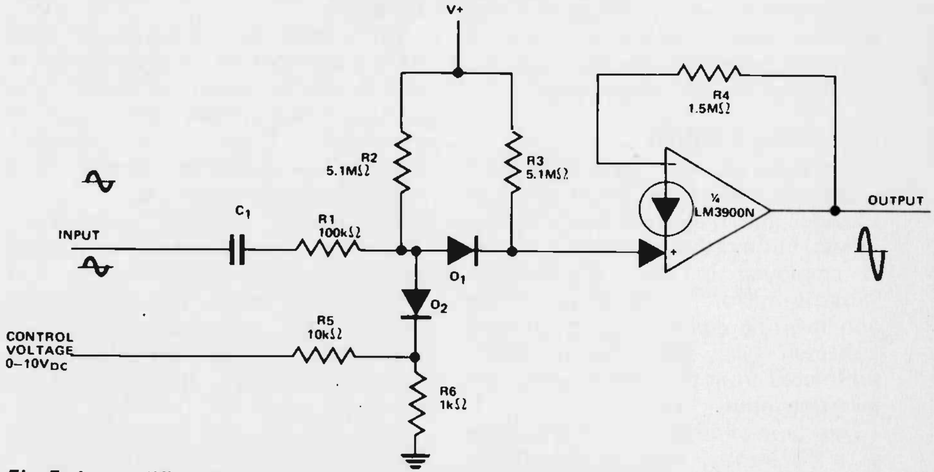


Fig. 7. An amplifier which has a gain controlled by an input voltage.

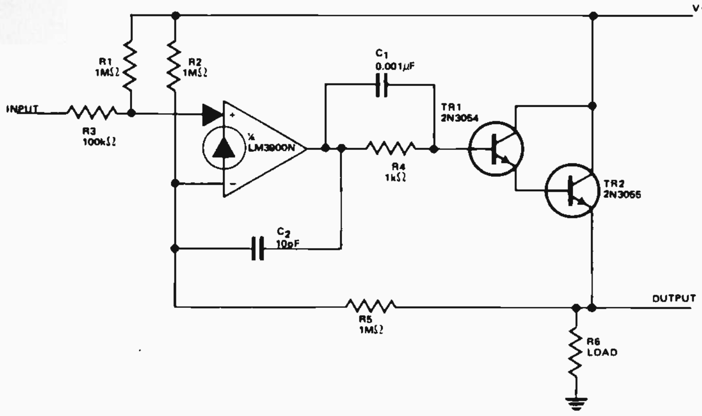


Fig. 8. A direct coupled power amplifier.

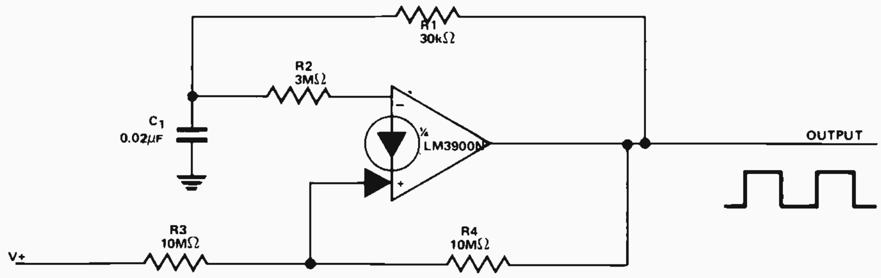


Fig. 9. A simple square-wave generator.

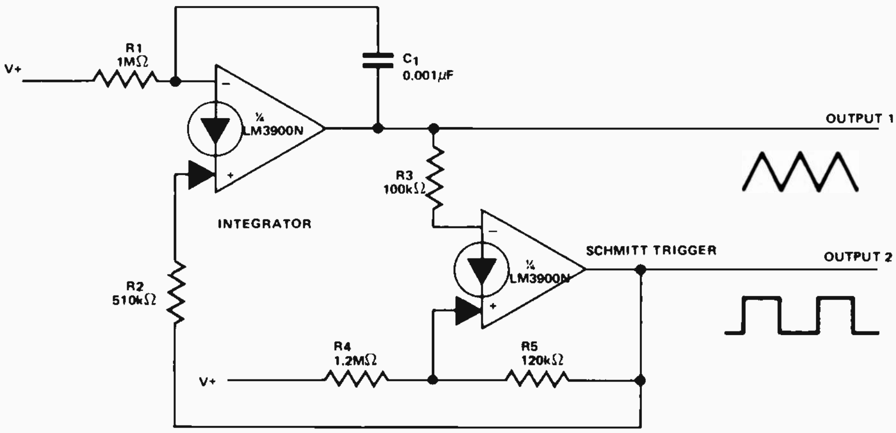


Fig. 10. A circuit for generating triangular and square-wave.

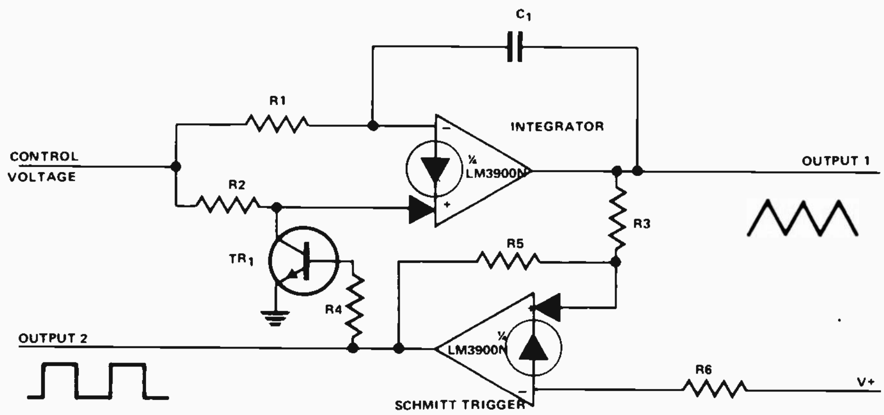


Fig. 11. A voltage controlled oscillator which produces triangular and square-waves.

power supply line will appear on the output at half amplitude.

NON-INVERTING AC AMPLIFIER

The circuit of Fig.5 shows an amplifier which provides an output in phase with the input. The gain is equal to $R_3/(R_1 + r_d)$ where r_d is the small signal impedance of the input diode. The value of r_d is equal to 0.026 divided by the current passing through R_2 to the non-inverting input.

The capacitor values should be chosen so that the impedance of these components is considerably less than the circuit impedance at the points concerned.

HIGH IMPEDANCE AND HIGH GAIN

The circuits of Figs.4 and 5 have an input resistance, R_1, of 100 k ohm. If this resistor is increased to provide a higher input impedance, the gain of the circuit will fall. However, the circuit of Fig.6 has been designed so that it provides both a high input impedance and a high gain using a simple amplifier. With the component values shown, the input impedance is one megohm and the gain 100.

The voltage applied to R_2 is made equal to the output voltage (which is half the supply voltage). The value of R_2 is equal to the sum of R_3 and R_4; these resistors set the dc bias. If desired, R_2 may be made 4 megohms and its lower end connected to the V^+ supply.

Resistors R_4 and R_5 form a potential divider so that only 1/100 of the alternating output voltage is developed across the C_2 – R_5 circuit. This fraction of the output voltage is fed back to the inverting input via R_3. As R_3 and R_1 are equal, the gain is R_4/R_5. As R_5 is decreased, the gain approaches the open loop gain of the amplifier.

VOLTAGE CONTROLLED GAIN

An amplifier with a gain which can be controlled by the value of a steady applied voltage is shown in Fig.7.

A current flows from the positive supply through R_3 to provide a bias which prevents the output of the amplifier from being driven to saturation as the control voltage is varied. When D_2 is non-conducting, the currents passing through both R_2 and R_3 enter the non-inverting input and the gain is a maximum. This occurs when the control voltage approaches 10 V.

The gain is a minimum when the control voltage is zero. In this case D_2 is conducting and only the current passing through R_3 enters the non-inverting input of the amplifier.

DIRECT COUPLED POWER AMPLIFIER

In the circuit of Fig.8, the output from an LM3900N amplifier is fed to a Darlington pair of power transistors. This circuit can deliver over three amps into a suitable load when the transistors are correctly mounted on heat sinks.

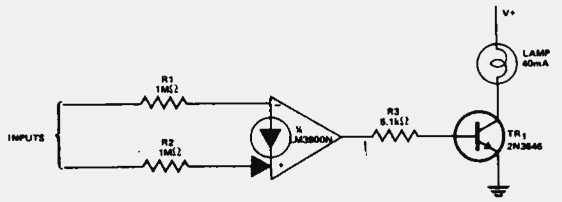


Fig. 12. A voltage comparator with an indicator lamp.

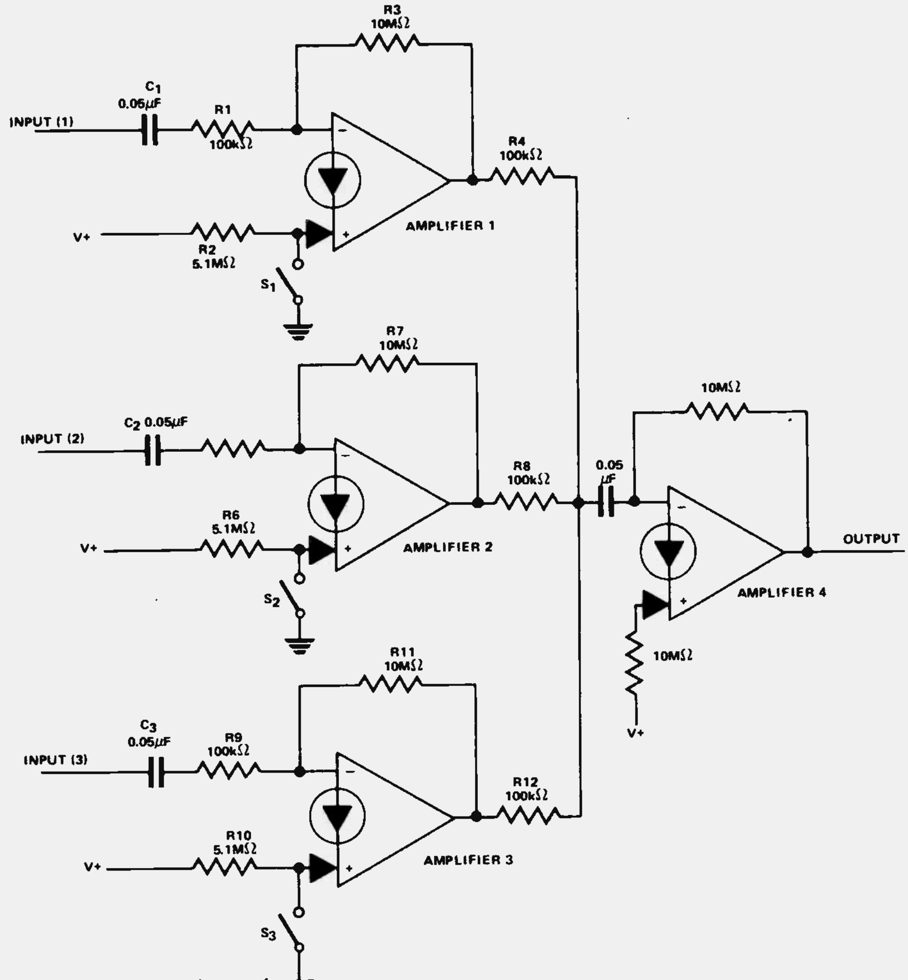


Fig. 13. An audio mixer unit.

SQUAREWAVE GENERATOR

The multiple amplifiers in the LM3900N device are very suitable for use in waveform generators at frequencies of up to about 10 kHz. Voltage controlled oscillators (the frequency of which is dependent on an input voltage) can also be designed using the device.

A simple square wave generator is shown in Fig.9. The capacitor C_1 alternately charges and discharges between voltage limits which are set by R_2 R_3 and R_4. The circuit is basically of the Schmitt trigger type, the voltages at which triggering occurs being approximately $V^+/3$ and $2V^+/3$.

TRIANGULAR WAVEFORM GENERATOR

A triangular waveform generator can be made by using one amplifier of a LM3900N device as an integrator and another amplifier as a Schmitt trigger circuit. A suitable circuit is shown in Fig.10; it has the unusual advantage that only the one power supply is required.

When the output voltage from the Schmitt trigger circuit is low, the current flowing through R_2 is integrated by C_1 to produce the negative slope of the triangular wave at output 1. When the output 2 voltage from the Schmitt trigger is high, current flows through R_2 to produce the rising part of the waveform at output 1.

The output waveform will have good symmetry if $R_1 = 2R_2$. The output frequency is given by the equation:

$$f = \frac{V^+ - V_{BE}}{2R_1C_1V}$$

where $R_1 = 2R_2$, V_{BE} is the steady voltage at the inverting input (0.5 V) and V is the difference between the tripping points of the Schmitt trigger.

VOLTAGE CONTROLLED OSCILLATOR

A simple voltage controlled oscillator circuit which produces both triangular and square wave outputs is shown in Fig.11. As in Fig.10, one amplifier is employed as an integrator.

Then the output of the Schmitt trigger is high, the clamp transistor TR_1 is conducting and the input current passing through R_2 is shunted to ground. The current passing through R_1 causes a falling ramp to be formed.

When the Schmitt circuit changes state, its output switches TR_1 to the non-conducting state. The current flowing through R_2 can be made twice that flowing through R_1 ($R_2 = R_1/2$) so that the rising part of the ramp has a similar slope to the negative part.

The greater the value of the control voltage in Fig.11, the greater the frequency of oscillation. However, the voltage must exceed the constant input voltage (V_{BE}) or the circuit will fail to oscillate.

VOLTAGE COMPARATOR

The circuit of Fig.12 shows how an LM3900N amplifier may be employed to compare two input voltages and to indicate the result by means of a small lamp. If the input voltage connected to the non-inverting input is appreciably more positive than the other input, the output of the amplifier will provide a positive voltage which renders TR_2 conducting. The lamp will then be illuminated.

One of the inputs may be a reference voltage so that one can then compare a single input voltage against this constant reference.

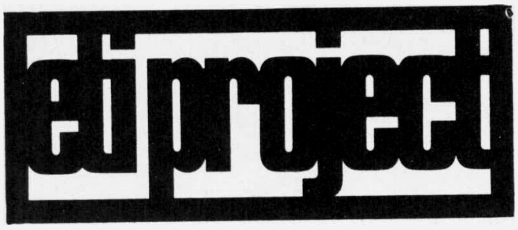
AUDIO MIXER

The amplifiers of a LM3900N device can be conveniently used to make a mixer unit for audio purposes; the unit enables three separate audio signals to be mixed together to produce a composite output. The circuit shown in Fig.13 provides this facility using only a single LM3900N device and also enables any one channel to be selected by switches. The currents passing through the resistors R_4, R_8 and R_{12} are summed in the input circuit of the fourth amplifier.

If S_1 is open, amplifier 1 will be driven to saturation by the current passing through R_2. It will therefore be inactive.

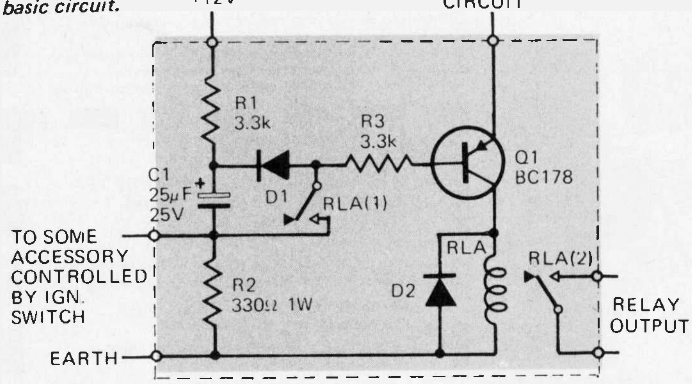
CONCLUSION

This short article has attempted to show a few of the numerous applications of this economical integrated circuit. Many more applications (such as phase locked loops, temperature sensing circuits, differentiators, tachometers, staircase generators, active filters, etc) are given in the report AN-72 mentioned previously. ●


HEADLIGHT REMINDER

Electronic 'reminder' safeguards against flat batteries.

Fig. 1 The basic circuit.



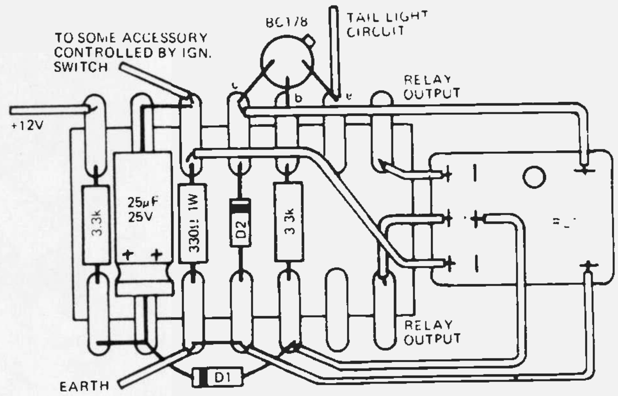


Fig. 2. How the components are connected.

HOW IT WORKS

Normally capacitor C1 is discharged via R1 and the closed switch contacts of an accessory wired via the ignition switch. If the ignition is now switched off, C1 will charge rapidly via R2 thus producing a negative going pulse at the base of transistor Q1.

If the vehicle's headlights (or side and tail lights) were switched on at this time, this pulse will turn on Q1, and close RLA.

The relay contacts RLA(1) and RLA(2) now close and contacts RLA(1) connect the base of Q1 to ground via R2 and R3 thus causing the relay to 'latch on'.

If either front door of the vehicle is opened with the relay in the latched condition an earth will be extended to the audible alarm device via the now closed contacts of RLA(2) and the closed door light switch.

The audible warning will cease immediately the door is reclosed. Q1 will of course be cut off and the relay reset when the lights are turned off (thus removing the positive voltage from the emitter of Q1).

If at any time it is required to disable the alarm circuit all that is necessary is – having first switched off the ignition – to switch the lights off and then on again. The circuit will revert to the status quo next time the ignition is switched on.

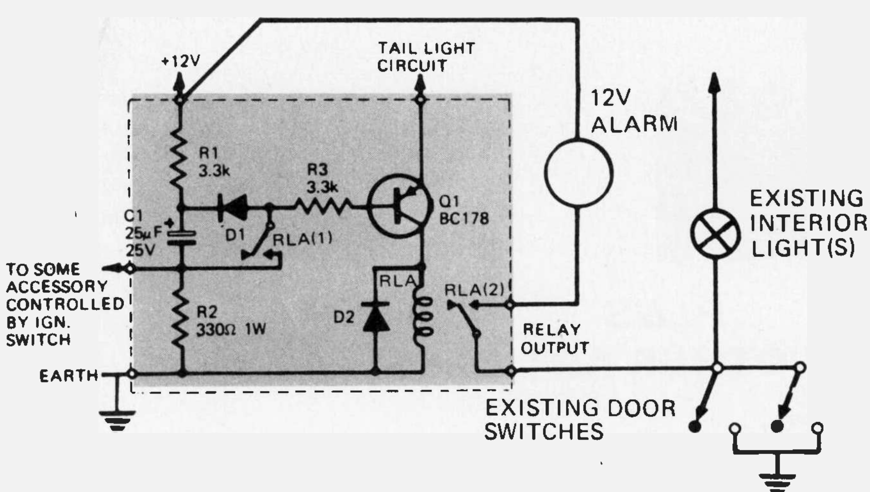


Fig. 3. How the warning circuit is wired into the vehicle's electrical system.

A CAR'S headlights cost approximately ½p an hour whilst in use. Until you forget to turn them off.

Then you are up for recharging the battery, tow starting, apologising to the managing director who has just waited two hours to discuss your future with the company, placating uptight parents whose daughter you've returned just after they realised it was now daylight, or whatever combination of circumstances are least favourable to your immediate situation.

To avoid such predicaments is relatively simple and a number of circuits have been published that provide an audible warning if the ignition is switched off whilst the headlights or sidelights are still burning.

These circuits are simple and effective but invariably fail to cater for those occasions when one requires lights to be on whilst the ignition is switched off.

Here then is a slightly more complex circuit that provides a 'headlight on — ignition off' warning as the driver opens a door to leave the vehicle. The

PARTS LIST – ETI-307

R1	–	3.3k 5% ½W
R2	–	330 ohms 5% 1W
R3	–	3.3k 5% ½W
D1	–	1N4001 – 1N4005
D2	–	" "
D3	–	" "
Q1	–	BC178
C1	–	25 uf 25V electrolytic cap.
	–	miniature relay 100-300 ohm coil two change-over contacts
	–	alarm, bell etc. tagstrip etc.

GETTING THE COMPONENTS

TRANSISTOR No-one should have trouble on the BC108 — anywhere selling transistors will have them. If you have a negative earth then the PNP equivalent is the BC178, as advertised by Bi-Pak, Trampus, etc. Other suitable PNPs are the BC478 or the BCY72.
ALARM This should operate on 12V and you can use a simple buzzer or some electronic alarm. Doram sell an Audible Warning Device which gives a piercing 2600Hz modulated tone when connected to a car battery (if you use Doram you can buy the BC478 from them).
RELAY Given the range 100Ω to 300Ω you should be able to find a suitable 12V relay in a mail-order catalogue (the contacts need be only two, normally open, types). Doram have a suitable 160Ω one, Electrovalue a 100Ω one, and so on.

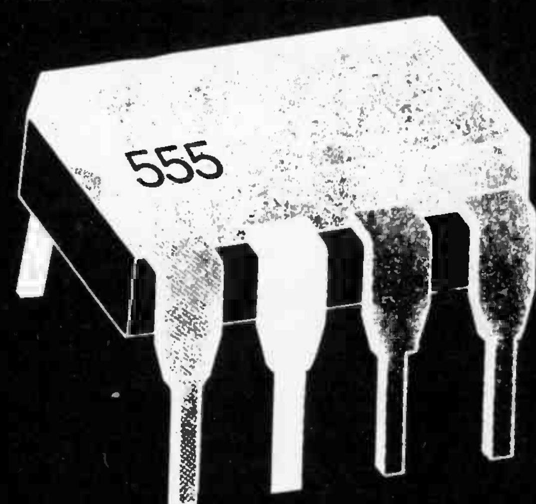
alarm ceases as soon as the driver closes the door.

The basic circuit is shown in Fig.1. The components may readily be mounted on matrix board or tag strips, and wired as shown in Fig.2.

As shown in Fig.1, the circuit is suitable for vehicles with a negative earth electrical system. To convert the circuit for use with positive earth vehicles replace the BC 178 by a BC 108 (the connections are the same) and reverse the diodes and the 25 μF capacitor.

Figure 3 shows how the basic circuit is wired into the car's electrical system. The alarm unit may be a buzzer, bell or even a flashing light. The existing door-operated interior light is used to extend an earth to the relay thus obviating the necessity to install any additional switches.

The lead marked 'tail light circuit' should be connected to the live side of the tail light wiring. (If a headlight only warning is required, this lead should be connected to the live side of one of the headlights). Further leads connect the unit to earth, the 12V vehicle supply and to the live side of any accessory that is wired through the ignition switch. ●



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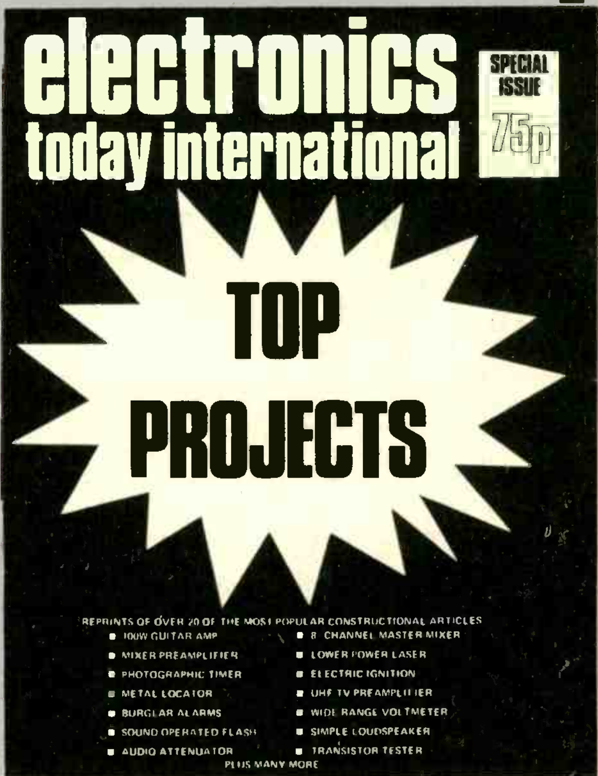

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March 1975

SPACE CRAFT GUIDANCE

The above picture shows the Soyuz—Apollo link-up planned to take place later this year. When Soyuz is in orbit 270km above the earth Apollo will be launched into a 200km orbit. Then Apollo will be manoevered until the two spacecraft can dock.

For the last two years NASA have been working on the docking module (seen in the picture attached to Apollo) and both crews have be training.

SPACE EXPLORATION has necessitated the development of many types of sophisticated guidance and navigation systems. The type actually used depends very much on the specific application.

The basic forms of guidance may be classified as inertial or programmed semi-inertial, that is, basically inertial but incorporating some other outside guidance system; radio or command; celestial or star-tracking; and infra-red.

Advanced systems may well use combinations of some or all of these. For example a scientific satellite once in orbit, may well use infra-red guidance to lock on to the sun, then celestial guidance to find a reference star. These provide the basic data for orientating the spacecraft in space. Once this has been established an inertial guidance system may be used to maintain the desired attitude and to generate navigational data.

An inertial guidance system is completely independent of information from outside the spacecraft (in its basic form). Hence it is the basic, and most reliable, form of guidance used in spaceflight.

Inertail guidance may be said to be the method of determining position and velocity without referring in any way to the world around the vehicle. The system does not depend upon receiving radio signals, or upon a measurement or count of any kind. Its fundamental devices are accelerometers, and gyroscopes used in conjunction with some form of computation.

Such a system measures the **acceleration** of the vehicle by measuring the force on a body within the vehicle due to this acceleration — in much the same way that we feel the pressure of the seat against our back when our car accelerates. The device that performs this measurement is known as an **accelerometer.**

We also wish to know the **attitude** of our spacecraft, etc, with respect to some predetermined orientation — this is determined by **gyroscopes.**

THE GYROSCOPE

The gyroscope (hereafter called a gyro) was used as early as 1744, to provide a stable platform for sextants. A stable platform was necessary so that the rolling and tossing of the ship did not affect measurement. The principle of operation is as follows.

If a heavy wheel is spun at high speed it tends to maintain its axis of rotation in the initially set up direction. In fact, if we push on the axle, it strongly resists any attempt to change position. Thus if such a wheel is mounted within pin-bearing frames (called gimbals) as shown in Fig.1, it will maintain its position regardless of the way that the container is turned. Such a gimballed wheel forms a basic gyro.

The term "inertial guidance" comes from the axial-inertia characteristic of the gyro — that is, its resistance to having its axis of rotation changed — because this gives it the ability to act as a directional pointer. Once pointed at a given star, a gyro will *remain* pointed at that star regardless of spacecraft manouvering. Thus, using the gyro as a reference, the spacecraft may be navigated to any point in the universe.

To put the gyro to work in a guidance system we need to obtain an output from it whenever the spacecraft changes orientation. Another characteristic of the gyro known as *precession* is used for this purpose.

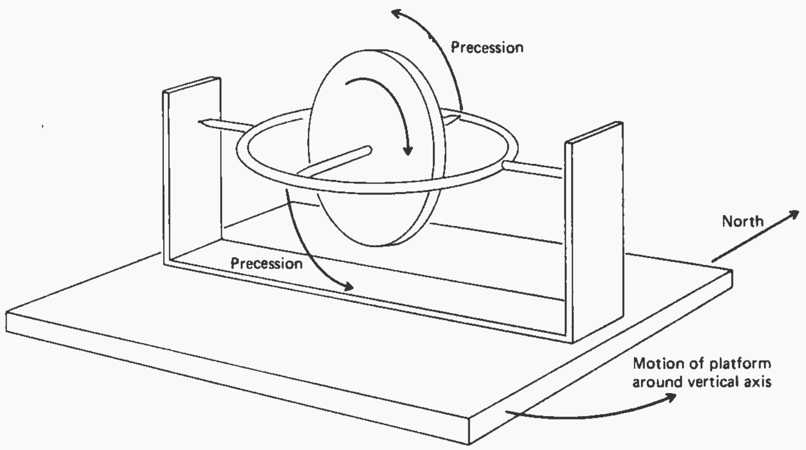


Fig. 2. How a gyrocompass works. If the assembly is caused to change direction in the horizontal plane, the rotating assembly 'precesses'. This so-called 'precession' is measured, thus providing data about the amount of directional change.

GYROSCOPIC PRECESSION

If the gyro is mounted on a platform with a single gimbal, so shown in Fig.2, and its axis is, for example, pointed to the north it will try to maintain its northerly direction. If the platform is now turned horizontally away from north, the gyro axis will move in a vertical plane.

This tilting of the spin axis is a basic principle of the gyro called precession, and may be used to measure the deviation of the platform from its preset direction. The gyrocompass, invented by Sperry around 1896, is based upon this principle, as indeed are all modern inertial guidance systems.

There are many interesting examples of precession in everyday experience. For example, when a car turns a curve, a rotational force is applied to the car flywheel axis (which is in effect a gyro), and as a result, a precessional force is generated on the car. If the flywheel is rotating counterclockwise, as seen from the rear of the car, the front of the car will be pushed downwards when making a left-hand turn, and upwards when making a right-hand turn. Hence racetracks for cars tend to have left hand circuits in order that higher cornering speed may be obtained with safety.

Similarly an aircraft will tend to fall when banking to the left, and rise when banking to the right.

ACCELEROMETERS

We have established the value of the gyro as a means of relating spacecraft attitude to a predetermined axis but, this is not sufficient information to navigate by — we also need to know any acceleration to which the spacecraft is subjected. That is, the gyro doesn't care whether the spacecraft speeds up or slows down, so long as it always points in the same direction. An instrument which *does* provide this very necessary measure of acceleration is known as an accelerometer.

There are many types of accelerometer but perhaps the most basic is the simple pendulum. When a pendulum system is accelerated in any direction the pendulum will be deflected, in the opposite direction, by an amount proportional to the acceleration. Obviously, however, once the acceleration ceases the pendulum would oscillate back and forth. Hence the system requires some form of damping to eliminate these unwanted secondary swings.

In addition an ordinary pendulum would not work too well in space and sprung mass systems which don't rely on gravity would be more practical (Fig.3).

A new accelerometer from SE Labs. The EGD-240 accerlerometer is a low cost sensor incorporating semiconductor technology and microcircuitry design.

Accelerometers use a variety of transducers to detect the deflection — piezo-electric crystals, strain gauges vibrating wire and variable-reluctance transformers etc are all used. The design of accelerometers is very demanding for, in applications such as ballistic missiles, accurate velocity determination is of prime importance. For example an ICBM having a range of about 5000 nautical miles and travelling at a rate of more than 6000 metres per second would miss the target by almost two kilometres if the velocity error was only 0.3 metres per second.

The accelerometer may rightly be said to be the essential element of an inertial guidance system, the gyros being used merely to establish a space-stable platform for the mounting of these devices.

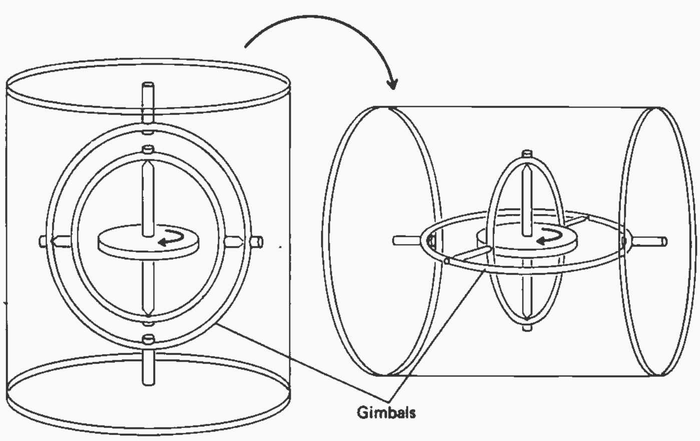


Fig. 1. This gyroscope is mounted in gimbals so that the rotating mass always points in the same direction — regardless of 'container' attitude.

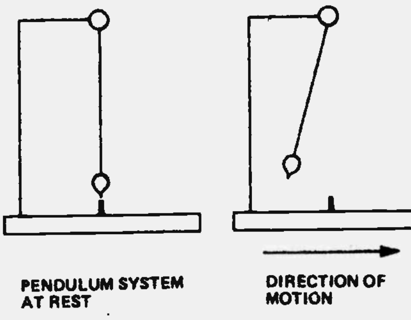


Fig. 3a. Simple pendulum.

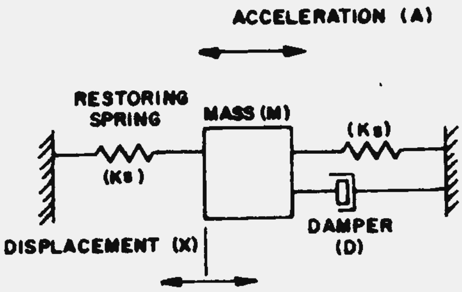


Fig. 3b. Translation system.

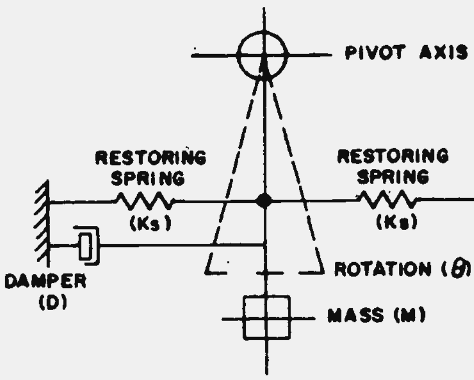
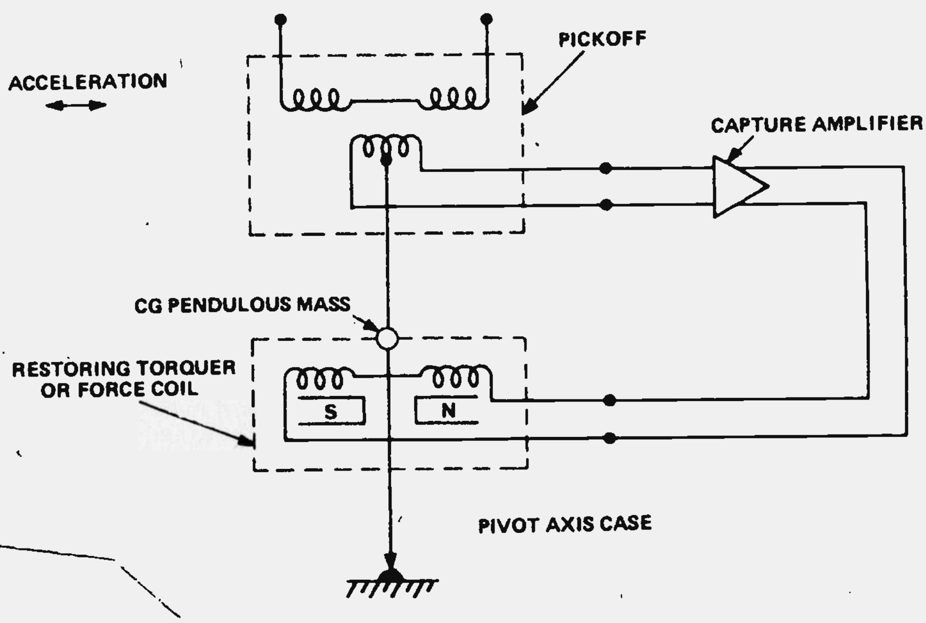


Fig. 3c. Rotational system.



...ical force balance pendulous accelerometer utilizes a differential transformer type ...) gain capture amplifier, and a dc permanent magnet force coil. These features ...ty...ry many of the high precision force-balance accelerometers currently manufactured.

THE INERTIAL PLATFORM

The first use of a gyro in an inertial guidance system was made in 1896. A gyro, mounted with a torpedo was used to maintain the torpedo's course regardless of wave motion and ocean currents. Mechanical linkages to the rudders corrected any deviation of the torpedo from the direction pointed by the gyro.

In the modern world of ballistic missiles and spacecraft, a straight line course is seldom, if ever, required. For example the ICBM describes a parabolic curve. A spacecraft may undergo any number of complex manoeuvres. Thus the gyro in such applications is not used to directly control the spacecraft. It is used, however, to establish a space-stable platform upon which the accelerometer and star trackers etc are mounted.

Figure 5 illustrates how such a platform is mounted in a missile or spacecraft. Gyros are fitted to the inertial platform on three, mutually-perpendicular axes. By using three axes the motion of the vehicle may be accurately defined in three dimensions. These axes are defined universally as the ROLL, PITCH and YAW.

Imagine a missile in flight. It may **spin** as it flies — this is the roll axis. It may **deviate** left or right — this is the **yaw** axis, and it may **deviate up or down** — this is the **pitch** axis. Regardless of any missile motion, the gyros on the inertial platform maintain it in the same spatial plane.

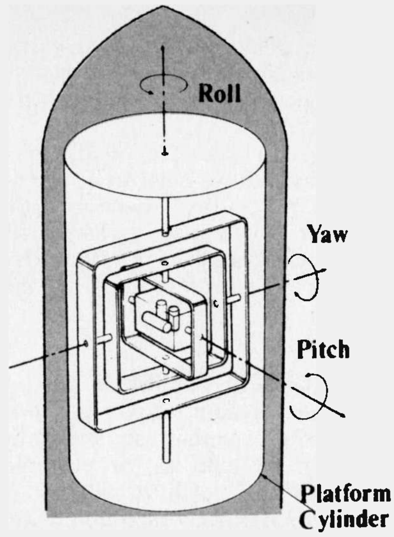


Fig. 5. Orientation of the gimbals at the launch of the Black Arrow launch vehicle which put "Prospero" (Britain's first technology satellite) into orbit in 1971.

Mounted on the same platform are three accelerometers, also aligned with the roll pitch and yaw axes, which measure any acceleration of the missile or spacecraft in the direction of these axes.

The continuous, three-axis acceleration data is fed to a digital computer which calculates, using the equations of motion, the instantaneous vehicle velocity and position.

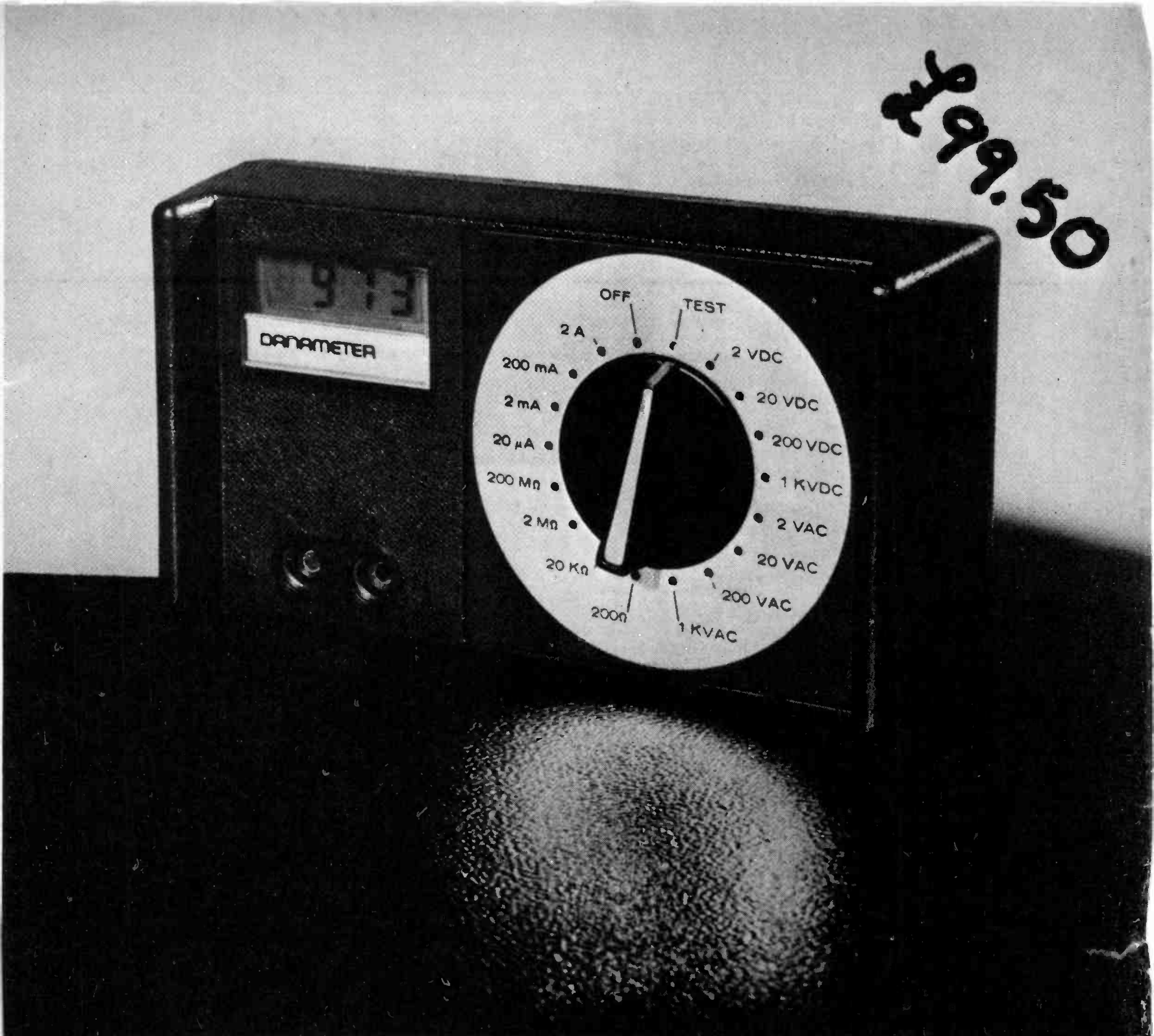
A guidance law pre-programmed into the computer determines the optimum vehicle attitude and velocity required to attain the desired course, or orbit etc, with the least expenditure of fuel. This *required* velocity and attitude is compared by the computer with the *actual* parameters derived from the inertial platform. By this means error signals are generated, which (via the vehicle auto-pilot), control engine power and/or gas-jets to correct the velocity and attitude.

FERRANTI SYSTEMS

The Ferranti system for the ELDO launch vehicles used a four gimbal FE610 inertial platform (see the photo on page 43) and an Electronics Unit. The Platform's instruments were three miniature floated rate integrating gyroscopes and three accelerometers. Synchros fitted to the gimbals gave attitude information. The Electronics Unit contained servo loop amplifiers for the Platform, accelerometer capture amplifiers, accelerometer encoders and an internal power converter. The continuous current from the accelerometers is converted into pulses by the Analogue to Digital converter. Each pulse corresponds to a velocity change of 1m/s.

Ferranti systems were used in the Black Arrow and in last year's X4 satellite. The X4 was developed in the UK as a complex civil satellite. The

Continued on page 43



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SPACE CRAFT GUIDANCE

Continued from page 40

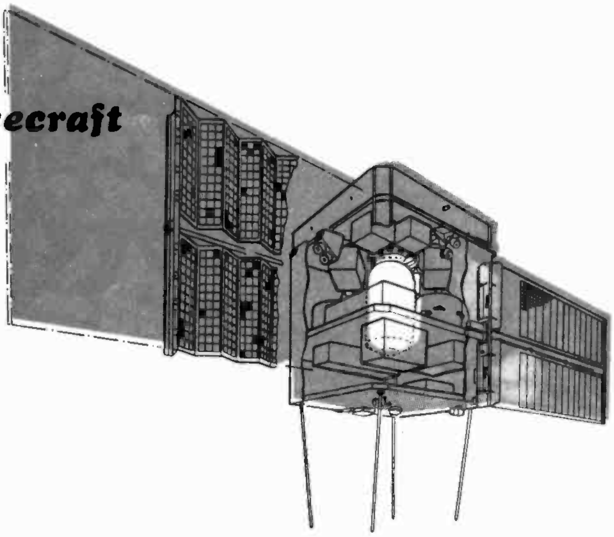
Testing an Inertial Platform at the Edinburgh Labs. of Ferranti.

This is the sensing element of the inertial guidance system used in the ELDO satellite launch vehicle. This was developed by Ferranti in 1969 when ELDO decided that an onboard navigation system was needed to replace ground control. Previously the vehicles had only attitude monitoring equipment.

Attitude Sensor used in the X4 used the three basic orthogonally mounted rate integrating gyroscopes and a fourth gyroscope inclined at equal angles to the main axes. This gyro is a stand-in to be used if required.

Inputs to the gyro torque motors are from earth and sun sensors. Once the satellite pitch axis is normal to the orbit plane, the pitch gyro may be torqued with an accurately known current which represents the orbit rate, so that the satellite will remain earth-pointing even when the earth sensor is switched off.

X4 Spacecraft



DIGITAL EQUIPMENT

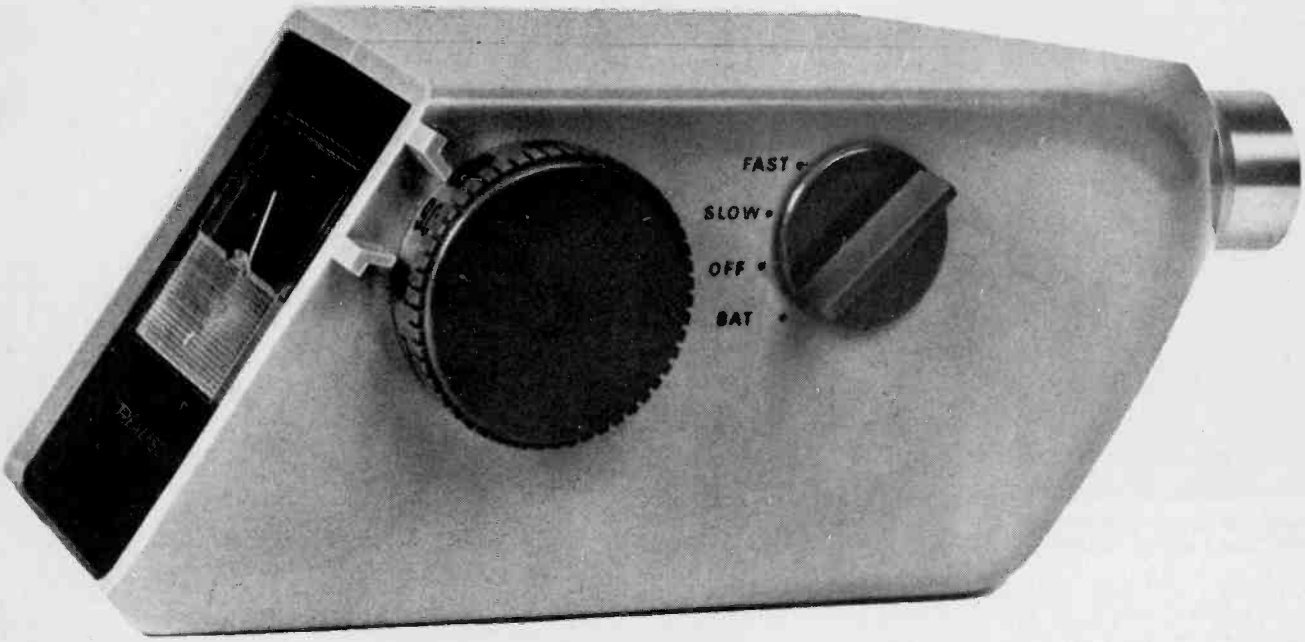
Digital Inertial Navigation and Guidance Equipment has been developed by Ferranti using the same Inertial Platform used in the Black Arrow and ELDO firings. The DINGE Inertial Platform incorporates a small powerful digital computer and associated electronics in a box measuring 427mm x 334mm x 242mm and weighing 20.5kg. DINGE is being used in the Panavia Multi Role Combat Aircraft and in the Mitsubishi FS-T2 Ground Support Aircraft.

USE IN SPACE TRAVEL

In a ballistic missile, or aircraft, the gyro platform is set up and orientated with reference to terrestrial planes of reference. But in space travel we must fix our planes of reference on the universal scale. Hence, once the spacecraft achieves parking orbit, a star tracker mounted on the inertial tracker is used to establish the spacecraft position by sighting on two or more known stars. Then if necessary the inertial platform is realigned to a more suitable orientation and the computer fed with the present position and the desired future position (plus many other factors such as gravitational forces etc). From this data the computer determines the optimum attitude and time for the spacecraft to depart from orbit and thus — we are on our way to the stars. ●

eti product test

REALISTIC MUSIC AND SOUND LEVEL METER



BASICALLY, a sound level meter measures the intensity of acoustic levels (sound pressure waves) over a wide frequency and dynamic range. Such measurements are useful for setting up hi-fi equipment in the home, public address equipment in halls and checking sound levels in factories, schools and out of doors.

The 'Realistic' Sound Level Meter consists of a microphone and special amplifier together with a calibrated (dB) meter that provides a total intensity range of 60 to 116dB in five ranges. The calibration is directly related to a 0dB reference level which is the threshold of hearing at about 0.0002 dynes/cm^2. The meter is battery operated and the mode switch has three positions, one marked BAT which reads the battery voltage on the meter and then two positions for reading sound levels, one being for instantaneous or peak meter deflection and the other for a slow sustained reading for an average value. The range selector switch covers 60 to 116dB in steps of about 16dB to provide overlap and the accuracy of the meter is ±2dB at 114dB sound pressure.

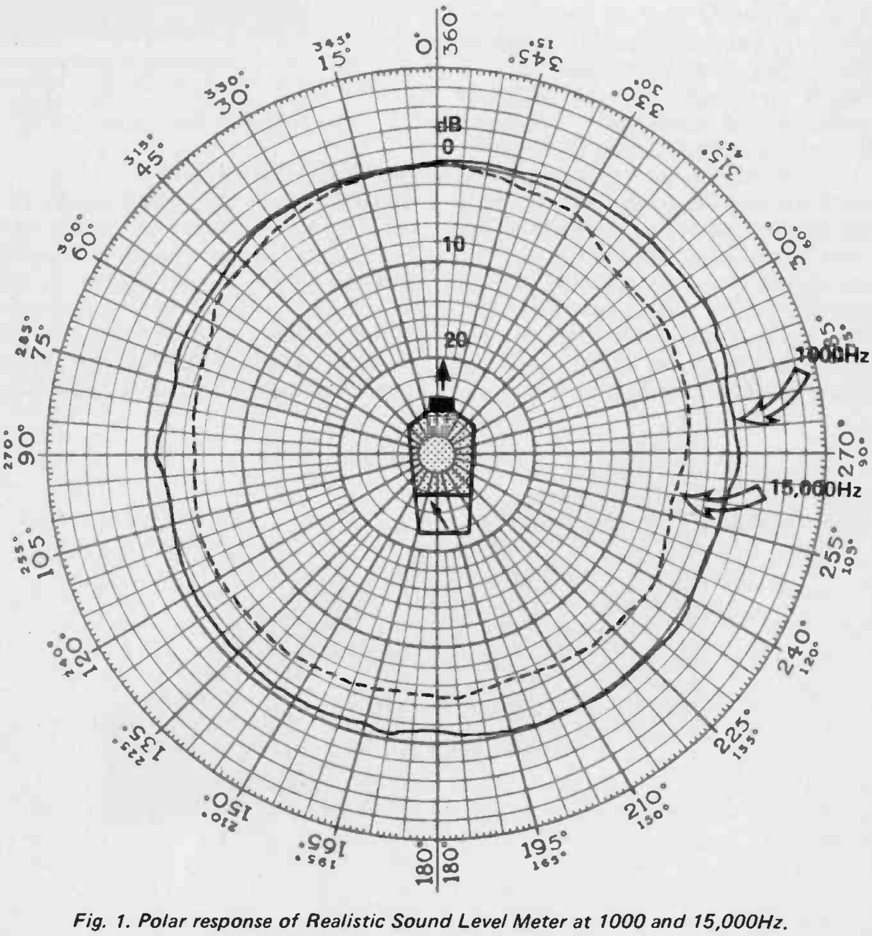


Fig. 1. Polar response of Realistic Sound Level Meter at 1000 and 15,000Hz.

SPECIFICATION

Range:	60 to 116dB in 5 ranges.
Accuracy:	±2dB at 114dB sound pressure.
Standard:	0dB = 0.0002 dynes/cm^2.
Meter Ballistics:	Fast to ASA standard. Slow for average levels.
Output Voltage:	1V average ref 1000Hz.
Response:	40 to 14kHz ±2dB.
Distortion:	Less than 2%.
Battery:	9V Type PP3.
Microphone:	Dynamic omni-directional.
Price:	£26.50 (inc. VAT).

USES

There are numerous uses for a sound level meter and one at least for hi-fi enthusiasts is for checking on sound level and distribution from hi-fi systems. An experiment mentioned in the instruction booklet for instance is to take the meter to a live performance concert and compare the readings obtained with readings taken from the same music from a record, the object being to compare overall loudness and dynamic range. On the other hand high power reproducing systems can produce sound pressure levels high enough to cause damage to hearing. A 1kHz tone at 95 – 106dB can cause ear damage within a very short time and full frequency (music) sound at these levels is even worse.

A sound level meter also has its uses in loudspeaker positioning for beat stereo effect, checking room resonance at different frequencies (a sine-wave generator is required for this) and in setting up public address equipment in large halls. Excessive noise levels in offices, factories or outdoor machinery can be measured and there are applications in schools and colleges for acoustical studies and the like. The effectiveness of sound proofing and the sound absorption factor of different building materials can be verified. The instruction booklet supplied goes into considerable detail about the operation of the meter, its uses and the interpretation of readings. It contains a circuit of the meter, a table of relative sound levels and a polar response of the built-in microphone which is reproduced in Fig. 1.

PERFORMANCE

With the 'mode' switch set to FAST the calibration is in accordance with the ASA standard i.e., the response is similar to that of natural hearing and the meter responds very quickly to changes in sound level. The overshoot in this mode is not more than 1dB. With the mode switch set to SLOW the meter is damped and so indicates an average value which is more suitable for checking on music levels. An output signal jack socket is fitted so that sound can be displayed on an oscilloscope or even recorded for reference and, as for the frequency response is 40 to 14kHz, the microphone can be used in the normal way.

Various tests were applied to check calibration which was within the limits specified i.e., to about ±2dB. This meter should not however, be regarded as a laboratory instrument, which would cost considerably more anyway but rather as a general purpose unit capable of providing a good approximation of sound levels. It is well made and quite compact, can be held in one hand and has numerous and useful applications as already outlined. It is of USA manufacture and sold exclusively by the Tandy Corporation in their various shops at £26.50. ●

ELECTRONIC COMBINATION LOCK

There's only one chance with this unusual combination lock — any incorrect setting will sound an alarm!

THIS electronic combination lock is a simple device which may be used as a security device, or just for amusement. Very few parts are required and most of them will probably already be in the experimenter's junk box.

A total of 1000 combinations are provided by three, eleven-way switches, only one setting out of the possible 1000 will actuate the output relay (and hence any other device required to be operated). More combinations may be provided by simply wiring further switch banks in series with the existing three.

To prevent people from just rotating switches until the lock eventually opens, "lock" and "unlock" push buttons have been provided. Thus once a switch selection has been made the "unlock" button must be pressed to open the lock. Should *any* incorrect selection be made the alarm will sound. The lock push button must then be pressed to reset the alarm. There is therefore no way in which an intruder can test different combinations, without the alarm sounding, except in the 1 in 1000 chance of selecting the correct combination the first time.

CONSTRUCTION

Construction is very simple. We built our unit into a metal box, but if the unit is meant to prevent access to somewhere, or something, (such as the biscuit tin!) it could well be built directly into the lid or door etc.

Points to watch are the connections to the BC558 transistor, especially as there are two different base connections available, and that the alarm and relays have voltage ratings applicable to the selected supply voltage. The supply voltage may be anything convenient, up to a maximum of 30 volts, this being limited by the rating of the transistor specified. ●

PARTS LIST
ETI 233

R1	Resistor	10 k 20% ½W
Q1	transistor	BC178, BC558 or similar
D1	diode IN914 or similar	
PB1	push button switch (normally closed)	
PB2	push botton switch (normally open)	
RLA, RLB	relay double pole change-over, voltage to suit battery supply used.	
SW1 2, 3	Switches single pole 11 position rotary.	
Alarm	- buzzer etc. to suit battery supply used.	

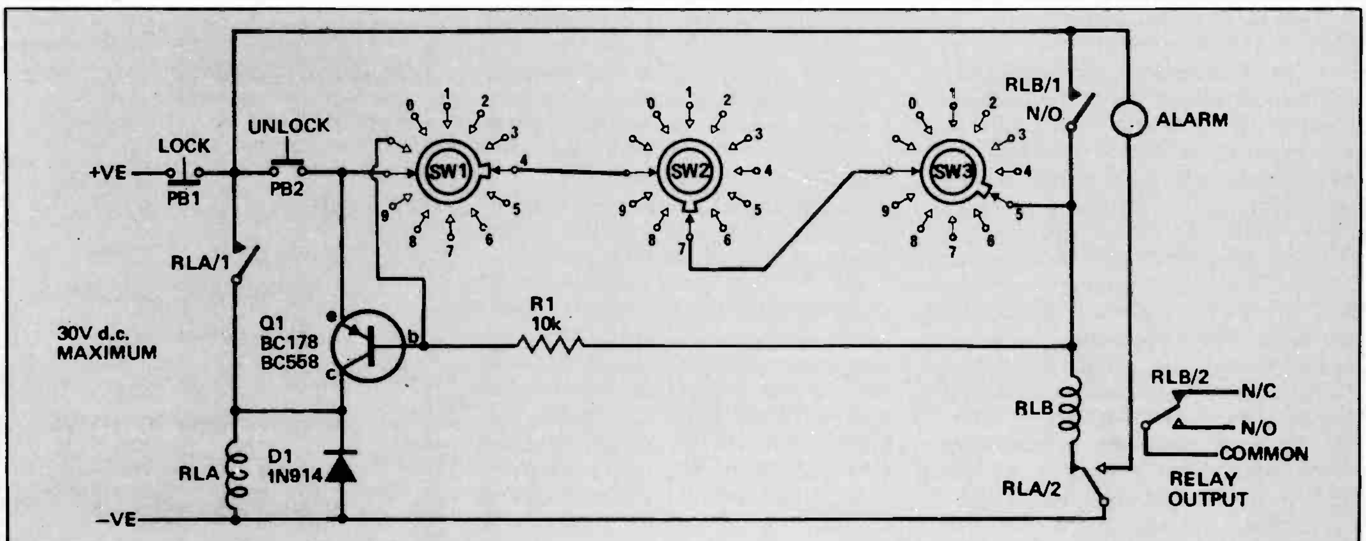
HOW IT WORKS

The three switches (SW1, 2 and 3) are prewired to some specific number. In our circuit diagram the switches are wired to unlock with 475 selected.

When the unlock push button is pressed, power is applied to Q1 and SW1. If the switches are set to the correct "UNLOCK" code, power is also applied to relay B causing it to close, RLB/1 contacts therefore close latching relay B on. The switches can now be altered without relay B opening.

If, however, when the "UNLOCK" pushbutton PB2, is pressed, the switches are not in the correct code position relay RLB is not actuated. Nevertheless, Q1 turns on due to base current flowing through the coil of RLB and R1, and RLA closes. Contacts RLA/1 therefore close, latching on RLA, and contacts RLA/2 change over disconnecting RLB and actuating the alarm. Only by pushing the "LOCK" button can the alarm be de-activated and a new combination tried. If desired the alarm could be connected across the coil of RLA rather than in the position shown.

The switches should normally be left in the number 11 (blank) position. If in this position the unlock button is pressed the alarm will not be actuated. This prevents accidentally raising the alarm.



Sinclair Project 80

For elegant, versatile, stereo hi-fi systems designed and built by you!

Until recently, if you wanted a first-class hi-fi system you had two ways to get it.

You could buy the individual electronic components and build a system from scratch. If you were an electronics genius – fine.

Or you had to buy ready-made units. Expensive – and dull. About the only creative pleasure you'd get would be matching your amp and your speakers, or making your speaker enclosures.

So what's new?

A comprehensive hi-fi system, combining the enjoyment and satisfaction of build-it-yourself (without too much struggle) . . . a real value-for-money feeling . . . and results of the highest quality.

It's the new Sinclair Project 80.

How does Sinclair Project 80 work?

Project 80 is a comprehensive set of hi-fi modules, or sub-assemblies. Amps . . . pre-amps . . . FM tuners . . . stereo decoders . . . control units . . . everything you need to assemble hi-fi units. They're all designed to look alike and they're all completely compatible with each other. Simply decide on the specifications of the unit you want to build . . . buy the necessary modules . . . connect them . . . and house them.

No need to buy everything at once for your eventual set-up. All the modules are designed so that you can add to them as your system grows – whether or not it's based on Project 80.

This applies to refinements, like filters . . . to up-grading, adding a second set of amps, say, for greater output . . . or to real innovation, like quad. (Add a Project 80 quad decoder, a power supply, a pair of amps, and a pair of speakers – and your stereo's gone quad.)

Is it difficult to build?

Not at all. The modules are complete in themselves. All you do is connect them to your turntable . . . your speakers . . . or to each other. It's absorbing, but if you can solder wires to a 5-pin DIN plug, you can build a complete system with Project 80.

And if you're not so hot with a soldering iron? Use Project 805. Project 805 uses Project 80 modules, but provides special clip-on tagged wire connections – absolutely *no* soldering required.

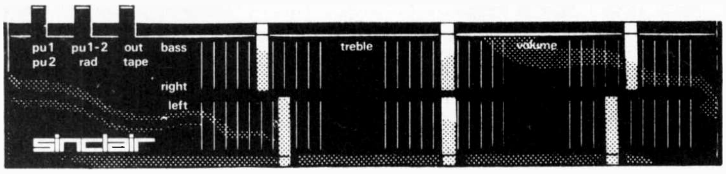
And, of course, both Project 80 and Project 805 come complete with instructions for easy, step-by-step assembly. But if you do run into problems, just call our Consumer Advisory Service who are always happy to help.

OK. Where do I go from here?

Over the page! There you'll see for yourself the exacting specifications to which Sinclair Project 80 modules are made, and you'll see some suggested systems.

As you skim the suggestions, remember all Project 80 modules are backed by the remarkable no-quibble Sinclair guarantee. Should any defect arise from normal use within a year, we'll service the modules free of charge. What could be fairer than that?

Choose the Project 80 modules that are right for you.

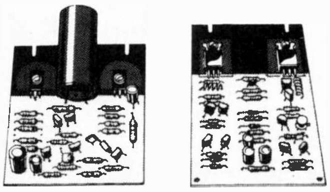


Project 80 pre-amp/control unit

The control centre of Project 80. With its distinctive white-on-matt-black styling and plastic control sliders, it's a pleasure to look at, as well as to use.

Specification
(9 ½ in x 2 in x ¾ in.) Separate slider controls on each channel for treble, bass and volume. **Inputs:** *PU* magnetic – 3 mV (RIAA corrected), ceramic – 350 mV; *Radio* 100 mV; *Tape* 30 mV. **S/N ratio:** 60 dB. **Frequency range:** 20 Hz to 15 kHz ± 1 dB. **Outputs:** 100 mV and tape plus AB monitoring. **Press buttons** for PU, radio and tape. **Operating voltage:** 20 V – 35 V.

Price: £13.95 + VAT



Project 80 power amplifiers

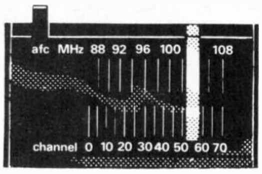
Two different amplifiers, designed to be used separately or combined, with Project 80 modules or as add-ons to existing equipment. Protected against short circuits and damage from mis-use.

Z40 Specification
(2¼ in x 3 in x ¾ in.) 8 transistors. **Input sensitivity:** 100 mV. **Output:** 12 W RMS continuous into 8 Ω (35 V). **Frequency response:** 30 Hz – 100 kHz ± 3 dB. **S/N ratio:** 64 dB. **Distortion:** 0.1% at 10 W into 8 Ω at 1 kHz. **Voltage requirements:** 12 V – 35 V. **Load imp:** 4 Ω – 15 Ω; safe on open circuit. Protected against short circuit.

Price: £5.95 + VAT

Z60 Specification
(2¼ in x 3⅘ in x ¾ in.) 12 transistors. **Input sensitivity:** 100 mV – 250 mV. **Output:** 25 W RMS continuous into 8 Ω (50 V). **Frequency response:** 10 Hz to more than 200 kHz ± 3 dB. **S/N ratio:** better than 70 dB. **Distortion:** 0.02% at 10 W into 8 Ω at 1 kHz. **Voltage requirements:** 12 V – 50 V. **Load imp:** 4 Ω min; max safe on open circuit. Protected against short circuit.

Price: £7.45 + VAT

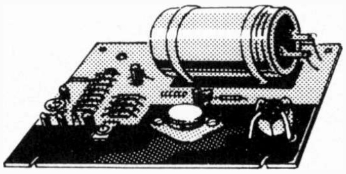


Project 80 FM tuner

Excellent reception from a tuner only 3½ in long x ¾ in deep! Styled to match Project 80 control unit.

Specification
(3½ in x 2 in x ¾ in.) Tunes 87.5 MHz to 108 MHz. **Detector:** IC balanced coincidence (IC equivalent to 26 transistors). **Distortion:** 0.3% at 1 kHz for 30% modulation. **Sensitivity:** 5 μV for 30 dB signal to noise. **Output:** 100 mV for 30% modulation. **Aerial imp:** 75 Ω or 240-300 Ω. **Features:** dual Varicap tuning, 4-pole ceramic filter, switchable AFC. **Operating voltage:** 23 V – 30 V.

Price: £13.95 + VAT



Power supply units

Range of power supply units to match desired specification of final system.

PZ5 Specification
Unstabilised. 30 V output. Including mains transformer.

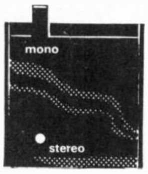
Price: £5.95 + VAT

PZ6 Specification
Stabilised. 35 V output. Including mains transformer.

Price: £8.95 + VAT

PZ8 Specification
Stabilised. Output adjustable from 20 V to 60 V approx. Re-entrant current limiting makes damage from overload or even shorting virtually impossible. Without mains transformer.

Price: £8.45 + VAT

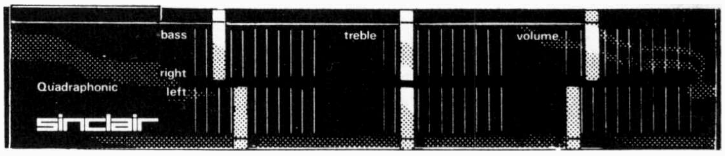


Project 80 stereo decoder

Designed for use with Project 80 FM tuner. Sold separately to keep down the price of a mono FM system, but also to make the stereo decoder available for use with existing mono FM tuners.

Specification
(1¾ in x 2 in x ¾ in.) 1 IC equivalent to 19 transistors. LED stereo indicator glows red.

Price: £8.95 + VAT

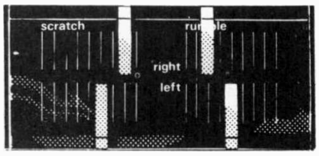


Project 80 SQ quadraphonic decoder

Combines with and exactly matches Project 80 control unit for true quadraphonics. This unit is based on the CBS SQ system and is a complete quadraphonic decoder, rear channel pre-amp and control unit.

Specification
(9½ in x 2 in x ¾ in.) Connects with tape socket on Project 80 control unit or similar facility on any stereo amplifier. Separate slider controls on each channel for treble, bass and volume. **Frequency response:** 15 Hz to 25 kHz ± 3 dB. **Distortion:** 0.1%. **S/N ratio:** 58 dB. **Rated output:** 100 mV. **Phase shift network:** 90 ± 10 · 100 Hz to 10 kHz. **Operating voltage:** 22 V – 35 V.

Price: £18.95 + VAT



Project 80 active filter unit

Eliminates scratch and rumble (high and low-frequency noise).

Specification
(4¼ in x 2 in x ¾ in.) **Voltage gain:** –0.2 dB. **Frequency response:** filter at zero: 36 Hz – 22 kHz; **HF** (scratch) out: variable 22 kHz to 5.5 kHz, 12 dB/octave slope; **LF** (rumble) out: –28 dB at 28 Hz, 9 dB/octave slope.

Price: £7.45 + VAT

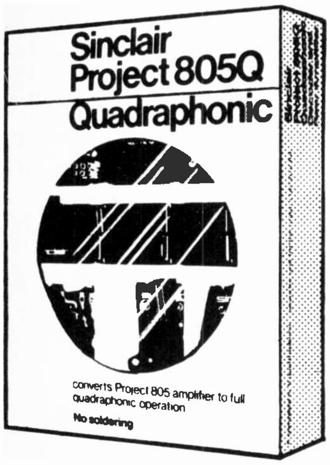
Some system suggestions from Sinclair

Project 805 amplifier kit

Contains following Project 80 units:

Project 80 control unit
2 x Z40 power amplifier modules
1 x PZ5 power supply unit
Masterlink unit
On/off switch
plus pre-cut wiring loom with clip-on tagged wire connections, nuts and bolts, instruction manual.

Price: £39.95 + VAT



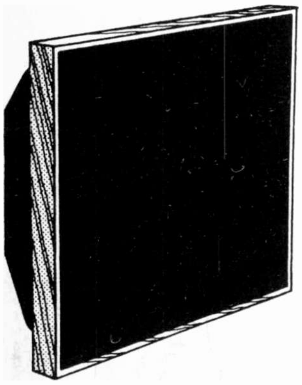
Project 805Q quadraphonic add-on kit

Converts your existing stereo hi-fi system to quad using solderless connections.

Contains following Project 80 units:

Project 80 SQ quad decoder/rear channel pre-amp and control unit
2 x Z40 power amps
PZ5 power supply unit
Masterlink unit
On/off switch
plus pre-cut wiring loom with clip-on tagged wire connections, nuts and bolts, instruction manual.

Price: £44.95 + VAT



Sinclair Q16 speaker

Original and uniquely designed speaker of outstanding quality.

Specification
(9⅜ in square x 4¾ in deep.)
Pedestal base. All-over black front. Teak surround. Balanced sealed sound chamber. Special driver assembly. **Frequency response**: 60 Hz to 16 kHz.
Power handling: up to 14 W RMS.
Impedance: 8 Ω.

Price: £8.95 + VAT

1. Quadraphonic system: 25 W per channel RMS
Pre-amp/control unit + quadraphonic decoder + 4 x Z60 amps + 2 x PZ8 mains power supplies + (2 x mains transformers) + (4 x equivalent speakers) + (turntable). Total Project 80 cost: £79.60 + VAT.

2. Stereo amplifier: 12 W per channel RMS
Pre-amp/control unit + 2 x Z40 amps + PZ6 power supply + 2 x Q16 speakers. Total Project 80 cost: £52.70 + VAT.

3. Stereo tuner/amplifier: 12 W per channel RMS
Pre-amp/control unit + FM tuner + stereo decoder + 2 x Z40 amps + PZ6 power supply + 2 x Q16 speakers. Total Project 80 cost: £75.60 + VAT.

Other applications

4. PA system
(Mic) + pre-amp/control unit + Z40 amp + PZ6 power supply + 2 x Q16 speakers. Total Project 80 cost: £46.75 + VAT.

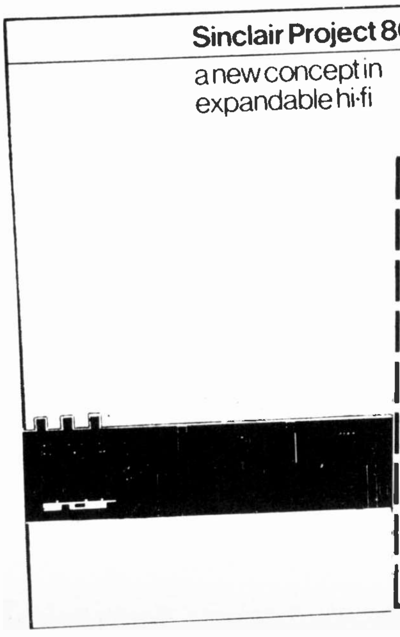
5. Convert existing mono record-player to stereo
Pre-amp/control unit + Z40 amp + Q16 speaker. Total Project 80 cost: £28.25 + VAT.

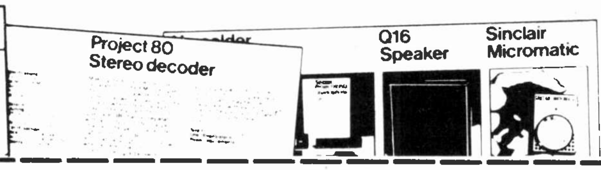
What more can we tell you?

The basic facts are covered on these two pages: And you'll find Project 80 at stores like Laskys and Henry's.

But before you look, why not get really detailed information? Clip the FREEPOST coupon for the fully-illustrated Project 80 folder – today!

Sinclair Radionics Ltd,
London Road, St Ives, Huntingdon, Cambs., PE17 4HJ.
Telephone: St Ives (0480) 64646.





To: **Sinclair Radionics Ltd, FREEPOST, St Ives, Huntingdon, Cambs., PE17 4BR.**

Please send me, by return post, a copy of the fully-illustrated Project 80 folder.

Name ______________________

Address ______________________

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Please print FREEPOST – no stamp needed. ETI/3/75

UNDERSTANDING COLOUR TV

PART TWO Sending Colour by TV.

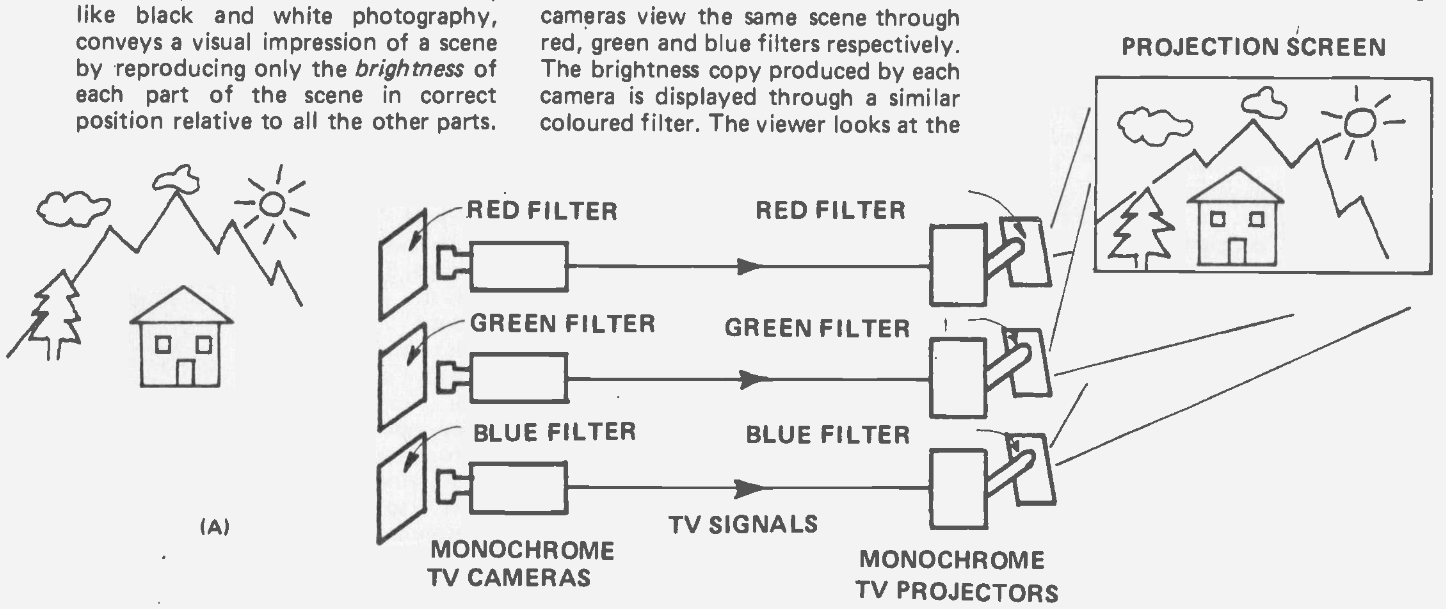
The aim of this series is to explain the basically simple principles which, when combined, make the near-miracle of colour television possible. The intention is to avoid intensive explanations of any step in the process (as a specialist may require) since this would cause a general reader to feel adrift. Instead we shall describe the fundamentals which are essential matter for anybody seeking a broad understanding of colour television.

IN PART 1, last month, it was shown that the human eye can be persuaded to see almost any colour merely by presenting it with a mixture of three lights of the primary colours red, green and blue in suitable proportions. The only shortcoming of the illusion is that the full vividness (saturation) of most of the pure spectral colours cannot be simulated, but it is acceptable for television.

Ordinary monochrome television, like black and white photography, conveys a visual impression of a scene by reproducing only the *brightness* of each part of the scene in correct position relative to all the other parts. For many purposes this 'brightness copy' is adequate since we can recognise most objects by their shape alone, and guess at their colours from experience. Colour TV on the other hand requires three brightness variables — one for each primary colour.

Fairly obviously, a workable colour television link can be made by using three monochrome television links as follows: Three monochrome television cameras view the same scene through red, green and blue filters respectively. The brightness copy produced by each camera is displayed through a similar coloured filter. The viewer looks at the red, green and blue brightness copies superimposed and therefore sees the original colour scene. This simple scheme is sometimes used for closed-circuit projection television, in the form shown in Fig.9.

Unfortunately the scheme is impracticable for domestic colour television. The main objection is to the use of three transmitting channels. This would involve expensive triplication of transmitting and receiving equipment, ineffective use of transmitter power, and excessive occupation of valuable frequency space (a single television signal fills a bandwidth that could otherwise be occupied by at least 400 different radio programmes!). Another objection is that standard monochrome receivers, of which large



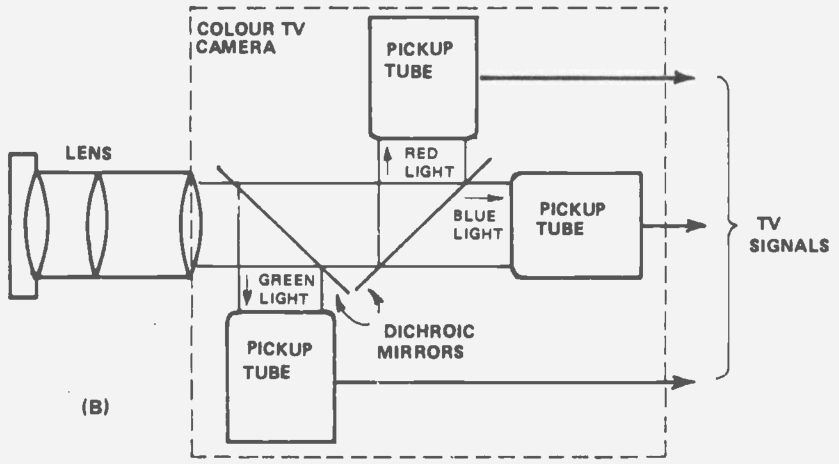


Fig. 9. A workable colour tv link can be made by using three monochrome links to copy the brightness of a scene independently in each of the three primary colours. Fig. 9a (top) shows a simple closed-circuit projection tv system. To reduce registration problems a single lens can be used to view the scene, and dichroic mirrors used instead of filters to split the light into its primary colour components, to give the usual arrangement of a colour tv camera shown in Fig. 9b (below).

numbers will probably always be in use, would give poor pictures since any single colour channel has an unnatural colour bias, e.g.: a bright red object is 'black' to the blue channel since it reflects no blue light.

The solution of these two problems of restricted bandwidth and compatibility with monochrome receivers was the major achievement which made domestic colour transmission possible.

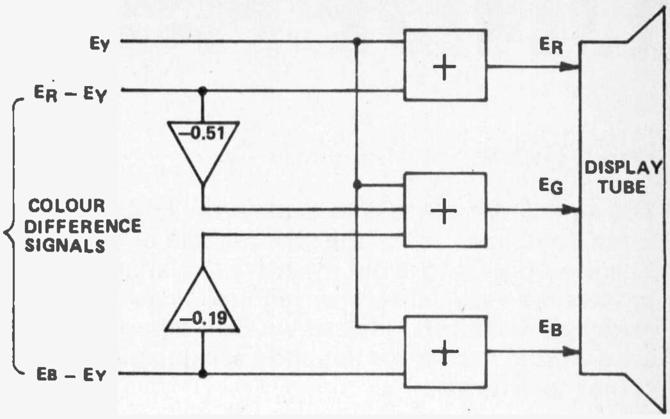
MONOCHROME COMPATABILITY

This demands that a colour television signal should resemble a monochrome signal so closely that a viewer of a monochrome receiver sees a monochrome picture which ideally is not degraded in any way, so that he cannot even tell whether the transmission is colour or monochrome!

The relative brightness of different coloured objects in the monochrome picture must be correct. The eye sensitivity curve in Fig.2 last month shows that the eye is somewhat more sensitive to green than red or blue, and therefore the colour green should appear brighter in the monochrome picture than the others. If a scene is being viewed by a colour camera (such as in Fig.9b), the three tubes of which have been adjusted for equal sensitivities, the output signals can be added together in the following conventional proportions to give a brightness or *luminance* signal 'E_Y' whose colour response resembles Fig.2 and will therefore give a good monochrome picture:—

$.3\ E_R + .59\ E_G + .11\ E_B = E_Y$ where E_R, E_G, E_B are the voltage outputs of the three colour tubes for any part of that part of the scene, E_Y = luminance level of that part of the scene.

Fortunately it is easy to add voltages in these proportions by means of resistor networks and summing amplifiers.



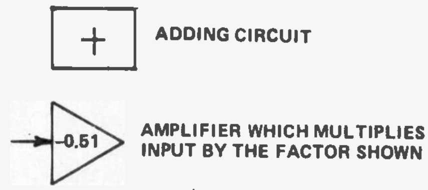


Fig. 10. Process by which a receiver reconstructs the primary colour signals required by the display tube from the luminance signal Ey plus the two colour difference signals.

COLOUR DIFFERENCE SIGNALS

Transmitting luminance solves the compatibility problem but, at first sight, appears to occupy all the frequency space available for one television channel. For colour we must transmit three channels of information from which the colour receiver can reconstruct E_R, E_G, and E_B. Since compatibility requires E_Y to be transmitted, it would be convenient to transmit two further variables:

$E_R - E_Y$
and $E_B - E_Y$.

These are known as colour difference signals and are of interest only to colour receivers. In the receiver, E_R and E_B can be reconstructed simply by adding particular pairs of signals together thus:

$(E_R - E_Y) + E_Y = E_R$
and $(E_B - E_Y) + E_Y - E_B$

It is not necessary to transmit more than the three signals E_Y; $(E_R - E_Y)$ and $(E_B - E_Y)$ for the receiver to be able to reconstruct the third primary colour signal E_G as well, since it can be obtained from:

$-\ .51\ (E_R - E_Y) - .19\ (E_B - E_Y) + E_Y = E_G$

To prove this just write the equation again, replacing E_Y each time it appears by its full form ($.3\ E_R + .59\ E_G + .11\ E_B$). Try it!

The colour difference signals have peculiar properties which are worth summing up.

1. In conjunction with the luminance signal they provide sufficient information for a colour receiver to reconstruct E_R, E_B and E_G. The process is summarised in Fig.10.

2. A monochrome receiver does not use the colour difference signals, only the luminance signal which contains all the brightness information of the scene.

3. The colour difference signals convey no brightness information. Together they specify points on the triangle of reproducible colours, and their axes were shown in Fig. 6 last month. Thus they convey information on the *hue* and *saturation* of any colour.

4. Unlike E_Y their values can go positive or negative.

5. For white, black or any shade of grey, both colour difference signals are zero. Thus the converse compatibility requirement of a colour receiver being able to receive a monochrome transmission is neatly solved since no colour difference signals are transmitted and their values are effectively zero.

BANDWIDTH

Somehow the two colour difference signals must be transmitted together with the luminance signal in spite of the fact that the luminance signal can

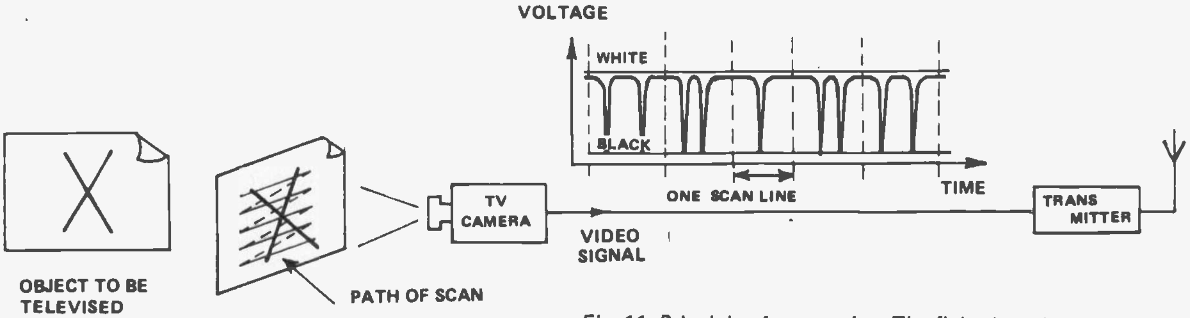


Fig. 11. Principle of tv scanning. The flyback at the end of a scan line to the start of the next is assumed to be instantaneous.

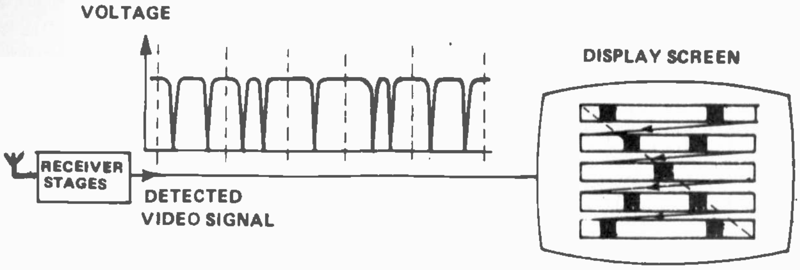


Fig. 12. Television display. The screen is scanned in synchronism with the camera by a spot of brightness controlled by the video signal. If the scan is sufficiently fast, an illusion of the televised scene is created.

be expected to take up all the available frequency space for a television signal, and in such a way that neglible interference between the three signals occurs! The requirement seems impossible until the nature of television bandwidth is understood.

Referring to monochrome television, at any instant the television camera produces a voltage which represents the brightness of a single small part of the scene. To convey brightness information about the whole scene, the pickup tube in the camera 'scans' the scene in horizontal sweeps (lines) each a little below the previous one, similar to the movement of your vision in reading this paragraph. The output voltage therefore varies as the scan passes across light and dark objects, this forming the *video* signal. This is shown in Fig.11 where the output waveform can be related to the simple picture shown. When the whole scene has been scanned, the scan begins again from the top.

It is arranged that the receiver produces a spot of light on its screen which scans the screen surface in synchronism with the camera scan. At any time the brightness of the spot is made proportional to the voltage from the camera. If the scan is so fast that each part of the screen is rescanned before the visual impression of the previous scan has faded, the eye has the impression of a complete picture as shown in Fig.12.

Clearly the video signal must at times change very rapidly between its 'black' value and its 'white' value. It is vital to know the fastest it might change. The following factors determine this.

1. The faster the scan the faster the video signal may have to change. In most countries a whole picture, called a frame in comparison with cinematography, has 625 lines to give adequate vertical resolution. Successive pictures must be presented to the eye about 50 times a second or flicker is intolerable. This could imply a need to scan all 625 lines every $\frac{1}{50}$ second but a technique called interlaced scanning is used to halve the scan rate. The spot scans every *alternate* line in $\frac{1}{50}$ second, then scans the remaining lines in the next $\frac{1}{50}$ second. Each of these scans of 312½ lines is called a field. From a distance the eye sees the field flicker rate (50 per second), not the frame flicker rate (25 per second). Since 312½ lines are scanned in $\frac{1}{50}$ second, each line is scanned in 64 millionths of a second (64 μS).

2. The finer the detail of the scene, the faster the video signal must change. It is reasonable to expect the picture resolution horizontally to be about as good as it is vertically. Combining factors such as the loss of some vertical resolution because about 40 lines are necessarily outside the picture area, and the rectangular shape of the screen, the absolute maximum horizontal resolution desirable is the ability to display about 320 pairs of alternate bright and dark patches across a line. While this is unlikely to occur in a picture, such fine detail can occur in parts of scenes and the video signal would then have to change at a frequency of about $\frac{320}{64\mu S}$ = 5 MHz. In practice an absolute limit is set at 5.5 MHz – see Fig. 13a). This applies both to monochrome video signals and to the luminance signal for colour television.

Thus in theory the luminance signal might at different times have any frequency from zero to 5.5 MHz, depending on the scene detail being scanned. Apparently there is no frequency space available for our colour difference signals since 5.5 MHz is all the bandwidth allowed for a television channel, and any attempt to reduce the luminance signal bandwidth would cause blurred (reduced horizontal resolution) pictures.

However examining the actual

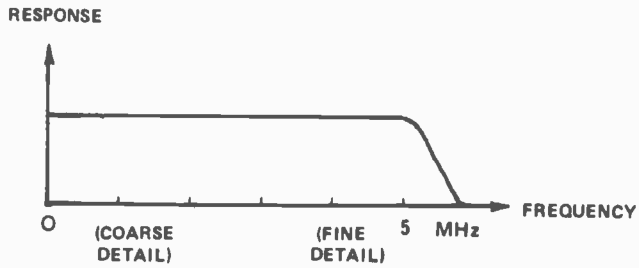
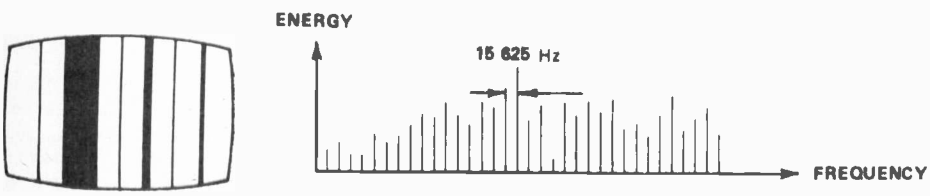
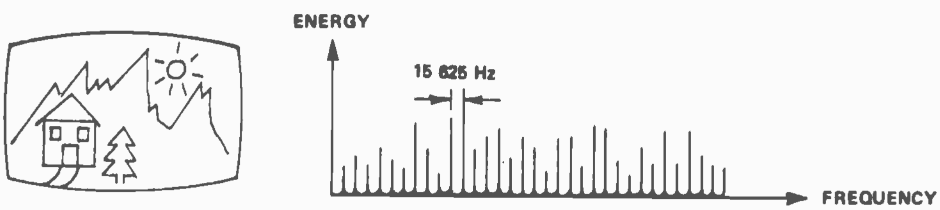


Fig. 13.

a) To ensure a luminance signal does not occupy excessive bandwidth it is passed through a filter of the response shown, which permits adequate picture resolution.



b) A scene containing only horizontal detail would cause a luminance signal containing only harmonic frequencies of 15 625 Hz.



c) The luminance signal for typical real scenes still tends to contain energy concentrated at multiples of 15 625 Hz.

occupation of the 5.5 MHz bandwidth by the luminance signal shows that some frequencies are far more likely to occur than others! For all likely scenes to be televised, the waveform produced by a typical scanning line is fairly similar to the line before and the line after. If we imagine a scene where every line waveform is *exactly* the same (a picture of a row of vertical bars perhaps), a mathematical description of the video signal would be:

(complex waveform of one line) X (line scanning frequency).

Although the complex line waveform might consist of many frequencies, the video signal would consist only of whole multiples (harmonics) of the line scanning frequency, which is $\frac{1}{64\mu s}$ = 15 625 Hz. (Fig. 13b). The frequencies between these harmonics would not occur at all! Although a real scene is not like this, all real scenes tend to give video waveforms containing little or no energy midway between line frequency harmonics.

COLOUR DIFFERENCE BANDWIDTH

Clearly the luminance signal does not fill the available bandwidth as completely as it appeared, which might offer a possibility of finding room for the colour difference signals. Can the extra bandwidth requirement first be minimised?

Another property of the eye ensures it can. The eye is insensitive to fine *colour detail* i.e. differences in colour between adjacent small areas. It is far more sensitive to brightness detail, which the luminance signal provides. The bandwidths of the two colour difference signals can be considerably restricted to 1 MHz, resulting in reduced horizontal colour resolution, without seriously affecting the colour picture. The eye tends to extract fine detail from the luminance information, and be satisfied by correct colours only for comparatively large objects in the scene.

Like the luminance signal, the colour difference signals contain energy mainly at harmonics of line scan frequency.

COLOUR DIFFERENCE SUBCARRIER

The trick which makes it possible to add the colour difference signals to the luminance signal without interference is to *multiply* (modulate) them by a special high frequency known as the *sub*carrier, to distinguish it from the transmitter carrier frequency. Amplitude modulation of a carrier produces *sidebands* or frequencies spaced away from the carrier by the modulating frequency. Since the colour difference signals contain mainly line frequency harmonics, the sidebands produced will be at line-frequency steps either side of the subcarrier frequency, up to ± 1 MHz away from it. We are free to choose the subcarrier frequency. If it is placed between two high harmonics of line frequency, all the colour difference sidebands will occur in the 'dead gaps' of the luminance frequency spectrum. The modulated subcarrier can therefore be added to the luminance signal with minimum interference as shown in Fig.14. The process is called 'frequency interleaving' for obvious reasons.

Since the modulated subcarrier is an ac signal it has no nett dc value and therefore does not affect the output level from the simple diode envelope detector in a monochrome receiver, which therefore responds only to the luminance signal. The subcarrier oscillation does tend to produce fine dots on the monochrome picture but using suppressed carrier modulation, plus very careful choice of subcarrier frequency, make this effect entirely negligible.

Part 3 next month will explain how it is possible to modulate *both* colour difference signals on the single subcarrier and the remarkable implications of the method chosen, summed up in the magic word PAL! ●

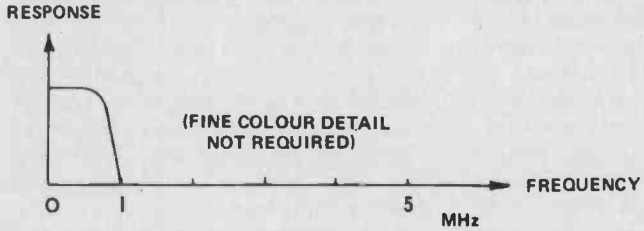
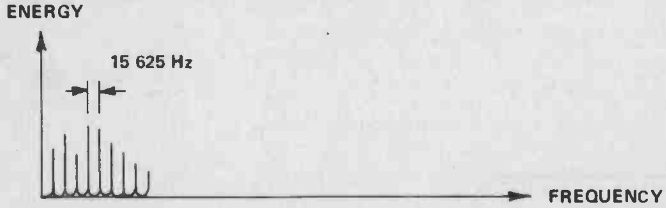
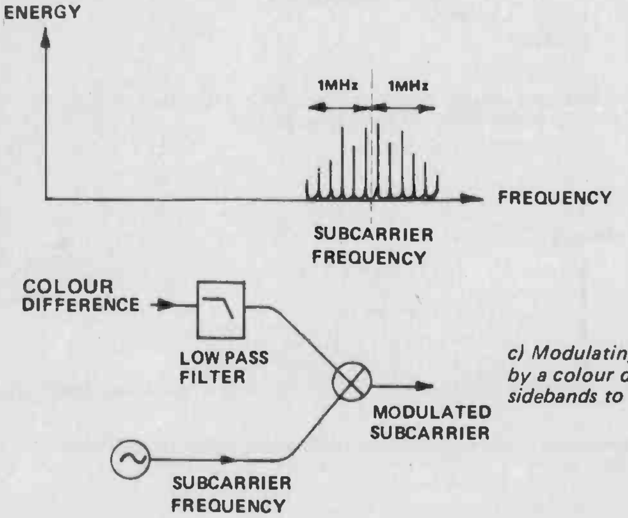


Fig. 14

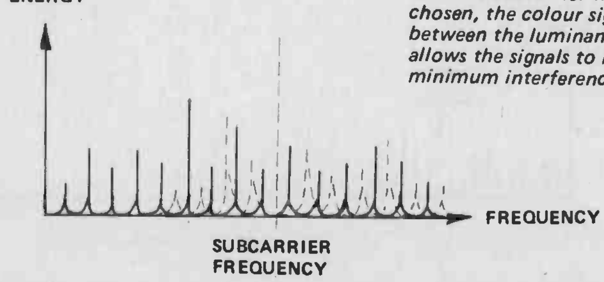
a) The colour picture does not suffer much if both colour difference signals are passed through low pass filters with this response.



b) Energy in the colour difference signals tends to be concentrated at harmonics of line frequency.



c) Modulating a high frequency (subcarrier) by a colour difference signal produces sidebands to ± 1MHz.



d) If the subcarrier frequency is carefully chosen, the colour signal sidebands lie between the luminance energy peaks. This allows the signals to be added together with minimum interference.

ELECTRONICS -it's easy! PART 13

The operational amplifier — basic principles

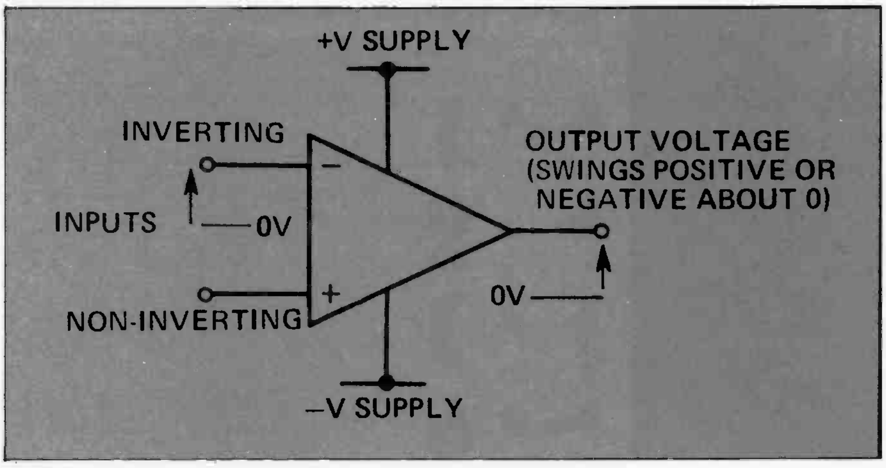


Fig. 1. The basic symbol and connections for an operational amplifier.

IN THE TWO previous sections we explored the role of basic amplifier circuits and investigated how adding extra passive components converts the basic active device into a practical amplifier building block.

These days the cheapest and most straightforward method of amplifying signals is to use one of the many, readily available integrated-circuit operational amplifiers (the op-amp). The methods of using op-amps are universal even though various types may differ in details such as stability and cost etc.

We will see that, provided the basic operational amplifier has a dc gain of 10 000 or more, and draws very little input current, the internal design is of little consequence.

The operation of the complete amplifier system (whether it be based on transistors, ICs or even valves) is determined primarily by the way components are connected around it. That is the basic op-amp unit can be made to perform literally hundreds of different functions by adding appropriate external circuitry. It is this extreme degree of versatility, plus the extraordinarily low price of IC devices that make op-amp techniques so attractive.

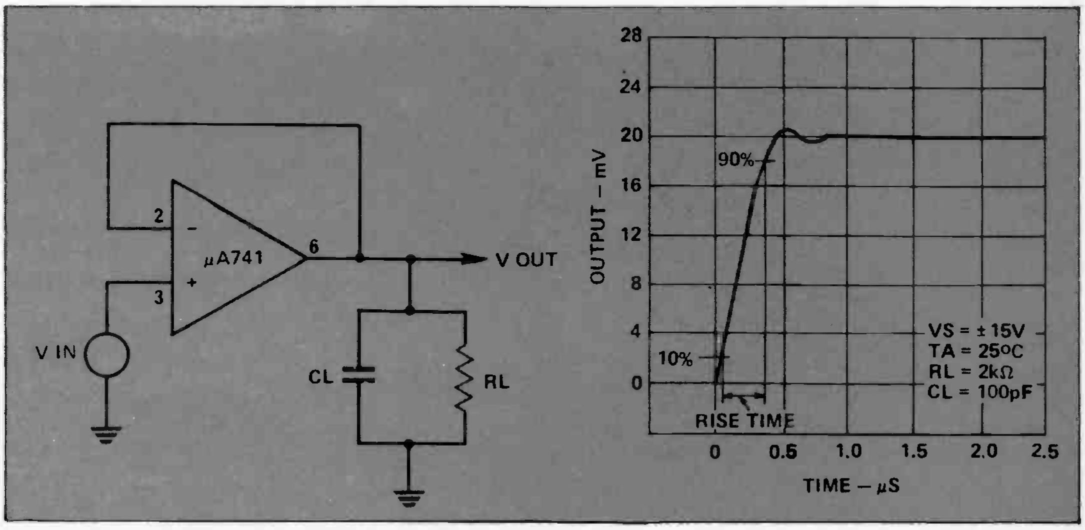
Before we move on to see how such versatility is achieved, we must study the terms used to describe the characteristics and performance of operational amplifiers.

LINEAR VERSUS DIGITAL

We have already described how a transistor stage may be used to amplify, with low distortion, continuously varying voltage or current signals. Circuits that perform this way — they increase the level of complex waveforms without changing them in any other way — are said to be LINEAR systems. By contrast, it is also possible to use the same basic active element so that it is either fully 'on' or fully 'off', depending on whether the input signal is above or below a preset level. The device actually moves through the linear region so quickly that it is no longer a linear device but a switch. There are many kinds of switching circuits and the entire range of such devices and circuits is loosely classified as DIGITAL (digital meaning ON/OFF or step by step operation). Digital devices and circuitry will be studied in more detail later in this course.

Integrated circuits, therefore, are catalogued by the makers as either linear or digital devices. The op-amp

Fig. 2. Transient response of a 741 type op-amp to a step input change. The test is performed using the circuit shown at left — basically a voltage follower circuit.



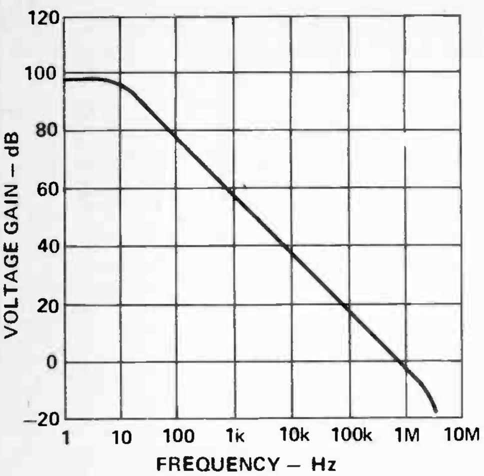


Fig. 3. The open loop (no feedback) frequency response of a 741 op-amp. The constant roll off of 6 dB/octave is built in to ensure stability.

selection form a sub-group of the linear range — others being voltage regulators, oscillators and special purpose units such as timing circuits. It is worth knowing that it is often possible to make a linear circuit perform a digital function but usually the reverse does not hold. In principle at least, the op-amp can be made to fulfil just about all signal processing black-box requirements but to conserve space and power, and to keep costs down, it is usually better to use special-purpose ICs for many applications. Selecting the right component is largely a matter of comparing the cost of various alternatives for the particular job. It may well be better to use a modified op-amp, or even a discrete circuit, to fill a special task rather than await delivery of an exactly right, but harder to procure, special IC.

COMMON LINEAR TERMS

These terms tie in with the general schematic for an op-amp, given in Fig 1. The amplifier itself does not necessarily require a zero/volt connection, it amplifies the *difference* between voltages at the two input terminals.

Large Signal Voltage Gain

This is the ratio of the maximum output voltage swing (under appropriate loading conditions) to the change in input required to drive the output from zero to this voltage. A typical value of gain is 200 000 with an output swing of ±10 V. The input change, therefore, needed to provide full output swing is a mere 50μV. This may seem alarmingly small — a copper to solder terminal connection (forming a thermocouple) will generate signals of the order of 5 to 10μV with small temperature changes! In practice, however, it is rare to use the full gain capability. Gains approaching infinity are necessary, however, so that the performance of the amplifier is entirely dependant on the input and feedback networks — not on the device itself.

Input Offset Voltage

A differential voltage of only 50 microvolts is necessary to provide full output swing. However due to manufacturing tolerances the matching of the input transistors may not be exact and a small offset voltage may be required at the input to balance the amplifier under no-signal conditions.

This voltage is normally less than 6 mV, but could be troublesome in a low level dc amplifiers. Therefore provision is made on most op amps for connecting a potentiometer to null out this voltage, thus making the output zero under no-signal conditions.

Input Bias Current

All operational amplifiers (and also transistor amplifiers) require a small steady-state input current called the input bias current.

Input Offset Current

The difference between the two bias currents in a differential op amp is known as the input-offset current, and is specified at a particular temperature. With equal resistances in series with the two input terminals, it is only this difference in bias currents which produces an offset error. When the input source impedances are high the effect of input-offset voltage is far less than that of bias and off-set currents.

A typical value of input offset current would be 50 nanoamps (50 x 10^{-9} amps), but may be much lower in more expensive op-amps.

Input Resistance

With one of the two inputs grounded, the input resistance is that seen looking into the other input. A general purpose op-amp exhibits around 0.5 megohm input resistance. Some better quality amps go higher and the ideal, as we shall see later, is an infinite input resistance.

Feedback, when applied, modifies this value considerably, may reduce it to zero (inverting amp) such that the input impedance is the value of the resistance in series with the input, or may increase it to several megohms (non-inverting amplifier).

Output Voltage Swing

This tells us how far the output voltage can change in both positive and negative directions. It will always be a little less than the supply voltage. For a supply of ±15 V a typical swing (without distortion occuring) would

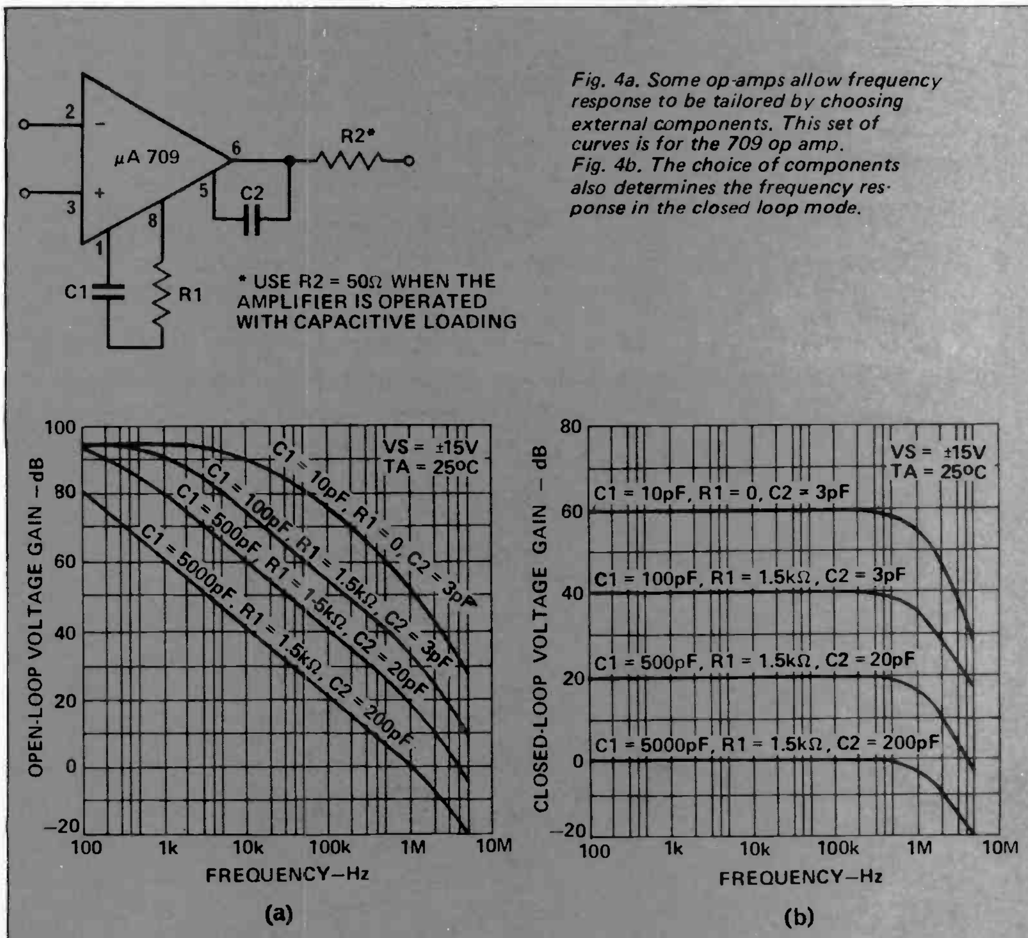


Fig. 4a. Some op-amps allow frequency response to be tailored by choosing external components. This set of curves is for the 709 op amp.
Fig. 4b. The choice of components also determines the frequency response in the closed loop mode.

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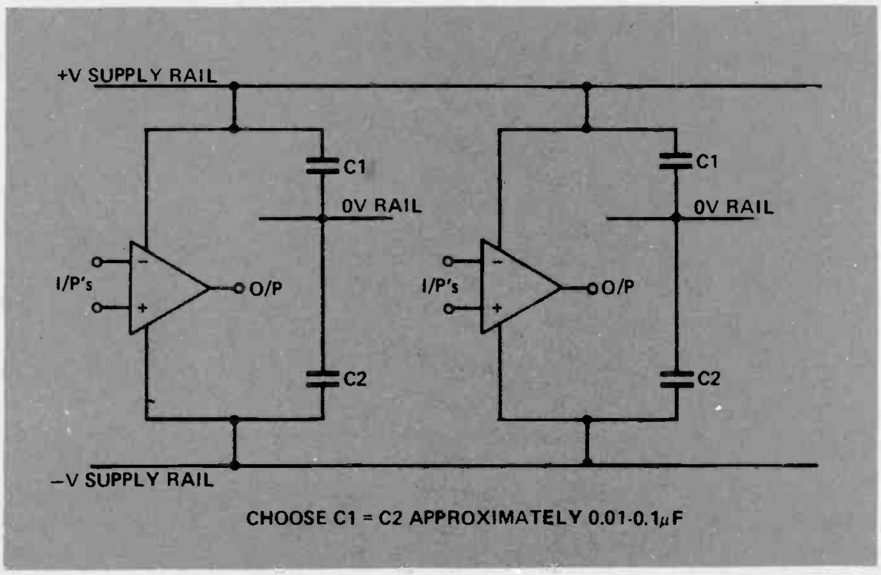


Fig. 5. Each op-amp should have decoupling capacitors across power supply lines to ensure that transients are not coupled from one amplifier to the other through the power rails.

be ±12 to ±14 V. Op-amps work satisfactorily over a wide range of supply voltages — voltages less than the maximum specified may be used.

Input Voltage Swing

This value must not be exceeded if the amplifier is not to be damaged. In most modern op-amps, such as the LM301, 741, etc, the inputs can be taken to the supply rail together and in some amplifiers may be taken to opposite supply rails (that is, 30 volts between them) without damage. However some older types such as the 709 may only withstand a common mode voltage of ±8 volts and a maximum differential voltage of ±5 volts.

Input common mode rejection ratio

This is the ratio of the input voltage range, to the maximum change in input offset voltage over this range. It is quoted in decibels being typically 80-90 dB i.e. if the inputs are moved by 10 V the offset voltage could change by 1 mV.

Output resistance

A typical value of output resistance measured into the output terminal with the output near zero volts) is around 100 ohms. This measurement is made with a small signal level and at approximately 400 Hz to avoid dc drift problems. This however is the open loop (no feedback) output impedance and is substantially reduced when feedback is applied. The maximum load which can be connected to an operational amplifier is not determined by the output impedance but by the current that the op-amp can supply (typically 10 mA).

Output power

The normal op-amp is usually designed for low power output only. If power is required a power stage of discrete transistors (or special power ICs) is added after the op-amp.

Supply Voltage Rejection Ratio

This relates the change in input offset voltage to the corresponding change in supply voltage producing it. It expresses how well the circuit ignores voltage supply variations due to mains fluctuations etc.

Typical values lie around 100 μV change per volt of supply change. In critical dc amplifiers the power supply, therefore, must be stabilised (that is, the voltage must not change with respect to zero). For example, if the design can tolerate only 10μV change in input offset voltage the supply must be stable to within 100 mV of its magnitude.

However for general applications rejection of supply voltage changes is sufficiently good that close regulation is not required.

Power consumption

Even when an op-amp is not providing an output, that is when the output voltage is at zero, the circuit still consumes power. This value is usually quoted for zero output conditions (the greatest internal power loss across them) and is in the region of 100 mW.

Peak output current

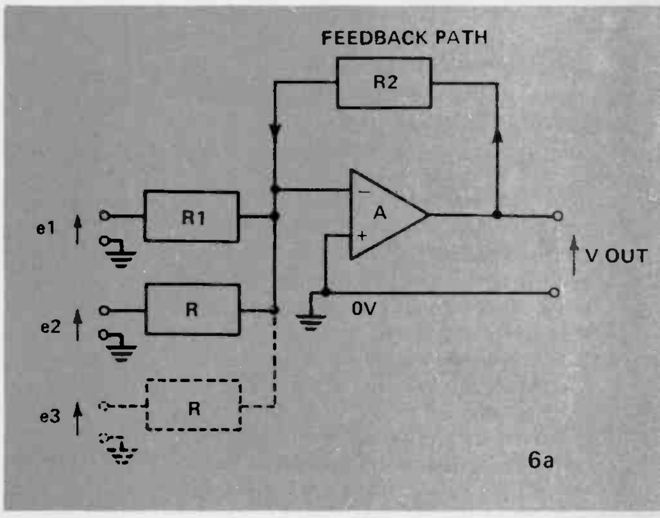
The output current must not exceed the stated value or internal permanent damage may occur. Many designs, however, now incorporate protective circuitry that enables the output to be short-circuited without damage.

Dynamic response of operational amplifiers

A dc amplifier, one might think, has no need to handle fast changing signals. In fact, it is quite normal for it to need a good frequency response extending to tens of megahertz. Examples of this are the wide band ac amplifier having a response down to dc and a dc amplifier which will faithfully reproduce a sudden voltage change in a control system. In such cases the system designer needs to know more than just the dc large-signal gain of the op-amp — he needs to know the gain at all frequencies.

The response of the op-amp to a step input voltage is called its transient

Fig. 6a. General circuit configuration for an inverting amplifier.
Fig. 6b. General circuit configuration for a non-inverting amplifier.

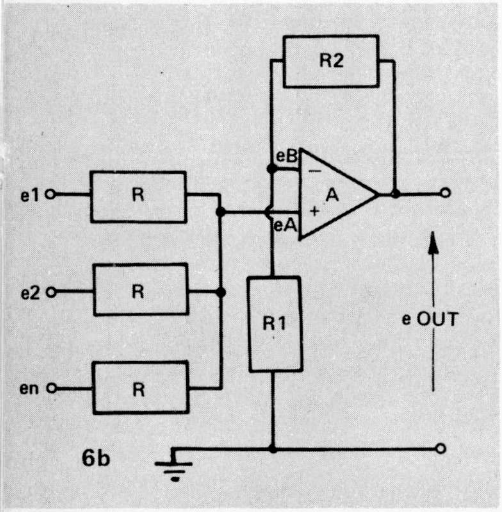


response. That is, this parameter defines how the output of the op-amp will follow an input change with time under closed-loop (with feedback) conditions. The usual way that this is quoted is by an amplitude/time graph — as given in Fig. 2 — which shows how the output changes when a 'perfect' step-rise in input voltage is applied. Note also that the diagram indicates the load resistance value, the capacitance of the load, the supply voltage and the device temperature: each of these will alter the shape.

A second dynamic characteristic is the frequency response. Figure 3 shows a typical response curve (note that such curves vary greatly with different amplifiers) for an op-amp without feedback (called open-loop operation). In general such curves always have the same basic shape; flat to begin with and then falling off at the same rate of 6 dB per octave (20 dB decade). There is a good reason for such a characteristic — it ensures stability in closed-loop working.

If the slope were increased the amplifier could introduce excessive phase shift. Thus the feedback could become positive rather than negative and the amplifier may oscillate. Some op-amps have facilities for the circuit designer to provide external compensation to the IC. This usually consists of an RC network or a single capacitor, the values being selected to suit the application. Figure 4 show how these values alter the frequency response of the popular 709 type of op-amp.

A third important dynamic term is Slewing Rate. A typical value is stated at 0.5 V/µs, meaning that the output can change no faster than half a volt in each microsecond. The value is quoted for a feedback connection of unity gain — at other values of gain the rate will be different. Thus although the amplifier may well handle a small signal at a given frequency a large signal at the same frequency may well be distorted because of the slew-rate limitation.



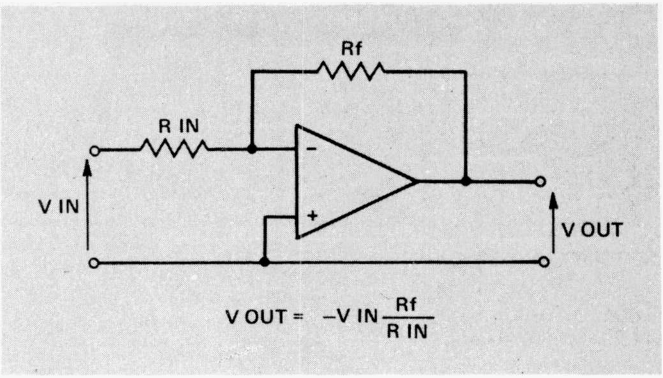


Fig. 7. In this configuration the stage gain is determined by the ratio of Rf to Rin — **not** *by the device gain.*

The above terms are those commonly encountered. Other more obvious parameters are given — temperature range of operation, and lead temperature when soldering. The manufacturers of ICs also give a variety of curves for various parameters — voltage gain versus supply voltage, power dissipation versus temperature and many more. These are all helpful from time to time but, in general, the casual user will not need to explore them in depth.

THE MAGIC OF FEEDBACK

The basic op-amp will only accept very small input signals because of its enormous gain. At first sight this seems to be a peculiar way to go about things for surely the optimum would be to design the internal circuitry to give the gain needed and no more. We will soon see that there is a better, and more versatile way of obtaining any required gain (by adding a simple network to the amplifier). For this concept to work correctly, the amplifier must have a very high gain.

The two basic amplifier circuits are illustrated in Fig 6. The circuit of Fig 6a is an inverting amplifier and that of Fig 6b a non-inverting amplifier.

For the purposes of our discussion we must assume that the amplifier has an infinite input resistance and infinite gain. The input signal (in Fig 6a) is applied via R1 and the output is fed back to the input via R2.

Thus, as the ideal amplifier draws no current, the current in R1 is

$$I_{R1} = \frac{e1}{R1}$$

and the current in R2 $= \frac{V\,Out}{R2}$

A theorem not yet covered (called Kirchoff's Laws) states that the sum of the currents at any point in a circuit must be zero. Therefore $I_{R2} = I_{R1}$

By Ohm's Law: $\frac{e1}{R1} = \frac{V\,Out}{R2}$

Now the gain $A = \frac{V\,Out}{e1}$

$$\therefore \quad A = \frac{R2}{R1}$$

How convenient! The gain of the amplifier may be set by adjusting the ratio of R2 to R1. In a practical amplifier there is some error because the input impedance is not zero and the gain is not infinite. But providing the amplifier open-loop gain is in excess of 10 000 the error may be disregarded.

For the non-inverting configuration it may be shown that the gain is

$$A = 1 + \frac{R2}{R1}$$

Hence it may be seen that any reasonable gain may be programmed by simply selecting two resistors, and that drastic changes in device open-loop gain will have little effect on the closed-loop gain.

The open-loop gain should be at least 10 dB higher than the closed-loop gain at all working frequencies to maintain frequency response of the amplifier within 3 dB. (See graph of open-loop gain versus frequency.)

The effects of using feedback are as follows:—

Inverting Amplifier

Output impedance is reduced by the loop gain. That is, if the amplifier has a gain of 10 and the output resistance is 150 ohms, the closed loop output impedance falls to 15 ohms.

As the amplifier always tries to keep its input terminal at zero the input impedance is equal to the value of R1.

Distortion is reduced by feedback by I/A.

Common mode rejection is improved and the stability is improved.

Non Inverting Amplifier

Output impedance is reduced by the loop gain.

Input impedance is increased by the loop gain, (but is limited by common mode impedance and resistances connected between non-inverting input and ground.

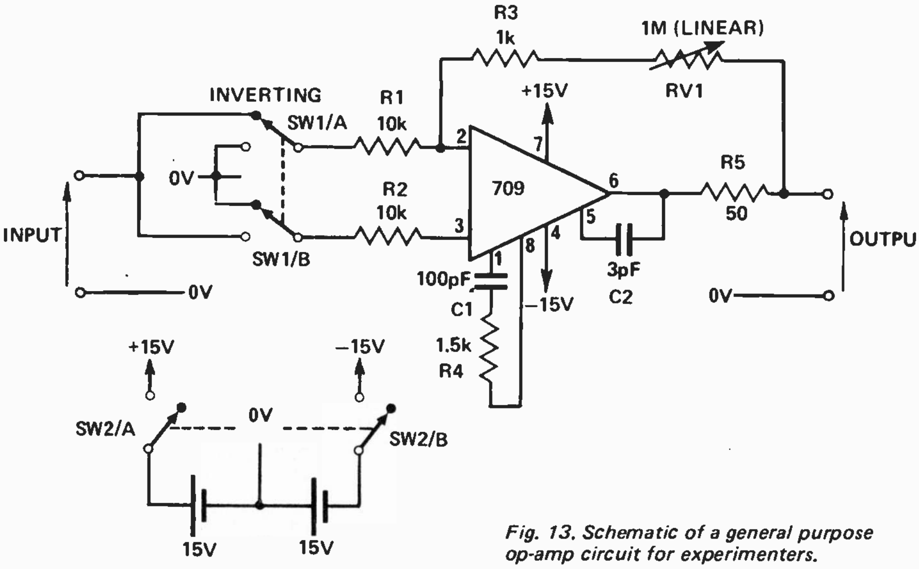


Fig. 13. Schematic of a general purpose op-amp circuit for experimenters.

The circuit given in Fig 13 is based on a Fairchild application note and uses the currently cheapest op amp, the 709 series. As power drain is low two dry cells may be used thus avoiding the expense of a mains power supply.

To obtain non-inverting or inverting operation, a changeover switch has been included to ground the appropriate input to the op amp. Components C1, R4 and C2 have been chosen to obtain the maximum bandwidth of 0.5 MHz.

The output impedance of the unit is less than an ohm but the peak output current should not exceed 20mA. The power dissipation of the amplifier must not exceed 250 mW so even 20mA may be too much under some circumstances.

The input impedance in the inverting mode is the value of R1. Hence if a higher input impedance is required then R1 should be increased. Note that R2, R3 and RV1 must also be increased proportionately to maintain the gain ratios.

Do not use values in excess of 10 megohm as stray capacity and leakage resistances will then affect stability and accuracy.

CONSTRUCTION

The form of construction is largely a matter of individual preference. We suggest that a small diecast box be used. By mounting the switches and potentiometers through the bottom of the box (rather than onto the lid) the lid may be removed for access.

The gain control should be marked by experimentally verifying gains at various positions of the control. A multimeter may be used to compare input and output, to determine gain, but use a low frequency (e.g. 400 Hz) from a low impedance source, so that the accuracy of the multimeter itself does not affect results.

USING THE AMPLIFIER

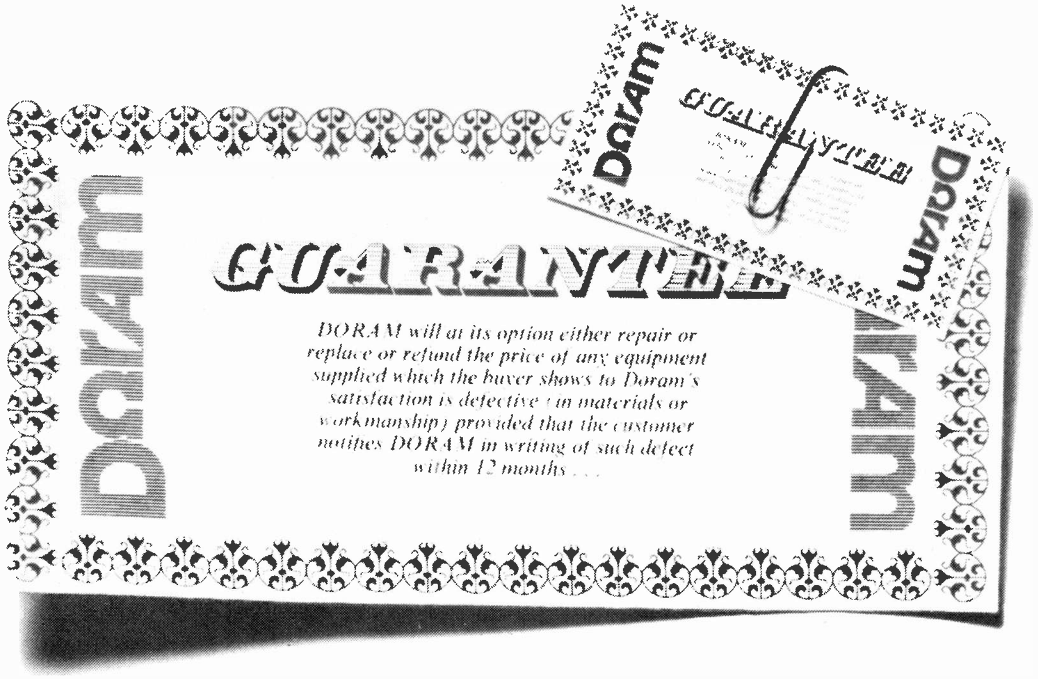
Basically the unit is a single-input, variable-gain dc amplifier. We have seen in the theory section however that it can be used for other purposes.

To use the unit for amplifying ac, use a capacitor in series with the input to isolate any dc component of the previous circuit. Make sure that the reactance of the capacitor is less than the value of R1 at the lowest frequency of interest.

To mix signals, simply add additional 10k resistors from each input to the summing point (pin 2).

An integrator may be constructed by replacing R2 and RV1 with a capacitor.

Thus, as well as being a useful tool, the amplifier may be used to increase your understanding of op amp techniques. ●



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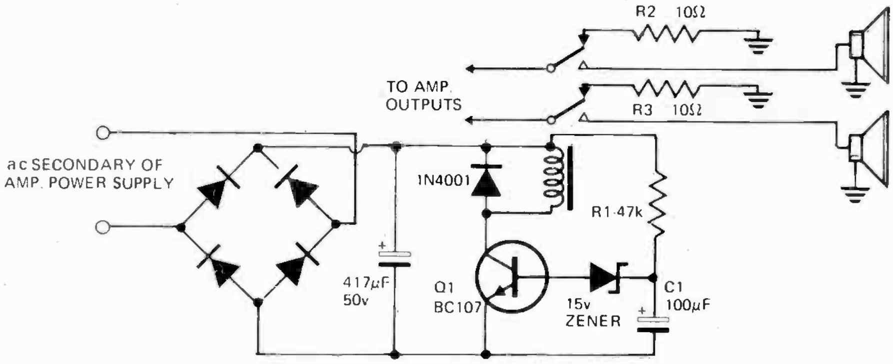
tech-tips

PLOP ELIMINATOR



Many hi-fi amplifiers cause an only-too audible 'plop' in the speakers when switched on. The 'plop' is not only disconcerting but can also be damaging to low-power capacity speakers.

The plop is generally caused by the momentarily high inrush current to the series output capacitors.

The circuit shown here brings the speakers into circuit only *after* charge on the output capacitors has been established.

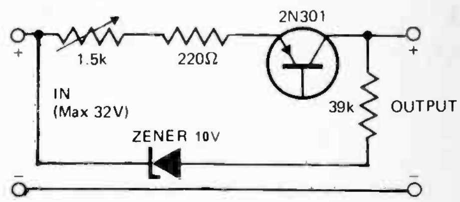
The unit is connected by wiring the rectifier bridge input to the AC secondary winding of the amplifier power supply.

Immediately the amplifier is switched on, C1 charges through R1. When the voltage exceeds the Zener voltage of the diode in series with the base, the transistor conducts and closes the relay.

As soon as the power is shut off, the small smoothing condenser quickly discharges itself through the relay and de-energises it.

The two resistors R2 and R3 provide an alternative path for the onrush current when the amplifier is switchd on.

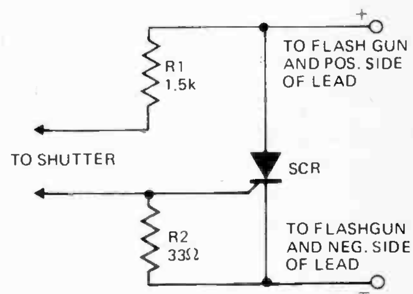
SIMPLE CONSTANT CURRENT CIRCUIT



A series transistor is used as a variable resistor for this constant current supply.

The output current is held within 10% over a range of loads from a short circuit to 500 ohms. The required current is set by the potentiometer. The transistors specified will handle voltages up to 32 V.

SHUTTER SAVER

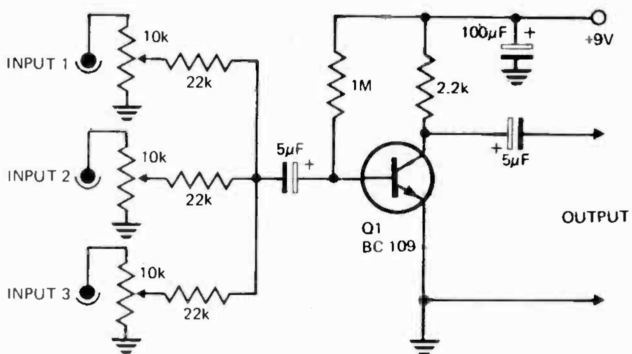


This three component device will keep sparks out of your camera shutter, when using a flash gun, by letting an SCR carry the firing current.

Closing the contacts in the camera shutter applies a triggering voltage, developed across the divider R1, R2, to the gate of the SCR., so firing the SCR and hence the shutter. The value of R1 must be as high as possible, but low enough to carry the needed gate current which may vary from 0.5 mA to a few milliamps. The value of R2 must be sufficiently high to develop necessary gate triggering voltage. R1 and R2 may need to be varied with SCR selected. The SCR should have a rating of 200 volts. If the device is used with a battery-capacitor flash, which operates at about 22 volts, R1 and R2 must be adjusted to suit.

The components can be assembled in a plastic pill tube, fitted in the middle of a flash lead.

ONE TRANSISTOR AUDIO MIXER



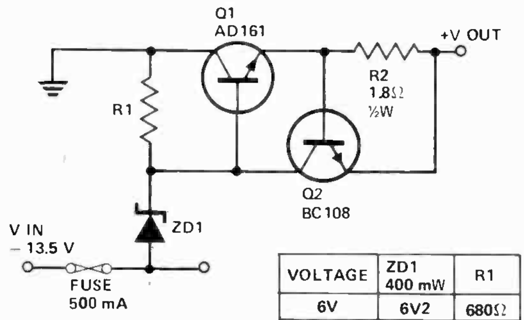
Three ihputs are shown on our circuit but more can be added if required.

Each input has its own level control.

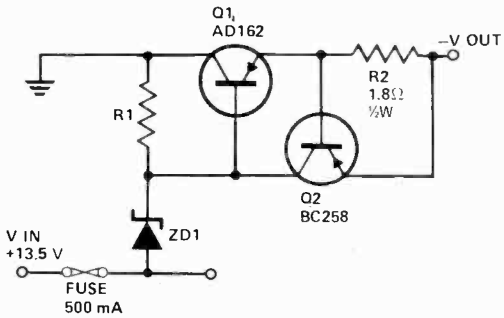
Sensitivity is 500 mV output for 25 mV input. This is more than adequate to drive most amplifiers.

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 the Editor, Electronics Today International 36 Ebury Street, London SW1W 0LW.

LOW VOLTAGE STABILIZERS HAVE SHORT CIRCUIT PROTECTION



VOLTAGE	ZD1 400 mW	R1
6V	6V2	680Ω
7.5V	7V5	390Ω
9V	9V1	220Ω



These short-circuit protected stabilisers give 6, 7.5 and 9 V from an automobile battery supply of 13.5 V nominal, however, they will function just as well if connected to a smoothed dc output from a transformer/rectifier circuit.

Two types are shown for both positive and negative earth systems. The power transistors in each case can be mounted on the heatsink without a mica insulating spacer thus allowing for greater cooling efficiency.

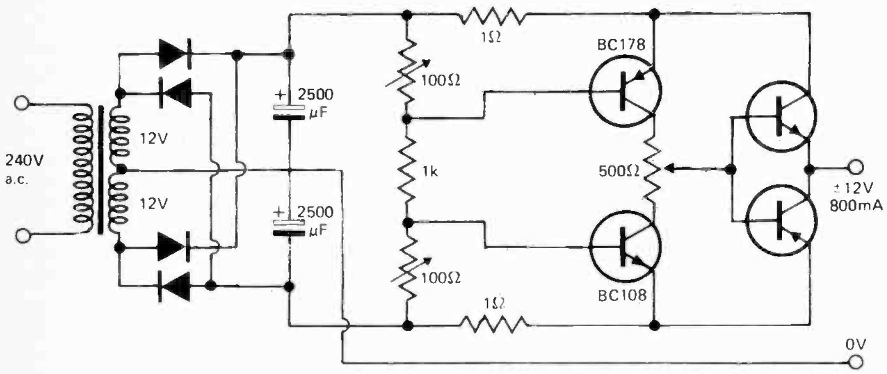
Both circuits are protected against overload or short-circuits.

The current cannot exceed a value of 330 mA. Under normal operating conditions the voltage across R2 does not rise above the 500 mV necessary to turn Q2 on and the circuit behaves as if there was only Q1 present.

If excessive current is drawn, Q2 turns on and cuts off Q1 protecting the regulating transistor.

The accompanying table gives the values of R1 for different zener voltages.

VARIABLE POWER SUPPLY GIVES POSITIVE OR NEGATIVE OUTPUT



A variable power supply using complementary output transistors is capable of swinging the voltage at the output from +12 V through zero to – 12 V.

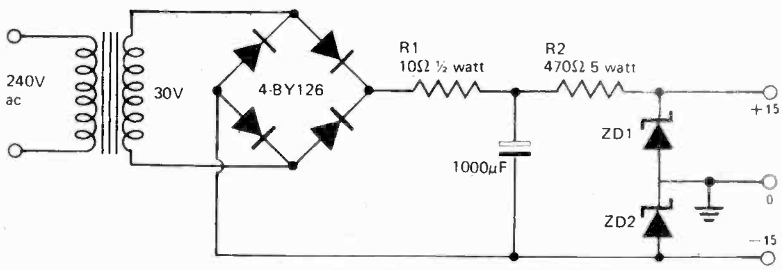
The two output transistors can be types BD 135 – BD 136. These are both cut off when the 500 ohm potentiometer is centred.

Rotating the potentiometer in either direction will give positive or negative output voltages up to 12 V and 800 mA. The series resistors (1 ohm) monitor output current and when this exceeds a level preset by the 100 ohm trimmers will current limit the output.

DUAL POLARITY SUPPLY POWERS OP-AMPS

Ever been bothered by the lack of a dual supply for your op-amp circuits? This simple circuit gives positive and negative supply from a single transformer winding and one full-wave bridge.

Two Zener diodes in series provide the voltage division and their centerpoint is earthed. (N.B. the smoothing electrolytic must not be earthed via its case).

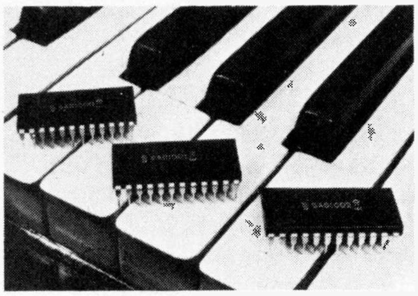


ZD 1 and ZD 2 = 15V ZENER DIODES – BZX70 C15

Continued from page 8.

REMOTE TV & VCR CONTROL

Three integrated circuits which allow the joint remote control of a TV set and a video recorder with a total of 36 ultrasonic frequencies have been developed by Siemens. The module SAB 1000 is used as the transmitter, the module SAB 1001 as the receiver and the module SAB 1002 as the analog memory.



The first of the three MOS integrated circuits, the transmitter module SAB 1000, generates the 36 ultrasonic frequencies in the range 33.2 to 45.8kHz. The incoming ultrasonic frequencies are accepted by the receiver module SAB 1001 after preliminary amplification and divided into three 12-channel groups. The first group activates the channel memories for the various receive programs. The two other groups at the same time prevent the memory module SAB 1002 from responding. The latter IC is capable of controlling four analog functions - for example brightness, colour intensity, colour saturation and contrast.

Channel 24 at the end of the second group has a special duty. Its task is to switch the TV set with preheated picture tube to the stand-by condition as soon as one of the appropriate buttons has been actuated for longer than 0.7s. The period is the same when one of the program buttons is used to switch on the TV set. In addition to the four control options, the analog memory SAB 1002 also features an OFF/ON function, which can be used for a voice/music button, channel superposition (time of day), AFC, ambient light control, brightness or colour killing.

The ICs SAS 580 and SAS 590 (the latter in duplicate) are used as digital memories of the remote-controlled devices. These ICs were developed as switching amplifiers for sensor buttons. They provide the circuitry that allows for direct control to be installed in the TV set or video recorder with no appreciable outlay. The buttons on the hand-held controller are also of the sensor type.

For the remote control of a colour TV set only 24 channels are normally required nowadays. The Siemens concept affords the option of simultaneously driving a video recorder, for example, with the 12 free channels. Commercials interrupting a programme could be kept off the tape by the viewer in his armchair with the aid of a rapid stop key. The same considerations apply for the operation of a radio set. The new method of remote control for several devices could also be used for tape recordings.

WORLD'S MOST ACCURATE WATCH

The Science Museum has accepted a new electronic wristwatch, with a guaranteed accuracy of within one second a month, for permanent display in the Time Measurement Gallery.

With its unprecedented accuracy of a second a month, the new model, called the Marine Chronometer, is claimed to be the world's most accurate and technically advanced wristwatch. A quartz crystal and a $4mm^2$ IC are driven by an aspirin-sized battery.

An unusual feature of the watch is a device for setting the hour hands independently of the second hands, so this does not affect its accurate timekeeping (an important advantage for members of the 'jet set' flying from one time zone to another).

The Marine Chronometer is resistant to water, shock, magnetic fields, humidity, dust, and temperature changes. It has a stainless steel case and bracelet, and sells for £680.

HF AERIAL OVERCOMES SKIP–DISTANCE

Skip distance is the distance between a transmitter and the closest skywave reception area. It is caused by high angle radiation not being reflected back down to earth from the ionosphere. In practice, it means that HF radio contact is impossible when the groundwave (the direct-line signal which reaches nearby receivers) is blocked by hills or when the skip distance increases as the ionosphere gets higher as night falls.

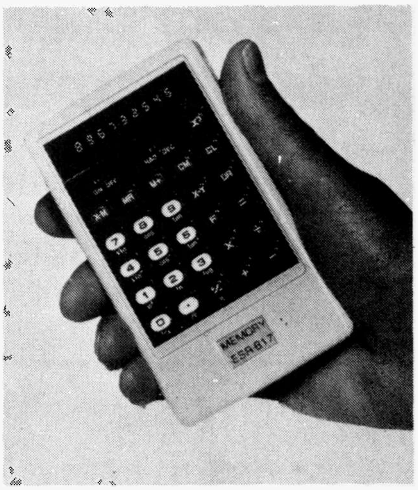
Racal have a new type of transportable HF arerial system which they claim can overcome the skip-distance problem. They are for use with manpack-type equipment having an output of 20-100 watts pep, operating in the 2-10MHz frequency range.

The omni-directional aerial consists of a horizontal loop of wire only 6 feet off the ground suspended on four fibreglass masts. Tests carried out in many parts of the world prove that the skywave return is extremely close to the point of transmission, in fact loud and clear communication has been achieved between two stations little more than one mile apart, seperated by 5000ft peaks, where conventional aerials failed completely. Racal claim the new aerial will generally provide very reliable communication over an unbroken distance from 0 to 500 miles.

Another feature is the ability of the aerial to radiate on the second harmonic of the standard frequency (not at the same time, I hope). This means a standard aerial operating at 3.5MHz will also resonate at 7MHz so there is no need to change aerials between day and night use.. The aerial is lightweight, and can be erected by one man in approximately 15 minutes.

NEW MATHEMATICAL CALCULATOR

The new mathemetical calculator ESR 817 from Memory Devices Limited offers remarkable value for money in pocket sized calculators. It provides a full range of mathematical functions — normal and inverse trigonometric functions with calculations in degrees or radians; natural square roots, π entry and an X^Y facility.



All the numerical entry keys have double functions. Additional features include chain operation, constant operation with any arithmetical function mode and a memory with an accumulating capability. Also when overflow in mid calculation is indicated, calculations can proceed to 8 figure accuracy by using the clear key.

The calculator is powered from an internal rechargeable NiCd battery. The price of £49 includes the mains powered battery charger and a handy protective carrying case. From MDL, Central Avenue, East Molesey, Surrey.

ELECTRONIC TUNING FORK

The EMT 117 TS Tuning Standard, is a highly stable, precision tuning aid of pocket-size dimensions and weighing less than a pound. The design employs CMOS technology and the generated frequency is independent of temperature changes over the range 10°C to 40°C. A clearly marked knob allows the frequency to be adjusted in 1Hz steps between 435Hz and 445Hz and the accuracy exceeds the requirements of DIN 1317.

Special harmonics added to the fundamental frequency give the tone the sound of an oboe, the instrument normally used by the orchestras for tuning. A switchable vibrato makes the sound even more true to life. Tuning of boroque instruments, conforming to the tuning standard agreed at the Vienna Conference of 1885, as well as modern orchestras is possible.

The unit contains its own 9V battery but also has connections for an external power supply to be used. A loudspeaker is built in and audio output terminals are provided.

F.W.O. Bauch Ltd., 49,Theobald Street, Boreham Wood, Herts.

DEVICE DISPLAYS HEART RATE ON BEAT-TO-BEAT BASIS

A digital computing cardiotachometer, first used by NASA physicians to monitor instantaneously the pulse rates of astronauts performing underwater training activities, is being used in non-space oriented medical applications.

The device was developed originally by engineers at Marshall Space Flight Centre, Huntsville, Ala., to monitor on a beat-to-beat basis the heart rates of astronauts undergoing training in the centre's neutral buoyancy simulator (NBS), an underwater training laboratory used to simulate the weightless conditions encountered in space.

The device, which provides a numerical display of a subject's pulse rate 0.3 seconds after detecting his second heart beat, was used at Veteran's Administration Hospital and University Hospital in Birmingham, Ala., for approximately a year. It is now being used in routine physical examinations given to personnel at Marshall's employee medical facility.

Designed to operate in conjunction with a standard electrocardiographic unit, the device employs an electronic digital system to use the time between two consecutive heart beats to calculate a patient's pulse rate in beats per minute.

The cardiotachometer is about the size of an ordinary shoe box and weighs approximately 2.2 kilograms.

PARIS COMPONENTS SHOW

Dates for this year's International Electronic Components Exhibition are 2nd to 8th April (closed Sunday 6th) and the venue will be Parc des Expositions, Porte de Versailles, Paris 15.

This is of course the biggest components exhibition held: last year there were 1,138 exhibitors, more than half of them non-French companies. This year about 60 U.K. companies are expected to participate.

SELF-INSTRUCTION COURSES IN DIGITAL LOGIC

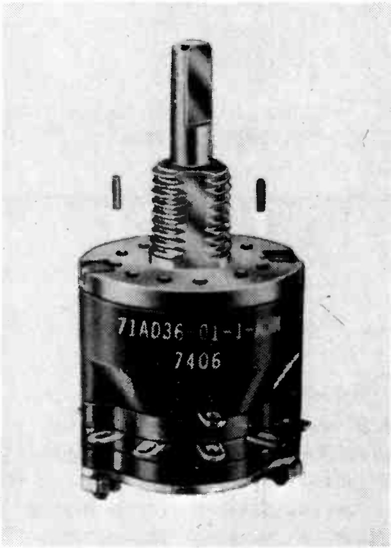
Two teach-yourself courses in digital logic, electronics and systems design, are now published by Cambridge Learning Enterprises. The elementary course, Digital Computer Logic and Electronics, comes in four volumes: Basic Computer Logic; Logical Circuit Elements; Designing Circuits to Carry Out Logical Functions; Flip-flops and Registers. The course was originally developed to help to train maintenance engineers in a computer company, and assumes no knowledge except simple arithmetic.

The more advanced course, Design of Digital Systems, covers all the material in the elementary course but more thoroughly, going on to more complicated topics, such as calculator and computer design. It comes in six volumes: Number Systems; Boolean Logic; Arithmetic Circuits; Memories and Counters Calculator Design; Computer Architecture.

Both courses proceed by a question and answer method, allowing everyone to learn at their own pace. On each page a new piece of information is given, followed by a question designed to test real understanding of the information. The answer is given at the top of the next page. The student can move on to the next piece of information if he gets the right answer but, if he gets it wrong, is advised to re-read the information until he sees how the right answer is arrived at.

The books are available by mail order with a money-back guarantee, and can be ordered from Cambridge Learning Enterprises, Rivermill House, St. Ives, Huntingdon, Cambs. Prices: £3.95 per set for Digital Computer Logic and Electronics, £5.95 per set for Design of Digital Systems, or £9.25 for a set of each (including packing).

MINIATURE ROTARY SWITCHES WITH ADJUSTABLE STOPS



Miniature rotary switches with adjustable stops are available from Highland Electronics Limited (33 Dallington Street, London EC1V 0BD). The position of the stops can easily be changed from front of switch, which is available with 30° or 36° index angles, one to four poles per deck and up to 12 decks per switch. This 0.75 in diameter series is coded "71AD".

WARNING

The item in Tech-Tips, February 1975 issue, entitled "Finishing Front Panels" contains a dangerous suggestion. A reader has pointed out that adding hot water to caustic soda is **extremely dangerous***: there is a lot of heat generated, and strong alkali could be splashed into your eyes. The correct method is to add the caustic soda to the water slowly stirring all the time.*

MINI-ADS

FOR FURTHER INFORMATION
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01-730-8282

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