Hobby Electronics

February 1979

40p

HOLOGRAMS

Short Wave Radio
Tune in the world

Scratch / Rumble Filter
Add-on for your audio system

CA3130 Projects
Several household circuits

Into Electronics
Getting to know transistors

Video Tape Recorders
How they work: How to choose

History of Radioactivity
How it was discovered

Sine / Square Wave Generator
Test gear project

Instant Circuit Layout
Converting diagrams into projects

ambit® international

Production of the new catalogue has been held up for a few weeks - since we have just been appointed as distributors for two of the most exciting ranges of radio components products yet : The Micrometals range of iron dust torroids cores and formers, and the OKI range of VLSI for digital frequency displays for receivers. We apologize for any inconvenience, but these two ranges are really worth the wait, and include some products you will find hard to believe, like the MSM5523 IC, an IC with less than ten external components that gives AM frequency readout to 1kHz from LW to 39.999MHz, FM frequency readout in 100kHz steps - (all usual IF offsets programmable by diodes), a 24 hour format clock with 12 hour display, independent on and off timers, time signals on the hours, stopwatch facility and a sleep timer. This costs £14 with its timebase crystal, and makes all that has gone before an expensive and time wasting excercise. Rather like the way the Intersil ICM7216 has revolutionized the instrument counter market. (See the OSTS ad.) And those of you familiar with Amidon and IG dust torroids, favoured in many new RF designs, will be pleased to know Ambit will be stocking a broad range of the Micrometals types for applications from EMI filters to RF PA stages.

OKI frequency counter ICs: details In cat2

MSM5523	for CA LEDs with RHOP such as FND507	£14 inc xtal
MSM5525	for 3½ digit LCD AM/FM with direct segment drive, no clock or timers	£11 inc xtal

Other types for fluorescent displays etc OA

Other new semiconductor additions:

KB4437	pilot cancel mpx decoder	4.35
KB4438	muting stereo preamp	2.22
HA1370	supercedes TDA2020	2.99
TDA1090	HiFi AM/FM	3.35
TDA1220	low cost AM/FM	1.45

PRICES DOWN ON VMOS: as expected, this new technology in power transistorsis getting cheaper. 120v comp pairs /100W for £10.00

Price reduction on CA3189E ....now £2.20

New varicaps: to add to the biggest range.....

KV1211 2:9v bias to tune MW, like the KV1210, but a double diode £1.75

New pilot tone filters from TOKO...............

208BLR series, individual per channel with a 26/38kHz version for pilot cancel decoder applications. Flat to 15kHz £0.90

New crystal filter for amateur NBFM..........

TOYO 10M4B1 with over 90dB adjacent ch. rejection for 2m NBFM. 10.7MHz £14

New ceramic IF filters for 455kHz..............

CFM455H 6kHz/6dB, 15kHz max /60dB - ideal for MC3357 etc. £10

A brief summary of some of our range of ICs:
TDA1062/1.95; TDA1083/1.95; HA1197/£1.40 CA3123E/£1.40; TBA651/£1.81; CA3089/1.94 HA1137/£2.20; MC1310/£2.20; HA1196/£3.95 KB4424/£2.75; KB4423/£2.53;SD6000/£3.75 KB4412/£2.55; KB4413/£2.75; KB4417/£2.55 MC1495L/£6.86*; MC1496P/£1.25 LM381N/£1.81; LM1303/£0.99; ULN2283B/ £1.00; LM380N/£1; TBA810AS/£1.09 TCA940E/£1.80; TDA2002/£1.95; ICL8038CC/£4.50*; NE566/£2.50*; NE567/ £2.50*; NE560B/£3.50; NE561B/£3.50; NE562B/£3.50*; NE565A/£2.50*

SEE THE OSTS ADVERT FOR CMOS/TTL REGULATORS, OPTO DISPLAYS, and other types of linear devices.

Some transistors for RF specifically:
BF256LB/0.34; 40822/0.43*; 40823/0.51* 40673/0.55* ; BF900/961/0.80*; BF960/1.60* BF224/0.22; BF274/0.18; BF195/0.18; BF240/0.22; BF241/0.22; BF362/0.70; BF479/0.86; BF679S/0.70; BFY90/0.90*

PIN and other Varicap diodes:
BA102/0.30; BA121/0.30; ITT210/0.30 BB104B/0.40; MVAM2/£1.48; MVAM115/ £1.05; MVAM125/1.05; KV1210/£2.75 BA479/0.35; TDA1061/0.95; BA182/0.21

METER MADE low cost panel meters : 3 x 930 series with blanks and dry transfer sheet of scales and ledgends for £12.5 *

At last, DIY HiFi which looks as if it isn't.

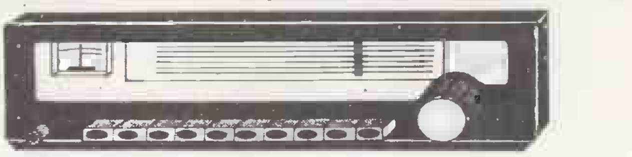
That's not to say it doesn't look like HiFi - just that it doesn't look like the usual sort of thing you have come to associate with DIY HiFi. The Mk3 outstrips and outperforms all British made HiFi tuners, and most imported ones too. Certainly at the price, there isn't one near it. But more than that, it looks superb . A small pic here would be an insult, so send an SAE for details on the kit that looks as if isn't. It's something else............

- Exceptionally high performance - exceptionally straightforward assembly
- Baseboard and plug-in construction. Future circuit developments will readily plug in, to keep the MkIII at the forefront of technical achievement
- Various options and module line-ups possible to enable an installment approach to the system

and now previewing the matching 60W/channel VMOS amplifier:

- Matching both the style and design concepts of the MkIII HiFi FM tuner
- Hitachi VMOS power fets - characterized especially for HiFi applications
- Power output readily multiplied by the addition of further MOSFETs
- VU meters on the preamp - not simply dancing according to vol level
- Backed with the usual Ambit expertise and technical capacity in audio

The PW Dorchester-LW,MW,SW,& FM stereo tuner



In much the same way as we have swept away the 'old technology' in frequency/timer counters - with the OKI and Intersil single IC counters, we now offer a single IC "All Band" radio tuner. Don't confuse this one chip radio with things like the ZN414 - for this is a genuine superhet receiver with a mechanical AM IF filter, and ceramic IF filters for FM. The AM section employs a balanced input mixer section, covering all broadcast bands - plus a BFO and MOSFET product decetor for SSB/CW - though at this price, the tuner is not intended as a "communications receiver" - although we know of many lesser designs that make that claim. The AM sensitivity is nevertheless better than 5uV, and FM sensitivity is 1.2uV for 30dB S/N. As a multiband broadcast superhet receiver, it is a unique constructor project that fulfills the requests we very frequently get for a general coverage circuit that isn't over complicated. The set has CA3089E FM performance, with mute etc., and a PLL stereo decoder with full pilot tone filtering.

The tuner board - with "on board" PCB mounted switching, all components etc : £33.00
The case/cabinet with PSU, meter and mechanics etc £25.00
An SAE for full details please. See the feature article in Practical Wireless (Dec/Jan)

TERMS etc: CWO please, VAT on Ambit Items is generally 12½%, except where marked (*). Catalogue part 1:45p, part 2 50p all inclusive. Postage 25p per order, carriage on tuner kits £3. Phone Brentwood (0277) 216029/227050 9am-7pm. Callers welcome inc. Saturdays .

2 Gresham Road, Brentwood, Essex.

OSTS

Since AMBIT introduced the "One Stop Technology Shop" to our service, we have been pleased to see just how many users of electronic components appreciate our guarantee to supply goods only from BS9000 approved sources. More than ever, professional and amateur electronics engineers cannot afford to waste time on anything less than perfect pedigree products.

SEE THE AMBIT AD TOO!

CD4000 CMOS

4000	17p	4059	563p	4522	149p
4001	17p	4060	115p	4527	157p
4002	17p	4063	109p	4528	102p
4006	109p	4066	53p	4529	141p
4007	18p	4067	400p	4530	90p
4008	80p	4068	25p	4531	141p
4009	58p	4069	20p	4532	125p
4010	58p	4070	20p	4534	614p
4011	17p	4071	20p	4536	380p
4012	17p	4072	20p	4538	150p
4013	55p	4073	20p	4539	110p
4016	52p	4075	20p	4541	141p
4017	80p	4076	90p	4543	174p
4018	80p	4077	20p	4549	399p
4019	60p	4078	20p	4553	440p
4020	93p	4081	20p	4554	153p
4021	82p	4082	20p	4556	77p
4022	90p	4085	82p	4557	386p
4023	17p	4086	82p	4558	117p
4024	76p	4089	150p	4559	388p
4025	17p	4093	50p	4560	218p
4026	180p	4094	190p	4561	65p
4027	55p	4096	105p	4562	530p
4028	72p	4097	372p	4566	159p
4029	100p	4098	110p	4568	281p
4030	58p	4099	122p	4569	303p
4031	250p	4160	90p	4572	25p
4032	100p	4161	90p	4580	600p
4033	145p	4162	90p	4581	319p
4034	200p	4163	90p	4582	164p
4035	120p	4174	104p	4583	84p
4036	250p	4175	95p	4584	63p
4037	100p	4194	95p	4585	100p
4038	105p	4501	23p		
4039	250p	4502	91p		
4040	83p	4503	69p		
4041	90p	4506	51p		
4042	85p	4507	55p		
4043	85p	4508	248p		
4044	80p	4510	99p		
4045	150p	4511	149p		
4046	130p	4512	98p		
4047	99p	4513	206p		
4048	60p	4514	260p		
4049	55p	4515	300p		
4050	55p	4516	125p		
4051	65p	4517	382p		
4052	65p	4518	103p		
4053	65p	4519	57p		
4054	120p	4520	109p		
4055	135p	4521	236p		

Micromarket PRICES SLASHED

6800 series		8216	1.95	2114	£10
6800P	6.50	8224	3.50	2708	£10.55
6820P	£6	8228	4.78	**Development**	
6850P	2.75	8251	6.25	MEK6800	£220
6810P	£4	8255	5.40	TK80	£306
6852	3.65	**MEMORIES**		AMI, Signetics, TI, Intersil, Harris etc. OA	
8080 series		2102	£1.70		
8080	6.30	2112	£3.40		
8212	2.30	2513	£7.54		
		4027	£5.78		

Voltage Regs

NEW LOW PRICES

7800 series UC TO220 package 1A	all 95p
7900 series UC TO220 package 1A	all £1
78MUC series TO220 package ½A	all 90p
78LCP series TO92 100mA	all 35p
L200 up to 3A/adjustable V&A	195p
78MGT2C ½amp adjustable volts	175p
79MGT2C ½amp adjustable volts	175p
723C precision controller	65p

MAINS FILTERS FOR NOISE/RFI etc

1 amp in IEC connector	£4.83
5 amp in 'wire in' case	£3.87
NE550A	73p

LINEARS non-consumer

BIMOS		LM339N	66p
CA3130E	84p	LM348N	186p
CA3130T	90p	LM3900N	60p
CA3140E	35p	709HC to5	64p
CA3140T	72p	709PC dil	36p
CA3160E	90p	710HC to5	65p
CA3160T	99p	710PC dil	59p
Op amps		723CN	65p
LM301AH	67p	741CH to5	66p
LM301AN	30p	741CN 8dil	27p
LM308H	121p	747CN	70p
LM308N	97p	748CN	36p
LM318H	279p	NE531T	120p
LM318N	224p	NE531N	105p

OPTO 7 seg displays

0.43" High Efficiency HP:

5082- 7650	red CA	233p
5082- 7653	red CC	
5082- 7660	yellow CA	
5082- 7663	yellow CC	
5082- 7670	green CA	
5082- 7673	green CC	

0.3" Standard HP

5082- 7730	red CA	147p
5082- 7740	red CC	

0.5" Fairchild

FND500	red CC	150p
FND507	red CA	150p

TTL :Standard AND LP SchottkY

	'N'	'LSN'
7400	13	20
7401	13	20
7402	14	20
7403	14	20
7404	14	24
7405	18	26
7406	38	
7407	38	
7408	17	24
7409	17	24
7410	15	24
7411	20	24
7412	17	24
7413	30	52
7414	51	130
7415		24
7416	30	
7417	30	
7420	16	24
7421	29	24
7422	24	24
7423	27	
7425	27	
7426	36	27
7427	27	29
7428	35	32
7430	17	24
7432	25	24
7433	40	32
7437	40	24
7438	33	24
7440	17	24
7441	74	
7442	70	99
7443	115	
7444	112	
7445	94	
7446	94	
7447	82	
7448	56	99
7449		99
7450	17	
7451	17	24
7453	17	
7454	17	24

	'N'	'LSN'
7455	35	24
7460	17	
7463		
7470	28	
7472	28	
7473	32	
7474	27	38
7475	38	40
7476	37	
7478		
7480	48	
7481	86	
7482	69	
7483A		
7484	97	
7485	104	99
7486		40
7489	205	
7490	33	90
7491	76	110
7492	38	78
7493	32	99
7494	78	
7495A	65	99
7496	58	120
7497	185	
74100	119	
74104	63	
74105	62	
74107	32	38
74109	63	38
74110	54	
74111	68	
74112	88	
74113		38
74114		38
74116	198	
74118	83	
74119	119	
74120	115	
74121	25	
74122	46	
74123	48	
74124		
74125	38	44

	'N'	'LSN'
74126	57	44
74128	74	
74132	73	78
74133		29
74136		40
74138		60
74139		60
74141	56	
74142	265	
74143	312	
74144	312	
74145	65	
74147	175	
74148	109	
74150	99	
74151	64	84
74153	64	54
74154	96	
74155	54	110
74156	80	110
74157	67	55
74158		60
74159	210	
74160	82	130
74161	92	78
74162	92	130
74163	92	78
74164	104	
74165	105	
74166		
74167	20	
74168		
74169		200
74170	230	200
74172	625	
74173	170	
74174	87	120
74175	87	110
74176	75	
74177	78	
74180	85	
74181	165	350
74182	160	
74183		210
74184	135	

	'N'	'LSN'
74185	134	
74188	275	
74190	115	92
74191		
74192	105	180
74193	105	180
74194	105	187
74195	95	137
74196	99	110
74197	85	110
74198	150	
74199	160	
74248		90
74249		93
74251		90
74253		105
74257		108
74258		153
74259		420
74260		153
74261		353
74266		40
74273		124
74275		312
74279		52
74283		120
74290		90
74293		95
74295		120
74298		100
74324		157
74325		242
74326		247
74327		237
74352		100
74353		100
74362		715
74365		49
74366		49
74367		43
74368		49
74373		77
74374		77
74375		60

	LSN
74377	124
74378	93
74379	130
74386	37
74390	140
74395	139
74396	133
74398	180
74399	150
74445	92
74447	90
74490	140
74668	110
74670	249

MISCELLENY
NE555 30p
NE556 78p
NE558 180p
ICM7217 950p
ICM7208 1495p
ICL7106CP - LCD DVM IC 955p
LCD DVM KIT 2480p
3½ digit LCD display 1150p
ICL7107 LED DVM kit 2065p
ICM7216 - 8 digit 10MHz DFM/ timer £19.82 (for LED C.Cath)
SCALAR ICs
8629 150MHz divide by 100 420p
95H90DC 780p
11C90DC 1400p
8618 -new-divide by 100 or 10 for 120/60MHz 450p

The ICL7216BIPI is still the cheapest way to make a full 8 digit/ 10MHz frequency counter/timer, and with 10 external components + display - it is also one of the simplest. For £19.82, it takes a lot of beating. The mains filters have been extended now to include a 6amp IEC version at £5.10, and with the amount of electronic noise on the average supply (next door's fridge, for instance) it is a really worthwhile addition to any sensitive equipment. LPSN TTL now includes many more of latest types, all - of course - are absolutely prime first quality types. And don t forget our range of OPTO displays includes Hewlett Package high efficiency 0.43" types in all colours - renowned as the finest quality in the market. For other types of component - discrete LEDs, radio and audio devices, tuner modules, kits etc., see our other advertisement for more details - or send for the AMBIT catalogue system. Part one (45p) includes details of our background 'standard' items, and the new part two includes all the latest introductions and developments, plus a rundown on OSTS.

TERMS: CWO pse., VAT to be added at 8% (inland), pp 25p per order. When ordering from the OSTS and Ambit - a single combined remittance and pp charge is sufficient. Account details OA

2 Gresham Road, Brentwood, Essex.

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Monitor

Laser Discs

Marketing of the Philips and MCA optical videodisc system began on Friday December 15th) in Atlanta, USA.

Britain may be the second country to have this development and Philips will be trying to get it on the market in the UK as early as possible in 1980.

The system features a videodisc player manufactured and marketed by North American Philips' Magnavox subsidiary under the trade name "Magnavision (R)" and pre-recorded videodiscs manufactured and marketed by MCA under the trademark and trade name "MCA Discovision (R)."

Magnavox officials said the videodisc player will have a suggested retail price of $695 (£350), and stated that a typical half-hour videodisc programme will be sold at a suggested retail price of about $5.95 (£3). Complete two-hour recent feature pictures will retail for about $15.95 (£8).

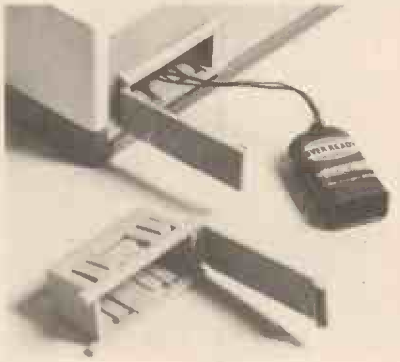
The Philips and MCA system consists of pre-recorded discs played on an optical videodisc player that attaches to a home television receiver. The MCA Discovision Disc is grooveless and resembles a long-playing record.

The Magnavision player employs an optical system — a tiny, low power, laser light beam — to relay images and sound from the videodisc to the viewer's TV screen. No needle or stylus ever touches the disc, so that repeated handling or use will not wear out or diminish quality. The system's discrete stereo sound tracks can also be played through a home stereo amplifier, providing a sound of a higher fidelity than that afforded by the television sound system.

VERO Have A Case!

This nifty little number could take a lot of the heartache out of battery powered projects. We've all gone through the temper shredding ritual of panel removal to get to exhausted power cells within our beloved box.

This battery holder fits externally, creating a compartment which can be opened without



the need to open the whole case. Somehow commercial equipment always seemed to have one of those didn't it? Well this just clips into a panel up to 3mm thick and takes a PP3.

Supplied as a kit the holder comes complete with connector and lead for less than a quid, and what'll that buy you these days? Vero Electronics, Industrial Estate, Chandlers Ford, Eastleigh, Hampshire.

Well Oiled MPU

Oil flowing from the Esso/Shell Spar buoy in the Brent field will have to pass a computerised metering system, based on Z-80 microprocessors. Six of the J-R8/3s will be controlled by one JZ80. Or to put it in English, six flow meters will be controlled by one central processor unit.

Functions such as batch control, ratio monitoring, scaling for flow etc can be handled by the flow units, and the processor or 'brain' unravels the information and presents it on a bank of LED displays.

As well as simple flow monitoring such complex computations as flow computation and automatic temperature compensation are possible 'on-line.' Two central processors are installed to make sure that if one packs in there will be another ready to shuffle across on its pins automatically and take over.

Although we prefer our 'bubble', this pic was sent to us by ITT to celebrate their firm order for their 6100 ADX message switching systems.

News from the Electronics World

Britain A Satellite Power

THE Royal Navy has had installed its first shipborne communications terminal for working via commercial maritime satellites. Supplied by International Marine Radio Company (IMRC) of Croydon, the terminal has been fitted into a Navy ice patrol vessel, HMS Endurance.

About a year ago the Navy, which had been watching the performance of the Marisat system, decided that there might be advantages in using commercial satellite communications for some of its non-strategic applications. The Navy sees the system being used, initially, on Naval auxiliary craft such as ice patrol vessels and perhaps, hydrographic survey ships. There are at present about 150 Marisat terminals on board merchant ships — including one on the QE2.

The terminal receives and transmits via retransmission from a satellite in synchronous orbit. That is, one which maintains its position over a particular point on the globe.

At present there are three such satellites, at 22,240 miles altitude over the Atlantic, Pacific and Indian Oceans. Corresponding shore stations are in Connecticut and California, with one in Japan serving the Indian Ocean satellite. These shore stations interconnect with the worldwide telephone/data and telex networks. Thus, a ship equipped with an appropriate terminal can exchange messages with any other telephone or telex user. Telex, voice, facsimile and data communications are also possible.

JOHN MILLER-KIRKPATRICK

It is with deep regret that we have to announce the death on December 12th, 1978, of John Miller-Kirkpatrick in his early thirties.

John was one of the best known, and best liked personalities in the hobby electronics field and in the last six or seven years did much to popularise the advanced components that have appeared in that time.

Even though he never wrote for Hobby Electronics, he was one of the popular authors in our sister magazine ETI and just a few days before his tragic death we had talked to him about contributing to HE.

John was one of the true innovators in the electronics field and he will be missed sadly. Our sympathy goes out to his wife and two daughters.

Write to Buzby

Philips have developed a rather ingenious little attachment for the telephone, called the Scribofoon. It enables you to send written messages over an ordinary phone line — and talk at the same time! The Scribofoon comprises a display screen and a writing pad — the pad contains a network of wires, separated by a thin plastic sheet. The wire network is scanned by the electronics and when the special pen is laid on the pad its position is transmitted to the other unit's display.

The device uses a small section of the audio spectrum to communicate and the gap is not noticeable during normal conversation.

Drawings can also be stored on cassette along with a commentary. Philips are planning to test market the Scribofoon in Holland early this year.

Mobile Satellite

The Independent Broadcasting Authority recently demonstrated their transportable satellite ground station. For the demonstration ITN set up a complete news room in the Wembley Conference Centre in London and the 5.45 news was sent out live via the European Orbital Test Satellite (OTS) — back down to Goonhilly Down and then by the normal distribution network. OTS was launched last May as an experimental geostationary communications satellite and the forerunner of a possible European Communications satellite due in the 1980s.

As well as the news transmission, the IBA Teletext service, Oracle, also made the 45 000 mile round trip — and was decoded successfully afterwards. The main use for the mobile ground station is expected to be in outside broadcasting.

Move To Good Lighting

All discos are equipped with sound-to-light units and most are pretty much identical too.

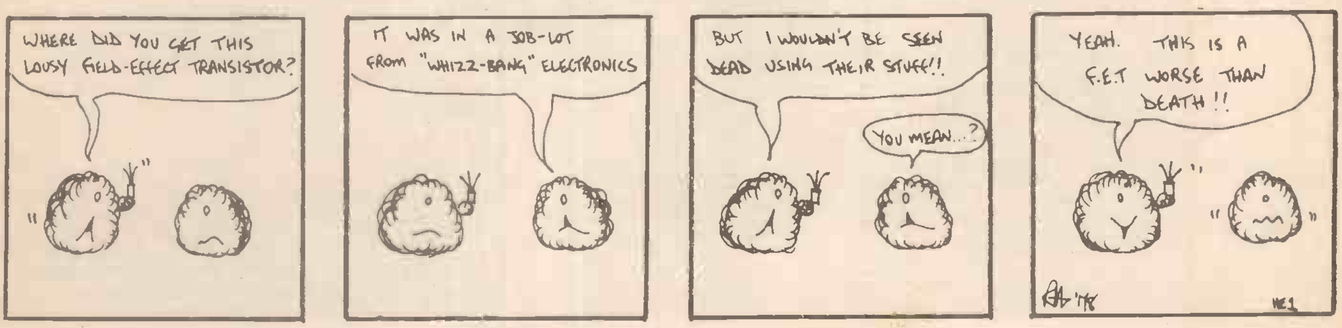
They operate by "looking' at different frequency bands of the music being played, and flashing lights to match peaks within those bands. Its a long time since anyone thought of doing things any differently . . . .

Proxima 3 is a new sound to light unit. Proxima 3 does not care what music is being played, it 'looks' at the people dancing around using radar and modulates the lights accordingly. So the harder they dance, the better the light show presumably.

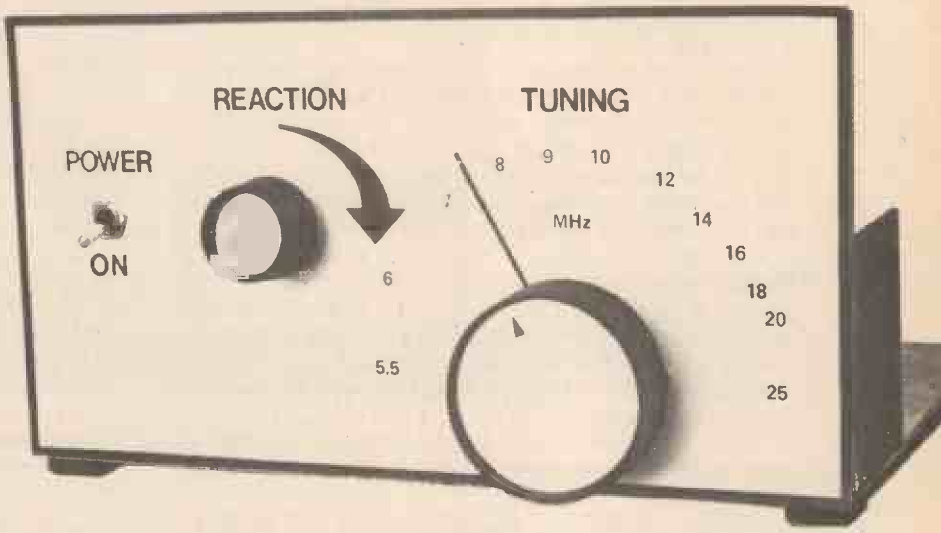
Apart from discos this could be of great use to singers and groups — their cavortings and posturing transformed to something remotely pretty.

There are three channels to each Proxima 3, and each of those can take up to 1 kW of lighting load. The radar section works on the Doppler principle — that moving objects produce a change of frequency in reflecting energy — and detects the change by mixing both the reflected microwaves and the transmitted waves together.

The difference is the 'change' signal which controls the lights. Very winning all this, and about time too. About £180 from: Caledonian Microwaves, Tyock Industrial Estate, Elgin, Moray, Scotland.



Short Wave Radio



Regenerative circuits are extremely sensitive and excellent performance can be achieved using only a few components. Our SW receiver here covers all bands in the 5.5-25 MHz range.

APART FROM THE very early sets, which were based upon coherers and other devices you rarely hear of today, the first radios were very straightforward designs totally unlike today's sophisticated superhets. The early Tuned Radio Frequency (TRF) sets were simply a tuning circuit with some gain and a detector circuit. Later designs used positive feedback, in the form of reaction, to increase the performance and it is still possible to get a lot of fun from sets of this type.

By using modern solid state components a very simple reaction set can be built which offers surprisingly good performance at low cost. The Field Effect Transistor has almost identical performance to the valves that were the only available components when this type of circuit was common but FETS do not require the complex (and dangerous) power supplies of days gone by.

The circuit of Fig 1 uses an MPF 131 dual gate MOSFET as a regenerative detector, followed by a BC548 audio amplifier stage which is capable of driving a crystal earpiece, high impedance headphones, or being fed to the input of an amplifier. The frequency coverage is approximately 5.5 to 25 MHz, or 54 to 12 metres.

This coverage includes many interesting features such as the international broadcast bands at 49, 31, 25, 19, 16 and 13 metres, as well as amateur bands at 40, 20 and 15 metres.

OPERATION

Satisfactory operation depends on the proper use of regeneration, which unless operated correctly will result in poor performance and interference to neighbouring sets.

Initially, set CV1 about half-closed and increase the regeneration until a point can be found where signals are

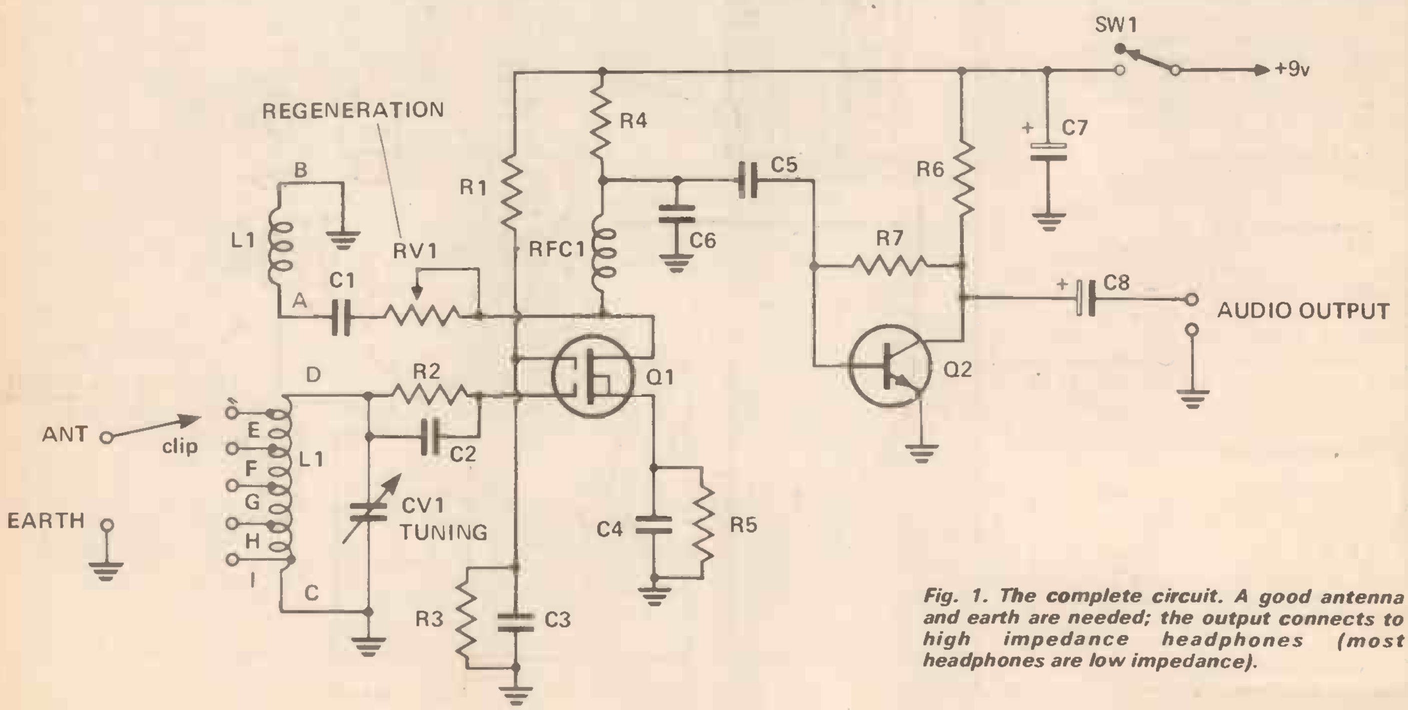


Fig. 1. The complete circuit. A good antenna and earth are needed; the output connects to high impedance headphones (most headphones are low impedance).

How it Works

Signals from the antenna are coupled into the tuned circuit (L1, CV1) via the clip lead and the coil taps. The tapping point is varied to give the best match from the antenna to the circuit, yielding the best performance.

The tuned circuit acts as a filter, only letting the desired frequency through to the FET (Q1), since the tuned circuit resonates at a frequency set by the position of the variable capacitor, (CV1). As the value of the capacitor is varied, so the resonant frequency of the tuned circuit, and the frequency of reception, is varied.

The radio frequency signal at the desired frequency is then fed to the FET (Q1), where it is amplified and appears at the drain. Because the radio frequency choke (RFC1) presents a high impedance (or near open circuit) to radio frequencies the signal passes through C1 and RV1 to the regeneration coil wound on L1. Some of this signal, the amount determined by the setting of RV1, is coupled back to the tuned circuit.

For regeneration to occur, the signal fed back to the input must be the same polarity or 'phase' as the incoming signal. A phase reversal occurs in the FET, so a second phase reversal is necessary. This is achieved by connecting the feedback to the reaction coil upside down (i.e. to the bottom of the winding, and the earth to the top). In this condition of positive feedback the circuit can be made to oscillate.

The feedback signal now passes through the tuned circuit again to the FET, although this time it is 'detected' before it is amplified once more. Detection recovers the audio information from the signal before audio amplification. The radio frequency choke looks like a short circuit to the low frequency audio signal which passes through it. It cannot however pass through resistor R4, but is coupled to the audio amplifier (Q2) via C5, where it is amplified before being fed to the output. Any unwanted RF signal which happens to get through the RF choke is shorted to earth by a small value capacitor (C6).

Maximum circuit gain, and therefore maximum audio output, occurs when the regeneration control is advanced so that the circuit is just not oscillating. This point also yields the best 'selectivity', or the ability to distinguish between close stations.

Parts List

Resistors all ¼ W, 5%

R1	4k7
R2	1M2
R3	10k
R4	2k2
R5	1k
R6	10k
R7	4M7

Potentiometer

RV1	2k lin pot

Capacitors

C1	10n ceramic
C2	270p ceramic
C3,4	100n ceramic
C5	100n ceramic
C6	1n ceramic or polyester
C7	10µ tantalum 16V
C8	4µ7electro 16V

Variable Capacitor

CV1	415p tuning capacitor or similar (see text)

Semiconductors

Q1	MPF 131 dual gate MOSFET
Q2	BC548 or similar

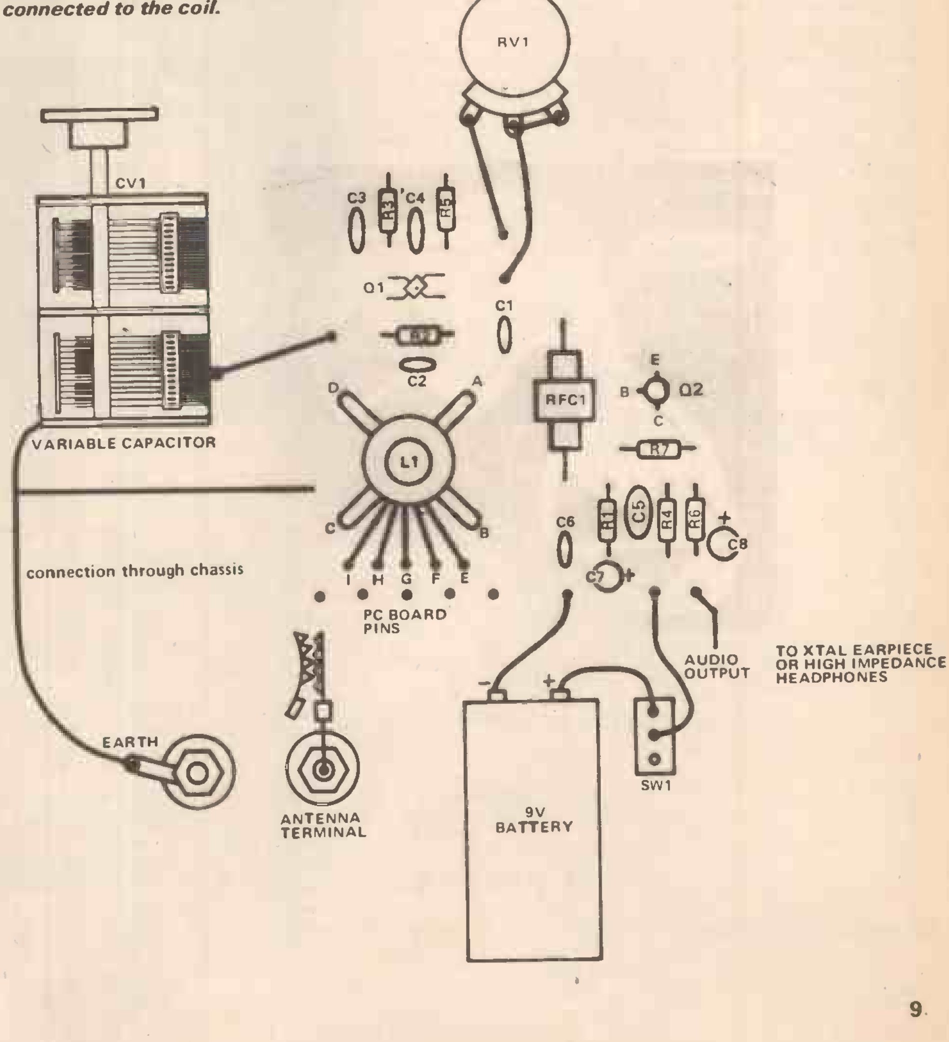
(Q1 is not widely advertised but is being stocked for this project by Stevenson Electronic Components. The cost is 98p but see their ad for carriage charges).

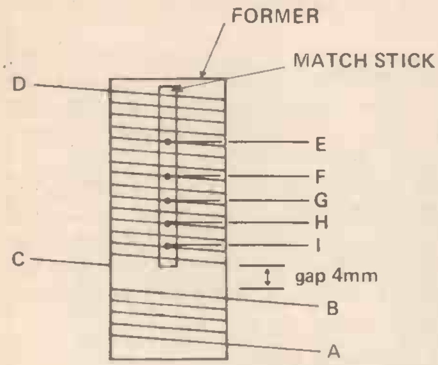
Miscellaneous

Coil Former: 12 × 30 mm air cored;
RFC1 2.5 mH RF choke

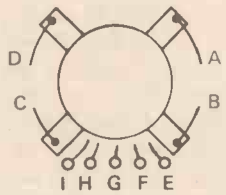
SPST on/off switch, planetary drive, 5 to 1 reduction length of 28/30 swg enamelled wire. 9V battery and battery clip knobs, rubber feet, crystal earpiece or high impedance headphones, headphone socket.

Fig. 2. The component layout on the printed circuit board. To save switching, connect a crocodile clip to a short piece of wire from the antenna socket and connect it to the pins connected to the coil.





L1



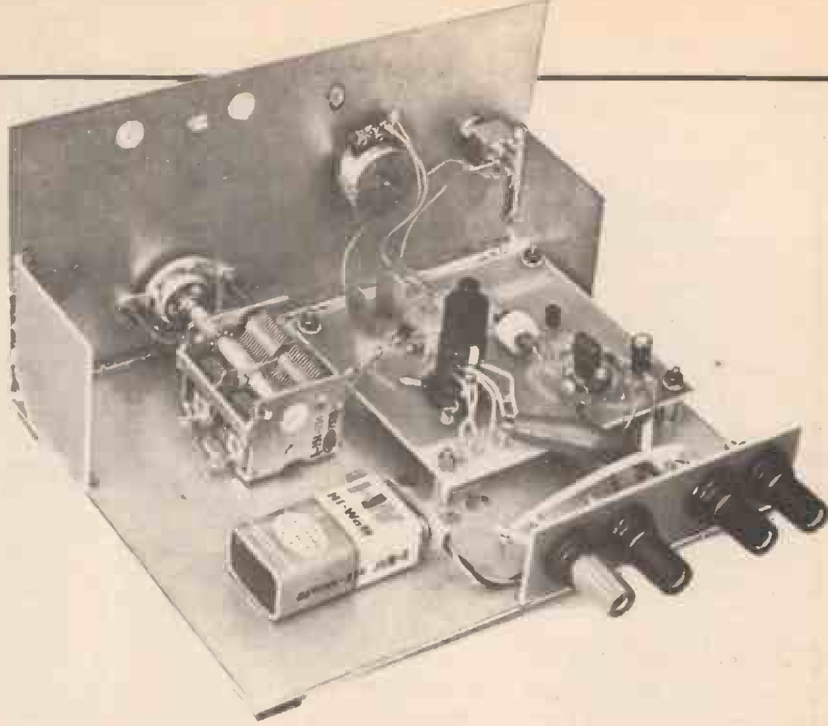
L1
TOP VIEW

Table 1 — Coil Winding Details

Wound on a former 12mm diameter and at least 30mm long. Plastic ½in. conduit is ideal.

Reaction coil: 4 turns of 28/30 swg enamelled wire, closewound at the base of the former in a clockwise direction.

Tuning coil: 15 turns of 28/30 swg enamelled wire, closewound, starting 4 mm above the top of the reaction winding in a clockwise direction. Taps at 2, 4, 6, 8 and 11 turns from the bottom of the winding. Turns which are tapped are raised over a matchstick.



Rear view of the project. The slow-motion drive can be seen.

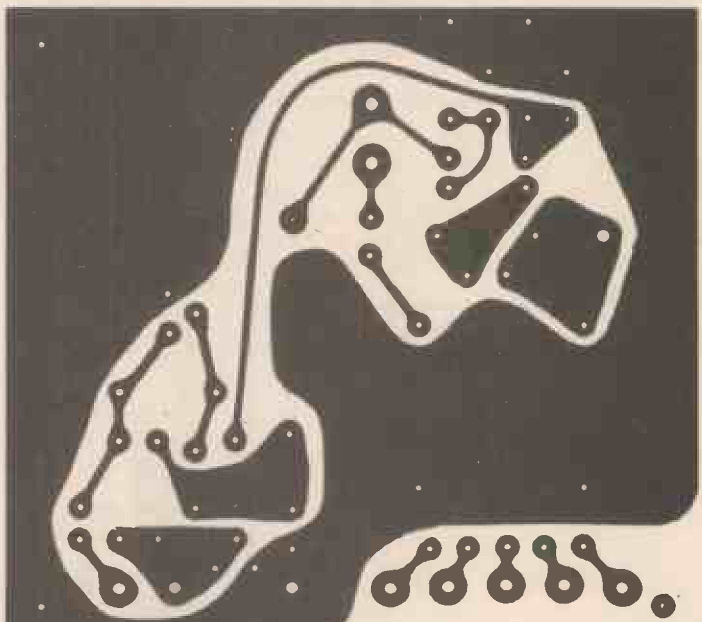
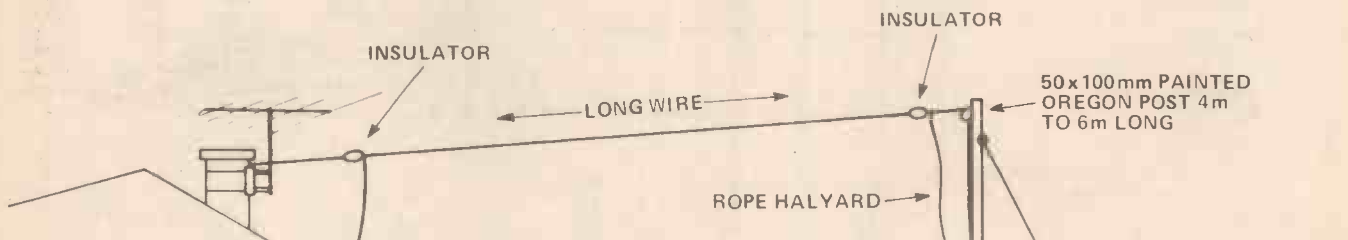


Fig 3. The PCB pattern shown here full size.



A good aerial is essential to get reasonable reception results.

heard when tuning. Increasing the regeneration will increase the volume, until a point is reached where a whistle is heard when tuning across a station. The most sensitive point is where this whistle just fails to arise.

Regeneration has to be adjusted in conjunction with the tuning, because the setting of RV1 will change as the set is tuned across the band. The tapping position of the coil also influences regeneration, and may have to be lowered to obtain correct operation on some frequencies. The tapping point found to give the best results will also depend on the length of antenna used. As a starting point, try the middle tap and then move the tapping point up or down the coil to give the strongest signals, while still able to achieve regeneration.

Reception of CW (continuous wave) signals is possible by using the regeneration control so the set is just oscillating, while the tuning gang is set so that a beat note is heard. This can also be done for SSB signals, but the tuning will be very critical.

CONSTRUCTION

All the components except the tuning capacitor are mounted on a printed circuit board (see Fig 2). Other types of construction such as Veroboard can be used, but may not offer the same repeatability of results. The coil (L1) is wound separately as in Table 1 and later mounted on the PC board.

In our receiver we used one section of a second hand dual tuning gang. Most gangs from an old radio will do as long as only one section is used, the lowest frequency of operation depending on the value of capacitance.

The chassis is 175 by 90 mm and 140 mm deep, and is constructed entirely from single sided PC board (copper side inward). This method is both cheap and easy, the front panel being soldered on to the base plate. Squares of PC board are soldered into the ends for rigidity of the front panel.

A planetary drive mechanism is used with the tuning capacitor and is attached to the front panel with two nuts and bolts. A plastic cursor can be cut from a sheet of thin perspex and attached to the outside of the drive mechanism with Araldite to provide a dial pointer.

The regeneration potentiometer and the ON/OFF switch are also mounted on the front panel, with the antenna, earth and output connections mounted on a small piece of PC board at the rear. All wiring should be kept as short as possible, especially to the regeneration control and the tuning capacitor.

ANTENNA AND EARTH

Although some signals can be heard with a small indoor antenna, an outdoor antenna is much better. The antenna should be as long and as high as practicable, running perhaps from the house to a tall tree or other building. Figure 3 shows a typical antenna installation which will give good results. The lead-in from the antenna should be kept as short as possible, so a good position for the set would be close to a window.

An earth is not essential but is generally worthwhile, since it can help to avoid the effects of hand capacity by grounding the metal chassis. The set can be earthed to a water pipe or run to a metal spike driven into the ground.

PERFORMANCE

The number of short wave signals that can be heard depends upon the time of day, early morning, late afternoon and night being the best. After a few periods of listening at various times you will know what to expect. Using an indoor antenna we were able to receive strong signals throughout the day and the number of stations heard rapidly increased towards dark. **HE**

Video Tape Recorders

As each week passes, advertisement and media coverage of video cassette recorders becomes more prolific, but why are such units so expensive, how do they operate, and what are the differences between the various different recorders? Angus Robertson reports.

PERHAPS THE FIRST question that should be asked when discussing video cassette recorders is why bother to record at all? After all, video recorders are still very expensive (and likely to stay that way), and one's money could surely be spent much more usefully on something like a home computer! Video cassette recorders appeal to several different groups of people.

Fanatics of particular programmes such as football or perhaps even *The Prisoner* will buy a video cassette recorder enabling them to archive such programming, but do bear in mind that this is still relatively expensive costing about £5 per recorded hour, although of course the tape may be reused lots of times if permanent recordings are not required. Many groups of people work unsocial hours which means they miss most evening programmes and have to make do with odd schools programmes and test card during the day. A video cassette recorder with a suitable electronic timer can record some of these programmes and thus timeshift them to a more suitable viewing time.

Alternatively even those of us that work relatively normal hours find a video cassette recorder invaluable for recording programmes that would have otherwise been missed, or even enabling specific programmes to be watched at more convenient times — particularly useful at Christmas when many meal times will no longer have to be scheduled around the TV programme schedule. It also enables programmes on conflicting channels to be watched since one channel can be recorded while simultaneously watching a second. Finally, libraries of video cassette programmes are beginning to become available so one can now rent or buy feature films and other entertainment and documentary type programming to watch at home.

JVC's HR-3300 VHS cassette recorder. These machines can take cassettes which will record for 3 hours. The VHS system has been adopted by more companies than any other.

OPERATING PRINCIPLES

In essence, video cassette tape recorders operate much like normal audio tape recorders, but are umpteen times more complicated. The bandwidth of a normal audio channel ranges up to about 15 kHz, while that for television pictures is about 5.5 MHz, some 350 times greater. To enable high bandwidths to be recorded, the tape could be run at higher longitudinal speed but obviously such speeds are difficult to obtain — nevertheless, the BBC did develop an early video tape recorder called VERA in the 1950s which ran tape at 200in/s, but it was superseded very quickly by a recorder developed by Ampex in America. Although now 25 years old, the mechanical transport format of the video tape recorders used by broadcasters today is identical.

The principle of video recording is simple. Since increasing the longitudinal tape speed presents terrific problems, a ½in wide tape is used in consumer machines and the video recording heads made to rotate at high speed relative to the more slowly moving tape, thus laying a large number of long tracks at an angle across the tape (Fig. 1). Audio is recorded as a separate longitudinal track much like a normal audio tape recorder, and a third control is also recorded. This provides identification of the position of each video track so that when replayed the video tape can be precisely positioned, otherwise the video heads might not cover the same path as those during the recording.

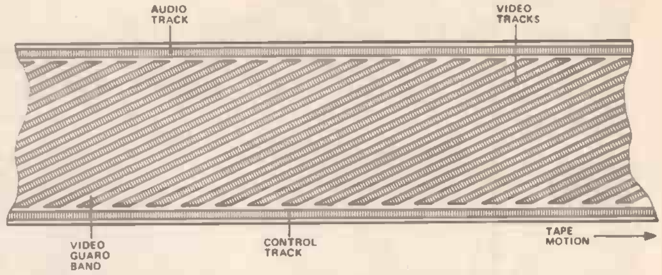


Fig. 1. The high tape head to tape speed is achieved by rotating the heads to give diagonal strips of recorded material. The audio is recorded on a narrow track on one edge.

The Grundig SVR 4004. Although marginally the costliest system it will take 4 hour tapes, has by far the most advanced timer and the fastest writing speed.

Early video tape recorders used open spools of video tape in much the same way as tape recorders, but the complex rotating head assembly means that threading is rather complex; so much so that it is really impractical for consumer use. The video cassette was developed to covercome this. Although insertion of the cassette is simply accomplished, the video cassette recorder then has to remove tape from the cassette and thread it around the rotating video heads. Basically, when the cassette is inserted, the video tape is located behind four guides mounted on a platter that can be rotated by a small motor. The tape is then located around half of the head drum which houses the rotating video heads. So that television pictures may be continuously recorded, there are actually two video heads on opposite sides of the drum which record alternate video tracks.

The audio and control tracks are recorded on a conventional looking audio head(but rather wider to cover both edges of the half inch tape) and a separate erase head covers the whole tape width. This type of tape threading where guides rotate is used on most video cassette recorders, but has the disadvantrage of requiring a few seconds to thread. With this in mind, JVC developed a slightly faster loading system somewhat less mechanically complex using two parallel guides moving in a single direction.

Because of these complex requirements for threading and rotating heads, video cassette recorders are extremely complex machines with a vast number of expensively produced mechanical parts including at least three separate motors (tape drive, rotating head drum drive, and threading). This is the primary reason why the price of video cassette recorders is unlikely to be significantly reduced.

ELECTRONICS

The problems of recording colour television pictures economically took many years of research and it was only in 1973 that the first consumer oriented video cassette recorder was introduced by Philips. Late 1977 saw the introduction of the second generation of video cassette recorders which provided considerably

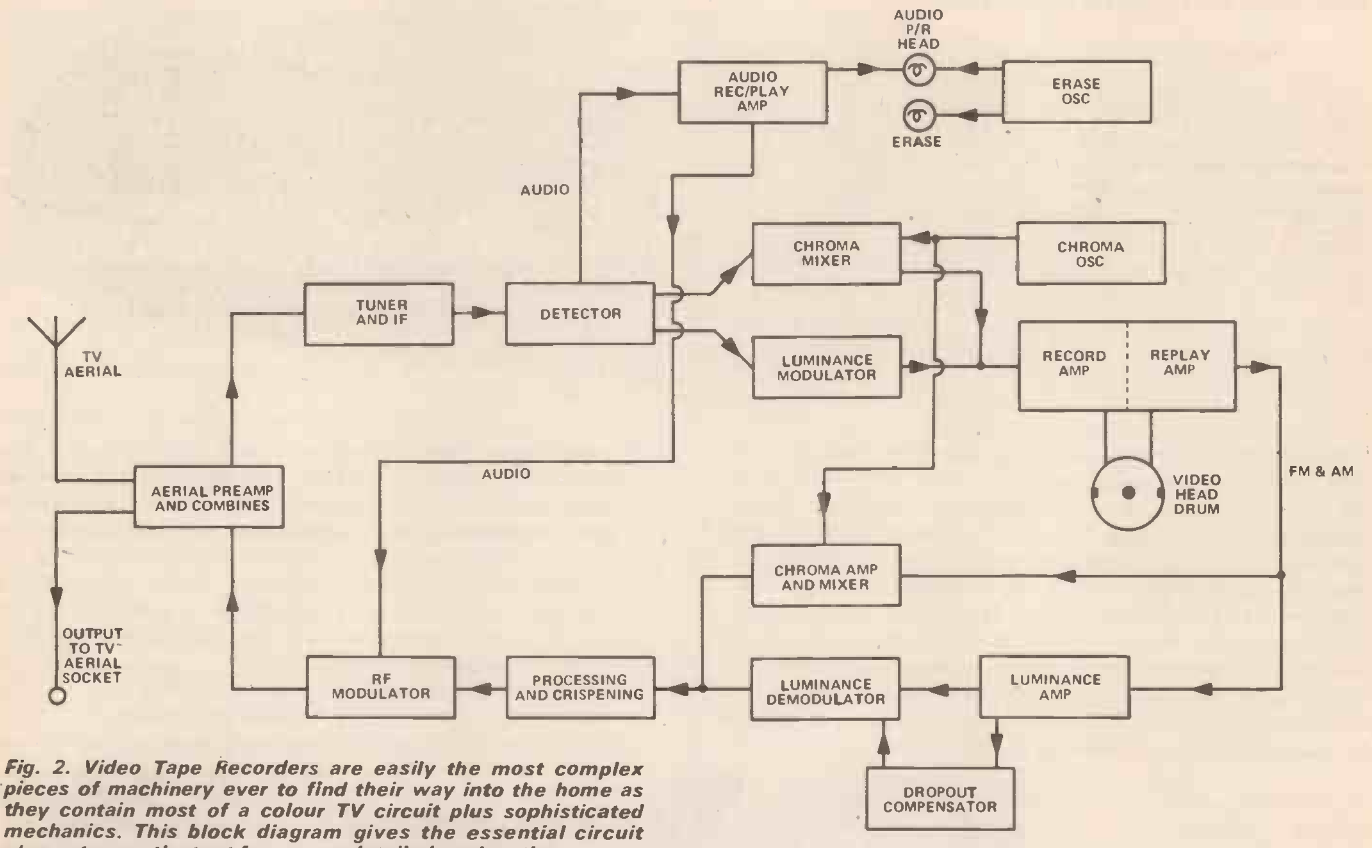


Fig. 2. Video Tape Recorders are easily the most complex pieces of machinery ever to find their way into the home as they contain most of a colour TV circuit plus sophisticated mechanics. This block diagram gives the essential circuit elements; see the text for a more detailed explanation.

improved recording time and these are discussed in this article.

Figure 2 shows a schematic of the basic signal processing circuitry blocks required for a consumer video cassette recorder with tuner. Since domestic television receivers have no facilities for video inputs or outputs, the video cassette recorder must be designed to operate connected from the aerial which is plugged into the recorder, and a lead taken from the recorder to television set. Thus the recorder needs some form of aerial splitter, usually with a preamplifier, which feeds the TV set and the built-in TV tuner. The detector separates audio, luminance (brightness of the picture) and chrominance (colour) which are then processed and recorded separately on the video tape using different techniques. Audio is recorded conventionally using a single head for recording and playback with an erase oscillator and head covering the full width of the half inch tape.

Recording television pictures is somewhat more complicated. Fig 3 shows the transmitted television spectrum which comprises an amplitude modulated 5.5 MHz bandwidth luminance signal (the higher frequencies containing the finest detail of the picture) and the chrominance signal, phase modulated onto a suppressed 4.43 MHz carrier. Since all the picture detail is carried in the luminance, the chrominance bandwidth is restricted to about 1.5 MHz. Although these high frequencies can be recorded directly on to video tape if the relative tape/head speed is sufficiently high, there is another limitation. Due to the wavelength of frequencies and the physical gap distance in any recording head, there is a theoretical limit of about nine octaves that may be recorded onto magnetic tape. These nine octaves

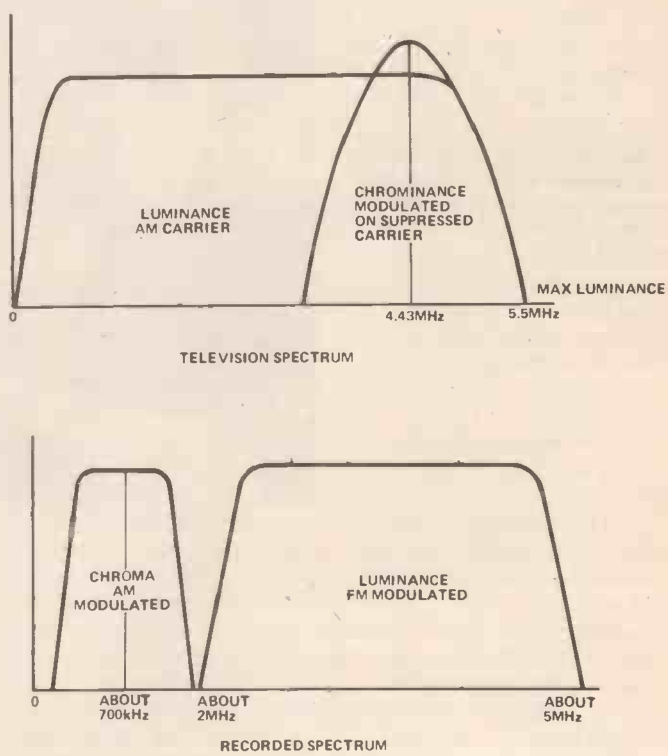


Fig. 3. To get the most out of a tape recorder, the original TV spectrum is considerably rearranged when put on the tape. The whole luminance section (the monochrome picture) is shifted up the spectrum and is frequency modulated. The colour information is slotted onto lower frequencies and amplitude modulated.

The Philips N1700. This machine uses the same cassettes as their earlier models but gets twice the time from them. The timer allows the user to set for recording up to three days ahead.

conveniently cover the audio spectrum between 50 Hz and 20 kHz but is obviously insufficient to cover the 50 Hz to the 5 MHz of video frequencies. However, by frequency modulating this wide bandwidth video signal onto a carrier, all these frequencies can be effectively shifted up the spectrum where they can be very conveniently handled, within this octave limitation.

In practice, the highest recorded frequency on the video tape is still limited by the relative head/tape speed, and it is only typically possible to record about 3 MHz of the 5.5 MHz transmitted bandwidth on a consumer video recorder. Thus, during recording some of the finer picture detail is lost although this may be subjectively improved upon replay. However, the vital colour frequencies are located around 4.43 MHz, so a separate arrangement is made to record these. The chroma carrier is modulated with another carrier, the lower sideband of which falls somewhere around 700 kHz, this then amplitude modulated and recorded directly on the video tape.

It can thus be seen that the frequency limited colour signals are recorded below the luminance information. Since this luminance is frequency modulated, it may be recorded directly onto the video tape without any form of bias. Nor does the level being replayed from the tape significantly vary the picture unless drop out (missing tape coating) causes a total loss of signal. Hence in the replay chain, a drop out compensator monitors this replayed level and upon discovering a drop out, replays the previous television line (which it continually stores) so filling the space. Otherwise the replay chain is similar to that of recording with a luminance demodulator and chroma mixer, after which the signals are combined, electronically 'cleaned up' and 'crispened' using high frequency boost to recreate some sharp edges or detail in the picture.

The replayed video and audio are then combined in the RF modulator which is essentially a microminiature television transmitter operating somewhere around channels 33-45 in the UHF band. This modulated output is then combined with the incoming aerial signal and sent to the television receiver where it can be tuned on a spare preselector. There are also electronic servo circuits in video cassette recorders which ensure that the head drum spins at a precise speed and which also control the tape speed and physical location of the tape relative to the control track pulses. Accuracy of speed is essential otherwise the picture will appear to shudder on the TV set and in the worse case, will break up and be lost altogether.

Looking back at Fig 1, it can be seen that between each video track is a guard band that prevents interference in much the same way as crosstalk in audio. However, this is obviously wasteful on video tape, and techniques have been developed which allow this guard band to be eliminated completely and thus provide considerably improved recording times. Basically, the two rotating video heads are tilted slightly in opposite directions so that alternative recorded tracks have a different azimuth. If while scanning one track, a video head slightly covers an adjacent track, the level replayed will be considerably reduced and thus cause little interference. Three hour recording times would not have been economically possible without this development, although in America another technique termed 'skip field' recording has been used to double recording times. A television signal comprises 25 frames per second, each made up from two interlaced fields where

Shown here together, one can quickly see the identical origins of two machines, one with a Japanese brand name, the other a British one. Table 2 overleaf shows which companies are using which system.

TABLE 1 COMPARISON OF THE FOUR DIFFERENT VIDEO CASSETTE FORMATS

Format	Max play time	rewind/hr	cost/hr	cassette size	tape speed	writing speed	shop price
Grundig SVR	4hr	0.93min/hr	£5.40	127x41x145mm	3.95cm/s	8.21m/s	£775
JVC VHS	3hr	1.3min/hr	£4.83	185x25x104mm	2.34cm/s	4.83m/s	£739
Philips VCR-LP	2½hr	1.8min/hr	£6.18	127x41x145mm	6.56cm/s	8.1m/s	£639
Sony Betamax	3¼hr	1.6min/hr	£4.15	156x25x96mm	1.87cm/s	6.6m/s	£750

every other line belongs to one field, thus making the total 50 fields per second. If every other field is 'skipped', recording time is doubled but at the expense of reduced vertical resolution and occasional 'jerkiness' of movement. These penalties are such that skip field is not commercially available in Britain.

PRODUCTS

Although there are some 16 different video cassette recorders available on the market, these break down into four different 'formats' of which machines within a particular format have interchangeable video cassettes. But there are basically only five actual manufacturers who produce units which are then marketed by other companies, often with cosmetic changes. Although such multiple branding might not be particularly beneficial to the manufacturer's corporate image, it does mean that multiple organisations are promoting one particular product which does make for considerably improved impact in the all-important 'war' to become the standard video cassette format.

Table 1 provides a comparison of the four different video cassette formats from Grundig, JVC, Philips and Sony. One point that should be made immediately is that the earlier Philips format simply termed **VCR** and used until about a year ago, only provided one hour playing time — so if buying a secondhand Philips video cassette recorder, the latest **N1700** is really the only unit to buy. Video cassettes to match all these formats are available from a variety of companies. For instance VHS cassettes can also be found under Thorn, TDK, Ampex and Fuji labels, VCR-LP from Agfa, BASF and 3M, while Betamax is becoming available from 3M. Actual tape cost will vary between different brands and upon the discount found but the figures quoted should provide an approximation.

Essentially, all the video cassette recorders indicated in Table 2 under the respective formats, offer similar facilities. These include all normal tape transport controls, built-in TV tuner with eight channel preselectors, and electronic clock/timers with varying facilities. The timer found on the VHS is currently the most basic and only allows the recorder to be set to start up to 24 hours ahead in one minute steps — the video cassette runs until stopped automatically at the end of the tape. Philips and Sony can both be set three days ahead, Philips in one minute steps, Sony in quarter hour steps. The Philips timer also provides a recording duration so the tape can be set to stop. Grundig currently has the most advanced timer providing up to 10 days advance setting. However, during 1979 expect to see upmarket models becoming available with rather more complex timers. These will provide such facilities as permitting several different programmes, on varying channels, to be recorded during a 10 day period within the confines of a single cassette length. Such timers are essentially programmed microprocessors and should be considerably more versatile than existing recorders.

Apart from Sony and Grundig, still frame is not provided officially on the other consumer video cassette recorders, but can in some cases be found by careful manipulation of the pause control — on the other hand some VHS machines actually go into fast forward while

TABLE 2

SVR	VHS	VCR-LP	Beta (max)
Grundig SVR4004	JVC HR-330	Philips N1700	Sony SL8000UB
ITT SVR240	Akai VS 9300		Toshiba V-5250
	Ferguson 3239		Sanyo
	Nordmende		
	Baird 8900		
	Multibroadcast 8900		
	DER 8900		
	Granada 8900		
	Mitsubishi HS200		
	National Panasonic NV8600B		

The Panasonic VHS shown here is compatible with the other varieties mentioned, although it is made to a different mechanical design

Sony's Betamax — the most recent entrant onto the British market but a machine that has done extremely well on the US market. The Betamax is the cheapest on tape usage but this advantage is not as great as it sounds. Most VCR owners find they need only 6-10 tapes and rarely do they keep recordings for long.

slightly depressing 'pause.' Proper still frame and, in the case of JVC double speed playing, will become available on the next generation of video cassette recorders.

Another facility that comes in particularly useful are connectors for video and audio. These enable recorders to be connected together for copying without the loss of quality resulting from connecting aerial leads due to losses in the modulator and tuner combination. However unfortunately there is no standard for these connectors and each manufacturer has its own ideas. Video and audio connectors are standard with JVC and Sony (and derivatives), but extra on Philips and Grundig.

One other point that bears examination is the video-tape threading. As mentioned earlier, the removal of tape from the cassette is performed automatically by the recorder, but different machines using different principles. The Philips **N1700** automatically threads when turned on, but in order to protect the tape which is threaded around the rotating heads, the unit turns itself off after about one minute. This can be rather frustrating if one is waiting to record a programme, but has the advantage of immediate operation when play or record are selected. On the other hand the JVC HR-3300 recorder only threads when the play control is selected which gives a three second delay before pictures are seen. On the other hand fast winding is considerably better since the tape does not have to negotiate a multitude of guides. The Grundig SVR4004 follows the Philips principle and also has unique remote control of all operating functions, while the Sony Betamax also follows the Philips tradition.

OTHER FORMATS

All the video cassette recorders mentioned so far have been designed to operate exclusively on British television using the PAL colour system. If it is required to send video cassettes to other parts of the world or vice versa, another, older format can be used called U-Matic which is available from Sony and National in multiformats. North America use the NTSC colour system, France, the Soviet bloc and much of the Middle East, SECAM, while PAL is used by civilised Europe. Provided a multistandard television receiver is used, video cassettes recorded in any of the areas can then be replayed in other countries. For instance, when one retires (for either age or tax purposes) to the south of France or the Caribbean, one can arrange a supply of civilised programmes to be flown out . . . However *U-Matics* are a few hundred pounds more expensive than the earlier formats and use rather more expensive and bulky tape. On the other hand the quality is somewhat better and twin audio tracks are available for stereo. The U-Matic format is somewhat more versatile than the others in that programmes can be made using special portable and editing video cassette recorders.

CONCLUSIONS

Before you actually dash out to the shops, first consider whether you actually want to buy a video cassette recorder, or if renting might be advantageous. Depending upon model and discount, present prices vary between £600 and £750 to buy, while renting costs £18 per month. Remember that once purchased, a video cassette recorder is unlikely to have a particularly high secondhand value since new formats and better machines seem to be appearing each year. Also there are a vast number of extremely delicate moving parts inside and all video cassette recorders require competent servicing (which is difficult to find); at least annually. If the video heads require replacing, a potential bill of £70-£80 could arrive.

Philips video cassette recorders can be rented from Visionhire, while VHS units are available from Radio Rentals (Baird), Multibroadcast, DER and Granada for £18 a month, six months advance payment and minimum rental period of one year. This includes six monthly servicing, and one free video cassette. Including servicing, one would probably break even after about five or six years if buying, but on the other hand when a new model with improved facilites is released, one only has to pay another six months advance rental and you can immediately exchange the old unit for new. Worth thinking about?

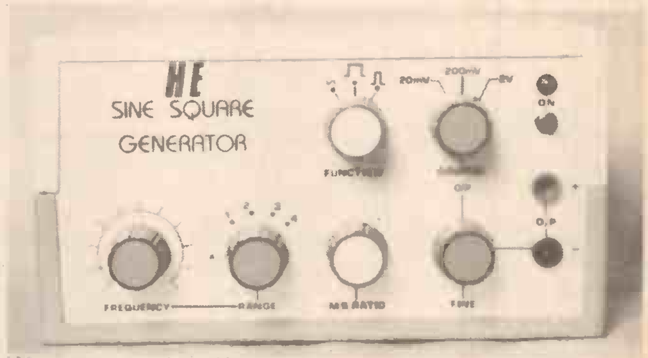
HE

Sine/Square Wave Generator

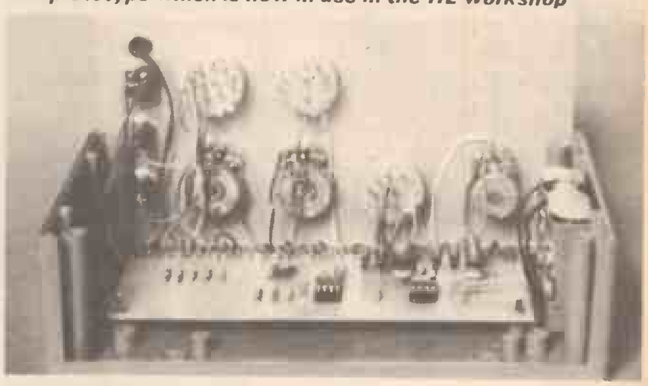
This is the first of an HE Test Gear series. It's a low-cost high-quality sine-square generator that covers the 15 Hz to 150 kHz frequency range.

A SINE-SQUARE GENERATOR is an essential piece of equipment to anyone interested in testing, designing, or experimenting with audio or low-frequency circuits or filters. HE's generator is a low-cost high-quality battery-powered instrument that deserves an honoured place in any electronics workshop.

Our generator covers the frequency range 15 Hz to 150 kHz in four switch-selected ranges. It produces good low-distortion amplitude-stabilised sine waves, and fast rise-time square waves: It also has a facility for generating square waves with variable mark-space ratios. All output levels are adjustable via a fully variable fine control and a 3-position switched attenuator. The instrument draws a typical drain current of about 10mA from each of its two batteries.



Our prototype which is now in use in the HE workshop


Internal view of the unit

BOUNCE — BOUNCE.

Our generator is a high quality design. The final performance quality of the complete instrument depends on the quality of the fine frequency control, dual-gang log pot RV1, and its drive control mechanism. On our prototype we used an inexpensive carbon-track item for RV1, with direct drive to its spindle, but this gives a very adequate performance.

Using a poor quality component in the RV1 position results in the output amplitude level of the sine wave varying erratically (and sometimes temporarily collapsing) as the operating frequency is varied. This phenomenon is known as *'bounce'*, and is caused by poor tracking or mismatch between the two sides of the dual-gang pot.

CONSTRUCTION.

If the overlay is followed carefully, the on-board components should present no constructional problems. Take care, however, to fit the IC's and the LED the right way round: the thermistor can be fitted either way round.

There is a good deal of wiring between the PCB and the front panel: if you take care in following the overlay in conjunction with the circuit diagram, however, you should have no problems.

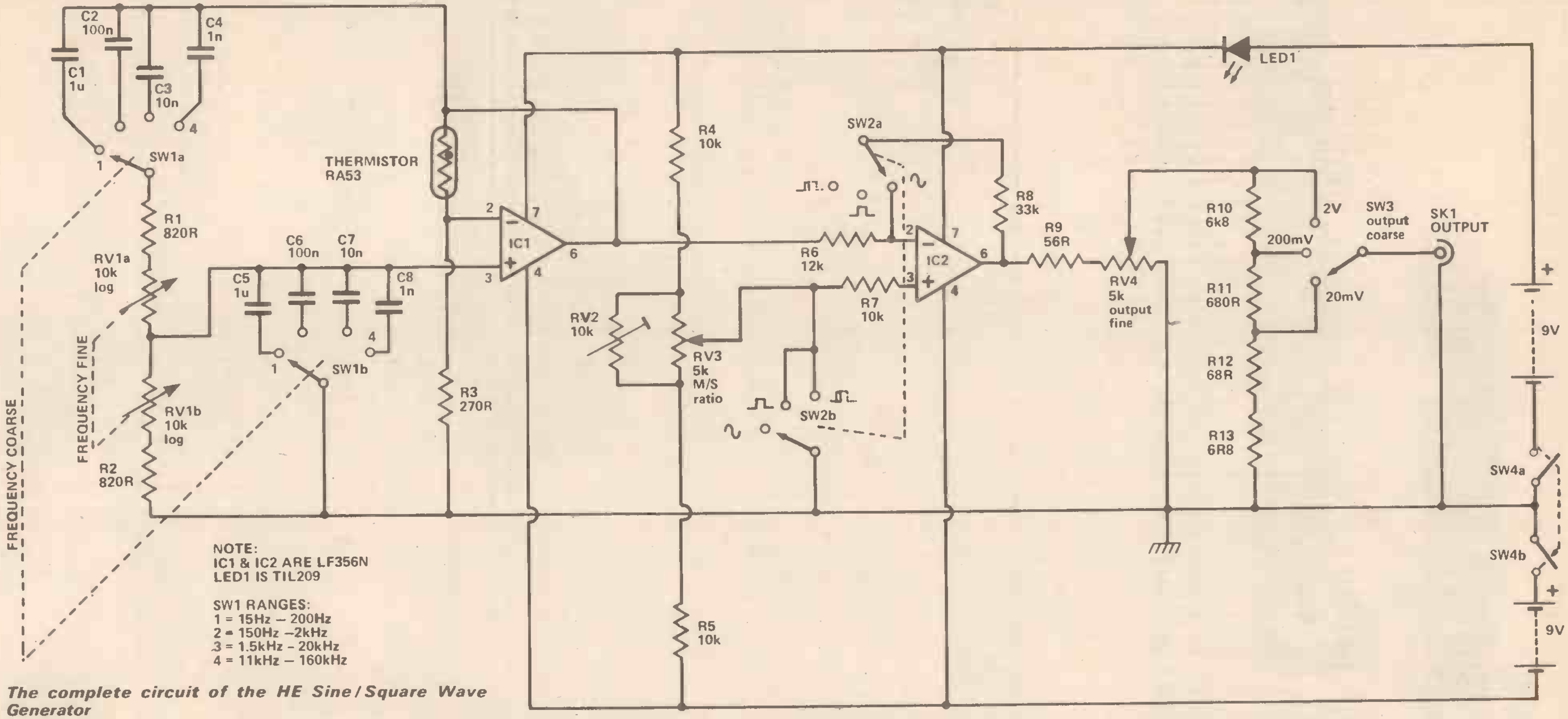
When construction is complete, double-check all wiring, fit the two batteries, and switch on: The LED should light. Connect the output of the instrument to a 'scope (if you have access to one) or to a pair of high impedance earphones. Set the front panel controls to SINE mode, with minimum attenuation, and check that a pure sine wave is available and that its frequency is variable via RV1 and S1. Repeat in the SQUARE WAVE and variable M/S RATIO modes: in the variable M/S mode pre-set pot RV2 can be adjusted to restrict the ratio variation range of RV3 to within reasonable limits.

CALIBRATION.

To calibrate the fine frequency scales, you need access to either a digital frequency meter or to an oscilloscope and an accurate LF generator. If you don't have direct access to these instruments, you may find that your local technical college will be some assistance.

When you are calibrating the instrument, you can either accurately and painstakingly mark up each one of the four individual frequency ranges, or just roughly mark up one of the middle ranges and use that as an approximate guide to the rest.

Sine/Square Wave Generator



The complete circuit of the HE Sine/Square Wave Generator

How it Works

THE HEART OF THE sine-square generator is a sine-wave oscillator. Fig. 1 shows, in simplified form, the essential circuit and operating conditions of a sine-wave oscillator. It consists of a frequency-selective network (either R-C or L-C) which produces a phase shift of y° and a gain (or attenuation) of A2 as the desired oscillation frequency (f_o), and an amplifier with a gain of A1 and a phase shift of x° at f_o.

It is an essential condition of oscillation that the sum of the two phase shifts equal O° (or 360°) at f_o and that the product of the two gains equal unity or greater under this condition: for pure sine wave generation, the two gain products must equal precisely unity at f_o.

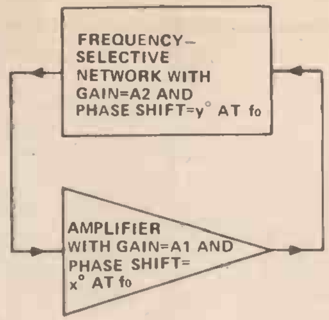
The most popular R-C frequency selective network used in low-frequency sine-wave oscillators is the Wien network shown in Fig. 2. This circuit is symmetrical, i.e., R1 = R2 = R, and C1 = C2 = C. The outstanding feature of the Wien network is that the phase relationship of its output to input signal varies from —90° to +90°, and equals zero at a precise 'centre' frequency (f_o) of 1/6.28 CR: At f_o the circuit has a gain of 0.33. Note that f_o can be simply varied by replacing R1 and R2 with a dual-gang pot.

Figure 3 shows how the basic Wien network can be coupled up to an operational amplifier, together with a simple but effective automatic gain control network, to form a fixed-frequency oscillator: The work comprises RV1-R1-R2 and C1-C5, or C2-C6, or C3-C7, or C4-C8. The frequency range of the oscillator is variable from about 15 Hz to 150 kHz in four decade ranges.

The sine wave output of IC1 is fed to the input of IC2. When the instrument is set to the SINE mode IC2 acts as a simple amplifier with a gain of about three, so a sine wave is available at the output of the instrument via the RV4 and R10 to R13 attenuator network. In the SQUARE WAVE mode IC2 is used as an open-loop voltage comparator, with a reference voltage of zero set on its non-inverting (+) input terminal, and converts its sine wave input into a symmetrical square wave output signal. In the variable M/S RATIO mode IC2 is gain control network is an attenuator, comprising a negative-temperature-coefficient thermistor and R3, wired between the output and one input terminal of the op-amp. This basic oscillator circuit is used as the heart of our sine-square generator project.

Turn now to the main circuit diagram of the sine-square generator. Here, the Wien sine wave oscillator is designed around IC1: The Wien network is again used as a voltage comparator, but in this case a variable reference voltage is set on the non-inverting terminal of the IC, and a non-symmetrical 'square wave' output is available from the circuit.

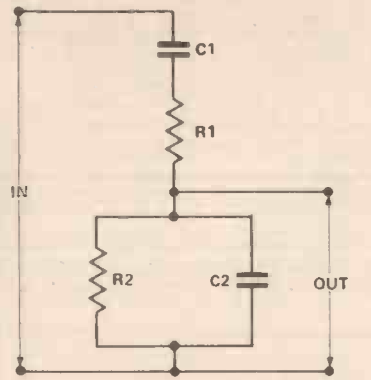
The circuit is powered from two 9 volt batteries: the positive supply current (about 10 mA) flows to the circuit via light-emitting diode LED 1, which illuminates to indicate that power is on.



CONDITION FOR OSCILLATION: x°+y°=0° (or 360°)

CONDITION FOR SINE-WAVE GENERATION: A1 x A2 = 1

Fig. 1



R1 = R2 = R

C1 = C2 = C

PHASE SHIFT = 0° AT fo

$f_o = \frac{1}{6.28\,CR}$

$A = \frac{V_{out}}{V_{in}} = 0.33$ AT fo

Fig. 2

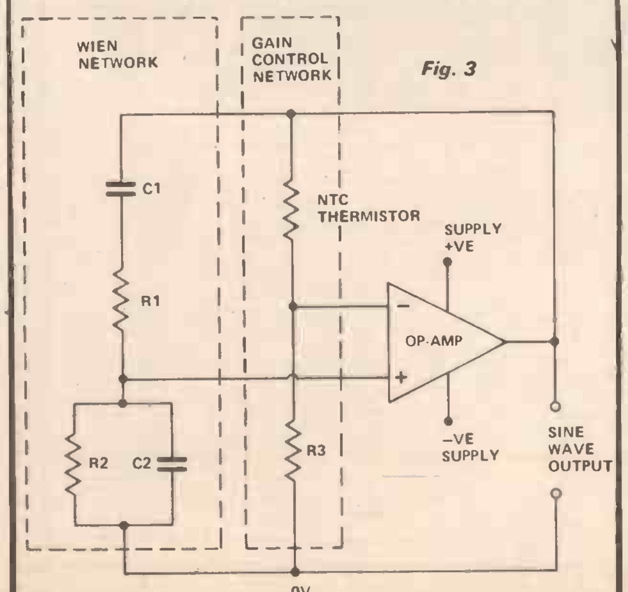


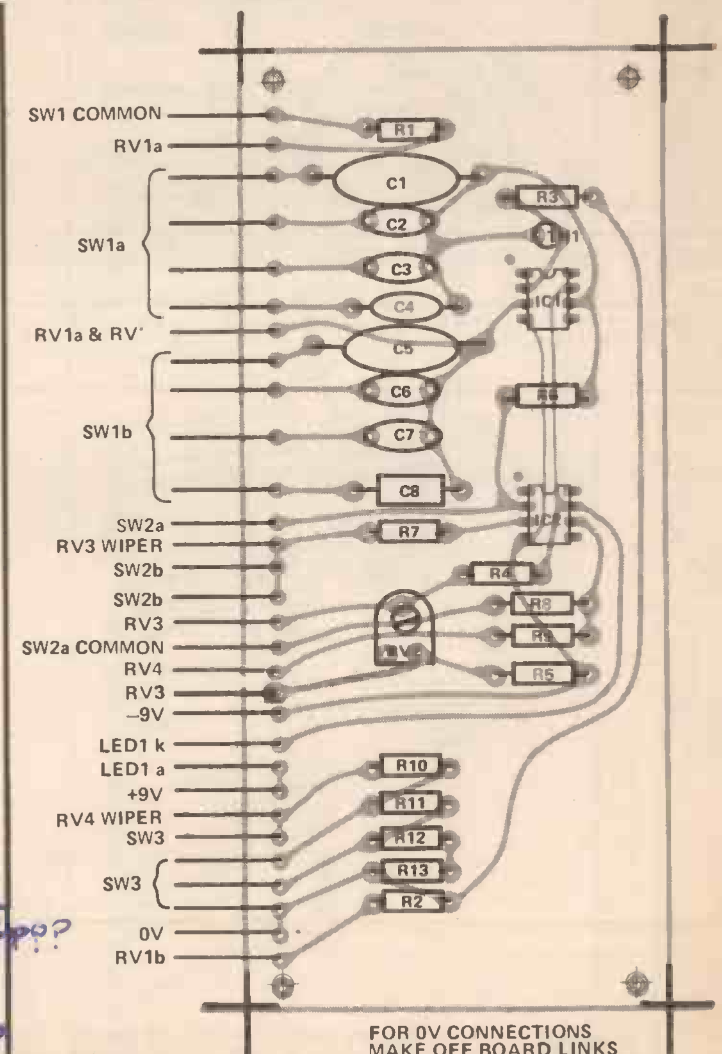
Fig. 3

Parts List

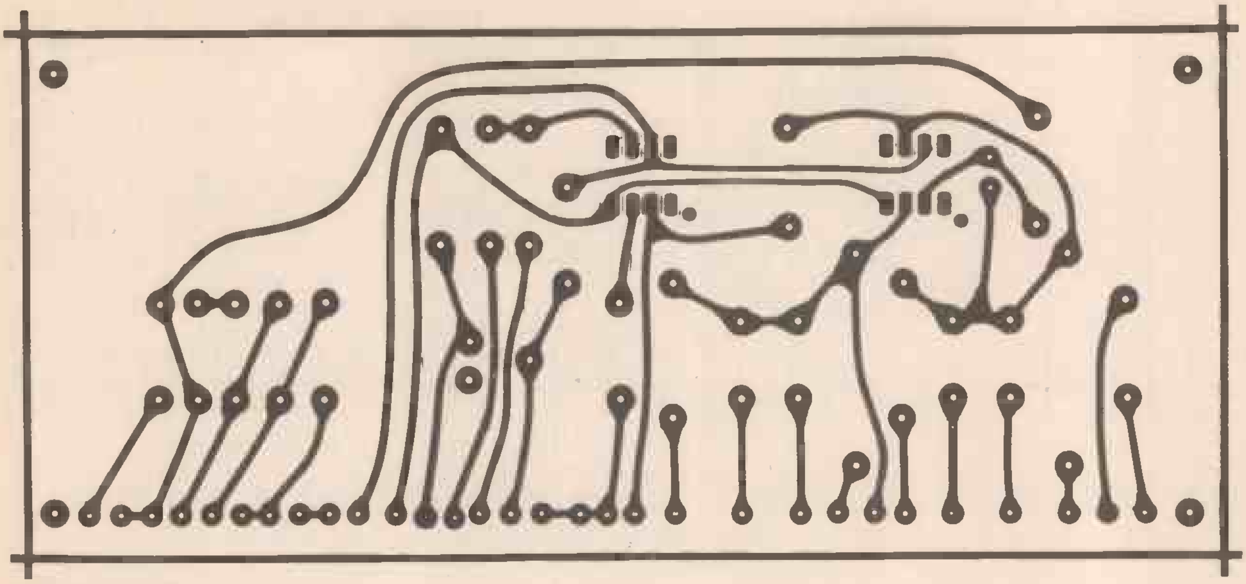
RESISTORS:—		
R1, R2	820R	
R3	270R	
R4, R5, R7	10k	
R6	12k	
R8	33k	
R9	56R	
R10	6k8	
R11	680R	
R12	68R	
R13	6R8	
TH1	RA53	
CAPACITORS:—		
C1, C5	1µ0 (Tant)	
C2, C6	100n (poly)	
C3, C7	10n (poly)	
C4, C8	1n (poly)	
SEMICONDUCTORS:—		
IC1, IC2	LF356	
LED	TIL209 (Red)	
POTS:—		
RV1 a + b	10k	Dual Log
RV2	10k	Preset
RV3	5k	Lin
RV4	5k	Lin
MISCELLANEOUS		
SW1	2 pole	4 way
SK1	2 off	4mm sockets
SW2	2 pole	3 way
SW3	1 pole	3 way

SW4 DPDT min toggle 2 off PP3 Vero case

Knobs to suit, PCB to pattern



The component overlay.



The PCB pattern

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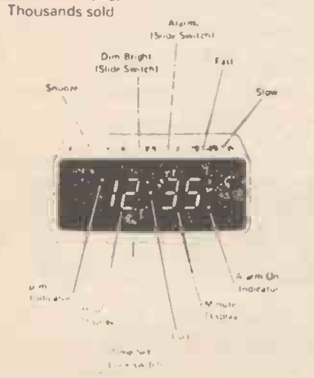

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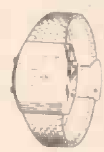

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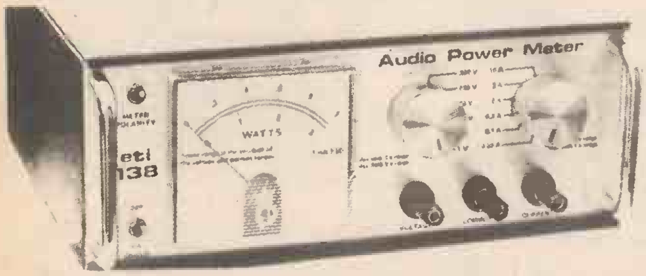
What to look for in the March issue: On sale Feb 2nd

Articles mentioned here are in an advanced state of preparation but circumstances may affect the final contents.

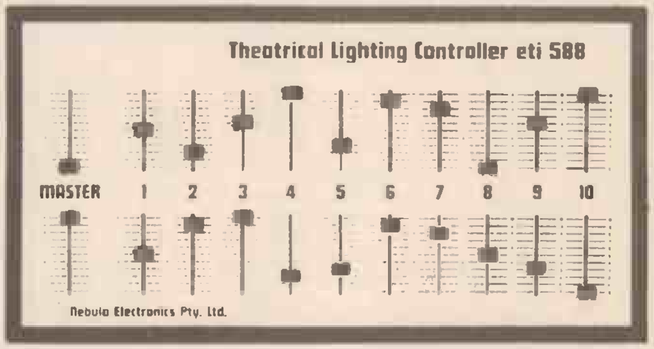
VIDEOGRAPH

SPLASH your hi-fi all over the TV screen. Produces an entirely original TV display to the tune of you music. Especially interesting video techniques employed here, which should be well worth the read — a full kit of parts is also available.

AUDIO POWER METER



O.K. so you've seen circuits for these things before. Even from us. But even we're proud of this one. Facilities are extensive, and readings are more accurate than you're liable to need. Built simply and at very reasonable cost this design will undoubtedly emerge as the 'standard' in its field. If you're interested you know where to look.



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CLIP AROUND HERE!

A2D4U

Tim Orr now turns his circuit infested brain to the subject of Analogue to Digital techniques and circuitry. He discusses the theory, gives the circuits to experiment with and talks over the applications. Not be be missed.

CELLULAR Logic Image Processing to be exact. And its all about processes like perimeter finding — producing the outline of an object (skeletonising) — finding the set of lines which are unbroken and follow the objects shape. This sort of process can be used in such diverse applications as fingerprinting, intruder detection, character recognition, chromosome counting and production control!! Phil Cohen has been to see the inventor and come back with this in depth discussion which even includes a Basic program to simulate the process!

A Histoy of Radioactivity

RADIOACTIVITY was first detected about eighty years ago and its discovery has lead to some spectacular advances. From the study of radiation scientists have been able to explain many of physical science's fundamental principles.

Radioactivity occurs in nature, and can also be man-made. The natural sources are all around us in the form of radioactive elements dispersed throughout the soil and vegetation. Areas of high background radioactivity are usually associated with concentrations of naturally occurring radioactive elements, particularly uranium and thorium.

Another natural source is constant radiation from outer space. Fortunately the earth's atmosphere filters out most of it, but some of the more intense types of cosmic rays penetrate the atmosphere and are more detectable at sea level.

Man-made radiation takes many forms and can be generated in large particle accelerators, through the release of energy in an atomic explosion, in a nuclear reactor, or x-ray tube.

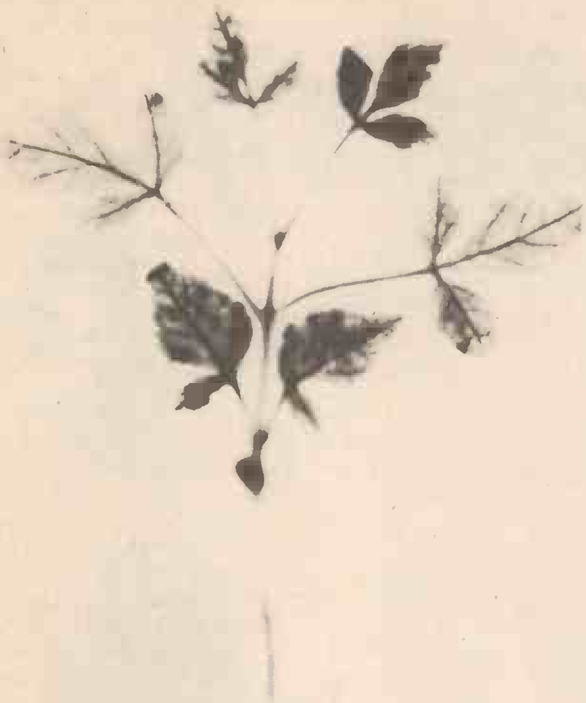
THE DISCOVERY OF RADIOACTIVITY

The nineteenth century was a period of intense scientific activity. The medieval attitudes that had fettered scientists were disappearing, and the age of the true experimenter had come. Scientists throughout the world were tackling problems on a broad front, laying the groundwork for the fundamental principles of modern science. By the middle of the century Coulomb, Volta, Oersted, Faraday, and many others had evolved the laws of electricity and associated phenomena which hold to this day.

The electric spark had always been a source of interest to investigators, and with the development of the induction coil, high voltage sparks could be produced. As a further interest, tneir behaviour in a vacuum was investigated. A glass tube. with two electrodes fused into the glass at each end was made, and the tube was then evacuated with a vacuum pump. The two end electrodes were connected to the output of an induction coil and the effects observed.

The operator uses long tongs to keep his body away from the radioactive material in the container, whilst the monitor continuously checks the radiation level. (Courtesy Nuclear Enterprises Ltd.)

Simple radioactivity measuring equipment. The end-window Geiger tube is shown at the front. The meter indicates the counting rate. (Courtesy: ESI Nuclear Ltd.)



Radiograph of a plant which was placed in phosphorus-32 for a time and then pressed against x-ray film which was subsequently developed. The young rapidly growing leaves absorb more phosphate than the older leaves and therefore appear darker. (Courtesy: Kodak Ltd.)

The result was unexpected, and became the subject of intense investigation.

One of the investigators was German physicist Julius Pflucker. He observed that, as the air in a discharge tube is gradually pumped out and a high voltage applied to the tube, when the pressure is low enough, long thin streamers of light pass down the tube. As the pressure decreases further, these streamers expand out until the whole tube is filled with a glow. Still further reduction of pressure (towards a near vacuum) causes the glow to first become striated with dark areas then gradually increasing till the glow almost disappears, but with the glass walls glowing a yellowish-green colour in the region opposite the cathode.

It was obvious to Pflucker that this fluorescence in the glass was caused by some unknown invisible rays hitting the glass. Since these rays appeared to come in straight lines from the cathode he called them *cathode rays*.

From this time events began to move fast, and there was a growing excitement among scientists as several investigators performed experiments to determine the nature of these rays.

In 1895 a German physicist, Wilhelm Roentgen was experimenting with a discharge tube at very low pressure. He became particularly interested in the fluorescence (visible light) produced in a nearby zinc-sulphide screen by radiation coming from the tube. The fluorescence continued when the discharge tube was covered with black paper. Not knowing the nature of this radiation, he called it the unknown 'X'. Roentgen rays are now commonly known as X-rays.

The stage was set for the discovery of radioactivity.

Henri Becquerel, who was greatly interested in the phenomenon of fluorescence, had set up a similar apparatus to Roentgen's and used it to "excite" chemical compounds to observe whether they fluoresce or not. Among the compounds tested were some uranium salts.

From these observations two facts came to light. One was that some uranium compounds would fluoresce when exposed to X-rays. (That is they emitted visible light). Second, while X-rays were not visible to the human eye, they exposed photographic plates, even when wrapped inside black, light-tight paper.

He then conducted an experiment to see if the reverse reaction could be brought about. He supposed that if he exposed the uranium salt to visible light, then the salt should be excited to give off X-rays, which could be detected by photographic film. The results of his experiment seemed to be confirmed when he developed the photographic plate on which the uranium salt had been placed. The plate was exposed. It seemed the experiment had worked in reverse. However, Becquerel found that the plate was also darkened when the crystals were *not* exposed to light. He then prepared some crystals of the uranium compound under conditions of total darkness, without exposing them to light at any stage, and repeated the experiment. Again the plates were exposed. Further tests showed that all uranium compounds, including those that did not fluoresce, gave the same effect.

He now proceeded to investigate this new radiation and found that it could penetrate materials in a similar fashion as X-rays — seemingly unending production of energy by the uranium apparently contradicted the law of the conservation of energy.

Thus was ushered in our present atomic or nuclear age, for Becquerel had discovered radioactivity.

Madame Curie, as a young post-graduate student in Paris, investigated minerals which she found in her school's extensive collection of

Monitor for checking the contamination of personnel working with radioactive materials. It comprises a vertical array of 11 beta/gamma Geiger detectors with an additional detector for monitoring the soles of shoes. An alarm bell is included in this equipment, whilst the tone chimes sound when there is no contamination. (Courtesy: Nuclear Enterprises Ltd.)

The patient has been given an injection of a radioactive material which is rapidly excreted by the kidneys. The two detectors, one behind each kidney, drive the pen recorder above the patient's head which produces a chart containing kidney function information. (Courtesy: U.K.A.E.A.).

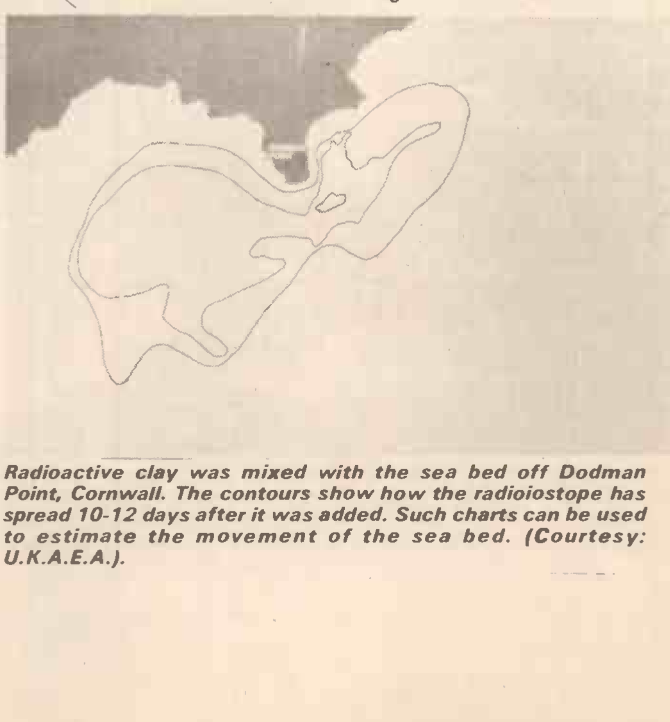
mineral samples. Many of these contained uranium and thorium. Many considered her efforts a waste of time. However, this "waste of time" brought a surprising result. Observations on the uranium-bearing minerals pitchblende and chalcolite showed that they have a radiation four times as strong as an equivalent amount of pure uranium. Repeated tests yielded the same results. Marie Curie concluded that the mineral pitchblende emits radiation four times as strongly as it should do. Therefore, in addition to uranium it must contain small amounts of an unknown element that is so radioactive that even a small admixture increases the radioactivity of the uranium mineral fourfold. In the subsequent search, Pierre and Marie Curie refined several tons of ore over four years, finally isolating 100 milligrams of pure radium chloride. In the intermediate stages they also discovered another radioactive element, Polonium.

By 1900 Max Planck had revolutionised physics with his theory of quanta, or discontinous emission of energy. Following work by F. Soddy and W. Ramsay in Montreal, demonstrating that radium disintegrates with the emission of helium, their mentor Ernest Rutherford demonstrated in 1907 that the alpha particle is a nucleus of ionised helium.

A few years later Rutherford and Niels Bohr proposed the "planetary system" models of the atom. In 1919 the first artificial nuclear disintegration was produced by Rutherford. He succeeded in transmitting one element into another (nitrogen into oxygen), a thing that alchemists had been trying to do for centuries.

Meanwhile, just one year later, regular radio broadcasting began in the U.S. An offshoot of the early vacuum tube demonstrating the Edison effect had been perfected by de Forest. It had ushered in the electronics era.

By 1932 two British scientists, J. D. Cockroft and E. T. S. Walton, achieved atomic disintegration by bombarding lithium with accelerated protons. This resulted in the lithium atom splitting up into two alpha particles.



Radioactive clay was mixed with the sea bed off Dodman Point, Cornwall. The contours show how the radioiostope has spread 10-12 days after it was added. Such charts can be used to estimate the movement of the sea bed. (Courtesy: U.K.A.E.A.).

Then came an announcement that meant little to the man in the street or the politician, and which received little publicity in the press.

Otto Hahn and Fritz Strassman announced that they had succeeded in splitting the uranium nucleus by neutron bombardment. They considered the possibility of a chain reaction. The energy released with their small sample was equivalent to 25 million kilowatts per kilogram of uranium.

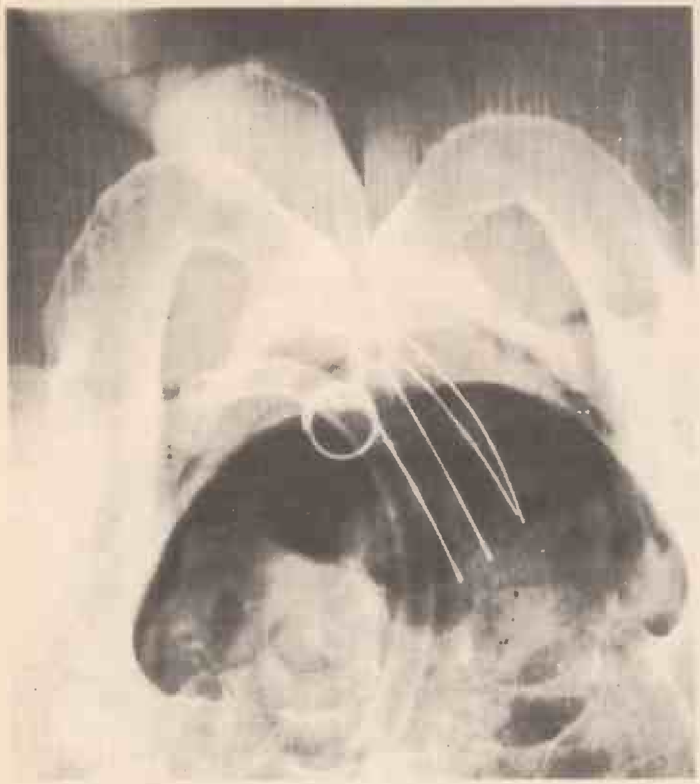
NUCLEAR FISSION

Hahn and Strassman had induced nuclear fission (splitting the nucleii of uranium atoms into two parts) by neutron bombardment. However they found it hard to understand how this had taken place, and did not at first believe their results.

But Hahn and Strassman's doubts were soon resolved by two scientists working at the Bohr Institute in Copenhagen. Lise Meitner and Otto Frisch who performed further experiments, concluded that Hahn and Strassman were correct. They coined the phrase "nuclear-fission".

On January 16th, 1939, exactly ten days after Hahn's announcement, two short notes about the Copenhagen findings were sent to the English publication *Nature*.

Two days later, Niels Bohr travelled to the USA for a hurried conference with physicists in Washington. He presented Meitner and Frisch's results to an astonished audience, even before they had appeared in print. Enrico Fermi, already in the USA as a refugee from Italy was also present. The conference at Washington continued with heated discussions well into the night. Many new possibilities came to light. Most notable was that fragments



X-ray photography showing tantalum wire 'hairpins' implanted in the bladder. The radioactive wire contains the isotope tantalum-182 which irradiates a tumour. (Courtesy: Royal Marsden Hospital and U.K.A.E.A.).

of the split uranium nucleus contain a large surplus of neutrons and there was the possibility that these free neutrons would in turn split further atoms of uranium.

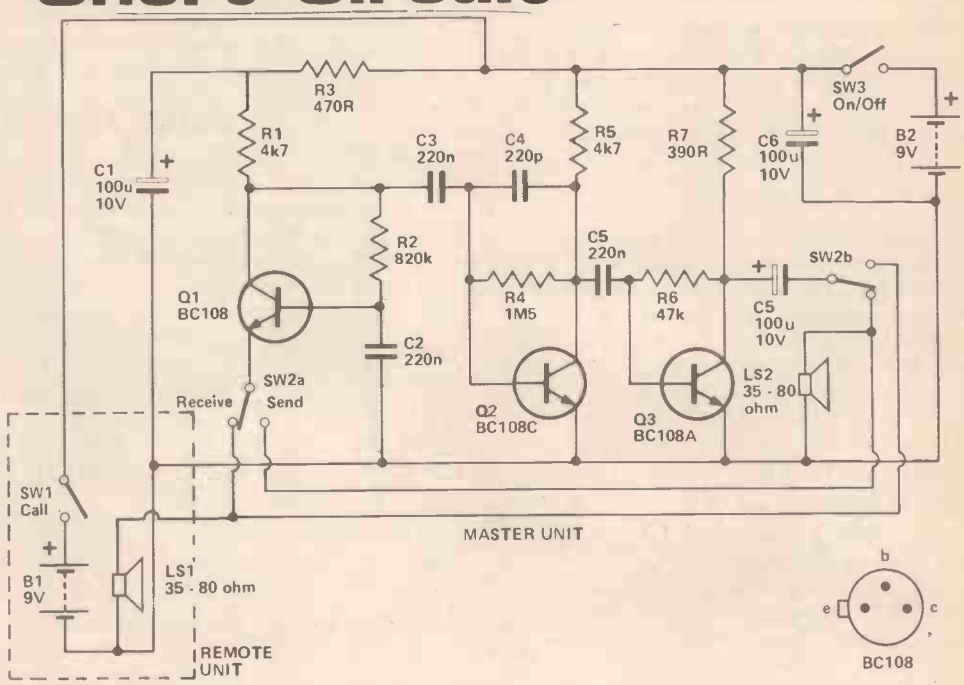
This was the first time that the notion of a chain reaction cropped up. The question arose as to what becomes of the free neutrons that the uranium fission fragments must contain in abundance.

The answer came in March at the Paris Academy when Frederick Joliot and colleagues Dode, von Halban and Kowarski presented their results. They had confirmed that free neutrons are produced, and surmised that these induced the fission of further uranium nuclei, so producing more neutrons and so on, like an ever-swelling avalanche.

It was in this report that the words "reaction a chaine" were used. The words were to gain currency as *'Nuclear Chain Reaction'*. Visions were conjured up of mighty machines fed by uranium, which could supply whole countries' energy needs, running on a handful of uranium fuel. However, at the time a more grim vision overshadowed this; one that mocked the achievements of human culture; the atomic bomb. . . but that's another story . . . **HE**

Short Circuit

HOME INTERCOM



This intercom uses a straightforward three transistor amplifier which gives quite a good quality output (by intercom standards) and an adequate output power of a few tens of milliwatts.

As is normal practice with intercom designs, the loudspeaker in each station also doubles as a sort of moving coil microphone when 'sending'. The position of SW2 determines whether the slave unit is 'sending' and the master station is receiving, or vice versa. Ideally this should be a biased switch which automatically returns to the 'receive' position when released. This enables the remote unit to call the master one if the operator closes SW1 so as to connect power from B1 to the amplifier, and then talks into the microphone in order to attract the attention of the person at the master station. If SW1 is not a biased switch, it could be left in the 'send' mode, preventing the remote station from calling the main one. SW3 is the ordinary on/off switch at the master station.

The amplifier is a three stage unit capacitive coupling between stages. A common base input stage (Q1) is used as this gives a low input impedance. This is desirable as it minimises stray pick-up of mains hum and radio interference in the connecting cable, and it also gives a good match to the microphones. The following two stages are both straightforward common emitter amplifiers. C4 rolls off the high frequency response of the circuit and this aids stability. It can also help to prevent RF breakthrough.

The prototype was tried with connecting cables up to about 10 metres or so long, and gave perfectly good results. It should work with considerably longer connecting cables if necessary. A three core connecting cable is required and this can conveniently be thin three cored mains lead.

Scratch and Rumble Filter

Improve the quality of those old discs — and other things — with this simple but versatile Rumble and Scratch filter.

MANY OLD and not-so-old discs produce noises that they're not supposed to. They produce high-frequency 'clicks' from scratches on the faces of the actual discs, and low-frequency 'rumbles' from the record player turntable mechanism. Our Rumble-Scratch filter helps eliminate these nasty noises from an amplifier system.

The Rumble-Scratch filter incoporates two good quality filter systems, which process the record player pick-up signal as it passes on to the systems power amplifier stage. The first of these filters is a 'high pass type, which chops off the unwanted low-frequency rumble signals, and the second filter is a 'low-pass' type, which gets rid of the unwanted high-frequency scratch signals.

The Rumble-Scratch unit is battery powered, and quite versatile. Its low-frequency and high-frequency cut-off points can each be switch-selected to any one of three cut-off settings and each filter has a switched 'bypass' facility. The unit can easily be built in mono or stereo versions, with or without the switched cut-off frequency facility, to satisfy individual reader tastes.

Inside the stereo version of the filter — two identical PCBs are used, but only a single battery and power switch are needed.

The finished filter. Note the two range switches, for the rumble and scratch sections, and the frequencies which they select.

CONSTRUCTION—THE BOARD

Construction of the board should present few problems. Decide at the outset if you want a mono or stereo version of the unit, and if you want the cut-off frequency switching facility. mono versons need only a single PC board. Stereo versions need two PC boards, and must have all compatible switches except S5 ganged together, e.g., S1 and S3 must be 2-gang 3-way types for mono and 4-gang 3-way types for stereo. Note that a single battery can be used to power the pair of boards used in a stereo set-up, since each board draws less than 2mA of current.

USING THE UNIT

The unit provides unity voltage gain at mid-band frequencies, and can readily handle signals from a few millivolts up to a couple of volts RMS. The design uses low-noise BC109 transistors, and can be used to interface directly between low- to medium-impedance pick-ups or pre-amplifiers and a main power amplifier.

The unit has uses other than as a mere Rumble-Scratch filter, and can be used to improve or modify the quality of any audio signal It is, for example, useful for improving the sound quality on poor quality radio reception, or reducing the 'hum' from an audio system.

Scratch and Rumble Filter

Parts List

RESISTORS:—	
R1	27k
R2	12k
R3	2k7
R4	15k
R6	220k
R7,	4k7
R9	10k
R10	820R

SEMICONDUCTORS:—

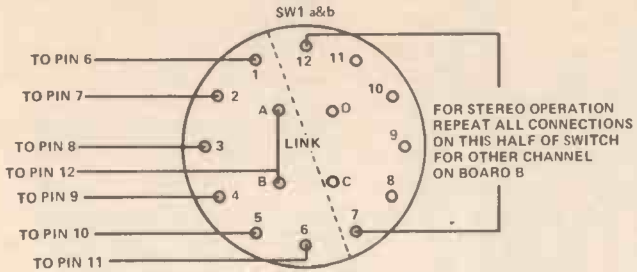
Q1, Q2	BC109
LED 1	TIL209

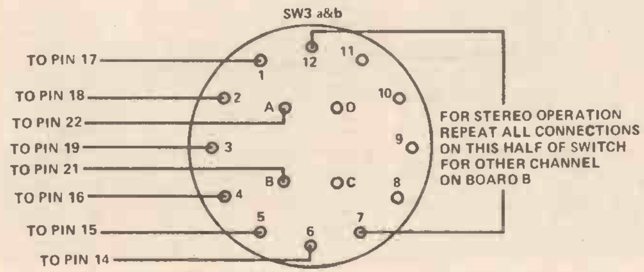
CAPACITORS:—

C1, C4, 68n
C2, C5, 100n
C3, C6, C9, 220n
C7; C8, C16 1µ0TANT
C10, C13, 10n
C11, 22n
C12, C15, 4n7
C14, 2n2

MISCELLANEOUS

SW1, SW3, 4 pole, 12 way wafer switch
SW2, SW4, D.P.D.T. Toggle
4 off phono sockets
Case Type B2 from Maplin
Knobs to suit. PP3 battery

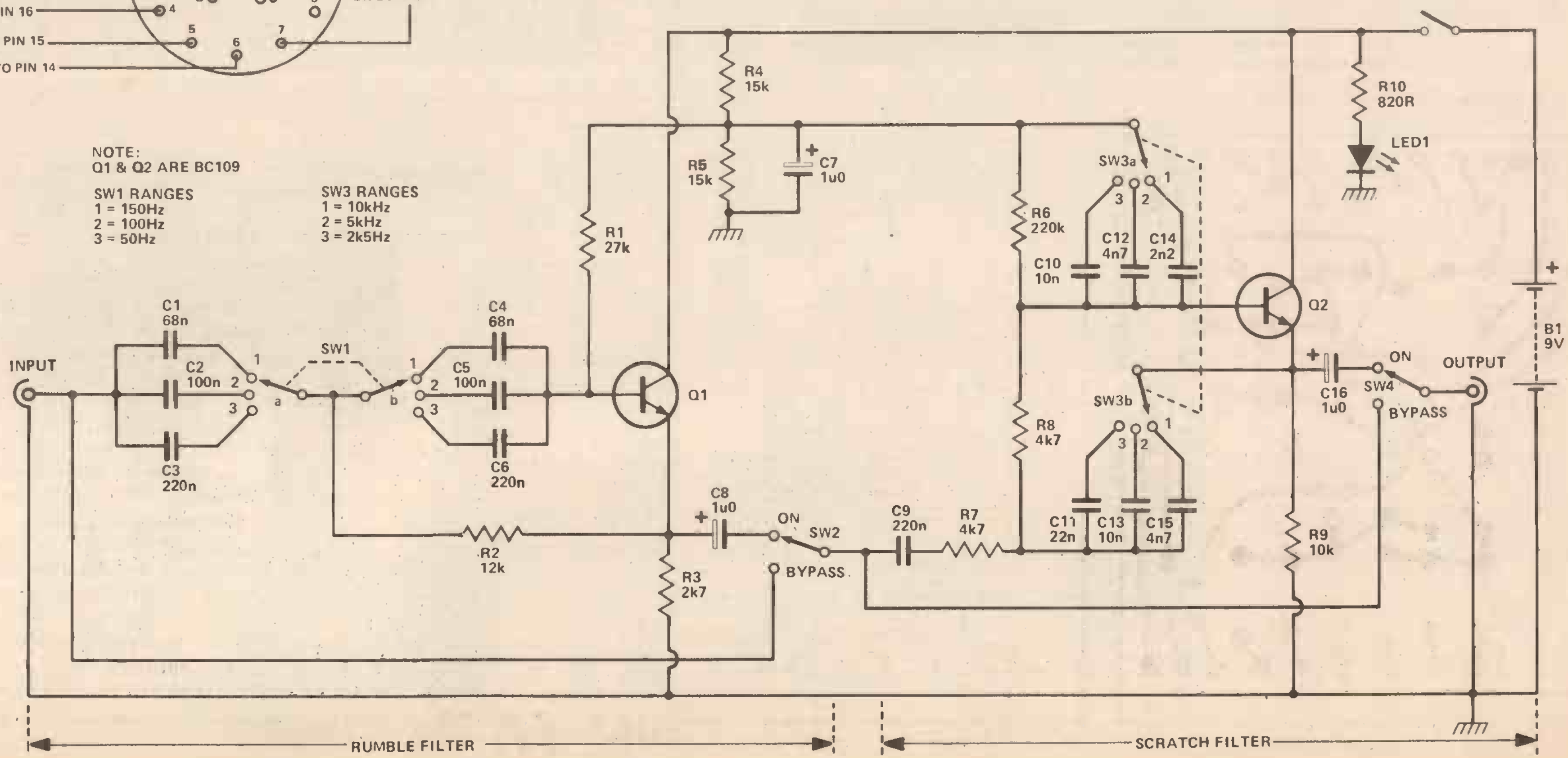




NOTE:
Q1 & Q2 ARE BC109

SW1 RANGES
1 = 150Hz
2 = 100Hz
3 = 50Hz

SW3 RANGES
1 = 10kHz
2 = 5kHz
3 = 2k5Hz



How it Works

Figure 1 shows the block diagram of the mono version of the Rumble-Scratch filter. The input signal (derived from the turntable pick-up) is first fed through a high-pass filter (which rejects unwanted low-frequency RUMBLE signals and is then fed through a low-pass filter (which rejects unwanted high-frequency SCRATCH signals). Each filter can be by-passed via a simple switch if required, so the input signal can be passed through either one, both, or neither of the filters.

Figure 2 shows the circuit (a) and performance graph (b) of a simple single-stage passive high-pass filter. At low frequencies capacitor C1 presents an impedance that is high relative to R1, so a lot of signal attenuation occurs between the input and output terminals. At high frequencies C1 presents an impedance that is low relative to R1, so negligible signal attenuation occurs between input and output.

The frequency at which the output signal is 3 dB down on the input signal of a pass filter is conventionally known as the BREAK frequency.

Note in Fig 2(B) that the graph shows a smooth ROLL OFF or SLOPE up to the break frequency point: A single stage filter has a slope or roll off of 6 6dB/ocatave, i.e., the signal output level doubles if the input frequency is doubled.

A number of filter stages can be cascaded to give a roll off of greater than the basic 6 dB/octave: Usually, some kind of electronic buffering or feedback is used between the individual sections of a multi-stage pass filter system.

Figure 3 shows the circuit (a) and performance graph (b) of a two-stage high-pass filter. This design is known as a Butterworth filter, and is the type used as the RUMBLE section of our project: It has a sharp break frequency, and gives a SLOPE or ROLL OFF of 12dB/octave.

The basic high-pass filter of Fig. 2 can be made to act as a low-pass type by simply transposing the positions of C1 and R1, as shown in Fig. 4. Figure 5 shows the two-stage (second order) Butterworth version of the low-pass filter. This is the design that is used as the SCRATCH filter in our project.

In the complete project (see main diagram) the high-pass or rumble filter is designed around Q1 and R1-R2-C1-C2, and the low-pass or scratch filter is designed around Q2 and R7-R8-C6-C7. Resistors R4-R5 and by-pass capacitor C5 provide the low-impedance bias point for the two transistor stages. The low-frequency break point of the RUMBLE filter can be varied via 3-way switch S1, and the high-frequency break point of the SCRATCH filter can be varied via S3.

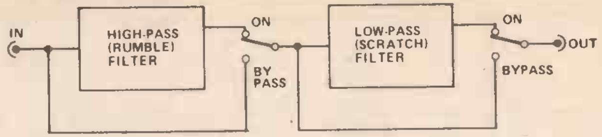


Fig. 1

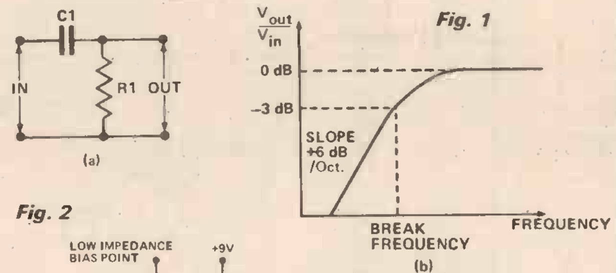


Fig. 2

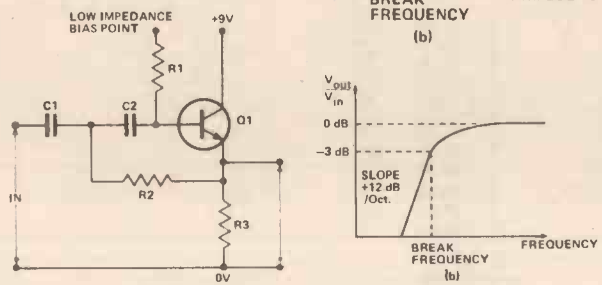


Fig. 3

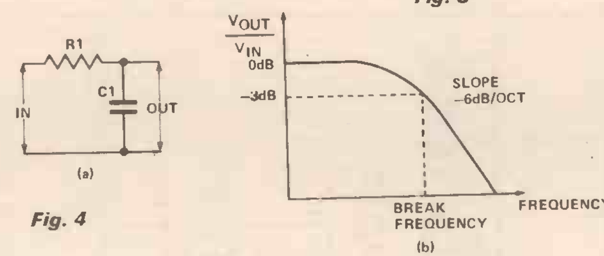
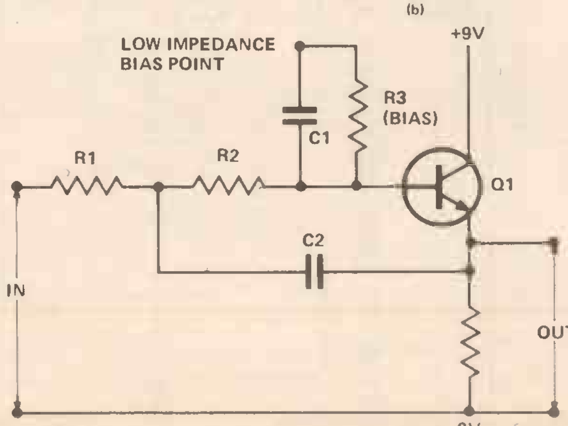


Fig. 4



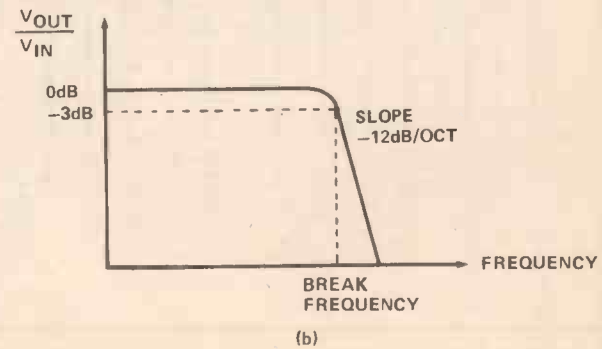
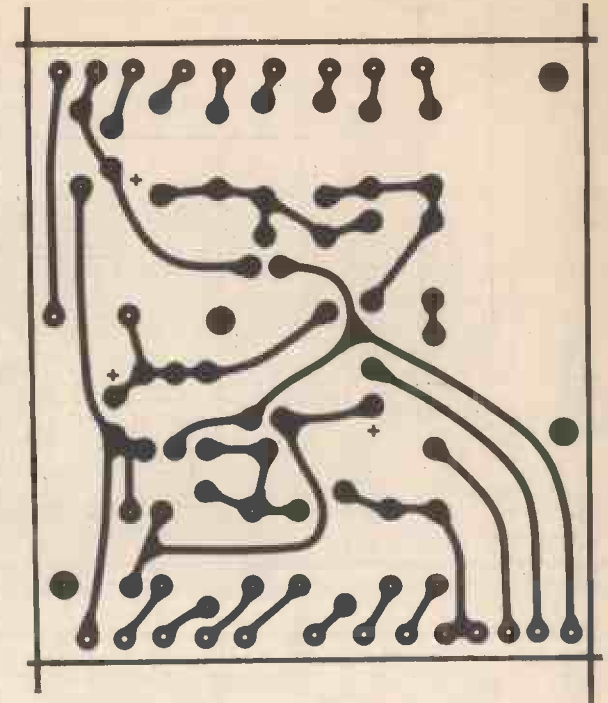
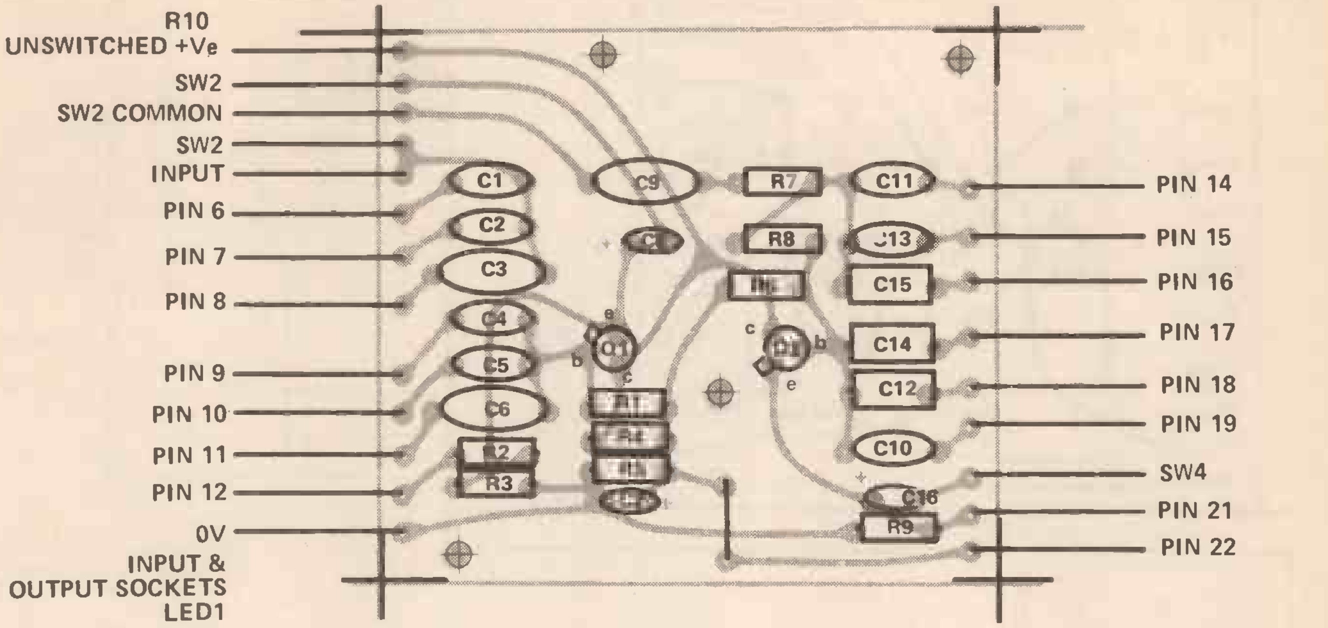


Fig. 5



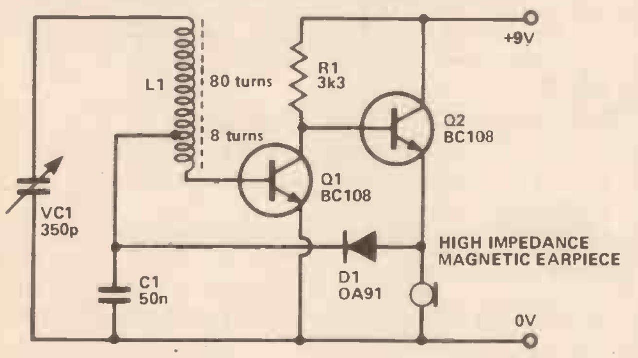
Above is shown the PCB foil pattern for this project



How to position the components on the PCB.

Short Circuits

TWO TRANSISTOR RADIO



Although transistors are cheap, this was certainly not true some years ago and transistors were made to work at maximum efficiency. A common technique in simple radio circuits was to use a reflex circuit, that is one transistor amplified both at RF and AF.

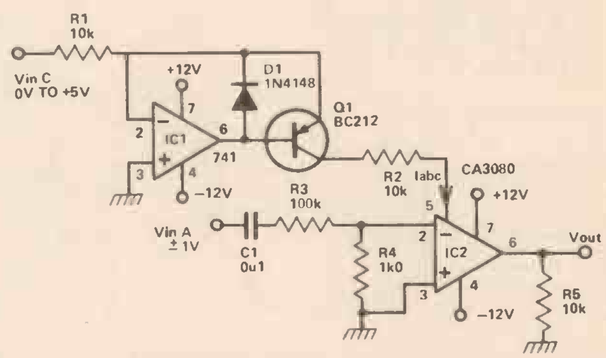
The circuit shown uses very few components yet the operation is surprisingly complex. The coil L1 is made from 88 turns of enamelled copper wire (32 swg for example) on a 5/16 in ferrite rod about 4in long with a tap at 8 turns. The tuned circuit is made up from VC1, the 80 turns of L1 and C1. The latter has practically no effect upon the circuit as it is a very high value for RF purposes.

The RF signals picked up in circuit appear at a very high impedance which does not connect well to a regular transistor amplifier but the 8 turns act as an autotransformer giving a good match to the base of Q1. This transistor amplifies the RF which is fed to Q2 which acts as an emitter follower. The RF appears at the emitter of Q2 but the high impedance magnetic earpiece acts as an RF choke so the signal is passed through D1 and is detected by it and smoothed by C1. The signal is now at audio and it is connected to the base of Q1 via the 8 turns and is again amplified but this time it drives the earpiece. Certainly some audio is fed back but this acts as negative feedback. The base bias for Q1 is also supplied via the diode.

Most general purpose small signal transistors such as a BC108 will work well in this circuit. R1 is worth experimenting with to obtain the best possible performance.

Note that most earpieces are 8 ohm types and will barely work in this circuit, high impedance types are less common than they used to be but are available — the impedance should not be less than 250 ohms. The value of VC1 is not very critical — almost all of the transistor type tuning capacitors will work.

THE CA3080 USED AS A VCA

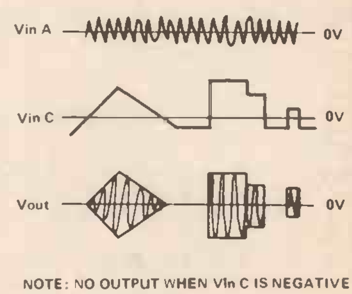


A simple voltage controlled amplifier (VCA) can be made using a CA3080 which is an Operational Transconductance Amplifier made by RCA. This is basically an op-amp with an extra input at pin 5. A current I_{abc} is injected into this input and this controls the gain of the device linearly. Thus by inserting an audio signal (± 10 mV) between pin 2 and 3 and by controlling the current on pin 5, the level of the signal output (pin 6) is controlled.

In effect, the audio signal is multiplied by the current I_{abc}. The output of the CA3080 is a current output and so a resistive load (R5) is needed; R5 in fact becomes the output impedance of the circuit.

The current controlling the CA3080 is generated with a voltage to current converter IC1, Q1, R1. This circuit linearly converts Vin C into a current (I_{abc}) where:

$$I_{abc} = \frac{Vin\ C}{R1}$$



When Vin C = 0 V, I_{abc} is 0 so the CA3080 is turned off. When Vin C is positive, I_{abc} is generated and so the VCA is turned on. When Vin C goes negative, I_{abc} is off so no output is produced from the VCA (see diagram).

The VCA finds many uses in the automatic control of signal levels and in generating envelope contours in electronic musical equipment.

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This book is for the beginner who wants just enough practical knowledge of electronics to pursue a hobby.

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Put electronics to work for you in your home. The authors present thirteen interesting and fun projects that use the latest solid-state devices and ICs.

BUILD-IT BOOK OF SAFETY ELECTRONICS by Graf and Whalen £3.45
Contains ideas for building several novel projects to protect toddlers from invading the medicine chest to a motel room from a burglar; and to scare a car thief and more. Thirteen tested safety projects are detailed.

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Kit Review

VARIABLE POWER SUPPLY

You must know about batteries. They're the things that run out when you need them most and are the wrong voltage or are the ones not stocked by the corner shop. And meanwhile there's your latest microprocessor controlled laser cannon waiting for an 8.7 volt power supply before you can take over the world. What can be done?

The obvious answer is to get an adjustable power supply. This is a device that can supply the 8.7 volts for your laser cannon and can then be used to supply 5 volts for a TTL project and after that to supply practically any voltage needed to get any project working (if you're in the habit of building up our short circuits on a breadboard you'll immediately see the advantages of this). About the only disadvantage of a power supply such as this is that it derives its output from the mains — which means that it is not portable and that it won't work during a power cut.

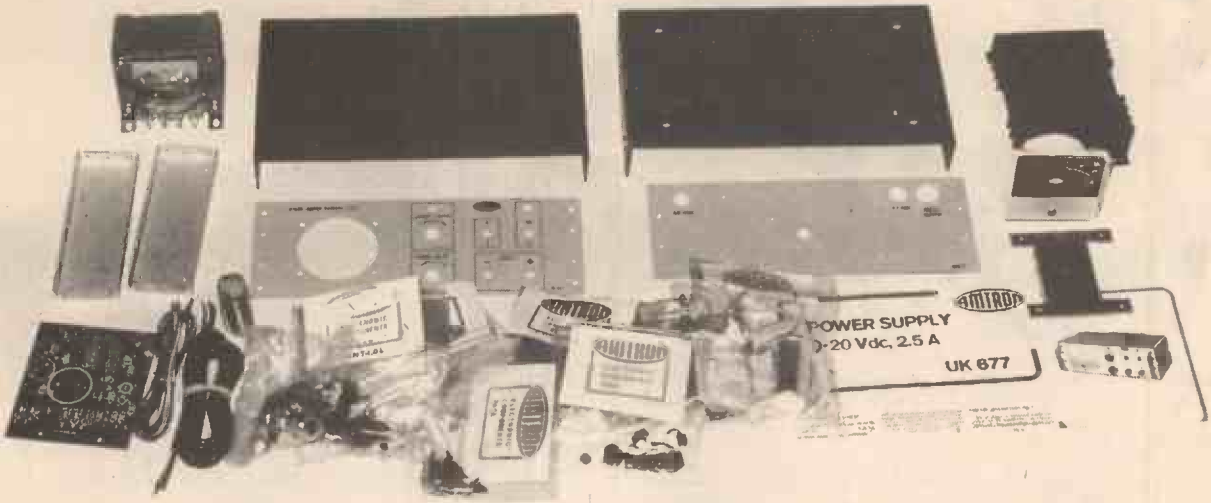
The Amtron kit we review this month is just such unit, with an output voltage adjustable from 0 to 20 volts, and, in addition, a current limiter adjustable from 0 to 2.5 amps.

OPEN THE BOX

What you get, once you've tipped the bits out of the box, can be seen in our photograph. The front and back panels are wrapped in tissue to prevent scratches, and the transformer in an expanded polystyrene case (which, in this instance was in the final stage of disintegration and had shed little bits of itself all over the place). All the components, nuts, bolts etc. come in plastic bags so that the amount of sorting out to be done is kept to a minimum. You also get a generous hunk of solder, the mains cable and connecting wire (but more about that later).

The instrument case comes as six pieces — front, back, top, bottom and two sides. It's all made from aluminium, and when put together the result is very light but sturdy.

Below: the completed unit.



Above: the uncompleted unit.

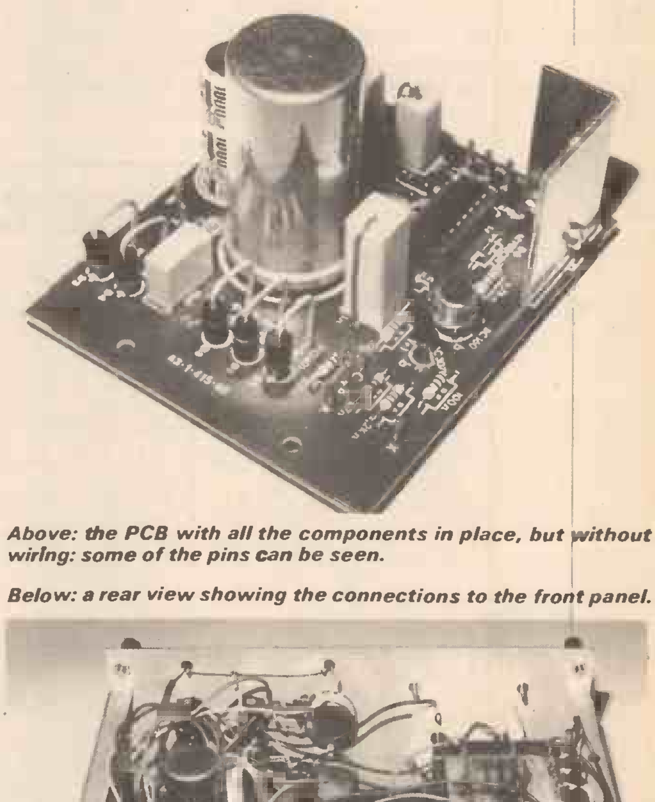
PICK UP THE PIECES

The instructions that come with the kit are superb — in fact you get a brief history of power supplies; a circuit description (How it Works), and construction details complete with overlay and exploded diagrams and brief notes on soldering and technique. There's no colour code for resistors, though — but it's not that great a problem to find one of those (hint: try this magazine).

Building up the PCB is quite easy with reference to the instructions and the overlay; the component positions are printed on the board as well. The rest of the hardware also goes together quite easily — self tapping screws are used extensively which, despite initial reservations, seemed to do the job quite well. Two points arose the bolts for mounting the power transistor on to the heatsink were too short (so I left a couple of washers off), and the mains cable grip was impossible to fit — I had to cut a bit out to use it.

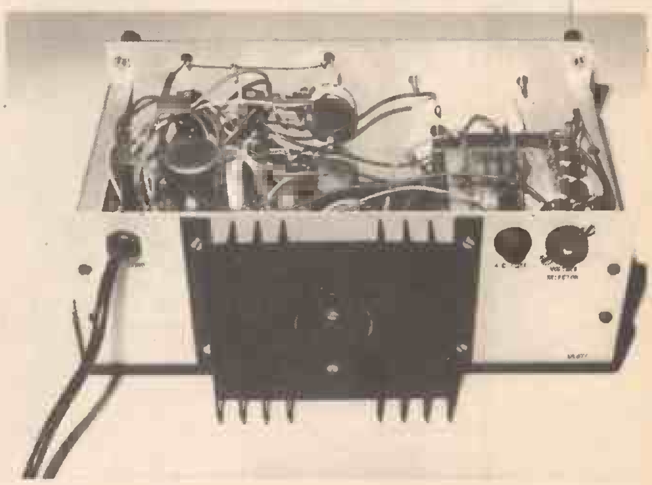
Then came the irritating bit — wiring up. As can be seen there is a lot of this to be done. Having followed the instructions I found the PCB surrounded on three sides by the case, and very difficult to get at. As the wiring up progressed the problem was added to by adjacent wires. Then the wire ran out, and I had to strip down some mains cable (disabling my bedside alarm clock) to finish the job. The net result, which is only partly my fault, is an untidy mess of cables all over the place.

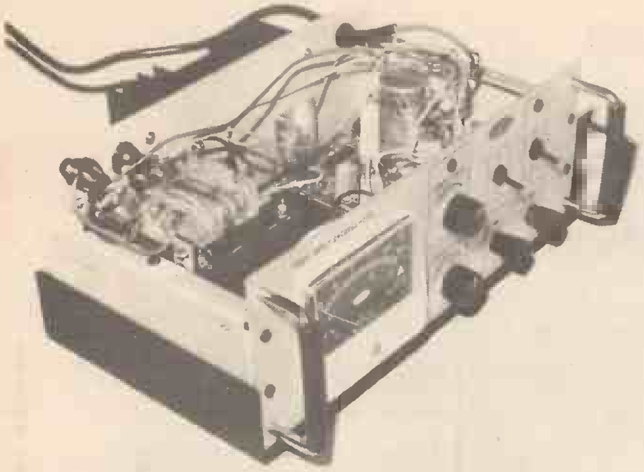
There are a couple of faults to mention here — one is potentially very dangerous. The solder terminals to the transformer which lie very close to the top panel are not insulated. As these carry mains currents they really must be covered with insulating tape; otherwise a very bad shock could result from pressure on the case bringing the panel into contact with them. The PCB is mounted on one of the side panels by a couple of self-tapping screws — the result being not nearly as stable as it should be.



Above: the PCB with all the components in place, but without wiring: some of the pins can be seen.

Below: a rear view showing the connections to the front panel.





With the lid off the exposed transformer tags can be seen at the left of the box.

TURN IT ON

Then comes the inevitable moment of truth: connect it up to the mains and throw the switch to 'on'. Nothing happened. So I turned it off — and on came the 'power' LED. I'd connected the mains switch up backwards. A minor problem, and entirely my own fault.

Having sorted the mains switch out the next step was to calibrate the unit; the instructions explain how to do this using either a precision resistor or a standard ammeter — I used an ammeter. Calibration involves only the adjustment of a preset potentiometer and is perhaps the least time-consuming operation involved in building the kit.

TRY IT OUT

It seems to work. The only problem was a duff LED on the current limiter — but here at Hobby we have an endless supply of LEDs. Comparing the meter with a test meter didn't show up any discrepancies: and a number of our battery powered projects were quite happy when powered by the unit.

FINAL WORDS

All in all, this seems to be a nice little box of tricks. The only reservations I have can be summarised in the following words of wisdom

— Have a supply of wiring of your own; there's not enough in the kit. This also means that you could connect up the PCB before mounting it in the box — but if you do that also get some cable ties to tidy the job up afterwards.

— Use insulating tape on the transformer connections — or better still some heat shrink sleeving — but do something.

— Buy some silicone grease for mounting the power transistors as this isn't included with the kit.

— Buy a mains plug.

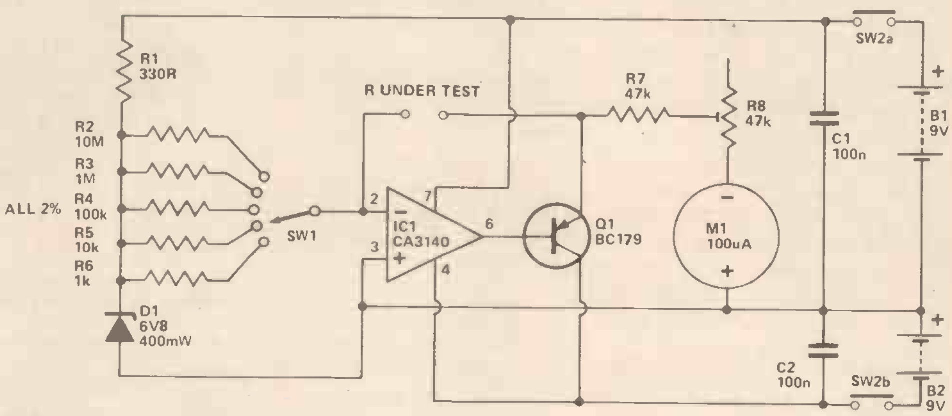
This kit is available from:

Amtron
7 Hughenden Road,
Hastings,
East Sussex
Telephone: Hastings 436004

Price: £39.67 including VAT

Short Circuit

LINEAR SCALE RESISTANCE METER

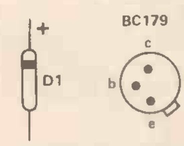


Although even the most simple of multimeters have resistance ranges, many instruments only have a few ranges, and these have a reverse reading, non-linear scale. This often results in poor accuracy and inconvenience in use. This simple circuit has five measuring ranges from 1k to 10 Megohms FSD (full scale deflection) with a forward reading linear scale on all ranges.

The unit consists basically of an operational amplifier used in the inverting amplifier mode. Transistor Q1 is used as an emitter follower output buffer stage, and on the 1k range the output sink current capability of the amplifier would be inadequate without the inclusion of this stage. R1 and D1 provide a stable reference voltage of 6.8 V (nominal) which is fed to the input of the amplifier. The gain of the amplifier is determined by two resistors, one of which connects the input signal and the inverting (—) input of the op amp. This resistor is one of R2 to R6, depending upon the setting of SW1. The other resistor connects between the amplifier output and the inverting input, and in this case is the resistor under test.

The voltage gain of the circuit is equal to the value of the input resistor divided by the value of the test resistor. Thus, with SW1 switched to the 10k range for example, a 10k test resistor would give a voltage gain on one, and the output would swing 6.8V negative. This would give FSD of the simple voltmeter circuit comprised of R7, R8 and M1, which is connected across the output and has a FSD sensitivity equal to the reference voltage. If the test resistor had a value of 5k, then the circuit would have a voltage gain of only 0.5, and only half FSD of M1 would result. A resistor of 1k in value would give a gain of 0.1 and a deflection of only 10% of FSD. As will be apparent from this, there is a linear relationship between the test resistor value and the meter reading, and the FSD value is equal to that of the resistor selected by SW1.

SW2 is the on/off switch and should be a non-locking push-button switch, or some other type biased to the off position. This is only operated when the resistor has been connected to the test clips as the meter will be deflected beyond FSD if power is applied to



the circuit with no test resistor connected (or one of greater value than the FSD value of the range). The meter will not be damaged if this is accidentally done since a maximum meter overload of only about 30% or so can occur.

In order to calibrate the unit, connect a close tolerance resistor of the same value as that selected by SW1 across the test clips and adjust R8 for precisely FSD of M1.

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CA3130 Projec

OPERATIONAL AMPLIFIER integrated circuits have become increasingly popular in circuits for the amateur electronics enthusiast. The reason for this is not hard to discover, and is simply that these are probably the most versatile type of semiconductor device currently available. They are also among the least expensive of integrated circuits, and often have an economic advantage over alternative circuit elements.

The CA3130 is manufactured by RCA and is a relatively new device. It is not as inexpensive as certain other popular operational amplifiers, such as the 741C and 748C types, but it is a more advanced in design than its less expensive rivals. This means that it is often capable of a higher level of performance than other devices, and that fewer discrete components are needed. This tends to offset its cost disadvantage.

OPERATIONAL AMPLIFIERS

A theoretically perfect op amp has an infinite voltage gain, infinite input impedance, zero output impedance, infinite bandwidth, and is capable of giving a peak to peak output voltage swing which is equal to the supply rail potential. The circuit has two inputs, and these are termed the inverting input, and the non-inverting.

If the non-inverting input is made positive of the inverting one, the output of the amplifier will swing positive. If the non-inverting input is negative with respect to the inverting one, the output swings negative. In a theoretically idealised op amp any difference in potentials between the two inputs will be enough to send the output fully positive or fully negative, but of course, no practical amplifier can achieve theoretical perfection for this parameter. Neither can it achieve theoretical perfection in any of the other parameters listed earlier, but most modern devices come close enough to be regarded as perfect in most respects. For instance, most op amps have a voltage gain of something like 100 000 times, and the typical figure for the CA3130 is some 900 000 times.

In a few switching applications this full gain is required, but in all circuits needing linear amplification, this gain is greatly reduced by the application of negative feedback.

One parameter in which many well-known devices fall short of theoretical perfection is that of input impedance. Bipolar transistors have relatively low input impedances, and since these form the basis of the input circuitry of most op amps, this shortcoming exists. An example is the 741C IC which has a typical input impedance of 2M with a minimum figure of 300k. This is not high enough for many applications, and even though the input impedance is increased to quite a large extent by the utilisation of negative feedback, the input impedance may still be too low.

Two chip op amps have been available for some time and these use a FET input stage on one chip, and the remaining circuitry is contained on a second chip, FETs have extremely high input impedances, and these two chip devices achieve input impedances of thousands of Megohms. However, this is achieved at a price which puts them beyond the use of most amateurs, the actual cost being something like ten times that of a 741C.

The CA3130 is manufactured using techniques which enable the FET input stage and the main bipolar circuitry to be contained on a single chip. It is far less expensive than the two chip ICs and is a very practical proposition. It uses a CMOS (complementary metal oxide semiconductor) input stage which has a voltage gain of only about five times. This is followed by two bipolar amplifying stages, the first having a voltage gain of 6 000 and providing most of the unit's gain. The second is a Class A output stage which has a voltage gain of about 30 times.

Some operational amplifier ICs have internal compensation components, but the CA3130 does not. The purpose of the compensation circuitry is to reduce the upper frequency response of the device and so prevent it from becoming unstable. When used at low gains quite a high degree of high frequency roll-off must be used, but when used at high gains little or no roll-off is needed. Thus, if internal compensation is used, this must provide enough high frequency attenuation to prevent instability at low gains. This limits the bandwidth of the device unnecessarily when it is used at comparatively high gains.

Therefore using external compensation is not really a disadvantage even if it does slightly increase the number of discrete components required. It enables the bandwidth of the device to be optimised for any level of voltage gain. In the case of the CA3130 only a single low value capacitor is used to provide the necessary frequency compensation.

PERFORMANCE FIGURES

As will be seen from the main performance figures of the CA3130, which are given below, this device has a high level of performance.

Input Impedance	1.5 million Meg ohms
Open Loop Voltage Gain (the gain without negative feedback)	900,000 times
Input Bias Current	5pA (1pA = 1 millionth of a micro amp).
Gain-Bandwidth Product	15 MHz
Slew Rate	30 V/micro sec.
Operating Temperature Range	−55 to +125 degrees C
Supply Voltage Range	5 V to 16 V ofr a balanced positive and negative supply of ± 2.7 V, to ± 8 V.
Current consumption from 9V supply with output at half supply voltage	2.5 mA

The above are all typical ratings.

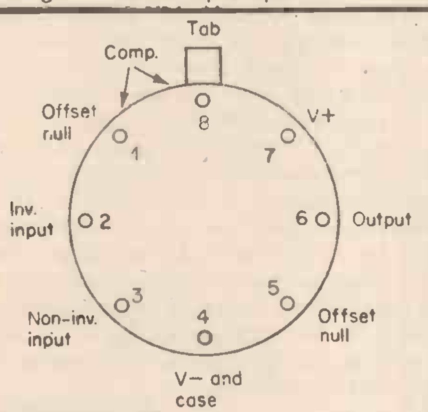
The CA3130 is contained in a TO-5 8 lead metal encapsulation, and its leadout diagram is shown. There are several versions of the IC and the CA3130T and CA3130S versions are the ones that are required for the circuits described. The CA3130T has a standard TO-5 and leadouts whereas the CA3130S has its leadouts formed into an 8 pin dual in line configuration. These two devices are electrically identical.

ts

This article is taken from chapter 5 of '50 Projects Using IC CA3130' by R. A. Penfold, published by Bernards at 95p. It describes several practical circuits using this RCA Op Amp.

Other versions of the CA3130 have a more rigid specification in some respect or other, and these will work in these circuits. They are however, more highly priced than the two basic versions.

One advantage over this device when compared to most other op amps is that when lightly loaded, the output can swing to within a matter of a few millivolts of either supply line. Most other devices can only manage an ouput swing (peak to peak) of about 4 volts less than the supply voltage. This enables the CA3130 to be used in simple circuit configurations which would not be possible using most other op amps.



Leadouts of the CA3130

HANDLING THE DEVICE

As many readers will be aware, CMOS devices can be damaged quite easily if they are subjected to high voltage static charges, and precautions must be taken not to destroy them due to careless usage and handling. The CA3130 is not as easily damaged as some CMOS devices. This is partly due to the fact that only the input circuitry is of the CMOS variety, but also there are zener protection diodes incorporated in the IC.

Even so it is advisable to take reasonable care when using and handling these ICs. Usually the devices are supplied with their leadout wires pushed into a piece of conductive foam. They should be left in this until it is time to connect the device into the rest of the circuit. The IC should be the last component to be soldered into circuit.

Use a soldering iron with an earthed tip when connecting the device. It is not a good idea to apply an input signal to any semiconductor device when the power supply is not connected, and the CA3130 is no exception to this.

OFFSET NULL

Most op amps have an offset null facility and the CA3130 is one of these devices. The purpose of the two offset null leadouts is to enable the output to be adjusted to zero (in the case of a dual supply), or to half the supply voltage (in the case of a single supply) even though the input terminals are not at quite the same voltage. This is a useful feature, but it is not required in any of the circuits described here.

METRONOME

A conventional metronome uses a purely mechanical mechanism to produce a series of clicks at regular intervals. It is quite easy to simulate this electronically, and the simple circuit shown in Fig. 1. performs this task.

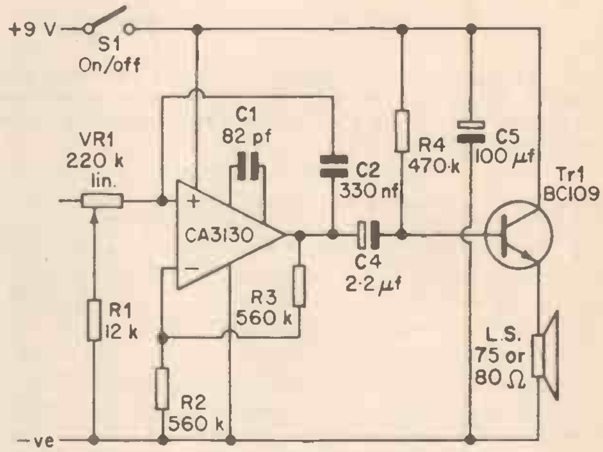


Fig. 1. Here the IC is converted as a low frequency oscillator operating over the range of 50-200 pulses per minute, this is determined by C2 and VR1. The transistor acts as a simple amplifier to drive the loudspeaker.

This circuit is basically an oscillator but the circuit values have been adjusted to provide a slow rate of oscillation and by enabling the time constant of the feedback circuitry to be varied, the oscillation frequency is made variable. VR1 can be adjusted to produce any beat rate from about 50 beats per minute to over 200 beats per minute.

In this application the output drive of the CA3130 is not sufficient to produce an adequate volume from the speaker without some additional amplification at the output. An emitter follower buffer stage has, therefore, been included at the output, and this uses only two components (Tr1 and R4).

It is necessary to mark a dial around the control knob of VR1 so that the unit can be quickly set to any desired beat rate. This is quite easily done as the relatively low frequency range of the unit means that it is quite possible to count the number of pulses produced per minute. It will be quicker if one counts the number of pulses emitted during a fifteen second period, and then multiplies this by four to find the number produced per minute.

RAIN ALARM

It is quite a well known fact that pure water is a very poor conductor, and it would probably be more accurate to call it an insulator. Fortunately, raindrops do not consist of pure water and contain relatively high levels of impurities which are picked up from the atmosphere. These dissolve in the rain drops to produce very weak solutions which have fairly low resistances.

The circuit of a simple rain alarm using a CA3130 is shown in Fig.2. This consists of three basic parts, the sensor, an electronic switch, and an audio alarm circuit.

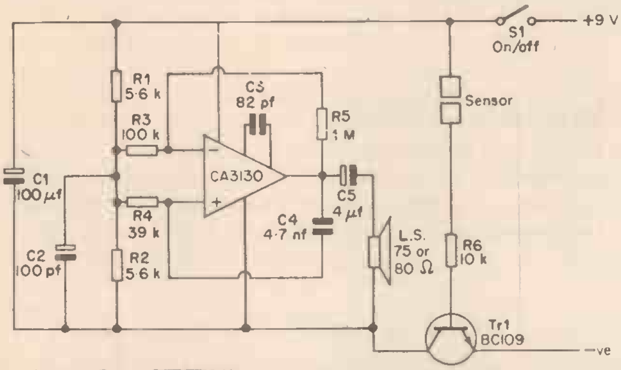


Fig. 2. Rain alarm circuit. Basically an audio oscillator with the negative supply controlled by Tr1. When a drop of rain bridges the sensor, Tr1 acts as a low value resistor allowing current to reach the rest of the circuit.

There is more than one way of arranging a suitable sensor, but probably the most simple method is to use a piece of veroboard; 0.1 in. matrix is best for this purpose as it has the most strips for any given area. A piece having 24 strips by 50 holes should be adequate. If the strips are numbered 1 to 24, all the even numbered strips are connected together by link wires on the non-coppered side of the board. All the odd numbered strips are then similarly connected together. One set of strips then connects to the positive supply line of the rain alarm circuit, and the other connects to R6.

The sensor is positioned at any convenient spot outside the house where it is not shielded from rainfall. It is connected to the rest of the circuit via twin insulated cable, and this cable can be several yards long if necessary. The sensor is positioned copper side up so that any raindrops that fall on it form an electrical bridge between two adjacent strips.

With no raindrops on the sensor, Tr1 is cut off and only minute leakage currents will flow in the circuit. This is very important as it ensures that the battery has a very long life and is not run down even when the alarm is not sounding.

When water is present on the sensor, a base current is supplied to the unit through R6 and the sensor. R6 is a current limiting resistor, and is needed to ensure that Tr1 does not pass an excessive base current. Tr1 is used as the electronic switch and when it is biased into conduction it supplies power to a simple audio oscillator utilising a CA3130 IC. This causes an audio tone to be emitted from the unit which is, of course, situated inside the house where it will alert the user.

LIGHT SWITCHES

Switches that are operated automatically by changes in light intensity are among the most useful and popular of electronic projects. They can be used as the basis of many gadgets, such as porch lights that automatically turn on at night, and off at daybreak. Burglar alarm systems can also incorporate this type of switch. They can also be used in applications outside the home, such as in automatic park lighting on cars.

When used as a comparator, an operational amplifier makes an ideal basis for a photo sensitive switch. The circuit diagram of a simple photo switch incorporating a CA3130 IC is shown in Fig.3. This is designed to close

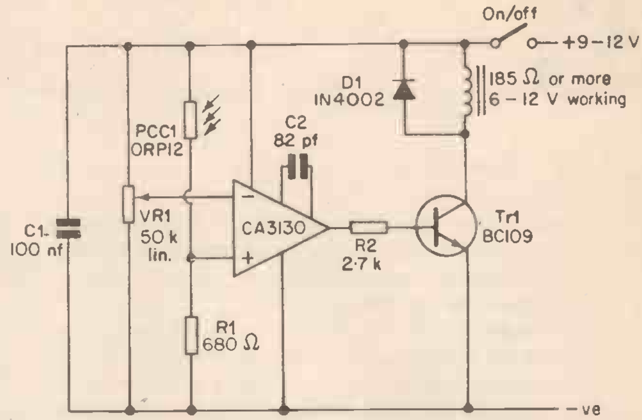


Fig. 3. If the light falling on PCC1 falls below a certain level, the output of IC1 goes high, turning on Tr1 which operates the relay.

the relay contacts when the light falling on the photocell drops below a certain preset level.

VR1 is adjusted so that under normal conditions there is a higher voltage at the inverting input than there is at the non-inverting input. This causes the output of the IC to be normally low, with TR1 cut off and no significant current flowing through the relay coil.

If the level of light falling upon PCC1 should now drop for some reason, the resistance of PCC1 will increase the voltage at the inverting input will fall. If it falls below the voltage at the non-inverting input, the output of the IC will swing high and will turn Tr1 hard on. This will cause the relay to be activated.

When the light level on PCC1 returns to normal, the relay will turn off once again. By adjusting VR1, this circuit can be adjusted to switch over at virtually any light intensity one desires.

If the relay has changeover contacts, it can be connected so that it either switches the ancillary equipment on when the light level falls below the threshold level, or so that it switches it on when the light level rises above the threshold level. If the relay only has make contacts, it can only be used to perform the former.

The circuit can be modified very easily to enable a relay having only make contacts to turn the ancillary equipment on when the light intensity rises above the threshold level. The modified circuit is shown in Fig 4.

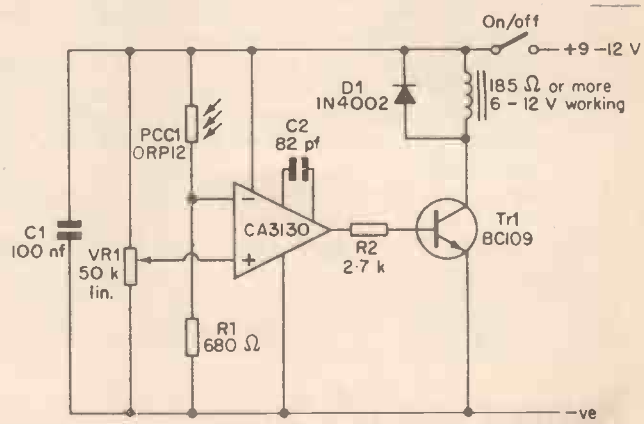


Fig. 4 Connecting Fig. 3. differently, the same components can be used to switch when the light level increases.

All that has been done here is that the inputs of the IC have been swopped over. Now, under normal conditions VR1 is adjusted so that the voltage at the inverting input is more than that at the non-inverting input, just as before. However, when the light intensity on the photo conductive cell increases, the voltage at the non-inverting input increases, and the output of the IC goes high. This operates the relay, and also the ancillary equipment. This circuit thus operates in the reverse manner to that of the previous design.

LATCHING CIRCUITS

For certain applications a photo switch that latches is required. This type of switch differs from those just covered in that once the relay comes on, it remains on, regardless of any further changes in the light intensity falling on the photocell.

Circuits such as this can be used in burglar alarms, for example. A photo cell can be positioned so that when light from an intruder's torch falls upon it, the circuit operates an alarm circuit. Obviously this arrangement is of little use if the alarm only sounds while the light from the intruder's torch is actually on the photocell. What is required is a circuit where once triggered, the alarm remains on until it is turned off.

A latching version of the circuit of Fig. 3 appears in Fig. 5. This works in much the same manner as the original circuit, except that when the output of the IC goes high, an additional transistor (Tr1) is turned on by

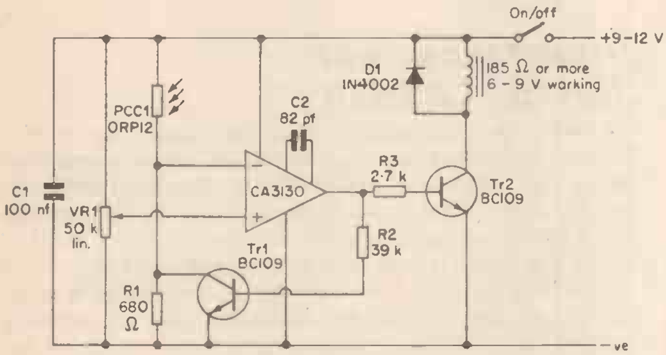


Fig. 5. A modification to Fig. 3. which holds the relay on, once it has switched, irrespective of the level of light falling on PCC1.

the current flowing from the output of the IC and through current limiting resistor R2. Tr1 is turned hard on, and the voltage at the inverting input becomes almost equal to that of the negative supply rail. Changes in the resistance of PCC1 will not greatly affect this voltage, and so the circuit latches in this state until it is switched off. Upon turning the circuit on, it will function normally until it is triggered, whereupon it will latch again.

A latching version of the circuit of Fig. 4 is shown in Fig. 6. Once again, this operates exactly in the same manner as the original until the output of the IC goes

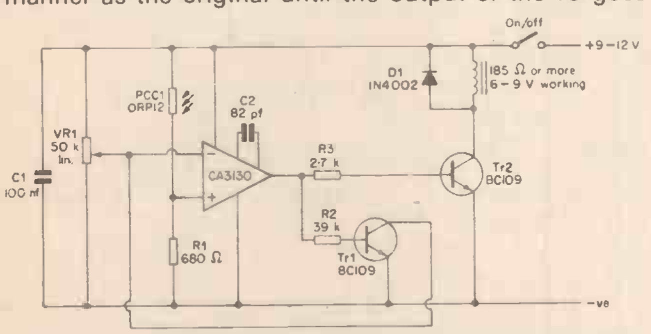


Fig. 6. A latching version of Fig. 4. makes a circuit which operates nicely as a burglar alarm.

high. Then Tr1 is turned on and the potential at the inverting input of the IC falls to virtually zero.

Even when the photo cell is in almost total darkness, the voltage at the non-inverting input is more than that at the inverting one, and the relay contacts remain closed.

The relay used in these circuits can be any type having a coil resistance of 185 ohms or more and an operating voltage of 6 to 9 V. The contacts must be chosen to suit the particular application which the circuits are employed.

It is not very economical to power these circuits from ordinary batteries as this type of device is normally left turned on for prolonged periods.

Also, the current consumption is quite high when the relay is closed, being something like 10 to 30 mA., depending upon the type of relay used. It is therefore advisable either to power these circuits from a mains supply or rechargeable batteries, whichever is most appropriate to their application.

The latching circuits can be reset by simply turning the units off, and then switching them on again. If a separate reset switch is preferred, this can be provided by connecting a push-to-make non-locking push button switch between the negative supply rail and the base of Tr1. This modification is suitable for use with either circuit.

SOUND ACTIVATED SWITCH

Sound activated switches have a multitude of uses. In the home, the most obvious use for one is a baby alarm. They can also be used in burglar alarm system. They also find uses in the field of amateur radio (in VOX, or voice operated switch systems), and can be used to automatically operate a tape recorder, when dictating something for example.

Operational amplifiers can easily achieve the high voltage gains required in this type of equipment and can be used as the basis of a simple but effective sound activated switch. Fig. 7 shows the circuit diagram of such a unit.

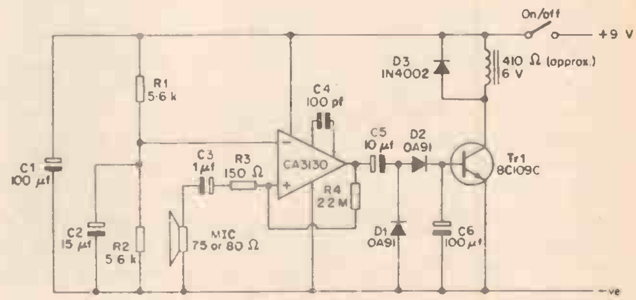


Fig. 7. A sound operated switch circuit which has applications as a baby alarm.

The purpose of the IC is to amplify the very low level microphone signals to bring them up to a level which can be used to operate a switching transistor. In this design the microphone is actually a miniature high impedance loudspeaker which is used as a sort of moving coil microphone. The IC is used in the inverting mode and it has a voltage gain of more than 10 000 times. Even an input signal of less than a millivolt generates an output of a few volts peak to peak at the output of the IC.

The output if the IC is fed via C5 to a rectifier and smoothing network using D1, D2 and C6. The output of this network is a positive DC bias. Provided a reasonably high sound level is received at the microphone, this bias will be strong enough to bias Tr1 virtually into saturation. This operates the relay which, in turn, switches on the controlled equipment.

This circuit has hysteresis, which is desirable in most applications. The hold on time of the circuit with the values specified is about 1 to 2 seconds. If required, this can be altered by changing the value of C6.

In order to obtain good sensitivity and battery economy it is necessary to use a relay having a fairly high coil resistance. This should preferably be 400 ohms or more. The author used an RS open printed circuit relay on the prototype. This has a coil resistance of 410 ohms and an operating voltage (nominal) of 6 volts. The relay should not have an operating voltage of less than 6 volts. If high speed operation is required, a reed relay should be used.

The prototype is quite sensitive, and talking at normal volume levels causes the unit to operate even at a distance of several feet. The exact sensitivity of each unit will vary according to the type and make of speaker/microphone used, current gain of Tr1, and similar parameters. The sensitivity obtained should always be high enough for the majority of applications though.

One point must be borne in mind when constructing this equipment. The relay and the microphone should not be housed in the same case, and should not even be in close proximity to one another. If they are, then as the relay turns off, the sound it produces will activate the unit. After a second or so the unit will turn off again, and the noise generated by the relay will again activate the unit. The circuit will continue to oscillate in this manner for as long as power is applied to the circuit.

In most applications there is no need to mount the microphone and the relay in the same casing anyway. If, for example, the unit is employed as a baby alarm, the microphone would be mounted in its own case near the baby with the rest of the unit in a separate case situated near the user. Screened cable must be used to connect the microphone to the main unit, and as a low impedance microphone is used, the cable can be several yards long if necessary.

Some readers may be puzzled about the inclusion of a diode across the relay coil in this circuit, and in the photo switches described previously. This is a protection diode which is needed because of the high reverse voltage that is developed across the relay coil when the supply is switched off. This voltage is generated as the magnetic lines of force across the solenoid quickly decay and cut through the turns on the coil. The voltage generated can be high enough to damage any of the semiconductor devices of the circuit, even though it is at a high impedance.

D3 acts as a sort of low voltage zener diode, and it limits this voltage to only about 0.5V in peak amplitude. There is no need to add any form of current limiting circuit in series with D3, as this current is limited to a safe level by its high source impedance. Do not be tempted to omit D3, as this would almost certainly turn out to be a false economy.

LATCHING VERSION

This is another example of device that must be made to latch if it is to be usable in certain application, such as burglar systems. This is quite simple to achieve, and the modified circuit diagram for this purpose appears in Fig.8.

This circuit operates in exactly the same way as the

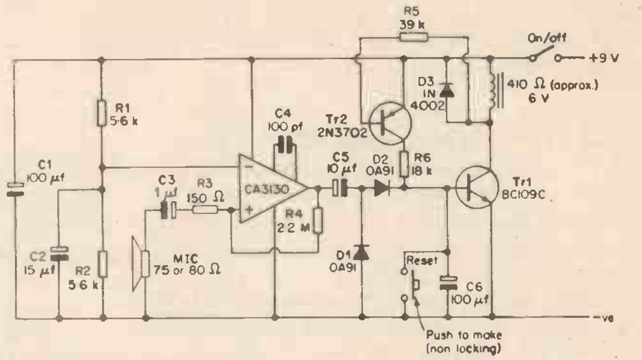


Fig. 8. A self-latching version of Fig. 7. In this arrangement Tr1 and Tr2 act in much the same way as a thyristor (SCR).

original unit the relay is energised. When this happens, Tr2 is turned on by the base current flowing via R5. This causes a current to flow through the emitter and collector of Tr2, through R6, and into the base of Tr1. Tr1 is held on by this current, and even if no further sound is received by the microphone, it will remain on. Tr1 and Tr2 are, in fact, operating as a sort of thyristor.

CHRISTMAS TREE LIGHTS FLASHER

The usual way of getting the lights on a Christmas tree to flash on and off is to use a string of series connected bulbs, with one of these being of the bi-metal strip flashing type. When this bulb is on, it completes the whole circuit, and all the bulbs come on. When it is off, it breaks the series circuit, and all the bulbs go off.

This arrangement is very simple and works quite well, but it does have the slight drawback that an ordinary flashing bulb is rather erratic in operation, and does not usually give a very regular flash rate.

The circuit of Fig.9. can be used to operate the lights, and this will flash them on for a period of about 1 second with a similar time elapsing between flashes.

A squarewave generator for utilising a CA3130 IC forms the basis of the circuit. Normally when a slow rate of oscillation is required, as it is here, a high value of timing capacitor must be used. This is not the case here, however, as the high input impedance of the IC enables a high value of time resistor (R4) to be used, and so relatively low timing capacitance (C3) can be used.

The output of the IC drives a common emitter amplifier via the current limiting resistor, R6. When the

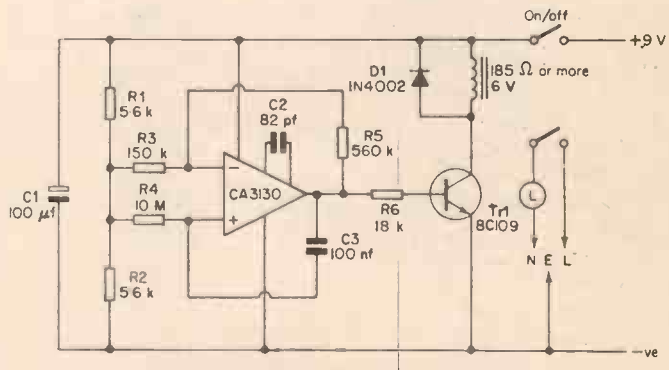


Fig. 9. C3 and R4 make the IC oscillate slowly and in turn the relay switches on and off in sympathy.

output of the IC goes high, Tr1 is turned on and the relay is energised. When the output of the IC is low, Tr1 is cut off and the relay receives no significant current. The relay contacts are used to control the lights, and it is essential to check that these have a high enough rating for the voltages and currents involved. It is advisable to have contacts that are rated well in excess of the current drawn by the lamps, as when power is first applied to a lamp a heavy surge current flows. This is because the cold resistance of a lamp is far lower than its normal hot working resistance. With the lamps being constantly turned on and off there is a constant string of current surges for the contacts to handle.

One might think that the relay would be short lived in this circuit anyway, as with such rapid switching it would soon wear out. This is not the case though, as any modern relay of reasonably good quality is guaranteed to last for several hundred thousand operations. The unit can be battery operated, but since it is controlling a mains load, it would be more logical to construct a mains power supply for it.

SIMPLE ORGAN

The field of electronic musical instrument and effects is one which has increased greatly in popularity over the past few years, and it must now rate as one of the most popular branches of electronics. Electronic musical instruments need not be complicated, and a simple electronic organ can be built using very few components indeed. A simple circuit of this type using a CA3130 IC as a tone generator is shown in Fig.10.

Here the CA3130 is used once again as a squarewave generator, with the output of the IC being used to drive a common emitter transistor amplifier. R4 is a current limiting resistor and VR1 is the volume control. This is a very economical arrangement as DC coupling is used, and a DC blocking capacitor and bias resistor for Tr1 are therefore unnecessary.

A high impedance loudspeaker is used as the collector load for Tr1, and quite a high volume level (for such a simple instrument) is available. The circuit is most efficient if a high impedance speaker is used, but it will work using speakers with impedances as low as 15 ohms. When using a low impedance speaker R4 should be increased in value to 39k.

A different timing resistor is used for each note, and the preset resistors are used here as it is necessary to be able to adjust each tone for tuning purposes.

There are many ways of arranging a simple keyboard for the instrument, but almost certainly the easiest and most practical method is to etch one along the lines shown in the circuit diagram. The enclosed shaded areas represent the coppered areas of the PCB. A test prod, or anything similar to this (wander plug, banana plug, etc.) can be used as the stylus, and the desired note is obtained by placing this on the appropriate part of the keyboard, so that the necessary circuit is completed and the circuit oscillates.

R6 ensures that when the stylus is not placed on the keyboard, and the circuit is not oscillating, the output of the IC goes low and Tr1 is cut off. This gives a very low quiescent current consumption of only about 1 mA. If R6 were to be omitted, the output of the IC would go high under quiescent conditions, and a current of up to about 50 mA, would flow through Tr1 and the speaker. Apart from giving poor battery economy, a large standing current would not be very good for the speaker.

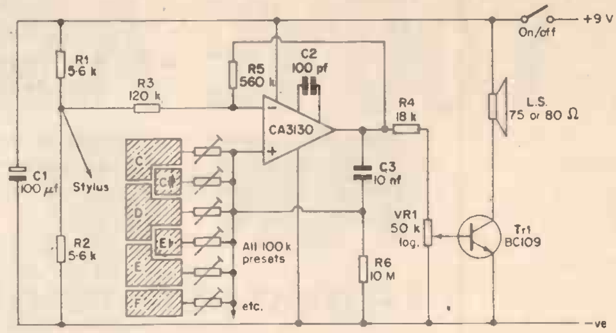


Fig. 10. You can make an electronic organ using the circuit shown here. The stylus is touched onto the sections of the PCB to vary the frequency at which the CA3130 oscillates. By tuning the presets you can make almost all musical notes.

The current consumption of the unit when the tone generator is oscillating varies from about 1 mA to30 mA, depending upon how well advanced the volume control is. The output stage is a sort of Class B amplifier, and so the higher the volume level is adjusted, the greater the current consumption. The circuit thus provides the longest possible battery life.

The unit can be tuned over a range extending from well below middle A to the A several octaves above this. By adjusting a preset for a very low value the unit will in fact oscillate at frequencies of the upper limit of human hearing. By increasing the value of C3 the unit can be made to oscillate at frequencies as low as one wishes.

It is therefore possible to obtain a range of several octaves if required, by using the appropriate number of presets and keyboard positions. For most purposes a single or two octave version will be sufficient. This would have a compass from middle C to the C either one or two octaves above this. Thirteen 100k presets are needed for a single octave unit, and twenty five are required for a two octave version. This gives a chromatic scale.

The unit can be tuned against a piano, organ, pitch pipes, or virtually any properly tuned musical instrument. A reasonably musical ear is required for this, as not everyone will find it possible to tune the notes on the organ to those produced by the instrument it is being tuned against. However, most people will find that this is not too difficult after a little practise.

It should perhaps be pointed out that this instrument is not polyphonic, and cannot be used to play chords. It can only produce one note at a time. The tone is quite pleasant though, particularly at the low frequency end of the compass, and if a reasonably large speaker is used. The absence of chords also makes the unit very easy for a beginner to play. **HE**

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Holograms

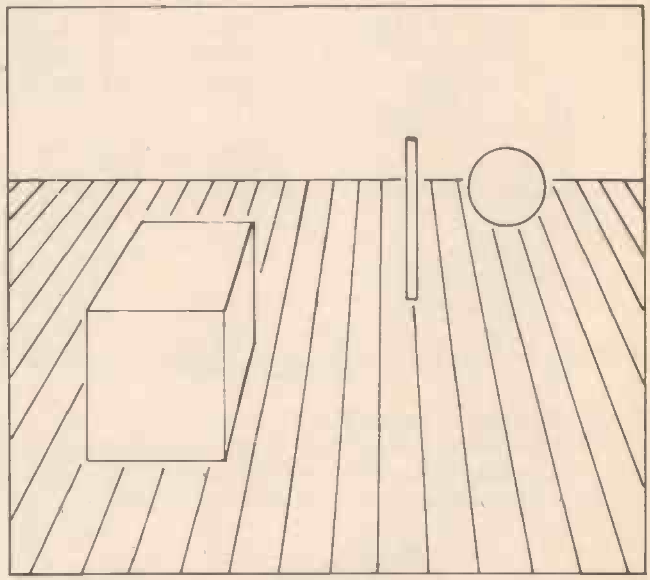
'Seeing is believing'; no longer is this true. Holograms — or 3-D images — are in their infancy but what has been achieved so far is remarkable. Rumours are widespread about work being done on holographic TV: we cannot get these confirmed. Jim Perry reports on progress so far.

THE THEORY OF HOLOGRAMS was developed in 1948, by Professor Dennis Gabor. He was researching at the British Laboratories in Rugby, and orginally called it 'Wave Front Reconstruction'. The basis of the discovery was that you could reconstruct a three-dimensional image with the aid of a photographic plate and a source of strong light. The word holography is derived from the Greek *holos* meaning whole, and literally means the study of whole images.

Professor Gabor was unable to develop holography very much further, as suitable photographic materials and light sources were not available. He was able to produce weak, blurred images with the aid of mercury vapour lamps — just good enough to prove the theory, but many sceptics branded his discovery as an invention without a future.

After the invention of the first working laser in 1960 interest was rekindled in Gabor's theories of three-dimensional images. In 1962 two researchers at the University of Michigan — Leith and Upatnieicks — demonstrated the effect by repeating Gabors earlier experiments. This time they had much better photographic materials and a laser light source. The results were much better than Gabor's but the light sensitive plates were now the weakest link in the chain. As holography had appeared to have no future, research on suitable photographic materials had been non-existent for a long time.

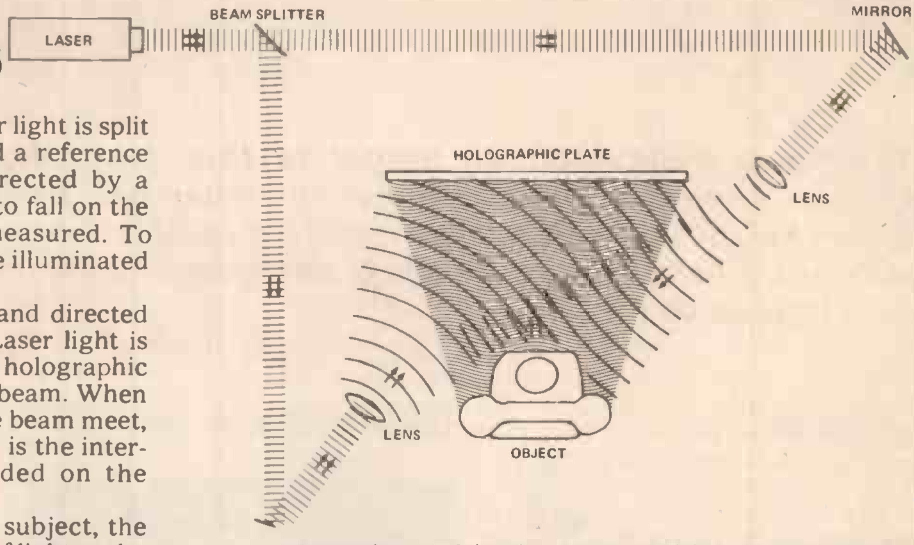
Holographic plates are coated with a thin layer of silver bromide crystals in gelatine with dye. Research into the best construction of the plate has been immense in the last few years, the leaders in holographic plate manufacture being Agfa-Gevaert of Belgium. The colour of a hologram depends primarily on the colour of light which was used in making it and the processing used — a red laser will produce a red hologram. Work on full colour images is being done with holographic plates sensitive to three colours, making separate exposures with different light sources.



Two dimensional pictures such as this do not change with different viewing angles. With a hologram the sphere would move behind the pole, and the cube could obscure the pole if the viewing angle was changed, by moving your head.

At first not a very impressive shot (above); a magnifying glass (in focus) with out-of-focus bottles in the background but these two photographs together demonstrate well the wonder of holograms for if we refocus the bottles appear sharp. We can also move to the left which would bring the bottles on the right into view — and still in focus.

How it Works



To make a hologram a beam of laser light is split into two parts, an object beam and a reference beam. The reference beam is directed by a mirror through an expanding lens to fall on the holographic plate. The angle is measured. To view the hologram it will need to be illuminated from the same angle.

The object beam is also spread and directed onto the subject being recorded. Laser light is reflected from the subject onto the holographic plate, where it meets the reference beam. When the reflected light and the reference beam meet, interference patterns are formed. It is the interference patterns that are recorded on the holographic plate.

To reconstruct the image of the subject, the hologram is illuminated by a beam of light at the same angle as the reference beam that was used for recording the hologram. The three-dimensional image appears behind the plate, the same size and in the same position as the original subject. When you view the image from a different angle it appears to change as in real life.

NOW YOU SEE IT . . .

The time needed to expose a hologram, until recently, was in the order of seconds to minutes — not much use for quick family snaps! The exposure time depends on the laser intensity and plate sensitivity. After exposure the plate is developed in the same way as a normal photographic film, and then bleached to give a complex diffraction grating image.

To view a hologram it needs to be illuminated with a suitable light. Until recently this had to be a laser but there are some holograms available now that can be viewed in normal 'white light'. However, the quality is not as good as laser-illuminated types.

When recording a holographic image the light waves from the subject are not focused to a point, as in normal photography. They are allowed to spread out. This means that any part of the hologram has information about the subject from its own viewpoint. If broken, the pieces of hologram each produce a complete image! Another unique property of a hologram is that more than one image can be stored on the same plate. By changing the angle of the laser reference beam between exposures, as many images as required can be recorded on the same hologram. To view the different images the hologram is illuminated with a laser with the same angle of beam as was used when it was exposed.

THE FUTURE

Full colour holography is a definite possibility. The main problem is producing holographic plates with a sufficiently fine grain.

Multiple frame pulsed holography is under development — the holographic moving picture. At the moment the viewing angle is very limited but you may be able to see a very realistic 3D 'Space Wars' in the next decade or so!

Multiplex holograms are made from a series of still photographs, or a cine film, and a series of slit holograms are made — one for each of the images. This technique can be used to give an allround view of a subject, but either vertical or horizontal parallax is lost.

Bulk information storage, special visual effects, 3D movies, are just some of the exciting possibilities of holography. It was once a technique without a future, now it is a technique of the future. **HE**

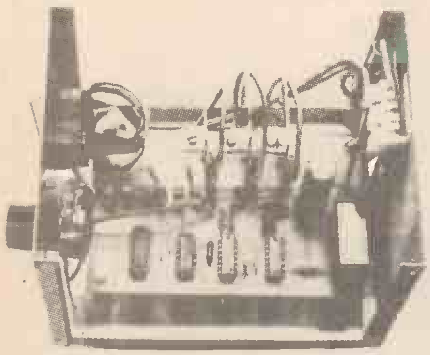
Photographs by Theo Bergström

The tap shown here is a hologram but both hands and the cup are real.

Next Month

Hobby Electronics

Light Chaser



A light chaser is a mechanical or electronic gadget which controls three or more lights arranged in a chain; these are flashed on, one at a time, in sequence to create an illusion of movement. They are used at fairgrounds, in advertising, in shop windows and in discos. Our project to build one is both simple and easy to build.

Decibels

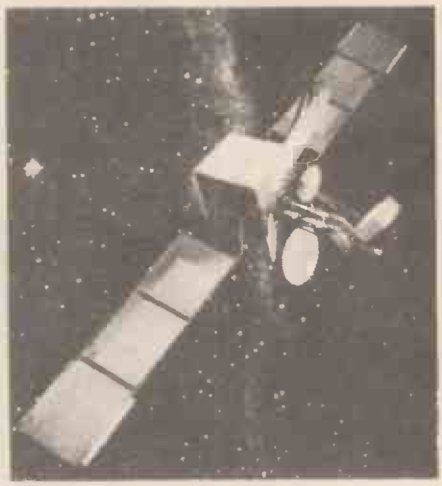
dB

Not surprisingly those who are new to electronics are confused by the apparently crazy use of decibels to describe gain or attenuation. Why not use easily understood numbers? We tell you and hope to convert you.

Photographic Timer

A project for those of you who do more than click the shutter. Our unit is in the mains lead to your enlarger (although battery operated) and allows you to set exposure times between 0.9 and 100 seconds in two infinitely variable ranges.

Communications Satellites

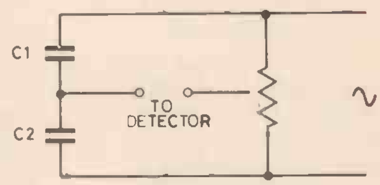


Speak to someone on the 'phone outside Europe and the chances are that your voice will spring out into space for thousands of miles on the way. The commercial ends of the space programme are described.

Telephones

Do you know how the 'phone, one of the most widespread pieces of electronics, works? Lots of exciting things are happening on this front; we pull back the curtain and take a peep next month.

Crossing your Bridges



The Wheatstone Bridge is one of the commonest circuit configurations in electronics. Next month K. T. Wilson examines the theory of this and describes the variations that we now use.

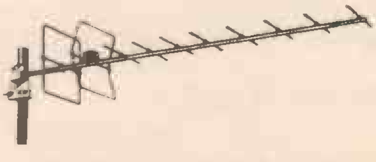
Experimenters Power Supply

Second in our series of test gear projects is a 0-20V, 1A bench power supply, stabilised of course as well as short circuit protected.

Workshop Test Gear

The HE project team have prepared a feature giving their views about what you need in the way of test gear in your workshop. It's a thoroughly practical approach and continually bears in mind the limitations of finance.

How TV Signals are Propogated



Put up an aerial in most areas of Britain and you'll have no trouble in getting a good signal but that's only because the broadcast engineers have taken into account a multitude of factors. We take a look at this subject in the March issue.

The March issue will be on sale February 9th

The items mentioned here are those planned for the next issue but circumstances may affect the actual content.

Into Electronics

by Ian Sinclair — Part 4

Last month we introduced the transistor. In this part we look at practical circuits, coupling stages, gain, feedback and the rules-of-thumb that are used in design.

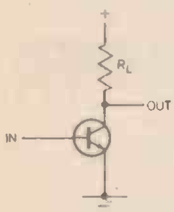
IN THE PREVIOUS PART we ended up with transistor amplifiers and their voltage gain, which is

$$\frac{\text{signal voltage out}}{\text{signal voltage in}}$$

Table 4.1 summarises the methods of calculating just how much voltage gain you can get from a single-transistor amplifier; the current gain is, of course, the figure h_{fe} which can be measured for any transistor. A simple circuit for measuring h_{fe} is shown in Fig. 4.1; it is usable only for silicon NPN transistors, but that's the type we mostly use now anyhow. Assuming that the transistor starts to conduct for about 0.5 V between the base and the emitter, the resistor R1 makes the current into the base about 5 uA. Now if the h_{fe} value for the transistor happens to be 200, the collector current caused by this base current will be 200 × 5uA, which is 1,000 uA, or 1 mA and the 1 mA meter which is connected in the collector circuit will read full-scale. The meter reading is in fact, proportional to the h_{fe} value, as the calibration graph shows. Simple enough, isn't it?

Transistors give a goodly amount of voltage gain. As the simple rule-of-thumb in Table 4.1 shows, with 5 V DC dropped across the collector load resistor, for example, we can expect a voltage gain of 5 x 40 = 200 times. Do we ever get this much gain? Yes, but *only* if

TABLE 4.1
CALCULATING VOLTAGE GAIN



(1) $G = \frac{h_{fe} R_L}{r_{ie}}$ where h_{fe} is current gain, R_L is value of load resistor, and r_{ie} is input resistance.

(2) $G = g_m R_L$ where g_m is mutual conductance and R_L is load resistance. The value of g_m is 40 mA/V for each 1 mA of steady collector current (bias current)

(3) G = 40 × (d.c. voltage across R_L)

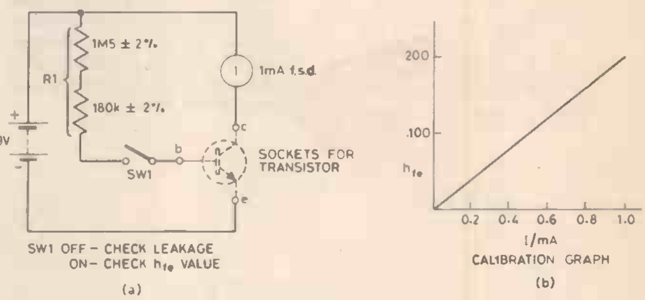


Fig. 4.1. Simple transistor tester circuit (a), with calibration graph (b). If any reading appears on the meter before SW1 is pressed, the transistor is leaky and should be rejected.

there is nothing in the circuit to act as a potential divider for signals, and that's rather rare.

Look at Fig. 4.2 for a moment. This is what's called an equivalent circuit, which uses a combination of conventional components to give us some idea of what a transistor does in a circuit. There's always an input resistance, for example, which is equal to the ratio $\tilde{V}b/\tilde{I}b$. The squiggles above the letters indicate that these measurements of base voltage and current are of AC signal voltages and current, not DC. This quantity, written as Rie is not a constant resistance, its value depends on the amount of steady bias current that is passing through the transistor. A close approximation for modern transistors is $R_{ie} = h_{fe}/g_m$ with R_{ie} in kilohms. For example, a transistor with the usual g_m

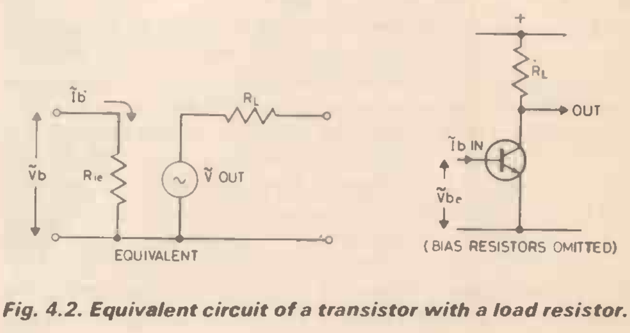
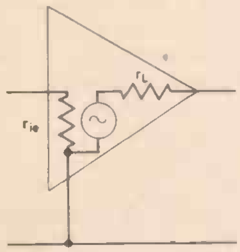


Fig. 4.2. Equivalent circuit of a transistor with a load resistor.

value of 40 (with 1 mA collector current) and an h_{fe} value of 100 will have an R_{ie} value of 100/40 k, which is 2.5k.

The output resistance of a transistor can be measured as the ratio $\tilde{V}c/Ic$, with the base current fixed, but this quantity is not particularly useful to us. For one thing, it represents a resistance connected in parallel, and we want to find an equivalent series resistance. Fortunately, the value of this resistance is so high (around 40 k) that we can ignore it in comparison to the low values of collector load resistors that we use. When we connect a load resistance to a transistor to make it a voltage amplifier, the output resistance for the amplifier becomes just the value of the load resistance.

The equivalent circuit shows both quantities, input resistance and output resistance as if they were resistors wired into the circuit, with the actual voltage amplifier completely separate. What's the point? Well, take a look at Fig. 4.3 which shows a voltage amplifier transistor connected between two others, each with the same values of input and output resistances. Drawing each



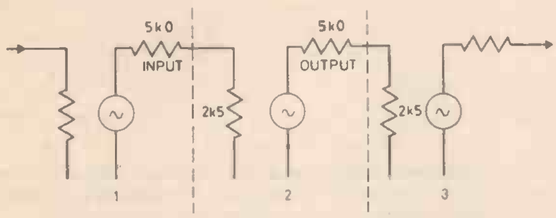


Fig. 4.3. Signal losses. (a) One method of showing input and output resistances of an amplifier. (b) Equivalent circuit of three identical transistor amplifier stages; Stage 2 is affected by the output resistance of stage 1, and by the input resistance of stage 3.

amplifier stage like this shows that the output and input resistances act as potential differences for signals that we are trying to amplify. Incidentally, because we are talking only of signals, we do not need to draw in capacitors, we assume that they pass signal currents perfectly.

At the input, the signal comes through a resistance of 5k (the output resistance of that stage) and is passed into an input resistance of 2.5k, so that the division ratio is

$$\frac{Rin}{Rout + Rin} = 2.5/7.5, \text{ or } 0.33$$

At the output, exactly the same happens, so that our voltage gain of 200 becomes now 200 × 0.33 × 0.33 = 22.2, which is not exactly quite so impressive. With gains like this, who needs losses?

This potential divider action isn't confined to transistors, of course. Every transducer that we use has its internal resistance which can be represented by a resistance in the equivalent circuit. An example will show why a single-transistor amplifier is not enough for our purposes, even with a voltage gain of 200 times. Suppose we have a pick-up cartridge with an internal resistance of 5k (often called source resistance) and an output of 5 mV, which is rather on the high side for such gadgets. We might think that an amplification of 200, which could give a signal of 5 × 200 mV which is 1V might be enough to drive a loudspeaker with a resistance

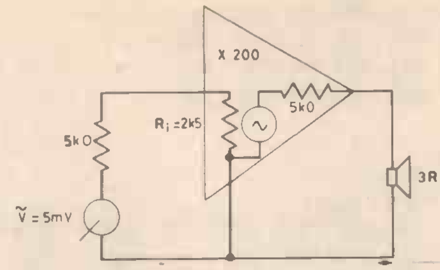


Fig. 4.4. Single-transistor amplifier, input from a pick-up cartridge, output to a loudspeaker.

of 3 ohms. After all, if the voltages are RMS, then the power output should be V^2/R, which will be 0.33 watt, about the amount we get from a small pocket radio.

The equivalent circuit shows why it won't work. At the input, the signal is divided by the ratio 2.5/7.5 = 0.33, just as before, and at the output the division is enormous, with the 5 k output resistance of the amplifier feeding a 3 ohm loudspeaker, division ratio 3/5003. The signal voltage that we actually get across the speaker is therefore:

$$5 \times 0.33 \times 200 \times \frac{3mV}{5003}, \text{ which is } 0.199 \text{ mV.}$$

The words 'dead loss' spring to mind . . . . To succeed at this sort of thing we need a higher input resistance and a much lower output resistance, and these desirables, rather than just voltage gain, are why we make use of amplifiers with more than one transistor.

HOW TO REDUCE GAIN PAINLESSLY

No, we're not joking. One of the most useful circuit tricks we know is one that reduces voltage gain; it's called **negative feedback.** After what we've just been through, this may look mad, but voltage gain isn't everything. If we take a bit of care over input and output resistances we can get a lot of voltage gain from a few transistors.

For example, even if we get a voltage gain of only 20 times from a transistor which is connected to two others, then the three of them should give a voltage gain of 20 × 20 × 20, which is 8,000 times, a pretty healthy gain, and more than we usually need. Now this 'ere negative feedback isn't like income tax; *your sacrifice of gain is never in vain.* When we reduce the gain of an amplifier, using negative feedback, we can obtain the following advantages:

1. Changes in the input and output resistance values. For example, we can obtain higher input resistance and lower output resistance.
2. Reduction in distortion. The transistor behaves as if the graph of output current/input voltage were rather more like a straight line.
3. Reduced noise. The noise signals caused by electrons bouncing around in the transistors and the resistors are reduced.
4. Greater bandwidth. The gain of the amplifier, though less, will stay constant over a greater range of frequencies.
5. Better tolerance of change. The replacement of a transistor in the circuit or changes that take place in resistor values as the components grow old, have less effect on the gain of the amplifier.

Quite an impressive list of advantages for the sacrifice of a bit of gain, you'll agree. So how do we go about it?

We apply negative feedback to an amplifier by taking some of the output signal and subtracting it (that's the negative bit) from the signal at the input. It sounds complicated, but it isn't really, if you remember that subtracting signals is the same as adding signals that are inverse (or out of phase).

Figure 4.5 shows the idea; adding the voltages of signals that are in phase (coinciding) gives a larger wave, but adding the voltages of waves that are in antiphase (one wave the inverse of the other) gives a smaller wave,

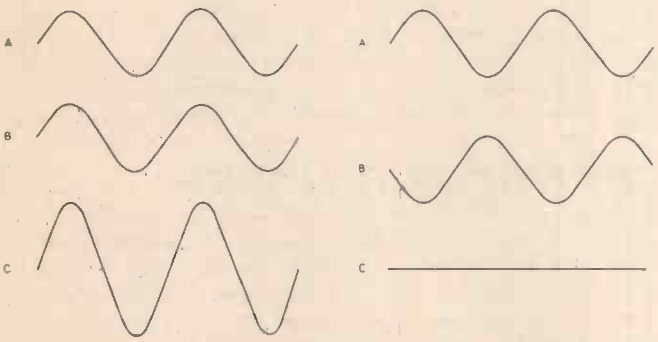


Fig. 4.5. Adding wave voltages. (a) in phase, (b) in antiphase. The sum or resultant wave can be large or small depending on the phase of the waves being added.

the result of subtraction. Negative feedback therefore means making a connection between an amplifier input and an output that has an out-of-phase signal. No signal will be lost at the output by doing this, apart from the "potential divider" losses we always get.

Figure 4.6 is a pretty obvious example of negative feedback. The signal at the collector of a common-emitter amplifier is inverted with respect to the input signal. This is because a rise in the steady voltage at the base would cause more base current, so more collector current, therefore more voltage drop across the load resistor, and so a drop in the steady voltage at the collector. The same action must be true for signal voltages, which are just variations in the steady voltages, so that any signal path connected between output and input in this amplifier will cause negative feedback; we have used this as a bias method, feeding back DC rather than just signal. This kind of feedback is called **shunt feedback,** and one of the effects that shunt feedback has is that it lowers the effective input resistance of the amplifier.

Curiously enough, this is not necessarily a disadvantage. If the signal is fed into the amplifier through a source resistance Rs, which might be the resistance of a

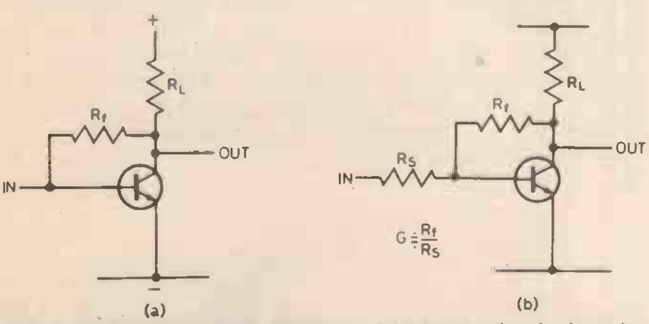
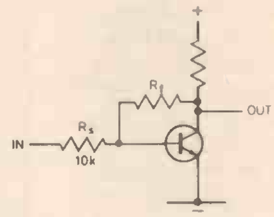


Fig. 4.6. Shunt negative feedback (a) simple circuit, ignoring bias. (b) Rule-of-thumb formula for finding gain. Rs is the "source" resistance, either wired in circuit or part of the previous stage resistance.

TABLE 4.2

COMPUTED VOLTAGE GAIN — SHUNT FEEDBACK



R_f value (k)	Gain	R_f/R_s
10	0.99	1.0
20	1.97	2.0
30	2.94	3.0
40	3.9	4.0
50	4.8	5.0
60	5.8	6.0
70	6.7	7.0
80	7.6	8.0
90	8.5	9.0
100	9.5	10.0
200	18.0	20.0
300	25.9	30.0
400	33.0	40.0
500	39.8	50.0
1000 (1M)	66.4	100.0
2000 (2M)	99.7	200.0

Assuming voltage gain before feedback of 200 times.

transducer or the output resistance of another transistor, then the voltage gain of the amplifier with its feedback in action is Rf/Rs. If we make Rf = Rs, then the voltage gain is unity, (one). This rule of thumb assumes that the voltage gain of the amplifier without the feedback is much greater than the voltage gain with the feedback. Try it for yourself; assemble the circuit of Fig. 4.6 and check the effect on voltage gain (measured with a 1 kHz signal) of various resistors, Rf. A set of computer-generated figures is shown in Table 4.2 for comparison. The values that are obtained by the simple formula Rf/Rs hold reasonably well up to a gain of about 10, assuming that the gain with no feedback is 200 times.

That's one type of negative feedback circuit, but there is another type which also can be used on a single transistor. Fig. 4.7 shows the circuit, and this time it's not so easy to see why there is negative feedback, where it comes from and where it goes to. The answer is that

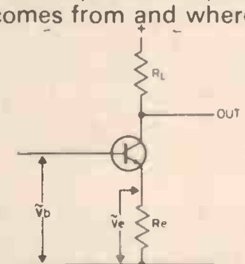


Fig. 4.7. Series negative feedback using the emitter resistance Re.

the feedback in Fig. 4.7 is caused by the emitter resistor Re, and the feedback signals come from the emitter current and affects the base-emitter voltage. The action is something like this.

Imagine a signal at the input causing a signal current between the collector and the emitter. Now think of a portion of that signal input, the rising-voltage portion of a sine-wave for example, which increases the voltage between the base of the transistor and the negative line. This causes the collector current to increase, so the emitter current will also increase. The emitter current, flowing through the emitter resistor Re will then cause an increase of voltage at the emitter. That's what causes the negative feedback. Why?

The signal at the input of the transistor that causes the change of collector current is the signal voltage between the base and the emitter. If the base voltage and the mitter voltage were to rise by, for example, 1V each, then there would be no change in the voltage between base and emitter, which means no change in the input to the transistor.

The actual signal into the transistor is $\tilde{V}b$-$\tilde{V}e$, where the squiggles, as usual, remind us that we are now talking about AC signal voltages. Vb is the signal voltage between the base terminal and ground, Ve is the signal voltage between the emitter terminal and ground.

This is a type of negative feedback that we call **series feedback** and it has some quite different effects. For one thing, it raises the input resistance of the amplifier quite noticeably. The extra input resistance is approximately $h_{fe} \times$ Re, so that for a transistor with h_{fe} = 100, and Re = 330R, the input resistance is raised by 100 × 0.33k = 33k, quite an improvement. Series feedback also raises the output resistance of the transistor, but since the output resistance of the *amplifier* depends more on the resistance of the load resistor, this has little noticeable effect.

This type of feedback is not so easy to test practically, because any change in the emitter resistance will affect the bias of a transistor. Fig. 4.8 shows a method, though. The emitter resistor is a 1k potentiometer with a capacitor C2 connected between the wiper arm of the

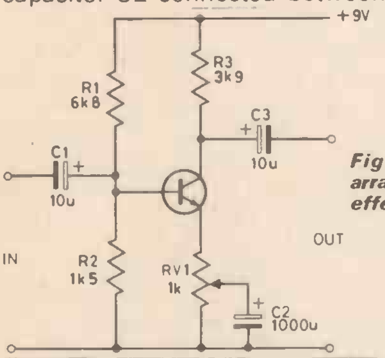


Fig. 4.8. A practical arrangement for testing the effect of series feedback.

potentiometer and the ground line. There is always a 1k resistance between the emitter and ground, so that the bias is unchanged by varying the potentiometer setting, but the capacitor will by-pass part of the 1k as far as AC signals are concerned. When the potentiometer is set so that the whole of the 1k is bypassed for AC, the gain of the amplifier will be at its maximum value (remember the effect of the coupling resistances). Typical computed figures of gain are shown in Table 4.3, assuming that h_{fe} is about 100 and that the bias current is about 1 mA. Try it for yourself.

This series feedback circuit can be troublesome, though, because it can lead to low gain when we don't want low gain. If we use the bias circuit of Fig. 4.9 (and who doesn't?) then the effect of the emitter resistor which does such a good job of stabilising the bias, because of negative feedback of DC, is to make the gain of the amplifier rather low, about equal to R_L/Re. We can get round this by remembering that it's only the resistance to signal currents that causes the negative

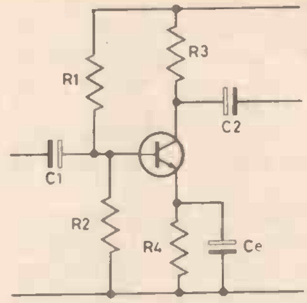
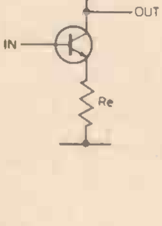


Fig. 4.9. Using a decoupling capacitor (Ce) so that there is no series feedback caused by the emitter resistor R4.

feedback. If we connect a large-value capacitor, Ce, between the emitter of the transistor and the ground line, then Re is a short circuit as far as signal currents are concerned, provided that Ce is a large enough value. This capacitor is called the **emitter bypass capacitor.**

TABLE 4.3
COMPUTED GAIN VALUES — SERIES FEEDBACK
Assuming h_{fe} = 100



R_e (ohms)	G	R_L/R_e
100	31.2	39
200	17.3	19.5
300	12	13
400	9.2	9.75
500	7.4	7.8
600	6.2	6.5
700	5.3	5.6
800	4.7	4.9
900	4.2	4.3
1000	3.8	3.9
2000	1.9	1.9

THE EMITTER-FOLLOWER

In Part 3 we had a quick squint at a common-collector or emitter-follower circuit. It's just a logical development of the common-emitter amplifier, but with 100% feedback through the emitter resistor. The input is taken between the base terminal and the ground line, and the output is taken between the emitter terminal and the ground line, so that the whole of the output signal is fed back. The voltage gain is less than unity, but the input resistance is high, and the output resistance is very low. This combination makes the emitter-follower ideal to use as a **buffer stage,** a stage which can be used as a link

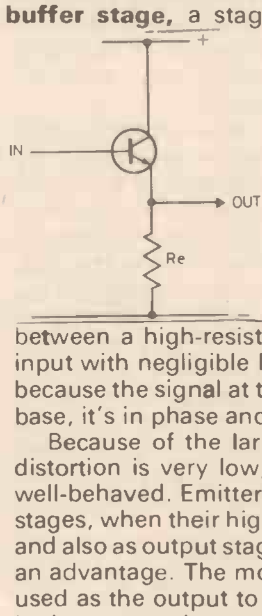


Fig. 4.10. The emitter-follower (bias arrangements omitted).

between a high-resistance output and a low-resistance input with negligible loss of signal. The name? Well it's because the signal at the emitter follows the signal at the base, it's in phase and almost the same amplitude.

Because of the large amount of negative feedback, distortion is very low, and the circuit is generally very well-behaved. Emitter followers are often found as input stages, when their high input resistance is an advantage, and also as output stages when a low output resistance is an advantage. The most popular type of circuit which is used as the output to a loudspeaker has two transistors both connected as emitter followers (Fig. 4.11). Because one transistor is NPN and the other is PNP, both can be fed with the same input signal. No load resistors are needed because the loudspeaker acts as the emitter load resistor for AC signals, and each transistor acts as the emitter load resistor of the other for DC current.

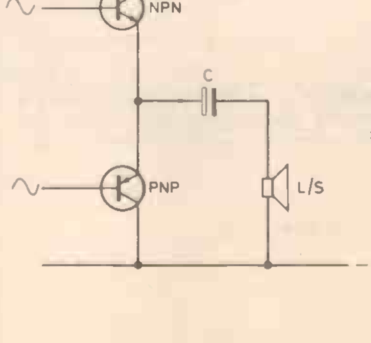


Fig. 4.11. The 'totem-pole' circuit, with two emitter followers, which is used as an output stage to drive loudspeakers. One transistor is NPN, the other PNP.

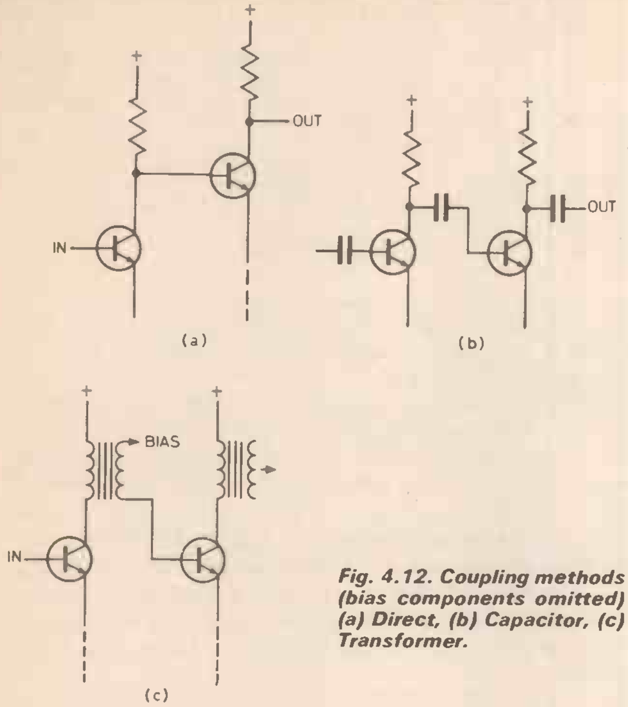


Fig. 4.12. Coupling methods (bias components omitted) (a) Direct, (b) Capacitor, (c) Transformer.

TWO-STAGE AMPLIFIERS

We've hinted often enough that we usually need more than one transistor in a complete amplifier, so now we need to look more closely at how we can make an amplifier with more than one transistor. Obviously we need to be able to transfer the amplified signal from the first transistor into the base of the second transistor, but there's more to a two-stage amplifier than that.

One of the big problems of a two-stage amplifier is to make sure that each transistor has the correct bias. If we just connected the collector of one transistor to the base of the next, it's unlikely, to say the least, that the bias would be correct. Direct coupling, as this sort of system is called, is not quite so simple. We'll look at some direct coupled arrangements later.

One obvious method is to use a capacitor for coupling. DC can't flow through a capacitor, so that we can have the collector voltage, say +6 V, on one terminal of a capacitor and a base voltage of, perhaps, 0.5 V on the other. This is the normal method of coupling signal between stages; it's usually called capacitor (or RC) coupling. Like anything that looks simple, there's a penalty to pay. The capacitor will happily pass high-frequency signals, but its reactance for low-frequency signals will cause the gain of the complete amplifier to be lower at low frequencies. The coupling capacitor behaves as if it were part of the source resistance of the first stage of the amplifier, so that it forms part of that potential divider for signals. Since the reactance of a capacitor is very large for low-frequency signals, the total gain for these low frequency signals is smaller. Another effect is that the phase of signals is shifted when the signal frequency is low. At low frequencies, the capacitor has time to charge and discharge, and the current through the capacitor in the coupling circuit of Fig. 4.13b is phase advanced by 90 , meaning that a sinewave current peak appears a quarter of a cycle earlier than the voltage peak when a steady sinewave signal is passing through. This causes a form of distortion, phase distortion, which alters the shape of signals such as square waves, though the effect on a sine wave is not so easy to detect since the shape is not changed.

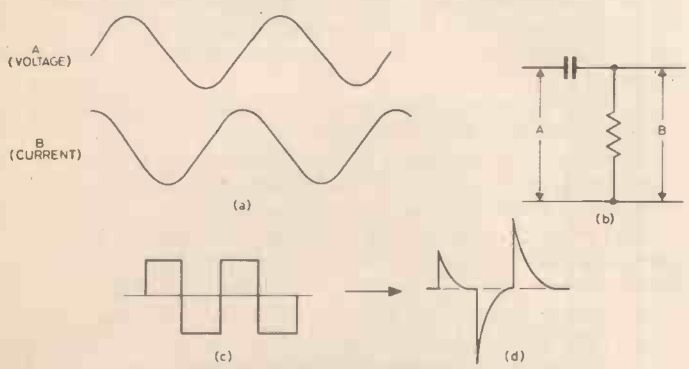


Fig. 4.13. The effect of capacitor coupling on low-frequency signals. (a) Phase shift of voltage relative to current, (b) in the coupling circuit, the output voltage (A) is not in phase with the input voltage (B) to the next stage. A low frequency square wave (c) becomes distorted to the spiked shape (d) unless very large capacitance values are used.

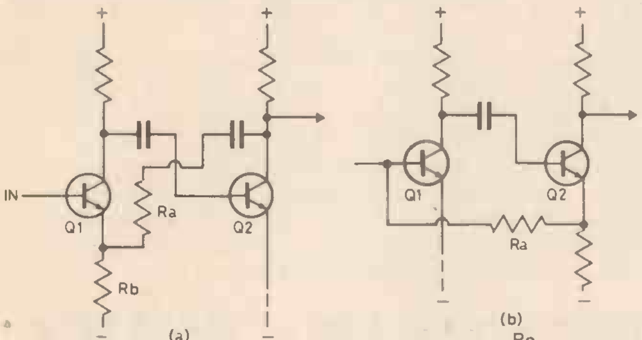
The big advantage of using capacitor coupling is that the bias of each transistor stage is unaffected by the coupling. The use of a transformer to couple signal from one stage to another is another way of ensuring that the bias is not upset. Transformers are seldom used nowadays on grounds of cost, size and weight, and also because of the odd effects that a transformer can have on the gain at various frequencies. Each winding of a transformer is an inductor, so that there will be resonance with any capacitor (including stray capacitances in the wiring and also between the turns of wire in the transformer). If these resonances are at frequencies in the range being amplified, the gain/frequency graph will have some very noticeable peaks or dips.

NEGATIVE FEEDBACK OVER TWO STAGES

Earlier in this Part, we used some rule-of-thumb methods for finding the voltage gain of single stage transistor amplifiers with negative feedback. These rule-of-thumb approximations become pretty exact if the gain of the amplifier before feedback is connected (**the open-loop gain**) is large. It's an advantage, then to have negative feedback applied to an amplifier of more than one stage, because the large amount of open-loop gain ensures that our calculations work out better. If, for example, the open-loop gain is very high, and 1/n of the output signal is fed back (so as to be negative feedback), then the factor n is called **loop gain (NOT** open-loop gain), and it also happens to be the value of voltage gain of the whole amplifier. For example, if 1/20 of the output voltage is fed back as a negative feedback loop, then the loop gain is 20, and the voltage gain of the complete amplifier is 20.

Now, as it happens, picking a fraction of the output signal is simple, we need only a potential divider, a pair of resistors. Using an amplifier with a high open-loop gain (before using feedback) therefore enables us to set the value of gain that we want by using only a pair of resistors. This makes circuit design a lot easier, because we do not now have to bother about calculating the gain of each stage of the amplifier with any accuracy, providing that the open-loop gain is high compared to the final figure of gain that we want. It's easier, in fact, to make a two-stage amplifier with a gain of exactly 20 times, using negative feedback, than to make a single transistor stage with a gain of exactly 20 without using feedback. We have, in addition, all the usual advantages of negative feedback, ensuring low distortion, low noise, and very little change of gain when transistors are replaced or when resistors age (apart from the two which set the loop gain). The reduction of distortion and noise, incidentally should be by the same factor as the gain is reduced, so that if the open-loop gain was 500, and the loop gain is 25, then the reduction factor is 25/500, which is 1/20, and the distortion should be only 1/20 as much as that of the open-loop amplifier, and so on.

How do we go about it? Well, connection from the second collector back to the first base certainly doesn't do it! That's **positive feedback** (try it!) because the signal at the collector of the second transistor has a signal that is *in phase* with the signal to the base of the first transistor. There are two possible connections that give negative feedback over a two-stage amplifier. One is to take signal from the output collector back to the input emitter, the other is to take signal from the output emitter back to the input base. The first method causes the input resistance of the amplifier to rise, the second method reduces the input resistance. Approximate figures for the loop gain (which will be the gain of the complete amplifier) are shown in Fig. 4.14.



(a) Gain = Ra / Rb (if Rb is small)

(b) Gain = Ra / Rie (where Rie is input resistance of Q1)

Fig. 4.14. Methods of connecting negative feedback over two stages. (a) Collector-to-emitter, (b) emitter-to-base.

DIRECT COUPLING

Two transistors can be direct coupled provided that some arrangement is made to keep the bias correct on each transistor. Fig. 4.15 shows one arrangement, with an emitter-follower feeding a common-emitter stage. Because the emitter-follower output signal is in phase

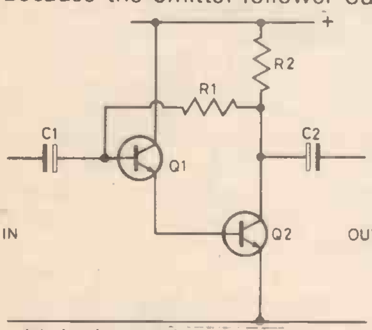


Fig. 4.15. Direct-coupling two stages together, using an emitter-follower and a common-emitter pair.

with its input signal, bias and negative feedback can be applied by the resistance R1. If we want this to act for bias only, the total resistance can be divided into two sections with a capacitor to remove (or 'decouple') signals.

Another two-transistor arrangement is shown in Fig. 4.16. This uses a shunt feedback stage feeding an emitter-follower. The negative feedback action of the

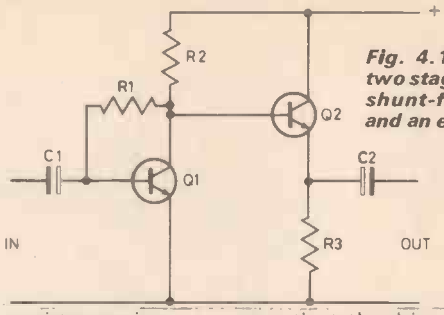
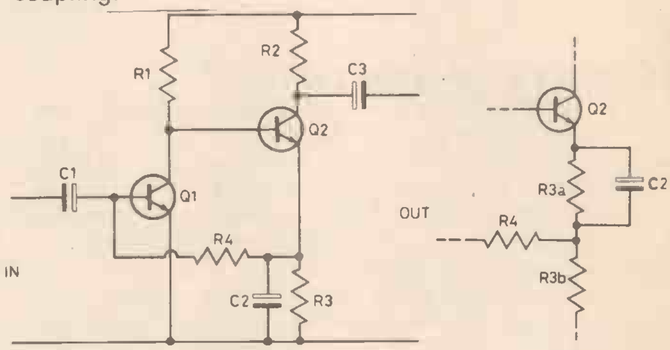


Fig. 4.16. Direct-coupling two stages together, using a shunt-feedback amplifier and an emitter-follower.

emitter resistor ensures that the biasing of the emitter follower is correct, and the biasing of the first stage is set by the shunt feedback resistor R1.

A very popular arrangement of two transistors which has a very large open-loop gain is shown in Fig. 4.17. Q1 is a common-emitter amplifier whose collector is directly coupled to the base of Q2. Q2 uses an emitter resistor, R3 which is decoupled by C2 to ensure that there is no negative feedback of signal, but bias is fed back through R4. Because the bias is obtained by DC feedback over two stages, the bias is very stable, and a surprisingly small number of components is needed compared to a two-stage amplifier using capacitor coupling.



(a) (b)

Fig. 17: A high gain two transistor circuit (a) with direct coupling negative feedback of signal can be achieved by removing C2, or by using the circuit in (b) where only part of R3 is bypassed.

SWITCHING ACTION

So far in this Part, we've assumed that we want linear amplification, with an output signal that is a near-perfect copy of an input signal. This isn't always so, and some of the most important applications of transistors are in circuits where there is no linear action to speak of, just a rapid change between the cut-off and the bottomed states. To see why a transistor should be useful for this type of action we need to know two (transistor) vital statistics.

1. The transistor does not conduct until the base-emitter voltage is about 0.5 V.
2. Once the transistor *is* conducting, each 60 mV increase in the base-emitter voltage causes the collector current to increase by ten times.

The second point needs illustrating. Suppose that a transistor has 1 mA of collector current flowing when the base-emitter voltage is 0.55 V. Then a change to a base-emitter voltage of 0.61 V (another 60 mV) will make the collector current 10 mA, and a change to 0.67 V (another 60 mV) will make the collector current 100 mA. This sensitivity to base-emitter voltage is why the transistor can be used for switching. Suppose, for example, that the collector load of a transistor is a relay which switches over at a current between 5 and 10 mA. If the transistor is set with 1 mA flowing, then a voltage

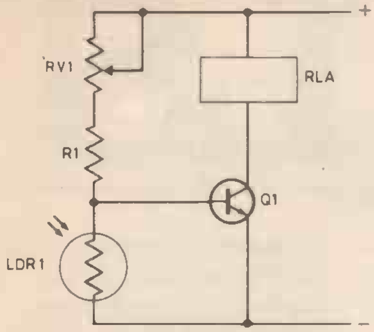


Fig. 4.18. Circuit for operating a relay when the light level drops.

change of only 60 mV will operate the relay with complete certainty.

Figure 4.18 shows a transistor circuit that will operate a relay when the light falling on a photoresistive cell LDR1 is cut off or reduced below a set value. The preset variable RV1, the fixed resistor R1 and the photoresistive cell LDR1 form a potential divider circuit across the supply voltage. The action of the photoresistive cell is that its resistance is low when light falls on the element, but removing or dimming the light causes the resistance to rise considerably. The variable resistor RV1 can be set so that with normal illumination on the photoresistor, the voltage at the base of the transistor is below the 0.5 V or so that is needed to start current flowing in the transistor. When the light dims, the resistance of the photocell rises, so that the voltage at the base rises. The transistor now switches on, and current will flow, switching the relay.

The sensitivity of this circuit can be increased by adding a current-amplifying stage (emitter-follower).

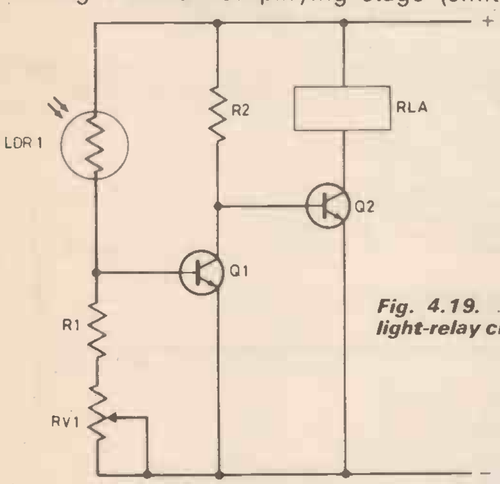


Fig. 4.19. more sensitive light-relay circuit.

This ensures that the current that is needed by the base of the switching transistor is supplied by the emitter-follower rather than by RV1 and R1. Another way of using two transistors is shown in Fig. 4.19 in which the sensitivity is increased by using the first transistor as a voltage amplifier. Note that the potential-divider circuit needs to be connected the other way round, because the first transistor must be switched *on* when the illumination is bright. The same basic circuit can be used along with a thermistor to make the switchover occur on a change of temperature.

Circuits like these have one flaw, though. Because they are so sensitive, the circuit can switch to and fro when the conditions (light or temperature or whatever we are detecting) are steady around the changeover point. If the input is at the critical value at which the circuit switches, then the relay 'chatters' as the transistors switch on and then off again with each tiny fluctuation of light or temperature as the case may be.

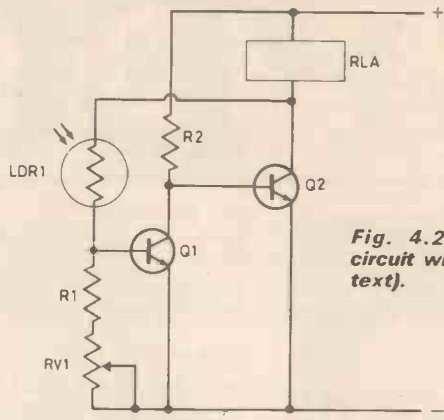


Fig. 4.20. A light-relay circuit with hysteresis (see text).

A small change in the circuit can correct this. In Fig. 4.20 the photoresistor is returned to the collector of Q2 rather than to the supply voltage. While the light is bright, Q1 is fully on and its collector voltage is bottomed, so low in voltage that Q2 is off; the collector voltage of Q2 is high. When the light level falls, however, the resistance of LDR1 increases, Q1 switches off, Q2 switches on, and the voltage at the collector of Q2 falls, ensuring that Q1 is now cut off *even* if the light becomes slightly brighter again and the resistance of LDR1 increases. This is positive feedback, and it acts to make a switchover much more definite. In the circuit shown, it is quite difficult to make the transistor switch back at all, and a more controllable circuit is that of Fig. 4.21 in which the amount of positive feedback is controlled between zero and maximum by the setting of RV2.

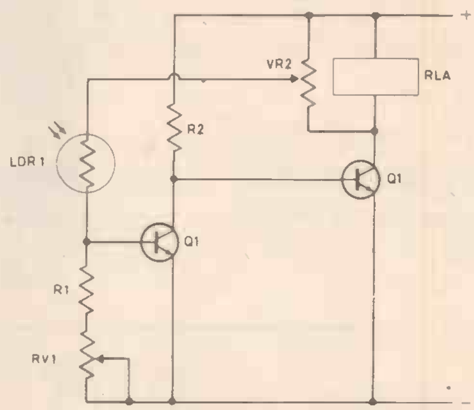


Fig. 4.21. A more controllable circuit with variable hysteresis.

RV2 can be adjusted so that there is enough difference between the inputs needed for switchover and for switchback to ensure that the circuit does not 'chatter'. This difference between switchover and switchback is called **hysteresis**, and is an important factor in switching systems. In an ordinary light-switch, for example, hysteresis is obtained mechanically by the use of a spring so that the switch always snaps over.

Positive feedback has now reared its head, so that in the next part we shall be looking at many more applications of positive feedback in oscillators. **HE**

In Part 5 we shall look at oscillators in many forms, how they work, what determines the frequency and what they are used for

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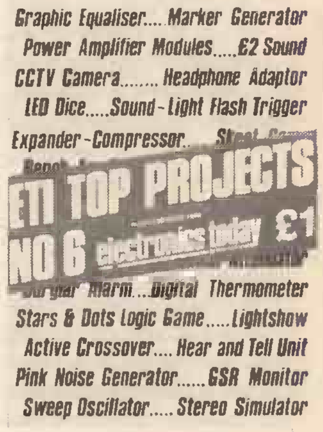

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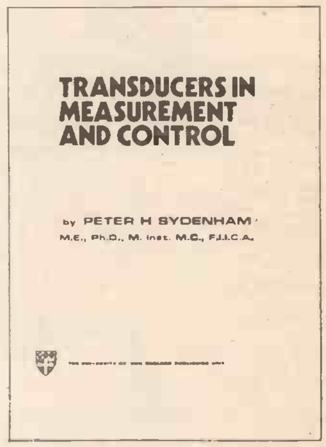

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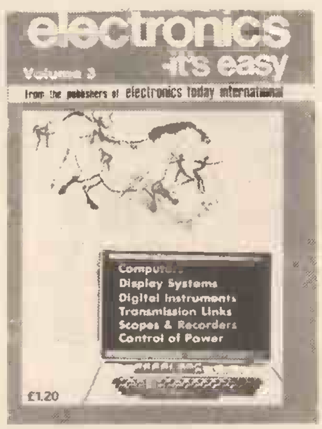

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Computer Glossary

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A **computer** is a machine for performing complex processes on information without manual intervention. **Analogue computers** perform this function by directly measuring continuous physical quantities such as electrical voltages. The best-known analogue computer is a slide rule. **Digital computers** represent numerical quantities by discrete electrical states which can be manipulated logically and hence arithmetically. Digital computers are sometimes referred to as **electronic data processing machines, EDP,** or **processors.** In order to distinguish the actual physical equipment from the programs which extend its usefulness, the former is called **hardware.**

The **central processing unit** (CPU) or **mainframe** is the portion of the computer which performs the calculations and decisions; the **memory** or **storage** is the part in which the data and programs are stored. The **core memory** is the main memory of many large machines; it is normally the only memory directly accessible to the CPU. Its name derives from its composition: small ferrite rings called **cores.** The computer may have additional memory devices; information is transferred between these and the core memory. The most usual such memories are **magnetic drums** (spinning cylinders with a magnetizable recording surface) and **magnetic discs** (flat spinning discs with magnetizable surfaces).

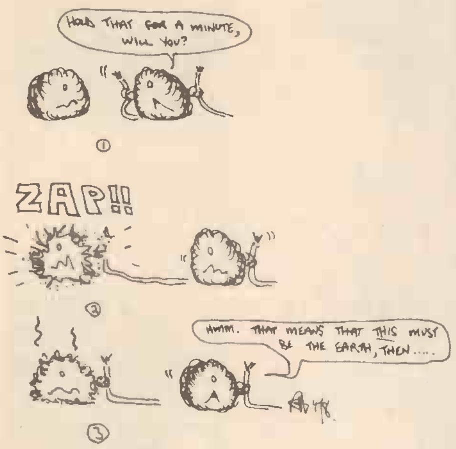
The capability of memory devices is measured in capacity and speed of access. The storage **capacity** of a memory is measured in **words** (also called **cells** or **registers**) which are usually of fixed length, consisting of 12 to 48 bits. This number is called the machine's **word length.** A **bit** (binary digit) is the minimum unit of information storage and has only two possible values. Capacity can also be measured in **bytes,** units of eight bits, each capable of representing one alphabetic or numeric symbol.

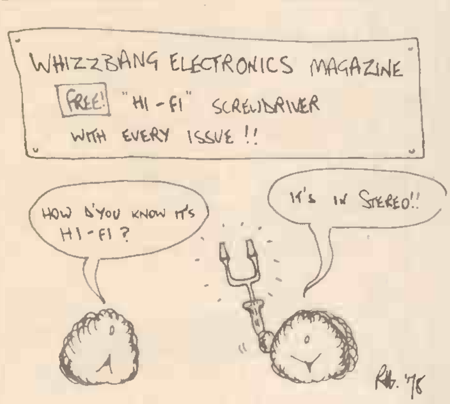
Access speed of a memory is the time it takes for the processor to obtain a word from memory. Core memory is called **random access** when any word can be obtained at any time without regard to its serial order. Drum, tape, and disc memories are **serial access,** because the words pass one at a time as they move past the station where they may be accessed. Speed is usually spoken of in terms of **milliseconds** (msec) (thousandths of a second), **microseconds** (μsec) (millionths of a second), or **nanoseconds** (nsec) (billionths of a second). One nanosecond is the time required for light to travel almost 300 mm.

The central processor and the memory constitute the computer per se; to get data and programs into the machine and the results out are the role of the **input/output equipment** or I/O.

Input devices convert information to a form in which it can be stored in the computer's memory. The commonest form of input is the **punched card** or **Hollerith card** (after its inventor). Input devices which accept cards are called **card readers** and the function they perform is commonly called **reading,** as is that of all input devices. Cards have 80 **columns** with 12 possible punch positions; normally, each column is used to represent one character. A set

Beasties





of cards is called a **deck**. Another form of input is **punched paper tape** — continuous tape approximately 25 mm wide, with holes punched across its width to represent characters or numeric quantities. **Magnetic ink character readers** have come to be used for input, particularly in banking; they can interpret characters printed with a special ink. More recently, **optical scanners** have appeared, which can read clearly printed or typed material of given type fonts.

Output devices usually include a **card punch** (which converts the characters stored in memory to punched holes in a card), a **tape punch** (which performs the same function for punched paper tape), and a **line printer** (which prints numerals, letters, and other characters of conventional design on continuous rolls of paper). When it passes information to these devices, the computer is **writing**. Recent additions to the output family include the **display device** which exhibits readable characters or graphic information on the face of a **cathode ray tube** or **CRT**. These images must be read at once, of course, since they are not permanent.

Information which can be taken away in permanent form (such as the output of a line printer) is called **hard copy**. A **plotter** is an output device which, under computer control, can draw continuous lines or curves on paper, thus producing graphs, maps, etc., in hard copy. **Magnetic tape** is widely used both as a form of memory and I/O. It can be stored conveniently away from the machine and can be read or written by the computer if it is put on a **tape drive** attached to the computer. It is the fastest type of I/O and the slowest type of memory except when used for serial reading.

I/O devices connected directly to the computer memory and under control of the CPU are spoken of as being **on-line**. They are placed **off-line** when they are used to perform independent functions. For example, it is common to exchange information between punched cards and magnetic tape off-line. Some devices are always off-line. They are **peripheral equipment** and are generally called collectively **electromechanical accounting machines** or EAM. These are frequently used independently of the computer and in fact antedate computers by many years. The most common are the **keypunch**, used to punch cards, the **reproducer**, which makes copies of decks of cards, and the **sorter**, which places cards in different bins as a function of which holes are punched. In some recent systems, another on-line I/O device has been added, the **console** or **terminal**. These are intended for the user to interact directly with the machine, and usually consist of a typewriterlike keyboard, and either a typewriterlike printing mechanism or another display device for output.

Information is stored in the computer's memory in the form of the presence or absence of a magnetic field. A collection of such 'yes or no' physical states is usually thought of as a **binary number** (a number whose only possible digits are 0 and 1). Depending on context, such numbers can have many meanings; in a sense, the numbers are **coded**. They can be interpreted as numeric quantities, **characters** (letters, digits, punctuation marks) or **instructions** or **commands** which will direct the computer to perform its basic functions (add, compare, read, etc.).

A set of instructions to perform a specified function or solve a complete problem is called a **program**. The computer performs such instructions sequentially. However as the computer can modify the data in its memory, it can also modify its program. This capability to modify its own directions is a case of the engineering principle called **feedback**, the modification of future performance on the basis of past performance. It is because of this distinctive feature that modern digital computers are sometimes called **stored program computers**. Parts of programs are sometimes called **routines** or **subroutines**. Subroutines which perform generally useful functions are sometimes combined into a **subroutine library**, usually on magnetic tape. Copies of relevant subroutines will be added to a program automatically and hence need not be

Computer Glossary

developed by hand. Single instructions in a program are sometimes called **steps**. When a sequence of program steps is operated repeatedly, the process is called a **loop**. Certain instructions compare two quantities and select either of two program paths on the basis of the result: these are called **branching instructions**.

The data on which a program acts are usually structured into tables. Individual values which control the operation of programs or subroutines are **parameters**. An organized collection of information in the computer or on tape is called a **file**, like the organized set of papers in a file cabinet. A **data base** or **data bank** is a large and complex set of tables which describe some aspect of the world outside the computer (a library catalogue, a student record file, a budget).

A **programmer** is a person who converts a problem into a set of directions to a computer to solve it. The function is sometimes broken down into several parts, particularly if the problem is very complex. The task of stating the problem in a clear and unambiguous form is performed by an **analyst** or **system analyst**. The technique of specifying methods of solution for mathematical problems is **mathematical analysis** or **numerical analysis**. A specific procedure for solving a problem is an **algorithm**. The process of writing the detailed step-by-step instructions for the computer to follow is **coding** done by a **coder**.

After a program is written, it is tested by letting it perform its function in the computer on test data to which the proper solution is known. This process is **code checking** or **debugging**. The coder will also produce some descriptions of this program and how it operates so that others may understand how it works, in case at a future date it is necessary to modify it. This **documentation** may include a **flowchart**: a graphic description or diagram of the various paths and branches followed by the program.

The repertory of instructions available to the programmer for a specific computer is that computers' **machine language**. Other **higher-order languages** have been developed to help the programmer by simplifying the tedious aspects of writing machine language; these are called **procedure oriented languages** or **problem oriented languages** or POL. Commonly used POLs are **Fortran**, **Algol**, and **Cobol**; the first two were devised mainly for scientific computation and the latter for business data processing. A new type is represented by **list processing languages**; because of greater flexibilities in dealing with data, these languages are particularly useful in non-numeric computations such as are frequently involved in research. Their particular virtues are most apparent in **heuristic processes**: methods where the precise method of solution is not spelled out but is discovered as the program progresses and as it evaluates its progress toward an acceptable solution. (Because this use of the word 'language' is somewhat misleading, human languages such as English are distinguished as **natural languages**).

Programs which convert higher-order languages into machines language are called **compilers**; programs which perform similar functions but at a much simpler level are **assemblers**. The term **translator** is used sometimes for compiler, but it is used less frequently because of the possible confusion with programs which perform translation between natural languages. **Interpreters** do not compile the entire program but translate and perform one statement of the program at a time; effectively, they perform both functions — compiling and running a program.

Software is the term used to refer to the totality of programs and procedures available on a computer; sometimes it is used more specifically to mean those programs of general usefulness (such as compilers) which are available to all users. These are sometimes called **utility programs**. All machines today have **operating systems** to aid the user (and the operator) in sequencing jobs, accounting, and calling up other utility programs. Operating systems or programs are also called **control programs**, **supervisors**, or **executives**.

Computer Glossary

Applications are the problems to which a computer is applied; the names for most common applications are self-explanatory, but some are not. A **simulation** is the representation of a real or hypothetical system by a computer process; its function is to indicate system performance under various conditions by program performance. **Information retrieval** is the name applied to processes which recover or locate information in a collection of documents. An **information management** system helps a user maintain a data base, modify it, and get reports from it. It is usually defined as a **general purpose device**; this means that it can accommodate a large range of applications. A **management information** system supplies to the management of an organization the data that it requires to make decisions and to exercise control. A **report generator** is a program which allows the user to specify in some simple way the content and format of reports which the computer is to produce.

To **run** a program is to cause it to be performed on the computer. Running a program to solve a problem or produce real results (as opposed to debugging) is called a **production run**. Installations in which the user runs his own job are called **open shops**. Installations which have a **computer operator** who runs the program for the user are **closed shops**. Computers are usually operated in **batch processing** mode; the operator assembles a batch of programs waiting to be run and puts them serially into the computer; output from all the programs is returned in one batch. **Turnaround time** is the time between the user's delivering his job to the centre and his receipt of his output. **Time sharing** is a method of operation by means of which several jobs are interleaved, giving the appearance of simultaneous operation. In many timeshared systems, users have individual terminals which are on-line. Such terminals may be located far from the computer; this is **remote access**. This allows users to interact with the computer on a time scale appropriate for human beings — on the order of a few seconds between responses. This capability is called operating in **real time**. Using the computer for frequent interaction with the user in this way is called an **interactive or conversational** mode of computing.

Like all electronic devices, computers sometimes break down. The prevention and correction of such situations is **maintenance**. **Preventive maintenance** finds failing components before they actually break down. **Reliability** is the measure of the frequency of failure of the computer. During **downtime** the machine is being maintained or repaired; during **uptime** it is available for normal productive use.

TERM	LINE	TERM	LINE
access speed	27	card reader(s)	42
Algol	136	cathode ray tube	59
algorithm	121	cell(s)	21
analogue computer(s)	2	central processing unit	10
analyst	118	character(s)	89
application(s)	161	closed shop(s)	179
assembler(s)	148	Cobol	136
		code checking	126
batch processing mode	180	coded	88
binary number	86	coder	123
bit	23	coding	123
branching	106	column(s)	43
byte(s)	25	command(s)	90
		compiler(s)	147
capacity, storage	21	computer	1
card, Hollerith	41	computer, analogue	2
card punch	52	computer, digital	4
card, punched	40	computer operator	178

HE

Reader's Letters

Metal Locators

Dear Sir,

In your article on Metal Locators (HE November '78) you said quite rightly that the sappers cleared mine fields during WW2 very successfully. The equipment was mainly valve-operated and (from pieces I have seen) very bulky.

The modern mine detector, however, is transistorised and quite reliable. Recently a distraught civilian came to us asking for help in finding his St. Christopher medallion which he had lost in a rugger match. We went to the area with a mine detector and after finding the general location of the loss, "boxed" it and began to search. I was doubtful that we would be successful, but we were — it was buried in about six inches of mud. We also found a collection of other metal objects, some as small as a half pence piece.

Bearing in mind the fact that the army mine detector was not designed for such use, it did remarkably well — all in all a nice piece of equipment and not to be taken as second to metal locators!

Staff Sergeant J. E. Ellis,
Royal Engineers

Current Affairs

Dear HE,

In Phil Cohen's "Electronics From Scratch" in your first issue he says "We always use I for current for some reason I can't fathom."

Well, we are learning electronics and while introducing Ohm's Law our teacher said that the 'I' may be from the Greek io?

I enjoyed reading your first issue — I like the way you start at the *beginning* of electronics. I hope that many have gained from it the same basic knowledge I have – and are now trying something more adventurous, as I am!

M. Shipp,
Twickenham

More computing!

Dear Sir,

I was fascinated to see your article on "Home Computers." It described them very concisely. I know from personal experience how difficult it is to grasp their ideas.

I also liked your "Hi-Fi Specs" article – many students in my position find these difficult to understand.

I hope you keep up your reports on "layman's computers."

M. R. Barclay,
Hurstpierpoint College,
Sussex.

We shall certainly be continuing to run articles on computing — it is a fascinating and expanding part of electronics and one which will no doubt be of great importance to all of us in the future.

I'm a SHE, not a HE

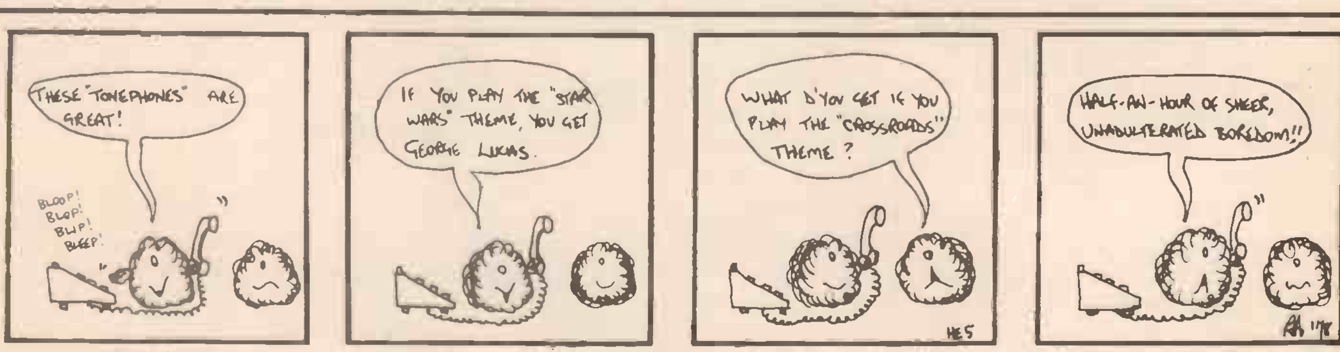
Dear Sir,

I thought that I would let you know that I might have been tempted to purchase one of your "HE" tee-shirts, but would object to having "I'm a HE man" written boldly across my middle, as I am a female, and proud of it!

Despite my complaint, I enjoy reading your magazine.

Ignrid Ashley,
South Croydon

Please send submissions for the letters page to: Hobby Electronics, 25-27 Oxford Street, London W1. Mark the envelope "LETTERS PAGE". Letters which are too long for publication will be suitably edited.



Instant Circuit Layout

Some of us have trouble translating a circuit which we can understand into a practical layout of components. K. T. Wilson holds our hand to guide us over this difficult step.

EVERYONE WHO'S ANYONE publishes interesting circuits. Seen our "Short-Circuits"? That's the sort of circuit that arouses the greatest interest and there's no doubt that many readers try them out, perhaps making their own modifications. Despite this, there are countless readers who find that circuit layout is a chore, a task that needs painful planning and lots of second thoughts. If you've never learned how to lay out a circuit properly easily, instantly — stay tuned — what follows is electronics-by-numbers; circuit layout with no sketches or plans, just the circuit diagram and a few scribbles.

THINK JUNCTION

There's no wizardry involved in instant circuit layout, but you have to be able to identify what is called a *circuit junction*. That's not the same as a semiconductor junction, but it's certainly a place where things join. At a circuit junction components join to each other, or to a negative or positive line, or to an input or output. Circuits consist of circuit junctions with components strung between them.

Figure 1 should make this idea of circuit junctions a bit clearer. The circuit is a straightforward one, a couple of transistors connected as an amplifier stage with DC feedback. In this circuit there are eight circuit junctions. Where are they? Well, one is at the input, because we have to take a signal to one lead or C1. Wherever there are connections, there's a circuit junction. We can mark it with a pencilled ring on the circuit diagram. There will be another similar junction at the output, and we can ring that one too.

Getting the idea? Each of these junctions is where components are connected together, and when you build a circuit you will need one line of a matrix board (like Vero or Blob) for each circuit junction. Have a look at the other junctions we have ringed in the circuit of Fig. 1 and see what you think of the show so far.

Now for the instant circuit layout. The circuit has eight junctions, so number your ringed junctions from one to eight. As easy as that!

Yes, it is, if all of the components have reasonably long leads, but if the transistors have short leads you will have to arrange your numbering so that the junctions where transistor leads are connected have consecutive or near-consecutive numbers. You don't, for example, want to have the collector of a transistor on junction number 1 and its emitter on junction 8. Fig. 2 shows a suggested numbering, one of many that are equally possible.

MATRIX BOARD

Now to build the circuit all you need is a piece of matrix board, the stuff with conducting lines of copper laid on a non-conducting board. If you use Blob-board, the tracks

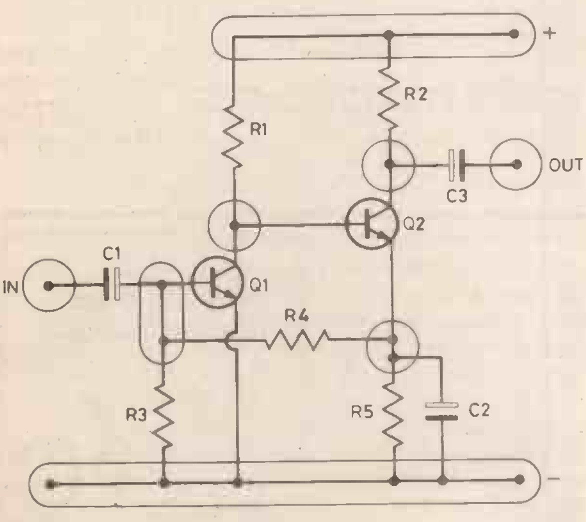


Fig. 1. Marking out circuit junctions.

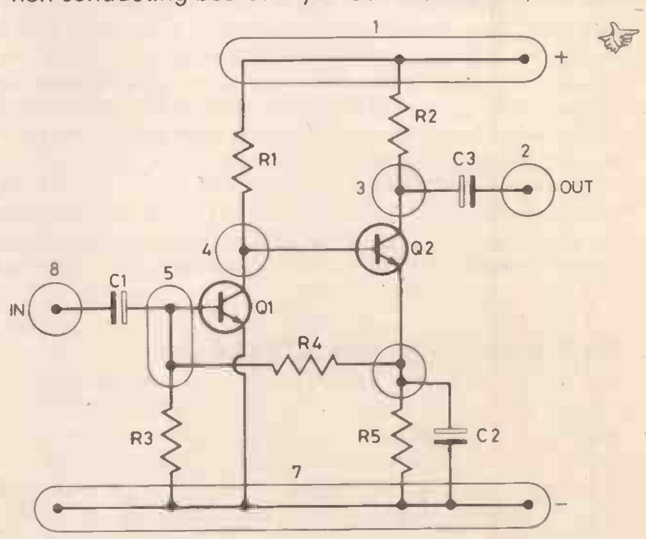


Fig. 2. Numbering the junctions.

are already numbered, so that you can start construction right away. If you use Veroboard you will have to pop into a stationer's shop and buy some of the white goo called "Liquid Paper" or "Tippex Liquid". This is a quick-drying liquid that sets matt-white, and it is used by sloppy typists (like me) to obliterate mistakes — it dries as white as paper and you can write on it. (You can also make it go a lot further by thinning it with Boots dry-cleaning fluid). Paint a stripe of this — there's a brush provided on the cap of the bottle — down the side of the Veroboard on each side, and let it dry for a minute (and I mean just a minute). Then you can number the strips of the Veroboard on each side — but make quite sure that each strip has the same number on each side!

What are you waiting for? You can build the circuit straight away now, because the position of each lead of each component is indicated on the diagram, Fig. 2.C1, for example, is connected between strip 5 and strip 8, with the positive end on strip 5.Q1 is connected with its emitter on strip 7, its base on strip 5 and its collector in strip 4. R1 is connected between strips 4 and 1, and so on.

With your circuit built, look how easy it is to check your connections. Instead of going through the circuit bit by bit, all you need to do is to check that each component is connected between the correct strips. Couldn't be easier. You'll find, incidentally, that a remarkable number of "Short Circuits" can be built on boards of up to 14 strips.

WHAT IF . . .

Now for the what-if department. What if your circuit needs more strips than you've got, what if the layout turns out awkward, what if you want to use ICs? We've thought about all these points, and here's how.

To start with, if your circuit is long rather than short, there are several things you can do. One is to break the circuit up into bits that will fit onto whatever number of strips you have on each board, and then connect several boards together. This after all is what everybody has to do with a really large strip — the old telly isn't built on one board, after all (well, not usually).

The other dodge is just to cut the strips so that you double the number of strips on the board. You don't have to cut all the strips, in fact, because it's most likely that you'll want to keep the + and — supply lines uncut. A 14-track board cut in this way, and leaving two uncut lines, will give you 26 lines to play with, and that's enough for a pretty large chunk of circuit. If that's not enough for you, there's no law to stop you making another lot of cuts. The important think, of course, is to identify each piece of track. The cut Blob-board tracks (if you *can* cut them, they're tough) can be identified by using the letters that are printed along the top of the piece of Blob-board. Cut Vero tracks can be identified by painting another lot of white goo and numbering. Most circuits, though, don't need anything like the number of tracks you can get by cutting.

THE AWKWARD SQUAD

Now for the awkward squad. There are several types of circuits, particularly the multivibrator family of circuits (astable, monostable, bistable) which are awkward to lay out on any sort of matrix boards, particularly if the transistors have short leads. There's a nice simple solution to this problem, and that is to use a mirror-image layout. Never heard of it? Look and learn, then.

In a mirror-image layout, the negative line, or wherever the emitters of the multivib transistors are connected to, is made the centre track of the board, and the outer tracks (1 and 14, for example, when a 14-track board is used) are connected together by a wire lead and used for the positive supply. If you're using PNP, reverse all that, of course. One transistor will have its emitter connected to the centre line, and the supply end of its collector load resistor to line 1. The other transistor of the pair will have its emitter connected to the centre track and the supply end of its collector load resistor to track 14, or whatever the outer track is numbered. Not clear? Take a look at the numbered junction diagram of Fig. 3, and the board layout alongside it, and you'll see what we mean. This is a particularly simple form of construction, and it adapts well to strings of multivib type

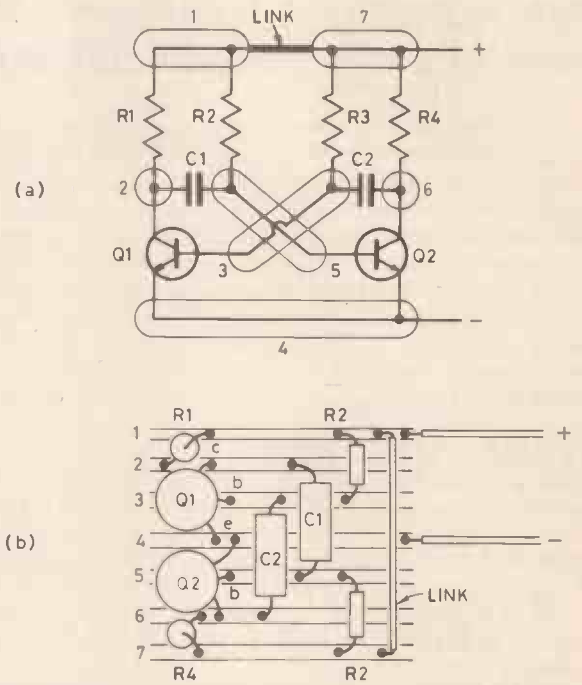


Fig. 3. Mirror-image layouts (A) Marked-out circuit (B) Board layout.

circuits, such as when a slow astable switches a faster one, or for bistable counters, or for long-tailed pair circuits all in a row. Short pulse generator circuits, consisting of an astable driving a bistable are also particularly easy to build this way.

INTEGRATED CIRCUITS

Now for these ICs. There's no doubt about it folks, lots of people don't like constructing IC circuits. As we'll show, though, Instant Circuit Layout makes IC circuits even easier to construct than discrete circuits. The key to it all, once again, is the numbering of the tracks on the board. Most IC circuits, particularly digital circuits, don't call for all that much in the way of other components. In addition, most of the components that are needed are strung either between one pin of the IC and the positive or negative lines, or between IC pins. This means that the number of circuit junctions we have to use is very often just equal to the number of IC pins.

Let's take an example. Fig. 4. shows a circuit for generating 6 different audio frequencies from a single TTL IC, a 7414. Just ignore the circuit for the moment. The IC is a 14-pin type and it will have to be mounted on

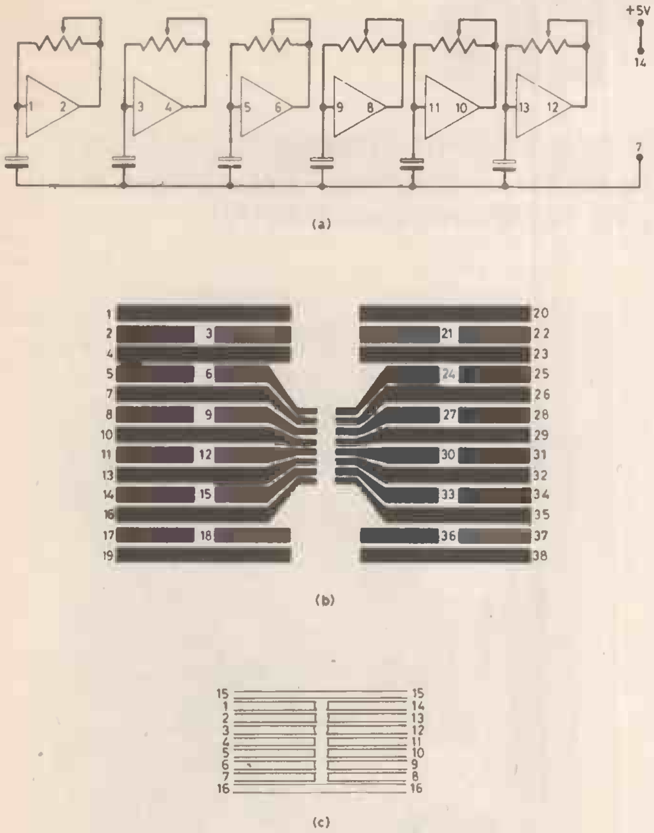


Fig. 4. Sample IC circuit (A), with 1-IC Blob layout (B) and 0-1in Vero cut-out diagram (C).

a board with tracks at 0.1in centres. Once again, if you use IC Blob-board you're home and dry because the tracks are numbered, and in addition the tracks fan out so that the connection of other components is easy. Conventional 0.1in Vero board will have to be cut as shown in Fig. 4c, and the tracks numbered. There is, however, a Verostrip and a DIP board which the cuts ready-made, so that only numbering is needed. O.K. so far? You should have in front of you a circuit diagram showing the IC pin numbers and a piece of board with numbered tracks. All you have to do now is to make these numbering systems agree! Suppose, for example, you're using ZB-1-IC Blob-board and pin 1 of the IC is going to be soldered to track 6. In your circuit diagram, then, you cross out the reference to pin 1 and write in the number 6. Pin 2 is on track 7, so that track 7 replaces pin 2 in the diagram and so on. With this done, you solder in the IC and then the other components are soldered in between the tracks as the diagram indicates.

Using DIP board? Then make your track numbering agree with the IC pin numbers and connecting up is equally easy; there's no need to change the numbers on the circuit diagram if you're using just one IC. If you're using several ICs, then letter them A, B, C, and so on, and letter your bits of track as well.

So you're sold on instant circuit layout? Well, there's just one more piece of good news. Most small circuits can be tried out on the solderless bread-boards, such as the DeCs Wonderboard, and the new OK boards. Now the tracks on several of these boards (all the DeCs and also Wonderboard) are numbered so that you can use this same scheme of instant layout to make your construction equally instant.

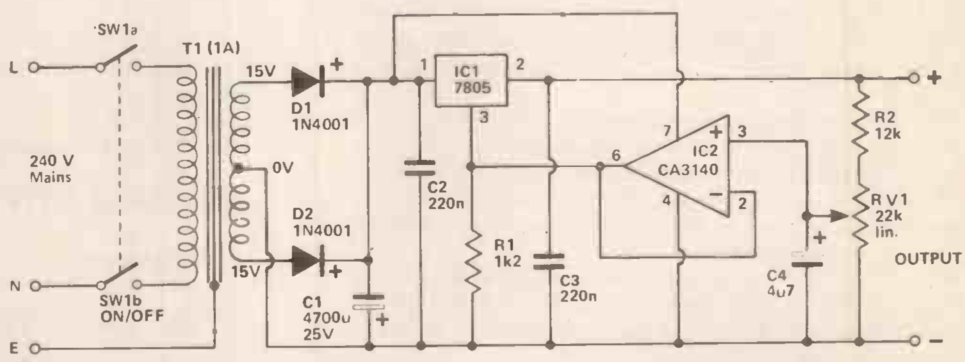
Now get to work . . . .

HE

Short Circuit

5-13V POWER SUPPLY

Although three terminal voltage regulators are often referred to as "fixed" voltage regulators, they can actually be used to provide output voltages other than their nominal ones, and can even be employed in variable voltage power supplies, as in the circuit shown here.



The three terminals of these voltage regulators are the input (pin 1), output (pin 2), and common (pin 3). The input voltage is applied to pins 1 and 3 with the correct polarity, and the stabilised output is extracted from pins 2 and 3. In effect, the device is actually stabilising the voltage at pin 2 at some fixed level above the potential at pin 3. Normally pin 3 is at 0 V, and so the output voltage is determined by the nominal output voltage rating of the regulator.

Voltages greater than that for which the device is intended can be obtained simply by raising the pin 3 voltage by the appropriate amount. For example, a 5 V regulator can be made to give a 9 V output if its common terminal is taken to a potential of 4 V. In this case a 5 V regulator is used, and its common terminal is taken to a variable voltage of about 0 to 8 V or so. This gives an output which is variable from about 5 to 13 V or so. The voltage is supplied by R2 and RV1 which are connected across the stabilised output so that regulation efficiency is not significantly impaired. This voltage is at too high an impedance to directly drive pin 3 of IC1, and so a simple buffer amplifier based on IC2 is interposed between the two. R1 is a ballast resistor. A CA3140 device has been chosen for the IC2 position since the output of this device can swing to within a few millivolts of the negative supply voltage. Many alternatives such as the 741C device have a minimum output voltage of about 2 V, which would give the power supply a minimum output voltage of approximately 7 volts, thus rendering the unit unsuitable for use with TTL and many other types of circuit.

The input voltage for the regulator circuit is derived from a conventional push-pull type step-down, rectifier, and smoothing circuit. C2 and C3 aid the stability of the circuit and should be mounted physically as close to the regulator IC as possible. C4 provides smoothing of the voltage at RV1 slider, and helps to give the circuit a very low output noise level of only about a millivolt or so. Regulation is also very good; the output falling by only about 70 mV between zero load and full output. The 7805 IC has current limiting circuitry which prevents an output current much in excess of 1 A from flowing.

Car Alarm

The electronic circuitry of a car alarm can be ultra-simple but is then usually complex to instal — and is prone to false alarms. Our circuit is actually complex in operation but is easy to build and quick to fit.

A STAGGERING numbers of cars are stolen each year. Some are stolen by professional thieves — and if one of these wants your car sufficiently enough then there's little that will stop them — alarms or otherwise.

But the majority of cars are not taken by professionals — they are stolen by people who use them for only a few hours — and then abandon them. Only too often in a vandalised state.

So if you fit a good reliable alarm it's odds-on that you will dissuade all but the most determined criminal.

Many different types of car alarm are currently available. The simplest have a sprung pendulum cantilevered out from an enclosure. If the car is moved, the pendulum moves against its spring restraint and causes two electrical contacts to come together — thus triggering the alarm. This type is simple and effective but very prone to false alarms.

Another type of alarm consists of little more than a self-latching relay which is triggered by a series of switches mounted in the vehicle's doors, hood, bonnet etc. It's very simple in operation but installation is a major job on many cars.

Yet another type sounds an alarm if the ignition is switched on before the alarm is disabled. Most thieves are aware of this type and often bypass them by disconnecting existing ignition wiring and running a new lead directly from the vehicle's battery to the coil.

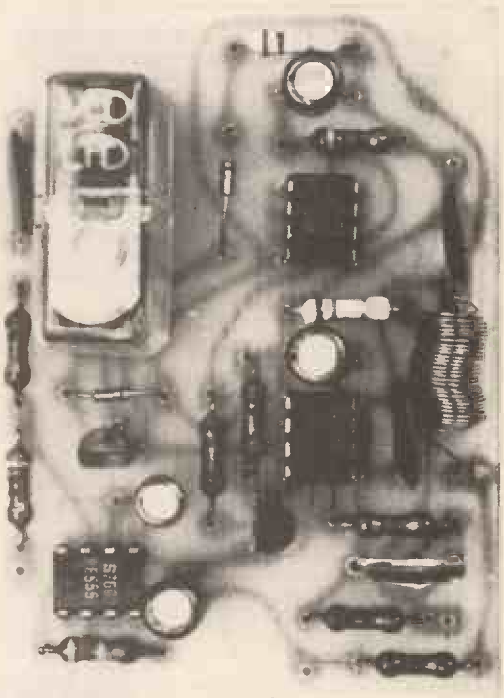
A further class of alarms is rather cleverer. These detect a voltage drop anywhere in the vehicle's electrical system — caused for example by the interior light coming on when a door is opened, pressing brake pedal and thus energising the stop light, starting the engine etc, etc.

The alarm described in this project works this way. It is also very easy to install. You simply connect it to any point which is normally 'live' at all times — such as the clock or the starter solenoid. We have added a facility which causes the alarm to be triggered if an external triggering point is earthed.

To comply with noise pollution regulations we have included a circuit which automatically turns the alarm off about 45 seconds after it has been triggered. The alarm is then automatically reset.

Almost all thieves are deterred by knowing that an alarm is fitted so we have included an LED (light emitting diode) which flashes once per second when the alarm is set. This LED should be mounted in a prominent place where it can be seen from outside the car.

Don't be deterred by the alarm's apparent complexity. As long as you build it using our printed circuit board layout you will not encounter any difficulties. L1 is a coil made of about 30 turns of 28 SWG wire on a 6mm former. The former can be removed after winding (neither the number of turns nor gauge of wire is critical). The completed board should be housed in a metal box which itself should be well earthed to shield the unit from electrical interference.



Our prototype board which shows that building it is not hard but the circuit is very sophisticated

The alarm output is a pair of relay contacts capable of switching up to six amps. These may be used to switch the existing horn — or preferably to switch power to an additional alarm horn mounted in an inaccessible position. The alarm pulses at roughly one second intervals.

INSTALLATION

Installation is a simple process. The unit must be connected to the vehicle's 12 volt supply at a point which is normally energised at all times. The supply to the electric clock (if fitted) is a good and usually accessible place. Failing this find a point on the main fuse box or starter solenoid switch which comes directly from battery. Do *not* connect directly across the battery as the unit relies upon voltage drop across the battery *and* connecting cables for its operation.

The connection to the 12 volt supply must be via a switch secreted somewhere outside the vehicle. Key switches are obtainable for this purpose from most locksmiths, hardware stores, etc.

The LED should be mounted in a prominent place and it is worth adding a window sticker advising that an alarm is installed.

It's really well worthwhile installing a loud and distinctive horn just for this unit — and mounting it in an inaccessible place. All you need to do is connect one side

Parts List

RESISTORS

R1	1k	½	watt	5%
R2	100k	"	"	"
R3,4	10k	"	"	"
R5	100k	"	"	"
R6	4M7	"	"	"
R7	10k	"	"	"
R8	470 ohms	"	"	"
R9	10k	"	"	"
R10	100 ohms	"	"	"
R11	470k	"	"	"

POTENTIOMETERS

RV1	10k trim pot

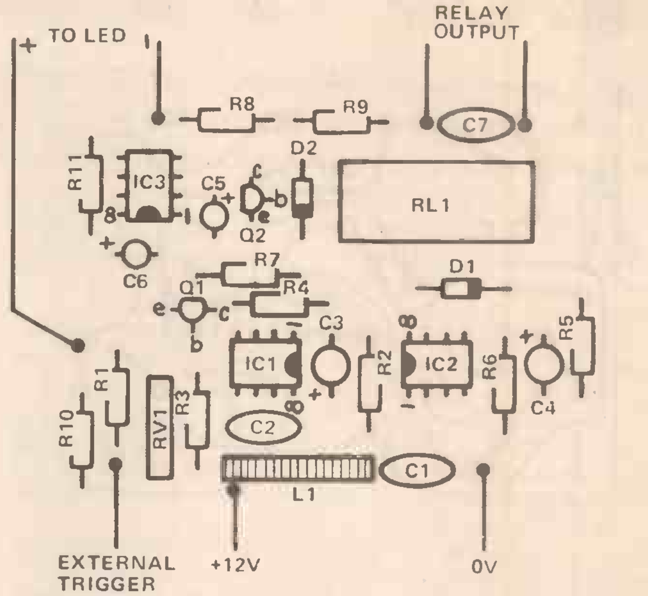
CAPACITORS

C1,2	100n disc ceremic
C3,4	10uF 25V electrolytic
C5	1uF 25V "
C6	10uF 25V "
C7	100 n disc ceramic

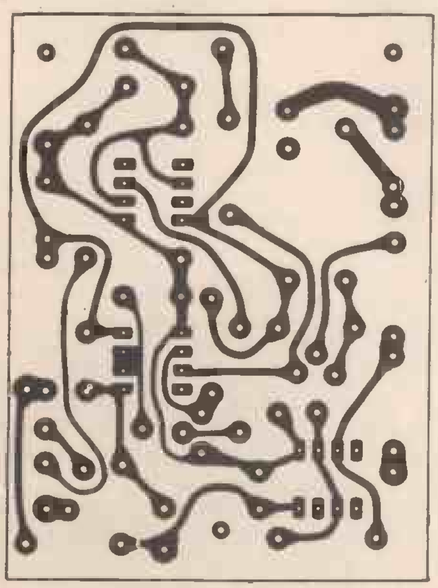
SEMICONDUCTORS

IC1-IC3	555
Q1,2	BC548
D1,2	diode 1N914
LED 1	light emitting diode
RL1	relay 12 volts 280 ohm coil, 6A contacts type

Printed circuit board
Coil L1 see text
Metal box to house unit.



The component overlay; compare this to the photograph of the prototype



The PCB pattern for the car alarm, shown here full size.

of the horn to the 12 volt supply — via heavy duty wire — and the other side to one side of the relay contacts. The other side of the relay contacts is then taken to earth.

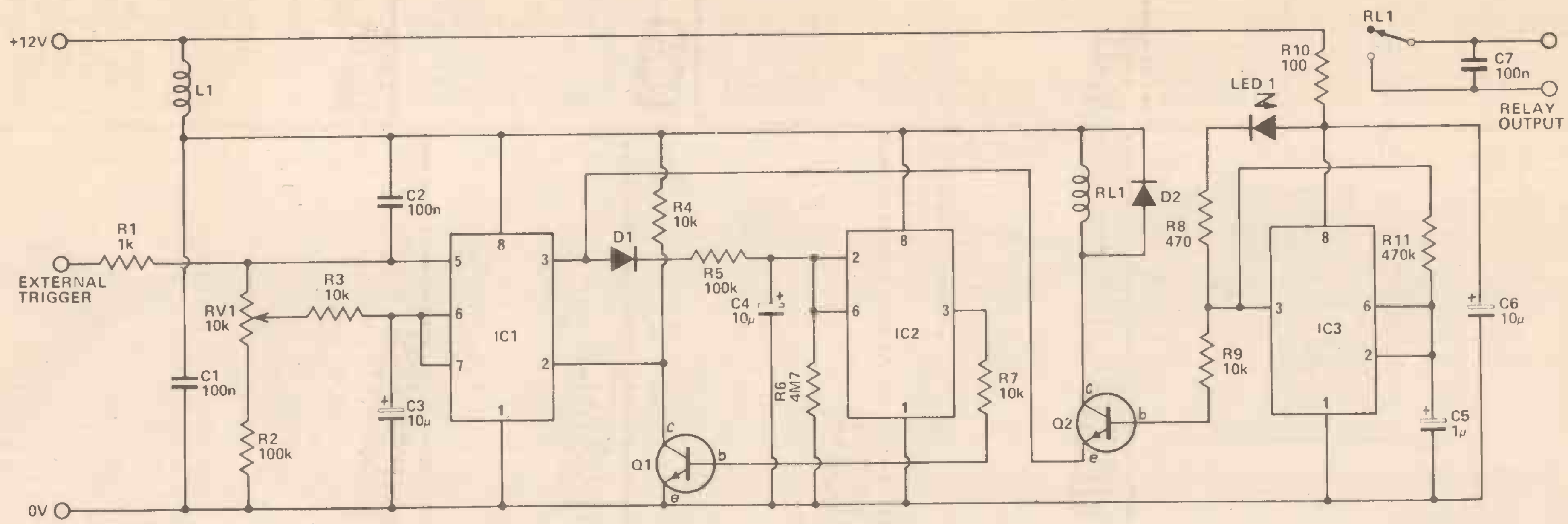
Apart from its ability to be triggered by voltage changes the alarm will also be triggered if the 'EXTERNAL TRIGGER' point is touched to the zero volt line. Thus you can arrange for a microswitch or mercury tilt switch to be fitted to the bonnet and/or boot to trigger the alarm if either are opened. You can of course protect the boot or bonnet in a possibly more useful way simply by installing inbuilt lights which are energised as the boot or bonnet is opened — the electrical load will then trigger the alarm in the usual way.

NOTES: Although apparently complex, the circuit is not critical in any way. If C4 or R6 are substantially different from the values specified then the 'alarm sounding' time will be other than the nominal 45 seconds. Apart from that though no component is particularly critical.

Some 'electric' clocks have clock-work mechanisms which are wound up every minute or so by an electric motor or solenoid. You can tell if you have one of these because they emit a clearly audible 'clonk' every time they wind. These clocks may trigger the alarm because the winder draws power from the vehicle's electrical system. This can usually be cured by connecting a 100 ohm resistor in series with the clock and a 1000 uF capacitor across the clock terminals. Both must be mounted as close as possible to the clock.

Once the unit is installed switch it on and adjust RV1 so that opening a door (thus energising the interior light) will trigger the alarm.

Car Alarm



The circuit of the HE Car Alarm. Read the 'How it works' carefully!

How it Works

The alarm works by detecting a voltage drop anywhere in the vehicle's electrical system. Its operating principle is rather complex but we trust it can be followed if one reads this section several times!

All three ICs are 555 timers used for various functions. Pin 5 of ICI is the 2/3rd reference level — that is if the voltage on pin 6 exceeds that voltage on pin 5 the IC will be triggered. Potentiometer RV1, which is connected to pin 5, is adjusted so that a voltage slightly lower than this appear on pins 6 and 7. These two pins are the upper threshold level and the internal discharge transistor of that IC. The lower threshold level is established by pin 2 which is connected to +12 volts via R4. Pins 6 and 7 are decoupled to the zero volt line by C3.

If any load is placed on the vehicle's 12 volt supply — to which of course the alarm system is connected — a voltage drop must occur even if only momentarily. This negative going signal will cause the 2/3rd voltage of pin 5 to fall relative to the upper threshold level voltage (which is maintained at a steady level by capacitor C3). If the 2/3rd voltage does fall below the upper threshold level then the output on pin 3 will drop to about 0.6 volts thus initiating the alarm sequence.

IC3 is an oscillator running continuously at 1 Hz — this signal is also used to energise the dashboard mounted LED to warn that the alarm is set. The 1 Hz signal drives the base of Q2 which in turn drives the output relay RL1. The emitter of Q2 is normally held at a level around 12 volts unless the alarm is activated — when, as described above — the output on pin 3 of IC1 drops to about 0.6 volts taking the emitter of Q2 with it and thus allowing Q2 to pulse the relay.

A timing circuit switches off and resets the alarm after (approximately) 45 seconds. Capacitor C4 is held at about 12 volts via D1 and R5 and as this voltage is applied to pins 2 and 6 of IC2 the output of that IC is 0V. When the alarm is triggered C4 is allowed to discharge slowly via R6. When the voltage on pins 2 and 6 falls to about four volts (this takes about 45 seconds) the output of IC2 goes high. This turns on Q1 thus resetting IC1 which in turn shuts off the alarm. Capacitor C4 then recharges and after three seconds or so the alarm is completely reset and if needed can be re-triggered.

The alarm sequence will also be initiated if the 'EXTERNAL TRIGGER' point is connected to the zero volt time. Thus bonnet or boot opening may be detected by installing mercury tilt switches etc.

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5K–2M2 DP switched 60p ea.
100Ω–2M2 horizontal or vertical preset 6p ea.

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Type	PIV	I		Type	PIV	I	
W005	50	1A	22p	2KBB10	100	2A	39p
W01	100	1A	25p	2KBB20	200	2A	45p
W02	200	1A	30p	2KBB40	400	2A	50p
W04	400	1A	35p	BY225	200	4.2A	100p

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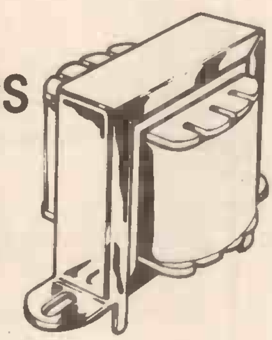

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AD162	38p	BD135	38p	2N2905	22p
BC107	8p	BD139	35p	2N2907	22p
BC108	8p	BD140	35p	2N3053	18p
BC109	8p	BF244B	36p	2N3055	50p
BC147	7p	BFY50	15p	2N3442	135p
BC148	7p	BFY51	15p	2N3702	8p
BC149	8p	BFY52	15p	2N3704	8p
BC158	9p	MJ2955	98p	2N3705	9p
BC177	14p	MPSA06	20p	2N3706	9p
BC178	14p	MPSA56	20p	2N3707	9p
BC179	14p	TIP29C	60p	2N3708	8p
BC182	10p	TIP30C	70p	2N3819	22p
BC182L	10p	TIP31C	65p	2N3904	8p
BC184	10p	TIP32C	80p	2N3905	8p
BC184L	10p	ZTX107	14p	2N3906	8p
BC212	10p	ZTX108	14p	2N4058	12p
BC212L	10p			2N5457	32p
BC214	10p			2N5458	30p
BC214	10p			2N5459	32p
BC477	19p			2N5777	50p
BC478	19p				
BC479	19p				
BC548	10p				
BCY70	14p				

DIODES

1N914	4p	1N4148	3p
1N4001	4p	1N5401	13p
1N4002	4p	1N5402	15p
1N4004	5p	1N5404	16p
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LS10	16p	LS138	54p
LS13	30p	LS139	50p
LS14	70p	LS151	50p
LS20	16p	LS153	50p
LS30	16p	LS155	80p
LS32	24p	LS156	80p
LS37	26p	LS157	45p
LS40	22p	LS164	90p
LS42	53p	LS174	60p
LS47	70p	LS175	60p
LS48	48p	LS190	80p
LS54	16p	LS192	70p
LS73	29p	LS193	70p
LS74	29p	LS196	80p
LS75	44p	LS251	60p
LS76	35p	LS257	55p
LS78	35p	LS258	55p
LS83	60p	LS266	40p
LS85	70p	LS283	60p
LS86	33p	LS290	55p
LS90	45p	LS365	45p
LS93	45p	LS366	45p
		LS367	45p
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741	22p	LM339	50p	NE565	120p
747	50p	LM380	75p	NE567	170p
748	30p	LM382	120p	SN76003	200p
CA3046	55p	LM1830	150p	SN76013	140p
CA3080	70p	LM3900	50p	SN76023	140p
CA3130	90p	LM3909	60p	SN76033	200p
CA3140	70p	MC1496	60p	TBA800	70p
LM301AN	28p	MC1458	35p	TDA1022	650p
LM318N	125p	NE555	25p	ZN414	75p

TTL

7400	12p	7493	34p
7401	12p	7494	52p
7402	12p	7495	52p
7404	12p	7496	50p
7408	14p	74121	25p
7410	12p	74122	33p
7413	25p	74123	40p
7414	48p	74125	35p
7420	12p	74126	35p
7427	24p	74132	50p
7430	12p	74141	56p
7442	43p	74148	90p
7447	55p	74150	70p
7448	58p	74151	50p
7454	14p	74156	52p
7473	25p	74157	52p
7474	25p	74164	70p
7475	32p	74165	70p
7476	28p	74170	125p
7485	70p	74174	68p
7489	145p	74177	58p
7490	32p	74190	72p
7492	35p	74191	72p
		74192	64p
		74193	64p
		74196	55p
		74197	55p

OPTO

LEDs	0.125in.	0.2in.	
Red	TIL209	TIL220	9p
Green	TIL211	TIL221	13p
Yellow	TIL213	TIL223	13p
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DISPLAYS

DL704	0.3 in CC	130p
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FND500	0.5 in CC	100p

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FULL DETAILS IN CATALOGUE

4001	15p	4029	60p
4002	15p	4040	68p
4007	15p	4042	54p
4011	15p	4046	100p
4013	35p	4049	28p
4015	60p	4050	26p
4016	35p	4066	40p
4017	55p	4068	20p
4018	65p	4069	16p
4023	15p	4071	16p
4024	45p	4075	16p
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		4518	70p
		4520	65p

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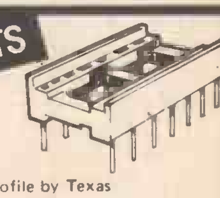
	100					8p
		220				10p
				470		15p
	1000					23p
10V		220				5p
				470		9p
	1000					13p
		2200				23p

SKTS



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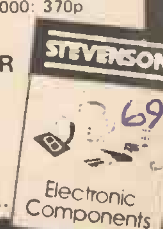

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O.S.T. Rules, O.K?

Ohm's Law is straightforward to most people but there are many occasions when it won't help us much in solving a problem. K. T. Wilson takes us through the steps to enable us to answer really tough problems.

MOST OF US know Ohm's law in its three forms V = R.I, R = V/I, I = V/R, and in the course of any sort of electronics work we use Ohm's law frequently, it becomes second nature, particularly in faultfinding. Is the current flowing through a particular transistor what we expect it to be? We don't usually measure the current as it means breaking the circuit, we simply measure the voltage across the emitter resistor and use Ohm's law to calculate how much current is flowing. Alternatively, we measure the voltage across the collector resistor and once again calculate the amount of current using Ohm's law.

We're so accustomed to using Ohm's law that it brings us up with a bit of a start when we find a problem which seems to be difficult or impossible to solve by Ohm's law alone. One type of problem of this sort is the two-supply problem, like the simple example in Fig. 1. In this type of circuit, a current through a resistor is supplied from two different sources — a situation we often find, for example, in the circuits of stabilised power supplies. The problem here is to find out how much current is flowing through the resistor. We can't assume that each supply will pass current as if the other supply were not there. In our example, the 10 V supply would pass a current of 10/3.3 mA which is 3.03 mA if we didn't have the 12V supply present, and the 12 V supply would pass a current of 12/3.7 mA, which is 3.24 mA if the 10 V supply didn't exist. We can't use these results, though. If the total current were 3.03 + 3.24 mA, a total of 6.27 mA, then the voltage across the 2k2 resistor would be, by Ohm's law, 6.27 x 2.2 = 13.8 V, which is more than either of the supply voltages, obviously wrong. Equally obviously, each supply must chip in a share of the current, but how can we calculate how much?

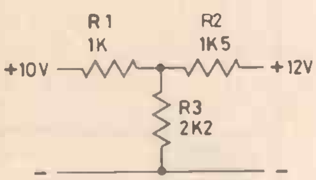

Fig. 1. The two-supply problem.

It's not at all difficult when you know how, and the 'how' is provided by a simple rule called the Superposition theorem. The Superposition theorem shows how the voltages across R3 can be added, separating the effects caused by each of the supply voltages. The solution takes as many steps as we have supplies — here goes!

1. Imagine the 12 V terminals shorted. The circuit now looks like Fig. 2, with R2 and R3 parallel. Combining 2k2 and 1k5 in parallel gives 892R, so that the circuit consists of a 10 V supply feeding 892R through a 1k series resistor. Using the potential-divider law, the voltage across the 892R resistor is now

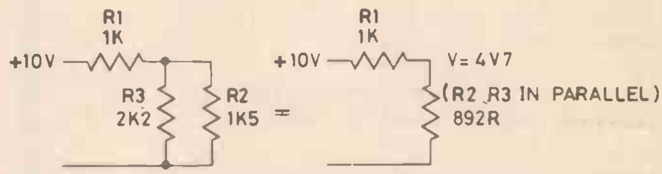

Fig. 2. How the circuit of Fig. 1 looks when the 12 V terminals are shorted.

$$\frac{10 \times 0.892}{1 + 0.892} = 4.7\text{ V}$$

(using units of kilohms for resistance). Note this value down.

2. Now imagine the 10 V terminals shorted, and the 12 V supply restored. The circuit now looks as in Fig. 3, with R1 and R3 in parallel. Combining 2k2 and 1k in parallel gives 687R, so that the circuit consists of 12 V feeding a 687R resistor through 1k5 series resistance. The voltage across the 687R resistor is now

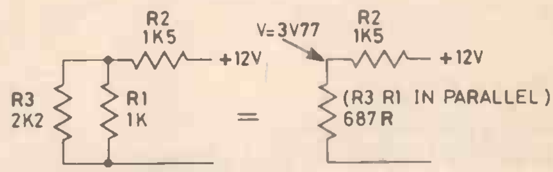

Fig. 3. How the circuit of Fig. 1 looks when the 10 V. terminals are shorted.

$$\frac{10 \times 0.687}{2.187} = 3.77\text{ V.}$$

Note this value too.

3. By the Superposition theorem, the total voltage across R3 when both supplies are present is simply the sum of the two voltages we have calculated: 4.7 + 3.77 = 8.47 V. By Ohm's law, the current flowing through the 2K2 resistor is

$$\frac{8.47}{2.2} = 3.85\text{ mA.}$$

This, of course, isn't the only way of solving such problems — there's another method using Kirchoff's Laws — but it's by far the easiest of all the methods, since all you need to know is how to find the sum of resistors in parallel, and how to use Ohm's law. Resistors in parallel, incidentally, are easily dealt with by most 'scientific' calculators. The sequence for resistors 2K2 and 1K5 is:

[2.2] [1/x] [+] [1.5] [1/x] [=] [1/x]

The display now shows the answer.

The Superposition theorem seldom appears in text books — perhaps the authors are told that it's cheating to show an easy method when there are complicated methods around — but it's a real life-saver for these kinds of problems. Just to recap on the method, what you do is to imagine every suppy voltage bar one shorted, then work out the resistances in parallel, and then the voltage across the resistors. Do this for each supply, and then add all the voltages. The total voltage is then the voltage which will be caused by all the supplies when the circuit is operating normally. That, incidentally, is where the name Superposition comes from — it means adding each voltage to the rest.

The idea behind the Superposition theorem is a very simple one — that a circuit consists of resistors and power supplies, and each power supply acts like a short circuit for another power supply. This simple idea can be extended to give one of the most useful rules in electronics — Thevenin's theorem. Never heard of it? You haven't lived — read on.

Thevenin's theorem states that any linear network can be represented by a voltage generator in series with a resistance. That's the way it's written in most textbooks, and you can be forgiven if you don't realise at once how useful this is. What is means is that any circuit containing resistances, no matter how complicated, behaves just like a power supply (with zero resistance) and a series resistor (Fig. 4), nothing more. This, of course, wouldn't be of much use unless we could easily

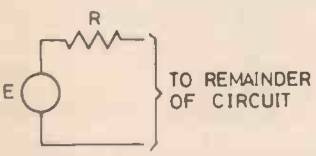

Fig. 4. By Thevenin's theorem, a linear circuit will behave like this — a voltage supply with a resistance in series.

calculate the voltage of the imaginary power supply and the value of the imaginary series resistance. Thevenin's theorem gives quite clear instructions.

(a) The supply voltage of the equivalent circuit is just the open-circuit voltage at the terminals of the circuit we are interested in,

(b) the resistance in the equivalent circuit is the total resistance between the terminals of the real circuit when the supply voltages are imagined short-circuited.

Let's look at an example — the potential divider in Fig. 5. Now when we use a potential divider circuit like this, we often assume that there is no current taken from the circuit. In such a case, the voltage at these terminals is given by the familiar potential divider equation

$$E\frac{R2}{R1+R2}$$

In our example, this voltage is

$$6\times\frac{6.8}{10.1}=4.04\text{ V.}$$

What you're never told in textbooks, though, is how to calculate the voltage at these terminals of a potential divider when you are drawing a current from it. Odd, when you think of it, because a potential divider circuit is the one we use almost universally for biasing the base of transistor circuits, and we can't always assume that the base current of the transistor is negligibly small.

Now, of course we can make use of Ohm's law, and after a long struggle find the voltage at the terminals when some value of current flows. Thevenin's theorem provides a much easier method, though. Let's take the values in the circuit of Fig. 5a. The supply voltage for the equivalent circuit is, by Thevenin's theorem, the open-circuit voltage at the terminals, which is just the 4.04 V we have calculated. The resistance between the terminals, assuming the supply to be short-circuited, is a 3k3 in parallel with 6k8, a value of 2k22. The circuit should therefore behave like a 4.04 V suppy with a 2k22 resistor in series (Fig. 5c). We can use Ohm's law to find out just what the effect of drawing current will be.

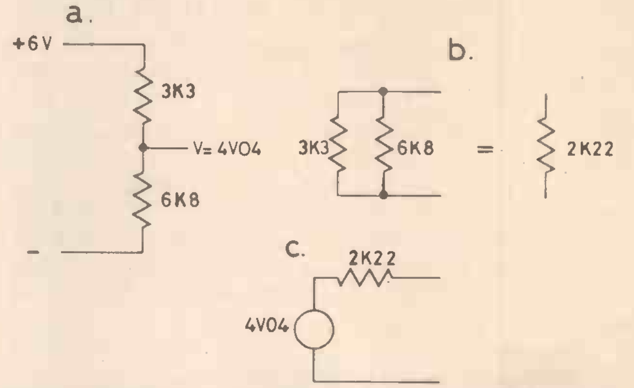

Fig. 5. A potential divider circuit (a) is equivalent to a voltage (the open circuit voltage) in series with resistance, found by combining the resistors in parallel (b). The result is shown (c).

For example, if we draw 1 mA from the circuit, there will be a drop in voltage of 1 x 2.22 V across the 2k22 resistor, so that the voltage at the output will be 2.22 V down on the open-circuit voltage of 4.04 V, making the output voltage 4.04—2.22 = 1.82 V. If we use this potential divider to feed a transistor whose base takes 80 uA, then the 80 uA will cause a drop of 0.08 x 2.22 = 0.177 V across the 2k22, and the voltage at the base will be 4.04—0.177 = 3.86 V. Even this small amount of current has caused a noticeable drop of voltage, and a voltmeter connected to the output of the potentiometer would cause an additional voltage drop, since most voltmeters take an appreciable amount of current from the circuit in which they are used.

Thevenin's theorem, however, really comes into its own when we have the sort of nightmare circuit which seems impossible to solve by Ohm's law. One which often crops up is the unbalanced bridge. Now the Wheatstone bridge network is a nice simple one when the bridge is balanced. If R1/R2 = R3/R4 (Fig 6a) then the current through R5 is zero, no problem. For some types of measurement though, we need to know how much current flows through R5 when the bridge is *not* balanced — one example is the use of thermistor bridge circuits for measuring temperature. This is a most frustrating problem to attempt to solve by any other method — let's look at the Thevenin method.

We start by removing R5, leaving the terminals X and Y (Fig 6b). If we can now reduce the rest of the circuit to one voltage and a resistance in series, as Thevenin's theorem promises, we can easily calculate the current which will flow when R5 is put into its place again. With the circuit now consisting of two potential dividers, the open-circuit voltage across XY is comparatively easy to calculate. The voltage at X is

$$9\times\frac{6.8}{10.1}=6.06\text{ V}$$

and the voltage at Y is

$$9\times\frac{5.6}{10.3}=4.89\text{ V.}$$

using the potential divider formula each time. The voltage between X and Y is the difference between these two, which is 6.06—4.89 = 1.17 V. It's this value of voltage which goes in as the supply voltage in the equivalent circuit.

Finding the resistance takes a little more agility in re-drawing the circuit. Fig. 6c shows the 9 V supply terminals short-circuited, and the circuit re-arranged so that we can see that it consists of R1 in parallel with R2, and R3 in parallel with R4, the two sets of parallel resistors being in series. Solving for 3k3 in parallel with 6k8 gives 2k22, and 5k6 in parallel with 4k7 gives 2k55, so that the total resistance is the sum of these two, 4k77. This, then, is the resistance in the equivalent circuit.

We can now find the amount of current flowing through any resistor connected between X and Y by using this equivalent circuit. For example, if we have 1kO connected between X and Y, the total resistance in the (equivalent) circuit is 5k77, the voltage is 1.17 V, so that the current is

$$\frac{1.17}{5.77} = 0.203 \text{ mA}$$

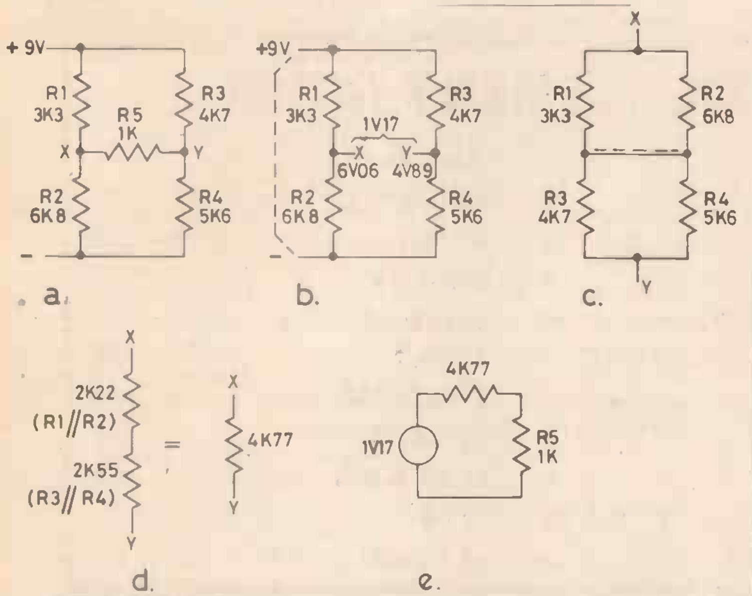

Fig. 6. The bridge circuit (a) is unbalanced. The open circuit voltage across R5 is easily found (b); finding the resistance (c) needs a little bit of re-drawing (d). The final equivalent is shown in :e).

or 203 uA. The bridge isn't far from balance in this example.

Just for a tail-piece, how about calculating the total current flowing from the 10 V supply through the circuit of Fig. 7. Very nasty by any method other than Thevenin, because you don't know how much current flows through the 4R resistor. The Thevenin method uses two steps —

(1) Remove the 4R, and find the equivalent circuit, which is a 0.67 V supply and a 1R86 resistor as in Fig. 7b.

(2) Replace the 4R, and find the current through it, which is 0.113 A. The rest of the problem is now good old Ohm sweet Ohm. We redraw the circuit, showing the current through the 4R resistor, and the other current I_1 and I_2 as in Fig. 7c. The voltage across the 1R and the 2R in series must be 10 V, since that's the supply voltage, and the voltage across the 2R and the 3R in series must also be 10 V. Because of the current through the 4R

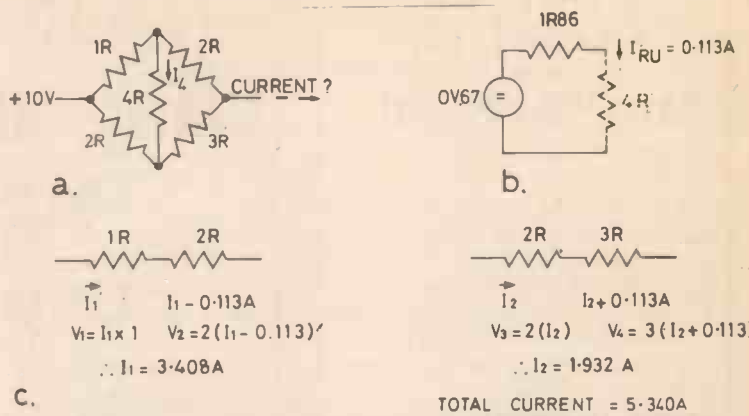

Fig 7. Another awkward circuit, almost impossible to solve by other methods.

'bridge' resistor, current I_1 flows only through the 1R, and I_1—0.113 A flows through the 2R. Similarly in the other branch, I_2 flows in the 2R and I_2+0.113 in the 3R. Solving gives I_1=3.408 A and I_2=1.932 A, a total of 5.34 A drawn from the 10 V supply. Comparatively easy be this method — but just try it any other way!

The title? Ohm, Superposition, Thevenin, of course. We wouldn't get very far in design work without them, and yet so many texts deal only with Ohm's law. If you want a good demonstration of how easy other rules make the solution of problems, just ask anyone who doesn't know them to solve one of the problems shown here — but first be sure that you can do it yourself by the OST rules! **HE**

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Good Evans

WHAT DOES a 74339 IC do, what is the lead out configuration of a BC108, where would i find the circuit diagram of a 5V, 1A power supply. The answers to these questions, and many more as they say could be found in any good data book or, perhaps, a painstakingly compiled collection of manufacturer's data. Any serious hobbyist should/must have access to this type of information. But what if I want to know how much a 74339 costs or to whom I should send my cash when I want to buy one.

The answer to these latter questions can be found in the catalogues now produced by many of the component supply companies advertising within the pages of Hobby Electronics. But wait — many of these tomes contain a hidden bonus that makes them just about invaluable to the Home Constructor. They contain all the device function, lead out data and circuit tips that the amateur is likely to want. Two birds with one tome!

The arrival of a new catalogue of the updating of an old favourite is welcomed by Hobbyists and people who work for electronic magazines (who in the case of HE all fall into the former group anyway) alike.

It just so happens that at this time we have both the launch of a brand new catalogue and the relaunch of an old favourite, it could be this fact that prompted these words.

Reissue would be the wrong word to use for the latest offering of the Maplin Catalogue. Dogeared copies of their bumper sized forerunner can be found in many an amateur's workshop. The latest effort designed to go one better contains details of the large range of electronic bits and pieces stocked by Maplin, large sections of data and a collection of projects (some in glorious colour) ranging from the super complex — electronic pianos et. al. — to those more within the reach of the likes of us.

Put down Jaws 4, Star Wars 6, the Private Life of Superman's Valet or whatever "bestseller" you happen to be reading and spend the night with Maplin. Spend the next with Watford.

Watford Electronics, like Maplin, can supply most of the amateur's electronic needs and have, unbelievably not had a catalogue to date. The reason has simply been that they have not had time to maintain their ever increasing stock, maintain service and find time to prepare a cat. Service came first! It's even better now and it was worth the wait.

Following the same lines as the Maplin offering with information data and, in Watford's case the promise of a DIY computer soon. A valuable addition to any book shelf.

Whether you're trying to keep up with the ever changing world of Electronics as a job — Oh such a responsibility — or just interested as a hobby add a catalogue to your list of musts. Just in case some of you have got the impression that Watford and Maplin have an exclusive in catalogue line, now's the time to put the record straight. Marshall's ACE, in fact just about every advertiser of components has a catalogue/stocklist that details a far greater range of devices and shows far more data than it is possible to display in a small advert.

WE — SWITCHES — 41

TOGGLE SWITCHES

Model	Type	Tags	Action	Rating	Size	Price p
Standard						
TS1	SPST	2	On-Off (chrome toggle)	250V a 2A	25.5 x 13.8 x 14mm	48p*
TS2	SPDT	4	On-On (chrome toggle)	250V a 2A	25.5 x 13.8 x 14mm	54p*
TS3	DPDT	6	On-On (chrome toggle	250V a 2A	29 x 18 x 17mm	58p*
Miniature						
TS4	SPST	2	On-Off (red dolly)	250V a 2A	12 x 6 x 9mm	54p*
TS5	SPDT	3	On-On (red dolly)	250V a 2A	12 x 6 x 9mm	59p*
TS6	SPDT	3	On-Off-On (chrome toggle	250V a 2A	12 x 8 x 11mm	78p*
TS7	SPST	3	On-Biased On (chrome toggle)	250V a 2A	12 x 6 x 10mm	85p*
TS8	DPDT	6	On-On (red dolly	250V a 2A	12 x 11 x 10mm	70p*
TS9	DPDT	6	On-Off-On (chrome toggle	250V a 2A	12 x 11 x 10mm	79p*
TS10	DPDT	6	On-Off-Biased On (chrome toggle)	250V a 2A	12 x 11 x 10mm	115p*
			Dollies are removable to give chrome toggle.			
Micro Miniature						
TS11	SPST	2	On-Off (chrome toggle)	250V a 2A	8 x 5 x 7mm	48p*
TS12	SPDT	3	On-Off (chrome toggle)	250V a 2A	8 x 5 x 7mm	52p*
TS13	DPDT	6	On-On (chrome toggle)	250V a 2A	8 x 5 x 7mm	59p*
			N.B. The above switches are marked 125V a 5A. Their rating at 250V is 2A			
Hi-Fi Type						
TS14	DPDT	6	On-On (Brushed aluminium tog)	250V a 2A	20 x 9 x 15mm	58p*
TS15	4PDT	12	On-On (Brushed aluminium tog)	250V a 2A	46 x 11 x 19mm	54p*

ROCKER SWITCHES

Model	Type	Tags	Action	Rating	Size	Price p
Standard						
RS1	SPST	2	On-Off (Black	250V a 10A	30 x 14 x 19mm	23p*
RS2	SPST	3	On-Off-On (White, marked 1-0-2	250V a 5A	30 x 14 x 16mm	30p*
RS3	DPST	4	On-Off (White with red markings	250V a 10A	30 x 25 x 20mm	40p*
RS4	SPST	3	On-Off (Red neon with chrome bezel	250V a 5A	25 x 11 x 22mm	52p*

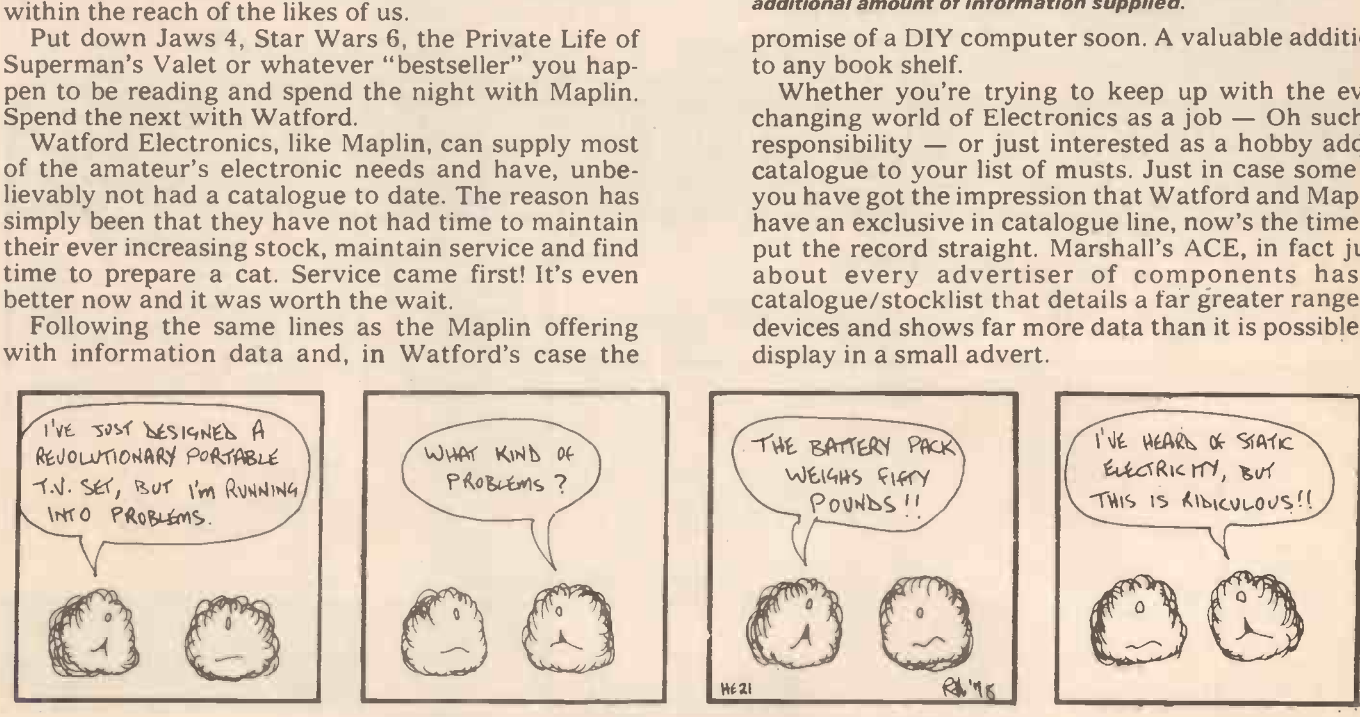
PUSH BUTTON SWITCHES

Model	Type	Tags	Action	Rating	Size	Price p
High Quality						
PB1	SPST	2	Push on-Push off (With Red Knob)	250V a 2A	11 x 7 x 17mm	65p*
PB2	SPDT	3	Push on-Push on (With Red Knob)	250V a 2A	11 x 7 x 17mm	70p*
PB3	DPDT	6	Push on-Push on (With Red Knob)	250V a 2A	11 x 11 x 17mm	85p*
Good Quality						
PB4	SPST	2	Push to make (Red top, chrome body)	250V a 2A	16 x 11mm (dia)	35p*
Miniature						
PB5	SPST	2	Push to make	250V a 1A	16 x 6mm (dia)	15p*
PB6	SPST	2	Push to break	250V a 1A	16 x 6mm dia	25p*
Printed circuit type						
PB7	DPDT	6	Push to make-Push to break (black	250V a 1.5A	25 x 9 x 7mm	54p*
PB8	DPDT	6	Push to make-Push to break / Less knob	250V a 1.5A	24 x 10 x 11mm	25p*
PB9	DPDT	6	Bank of 4 intercancelling switches Less knobs	250V a 1.5A	63 x 21 x 8mm	110p*
PB10	DPDT	6	Bank of 4 independent switches/ Less knobs (action as PB8)	250V a 1.5A	63 x 21 x 8mm	110p*
PB11	4PDT	12	Bank of 8 intercancelling switches/ complete with black knobs (limited stock	250V a 1.5A		215p*
PB Knob			Brushed aluminium knob for above		28 x 10mm dia	14p*
Foot Switch						
PB12	DPDT	6	Push to make-Push to break (Unmounted) heavy duty	250V a 2A	38 x 15 x 15mm	185p*
Pedal Switch						
PB13	SPST		Push to make - Release to break	250V a 5A		240p*

SLIDE SWITCHES

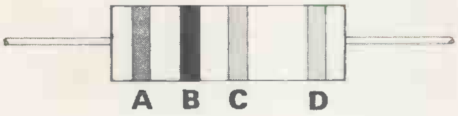
Model	Type	Tags	Action	Rating	Size	Price p
SS1	DPDT	6	On-On (Black slider) miniature	250V a 1A	15 x 7 x 7mm	13p*
SS2	DPDT	6	On-On (Black slider)	250V a 1A	22 x 13 x 8mm	14p*
SS3	DPDT	6	On-Off-On (Black slider)	250V a 1A	22 x 13 x 8mm	15p*
SS4	4PDT	12	On-On (Black slider)	250V a 1A	30 x 9 x 12mm	24p*

A page from Watford's new catalogue shows that much more is given than a crude description and cost. Most suppliers charge for their catalogues but this is quite fair bearing mind the additional amount of information supplied.



Hobby Electronics

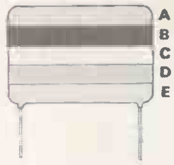
RESISTOR COLOUR CODE



	A and B	C
BLACK	0	- - ohms
BROWN	1	- - 0 ohms
RED	2	- k -
ORANGE	3	- - k
YELLOW	4	- - 0 k
GREEN	5	- M -
BLUE	6	- - M
VIOLET	7	
GREY	8	
WHITE	9	

	D (tolerance)
NONE	20%
SILVER	10%
GOLD	5%
RED	2%
BROWN	1%

CAPACITOR COLOUR CODE



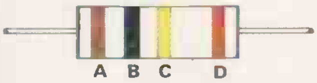
	C
BLACK	- - p
BROWN	- - 0 p
RED	- n -
ORANGE	- - n
YELLOW	- - 0 n
GREEN	

D (tolerance)	
BLACK	20%
WHITE	10%
GREEN	5%

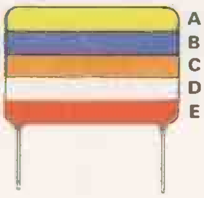
E (voltage)	
RED	250 V

A and B: As for resistors.

EXAMPLES:



A = 1, B = 0, C = - - 0 k, so value is 100 k; D = accuracy = 2%



A = 4, B = 7, C = - - n, so value is 47 n; D = accuracy = 10%; E = voltage = 250 V

BRITISH STANDARD COMPONENT MARKINGS

M (pronounced mega) means multiply by 1 000 000,
k (pronounced kilo) means multiply by 1 000,
m (pronounced milli) means divide by 1 000,
u (pronounced micro) means divide by 1 000 000,
n (pronounced nano) means divide by 1 000 000 000 and
p (pronounced pico) means divide by 1 000 000 000 000.

So when we write 10 mV, we mean (10 / 1000) V, or 0.01 V. Note: it is usual to leave the "F" and "ohm" out altogether when writing, but as we rarely talk about resistances less than one ohm or capacitances greater than one farad, this does not cause *too* much confusion.

Examples: 10 uV = (10 / 1 000 000) V = 0.000 001 V; 330 R = 330 ohms (R is used for ohms when no multiplier is needed); 10 k = 10 000 ohms; 3.9 mV = 0.003 9 volts; 3.9 u = 0.000 003 9 farads.

Now, at some stage, someone decided to jazz up the system by putting the suffix in place of the decimal point, so that: 4k3 is 4 300 ohms and 4u9 is 0.000 004 9 farads.

Also, in case one of the digits got lost, it was decided that there should always be at least three numbers or letters in the value, so: 5k is written 5k0, et cetera.

Examples: 3M0 = 3 M ohms = 3 000 000 ohms; 4n5 = 4.5 nF = 0.000 000 004 5 farads.

INTEGRATED CIRCUIT NUMBERS

TTL: (SN)74(90) — Example: DM 74121

manufacturer — device function (2 or 3 digits)

CMOS: (CD)40(42)(A) — Example: CA 4015 B

manufacturer — device function (2 digits) — electrical fragility (A = do not handle — static charges will destroy device; B or C = protected against static)

OTHER TYPES: (uA)(741) — Examples: LM 309, CA 3011, NE 555

manufacturer — device function (3 or more digits)

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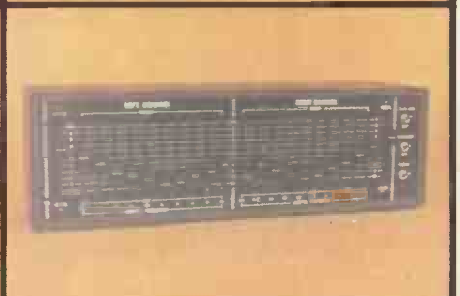

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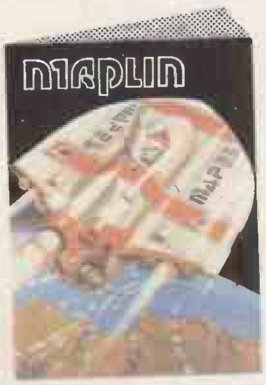

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