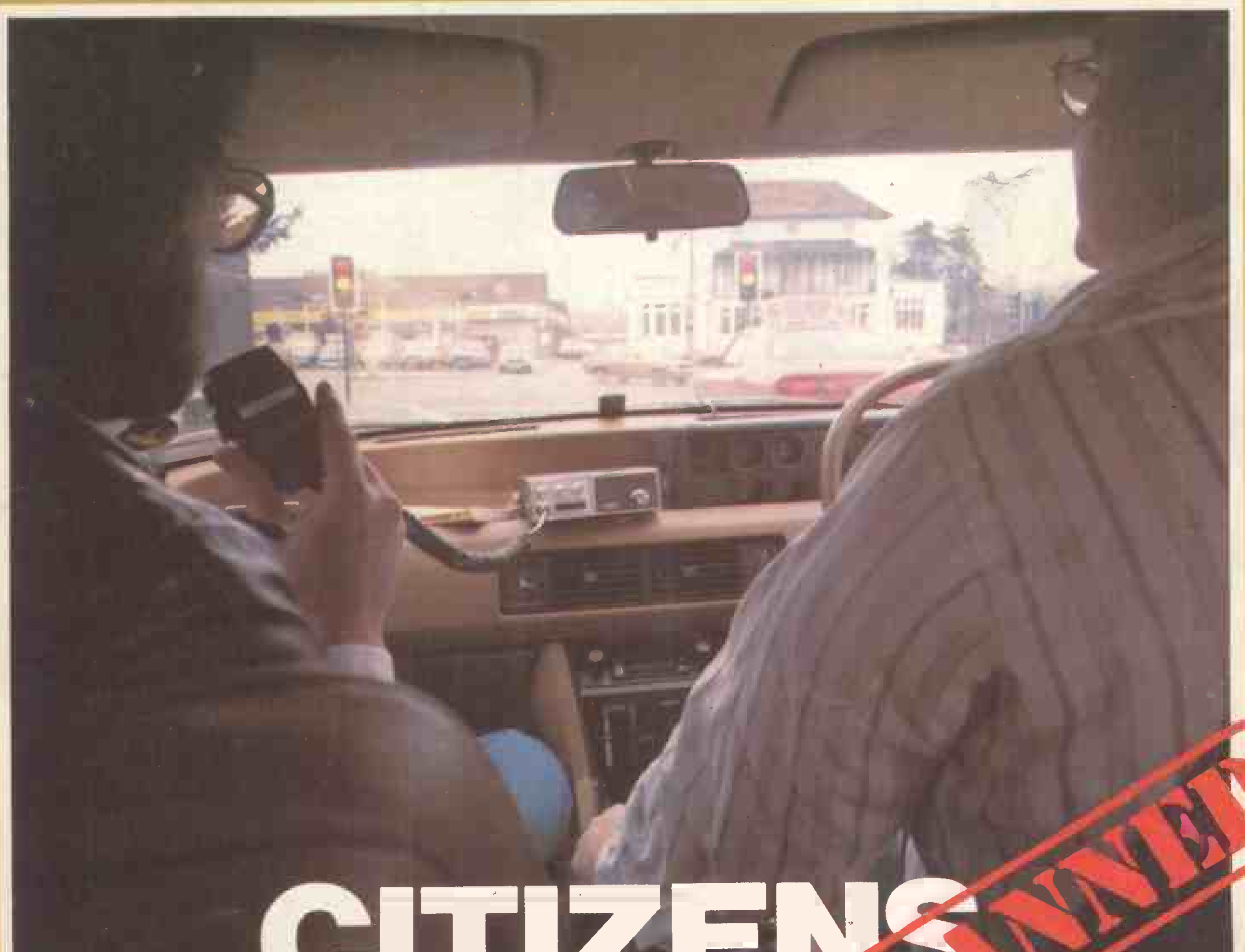
ISSN 0142-6192

Hobby Electronics

June '79
40p



CITIZENS BANNED

Moving Coil Multimeters
The most useful piece of test equipment

GSR Monitor
Galvonic Skin Reistance

Drill Speed Controller
One for the handyman

ASDR Envelope Generator
Novel sound effects unit

Display Techniques
A minor revolution

Internal Resistance
Critical design factors in electronics

ambit® international

The PW Sandbanks Metal Locator: a kit based on this recently published design for this uniquely effective type of metal locator is available for only £35.00 + 8% VAT. The kit closely resembles the appearance as published, except that a close fitting injection molded housing replaces the vacuum molded electronics box - to improve the enviromental suitability of the construction. Carriage for complete kits £1.

The New Catalogue - "Tecknowledgey Part 2"
Part 2 of the catalogue: by the time this advert reaches the press, part 2 should be on sale. Sorry it's late, but it contains so many new and interesting things that we felt we had to hold up production to include them. Part three by the autumn -and already there are many new items to go in! Part one 45p, part 2 50p. (inc PP etc).

Radio ICs

TDA1062	HF/VHF tunerhead	1.95
TDA1083	One chip AM/FM rx	1.95
TDA1090	One chip HiFi am/fm	3.35
TDA1220	One chip am/fm rx	1.75
HA1197W	HiFi AM tuner IC	1.40
CA3123E	AM tuner IC	1.40
TBA651	AM tuner IC	1.81
CA3089E	Famous FM IF system	1.94
CA3189E	As 3089+ deviation mute AF preamp, adj, agc	2.75
HA1137W	Improved S/N 3089	2.20
TBA120	limiting amp+detector	0.75
TBA120S	high gain	1.00
MC1350P	agc'd IF preamp	1.20
MC1330P	synch AM/video detector	1.35
KB4406	Cascode IF preamp	0.65
uA753	limiting FM preamp	1.95

Communications circuits

SD6000	DMOS RF/Mixer pair	3.75
KB4412	Bal mixers, IF+agc	2.55
KB4413	AM/SSB det. squelch,agc	2.75
KB4417	mic processor	2.55
MC3357	best thing in NBFM yet	3.12
MC1496P	popular double bal mixer	1.25

Multiplex decoders + noise blanker

MC1310P	popular PLL decoder	2.20
uA758	buffered 1310	2.20
CA3090AO	RCA PLL decoder	3.25
HA1196	improved PLL decoder with stereo preamps	3.95
HA11223	19kHz pilot cancel, low distortion, high S/N	4.35
KB4437	as HA11223 with remote VCO kill facility	4.55
KB4438	stereo MUTING preamp for post decoder mute	2.22
KB4423	impulse noise blanker	2.53

Discrete devices: more than ever:

BF960	800MHz/2.8dB nf mosfet	1.60*
BF961	200MHz/2.0dB nf	0.80*
40822	FM RF amp	0.43*
40823	FM mixer	0.51*
40673	Famous MOSFET	0,55*
2SJ49/2sK133	120v/100W MOSPOWER output devices	10.50*

LEDS: the best value today

	3mm	5mm	2.5x5mm
Red	0.14	0.14	0.17
Green	0.18	0.16	0.20
Yellow	0.18	0.15	0.20
Orange	0.22	0.29	0.24

100 off mix, 25% discount. All are AEG first grade types - absolutely no junk. 5mm clips for panel mounting 0.03 each

Misc. ICs for radio/audio applications

U237B	5 LED bargraph driver	0.80*
SAS6610	4 station touch tune IC	1.48*
SAS6710	adds 4 stations to 6610	1.48
MSM5523/4	LW,MW,SW and FM digital frequency readout plus clock, timers, stopwatch	£14*
MSM5526	LW/MW/FM DFM with direct drive for LCD	£11*
TCA730	DC volume control	3.50
TCA740	DC tone control	3.50
TDA1028	DC input switch	3.50
TDA1029	DC mode switch	3.50

Radio and Tuner modules
We cannot really list all the details we would like to here - but with advent of the new mark 3 tuner system, the Dorchester and matching AF units, Ambit offers you the widest choice ever, plus hardware and styling that matches the very high standards we have set in this new range.

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............

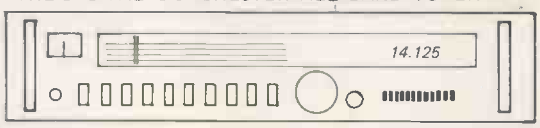
- ★ Exceptionally high performance - exceptionally straightforward assembly
- ★ Baseboard and plug-in construction. Future circuit developments will readily plug in, to keep the MkIII at the forefront of technical achievement
- ★ Various options and module line ups possible to enable an installment approach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

THE DIGITAL DORCHESTER ALL BAND TUNER



With styling and dimensions to fit in with the rest of AMBIT's new range of tuner & audio equipment.

When the new range of OKI digital frequency display ICs was announced, the original prototype of the Dorchester had been made - but since so many of you wanted to use the OKI frequency counterdisplay system with the Dorchester, we quickly designed a unit to incorporate the necessary facilities. The Digital Dorchester is designed in 19 inch form, and forms a perfect match for the other units in the range. If you don't want to go to the expense of the full Ambit DFM1 module, with AM/FM/Time/Timers, then the MA1023 clock module can be used instead.

The Dorchester has been described in PW Dec., Jan. and Feb. issues - but for those of you who may have missed it - it is an All Band broadcast tuner, covering LW/MW/SW and FM stereo in 6 switched ranges. Construction is very straightforward, with all the switching being PCB mounted - and the revolutionary TDA1090 IC used for AM/FM.

The electronics for the radio section of the Dorchester remain unchanged at £33.00, with 12.5% VAT. The hardware package, of case, meter, PSU now costs £33.00 + 8% with the MA1023 available for an extra £5 only.
For the fully digital version, with Ambit DFM1, the price is £56.50 + 8% VAT.

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.

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

6800P	6.50
6820P	£6
6850P	2.75
6810P	£4
6852	3.65

8080 series

8080	6.30
8212	2.30

8216	1.95
8224	3.50
8228	4.78
8251	6.25
8255	5.40

MEMORIES

2102	£1 70
2112	£3 40
2513	£7.54
4027	£5 78
2114	£10
2708	£10.55

Development

MEK6800	£220
TK80	£306

AMI, Signetics TI, Intersil, Harris etc OA

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

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

OPTO 7 seg displays

0.43" High Efficiency HP:

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

0.3" Standard HP

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

0.5" Fairchild

FND500	red CC	150p
FND507	red CA	150p

TTL :Standard AND LP SchottkY

SEE THE AMBIT AD TOO!

	'N'	'LSN'		'N'	'LSN'		'N'	'LSN'		'N'	'LSN'
7400	13	20	7455	35	24	74126	57	44	74185	134	
7401	13	20	7460	17		74128	74		74188	275	
7402	14	20	7463			74132	73	78	74190	115	92
7403	14	20	7470	28		74133		29	74191		
7404	14	24	7472	28		74136		40	74192	105	180
7405	18	26	7473	32		74138		60	74193	105	180
7406	38		7474	27	38	74139		60	74194	105	187
7407	38		7475	38	40	74141	56		74195	95	137
7408	17	24	7476	37		74142	265		74196	99	110
7409	17	24	7478			74143	312		74197	85	110
7410	15	24	7480	48		74144	312		74198	150	
7411	20	24	7481	86		74145	65		74199	160	
7412	17	24	7482	69		74147	175		74248		90
7413	30	52	7483A			74148	109		74249		93
7414	51	130	7484	97		74150	99		74251		90
7415		24	7485	104	99	74151	64	84	74253		105
7416	30		7486		40	74153	64	54	74257		108
7417	30		7489	205		74154	96		74258		153
7420	16	24	7490	33	90	74155	54	110	74259		420
7421	29	24	7491	76	110	74156	80	110	74260		153
7422	24	24	7492	38	78	74157	67	55	74261		353
7423	27		7493	32	99	74158		60	74266		40
7425	27		7494	78		74159	210		74273		124
7426	36	27	7495A	65	99	74160	82	130	74275		312
7427	27	29	7496	58	120	74161	92	78	74279		52
7428	35	32	7497	185		74162	92	130	74283		120
7430	17	24	74100	119		74163	92	78	74290		90
7432	25	24	74104	63		74164	104		74293		95
7433	40	32	74105	62		74165	105		74295		120
7437	40	24	74107	32	38	74166			74298		100
7438	33	24	74109	63	38	74167	20		74324		157
7440	17	24	74110	54		74168			74325		242
7441	74		74111	68		74169		200	74326		247
7442	70	99	74112	88		74170	230	200	74327		237
7443	115		74113		38	74172	625		74352		100
7444	112		74114		38	74173	170		74353		100
7445	94		74116	198		74174	87	120	74362		715
7446	94		74118	83		74175	87	110	74365		49
7447	82		74119	119		74176	75		74366		49
7448	56	99	74120	115		74177	78		74367		43
7449		99	74121	25		74180	85		74368		49
7450	17		74122	46		74181	165	350	74373		77
7451	17	24	74123	48		74182	160		74374		77
7453	17		74124			74183		210	74375		60
7454	17	24	74125	38	44	74184	135				

	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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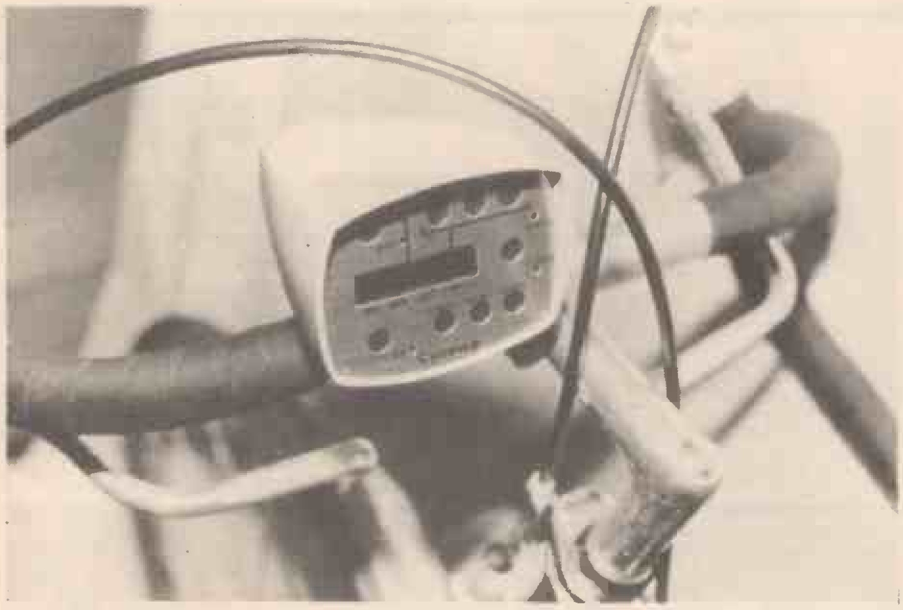
Monitor



MEGA-CYCLE?

It's good to see young engineers being encouraged to develop their ideas. We've just received the results of the 'Bike of the Future Design Competition', organised by the British Cycling Bureau.

In the Accessories and Components category John Colesby took a joint first prize (£250) for his 'Cyclometer'. A magnetic sensor on the front wheel is connected to the meter body on the handlebar. A readout of speed (MPH or KPH) is constantly available, along with maximum speed achieved, average speed and distance covered. In addition it can be used as a stopwatch and a 24 hour clock as an option.

Already plans are afoot to market the device commercially and it is hoped it will be generally available in the autumn for around £20-25.

RICH MAN'S TURNTABLE

If your bank balance is sufficiently fluid and you're really into Hi-Fi then this has got to be for you. We don't know if it sounds any better for costing £350.00 but just think how impressed the neighbours will be when they hear how much you paid for it. Seriously though, the turntable is an extremely well made device. It is destined for the professional user (they're the only ones who could afford it).

It features an electronic speed control with direct speed readout on an LED display. The turntable which is instant starting, provides for slip cueing without a loss in speed and it has back cueing with no drag. Lee Engineering Ltd will be marketing the 'QRK Electronics Galxy', you can find them at: Napier House, Bridge Street, Walton-on-Thames, Surrey.

IRON TAMER

If you've ever suffered from Nylo-sock solderitus (a large blob of solder stubbornly clinging to your skin). The infamous Solder Moth (known for eating large holes in poly-cotton material) or long mysterious scars all over your hands and body, then you're a victim of a wild soldering iron attack.

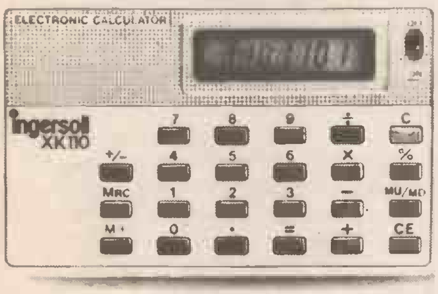
Soldering irons have been known to leap up without warning at an unsuspecting hobbyist, inflicting grevious wounds. A simple way to control these unruly beasts is to invest in a cage. Adcola, the soldering iron people have introduced such a device, called the L686S Safety Stand. It currently retails for £3.06. If you have any difficutly write to:- Adcola, Adcola House, Gauden Road, London SW4 6LH.

News from the Electronics World

CALCULATOR OF THE MONTH

This month's calculator offering hails from Ingersol of all people, (believe it or not Casio have **not** sent us anything this month!). This machine is very much in the 'credit-card' size range, weight is around 1.25 oz and measures 53 × 85 × 5 mm (approx.)

Features include the now mandatory 8 digit LCD display with fully floating decimal. In close attendance lurks a 4 function memory, percentage/square root and several other inidspensible features. You can expect a 2 000 hour battery life (how could we survive with anything less?) Price? Around the £18.95 mark at your local calc. emporium now.



SOLID STATE CAMERA

Well it had to happen, a really small solid-state camera has been launched upon the unwary British market. The heart of the camera is a 100 × 100 photodiode matrix on a 6mm² silicon chip. The uses are obviously very wide ranging, surveillance and military weapon guidance for instance.

The camera gives a fully line-interlaced TV output, compatable with most systems. The camera was developed in America by the Reticon Corporation. UK distribution is being handled by Herbert Sigma Ltd, Spring Road, Letchworth, Herts.

TINY TELLY

Latest news from Japan hints that the long awaited LCD pocket television will be available early next year. We've got some rather vague details, scxreen size is 2.4 inches, the set consumes only 1.5 watts (only!) and weighs in at 200 grammes. The LCD matrix has 57 600 picture elements (240×240 array). Judging from the rather poor picture we have, it looks rather like a cross betweden a powder compact and an Starship Enterprise communicator. We just wish they would hurry up we're dying to get our hands on one.

TECHNICAL ENQUIRY SERVICE

As you probably know we offer a Technical Query service for our readers (HE projects only please). If you've written to us and not received a reply it's because you didn't enclose a SAE. Sorry to all those who have called us every name under the sun but we really can't afford the postage. PS please mark your envelopes 'Technical Enquiry'.

ERRATA

If you find that your Digi-Bell project doesn't work very well we're sorry to say there was a little ommision on the PCB, a link between pin 1 of IC2 and the junction of C1 (-ve) and R2 was left out.

PARKING METER TIMER

Components for this project should be readily available from most suppliers.

The three position slide switch is available from Stevenson Electronics, or Watford Electronics.

The audible warning device (9v-15mA) can be obtained from Progressive Radio, 31 Cheapside, LIVERPOOL L2 2JD.

We're sorry that some information was omitted from last month's project and hope this will answer any queries.

We apologise to readers of HE for the lateness of recent issues. This has been due to printing problems outside our control; we hope that these will be short-lived.

MICRO-TAPE

The micro-cassette system was first introduced by Phillips several years ago. It has, over the past couple of years enjoyed a great deal of popularity. Several new micro-recorders using the Phillips format have appeared, finding many applications in dictation etc.

The model featured here is claimed to be the smallest yet. The machine is of American origin and measures only 4.1 × 2.5 × 1 inches and weighs just 8.5 ounces, real spy stuff. The recorder has a single slide control to operate record, stop, rewind and playback functions. Up to 1 hours playing time is available from each cassette, (30 mins per side).

The built-in electret microphone is capable of picking up whispered conversions from over 30 ft away. An LED indicator shows when a recording is in progress, and an audible end-of-tape alarm is included.

Obviously all this not going to be cheap an incredible £120 in fact. But as we've seen so many times in the past, prices have a habit of tumbling, very rapidly. If you've got the money (and inclination) contact: Lanier Business products Inc, 100 New Kings Road, London, SW6.

GSR Monitor

Get into the biofeedback scene and learn to relax scientifically with our Galvanic Skin Response Monitor

THE HE Galvanic Skin Response monitor is a sensitive resistance-monitoring instrument that produces an audible output that changes frequency in response to small changes in the 'victims' skin resistance. The instrument is intended for use in biofeedback experiments, as an aid to reducing or relaxing nervous tension.

The basic theory behind biofeedback is quite simple. Human beings, like most other animals, have the ability to exert a high degree of muscular control in response to visual, aural, thermal, tactile, and other 'sensed' feedback mechanisms. They can control virtually any physical or biological activity that they are able to sense or monitor.

Humans can't normally control functions like heart rate, blood pressure, body temperature, mental activity, emotional stress, etc, because they have no innate way of sensing these so-called 'automatic' actions. The biofeedback theory says that if you provide a person with an artificial means of sensing or monitoring any one of these functions, that person can soon learn to bring that function under conscious control.

MIND OVER MATTER

The biofeedback theory works out pretty well in practice, and biofeedback machines are now widely used in medical and scientific research establishments. One of the most interesting aspects of biofeedback applies to the control of functions of the mind such as nervous tension and anxiety. That's where the GSR monitor comes in.

ALL IN THE MIND?

The human body reacts in several ways when its owner is subjected to mental stress or strain. Extra adrenaline is released, the heart rate increases, and sweat gland activity and pore sizes increase. These last-mentioned two reactions are reflected in a change in the resistance of the skin. The resistance falls as tension increases, and vice versa.

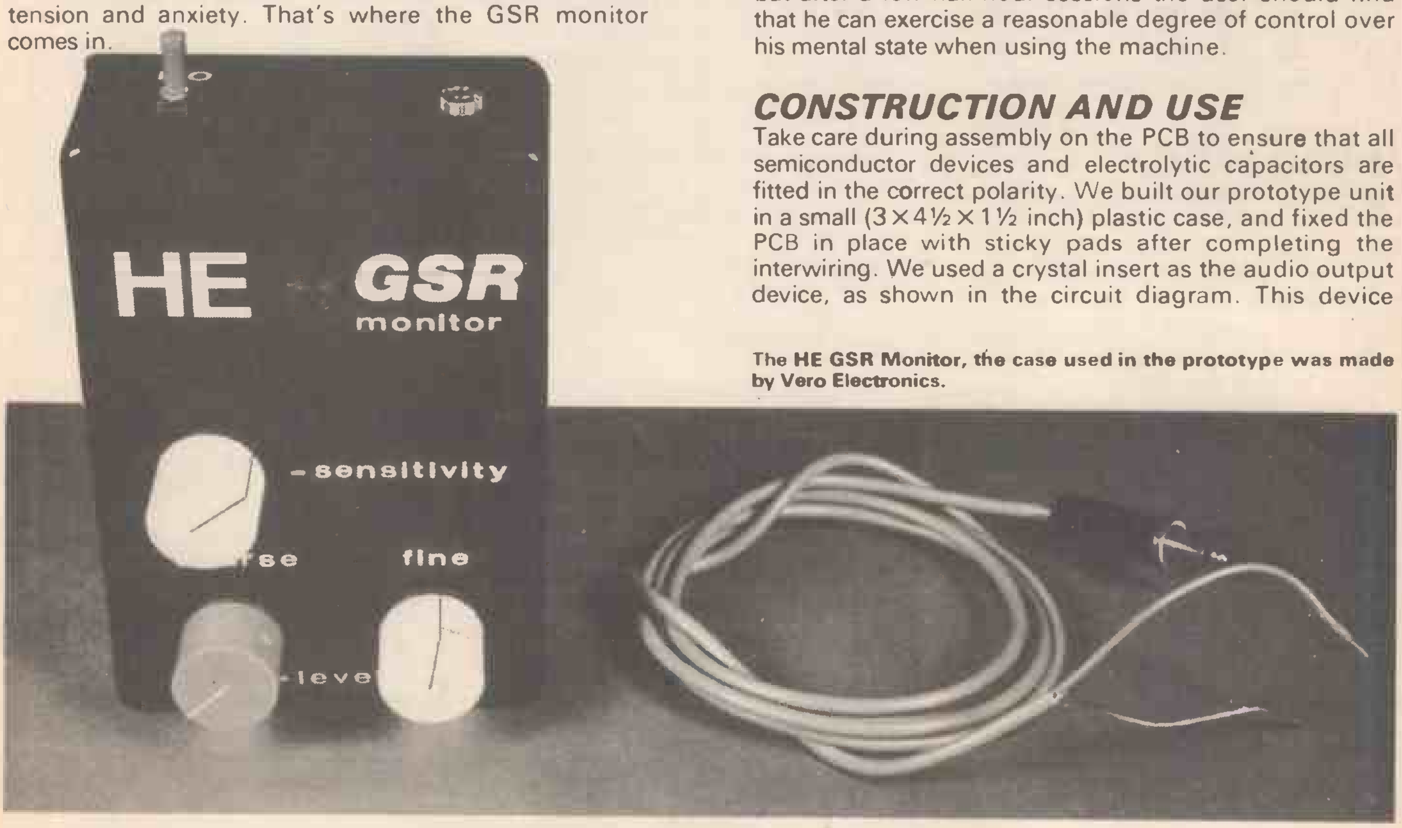
The GSR monitor gives a practical readout of the skin resistance by monitoring the resistance between the fleshy parts of two adjacent fingers of one hand via a pair of probes and conductive electrodes (steel wool held in place with sticky tape or a metal strap is OK), and presents this data to the user in the form of an audible signal that varies in frequency with the skin resistance and state of mental tension. The tone rises as tension increases, and vice versa.

GSR monitors are easy instruments to build. They normally cover the resistance range 5k0 to 1M0, and incorporate sensitivity and balance or level controls as a means of changing resistance ranges.

In use, the operator hooks himself up to the machine, adjusts it's controls to give a fairly low tone signal, and then patiently tries to reduce the tone frequency by relaxing his mind and body. A fair degree of practice may be needed to get the hang of things, just as a good deal of practice is needed to get the hang of riding a bicycle, but after a few half-hour sessions the user should find that he can exercise a reasonable degree of control over his mental state when using the machine.

CONSTRUCTION AND USE

Take care during assembly on the PCB to ensure that all semiconductor devices and electrolytic capacitors are fitted in the correct polarity. We built our prototype unit in a small (3×4½×1½ inch) plastic case, and fixed the PCB in place with sticky pads after completing the interwiring. We used a crystal insert as the audio output device, as shown in the circuit diagram. This device



The HE GSR Monitor, the case used in the prototype was made by Vero Electronics.

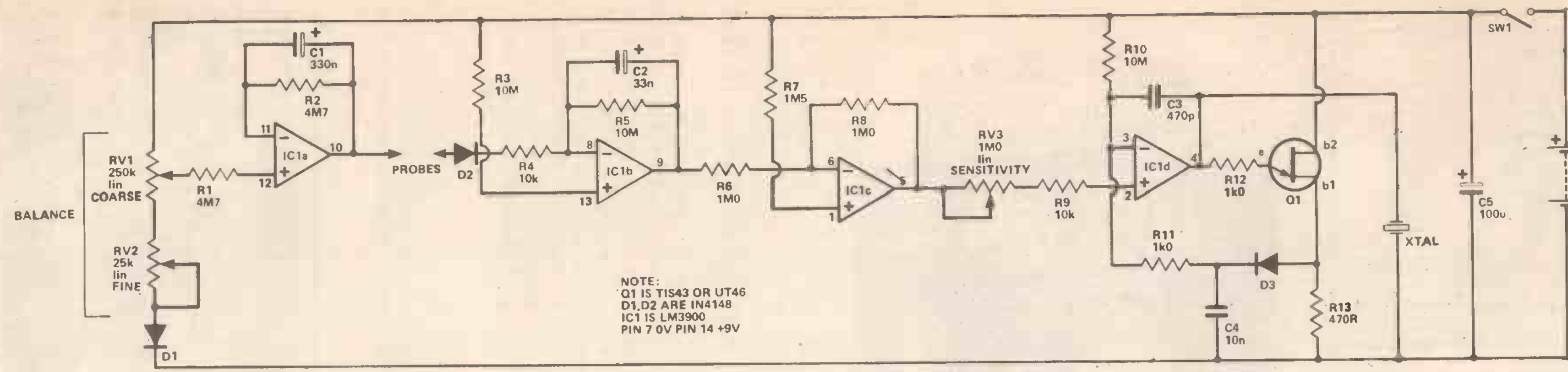


Fig. 1. Circuit diagram of the GSR Monitor, note that the xtal is either a crystal earpiece or microphone insert.

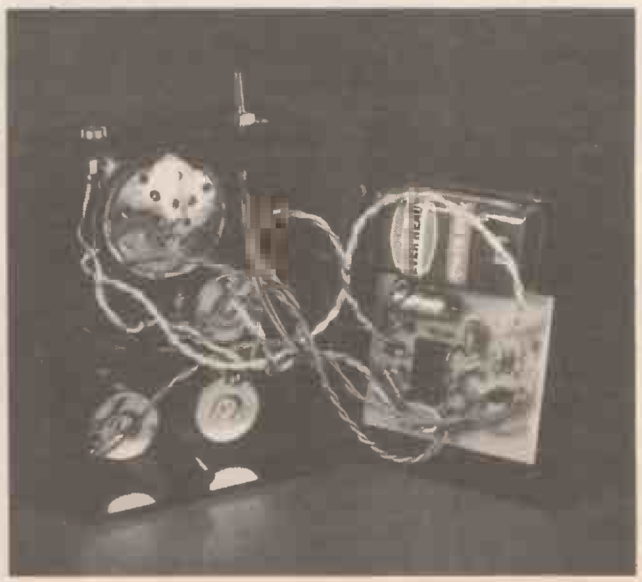
How It Works

The LM3900 used in this project contains four current-differentiating op-amps. More conventional op-amps like the 741 compare voltages present at their inputs. With the LM3900, voltages are presented to the inputs via resistors to provide input currents. A voltage will be produced at the output sufficient to drive a current through the feedback resistor and into the inverting input which is equal to the difference between the input currents The voltage appearing at the input pins will always be one diode-drop above ground; about 0.5 volts.

Nine volts from the battery is applied across RV1, RV2 and D1. IC1a acts as a voltage follower and the 0.5 to 9 V from the slider of RV1 appears at the output of IC1a. This provides a low impedance voltage source. Any noise is smoothed out by C1. A current, proportional to the applied voltage and the skin resistance plus R4 will now flow into the inverting input of IC1b . R4 prevents too large a current from flowing if the probes are inadvertently shorted. A small input current produces a large output voltage from IC1b which is then inverted by IC1c to provide the correct sense; an increase in skin resistance produces a decrease in pitch of the output tone.

IC1d and Q1 form a current controlled oscillator. IC1d is arranged as an integrator where current flowing into the non-inverting input causes the output voltage to rise at a certain rate. This would continue until the amplifier saturated, however, at about 6 volts, Q1 will suddenly turn on producing an increase in the voltage across R13. This causes a current to flow via D2 and R11 into the inverting input resetting the integrator and turning off Q1. C4 ensures that the pulse lasts long enolugh to fully reset the integrator. The cycle repeats at a frequency proportional to the input current which is controlled by RV3 producing an audible tone in the crystal insert.

Inside the GSR Monitor, everything fits easily into the case.



Parts List

RESISTORS (all ¼W, 5%)	
R1,R2	4M7
R3,R5,R10	10M
R4,R9	10k
R6,R8	1M0
R7	1M5
R11,R12	1k0
R13	470R
POTENTIOMETERS	
RV1	250k lin
RV2	25k lin
RV3	1M0 lin
CAPACITORS	
C1,C2	0.33u 35V tantalum
C3	470p polystyrene
C4	10n polyester
C5	100u electrolytic
SEMICONDUCTORS	
D1,D2,D3	IN4148
Q1	TIS43
IC1	LM3900
MISCELLANEOUS	

Crystal insert, SW1 SPST (on-off toggle switch), PP3 and connector, Vero case to suit.

Buylines

Approximate cost £4.00.
No special notes here. All components used in the project are standard, readily available types.

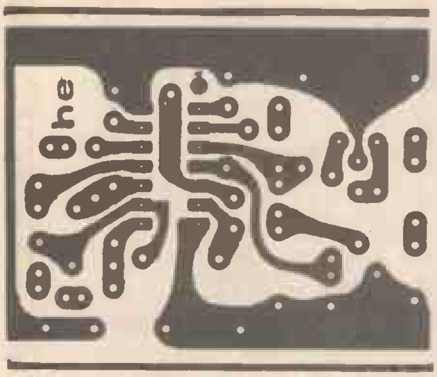


Fig. 3. PCB foil pattern for GSR Monitor, take care when soldering in the IC's to prevent solder blobs.

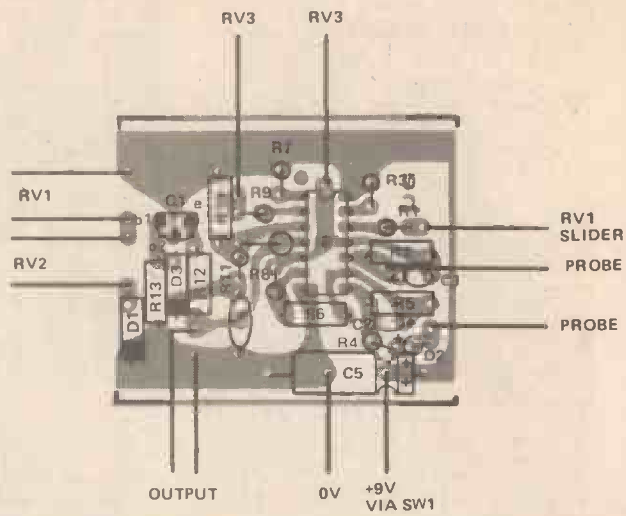


Fig. 2. Component overlay for GSR Monitor, make sure that all polarised coamponents, ie ICs, diodes etc are inserted the correct way round.

gives a rather low level of audio output, however, and some readers may prefer to use a crystal earpiece output instead, by making a direct substitution of the devices.

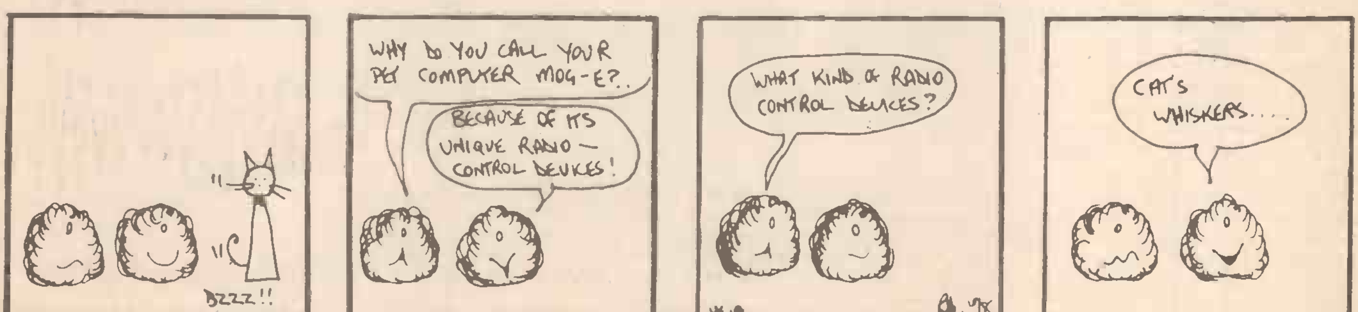
When construction is complete, connect a 100k resistor across the probes and switch the unit on. Now adjust the level and sensitivity controls to obtain a fairly low audio tone. Note that the LEVEL controls are very slow acting, and take several seconds to effect the tone signal, and that on most cases the COARSE LEVEL control can be left in the fully anti-clockwise position.

Next, reduce the effect value of the 100k probe resistor by shunting it with a 1M0 resistor, and check that the tone signal rises. Experiment with the LEVEL

Close-up of the PCB and battery, the PCB is mounted on to the case by double-sided sticky pads.

and SENSITIVITY controls to find a setting where the maximum possible frequency shift occurs when a small change is made in the value of the probe resistance. Experiment with different values of resistor, to get the 'feel' of the monitor.

When you are confident that the GSR monitor is ready for use, make up a pair of conductive electrodes from soft steel wool and bond them to the fleshy tips of two adjacent fingers of your non-dominant hand with sticky tape or wire, and connect them to the probes. Now just sit down and relax in a comfortable chair, and try to control the audio tone of the machine with your mind. After a few sessions of practice, you should be able to control the machine's tone, and your own mental state, without difficulty. If you can't, don't ring us, we'll ring you! **HE**



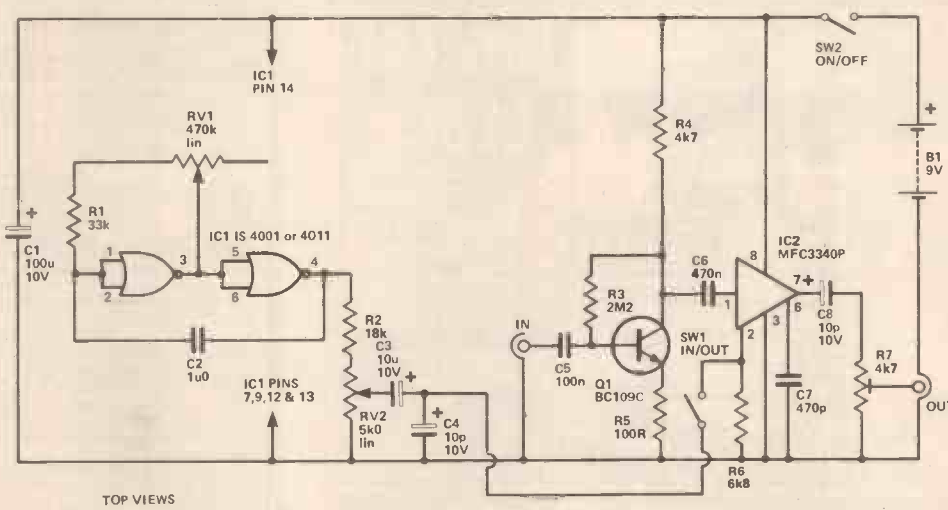
Short Circuit

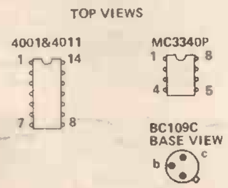
TREMOLO UNIT

This is one of the most popular types of special effect unit for use with guitars, the operation is to amplitude modulate the input signal with a low frequency signal. Thus a constant input as in (a) would emerge from the tremolo unit varying in amplitude at a low frequency as in (b).

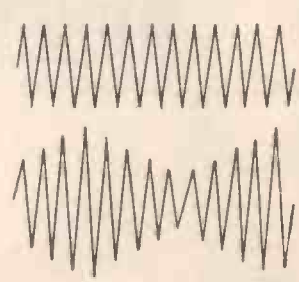
In this circuit the input signal is taken to the input of an electronic attenuator (based on IC2) via a common emitter amplifier using Q1. R6 sets the gain of the attenuator (with zero modulating voltage) at about unity, but the amplification provided by Q1 gives an output level of a few hundred millivolts. This can either feed a high level input of the amplifier, or R7 can be adjusted to attenuate the output to a level which is suitable to drive the ordinary guitar input. It is necessary to have the stage of amplification ahead of the IC2 so that this part of the circuit is handling a fairly high signal level, and gives a good signal to noise ratio.

The gain of IC2 can be varied by applying a control voltage to pin 2. This control signal is generated by a conventional CMOS astable circuit which uses two of the gates contained in IC1. The operating frequency of the astable can be varied from about 1 to 10 Hz by means of frequency control RV1. A squarewave signal is produced by the astable, and this must be filtered to remove the high frequency components in order to give a smooth and pleasant tremolo effect. This filtering is given by R2 and C4. RV2 controls the amplitude of the modulating singal and acts as the tremolo depth control. SW1 can be used to disconnect the modulation when the tremolo effect is not required.





a
b



Display Techniques

As digital electronics spreads from the lab. to everyday life, we are becoming more familiar with LED and LCD displays. Tim Orr goes into the pros and cons of a variety of display techniques.

A LOT OF ELECTRONIC equipment needs some sort of a display mechanism. A digital watch needs a number display that consumes almost zero power and which can be seen in daylight and in the dark. Pocket calculators need numerical displays. Digital multimeters and frequency meters need numerical displays. Pocket language translators (English to French for example) need an alphabetic display. Hand held audio spectrum analysers need an array of LED bar displays. In fact there is an enormous present and future requirement for all sorts of displays.

One of the oldest types of display is the light bulb, the incandescent lamp. This, however, requires a lot of power, which usually ends up as heat. It isn't very easy to build into products and it breaks too easily. The modern equivalent is the Light Emitting Diode (LED), the all electronic light source. It can be built in several colours — red, orange, yellow, green and even infra-red. It is basically a diode that emits light when the current passing through it is in the region of 4 to 40 mA. It is possible to construct the diode in a variety of shapes, a common one being the seven segment display (Fig. 1). The seven segments are seven diodes which can be turned off or on. In doing so it is possible to generate a variety of displays. Numbers from nought to nine and sometimes the letters A to F (a mixture of upper and lower case) are produced. The most common use of the seven segement display is to display numbers from some digital system, for example a counter.

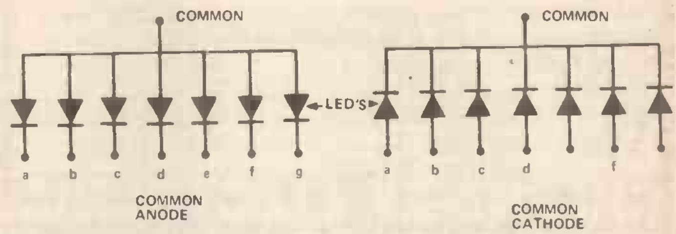


Fig. 1a. Schematic diagram of 7 segment displays

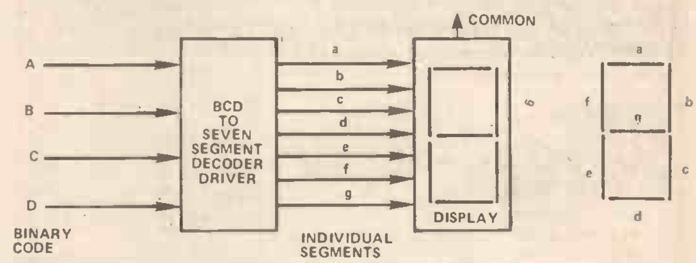


Fig. 1b. 4 bit binary input to 7 segment decoder

COUNT ON THIS

However, the output from a binary decade counter is in an unsuitable form to drive the display. It is in a code called BCD (Binary Coded Decimal), which consists of four signals. These have to be decoded so that the seven segments are turned on in the correct sequence as the count proceeds. The piece of electronics that does this is called a 'BCD to seven segment decoder driver'. Fig. 1c shows the truth table for one of these devices. Most decoders only work from 0 to 9, but a few will also give an A to F display as well. There are two types of seven segment LED displays. One is called 'common anode' because all the anodes are connected together, the other is called 'common cathode' because all the cathodes are common.

Each seven segment display has eight wires connected to it. Thus a ten digit calculator display could have 80 wires connected to it, which is clearly not a very good idea. It would also mean that the calculator integrated circuit would have to have something like 100 legs on it! The way in which large and even small

BINARY CODE / SEGMENTS / DISPLAY

D	C	B	A	a	c	b	d	e	f	g
0	0	0	0	ON	ON	ON	ON	ON	ON	–
0	0	0	1	–	ON	ON	–	–	–	–
0	0	1	0	ON	ON	–	ON	ON	–	ON
0	0	1	1	ON	ON	ON	ON	–	–	ON
0	1	0	0	–	ON	ON	–	–	ON	ON
0	1	0	1	ON	–	ON	ON	–	ON	ON
0	1	1	0	–	–	ON	ON	ON	ON	ON
0	1	1	1	ON	ON	ON	–	–	–	–
1	0	0	0	ON	ON	ON	ON	ON	ON	ON
1	0	0	1	ON	ON	ON	–	–	ON	ON
1	0	1	0	ON	ON	ON	–	ON	ON	ON
1	0	1	1	–	–	ON	ON	ON	ON	ON
1	1	0	0	ON	–	–	ON	ON	ON	–
1	1	0	1	–	ON	ON	ON	ON	ON	–
1	1	1	0	ON	–	–	ON	ON	ON	ON
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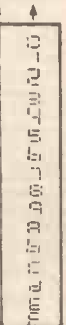

BCD (rows 0000–1001) — MOST DECODERS ONLY WORK FROM 0 TO 9

0 = LOGIC LOW
1 = LOGIC HIGH
ON = SEGMENT ON
– = SEGMENT OFF

Fig. 1c. Truth table for BCD to 7 segment decoder/driver

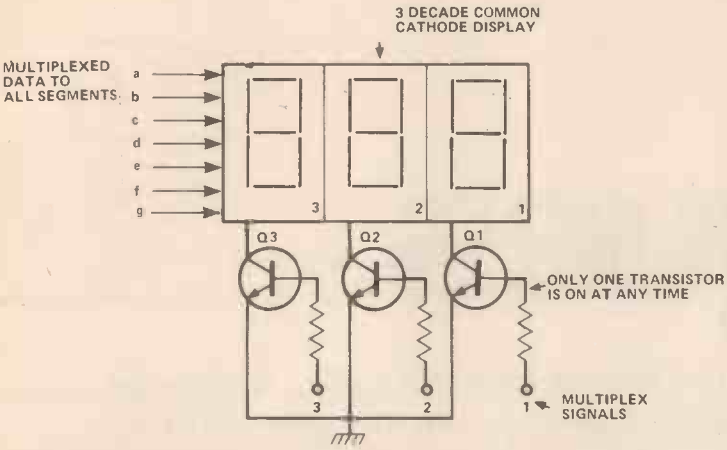

Fig 2. Multiplexing arrangements to reduce the amount of interwiring

displays overcome this problem is to use a process called multiplexing (Fig. 2). This reduces the number of wires from 80 for a ten digit display to 17 by time sharing the data. What happens is relatively simple. The 'a' segments in the display are connected together and so are all the other segments. However, each common cathode (or anode in the case of common anode), is separately turned on by a transistor. The sequence of operation is as follows. Transistor Q1 is turned on, the seven segment data for display 1 is selected and so display one lights up. Next Q2 is turned on, the data for display two is selected and so display two lights up. Then Q3 is turned on and then the process repeats itself.

SPEED

In a ten digit system each digit will only be on for 10% of the time. If the multiplex speed is fast enough the eye will not see the LED's being turned on and off and will see a continuous display. Take a LED display pocket calculator. Light up a few digits. They will not appear to flicker. Move the calculator rapidly in a circle and you will see the multiplexing process in operation as a string of flashing digits.

Most multiple seven segment displays are structured so as to be multiplexable. Also many of the integrated circuits that generate the display data output their information in a multiplexed format. Large scale integration (LSI) has produced many useful systems in a single pack. You can buy a Digital Voltmeter (DVM) and a multi-decade counter-decoder integrated circuit (Fig. 3). A few years ago if you wanted to build a four decade counter display system you would have needed four decade counters which generate the BCD codes. Also, four latches (four bits) to store the count. Also four BCD to seven segment decoder drivers and four seven segment displays. This totalled up to 16 IC's and over a hundred wires. However, using the new method, a four decade counter/latch/decoder/driver with multiplexed data output and a four figure display, the system is incredibly simple. This is because all those IC's have been stuck into one LSI chip. This trend towards LSI makes system design so much simpler. For instance a frequency meter can be constructed out of four or five IC's (Fig. 4), or a digital voltmeter can be made from only two IC's (Fig. 5). There are also many other LED displays and drivers. There is a dot matrix which can produce all the letters of the alphabet as well as numbers, (alphanumeric display). There are also some IC's that can light up a string of LED's for bar displays, the light of the bar being controlled by an analogue voltage. This is particularly useful for making LED audio level meters or a large SY matrix LED display.

HEAVY LED

There are some disadvantages in using LED's. They can consume a considerable amount of current and you

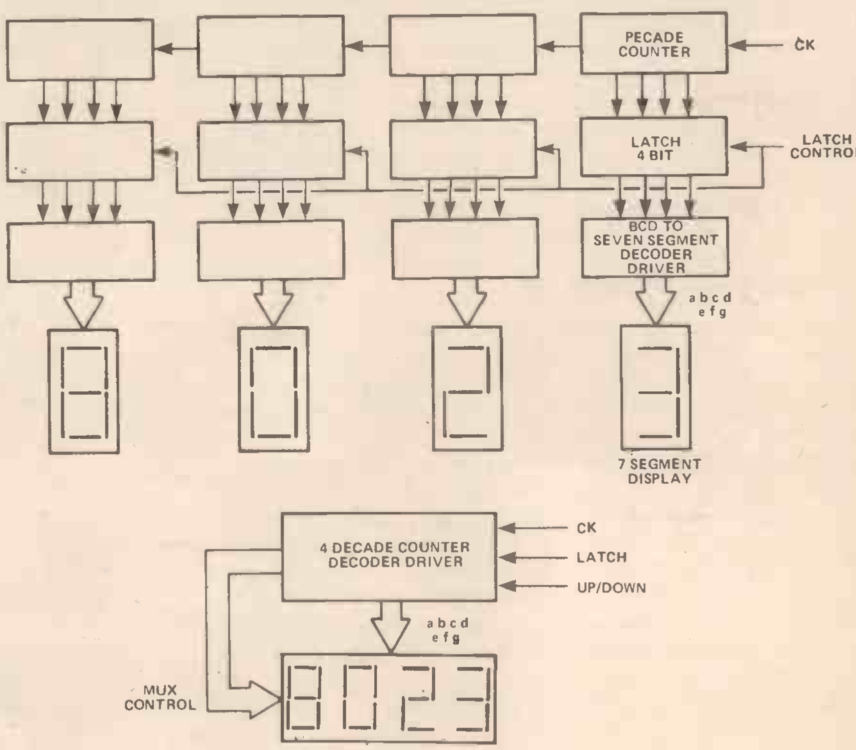

Fig. 3. Two methods of display driving, the older method (upper) uses quite a large number of individual IC's. Using LSI Technology all of this (lower) can be reduced to one chip

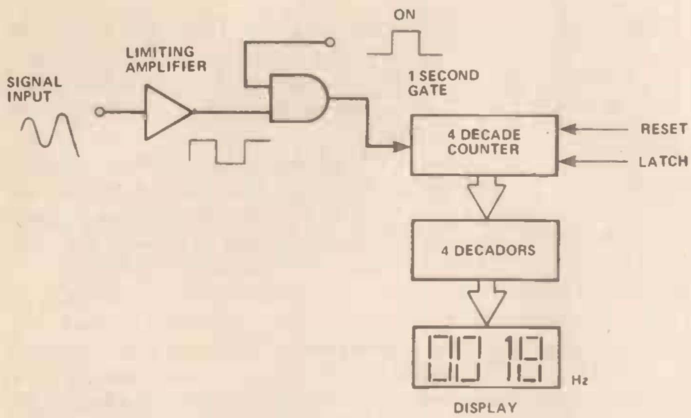

Fig. 4. Using LSI chips a frequency meter can be built using only a few chips

can't see them at all well in strong lighting conditions. This is where the liquid crystal display (LCD) is very useful. It consumes virtually zero power and it usually works on reflected light, so the brighter the better. The display is constructed by sandwiching a liquid crystal in-between two glass plates. The seven segment pattern is deposited on the glass in a thin transparent metal layer. These segments are connected to pins at the side of the display unit. The rear glass plate is one continuous electrode. When an electric field is applied between a front and rear electrode, there is a 'twist effect' that stops any light being transmitted. This makes the electrode appear black. Otherwise, with no field present, all the light can pass through the liquid crystal and so it appears transparent.

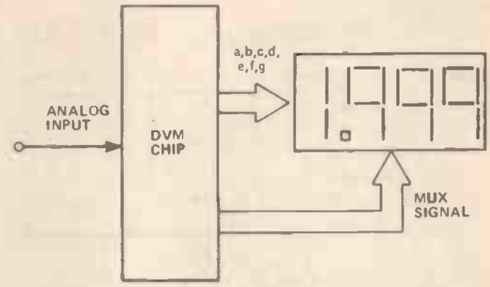

Fig. 5. Again LSI technology produces a simple DVM (Digital Volt Meter) from only a couple of chips

Liquid crystals can be constructed so that they have a reflective back electrode or they can be transmissive so that they can be illuminated from the rear. There are chemical light sources that can be used for rear lighting. These are small tubes of radioactive material that glow for ten to twenty years. (Beat that EverReady). However, the liquid crystal is slow in changing from dark to light and so cannot yet be used in a multiplexed system. As the pattern of the electrode determines the shape that you see it is relatively easy to get liquid crystal displays built to produce your own particular graphics. Also they are now becoming available in different colours and it has just been announced that a Japanese company has made a working model of a flat liquid crystal TV display although it is still in its early stages.

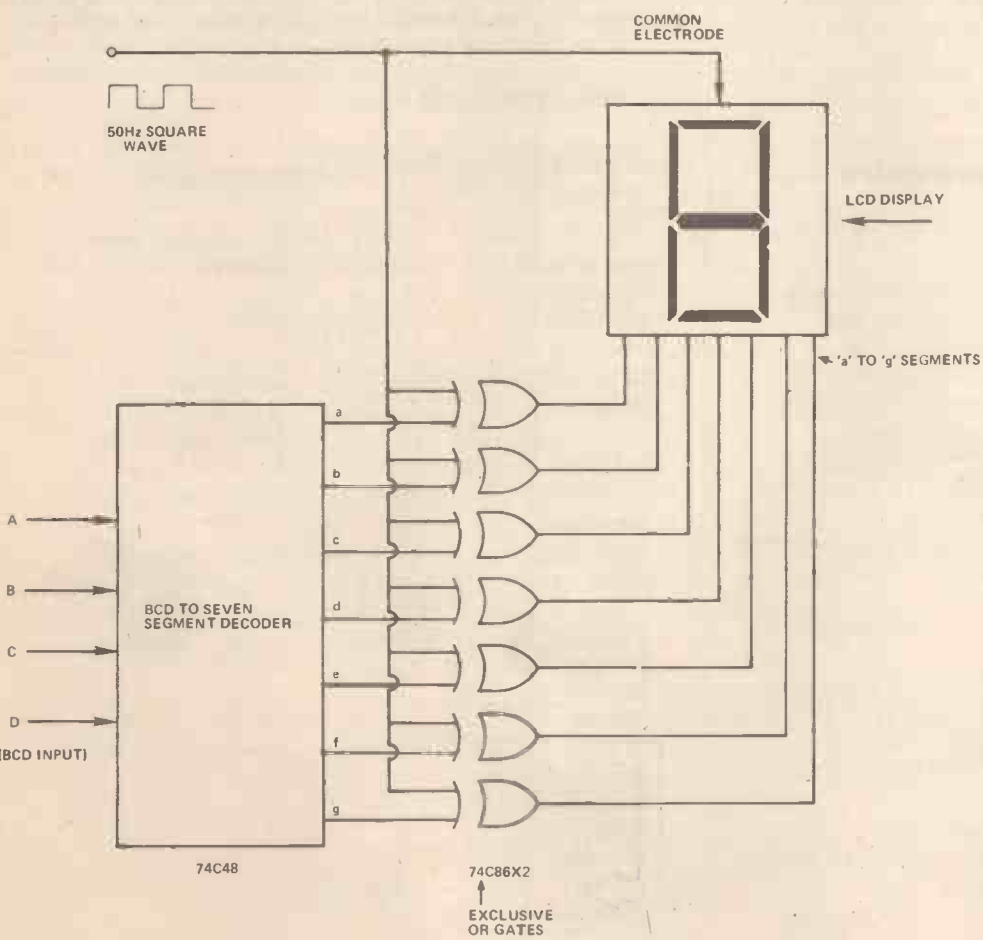

Fig. 6. A method of driving an LCD display using exclusive OR gales

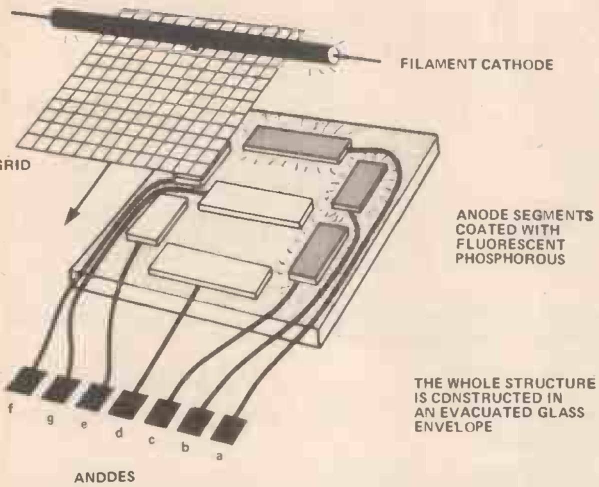

Fig. 7. Construction of a common anode Flourescent display

LONG LIFE

To ensure an LCD display has a long lifetime, the average DC component of the energising signal should be zero. This is usually obtained with an exclusive OR driving network as shown in Fig. 6. LCD displays do have a few disadvantages. They are rather expensive. They can easily be damaged by mechanical fracture and leakage of their hermetic seal. Also strong sunlight can eventually bleach their polarising filters.

Another very popular display medium is the fluorescent display. This is relatively inexpensive and combines high brightness with moderately low power consumption. The fluorescent display is rather like the old fashioned gas discharge tube. It is constructed inside an evacuated glass envelope and uses three electrodes, a cathode, which is a low temperature filament, a grid, which is a wire mesh that seperates the cathode from the anode (the grid is used to turn the display on and off), and the third electrode is the anode, which can be constructed in any shape, a seven segment being common (Fig. 7). The anode is coated with a fluorescent material that glows a green/blue colour when fast moving electrons (from the cathode) strike it. Thus, by connecting the right voltage to the anode segments (typically 24 V), a seven segment display can be generated.

LIGHT FANTASTIC

Fluorescent displays can be multiplexed and this is where the grid is used. The grid can be biased to collect all the electrons from the filament so that none strike the anodes of that digit and so no light is generated except on the display for which the seven segment data was intended. One company (ITRON) makes an enormous range of display shapes. These include seven segment displays with various characters like AM, PM, kΩ, V, A, analogue bar displays, 14 segment alpha-numeric displays, 5x7 dot matrices. I have also seen fluorescent aircraft altitude displays and enormous XY matrix.

Display technology is making great improvements all the time. Maybe in the next decade we can look forward to developments such as flat tube displays (making pocket TV and oscilloscopes possible) and multi-colour, fast moving multiplexable LCD displays. These could be linked to solid state TV cameras making all electronic cameras possible. The film for these devices could be erasable Read Only Memories. Maybe these will appear in the next decade, However, for those who want to purchase something now, here is a list of a few currently available products. Fig. 8. **HE**

Part number & manufacturer	Description
SN 7447 TEXAS	BCD to seven segment decoder driver
MM 74C912 National Semiconductors	6 digit BCD display decoder driver. 0→9 A→F outputs. Internal memory
MC 14511 Motorola	BCD to seven segment latch/decoder/driver
CA 3161E RCA	BCD to seven segment decoder/driver. Designed to go with the CA3162E A to D converter
TIL 311 Texas	LED dot display + store, decoder, driver. Displays 0→9, A→F (hexadecimal)
TIL 307 Texas	LED display + counter decoder driver
TIL 305 Texas	5x7 alpha numeric dot matrix display. Can display, A to Z, 0 to 9, and other symbols
DD10R ITT	Bar graph. 10 LEDs in a DIL package
LM3914 National Semiconductor	Dot/bar display driver. Converts an analogue input into a dot or bar display
UAA 170	Dot display driver. Converts

Part number & manufacturer	Description
SGS ATES	analogue input into dot display
MC14553 Motorola	3 digit BCD counter. Mux output
ZN1040 Ferranti	4 decade counter driver. Mux output
ICM 7217 Intersil	4 decade counter driver. Mux output
ICL 7106 Intersil	3½ digit DVM chip with LCD display outputs
ICL 7107 Intersil	3½ digit DVM chip with mux LED output
CA 3162E RCA	Analog to digital converter. 3 digit BCD outputs. Multiplexed. Designed to go with CA3161E
Fairchild Litronix Monsanto Texas	LED seven segment displays
ITT Brown Boveri Swarovski Beckman Hamlins	LCD seven segment displays
ITT Futaba	Fluorescent displays

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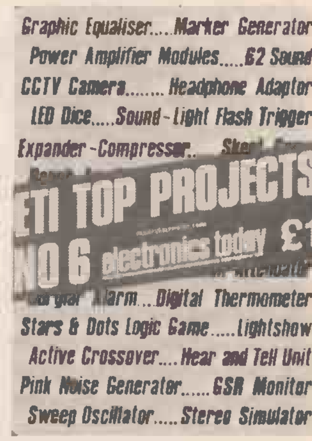

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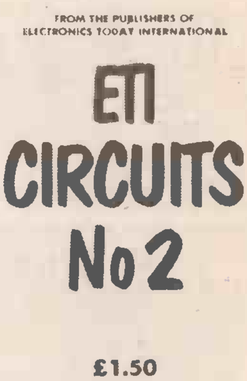

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Envelope Generator

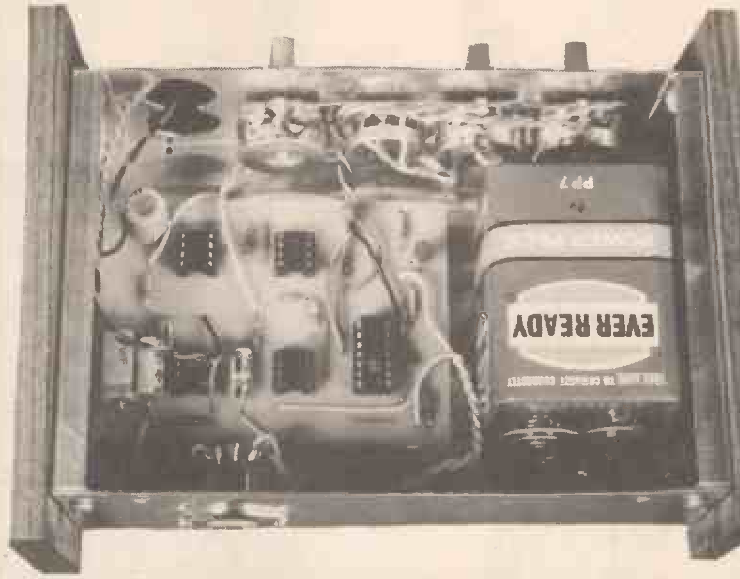
Here's a project that you can use to simulate the sound of any musical instrument, or used with the HE White Noise Generator to produce various sci-fi effects.

SO WHAT, YOU MAY ASK, is an ADSR (Attack, Decay, Sustain, Release) envelope generator, and what is it used for? It is a device that is used in electronic sound and music synthesis to mould the output sound envelope of a standard input signal (a tone or white noise signal) to the precise shape desired by the operator. By modifying the envelope, the operator can simulate the sounds of all types of musical instruments, or can simulate man-made sounds such as gun shots, explosions, steam engine 'chuffs', etc., or can create completely new 'science fiction' types of effects at will.

The action of the ADSR generator can be understood more clearly with the aid of the explanatory diagram of Figure 1. The top part of this shows what happens if you pass a steady tone signal through a linear transmission gate (an electronic switch) that is activated by an external control switch. The input signal appears at the output, with virtually zero 'Attack' time, as soon as the control switch is closed, it has a 'Sustain' amplitude identical to that of the input signal for the duration of the switch closure, and disappears with virtually zero 'Release' time as soon as the switch is opened again. The resulting output signal sounds completely artificial and uninteresting.

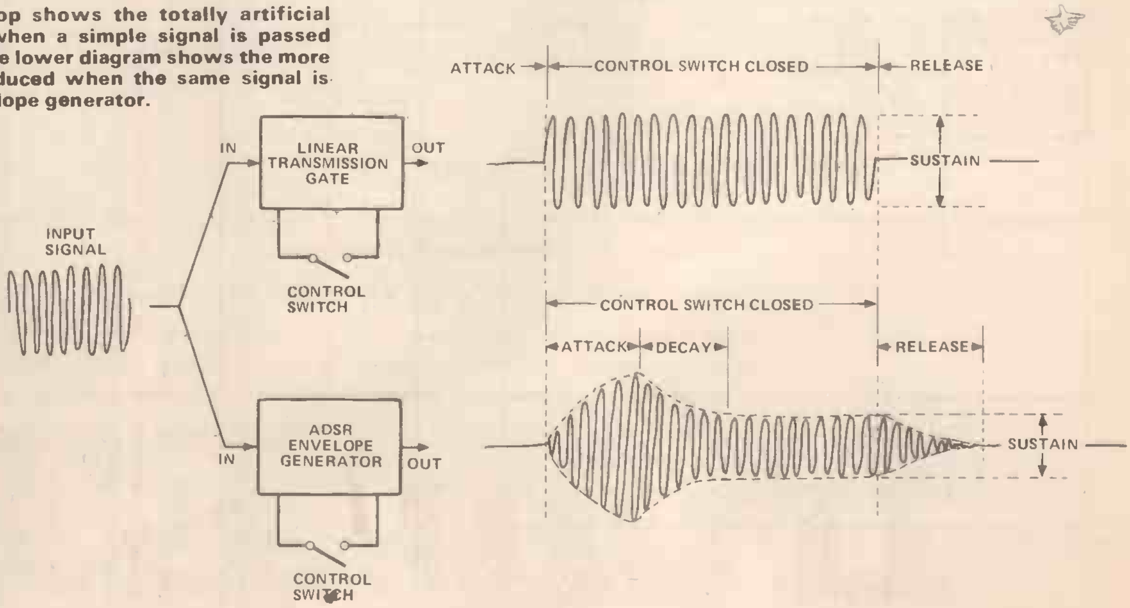
ATTACK AND DECAY

The lower part of the diagram shows what happens if the same input signal is passed through the ADSR envelope generator. When the control switch is closed, the amplitude of the output signal first rises from zero at a controlled 'Attack' rate to a peak value, at which point it 'Decays' at a controlled rate until it reaches a controlled 'Sustain' amplitude, which it then maintains for the



ADSR generator shown with the top removed, using the case specified it looks really professional.

Fig. 1. The diagram at the top shows the totally artificial waveform that is generated when a simple signal is passed through a transmission gate. The lower diagram shows the more realistic waveform that is produced when the same signal is passed through the ADSR envelope generator.



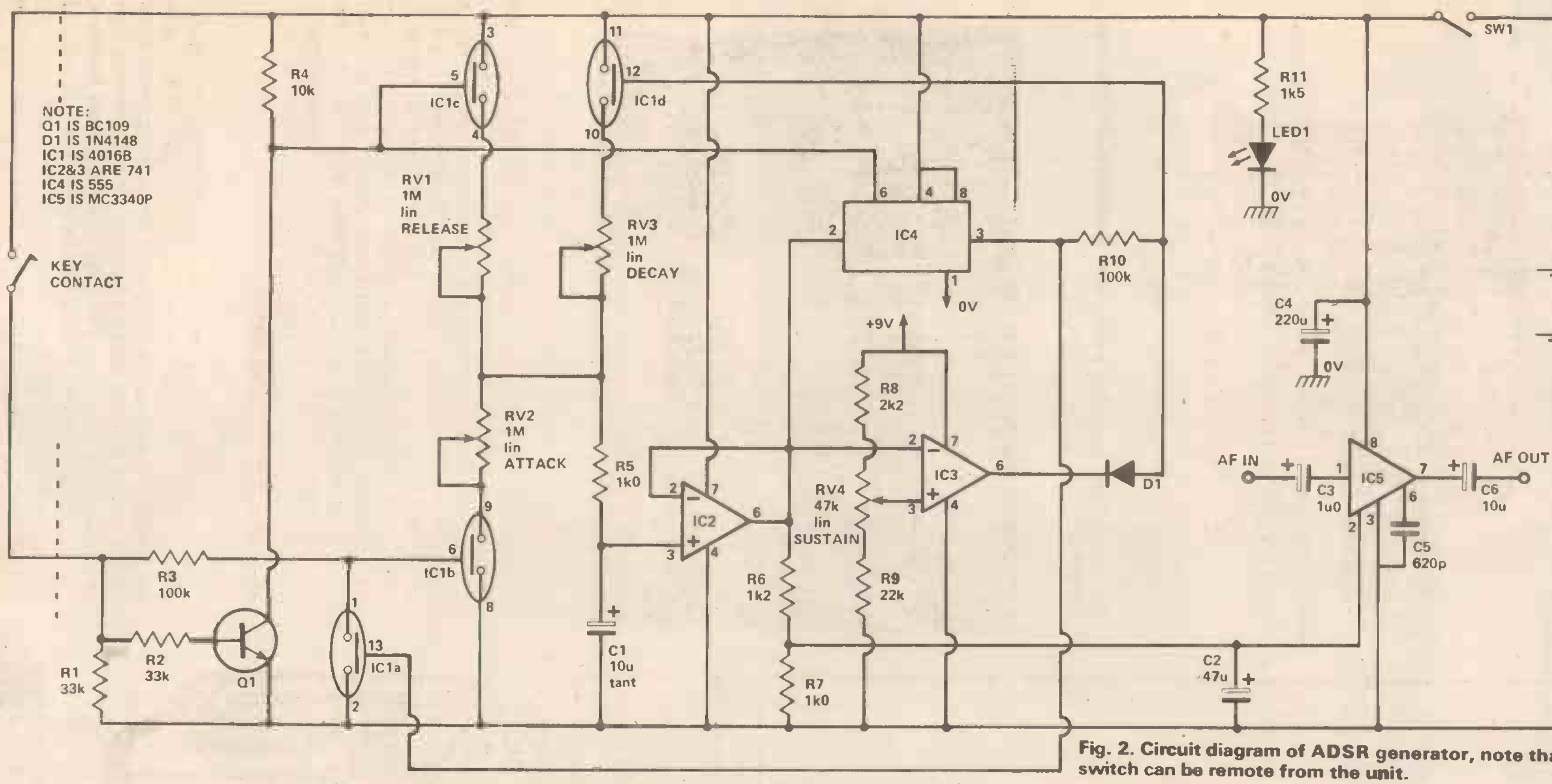


Fig. 2. Circuit diagram of ADSR generator, note that the contact switch can be remote from the unit.

How It Works

The audio signal to be controlled passes through IC5 which attenuates it according to the control voltage on pin 2. This voltage is generated across C1 and fed via voltage follower IC2, potential divider R6 and R7 and capacitor C2 to the control pin where a voltage of about four volts causes a large attenuation so that no signal appears at the output and a lower voltage about one and a half volts lets the signal pass.

To produce a sound envelope, the control voltage must be somewhere between these two extreme levels and this is achieved by connecting discharging and charging resistors to C1. So that different sound envelopes can be produced these are made variable and comprise RV1, 2, 3. R5 prevents excessive current flow through the transmission gates of IC1.

When the key contacts are open Q1 is off producing a high voltage (about nine volts) and the control input of transmission gate IC1c. This turns on the gate and RV1 is connected to nine volts via the few hundred ohms resistance of IC1c providing a charging path for C1. IC1b is off and very high resistance of several millions of ohms exists between its input and output. IC1d is also off as the output of IC4 is at a low level.

As the key contacts are closed, IC1c will turn off and IC1b will turn on causing the charge on C1 to leak away via R5, RV2 and IC1b. When the voltage across C1 reaches one third of the supply voltage, the output of IC4 will go high turning on IC1a which turns off IC1b and removes the discharge path. Also, IC1d will turn on and C1 will charge via R5, RV3 and IC1d. The voltage across C1 will continue to rise until it reaches a level set by RV4. The output of IC3 will go low turning off IC1d causing C1 to become disconnected from any charge or discharge path. The voltage will remain relatively constant thus sustaining whatever level of sound output has been achieved.

In practice the voltage across C1 will drop slightly owing to the leakage of C1 and the input current drawn by IC2. However, these effects are negligible so long as a tantalum capacitor is used for C1.

As the key contacts open, IC1c will turn on. The voltage across C1 will rise and the sound will fade to silence. The output of IC4 will go low again turning off IC1a, b, d, and preparing the system for the next key closure.

Parts List

RESISTORS (All ¼W, 5%)	
R1,2	33k
R3,10	100k
R4	10k
R5,7	1k0
R6	1k2
R8	2k2
R9	22k
R11	1k5
POTENTIOMETERS	
RV1,2,3	1M0 Lin
RV4	47k lin
CAPACITORS	
C1	10u 16 V Tantalum
C2	47u 16 V Electrolytic
C3	1u 16 V Electrolytic
C4	220u 16 V Electrolytic
C5	620p Polystyrene
C6	10u 16 V Electrolytic
SEMICONDUCTORS	
Q1	BC109
D1	IN4148
IC1	4016B
IC2,3	741
IC4	555
IC5	MC3340P
LED 1	TIL220
S1	Sub-min Toggle (on-off)

Case used on prototype is available from Maplin, Type B1. 5 pin. DIN socket (see text).

Approximate cost: £5.00

Buylines

All of the components in the ADSR circuit are commonly used types, and should be available from most suppliers that advertise in this magazine.

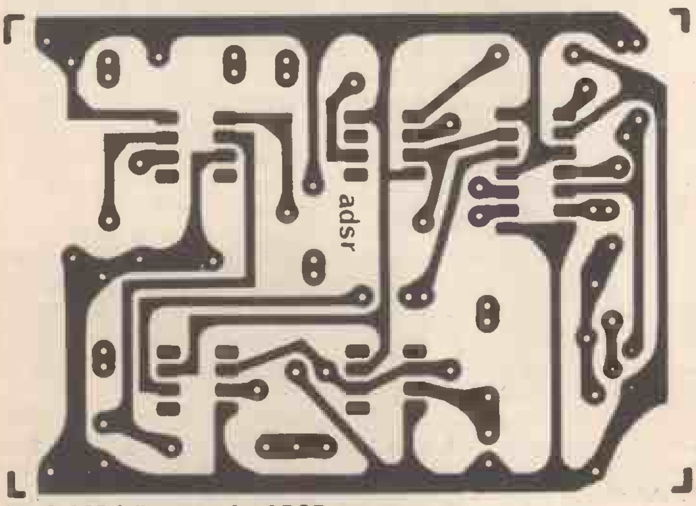


Fig. 4. PCB foil pattern for ADSR generator.

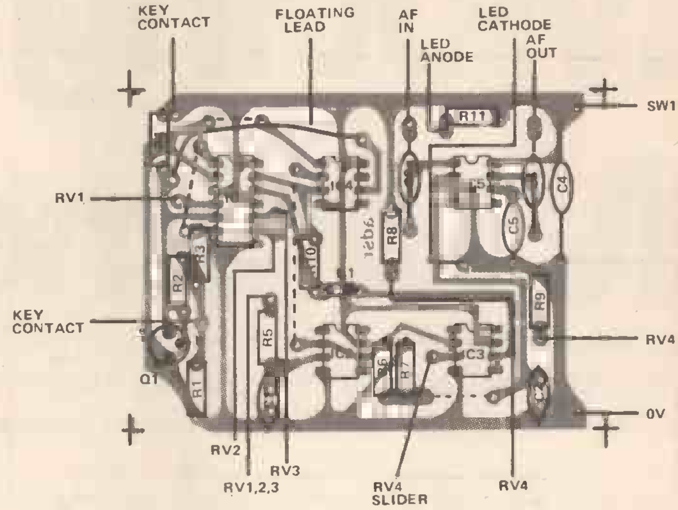
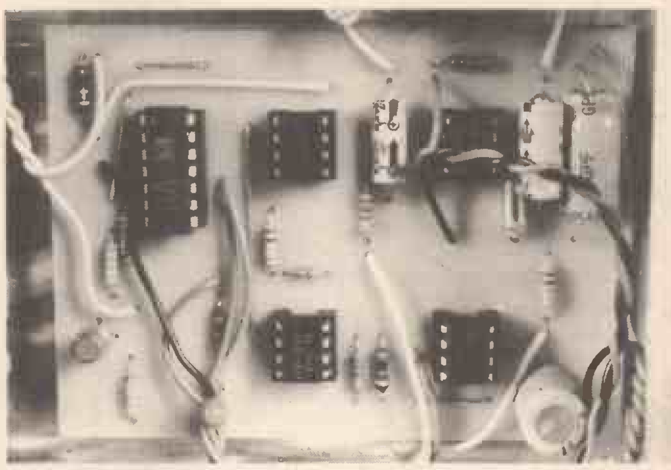


Fig. 3. PCB component overlay, note orientation of polarised components.



duration of the switch closure. When the switch is eventually opened again, the output signal amplitude falls to zero at a controlled 'Release' rate. The Attack, Decay, Sustain, and Release dimensions of the output sound envelope are all under the full control of the operator, and the resulting output signals can readily be made to sound natural and interesting.

The complete ADSR instrument is intended for use in conjunction with an input signal source (the April '79 HE White Noise Unit, which can also act as an oscillator, is ideal), and an output power amplifier. The instrument can be activated via either a single switch, or via a bank of parallel-connected keyboard switches, which can also be used to control the frequency of the unit's input signal.

CONSTRUCTION

All of the ADSR circuit components other than the pots, switch, and LED, are mounted on a single PCB. Take care when wiring up the PCB to observe the polarities of all semiconductor devices and electrolytic capacitors. On our prototype unit we mounted the PCB and battery, etc., in a metal case measuring approximately 6 x 4 x 2 inches. Interwiring of the PCB and controls, etc., should present no problems. The input, output, and control switch are coupled to our prototype circuit via a 5 pin DIN socket, but alternative connection methods can be used if preferred. **HE**

Moving Coil Multimeters

Moving coil meters are very versatile instruments. Ray Marston explains how they work and how to use them to measure voltage, current and resistance and how to convert them into multimeters.

MOVING COIL or D'Arsonval meters are the most basic and versatile measuring instruments in any electronics laboratory. Essentially, they are sensitive but relatively inexpensive current-measuring electro-mechanical devices that give a visual analogue readout of the magnitude of the current being measured. Individual moving coil meters are designed to measure only single ranges of DC current, but can easily be persuaded to measure a wide range of AC or DC voltages or currents by connecting them to suitable rectifiers, voltage multiplier resistors, or shunts. They can readily be adapted for use as resistance-measuring meters and form the basis of almost all good quality analogue multimeters.

In the next few pages we describe how moving-coil meters work and how to convert any existing meter to read alternative ranges by designing your own shunt and multiplier networks, etc. We also show the full circuit diagrams of two famous high-quality multimeters, the Avo 8 and the Avominor Mk 5.

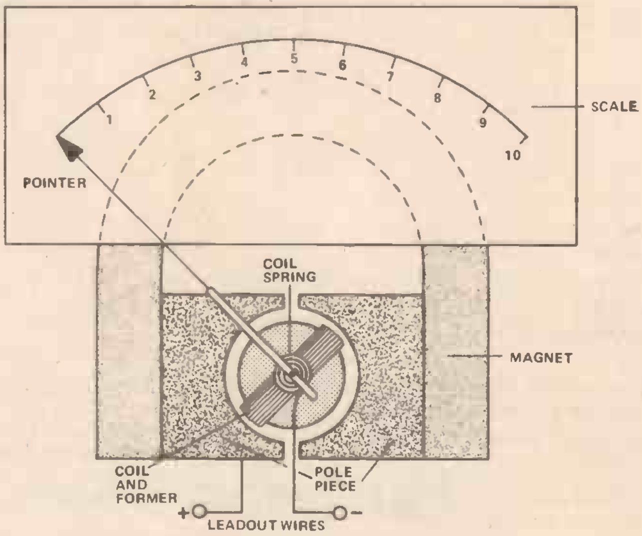


Fig. 1. Basic moving coil meter movement.

HOW MOVING COIL METERS WORK

The operating principle of a moving coil meter is quite simple. The meter incorporates a coil of fine wire wound on an aluminium former or bobbin that is supported by delicate bearings, so that the assembly can move under almost frictionless conditions (hence the title 'moving-coil'). Also mounted on the assembly is a pointer, which projects over a fixed and graduated scale enabling any degree of movement of the coil to be read off the scale. The coil is mounted within the powerful magnetic field of a fixed permanent magnet (see Fig. 1). Current can be fed to the coil via a pair of contra-wound coil springs, which are fitted at opposite ends of the bobbin in such a manner that their tensions balance out when the pointer is in the 'zero' position.

When current is passed through the coil a magnetic field is set up which interacts with that of the permanent magnet and applies a torque to the coil assembly. This rotates until a position is taken up in which the torque is balanced by the force of the two coil springs. The degree of rotation of the assembly, which includes the pointer, is directly proportional to the amount of current passed through the coil. Thus, the scale can be directly and linearly calibrated in terms of current.

All moving coil meters, irrespective of the manner in which their scales are calibrated, work on the basic principle outlined above, and inherently read only mean DC currents: they do not respond to AC. Most meters are designed with their 'zero' mark on the extreme left of their scales and thus respond only to positive DC currents. A few meters have their zero mark at the centre of their scale and can respond to both positive and negative DC currents. Virtually all moving coil meters are provided with a limited means of external zero adjustment, usually via a small screw-headed device fitted at the front of the meter.

The vast majority of moving coil meters have a basic sensitivity or full-scale current indicating capacity of between a few tens of uA and a few mA. The current *indicating* range of a meter can be increased above the basic value by wiring the basic meter in parallel with a low-value 'shunt' resistor, as shown in Fig. 2, so that the basic meter reads full-scale when the *total* current of the circuit is at the prescribed high value.

Alternatively, a meter can be made to give voltage readings by wiring the basic meter in series with a high value 'multiplier' resistor, as shown in Fig. 3, so that the basic meter reads full-scale when the voltage across the complete circuit is at the prescribed value. Similarly, the meter can be made to read AC quantities by feeding the quantities to the basic meter via a suitable rectifier or AC/DC converter network and can be made to read resistance values by connecting the test resistors to the basic meter via a suitable voltage source.

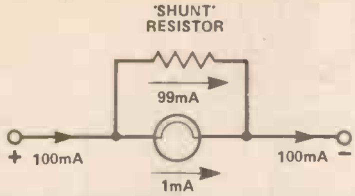


Fig. 2. The current indicating range of a basic meter can be increased by connecting it in parallel with a 'shunt' resistor.

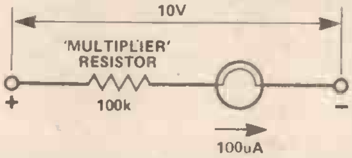


Fig. 3. A basic meter can be made to indicate voltage by wiring it in series with a 'multiplier' resistor.

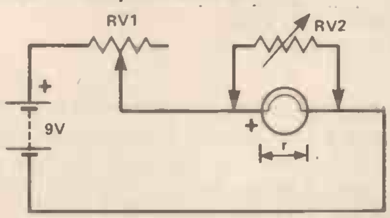


Fig. 4. Set-up for determining the internal resistance, r, of a moving coil meter. Method of use is explained in the text.

COIL SUSPENSION METHODS

All moving coil meters have their movements or coil units suspended on some kind of bearing assembly. Usually the bearings are of the jewelled type. Inevitably, a certain amount of friction occurs between the coil pivots and the bearings, and these meters consequently suffer from a characteristic that is known (in the trade) as 'stiction'.

At best, stiction causes a rising test current to give an indication that is slightly below the true value and a falling test current to give an indication that is slightly above the true value. Whenever an accurate measurement is to be made, these meters should be gently tapped with the finger to overcome stiction and give a true measurement. At its worst, stiction can cause a movement to jam at various points when it is fed with slowly varying currents.

A few moving coil meters have their movements suspended on a taut-band or rod, rather than on bearings. These taut-bands act rather like a torsion bar, with the bar or taut-band doubling as both a frictionless bearing and as a pair of contra-wound coil springs: current is fed to the coil via light-weight fly-leads. Meters of this type are known as moving-coil taut-band suspension meters. They do not suffer from stiction problems, but tend to be rather more expensive than conventional meters.

METER ACCURACY

One of the most important but least understood characteristics of a meter is its accuracy. The accuracy of a moving coil meter is invariably expressed in terms of percentage and may refer to the percentage error inherent in the absolute reading over the 'effective range' of the instrument, or to the 'percentage of full-scale value' error in an absolute reading over the 'effective range' of the instrument. The 'effective range' is defined as 'from 0.1 of scale range to full-scale value' in DC-indicating meters, and 'from 0.25 of scale range to full-scale value' in AC-indicating meters.

The most misunderstood 'accuracy' term is that relating to 'percentage of full-scale value'. A typical accuracy (possible error) value may be 2%. Take the case of a meter that is calibrated to give a full-scale reading of 100 volts. At full-scale the possible error of indication is 2%, or 2 V, so the true full-scale voltage is in the range 98 V to 102 V. At half-scale the possible error is still 2 V (= 2% of full-scale), so the true value of an indicated 50 volts is 48 V to 52 V and the absolute accuracy is 4%. At quarter-scale the true value of an indicated 25 volts is 23 V to 28 V and the absolute accuracy is 8%. Finally, at one-tenth of full-scale the true value of an indicated 10 volts is 8 V to 12 V and the absolute accuracy is a mere 20%.

The accuracy of most meters is specified in the 'percentage of full-scale value' term and the possible accuracy here is generally restricted by the stiction problem. High-quality jewelled-bearing meters, such as the Avo 8, give typical accuracies in the range 1% to 2% of full-scale. Poorer quality meters have typical accuracies in the range 3% to 5% of full-scale. Meters with taut-band suspension do not suffer from the stiction problem and typically give accuracies of 1% absolute plus or minus 1% of full-scale.

METER SENSITIVITY

The most important characteristic of a meter is its basic full-scale sensitivity or current-indicating capacity. This parameter may be expressed in either of two ways, either in direct terms of its FSD (full-scale deflection) current, or in terms of k/volt (kilohms per volt). The latter figure is of use when converting a milli- or micro-ammeter into a voltmeter and can be deduced by taking the reciprocal of the FSD current figure in milliamps. Thus, a 1 mA FSD meter has a sensitivity of 1 k/volt and a 100 uA FSD meter has a sensitivity of 10 k/volt.

The basic sensitivity of a meter is usually marked on its scale; if not, it can be determined by comparison with a standard meter. Sometimes it's useful to know the voltage that is required to give fsd on the basic meter and this value can be calculated by multiplying the meter fsd current by the meter internal (coil) resistance. The fsd voltage is commonly in the range 50 mV to 150 mV.

METER INTERNAL RESISTANCE

The coil of a meter has a resistance that may vary from a few ohms in low-sensitivity meters to a few thousand ohms in high-sensitivity meters. It is necessary to know the value of this resistance if the indicating ranges of a basic meter are to be changed. In some cases, the basic meter resistance value may be marked on the meter scale; if not, it can be determined by the method described below. Note that **NO ATTEMPT SHOULD EVER BE MADE TO DIRECTLY MEASURE THE COIL RESISTANCE OF A METER WITH AN OHMMETER**, since such an attempt may result in severe damage to the meter movement.

Fig. 4 shows the basic set-up for measuring the meter coil resistance. RV1 must have a value that is between

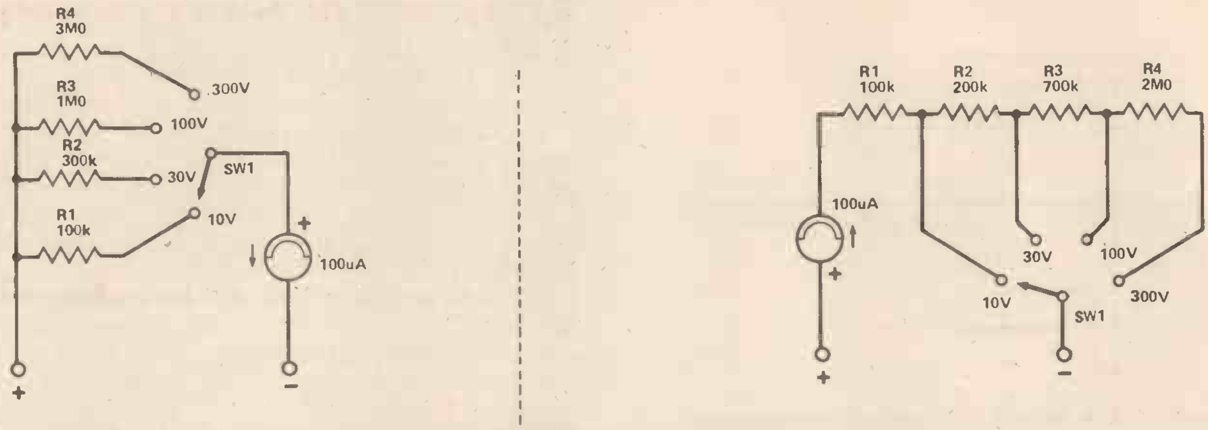


Fig. 5. Two alternative ways of switching multipliers on a 4-range DC voltmeter. Method (a) is sometimes used in low-cost multimeters. Method (b) is used in good-quality multimeters.

10 and 25 times the k/volt value of the meter. Initially, RV1 is set to maximum value, so that the meter draws less than full-scale current when it is first connected. Once the meter is connected, RV1 is adjusted so that the meter reads exactly fsd. A shunt resistor, RV2 (usually a decade resistance box), is then placed across the meter and adjusted until the meter reading falls to exactly half of the fsd value, at which point half of the total circuit current is clearly passing through the meter and half through the shunt, and RV2 has a value equal to the internal resistance of the meter. The measurement can be verified by briefly removing the shunt, at which point the meter indication should return to fsd.

The internal resistance value of the meter can then be established by noting or measuring the value of RV2. Note that RV1 should have a final in-circuit value that is at least 50 times greater that the measured internal resistance of the meter. If not, use a battery with a higher voltage than shown in Fig. 4, and increase RV1 accordingly, as excessive errors may otherwise enter the calibration due to non-constant currents through RV1.

An alternative method of determining the meter resistance using the same set-up as shown in Fig. 4 is to simply connect a precision resistor of known value across the meter in the RV2 position and note the change in meter reading that takes place. The internal meter resistance, r, can then be calculated from:

$$r = Rp(i - I)/I$$

where Rp is the value of the precision resistor in parallel with the meter, i is the fsd rating of the meter, and I is the new reading of the meter.

DC VOLTMETERS

A moving coil (milli- or micro-) ammeter can be made to measure voltages by adding a suitable resistor in series with the meter, as already shown in Fig. 3, the resistor being referred to as a 'voltage multiplier' resistor.

If a meter with a sensitivity of 100 uA fsd is to be used to measure 10 volts fsd, a multiplier resistor must be found of such a value that, when 10 volts are connected across the 'volt' terminals, a current of 100 uA must flow. If, for the moment, the internal meter resistance is ignored, it can be seen from Ohm's Law that the resistance is E/i, where E is the voltage and i is the fsd current of the meter. In this case the answer works out at 100 k, which is ten times the k/volt figure of the 100 uA meter (= 10 k/volt).

If the voltmeter was required to measure 100 volts fsd, the multiplier would have a value of IMO, or 100 × 10 k/volt. It can be seen, then, that all that has to be done (ignoring the internal meter resistance) to convert a basic moving coil meter to a voltmeter is to multiply the k/volt figure of the meter by the required fsd voltage in order to arrive at the correct value of series multiplier resistance.

When the internal meter resistance is to be taken into account the formula becomes:

$$Rm = (E/i) - r,$$

where Rm is the multiplier resistance and r is the internal meter resistance.

To take two examples in the use of this simple formula, assume that a meter with a sensitivity of 100 uA fsd (10 k/volt) and an internal resistance of 1 kO is to be used as a voltmeter measuring (a) 3 volts and (b) 30 volts fsd. The following results are obtained:

(a) Rm = 30 k − 1 k = 29 k.
(b) Rm = 300 k − 1 k = 299 k.

Note in case (a) that the exclusion of r from the calculation would have resulted in an error of 3.3% in the final results, but in the case of (b) an error of only 0.33%

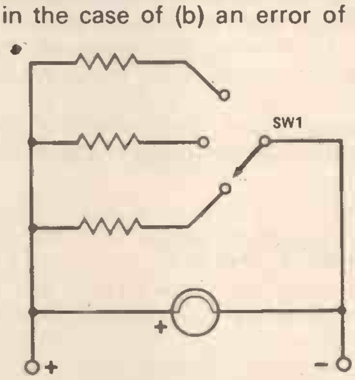


Fig. 6. How NOT to arrange shunt switching on a multi-range current meter. This method is often used in amateur-designed meters: the meter may be destroyed if the switch develops high contact resistance during a measurement.

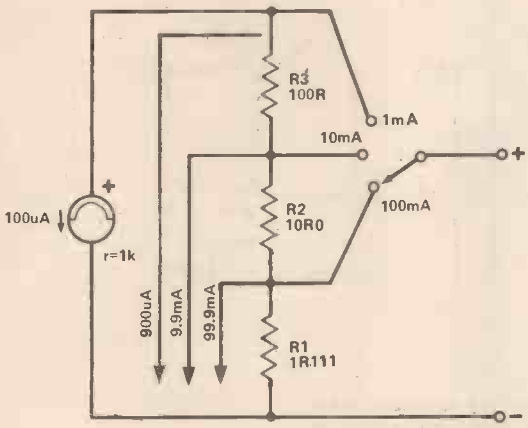


Fig. 7. Worked example of a 3-range universal shunt circuit, complete with range switch connections.

would have resulted from excluding r. It can thus be seen that the internal meter resistance can be ignored in cases other than when low voltages are to be measured.

When a moving coil 'voltmeter' is used it inevitably draws current from the circuit that is being measured, thus altering circuit conditions. The low current taken by the meter, the smaller are the influences that it has on the circuit under test. General-purpose meters that are used for measuring voltages in modern electronics circuits should ideally have sensitivities of at least 10 k/volt, and preferably of 20 k/volt or better.

MULTI-RANGE VOLTMETERS

If several voltage ranges are to be incorporated in a moving coil meter, two methods of range switching are possible., These are shown in Figs. 5a and 5b. To illustrate with an example, assume that a 10 k/volt meter is to give the following ranges: (a) 10 volts, (b) 30 volts, (c) 100 volts, and (d) 300 volts.

The multipliers required (r being ignored in all cases) are (a) 100 k, (b) 300 k, (c) 1M0, and (d) 3M0.

In the case of Fig. 5a the values of R1 to R4 are quite straightforward and are as above. In the case of Fig. 5b, however, things are not quite as simple. R1 measures the 10 V range, and is 100 k. But the 30 V range is made up of R1 and R2 in series, so R2 is 300 k — 100 k = 200 k. Likewise, (c) is made up of R1, R2 and R3 in series so R3 = 700 k. By the same token, R4 = 2M0.

The Fig. 5b method of range switching is widely used in good-quality multimeters and sometimes used in low-cost meters.

Resistors used for voltage multipliers should be high accuracy (1% or better) types, with low temperature coefficients. Wire wound or metal film types are best: carbon film resistors are also useable, but metal-oxide types are not, due to their poor temperature coefficients. In high-voltage multipliers, check that the voltage ratings of the multiplier resistors are not exceeded: if necessary, make the resistance up with several resistors in series, so that the applied voltage is distributed across the resistor chain.

EXTENDING CURRENT RANGES

To extend the current range of a basic meter a 'shunt' resistor is added across (in parallel with) the basic movement, as already shown in Fig. 2. A known fraction of the current under test passes through the shunt and the remainder passes through the meter, which can thus be calibrated in terms of the total current passed through the circuit. The ratio of the shunt and meter currents is determined by the relative values of the meter internal resistance and the shunt resistance.

The formula giving the required value of a shunt resistor, Rs, is:

$$Rs = n - 1 / r$$

where r is the meter internal resistance and n is the current multiplication factor (the number of times by which the required range is greater than the basic range). Thus, to convert a 1 mA meter to read 50 mA fsd, n = 50, and the term n — 1 = 49. Assuming the meter internal resistance to be 100 ohms, the shunt will be 100/49 = 2.04 ohms.

An alternative formula, which gives the same result, is:

$$Rs = \frac{Im \times r}{It - Im}$$

where Im is the fsd current of the meter, and It is the total fsd current of the circuit. Note that this formula finally resolves down to a simple V/I form, in which V is the fsd voltage of the basic meter, and I is the fsd shunt current.

Individual shunt resistors should either be permanently wired across the basic meter, or should be connected to the meter via low-resistance screw terminals. They should **NEVER** be switched into position using the circuit shown in Fig. 6, which is often used in

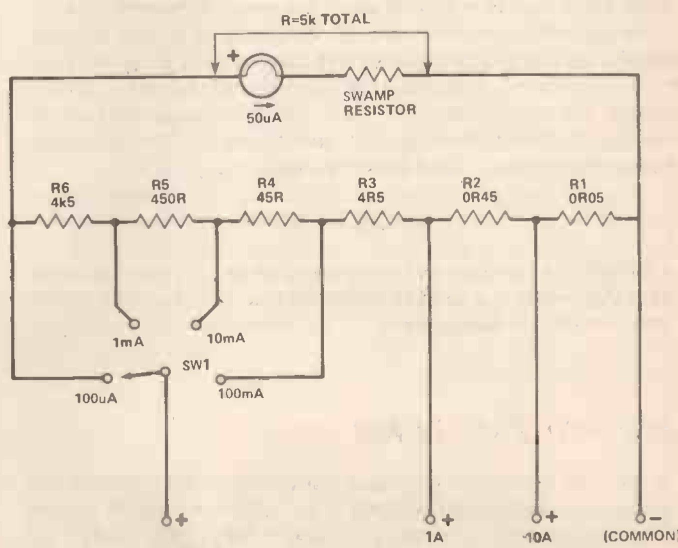


Fig. 8. Practical example of a swamp resistor applied to a 6-range current meter. The 100 uA to 100 mA ranges are switch selected. The 1 A and 10 A ranges are selected via screw terminals.

Fsd voltage sensitivity varies from 250 mV on the 100 uA range to 500 mV on the 10 A range.

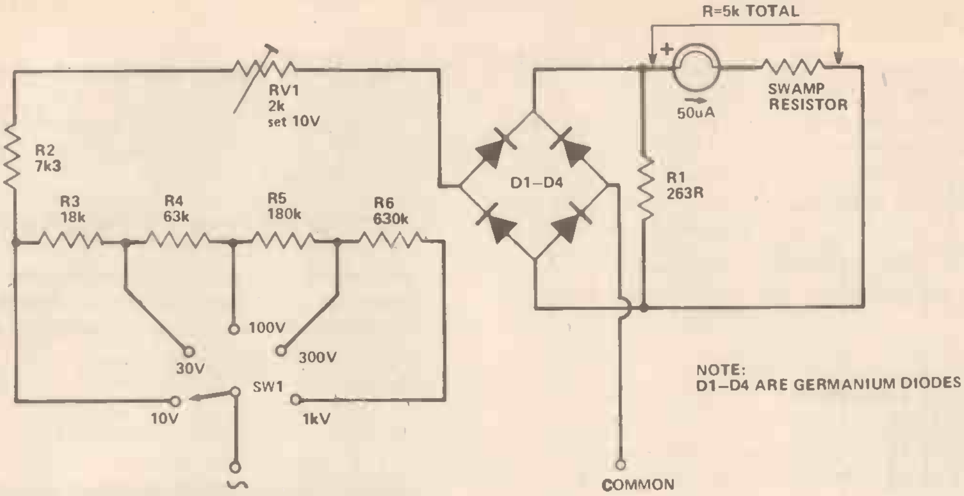


Fig. 9. Practical example of an AC voltmeter covering 10 V to 1 kV in 5 ranges. The meter sensitively is reduced to 1 k/volt via R1.

amateur-designed multimeters. The switch here is effectively in series with the shunt resistors and inevitably has an unpredictable amount of contact resistance that varies with time and wear, and consequently greatly effects the meter calibration. If the switch contacts go open circuit during a measurement, due to oxidation or a mechanical fault, all of the test current will go through the basic meter, causing possible destruction of the movement.

If a moving coil meter is to be used as a switched multi-range current meter, its circuitry should always be designed around a so-called 'universal' current shunt network.

THE UNIVERSAL SHUNT CIRCUIT

Figure 7 shows the practical circuit of a 3-range (1 mA, 10 mA, and 100 mA) universal shunt, complete with its switch connections. The range resistors are all wired in series and are permanently connected across the meter. The range switch is external to the shunt network, range changing being achieved by tapping into the shunt chain, so the switch contact resistance has no effect on the calibration accuracy of the meter on any of its ranges. Note that, since the basic meter is shunted on all ranges, the lowest effective current range of the circuit is greater than that of the basic meter.

The procedure for designing a universal shunt is very simple and is best illustrated by the practical example of Fig. 7, in which the basic meter has a sensitivity of 100 uA fsd, and an internal resistance of 1 k. The first step in the design is to determine the TOTAL resistance of the R1-R21-R3 chain, which determines the fsd value of the circuit on its LOWEST (1 mA) current range. The total resistance of the chain is given by:

$$Rt = \frac{r}{n-1}$$

where r is the internal resistance of the meter and n is the current multiplication factor. In the case of our example the answer works out at 1000/9 = 111.11 ohms.

The next step is to calculate the **TOTAL** value of the **HIGHEST** current shunt, which in this case is R1 and controls the 100 mA range. The formula for determining the total value of this and all other 'universal' shunts is:

$$Rst = r + Rt/n$$

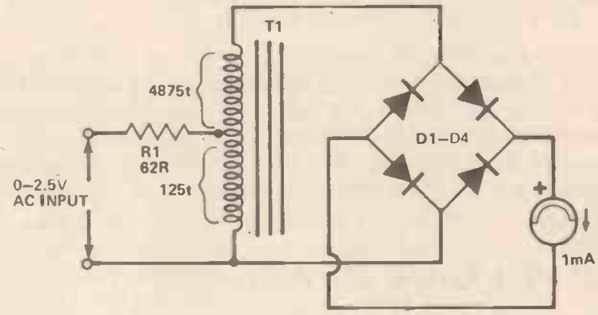


Fig. 10. Example of a low-value (0-2.3 V) AC voltmeter using a step-up autotransformer to give improved meter linearity. This circuit is used in the Avo 8 Mk 2.

and in this case gives a value of 1111.11/1000 = 1.1111 ohms for R1.

The same formula is used to find the values of all other shunts, and on the 10 mA range gives 11.111 ohms, but since this shunt comprises R1 and R 2 in series, the value of R2 = 11.111 — 1.1111 ohms = 10 ohms.

Finally, the total shunt value for the 1 mA range is 111.11 ohms, so the value of R3 = 100 ohms. The design procedure is then complete.

As a point of general interest it may be noted that, since the total resistance in series with the meter varies with each range of a universal shunt, the fsd voltage sensitivity of the circuit also depends on the current range selected. In our example the fsd sensitivity is 100 mV on the 1 mA range, 110 mV on the 10 mA range, and 111.1 mV on the 100 mA range.

A final point of interest is that it is a common practice in commercial instruments to make all current ranges above 1 amp accessible via screw terminals, rather than via a range switch, thus eliminating the need to use switches with very high current ratings. The terminals are wired directly to the range resistors on the universal shunt.

THE SWAMP RESISTOR

It is a common practice in multi-range commercial current meters to wire a so-called 'swamp' resistor in series with the basic meter, as shown in fig. 8.c This resistor has two purposes. On the one hand, it can be used to raise the total series resistance of the meter circuit to a level that precisely matches a previously designed universal shunt network. On the other hand, it can be used to compensate the temperature coefficient of the meter coil, and so give improved accuracy over a wide temperature range. The use of a swamp inevitably increases the fsd voltage value of the meter circuit.

MAKING CURRENT SHUNT RESISTORS

Shunt resistors with values greater than a few ohms can be made by connecting wire wound, metal film or carbon film resistors in parallel to give the desired value: the final resistor should have an accuracy of 1% or better.

Shunt resistors with values below a few ohms can be made up from Eureka or Constantin wire of suitable gauge, cut to suitable length. Most electronics reference books give data tables relating to these wires.

The precise length of wire for a shunt can be found by passing the full test current through the wire via a standard (precision) current meter, and then connecting the test meter across the wire via flexible leads and moving the leads along the wire until the required fsd is obtained, at which point the wire length is correct. One centimetre should be added to each end of the wire, to allow for soldering the shunt to suitable former terminals.

AC VOLTAGE MEASUREMENT

Moving coil meters respond to DC current only. Thus, to measure AC voltage it is necessary to rectify the signal and feed it to the meter via a suitable voltage multiplier resistor. A common means of rectification is via a bridge rectifier, as shown in Fig. 9. Special instrument rectifiers are available for the job, but four ordinary germanium rectifiers connected as a bridge will perform just as well.

All rectifiers have a non-linear action and are most non-linear near the 'zero' end of their characteristics curve. For this reason the rectifiers are usually operated from 0 to 1 mA in moving coil AC voltmeters, rather than from (say) 0 to 50 uA. Commercial meters thus have a far lower sensitivity on AC voltage ranges than they have on DC voltage ranges.

AC voltmeters are normally calibrated to read RMS values of a sine wave input. In this case the meter passes a current of 1.11 times the pure DC current. The 'multiplier' formula for AC voltage thus becomes:

$$Rm = E/i \times 1.11$$

where i is the pure DC fsd current in amps, remembering that this is normally of the order of 1 mA.

It is important to note on ranges below about 10 volts fsd that the scale readings become distinctly non-linear, particularly at their low ends. Fsd ranges below 2.5 V are rarely provided on commercial instruments, because of the non-linearity problem. It is necessary on low voltage ranges to allow for the rectifier resistance as well as the internal meter resistance when constructing voltage multipliers.

Some high-quality commercial multimeters, such as the Avo 8, use a step-up autotransformer to increase the voltage that is actually fed to the rectifier circuit from a low-voltage source, as shown in Fig. 10 and thus overcome the non-linearity problem mentioned above. The major disadvantage of this system is that the transformer places severe limitations on the usable frequency range of the instrument.

AC CURRENT MEASUREMENT

Alternating current is a difficult quantity to measure on a moving coil meter and the majority of commercial multimeters make no provision for such measurements. One exception to this is the Avo 8, which provides AC current ranges of 100 mA, 1 A, 2.5 A, and 10 A. The technique used on the Avo 8 is to feed the current through the windings of a step-up autotransformer; the meter and rectifier are connected to the output of the transformer, which steps up the voltage but reduces the current to them and thus overcomes non-linearity problems. The set-up is similar to that of the Fig. 10 circuit.

OHMMETERS: THE SERIES-CONNECTED TYPE

Moving coil meters can easily be converted to read resistance. Two basic types of ohmmeter are in common use and are known as the series-connected and the parallel-connected types.

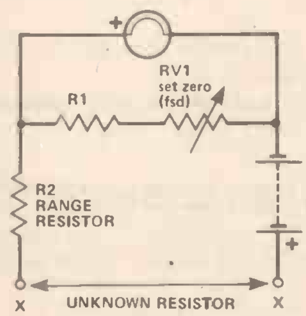


Fig. 11a. Basic circuit of a series-connected ohmmeter. R2 determines the centre-scale resistance value of the meter.

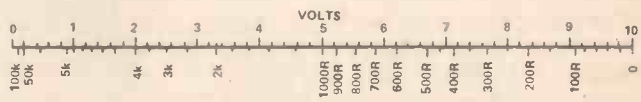


Fig. 11b. Resistance range calibration against a linear volts scale.

The most popular version of the series-connected ohmmeter is shown in Fig. 11a. This circuit has a set-zero variable resistor network wired in parallel with the meter and has a 'range' resistor wired in series with the combination: the value of this resistor is made the same as the required centre-scale resistance reading of the meter. The 'unknown' resistor is wired in series with the meter network, hence the name 'series-connected' ohmmeter.

In use, the X terminals of this ohmmeter are first shorted together and the variable resistor is adjusted to bring the meter pointer to fsd. The unknown resistor is then connected between the X terminals and the new current reading noted. The value of the unknown resistor can then be calculated from:

$$Rx = R(i/I - 1)$$

where i is the fsd current on the basic meter and I is its new current reading.

The meter scale can either be calibrated against a graph made on the basis of a few dozen sets of calculations based on the above formula (see Fig. 11b), or can be directly calibrated against a large number of accurately known resistors.

A major attraction of this circuit is that (a) its calibration accuracy is not influenced by minor changes in battery voltage and (b) once calibrated its scale values can be increased by (say) a factor of ten by simply increasing the value of range resistor R by a factor of ten and either increasing the battery voltage or the effective meter sensitivity by the same amount.

OHMMETERS: THE PARALLEL-CONNECTED TYPE

The parallel- (or shunt-) connected ohmmeter is used for measuring low and very-low values of resistance. The basic circuit is shown in Fig. 12 and the method of use is to first close SW1 and adjust the meter to fsd with the X terminals *open-circuit*. The unknown resistor is then connected across the X terminals and the new reading noted. The value of the unknown resistance can be calculated from:

$$Rx = rxi / i - I$$

where r is the internal resistance of the meter, i is the fsd current of the basic meter, and I is the new current indication.

Note in this circuit that high values of resistance give a high reading on the meter scale, and low values give a low reading: this is the reverse of the reading style given by the series-connected type of ohmmeter.

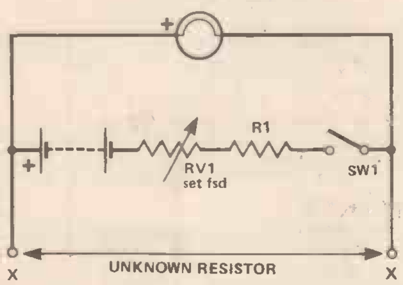


Fig. 12. The parallel-connected type of ohmmeter is used to measure low and very-low values of resistance.

METER OVERLOAD PROTECTION

Moving coil meters are delicate instruments and are easily damaged by overload currents exceeding their fsd values by 50% or more. Ideally, they should be provided with some means of overload protection. A limited degree of protection can be gained by wiring a pair of germanium diodes across the basic movement as shown in Fig. 13. The diodes are non-conductive until the voltage across the meter rises to a couple of hundred millivolts, at which level they start to conduct and shunt further excess current away from the movement.

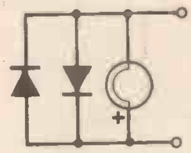


Fig. 13. A moving coil meter can be given a limited degree of overload protection by connecting two germanium diodes as shown.

COMMERCIAL MULTIMETERS: THE AVOMINOR MK 5

A very large range of commercial multimeters are available. They vary from cheap and nasty little things with only a few ranges, to expensive and superbly engineered instruments with thirty or more ranges.

One of the best known and most popular 'middle-of-the-road' multimeters in the U.K. is the Avominor. Figure 14 shows the full circuit diagram of the Mk 5 version of this instrument, and is reproduced by kind permission of Avo Ltd. The instrument has a total of 19 ranges.

The basic movement sensitivity of this multimeter is 60 uA fsd, but is reduced to 100 uA by the RV1 and R14 to R18 universal shunt that is permanently wired across the meter. The shunt provides DC current ranges of 100 uA to 1 amp fsd. No AC current ranges are provided.

Some high quality multimeters use a mechanical or electro-mechanical trip to give overload protection. In the Avo 8, for example, all inputs to the multi-meter terminals are passed to the meter circuitry via a set of contacts that are coupled to a sensitive mechanical trip which activates and breaks the contacts if the meter pointer exerts appreciable pressure against the scale end stops. This device gives good protection not just to the meter movement, but to all of the meter circuitry as well.

The fsd voltage sensitivity of the Avominor meter movement is set at 100 mV by swamp resistor R19, thus enabling the 100 uA current range to also function as a 100 mV DC voltage range. Other DC voltage ranges, from 2.5 V to 1000 V, are provided via the R1 to R19 multiplier chain. This same multiplier chain is also used to provide AC voltage ranges from 10 V to 1000 V fsd, but in this case the meter sensitivity is reduced to 1 k/volt by connecting R12 across the meter movement.

The Avometer Mk 5 has two resistance measuring ranges, which span an effective range of 5 ohms to 2MO. The multimeter is not provided with overload protection.

COMMERCIAL MULTIMETERS: THE AVO 8 Mk 2

The Avo 8 is reckoned to be a 'Rolls-Royce' amongst multimeters. They are expensive instruments to buy new, but an amateur can occasionally pick up a good second hand one at a reasonable price. A likely choice here is a Mk 2, and the circuit diagram of this particular specimen is reproduced in Fig. 15, by kind permission of Avo Limited.

The Mk 2 has some 31 measurement ranges, running from 50 uA to 10 amps and 2.5 V to 2500 V on DC, and from 100 mA to 10 amps and 2.5 V to 2500 V on AC, as well as three basic and two special resistance ranges. Sensitivity is 20 k/volt on DC and 1 k/volt on

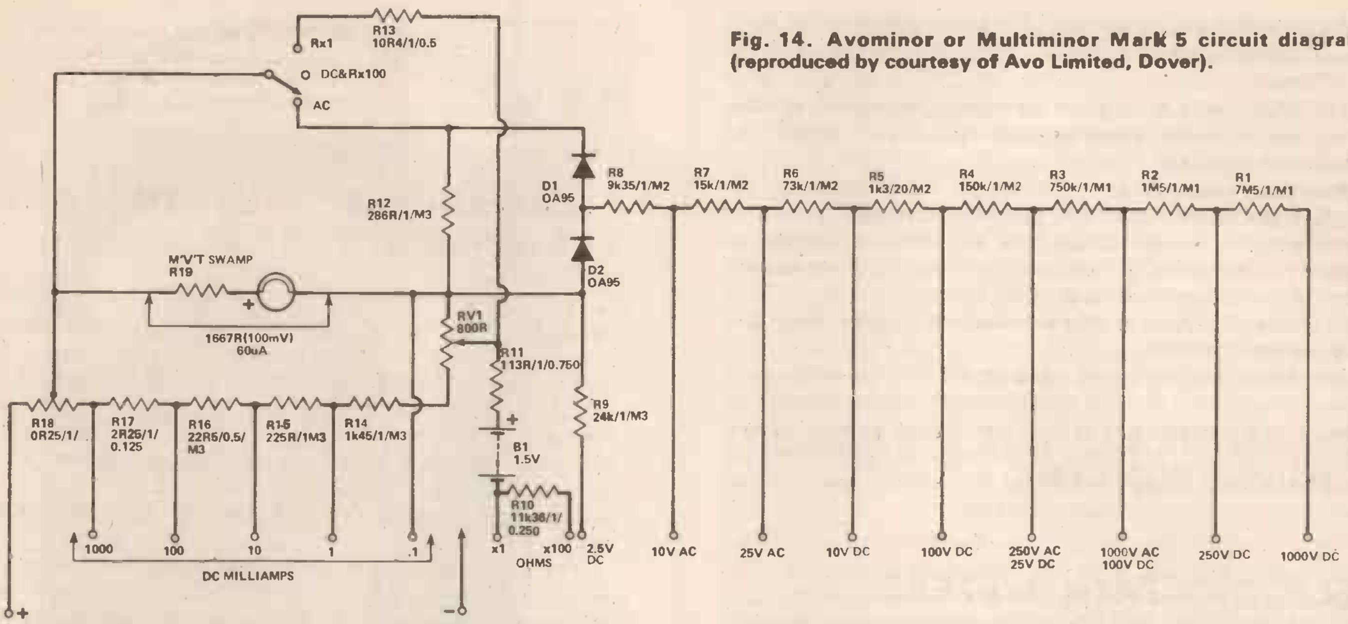


Fig. 14. Avominor or Multiminor Mark 5 circuit diagram (reproduced by courtesy of Avo Limited, Dover).

AC voltage ranges. The instrument is provided with a mechanical cut-out that gives excellent overload protection, as already described.

USING A MULTIMETER

A multimeter is a fairly easy instrument to use if you stick to the following basic rules;

(1). Most moving coil multimeters are designed to operate accurately only when their faces are in one specific physical orientation, usually horizontal. If you are taking an accurate measurement, never slope the meter at an angle and don't use it vertically if it's meant to be used horizontally.

(2). When measuring an unknown current or voltage, always set the meter to its highest range and then work down through the ranges until the correct one is found.

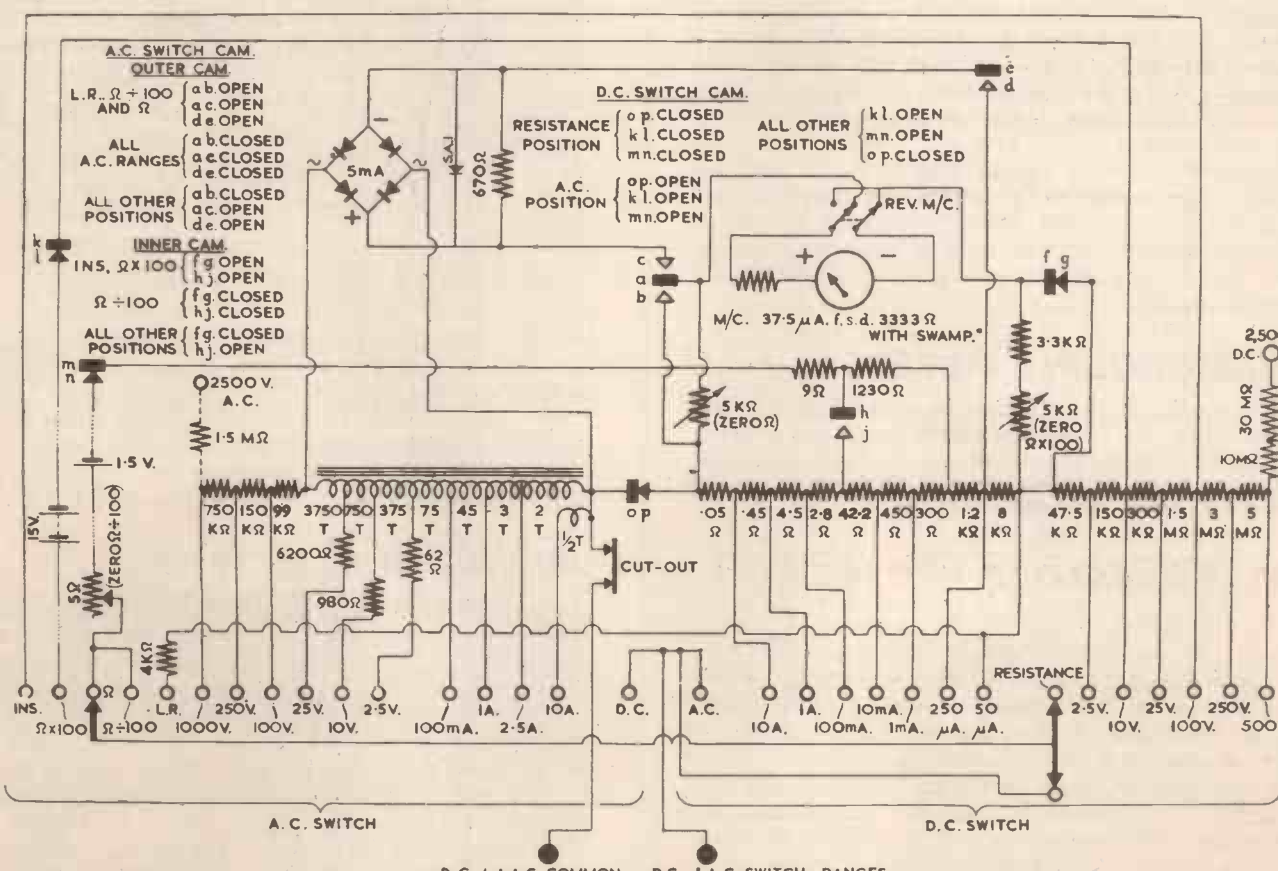


Fig. 15. Circuit diagram of the Model 8 Avometer Mk 2 (reproduced by courtesy of Avo Limited, Dover).

(3). When measuring an in-circuit voltage, always connect the meter across the voltage source, as shown in Fig. 16a.
(4). When measuring an in-circuit current, always connect the meter in series with the current source, as shown in Fig. 16b.
(5). When measuring an in-circuit resistance, always isolate the resistance from all other circuitry and then connect the meter across the resistor, as shown in Fig. 16c. Never try to measure the value of a resistance that has a voltage source applied to it.
(6). Always handle a multimeter with care. They are fragile instruments.
(7). When a multimeter is used on its voltage ranges, its input impedance (k / volt sensitivity x voltage range) will shunt any resistance that it is connected to and so will reduce the apparent value of voltage developed across that resistance. Always allow for this 'disturbance' effect when taking voltage measurements.

ELECTROSTATIC METERS

In the preceeding pages we have discussed only the moving coil type of analogue meter. There are, however, a number of other types of analogue readout meter that are occasionally encountered in an electronics laboratory. The three most common of these are the electrostatic meter, the thermocouple meter, and the moving iron meter.

Electrostatic meters are true voltmeters, and usually have fixed fsd sensitivities in the range 200 V to 30 kV. They are made up from one fixed and one moving set of vanes, which look and act just like a variable tuning capacitor. A pointer is fixed to the moving vane. When a voltage is applied across the vanes an electrostatic force is set up, and the moving vane rotates by an amount proportional to the force. The meter scales are non-linear and are cramped at the low end.

Electrostatic meters respond to both DC and AC voltages. They appear as capacitors to external signals and draw zero current from DC sources, and a frequency-dependent current from AC sources. They are widely used for high-voltage measurement, particularly in television work.

THERMOCOUPLE METERS

Thermocouple meters are widely used as RF voltage and power indicators at frequencies up to hundreds of MHz, and as wideband AC / DC transfer standards in electrical calibration work. They consist of a thermocouple (a junction of two wires made from dissimilar metals, which generates a voltage in each wire when the junction is heated) that has one set of its wires connected to an ordinary moving coil meter and the other set taken to the outside world via a pair of terminals. When a current is fed through this second set of wires it causes the thermocouple junction to heat up, a voltage in the set of wires connected to the meter, which thus deflects by an amount proportional to the current in the second set of wires.

The major attraction of the thermocouple meter is that its deflection is proportional to the true RMS current in the second set of wires and is not influenced by the shape or frequency of the waveform. The meter can thus be used for measurement from DC to hundreds of MHz and can be used as an AC / DC transfer standard. The two major disadvantages of the thermocouple meter are that its scale follows an approximately square law and that the thermocouple is very fragile (it can be burnt out by quite small overloads).

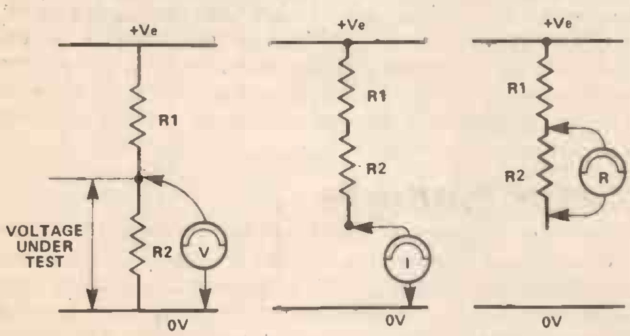


Fig. 16. Correct way to use a multimeter to measure in-circuit (a) voltage, (b) current, and (c) resistance.

The Avo 8 Mk 3.

MOVING IRON METERS

These meters are widely used as AC or DC volt or current meters in low-accuracy applications, such as in battery chargers, etc. They have a fixed coil, through which the measured current is passed, and an iron vane that is mounted on a spindle that is coupled to a pointer. When a current is passed through the coil it sets up a field which repels the vane and causes the pointer to move.

This type of meter is cheap and robust, but has a low sensitivity. It responds equally well to AC and DC, but has a non-linear scale and generally has poor accuracy. It is current operated, and thus can be used in both current and voltage indicating applications. **HE**

Internal Resistance

Resistance is the property which makes it harder for electronics to flow — not hard to understand but what is the effect of resistance within a current generator which is actually causing those electrons to travel? K. T. Wilson examines the internal resistance in batteries.

EVER USE a battery, or a mains supply? Of course you do but do you know what voltage was present. It's not a daft question. You may have a battery labelled 9 V or a power supply labelled 12 V but that's no guarantee that these are the voltages which are given out when you start to take current from the battery or the power supply. You can find, for example, that your 9 V battery gives only 7.2 V when you connect it to a circuit that needs a fair amount of current, or that your mains supply which should be a 12 V gives only 11 V.

TWO PIECE SUPPLY

All this is caused by what is called internal resistance, which is the total resistance of the materials inside the battery or the components and circuits inside the power supply. When we use the phrase 'electrical circuit' we really mean it — electric current goes all the way round, and the flow of current is affected by resistance anywhere in the circuit — including the inside of the battery or the power supply. This internal resistance causes the battery or power supply voltage to drop when we connect a circuit to it. Let's see why. Imagine a battery or a power supply in two pieces (Fig. 1). One piece is a perfect supply giving 9 V no matter what current is taken. The other bit is a resistor of 12 ohms in series. The terminals represent the terminals of the battery.

OHMS'S LAW AND ALL THAT

This is an equivalent circuit, meaning a 'theory' circuit which behaves in exactly the same way as a real one. For any real circuit, we can draw up an equivalent which is a lot easier to work with. Let's see how this one works out. If we don't take any current from this circuit, the voltage at the terminals is just the 9 V of the supply — we sometimes call this quantity the EMF (Electro-motive force) of the supply. When we take some current from the circuit, though, there will be a voltage drop across the 12 ohm resistor. How much voltage drop? Ohm's Law tells us. Suppose we take 100 mA, which is 0.1 A, then the voltage drop is $0.1 \times 12 = 1.2$ V. Now all the voltage which we can get in the circuit comes from the battery action, which converts the chemical reaction inside the battery into electrical voltage.

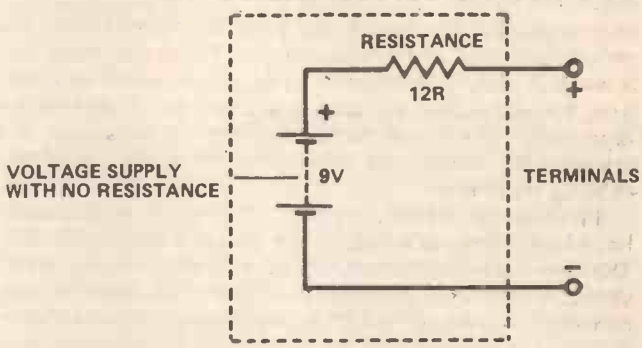


Fig. 1. Equivalent circuit of a battery or power-pack. If we think of the voltage generator part separate from its resistance, the action is much easier to understand.

The voltage at the terminals is therefore less, 1.2 V less, than the voltage which the battery generates. The terminal voltage is 9 V, $1.2 \text{ V} = 7.8$ V. This particular battery will therefore give only 7.8 V at its terminals when a current of 100 mA is drawn.

For a lot of electronic circuits, this change of voltage when current is drawn doesn't matter until the battery voltage starts to drop. This incidentally is what causes owners of multimeters to think they have something wrong with their radio, calculator or flashguns when all that's needed is a fresh battery . . . Why? They take the battery out and measure the voltage. Unless the battery is in a really bad way, the voltage that is measured will be the open circuit voltage, which can easily be quite normal. What you should test is the voltage at the terminals of the battery when the circuit is connected and working. A dud battery gives a very low voltage on this test because the internal resistance increases as the battery gets old and grey.

FUSSY CIRCUITS

There are circuits, though, which definitely dislike having a supply when the current changes. Even stereo amplifier circuits object a bit — it's not at all unusual to find that the maximum power per channel is quite different when both channels are in action than when, only one is driven at a time. Radar and computing circuits are distinctly fussy about changes of voltage too, so that the effect of internal resistance on a power supply is a bad thing as far as these circuits are concerned.

The answer to the problem is a voltage stabiliser circuit, which keeps the output terminals of the supply at the same voltage even when the current changes. Don't get too excited by the idea, though. A stabilising circuit isn't magic — it can't increase the voltage of a supply to compensate for the voltage drop of the internal resistance. What a stabiliser circuit does is to let us use a supply whose open-circuit voltage is much higher than we need. The stabiliser then acts as a controller keeping the voltage down to the level we need. For example, if we wanted to replace a 9 V battery supply by a stabilised supply, we would use a 15 V (or higher) supply. The stabiliser would then reduce this 15 V to 9 V. As more current is taken from the circuit, causing the 15 V to reduce to, perhaps, 12 V, the stabiliser adjusts automatically, reducing the 12 V to 9 V. Nostabiliser can cope if the amount of current that is taken from the circuit causes the supply voltage (before stabilisation) to fall below or even near the level of the stabilised voltage that is needed.

ALL DOWN TO ZENERS

The simplest form of voltage stabiliser is the Zener Diode. The Zener Diode is a silicon junction diode whose junctions are made by the same process as is used for silicon transistor junctions. We can, in fact, use the base-emitter junction of a silicon transistor as a Zener Diode — for several dozen 2N697's tested, the average Zener voltage was 15 V. The current voltage graph of the Zener Diode is shown in Fig. 2. As the reverse voltage across the diode is increased, the diode suddenly conducts at a voltage called the reverse breakdown voltage or Zener voltage. Once this voltage is reached, the current through the diode can be varied considerably with no change in the voltage. This makes the Zener Diode a very useful stabiliser. The circuit used is shown in Fig. 3. A voltage supply which must be several volts greater than the Zener Diode voltage is used to feed current to the Zener Diode through a resistor R. The value of R determines how much current can be taken out of the circuit before the Zener stops Zenering. For example — with a 5.6 V Zener Diode and a 9 V supply, the voltage across R is 9 — 5.6 = 34 V. If the value of R is 100 ohms, then the current flowing into the Zener Diode is I = V/ R = 3.4/0.1 = 34 mA (using 100R = 0.1 k.

Now if we connect a load resistor across the Zener Diode, it will take some current. If the Zener Diode does its stuff, the voltage across it must stay at 5.6 V, and the current that flows into the load is taken at the expense of the Zener Diode. If, in our example, the load takes 30 mA, then the Zener Diode takes 4 mA. This way, there's still a total of 34 mA flowing and the voltage drop across R is the same. If we tried to draw 34 mA from the Zener Diode circuit, though, we would expect to run into trouble, because that leaves no current passing through the diode and therefore no stabilisation.

A regulator of this type is called a shunt regulator because the device which carries out the regulation — the Zener Diode in this example — is in shunt (or in parallel) with the load.

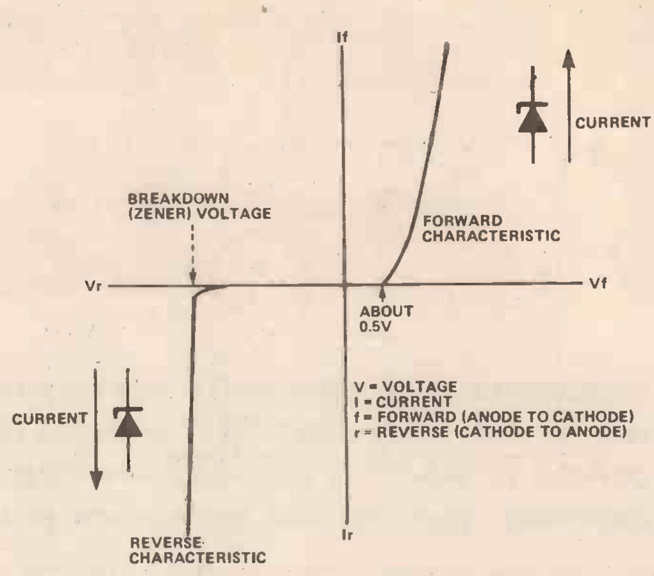


Fig. 2. Current-voltage graph (or characteristic) for a Zener Diode. The part of greatest interest to us is the reverse characteristic.

A shunt regulator works by keeping the current flowing from the supply at a constant value, allowing the load to tap some off as required at the expense of the regulator. The current through R is constant, so that the power rating of this resistor has to be watched. The Zener is dissipating most power when the load is drawing no current, so that this type of regulator is most useful for loads which draw some current all the time.

The device in shunt with the load doesn't have to be a Zener Diode. Fig. 4 shows a circuit sometimes called the amplified Zener which uses a transistor — which can be a high current type — along with a Zener Diode. In this circuit, the Zener Diode is connected between the collector and the base of a transistor, keeping the voltage between the two at the Zener Diode voltage. A low-current, low-power Zener can be used and we usually have to add a load resistor to keep enough current flowing through the Zener Diode for stabilisation. When this combination of transistor and Zener Diode is connected in circuit with a resistor, as if the whole circuit were a Zener Diode, the circuit acts as a shunt stabiliser. When the supply is switched on, current will flow through R1 so that the output voltage rises. When the output voltage rises above the Zener voltage, the voltage at the base of the transistor will also rise until the transistor starts to conduct with about 0.5 V between base and emitter. When the transistor starts to conduct,

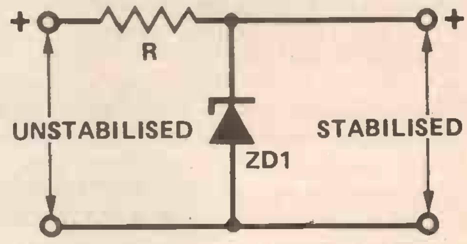


Fig. 3. A simple Zener Diode stabiliser circuit.

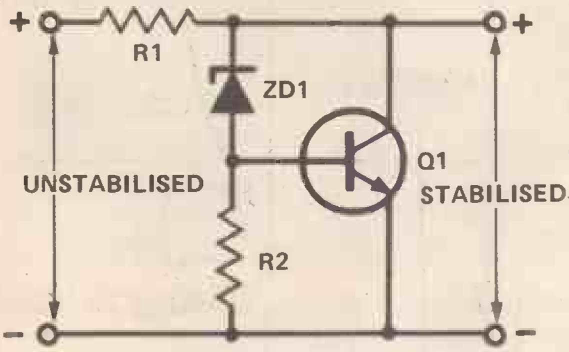


Fig. 4. The Zener-and-transistor shunt regulator, or "amplified-Zener" circuit.

the output voltage is stabilised. Why? Well, for any silicon transistor, a change of base voltage of 0.06 V is enough to cause the collector current to change by a factor of ten. For example, if the transistor passes 1 mA collector current at 0.55 V and the base, then at 0.55 + 0.06=0.61 V on the base the collector current will be 10 mA. The base voltage, therefore, stays pretty well fixed, because, even a slight increase in base voltage will cause a large increase of collector current and so a large voltage drop across R1 and that will cause the base voltage to drop!

The result is that the base voltage stabilises at around 0.55 V, and the output voltage at the collector is just the Zener Diode voltage greater. If we use a 5.6 V Zener, for example, the stabilised voltage will be 5.6 V + 0.55 V, about 6.15 V. We can, of course, choose the stabilised output voltage by choosing the Zener Diode voltage.

That's our answer to the internal resistance problem, but it's only part of the answer. There's another type of stabiliser circuit, the series stabiliser which works rather differently, but that will have to wait for another time.

HE

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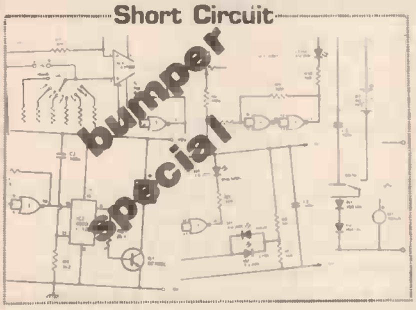
Next Month

BUMPER SHORT CIRCUIT ISSUE

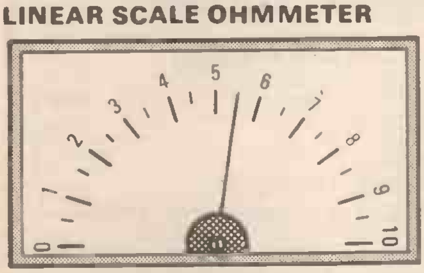


Look out this month for more than your usual share of our very popular Short Circuit feature. Plenty of circuit designs for you to develop and experiment with.

SHARK

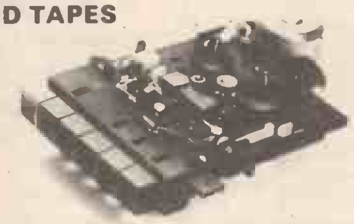
Not a game for the nervous. An LED-based game for two players which involved two swimmers in a race for survival in a shark-infested sea. Which of these two castaways will reach the safety of the island? The unfortunate one is swallowed by the hungry shark, accompanied by a shrill scream. All good family fun!

LINEAR SCALE OHMMETER



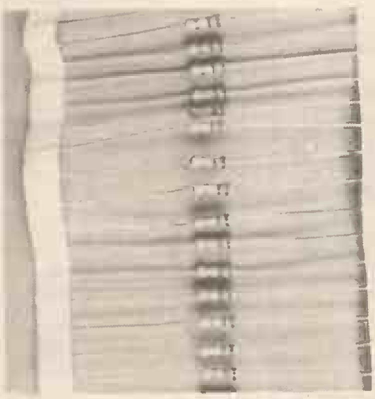
If you ever look at a multimeter on the ohms range you'll notice that most of the numbers are all squashed up one end; this makes accurate readings difficult. The HE Ohmmeter overcomes this difficulty with a linear scale. The range of resistance covered is from 1 k to 1 M ohms in four ranges, a useful addition to any workshop's range of test equipment.

CASSETTE DECKS AND TAPES



Next to the TV and Transistor radio, the Cassette tape recorder is probably the most common piece of domestic electronic equipment. Next month Gordon King takes a close look at what has made the Compact Cassette so popular and one or two of its advantages and drawbacks, warts and all.

RESISTORS

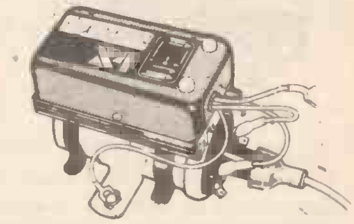


Following the success of our feature on Capacitors (according to our reader questionnaire) we're doing a follow up on the ins-and-outs of Resistors. Like Capacitors it's *not* going to be a formula-strewn study but a rather slanted look into their construction and use. So if you've never heard of Thick Film resistors and Metal Oxide, now's your chance.

HOBBY CHIT CHAT

Ray Marston our Project Editor/Designer starts a new monthly series looking at our fast-moving hobby from the technical point of view. These articles are designed to take a look into the worlds largest growth industry, what's new and how it will affect us in our daily lives as well as a more specific look at our own side of the fence in HE.

KIT REVIEW

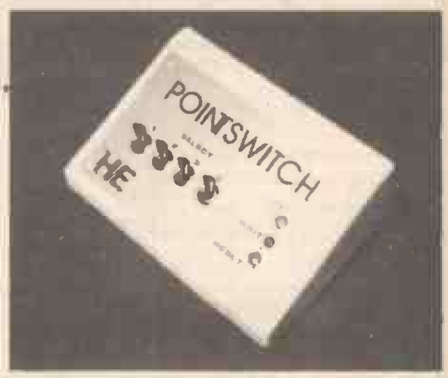


One for the motorist this month, we have built up an Electronic Ignition system from Sparkrite (X4); read all about it next month.

LINEAR ICs

If you've been wondering what's going to happen now Into Electronics has finished, don't worry. Ian Sinclair has begun his follow-up series Linear ICs. Month by month the articles will introduce most aspects of IC use, construction and theory. With the background knowledge gained from Into Electronics your understanding of new technology should increase dramatically.

POINTS CONTROLLER



Another project for model railway buffs. This unit gives full control over an unlimited number of electro-mechanical points using a push-button control. This makes an ideal companion to our HE Model Train Controller featured in the April issue.

BABY ALARM

A really simple project to keep one ear on the kids whilst you're building your latest HE project.

The July issue will be on sale June 8th

The items mentioned here are those planned but circumstances may affect the actual contents

Hobby Electronics

CLOCK RADIO

Size: 177mm x 90mm x 47mm.

You probably won't believe us as we're selling the goods but we're going to tell you anyway! We have *rejected* eight clock radios for Marketplace, they were all cheap enough but the quality was so poor that we couldn't have lent our name to them. However, we are now able to offer a portable LCD Clock Radio to you which meets our standards.

The clock is a 12-hour one with AM/PM indicated and a back light. The radio is Medium Wave and FM with very nice quality for a small speaker — for FM there's a telescopic aerial. The alarm can be either a 'beep-beep' type or the radio, there's also a snooze facility.

The case is sensibly rugged and is printed on the back with a World Time Zones map, a bit of a cheek really, especially as the time is relative to Japan!

We won't even mention the RRP — but just check on comparable prices — you'll find ours a bargain.

An example of this Clock Radio can be seen and examined at our Oxford Street offices.

£20·50

(Inclusive of VAT and Postage)

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Please find enclosed my cheque/P.O. for £20.50 (payable to Hobby Electronics) for my Clock Radio.

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Please allow 21 days for delivery UK only

Marketplace

DIGITAL ALARM CLOCK

Size: 100mm x 130mm x 60mm.

Over 10% of Electronics Today International's readers have purchased a digital alarm clock from offers in that magazine — the offer is now extended to Hobby Electronics readers. This is a first rate branded product at a price we don't think can be beaten.

The Hanimex HC-1100 is designed for mains operation only (240V/50Hz) with a 12 hour display, AM/PM and Alarm Set indicators incorporated in the large display. A switch on the top controls a Dim/Bright display function.

Setting up both the time and alarm is simplicity itself as buttons are provided for both fast and slow setting and there's no problem about knocking these accidentally as a 'locking switch is provided under the clock. A 9-minute 'snooze' switch is located at the top.

An example of this digital alarm clock can be seen and examined at our Oxford Street offices.

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Name . . . .

Address . . . .

. . . .

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Please allow 21 days for delivery. UK only.

LCD CHRONOGRAPH

We feel we've got to tell you carefully about this offer. Why? Because our price is so enormously lower than anywhere else you may suspect the quality.

The exact same watch is currently being offered by another magazine as a special at £24.95 — some of the discounters are selling it at £29.95 the price to HE readers for exactly the same watch is £12.95.

The display is LCD and shows the seconds as well as the hours — and minutes — press a button and you'll get the date and the day of the week.

Press another button for a couple of seconds and you have a highly accurate stopwatch with hundredths of a second displayed and giving the time up to an hour. There is a lap time facility as well — and of course a back light.

Our Chrono comes complete with a high grade adjustable metal strap and is fully guaranteed.

An example of this LCD Chronograph can be seen and examined at our Oxford Street offices.

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LCD CHRONO

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Address . . . .

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Please allow 21 days for delivery. UK only.

Citizens Banned

We in the British Isles are in a somewhat strange position at the moment, in our midst there are several thousand people breaking the law just by talking to each other, they are using a two-way communications system that is currently illegal. Many of the worlds so-called underdeveloped or politically restrictive countries freely accept CB (Citizens Band) so why not the UK? Richard Maybury and a few CBers (who wish to remain anonymous for obvious reasons) take a look at one of the most contentious subjects in our hobby today.

CHANCES ARE that unless you're a CB'er or have seen the film 'Convoy' all that is pretty meaningless. CB stands for Citizens Band, a short range, two way radio communications system, operating on the Short Wave at around 27 MHz using AM speech modulation.

CB first came into the world in America during the fifties where a Citizens Band was set aside for anyone to use requiring only the formality of a licence. No exams, just a straight fee. The only limitations were the band-spread (for obvious reasons) and output power, limited to 4 watts.

So why are we writing about an American phenomenon? Well it's not anymore, most of Europe, including some 'Iron Curtain' countries have legalised CB, as well as Australia, New Zealand and Canada, nearly everyone except for poor old Britain and Eire. However, although it's illegal it's reckoned by official sources that around 10 000 CB sets are operating in London alone. We would put the figure much higher, there really is a whole subculture out there most of us know nothing about.

CONVOYS AND COPS

Practically all of the 'Rigs' (CB transceivers) in this country are illegally imported, its difficult to say where from but we suspect it's a fair split between the States and Europe.

The craze in Britain really started in earnest about a year ago, inspired probably by the film and record 'Convoy' and the upsurge of interest in America around the mid seventies (due to the oil crisis and the nation-wide 55 mph speed limit). Hardly one American 'cop' show seems to pass without at least one reference to CB.

The current American system, and hence our own British system uses a sophisticated 40 channel arrangement over the 26.9 to 27.4 MHz range. Most rigs use a 'channel synthesizer' a clever device that requires only a couple (sometimes three) crystals to transmit and receive on all 40 channels. As most rigs are either destined for the American or American orientated markets they usually operate with a maximum of 4 watts RF. This is quite sufficient for a 10-15 mile range under normal atmospheric conditions. With the addition of a 'Burner' or 'Boots' (RF power amplifier in CB slang) and an aerial pre-amplifier it's quite possible to hold a Trans-Atlantic conversation utilising 'skip'. This is possible at the moment due to high sunspot activity, but will disappear in a few months. (Skip is where the RF signal 'bounces' around the upper layers of the atmosphere).

Nearly all these rigs are manufactured to strict FCC (Federal Communications Committee) regulations. So co-channel interference and RF splattering are kept to a minimum. It says a lot for the good design of these rigs, after all when was the last time CB interfered with you? (No, that's not an invitation for 10,000 of you to write in with your tales of woe).

In all fairness though RC (radio control) modellers and certain hospital paging systems operate on two or three of the 40 channels so it can interfere with legitimate users. We are told that quite a strict code of practice exists among CBers and these channels are avoided.

This rather novel CB rig has 80 available channels, by pressing the 'Hi,Lo' switch the set will operate up to 28MHz, we believe this type of rig is now available in the UK.

Below is an example of CB chat, on the left is what you might hear, just for fun we translated it into English, even we were surprised as to how formal it sounds.

"Breaker one four, breaker one four, any breakers got their ears on c'mon."	"Is anyone listening on channel 14, Is anyone listening on channel 14? Please reply. Over".
"Yeah, bring it back the breaker, you've got Moondancer comeback with your handle, break".	"Yes, I'm receiving you, my callsign is Moondancer, please reply with your callsign. Over."
"That's a four Moondancer, this the Sewerman, reading you in the nines, break".	"Very good, Moondancer, my callsign is Sewerman, receiving you loud and clear. Over."
"Yeah, Sewerman comeback with your rough twenty, break".	"Very good Sewerman, approximately where is your location. Over."
"My rough twenty is the Hackney area, what kinda rig you runnin'? Break".	"My approximate location is the Hackney area, what kind of apparatus are you using. Over."
"Yeah, that's a four, I've got a straight 40 channel digital and I'm running barefoot, is that a four? Break".	"Yes, that's satisfactory, I'm using an ordinary 40 channel tranceiver with digital display, do you understand? Over."
"For sure, for sure good buddy, I've got my boots on so my copy's pretty good, break"	"Yes I understand, I'm using an RF power amplifier on my apparatus; so you are probably receiving me loud and clear, Over".
"This is Firebird sitting on the side there, have you had any copy from Lucky Lady? Break"	"This is another Citizens Band operator listening in. My callsign is Firebird. Have you heard from a CB'er called Lucky Lady. Over."
"This is the Sewerman, negatory on that Firebird, it's pretty quiet so far, break".	"This is the Sewerman again, I'm afraid I haven't heard from this lady, it's been very quiet so far. Over."
"Yeah, Sewerman, give me a ten nine on that, the eyeties are treading all over us, break"	"Excuse me Sewerman, would you repeat your last message, the Italian gentlemen are rather loud at present. Over."
"That's a four Firebird, she's not been on channel so far, is that a four? Break".	"Sorry Firebird, I'll repeat my message, as far as I know she has not been using her apparatus, do you understand, Over."
"That's a four Sewerman, do you fancy an Eyeball? Break".	"Yes, thank you Sewerman, would you like to make my acquaintance? Over."
"Negatory on that Firebird. I'm near my works twenty, so I've got to go down, so I'll wish you all the high numbers and breaker, break".	"No, thank you Firebird, I'm nearing my place of work so I'm going to have to switch off, before we part may I wish you the best of luck and may all your future conversations be interference free, Over and out."
"Yeah, breaker break Sewerman, all the good numbers. Moondancer, you still on channel, C'mon"?	"Yes, thank you for all your good wishes, may I wish you the same. Over and out. Moondancer are you still receiving on channel 14, Over."
"That's a four Firebird, what's your rough twenty now? Break".	"Yes, that's correct, where are you now? Over."
"Yeah standby Moondancer, I'm in the traffic, Break"	"Excuse me for one moment, I'm in a traffic jam, and unable to transmit. Will you bear with me for a few moments? Over."
"Yeah standing by, Break".	"Certainly, I'll wait for a while. Over."
"Moondancer, you still on channel, C'mon"?	"Moondancer are you still there? Over."
"That's a four Firebird, do you want to move up to two five, two five? Break".	"I certainly am, would you like to select another channel, 25, for example, Over."
"Yeah Moondancer, see you there, Break".	"Certainly, Moondancer, I will await your call, Over."
"Yeah Firebird, you go your wheels moving? Break".	"Excuse me Firebird, but are you mobile? Over."
"That's a four, I've got to go down now, cos I need a ten one hundred maybe I'll catch you later, is that a four? Break".	"Yes, I am, but I must switch off now as I need to answer the call of nature rather urgently, possibly we can talk later, is that agreed, Over."
"That's a four, all the high numbers good buddy, and breaker, Break".	"Yes, certainly, may your reception remain clear my friend, and Over and Out."
"Yeah breaker break".	"Yes. Over and Out."

Citizens Band Frequencies

Channel No.	Channel Frequency (MHz)	Channel No.	Channel Frequency (MHz)
1	26.965	21	27.215
2	26.975	22	27.225
3	26.985	23	27.255
4	27.005	24	27.235
5	27.015	25	27.245
6	27.025	26	27.265
7	27.035	27	27.275
8	27.055	28	27.285
9	27.065*	29	27.295
10	27.075	30	27.305
11	27.085	31	27.315
12	27.105	32	27.325
13	27.115	33	27.335
14	27.125	34	27.345
15	27.135	35	27.355
16	27.155	36	27.365
17	27.165	37	27.375
18	27.175	38	27.385
19	27.185	39	27.395
20	27.205	40	27.405

* Channel 9 shall be used for emergency.

A Walkie-Talkie radio working at CB frequencies, these handsets are usually only capable of operating at very limited power, the one shown is an exception using 2 watts RF power.

LIVING IN HARMONY

A lot has been said about Harmonic Interference, the fundamental 27 MHz signal can be propagated on to the 54 and 81 MHz bands, (2nd and 3rd harmonics) but we're sure that very little actual interference occurs with such limited output power.

The recently formed CBA (Citizens Band Association) advocate the legalisation of a CB network on the 230 MHz band (VHF) with frequency modulation. There's a lot to be said for this as many of the technical problems would disappear. We feel however there are no simple solutions but for good or bad CB is here to stay in the UK. Hopefully what happened in Australia can be avoided here. CB users innundated the authorities, catching the so-called pirates proved impossible so the government were forced to legalise it.

We in Britain have a golden opportunity at the moment to start a new system. With the hindsight of all the other countries we could be a world leader in CB personal communications.

During the past few years a lot of UK electronics manufacturers have been bleating about cheap Oriental imports ruining their business. With a new system just think of all those jobs that would be created.

FOREIGN CUSTOMS

The Home Office and Post Office naturally seem to take a pretty dim view of CB, (they're probably thinking of all that lost revenue) with so many CB operators on the air they have a near impossible task trying to catch them. As it is not actually illegal to own a CB rig (it is to use it though), you've virtually got to be caught in the act. As most, if not all CBers are mobile it is a fair bet that unless they do something very stupid they're not going to get caught.

Of course if the rig was illegally imported (smuggled to you and me) that's another kettle of fish. We've heard of people's houses being searched and CB equipment being confiscated, so beware.

Inside a typical rig. The RF section can be clearly seen (IF coils). The missing components are, we believe used for a SSB (Single Sick Band) option.

Government opposition to CB has always centred around three main arguments. The first is lack of airspace, but as the CBA point out the 230 MHz band is fairly free, much of it unused since World War II.

Number two is use of CB by criminal elements, this

GLOSSARY OF TERMS

ANTENNA	The aerial to which the transceiver is connected.
APA	Aerial Pre-Amplifier, used in conjunction with a RF power amplifier (see Burner or Boots).
ATU	Aerial Tuner Unit, device to give optimum matching between TX/RX and aerial.
BACKDOOR	End CB operator in a convoy.
BASE TWENTY	The home of a CB operator.
BIG CIRCLE	The North Circular Road in London.
BLEEPER BREAKER	A coded bleep to signify the end of a transmission.
BOOTS	See Burner.
BREAKER	A CB operator.
BRING IT BACK	A phrase to indicate that a reply is required.
BURNER	A RF power amplifier, often with a power output in excess of 100 watts.
BUST	Getting caught.
CHANNEL	British/American CB utilises 40 separate channels.
COMEBACK	Similar to 'Bring it Back' or 'Break'.
COPY	Received message.
C'MON	See Bring It Back etc.
DF	Direction Finding.
DX	Long Distance.
EARS	"Got your EARS On", means are you listening.
EARWIG	Listening in to a conversation.
EYEBALL	A meeting between two or more CBers usually arranged with a succession of coded messages denoting place names.
EYETIES	A somewhat unkind name for the Italians who dominate the CB channels during the early part of the day.
FIVE	"Give me a FIVE", means transmit the numbers one to five for establishing signal strength.
FOUR	"That's a FOUR", means simply yes.
FRONT DOOR	First CBer in a convoy.
GOING DOWN	Going off the air, switching off.
HANDLE	A Breaker's code name.
HOLE IN THE WALL	An area of poor signal strength.
MEANIES	Any anti-CB authorities such as Home Office, Post Office etc.
MIKE	Microphone.
MOBILE	On the road, moving.
MUSH	Noise, masking or interrupting the signal.
NEGATORY	No, Negative.
NUMBERS	"ALL THE HIGH NUMBERS, GOOD BUDDY", is a cordial farewell, referring mainly to the Ten Code.
ON CHANNEL	On the air.
OPEN	As On Channel.
READING	Clarity of reception.
RIG	CB Transceiver.
ROGER	Yes, OK.
ROLLER SKATE	Production line car.
RUBBER STATIONARY	Static, not moving.
RUNNING BAREFOOT	Operating without a Burner, or Boots.
SEAT COVER	Lady friend or wife.
SMOKEY BEAR	The Police.
SMOKEY TOWN	London.
STEREO	"Getting you in STEREO", coming through loud and clear.
SWR	Standing Wave Ratio, a method of determining the quality of match between the Rig and aerial.
SPAGHETTI	Italians again, wall to wall spaghetti denotes the Italians are active on the particular channel.
TEN CODE	A code devised in America many years ago to convey often repeated messages quickly and clearly. Some examples are given below.
TEN ONE	Signal strength and readability are poor.
TEN FOUR	Yes.
TEN NINE	Repeat last message.
TEN ONE HUNDRED	Subtle way of expressing one's desire to answer the call of nature.
TAKE IT DOWN	Move to a (specified) lower channel.
TAKE IT UP	Move to a (specified) higher channel.
TWENTY	A rough twenty is an approximate location.
WALL TO WALL	"Gettin' you WALL TO WALL", receiving you loud and clear. (Or Wall to Wall and Treetop tall.)
WHEELS	A general term for any kind of vehicle.

These are only a few of the currently used phrases and codes. There are obviously many regional variations and dialects, as well as a few rather specific references to locations etc, that we left out deliberately to protect our contacts who are active CB operators.

has got to be self-defeating, only a very stupid villain would discuss his dastardly deeds over the air knowing that hundreds, possibly thousands of people are listening.

Lastly we have administration if CB were ever legalised. This we find very hard to believe, we're sure the PO would find a way of collecting some form of taxation very quickly indeed. The CBA propose that every rig be given a unique identity with a tamper-proof IC module, integral with the system, very simple, very cheap.

PROSECUTION

Actual figures of prosecutions are obviously a little sketchy but we have found out from reliable sources that the number of people taken to court under the Wireless Telegraphy Act, pertaining directly to CB "could be counted on your fingers and toes", to quote an official source. On illegal imports the figures are probably much higher.

A 40 channel rig of the type that are finding their way into this country, as you can see it is not much larger than an ordinary car radio.

TRANSMITTER SPECIFICATION:

- Modulation: 90%
- Frequency tolerance: 0.003%
- Spurious suppression: 60db
- Harmonic suppression: 60db
- Output power: 4W

RECEIVER SPECIFICATION:

- Sensitivity: 0.7µv for 10db S+N/N
- Adjustable channel rejection: 70db
- AGC range: 80db
- Squelch range: 0.7µv — about 300uv
- Frequency response: 500-2.5KHz
- Audio power: 4W
- Dimension: 174.6mm(W)×57.2mm(H)× 181.8mm(D)

Fairly typical specifications for a 40 channel CB rig (FCC Specs.).

It seems that every CBer we've spoken to during our research for this article has some tale of someone who knows someone else who's been 'done' but in actuality the figures do not bear these stories out. The CB fraternity seem to have an almost paranoid fear of prosecution, going to extreme lengths to mask their identity with code names and equally furtive enterprises, with some justification we hasten to add.

LIFE SAVER

Those were some of the legal drawbacks and technical problems, so what are the benefits? Juding from the American experience it seems that CB is an astounding success. The US has one channel (channel 9) set aside for emergencies only. All the police and ambulance services constantly monitor channel 9. If for instance a CB operator is present at the scene of a motor accident, (and it's quite likely with over 30 million rigs in operation) help can be summoned swiftly. Its reckoned to have saved countless of lives in the past few years. The police (Smokey Bear, remember Convoy) actually encourage the use of CB as an aid to road safety. If a CBer sees a police speed trap (a radar trap is referred to as Smokey with a camera) a message is sent to all nearby, resulting in an almost instant slow-down of traffic in the vicintiy. Even people without CB take notice. It's even rumoured that the police send fake speed trap warnings themselves and can control vast areas of road without actually showing their presence. Now isn't that cunning.

HE's VIEW

The explosion of interest in Citizens Band Radio, legally in most countries, illegally in Britain, shows there is an enormous interest in it. Since the equipment is manufactured to very rigid technical standards the only sensible argument is that there is not frequency space available.

The authorities (Home Office now, Post Office in the past) are extraordinarily defensive about available frequency space and have used this as a 'trump' card often in the past. The reasons for forcing the pirate radio stations off the air were supposed to be technical when they were really political. There *were* good political reasons — the pirates were uncontrolled and not answerable to anyone but non-availability of frequencies was used as an argument — yet we've managed to fit about 40 local radio stations on the air since the pirates were silenced.

Other countries with higher densities of population and radio traffic than in Britain have made the frequency space available; this alone should make us discount technical arguments. This leaves the political aspects which are best summed up by 'if practically every democratic nation (and some undemocratic ones) permit it, what is so special about Britain that we must be out of step?'

At the moment is looks like CB will grow and grow in Britain, irrespective of the legal situation; the Home Office may be able to stunt this by devoting enormous resources to tracking down and prosecuting the operators but this publicity would cause a lot of people to ask the fundamental question "why *shouldn't* we have CB?"

If the authorities had acted earlier, CB could have been allocated onto more suitable frequencies and been properly regulated.

It may already be too late.

Anyone who has driven those long miles up the M1 or any long motorway for that matter will testify to the fact that is all too easy to fall asleep at the wheel. For want of someone to talk to and keep alert many, many lives may have been saved. What a boon it would be to the housebound and lonely.

WHO OWNS THE AIR

The big question of course is will it ever be legalised in the UK? Hopefully the answer must be yes. But not, we

hasten to add, by force. It would be unwise to follow in the footsteps of Australia, so what system should we adopt?

There is the established 27 MHz band, plenty of available equipment and well established technology but with inherent interference problems and other channel users, could they co-exist. Then there is the proposed 230 MHz band. By using VHF with frequency modulation most of these problems would disappear. As it is just a proposal there are no manufacturers building suitable equipment in any volume, so there is the potential of job creation. But would the price of such equipment be prohibitive, limiting its usage to the privileged few?

CITIZEN BANNED

The attractions of CB are hard to define. It's possible to make a lot of anonymous friends very quicly. The vast majority of operators follow the unwritten rules — if a "breaker" isn't referred to by his "handle" (call sign) he'll be called a "good buddy" and the whole language is almost elaborately courteous: bad language and swearing is very rare and those who use it are frozen out by other operators.

Most CBers are eager to speak to newcomers and give advice — but anonymously. The security amongst the breakers is very strict.

It's almost impossible to tell who is a CB operator by looking at their "wheels" (transport). The most popular aerials are those which are very similar to car radio whips or telescopics and those which are clearly not in this category are usually legitimate radio amateurs or two-way radio telephones.

Technically you're not even allowed to listen (your TV licence allows you only to listen to legitimate broadcast stations or recognised amateurs) but many readers will have access to a communications receiver going up to 30MHz and you can hear the CB operators — especially on 27.125 MHz (channel 14) which is used (in London) to establish contact.

A surprising number of women operate CB, our contacts inform us that any night of the week at least half a dozen lady breakers can be heard over the air, and very good they are too we're told, yet another step for women's equality?

AERIALS

A great deal has been said about antennas, much emphasis is placed upon the 'magic' 1 to 1 SWR ratio. The SWR figure denotes the quality of match between the transceiver. The output power will be attenuated by

A CB/Radio/Cassette player combination, a true in-car-entertainment centre.

Somewhere in Smokey town, a breaker keys his mike

the presence of Standing Waves in the aerial lead or connections between rig and antenna.

The figure of a 1 to 1 SWR is almost impossible to achieve (despite what people may claim) and a digure of around 2:1 will show only a slight drop in output. Above this figure problems may arise with voltage peaks but as most CB sets are protected against this it's unlikely to cause any trouble.

The positioning of an antenna, however, is very important. For the greatest efficiency it should be as high as possible, this usually means mounting it on the roof of the car. For the greatest omni-directional propogation (All round or symetrical reception and transmission) it should be mounted in the centre of the roof.

SLANG

The slang used in this country is mainly of American origin. Gradually though English terms are beginning to creep in. (But not we hope the ultra formal language used by Hams, almost totally devoid of humour). As you will see from the glossary there are many phrases that sound quite amusing but we're assured they're all tried and tested, being the easiest way to convey information over what is a potential very noisy communications medium.

POWER OUTPUT

Probably the most controversial side of CB. The American (and most other countries) systems are limited to around 4 watts RF output. People being naturally adventurous are adding Burners (RF power amplifiers) to their rigs. The availability of these burners have been made simple by the Ham fraternity (10 metre power boosters) so power output in excess of 100 watts is quite common. Unfortunately this leads to 'splattering' (co-channel and harmonic interference). This interference can occur over quite a large area. Indeed from our information it seems that most CB prosecutions have involved people using burners. 4 watts would seem to remain fairly inconspicuous.

WHAT DO YOU THINK?

These are the basic arguments for and against CB, a system of one kind or another must be adopted so a decision must be made soon otherwise it will be too late. If you've got any strong views one way or another, why not drop us a line.

You don't have to put your name to it if you are a CB operator, just your 'handle' will do. HE as a magazine would like to follow up this article if response proves sufficient.

If you really do want to get actively involved contact the CBA at 16 Church Road, St Marks, Cheltenham, Glocs GL51 7AN. **HE**

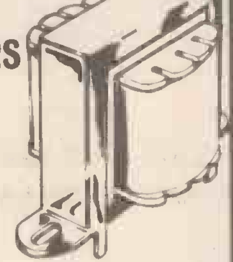
STEVENSON
Electronic Components

REGULATORS

78L05	30p	7805	60p	79L05	70p	7912	80p
78L12	30p	7812	60p	79L12	70p	7915	80p
78L15	30p	7815	60p	7905	80p	LM723	35p

HARDWARE

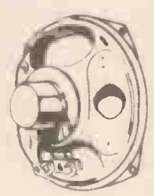
MINIATURE TRANSFORMERS



240 Volt Primary

Secondary rated at 100mA. Available with secondaries of: 6 - 0 - 6, 9 - 0 - 9 and 12 - 0 - 12. 92p. each.

LOUDSPEAKERS

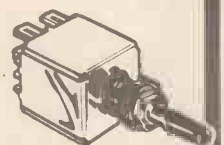


56mm dia. 8 ohms 70p
64mm dia. 8 ohms 75p
64mm dia. 64 ohms 75p
70mm dia. 8 ohms 100p
70mm dia. 80 ohms 110p

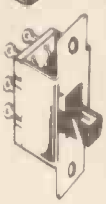
TERMINALS

Rated at 10A. Accepts 4mm plug, black, blue, green, brown and red . . . 22p

SWITCHES



Subminiature toggle. Rated at 3A 250V.
SPDT 70p SPDT centre off 75p
DPDT 80p DPDT centre off 95p



Standard toggle
SPST 34p DPDT 48p

Wavechange switches.
1P12W, 2P6W, 3P4W or 4P3W all 43p ea.

Miniature switches (non-locking)
Push to make 15p Push to break 20p

Slide switches (DPDT)
Miniature 14p Standard 15p

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Ideal for use on mixers etc. Push on type with black base and marked position line. Cap available in red, blue, green, grey, yellow and black. 14p

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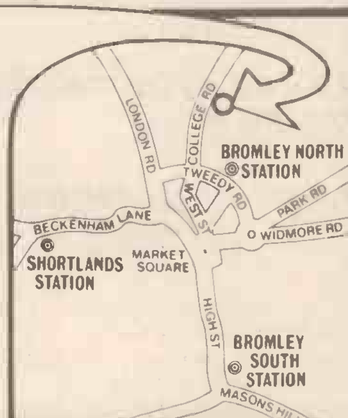

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				2N697	12p
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AC128	16p	BCY72	14p	2N2907	22p
AC176	18p	BD131	35p	2N3053	18p
AD161	38p	BD132	35p	2N3055	50p
AD162	38p	BD135	38p	2N3442	135p
BC107	8p	BD139	35p	2N3702	8p
BC108	8p	BD140	35p	2N3704	8p
BC109	8p	BF244B	36p	2N3705	9p
BC147	7p	BFY50	15p	2N3706	9p
BC148	7p	BFY51	15p	2N3707	9p
BC149	8p	BFY52	15p	2N3708	8p
BC148	9p	MJ2955	98p	2N3819	22p
BC177	14p	MPSA06	20p	2N3904	8p
BC178	14p	MPSA56	20p	2N3905	8p
BC179	14p	TIP29C	60p	2N3906	8p
BC182	10p	TIP30C	70p	2N4058	12p
BC182L	10p	TIP31C	65p	2N5457	32p
BC184	10p	TIP32C	80p	2N5458	30p
BC184L	10p	ZTX107	14p	2N5459	32p
BC212	10p	ZTX108	14p	2N5777	50p
BC212L	10p				
BC214	10p				
BC214L	10p				
BC477	19p				
BC478	19p				
BC479	19p				
BC548	10p				
BCY70	14p				

DIODES

1N914 3p 1N5401 13p
1N4001 4p BZY88ser 8p
Full spec product.
1N4148 £1.40/100 £11/1000

LINEAR

THIS IS ONLY A SELECTION!

		CA3140	38p	NE555	21p
		LM301AN	26p	NE556	50p
		LM318N	85p	NE565	85p
		LM324	45p	NE567	170p
		LM339	45p	SN76003	200p
709	28p	LM380	75p	SN76013	140p
741	16p	LM382	120p	SN76023	140p
747	40p	LM1830	150p	SN76033	200p
748	30p	LM3900	50p	SN76477	220p
CA3046	55p	LM3909	65p	TBA800	70p
CA3080	70p	MC1496	60p	TDA1022	650p
CA3130	90p	MC1458	32p	ZN414	75p

CAPACITORS

TANTALUM BEAD each
0.1, 0.15, 0.22, 0.33, 0.47, 0.68, 1 & 2.2uF @ 35V 8p
4.7, 6.8, 10uF @ 25V 13p
22 @ 16V, 47 @ 6V, 100 @ 3V 16p

MYLAR FILM
0.001, 0.01, 0.022, 0.033, 0.047 3p
0.068, 0.1 4p

POLYESTER
Mullard C280 series
0.01, 0.015, 0.022, 0.033, 0.047, 0.068, 0.1 5p
0.15, 0.22 7p
0.33, 0.47 10p
0.68 14p
1.0uF 17p

CERAMIC
Plate type 50V. Available in E12 series from 22pF to 1000pF and E6 series from 1500pF to 0.047uF 2p

RADIAL LEAD ELECTROLYTIC

63V	0.47	1.0	2.2	4.7	10	5p
			22	33	47	7p
	100					13p
			220			20p
25V	10	22	33	47		5p
	100					8p
		220				10p
				470		15p
	1000					23p

CONNECTORS

JACK PLUGS AND SOCKETS

	screened	unscreened	socket
2.5mm	9p	13p	7p
3.5mm	9p	14p	8p
Standard	16p	30p	15p
Stereo	23p	36p	18p

DIN PLUGS AND SOCKETS

	plug	chassis socket	line socket
2pin	7p	7p	7p
3pin	11p	9p	14p
5pin 180°	11p	10p	14p
5pin 240°	13p	10p	16p

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Suitable for low voltage circuits. Red & black. Plugs 6p each Sockets 7p each.

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Available in blue, black, green, brown, red, white and yellow. Plugs 11p each Sockets 12p each

PHONO PLUGS AND SOCKETS
Insulated plug in red or black 9p
Screened plug 13p
Single socket 7p Double socket 10p

VERO

Size in.	0.1in.	0.15in.
2.5 x 1	14p	13p
2.5 x 3.75	42p	40p
2.5 x 5	52p	50p
3.75 x 5	60p	60p
3.75 x 17	195p	180p

Veropins single sided per 100
0.1in 35p
0.15in 40p

BOXES

Aluminium boxes with lid and screws

	Length	width	height	
AL1	3	2	1	48p
AL2	4	3	1	58p
AL3	4	3	2	65p
AL4	6	4	2	70p
AL5	6	4	3	85p
AL6	8	6	2	116p

THYRISTORS

Plastic cased Thyristors Texas

	4A	8A	12A
100V	36p	45p	62p
200V	42p	53p	68p
400V	51p	66p	86p

TRIACS

Plastic cased Triacs. Texas. All rated at 400V.

4A 70p 12A 90p 20A 185p
8A 80p 16A 95p 25A 215p

CMOS

		4018	55p	4050	25p
		4023	12p	4066	35p
		4024	40p	4068	18p
4001	12p	4026	90p	4069	12p
4002	12p	4027	30p	4071	12p
4007	12p	4028	48p	4081	13p
4011	12p	4029	50p	4093	45p
4013	28p	4040	60p	4510	65p
4015	50p	4042	50p	4511	65p
4016	30p	4046	90p	4518	65p
4017	48p	4049	25p	4520	60p

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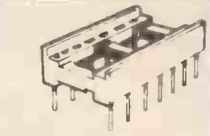
SKTS



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8 pin 8p 16 pin 11p 28 pin 22p
14 pin 10p 24 pin 18p 40 pin 32p

Soldercon pins 100 50p 1000 370p

OPTO

LED's	0.125in.	0.2in	each	100+
Red	TIL209	TIL220	9p	8p
Green	TIL211	TIL221	13p	12p
Yellow	TIL213	TIL223	13p	12p
Clips	3p	3p		

DISPLAYS

		each	100+
DL704	0.3 in CC	130p	120p
DL707	0.3 in CA	130p	120p
FND500	0.5 in CC	100p	80p

RESISTORS

Carbon film resistors. High stability, low noise 5%.

E12 series 4.7 ohms to 10M. Any mix:

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0.5W	1.5p	1.2p	1p

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Electronic Music

In this second part of his article, Tim Orr continues to describe how musical notes and other effects are produced from electronic circuits.

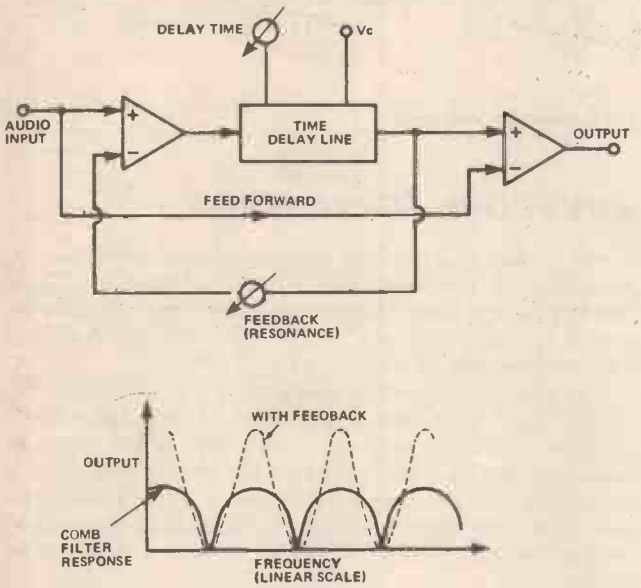


Fig. 9. A COMB filter described in part one

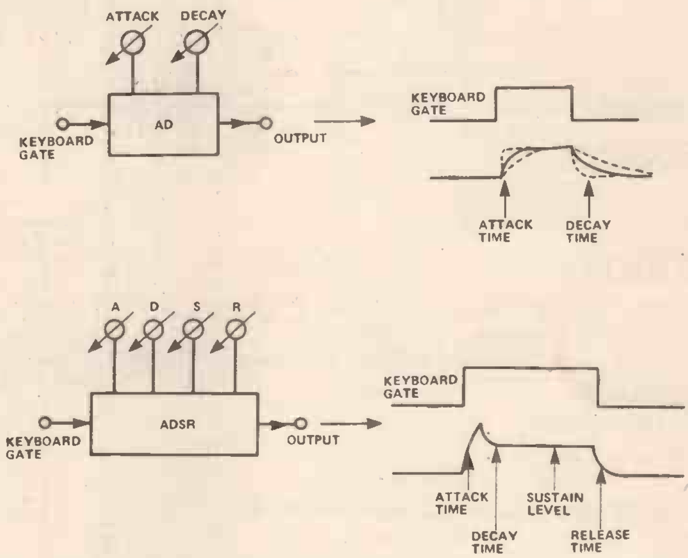


Fig. 10. Contour generators

Contour generators produce the VCF sweep and the amplitude envelope of the waveform that comes out of the synthesiser. They are generally initiated and terminated by the gate voltage from the keyboard. Firstly the AD waveform. When the keyboard is pressed, it starts on an exponential charging curve which has an attack time constant determined by the setting of the ATTACK knob. When the keyboard is released the waveform discharges back to where it started from with a time constant set by the DECAY knob. This AD waveform is used to sweep the VCF and sometimes in simpler systems to generate an envelope waveform and even to modulate the VCO.

The ADSR is a similar process to that which occurs in some keyboard instruments. A note is played which then decays away with its natural time constant, but when the note is released the strings are damped and the note is muted. This system has three time constants, an initial attack, a decay and a release. The ADSR is able to synthesise these three time constant parameters, but it also has a sustain level control, thus enabling infinite sustain as long as a note is pressed.

In conventional stringed keyboard instruments time constants are proportional to pitch of the note, low frequency notes have long decay times and vice versa. Also the harder the keyboard is hit the louder the note (keyboard dynamics) and the sharper the harmonic structure. It is possible to synthesise all these effects but with the present state of the art it is still rather complex and expensive. Most synthesisers go for the simple solutions as shown in Fig. 10.

VOLTAGE CONTROLLED AMPLIFIER

The job of the VCA is to produce a signal which is the product of the audio signal times the contour signal. This type of unit is known as an amplitude modulator or a two quadrant multiplier. When the contour voltage returns to zero, the output of the VCA is zero.

Another type of modulator is a four quadrant multiplier some times known as a ring modulator. This has two inputs and produces an output which is the true arithmetic product of the inputs.

Ring modulators are typically used to manipulate natural sounds. If speech is used as one input and a low frequency (50-100 Hz) oscillator as the other, the ring-modulated output sounds rather mechanical, just like a 'Dalek'. What the ring modulator is doing is

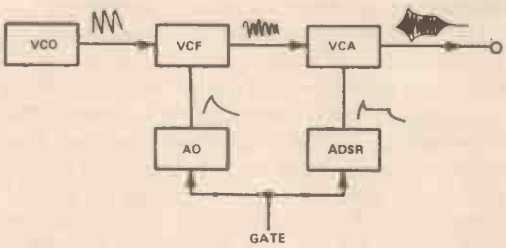
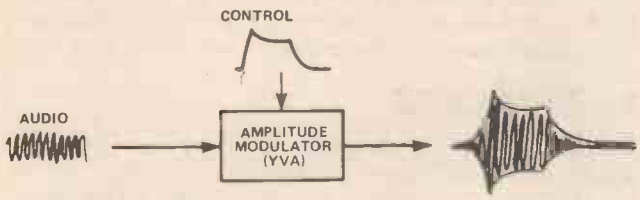


Fig. 11. Typical synthesiser structure



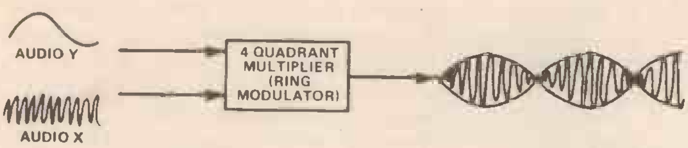


Fig. 12. Voltage controlled amplifiers (VCA)

producing two mixed outputs from the two inputs. If the two inputs were two sinewaves of frequencies fx and fy, then the output is made up of two sinewaves mixed together of frequencies f(x+y) and f(x—y). These are known as the upper and lower sidebands respectively.

FREQUENCY SHIFTER

A frequency shifter acts similarly to the ring modulator except that it separates the upper and lower sidebands. This enables a natural sound to be shifted up or down in frequency. The process is known as single sideband modulation in telecommunication jargon. The overall effect is to make a harmonic sound in-harmonic. This is because all the harmonics will be shifted by the same frequency increment and so will lose their integer relationships.

The frequency shifter uses an oscillator that generates sine and cosine waveforms. The audio signal to be processed is passed through a dual phase shifting network such that two outputs in phase quadrature (always 90° apart) are generated. The audio signals and the sinewaves are multiplied together by two ring modulators, the outputs of which are added and subtracted to produce the 'down' and 'up' shifted outputs. The amount of frequency shift is the frequency of the quadrature oscillator.

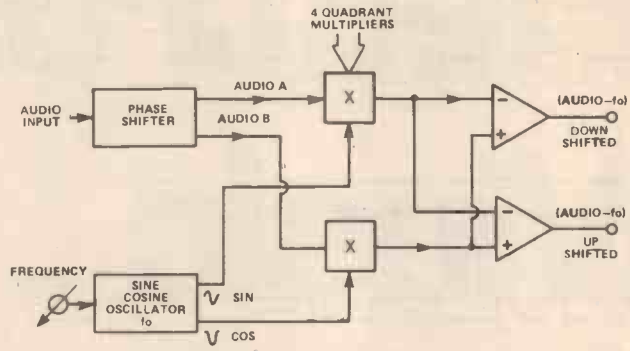


Fig. 13. Arrangement of a frequency shifter

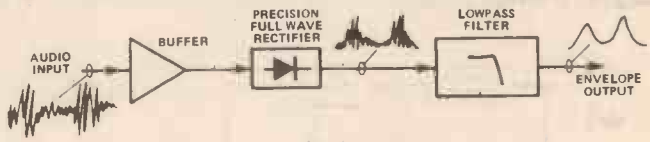


Fig. 14. Envelope follower

ENVELOPE FOLLOWERS

When processing natural signals, from speech or a guitar say, it is sometimes desirable to have a voltage that follows the envelope of the signal. This can then be used to control VCA's or VCF's or other devices. A simple envelope follower is shown in Fig. 14.

The input signal is full wave rectified by a precision rectifier and then lowpass filtered. There are lots of problems with this method. If the filter is set too high then there will be lots of ripple on the envelope output. If it is set too low, the unit will be slow to respond and may even miss short signals. Perhaps the best system would be one that uses a true RMS detector which can now be bought in an IC.

SPRING LINE REVERBERATION

Synthesised sounds can very rapidly become uninteresting. This is partly due to the unchanging quality of their sound. Listen to a sustained note on a flute or a single piano note. There are lots of interesting things going on all the time. The pitch might be wobbling (also the amplitude). The harmonic structure will be changing. There will be, in the case of the piano, sympathetic resonances in the neighbouring strings. One way of reintroducing interest into synthesised sounds is by use of artificial reverberation.

The spring line reverberation unit is a small mechanical device that finds use in electronic organs, practice amplifiers and synthesisers. The unit consists of two long (10 inch) springs connected together at each end. At one end there is an electromagnetic driver, and at the other a magnetic pick up. The input signal is amplified and drives the driver coil. This causes the springs to vibrate and these vibrations propogate down the length of the springs. The pick-up coil receives these vibrations, the signal from which is amplified and mixed with the original. The result is a reverberant quality to the sound output.

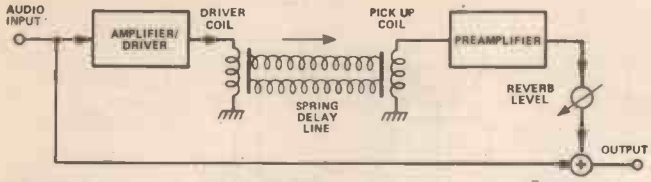


Fig. 15. Spring Line Reverberation

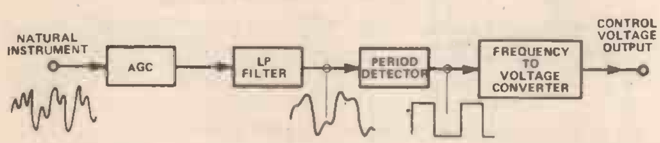
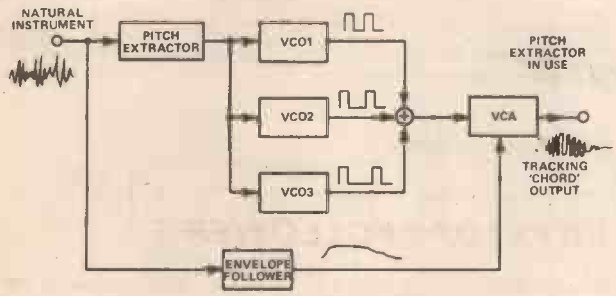


Fig. 16. A pitch extractor (above) and its place in a block diagram (below)



PITCH EXTRACTOR

Several companies have recently introduced guitar synthesisers. These are synthesisers that are controlled by the normal controls of the guitar. In these cases, the guitar has been greatly modified so that its strings and frets act as various forms of electronic contacts. Thus it is possible to control a synthesiser from a guitar. There is, however, another way of doing this and that is by using a pitch extractor. This uses an unmodified guitar and analyses the signal from the pick-up. It performs various electronic processes on the signal so that the fundamental note is extracted, which is then converted into a control voltage that can drive a bank of VCO's say. If an envelope follower and a VCA are used as well then a tracking chord with the amplitude envelope of the guitar signal can be synthesised.

The problems of pitch extraction are numerous and possibly will never be properly solved, but to date there are several devices on the market which work quite well.

SEQUENCERS

Sequencers are used to generate a repetitive rhythm or to memorise a relatively long passage of music. They do this by storing the control voltages necessary to resynthesise it. A digital sequencer memorises a musical melody that is 'played in' via a conventional keyboard. It remembers the pitch voltage and the gate signal as a function of time. Various controls such as 'record, play, stop, recirculate, transpose sequence', are usually available. One such machine, the EMS JKS, is shown below. Note that the keyboard is a 'touch' rather than a mechanical device.

An analogue sequencer is shown in Fig. 18. The sequence is programmed in on a series of pots. The electronics are usually very simple, a counter-decoder or a multiplexer is the usual solution. Also, as there is no keyboard, the parts costs are kept low, but it does suffer the problem of being more complicated to program.

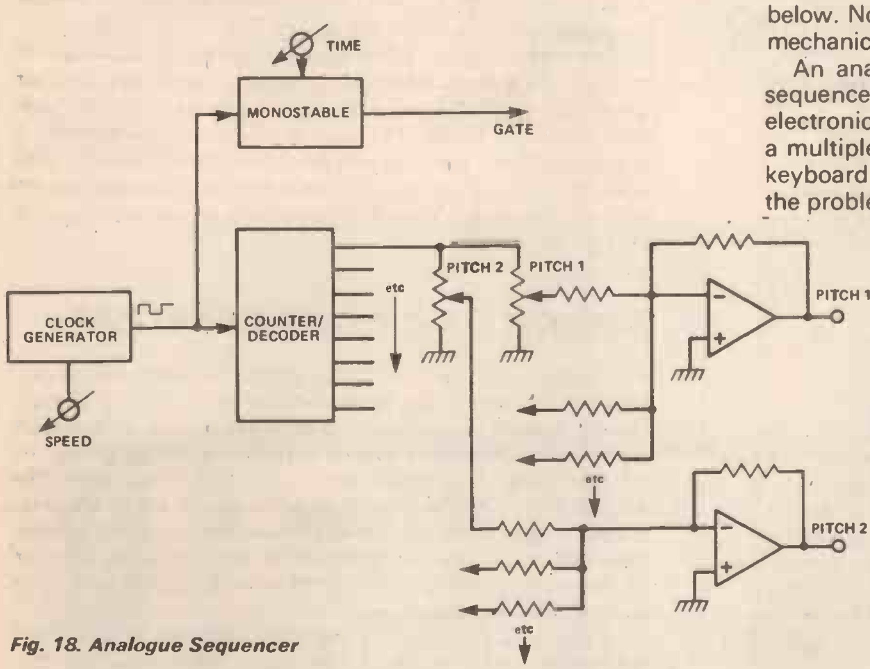
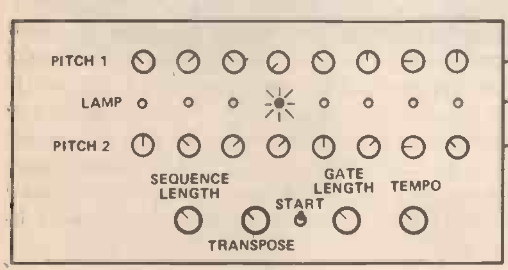


Fig. 18. Analogue Sequencer



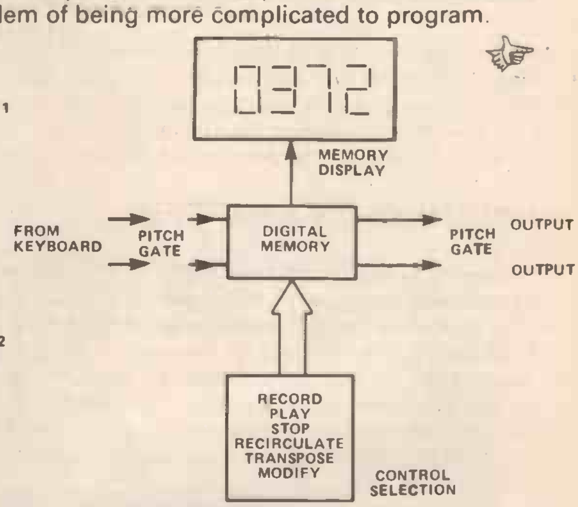


Fig. 17. Digital Sequencer

The EMS JKS Sequencer

CHANNEL VOCODERS

The Vocoder is a recently introduced piece of EM equipment for processing speech and natural instruments. The concept of vocoders is quite old but it was not originally intended for anything other than telecommunications. The machine has two inputs, one for speech and one for excitation and one output. It analyses both inputs into lots of different frequency bands and then combines them into one output. This output has the articulation of speech and the line spectrum (the harmonic structure) of the excitation. If speech and an electric organ (excitation) are used, then the vocoded output is a 'talking organ'. The organ speaks and yet retains the sound structure and melody of the original organ. The vocoder can do other tricks like time compression and expansion, freezing sounds, changing peoples vocal characteristics. It can also operate on two instruments combining them to produce a new one. Fig. 20 shows a commercial unit.

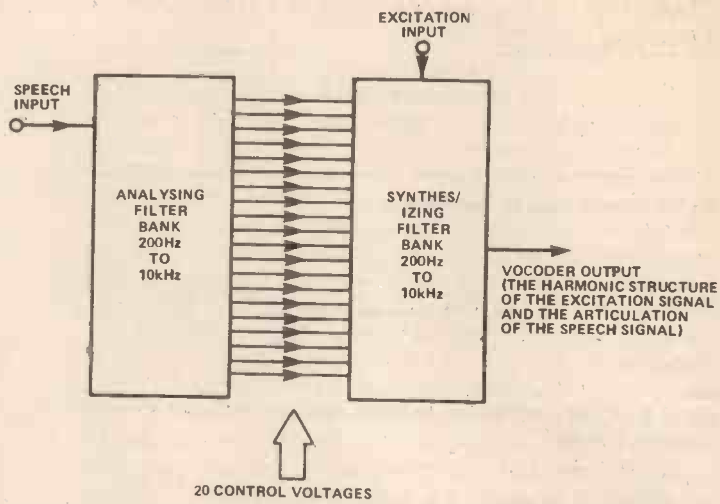


Fig. 19. 20-Channel Music Vocoder, a breakdown of one channel is shown in greater detail

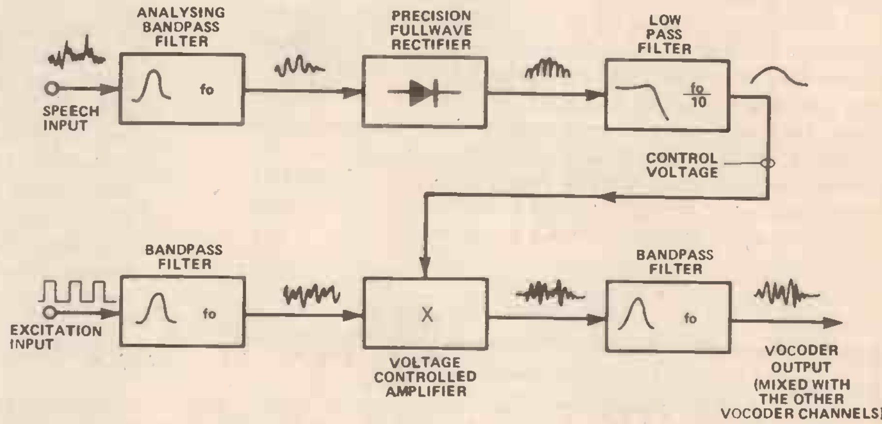
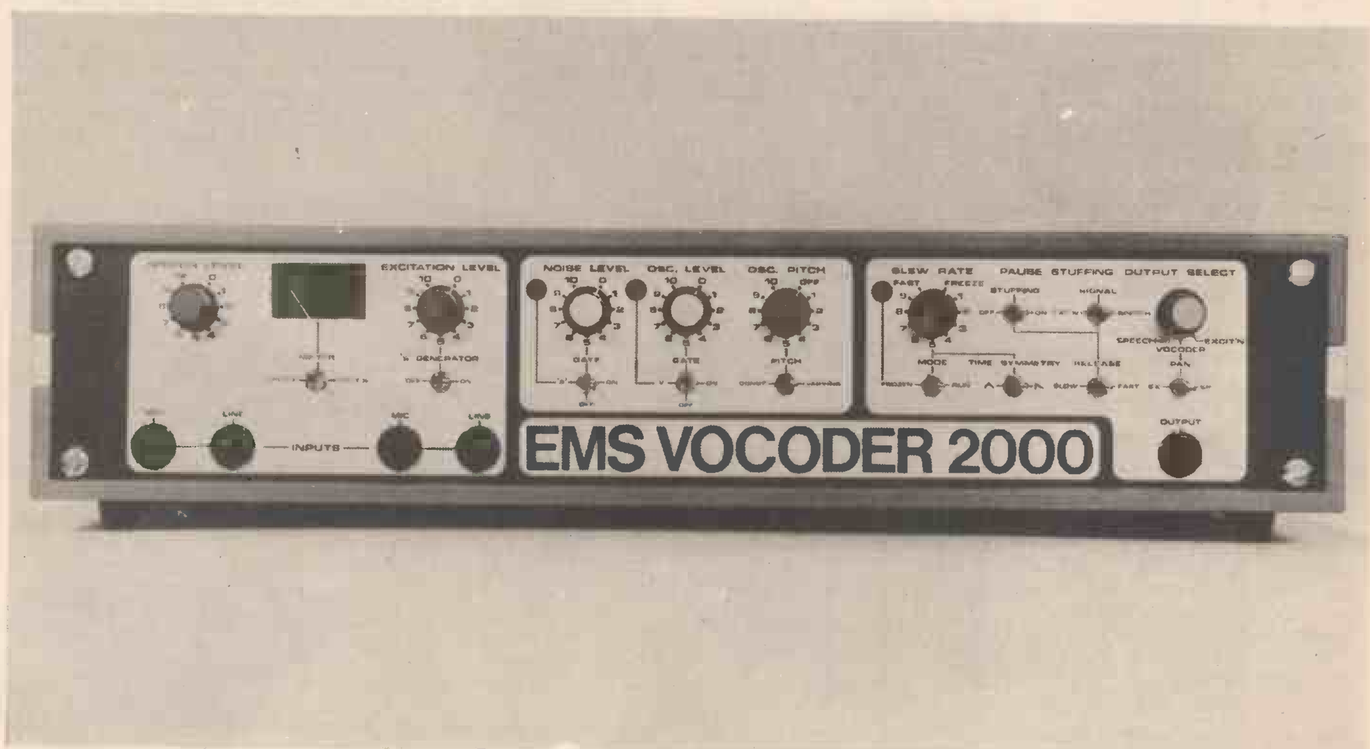


Fig. 20. The EMS Vocoder 2000



COMPUTER MANIPULATION AND SYNTHESIS

Originally EM was produced in studios and a lot of it was done by tape tricks. Synthesisers now produce most EM and some machines have a very high level of technology in their design. Computers have also produced EM for quite a while, but these have been large expensive installations. Using a computer it is possible to synthesise all the sounds or to use the computer as a sound processor. Apart from the computer there is no real hardware at all. All the processing is done using the computer program (the softwave). Natural sounds are introduced to the system via an ADC (analogue to digital converter) and sounds produced by the computer leave via a DAC (digital to analogue converter), Fig. 21. By using computer techniques it is possible to manipulate sounds in new and interesting ways. I heard one such manipulation whereby a piece of music performed on a saxaphone gradually transmitted itself into a violin.

Perhaps as microprocessors get larger and faster we will see a growth in microprocessor EM peripherals.

Technology has got a firm grip on the music and EM industry, but the sounds generated are still almost totally dependent on the skills of the operator. To bear this out I can cite the following example. In the last few years I have designed seven synthesisers, two vocoders, six guitar effects units, one sequencer, one frequency shifter, two guitar amplifiers, one quadraphonics effects generator, a pair of high quality converters for computer music . . . and I still can't make any music! **HE**

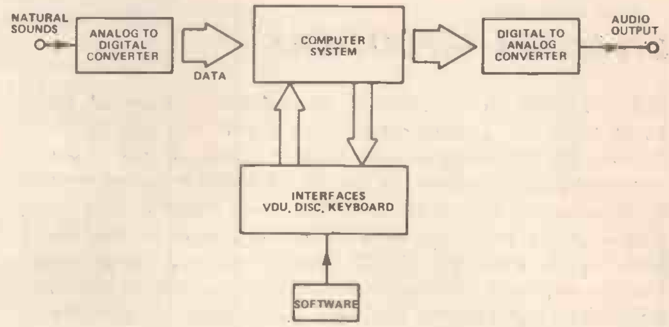
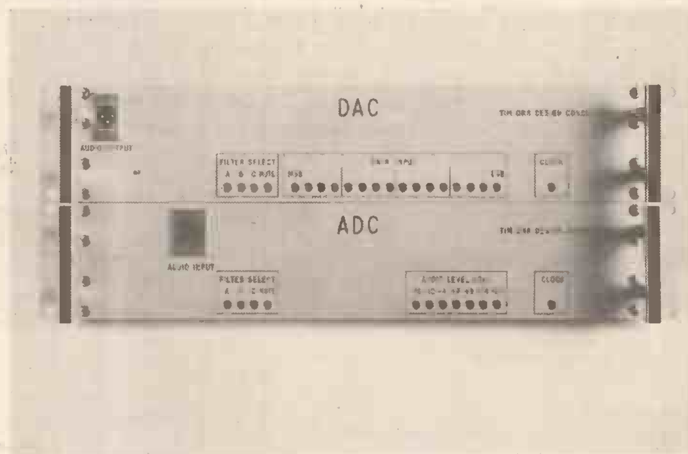


Fig. 21. Computer manipulation and synthesis block diagram with a commercial unit shown below



Short Circuit

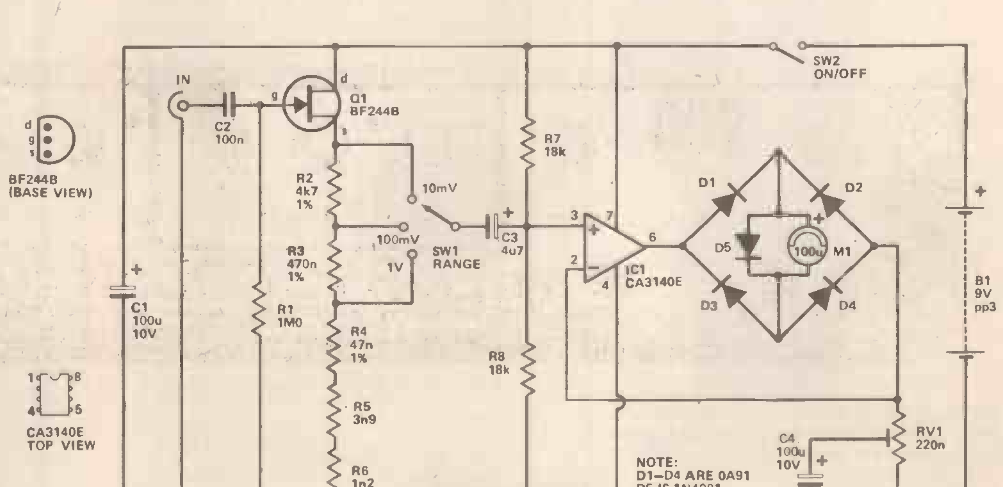
A. F. MILLIVOLT METER

This simple and inexpensive millivolt meter has three measuring ranges of 10mV., 100mV., and 1 V. RMS full scale sensitivity. The frequency response has −1dB. points at about 20Hz and 75kHz. The instrument is suitable for making audio noise, frequency response, and gain measurements, and would be useful to any beginner interested in the field of audio.

The unit uses a conventional arrangement with a non-inverting op. amp. circuit feeding a meter via a bridge rectifier. The negative feedback loop is taken to the inverting input by way of the rectifier and meter circuit rather than direct from ICI output. With low voltages applied to the rectifiers they have a high forward resistance, but this results in little feedback and the amplifier having a high level of gain. Thus small input signal amplitudes which would otherwise produce no meter deflection due to the high rectifier resistance are boosted to the point where they give the appropriate meter reading. Therefore, although the rectifier is inherently non-linear, it produces opposing non-linear feedback which compensates for this and gives the unit linear scaling. RV1 is used to adjust the circuit to the correct sensitivity and D5 protects the meter against sever overloads.

Q1 is used as a low noise source follower buffer amplifier which gives the circuit a high input impedance of about 1 Meg. This ensures that the instrument imposes little loading on the equipment under test. An attenuator is incorporated at the output of the buffer stage, and this can be used to reduce the basic 10 mV. sensitivity to 100 mV. or 1 V. FSD. The attenuator does not need any frequency compensation as it is in a low impedance part of the circuit.

To calibrate the unit it is switched to the 1 V. range, RV1 is set at maximum resistance, and with a 1 V. RMS audio source connected to the input, RV1 is adjusted for full scale deflection of the meter. The 1 V. audio source can be provided by an AF signal generator set to the correct output level with the aid of a multimeter switched to a low AC volts range.



Kit Review

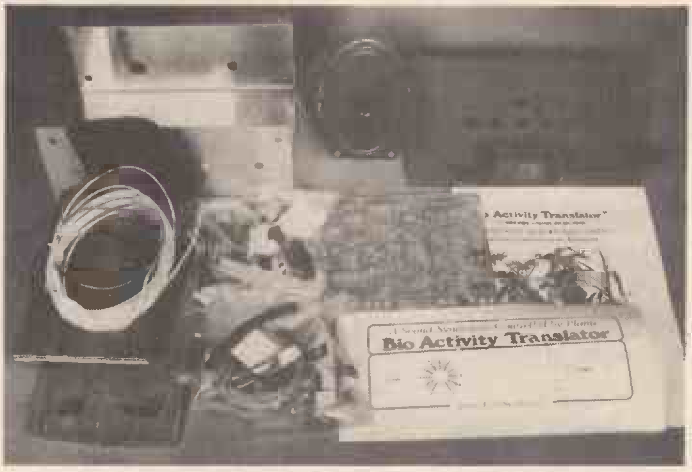
Bio Activity Translator

Do you ever wonder what your plants are thinking? This months kit review will enable your shrubs to sing, its suprprising how melodic they can be.

HAVE YOU EVER wondered what your plants would say if they could talk? If you have a clear conscience (when did you last water them?), then this unit will give them a voice. With the aid of the Bio Activity Translator your plants won't talk to you, but they will *sing*. The Translator combines a biological amplifier and a sound synthesiser in one instrument.

WHY . . .

The assembly instructions include a brief explanation of the principle of the system. Ionic differences across cell membranes produce a bioelectric potential. Thus, all plants generate small electric potentials naturally, directly related to respiration, photosynthesis, and other chemical reactions which are all part of the plant's metabolism. The Bio Activity Translator produces an audio analogue of the plant's response to its surroundings.



The kit as it comes out of its box, everything is there, only batteries are needed to complete the kit.

. . . AND HOW

The natural potential of the plant is amplified and used to increase the gain of a voltage controlled amplifier and turn on a pulse generator. The pulse generator, in turn, triggers a sample and hold circuit. A pulse is also applied to an envelope network to provide extra attack on the sound. The sample and hold network provides a stepped control voltage which follows the biological signal to a voltage controlled oscillator. Thus, the pitch produced is proportional to the level of the biological signal. The rate

The finished product, and very professional it looks too, output sockets are provided in the rear of the case to feed into your hi-fi system.

of change of the biological signal affects the period of the pulse generator and the gain of the voltage controlled amplifier, so that the pitch, speed and volume of the notes produced are all controlled by the biological signal.

CONSTRUCTION

Everything you need to complete the kit (except your trusty soldering iron, solder and screwdriver, of course) is included. Construction is simplified by the clearly marked printed circuit board. Component outlines and numbers are printed on the board, so all you have to do is pick out the right component from the pack and plug it in. We were a little puzzled with where to fix the battery retaining clips. The assembly instructions din't help us there. However, we found that they screwed directly into the wooden end cheeks of the attractive case.

OPERATION

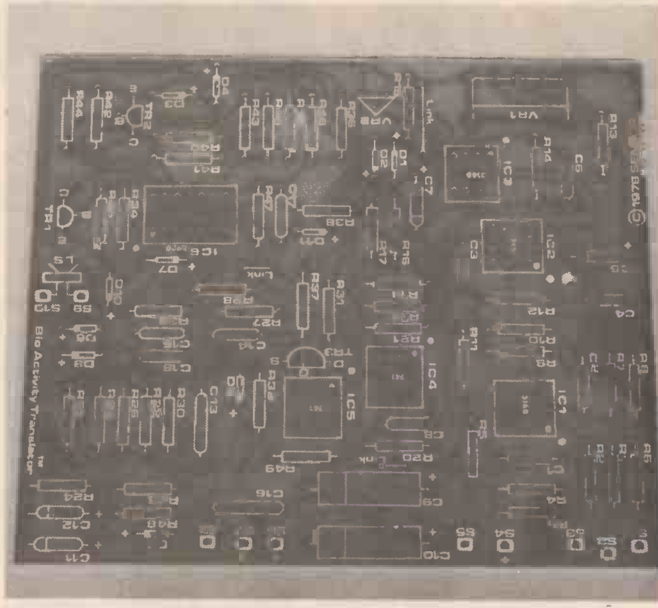
Calibration couldn't be simpler, involving the adjustment of one preset potentiometer in conjunction with the front panel gain control. The signal is collected by two electrodes with an earth probe to minimise the effects of static electricity. The two electrodes are attached to a clip so that they can be clamped on each side of a leaf or stalk. The earth probe is pushed into the soil.

If you connect your Translator to your favourite Monstera or Rubber Plant and switch on, you will hear a complex pattern of sound, controlled by the plant itself. The sound produced seems to vary from plant to plant and whether the room is light or dark. The system is very sensitive to movement. Shaking the plant produces a dramatic response. We found that outdoor plants made the most satisfactory subjects.

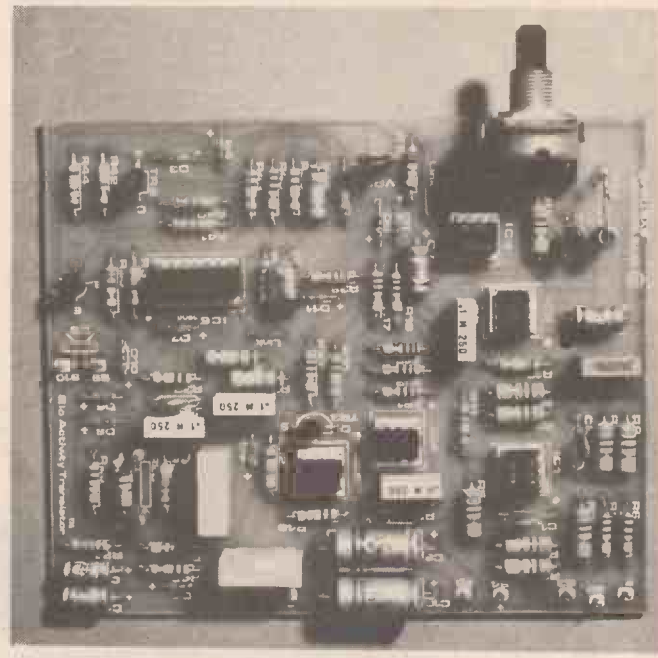
There seems to be unlimited room for experimentation here. The manufacturer has fitted two output sockets on the back of the unit, so that the output can be fed to another amplifier or an analyser of some sort. Try clipping the electrodes to your finger to produce a musical pulse.

The Bio Activity Translator is available from Jeremy Lord Synthesisers, 52 Becmead Avenue, London SW16 and costs from £18.95.

The components in their packs, do check for any ommissions.



The PCB, assembly is simple, just follow the markings.



The PCB assembled awaiting installation.

The front panel of the Bio-Activity Translator.

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Short Circuit

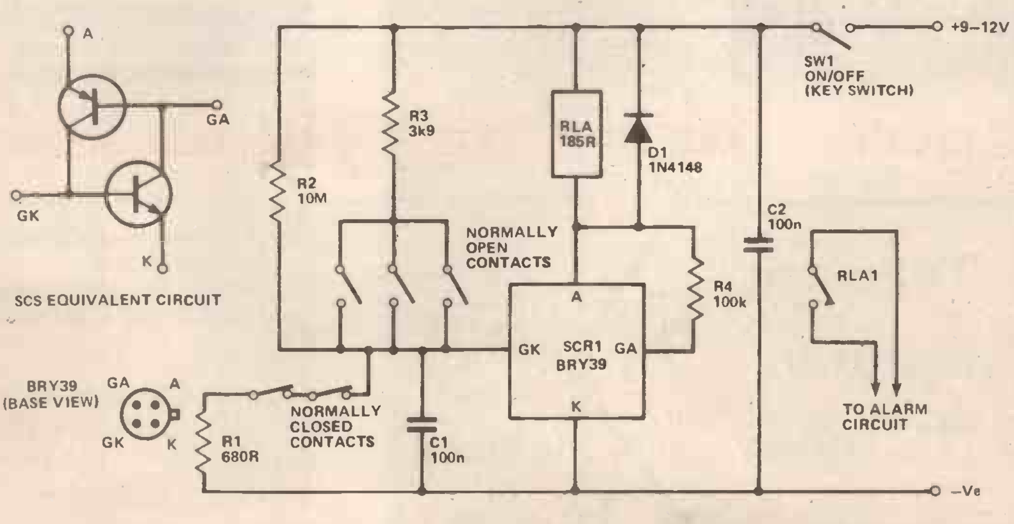
BASIC BURGLAR ALARM

A burglar alarm circuit can be very simple if non-essential facilities such as entry and exit delays are omitted, and such a circuit is shown here. It can be used in conjunction with normally open (NO) or normally closed (NC) contacts which can be the usual door and window switches, trigger mats, etc.

SCR 1 is a silicon controlled switch (SCS) which is an NPN/PNP integrated pair of transistors connected to form a highly sensitive thyristor. As the circuit stands, R1 ties the CK terminal to the negative supply and prevents SCR 1 from triggering. The relay will not be energised and the alarm will not sound. If one or more of the NC contacts should open, SCR 1 will be switched on by the gate current it receives through R2, since R1 is then switched out of circuit. Even if the contacts should close again, SCR 1 will remain in the on state because it has a built-in latching action. Thus the relay will be activated and its contacts connect power to the alarm generator. The circuit can also be triggered by one or more of the NO contacts closing, as R3 then provides an adequate gate bias to switch on SCR 1. Once triggered the circuit can only be reset by switching off using SW1. The current through SCR 1 then falls to zero and the latching action is defeated so that the circuit is ready to commence operation once again when SW1 is closed.

Although only two sets of NC contacts are shown, any number of contacts connected in series can be used. Similarly, any number of NO contacts connected in parallel can be utilized. If no NC contacts are used, R1 should still be included between the GK terminal of SCR 1 and the negative supply rail. C1, C2, and R4 are needed to prevent spurious operation due to stray pick-up of noise spikes or noise pulses on the supply lines. D1 is a protective diode which suppresses the high back EMF developed across the relay coil as it de-energises.

The standby current consumption of the unit is only about 1uA and so the unit can be economically run from ordinary dry cell batteries if desired.



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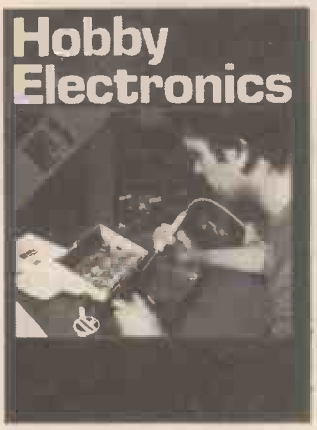

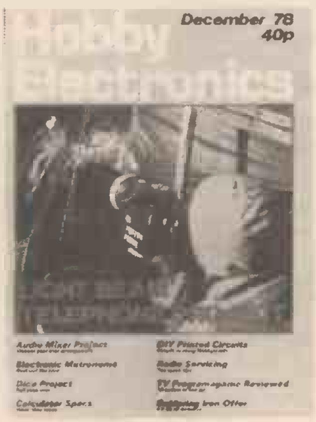

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Into Electronics

by Ian Sinclair Part 8

Goggle-boxes, fighter-finders and number-crunchers. Ian Sinclair concludes his interesting and instructive guide to the sometimes daunting field of Electronics, and proves it really is easy.

IN THE EARLY days of radio, the problem of transmitters interfering with each other was not serious; there weren't enough of them, and they all had pretty low power outputs. Later on, with many more transmitters in use, the problem seemed to be solved by making each transmitter work at a different frequency — after all, there's a lot of different frequencies to play with. This wasn't enough, though, and here's why.

We can generate a carrier wave of almost any frequency we like, using an oscillator and a set of frequency multipliers. A carrier is a pure sine-wave, which has a single frequency, so that we could have an enormous number of carriers, perhaps one at every 500 Hz all the way from 100 kHz upwards. The trouble is that a carrier by itself is rather useless, and to carry information, audio or otherwise, it must be modulated. Now a modulated carrier is quite another thing, because it no longer has the shape of a simple single sine-wave. If we use a very selective receiver to measure the amplitude of each frequency that is present in a modulated carrier, we find that there are now frequencies present which are neither carrier frequency nor audio frequency — it's the familiar old story of the mixer again. These new frequencies are called *sidebands* and there will be two of them. The upper sideband is at the frequency which is the carrier frequency plus modulation frequency, and the lower sideband is at a frequency which is carrier frequency minus modulation frequency. For example, if we modulate a 1 MHz carrier with a 10 kHz sinewave, we find that the complete modulated signals consists of three frequencies, the carrier at 1 MHz, the lower sideband at 990 kHz, and the upper sideband at 1.010 MHz.

If the modulating signal is not a single sinewave but a mixture of frequencies such as we get with speech and music, then the sidebands will also consist of a mixture of frequencies on each side of the carrier. It's these sidebands which decide how many transmitters we can use in a given range of frequencies, because transmitters will interfere with each other if their sidebands overlap (Fig. 8.2) even though their carriers are spaced well apart. The bandwidth, which is the range of frequencies from the carrier to the end of one sideband, is the important factor that decides how transmitter frequencies can be allocated.

SIDETRACKED

The problem of these sidebands and the bandwidth that each transmission takes up has occupied many engineers for many years. For various reasons, the range of frequencies that we call the medium waveband has been the most useful for broadcasting — the reasons include transmitter range and ease of reception. The result is that every country in the world wants to transmit on the medium waveband, but the sad fact is that there simply isn't enough room.

Various international conferences have tried to allocate frequencies spaced 10 kHz apart (so that sidebands above 5 kHz cannot be used) fairly among the nations, trying to ensure that transmitters working on closely spaced frequencies were large distances apart. These schemes could have worked but for the rogue — countries which choose to ignore the frequencies allocated to them, and, of course, the pirate radios who find a fair bit of profit in ruining other people's reception. All of this

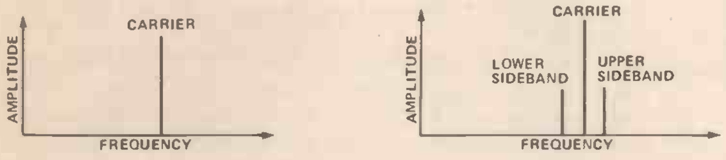

Fig 8.1 An unmodulated carrier is a sinewave. On a graph of amplitude plotted against frequency (a) it appears as a single line. A modulated carrier plotted in the same way (b) shows sidebands.

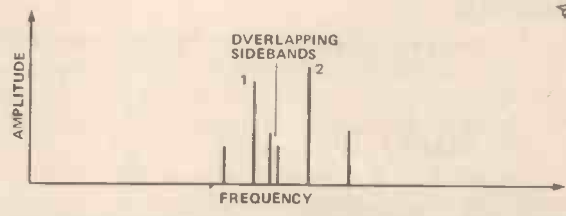

Fig. 8.2 The sidebands of two transmitters can overlap causing interference.

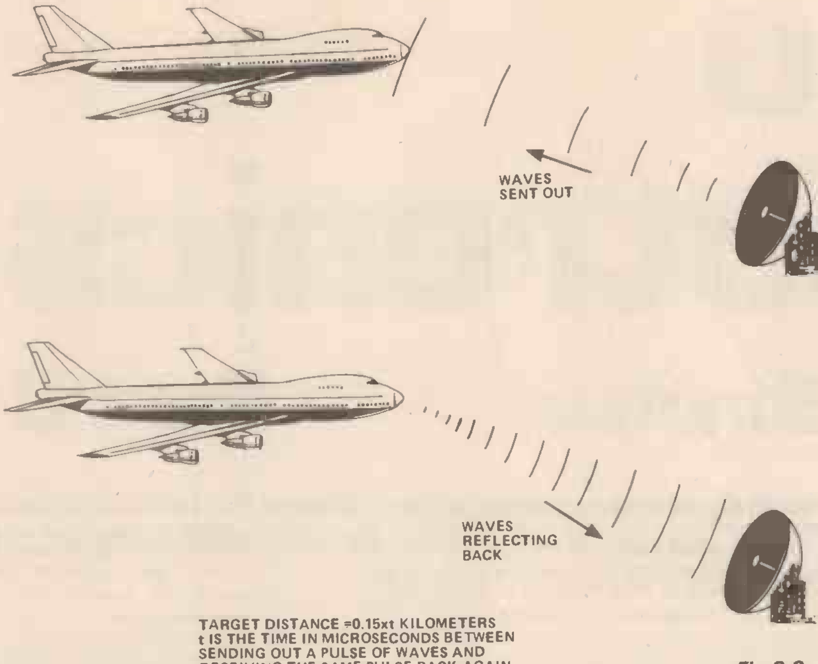

Fig 8.3 Principle of radar.

has now made the medium waveband unsuitable for serious broadcasting.

HIGH FREQUENCY

High quality transmission needs the transmission of audio frequencies up to about 14 kHz; radar and TV need much greater bandwidths than this (TV, for example needs about 6 MHz) so that the medium waves are totally unsuitable for such purposes. This is the reason for the extensive use now of the high frequencies, around 90 MHz for high quality sound transmissions, 450 to 800 MHz for colour TV, and 10 000 MHz or more for radar. There's lots more room up there. For example, the bit of the VHF band that we use for stereo broadcasting is ten times the range of frequencies that we have on the whole of the medium waveband.

As a useful bonus, the range of transmitters is not so great, so interference is much less of a problem. Another great advantage of using these frequencies is that we can make use of different methods of modulation, such as frequency modulation, which need greater bandwidth. For example, the FM stereo broadcasts that we transmit in this country need a bandwidth of 220 kHz, even though the audio bandwidth is only 14 kHz; at higher frequencies we can use power-saving methods like pulse modulation.

BOUNCING THE BEAM RADAR

Radar, as anyone will tell you, consists of bouncing radio waves from a target and finding how long it takes for the reflected signal to return. It's like moonwalking — easy if you happen to have all the equipment, but you have to be able to build the equipment first.

The first bit of equipment you need for a radar transmitter is an oscillator which will generate a carrier with a frequency of 1000 MHz or more, preferably up in the 10000 MHz region. Why such a high frequency? One reason, of course, is that there's plenty room for bandwidth, but there are more pressing reasons.

All radio waves travel at the same speed of 3×10^8 m/s (three hundred million metres per second), but the wavelength, the distance from one peak of a wave to the next while in flight is equal to speed divided by frequency. Like all other waves, radio waves will reflect well only from objects which are several times the size of a radio wavelength (ever heard of diffraction?) The wavelength of a 1000 MHz wave (sometimes called 1 GHz, one Gigahertz) is 300 mm, which is just about small enough to bounce from the front of a large aircraft or a medium-sized ship, though we might not get much reflection from a slim fighter. If we want to obtain good reflections from smaller objects, or to be able to distinguish more detail of a larger one (to have better resolution, as we say) then we need to use waves of shorter wavelength, a few centimetres or even millimetres, and that means much higher frequencies.

THE LONG AND SHORT OF IT

Radar requirement number one, therefore, is a generator of high frequency waves, preferably one that can churn out a lot of power, because only a tiny fraction of all the power that is sent out will ever return, even under the most favourable circumstances (Fig. 8.4). The wave generator that's used for all the larger radar transmitters is a device called the magnetron, which spins electrons round at very high speeds past a tuned circuit which consists of a hole in a piece of metal (called a cavity, which sounds uncomfortably like something dental). Magnetrons that are used for most radar purposes do not oscillate continuously, but are turned on and off in short pulses.

The short pulse is the next requirement. If we are to be able to detect the faint reflected wave from a distant object, we will ruin our chances if the transmitter is still belting out thousands of watts. In addition, because we want to measure the time that passes between sending out a pulse and detecting the echo, we need to use a short pulse so that we can measure the time more precisely (Fig. 8.5).

Using a short pulse has another advantage. Magne-

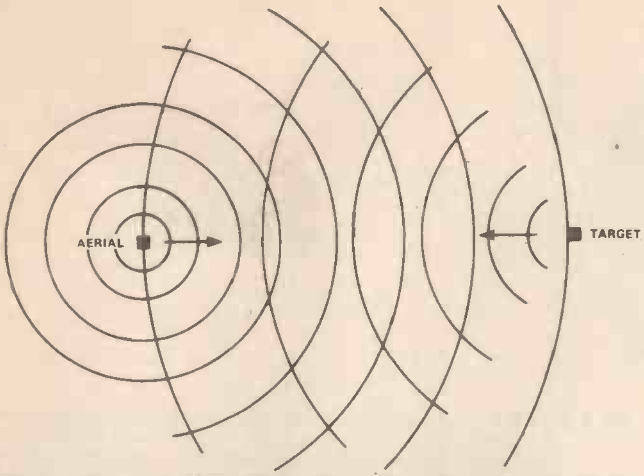

Fig 8.4 ***The wave sent out by the transmitter spreads out, and only a tiny fraction of it strikes the target. The reflected wave from the target also spreads out, and only a tiny fraction of it strikes the receiver aerial. In practice the ratio is not as bad as it looks, because the transmitted wave can be focused to some extent into a beam.***

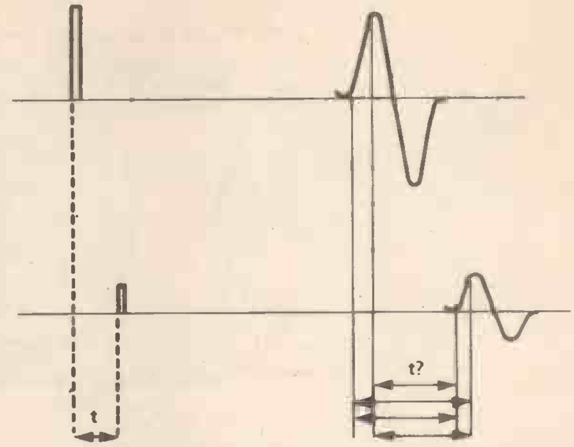

Fig 8.5 ***The advantage of using a pulse. We can easily measure the time between pulses, counting microseconds between the steep sides. (a)***
(b) A sine wave is useless for this because we cannot be certain where to start or stop the time measurement.

trons, like all other active devices, have to dissipate heat, using water cooling or forced air cooling. The amount of heat that has to be dissipated depends on the average power that is dissipated and that's the advantage of the short pulse. For example, if we have a magnetron which will dissipate 5 kW continuously, and we switch it on for 10 uS in every millisecond, then the power that can be handled for that 10 uS can be $5 \times \frac{1000}{10} = 500$kW. Now a short pulse of 500 kW is much more effective from the range point of view than a steady wave at 5 kW, so that the use of pulses enables us to obtain a much greater range than would otherwise be possible.

THE WERE ARE YOU NOW SPOT

Fig. 8.6 shows a block diagram of a radar transmitter. An astable generates synchronising pulses, usually at around 1 kHz. A monostable then generates a short pulse which is used to start off all the action. One piece of action that is started off is a high voltage pulse generator which, when the trigger pulse arrives, switches the magnetron on and off. During the time of this pulse, the magnetron is oscillating with a very high power output, so that the transmitting aerial is sending out microwaves like mad.

The trigger pulse also starts the timing operation, usually by starting the sweep on a CRT. Some time, a long time in terms of microseconds, after the magnetron has stopped oscillating, the reflected pulse returns. It is then picked up on the aerial, amplified in a superhet receiver (we did say that they had a lot of uses) and used to brighten up the CRT display (what part of the CRT is used for this, do you think?), so that a blob of light appears. Because the sweep voltage has been deflecting the CRT, the blob will appear some distance away from the start of the sweep — and this distance is proportional to the range of the target.

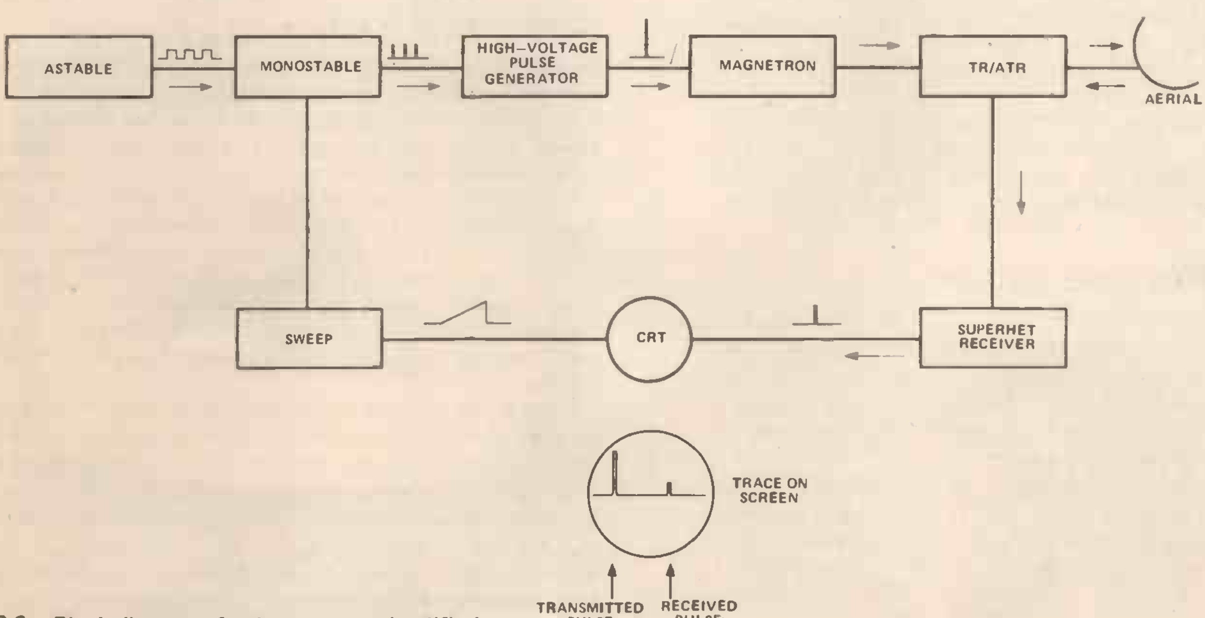

Fig 8.6 ***Block diagram of radar system, simplified.***

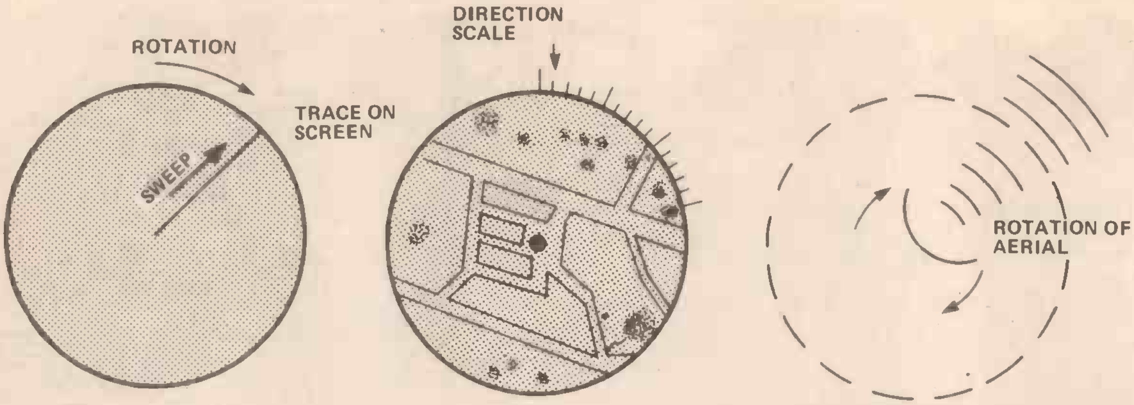

Fig 8.7 PP1 Trace (a) direction and rotation of sweep on screen (b) rotation of aerial in step with rotation of sweep (c) typical trace, showing transmitter at centre and the surroundings, with stationary objects and moving targets. A long persistance tube is used, so that the targets leave trails to indicate their movement.

Want a bit more detail? Well, both receiver and transmitter use the same aerial, with protection circuits to ensure that the high power transmitter pulse does not get into the receiver circuits and that the weak returning pulse does not get lost in the transmitter circuits. The devices used for this job are called TR and ATR cells, life's too short right now to deal with how they work.

A PLAN FOR THE FUTURE

The type of display that's used for most radar receivers is the PPI, Plan Position Indicator. In this type of system, the CRT sweep starts from the centre of the screen each time, and moves out to the edge. The aerial rotates, and its rotation is synchronised to the timebase action so that the direction of the sweep is linked to the direction of the aerial. In this way, during one rotation of the aerial, the radar sweeps the skies right around the transmitting station, and the CRT display shows the transmitter as a spot at the centre of the screen, with the targets as blobs of light. The distance from the centre of the CRT to any target measures the range of that target, and the direction is indicated on the scale of degrees around the edge of the CRT (Fig. 8.7). A lot of modern radar sets also use a 'nodding' aerial to measure the height of targets, and the two lots of information are fed into a computer, so that the final display can show figures of height and speed beside each target blob.

Pulse PPI radar is just one widely-used form of radar, and we could fill a book or more on the details of this and others, such as FM rangefinder radar, Doppler speed radar and others. All we can do here is to refer the interested reader to books that specialise in this important branch of electronics. Unfortunately, the books your neighbourhood library may have in stock will probably have been written twenty years ago, or even more.

VISION ON

Let's scratch briefly at the surface of another topic, television. The problem here is how to convert a picture into a waveform. Sound broadcasting is easy by comparison; the transducer simply has to convert the sound waves into electrical waves at the same frequency. Light waves are already electrical, but at a frequency which is too high to be dealt with by electrical circuits; what we need is a signal which shows the position and brightness of everything in the picture for black & white TV, and with colour added for the de luxe version. The problem was tackled nearly a hundred years ago by Nipkov, who invented the idea of scanning.

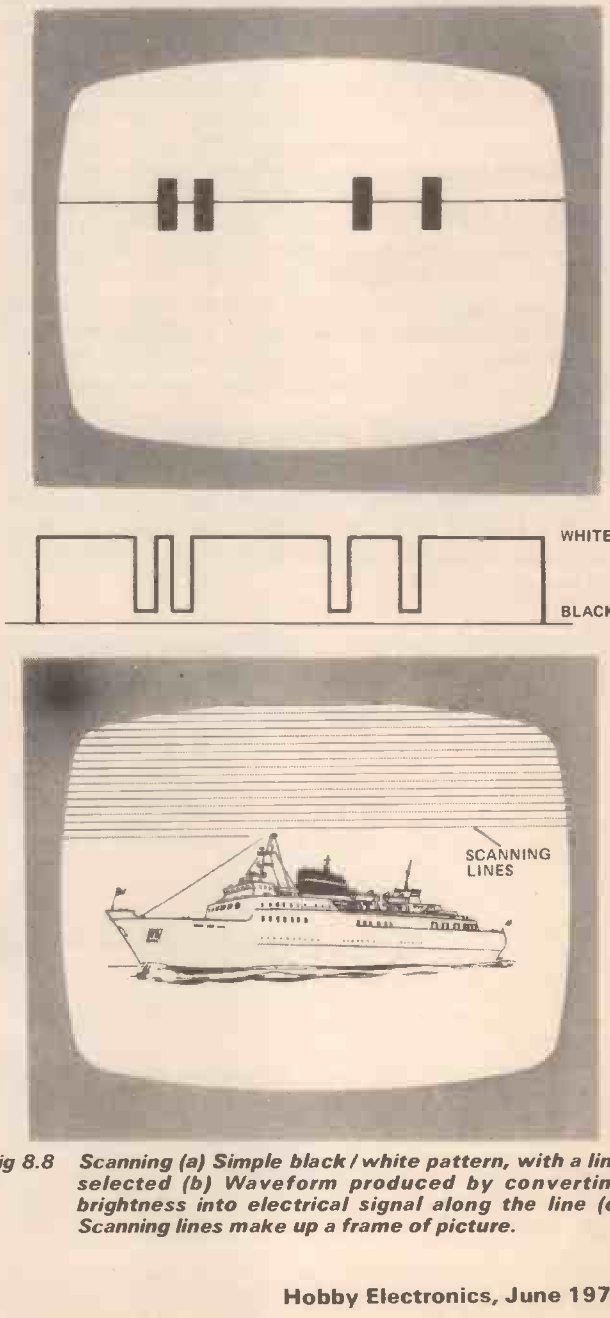

Fig 8.8 Scanning (a) Simple black/white pattern, with a line selected (b) Waveform produced by converting brightness into electrical signal along the line (c) Scanning lines make up a frame of picture.

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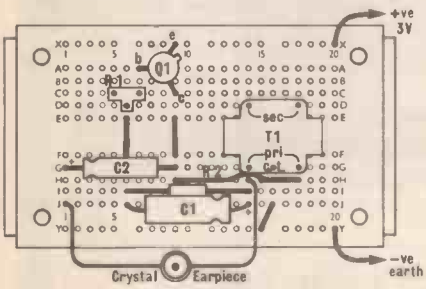

YOU WILL NEED

- **B1, B2** – 2xl.5V AAA batteries
- **C1, C2** – 50 uF, 12-VDC electrolytic capacitor
- **E1** – Crystal earphone
- **Q1** – Motorola HEP-230 pnp transistor
- **R1** – 5000-ohm pot
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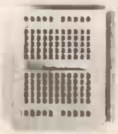

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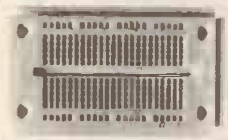

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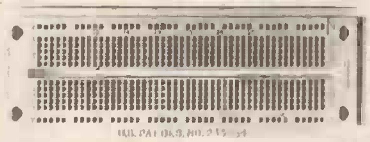

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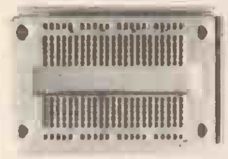

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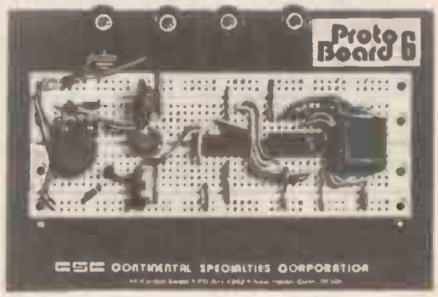

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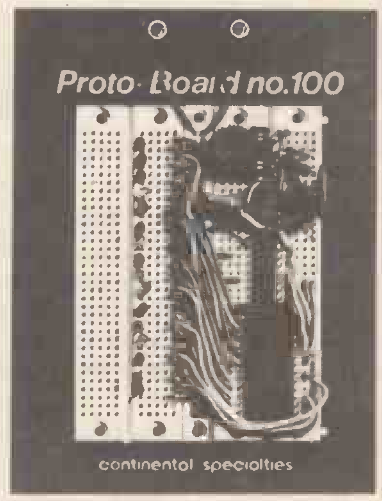

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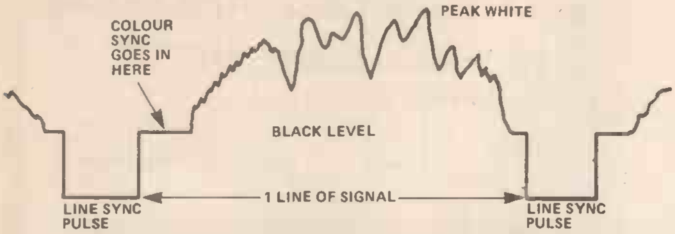


Fig 8.9 *Line waveform. The sync pulse causes the receiver timebase to flyback ready to start the next sweep just as the video signal starts. The amplitude of the sync pulses is less than the amplitude of a block signal, so that sync signals cannot appear on the screen.*

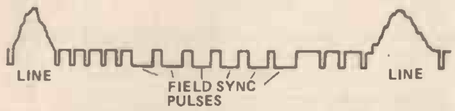


Fig 8.10 *Line and field sync pulses. A set of field pulses is transmitted so that the receiver can separate them from the line pulses.*

Scanning means selecting a line along the picture, and measuring the brightness of bits of the picture along that line, rather as we are taught to read by making our eye scan the words from left to right (around these parts at least) along each line of print. The result of scanning a line at a steady speed, using something like a photocell, is a waveform whose period is equal to the time taken to scan the line (Fig. 8.8). Now if we select another line slightly below the first one, we can obtain another chunk of wave, and by continuing this process we can analyse the whole picture into a set of waveforms.

IT'S A FRAME-UP

A complete set of lines of picture makes up a frame, a complete picture, and the history of the cinema shows us that if we can show about 20-30 frames per second we can obtain the illusion of movement. For historical reasons, we choose here to make the frame rate half the mains frequency rate, so that our frame rate is 25 Hz; because the mains frequency in the USA is 60 HZ, they use a frame rate of 30 Hz. The idea originally was to synchronise the picture rate to the mains frequency.

Synchronisation is one of the most important features of TV, and the idea appears to have been suggested by the true pioneer of TV as we know it today, Campbell-Swinton who in 1910 took out a patent which was as near as tuppence to a block diagram of a modern TV system, even to the CRT, which at that time was just a laboratory curiosity. The synchronisation problem is something like this. The signal, called the video signal, for each line of transmitted picture, must be used by the receiver to create a line of picture which fits into the same position in a frame. Unless this synchronisation is perfect, the received signal will build up into a scrambled picture — a mass of dots of different brightness which make no sense. The sort of thing, in fact, that we see when the line hold or frame hold controls on the old telly have been thoughtlessly twiddled. We can make sweep circuits which will run at a steady speed for the time of one line, and so what we need is to be able to synchronise the start of each line sweep, so that the sweep of the receiver will start just as the first part of the video signal for that line is starting.

This is done by transmitting a synchronising (sync.) pulse just before the start of each line of video signal. The waveform of a line of signal looks as shown in Fig. 8.9, with the sync. pulse and the video waveforms. We can arrange things at the receiver so that the CRT of the receiver is cut-off (no electron beam) until the video signal starts, so that the sync. pulse and any unwanted signals during this time have no effect. This cut-off time is also used to transmit the sinewave synchronising signals for colour.

INTERLACING

We need another timebase to sweep the screen vertically, top to bottom, both at the camera and at the receiver, to ensure that each line is equally spaced from its neighbours, and that we have the correct number of lines in each frame. This field sweep as we call it is at a much lower rate than the line sweep, because we don't need anything like as many field sweeps per second as we need line sweeps. This timebase also needs to be synchronised, so that another sync. pulse is needed. In fact, a whole set of pulses is transmitted at the start of each vertical sweep, so that the receiver can sort out which is a line pulse (a single) and which is a field pulse (one with a wife and family).

Now at this point a complication arises. For a bright picture to be free of flicker, we need something like 50 vertical sweeps per second, and this has the advantage of being tied to the mains frequency. If we use the full number of lines per frame, 625 in the UK and most of Europe, 525 in the USA, then the bandwidth that we need to transmit the signal turns out to be a bit on the large side, around 12 MHz. If, on the other hand, we cut down the number of lines in each frame, the picture looks liney, like a five-barred gate. So what do we do?

The answer, folks, is interlacing. Each vertical scan, or field, consists of the alternate lines of the picture, lines 1,3,5,7 . . . . . and so on. The next field has lines 2,4,6,8, who do we appreciate and all the rest of it. It takes two fields to make up a complete frame of picture; the first field starts with the beginning of line 1, and ends halfway along a line (312½), the second field starts halfway along a line, and ends at the end of a line. How do we arrange this? Well it's quite automatic provided we choose the correct frequencies for the timebases, and there's nothing that has to be done which wouldn't also have to be done if we didn't yse interlacing. Not all brilliant inventions need hardware, you know.

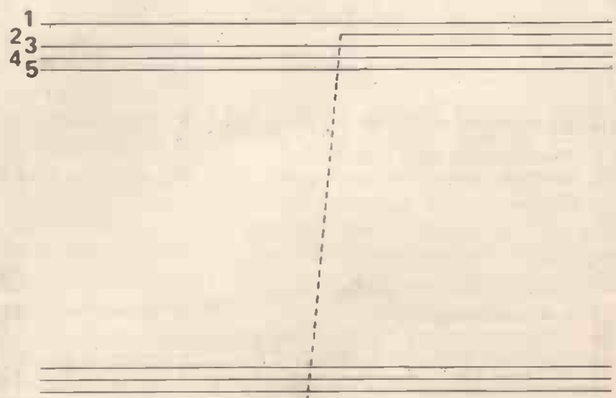


Fig 8.11 *Principle of interlacing. Lines, 1, 3, 5 etc. are traced in the first field, lines 2. 4. 6 etc. in the second. The two interlaced fields make up a complete frame of lines.*

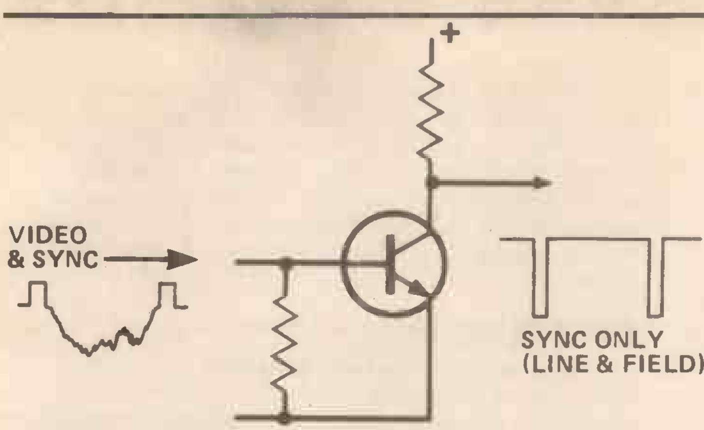


Fig 8.12 Separating sync signals from video.

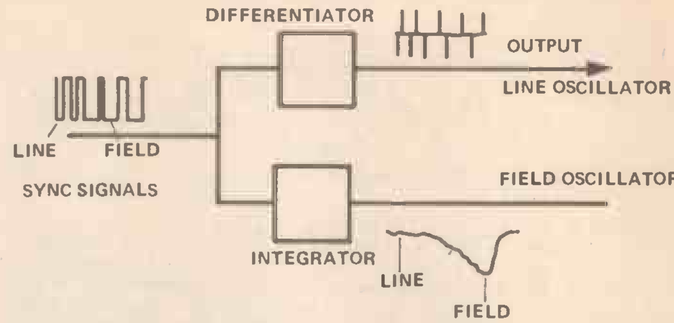


Fig 8.13 Separating the two sync signals from each other.

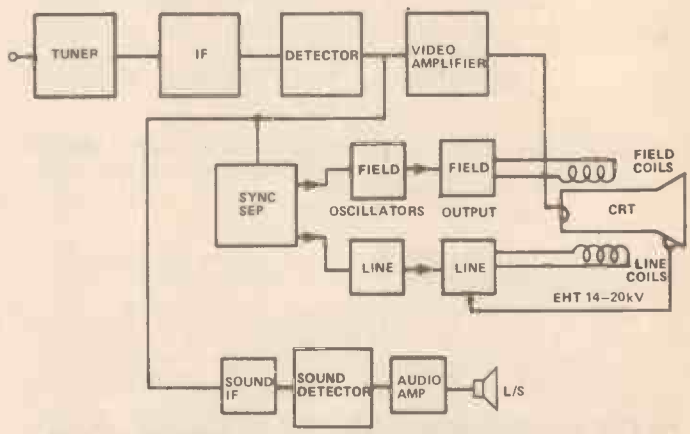


Fig 8.14 Simplified block diagram of B / W TV.

KEEPING IN STEP

Take a look now at how some of these operations are carried out at the receiver — what does on at the transmitter is a bit more complicated, we'll leave that alone right now. The signals from the aerial are fed into a superhet receiver (what else?) and amplified at an intermediate frequency of around 36 MHz, with a 6 MHz bandwidth. Concentrating on the video signal at the moment, this is obtained by a simple diode demodulator (because the video signal is amplitude modulated) and consists of what is called 'composite video', that is picture signal plus sync. pulses. Now the way the video signal is designed, the actual picture signals start at about 23% of the peak signal amplitude, so that a piece of picture that is black corresponds to a voltage level which is about 23% of peak white. Any voltage less than this 23% does not register on the screen, so that this first 23% of the signal voltage can be used for sync pulses. In the receiver, we need to use these pulses, free of video signal, to synchronise the timebases, so that the first stage of a receiver after the demodulator is a sync. seperator which, as the name suggests, separates the sync signals from the video signals and also from each other.

Taking these one at a time, the sync. signals are separated from the picture signal by their amplitude difference. The composite signal as it leaves the demodulator is inverted so that the sync. signals are the most positive part of the signal. Now take this waveform to the base of a transistor which has no bias, and only the tips of the sync pulses will cause the transistor to conduct. The waveform at the collector is therefore a set of sync. pulses with no video signal at all.

Next problem, to separate a line sync. pulse from the field pulses. The output of the sync. separator feeds a differentiating circuit and also an integrating circuit. Each sync. pulse will produce a couple of spikes from the differentiating circuit, and the output of this circuit can be used, though nowadays after a lot of processing, to synchronise the line timebase. Single short pulses produce very little output from the integrating circuit, but a set of longer pulses, all coming in quick succession, causes a slow-rising pulse out of the integrator, and it's this pulse that we use to start the field timebase.

The timebase circuits themselves, are always astables, because they must continue to run even if the sync. pulses do not appear. They are used to drive current through scanning coils slipped over the neck of the CRT. The field timebase is usually fairly straightforward, but the line timebase of the modern telly is a fearsome bit of circuitry. The line deflection coils have a fair bit of inductance, and when the current through them stops at the end of the line scan, the back-emf is pretty large, several thousand volts. This is stepped up in a line-output transformer, and used to provide the high voltage for the tube.

SOUNDING OUT

Oh, yes, we nearly forgot about the sound signal. It's modulated onto another carrier which is at a frequency 6 MHz higher than the vision carrier frequency. Back in the old days, this used to be separated out at the mixer of the superhet and its different IF amplified separately. Nowadays, a wideband IF amplifier strip amplifies both sound and vision signals in one go, and the separation now takes place at the vision detector. A detector diode will not demodulate an FM signal, so what happens at the diode is signal mixing — the vision carrier beats with the sound carrier to produce a 6 MHz signal, which is still frequency modulated with the sound signal. This only needs a little bit more amplification to be demodulated by an FM detector. After that it's volume control, voltage amplifier, power amplifier and speaker just like any old radio.

We've left out colour. That's because life's too short, but you now should know enough about the basics of TV to pick up a more specialised book on TV and be able to understand it. Some of the books in the Beginner's Guide series are very useful if you want to read further.

NUMBER CRUNCHING

Number crunching is what a computer or calculator does, and we're going to look at how it goes about it. OK, a computer, even a pocket calculator, is a fearsome bit of electronics, and I wouldn't like to start designing one from scratch. Someone once said, though, that Science consists of reaching for the stars with the

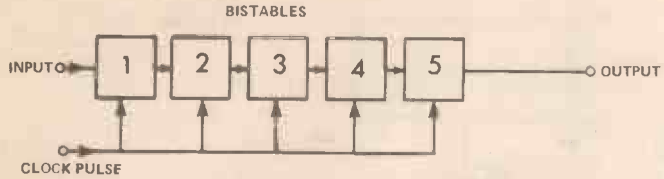
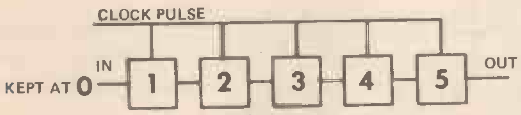
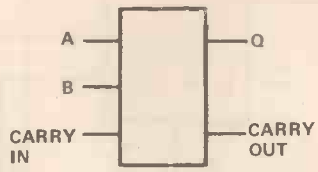


Fig 8.15 Shift register principle. A set of bistables is connected together with a clock pulse used to control each bistable. At a clock pulse, each bistable passes on its output, 0 or 1, to the next bistable in line.



1	2	3	4	5	
1	0	1	1	0	STARTING CONDITIONS
0	1	0	1	1	AFTER 1st CLOCK PULSE
0	0	1	0	1	AFTER 2nd CLOCK PULSE
0	0	0	1	0	AFTER 3rd CLOCK PULSE
0	0	0	0	1	AFTER 4th CLOCK PULSE
0	0	0	0	0	AFTER 5th CLOCK PULSE

Fig 8.16 Action of a shift register. Five clock pulses will shift out all the signals from this 5-stage register.



A	B	Cin	Q	Cout
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Fig 8.17 The full-adder (a) and its truth table (b). The carry terminals are needed from the 1's carried from the previous addition or to the next one.

advantage that you're standing on the shoulders of everyone who has gone before you. Some of these guys were pretty tall, and we'll make full use of them.

The cleverness of calculators and computers is not in the circuits so much as the way in which they're arranged — they even talk about computer architecture. The circuits are logic gates, bistables, and memories, mainly, types of circuit that we've met before, but in huge quantities, and connected together in a way that makes a lot of difficult calculations very easy to carry out. Every circuit, though, is working in binary code, so that the only digits that are used inside the machine are 0 and 1. The question is how. Fasten your safety belts and we'll take a brief look.

One particularly important use of bistables is in a circuit called a shift register, sometimes just register, which appears in all calculators and computers. We're not going to look at a detailed circuit of a shift register, but we need to know what it does, with the aid of Fig. 8.15. The shift register is a set of bistables, each connected so that the signals at the collector of one bistable are taken to the bases of the next, and so on. The bistables are not the simple bistable type we have looked at, but what are called clocked bistables, in which no action takes place until a clock pulse, a sort of sync. pulse, arrives. Each bistable in the shift register is connected to the same clock pulse oscillator.

CLOCKING-IN

Imagine now that this string of bistables is working and the output of each bistable is represented by the voltage of one of the collectors, 0 or 1. Now look at what happens when a clock pulse comes along. Each bistable (Fig. 8.16) hands on the digit that it has at its collector to the next bistable in line (to the right of the diagram). This is where the name shift register comes from, each digit is shifted one stage onwards when the clock pulse arrives. What happens at the first and the last bistables? At the first of the bistables, any number, 0 or 1, that is present will be shifted (or loaded, as we say) into the first bistable when the clock pulse arrives. If the input to the first bistable is 0, then a zero will be shifted into the register at the first clock pulse; if the input is at 1, then a 1 is shifted in. At the output, a 1 or a 0 will be shifted out as each clock pulse comes along. Not terribly difficult really, just a shift of one place on each clock pulse, and yet this is the circuit which above all makes computing possible. Why? Because the action of the shift register is controlled by the clock pulses, and because every operation in computing can be carried out by a combination of logic gates and shifting.

BINARY ADDITION

Let's look at some examples. Adding is carried out with two numbers at a time, as we know from using a calculator. Adding in binary is just as easy as adding in decimal, but how do we do it electronically? We can connect up NAND and NOR gates to form a circuit called a full adder, whose truth table is shown in Fig. 8.17, and this circuit will add two binary digits, plus any carry from a previous stage. The output is a digit, and another carry. The important thing is that this adder can cope with only one digit from each of the numbers being added (plus the carry) so that we have to present the digits of the numbers one step at a time. If, for example, we add 001011 to 101101, then we start with the least significant digits, the 1's in the last place. With these 1's at the inputs, the adder will produce a zero at the output and a 1 at the carry. The next digits are the bits 1 and 0, with the carry 1 from the last step, so the adder once again produces a zero output and a carry 1, and so on. How do we ensure that the adder is presented with a bit from each number at a time? Yes, that's right, we feed the digits from shift registers. One shift register stores 001011, the other stores 101101. The outputs of the shift registers are connected to the inputs of the adders, and another little shift register is used to store the carry. When a clock pulse arrives, the digits stored in the final bistable of each shift register are shifted into the input of the adder — which adds them. The output bit can then be shifted 8.12 into another shift register, and the carry bit stored in its own little shift register. On the next clock pulse, the next pair of digits come tumbling out of their shift register, plus the carry bit from last time round. The output is shifted into the output register, the next carry into its register and so on. There are six bits (digits) in each number, so that six clock pulses are needed to carry out this addition. After these six clock pulses, the output register will store the sum of the two numbers, 111000.

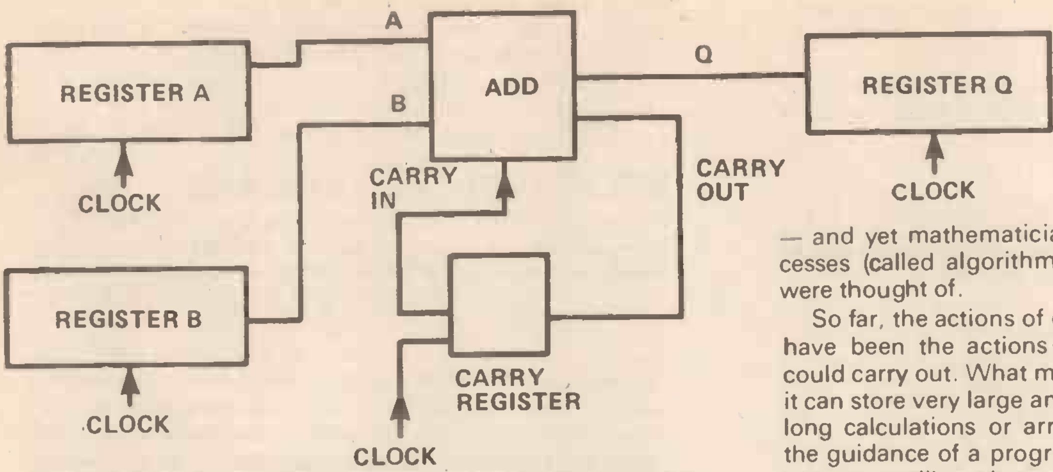


Fig 8.18 An adder used with registers to add two binary numbers.

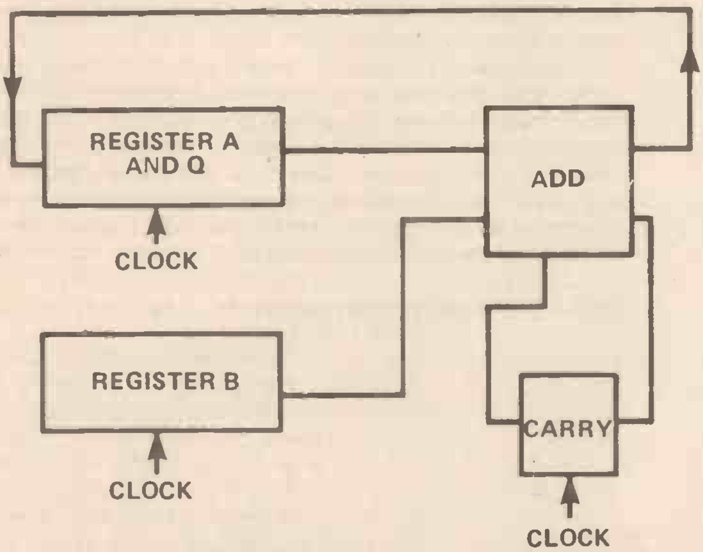


Fig 8.19 A neater arrangement in which the answer is fed into register A at the same time as the number A is clocked out.

REMEMBER THIS

We've described this in terms of three main registers, but most calculators would use only two (they are always referred to as memories). As each set of bits was added, the sum would be fed back to the input of one of the registers which had previously been used to store one of the numbers. That way it is then ready to be added to the next number. One of the main registers in a calculator is always hooked up to the display, and this is always the register into which a number is placed by using the keys. The other register is then used for the output from the adder, until the equals key is pressed, when the second register clocks its contents into the display register.

We've spent a lot of time on addition, and the reason is that all binary arithmetic consists of addition and shifting. Subtracting in binary, for example, consists of inverting each digit (0 for 1, 1 for 0) and adding 1 to one of the numbers, and then adding. Multiplication consists of shifting and adding, and division can be carried out by a similar, but more tedious process. The clever part of most modern calculators is the way in which other functions, such as log, sin, x_y, and so on can be calculated by using only addition and shifting processes — and yet mathematicians had worked out these processes (called algorithms) centuries before calculators were thought of.

So far, the actions of calculators that we've looked at have been the actions that any old pocket calculator could carry out. What makes a computer different is that it can store very large amounts of numbers and carry out long calculations or arrangements of numbers, under the guidance of a program. Storage of information in a computer will not be confined to the registers, because other forms of storage such as punched cards, magnetic tape, paper tape and magnetic discs ('floppies') can be used to store information and read it in when needed.

Let's think of a simple example to illustrate what goes on. The resonant frequency (remember) of a coil of inductance L and a capacitor C in series is given by

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Now if you were to start working this out on your pocket calculator, you would probably start by entering the value of L, pressing the [×] key and then entering the value of C. Using the [=] key then gives LC, and a quick stab at the [√] key gives the square root. The next lot of key strokes is [×]2[×][π][=], so that the whole denominator has been calculated. Finally, pressing the [1/x] key inverts the number to give the result in Hz.

KEYS FOR GATES

What happens each time a key is pressed? Quite a lot of circuits are switched about, using gates, but the whole process is triggered off by one connection being made, so that some part of the circuit is switched from 0 to 1 or the other way round. Any action like this that can be done by a switch can just as easily be done by the output of a gate, and we can design gates that will close for any combination of inputs we like. Suppose, for example, that we have a set of gates, each with three inputs, and that their normal output is 0. We can design these gates so that one of them switches over for the input 001, another for 010, a third for 011, and so on, with each gate switching only for its own code number. Now if each of these gates activates a set of command circuits like [×], [=], [+], [1/x], and so on, then these operations will be carried out on the numbers in the main registers when the code numbers 001, 010, 011, etc, are presented to the gates.

Programming a computer consists of entering these code numbers, in the correct order, into a set of program registers. We aren't stuck with the instructions + × = and similar functions either. We can use the gates to cause new numbers to be read in from a register or from tape, or to store an output in a memory register, or print it on a printer. Our calculation of resonant frequency might start something like this.

First we load the values of L and C into memory registers. This is done by an instruction to the computer; code numbers which activate the correct gates so that the numbers that follow on the next set of clock pulses are stored in different registers. Each register has a reference number, so that we know which one is used for each quantity. Assuming that the computer is already programmed, we can now press the start (or execute) key and watch what happens.

The first program register reads out with the first set of clock pulses and it has the effect of activating a set of gates. These gates allow the next bunch of clock pulses to shift the digits that represent the value of L into the main register, called the accumulator. The next clock pulse moves the program (we usually talk about the program counter) one step on, so that the clock pulses that follow set the gates for the instruction 'multiply'. That done, the next clock pulse moves the program on, and the next bunch of clock pulses brings the value of C out of store, and at the same time carry out the multiplication that has been set up ready. The program moves on, with the instruction [=] clocking the result of the multiplication back into the accumulator. Move on again and this time the pulses set up the circuit for finding the square root. We needn't go over it all, because you can see what is happening at the end of each operation, the next clocking activates a program step, which in turn carries out the next instruction.

FAST FIGURES

What makes it all so useful? Well, one thing is speed. The clock pulses in a big computer have a fast rate, 5 MHz or more, so that it doesn't take too long to go through a set of instructions. Even more important is that we can program in decisions. For example, we can include instructions that command the computer to compare the number that is in the accumulator with zero, and to go to another part of the program if the number in the accumulator is equal to zero, or alternatively, less than zero, or greater than zero. This type of instruction, called a conditional transfer, makes a computer much more useful than a simple calculator, because the computer can be made to produce more than one answer, or to work out a whole series of similar steps. We can, for example, program the computer to calculate the reactance of a 470 p capacitor at 1 kHz, 2 kHz and at every 1 kHz upwards to 1 MHz, and then to stop and print out the answers. This sort of job is very tedious even with a calculator, because there are 1000 calculations needed. The computer can be programmed to carry out the calculation for 1 kHz, print the answer, add 1 to the number of kHz in the store for L and carry on. Each time round, it can be asked to take the figure of frequency, subtract 1000, place in the accumulator and compare with zero. If the answer's not zero, carry on. If it is zero, stop. That way, when the frequency of 1000 kHz (=1MHz) is reached, the computer calls it a day.

WATCH YOUR LANGUAGE

The program as it is stored in the program register of the computer is just a string of figures, called machine code, which will have a different job to do in each different machine. Micro-computer have to be programmed using these machine codes, but large computers use what are called High-Level languages. A high-level language consists of instructions which are represented by letters, such as LDA, JUN, RNA, which can be typed onto an instruction tape. Each of these instructions may need many steps in machine code, and has to be converted into machine code by a circuit called a compiler, which consists of a set of gates. The high-level languages can then be used on any computer whose manufacturers have made a suitable compiler.

Once again, of course, we've only scratched the surface of a very large topic. If you want to take it further, then books alone are not really useful, because you need some practical experience with a computer. Many Technical Colleges run courses in Computer Science, and such courses include programming. On a less ambitious level, you can teach yourself a great deal about programming by learning to use a programmable calculator such as my favourite, the TEXAS T1-57. This is a miniature computer on which the program steps are entered by pressing keys rather than by a tele-type.

We've reached the end of this particular road now, and you've on your own. Along with the practical experience that the projects in HE will supply, plus some good advice at school or college, you now have enough background in electronics to tackle the London OA paper, or even the C & G 224 Part 1 — but remember that both of these require some observed practical work, and the London OA needs an essay of 1000 words as well. All in all, though, it's not a bad achievement for reading your favourite magazine for eight months, is it?

HE

PROGRAM INSTRUCTIONS	MEANING
LRN	Calculator memories following steps as a program
RCL 1	Display contents of memory 1
×	and multiply by
RCL 2	Contents of memory 2
=	Display the product
√x	Take the square root
1/x	Invert
×	Multiply by
RCL 3	Contents of memory 3
=	Display product
R/S	Stop, and leave last result displayed
LRN	Signals end of program

RUNNING THE PROGRAM — Finding resonant frequency of 35 uH and 500 p

KEY STEPS	MEANING
CLR	Clear the display of any figures
5.03 STO 3	Stores the number 5.03 in memory 3
35 STO 1	Stores the value of inductance in memory 1
.5 STO 2	Stores the value of capacitance in memory 2
RST	Ensures that program is reset to the start, ready to run
R/S	Runs program — display reads 1.2, which is frequency in MHz

Formula used for this program is

$$f = \frac{5.03}{\sqrt{L \times C}}$$

with f in MHz, L in uH and C in n

Fig 8.20 A program for finding resonant frequency, using a TEXAS T1-57.

electronics today international

What to look for in the July issue: On sale June 1st

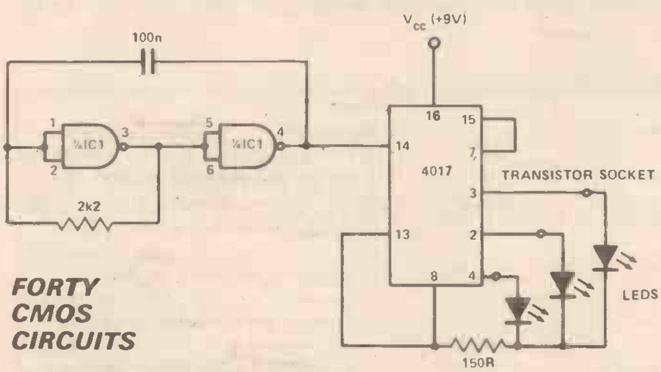
TELETEXT BOX

ETI goes Teletext next month. A full spec design including full colour and double height characters. Remote control is by ultrasonics, so there is no need to move from your armchair to change the page. The circuit is based upon the Mullard chip set — long awaited that is.

Emphasis has been placed upon ease of construction — the PCBs are plated through and silk screened and everything mounts to the board. With all this offer and with commercial units running at £200 plus you'd expect this kit to cost the earth would you not? Well it will set you back under £160 complete and we don't think that's bad! Don't miss this.

POLYPHONIC KEYBOARD CONTROLLER

We've struck the right chord here. Give up those one note wonders and take up polyphonics — you can't get arrested for it and it'll make your oscillators warble for joy. Play away up to 8 times simultaneously and don't feel guilty about it!



FORTY CMOS CIRCUITS

Another family size, bumper bundle of goodies from our bionic project editor, Ray Marston. In past issues he's covered 555s and 741s. This time it's the turn of CMOS circuits. He's got forty, yes forty, of the little beauties for you. You can't afford to miss them.

SOIL MOISTURE INDICATOR

Don't drown your Dahlias. The most common cause of premature plant death (murder) in the home is over-watering. If you don't want the Sweeney hammering on your door in the middle of the night, we strongly suggest that you build this moisture indicator. Think of it as a happiness guide for your busy Lizzie.

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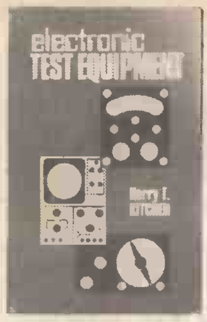

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Drill Speed Controller

An easy-to-build gadget that lets you vary the speed of your power drill, or any other domestic appliance that is powered by a universal electric motor.

THIS PROJECT CAN BE USED to control the speed of virtually any domestic electric drill, power saw, grinder, sander, or other power tool that incorporates a universal electric motor. It enables the motor speed to be smoothly varied from zero to about 75% of maximum via a single control, and incorporates built-in compensation to maintain the motor speed virtually constant at any given speed setting, regardless of changes of load. This latter facility is of great value when tackling low speed jobs like drilling masonry or using fly-cutters on sheet metal, etc.

The drill speed controller is housed in a standard MK surface mounting bakelite box, as used for normal house wiring work. The box plugs into the mains via a cable, and the drill plugs into a standard mains outlet socket that is built into the controller box front cover.

CONSTRUCTION

All components except C1, RV1, and SW1 are mounted on the single PCB, so construction should present few problems provided that care is taken to fit all semiconductors in the correct polarity. It must be emphasised, however, that the controller is connected directly to the mains without the use of an isolating transformer, so care must be taken to ensure that there is no likelihood of any dangerous conditions arising. Under no circumstances touch the wiring when the unit is connected to the live mains.

The SCR used on the prototype circuit is a C106C type, but the design can in fact be used with virtually any 400 volt SCR with a current rating greater than 3 Amps. We didn't bother to fit a heat sink to the SCR on the prototype, but it is probably a good idea to do so in practice. If you do fit a heat sink, make sure it can't come into contact with any other components or wires.

RV1 is mounted on a MK planking plate, suitably drilled, that screws to the right front half of the surface box. C1 is soldered directly across the terminals of RV1, with its positive side going to the R1-side of the pot.

The HE Drill Speed Controller connected up to our workshop drill, already it has found a regular place in our toolkit.

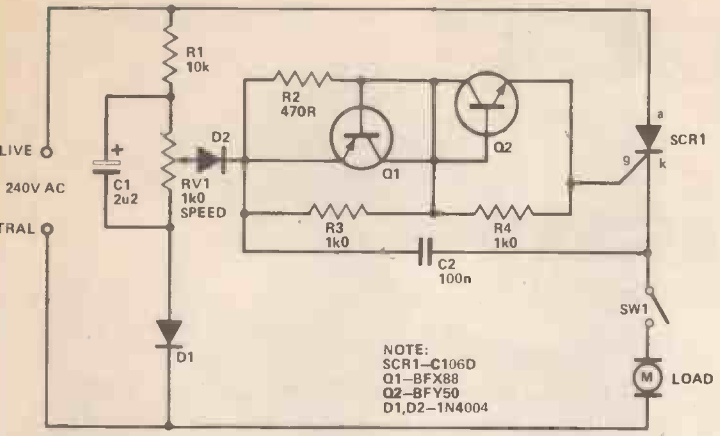
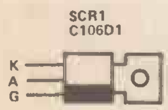


Fig 1. Circuit diagram of the HE Drill Speed Controller.



Leadout for TH1. Note the position of the heat-sink mounting hole.

Parts List

RESISTORS (All ¼W 5% unless stated)

R1	10k 5W
R2	470R
R3,R4	1k0

POTENTIOMETER

RV1	1k0 2W

CAPACITORS

C1	2µ2 63V
C2	100n polyester

SEMICONDUCTORS

SCR1	C106D
Q1	BFX88
Q2	BFY50
D1,D2	IN4004

MISCELLANEOUS
MK surface box list no 2025, MK 13A switched socket. MK 13A plug. MK single blanking plate.

How it Works

A universal motor, when running, generates a voltage that opposes that of the supply. This voltage is called the back EMF, and is proportional to the motor speed. The HE drill speed controller uses this back EMF to sense motor speed, and automatically adjusts the power fed to the motor so that it's speed remains reasonably constant under varying load conditions. The speed setting is variable via RV1.

Because of its back EMF characteristics, a universal motor runs at about 75% of its normal maximum speed when it is fed from a half wave rectified power line.

The HE controller uses an SCR (silicon controlled rectifier) to gate half-wave power to the drill motor. The SCR acts like a very fast self-latching power switch. The point at which it turns on during a half cycle depends on the setting of RV1, and on the back EMF of the motor. If the SCR is turned on near the end of each positive half cycle, very little power is fed to the motor; if the SCR is turned on at the start of each positive half cycle, high power is fed to the motor. The SCR turns off automatically at the end of each positive half cycle.

In the initial description of circuit operation, let's assume that SW1 is closed, and let's also ignore the presence of Q1-Q2 and their associated resistors and C2, and assume that D2 is connected directly to the gate of the SCR. In this case R1-RV1 and D1 form a half-wave voltage divider that feeds an adjustable voltage to the gate of the SCR via D2. The SCR turns on when it's gate becomes slightly positive to it's cathode, and the point at which this occurs depends on the setting of RV1 and on the back EMF, and hence speed, of the motor.

Suppose, for example, that the motor is lightly loaded, and RV1 is set so that the motor runs at half-speed under this condition. If the load is now removed the motor speed will tend to increase, thus increasing the back EMF and countering the voltage set by RV1, so that the SCR will tend to fire later in each cycle and thus reduce the speed of the motor. The reverse action occurs if the motor load is increased. In either case, a negative feedback effect occurs which tends to cause the motor to operate at a constant speed in spite of load variations.

In extreme cases, when the controller is set for very low speed operation, this negative feedback causes power to be fed to the motor in 'bursts' or 'skip cycles' of half-wave power when the motor is lightly loaded, so that the motor seems to give an erratic form of operation. Capacitor C1 is fitted to reduce this skip cycling effect and give smoother operation.

The action of the Q1-Q2-C2 network, when it is triggered, is such that the SCR has to be supplied with gate current that is derived from RV1 slider. If the SCR is a sensitive type, like the C106D, RV1 can provide this gate current without trouble, but if the SCR is a low sensitivity device, RV1 may not be able to supply adequate gate current. Q1-Q2 and C2 are used to overcome this problem.

Q1-Q2 and their associated resistors act as a voltage-sensitive switch. In each half-cycle, C2 is able to charge up via RV1 slider. As soon as the C1 voltage rises to a suitable value, Q1 and Q2 both switch on and partially discharge C1 into the gate of the SCR, thus delivering a pulse of high current to the SCR gate, quite independently of any current-drive limitations of RV1 slider. The Q1-Q2 and C2 network thus enables virtually any SCR to be used in the SCR1 position, almost irrespective of its gate sensitivity characteristics.

Note when using the drill (or any other appliance) at low speeds that it's motor will run rather hotter than usual, since the motor's cooling fan efficiency is greatly reduced at low speeds. It is wise to occasionally pause and allow the motor to cool down when using it for long periods at low speeds.

Switch SW1 is incorporated in a MK 13 amp switched socket, that screws to the left front half of the surface box.

USING THE CONTROLLER

Plug the controller into the mains, plug the drill into the controller, and switch both units on. The drill speed can be varied from zero to about 75% of full speed via RV1. Note that there may be a 'dead' zone at both the low speed and high speed ends of the control, due to different drill motor characteristics and component tolerances within the controller. This is quite normal.

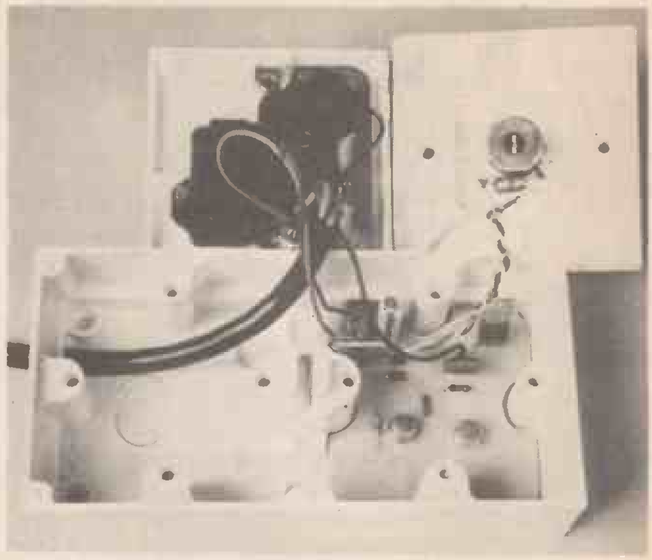
At very low speeds the drill runs rather jerkily under low load conditions, due to the 'skip cycling' method of speed regulation that is used in the design. This jerkiness decreases or disappears when the drill is loaded up.

Mounting capacitor C1 on the control potentiometer RV1.

Buylines

All electronic components in this project are readily available types. The SCR can be almost any 400 volt type with a current rating greater than 3 amps.

The MK products, such as the surface box, etc, are available from most large retailing stores and from D.I.Y. and electrical hardware shops.



Inside the HE Drill Speed Controller, use of a PCB is strongly recommended, especially when using a mains-driven project.

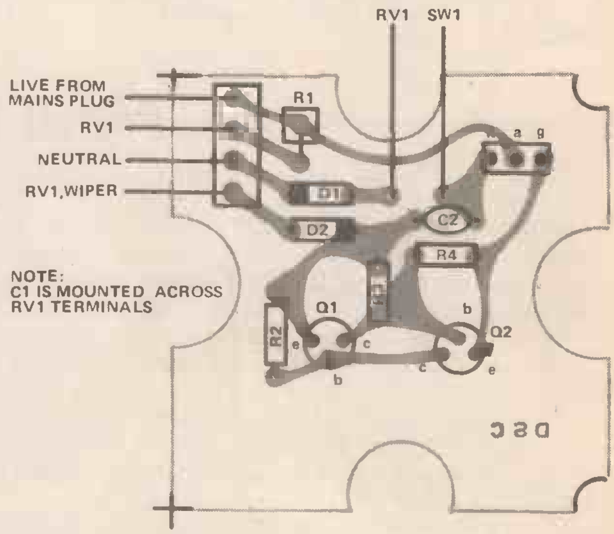


Fig 2. PCB overlay, note position of the thyristor.

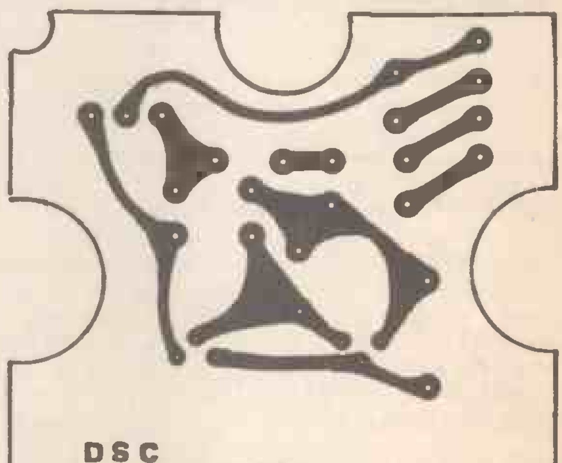


Fig 3. PCB pattern for HE Drill Speed Controller.

Hobbyprints

An easy, patented method of making PCBs for HE projects.

For some time it has been possible to buy acid resist rub-down pads and track — in fact we use them in the HE workshops and they work very well. HOBBYPRINTS take this idea a stage further — the complete PCB pattern is already on the sheet and can be rubbed down in seconds — and the patterns are nice and crisp, made from the original artwork, used for the prototype.

If you have the facilities for ultraviolet exposure, HOBBYPRINTS make excellent masters — being solid black on a translucent film. With this method you can use the HOBBYPRINTS time and time again!

HOBBYPRINTS are produced exclusively for HE, and the whole system is protected by patents 1445171 and 1445172. Each month we will be bringing out a new HOBBYPRINT, containing the patterns for each issue's projects.

HOBBYPRINT A (November HE)
5 Watt stereo amplifer, Waa-Waa pedal, Bedside radio.
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HOBBYPRINT F (April HE)
Train controller, Cistern Alarm, Transistor Tester
HOBBYPRINT G (May HE)
Parking meter timer, Digibell, Power supply, Sound effects unit

How to use HOBBYPRINTS.

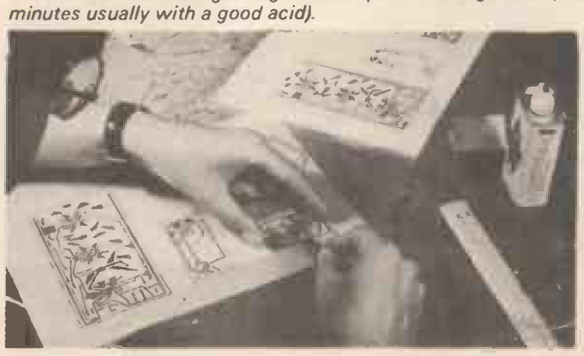
1. Clean the PCB as you would for any work giving it a rub down with fine sandpaper (we even supply this in the kit). A quick wipe over with lighter fuel will help to remove any grease marks.

2. Lay down the HOBBYPRINT and rub over with a soft pencil until the pattern is transferred to the board. Peel off the backing sheet carefully making sure that the resist has transferred. If you've been a bit careless there's even a 'repair kit' on the sheet to correct any breaks!

3. Cut the board to size and put it in the Ferric Chloride.

4. When etching is completed, wash the board and use the sandpaper or a scouring powder to remove the resist. The resist pattern is pretty hardy but is easily removed at the final stage.

5. All you've got to do now is drill the board. Time? Only about ten minutes from beginning to end plus etching time (15 minutes usually with a good acid).



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Short Circuits

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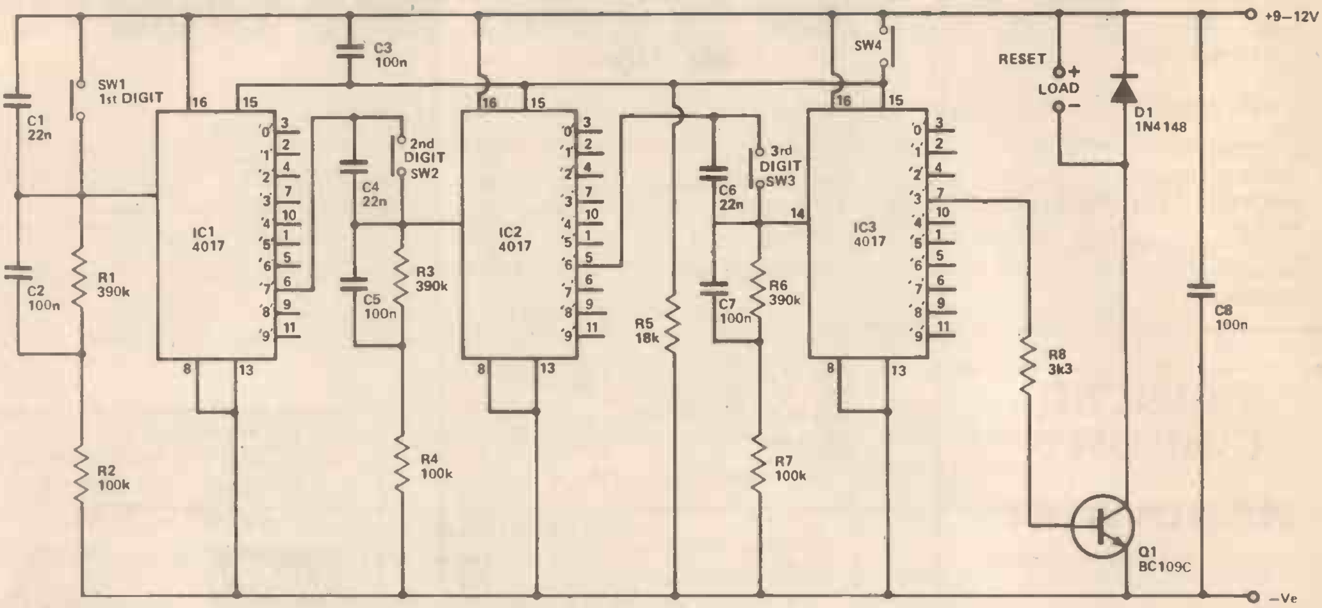
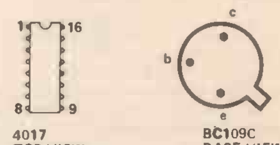




4017 TOP VIEW

BC109C BASE VIEW

This electronic combination lock can be used instead of a keyswitch as the on/off switch for a burglar alarm or other equipment, or it can be built for its novelty value. It is unusual in that it has three push button switches which are fed with the combination, the number of times each switch has to be pressed corresponding to its combination number. The switches must be operated in the correct order, and in practice they would not be arranged so that they had to be operated starting with the left hand switch and working across to the right hand one. Thus it is possible that someone knowing the correct combination number would still be unable to "crack" the unit.

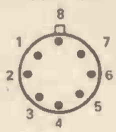
SW1 is the first switch, and a clock pulse will be fed to IC1 each time it is operated. C1, C2 and R1 are needed to prevent contact bounce from giving faulty operation (even the cheapest of push button switches will be reliable enough). IC1 is a 1 of 10 decoder, and when power is initially applied to the circuit it is reset to zero by the positive pulse generated by C3 and R5. In other words the '0' output will be high and the other nine will be low. As pulses are fed to IC1 using SW1, outputs '1', '2', '3', etc. will successively be the single output that assumes the high state.

The next stage is identical to the first, but is driven from the '7' output of IC1, and so seven pulses must be fed to IC1 before IC2 can be clocked using SW2. The third stage is fed from the '6' output of IC2, and so six pulses must be fed to IC2 using SW2 before IC3 can be clocked using SW3. After three clock pulses, IC3 output '3' will go high, switching on Q1 and applying power to the load. This can be a solenoid, a relay, or any DC load requiring 9 to 12 V. at no more than 100mA. If an error is made when entering the combination, the circuit is reset using SW4 and the combination is entered from the beginning.

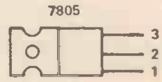
Of course, as shown the circuit has a combination of 7-6-3, but by using the appropriate outputs of ICs 1 to 3 any three digit combination can be obtained. The circuit has a standby current consumption of only about 3uA., rising to about 3mA. (plus the load current) when it is switched to the on state.

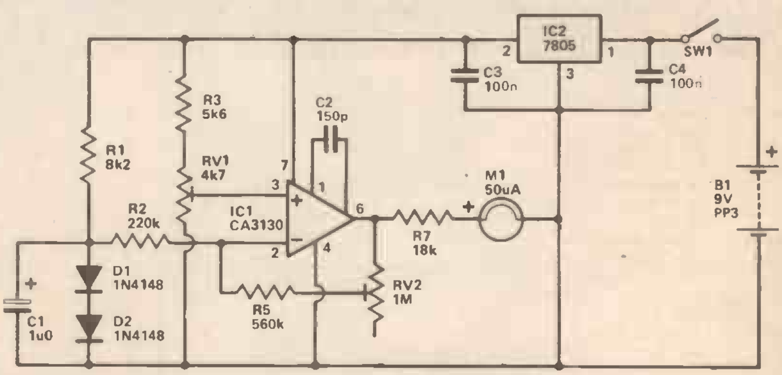
ELECTRONIC THERMOMETER

CA3130 TOP VIEW



7805





This thermometer covers a range of 0 to 50 degrees Centigrade with a linear scale so that the temperature can be read directly from the scale of the 50uA. meter. A range of 0-100 degrees Centigrade can be obtained by substituting a 100uA. meter.

The unit uses silicon diodes D1 and D2 as the temperature sensors, and these would normally be mounted in some form of probe which can be positioned many metres away from the other circuitry if necessary. C1 filters out any noise picked-up in the connecting cable. D1 and D2 are given a small forward bias by R1, and this is made only small so that there is no significant self heating of the diodes. The voltage produced across the diodes is nominally 1.2 V., but it actually varies by about 2mV. per degree C. per diode, or about 4 mV. across both diodes. This voltage is fed to the input of an op. ap. inverting amplifier which utilizes IC1. With the probe at 0 degrees C. (which can be achieved by immersing the probe in ice) R4 is adjusted for the highest voltage at IC1's non-inverting input that gives zero output voltage. This compensates for the quiescent voltage across the diodes, and gives zero reading on the 1 V. FSD voltmeter circuit which consists of R7 plus M1 and is connected across the output of the amplifier.

If the diodes are now heated to 50 degrees C., the voltage across them will fall by approximately 200 mV. (4 mV. x 50 degrees C. = 200mV.), and this is amplified by a factor of 5 by the amplifier to give about 1 V. at its output and roughly full scale deflection of the meter. In practice R6 is used to adjust the gain of the amplifier so that precisely full scale deflection is produced, and the unit functions as an accurate thermometer. Of course, R6 can be given the correct setting with the probe at any known temperature which corresponds to a reasonably substantial meter deflection, and the unit does not have to be calibrated at 50 degrees C.

The circuit requires a very stable supply of about 5 V., and this is obtained from a 9 V. battery using a 5 V. monolithic regulator (IC2). C3 and C4 should be mounted close to IC2 in order to prevent instability.

AD INDEX

SILICON DIODES (1N4148 specification). These high quality components represent remarkable value at 50 for 50p, 150 for £1, 500 for £3, 1,000 for £5. **CARBON FILM RESISTORS** (5%, ¼, ⅓W), 20 each of 30 different values plus sample 10 of above diodes for £3. Post free from D. Johnston, 12 Balgillo Road, Dundee DD5 3LU.

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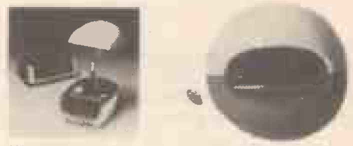

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	Stereo Amplifier	H002	3.90	43.95	BEHL
	Waa Waa Pedal	H003	.90	6.90	BEH
Oec 78	Push Button Oice	H005	1.10	5.85	BEHL
	H.E. Metronome	H006	.85	6.40	BEHL
	Photon Phone	H007	1.60	—	BEGH
	H.E. Mixer	H008	3.25	23.35	BEGHL
Jan 79	Graphic Equaliser	H009	3.25	24.55	BEGHL
	Flash Trigger	H010	1.10	13.50	BEHL
	Variwiper — Relay	H011R	.90	7.30	BEH
	Variwiper — SCR	H0115	.90	4.10	BEH
	Touch Switch	H012	1.15	4.95	BEH
Feb 79	Short Wave Radio	H013	1.40	11.95	BFH
	Sine/Square Wave Generator	H014	1.95	25.95	BEHL
	Scratch & Rumble Filter (Mono)	H015	1.45	14.40	BEHL
	Scratch & Rumble Filter (Stereo)	H015S	2.90	18.45	BEHL
	HE Car Alarm	H016	1.20	8.35	BEHL
Mar 79	Light Chaser	H017	2.00	14.25	BEH
	Casanova's Candle	H018	1.10	5.95	BEH
	Tone Control	H019	1.00	8.80	BEGHL
	Photographic Timer	H020	1.25	9.95	BEGJL
Apr 79	Model Train Controller	H021	1.40	21.95	BEHL
	Cistern Alarm	H022	.80	2.20	BEHL
	Transistor Gain Tester	H023	.75	5.25	BEGHL
May 79	PSU	H024	1.93	TBA	TBA
	Parking Meter Timer	H025	.92	TBA	TBA
	Oigibell	H026	1.35	TBA	TBA
	White Noise Generator	H027	1.67	TBA	TBA

KEY TO KIT CONTENTS

A. Vero-board(s).
B. Printed Circuit Board(s).
C. With Screen printed component layout.
D. Tag strip.
E. All Resistors, potentiometers, capacitors, semi-conductors.
F. As E but with exclusions. Please ask for details.
G. Dil and/or transistor sockets and/or soldercon pins.
H. Hardware includes switches, knobs, lamps and holders, fuses and holders, plugs and sockets, microphones, transformers, speakers, meters, relays, terminal blocks, battery connectors, etc. BUT excludes nuts, bolts, washers, connecting wire, batteries and special miscellaneous items.
J. As H but with exclusions. Please ask for details.
K. As H but including connecting wire.
L. Suitable case(s).
M. Suitable case with screen printed facia.
N. Full kit to magazine specified standards.
P. Kit with professional finish — incorporating all prime features including screen printed pcb and case where appropriate.

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Reader's Letters

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.

AIR PISTOLS

Dear Sir,

I have brought five editions of HE and have usually found something of interest in it. I made one of the Short Circuits (Power Supply with Transistor Regulation) and it works very well. The thing I like about it, is being able to adjust the voltage to precise limits.

I am not interested in Hi-Fi, Scratch Filters, Metal Locators, Train Controllers, Photo Timers and all this stuff which seem to appear in your rivals from time to time.

What I am interested in however are Air Rifles and Pistols and I would like to make an electronic chronograph to measure the muzzle velocity of a pellet as it is fired from the gun. So how about one, I've never seen such a circuit published before but they are available commercially.

E. Rawstron
Lancashire.

It's good to hear from someone who knows exactly what they want, unfortunately such a circuit is slightly out of our province, we try to aim for less specific projects. A quick word with our workshop confirmed that such a circuit would be extremely complex to build and calibrate but we're passing the idea on to our sister magazine ETI. Anyway keep on sending in your ideas, quite a few similar ideas, have, in the past resulted in actual projects.

INTO ELECTRONICS

Dear Sir.

I have only just discovered your magazine and find it very interesting, especially the article entitled 'Into Electronics' by Ian Sinclair. As I have only brought the April issue, I am wondering whether it is possible to obtain the five parts of this article which have appeared in previous issues.

G. McGowan
Huddersfield.

You must be blessed with second sight, we are trying to make some room in our back numbers department (see backnumbers ad. elsewhere in this issue) and we are bringing out an 'Into Electronics' special. Not only does it contain the whole 'Into Electronics' series but a selection of equally informative articles ranging from 'Audio Transducers' to 'Making your own PCB'. Price will be £1 and we expected it to be on sale within a couple of weeks.

SINE/SQUARE GENERATOR tipped as favourite

Dear Sir.

I assume that the output control labelling shown in the photograph is deliberate, indicating that in the stakes for the best runner in the 'Inexpensive Test Gear Handicap' the 'COURSE' control of HE Test Gear is the winner every time!

G. L. Macmillan
Bahrain (Arabian Gulf)

Glad to see you're on form, it's odds on that any mistake won't go unnoticed furlong. Now we're over that hurdle we hope we will not be saddled with any more unbridled letters of criticism over our spelling.

CAPACITORS

Dear HE

I read and enjoyed your article "Capacitors, The Inside Story", and was wondering whether you could do similar articles on Transistors, Resistors, Diodes and ICs in future editions.

Could you also include something on Oscilloscopes, Synthesizers and Microprocessors.

Jonathon Button
Littleton.

What a lovely man. Your wish is our command. 'Resistors' are scheduled for the July issue. As you will have seen Electronics in Music has been featured (May-June). As for the others they are in the pipeline but no firm date as yet.

PC BORED

Dear Sir,

I enjoy reading your magazine but there is one thing I would like to point out. This is the use of printed circuit boards in nearly all of your projects. These can be quite expensive to buy or make. Several expensive things have to be bought to make these including a small drill and etchants. So, in future it would be easier if you could use strip board for some of your projects.

C. Jackson,
North Yorkshire.

We have had quite a few letters recently on this subject. We really do believe a project looks neater, has a better chance of working and is easier to repair on a PCB but you are the bosses. In the coming issues we will feature at least one or two projects exclusively designed for Vero-Board fans.

QUARTZ LCD 5 Function

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Very slim, only 6mm thick.

M1

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M2

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M3

QUARTZ LCD ALARM 6 Function

Hours, mins., secs., month, date, back-light, 24 hour ALARM. Adjustable stainless steel bracelet. Only 9mm thick.

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M4

QUARTZ LCD ALARM 7 Function

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M5

QUARTZ LCD Alarm Chronograph with Dual Time Zone Facility

Constant LCD display of hours and minutes, plus optional seconds or date display, plus day of the week and am/pm indication. Perpetual calendar, day, date, month and year. 24 hour alarm with on/off indication. 1/10 second chronograph measuring net, lap and first and second place times. Dual time zone facility night light. Only 9mm thick.

£24.65

M6

SOLAR QUARTZ LCD Chronograph with Alarm Time Zone Facility

Constant LCD display of hours and minutes, plus optional seconds or date display, plus day of the week and am/pm indication. Perpetual calendar, day, date, month and year. 24 hour alarm with on/off indication. 1/10 second chronograph measuring net, lap and first and second place times. Dual time zone facility night light. Only 9mm thick.

£27.65

M7

QUARTZ LCD Alarm Chrono

22 function, 6 digit. Hours, mins., secs., date, day of week, stopwatch, split time, alarm, second watch (dual time), back-light. FRONT BUTTON OPERATION.

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METAC ★ PRICE

M8

SOLAR QUARTZ LCD Chronograph

6 digit, 11 function. Hours, mins., secs. 1/100, 1/10 secs., mins. Split and lap modules. Auto calendar and back light. Powered from solar panel with battery back-up.

£13.65

M9

SEIKO Alarm Chrono

LCD, hours, mins., secs., day of week, month, day and date, 24 hour Alarm, 12 hour chronograph, 1/10th secs., and lap time. Back light, stainless steel, HARDLEX glass.

List Price £130.00

METAC PRICE

£105.00

M10

SEIKO Chronograph

LCD, hours, mins., secs., day of week, month, day, date, 12 hour chronograph, 1/10th secs. and lap-time. Back light, stainless steel water resistant, HARDLEX glass.

List Price £85.00

METAC PRICE

£68.00

M11

SOLAR QUARTZ LCD 5 Function

Genuine Solar

Solar panel with battery back-up. Back light and auto calendar. Hours, mins., secs., day, date. Quality metal bracelet.

£ 9.95

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M12

HANIMEX Electronic LED Alarm Clock

Features and Specification: Hour/minute display. Large LED display with p.m. and alarm on indicator. 24 Hours alarm with on/off control. Display flashing for power loss indication. Repeatable 9-minute snooze. Display bright dim modes control. Size: 5.15" x 3.93" x 2.36" (131mm x 11mm x 60mm). Weight: 1.43 lbs (0.65 kg).

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M13

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M14

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M15

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M16

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