Practical Electronics

OCTOBER 1966

PRICE 2/6

FREE inside!

"PRINTED WIRING" BOARD

with details of 6 Interesting Projects to build


ADCOLA

Transistorised
FM Tuner

HIGH QUALITY: LOW NOISE: BATTERY OR MAINS OPERATION

Reproduction stands favourable comparison with tuners costing 3 times as much. Come and hear it (and compare it) at any of our branches or send to Brighton without delay as we anticipate a very heavy demand.

This beautifully compact 6 transistor machine (size 6in. x 4in. x 2¼in.) will give quieter, more interference-free reception. Months of use from a standard 9 volt battery or its small power requirements can be drawn from any amplifier. Low noise frequency changer with smooth 2 gang tuning feeding no less than three I.F. stages coupled to a double-tuned discriminator terminating in an L.F. stage giving ample output for all quality amplifiers.

Note audio amplifiers of very interesting specification in the course of preparation.

15 WATT TUNER AMPLIFIER KIT
consisting of FMT41 tuner and the excellent Sinclair Z.12 (built) together with complete integrated control kit consisting complete vol. on/off, treble and bass, component sets with complete connecting instructions and circuits.

£13.19.0 or complete with AC mains power pack £17.18.6. Complete control kit only with circuits 25/-.

avoid disappointment

ORDER NOW £8-10

VALUE IN VALVES

GUARANTEED 3 MONTHS BY RETURN OF POST

Satisfaction or Money Back Guarantee on goods if returned unused within 14 days. ALL VALVES ARE NEW UNLESS OTHERWISE INFORMED. FREE TRANSIT INSURANCE. POSTAGE 1 valve 9d., 2-11 6d. per valve. Free over 12.

1L4	2/3	6L6G	7/-	30F5	8/3	ECF80	7/6	KT61	11/-	TDD4	7/-
1R5	4/9	6L18	7/9	30FL1	9/6	ECF82	7/6	KT63	5/9	U18	7/6
1S4	4/9	6LD20	8/6	30L15	9/6	ECH21	10/-	KT66	14/-	U22	6/9
1S5	4/6	6P25	11/-	30P4	9/6	ECH35	11/-	KT88	21/-	U25	8/6
1T4	3/-	6P28	9/-	30P12	7/-	ECH42	8/6	KTW61	5/9	U26	8/9
2D21	5/6	6Q7G	5/6	30PL1	9/3	ECH81	6/9	KTW63	5/-	U35	12/6
3A5	6/-	6Q7GT	8/9	35C5	8/6	ECH83	7/3	KTZ63	7/-	U37	11/-
3Q4	5/3	6SL7GT	5/6	35L6GT	8/-	ECL80	5/9	MU14	7/-	U107	12/6
5U4G	4/6	6SN7GT	4/6	35W4	6/-	ECL82	7/6	N37	9/6	U191	9/6
5Y3GT	4/9	6U4GT	9/6	35Z4GT	5/6	ECL83	9/6	N78	13/-	U281	8/6
5Z4G	6/9	6V6G	4/6	50L6GT	8/6	ECL86	9/6	N108	13/-	U282	15/-
5Z4GT	9/6	6V6GT	5/9	80	5/-	EF36	3/3	PC86	10/-	U329	8/6
6/30L2	8/9	6X4	4/6	185BTA	19/6	EF39	5/-	PC97	7/6	U801	19/-
6A8G	7/9	6X5G	5/-	807	8/-	EF40	10/-	PCC84	6/6	UABC80	6/6
6AK5	4/9	6X5GT	6/-	955	2/6	EF41	8/-	PCC85	7/6	UAF42	7/9
6AQ5	5/-	7B6	9/6	958	2/-	EF50	3/3	PCC88	11/9	UB41	6/6
6AT6	5/-	7B7	6/6	AZ31	7/9	EF80	4/3	PCC89	9/9	UBC41	7/6
6BA6	5/6	7C5	7/9	CBL31	19/-	EF85	6/-	PCC189	11/-	UBC81	6/3
6BE6	5/6	7C6	6/9	CL33	9/-	EF86	7/6	PCF80	6/9	UBF80	7/6
6BH6	5/-	7H7	5/-	CY31	7/6	EF89	6/6	PCF82	6/-	UBF89	7/6
6BJ6	6/-	7S7	14/6	DAF96	7/3	EF91	3/-	PCF86	8/3	UBL21	9/9
6BR7	8/6	7Y4	5/-	DF92	3/-	EF92	3/-	PCL82	7/9	UC92	6/9
6BW6	7/6	10C1	11/-	DF96	7/3	EF183	8/-	PCL83	8/9	UCC85	7/3
6BW7	5/-	10C2	12/6	DK92	7/-	EF184	8/-	PCL84	8/3	UCF80	8/6
6C4	2/3	10F1	7/6	DK96	7/3	EL32	3/9	PCL85	8/6	UCH21	9/3
6C5	5/6	10LD11	14/6	DL92	5/-	EL33	11/-	PCL86	9/6	UCH42	8/6
6C6	4/-	10P13	8/6	DL94	6/6	EL34	11/-	PL33	8/6	UCH81	7/-
6C9	11/-	10P14	9/6	DL96	7/3	EL35	6/-	PL36	8/9	UCL82	8/-
6CD6G	17/-	12AT7	4/9	EABC80	6/6	EL38	15/-	PL38	12/6	UCL83	10/-
6D6	3/-	12AU7	4/9	EAF42	7/6	EL41	8/6	PL81	7/9	UF41	7/9
6F1	6/6	12AX7	6/-	EB41	4/-	EL42	8/6	PL82	5/9	UF42	6/9
6F6G	4/-	12J7GT	8/-	EB91	2/-	EL84	6/6	PL83	6/-	UF85	7/6
6F13	4/6	12K7GT	4/-	EBC33	6/-	EM80	7/-	PL84	7/-	UF89	5/9
6F14	5/-	12K8GT	9/6	EBC41	6/6	EM81	7/3	PY31	7/6	UL41	8/6
6F15	9/6	12Q7GT	5/-	EBC81	6/6	EM84	7/9	PY32	9/-	UL44	14/-
6F23	8/6	14S7	14/6	EBF80	7/6	EY51	7/6	PY33	9/-	UL46	8/3
6J5GT	4/6	19AQ5	5/-	EBF89	7/-	EY86	7/3	PY80	5/9	UL84	6/9
6J6	3/3	20D1	8/9	EBL21	10/6	EY88	8/6	PY81	5/9	UM80	9/6
6J7G	4/9	20F2	9/6	ECC40	8/9	EZ40	6/6	PY82	5/6	UY21	8/9
6J7GT	7/9	20L1	16/-	ECC81	4/9	EZ41	6/6	PY83	5/9	UY41	6/-
6K7G	1/6	20P1	9/6	ECC82	4/9	EZ80	5/6	PY88	8/6	UY85	5/6
6K7GT	4/9	20P3	9/6	ECC83	5/9	EZ81	6/-	PY800	6/6	VR105	5/-
6K8G	3/-	20P4	17/-	ECC84	7/-	FC4	8/-	PZ30	9/6	VR150	5/-
6K8GT	8/-	25L6GT	7/9	ECC85	5/6	GZ32	9/6	SP61	2/-	X66	7/9
6L1	9/6	25Z4G	6/6	ECC88	9/-	GZ34	10/6	T41	6/9		

100 HI-STABS 1% to 5% 100Ω to 5mΩ 9/6

CO-AX. low loss, 6d. yd., 25 yds. 11/6; 50 yds. 22/-; 100 yds. 42/6. Plugs, 1/3.

100 RESISTORS SIZES ½-3 watt 6/6

MICROPHONE CABLE. Highest quality black, grey, white, 9d. per yard.

100 CONDENSERS 9/6

Miniature Ceramic, Silver Mica, etc. 3pF to .1μF. LIST VALUE OVER £5.

BARGAIN PARCELS

Enormous demand of our 7 lb. Parcels has prompted us to offer a wider range which will include such items as far and weight allows—including variable condensers, i.f. coils, loudspeaker plugs/sockets, knobs, pots, condensers, resistors, nuts, bolts, cabinet fittings, switches, transformer choke, rectifier, transistors.

TRY ONE!

3 lb.	PARCEL (Carr. 3/-)	8/6
7 lb.	PARCEL (Carr. 5/-)	17/6
14 lb.	PARCEL (Carr. 5/6)	29/-

LOUDSPEAKERS. 3Ω Top Makes.
6½in. **7/6** 5in. 7 x 4in. **8/6**

HITACHI PORTABLE TAPE RECORDER

STOCKS GOING FAST! Latest Hitachi. Fabulous quality reproduction of music, 6-transistor, 1⅞in. and 3¾in. speeds. Output 500 mW high quality speaker. Fast forward and rewind. Battery level and record level meter. Precision capstan drive. Size 8$\frac{3}{16}$ x 3⅞ x 6¾in. Genuine normal price of 35 gns. Unrepeatable. All spares available. With tape, tape reel, mike, etc. **19 Gns.**

CAR RADIOS

Latest Autolux fully transistorised complete with speaker and fittings. Large purchase enables us to sell these superb sets (normally approx. 14 gns.) at the amazing price of **8 Gns.**

RADIOGRAM CHASSIS

QUALITY BARGAINS

Heavy duty A.C. mains, complete with large dials.

Stereo AM, 6 valve, all wave (normally 17 gns.).	11 Gns.
Mono AM/FM, 6 valve (normally 18 gns.).	12 Gns.
Stereo AM/FM, 7 valve (normally 23 gns.).	17 Gns.

HALF PRICE STEREOGRAMS

Large purchase well known portable Record Players with ingenious Split Cabinet giving two separate high quality loudspeakers, plus main unit with Garrard Deck and crystal clear amplifiers. Compact, powerful, amazing value. Autochanger Model complete Diamond Cartridge normally 39 gns., 19 gns. Non-Autochange model with SRP72 Deck, normally 29 gns., 14 gns. S.A.E. full description.

ENORMOUS PURCHASE. GUARANTEED. APPROX. HALF PRICE. WORLD FAMOUS MAKE

★ TAPE ★

We offer you fully tensilised polyester/mylar and P.V.C. tapes of identical quality hi-fi, wide range recording characteristics as top grade tapes. Quality control manufacture. They are truly worth a few more coppers than acetate, sub-standard, jointed or cheap imports. TRY ONE AND PROVE IT YOURSELF.

Standard Play			Double Play		
3in.	150ft.	2/3	3in.	300ft.	4/-
4in.	300ft.	4/6	4in.	600ft.	8/-
5in.	600ft.	7/6	5in.	1,200ft.	15/-
5¾in.	900ft.	10/6	5¾in.	1,800ft.	19/6
7in.	1,200ft.	12/6	7in.	2,400ft.	27/-

Long Play			Triple Play		
3in.	225ft.	2/9	4in.	900ft.	13/-
4in.	450ft.	5/6	5in.	1,800ft.	25/-
5in.	900ft.	10/6	5¾in.	2,400ft.	34/-
5¾in.	1,200ft.	13/-	7in.	3,600ft.	44/-
7in.	1,800ft.	18/6			

Quadruple Play
3ft. 600ft. 8/-

Postage 1/- reel
Post Free less 5% on three reels. Quantity and Trade enquiries invited.

ELPICO MONO PREAMPS

DPA15. Latest black/satin chrome finish multiple input channels selector, base and treble controls. Matches all pickups and mikes. Provision tape recording. Normally 10 gns. our price **5 Gns.**

TRANSISTORS

GUARANTEED TOP QUALITY

Mullard Matched Output Kits OC81D and 2-OC81	9/6
R.F. Kits OC44, OC45 (2) 3 transistors	9/6

GERMANIUM DIODES

General Purpose miniature detector A.V.C. etc. 6/6 doz.	8d.
Gold Bonded highest quality Individually tested 9/6 doz.	1/-

SILICON RECTIFIERS

Guaranteed performance. Top makes. Tested 250v. working.

120 ma. (3 for 6/6)	2/9	500 ma. (3 for 19/6)	7/6

LATEST GARRARD

Stereo cartridge fitted for 17/6 extra.

SRP12	£4. 6. 0
SP25	£9.19.0
AT5	£7.13.0
Model 1,000	£6. 5.0
Model 2,000	£7.19.0
Model 3,000	£8.19.0
AT60	£10.10.0
A70	£19.10.0
LAB80	£24.17.6
401	£29.19.0

All Factory Fresh. All with cartridge.

B.S.R.

TU14	59/-
GU17	£4. 5.0
UA14	89/-
UA16	99/-
UA25SS	£5.10.0

NEW *BRANCH WITH HUGE STOCKS*

★ 132 MONTAGUE
(Tel. 2585)

WORTHING

(Late Crays of Worthing Ltd.)

Old and New Customers Welcomed—Hi-Fi Dem. Rooms

Stockists of Leak, Quad. Chapman, Goodman, Armstrong, Tripletone, Linear Rogers, Truvox, Ferrograph, Wharfedale, etc., etc.

TECHNICAL TRADING

Post: 1lb. 1/6, 1½lb. 2/6, 2lb. 2/9, 4lb. 3/3, 6lb. 4/-, 14lb. 5/6
All Mail Orders: **to BRIGHTON Please**

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★ **BRIGHTON** Park Crescent Place Tel. 680722
★ **PORTSMOUTH** 350-352 Fratton Road. Tel. 22034
★ **SOUTHAMPTON** 72 East Street Tel. 25851

All Branches—E.C. Weds.

FULLY GUARANTEED INDIVIDUALLY PACKED

VALVES

AC/HL	4/6
ACP4	6/-
AC6PEN	5/-
AL60	5/-
AR8	5/-
ARP3	3/-
ARP12	2/6
ARP24	10/-
ATP4	2/3
ATP7	5/6
AU7	55/-
AZ31	9/-
B6H	15/-
BD78	40/-
BL63	10/-
BS4	8/-
BS5	20/-
BS84	47/6
B2134	16/-
CC3L	2/-
CF23	10/6
CL33	9/-
CY31	6/6
D1	1/6
D41	3/3
D61	6/-
D77	3/3
DA30	12/6
DAF96	6/-
DD41	4/-
DF73	5/-
DF91	3/-
DF92	3/-
DF96	6/-
DH63	5/-
DK96	5/6
DL92	4/-
DL93	4/-
DL94	5/9
DL96	7/-
DL810	8/-
DY86	7/6
E80F	23/-
E88CC	12/-
E90CC	10/-
EA50	1/-
EA73	7/-
EABC80	5/9
EAC91	3/6
EAF42	8/-
EB34	1/6
EB91	3/-
EBC33	6/-
EBC41	8/6
EBC80	5/-
EBF80	6/6
EBF83	7/6
EBF89	6/9
EBL31	20/-
EC52	4/-
EC53	12/6
EC70	4/-
EC90	2/-
EC91	3/-
ECC81	4/-
ECC82	5/-
ECC83	6/-
ECC84	5/6
ECC85	6/6
ECC91	4/-
ECC189	9/6
ECF82	7/-
ECH42	9/-
ECH81	5/-
ECH83	7/6
ECL80	6/-
ECL82	7/6
ECL83	10/-
ECL86	9/-
EF36	3/6
EF37A	7/-
EF40	8/-
EF41	6/-
EF50	2/6
EF52	6/-
EF53	4/6
EF55	8/-
EF71	7/6
EF72	5/-
EF73	5/-
EF74	4/-
EF80	5/-
EF85	4/6
EF86	6/6
EF89	5/-
EF91	3/6
EF92	2/-
EF95	5/-
EF95	5/-
EF183	8/-
EF184	8/-
EH90	7/6
EL32	3/9
EL34	10/-
EL35	5/-
EL37	16/-
EL36	17/6
EL41	9/-
EL42	8/-
EL50	8/-
EL81	8/-
EL83	6/3
EL84	5/-
EL85	8/-
EL91	4/6
EL95	5/-
EM80	6/-
EM81	7/6
EM84	6/3
EN31	10/-
ESU74	80/-
ESU208	6/-
EY51	5/6
EY86	6/6
EY91	3/-
EZ40	6/6
EZ41	6/6
EZ80	5/6
EZ81	4/6
F/6057	5/-
F/6061	5/-
F/6063	4/-
FW4/500	6/6
FW4800	8/6
G1/236G	9/-
G50/2G	5/-
GM4	45/-
GZ32	10/-
GZ34	10/-
HK54	22/6
HL2K	2/6
HL23	6/-
HL23DD	5/-
HL41	4/-
HVR2	9/-
K3A	30/-
KT32	8/-
KT33C	6/-
KT44	5/9
KT63	4/-
KT66	16/-
KT67	15/-
KT76	8/6
KT88	22/-
KTW61	4/6
KTW63	2/-
KTZ41	6/-
KTZ63	5 -
MH4	5/-
ML6	6/-
N78	15/-
NE17	7/-
OA2	5/9
OB2	6/-
OB3	7/-
OC3	5/-
OD3	5/-
OZ4A	5/-
PC86	9/-
PC88	9/-
PC97	9/6
PC900	12/-
PCC84	6/-
PCC89	10/-
PCF80	7/-
PCF82	6/6
PCF84	6/-
PCF86	8/-
PCF802	11/-
PCF805	11/-
PCL81	9/-
PCL82	7/-
PCL83	8/6
PCL84	7/-
PCL85	8/6
PCL86	8/-
PEN25	4/6
PEN46	2/-
PFL200	17/6
PL36	9/-
PL38	16/-
PL81	7/-
PL82	6/6
PL83	6/-
PL84	6/6
PL500	15/-
PM24A	5/-
PT15	10/-
PT25H	7/6
PT25M	7/6
PX4	14/-
PX25	9/-
PY33	9/6
PY80	5/6
PY81	5/6
PY82	5/6
PY83	6/-
PY800	8/-
PZ1-35	9/-
PZ1-75	12/-
QP21	6/-
QP25	5/-
QP230	5/-
Q895/10	5/6
QS1202	8/-
QV04/7	8/-
R10	9/-
R8	8/-
RK72	6/-
S11E12	10/-
S130P	15/-
S130	12/6
SP2	8/6
SP41	1/6
SP61	1/6
SP210	3/6
T41	10/-
TP22	5/-
TP25	15/-
TT11	5/-
TT15	35/-
TTR31	45/-
TZ20	16/-
U81	8/-
U12/14	8/-
U17	5/-
UCL82	8/-
UCL83	9/-
UF41	8/6
UF89	6/-
UL41	7/6
UL84	5/6
UU5	7/-
UU9	8/6
UY21	7/6
UY85	5/-
VP23	3/-
VP133	9/-
VR99	5/-
VR105/30	5/-
VR150/30	5/-
1A5GT	5/-
1B22	30/-
IC5GT	6/-
ID8GT	6/-
1E7G	7/6
IF2	3/-
1G6GT	6/-
1L4	2/6
1LA6	6/-
1LC6	7/-
1LH4	4/-
1N21B	5/-
1N43	4/-
1N70	4/-
1R4	5/-
1R5	3/6
1S4	5/-
3Q4	6/-
3Q5GT	7/6
3S4	4/-
3V4	5/9
4C27	35/-
4D1	4/-
5A173G	5/-
5A174G	5/-
5B/251M	40/-
5B/253M	15/-
5B/254M	40/-
5B/255M	35/-

TRANSISTORS

OC16	20/-
OC22	23/-
OC25	12/-
OC35	12/6
OC44	6/-
OC45	5/-
OC71	4/6
OC72	6/-
OC73	10/-
OC81	5/-
OC81D	5/-
OC81M	7/-
OC82	10/-
OC82DM	6/-
OC83	6/-
OC83B	5/-
OC122	16/-
OC170	6/-
OC200	10/6
OC201	12/6
OC202	15/-
OC203	12/6
OC204	17/6
OC206	22/6
AAZ12	6/-
AC126	7/6
BCZ11	7/6
BY38	7/6
XC141	10/-
XC142	15/-
XC155	20/-
XC156	22/6
2N247	9/6
2N412	7/6
2N502	47/-
2N585	10/6
2N1090	20/6
2N1091	29/-

U18	6/-
U25	11/-
U26	11/-
U27	8/-
U50	4/6
U52	4/6
U191	11/6
U801	17/-
UABC80	6/-
UAF42	9/-
UBC41	6/-
UBF80	5/6
UBF89	6/6
UBL21	10/-
UCC85	6/6
UCH42	8/-
UCH81	6/-
VU33A	4/-
VU39	6/-
VX3208	5/-
W21	5/-
W118	8/-
W119	8/-
X66	7/6
X81M	18/-
X118	8/-
X145	8/-
YF	1/-
Y63	5/-
Y65	4/-
Y66	8/-
Z800U	20/-
Z801U	10/-
1A3	3/-
1S5	4/6
1T4	3/-
2A3	5/-
2B26	8/-
2C26	7/-
2C26A	3/-
2C34	2/6
2C45	22/6
2C46	30/-
2C51	12/-
2D21	5/-
2X2	3/-
3A4	4/-
3B7	6/-
3B24	5/-
3D6	4/-
3E29	50/-
5R4GY	9/-
5TR	7/-
5U4G	4/6
5V4G	6/-
5X4G	8/6
5Y3G	4/6
5Y3GT	5/-
5Y3WGTB	9/-
5Z4G	6/6
5Z4GT	8/-
6AB7	4/-
6AC7	2/-
6AG5	2/6
6AG7	6/-
6AH6	10/-
6AJ7	3/-
6AK5	5/-
6AK6	6/-
6AK7	6/-
6AL5	3/-
6AL5W	7/-
6AM5	2/6
6AM6	4/-
6AQ5	7/-
6AQ5W	9/-
6AS6	4/-
6AS6W	9/-
6AS7G	20/-
6AT6	4/-
6AU6	7/-
6AX4	8/-
6B4G	16/-
6B7	6/-
6B8G	2/6
6BA6	5/-
6BA7	5/-
6BE6	6/-
6BJ6	7/6
6BJ7	7/-
6BR7	9/-
6BW6	8/-
6C4	2/-
6C5G	2/6
6C5GT	4/-
6C6	4/-
6C6G	3/-
6C8G	3/-
6CH6	4/6
6CL6	9/-
6CW4	12/-
6D6	3/-
6E5	6/-
6F5G	5/3
6F5GT	5/9
6F6G	4/-
6F7	6/-
6F17	5/-
6F8G	6/6
6F12	4/6
6F13	5/-
6F32	4/-
6F33	3/-
6G6G	2/6
6H6M	1/6
6J4WA	10/-
6J5	6/-
6J5G	2/-
6J6	3/6
6J6W	6/-
6J7G	5/-
6J7M	8/-
6K6GT	5/6
6K7G	2/-
6K7GT	4/9
6K8G	3/-
6K8GT	8/3
6K8M	8/6
6L6G	6/-
6L6GA	7/6
6L7G	4/-
6L34	4/6
6LD20	5/9
6N7	6/-
6N7G	5/9
6P25	12/6
6Q7G	5/-
6R7	5/6
6SA7	7/-
6SA7GT	6/6
6SK7GT	4/-
6SC7	7/-
6SC7GT	5/-
6SF5GT	5/6
6SH7	3/-
6SJ7	5/-
6SJ7GT	5/6
6SJ7Y	6/6
6SK7	4/6
6SL7GT	5/6
6SN7	3/6
6SQ7GT	6/-
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A stereo pre-amp/control unit to ensure high fidelity at its best with a saving of pounds

Sinclair's newest unit, the Stereo 25 has been designed specially to obtain the very finest results used in conjunction with two Sinclair Z.12's for stereo reproduction. The best quality components, individually tested before acceptance, are used in its construction, ganged controls are carefully checked for matching, whilst the overall appearance of this very compact de-luxe pre-amp control unit reflects the professional elegance which characterises all Sinclair designs. The front panel is in solid brushed and polished aluminium with beautifully styled solid aluminium knobs. Mounting and connecting the unit is simple, and the generous output of the PZ.3 is more than enough to power the Stereo 25 together with two Z.12's for stereo. Hj-fi enthusiasts seeking the ultimate in equipment for domestic listening will find all they want from this combination of Sinclair units, and with a Micro FM to provide the radio, their installation will compare favourably with anything costing up to FOUR TIMES as much.

THE STEREO 25 MAY BE USED WITH ANY STEREO HI-FI POWER AMPLIFIER

■ Technical Specification

Performance figures were obtained using the Sinclair Stereo 25 fed to two Z.12's and the entire assembly powered by a PZ.3 Power Supply Unit.

■ **SENSITIVITY** for 10 watts into 1.5 ohms load per channel
Mic.—2 mV into 50 K ohms
Pick-up—3 mV into 50 K ohms
Radio—20 mV into 4.7 K ohms

■ **FREQUENCY RESPONSE** (Mic. and Radio)—25 c/s to 30 kc/s ± 1dB extending to 100 kc/s ±3dB

■ **EQUALISATION FOR P.U.** Correct to within ± 1dB on RIAA curve from 50 c/s to 20 kc/s.

■ **TONE CONTROLS**
Treble +12dB to —10dB at 10 kc/s
Bass +15dB to —12dB at 100 c/s

SIZE—6½ × 2¼ × 2½ ins. overall, plus knobs.
FINISH—Front panel in brushed and polished solid aluminium with solid aluminium knobs. Black figuring on front panel.

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A COMPLETE HIGH FIDELITY STEREO ASSEMBLY FOR £22.18.0

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SINCLAIR STEREO 25

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"Congratulations on your F.M. set. You certainly are the leaders in miniature electronics."
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"The Micro-6 is tremendous and all 7 local stations here in Melbourne are easy to tune. I wish to congratulate you on your excellent design."
L.M.C., Bentleigh, Victoria.

"I've found your Micro-6 excellent. The volume is more than adequate, with fantastic tone."
S.M., Box Hill, Victoria.

JAMAICA

"The reception and sound is superb (Micro-6), and I found the instructions very clear."
R.R., Kingstown.

NEW ZEALAND

"I have received your Z.12 amplifier. I am extremely pleased with its performance, and it is well worth the cost. Thank you for your prompt delivery."
B.R.L., Howick, Auckland.

SWAZILAND

"May I congratulate you on the Micro F.M. The performance of this tiny radio has amazed friends who just cannot believe it works until demonstrated. I am roughly thirty miles from the station in mountainous terrain, and without any extra aerial a good signal is produced."
D.J.B., Mhlambanyat.

SOUTH AFRICA

"Much to my delight, the tuner (Micro F.M.) performs splendidly, fully justifying the modest outlay called for. The tuner picks up all the F.M. programmes. I am now anxious to purchase two Z.12 amplifiers."
P.E.R., Florida, Transvaal.

U.K.

"I am extremely pleased with the Z.12 amp. (connected to the tape head). The firm of Sinclair will always rate highly in my esteem."
B.C., Glasgow.

"The finish and general quality is very good (Micro 6). It is fantastic that a transistor radio can be so compact."
N.R.C., Bishop's Stortford.

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START BUILDING WITH SINCLAIR TODAY

TWO SETS THAT HAVE CHANGED THE FACE OF RADIO

MICRO FM

7 TRANSISTOR SUPERHET F.M.

The world's only combined pocket-sized F.M. Tuner and personal receiver

WITH BRUSHED AND POLISHED ALUMINIUM FRONT PANEL AND SOLID ALUMINIUM TUNING CONTROL

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Technical Specification

THE SINCLAIR MICRO FM is a completely self-contained double-purpose F.M. superhet. It uses 7 transistors and 2 diodes. The R.F. amplifier is followed by a self-oscillating mixer and three stages of I.F. amplification which dispense with I.F. transformers and all problems of alignment. The final I.F. amplifier produces a square wave which is converted so that the original modulation is reproduced exactly. A pulse-counting discriminator ensures better audio quality. One output is for feeding to amplifier or recorder and the other enables the Micro F.M. to be used as an independent self-contained pocket portable. A.F.C. "locks" the programme tuned in. The telescopic aerial included is sufficient in all but the worst signal areas. Case size—$2\frac{13}{16} \times 1\frac{11}{16} \times \frac{3}{4}$ in. plus aerial.

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- **AMAZING POWER, RANGE AND SELECTIVITY**

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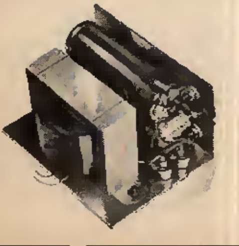

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STEREO 25 de luxe pre-amp and control unit See page 683

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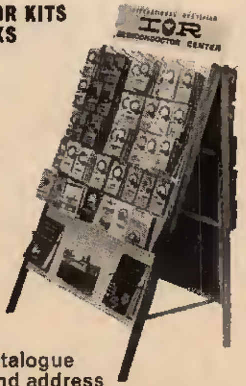

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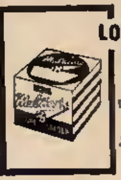

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The unit forms the drive system of the 'Minette' enclosure for details see separate leaflet.

Patents applied for.

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Latest models now available from stock—for use with the Magnavox 363 Tape Deck

½ track model .... LASKY'S PRICE £14.19.6

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Carriage and Packing 4/6 extra

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SPECIAL INTEREST ITEMS!

SPECIAL PURCHASE—UHF/VHF T.V. TUNERS

Well known British makers' surplus stocks. Now available for the first time to the Home Constructor.

TRANSISTORISED UHF MINIATURE MODEL
Shielded metal case only 3½ × 1½ × 3in. Fully tunable—complete with two AF 139 transistors. LASKY'S PRICE 39/6

VALVE UHF MODEL *(illustrated)*
In metal case size 4 × 6 × 1½in. Fully tunable—complete with PC86 and PC88 valves. LASKY'S PRICE 29/6. Without valves 12/6

TRANSISTORISED VHF MODEL 1
Miniature turret type fitted with 12 sets of coils and 3 Mullard AF102 transistors. In metal case size 4 × 2 × 3½in. LASKY'S PRICE 29/6

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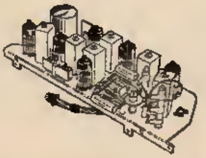
Sub-miniature turret type fitted with 12 sets of coils and 3 Mullard AF102 transistors In metal case size 3 × 1½ × 2½in. LASKY'S PRICE 37/6

Add 2/6 Post and Packing on each.

MAKERS' SURPLUS TELEVISION IF AMPLIFIERS



38 Mc/s. Contains a large number of components, IF transformers, resistors, capacitors, etc., and the following valves: 2xPCF80, 1xEB91, EF80, EF183 and EF184. Overall size 11½" × 3½" × 4" deep. Ideal for servicemen and experimenters. This IF amp. when used with the Valve model UHF Tuner (above) provides a suitable conversion for B.B.C.2. No circuit available.

LASKY'S PRICE **39/6** Post 2/6

GORLER UT 340 FM/VHF TUNING HEART

Permeability tuned — covering 87 to 108 Mc/s. For use with one ECC85 valve. In metal case, size 3 × 2½ × 1¼in. Circuit supplied
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THE MICRO-6 miniature radio only 1⅘ × 1 3/10 × 1½in.	£2 19 6
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CONSTRUCTORS BARGAINS

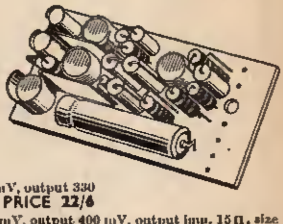
The "Sixteen" Multirange METER KIT

This outstanding meter was featured by *Practical Wireless* in the Jan. '64 issue. Lasky's are able to offer the complete kit of parts as specified by the designer.
RANGE SPECIFICATION: D.C. volts: 0-2.5-25-50-250-500 at 20,000Ω/V. A.C. volts: 0-25-50-250-500 at 1,000Ω/V. D.C.current: 0-50μA, 0-2.5-50-250mA. Resistance: 0-2,000Ω, 0-200kΩ, 0-20 MΩ. Basic movement: 40μA f.s.d. moving coil. With universal shunt full scale deflection current is 50μA. Black plastic case—3¾ × 5¾ × 1⅞in. Controls: 12 position range switch; separate slide switch for A.C. volts—D.C. ohms; ohms zero adjustment pot, meter, meter zero. Power requirements: One 15v. and one 1.5v. batts. Complete with all parts and full construction details. H.P. Terms available.

LASKY'S PRICE **£5.19.6.** P. & P. 5/-

Data and circuit available separately, 2/6; refunded if all parts bought. Pair of batteries 2/- extra.

NEW—LASKY'S MINIATURE TRANSISTOR AMPLIFIER MODULES



Incorporating the very latest circuitry to provide high sensitivity and good quality in conjunction with extreme small size and compactness. High quality Newmarket transistors used throughout. All designed to operate on 9v. miniature battery. **Add 1/-on each for post & packing**

TYPE LRPC 1. 3 transistor. Input sens. 50 mV., output 150 mW, output imp. 40Ω, size 2 × 1 × ¾in....... PRICE 27/6

TYPE LRPC 2. 5 transistor. Input sens. 1mV, output 330 mW, output imp. 15Ω, size 2¼ × 1¼ × ¾in.... PRICE 22/6

TYPE LRPC 3. 5 transistor. Input sens. 5 mV, output 400 mV, output imp. 15Ω, size 2¼ × 1¼ × ¾in. .... PRICE 25/-

TYPE LRPC 4. 5 transistor. Input sens. 150 mV, output 330 mV, output imp. 15Ω, size 2¼ × 1¼ × ¾in. .... PRICE 22/6

TYPE LRPC 5. 6 transistor. Input sens. 8mV, output 3W, output imp. 3Ω, size 5¼ × 1¾ × 1in. .... PRICE 59/6

TYPE LRPC 7. 6 transistor. Input sens. 8mV, output 1W, output imp. 8Ω, size 3 × 1¾ × ¾in. .... PRICE 39/6

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Many other Garrard models available, ask for Lists.

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10W POWER AMP. MA-12

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Oxford

UXR-1

GC-1U

"OXFORD" LUXURY PORTABLE Model UXR-2. Specially designed for use as a domestic or personal portable receiver. Many features, including solid leather case. Kit **£14.18.0** incl. P.T.

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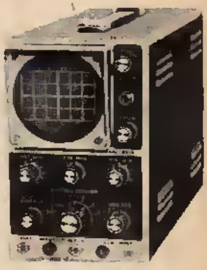

OS-2

3" LOW-PRICED SERVICE OSCILLOSCOPE. Model OS-2. Compact size 5" × 7⅜" × 12" deep. Wt. only 9¾lb. "Y" bandwidth 2 c/s–3 Mc/s ±3dB. Sensitivity 100mV/cm T/B 20 c/s–200 kc/s in four ranges, fitted mu-metal CRT Shield. Modern functional styling. Kit **£23.18.0** Assembled **£31.18.0**

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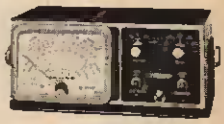

VVM, IM-13U

DE LUXE LARGE-SCALE VALVE VOLTMETER. Model IM-13U. Circuit and specification based on the well-known model V-7A but with many worth-while refinements. 6" Ernest Turner meter. Unique gimbal bracket allows operation of instrument in many positions. Modern styling. Kit **£18.18.0** Assembled **£26.18.0**

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AM/FM TUNER

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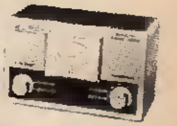
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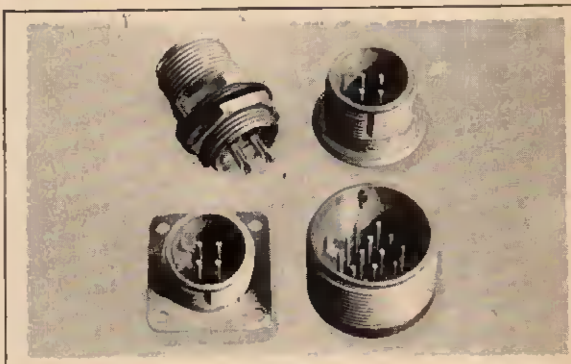

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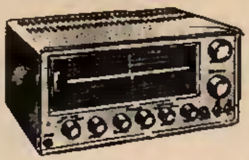

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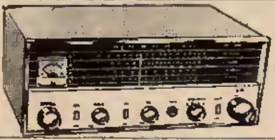

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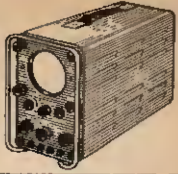

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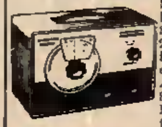

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2mA.	22/6	1A D.C.	22/6	750V D.C.	22/6
5mA.	22/6	2A D.C.	22/6	15V A.C.	22/6
10mA.	22/6	5A D.C.	22/6	50V A.C.	22/6
20mA.	22/6	3V D.C.	22/6	150V A.C.	22/6
50mA.	22/6	10V D.C.	22/6	300V A.C.	22/6
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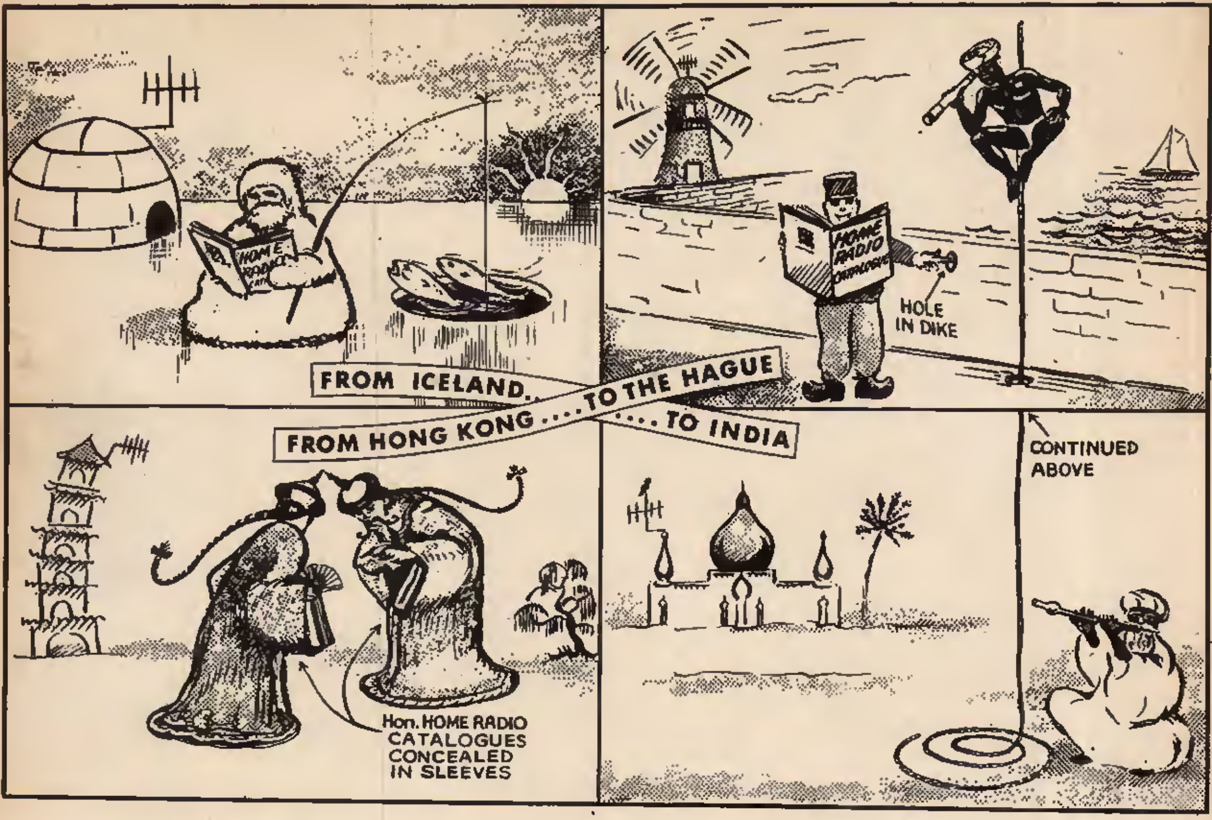

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VOL. 2 No. 10
OCTOBER 1966

Practical Electronics

PLUMBING THE DEPTHS

SCIENCE fiction may have encouraged the belief that some of the world's sociological and economic problems will have to be solved by migration to other planets. Notwithstanding the impressive progress in space exploration, this is likely to remain a (very) long-term plan. We are sure the next few generations will just have to continue being dependent on the earth for living space and sustenance!

Not that the problems arising from the alarming rate of population growth have escaped the attention of many authorities throughout the world. In this connection expert opinion is unanimous that we can no longer afford to neglect the vast potentialities of that three-quarters of the earth's surface covered by the seas and oceans.

Knowledge of these areas is still very limited and oceanography is a comparatively young science. But it is fortunate that attention is being directed towards ocean exploration and exploitation at this present time when electronic technology has reached such an advanced stage.

Echo sounding devices have already played a large part in the charting of the ocean floor. These and many other electronic instruments will figure prominently in future exploration of these vast regions. This was made clear at a five day conference entitled "Electronic Engineering in Oceanography" organised by the Institution of Electronic and Radio Engineers and held recently at Southampton University. Scientists and engineers from many countries contributed to this conference, the first of its kind to be held in Europe.

The underlying purpose of this interchange was to discover how the food productivity of the seas can be increased, but there were many other important matters under discussion, including the exploration of new sources of power such as oil and gas fields, as well as pure scientific and geophysical research. A wide variety of measuring and recording systems developed for these special needs was described.

All the indications are that oceanography will provide abundant new opportunities for the electronics industry. Moreover, success in this latest area of development should bring tangible benefits to the world's expanding population long before the first emigration space ship leaves for Mars!

THIS MONTH

CONSTRUCTIONAL PROJECTS

SPECIAL SERIES

GENERAL FEATURES

NEWS AND COMMENT

Our November issue will be published on Thursday, October 13

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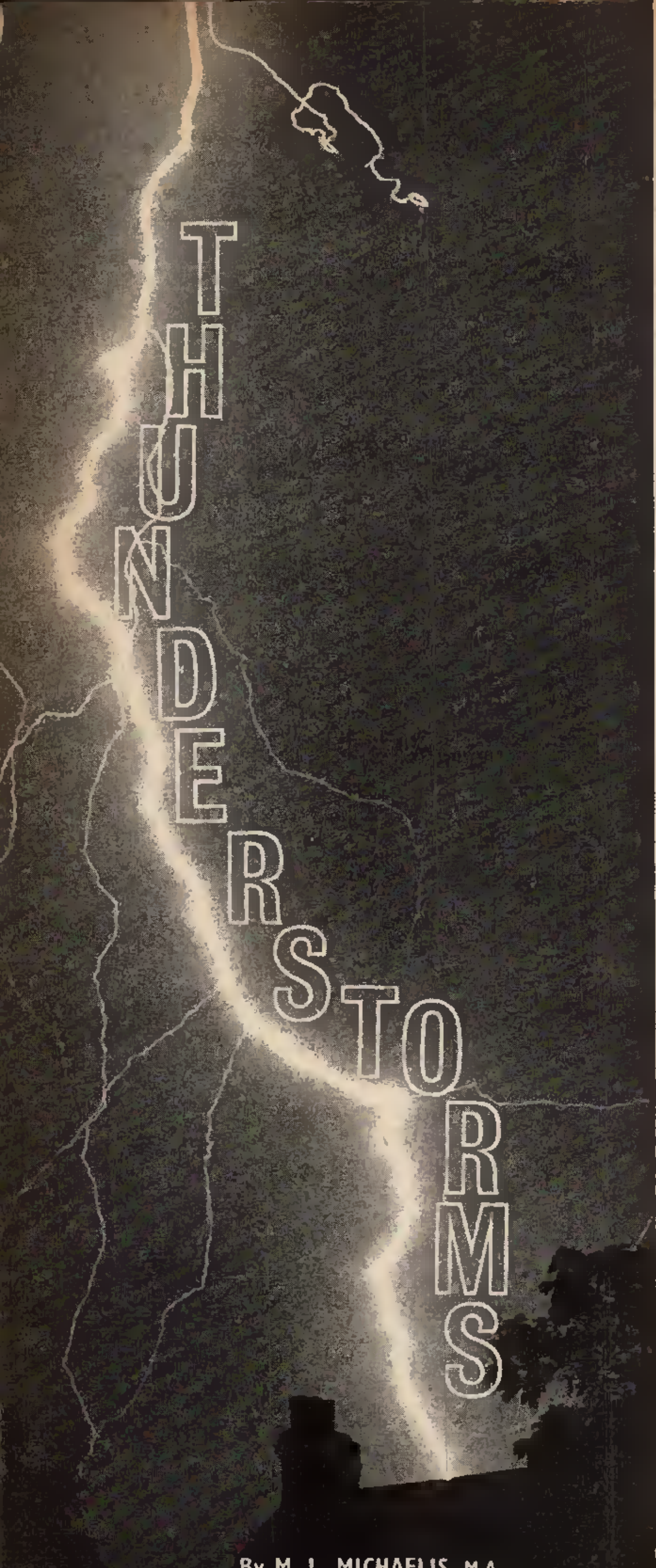
THUNDERSTORMS



By M. L. MICHAELIS, M.A.

Nobody *really* knows how the electricity is generated by a thunderstorm.

In this article the established facts about thunderstorms are narrated and the author then goes on to formulate his own ideas which are based upon practical experiments

Nature has been producing very effective electronic devices long before man had even conceived the idea of the electron. Twentieth century inventions have long been paralleled by natural creations of similar basic function. Thus the eye with associated nerves and brain section is an electronic equipment comprising an efficient navigational radar with information storage facilities, built to dimensions not reached by even the latest man-made micromodule circuit techniques. Even experienced technicians seldom pause to be impressed by these achievements of Nature.

Exceptions to this rule are those displays of natural electronics which lead to spectacular phenomena, and thunderstorms here rank high up on the list. Since at least one hundred years, scientists have been trying to find out how thunderstorms produce their immense electrical energies of several million kilowatt-hours per cumulonimbus cell (thundercloud), whereby a large storm system may consist of 100 or more such cells. To this day, no final answer has been found.

For the duration of its average active lifetime of about 15 to 30 minutes, each cumulonimbus cell runs at an electrical power of about ten thousand megawatts, which exceeds the rating of even the largest man-made turbo-generators feeding the national grid system.

The principle of this powerful natural electric generator is not yet understood. However, we do know a great deal about the qualitative properties and structure of thunderstorms, and the first sections of this article will be devoted to these accepted facts.

AN EXPLOSION OF WARM MOIST AIR

Some meteorologists have aptly described the thunderstorm as an explosion of warm moist air.

The essential starting requirements for the development of a thunderstorm are warm air of high humidity located as close to the ground as possible. Such air already contains all the vast energy which is ultimately unleashed in the storm. It is latently present in two forms, neither of which are electrical. The first form is simply the compression of the low-lying air, due to the weight of the other air masses above it. The second form is the latent heat of vaporisation of the water vapour content. Most of the energy is locked-up in this second form, but the first form is sometimes more important in getting the process started, i.e. in lifting the moist air to a level at which condensation can start and the liberated latent heat can then take over control. Thus there is no mystery about the source of the energy as such.

The thermodynamic energy content of roughly one billion tons of air participating in each cumulonimbus cell, including the latent heat of a quarter of a million tons of water carried thereby, is about ten times greater than the ultimate electrical energy output of the cell. We thus know that its efficiency in converting heat energy into electrical energy is roughly 10 per cent The question is to determine the nature of the mechanism adopted for this energy conversion.

TYPES OF THUNDERSTORMS

Thunderstorms are not ready-made structures which float along with air masses, approaching, passing overhead and then proceeding elsewhere. They are dynamic processes *involving* entire parcels of air which finally take the form of a cylinder with anvil crown, often ten miles high and ten miles in diameter.

When mature, the accompanying cloud structure has an appearance in many ways similar to the mushroom of an atomic explosion. This is not usually visible as

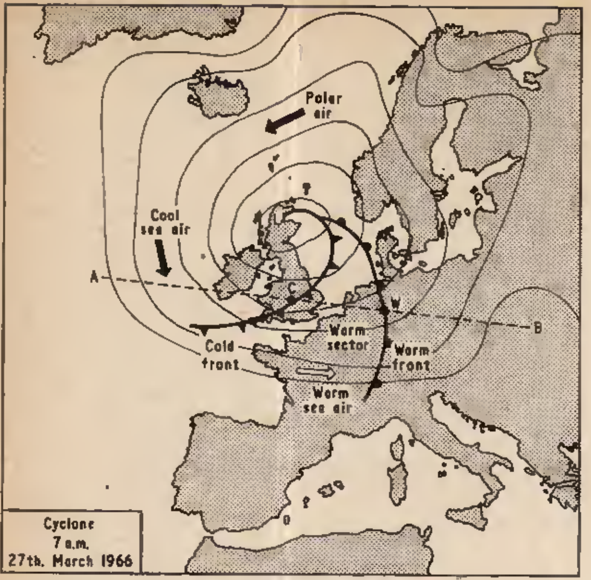


Fig. 1 (left). Plan representation of a cyclone (depression)

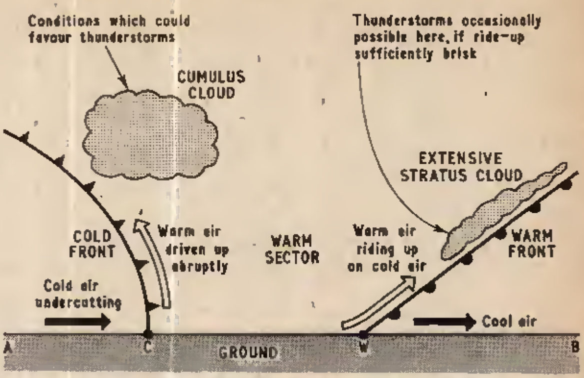


Fig. 2. Vertical section through a cyclone at ACWB in Fig. 1

such from the ground, also by no means always on aerial photographs either, because many cells in different stages of development may merge into a more extensive cloud structure covering large areas. It is well established that each cell undergoes a distinct life-cycle of its own, independent of neighbouring cells in a composite storm system and lasting about one hour inclusive of all phases. During the active part of its lifetime, which normally does not exceed half an hour, the cell seldom drifts further than through its own diameter, i.e. 5 to 15 miles. In some cases it may not move at all. When thunderstorms appear to travel over distances of hundreds of miles, this is always by way of regeneration of fresh independent cells adjacent to older spent ones. Large storm areas involve numerous cells which happen to be active simultaneously.

Thundercells are officially known as *cumulonimbus cells*. This term is derived from the cloud structure, whereby cumulus clouds are the frothy upward-rising structures so familiar on fine days and "nimbus" is the suffix for any cloud-type producing precipitation.

Thunderstorms are generally classified into two groups, the *thermal* (convectional) variety and the *frontal* (cyclonal) variety. The same cumulonimbus cell is produced in either case, the difference merely lying in the nature of the *initial* conditions which cause the warm moist air to rise to the point of water condensation. In practice, the distinction between thermal and frontal character is by no means clear-cut in many storms, the behaviour is also modified by the topography, and any distinction is largely irrelevant by the time the cell reaches maturity.

CYCLONAL INITIATION

Initial lifts of moist air to the point where latent heat release can take over rapid thunderstorm development are very frequent at the fronts of cyclonal disturbances, particularly at the cold front, where cold air is undercutting the moist warm air and forcing it upwards abruptly.

THE STRUCTURE OF A THUNDERCELL

Every thundercell passes through three phases, the *cumulus* phase, the *mature* phase and the *dissipating* stage.

During the cumulus phase, huge volumes of air are rushing into the rapidly growing cell, with towering production of cumulus cloud. In the mature stage the cell has attained its full dimensions of about a thousand cubic miles, strong precipitation is forming and raining or hailing out, ice and rain are present simultaneously in the cloud which is now towering far above the frost level, and downwind as well as upwind sections have developed, producing wind shear and friction surfaces.

The onset of ice production in the upper regions of the cell is coincident with the onset of strong radar reflections at centimetric wavelengths, so that it can be determined quite accurately. The first flash of lightning appears roughly eight minutes later. The electrostatic field near the cloud maintains normal fine-weather values of about +250 V/m at ground level until the ice production, marked by the appearance of centimetric radar reflections, commences. In the following two minutes, the field strength drops to zero and then reverses polarity, climbing to about −3 kV/m in the remaining six minutes before the first flash of lightning darts out of the cloudbase and strikes the ground.

From measurements of the wavelengths of electromagnetic radiations as well as instantaneous field changes, it is known that this first flash originates at a height of just over two miles. The cloudbase usually rests at a height of about a mile, so that at least one half of the track of the first lightning flash is inside the cloud. Subsequent flashes are found to originate from increasingly greater heights, finally from a height of about six miles, so that five miles of the track are invisible inside the cloud and one mile is visible in the air below.

These observations show that electric charges begin to build up when the crown of the thundercell has passed the frost level and ice is forming, not earlier. The lower regions of the cell thereby acquire negative charge (a surplus of electrons) and the upper regions a positive charge (deficiency of electrons). The negatively charged region encompasses a layer about one mile thick by the time sufficient potential difference has been established for the first lightning flash to take place. This negative region grows to a thickness of about five miles, i.e. to approximately half the total height of the thundercell, in the course of its further electrical activity. It appears that water and ice, but certainly ice, are essential before the generation of electricity can take place in the thundercell.

CHARGING THE ICE-WATER MIXTURE

Most hypotheses so far put forward for an electrification mechanism are concerned with the possible behaviour of ice and water when in mutual contact under the extremely turbulent conditions inside a thundercell.

It can be demonstrated in the laboratory that a water spray or even an air jet directed at ice will cause electric charges to build up on the ice. Disruption of water drops also produces charges which can be collected on ice particles. The conversion of ice particles into sleet, subsequent breakup in lower regions of the cloud and all manner of analogous physical processes produce demonstrable electrostatic effects. If water droplets and ice particles thereby acquire opposite charge polarities, there is little difficulty in visualising their rapid separation through the influence of the mechanical turbulence, before neutralisation can take place.

Electronically this is equivalent to driving apart the plates of a capacitor whilst maintaining the charge. This is a straightforward way to boost voltage and convert mechanical energy into electrical energy. The problem is to obtain sufficient electric *charge* in the first place. It is just here that most hypotheses so far put forward fall short of actual requirements. To make matters worse, many of the processes with the best yields produce the incorrect polarity, or either polarity by chance. But thundercells are *always* negative at the base and positive at the crown.

HOW MUCH CHARGE IS REQUIRED?

Electrostatic field measurements around thundercells and flashes of lightning have revealed that an average ground discharge dissipates 20 coulombs and the repetition rate is about 20 seconds. In other words, the charge source must be able to deliver an externally manifest mean current of 1 amp for 15 to 30 minutes before it is exhausted. It is rather difficult to visualise more than a small fraction of this current from most individual ice-water turbulence mechanisms, so that several of these would have to operate simultaneously, if it should turn out that the actual mechanism really is based on them.

Aerial photograph of a mature thundercell

(TIME and LIFE, New York)

EQUIVALENT ELECTRICAL CIRCUIT

A discharge can take place when the accumulation of charges has built up to the breakdown voltage. The discharge may take place entirely within the cloud, between its oppositely charged regions, or via a circuit external to the cloud. It is found that about 85 per cent of the discharge current takes the former path, leaving only some 15 per cent for the external circuit involving ground strokes of lightning with their mean current of 1 amp for each thundercell. The net current including the internal dissipation is thus about 7 amp. Fig. 3 shows an equivalent circuit for describing the properties of the discharges in detail.

The internal shunt resistor R_s represents the internal discharges. Its value is typically 200 megohms and since it carries a current of 6 amp, the e.m.f. of the thundercell is approximately 1,200 megavolts. This source of e.m.f. is depicted in series with a rectifier diode to emphasise the important fact that thunderstorms are never found with the opposite polarity. The power dissipated in R_s is clearly about 7,200 megawatts, whilst some 1,200 megawatts mean power are dissipated in the resistors of the external circuit branch.

The lightning flashes to ground are depicted by the resistor R_g whose value is typically 800 megohms and thus dissipates nearly two-thirds of the total external power. The ground discharges must be balanced by discharges into the ionosphere, which are usually of a corona or glow character. They are depicted by the resistor R_t whose value normally lies around 480 megohms. The external circuit is completed by the leakage resistance R_L between the ionosphere and ground. This has the very low value of 145 ohms, because the entire atmosphere of the world is available for it. It is common to the circuits of all thunderstorms throughout the world and is found to be carrying

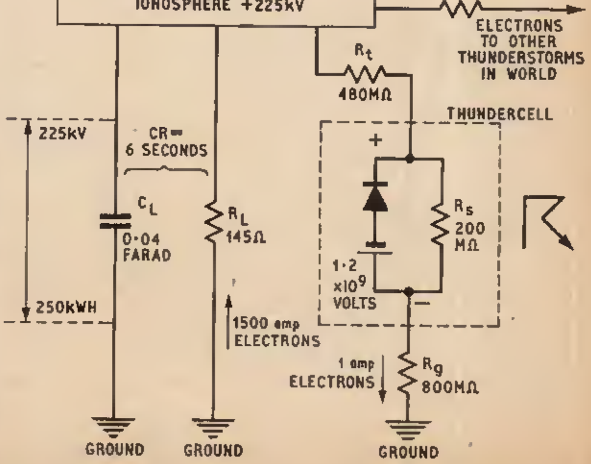


Fig. 3. Equivalent electrical circuit of a thunderstorm

a total current of 1,500 amp which is a measure of the average total thunderstorm current for the whole world. This current produces a voltage drop of about 225kV across R_L, i.e. between the ionosphere and ground. The conductivity giving rise to R_L is largely due to ionisation in the atmosphere at large, due to cosmic radiation. If ground flashes of lightning individually transfer 20 coulombs and the combined world return current is 1,500 amp, there must be 75 ground flashes of lightning per second in the world taken as a whole. Thunderstorms are thus *extremely* common.

Although the height of the ionosphere layers differs and fluctuates, we may consider 0·04 farad as an approximate value for the spherical capacitor constituted by the ionosphere and the ground. In conjunction with $R_L = 145$ ohms, this gives a storage time constant of about six seconds, during which time a mean number of 450 flashes of lightning are expected throughout the world. Assuming normal statistical behaviour, we can expect a random fluctuation of about ± 5 per cent. Fluctuations of ionospheric capacitance due to changes in height of the layers, sunspot activity, etc. are obviously much greater, so that it is not possible to employ observed fluctuations of the fine-weather return current through R_L for drawing conclusions about non-random fluctuations of worldwide thunderstorm activity.

It is interesting to note that all the thunderstorms in the world may be treated as transformer and rectifier of a power pack, with the ionospheric capacitance as reservoir capacitor and the resistor R_L as load resistor. The output power is then about 340 megawatts, whilst some 250kWh are stored in the reservoir capacitor. These figures clearly represent only a small fraction of the total electrical power, most of which is dissipated inside the thundercells and by the lightning flashes immediately below them.

Let us conclude this section by recapitulating the polarities. These are never the reverse. The ionosphere rests about 225kV *positive* with respect to ground. It draws up electrons from the ground. This fine-weather upstream of electrons takes place throughout the world, except at those isolated locations where thunderstorms happen to be taking place. The ionosphere delivers the electrons into the positive tops of all thundercells. The lightning flashes out of the negatively charged bases of all thundercells convey the electrons back into the ground, to complete the global circuit.

LIGHTNING TRACKS

Lightning discharges out of the base of the thundercell are propagated by a pilot and return stroke, instead of by a direct-shot discharge. The pilot advances out of the cloud in steps of 10 to 100 yards at a time and consolidates each step by transferring negative charge out of the cloud to the extremity of the pilot. This process is usually accompanied by branching, whereby not all branches need reach the ground finally. When any heads of the pilot have come within a few dozen yards of the ground, they become able to distinguish differences in topography and conductivity and seek optimum points within their range for striking the ground. The return stroke is thereupon initiated and taps-off all the negative charges stored along the pilot track.

This process is almost instantaneous and gives rise to a massive current pulse of many thousands of amperes, accompanied by most of the visual and audible effects. Several further discharges out of the cloud usually follow in quick succession along the prepared track. The whole sequence, including the pilot, takes approximately one second. The essential function is to convey electrons from the cloudbase into the ground.

The discharge current will distribute roughly hemispherically from the point at which the discharge enters the ground. Even if the ground resistance is only a fraction of an ohm per yard, voltage drops of several kilovolts can still arise under these conditions between the legs of a walking person standing close to the point of direct entry into the ground, or entry via a lightning arrestor, tree or other tall object. Such potential differences can electrocute a person even if he has not been struck directly. When surprised by thunderstorms, it is thus important to keep away from preferred objects of entry, to keep both feet close together and not to touch the ground or other objects with the hands or other parts of the body. It is also advisable to squat down low.

All types of trees are dangerous to stand under, since they will attract the pilot if its head happens to pass sufficiently close. Certain types of trees with a smooth bark offer excellent surface conductivity when wetted by the torrential rainfall accompanying thunderstorms, so that the discharge current does little or no damage to the tree. Other rough-barked trees offer little surface conductivity, so that the discharge passes through the internal sap ducts and may explode the tree. This visible damage has led to the quite false belief that such types of trees are preferred by lightning.

The useful function, if any, of lightning conductors on buildings is still a debatable point. Lightning is not the only means by which a thundercell can discharge electrons to ground. Corona discharge, especially at elevated pointed objects, is also possible and some authorities maintain that a good lightning conductor can reduce the frequency and intensity of lightning flashes in its vicinity by draining off charge quietly. Other sources state that the chief function of the conductor is to provide an easy path to ground *if struck*, thus minimising the resulting damage. This is analogous to the smooth-barked trees which often survive unscathed when struck by lightning.

WORLDWIDE DISTRIBUTION OF THUNDERSTORMS

An important fact is that thunderstorms are very much rarer at sea than over land, whilst inland they are most frequent over geologically disturbed areas. They are commonest over equatorial land masses and their frequency drops to zero approximately at the pack-ice boundary as polar regions are approached. This might well be expected and explained by the reduced solar radiation intensity in high latitudes. But not so the fact that thunderstorms are rare over equatorial and temperate oceans. Cyclonal lifts should here be possible, and indeed cloud formations and storm intensities akin to thunderstorms are produced—but often without the accompaniment of electrical phenomena.

POSITIVE CHARGE ISLANDS

More detailed observations of the electrostatic fields around thundercells have shown that the potential gradient once again drops to zero and returns to fairly high positive values when a cell is directly overhead.

This means that small islands of positive charge must be located within the main region of negative charge in the cloudbase. These positive islands are independent of the main positive charge in the crown and they are much smaller. They appear to be associated with the region in which the heaviest rainfall is leaving the cloudbase (Fig. 4).

ALPHA-RADIATION IN THUNDERCELLS

All land masses contain minute traces of uranium and radium, in whose radioactive decay chains exist isotopes of the *gaseous* element emanation, chiefly the gas radon. This seeps out of the rocks and into the air. In spite of the extremely minute quantities of material involved, the resulting radioactivity imparted to the air is quite appreciable, on account of the intense specific activity of these substances.

A useful unit for the radioactivity of a specimen is the *picocurie* (10^{-12} curie), corresponding to 2·2 disintegrating atoms per minute. The radon activity in continental air masses is about 100 picocurie per cubic yard. At sea it is very much less, because water tends to dissolve emanation gases rather than injecting them into the air. Over geologically disturbed areas the radon content of the air can be much greater. A mature thundercell contains about 10^{12} cubic yards of air, so that over land masses it may be expected to contain *at least* 100 *curie* of radium emanation and its first daughter product radium A, both of which are intense alpha-emitters. Now 100 curie of an alpha-emitter produce $2{\cdot}2 \times 10^{14}$ alpha-particles per minute, representing an electric current of about 1 microampere.

The alpha-particles are ejected from the radioactive atoms with an energy of 6 million electron volts and are known to dissipate this energy by producing short tracks of dense ionisation. If each ionisation requires a volt or two, which is a reasonable figure for ice, it is clear that a charge multiplication factor of several million is feasible before the energy of the primary alpha-particles has been expended in this manner. The total charge production by this mechanism alone could thus amount to several amperes, which is of the required order of magnitude to account for the observed electrical phenomena of the thundercell.

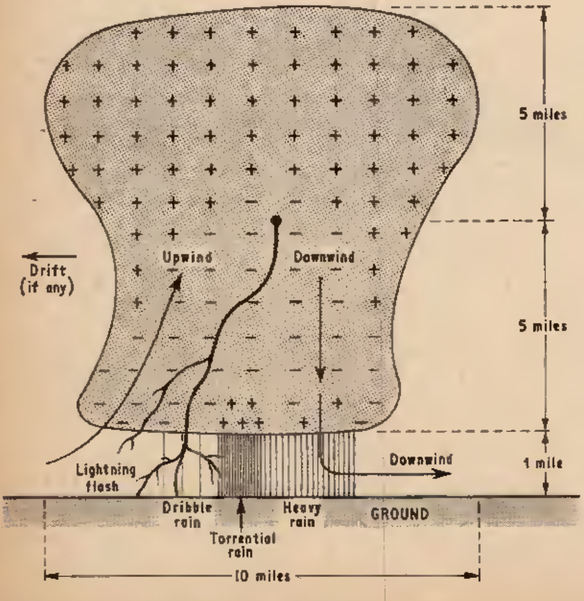


Fig. 4. Sketch of a mature thundercell

There can hardly be any doubt about the production of these charges. Continental air masses engaged in a thundercell contain this amount of alpha-radioactivity and the familiar ionisation phenomena thus *must* take place. The question open to discussion is whether these charges simply recombine on the spot and then contribute nothing to the electrification of the thundercell, or whether the turbulence can get a grip on them sooner, hurling them apart to build up the huge amounts of electrical energy produced in a thundercell. As an alternative, the alpha-ionisation may induce sufficient partial electrification for producing conditions favourable for large-scale exploitation of one or more of the conventional mechanisms.

This hypothesis would give a clear reason why thunderstorms are rare at sea although otherwise similar storms but lacking electrical phenomena are not infrequent there. The concentration of radium emanation in the air is inadequate remote from land masses. The time taken for air masses to move well out to sea is comparable with or long relative to the 3·5 day half-life of the emanation, so that there is not much left by the time the air gets there.

A second argument is more involved and is based on the author's own experimental observations of the emanation product radioactivity in thunderstorm rainfall. This work has been handicapped by the fact that only a single station was operated at a fixed site, waiting for whatever weather happened to come by chance. The results are necessarily more confused than if several mobile or airborne stations had been operated simultaneously to approach and encircle the weather patterns of interest, aided by all other meteorological services and methods of location.

ELECTRONIC EQUIPMENT AND METHOD

The principle was to make comparative studies of the initial concentrations and decay rates of the mixed emanation products for successive small samples of rainwater taken in the course of thunderstorms and other kinds of rainfall, aiming to detect systematic trends and differences for drawing possible conclusions therefrom. This called for the construction of an efficient multi-channel ratemeter system with chart-recording facilities for comparing the radioactive decay of successive samples of rainwater on a common time scale. It is essential to ensure a high degree of circuit stabilisation against random electrical or thermal drifts. A great deal of work was involved in designing a fully satisfactory electronic equipment, but all problems on this score have been solved.

Coaxial Geiger-Muller counter tubes for liquid samples have chiefly been employed as radiation detectors. These are almost exclusively responsive to the high-energy beta and gamma radiation of radium C. If a sample contains equilibrium amounts of all the successive decay products of radium emanation, then a mean decay half-life of about 35 minutes will be observed, corresponding to the equilibrium sequential decay of the products. If radium C is deficient, then it must first of all be produced from its forerunners, so that the measured activity will initially *increase* over any time from 10 to 90 minutes, before a decay can commence for the mixture as a whole. On the other hand, if radium C is in excess, its forerunners may be ignored and the observed mean half-life of the sample will approach more closely to the short 19 minute half-life of pure radium C. A detection system which is exclusively responsive to radium C is thus quite sensitive to variations in the proportions of this isotope relative to its forerunners.

RESULTS AND DISCUSSION

Of the various systematic trends indicated in the course of these experiments, only two are of outstanding importance in relation to thunderstorm electricity. The first effect was noted at an early stage, since it can interfere with the method of taking samples. These are caught in a large plastic photographic developing tray. If the rainwater is poured therefrom straight into the radiation detector system, rather low readings and short decays corresponding to an excess of radium C are generally observed. If the tray is subsequently washed down with an equal volume of dilute nitric acid and the washings are then run parallel on another ratemeter channel, rather high readings and long decay times, corresponding to deficiency of radium C, are observed. In many cases filtration of the water prior to measurement can bring this separation process to virtually quantitative completion. The earlier product radium B, possibly even radium A, thus shows a great tendency to deposit out of the water onto any available solid surface, whilst that portion of the radioactivity which has already decayed as far as radium C remains in homogeneous solution. This observation is significant, because it means that similar deposition phenomena might be expected inside a thundercell, once ice begins to form and presents a solid deposition surface.

This brings us to the second important trend which has been noted. Thunderstorms usually commence with isolated large drops of rain for a few minutes, followed by a fairly sudden transition to torrential rainfall. In most cases there appears to be an equally sudden transition in the nature of the radioactivity in the rainwater. The initial drops tend to show high specific concentrations, but short decay times, so that they contain radium C in excess, having lost the earlier products. The early portions of the torrential rainfall contain much lower specific concentrations (yet greater total amounts of activity), but have quite long decay times, showing that here radium C is deficient and the earlier products predominant.

Now it is known that the large raindrops of the torrential rain result from melted ice particles which have grown at the expense of smaller water or cloud particles in the upper regions of the cloud, often after several journeys up and down through the cloud in the turbulence streams. Thus the author's observations could be taken as evidence that the ice in a thundercell accumulates large fractions of the emanation product radioactivity arriving with the inrushing air.

Furthermore, in a mature thundercell the boundary between the indefinite earlier section and the start of the torrential rainfall is also roughly the dividing line between the inrushing upwind and the outgoing downwind, i.e. it is the wind shear and friction surface. If most of the alpha-radioactivity really is concentrated in this region of maximum turbulence, there would indeed be a better chance for the turbulence to get a grip on the resulting intense ionisation, in order to separate the charges to the observed magnitudes.

The author must emphatically point out that this is still pure conjecture. The observed behaviour of the radioactivity is fact, but the interpretation put forward may be right or wrong. Other explanations are conceivable, but the type of further experiments necessary to decide the issue are obvious and feasible.

DETERMINATION OF POLARITIES

On the basis of the alpha-radioactivity hypothesis as a mechanism for the electrification of thunderstorms, it would be necessary to depart even further into the realm of pure conjecture in order to give a plausible explanation of the definite polarity, i.e. of the "rectifier behaviour" of the thundercell. Nevertheless, at least one reasonably straightforward mechanism is conceivable.

The crystal structure of ice is an array of rather loosely packed oxygen atoms, with interposed protons (hydrogen bonds) holding the oxygen atoms further apart than a spacing corresponding to close packing. It would be conceivable that the radiation of intense alpha-activity accumulated on the ice could smash-out protons, which are positively charged and very readily attached to small particles in the upstream which then carries them aloft to the crown of the cloud. The negatively charged ice crystals would ultimately drop out as rain to the base of the cloud. By the time they get there, the radioactive products could have decayed through radium B and radium C to radium C', which is once again an intense alpha-emitter and might thus attempt to repeat the process in miniature in the cloud base. This could account for the observed islands of positive charge inside the principal negatively charged region at the bottom of the mature thundercell.

In conclusion, it should be noted that the e.m.f. of a thundercell falls into the same class as many of the more powerful man-made particle accelerators, i.e. it is ample for inducing a whole variety of nuclear reactions. At the high beam currents involved, it might be worth considering whether nuclear reactions play any role in the behaviour of a thundercell. But this is really begging the question, for we are looking for a mechanism leading to the creation of the high voltages and powers, not for secondary effects produced by these voltages once they are established. ★

MINIBOARDS

The constructional articles in this month's issue are mainly devoted to building six electronic circuits, any one of which can be made up on the sample piece of Veroboard given free with this issue.

IT WILL be seen from the diagrams just how much can be packed on to a small board 2½in × 1¼in containing 119 holes and seven copper strips. This sample piece has been manufactured specially for PRACTICAL ELECTRONICS and is not generally available in the size given; neither can extra samples be purchased in this size. However, extra pieces can be cut from the larger sizes generally available.

The holes in the board are arranged in a 0·15in square matrix, each row of holes being given a code number or letter for easy location of component wires.

Where a large number of components are mounted on the board it is often necessary to make breaks in the copper strips to isolate two or more distinctly different parts of the circuit.

There are a number of ways of breaking the strips, but in any case care must be exercised to prevent the wanted part of the strip being lifted. They are bonded on to the board and being very thin (0·0015in) and only 0·1in wide they can be easily damaged.

There is a special tool on the market which will make clean circular cuts in the strip. This tool, the spot face cutter, looks like a short twist drill with a centre spigot and wooden handle (see photograph). The spigot is located in the appropriate hole where the break is to be made. A firm but gentle twist on the tool will cut the copper.

An alternative method is to use a sharp thin bladed penknife, adopting a backward and forward "sawing" action. The piece of copper to be removed should be cut on either side of the hole. It can then be lifted as before. Be careful not to allow the knife blade to cut adjacent strips.

It is sometimes necessary to link two or more strips; this is done with link wires on the top of the board.

PROJECT CONSTRUCTION

Each article in the *Miniboards* series is easily recognised by the grey symbol M. The projects are not intended to be self-contained units that will be used on their own; that is why no housing or cabinet details are provided. It was envisaged that the constructor would be able to incorporate his selected project into a more complex piece of equipment that he has already or can build with it.

Due to the density of components on the boards a few hints might be helpful to make construction easier.

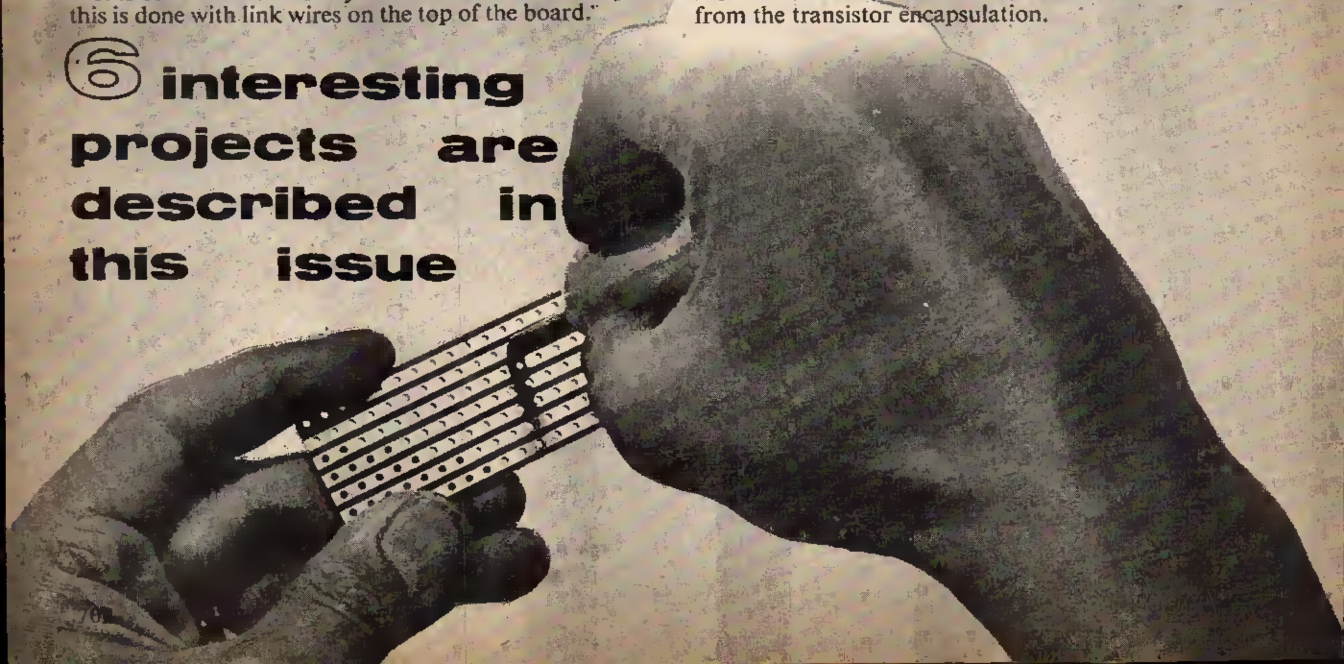
Always start by cutting the breaks in the copper strips where necessary. Secondly, if link wires or flying leads are required solder these in position; p.v.c. covered wire is recommended. Next, insert the components on the top (plain) side of the board commencing at one end and working your way out to the other end. This will avoid accidentally touching a component with the soldering iron and give sufficient room to manipulate with a pair of round nosed pliers.

For the most efficient soldered joint, insert the wire through the hole, bend over and cut off the surplus, leaving about $\frac{1}{16}$in of wire laying flat on the strip to solder.

Most of the components are mounted on end with the top lead bent down to pass through a nearby hole. The components should not touch the board, but be left standing on their connecting wire about ¼in above the board. This provides a maximum degree of air circulation around the components. It is better to leave the wires too long rather than too short.

A word of advice concerning transistors: always use a heat shunt—a pair of pliers—gripping the lead-out wires between the soldering iron and transistor itself. Do not bend the lead-out wires closer than 1·5mm from the transistor encapsulation.

6 interesting projects are described in this issue



M1

LIGHT OPERATED SWITCH

THE first of this series of Miniboard projects is probably the easiest from both the theoretical and the constructional points of view.

The unit contains a light sensing element and an electronic switch. The switch is off under normal daylight conditions, but when the light falls to a pre-determined level, such as at dusk, the switch automatically changes state and switches on. It may be used to operate an external device, such as a lamp or an alarm circuit.

The unit can be modified to give a number of alternative modes of operation, for example, switch is normally on but switches off when the light falls to a pre-determined level, or switch is normally off but switches on when light is raised to a pre-determined level.

HOW IT WORKS

The complete circuit of the unit is shown in Fig. 1. The light dependent resistor X1 is a cadmium sulphide photocell; the resistance of this device varies with the light intensity.

Under conditions of extreme darkness the resistance is in the order of a couple of megohms, falling to as low as a few hundred ohms in extremely bright conditions. X1 is connected in series with VR1, the two components forming a potential divider circuit. As the light level falls the voltage at the junction of VR1 and X1 rises.

TR1 is an emitter follower or impedance changer, with emitter load VR2. The emitter follower has a relatively high input impedance compared with the output, with an amplification factor of almost one. Because of its high input impedance, TR1 causes negligible shunting across X1; the voltage appearing at TR1 emitter is very nearly the same as that on its base.

SCHMITT TRIGGER

TR2 and TR3 constitute a Schmitt trigger; this is a two state circuit in which either TR2 is on and TR3 off, or TR3 is on and TR2 is off. The state of the circuit can be changed by applying a suitable trigger potential to TR2 base.

In the circuit shown in Fig. 1, R1 and VR2 form a potential divider base-bias network for TR2. The bias voltage is such that TR2 is normally off, with its collector at near full negative rail potential, and TR3 is switched on with its collector at near zero volts. TR4 is wired as an emitter follower, d.c. coupled to TR3 collector. In the prototype circuit a 6 volt 40mA bulb is used as the emitter load of TR4.

COMPONENTS . . .

Resistors

R1	47kΩ	R4	10kΩ
R2	5·6kΩ	R5	5·6kΩ
R3	22kΩ	R6	470Ω

All 10%, ¼ watt carbon

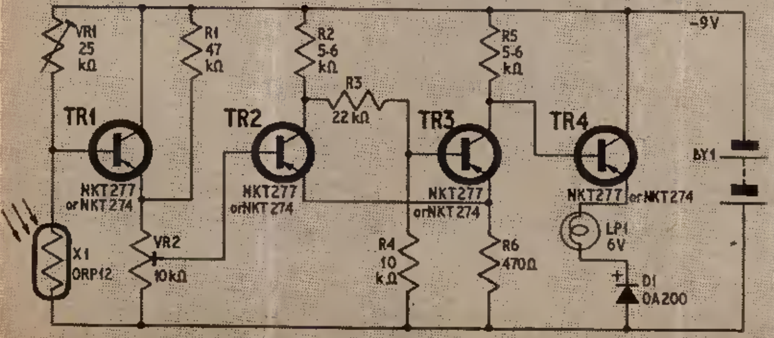


Fig. 1. Circuit diagram of the light operated switch

Potentiometers
VR1 25kΩ } preset skeleton
VR2 10kΩ } miniature

Photo Sensitive Device
X1 ORP12 (Mullard)

Transistors
TR1, 2, 3, 4 NKT277 or NKT274
(4 off) (Newmarket)

Diode
D1 OA200 (Mullard)

Lamp
LP1 6 volt 40mA (or relay, see text)

Battery
BY1 9 volts type PP7 or PP9

Miscellaneous
Sample piece of Veroboard
Battery connectors
P.V.C. covered wire

If diode D1 is omitted from the circuit it would be found that, although TR4 base (and TR3 collector) are at near zero volts, sufficient negative bias would still be available to cause TR4 to conduct quite heavily (to approximately 30mA). Diode D1 effectively raises the emitter potential of TR4, reducing the negative bias condition, and reducing the emitter current to approximately 2mA with the Schmitt trigger off.

As the external light level falls and the resistance of the l.d.r. rises, the potential at TR1 base (and emitter) rises; the voltage on TR2 base rises also. When the voltage on TR2 base rises sufficiently, the Schmitt trigger circuit will switch very sharply. TR2 collector falls to near zero volts and TR3 collector rises to near full negative rail potential. The base of TR4 also rises to near full negative rail potential and the transistor conducts heavily, lighting the bulb LP1.

When the external light level rises again, the potential on TR2 base falls; when this potential falls to a sufficiently low level, the Schmitt circuit again switches, reverting very sharply to the off state.

It should be noted that there is a small difference between the potential required to switch the Schmitt circuit on and that required to turn it off again; the difference between these two potentials is referred to as "backlash". By adjusting VR1 and VR2, the circuit can be set to switch at any required light level with negligible backlash.

CONSTRUCTION

Construction is fairly simple. All components except R1 are mounted vertically (see introductory article). Start by breaking the copper strips. Solder the flying leads for the battery to the Veroboard where shown in Fig. 3.

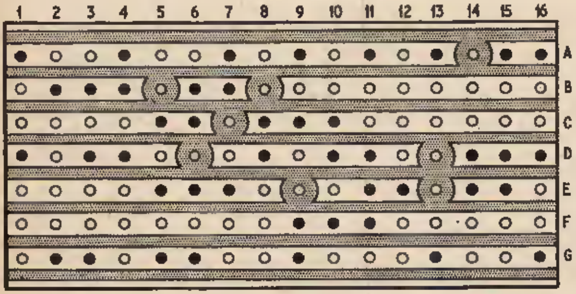


Fig. 2. Underside of the component board

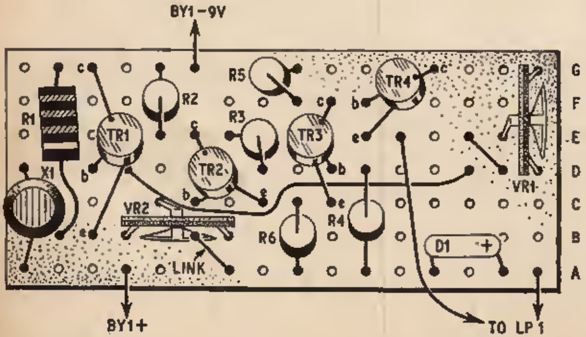


Fig. 3. The components in position on the board

When assembling the unit, start by mounting VR1, X1, TR1, and VR2. Now check that this part of the circuit functions correctly, by temporarily connecting a 9 volt battery and using a voltmeter to check that the voltage at TR1 emitter varies with the light level. Next, wire up the Schmitt trigger circuit, then check that it functions correctly. Finally, wire up TR4, LP1, and D1, and check that the complete circuit functions correctly.

Transistors NKT277 are industrial types; the NKT 274 is suitable as an alternative.

VARIATIONS OF THE CIRCUIT

In the circuit shown in Fig. 1, LP1 is normally off, but switches on when the light level falls to the preset value. If it is required that LP1 should be normally on, but switches off when the light level falls to the preset value, modify the circuit by breaking the connection between TR4 base and TR3 collector and re-connecting TR4 base to TR2 collector. If it is required that LP1 should be normally off but switches on when the light level rises to a pre-determined value, modify the circuit by transposing the positions of VR1 and X1.

Finally, if it is required that LP1 is normally on but switches off when the light level rises to the pre-determined value, modify the circuit by transposing VR1 and X1 and breaking the connection between TR4 base and TR3 collector and re-connecting TR4 base to TR2 collector. To cover a wide range of light intensity it may be necessary to increase the value of VR1.

LP1 may be replaced by a 6 volt relay, if required. The relay resistance must be greater than 120 ohms; with resistance greater than about 1,000 ohms, diode D1 may be omitted from the circuit.

Although LP1 is marked as a 6 volt 40mA bulb, it may be found that it actually takes a current of about 70mA, due to the wide manufacturing tolerances. Make sure that the resistance of LP1 or any alternative load in the emitter of TR4 is not so low as to allow currents greater than about 80mA to flow, or TR4 or D1 may be damaged.

USING THE UNIT

To set the unit to operate at the required degree of darkness, set VR1 at about mid-travel and turn the moving arm of VR2 so that it is at near zero potential. Now reduce the intensity of light falling on the face of X1 to the trigger level required; adjust VR2 to the point where LP1 switches on.

Now slightly increase the level of light falling on X1; LP1 should switch off again; if it does not, systematically adjust VR1 and VR2 until a combined setting is obtained at which the required trigger level is achieved with a minimum of "backlash".

APPLICATIONS

The circuit has many uses: it may be used to switch the parking lights of a car on automatically at dusk and off again at dawn, or to carry out a similar function with house lighting. It can be adapted as a lamp economy unit for "pot-holing" or to give automatic operation of a torch.

The circuit may be used to trigger a "light-beam" type of burglar alarm; it may be used as the basis of a counting unit, the output of the unit being fed to an electro-mechanical counter, while the articles that are being counted are made to make and break a light beam that is directed on to the light dependent resistor. The reader will, no doubt, find many other uses for the "Light Operated Switch". ★

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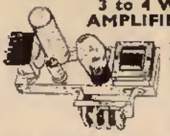

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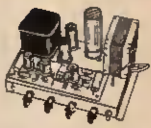

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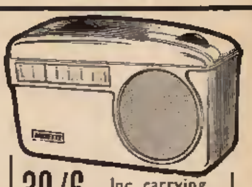

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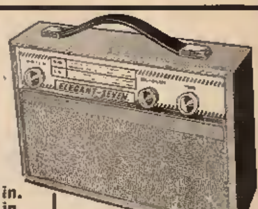

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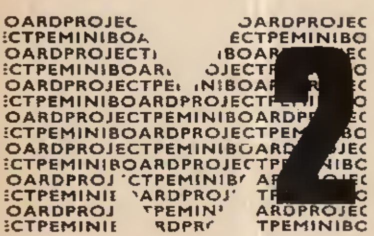


THIS circuit has been deliberately designed in its present simplified form, as its primary purpose is intended to illustrate the general design features of the Wien bridge oscillator circuit. It is possible to incorporate this unit in a more complex arrangement to provide an audio signal generator, as shown last month.

GENERAL PRINCIPLES OF OSCILLATORS

To cause an electronic circuit to oscillate, the main requirement is that the output of an amplifier, with a voltage gain greater than 1, should be fed back to, and in phase with, its input.

The circuit will then oscillate, but the frequency of oscillation and the shape of the waveform needs to be controlled. To obtain full frequency control, a filter network must be introduced into some part of the circuit, in which case it is the overall gain of the circuit that must be made greater than 1. If a pure sine wave output is required from the circuit, the overall gain must be held constant at exactly 1.

WIEN BRIDGE

One of the most useful filter networks for use as the frequency determining section of an audio or low frequency oscillator is the Wien bridge, shown in basic form in Fig. 1.

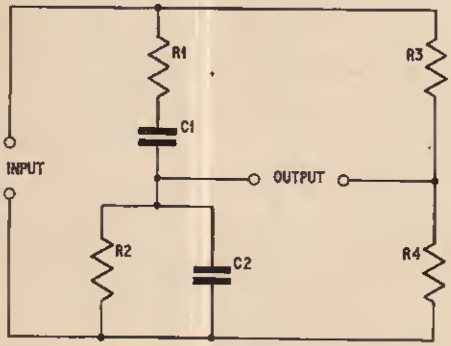


Fig. 1. Basic circuit of a Wien bridge network

The important feature of this particular network is that the output signal is out of phase with the input at all except one particular frequency; the frequency at which input and output are in phase is determined by the component values of the bridge.

In actual practice the Wien bridge is usually designed to give an actual "null", by suitable selection of the values of R3 and R4, at the required frequency. For use in an oscillator, this "null" condition is not needed; R3 and R4 can be left out of the circuit and the output signal taken from between the C1, R2, C2 junction and earth. This modification makes no difference to the phase relationships of the circuit.

It is more or less standard practice to select the values of the Wien network such that R1 = R2 and C1 = C2. In such a case, the attenuation factor of the Wien network is 3 at the frequency corresponding to zero phase shift. The tuned frequency is given as:

$$f_0 = \frac{1}{2\pi R_1 C_1}$$

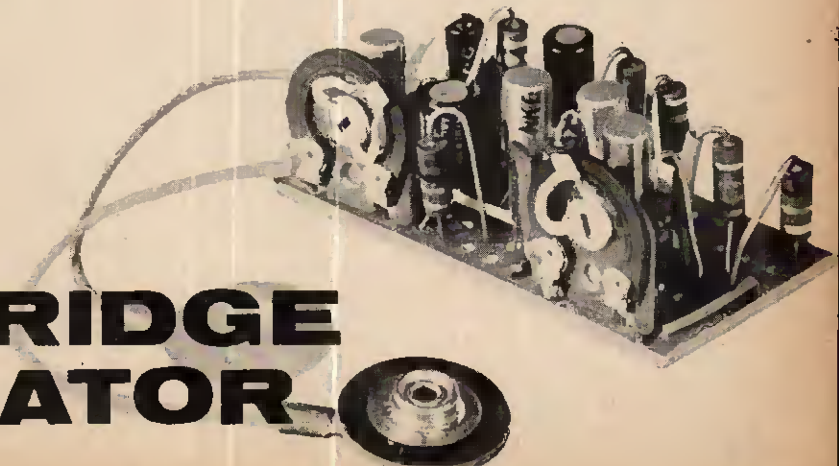
OSCILLATOR CIRCUIT

The basic circuit of an oscillator using the Wien network is shown in Fig. 2. The input and output of the amplifier are in phase and the overall gain is unity.

The Wien network in the circuit of Fig. 2 is made up as follows: R9 and C2 correspond to R1 and C1 of Fig. 1, while C1 of Fig. 2 corresponds to C2 of Fig. 1; R2 in Fig. 1 corresponds to R8 and VR1 in series in Fig. 2. R1 and R2 in Fig. 2 are in parallel (from an a.c. point of view) and have some small effect on this arm of the network, although the primary function of R1 and R2 is to provide base bias to TR1.

By using this method of connection, it is possible to vary this combined resistance and thus the frequency, without appreciably changing the base bias conditions. In the interest of good frequency stability over a reasonable temperature range, the base current of the first transistor of the amplifier should be either very constant or very small compared to the oscillatory currents of the Wien network.

In the circuit in Fig. 2 the second of these alternatives is used, TR1 and TR2 being a Darlington pair to give very high gain, with correspondingly low base current to TR1. TR1 and TR2 can be regarded as a



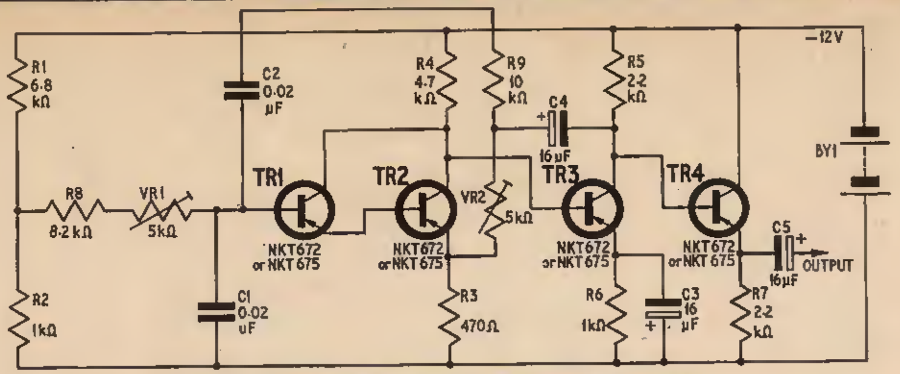


Fig. 2. Circuit diagram of the Wien bridge oscillator

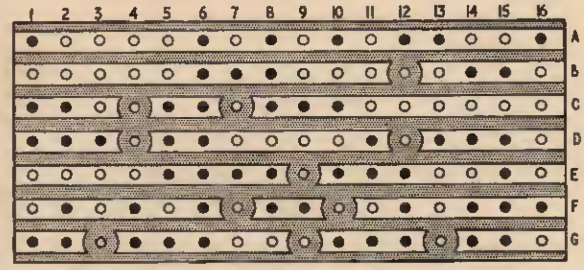


Fig. 3. Underside of components board

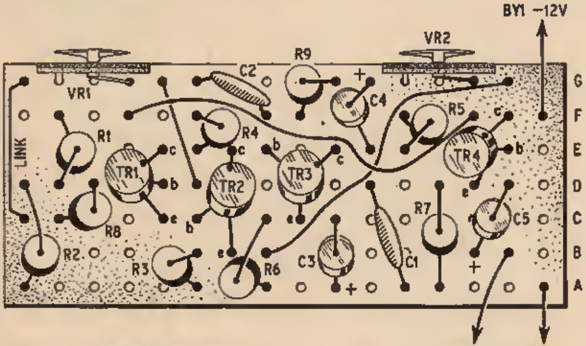


Fig. 4. Component layout

COMPONENTS . .

Resistors

R1	6·8kΩ	R6	1kΩ
R2	1kΩ	R7	2·2kΩ
R3	470Ω	R8	8·2kΩ
R4	4·7kΩ	R9	10kΩ
R5	2·2kΩ		

All 10%, ¼ watt carbon

Potentiometers

VR1, VR2 5kΩ preset skeleton miniature (2 off)

Capacitors

C1, C2 0·02µF ceramic (2 off)

C3, C4, C5 16µF elect. 15V (3 off)

Transistors

TR1, 2, 3, 4 NKT672 *or* NKT 675 (4 off) (Newmarket)

Battery

BY1 12 volt (Type PP1, 6 volt, 2 off in series)

Miscellaneous

Sample piece of Veroboard

Battery connectors

P.V.C. covered wire

single, very high gain transistor, connected as a common emitter amplifier, with collector load R4, an uncoupled emitter resistor R3, and base bias voltage divider network R1 and R2.

A second common emitter amplifier TR3 has its base directly coupled to the collector of TR2; the collector of TR3 is coupled, via C4, to the input of the Wien network, completing the positive feedback path. The collector of TR3 is also coupled, via C4 and VR2, to the emitter of TR2; this part of the circuit forms a negative feedback loop, by which the gain of the amplifier can be reduced to approximately 3, i.e. the overall gain of the circuit can be set at 1.

Finally, the output of the Wien bridge oscillator, taken from TR3 collector, is directly coupled to the base of TR4, an emitter follower, which gives a low impedance output from the unit via C5.

CONSTRUCTION

Construction is fairly involved and will need some degree of patience and practical ability.

Following the procedure outlined in the introductory article, cut the copper strips according to Fig. 3. Then assemble the wires and components, starting at one end and working through to the other end.

When complete, check the wiring and connect the battery. If an oscilloscope is available, monitor the output and check that the unit is functioning. If no oscilloscope is available, connect the output to an audio amplifier, or a.c. voltmeter. If no output is obtained, try adjusting VR2.

The transistors NKT672 in the circuit diagram (Fig. 2) are industrial types, but suitable alternative types, NKT675 may be more easily obtained. In case of difficulty the manufacturers will advise.

SETTING UP

An oscilloscope will be found to be most useful. Set VR1 to mid-travel and VR2 to maximum resistance; the overall gain of the circuit will be greater than 1 and the output waveform will be severely distorted, approaching a square wave. Now slowly decrease the resistance of VR2; the waveshape will improve until a point is reached at which a nearly pure sine wave (about 6 volts peak-to-peak) is obtained. Decreasing the resistance of VR2 further will result in a decrease in amplitude and distortion. Eventually, oscillation will cease completely as the overall gain falls below unity.

Next, reset VR2 to give a sine wave of about 3 volts peak-to-peak. Now change the setting of the frequency control VR1 both to increase and to decrease the frequency; it will be noticed that, as the control is turned in one direction, the distortion of the waveform increases, while in the other direction the amplitude decreases until oscillation ceases completely. These changes are due to the changing levels of attenuation that occur in the Wien network as the relative values of resistance in the upper and lower arms are altered; the attenuation factor is three, only when the two arms hold the same values of resistance and capacitance.

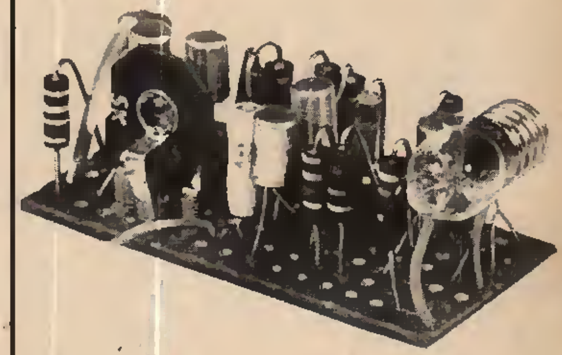
WIDER FREQUENCY RANGE

Using the component values shown the frequency range of the unit is about 800–1,000c/s. If lower frequencies are required, increase the values of C1 and C2; for higher frequencies, decrease the value of these two capacitors. The circuit will operate satisfactorily up to several hundred kilocycles per second.

If a variable frequency oscillator is required, replace R9 and the R8–VR1 combination with a twin ganged 10 kilohm potentiometer. This modification will largely overcome the variations in waveform level and shape that can occur when only a single resistive arm is used to vary the frequency.

For really good results, as are required in a signal generator, some form of automatic amplitude stabilisation is essential; it will probably be found that, if VR2 is replaced by a thermistor (type R53) and R3 is replaced by a 500 ohm preset potentiometer with its moving arm connected to the zero line via a 50μF capacitor, the required results can be obtained by adjusting the 500 ohm preset for minimum distortion, at any frequency. It may, however, be necessary to experiment by wiring a resistor in series or in parallel with the thermistor for optimum results. ★

TIME SWITCH



THE time switch described in this article consists, essentially, of an electronic time delay circuit which feeds an electronic switch. At the moment when power is supplied to the unit, the switch is off; after a predetermined time delay, the switch changes state very rapidly and flips on. By making a suitable choice of time delay components, time delays ranging from a fraction of a second to a few minutes can be obtained.

If required, the circuit's mode of operation can be changed so that, as soon as power is supplied to the unit, the switch turns on, but turns off again after a predetermined time delay. The switch may be used to operate a low power lamp or an external circuit via a relay.

TIMING CIRCUIT

The full circuit diagram of the unit is shown in Fig. 1. The time delay circuit is built around the first two stages TR1 and TR2, which are connected as a Darlington pair.

This configuration has a high input impedance which matches the high reactance of a large capacitor in the integrator circuit of C1 and R2. Here, TR2 is connected as an emitter follower, with emitter load VR1; the second transistor, TR1, is also wired as an emitter follower, but in this case its emitter load is the base of TR2. Thus, the circuit can be regarded as an emitter follower circuit in which the current gain h_{FE} is the product of the two individual transistor gains. The input impedance of an emitter follower is given approximately as the product of h_{FE} and the emitter load.

Returning for the moment to Fig. 1, the actual circuit used in the electronic time switch, R2 and C1 can be regarded as the time constant circuit. An additional resistor, R10, connected between TR1 emitter and the common positive line, is used to give d.c. stabilisation to the circuit.

The output waveform of a simple integrator CR circuit follows that of an exponential graph. For many applications, including that of the electronic time switch, it is more useful to have a waveform that rises linearly with time instead of exponentially. If the actual charging current (or the voltage across R) is kept constant during the charging cycle, the required linear voltage rise would be obtained.

An isolating resistor R1 is interposed between the main time constant resistor R2 and the negative supply.

One feature of the emitter follower circuit is that the voltage on the base is almost the same as that on the emitter. The voltage on the base of TR1 is "seen" at the emitter of TR2. The emitter of TR2, being coupled via C2 to the "top" end of R2, thus, results in the same changing voltage appearing at each end of R2. Therefore, the voltage across R2 is virtually constant. Thus, the output voltage at the emitter of TR2 rises linearly with time. This part of the circuit is a "bootstrap" sawtooth generator.

AIMING VOLTAGE

If a ruler is placed tangentially against an early part of the exponential rise curve, and a line projected to the point where it intersects the vertical line corresponding to the CR time, the point of that intersection will represent some particular voltage (since the vertical axis represents volts), which is referred to as the "aiming voltage" at that particular instant.

With the exponential rise CR circuit, if a supply of 9 volts is used, the initial aiming point of the waveform may be several hundred volts, falling rapidly towards 9 volts with time. With the linear sawtooth generator also operating from a 9 volt supply, an aiming potential of several hundred volts may be maintained throughout a major part of the cycle!

TRIGGER

The rest of the circuitry of the time switch shown in Fig. 1 is fairly straightforward. The two transistors TR3 and TR4 constitute a Schmitt trigger, i.e. a two state circuit in which TR3 is normally off and TR4 is on. When a sufficiently large negative voltage is fed to the base of TR3, the circuit will trigger and rapidly change state, TR3 switching on and TR4 off.

The linear rising voltage from the bootstrap circuit is used to trigger the Schmitt via a diode D1. Variable time constants are obtained by varying the voltage level obtained from TR2 by adjusting VR1. The main function of D1 is to prevent the d.c. voltage across VR1 being reflected on to the base of TR3, which is at a higher potential. D1 also ensures that only negative trigger voltages are applied to TR3.

TR5 is an emitter follower, with its base directly coupled to TR4 collector. Since TR4 is normally on, its collector is normally at near ground potential; D2 imparts a certain amount of emitter bias to TR5 so that, with TR4 collector at near zero volts, TR5 is biased to near cut-off. When the Schmitt circuit triggers, TR4 switches off and its collector goes to near the full negative rail potential; TR5 is biased on and conducts heavily, illuminating the lamp LP1.

CONSTRUCTION AND TESTING

All components are mounted vertically on the sample Veroboard panel (see introductory article). Start construction by breaking the copper strips in the positions shown in Fig. 3 and connecting the battery leads.

Next, wire up the bootstrap circuit TR1 and TR2. If a voltmeter is available, set it to the 10 volt d.c. range and connect it across VR1. Connect the battery to the circuit so far built. The voltage across VR1 should rise to about 0·5 volts and remain steady for a second or so, after which it will rise, in a linear fashion, to about 5·5 volts in about 25 seconds; the voltage

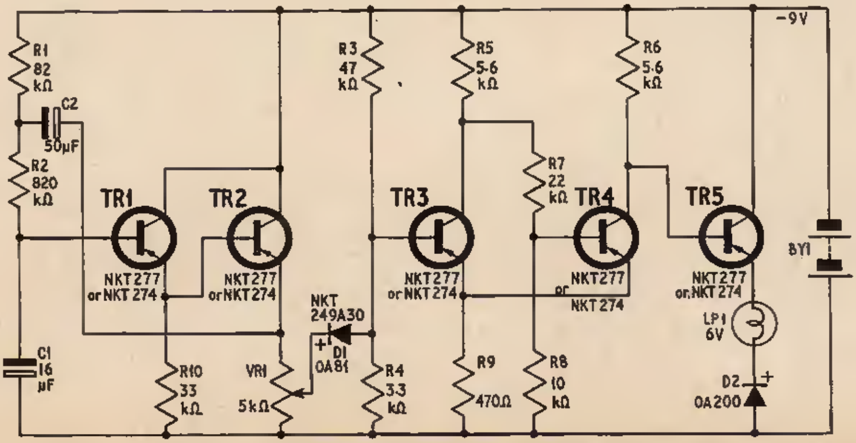


Fig. 1. Circuit diagram of the complete time switch

will then continue to rise at a slower rate up to about 6·5 volts. These figures are not critical and are only for guidance.

Now wire up the Schmitt trigger circuit and check that it functions correctly; connect the voltmeter to to TR4 collector and battery positive. Initially, it should read about 0·8 volts, but after a few seconds should jump to 6 volts or more as the circuit triggers.

If triggering does not occur, check that VR1 has not been turned down too far. Finally, wire up TR5, LP1, and D1, and check that the circuit functions correctly, operating the lamp after the predetermined time delay governed by the values of R2 and C1.

Transistors NKT277 and diode NKT249A30 are industrial types; suitable alternatives are the NKT274 and OA81 respectively.

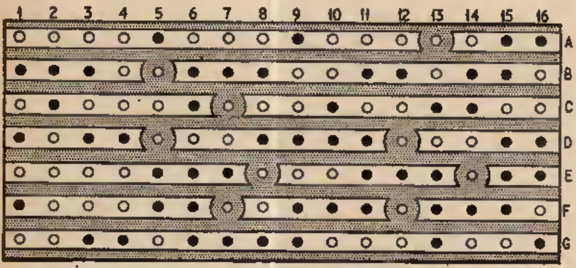


Fig. 2. Underside of the component board showing the copper strip breaks

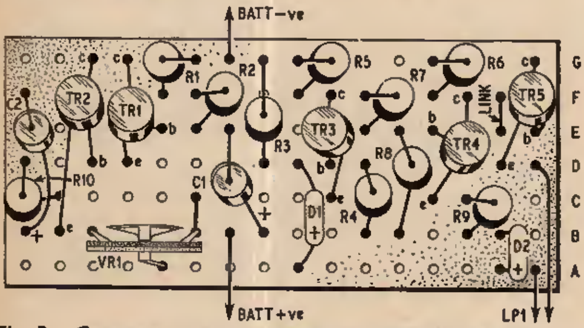


Fig. 3. Components are vertically mounted on top of the board

VARIATIONS

In the form shown in the circuit diagram, LP1 is normally off, but comes on after a predetermined time delay. If it is required that LP1 should be normally on instead, and switch off after the time delay, break the connection between TR5 base and TR4 collector and reconnect TR5 base to TR3 collector. If required, LP1 can be replaced by a 6 volt relay of resistance greater than 120 ohms; if the relay resistance is greater than 1000 ohms, D2 can be omitted from the circuit.

If longer or shorter time delays are required than are available with the circuit as shown, they can be obtained by increasing or decreasing the value of C1. If consistent time constant values are required, non-electrolytic capacitors should be used in place of C1 and C2, but at high values these capacitors will be rather more bulky.

USING THE UNIT

To set the unit initially to give an arbitrary time constant, set VR1 to near zero output and connect the supply. As soon as the required time period has elapsed, advance the arm of VR1 until the lamp comes on; final adjustment should be made by trial and error.

If electrolytic timing capacitors are used, considerable timing errors may be obtained between the first and all subsequent cycles in a series. This trouble is not usually experienced with non-electrolytic capacitors with a paper dielectric.

COMPONENTS . . .

Resistors

R1	82kΩ
R2	820kΩ
R3	47kΩ
R4	3·3kΩ
R5	5·6kΩ
R6	5·6kΩ
R7	22kΩ
R8	10kΩ
R9	470Ω
R10	33kΩ

All 10%, ½ watt carbon

Potentiometer

VR1 5kΩ preset skeleton miniature

Capacitors

C1 16μF elect. 15V } (see text)
C2 50μF elect. 12V

Transistors

TR1, 2, 3, 4, 5 NKT277 or NKT274 (5 off) (Newmarket)

Diodes

D1 NKT 249A30 (Newmarket) or OA81 (Mullard)
D2 OA200 (Mullard)

Battery

BY1 9 volt type PP3

Lamp or Relay

LP1 6V 40mA (see text)

Miscellaneous

Sample piece of Veroboard
Battery connectors
P.V.C. covered wire

After completing each cycle, C1 and C2 should be discharged through a low resistance of about 100 ohms.

With the component values shown in the circuit diagram, the unit will give time delays in the range of 2½ to 25 seconds with good reliability. There may be some variation in the long term accuracy of the timing cycles with large changes in operating temperatures.

If the value of C1 is increased to give a longer time constant, the value of C2 should also be increased in proportion.

This circuit can be used in many applications but for accurate timing (for photographic processing) use a non-electrolytic capacitor for C1. ★

5

EXPERIMENTS in LOGIC DESIGN

by S. T. ANDREWS

LAST month's article concluded with the development of a practical logic diagram for the Q register. We continue now with the development of the 0/1 discriminator in a similar manner.

THE 0/1 DISCRIMINATOR

The 0/1 discriminator can take several forms. In brief, the requirements are as follows: it is set so that, whenever a "test-Q" pulse is applied to the Q register, a pulse leaves the discriminator on a 1 wire if the test pulse finds a 1, or on a separate 0 wire if the tested bit is a 0. A 1 is represented in this equipment as a voltage pulse and a 0 as the absence of a pulse, if a 1 is present in a tested bit of Q a pulse will flow along the common output wire when the appropriate gate is opened.

This output pulse will be coincident with the input test pulse so the discriminator can be produced by the combination of two gates and a negator (or inverter), connected as in Fig. 5.1a. If, at any given "test-Q" pulse position, the bit in y is a 1 then a pulse will travel along the output wire and be AND-gated in F with the original test pulse, this will give an output on the 1 wire. At the same time the test pulse will be applied to the other gate E but there was an output from Q so this will be inverted by D to give no signal at the second input to E.

(Remember that a negator gives an output signal when there is no input, but no output when there is an input. The simplest form of negator or inverter circuit is shown in Fig. 5.1b. In the absence of an input the collector of TR1 is at the potential of the − 9 volt line, i.e. a "1" output. With a 1 input (i.e. a negative voltage) the output potential falls as the transistor conducts and so gives an 0 output.)

Thus there is no output on the 0 wire. If the test pulse fails to find a 1 there is no output from Q, so gate F will not operate and D will produce an output signal. This will be gated with the test pulse in E to give an output on the 0 wire.

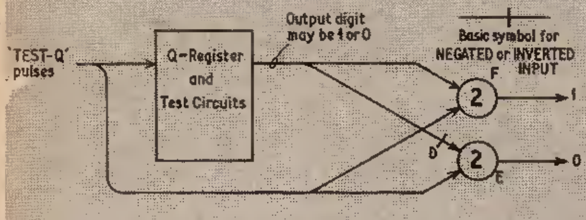


Fig. 5.1a. The 0/1 discriminator

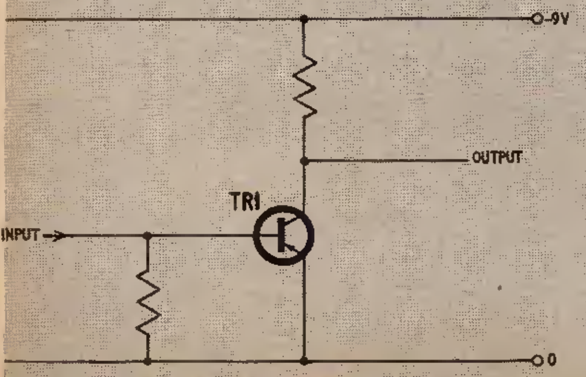


Fig. 5.1b. Simple negator or inverter circuit

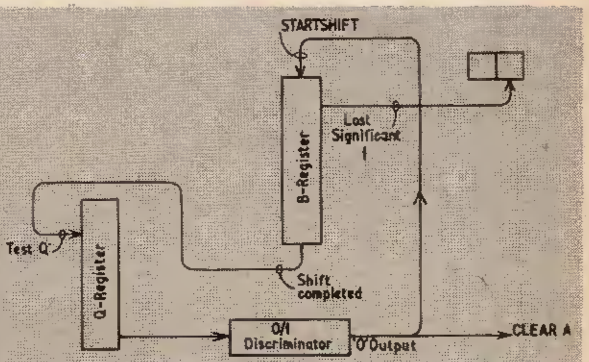


Fig. 5.2. Required logical system when the discriminator finds a 0

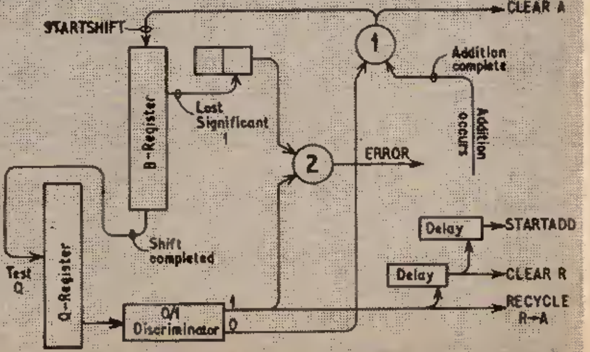
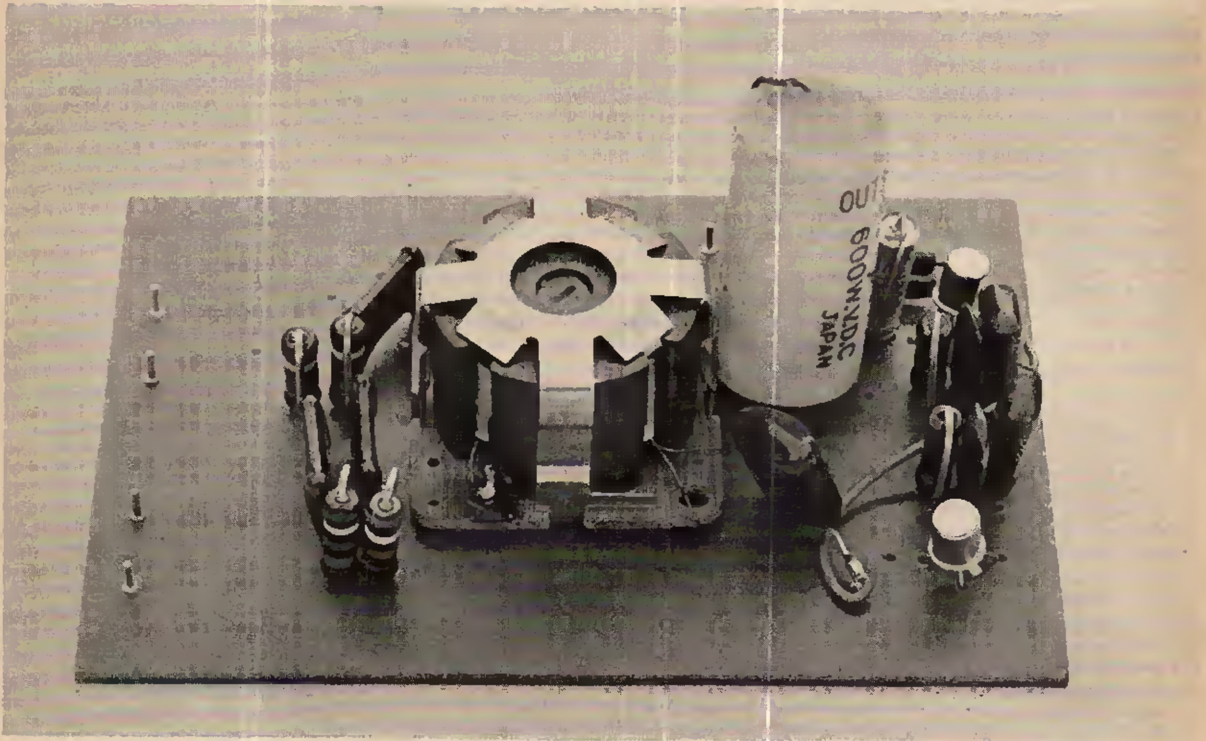


Fig. 5.3. Complete logical system associated with the Q-register, discriminator, etc.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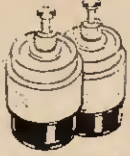

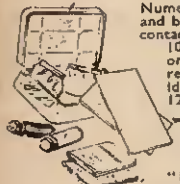


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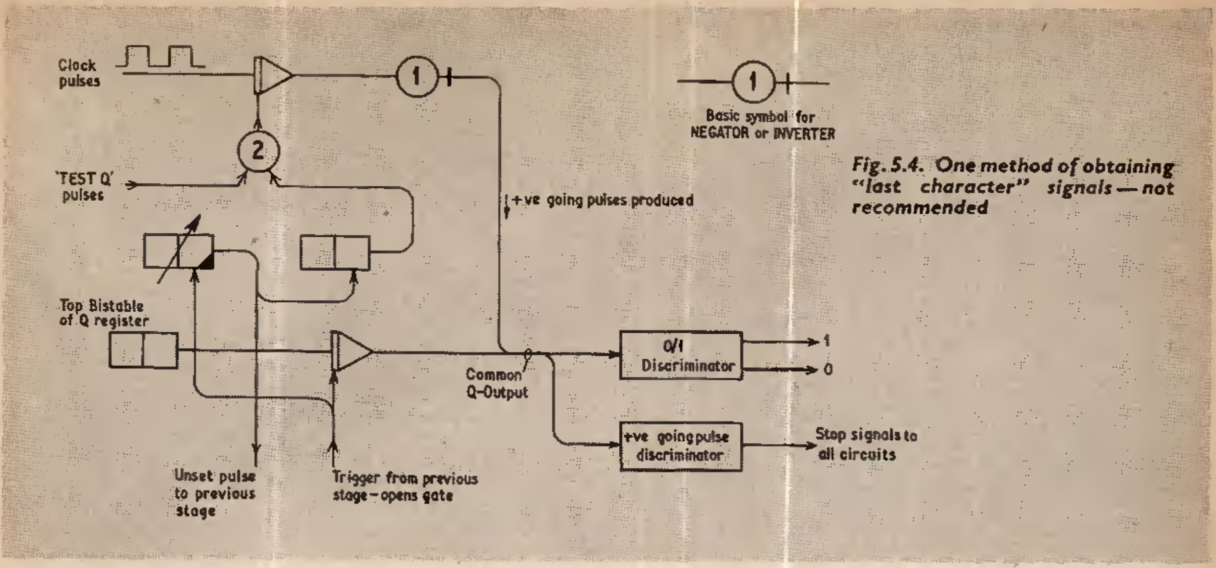

Fig. 5.4. One method of obtaining "last character" signals—not recommended

Linking the circuits of Figs. 4.5 and 5.1 gives the complete system for testing Q bit by bit and discriminating between 0's and 1's contained in each bit.

The flow diagram of Fig. 4.4 shows what happens after each test of Q. If the bit is a 0, A is cleared and B is shifted up one place, the usual check being made to see if a 1 is lost—if this does happen a bistable is set. These two events can be made to happen simultaneously since they are independent and this saves a little time. The shift takes a lot longer than the clearing of A and when the shift is complete a "shift completed" pulse leaves the shift network (see Fig. 3.3—August) and this is used to start testing the next bit of Q. One logical set-up which will do this is given in Fig. 5.2.

If the discriminator brings up a·1 then the events are slightly more complex. From the flow diagram it is seen that an output on the 1 wire will, successively, recycle the content of R to A, clear R and then add A + B to give a new value of R. After this it enters the part of the loop taken when a 0 is found so A is cleared, B is shifted and the next bit of Q is tested. Fig. 5.3 shows the complete output logic from the discriminator, for both 0's and 1's, the action is seen to correspond with the process described above.

COMPLETE MULTIPLICATION NETWORK

Fig. 5.3, together with the shifting circuits and Q-testing circuitry, forms almost the entire multiplication network. To complete the system two small additional sections are required, (1) an input section which, when triggered, causes the operands to be written into B and Q and causes the loop to be entered for the first time, (2) an output section which senses when all the bits in Q have been tested and then causes the loop to be left, the answer in R to be printed, and the whole process terminated.

The "start" circuits are easy enough. The input pulse causes the operands to be written into the appropriate registers and, after a suitable delay, opens the output gate of the first bit of Q. This automatically causes the loop to be entered and it then continues by itself until the test circuits in Q find a " last character" signal.

This "last character" signal, which must be made to end the calculation, can be done in a number of ways. One technique opens a gate as before, on arrival of the last "test-Q" pulse, but instead of having a bit of Q as input to the gate it has the normal clock pulse signal. The output from the gate is inverted completely, i.e. it is turned into a series of positive-going pulses which are not normally found anywhere in the machine. These pass into the common output line and are detected by a special type of discriminator set to detect positive-going signals. When it finds one it applies "stop" signals to all circuits and prints R. This method is shown in Fig. 5.4. It is a cumbersome method and although the principle is all right it is not really wise to introduce a new type of pulse for this purpose only.

A much better method uses the clock pulses gated as before, but instead of passing them into the common output line it passes them directly to the "stop" circuits. Thus the last bit of Q is tested in the usual way and the delay unit and bistable are set as if there was another bit to be tested. However the next "test-Q" pulse opens a gate as usual but this, unlike all previous ones, passes clock pulses instead of a digit, and these clock pulses stop all further action of the system. It is this method which will be used in our machine.

The complete logical system for multiplication, showing input/output circuits, Q-register with testing circuits, discriminator, and shifting elements, is given in Fig. 5.5. The only thing not shown is the adder since this is the same as the original type. The B register, however, is shown, as this is the shifted one.

DESCRIPTION OF LOGICAL DIAGRAM

The multiplication process is begun by applying a single pulse to the "start" point. This causes the operands to be sent to the input registers, x into B and y into Q, it also initiates a delay element, A. After a delay A produces a pulse which opens a gate and allows the digit stored in Q1, the least-significant bit, to enter the discriminator; through R the same pulse also enters the discriminator which is formed of elements D, E and F; finally, it sets a bistable, S, in the "test-Q" network. If Q1 held a 1 then the AND

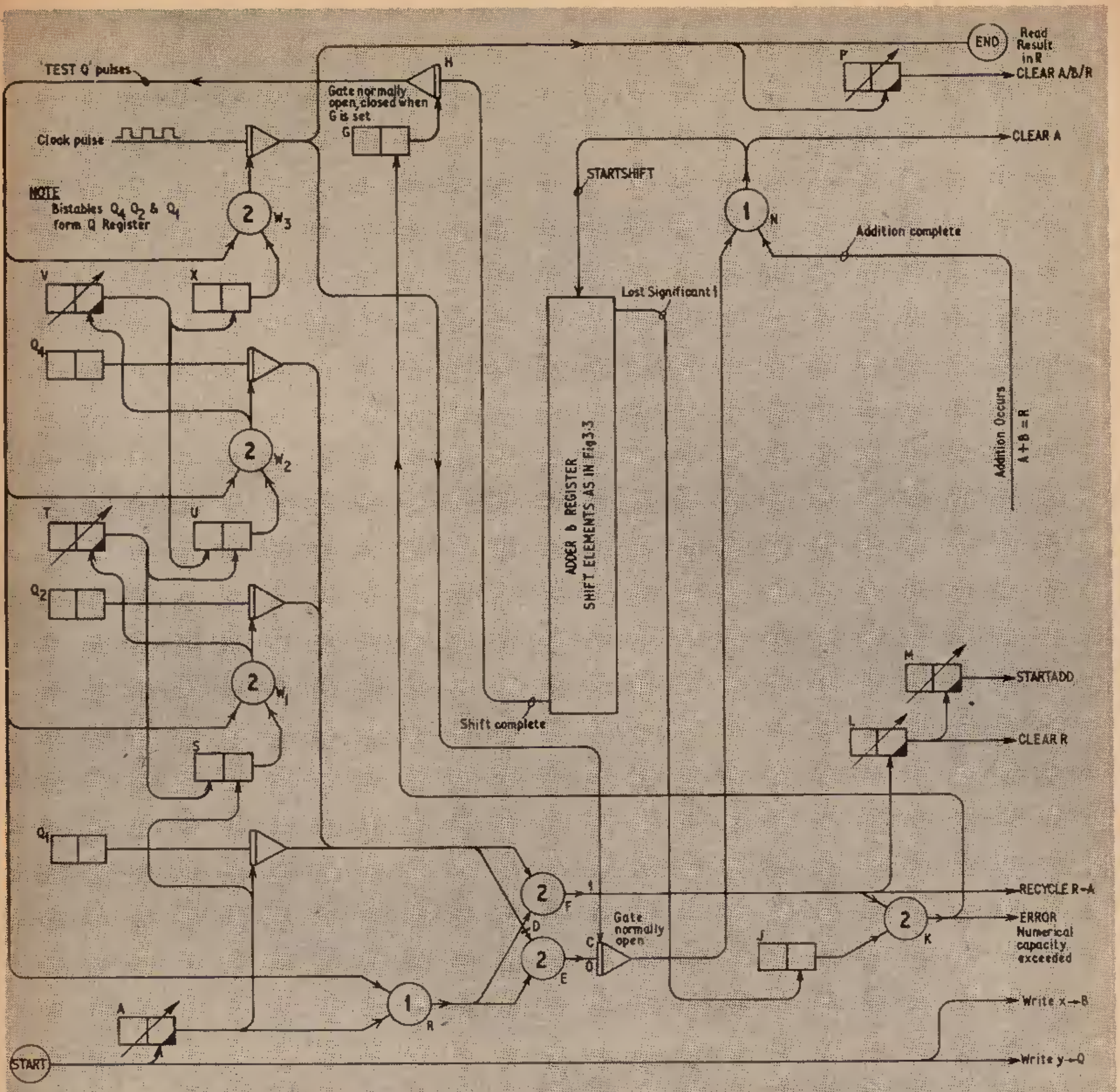

Fig. 5.5. Multiplication logical diagram—complete system

gate F will produce an output on the 1 wire, if Q1 held a 0 the output will be on the 0 wire from E.

Both these outputs from the discriminator are treated exactly as in Fig. 5.3: a 0 passes through the OR gate N, clears register A and initiates the upward shift of the number in register B. When this has been done a "shift completed" pulse is produced, passes through gate H which is normally open and becomes the first "test-Q" pulse. If the digit in Q1 was a 1 it would do three things, recycle R to A, then clear R after a delay given by element L, and then start addition after a further delay given by M.

When the addition is complete an appropriate pulse is sent to gate N where it enters the loop at the point reached directly if the discriminator test had found a 0. Thus A is cleared, the shift of B occurs and the next "test-Q" pulse is generated. This is applied, via gate H, to a series of AND gates, called W1, W2 . . . but only W1 will allow it to pass. This is because bistable S is already set and so only W1 has the necessary two inputs to give an output. The "test-Q" passed by W1 opens Q2 gate and this digit passes into the 0/1 discriminator together with the original test pulse. The action is the same as before, and depends on whether Q2 held a 0 or a 1.

The gating pulse which opened Q2 gate was also used to initiate another delay unit, T. In due course this unsets S and sets U instead, consequently when the next "test-Q" pulse arrives it will be gate W2 which will have two inputs, so it will be the digit in Q4 which gets tested next. The gating pulse from W2 also sets the next delay element, V, which unsets U and sets X.

After the bit in Q4 has been tested and the appropriate action taken, the next "test-Q" pulse is produced.

In the logical diagram of Fig. 5.5 the Q register is shown as having only three digit places, but this is only for simplicity and in practice there is no reasonable limit to the number which could be used. Each successive test pulse reads the content of the next bit of Q and the appropriate part of the loop is entered.

In Fig. 5.5 the fourth position, gated by a pulse from W3, produces the "last character" signal. In practice any number of stages could be inserted, each having the delay elements T/V and the bistables U/X, and a W gate. The extreme top position, however, must always be of the type shown in Fig. 5.5.

When the last test pulse arrives it passes through W3 only since, of the bistables, only X will be set at this time. The final gate will open but instead of one of the Q digits, the clock pulse is passed and used to initiate the terminating action for the multiplication. It closes gate C at once, otherwise the discriminator would assume that the test pulse was a normal one which had found a 0. Also it causes the final answer to read from R and, after a delay, causes all bistables to be cleared.

All this supposes that numerical capacity has not been exceeded, but the checking circuits are constantly monitoring this. If a significant 1 is lost by the shift bistable J is set and remains set until the end of the calculation or until it is manually reset. The output from J is AND-gated with the 1-output from the discriminator in gate K. If a 1 is found by the discriminator after J has been set then an error signal is generated and a set signal passed to bistable G. This closes gate H so that when the shift finishes the "test-Q" pulse is blocked and the calculation stopped.

This description shows how the flow diagram of Fig. 4.4 is converted into a logical diagram. The two loops, or rather the main loop with its entry point if the Q-bit was a 0, seen in Fig. 4.4, is transferred into a recognisable loop in Fig. 5.5. If the discriminator brings up a 1 the signal goes through elements L, M, the adder, gate N, the shift network, and then tests the next bit of Q, applying it to the discriminator to complete the loop. If the bit were a 0 it by-passes the first part of the loop and enters at gate N.

This is by no means the only way in which multiplication can be performed but it is a method which lends itself to reasonably easy explanation.

Division may be done by a somewhat similar process, but using repeated subtraction instead of addition. The division process will be considered next month, but it is somewhat more complex and it is advisable to get an idea of the multiplication technique before attempting to understand division. The design of such circuits is fascinating but it needs to be taken slowly and step by step.

Electronics, Instruments, Controls and Components

EXHIBITION and CONVENTION

This is the 21st Annual Exhibition and Convention to be held by the Institution of Electronics at Belle Vue, Manchester from 27 September to 1 October 1966.

Separate tickets issued for the exhibition and lectures may be obtained (free of charge) from the Exhibition Secretary, Institution of Electronics, 78 Shaw Road, Rochdale, Lancashire.

Catalogues giving full details in advance—price 4s 9d post free on receipt of addressed label.

SILICON PLANAR

SCREENED TRANSISTORS

Since the P.E. Transistor Guide booklet was prepared new types of transistor have been announced.

Neutralising circuits in television i.f. amplifiers are now made unnecessary by a new type of high-gain *npn* silicon planar transistor, known as Mullard TVistors.

In these devices an integrated screen formed by an additional layer diffused into the collector surface under the base contact bonding area reduces, by a factor of four, the high feedback capacitance inherent in planar construction.

Because of their very low feedback capacitance—only 150mpF (150×10^{-3}pF) for the BF167 and 230mpF for the BF173—and high forward transfer admittance, the integrated screen devices have a figure merit which is four times greater than that of a conventional planar transistor. This enables the designer to produce simple i.f. amplifiers with consistent performance and adequate gain.

INTEGRATED SCREENING

The integrated screen is a thin layer of *p*-type material diffused into the collector surface under the base contact bonding area. The junction between the *n*-type collector and the *p*-type screen acts, in effect, as a reverse biased diode.

Without the screen the base-collector bonding area capacitance would be in the region of 500mpF, to which must be added the junction capacitance of the actual transistor. In a typical BF167 with integrated screen, the total feedback capacitance is only 150mpF—less than a quarter of that of the unscreened device.

Due to the presence of the screen, the base contact area capacitance is transformed into additional capacitance at the input and output of the transistor. In i.f. amplifiers these capacitances do not cause any problems because they form part of the tuning capacitances of the bandpass filters.

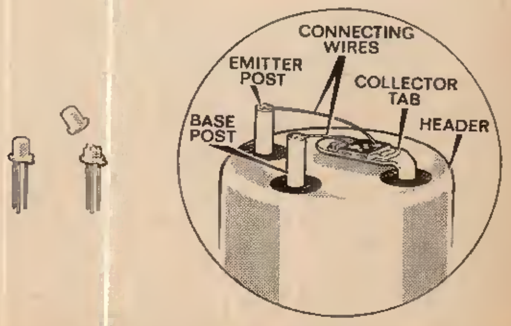

Fig. 1. Assembly of an "integrated screen" silicon planar transistor

BF167

The BF167 is intended for use as a television i.f. amplifier with forward gain control. Its characteristics provide consistent control of up to 60dB over the required current range. The i.f. gain-control characteristic is controlled in order to maintain consistency in the transfer of a.g.c. from the i.f. amplifier to the tuner.

BF173

The BF173 has a high dissipation (200mW at 45 degrees C), a low bottoming voltage (7V) and maintains its gain over a wide range of current levels. It is therefore particularly suitable for use in the final stage of the video i.f. amplifier where high output and good linearity are essential requirements.

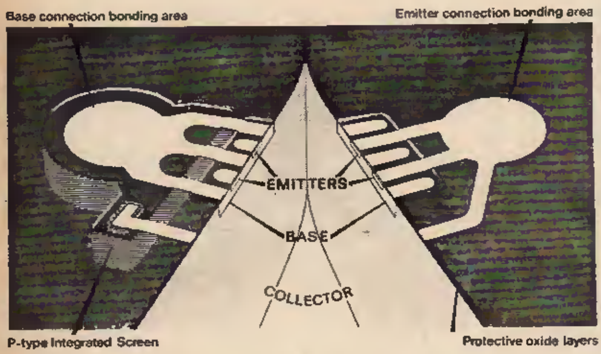

Fig. 2. Cut-away section showing the construction of the "integrated screen" silicon planar transistor

OTHER ENTERTAINMENT TYPES

Complementing the BF167 and BF173 are five other new silicon transistors specifically designed for domestic receivers.

BC107

Now rated for a collector voltage of 45V, the BC107 TVistor is particularly suitable for use in television timebase and oscillator stages. Its low bottoming voltage and high collector voltage make it especially suitable for driver applications.

BC108

The BC108 fulfils the wide range of functions in audio and other circuit applications where high gain and high impedance are required. It is also suitable for use in a.g.c. amplifiers, video output drivers and sync separator stages of television receivers. Audio applications include the pre-amplifier stages of radios and record-players.

BC109

A low-noise (2dB), high-gain transistor for the pre-amplifier stages of tape-recorders and high-quality audio equipment.

BF184

Features of the BF184 are its high d.c. current gain and high input impedance which results from its high f_T. It is therefore especially suitable for use in the gain controlled and final i.f. stages of car radios and mains or battery operated a.m./f.m. receivers.

The BF184 is also suitable for use in television sound i.f. amplifiers.

BF185

Because it maintains a very low noise figure over a wide range of source impedance the BF185 has an obvious application in the first stage of car radios and f.m. receivers. Its f_T also makes it suitable for use in the self-oscillating mixer stage of f.m. receivers. ★

Meetings . . .

SOCIETY OF ELECTRONIC AND RADIO TECHNICIANS

LONDON
Date: September 23
Title: The Development of the Loudspeaker Ralph West, B.Sc., M.I.E.R.E.
Time: 7 p.m.
Address: Institution of Electrical Engineers, Savoy Place, W.C.2.

INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY

LONDON
Date: September 26–28
Title: Advances In Electron Microscopy

Advance registration for attendance at this meeting is necessary. Details and application forms from: The Meetings Officer, 47 Belgrave Square, S.W.1.

ELMWOOD TAPE RECORDING AND RADIO CLUB

STOCKTON-ON-TEES
Date: September 17
Title: Festival Of Sound
Time: 10 a.m. to 8 p.m.
Address: Elmwood Community Centre, Hartburn, Stockton-on-Tees.

BRITISH AMATEUR ELECTRONICS CLUB

PENARTH
Date: September 15
Time: 7 p.m. to 9 p.m.
Address: Penarth Secondary School, St. Cyres Road, Penarth.

CONFERENCE AND EXHIBITION

LONDON
Date: October 11–12
Title: Ultrasonics For Industry 1966
Time: 9.45 a.m. to 5 p.m.
Address: St. Ermin's Hotel, Caxton Street, St. James's, S.W.1.

Applications to attend the conference should be made before September 23 to "Ultrasonics", Dorset House, Stamford Street, S.E.1.

COURSES: Preparation for MAY 1967 R.A.E.

LONDON
Days: Thursday Evenings
Subject: Theory and C.W.
Time: 7 p.m. to 10 p.m.
Address: Battersea Institute, Spencer Park Branch, Trinity Road, London, S.W.18.

Days: Wednesday Evenings
Subject: Theory Only—New Course
Time: 7.30 p.m. to 9.30 p.m.
Address: Catford and Lewisham Institute, Stainton Road (Brownhill Road), London, S.E.6.

Enrolment at both Institutes commences September 19.

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SPECIFICATION

Output Voltage
Output 1. 8–13·5 volts preset as required
2. 5–25 volts continuously variable

Current Capacity
Output 1. 150mA when both outputs are in use
2. 500mA maximum at 24 volts output

Voltage Stability
Less than 1 per cent change over the current range 10 to 500mA

Ripple
Less than 5mV r.m.s. total at 10 volts output

Output Voltage Indicator
Meter 1mA f.s.d. wired to read 0 to 10V or 0–25V (switched ranges)

Many power supply units available on the domestic market are of the type known as "sagging" supplies, i.e. the voltage across the load is inversely proportional with the current through it, neglecting the small power lost through heat dissipation.

The diagram in Fig. 1 shows the theoretical circuit of such a supply: V_1 is the e.m.f. produced by a d.c. supply with internal source resistance R. The current drawn by the load is I and the voltage or potential difference across the load is V_2.

Let us assume a voltage $V_1 = 20$ volts from the supply. Then under virtually zero current conditions V_2 will approximate to V_1 or 20 volts. If we assume that $R = 10$ ohms, then increase the current through R to 100mA, then we can say that

$$\begin{aligned} V_1 - V_2 &= I \times R \\ &= \frac{1}{10} \times 10 \\ &= 1 \text{ volt} \\ \text{therefore } V_2 &= V_1 - 1 \\ &= 20 - 1 \\ V_2 &= 19 \text{ volts.} \end{aligned}$$

If we were to assume that $I = 1$A, then

$$\begin{aligned} V_2 &= V_1 - (I \times R) \\ &= 20 - (1 \times 10) \\ &= 10 \text{ volts.} \end{aligned}$$

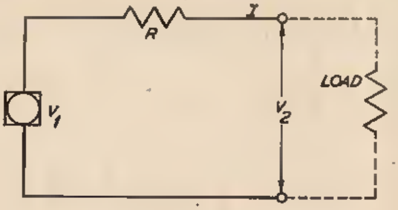


Fig. 1. Theoretical circuit of a d.c. power supply

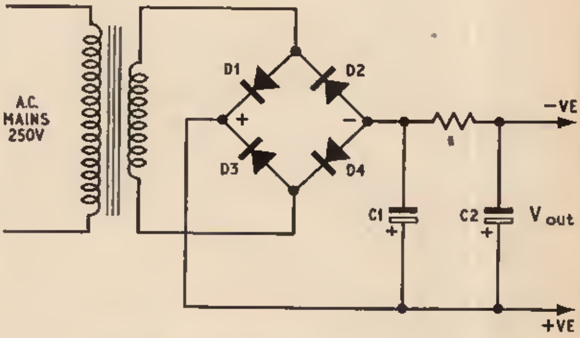
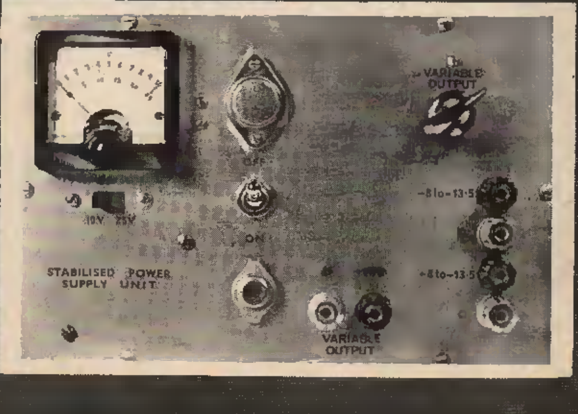


Fig. 2. Circuit diagram of a "sagging" power supply

TEST 3 GEAR TRIO



A "sagging" supply as shown in Fig. 2 is quite satisfactory in some cases, but as class B complementary output stages are being used more frequently in amplifier designs, considerable care has to be taken in ensuring that the maximum supply voltage does not exceed the working tolerances of the components, nor cause the quiescent current of the output stage to increase and thus endanger the temperature stability. At the low end of the voltage range the power supply should establish the correct working voltage at the required current.

It is difficult to attain both of these conditions and yet meet the smoothing requirements without reverting to the use of an expensive choke. The inclusion of such a choke will affect the voltage regulation and quite obviously will provide better smoothing.

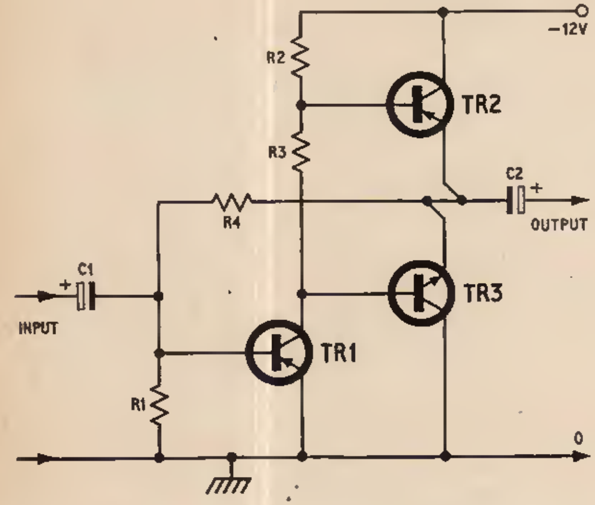


Fig. 3. Typical class B output stage

The current requirement for, say, a three watt amplifier can be considerably greater than one envisages at first sight. Considering the class B output stage shown in Fig. 3 if we assume a supply voltage of 12V and a speaker loading of 5 ohms the maximum peak-to-peak output voltage would be in the order of 11V and the peak output voltage would be 5·5V. The peak current under these conditions would be

$$I_{\text{peak}} = \frac{V_{\text{peak}}}{R_L} = \frac{5{\cdot}5}{5} = 1{\cdot}1\text{A}$$

where R_L is the load resistance.

This is indeed a heavy current and, as we can see from our earlier example, our sagging power supply would vary between approximately 10 and 20V. Under musical drive conditions the smoothing capacitor would help to smooth out some of these irregularities, but under sine wave conditions, which by necessity our testing procedure would have to encompass, the supply would not react as in the dynamic conditions.

The circuit of Fig. 4 shows a stabilised supply unit designed to give two outputs, one of which is continuously variable between 5 and 25V; the other, at any preset figure between 8 and 13·5V, is available on two pairs of terminals.

CIRCUIT DESCRIPTION

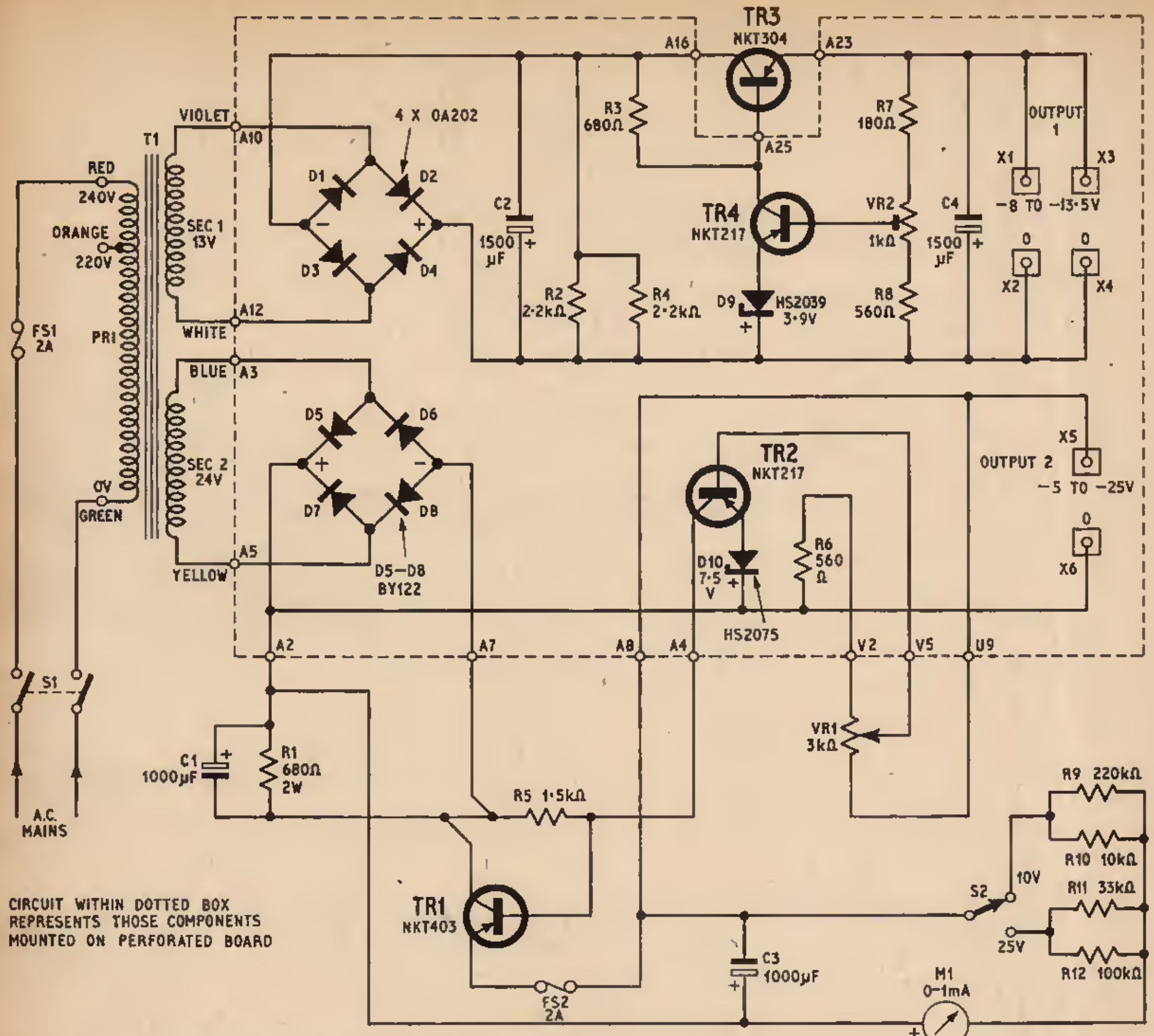
The basic circuit for each supply is the same with the exception of the monitor circuit M1, so a description of one section only (output 2) will be given. If we present the circuit in the more conventional form shown in Fig. 5, it takes the shape of the well-known d.c. coupled feedback pair with R_L representing the variable external load. As the load upon the circuit becomes heavier more current is drawn by R_L thus lowering the output voltage V_{out}.

This voltage is monitored by the base of TR2 and, as this biasing voltage decreases, so the current flowing through TR2 and R_L decreases. This causes the base

continued on page 725

R. HIRST

TRANSISTOR STABILISED POWER SUPPLY



CIRCUIT WITHIN DOTTED BOX
REPRESENTS THOSE COMPONENTS
MOUNTED ON PERFORATED BOARD

Fig. 4 (above). Complete circuit diagram of the transistor stabilised power supply

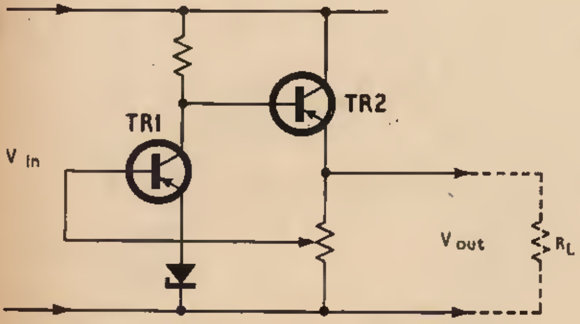


Fig. 5. Basic theoretical circuit of a d.c. supply stabiliser

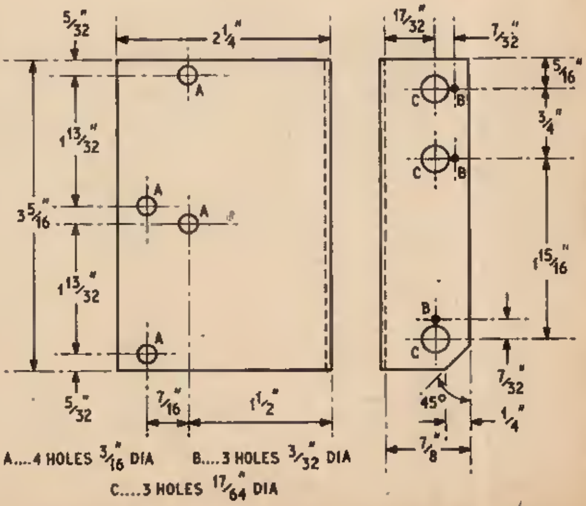


Fig. 6. Aluminium bracket for mounting C1 and C3

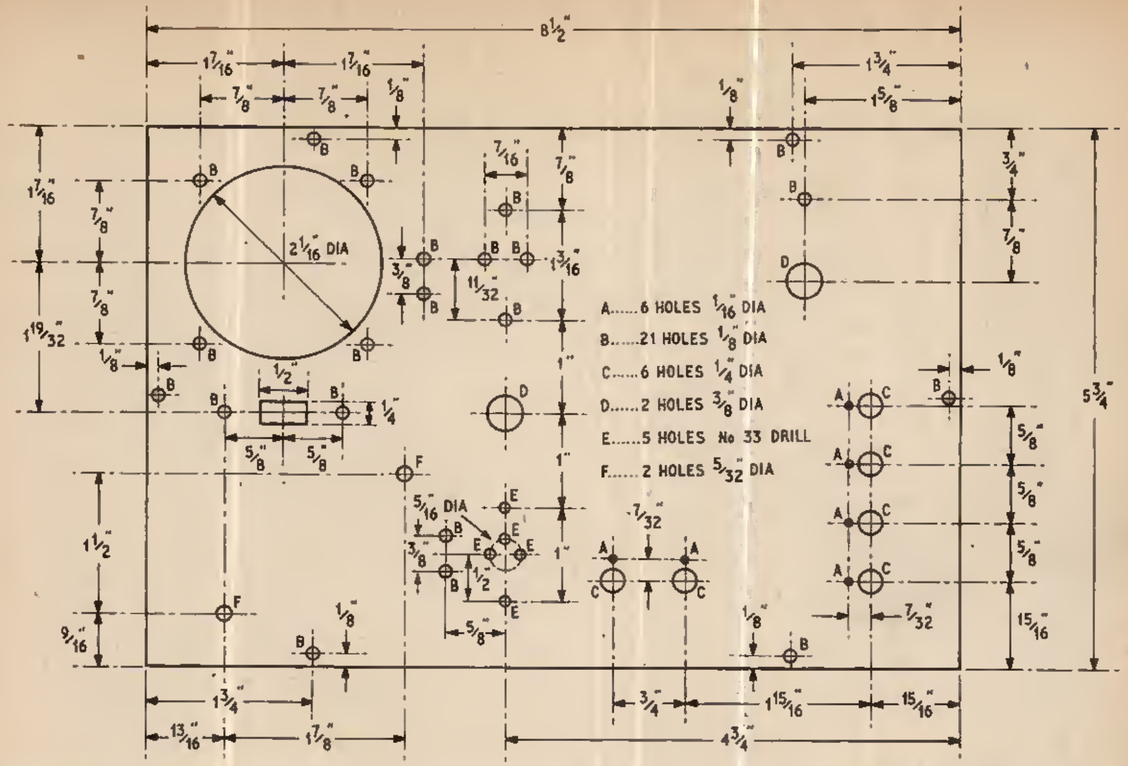


Fig. 7. Drilling details of the front panel. Holes C are for the terminals which also hold the component assembly board in position

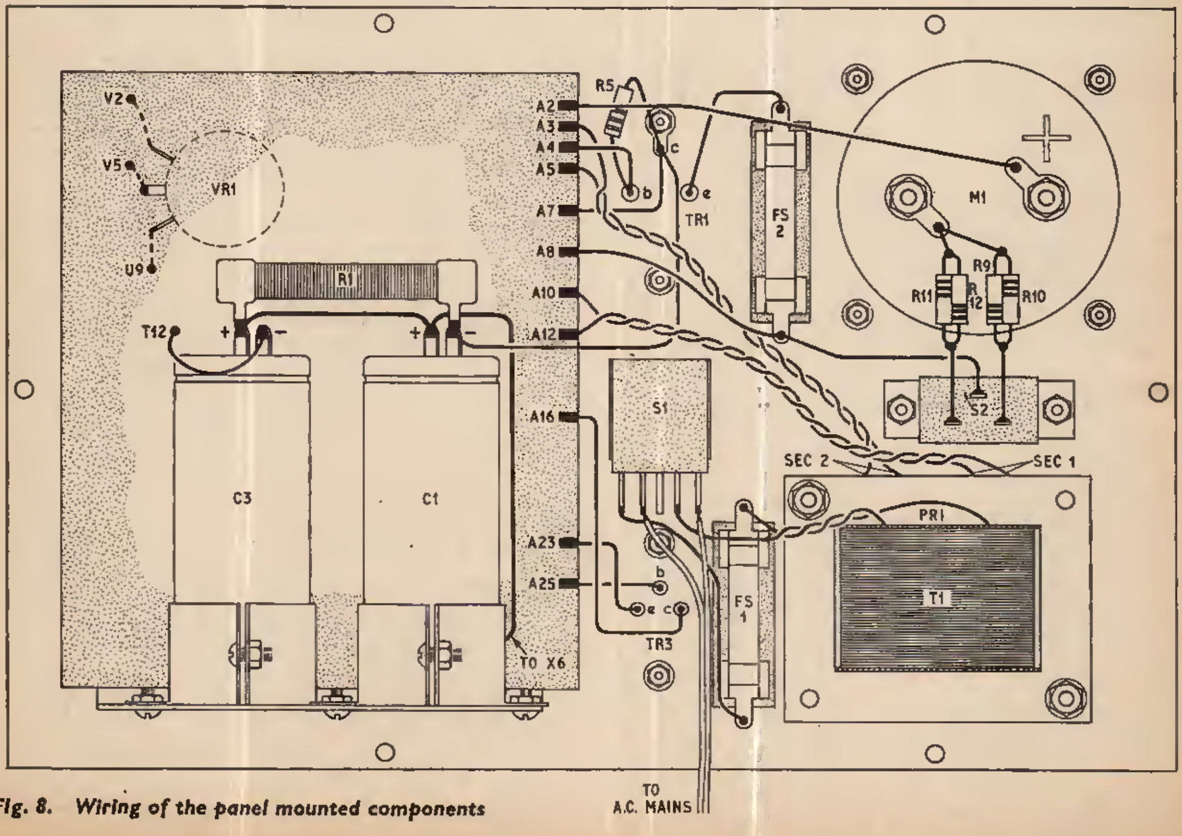


Fig. 8. Wiring of the panel mounted components

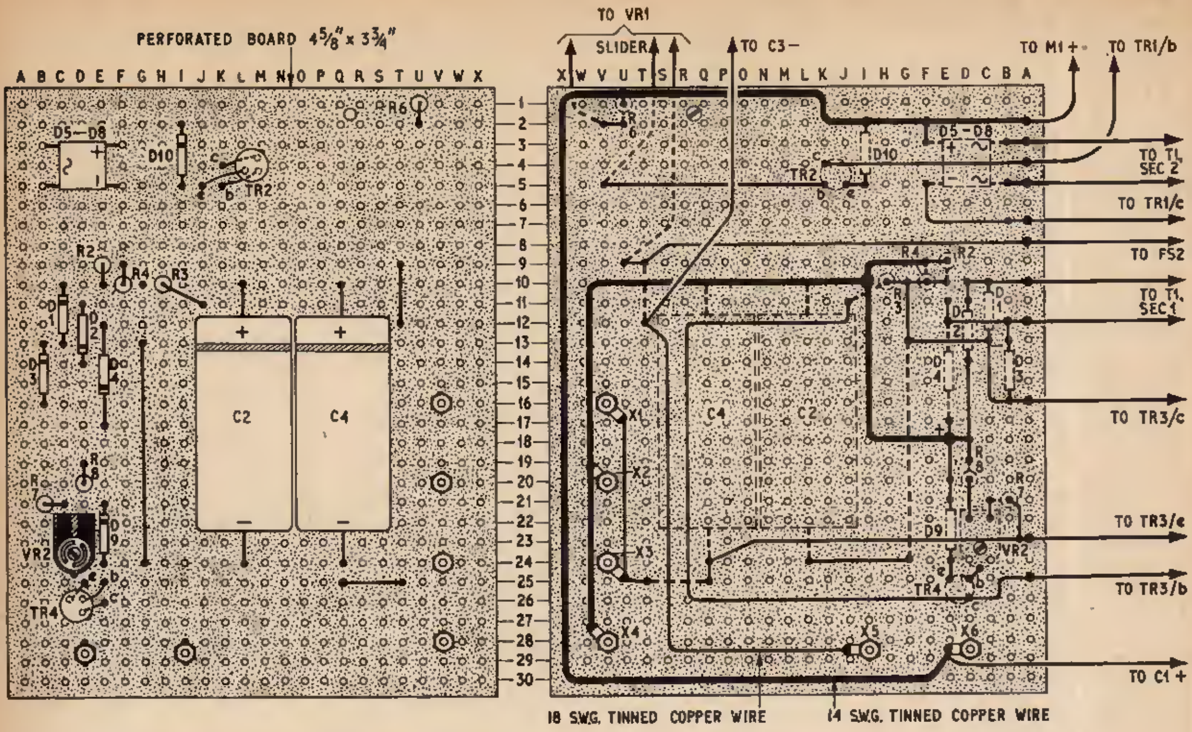


Fig. 9. Component layout and wiring on the perforated board with external connections

COMPONENTS . . .

Resistors

*R1	680 Ω	R7	180 Ω
R2	2·2k Ω	R8	560 Ω
R3	680 Ω	R9	220k Ω
R4	2·2k Ω	R10	10k Ω
R5	1·5k Ω	R11	33k Ω
R6	560 Ω	R12	100k Ω

All 10%, ½ watt carbon except
*R1 which is 2 watt wirewound

Potentiometers

VR1 3k Ω wirewound "Midget" type (Radiospares)
VR2 1k Ω linear carbon preset

Capacitors

C1 1,000μF elect. 50V
C2 1,500μF elect. 25V
C3 1,000μF elect. 50V
C4 1,500μF elect. 25V

Transformer

T1 Mains transformer. Pri. 0–220–240V; Sec. 1 13V 150mA; Sec. 2. 24V 500mA (Type LX 3391) (Belclere Company Ltd., 385 Cowley Road, Oxford.)

Transistors

TR1 NKT 403
TR2 NKT 217
TR3 NKT 304
TR4 NKT 217
} (Newmarket)

Diodes

D1–4 OA202 (4 off) (Mullard)
D5–8 BY122 bridge rectifier (1 off) (Mullard)
D9 3·9V Zener diode HS2039 (Hughes) *or* ZL3·9 (Brush)
D10 7·5V Zener diode HS2075 (Hughes) *or* ZL7·5 (Brush)

Switches

S1 Double pole, on-off, toggle
S2 Single pole, 2 way, slide switch

Meter

M1 0–1mA f.s.d.

Terminals

X1–6 4mm screw terminals (6 off) (Radiospares)

Fuse

FS1 2A cartridge fuse and holder
FS2 2A cartridge fuse and holder

Miscellaneous

Wooden box made up 8·5in × 5·75in × 2·5in
Aluminium panel 18 s.w.g. 8·5in × 5·75in
Perforated s.r.b.p. panel 0·15in hole matrix, 4·625in × 3·75in
14 and 18 s.w.g. tinned copper wire
P.V.C. covered flexible wire
Mounting pillars ⅜in long (4 off)
Mounting clips for C1 and C3 (1in dia.)

voltage of TR1 to become more negative; in consequence TR1 emitter voltage rises thus restoring the original condition.

Relating this to the circuit in Fig. 4, V_{in} is supplied by T1 SEC. 2 and rectified by D5–D8, which is a full wave bridge rectifier. In turn the output voltage is set by VR1 with D10 maintaining a constant reference voltage. The meter circuit is switched so that it will read the output on two ranges: 0–10V and 0–25V.

CONSTRUCTIONAL NOTES

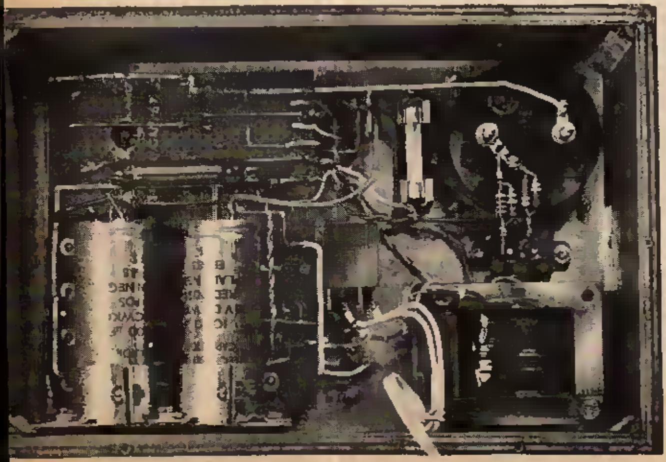
The large smoothing capacitors C1 and C3 are mounted on a bracket attached to the front panel by the same long screws used to hold the terminals and component board in position. Drilling details of this bracket are shown in Fig. 6.

The metal front panel is made from 18 s.w.g. aluminium and is cut out and drilled as shown in Fig. 7. The finish is obtained by liberally smearing the surface of the metal with oil and then rubbing with fine wire wool from left to right, endeavouring to maintain a relatively straight action. After 2 or 3 minutes the surface can be wiped dry with some soft cotton rag until all traces of oil are removed. This can be more easily attained by washing the surface of the front plate with a liquid detergent.

The front panel is used as the heat sink for the power output transistors. TR3 should be mounted with the mica washer between transistor and front panel. For better heat dissipation both sides of the mica washer should be smeared with silicon grease. The insulating bush should be used to isolate the mounting clamp from the front panel otherwise a short would most definitely lead to irrepairable damage to the power transistors. All the mounting accessories for TR3 may be obtained from the manufacturers (see components list).

The lettering was taken from a Letraset pack type K 10 and fixed to the surface according to the instructions on the pack. Finally the lettering can be very lightly brushed over with ordinary clear varnish. Under no circumstances must nail varnish or any acetate varnish be used otherwise the lettering will dissolve.

The meter was a Sifam type M 202, 1mA f.s.d., with an original scale of 0–10. One must be extremely careful when opening the meter case to apply the second scale. The mounting of this item and the other smoothing components is shown in Fig. 8 and all the rest of the components are mounted on the board as shown in Fig. 9.



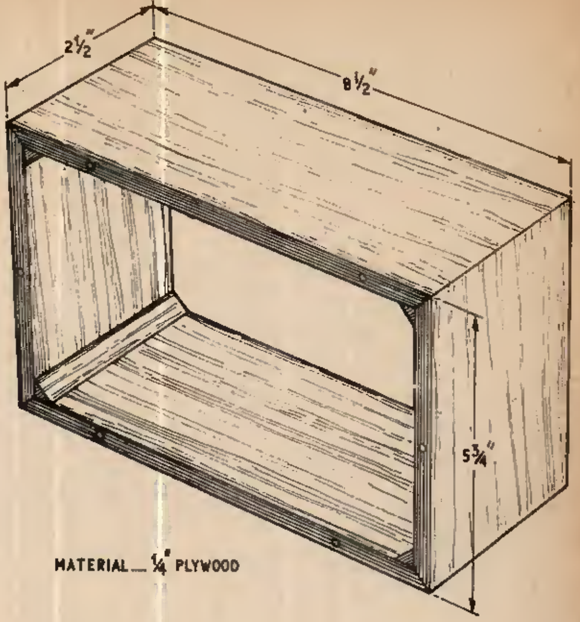


Fig. 10. Case construction showing corner fillets

All the wiring on the underside of the board should be made with 18 s.w.g. tinned copper wire with the exception of the earth return paths, that is the positive leads, and these should be wired with at least 14 s.w.g. tinned copper wire (see Fig. 9). All the joints should be mechanically sound prior to soldering.

Two separate outputs are provided from the preset supply to enable the user to run external test equipment such as a signal generator or a millivoltmeter.* With this in mind the mains transformer coding must be strictly adhered to so that the start and finish of both windings are connected as shown in Fig. 4. This will ensure that internal "earth" loops do not affect external measurements.

The case as can be seen from Fig. 10 was quite simply made from wood, glued and pinned and finally held rigid by the front panel, which is screwed in position.

SETTING UP

Prior to switching on a final check should be made to make sure that all connections have been made correctly. The variable supply should require no setting up at all. However the fixed supply can be set by adjusting VR2 so that the output reads 9V (or the voltage required) at the output terminals on the front of the panel. The variable supply will give up to 500 milliamps and the fixed supply up to about 200 milliamps.

Next month: Using the Test Gear Trio

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* If both millivoltmeter and signal generator (described in previous issues) are to be run from this supply simultaneously, it is advisable to make the common "earth" connection at the signal generator, leaving the millivoltmeter "earth" terminal floating.

ELECTRONORAMA

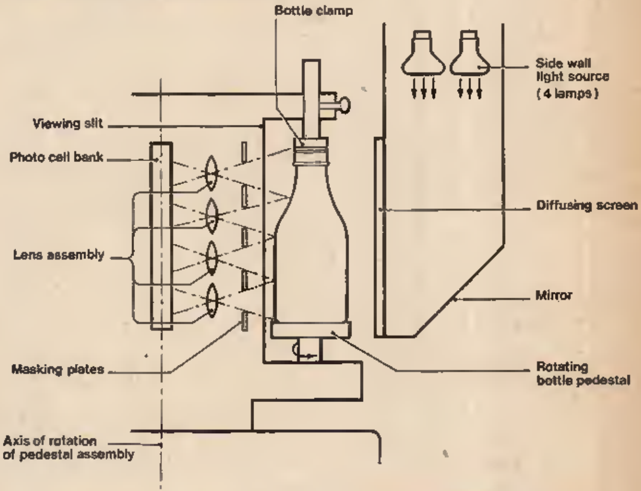
HIGHLIGHTS FROM THE CONTEMPORARY SCENE

Young Programmers

A MOBILE computer classroom, with an Elliott 903 computer, has been touring the country giving courses in computing for teachers.

Previously, boys at Westminster School, London, showed a high degree of aptitude and ability in programming during a voluntary "crash" course of only four days. Some of them are seen here (left) full of enthusiasm for what they are doing. It has been shown that young students are more adept in compiling a programme than many adults.

Seeing Through Glass



A NEW bottle inspection plant, claimed to be "the first in the world to check the entire bottle for foreign bodies and defects", has been successfully proved in trials.

An input conveyor feeds bottles to a star wheel, where the bottle is rotated and scrutinised by a scanning vertical slit of light. Further light beams are projected through the side of the bottle and are picked up by photo-electric cells.

The machine is able to detect cracks and dirty matter and store this information before the offending bottles are passed to the "reject" table. Up to 400 bottles per minute can be inspected by the machine which was developed by Fords (Finsbury) Ltd. of Bedford.

The drawing above shows schematically the optical system for horizontal scanning, via a vertical slit. On the left the bottles are conveyed to the inspection table (centre rear). In the foreground the memory trip circuits determine which bottles are to be directed to the "reject" table (right).

BEGINNERS start here... 24

An Instructional Series for the Newcomer to Electronics

This is the final article in our *Beginners Start Here* series, and in it we shall be considering the last link in our electronic chain—transducers. Actually, these devices form both the *last* and also the *first* links in an electronic system, as we have mentioned before.

We can classify transducers according to the nature of the stimulus to which they are sensitive (or, of course at the other end to the type of output they produce). Using this line of approach, we will start with the most common type of transducers—those sensitive to vibrations in a medium. These include all the microphones (sensitive to vibrations in the air), gramophone pick-ups (operated by mechanical vibrations of a stylus) and such devices as guitar pick-ups (working directly from the vibrating strings). All the reverse cases exist—converting the electrical signals to the corresponding vibrations.

The conversion of a mechanical vibration into the corresponding electrical oscillation, can be arranged by making use of the *magnetic effect*, in which a conductor moving in a magnetic field has a voltage induced across it or the *piezo-electric effect* in which mechanical twisting or bending sets up voltages across the faces of certain crystals such as quartz; or by the effects produced in *electrostatic induction*, in which voltages are changed by moving charged conductors relative to each other. Finally, a signal can be produced by making the stimulus alter the *electrical resistance* of a circuit.

ELECTRO-MAGNETIC TRANSDUCERS

The moving coil microphone is a direct example of the use of the magnetic effect. A light diaphragm is set vibrating by sound wave vibrations. A coil joined to the diaphragm is set in motion and because of the strong magnet surrounding the coil, voltages are induced across the ends of this coil. These signals can be amplified as required by electronic means.

A variation of this kind of transducer is the ribbon microphone, in which a single corrugated conductor acts as a diaphragm and "coil" all at once. The ribbon vibrates in the magnetic field, and voltages appear across it, as before.

In the so called *dynamic* microphone, an iron diaphragm moves in a magnetic field, altering the strength of the field through fixed coils. This alteration sets up voltages across the coils. A variation on this principle is found in guitar pick-ups in which the vibrating steel strings alter the magnetic field in sympathy through the pick-up coils, hence producing the electrical signal.

PIEZO-ELECTRIC TRANSDUCERS

Devices relying on the piezo-electric effect have become very common, and the crystal microphone is found in nearly all popular tape recorders, at amateur radio stations, and so on. It gives good quality signals and is inexpensive.

The diaphragm is directly joined to one corner of a fixed crystal, and any vibration flexes the crystal, thus producing a voltage across the electrodes.

Crystal units can be made to work at a very high frequency, even into the ultrasonic region, and they are found in hydrophones used under water in such systems as SONAR or ASDIC for detecting submarines or shoals of fish, by echoes of sound waves transmitted in the water.

Contact crystal transducers can be placed on engines and moving machinery to detect knocks, vibrations, and other tell-tale signals. The resultant readout on a cathode ray tube gives a great deal of information regarding troubles and faults. In a similar way, ultrasonic transducers can be used to detect flaws and cracks in structures, by actually transmitting high frequency sound waves into them, and detecting the echos and reflections with a contact microphone.

ELECTROSTATIC METHODS

The electrostatic or capacity microphone appears to be the simplest in construction, but in practice is difficult to make because the diaphragm must be light enough to follow the rapid vibration of the sound waves striking it, but stiff enough not to deflect and short circuit to the other electrode. The diaphragm must be very close to the other plate to produce a large enough change.

As its name implies, this device is a variable capacitor, whose capacity is altered by the sound wave moving one plate. The voltage across the terminals of this charged capacitor varies as the capacity changes, and the resultant signal can be fed to an amplifier. One interesting variation is found in the use of the capacity microphone directly in an r.f. oscillator, thus frequency modulating the output.

The capacity type transducer finds an important use in pressure gauges for such applications as measuring cylinder pressure changes in engines. The gauge is screwed into the cylinder, and the variations in pressure move the diaphragm, producing an electrical signal, which in turn can be employed to operate a pen recorder or cathode ray tube, after being amplified.

VARIABLE RESISTANCE TRANSDUCERS

One of the first microphones ever designed was the carbon type which is still used in the ordinary telephone.

This type of transducer makes use of the fact that pressure variations on packed carbon granules change the electrical resistance of the pack. Thus if a battery is connected in series with this device, the current flowing will vary in sympathy with the sound vibrations moving the diaphragm, which alters the pressure on the carbon granules behind it.

Except for the last, all the above mentioned devices are reversible and one comes across the moving coil loudspeaker, the crystal earpiece, and the ordinary (moving iron) earpiece. There are even ribbon and electrostatic loudspeakers. The crystal hydrophone is often used as the transmitting transducer as well as the receiver (by using pulse signals).

However, the construction of the transducers is often appropriate to their function, so that a moving coil microphone would not make an efficient loudspeaker, and loudspeakers are often too large for microphone use.

Notice the interesting exception of non-reversibility in the carbon microphone. Passing a signal current into it would warm it up, but no sound would be produced.

All the above devices can be immediately redesigned into the gramophone pick-up form, by connecting a stylus arm to the coil or crystal, etc. instead of the diaphragm. The common pick-ups are the crystal, moving coil, and moving iron types.

STRAIN GAUGES

It is only a short step from mechanical vibration to mechanical distortion. One is an "alternating" effect, the other a "direct" one.

Strain gauges are transducers which develop a signal proportional to the strain or distortion of the structure on which they are placed. The piezo crystal type can be used in this way, the strain bending the crystal to produce the output voltage.

Resistance strain gauges are the most common. The strain produces a change in the electrical resistance of a wire fixed to a flexible support, thus altering the current in a circuit. Such simple devices have been found to give valuable information concerning strains and stresses in bridges and other large constructional works, and in engines and other machinery.

LIGHT AND HEAT OPERATED DEVICES

Photocells come in a variety of forms, and we will mention two main types here. First the photoconductive kind, and then the photovoltaic type.

The photoconductive cells are usually made of semiconductor materials. Thus phototransistors give an output because light falling on the junctions produce current carriers and so the resistance alters. The resultant changes in current can be amplified and made to operate an output transducer, such as a door opener, relay, and so on. Another photoconductive cell is made of lead sulphide, and is extremely sensitive to infra-red rays falling upon it. Such cells are used in missiles and can guide them (via the electronics and rocket control operating transducers) onto the heat arising from cities hundreds of miles away, or onto the hot exhausts of aircraft at great distances. They are used to detect infra-red rays in scientific research.

The photovoltaic types include the selenium cells commonly used in photographic exposure meters. The light energy striking the active surface produces a voltage across the cell, and a microammeter reads the resultant current. In some cameras, the cell output controls the lens aperture directly, thus automatically adjusting the exposure for varying light conditions.

Solar cells are also of the photovoltaic type. So efficient are these silicon cells that they are used to generate power from the sunlight, in order to operate the electronics and control equipment in artificial satellites. A motor car has been driven along by the power generated from a "roof full" of solar cells. A number of cells are available on the amateur market and the current they produce will drive a small motor, or operate simple transistor radio receivers.

The thermocouple is an old device, and has been used as a thermometer for many years. This device converts thermal (heat) energy directly to electrical energy, as can be demonstrated by joining a piece of copper wire to iron wire and connecting up to a milliammeter. Heating the join with a match gives a deflection on the meter.

The thermocouple can be used as a sensing element in many temperature control systems used in modern industry, especially as modern semiconductor materials enable thermo-junctions to be made which are very sensitive.

FINALE

There are many specialised transducers for various jobs, and we will end this series with a note on just one or two. The rain sensor described in PRACTICAL ELECTRONICS, April 1966, is an example of a device especially designed for a given job. It is a form of resistive change transducer, the raindrops causing a sudden change in resistance which in turn produces the signal which operates the alarm system.

The Geiger counter tube is a good example of a specialised transducer producing electrical signals from specific input "stimuli". These devices can be designed to detect any atomic ray, or just alpha particles, beta rays or gamma rays on their own.

Our discussion of transducers is by no means exhaustive. But you, the reader, should now be able to understand reasonably well any device, and to appreciate its purpose and mode of action. You might even feel competent to design your own transducers for jobs around the house, plus the simple electronics to go with them. If so, this series of articles has served its purpose, and there is nothing left but to wish all the readers of *Beginners Start Here* all success in future projects. We are sure *you will never become bored with electronics!* ★

Fig. 24.1. The moving coil transducer has a cone shaped diaphragm which moves the coil relative to the magnet, as the cut-away diagram shows

Fig. 24.2. The ribbon moves in the magnetic field across the gap in the iron pole pieces. The design of the ribbon microphone makes it very directional for sound pick-up

Fig. 24.3. The simple dynamic type transducer has a soft iron diaphragm. In some types, the gap between diaphragm and magnet can be adjusted

Fig. 24.4. The crystal transducer is very light, in fact flimsy, in many cases. It can be made as small as ¼in dia.

Fig. 24.5. This cut-away view shows the principle of the capacity transducer. In practice, there are difficulties (see text). But this device has been used as a "proximity detector" by using external objects as the movable plate (such as a hand)

Fig. 24.6. The veteran of microphones is not noted for good quality performance, but it produces a large output signal. The carbon grains can usually be heard rattling if the device is shaken

Fig. 24.7. Resistance strain gauges are small paper bases (or special heat resistant material if appropriate) into which is fixed the wire element. They must be fixed to the structure properly, or inaccurate results are obtained

Fig. 24.8. A phototransistor. There is a maximum sensitivity direction, and a high output is obtained. The device has some amplification of its own

Fig. 24.9. Cadmium Sulphide cells have quite a wide resistance change from dark to ordinary daylight

Fig. 24.10. The specialised lead sulphide infra-red cell. It is about half the size of a little finger nail

Fig. 24.11. This simple experiment shows the thermoelectric effect in action. By using a known temperature bath, the meter can be calibrated in degrees

Fig. 24.12. The P.E. rain sensor as an example of a simple device doing a particular job

Fig. 24.13. The Geiger tube is a simple device, the atomic particles entering the end window ionise the gas inside, and a pulse of current flows through the tube. An electric counter records these pulses

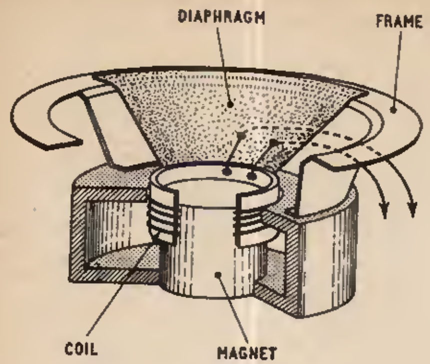


FIG. 24.1. MOVING COIL

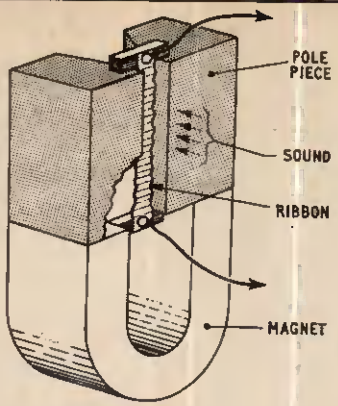


FIG. 24.2. RIBBON

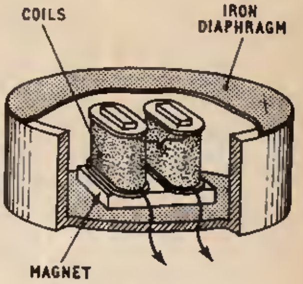


FIG. 24.3. DYNAMIC OR MOVING IRON

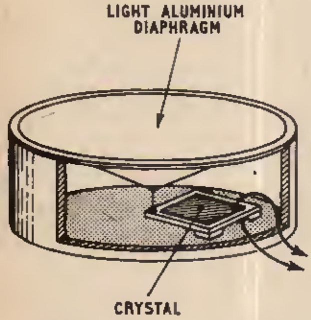


FIG. 24.4. CRYSTAL

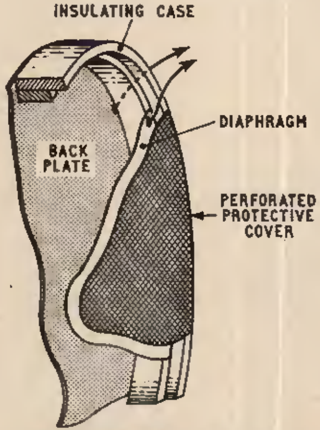


FIG. 24.5. ELECTROSTATIC OR CAPACITY

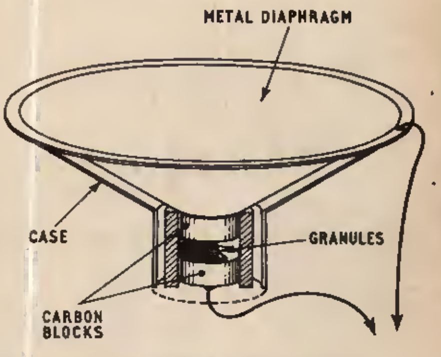


FIG. 24.6. CARBON MICROPHONE

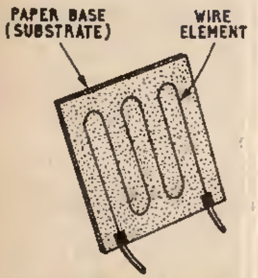


FIG. 24.7. RESISTANCE STRAIN GAUGE

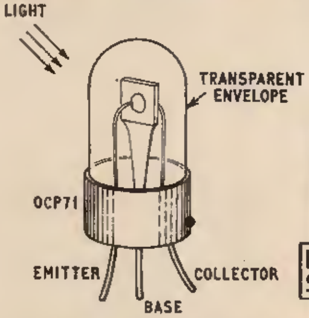


FIG. 24.8. PHOTOTRANSISTOR

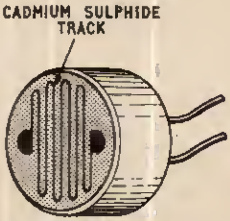


FIG. 24.9. CADMIUM SULPHIDE CELL

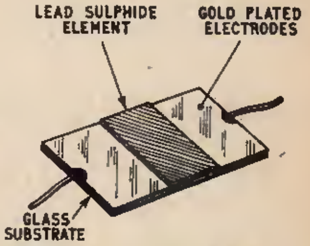


FIG. 24.10. LEAD SULPHIDE INFRA-RED CELL

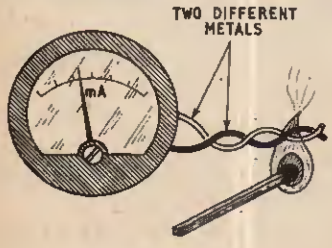


FIG. 24.11. THERMAL-COUPLE

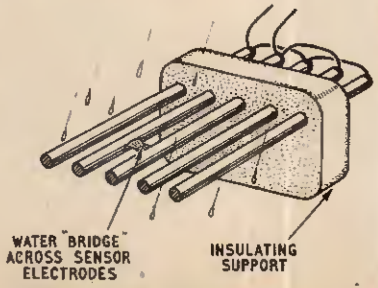


FIG. 24.12. RAIN SENSOR

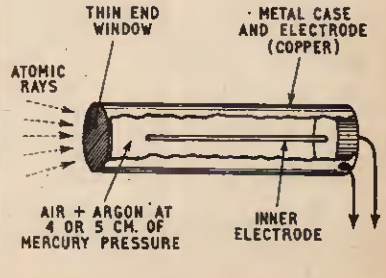
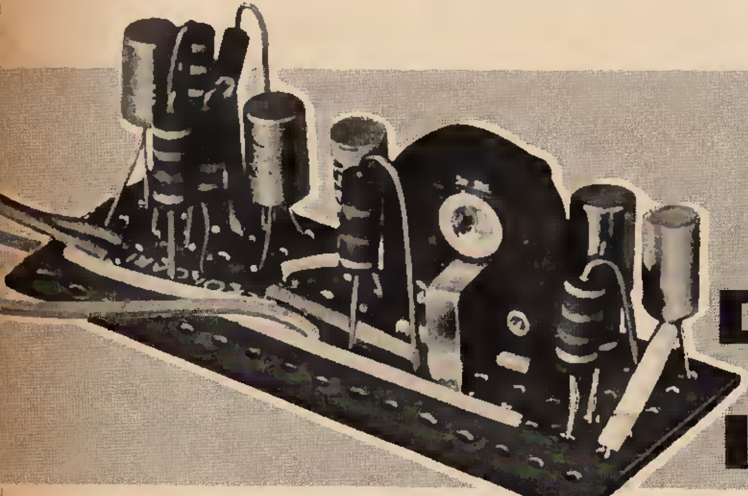


FIG. 24.13. GEIGER MULLER TUBE

M4 DIRECTION INDICATOR



THIS compact and simple little unit is specifically designed as an electronic flasher or turn indicator for use in a motor car or other vehicle with a 12 volt "positive earth" electrical system.

In essence, the unit consists of an electronic repetitive switch, which may be used to operate a small bulb, or a relay. Thus, the unit may be used to operate as a light flasher, a sound "bleeper", a transmitter keyer, or any other device which requires a repetitive automatic switch operating once per second.

ASTABLE MULTIVIBRATOR

The device consists basically of an astable multivibrator, TR1 and TR2, which is used to operate a common emitter amplifier TR3 (see Fig. 1). The external device (bulb or relay) acts as the collector load of TR3.

One disadvantage of the conventional astable multivibrator is that, as the circuit "switches state", a very large positive voltage, nearly equal in magnitude to the full supply voltage, is applied to one or other of the transistor base circuits. Thus, for satisfactory operation, the transistors used in the circuit must be rated to withstand twice the supply voltage.

Most general purpose germanium transistors have ratings of only 20 volts or so, and are thus not suitable for use as astable multivibrators operating from a 12 volt supply.

This is overcome in this circuit (Fig. 1) by inserting a resistor R6 in series with the supply to the multivibrator and decoupling the circuit with C1. Only a fraction of the 12 volt supply is fed to the astable circuit. Unfortunately, R6 and C1 form a time constant, with the result that, when the supply is initially connected to the unit, the voltage across the astable rises relatively slowly to its working voltage.

Hence the unit is slow to start. If we make a section of the two time constant circuits of the actual multivibrator common to each other, with VR1 acting as a common resistor, this trouble is largely offset, with the added advantage of making the operating frequency variable.

The collector of TR2 is directly coupled to the base of TR3 via R5, this resistor being selected to ensure that TR3 is driven hard on when TR2 is off. At the same time the emitter current of TR3 falls to a negligible value when TR2 is on. This action is assisted by D1, which artificially varies the emitter potential of TR3 to exaggerate the effect of the potential at TR2 collector. TR3 is, of course, operated from the full 12 volt supply.

CONSTRUCTION

Constructional details of the basic unit are shown in Figs. 2 and 3. Note that these details show the unit in a form suitable for bench demonstration purposes only, and, if the unit is to be mounted in a car, a slightly larger piece of Veroboard panel should be used, suitably drilled to provide mounting holes for the relay.

The layout of this circuit is in no way critical, and an alternative composition to that shown in Fig. 3 may be used, if preferred. Follow the constructional sequence as outlined in the introductory article.

VARIATIONS

The unit operates with a 1 : 1 mark/space (on/off) ratio. This ratio can be varied, within limits, by altering the values of C2 and C3 so that one is different from the other. The operating frequency of the unit can be increased by lowering the values of these two components, or lowered (to give operating cycles of several seconds) by increasing the values of C2 and C3.

The unit can be made to give two outputs from the collectors of TR1 and TR2: one off when the other is on, by suitably arranging relay contacts or, if no relay is used, by duplicating the TR3–D1–R5 circuit and connecting similarly to the collector of TR1.

COMPONENTS . . .

Resistors
R1 4·7kΩ
R2 4·7kΩ
R3 22kΩ
R4 22kΩ
R5 33kΩ
R6 1·8kΩ
All 10%, ¼ watt carbon

Potentiometer
VR1 150kΩ preset skeleton

Capacitors
C1 8μF elect. 15V
C2 8μF elect. 15V
C3 8μF elect. 15V

Transistors
TR1, 2, 3 NKT277 or NKT274 (3 off) (Newmarket)

Diode
D1 OA200 (Mullard)

Relay
RLA 700Ω type MH2 (Keyswitch Relays Ltd., 120-132 Cricklewood Lane, London, N.W.2)

Switch
S1 2-pole, 3 ways, toggle switch, centre-off

Battery
BY1 12V (car battery is used)

Lamps
LP1, LP2 Two pairs of 12V wing flashing indicators
LP3 12V Pilot dashboard lamp

Miscellaneous
Sample piece of Veroboard
Terminal block
P.V.C. covered wire

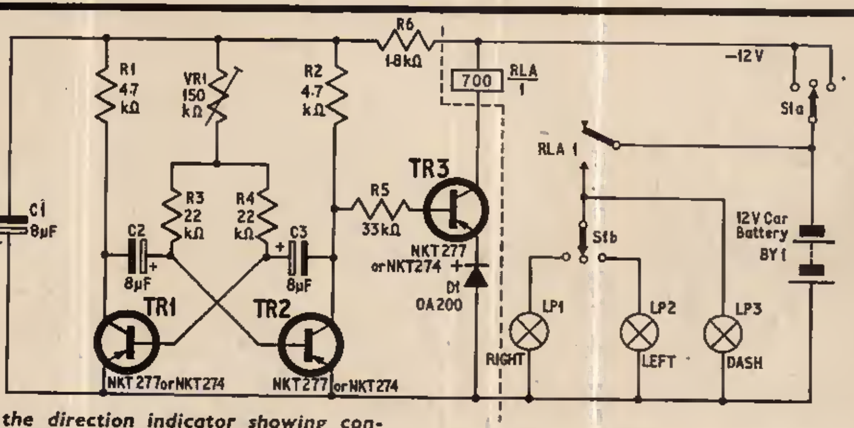


Fig. 1. Circuit of the direction indicator showing connections to the flasher lamps and 12V car battery. Components to the left of the dotted line are mounted on the Veroboard

APPLICATIONS OF THE UNIT

The unit is specifically designed to operate as a turn indicator, and the connections for this application are shown in Fig. 1. A single changeover relay, RLA, and a 2-pole, 3-way switch form the basis of the circuit. The switch is normally in the centre (off) position, but when it is turned to the left (or right) S1a connects the negative supply from the battery to the electronic unit.

Relay RLA operates, contact RLA1 opening and closing at the preset repetition rate, and alternatively connecting and disconnecting the left (or right) indicator bulb across the battery via S1b. At the same time the warning bulb in the dash-panel flashes on and off at the same repetition rate.

The repetition rate is set by VR1 (see Figs. 1 and 3), the most satisfactory speed being about 3 flashes per 2 seconds.

In other applications, the relay may be replaced by a bulb or by an alternative servo-mechanism. Care should be taken, however, to ensure that the emitter current of TR3 never exceeds 100mA, and preferably not more than 40mA.

If a relay is used, it should be designed to operate at 9 volts or less. If a 12 volt relay is used, its operation may be very slow and unreliable. ★

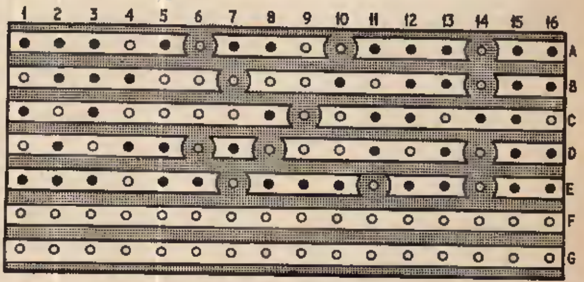


Fig. 2. Underside view of the component board

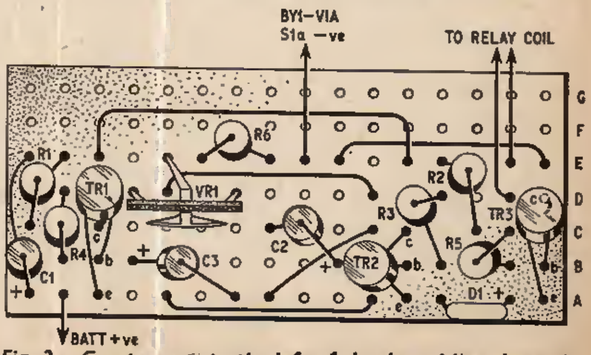


Fig. 3. Components to the left of the dotted line shown in Fig. 1 are assembled on this Veroboard

the 73 page

by Jack Hum
G5UM

Gregarious

Few recreational activities exhibit the degree of gregariousness—of flocking together—which is to be found among the followers of the hobby of amateur radio communication. What is more, this is a condition that prevails in almost every country of the world where the transmitting amateur is to be found.

There is never any need for a radio amateur visiting a strange city or country to feel lonely: a knock on the door of a fellow "ham" will gain him admission to a home he may never have seen before, having within it a person to whom he has possibly never talked over the air—indeed, who may not even speak his own language—yet who will at once make him welcome. To show one's QSL card, or to exhibit the magic diamond-shaped callsign badge in the lapel, is to be accepted anywhere in the world as a fellow radio amateur and kindred soul.

Of course, it is necessary to know *where* to knock! A copy of *The Callbook*, the radio man's directory of his confreres' callsigns and locations, is an indispensable part of the luggage. And as for not knowing much of the language of the person called upon, this turns out to be of little account in the light of the fact that English is the universal tongue on the amateur communication bands, and two radio amateurs of different nationalities will get along famously with its aid.

Field day contests are an important part of club activity. The picture shows G3OZH (left) and G2BLA resting after operating in a v.h.f. portable transmitting contest. Note the 145Mc/s aerial in the background

Paradox

Paradoxically, this self-generating, spontaneous feeling of world wide brotherhood to which something like half a million transmitting amateurs the world over are kin, begins with one solitary man in a lonely room. And it begins at a point in time well ahead of that never-to-be-forgotten day when his transmitting licence arrives. It begins, in fact, at that moment when the radio enthusiast, casting his mind over the infinite variety of practical electronics available for him to explore, decides that it is the short wave communication avenue down which he will travel, with possession of the coveted "ticket"—the transmitting permit—as the ultimate destination.

For months he will "go it alone", finding out via his classic communication receiver where the amateur bands are and how to master the special language that operators employ for efficient communication within them.

Then comes the moment when the lone listener feels a very considerable desire to want to belong to this friendly fraternity, to join up with the amateur radio group which his listening tells him exists in his own district.

How to do it?

By keeping his ears open! By noting the callsigns he overhears. By looking them up in *The Callbook* to see where their owners are located. Sooner or later someone local will be identified.

Over-Enthusiasm

When this stage is reached the thing to guard against is over-enthusiasm, and the urge to rush out and to call on the newly discovered local transmitting amateur, first to see a "real live station" in action and secondly to find out how to join up with the local radio group if one exists. Restraint is desirable. Friendly and gregarious though most radio amateurs are, not all of them welcome unannounced callers turning up at random intervals. Particularly to the consistent operator who puts out a prominent signal would it be embarrassing if every short wave listener in the area who heard him decided to look him up!

The proper and courteous thing to do is so obvious as to be stated here with some diffidence: write the man a letter, enclosing a stamped addressed envelope, and ask him when it will be convenient to pay him a visit.

Rarely is the recipient's reaction unfriendly. He will remember that *he* probably started his amateur radio career in just this way, that his local group can always do with an influx of new members with fresh thoughts and ideas to offer, and that this enquirer-out-of-the-blue may very well be a person worth fostering for the good of the amateur radio cause.

Two Other Courses

What if no local transmitting amateur is to be heard, how then is our lone-wolf short wave listener enthusiast to get into touch with similar like-minded people?

There are two things he can do—and it is a good plan to try both.

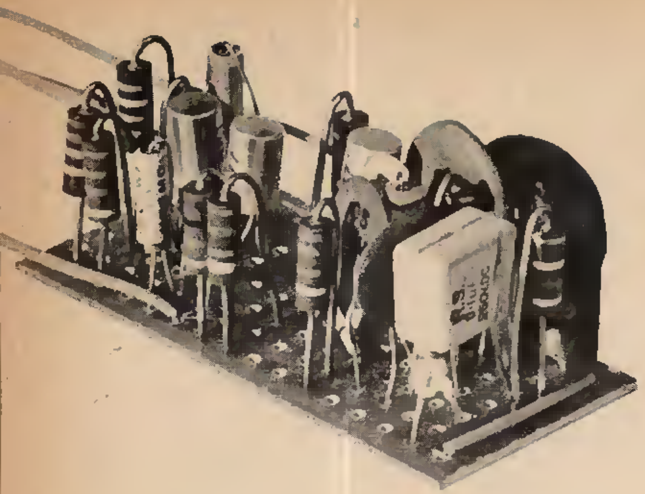
One of them is to invite the local newspaper to publish a paragraph—which it will probably be pleased to do, maybe in its gossip column—to the effect that moves are afoot to establish an amateur radio communications club locally, and that interested enthusiasts should get in touch with so-and-so at such-and-such address (meaning you). If a club already exists and you didn't know, you soon will!

Secondly, remembering that local groups of the Radio Society of Great Britain (which is the British transmitting amateurs' national body) flourish in scores of centres up and down the country, it is no bad thing to write to the R.S.G.B. (again enclosing that stamped addressed envelope) asking for the name of your Area Representative. Then get in touch with him—and the first steps towards enjoying amateur radio's gregariousness will have been taken.

NOTE.—The Callbook *referred to above is published by the R.S.G.B., 28, Little Russell Street, London W.C.1., price 6/-. It contains U.K. and Eire transmitting amateurs' callsigns, names and addresses.*

** It would be appreciated if readers writing in with queries arising from "The 73 Page" would accompany such enquiries with a stamped addressed envelope.

the 73



5

TUNED AMPLIFIER

At radio and high audio frequencies, an amplifier can be made frequency selective by incorporating an LC tuned circuit in the collector, base or emitter circuit of an amplifying stage. This is the normal practice, for example, in the r.f. and i.f. stages of a conventional radio receiver. Unfortunately, this system of tuning is not so practical at low audio frequencies, due to the very large values of inductance and capacitance that are necessary in the tuning system.

The tuned amplifier described here uses no inductive components, but nevertheless acts as a high-Q tuned amplifier, even at low audio frequencies. The unit is specifically designed to operate at 1kc/s, but its tuned frequency may be varied by altering the values of the tuned circuit components (see later section in this article).

FREQUENCY SELECTIVE ATTENUATOR

One method which may be used to make a conventional amplifier frequency selective is shown in Fig. 1a. Here, the amplifier gives a constant phase shift of 180 degrees, and has controlled negative feedback applied by feeding its output back to its input via a frequency selective attenuator. The attenuator gives maximum attenuation at the tuned frequency, and low attenuation to all other signals.

Thus, at the tuned frequency, only a negligible part of the output is fed back to the input, and the amplifier gain is high. At all other frequencies, a large part of the output is fed back 180 degrees out of phase to the input. The overall gain at these frequencies is thus considerably lower.

A number of RC circuits are suitable for use as the frequency sensitive attenuator, although some of them have their own particular disadvantages. The Wien bridge, for example, suffers from the fact that it is a four terminal network, making it difficult to mate the amplifier and the bridge circuits together.

The most useful RC circuit in this respect is the parallel or "twin-T" network, shown in Fig. 1b. This circuit is a three terminal equivalent of the Wien bridge. If the component ratios are as shown in the diagram, it shares the same general balance equation.

The twin-T network can be used on its own, if necessary, to act as a frequency rejecting circuit, wired in series with a conventional amplifier, to reject 50c/s pick-up from the mains, for example.

FINAL ARRANGEMENT

The full circuit diagram of the tuned amplifier is shown in Fig. 2. Here, the twin-T network is made up of R8, R9, R10, C4, C5, and C6.

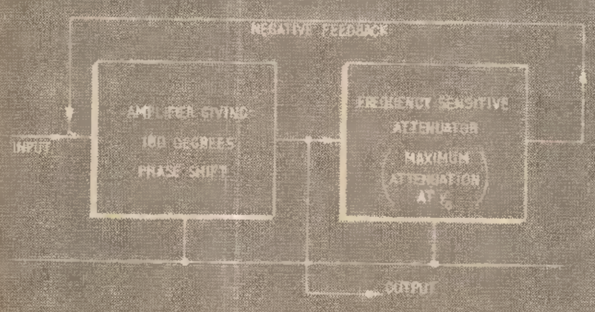


Fig. 1a. Block diagram of a frequency selective amplifier

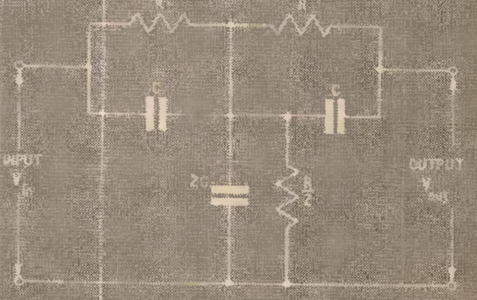


Fig. 1b. Twin-T filter network to reject a narrow band of frequencies

A conventional LC tuned circuit is normally required to have a fairly high value of Q, to give tuning "sharpness". Thus, the tuned amplifier is also required to exhibit high-Q tuning characteristics.

In this case, however, the Q is virtually independent of the characteristics of the filter network. In fact, Q is a function of the amplifier's voltage gain, the Q increasing with the gain. A very high gain circuit is thus essential if good results are to be obtained.

This high gain can be achieved in a number of ways: for example, cascade amplifiers could be used or a single transistor with controlled positive feedback, making the gain regenerative, could be utilised. One disadvantage with both of these systems is that the gain would tend to vary with temperature, resulting in possible instability of the amplifiers. If the gain became excessive, the unit would act as an oscillator.

In Fig. 2 this is overcome by connecting TR1 and TR2 together as a super-alpha pair, thus acting as a single transistor with a gain equal to the product of the two individual transistors. This very high gain stage is wired into a conventional common-emitter amplifier circuit, with R5 as the collector load and R6 as the emitter load.

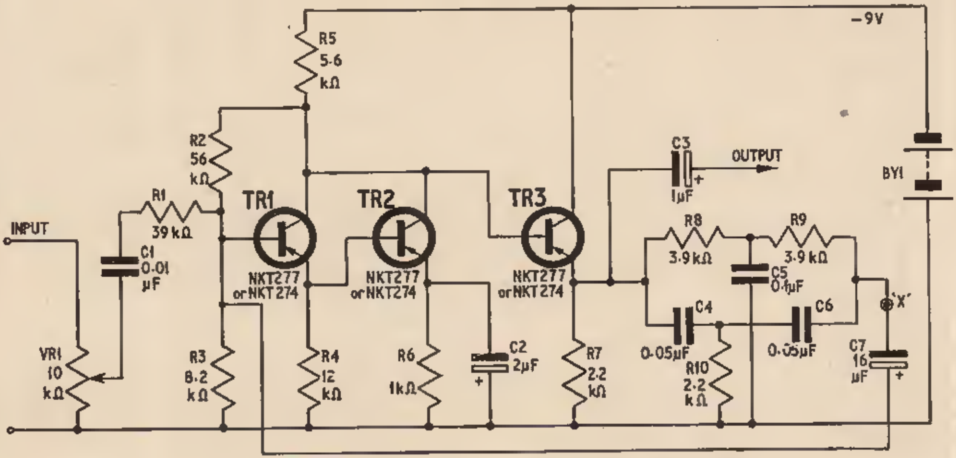


Fig. 2. Circuit diagram of the 1kc/s tuned amplifier

Base bias is provided via the voltage divider chain R2 and R3, but the "top" end of R2 is connected to the collectors of TR1 and TR2. Thus, controlled a.c. negative feedback is applied over the stage, tending to stabilise the gain of the amplifier.

Resistor R4 is used to compensate for the differing leakage currents that may occur between one transistor and another.

TWIN-T FILTER

The output of the collector of TR2 is directly coupled to the base of TR3, a conventional emitter follower. The low impedance output at TR3 emitter is coupled to the input of the twin-T filter circuit. The output of the unit is also taken from TR3 emitter, via C3. The output of the twin-T filter is fed, via C7, back to the base of TR1, to provide the selective negative feedback described above.

To prevent interaction between the feedback portion of the signal and the amplifier input signal, an isolating resistor R1 is connected in series between C1 and TR1 base. Since R1 and the input impedance of TR1 form a voltage divider, considerable attenuation takes place on the input signal, and the overall gain of the complete system is quite low.

The ability of the circuit to reject unwanted low frequency signals can be increased, as shown, by using a very low value of input capacitor C1 which forms a short time constant with R1.

A fairly low value of emitter decoupling capacitor C2 ensures that increased negative feedback will be applied to the amplifier and, at low frequencies, the gain will be reduced even more.

Additional moves to "tailor" the frequency response, such as wiring a low value capacitor in parallel with R5 to reduce the gain at high frequencies, are not recommended, as they generally tend to form a tuned filter with some other part of the circuit. This makes the final response of the unit unpredictable, and can result in its ability to pass two bands of frequencies.

VR1 is used as a simple input volume control, and may be omitted from the final unit, if preferred.

CONSTRUCTION

Construction of the unit is fairly simple, but the exact layout shown should be adhered to, as instability may possibly result with alternative layouts.

Use the sample piece of Veroboard and break the copper strips at the positions shown in Fig. 3.

Now wire up the unit as shown; do not wire the twin-T section just yet. When satisfied that it is wired correctly, carry out a functional check of the amplifier.

First, connect a low level input signal to the base of TR1 via a blocking capacitor, and check that the unit gives very high gain. The amplifier has a very low input impedance, and the input signal should be fed from a low impedance source to avoid misleading results. If satisfactory, connect the input to VR1 and check that the amplifier gain falls off as the input frequency is reduced below 1kc/s.

Finally, wire up the filter section of the circuit, and check that it functions as a sharply tuned amplifier at about 1kc/s. This can be done by connecting the output to an audio amplifier or a.c. voltmeter.

Transistors NKT277 are industrial types; the NKT274 is a suitable alternative.

VARIATIONS

The frequency of operation may be increased or decreased, as required, by altering the values of the twin-T circuit to conform with the frequency equation $f_0 = 1/(2\pi RC)$. The values of R8 and R9 should not be made greater than 4·7 kilohms each. If the frequency of operation is increased, lower the values of C4 and C6 to suit; if the frequency of operation is lowered, increase the values of these two components.

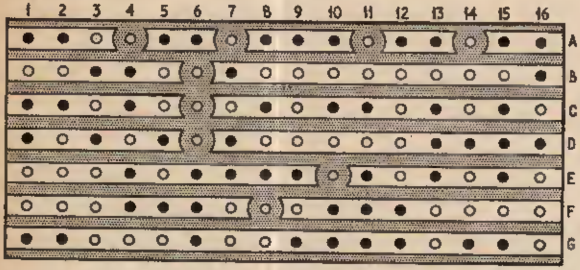


Fig. 3. Underside of the component assembly board

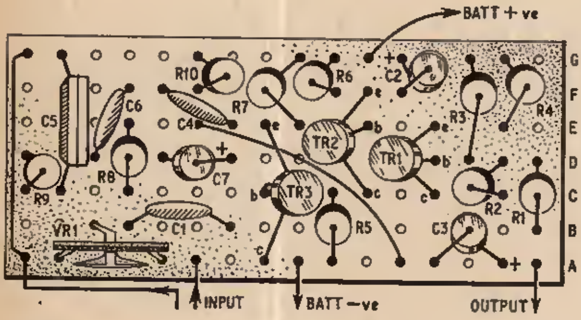


Fig. 4. Positions of components on the "top" of the board

The circuit can be made more, or less, complex as required by individual tastes. If only a low Q is needed TR1 and TR2 may be replaced by a single transistor, and the "top" end of R2 taken directly to the negative rail, its value being increased to 68 kilohms.

The circuit as shown in Fig. 2 may concede a small amount of frequency drift with changes in temperature. This can be eliminated by wiring a single transistor emitter follower, with its base coupled to the output of the twin-T via a capacitor (16μF), and its emitter coupled to the base of TR1 via C7 in the feedback circuit. The stage would be inserted at point "X" shown in Fig. 2.

The unit can be adapted to give variable tuning by replacing R8 and R9 with a twin gang 5 kilohm potentiometer, and providing switch selection of the remaining twin-T components.

The Q of the circuit can be varied by wiring a 100 kilohm potentiometer connected as a variable resistor with a 16μF capacitor in series, and connecting the combination between the base and collector of TR1.

USING THE UNIT

The unit may be used in a manner similar to an ordinary amplifier. If, however, the unit is built into a composite piece of equipment, some instability may be experienced, and the normal precautions should be taken to ensure that the negative supply rail is fully decoupled to a.c.

COMPONENTS . . .

Resistors

R1	39kΩ	R6	1kΩ
R2	56kΩ	R7	2·2kΩ
R3	8·2kΩ	R8	3·9kΩ
R4	12kΩ	R9	3·9kΩ
R5	5·6kΩ	R10	2·2kΩ

All 10%, $\frac{1}{4}$ watt carbon

Potentiometer

VR1 10kΩ preset skeleton miniature

Capacitors

C1	0·01μF disc ceramic 30V
C2	2μF elect. 15V
C3	1μF elect. 15V
C4	0·05μF disc ceramic 30V
C5	0·1μF polyester 250V
C6	0·05μF disc ceramic 30V
C7	16μF elect. 12V

Transistors

TR1, 2, 3 NKT277 *or* NKT274 (3 off) (Newmarket)

Battery

BY1 9 volts type PP3

Miscellaneous

Sample Veroboard
Battery connectors
P.V.C. covered wire

APPLICATIONS OF THE UNIT

The unit is ideal for use in the receiver section of a radio control system, it being far more reliable than a conventional reed, and giving far better frequency stability than a conventional pot core tuned amplifier.

Several units may be wired in parallel and fed from a common input, to give several different output frequencies, or two or more units may be wired in series to give very sharp tuning of a single frequency.

The unit may be used in a high quality a.c. bridge to reject the unwanted components of the detected signal.

It can also be used to operate a sound operated servo-mechanism. Using the same principle, two or more tuned amplifiers may be used to ensure that the servo operates only when a specific complex sound is received, i.e. the device operates as a sound actuated combination lock. ★

Origin

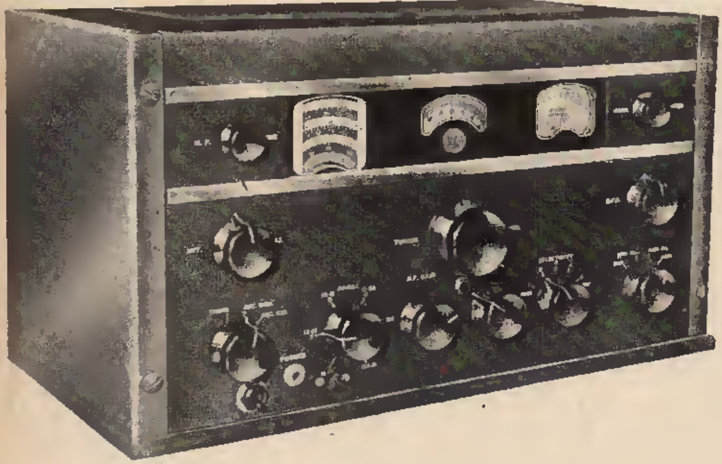
DURING the late war there existed an insatiable demand for ground station receivers for the multifarious jobs of point-to-point communication, air-to-ground reception, and intelligence monitoring. In the last stages of the war a receiver came into service which was regarded by delighted operators as representing the (then) ultimate for communication purposes. This was the AR88, which gave the impression from its ruggedness, the completeness of its electrical specification—and indeed for its beautiful appearance both inside and out—to have been developed almost regardless of cost. It is small wonder that, more than twenty years after its advent, it should still command a price in the region of £50.

As may be seen from the block diagram, the complement is very complete: there are two r.f. stages, three i.f., and an audio amplifier ahead of the output stage.

Waveranges Covered

Band 1	73 to 205kc/s
Band 2	195 to 550kc/s
Band 3	1,480 to 4,400kc/s
Band 4	4,250 to 12,150kc/s
Band 5	11,900 to 19,500kc/s
Band 6	19,000 to 30,500kc/s

(The LF version is quoted for the sake of completeness)



THE AR 88

Classic

Variants

Three versions of the AR88 are available, the basic model, the AR88D with output into a 600 ohm balanced line, and the AR88LF, with "long waves". In R.A.F. service these models were subjected to certain commonsense modifications that change them into the R1556, R1556A and R1556B respectively—but an AR88 by any other name remains as sleek. Use of the "LF" version confers the advantage of a standard frequency transmission in the form of the 200kc/s Light Programme transmission.

Basic Circuits

Two r.f. amplifiers, both	6SG7
Mixer	6SA7
Local oscillator	6J5
I.F. amplifier, three	6SG7
Detector, a.g.c., and noise limiter, two	6H6
C.W. oscillator	6J5
Audio amplifier	6SJ7
Output	6V6G or 6K6GT
Stabiliser	VR150/30
Mains rectifier	5Y3G

COMMENT: Throughout the circuit the AR88 employs 6·3 volt international octal valves of common types that should remain available for many years ahead.

COMMENT: What will be evident to the amateur short wave listener is the fact that all of the amateur h.f. allocations are included in the above ranges, not excepting the "Fourteen" and "Ten Metre" bands, often missing from classic communication receivers.

Intermediate Frequencies

Users intending to perform their own alignment should note that the i.f. in the AR88D is 455kc/s, but that in the AR88LF it is 735kc/s.

Power Requirements

A built-in power unit renders the AR88 operative on either low voltage American or standard British (190–260 volt) mains. It is possible to operate the receiver under portable conditions if 12 amp from a 6 volt accumulator can be tolerated: for this service a vibrator unit type M1–8319 is required.

Controls

The six controls ranged across the foot of the front panel are, from left to right:

Switch for "mains on", "transmit", "b.f.o. OFF" and "b.f.o. ON". In the "transmit" position the receiver is mute. In some modified models a separate "mains on" switch is added beneath this four-position rotary.

Frequency range switch, then r.f. gain and a.f. gain.

Selectivity Switch: selects a bandwidth of 16kc/s for good quality audio, and five other bandwidths of increasing sharpness.

Noise Limiter/A.G.C. A four-position switch which rotated clockwise gives:

1. A.G.C. and noise limiter out: for reception of c.w. under clear conditions;
2. A.G.C. out, noise limiter in: for reception of c.w. under interference conditions;
3. A.G.C. in, noise limiter in: for reception of 'phone under interference conditions;
4. A.G.C. out, noise limiter in: for 'phone reception in the clear.

We present this month the fourth article in our series, "Classic Communication Receivers". Intended as a guide to the prospective purchaser of a high performance receiver for use on the h.f. bands, this series gives the basic technical information he will need without delving too deeply into the circuitry. Readers should always make sure that a handbook or circuit diagram, at least, is supplied with any receiver purchased.

Dominating the front panel is the big tuning knob which gives mechanical bandspreading in the vernier tuning aperture immediately above it, and slow motion registering of frequency on the tuning dial to the left of it.

COMMENT: If at first glance the receiver front panel appears to bristle with controls, it is this profusion that gives the AR88 its flexibility, performance, and reputation. The tuning mechanism, a precision instrument designed to withstand rigorous operation, permits a signal once received on the logging scale to be found later with great accuracy. What is more, its featherlight operation takes the effort out of long periods of operation.

Full value from the AR88 comes only after experience has been gained with all of the controls, particularly the selectivity filter and the noise limiter.

Other Features

Few samples of the AR88 come without the tuning meter—though a few may have the maker's name plate in that position. The meter is a sensitive and extremely useful adjunct to reception.

The crystal filter, too, which can be set up by the operator to peak up c.w. signals to within 500c/s bandwidth is an indispensable tool in today's reception conditions. As for the noise limiter, using a 6H6 double diode, this is so famous due to its effectiveness as to have been adapted in many other designs of receiver.

COMMUNICATION RECEIVERS

Above this last control is the c.w. pitch control. Above that again is the noise limiter control, which selects the percentage of noise limitation required.

Remaining "occasional" controls are a simple variable tone control top left, with the aerial alignment control (the "peaker upper") below.

Final Comment

The AR88 has just one drawback: it is big (19¼in square by 11in high) and heavy (about 100lb). Although enthusiasts have been known to take it out on radio field-days, this is not an operation to be recommended.

For many years the AR88 has held its price better than most classic communication receivers, but this might ease with the advent of modern sets with their very different circuitry from the oldsters—and then some *really* bargain "Eighty Eights" may appear!

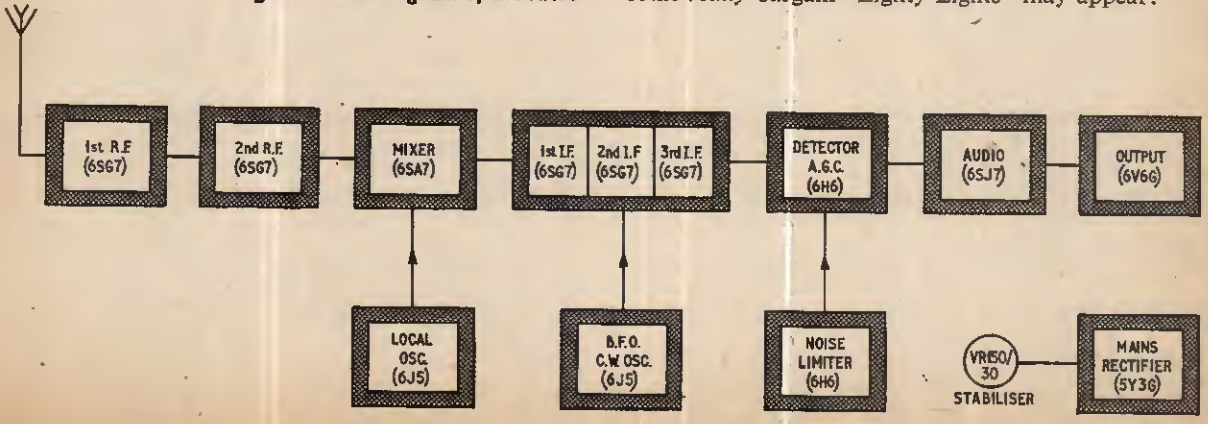


Fig. 1. Block diagram of the AR88

by G. WAREHAM

SHORT CUTS in CALCULATION

PART TWO—THE POWER OF TEN

There can be nothing more off-putting to the uninitiated than the profusion of "powers of ten" like 10^{-3}, 10^{9}, $10^{\frac{1}{2}}$ and so on, which occurs in mathematical formulae. Engineers and designers find such expressions of immense value when dealing with very large or very small numbers, particularly when using a slide rule instead of a set of log tables.

Effort is saved in several ways. The first is in writing down numbers which would otherwise have a lot of noughts in them. Instead of 2,000,000, write 2×10^{6}. A positive index number indicates the number of noughts. Instead of 0·00007, write 7×10^{-5}. A negative index number indicates the number of decimal places.

Most of the quantities which occur in radio engineering contain only a few significant figures with a number of noughts or decimal places. One virtue of writing them with index numbers if that one is much less likely to make an error in the decimal factor. Indices come into their own when numbers have to be multiplied or divided. For instance:

$$\frac{5 \times 10^{12} \times 12 \times 10^{9}}{3 \times 10^{9} \times 2 \times 10^{11}} = 100$$

There are only two rules, both very simple. The rules are:

(*a*) To multiply, add the indices,
(*b*) To divide, subtract the indices.

Thus, $5 \times 10^{12} \times 12 \times 10^{9} = 60 \times 10^{21}$
and $3 \times 10^{9} \times 2 \times 10^{11} = 6 \times 10^{20}$

Therefore $\dfrac{60 \times 10^{21}}{6 \times 10^{20}} = 10 \times 10^{1} = 100$

which is all very nice provided you know that $10^{1} = 10$. This may not be obvious, but it does come into a logical sequence:

$$\begin{aligned} 10 \times 10 \times 10 &= 10^{3} \\ 10 \times 10 &= 10^{2} \\ 10 &= 10^{1} \\ 1 &= 10^{0} \\ 1/10 &= 10^{-1} \\ 1/100 &= 10^{-2} \\ 1/1000 &= 10^{-3} \end{aligned}$$

and so on.

One other general point, before we get down to a practical example. Applying the first rule,

$$10^{\frac{1}{2}} \times 10^{\frac{1}{2}} = 10^{1} = 10.$$

but $\sqrt{10} \times \sqrt{10}$ is also equal to 10.

So $10^{\frac{1}{2}} = \sqrt{10}$.

In other words, raising something to the "power of one half" is just another way of saying: take its square root. Similarly $10^{\frac{1}{3}}$ is a cube root, $10^{\frac{1}{4}}$ a fourth root and so on.

RESONANT FREQUENCY

What is the resonant frequency of a tuned circuit composed of a 150pF capacitor and a 80μH inductor? The formula $f_0 = 1/(2\pi\sqrt{LC})$ assumes that L is in henries and C in farads. Indices come in useful here in avoiding noughts, because 1μH $= 10^{-6}$H and 1pF $= 10^{-12}$F. We write 150×10^{-12}F for 150pF and 80×10^{-6}H for 80μH, and forget about decimals. Also $\sqrt{(LC)} = (LC)^{\frac{1}{2}}$, which is just another way of writing the square root. Putting all this into our formula gives:

$$\begin{aligned} f_0 &= \frac{1}{2\pi\,(150 \times 10^{-12} \times 80 \times 10^{-6})^{\frac{1}{2}}} \\ &= \frac{1}{2\pi\,(12{,}000 \times 10^{-18})^{\frac{1}{2}}} \end{aligned}$$

At this point we exercise a little ingenuity so that we end up with a number whose square root is easy to find.

Let's deal with the index number first. Taking the square root is simplicity itself. You simply divide the *index* by two. Thus the square root of 10^{2} is 10^{1}; i.e. $\sqrt{100} = 10$. In the same way, the square root of 10^{-18} is 10^{-9}. We get into deeper water if the index is odd. For example, the square root of 10^{3} is $10^{1\cdot5}$, the value of which is not obvious. It's not as difficult as it looks, as we'll see in a moment, but for the time being note that, when taking square roots, we should if possible arrange for our indices to be even.

In the present example, 10^{-18} has an even index, but we still have to deal with 12,000, a rather large number. We could reduce it like this:

$$12{,}000 \times 10^{-18} = 12 \times 10^{3} \times 10^{-18} = 12 \times 10^{-15},$$

but this gives us an odd index and $\sqrt{12}$, which most of

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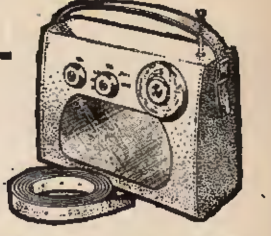

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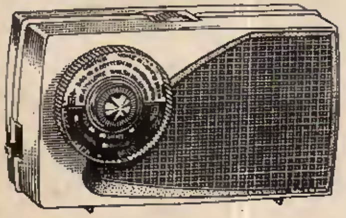

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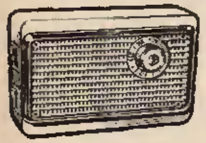

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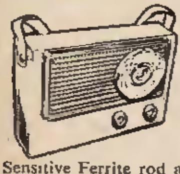

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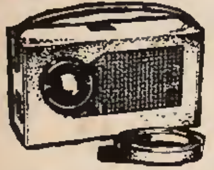

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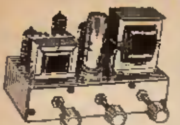

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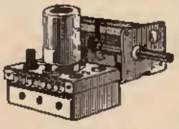

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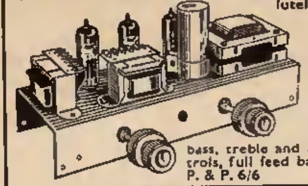

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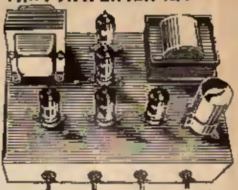

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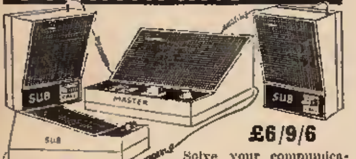

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us don't carry around in our heads. Try again:

$$12{,}000 \times 10^{-18} = 120 \times 10^{2} \times 10^{-18} = 120 \times 10^{-16}.$$

We now have an even index, and we have to find $\sqrt{120}$, which is so near to 11 that we can tolerate the small error.

To return to our formula, we can now write:

$$f_0 = \frac{1}{2\pi \times 11 \times 10^{-8}}\ \text{c/s}.$$

and since $1/10^{-8} = 10^0/10^{-8} = 10^8$,

$$f_0 = \frac{10^8}{2\pi \times 11}\ \text{c/s}$$

A negative index denominator equals a positive index numerator. To get the answer in Mc/s, divide by 1 million or 10^6:

$$f_0 = \frac{10^2}{2\pi \times 11} = \frac{100}{2\pi \times 11}\ \text{Mc/s}$$
$$= \frac{100}{6{\cdot}28 \times 11} = \frac{100}{69{\cdot}08}\ \text{Mc/s}$$

Which is approximately $100/70 = 1{\cdot}4$Mc/s.

Now let us see how we can deal with fractional indices. The commonest one is $10^{0\cdot5} = 10^{\frac{1}{2}} = \sqrt{10}$. This comes into other indices; e.g. $\sqrt{10^9} = 10^{4\cdot5} = 10^4 \times 10^{0\cdot5} = 10^4\ \sqrt{10}$. The thing to remember is that $\sqrt{10} = 3{\cdot}16$. This can sometimes be taken as 3 without serious loss of accuracy, and it can sometimes be cancelled out against π if this happens to come on the other side of the fraction ($\pi \simeq 3{\cdot}14$). Remember that $10/\sqrt{10} = \sqrt{10}$; this often enables $\sqrt{10}$ in the denominator to be transferred to the numerator, where it is less of a nuisance.

UNLIMITED!

IN THIS feature we hope, from time to time, to be able to publish suggestions submitted by some of our readers on the possible improvement of projects previously described in PRACTICAL ELECTRONICS; short contributions on other subjects may be included. The aim is not to find fault or undermine the abilities or knowledge of our contributors. It may well be that the original article is *par exellence* but it could be improved or adapted to suit individule requirements. The views expressed by readers are not necessarily those of the Editor.

FLIP FLOP TACHOMETER

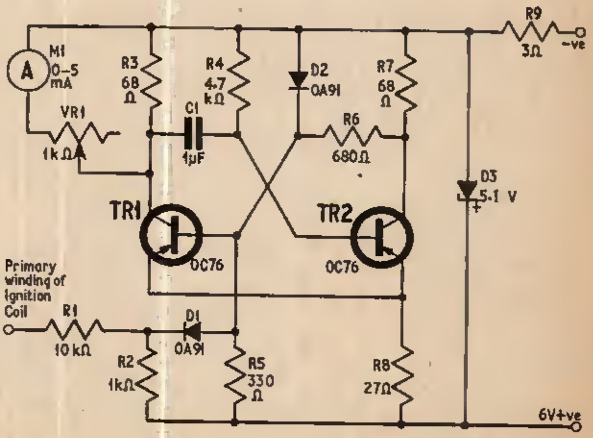
AFTER reading the article on "Logic Design" in the June issue I thought you might be interested in this circuit of a tachometer using a flip-flop.

The circuit is a monostable flip-flop, triggered by the pulse from the distributor, the transient peak of this pulse being 100 volts or more. The effective value of the pulse is reduced by R1 and R2.

In the stable state, TR2 is conducting, TR1 is cut off by the positive bias on its base. The first diode, D1, eliminates the positive half of the input pulse, and the negative half is applied to the base of TR1. TR1 then conducts, applying a heavy positive bias to TR2 base, thus cutting it off. The circuit remains in this state for a time (determined by R and C) and then flops back to the stable state again, thus producing a square waveform of the same frequency as the applied pulses. The 0–5mA meter reads the mean valve of the ensuing waveform, this mean value being proportional to the frequency, as the amplitude is constant.

The Zener diode stabilises the supply voltage so that the meter reading does not vary with battery voltage. The second diode D2 protects the circuit against transient peaks.

H. A. Cook,
Christchurch,
Hampshire.



A.M. TUNER CIRCUIT

I was especially pleased with the A.M. Tuner published in your "Bonanza Board" series in the March and April issues. I am very interested in miniature receivers and your circuit worked very well although the layout was rather critical if the printed circuit was not used.

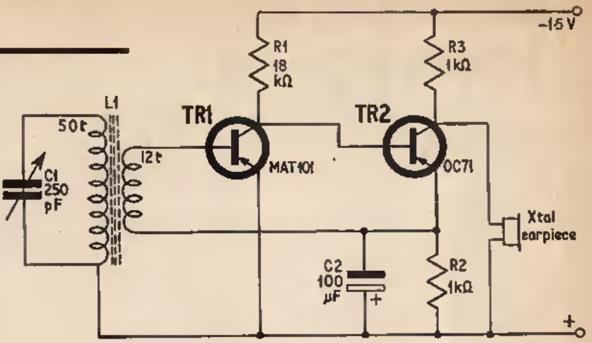
I "played about" with this circuit for some time and some of your readers might be interested in the one which I built as a result of my experiments. It works quite well on local stations driving a crystal earpiece.

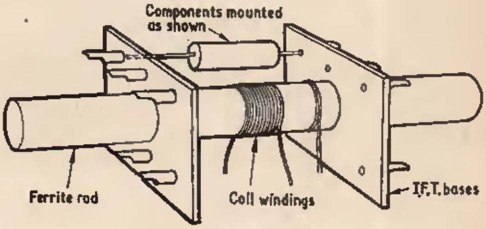
The main problem with respect to how small this receiver can be built is the length of the ferrite rod used to obtain satisfactory reception.—I managed to get reasonable volume from a 1½in length.

Two old i.f. bases were fixed on to the rod and the tags on the bases used to anchor the components. A small 250pF trimmer served as a tuning capacitor. "Red Spot" transistors worked just as well as OC71s in this circuit and an SB305 or any "MAT" type used in the second stage improves the performance.

B. A. Austin,
Solihull,
Warks.

This is a good circuit, almost identical to one I tried. One disadvantage is a poor ratio between base d.c. current and r.f. current in TR1. Another is that the circuit will only operate satisfactorily using low voltage power supplies. The crystal earpiece cannot be driven to so high a volume as with BB3, and the circuit does not tolerate a wide variation in d.c. operating conditions. However, the sensitivity of the receiver is very good.—A.J.B.





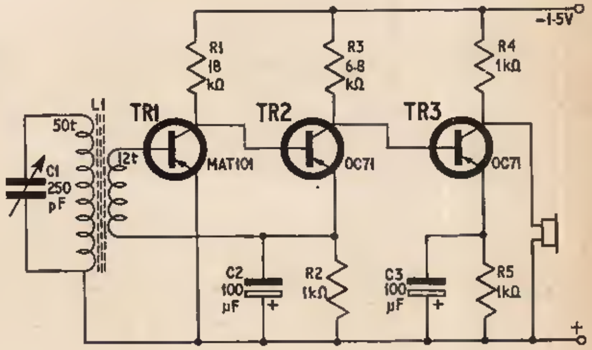


Fig. 1 (top). ***Simplified A.M. Radio Tuner***
Fig. 2 (centre). ***Ferrite rod component assembly***
Fig. 3 (right). ***Added stage for greater output***

ELECTROLYSIS FOR PRINTED CIRCUITS

In your articles on printed circuitry (March Issue), you are constantly stressing the danger of allowing the etching fluid to come into contact with the body. I do not know exactly what this substance is, but I know that nitric acid is also commonly used for etching.

The precautions needed to be taken when using these substances, together with the fear of acids which many people possess, may well discourage many people from attempting printed circuitry.

However, when making printed circuits, I now use a method which I once thought of and used when I had run out of acid during the local holiday week: this was electrolysis.

To make the circuit, simply paint the circuit design onto the laminate board with shellac and allow to dry, then attach a crocodile clip to an unpainted part with a lead running from the clip to the positive terminal of a car battery or low voltage transformer and rectifier unit. Immerse the board in copper sulphate solution and place a piece of copper wire somewhere in the solution so that it does not touch the board or clip. Attach this wire to the negative of the power source and the process will begin.

The unpainted copper will slowly pass into solution. When the current has ceased to flow, the unwanted copper should have all been etched away. If isolated patches of copper remain, it will be found that these are very thin and are easily removed with a pen-knife.

This process is both safe and cheap, as the amount of electricity used is almost negligible and copper is deposited from the solution and onto the negative wire at a rate equal to that at which it is being removed from the board, hence the copper sulphate solution remains at an almost constant concentration and none is lost. The slight increase in concentration is due to some loss of water.

For an average sized board, the length of time needed using 12V, 2oz would be about one hour.

This method has been thoroughly tested and used and I assure you that it is entirely successful.

P. R. Newell,
Blackburn,
Lancashire.

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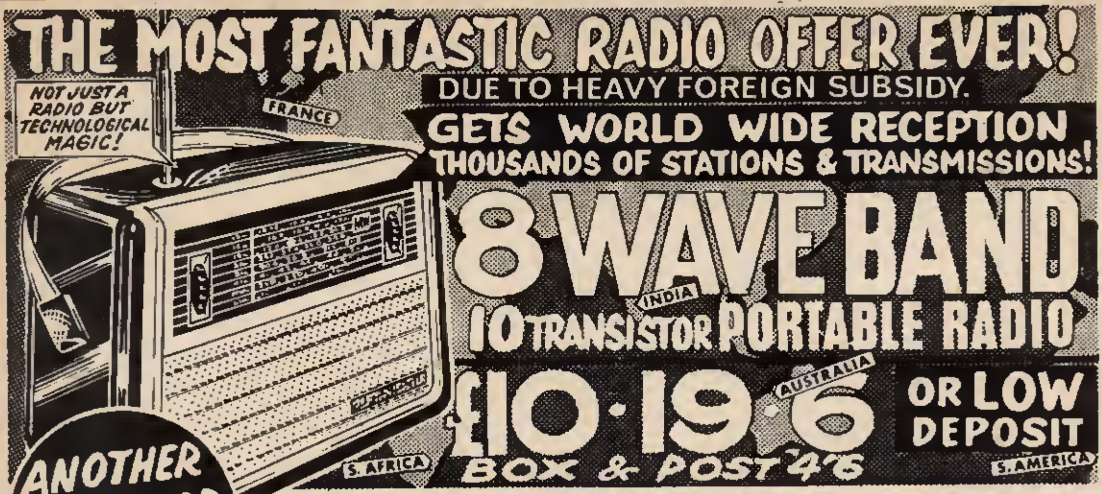
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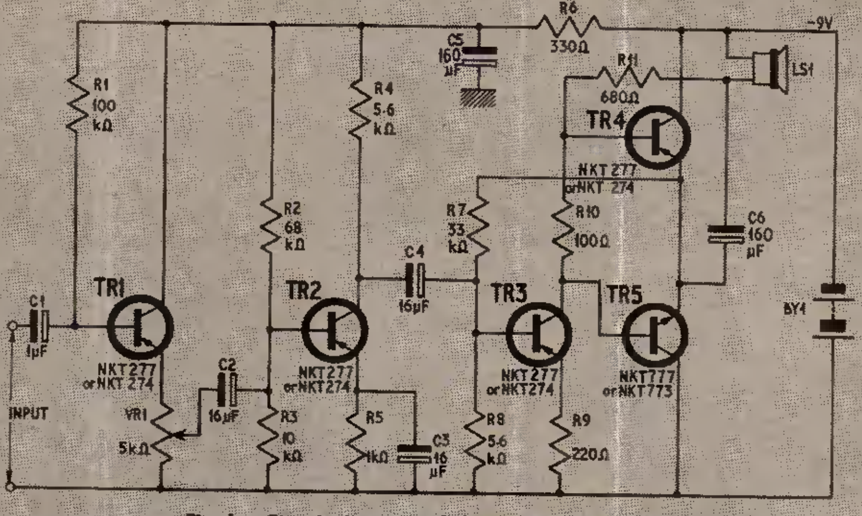

Fig. 1. Circuit diagram of the complete amplifier

THIS, the last of this series of Miniboard projects, describes a five transistor, transformerless, power amplifier, designed to feed up to 200mW to a 25 ohm speaker. The quiescent current of the complete unit is approximately 8mA. The first transistor of the amplifier is connected as an emitter follower, having an input impedance of 80 kilohms, thus making the unit suitable for use as an audio signal tracer, if required. For normal audio amplifier applications, this first transistor can be omitted from the circuit; a pre-amplifier would then be connected across the volume control.

COMPLEMENTARY SYMMETRY

The actual circuit (shown in Fig. 1) uses two output transistors TR4 and TR5, in complementary symmetry mode. TR5 is an *npn* type which is the load in the emitter of TR4 (*pnp*) connected as an emitter follower.

The actual output load R_L is the loudspeaker which is connected to TR4 emitter via C6. As far as a.c. is concerned the negative and positive supply lines are at virtually zero potential, due to the low impedance of the power supply, so the load can be effectively "grounded" to either positive or negative supply lines. The base of TR4 is connected to the signal source (in this case the driver stage output) with a source impedance Z_O.

The output impedance of an emitter follower is given approximately as the source impedance Z_0 divided by the current gain h_{FE} of the transistor. In the actual unit under consideration, Z_0 is 680 ohms and h_{FE} is 200 nominal, so the output impedance is 3·4 ohms nominal. If the output load R_L is made 3·4 ohms, the output voltage (peak) would be limited to half of the input voltage (peak), since the output impedance and R_L are in series and act as a potential divider. A near perfect match is then obtained between the loudspeaker and the source impedance. Similarly TR5 is also connected as an emitter follower with TR4 acting as its emitter load.

Thus, on the negative portion of the signal TR4 conducts and TR5 is cut-off, while on the parts of the signal that are positive TR5 conducts and TR4 is cut-off. R10 is used to give a degree of base-bias to the output transistors and prevent cross-over distortion.

The upper end of the main collector load resistor R11, of the driver transistor, is taken to the negative supply line via the 25 ohm speaker. A degree of negative feedback is thus obtained, which helps to

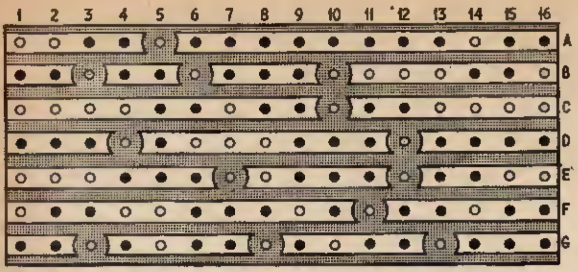

Fig. 2. Underside view of the board showing the copper strip breaks

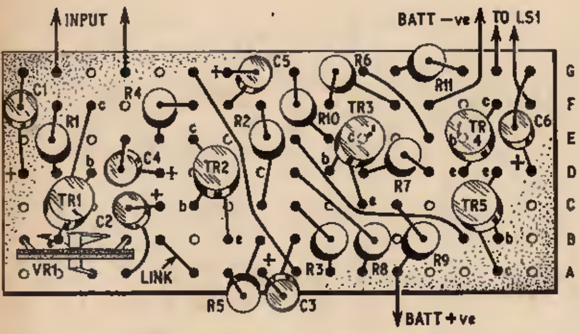

Fig. 3. Component layout on the board and connections for input and loudspeaker

reduce any distortion that could otherwise occur, due to the slightly uneven driving voltages on the bases of the two output transistors. This negative feedback also effectively lowers the source impedance of the driver stage, and thus the output impedance of the output stages. Resistors R7 and R8 form a voltage divider base bias network for TR3.

The upper end of R7 is directly coupled to the common emitter junction of TR4–TR5; d.c. negative feedback is thus obtained, stabilising the working voltages of TR3.

The driver stage is fed, via C4, from the common emitter preamplifier TR2, which in turn is fed from the emitter follower input circuit TR1. The emitter load of TR1 is a potentiometer, VR1, which serves as a volume control. To prevent overall positive feedback and consequent instability, the decoupling network R6 and C5 is inserted between TR2 and the output stages.

CONSTRUCTION

Following the procedure outlined in the introductory article break the copper strips in the sample piece of Veroboard as shown in Fig. 3 and connect the flying leads.

The components are fairly cramped on the board so it is probably best to start assembly by wiring up the output and driver stages. Before connecting the supplies to test this part of the circuit, check the wiring. Connect the 25 ohm loudspeaker; then connect the 9 volt supply with a milliameter in series.

Check that the current, with the base of TR3 shorted to ground via a large value capacitor, is less than 10mA. If a voltmeter is available, check that the voltage between the common emitter junction of the output transistors and battery positive is about 4½ volts. A functional check can now be made by removing the shorting capacitor from TR3 base and connecting an input signal to TR3 base via a blocking capacitor. The current will then rise significantly. If satisfactory, wire up and check the rest of the circuit, taking care to monitor the total current of the unit at all times.

COMPONENTS . . .

Resistors

R1	100kΩ
R2	68kΩ
R3	10kΩ
R4	5·6kΩ
R5	1kΩ
R6	330Ω
R7	33kΩ
R8	5·6kΩ
R9	220Ω
R10	100Ω
R11	680Ω

Potentiometer

VR1 5kΩ preset skeleton miniature or panel mounting control

Capacitors

C1	1μF	elect.	15V
C2	16μF	elect.	15V
C3	16μF	elect.	15V
C4	16μF	elect.	15V
C5	160μF	elect.	10V
C6	160μF	elect.	10V

Transistors

TR1, 2, 3, 4 NKT277 or NKT274 (4 off) (Newmarket)
TR5 NKT777 or NKT773 (Newmarket)

Loudspeaker

LS1 25 ohms, 5 inch, round (Plessey)

Battery

BY1 9 volt type PP9

Miscellaneous

Sample Veroboard
Battery connectors
P.V.C. covered wire

VARIATIONS

If the unit is to be used as a normal audio amplifier, either with a microphone, pick-up, or with a radio tuner, omit R1, C1, and TR1 from the circuit, and couple the input, via a 16μF capacitor, to the top end of VR1.

With the component values shown in the circuit diagram, the frequency response of the unit is considered to be adequate for normal domestic use, although the results are by no means hi fi. The low frequency response can be improved, however, by replacing C6 with a 1000μF capacitor.

Using a 25 ohm loudspeaker, about ·200mW of output power is available at reasonable quality; greater output power can be obtained using the same speaker, but distortion then becomes excessive. Undistorted output power can be increased by using a lower impedance speaker, but in this case larger transient currents have to be handled by the output transistors which may be damaged as a result.

Never disconnect the loudspeaker when the power supply is on or the output transistors may be damaged. It should be possible to use this amplifier with speaker impedances as low as five or even three ohms, but in this case a 100mA fuse should be wired in the negative supply line as a safety precaution against damaging the output transistors. The maximum output voltage that is available without distortion is about 7 volts peak-to-peak (approximately 2·5 volts r.m.s.), with a 25 ohm loudspeaker.

If the unit is to be built into a composite piece of equipment, replace VR1 with a front panel mounted volume control and knob. ★

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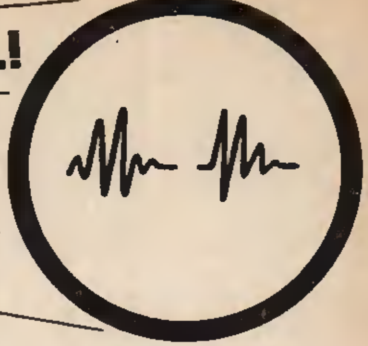

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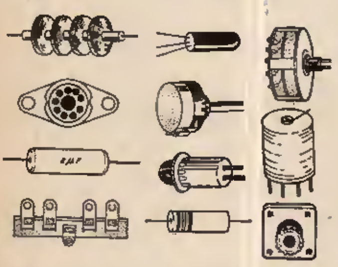

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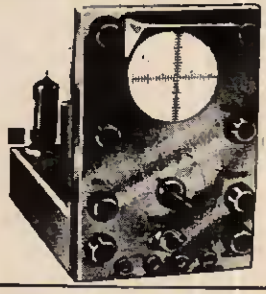

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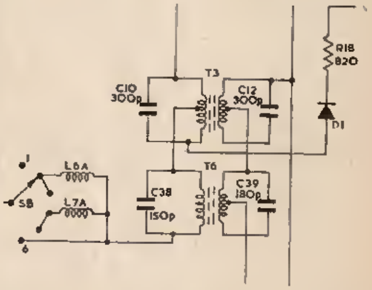

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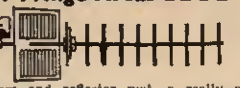

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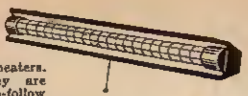

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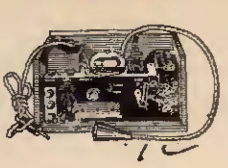

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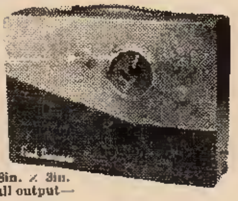

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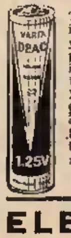

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JOHN VALENCE

JUST A DREAM

One's heart must go out to Lord Robens and his fellow members of the National Coal Board. With courage and imagination they embarked upon a vast programme of modernisation, calling in all the resources of modern technology. This planning reached a grand climax in the completion of the showpiece colliery at Bevercotes in Nottinghamshire. Twelve months ago the National Coal Board unveiled this, the first remotely controlled mine in the world, with electronically guided and controlled machinery.

What an inspiring picture this presented: here was one of the oldest industries of all—notorious for the severity of its working conditions—boldly deciding to take a gigantic step forward into the 21st century. A shining example for other industries to follow. A glimpse of the future, when all unpleasant and arduous toil would be undertaken by machines with man merely there to supervise their operation.

So we thought. Alas, this remains but a dream.

For some inexplicable reason, the mineworkers seem unappreciative of the new white-coated role they are being offered. A few million pounds worth of equipment including complex electronic installations lies entombed 3,000 feet below the surface, unused, at Bevercotes. The coal that might have been won during these past 12 months is estimated at about a million tons.

OFF THE BEAT?

Computers, infra-red devices, radio, and closed circuit television are some of the electronic aids now being mobilised for action in the campaign against the mounting crime wave.

Will this extended use of science and technology result ultimately in the disappearance from our streets of the "bobby"? I would not myself have thought this at all likely. But no less an authority than the Secretary General of Interpol, M. Jean Nepote, believes this to be so. By 1975, he forecasts, policemen will have vanished from the streets in Britain and their function will have been taken over by television cameras!

Such a state of affairs can hardly be contemplated. Just consider, for one thing, our guests from overseas. Whatever will they do when they want to be directed to say—The Tower, or wish to know when the Changing of the Guard ceremony takes place. And, in particular, let us consider those members of the fair sex one sees in the busy streets of the Capital gazing admiringly upwards into the face of an ever helpful bobby. They surely will find little recompense in the glassy eye of a television camera—even if it is part of an all knowing robot with a computer fed encylopaedic mind.

RELIABLE SERVICE

The radio and television rental system is hardly known in the U.S.A., where it is limited to such institutions as schools and hospitals. This is in sharp contrast to our own country, where the rental system is becoming increasingly popular with the general public. When colour arrives in Britain (all being well—end of 1967) it is predicted that at least 80 per cent of colour receivers in private homes will be hired on the rental basis. This at any rate was the view put forward by Mr. Robinson, Chairman of Radio Rentals Limited, when announcing a tie up between his firm and The Radio Corporation of America for the production of colour tubes in Britain.

Apart from the very real financial aspect, I suspect that the swing over to rental as opposed to private ownership has been greatly encouraged by the public's suspicion of the "servicing" fraternity. Perhaps this Cinderella of the radio and television trade could learn something from its counterpart in the U.S.A. Over there the private listener or viewer is dependent on the serviceman or "troubleshooter" and, one presumes, has no qualms about calling him in.

ALL-TALKING INSTRUMENTATION

The motorist has benefited very considerably from electronic developments. As readers of this magazine will know quite well, there are a variety of devices designed to assist the driver or to safeguard his vehicle. Nevertheless, what we have seen so far is apparently just the beginning.

For example, the Ford people, I understand, are developing "audio" speedometers and petrol and oil gauges. Miniature tape machines will give pre-recorded warning messages as the needle reaches a danger mark. The idea is to relieve the motorist of the necessity of frequently glancing at the dashboard instruments. I suggest that automatic muting of the car radio when the audio warning comes up is a vital adjunct to such a scheme.

Talking of car radio, the practice of driving along with the accompaniment of broadcast entertainment is so widespread now that it will doubtless surprise many younger readers to learn that the introduction of this amenity was fiercely opposed in some quarters in the early days as being a dangerous distraction. But, paradoxically, it was soon proved that a radio programme can help keep the driver alert, particularly on long solitary journeys.

"No thanks, I already have one"

Readout—
A SELECTION FROM OUR POSTBAG

Where has all the fuzz gone?

Sir—I have completed making the *Fuzz Box* described in the July issue, but have not obtained fully successful results with it.

On connecting up and plucking the guitar string softly, only a very small output can be obtained (far softer than without the fuzz box connected). However, on plucking the guitar string fairly hard, a very loud (much amplified above normal level, i.e. without the fuzz box) fuzzed note is obtained. This is satisfactory, except for the fact that this note lasts only for a few seconds on the bass notes, and even shorter on the treble notes. This, however, I suspect is due to the guitar's lack of sustain on the treble notes) before suddenly cutting out and reverting to the "tinny" output, as before. Just before cutting out, a crackle also appears, with the fuzz. Thus, it seems that whether the unit fuzzes or not is dependent upon the input supplied by the guitar.

In the unit which I constructed I was not able to obtain the correct values for all the components. But, since the margins of error are fairly small, I am not sure whether or not the fault can be traced to any of these.

S. F. Bywaters,
Hornchurch,
Essex.

Slight modifications may be necessary so as to make the fuzz box match the particular guitar output specification. The clipping stage preceded by the pre-amp has a definite minimum threshold input level which can be varied by changing the value of R3, altering the gain of TR2, or trying a different diode as D1. Any signal lower than the minimum trigger input level will not be reproduced at all. The circuit will give an illusion of sustaining the signal because, providing the input signal is over the threshold level, the output signal is always at the same level until cut-off point is reached, when the input level falls below threshold. The true sustain effect is not only unobtainable but also undesirable. If any such unit gave a sustain effect then any note played would carry on to give a cataclysmic discord if the next note was played soon after.—M. S-R.

The Roding Boys' Society

This radio and electronics group for boys has changed the Headquarters location, and the meetings are now held in Waltham Forest, London, E.17.

An expansion of the activities should now take place with the new facilities available to us.

Meetings will continue on Tuesday evenings, plus special activities on Saturdays.

Boys who are especially keen on radio/electronics are particularly welcome to visit the new Centre. If you are interested please contact:—

Ron Marchant,
154, Essex Rd.,
London, E.10.

CAN YOU HELP?

Letters for inclusion under this heading should be as brief as possible. Replies should be made direct to the readers concerned.

Sir—I have been trying to obtain some early issues, Nos. 1 to 10, but have had no luck. I wonder if any of your readers can help? I will, of course, pay the postal rates and charges.
B. Toffoli, 18, Farnley Street, Mt. Lawley, Perth, Western Australia.

Sir—I am interested in purchasing back number 1 to 12 of volume 1 and February 1966 at cost plus postage.
A. Balsillie, Science Dept., Williamwood High School, Seres Road, Clarkston, By Glasgow.

Sir—Can any reader supply me with all back copies for volume 1 as well as numbers 1 to 4 of volume 2?
O. W. Griffiths, P.O. Box 13504, Sinoville, Pretoria, South Africa.

Sir—Can anyone supply me with the first four copies of Practical Electronics? I would pay full price for these to complete my collection.
D. R. Fairbrother, Averill House, King's College, Otahuhu, Auckland, New Zealand.

Sir—Could any of your readers supply me with volume 1 complete with blueprints, etc?
J. A. Daykin, 14, The Avenue, Churchdown, Glos.

Back numbers are usually very quickly exhausted. We strongly advise all our readers that a standing order be placed with their newsagent to avoid any future disappointment.

Noise from the quiet sun

Sir—I read with interest the article on *Radio Astronomy* by C. B. Sibley in the August edition.

I should like to point out that the detection of thermal noise from the quiet sun is not as easy to detect as the writer suggests. The block diagram (Fig. 4) shows a radiometer or full power system which is quite suitable for detecting large solar outbursts and should give good results during maximum sunspot activity.

Trying to detect the quiet sun with this system would be impossible as all forms of man made interference will be shown on the pen recorder. As a result it would be difficult to sort out genuine solar signals from the unwanted ones.

My main purpose of writing this is to prevent any would-be constructors becoming disappointed if their efforts failed, as I have constructed similar equipment without producing any results.

The type of equipment that could be used very successfully by the amateur with a garden of moderate size is the phase-switched interferometer. This system takes more time and effort but the results are most satisfying as I have found with my own equipment.

M. J. Hale,
Secretary of the Radio
Astronomy Section,
The British
Astronomical Association,
London, S.E.9.

"Pop" mandolin

Sir—Having read Colin Greig's letter in the August edition, I think that I ought to make one or two comments in reply.

The first is that the original instrument, the *Electronic Mandolin*, designed by S. Chisholm in the June edition was made originally with the idea of being highly amplified in a "pop" group. Also if it is to be used for this purpose a crystal microphone would be useless as the risk of "feedback" and the picking up of extraneous noises would be too great.

If a crystal pick-up is used the tone would be extremely "tinny" and tend to reproduce the upper register of the instrument more than the lower one.

G. K. Mitchell,
Orpington,
Kent.

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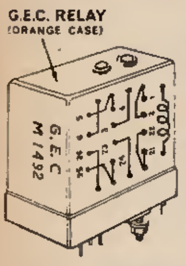

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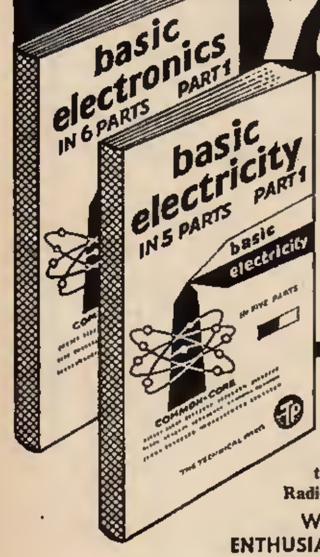

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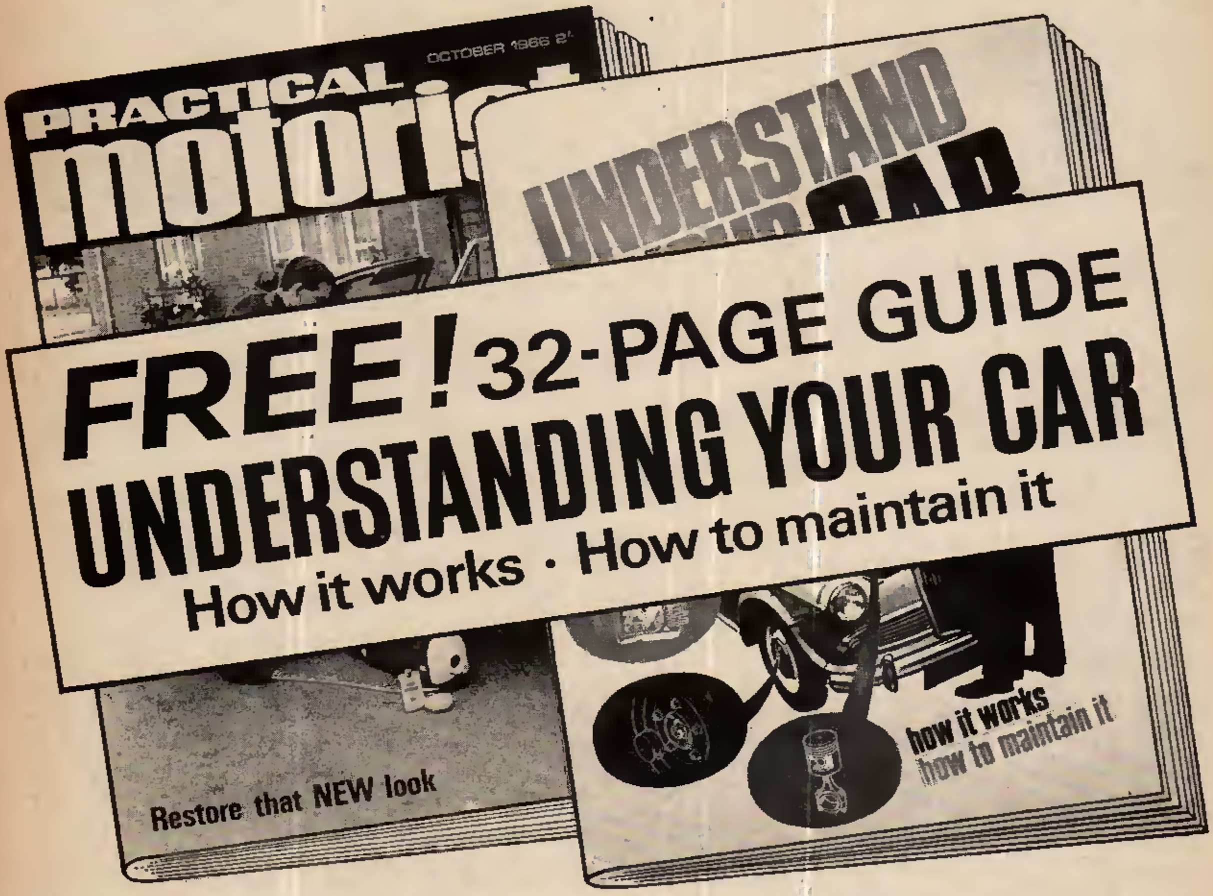
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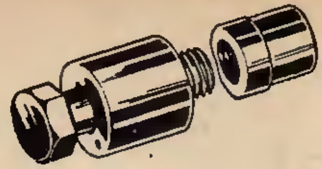

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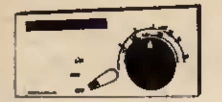

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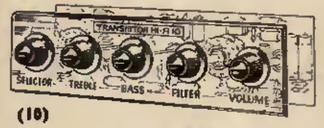

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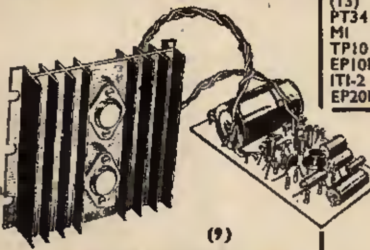

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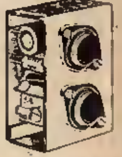

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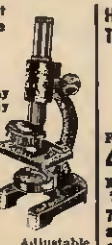

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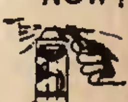

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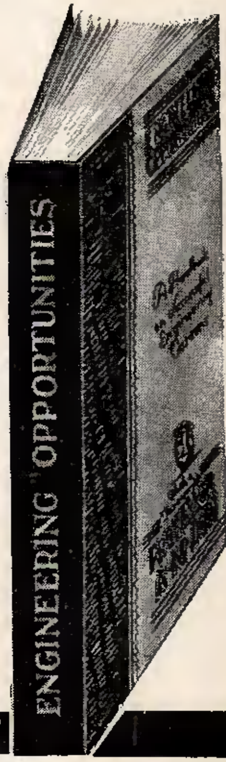

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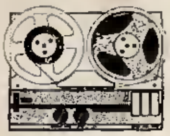

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(1) REGENT-6 MW/LW POCKET RADIO TO BUILD

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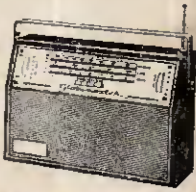

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