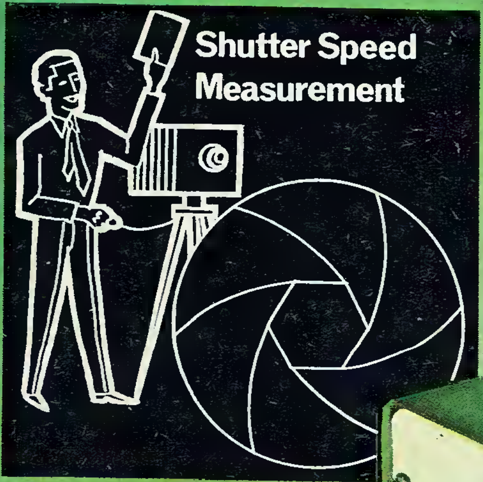
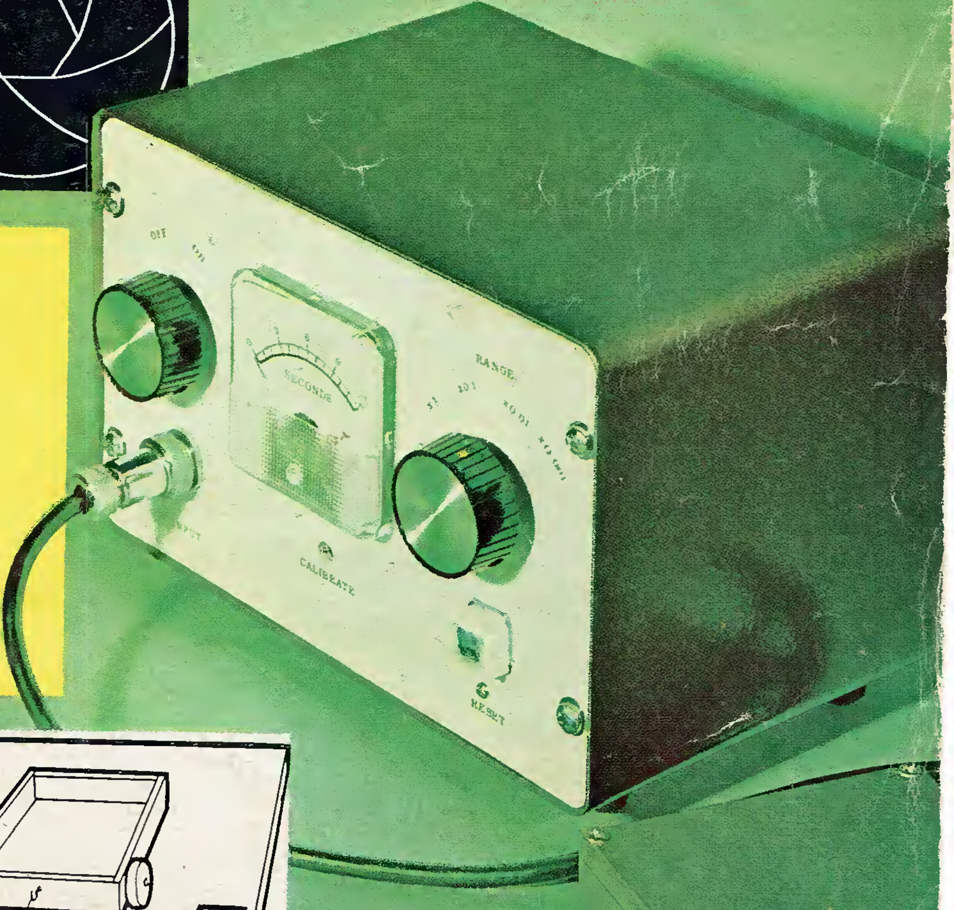
PRACTICAL
ELECTRONICS

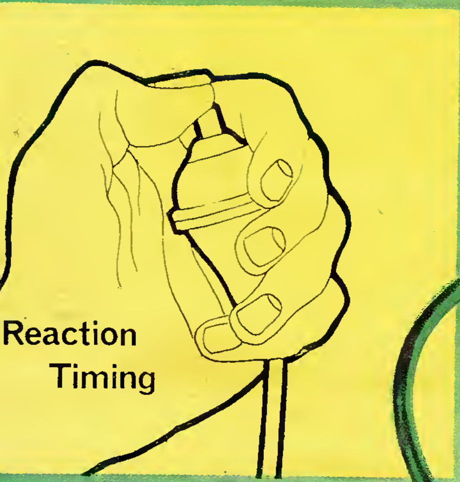
SEPTEMBER 1967

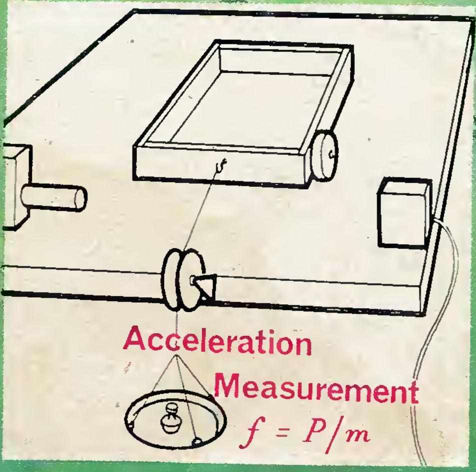
PRICE 2/6



ELECTRONIC STOPCLOCK







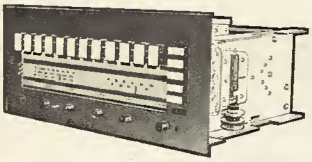
MEASURES INTERVAL
ELAPSED BETWEEN
TWO EVENTS

Four Ranges Covering
0·012 – 12 seconds

Lasky's Radio

SPECIAL INTEREST ITEMS!

EXCLUSIVE LASKY'S BARGAIN—SOLID STATE MULTIPLEX STEREO AM/FM TUNER/AMPLIFIER CHASSIS



Model T10E—made for U.K. use by famous North American manufacturer and originally installed in De Luxe Hi-Fi consoles costing several hundred pounds. The chassis is of outstanding appearance and quality and offers many unique features plus an extremely comprehensive specification.

Features ● Separate transistorised AM and FM tuners ● 3 AM wavebands—LW, MW and Continental T.R. band ● full FM cover with 5 push button preselected stations (sep. tuning controls for AM and FM ranges) ● built in multiplex decoder with unique FMX feature which provides automatic switching from mono to stereo when stereo signal is received and vice versa ● unique split amplifier facility for simultaneous play of radio plus any other source ● channel reverse ● switched inputs for tape and auxiliaries (sep. sockets for tape in and out) ● switched extension speaker outlet ● thermal safety trip ● socket for stereo headphones.

Tech. spec.: Output 10 watts RMS per channel; output imp. 8 Ω p.c.; sensitivity 50mV for 8W output at 1 Kc.; input imp. 100 K Ω p.c.; 12 unique tumbler type function controls, 8 push button wavechange and station selection controls, vol., bass, treble and balance controls, push button contour (loudness) control; illuminated tuning scale; AM ranges: MW 520-1640 Kc/s, LW 140-290 Kc/s, Continental TR 170-345 Kc/s; FM range 88-108 Mc/s with switched AFC. Operates on 200/250V A.C., 50 or 60 c/s. Size 17¾ × 8 × 12in.

LASKY'S PRICE 59 Gns. Post & Packing 20/-

A range of high quality Hi-Fi Console Cabinets by the same famous manufacturer is also available at almost ½ list price and may be seen at our Hi-Fi Audio Centres.

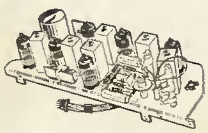
UHF T.V. TUNERS

Well known British makers' surplus stocks. Now available for the first time to the Home Constructor. Add 2/6 Post and Packing on each.

VALVE UHF MODEL

In metal case size 4 × 6 × 1¼in. Fully tunable—complete with PCC86 and PCC88 valves. LASKY'S PRICE **29/6.** Without valves **7/6**

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. Circuit supplied.

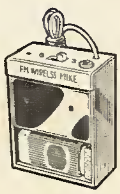
LASKY'S PRICE 29/6 Post 2/6

SPECIAL PACKAGE OFFER

Free standing table cabinet, size 17½ × 9 × 5¼in., finished in medium Mahogany. Scale marked 21 to 68 (UHF band). Designed to accept the above IF Amplifier with space for a Valve UHF Tuner **Cabinet only 27/6.** Post 3/6.

Special Package Offer IF Amplifier, UHF Tuner with valves and Table Cabinet. PACKAGE PRICE **59/6** Post 6/-

EXPORT TTC B4002 FM WIRELESS MIC.



Highly sensitive — suitable for either static or mobile use. Signal can be picked up by any FM radio or tuner which receives frequencies between 96-104 Mc/s. over several hundred yards. Size only 3 × 2½ × 1in. (in leather case). Operates on one PP3 type battery. Complete with neck cord, clip-on dynamic extension mike (1 × ¾ × 7/16in.) and battery.

LASKY'S EXPORT PRICE 10 Gns. Post Free. Anywhere in the World.

TTC 13/500. More powerful version of above—size 7½ × 1¾ × ¾in. Operates on one PP3 type battery. **LASKY'S PRICE 12 Gns.** Post Free. Anywhere in the World.

These cannot be operated in the U.K. owing to G.P.O. regulations.

WATER TEMPERATURE THERMOSTATS

British made—orig. for use in high quality washing machine. range adjustable between 114°F and 230°F. Rating 200/250 V.A.C., 20 amps (also D.C. up to 125 V.A.). Size 2¼×1¾×1½ with 18in. capillary tube and 6in. bulb. Single hole fixing—3/16in spindle.

LASKY'S PRICE 15/- Post 2/-

CONSTRUCTORS BARGAINS

THE SKYROVER De Luxe

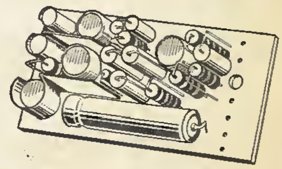
7 transistor plus 2 diode superhet, 6 waveband portable receiver covering the full Medium Waveband and Short Waveband 31-94M and also 4 separate switched bandspread ranges, 13M., 16M., 19M. and 25M., with Band Spread Tuning for accurate Station Selection. The coil pack and tuning heart is factory assembled, and tested. Uses 4 U2 batteries. 5 in. Ceramic Magnet P.M. Speaker. Telescopic and Ferrite Rod Aerial. Tone Circuit, wood cabinet, size 11½ × 6¾ × 3 in. covered with washable material, plastic trim and handle. Car aerial socket fitted.

Can be built for **£8 . 19 . 6** Post 5/- H.P. Terms: 60/- deposit and 11 monthly payments of 12/9. Total H.P.P. £10.0.3. **Data 2/6 extra:** refunded if you purchase parcel. All parts avail. sep. **Four U2 batt. 3/4** A simple additional circuit provides cover of the 1100/1950M Long Waveband. All components with construction data. Only **10/-** extra Post Free.

PEAK SOUND SA-88 TRANSISTORISED STEREO AMP AND PRE-AMP KIT

A high quality 17 watt, 14 transistor High Fidelity Integrated Amplifier which anyone can easily build using the revolutionary Peak Sound "Cir-Kit" wiring system. Size assembled only 10 × 2½ × 3 in. Complete kit with detailed construction data. **LASKY'S PRICE £12.19.6 Post FREE.**
POWER SUPPLY KIT for the SA-88 £3.10.0 Post FREE.

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. 40 Ω, size 2×1×⅝in....... PRICE **27/6**

TYPE LRPC 4. 5 transistor. Input sens. 150 mV, output 330 mV, output imp. 15 Ω. size 2½ × 1½ × ⅝in. .... PRICE **18/6**

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

TYPE LRPC 9. High to low impedance matching pre-amp.—input imp. 1 megohm, output imp. 2 k/ohms. Size 1½×1½×⅝in. .... PRICE **10/6**

TYPE LRPC 10. Magnetic tape replay pre-amp. designed so that a 450 mH head can be matched into any of the audio amplifier modules listed above. Size 2¼×1½×⅝in. .... PRICE **10/6**

TYPES LRPC 9 and **10** are ideal for use with **LRPC 1, 4** and **5** and are available at the reduced price of **7/6 each if bought with the LRPC 4.**

FULLY ENCAPSULATED MODULES

Special function modules — all one size 1½ × 1 × 1¼in. Complete with detailed function and installation instructions. Send S.A.E. for data.

TYPE PA-1. Public address amp. for use with carbon, crystal or Dynamic microphones. 3 Ω output imp. .... PRICE **30/-**

TYPE GR-1. Gramophone amplifier—provides sufficient power to fill average room. 3 Ω output imp. .... PRICE **30/-**

TYPE CO-1. Morse code practice oscillator — for use with morse key and 3 Ω speaker. .... PRICE **20/-**

TYPE MT-1. Metronome module—provides audible and visual beat from 30 to 240 beats per minute (for use with 3 Ω speaker or ind. lamp).......... PRICE **22/6**

SINCLAIR SUPER MINIATURE KITS

We stock the complete range. Write for details of package deals.

THE MICRO-6 miniature radio only 1⅘ × 1 3/10 × 1½in.	£2 19 6
THE MICRO-FM. (tuner/receiver)	£5 19 6
THE MICROMATIC mini-radio Kit £2.19.6. Fully built	£3 19 6
STEREO 25 pre-amp control unit fully built	£9 19 6
THE Z-12 12 watt amplifier and pre-amplifier. Fully built and tested	£4 9 6
PZ-3 power pack for Z-12	£3 19 6

TRANSISTORS **ALL BRAND NEW AND GUARANTEED**

GET S1, GET 85, GET 86 2/6; 873A, 874P 3/6; OC45, OC71, OC81D 4/6; OC 44, OC 70, OC 76, OC 81 5/6; pair (10/6); AF 117, OC 200 6/6; OC 42, OC 43, OC 73, OC 82D 7/6; OC 201, OC 204 15/-; OC 205, OC 206 19/6; OC28 24/6; OC 75 8/-.

TRANSFILTERS By BRUSH CRYSTAL CO. Available from stock.

TO—01B 465 kc/s. ± 2 kc/s.
TO—01D 470 kc/s. ± 2 kc/s.
TO—02B 465 kc/s. ± 1 kc/s.
TO—02D 470 kc/s. ± 1 kc/s.
TF—01B 465 kc/s. ± 2 kc/s.
TF—01D 470 kc/s. ± 2 kc/s.

9/6 EACH Post 6d

Branches

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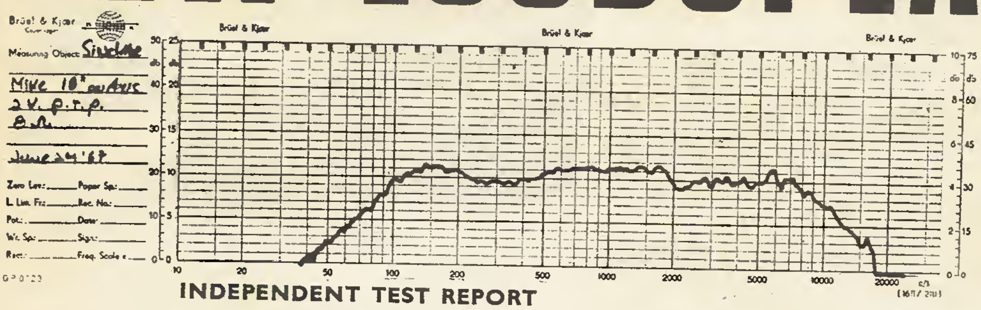
NEW LOUDSPEAKER



Unretouched reproduction of performance curve taken from a Sinclair Q.14 from stock. This is better than curves from speakers cost-up to £25.

INDEPENDENT TEST REPORT

The above curve was taken by an independent testing laboratory and shows clearly why the Q.14 achieves such remarkable standards of reproduction. Superb response is maintained between 60 and 15,000c/s, completely covering listening requirements and assuring the user of getting the best from the equipment to which the speaker is coupled.

WHY THE SINCLAIR Q.14 IS FAR AHEAD IN EVERY WAY

CONSTRUCTION

The sound, or pressure chamber and mounting baffle are of special high-density ultra-low resonant materials made possible by modern bonding and processing techniques. The sound chamber is of seamless construction and the loudspeaker mounted to ensure complete freedom from spurious "coloration".

LOADING

The Sinclair Q.14 has an input impedance of 15 ohms and will comfortably accept loadings in excess of 28 watts music power. This rating is far greater than that required for average listening requirements. However, using the Q.14 in module formation (a unique Sinclair facility) enables a very powerful system to be built up efficiently and economically. This makes an ideal quality P.A. system.

FREQUENCY RESPONSE

As the independently made curve shows, a remarkably smooth response is maintained between 60 and 15,000c/s. This extends comfortably beyond either end of the sound spectrum to provide true hi-fi standards.

REPRODUCING UNIT

A specially designed driver unit is used. It has an exceptionally high compliance in the cone suspension, a massive 11,000 gauss ceramic magnet and an aluminium speech coil. The cone is treated to ensure brilliant transient response.

CONTOURED PRESSURE CHAMBER

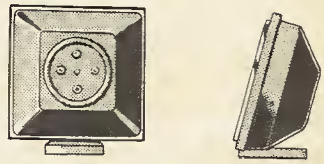
The shape and proportions of the sealed sound or pressure chamber have been determined mathematically thereby ensuring maximum energy to sound conversion ratio with forward sound "presence" and freedom from any directional effect. This is why the Sinclair Q.14 is ideal for stereo. Connections at the rear are marked for correct phasing when using two or more Q.14's.

SIZE

9¾in × 9¾in × 4¾in deep. A separate base for free standing position is provided as well as a template for wall or flush mounting. A neat solid aluminium bar inset is used to embellish the front of the speaker.

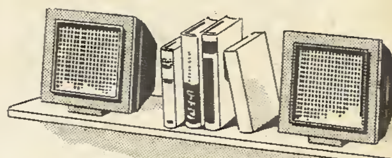
SEND FOR YOUR'S TODAY

£6.19.6

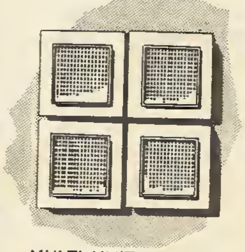


USING A SINCLAIR Q.14 SYSTEM

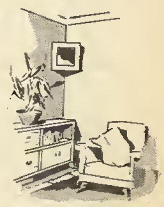
The size and form of the Sinclair Q.14 permit it to be used in a far wider variety of applications than with conventionally designed loudspeakers. This makes it possible to match the speaker to its environment much more easily and to achieve performance standards far better than anything in its size or price group. Here are some typical ways of using the Q.14. The enthusiast for hi-fi will find many more.



FREE STANDING BOOK SHELF ASSEMBLY
Ideal for stereo. A base is supplied with the Q14, which screws on for convenience.



CORNER SPEAKER AT ANY HEIGHT
The Q.14 will fit comfortably into a wall corner, taking up a minimum of space. The wall surfaces then contribute to the sound radiation.



MULTI UNIT ASSEMBLY
Any number of Q.14's can be flush mounted on to a flat surface, such as a false wall or room divider. They can also be arranged for P.A. work.

AN ALL–BRITISH SINCLAIR GUARANTEED PRODUCT

Hear one in your own home—your money refunded in full if not satisfied.

sinclair

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DE LUXE PLAYERS

4-Speed Mono Players 2-tone Cabinets 17×15×8½in. High flux loudspeaker and High Quality Amplifiers ready built. Quality output. Volume and Bass controls. Special instructions enable assembly in 30 minutes, only 5 wires to join. 12 months' guarantee.

TO BUILD YOURSELF

Post 2/6 per item.

PORTABLE CABINET As illustrated. To fit standard player or autochanger. **69/6**

RCS AMPLIFIER 3 WATT. Ready made and tested with UCL82 triode pentode valve and loudspeaker. **59/6**

SUPERIOR AMPLIFIER. Ready made and tested. Guaranteed better sound! Fully isolated AC Mains Transformer 4 watt output. ECL86 triode pentode valve. Volume and tone controls with knobs. Quality Loudspeaker. **89/6**

SINGLE PLAY MONO	
BSR GU7	£4.19.6
Garrard SRP12	£4.19.6
Garrard SP25	£10.19.6
Philips AG1016	£12. 9.6
Garrard A70	£19.19.6
Garrard LAB80	£24.19.6
Garrard 401	£29.19.6

AUTOCHANGE MONO	
BSR Superslim	£5.19.6
Garrard 1000	£5.19.6
Garrard 2000	£6.19.6
Garrard 3000	£8. 9.6
Garrard AT60 Mk. II diecast turntable	£12.19.6

All with mono cartridge (Stereo 12/6 extra)

GARRARD TEAKWOOD BASE WB.1 Ready cut for mounting 1000, 2000, 3000. SP25, AT60. **72/6**

A.18 TRANSCRIPTION TONE ARM with tracking template and two plug-in shells.. Original price £13.19.6. OUR PRICE **5 gns.** Decca Deram Stereo Diamond Cartridge £4.14.6 extra.

Q MAX CHASSIS CUTTER

Complete: a die, a punch, an Allen screw and key

⅜in.	14/6	⅝in.	15/9	1⅛in.	18/-	1⅜in.	20/6	2$\frac{3}{32}$in.	37/9
½in.	14/9	1in.	18/-	1¼in.	18/6	1½in.	22/6	2½in.	44/3
¾in.	15/6	1$\frac{1}{16}$in.	18/-	1⅝in.	20/-	2in.	34/3	1in. sq.	31/6

BARGAIN XTAL PICK-UP ARM Complete with ACOS LP-78 Turnover Head and Stylii 20/-; Stereo 30/-.
SPEAKER FRET Tygan various colours, 52in. wide, from 10/- ft.; 26in. wide from 5/- ft. SAMPLES S.A.E.
EXPANDED METAL Gold or Silver 12 × 12 in. 6/-.
NEW GARRARD GRAM MOTORS 2,500 r.p.m. 100-130v. 15/- pair for 200/250v. A.C. (in series), or 10/- ea. Post 2/6.

FULL WAVE BRIDGE SELENIUM RECTIFIERS: 6 or 12 v. outputs, 1½ amp., 8/9; 2 a. 11/3; 4 a., 17/6.
CHARGER TRANSFORMERS. P. & P. 2/6. Input 200/250 v. for charging at 6 or 12 v., 1½ amps., 17/6; 2 amps., 21/-; 4 amps., 25/-. Circuit free. Ammeter 0 to 5 amp, 10/6.

MOVING COIL MULTIMETER TK 25. 0-1,000v. A.C./D.C., ohms 0 to 100k. etc., **47/6**
MOVING COIL MULTIMETER EP10K. 0-1,000v. A.C./D.C., ohms 0 to 3 meg. etc., **79/6**
MOVING COIL MULTIMETER EP20K. 0-2,500v. D.C. 20,000 ohms per volt. 0-1,000v. A.C. Ohms 0 to 6 meg. 50 Microamps full scale. **99/6**

NEW MULLARD TRANSISTORS

OC71 6/-; OC72 7/6; OC81D 6/-; OC81 6/-; AF115 8/-; AF114 8/6; OC44 8/-; OC45 8/-; OC171 9/-; OC170 8/6; AF117 7/-. OC26 12/6; AD140 15/-; OC35 15/- Holders 1/3.

ARDENTE TRANSISTOR TRANSFORMERS
D3035, 7.3 CT : 1 Push Pull to 3 ohms for OC72, OC81 .. 11/-
D3034, 1.75 : 1 CT. Push Pull Driver for OC72, OC81 .. 11/-
D3058, 11.5 : 1 Output to 3 ohms for OC72, OC81... ... 11/-

TRANSISTOR MAINS ELIMINATORS. FAMOUS "POWER MITE". 9 VOLT. SAME SIZE AS PP9 BATTERY. FULLY SMOOTHED. 150mA. FULL WAVE CIRCUIT. **45/-**

WEYRAD P50 — Transistor Coils

RA2W 6 in. Ferrite Aerial with car aerial coil......12/6
Osc. P50/1AC.............. 5/4
I.F.P50/2CC 470 kc/s ... 5/7
3rd I.F. P50/3CC 6/-
Spare Cores..................6d.
Driver Trans. LFDT4......9/6
Printed Circuit, PCA1. ... 9/6
J.B. Tuning Gang 10/6
Weyrad Booklet 2/-

Volume Controls

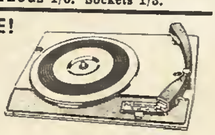
LONG SPINDLES. MIDGET SIZE 5 K. ohms to 2 Meg. LOG or LIN. L/S 3/-. D.P. 5/- STEREO L/S 10/6, D.P. 14/6.

80 Ohm Coax 6d yd.

Semi-air spaced Cable 100 yd. drum 50/- post free.
FRINGE LOW LOSS Ideal 625 lines **1/6 yd.**

COAXIAL PLUG 1/-. PANEL SOCKETS 1/-. LINE SOCKETS 2/-. OUTLET BOXES, SURFACE OR FLUSH 4/6. BALANCED TWIN FEEDERS 1/- yd., 80 or 300 ohms. TELESCOPIC CHROME AERIALS. 6in. extends to 23in. 6/6 each. CAR AERIAL PLUGS 1/6. Sockets 1/3.

SPECIAL PURCHASE!
B.S.R. GU7
9 volt Battery
Operated Record
Player Decks



4 speeds, automatic stop. Plays any size record. Complete with mono LP/78 xtal and sapphire stylus. (With stereo cartridge 12/6 extra). ONLY **69/6** P. & P. 5/6

STELLA RECORD PLAYER AMPLIFIER

4 watt. 2 stage. 3 to 7 ohm. Neg. feed back. UCL82. UY85. 200-250v. A.C. tapped input. Chassis size 8 x 2½ x 4in. high. Gold/Walnut knobs. Volume and Tone controls on separate Polished Wood Panel 6 x 2in. Brand new with makers' guarantee. BARGAIN PRICE P. & P. 2/6. **78/6**

NEW TUBULAR ELECTROLYTICS				CAN TYPES	
2/350 v.	2/3	100/25 v.	2/-	8/600 v.	9/6
4/350 v.	2/3	250/25 v.	2/6	16/600 v.	12/6
8/450 v.	2/3	500/15 v.	3/-	16+16/500 v.	7/6
16/450 v.	3/-	8+8/450 v.	3/6	32+32/450 v.	6/-
32/450 v.	3/9	8+16/450 v.	3/9	50+50/350 v.	7/-
25/25 v.	1/9	16+16/450 v.	4/3	60+100/350 v.	11/6
50/50 v.	2/-	32+32/350 v.	4/6	100+200/275 v.	12/6

SUB-MIN. ELECTROLYTICS. 1, 2, 4, 5, 8, 16, 25, 30, 50, 100, 250 mfd. 15v. 2/6; 500, 1000 mfd. 12v. 3/6 2000 mfd. 25v. 9/6. CERAMIC. 500 v. 1 pF. to 0.01 mfd., 9d. Discs 1/-.

PAPER TUBULARS
350v.-0.1 9d., 0.5 2/6; 1 mfd. 3/-; 2 mfd. 150v. 3/-. 500v.-0.001 to 0.05 9d; 0.1 1/-; 0.25 1/6; 0.5 3/-. 1,000v.-0.001, 0.0022, 0.0047, 0.01, 0.02, 1/6; 0.047, 0.1 2/6. E.H.T. CONDENSERS. 0.001mfd., 7kV., 6/6; 20kV., 10/6.

SILVER MICA. Close tolerance (plus or minus ½ pF.), 5 to 47 pF., 1/-; ditto 1% 50 to 800 pF., 1/-; 1,000 to 5,000 pF., 2/-. TWIN GANG. "0-0" 208 pF.+176 pF., 10/6; 365 pF., miniature 10/-; 500 pF. standard with trimmers, 9/6; 500pF. midget less trimmers, 7/6; 500 pF. slow motion, standard 9/-; small 3-gang 500 pF. 18/9. Single "0" 365 pF. 7/6. Twin 10/-. SHORT WAVE. Single 10 pF., 25 pF., 50 pF., 75 pF., 100 pF., 160 pF., 5/6 each. Can be ganged. Couplers 9d. each. TUNING. Solid dielectric. 100 pF., 300 pF., 500 pF., 3/6 each. TRIMMERS. Compression ceramic 30, 50, 70 pF., 9d.; 100 pF., 150 pF., 1/3; 250 pF., 1/6; 600 pF., 750 pF., 1/9.

250v. RECTIFIERS. Selenium ½ wave 100mA 5/-; BY100 10/-. CONTACT COOLED ½ wave 60mA 7/6; 85mA 9/6. Full wave 75mA 10/-; 150mA. 19/6; T.V. rects. 10/-.

NEW B.A.S.F. LIBRARY BOXED TAPE

7 in. L.P. 1,800 ft. 45/-; 7 in. D.P. 2,400 ft. 70/-
60 min. Cassette C60 (For Philips, etc.) 17/6
Spare Spools 2/6. Tape Splicer 5/-. Leader Tape 4/6.
Tape Heads: Collaro 2 track 28/6 pair, B.S.R. 4 track 99/6

MAINS TRANSFORMERS

Post 2/6 each

250-0-250 80 mA. 6.3 v. 3.5 a. 6.3 v. 1 a, or 5 v. 2 a. 25/-
350-0-350 80 mA. 6.3 v. 3.5 a. 6.3 v. 1 a, or 5 v. 2 a. 29/6
MT. 510/300-0-300 v. 120 mA., 6.3 v. 4 a....... 29/6
MINIATURE 200 v. 20 mA., 6.3 v. 1 a. 10/6
MIDGET 220 v. 45 mA., 6.3 v. 2 a............ 15/6
SMALL 250-0-250 50 mA. 6.3 v. 2 a.......... 19/6
HEATER TRANS. 6.3 v. 1½ a., 8/6; 6.3 v. 4 a. 10/6
Ditto tapped sec. 1.4 v., 2, 3, 4, 5, 6.3 v. 1½ amp. .. 10/6
GENERAL PURPOSE LOW VOLTAGE. Outputs 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 24 and 30 v. at 2 a. 25/-
1 amp., 5, 10, 15, 20, 25, 30, 35. 40, 55, 60, 29/6; 2 a., 47/6
AUTO TRANSFORMERS 0–115–230 v. Input/Output, 60w. 18/6; 150w. 25/-; 500w. 92/6; 1000w. 175/-.

CRYSTAL MIKE INSERTS

1½ × ⅜in. 6/6; BM3 1 × ⅜in. 7/6; ACOS 1⅜ × ⅜in. 8/6

ALL PURPOSE HEADPHONES

MOVING COIL HEADPHONES 100 ohms (ex. Govt.) 12/6
H.R. HEADPHONES 2000 ohms...12/6, 4000 ohms ...15/-
H.R. HEADPHONES 2000 ohms Super Quality 25/-

1967 GRAM CHASSIS

Post 5/-

Three Wavebands: Long., Med., Short. Gram. Five Valves: ECH81, EF89. EBC81, EL84, EZ80, 12-month guarantee. A.C. 200-250 v. Ferrite Aerial 5 watts 3 ohm. Chassis 13½in. × 7in. × 5in. dial size 13in × 4in. Two pilot Lamps. Four Knobs. Aligned calibrated. Chassis isolated from mains **£10.10**

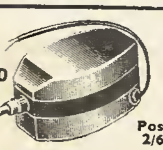
DE LUXE STEREO GRAM CHASSIS V.H.F., MW, SW 19-50m, SW 60-180m. Magic eye, push buttons, 6 valve plus rect. Size 15" x 7½" x 6" high **£19.19**

HIGH GAIN TV. PRE-AMPLIFIER BAND I B.B.C. Tunable channels 1 to 5. Gain 18 dB. ECC84 valve. Kit price 32/6 or 55/- with power pack. Details 6d.
BAND III I.T.A.—same prices. Tunable channels 7 to 13. Band I or III. Coils and circuit only, 9/6. Chassis 4/9, B.B.C. 2 SUPER BOOSTER transistor model. Ready built 75/-.

BLANK ALUMINIUM CHASSIS. 18 s.w.g. 2½in. sides, 7×4in., 5/6; 9× 7in., 6/6; 11×3in. 6/6; 11×7in. 7/6; 13×9in. 9/6; 14×11in. 12/6; 15×14in., 15/-.
ALUMINIUM PANELS 18 s.w.g. 12×12in. 5/6; 14×9in. 4/6; 12×8in. 3/6; 10×7in. 2/9; 8×6in. 2/-; 6×4in. 1/6.

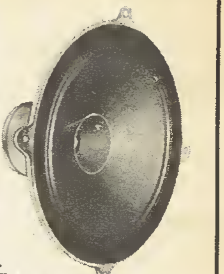
ALL PURPOSE TRANSISTOR PRE-AMPLIFIER
Gain 14: 1. 250v. or 9v. input. Ready built with Mu Metal input transformer for Mikes, Pick-Ups, Tuners. Instructions and circuit supplied. Post 2/6. **15/-**

THE INSTANT BULK TAPE ERASER AND RECORDING HEAD DEMAGNETISER



200/250 v. A.C.
[Leaflet S.A.E.
Post 2/6 **35/-**

BAKER 12 in. MAJOR



The ideal High Fidelity Loudspeaker for high output at home or public address, etc. Built in high efficiency tweeter cone. Voice Coil impedance 15 ohms. Max. Power 20 watts. Bass Res. 40/50 cps. Flux 14,000 gauss. Voice Coil diameter 1½in. Response 40-14,500 cps. Magnet material Alcomax, overall dia. 12½in., overall depth 6in.

Price **£8** Post Free

CATALOGUE S.A.E.

GROUP MODELS FOR VOCALS BASS, LEAD and RHYTHM GUITARS 30-10,000 cps. Voice Coils 15 ohms. Heavy duty.

'Group 25' 12in. 25w. **5gns.** **'Group 35'** 12in. 35w. **8½gns.** **'Group 50'** 15in. 50w. **18gns.**

Quality Horn Tweeters 3-16kc/s. 10w. 27/6. Crossover 14/6.
LOUDSPEAKERS P.M. 3 OHMS. 2½in., 3in., 4in., 5in., 7in. × 4in., 15/6 each; 8in. 22/6; 6½in. 18/6; 10in. 30/-; 12in. 30/-; (15 ohms 35/-); 10 × 6in. 30/-; 8 × 5in. 21/-; E.M.I. Double Cone 13½ × 8in., 3 or 15 ohm models, 45/-.
SPECIAL OFFER! 8 ohm. 2½in., 5in.; 15 ohm. 5in., 7 × 4in.; **15/6** 25 ohm. 5in., 6 × 4in.; 35 ohm. 3in., 5in., 7 × 4in.; EACH—ANY TYPE. 80 ohm. 2½in., 2¾in.
JACK SOCKETS Std. open-circuit 2/6, closed circuit 4/6; Chrome Lead Socket 7/6. DIN 3-pin 1/3, 5-pin 1/6; Lead 3/6, Phono Plugs 1/-. Socket 1/-. JACK PLUGS Std. Chrome 3/-; 2.5mm.; 3.5mm. 1/9; DIN 3-pin 3/6; 5-pin 5/-.
WAVE-CHANGE SWITCHES WITH LONG SPINDLES.
2 p. 2-way, or 2 p. 6-way, or 3 p. 4-way 3/6 each.
1 p. 12-way, or 4 p. 2-way, or 4 p. 3-way, 3/6 each.
Wavechange "MAKITS" 1 p. 12-way, 2 p. 6-way, 3 p. 4-way, 4 p. 3-way, 6 p. 2-way. Prices include click spindles, adjustable stops, spaces, etc., 1 wafer, 10/6; 2 wafer, 15/-; 3 wafer, 19/6.
TOGGLE SWITCHES, sp. 2/-; sp. dt. 3/6; dp. 3/6; dp. dt. 4/-.

DE LUXE TAPE SPLICER Cuts, trims, joins for editing and repairs. With 3 blades. **14/6**

4 CHANNEL TRANSISTOR MICROPHONE MIXER. Add musical highlights and sound effects to recordings. Will mix Microphone, records, tape and tuner with separate controls into single output. **52/6**

DYNAMIC MICROPHONE. Dual impedance 600 ohm/50K Hand, Floor or Desk mounting. Response 70-12,000 cps. **£6.6.0**

AM TUNER MEDIUM WAVE. Three Transistor Superhet. Ready built. Printed Circuit. Ferrite Aerial. Sizes 5½"×3½"×1½". Ideal for Tape Recorders. **79/6**

FM TUNER 88-108 Mc/s Six Transistor. Superhet. Ready built. Printed Circuit. Calibrated slide dial tuning. Size 6" × 4" × 2½". **£8.10.0**

3 WATT QUALITY AMPLIFIER. 4 Transistor Push-Pull Ready built, with volume control **65/-**

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High Fidelity Speaker Enclosures and Plans.............. 5/-
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RESISTORS. Preferred values, 10 ohms to 10 meg. ¼ w., ½ w., 1 w., 20% 4d.; 1½ w. 8d.; 2 w. 1/-; ½ w. 10% 6d. HIGH STABILITY. ½ w. 1% 10 ohms to 10 meg., 2/-. Ditto 5%. Preferred values 10 ohms to 22 meg., 9d.

5 watt / 10 watt / 15 watt } 0.5 to 8.2 ohm 3 w. WIRE-WOUND RESISTORS 10 ohms to 6,800 ohms { 1/6 / 1/9 / 2 -
10K, 15K, 20K, 25K, 68K, 10W. 3/-

MAINS DROPPERS. Midget. With sliders. 0.3 a., 1 K., 0.2 a., 1.2 K., 0.15 a., 1.5 K., 6/- each.
LINE CORD 100 ohms ft. twin plus resistance. 1/- ft.

WIRE-WOUND 3-WATT POTS. T.V. Type. Values 10 ohms to 30 K., 3/3, Carbon 30 K. to 2 meg., 3/-.

WIRE-WOUND 4-WATT STANDARD SIZE POTS. LONG SPINDLE VALUES 50 OHMS to 100 K., 7/6.

VALVE HOLDERS. Int. Oct. 6d. Mazda Oct. 6d.; B7G, B8A, B8G, B9A, Moulded 9d. Ceramic 1/-. B7G, B9A Cans 1/-. Valve base plugs B7G, B9A, Int. Oct., 2/3.

80 ONLY—SANGAMO 3 inch SCALE LABORATORY MOVING COIL METERS
Various calibrations and movements. 100 Microamp 55/-; 1 Milliamp 50/-, etc. Post 5/- extra. Send S.A.E. for list.

BRAND NEW QUALITY EXTENSION LOUDSPEAKER

In tough cream plastic cabinet with 20ft, lead and adaptors. For any transistor radio, intercom, mains radio, tape recorder, etc. 3to 15 ohm matching
Size: 7½" x 5½" x 3"
30/- Post 2/6

RETURN OF POST DESPATCH *Post and Packing 1/6 unless otherwise stated. C.O.D. 5/- extra. Full List 1/-.* *CALLERS WELCOME*

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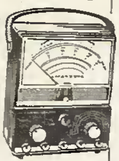
NEW MODEL 500. 30,000 o.p.v. With overload protection, mirror scale. 0/.5/1/2.5/10/25 / 100 /250/500 /1,000v. D.C. 0 / 2.5 / 10 / 25 / 100 / 250 500 / 1,000v. A.C. 0 / 50μA / 5 / 50 / 500mA. 12 amp. D.C. 0 / 60K / 6 Meg. / 60. Meg Ω. £8/17/6 Post Paid.

PROFESSIONAL 20,000 o.p.v. LAB. TYPE MULTITESTER

With automatic overload protection, mirror scale. Ranges: 1/10/50/250/500/1,000 volts, D.C. and A.C. 0-500 μA, 10 mA, 250 mA. Current: 0/20 K, 200 K, 2 megohm. Decibels — 20 to + 22db. £5/10/. P. & P. 2/6.

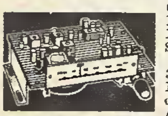
TE-900 20,000Ω/VOLT GIANT MULTIMETER 6in. full view meter. 2 colour scale. 0/2.5/10/250/1,000/5,000 V. A.C. 0/25/12.5/10/50/250/1,000/5,000 V. D.C. 0/50μA/110/100/500 mA/10 amp. D.C. 0 2K/200K/20 Megohm. £12/19/6. P. & P. 5/-.



MODEL ZQM TRANSISTOR CHECKER

It has the fullest capacity for checking on A, B and Ico. Equally adaptable for checking diodes, etc. Spec.: A : 0·7-0·9967, B: 5-200, Ico: 0-50 microamps, 0-5 mA. Resistance for diode 200Ω — 1 Meg. Supplied complete with instructions, battery and leads. £5/19/6. P. & P. 2/6.

★TRANSISTORISED FM TUNER★



6 TRANSISTOR HIGH QUALITY TUNER, SIZE ONLY 6in. × 4in. × 2½in. 3 I.F. stages. Double tuned discriminator. Ample output to feed most amplifiers. Operates on 9 volt battery. Coverage 88-108 Mc/s. Ready built ready for use. Fantastic value for money. £6/17/6. P. & P. 2/6.

NOMBREX TRANSISTORISED EQUIPMENT

ALL Post Paid With Battery

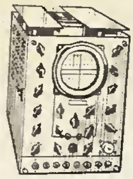
Model 22 P.S.U. 0-15v. D.C. £14. Model 30 Audio Generator 10 c/s-100 Kc/s £19/10/0. Model 31 R.F. Generator 150 Kc/s-350 Mc/s £12/10/0. Model 27 Signal Generator 150 Kc/s-350 Mc/s. £10/10/0. Model 63 Audio Generator 10 c/s-100 Kc/s £16/15/0. Model 62 C.R. Bridge £9. Model 66 Inductance Bridge £18. Model 61 P.S.U. 0.5-15v. D.C. £6/10/0.

SILICON RECTIFIERS

200 v. P.I.V. 200mA.	2/6
200 v. P.I.V. 6 amp.	5/6
400 v. P.I.V. 3 amp.	7/6
1,000 v. P.I.V. 5 amp.	7/6
400 v. P.I.V. 6 amp.	5/6
400 v. P.I.V. 8 amp.	7/6
1,000 v. P.I.V. 650 mA	6/6
800 v. P.I.V. 500mA.	5/6
800 v. P.I.V. 5 amp.	7/6
400 v. P.I.V. 500mA.	3/6
70 v. P.I.V. 1 amp.	3/6
150 v. P.I.V. 165mA.	1/-
150 v. P.I.V. 25 amp.	19/6
700 v. P.I.V. 100 amp.	49/6
400 v. P.I.V. 3 amp. (S.C.R.)	10/-
100 v. P.I.V. 5 amp. (S.C.R.)	13/6
200 v. P.I.V. 5 amp. (S.C.R.)	15/6
400 v. P.I.V. 5 amp. (S.C.R.)	17/6

Discounts for quantities. Post extra.

TYPE 13A DOUBLE BEAM OSCILLOSCOPE BARGAIN!

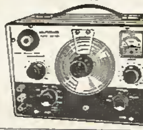


A high quality instrument, offered at a fraction of original cost. Timebase 2 c/s-750 kc/s. Separate Y1 and Y2 amplifiers up to 5.5 Mc/s. Built-in calibrators at 100 kc/s. and 1 Mc. Operation for 115/250 v. A.C. Available in excellent condition, fully tested and checked. £22/10/-. Carr. 30/-.

TE-20RF SIGNAL GENERATOR

Accurate wide range signal generator covering 120 kc/s-260 Mc/s on 6 bands. Directly calibrated. Variable R.F. attenuator. Operation 200/240 v. A.C. Brand new with instructions £12/10/-. P. & P. 7/6. S.A.E. for details.

LAFAYETTE TE-46 RESISTANCE CAPACITY ANALYSER



2 P.F. - 2,000 MFD. 2 ohms - 200 megohms. Also checks impedance turns ratio, insulation, 200/250 v. A.C. **Brand New £15.** Carr. 7/6.

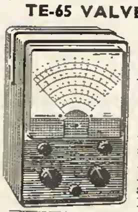
TE22 SINE SQUARE WAVE AUDIO GENERATORS

Sine: 20 cps to 200 kc/s on 4 bands. Square: 20 cps to 30 kc/s. Output impedance 5,000 ohms, 200/250 v. A.C. Supplied brand new and guaranteed with instruction manual and leads, £15. Carr. 7/6.

ARF-100 COMBINED AF-RF SIGNAL GENERATOR

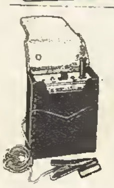
AF. SINE WAVE 20 - 200,000 cps. Square wave 20-30,000 cps. O/P. **HIGH IMP.** 21 v. P/P 600Ω 3-8 v. P/P. TF. 100 kc/s-300 Mc/s. Variable R.F. attenuation Int/Ext. Modulation Incorporates dual purpose meter to monitor AF output and % mod. on R.F. 220/240 v. A C. £27/10/-. Carr. 7/6.

TE-65 VALVE VOLTMETER



High quality instrument with 28 ranges. D.C. volts 1.5-1,500 v. A.C. volts 1.5-1,500 v. Resistance up to 1,000 megohms. 220/249 v. A.C. operation. Complete with probe and instructions, £15. P.P. 6/-. Additional Probes available: R.F. 35/-; H.V. 42/6.

F.M. WIRELESS MICROPHONE



94-104 Mc/s. Transistorised. Operates from 9 v. battery. Complete with additional secret tie-clip microphone. List £12/10/0. ONLY £6/15/0. P. & P. 2/6.

These cannot be operated in U.K.

COSSOR 1035 MK III DOUBLE BEAM OSCILLOSCOPES

Latest model using miniature valves. Perfect condition. £45. Carr. 30/-.

CATALOGUE

- ★ ELECTRONIC COMPONENTS
- ★ TEST EQUIPMENT
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We are proud to introduce our first comprehensive catalogue of Electronic Components and equipment. Over 150 pages, fully illustrated, listing thousands of items many at bargain prices. Free discount coupons with every catalogue. Everyone in electronics should have a copy.

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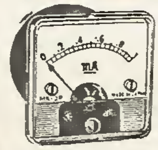


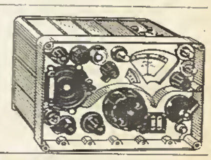
First grade quality, Moving Coil panel meters, available ex-stock. S.A.E. for illustrated leaflet. Discounts for quantity. Available as follows: Type MR. 38P. 1 21/32in. square fronts.

100-0-100μA	27/6	200mA	22/6	100V D.C.	22/6
500-0-500μA	22/6	300mA	22/6	150V D.C.	22/6
1-0-1mA	22/6	500mA	22/6	300V D.C.	22/6
1mA	22/6	750mA	22/6	500V D.C.	22/6
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
100mA	22/6	20V D.C.	22/6	500V A.C.	22/6
150mA	22/6	50V D.C.	22/6	"S" Meter 1mA	29/6

50μA	32/6
100μA	29/6
200μA	27/6
500μA	25/-
50-0-50μA	29/6

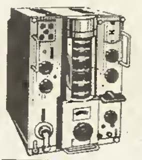
POST EXTRA. Larger sizes available—send for lists.

R209 MK. II COMMUNICATION RECEIVER



11 valve high grade communication receiver suitable for tropical use. 1-20 Mc/s on 4 bands. AM/CW/FM operation. Incorporates precision vernier driver, BFO. Aerial trimmer, internal speaker and 12 v. D.C. internal power supply. Supplied in excellent condition, fully tested and checked. £15. Carr. 20/-.

ADMIRALTY B.40 RECEIVERS

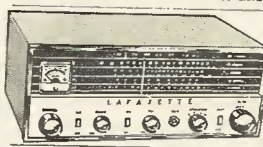


Just released by the Ministry. High quality 10 valve receiver manufactured by Murphy. Coverage in 5 bands 650 Kc/s.-30 Mc/s. I/F 500 Kc/s. Incorporates 2 R.F. and 3 I.F. stages, crystal bandpass filter, noise limiter, crystal controlled B.F.O. calibrator, I.F. output, etc. Built-in speaker, output for phones. Operation 150/230 volt A.C. Size 19¼in. × 13½in. × 16in. Wght. 114 lbs. Offered in good working condition, £22/10/0. Carr. 30/-. With circuit diagrams. Also available B41 L.F. version of above. 15 Kc/s-700 Kc/s, £17/10/0. Carr. 30/-.

LAFAYETTE KT-340 COMMUNICATION RECEIVER SEMI-KIT

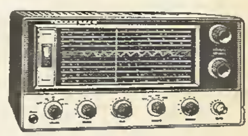
Build this wonderful receiver and save Pounds! Supplied semi-completed, main components ready mounted, R.F. Section already wired and aligned. Full and precise instructions supplied. Specification: 8 valves + rectifier, 4 bands covering 550 Kc/s—30 Mc/s. Incorporates 1 R.F. and 2 I.F. stages, "Q" multiplier, B.F.O., A.N.L. "S" meter, bandspread, aerial trimmer, etc. Operation 115/230v. A.C. Price **25 GNS.** Carr. 10/-

HAM-1. 4 BAND COMMUNICATION RECEIVER



4 wavebands covering 535 kc/s-30 Mc/s 5-valve superhet circuit. Incorporates S meter, B.F.O., BANDSPREAD TUNING, BUILT-IN 4in. SPEAKER, FERRITE AERIAL AND EXTERNAL TELESCOPIC AERIAL. Operation 220/240v. A.C. Supplied brand new with handbook. £16/16/0. Carr. 10/-.

NEW LAFAYETTE MODEL HA-700 AM/CW/SSB AMATEUR COMMUNICATION RECEIVER



8 valves, 5 bands incorporating 2 MECHANICAL FILTERS for exceptional selectivity and sensitivity. Frequency coverage on 5 bands 150-400 kc/s, 550-1,600 kc/s, 1.6-4.0 Mc/s, 4.8-14.5 Mc/s, 10-5-30 Mc/s. Circuit incorporates R.F. stage, aerial trimmer, noise limiter, B.F.O., product detector, electrical bandspread, S meter, slide rule dial. Output for phones, low to 2KΩ or speaker 4 or 8 ohms. Operation 220/240 volt A.C. Size 7¾in. × 15in. × 10in. Supplied brand new and guaranteed with handbook 36 GNS. carr. 10/-. S.A.E. for leaflet.

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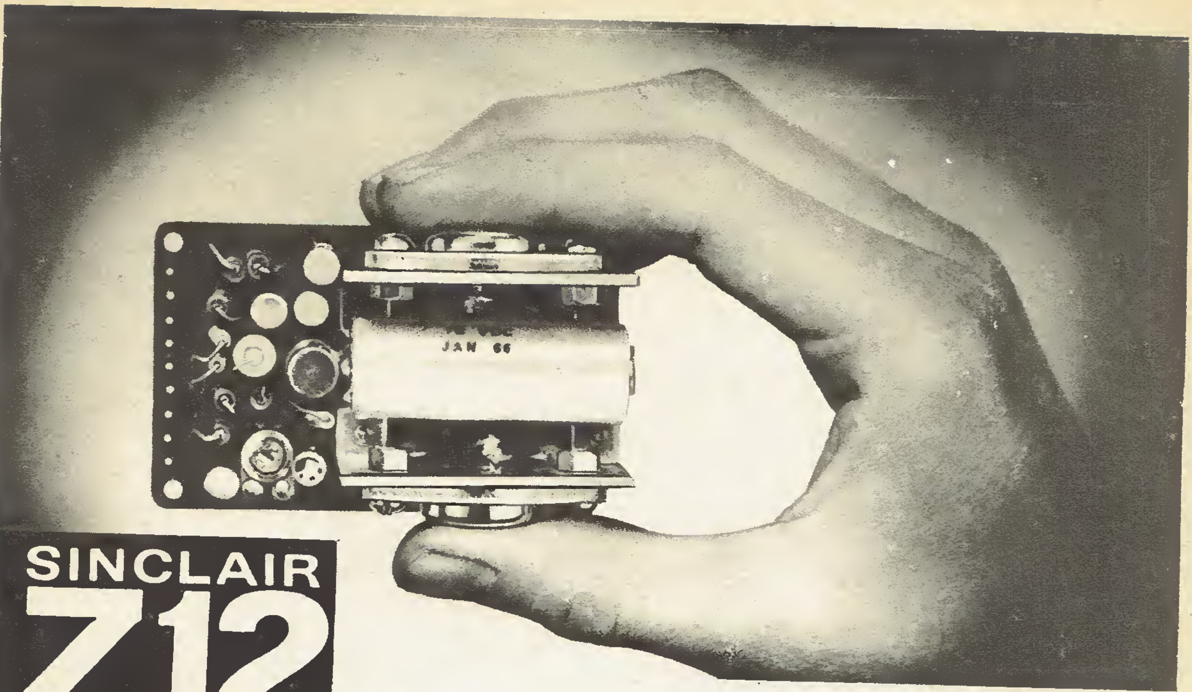
3-34 LISLE STREET, LONDON, W.C.2



SINCLAIR Z.12

COMBINED 12 WATT HI-FI AMP & PRE-AMP

- ULTRALINEAR CLASS B OUTPUT
- 12 WATTS RMS CONTINUOUS SINE WAVE OUTPUT (24 W. Peak)
- 15 WATTS MUSIC POWER OUTPUT (30 W. Peak)
- INPUT—2mV into 2Kohms
- OUTPUT suitable for 15, 7·5 and 3 ohm speakers. Two 3 ohm speakers may be used in parallel

SINCLAIR PZ.3 Transistorised mains power supply unit with ample output for two Z.12's and Stereo 25 together. **79/6**

Eight special H.F. transistors are used in the Z.12 to achieve results to compare favourably in every way with the costliest equipment you can buy. But the Z.12 is smaller, is more versatile and certainly saves you money. It is preferred not only for mono and stereo hi-fi, but it also enjoys enormous popularity fitted in electric guitars, used for P.A. and intercoms and many other instances where power and dependability are imperative. This superb amplifier with integrated pre-amp is supplied ready-built, tested and guaranteed together with the Z.12 manual which details matching, volume and tone control and selector switching circuits using one Z.12 in mono or two in stereo.

- 3in. × $1\frac{3}{4}$in. × $1\frac{1}{4}$in.
- 15-50,000 c/s ±1dB
- IDEAL FOR USE WITH BATTERIES

BUILT, TESTED AND GUARANTEED **89/6**

A NEW SINCLAIR LOUDSPEAKER
See previous pages

SINCLAIR STEREO 25

PRE-AMP AND CONTROL UNIT

For use with two Z.12's or any good hi-fi stereo system. The front panel is elegantly styled in solid brushed and polished aluminium with well styled solid aluminium knobs. Frequency response 25c/s to 30kc/s ±1dB connected to two Z.12's. Sensitivity Mic. 2mV into 50kΩ: P.U.—3mV into 50kΩ: Radio —20mV into 4·7Ω. Equalisation correct to within ±1dB on RIAA curve from 50 to 20,000c/s. Size $6\frac{1}{2}$in × $2\frac{1}{2}$in × $2\frac{1}{2}$in plus knobs.

BUILT, TESTED AND GUARANTEED **£9.19.6**

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MAINS MOTOR

made by Garrard for their best changers, laboratory balanced, size 2¾in. × 2¼in. Suitable for 115 V or 230/240 V working by re-arranging lead connections. 15/- each. P. & P. 4/6.

ACOS TYPISTS STETHOSCOPE

Made for use with Tape Recorder but equally suitable for radio or amplifier, or for a deaf person. 15/- each.

SIMMERSTAT

TYX-FL and TYX-F. Both popular types fitted to many cookers. Suitable for 230/240V up to 15 amps. Handy device to have around the workshop. 12/6 each.

SATCHWELL OVEN THERMOSTAT

Type TO. With capilliary tube and sensor. 20A A.C. type and as fitted to many cookers. Adjustable by control knob (not supplied) 12/6 each.

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150ft Scotch Tape on 3in spools. Normally 4/6 each. We offer 4 tapes for 10/-.

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Holds 2–3in spools. Supplied with one empty spool only. Fits the "Arrow" and several other tape recorders. 7/- each or 3 for £1.0.0.

FANE 20 WATT HI-FI SPEAKER

This is a 12in model with 2in voice coil. Really fantastic performance which will do justice to the best amplifier. Heavy cast frame, normally these retail at £7 or £8 each. We can offer a limited quantity at £3.9.6. 15 ohm coil only. Carriage and insurance 7/6. Similar model, especially designed for guitar amplifiers, same price. Please specify when ordering.

WHITE CIRCULAR FLEX

Ideal for lighting drops, twin made by BICC. Usually 8d per yd. 100yd coil for 30/-, plus 6/- postage.

EDGEWISE CONTROL

Morganite, as fitted many transistor radios. 2K or 5K with switch. 2/6 each or 24/- per dozen.

SCR's (THYRISTORS)

Piv	50V	100V	300V	400V
1 amp	6/6	7/6	8/6	9/6
3 amp	7/6	8/6	9/6	10/6
25 amp	30/-	35/-	47/6	60/-

SILICON RECTIFIERS

Tested and guaranteed

750mA	100V	1/3	1A	100V	3/-
	200V	1/6		200V	4/-
	400V	3/6		400V	6/-
3A	100V	3/6			
	200V	5/-	10A	100V	9/6
	400V	7/6		200V	12/6
	600V	9/6		400V	14/6

Sub-miniature glass encased—only approx. ⅜in long, wire ended.

400mA 50V 1/6 100V 2/6 200V 4/6

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Type No.	Price	Type No.	Price	Type No.	Price
2N1727	15/-	MAT120	7/9	OC72	5/-
2N1728	10/-	MAT121	8/6	OC75	6/-
2N1742	25/-	OA5	5/-	OC76	5/-
2N1747	25/-	OA10	6/-	OC77	7/-
2N1748	10/-	OA47	3/-	OC78	5/-
AC107	9/-	OA70	2/-	OC78D	5/-
AC127	9/-	OA79	2/6	OC81	5/-
ACY17	8/6	OA81	2/6	OC81D	5/-
ACY18	5/6	OA85	2/6	OC82	5/-
ACY19	6/6	OA90	2/6	OC83	5/-
ACY20	5/6	OA91	2/6	OC84	6/-
ACY21	6/-	OA200	3/3	OC139	8/6
ACY22	4/6	OA202	4/3	OC140	12/6
AF114	7/-	OC20	12/6	OC170	5/-
AF115	6/6	OC22	10/-	OC171	6/-
AF116	7/-	OC23	17/6	OC200	9/-
AF117	5/-	OC24	15/-	OC201	12/6
AF118	10/-	OC26	7/6	OC202	13/6
AF139	12/6	OC28	15/-	OC203	12/6
AF186	17/6	OC29	17/6	OCP71	15/-
AFZ12	15/-	OC35	12/6	ORP12	8/6
ASZ21	15/-	OC36	15/-	ORP60	10/-
BC107	14/6	OC42	6/6	SB078	6/6
BY100	4/6	OC44	4/-	SB305	8/6
BYZ13	7/6	OC45	3/6	SB251	10/-
MAT100	7/9	OC70	4/-	ST140	4/-
MAT101	8/6	OC71	3/6	ST141	6/-

MINIATURE WAFER SWITCHES

4 pole, 2 way—3 pole, 3 way—4 pole, 3 way—2 pole, 4 way—3 pole, 4 way—2 pole, 6 way—1 pole, 12 way. All at 3/6 each 36/- dozen, your assortment.

12v INVERTER

Fully transistorised for operating a 20W fluorescent tube. Size 6in long by 1½in by 1½in. £3.10.0. Post and insurance 3/-.

5 TRANSISTOR AMPLIFIER

Mounted on a printed board, size approx. 6in × 2½in with volume control, input microphone socket and push-pull output using pair of OC81. An excellent amplifier rated at 1W for gram or tape recorder. Price £2.10.0.

Where postage is not definitely stated as an extra then orders over £3 are post free. Below £3 add 2/9. Semi-conductors add 1/- post. Over £1 post free.

DRILL CONTROLLER

Electronically changes speed from approximately 10 revs. to max. Full power at all speeds by fingertip control. Kit includes all parts, case, everything and full instructions. 19/6 or ready made 32/6 plus 2/6 post and insurance

THE VECTRONOME CAPSTAN DRIVEN TAPE RECORDER

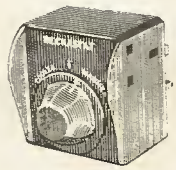
This is a truly portable self-contained instrument with built-in microphone and loudspeaker using a 5 transistor amplifier with PP output and suitable for operation from mains or by chargeable batteries. Tape capacity is 25 minutes on easily changed spools. A tape position indicator gives quick reference to any part of dictation. Recording level is automatically preset during dictation and can be adjusted to suit operator. Interlock prevents unintentional erasures. Tape speed controlled by fly wheel driven capstan. Very portable in neat case with carrying handle, overall size of which is approximately 6½ × 7½ × 2in. Price with tape, nickel cadmium rechargeable batteries and mains battery charger £9.19.6. (rather less than ⅓ original price). Postage and insurance 7/6. Unused and in perfect working order.

GARRARD AUTO RECORD PLAYER Model 2000

This is one of the latest products of the World's most experienced maker of fine record reproducers. Its superior features include—automatic playing of up to 8 mixed size records—stopping and starting without rejecting—manual playing—pick-up pivots to give low stylus pressure—large diameter turn-table for max. stability—adjustments include pick-up height—pick-up dropping position and stylus pressure. Size is 13¼ × 11¼in. clearance 4¾in. above 2¼in. below—fitted with latest hi-compliance cartridge for stereo—and mono L.P. and 78. Supplied complete with mounting template and service sheet. Offered this month at the Special Snip price of £6.9.6 plus 7/6 carriage and insurance.

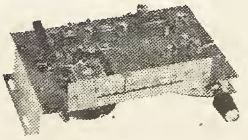
THIS MONTH'S SNIP

BECKASTAT



An Instant Thermostat. Simply push it into your wall socket and plug your fire or other appliance into it. Knob setting. Will save its cost in a season. Normally £3. We offer at 19/6 plus 2/- post. When ordering state whether for 13A or 15A socket.

F.M. TUNER

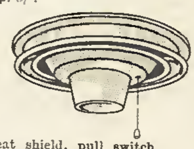


Of exceptional quality, giving really fantastic results with virtually no noise. Suitable for mains or battery operation. 6 transistors—three IF stages—double tuned discriminator. Complete, new, and built up all ready to work on chassis. Size 6in × 4in × 2in with tuning scale and slow motion drive. A £12.12.0 tuner for only £6.19.6 plus 3/6 post and insurance.

HURSEAL AUTOMATIC TIME SWITCH

12 hour, 15A, to control heating, lighting, radio, immersion heaters, etc. Regular price £4.4.0. Limited quantity 39/6 p. & p. 3/-.

HEAT AND LIGHT UNIT

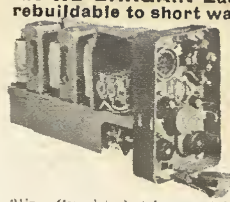


Bring luxury to your bathroom—have comforting heat where you now only have light—all the parts to build a full size (16in. diameter) model are now available—you will build it in an hour—12in. 750W circular silica-glass encased element—opal bowl for up to 100W lamp—non-rust spun reflector—white enamelled base heat shield, pull switch, magnificent unit as sold normally at £4.5.0. only 49/6 plus 7/6 carr. and insurance.

BATTERY OPERATED TAPE DECK

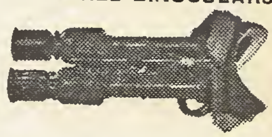
With Capstan control. This unit is extremely well made and measures approx. 6in × 5in × 2in deep. Has three piano key type controls for Record, Playback and Rewind. Motor is a special heavy duty type intended for operation off 4/5 volts. Supplied complete with 2 spools ready to install. Record, Replay head is the sensitive M4 type intended for use with transistor amplifier. Price £4.15.0. Post and insurance 4/6.

EX-WD BARGAIN Easily rebuildable to short wave radio



This is the 46 Receiver/Transmitter. It has a range of approx. 5 miles. Operates from dry batteries. Complete with six valves and in metal case. Size approx. 12in × 6in × 3½in. Complete but less crystal, not tested nor guaranteed. 19/6 plus 7/6 post and insurance. Should not be operated as a transmitter in the U.K.

See in the Dark INFRA-RED BINOCULARS



These infra-red binoculars when fed from a high voltage source will enable objects to be seen in the dark, providing the objects are in the rays of an infra-red beam. Each eye tube contains a complete optical lens system as well as the infra-red cell. These optical systems can be used as lenses for T.V. cameras—light cells, etc. (details supplied). The binoculars form part of the Army night driving (Tabby) equipment. They are unused and believed to be in good working order but sold without a guarantee. Price £3.17.6, plus 10/- carr. and ins. Handbook 2/6.

RECORD DECK

Heavy guage pressed metal plynth, size 13in × 11in. Fitted with Motor, Decca pick-up, on-off switch and 10in turntable. Motor normally mains working but 78 r.p.m. only. Could no doubt be altered to 33 or 45 r.p.m. Limited quantity only. 29/6 each, plus post and insurance 6/6.

9 VOLT PRECISION MOTOR

Intended for driving battery operated tape recorders and record players. Laminated, 6 Pole armature with Brush Gear and rapid start switch. Normally 25/-. Our Price 7/6, plus post and insurance 1/6.

MAINS TRANSISTOR POWER PACK

Designed to operate transistor sets and amplifiers. Adjustable output 6V, 9V, 12V for up to 500mA (class B working). Takes the place of any of the following batteries: PP1, PP3, PP4, PP6, PP7, PP9 and others. Kit comprises: mains transformer rectifier, smoothing and load resistor, 5,000 and 500 mfd. condensers. Zener diode and instructions. Real snip at only 14/6, plus 3/6 postage.

SENSITIVE HAND MICROPHONE

Dynamic type. Low impedance, moving ion, fitted in unusually neat plastic head with anti-microphonic coupling to handle. Extra small size, very sensitive. 15/- each.

POLYESTER FILLED FLUORESCENT CHOKE

Extra silent operation, suitable for 230/240V 40W tubes. Price only 13/6 or with two bi-pin push on ends, two spring tube clips, starter and starter holder 17/6 complete. Postage for kit or choke only is 4/6. 80W as above, price 17/6 for the choke or 21/- for the kit. Post 4/6.

STUPENDOUS OFFER—£11 for £2

The Princess Superhet

Only recently sold for £10.9.6. Note these features: ● Long & Medium Wave ● Long dial ● Push pull output ● A.V.C. and feed back ● Ferrite aerial ● Six transistors ● Cabinet size 4¾in × 3in × 1½in with carrying strap. You get everything you need and instructions. 39/6 plus 3/6 p. & p. Battery 1/9 extra. Data separately 2/6.

ELECTRONICS (CROYDON) LIMITED

(Dept. P.E.) 102/3 TAMWORTH RD., CROYDON, SURREY (*Opp. W. Croydon Stn.*)

also at 266 LONDON ROAD, CROYDON, SURREY

VOL. 3 No. 9
SEPTEMBER 1967

PRACTICAL ELECTRONICS

MICROELECTRONICS AND THE AMATEUR

MICROELECTRONICS has been described as the most significant development in the field of electronics since the invention of the transistor.

Last month we discussed the probable effects upon the industry as integrated circuits become widely adopted in place of traditional discrete components. We now propose to consider microlectronics from the amateur point of view.

In contrast to industry where the future trend will lead toward large scale conversion to integrated circuits, it is safe to predict that amateur constructors will continue to rely mainly on traditional components.

It is certain that lower prices and general availability will in due course make the integrated circuit an attractive proposition for some amateur purposes. Suitable applications will be found for the IC to *augment* discrete components, but certainly not to replace them. However, it must be admitted that the majority of "one-off" projects hardly justify the use of IC's, nor have these devices the flexibility required for experimental work in circuit design.

Nevertheless, from a novelty aspect alone these devices will naturally appeal to many. Building some relatively simple project like, for example, a compact audio amplifier, will provide a practical introduction to the new world of microcircuits. Such a project will, in fact, be presented to our readers next month.

But we think the most important and exciting contribution of the IC will be in making feasible the kind of projects which previously have seemed too ambitious for the private individual. The seeming complexity of many exotic electronic equipments is largely accounted for by the multiplicity of a number of quite ordinary "standard" circuits; the real complexity lies in the system of interconnections. Thus we can surely expect that the amateur designer, like his counterpart in industry, will find himself becoming more "systems" orientated.

With these new building blocks the drudgery of repetitive wiring work will disappear. Thus one of the disincentives to building complex equipment such as organs and calculating machines will be removed. With more extensive circuitry employed, the advantage of miniaturisation becomes immediately apparent. Spatial demands will be less—a not insignificant factor when limited accommodation has to be shared with other members of the family.

It would seem that the amateur will, in short, be able to enjoy the best of both worlds. The range of his potential activities, already of some magnitude, will be expanded further as the new devices become available. The limit will be set by his ambition—and his pocket.

THIS MONTH

CONSTRUCTIONAL PROJECTS

SPECIAL SERIES

GENERAL FEATURES

NEWS AND COMMENT

Our October issue will be published on Friday, September 15

All correspondence intended for the Editor should be addressed to: The Editor, PRACTICAL ELECTRONICS, George Newnes Ltd., Tower House, Southampton Street, London, W.C.2. Advertisement Offices: PRACTICAL ELECTRONICS, George Newnes Ltd., 15/17 Long Acre, London, W.C.2. Phone: 01-836 4363. Telegrams: Newnes London. Subscription Rates including postage for one year, to any part of the world, 36s.

time division multiplex (t.d.m.) group, the speech highways are time divided and as many as 100 conversations can be time shared on one highway. Each conversation is sampled at, say, 100 microseconds (μs) intervals for 1μs and the speech amplitude at that instant is passed forward. This is known as "amplitude modulation".

However, the amplitude may be coded in binary form and passed forward as binary digits and this is known as pulse code modulation (p.c.m.). The principal disadvantage with this system is the cost of the modulators and demodulators which are required for every subscriber.

In the space division group, a discrete path is provided for each conversation and this path makes use of reed relay crosspoints, "ferreed" crosspoints (a ferreed is a magnetically latched reed relay), or semiconductor crosspoints. The control of such an exchange is simpler than that of a time division exchange but the speech switching network requires more equipment than that of the t.d.m. exchange.

CENTRALISED CONTROL

The system, now being built for up to 2,000 lines is register controlled providing a separate physical path for each established speech path connection; switching actions are separated from the controlling actions. Moreover, all calls through the switching network for all lines are directed by one centralised electronic control, comprising a combination of magnetic cores, semiconductors and reed relays. This central control processes calls on a one-at-a-time basis but, because of fast electronic switching speeds, it can handle calls occurring *almost* simultaneously.

When calling through the new electronic system (see Fig. 2), the subscriber's telephone is connected to a line circuit which responds when the subscriber picks up his telephone. A pulse is produced and this is converted by the "calling number generator" into a pulse pattern representing the calling subscriber's directory number, for example 2114.

The register selector chooses a free register, and the calling subscriber's number is passed into it. The register then demands access to Call Control, this access being regulated by the register finder which prevents more than one register gaining access at any one time.

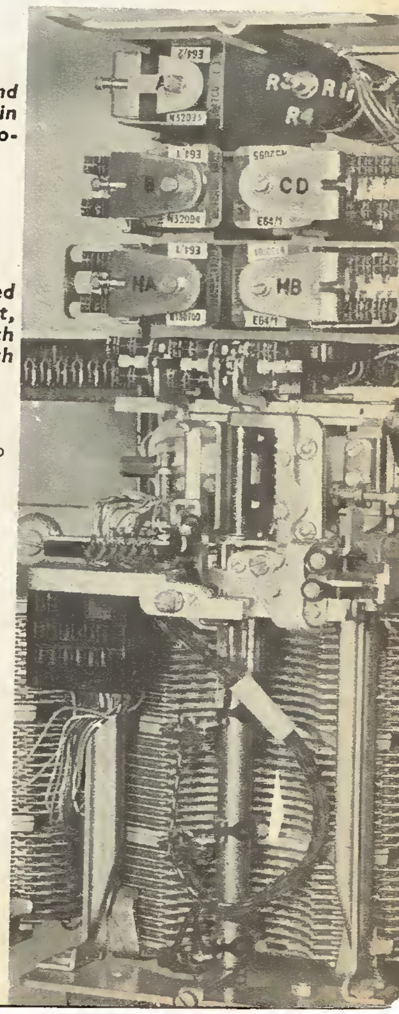
CALL CONTROL

Call Control instructs the register to pass the calling subscriber's number to the decoder. The output of the decoder is a potential on a unique lead representing the calling subscriber. This lead is threaded through the class of service field and then to its line circuit to operate the marker relay, which marks the *A* switch of the switching network to which the subscriber is connected.

At the same time the Call Control instructs the electronic speech path selectors to select a free "own exchange" supervisory relay set and a path through the *C*, *B*, and *A* switches to the calling subscriber. The chosen relay set is connected to the register via the register switch and the completion of the path is detected over a common lead from the line circuit to Call Control.

Call Control is then released from the register, which returns dial tone over the established path. This process from lifting the handset to dial tone being heard takes approximately 50 milliseconds.

The calling subscriber now dials the digits of the subscriber he wishes to call, for example 2132. The pulses generated by the dial are received in the register, counted, and stored. When he has completed dialling,



A two-motion selector and relay set used in conventional electro-mechanical exchanges

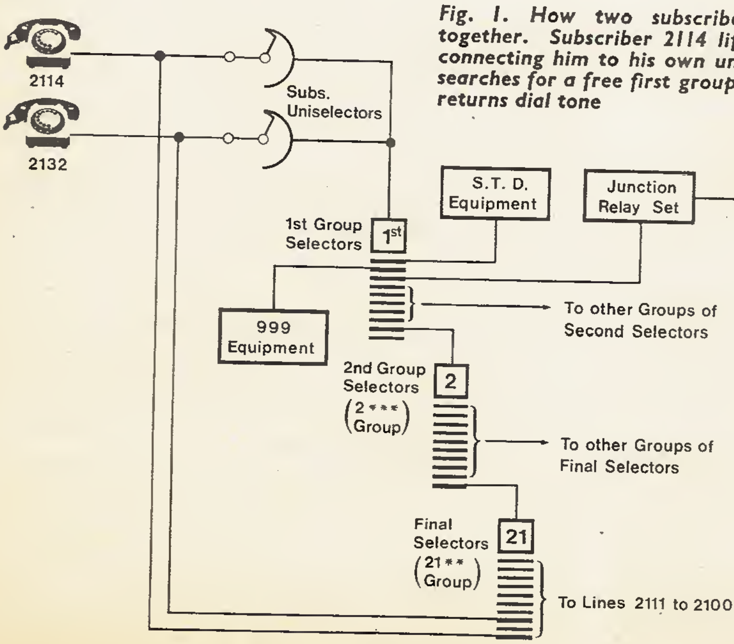


Fig. 1. How two subscribers are linked together. Subscriber 2114 lifts his handset, connecting him to his own uniselector which searches for a free first group selector which returns dial tone

representing a digit of the subscriber's number.

The wire from the subscriber's line circuit carrying the calling pulse (and threaded through the cores according to the subscriber's directory number) induces a pulse in the secondary winding of each core so threaded. The resulting pulse pattern is amplified, shaped and written into a queueing store awaiting the connection of a free register; this queueing store utilises small square-loop ferrite cores.

A signal from the store control causes the register selector to choose a free register, which is then connected to the queueing store. The information is read out of the store, amplified, lengthened, and used to switch reed relay stores in the register. The store is then released.

The queueing store can handle two calling numbers provided they occur more than 1ms apart; choosing a register, connecting it to, and releasing it from the store takes approximately 10ms. (These speeds are quite fast enough for exchanges in the small to medium range.) To cover spurious induced pulses the amplifiers of the store are arranged to ignore the first 5μs of any calling pulse.

PATH SELECTION

The selection of a path through the switching network is performed by a combination of the *B* switch selector, *C* switch selector, and supervisory selector. The choice of a register is arranged by the primary and secondary register selectors; the secondary selector chooses one of a group of registers, the primary selector chooses a register in that group; similarly with the register finders.

Each selector consists of five or six input gates in a logic circuit allowing only one gate to be operated at a time. Each gate receives its input signal from a switch, or register, indicating that the switch or register is free. The input gates are also controlled by a "start" signal.

Each gate has an output circuit which is connected to the same switch or register as the input lead. An output signal is generated only by the gate which has operated as a result of the selection process, and "marks" the chosen switch or register.

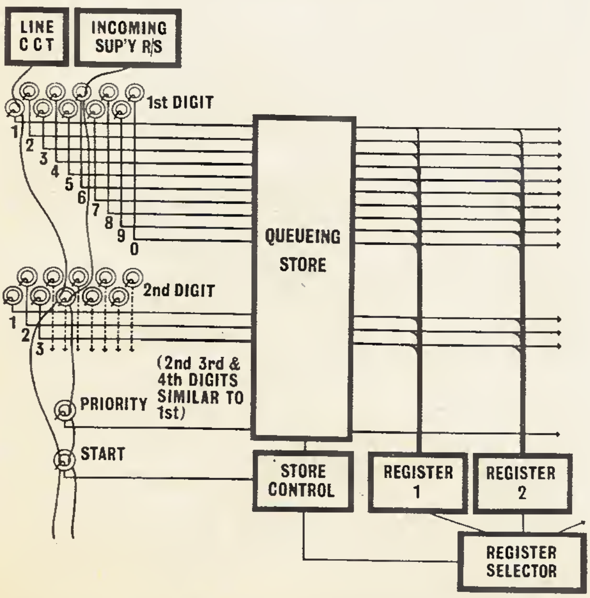
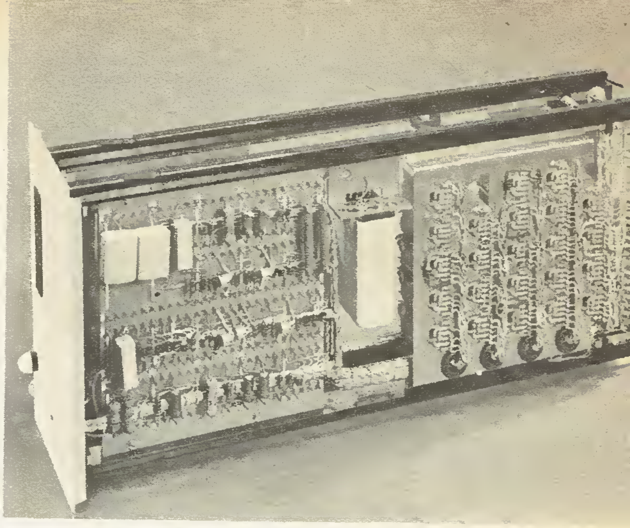


Fig. 3. Block diagram of the calling number generator



The supervisory relay set in the electronic exchange

The secondary register finder is brought into use when more than one register is demanding access to Call Control at the same time. The registers are divided into groups of five, and the secondary register finder chooses a group of registers with a demand signal. The start signal comes from the primary register finder.

All those gates with a demand signal and a start signal begin to operate but the lowest numbered gate immediately inhibits the higher-numbered gates, resulting in its own full operation and the cutting-off of all the others.

POWER SUPPLIES

The exchange operates from a conventional nominal 50V (negative) exchange battery, i.e. a battery whose voltage can vary between 46 and 52. A 50V positive supply also is needed for some of the circuits and if no suitable supply already exists it can be derived from the exchange battery by transistor inverters.

To avoid the distribution and security problems of providing further voltage rails, 60V transistors have been employed and the majority of the circuits use CV8760 transistors. An avalanche diode CV8805 is used for marking reed relay crosspoint switches and all other applications in the circuits.

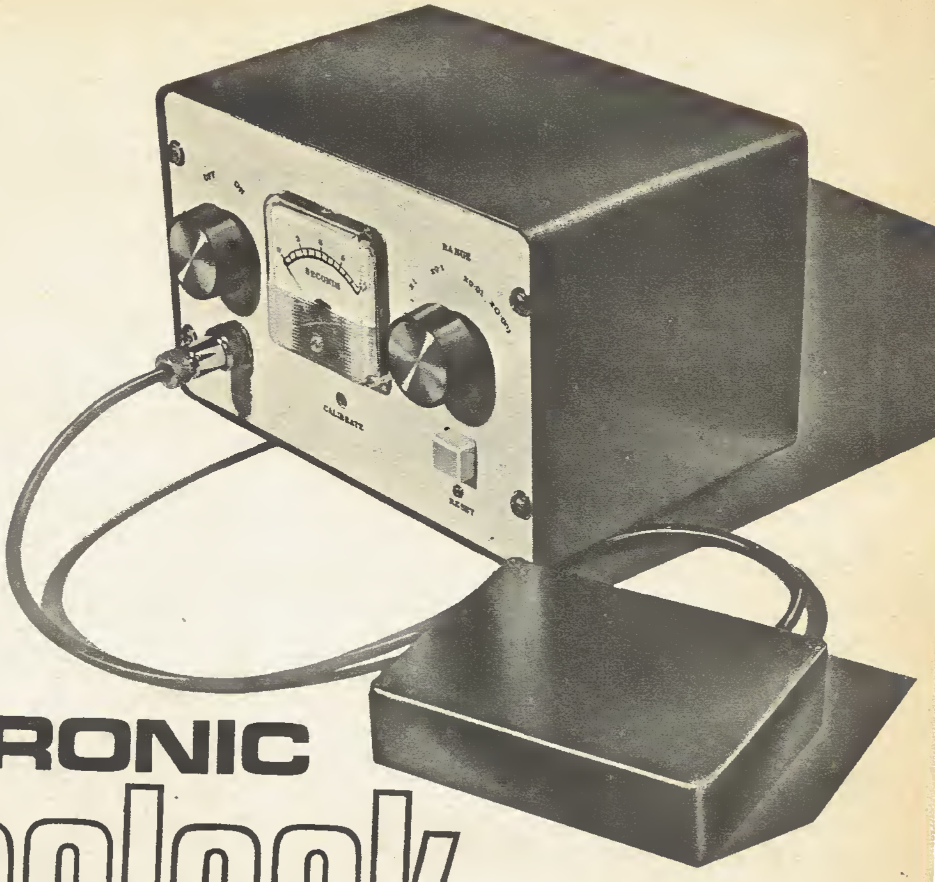
RELIABILITY AND SERVICE SECURITY

Production of equipment possessing absolute reliability is not practicable. Therefore, the exchange has been designed to be fault tolerant, allowing calls to be processed continuously and accurately despite the occurrence of occasional faults.

In the setting up and control of each call, use is made of equipment common to the whole exchange; such equipment is duplicated. Each set of common equipment is brought into service alternately every eight minutes under normal working conditions. On detection of a fault, the affected set is locked out and the other maintains service continuously; in the meantime, a signal is given to the maintenance control centre requesting the attendance, when convenient, of a maintenance engineer.

When any call fails to mature, owing to a transient fault, call control makes a second attempt in setting-up the call. The original path chosen, together with the numbers of the calling and called subscribers, is recorded on paper tape and this, together with alarm lamps, will enable the maintenance engineer to identify

A CONSTRUCTIONAL PROJECT USING PRE-PACKAGED CIRCUIT MODULES



ELECTRONIC stopclock

By M. L. Birch

THE instrument to be described in the following article, for want of a better name, has been termed an "Electronic Stopclock". Basically, it measures the interval of time elapsed between two events or stimuli which are fed to the instrument as electrical analogues. Where it differs from a conventional stopclock is in the range of times it can measure.

The instrument to be described has four predetermined ranges each having maximum periods of 12, 1·2, 0·12, and 0·012 seconds respectively.

Although the instrument is capable of resolving each of these ranges into 60 individual units of time (i.e. it is theoretically possible to measure a period of 0·2ms on the fastest range), there are other factors such as component tolerance and accuracy of meter reading which limit the usefulness to a resolving power of approximately 5 per cent of the selected range, and a tolerance of 10 per cent of the recorded value.

The instrument, therefore, does not make great claims for accuracy in its present form (even though this can quite easily be achieved by using more expensive components). However, it is an invaluable tool for the laboratory, school, photographic department or darkroom. Alternatively, it can be used with special input circuits to act as a velocity meter or a reaction time meter.

There is nothing revolutionary about the design of this instrument and there are indeed several instruments on the market which will do the job in the same way. However, the disadvantage with the latter is that the cost tends to be in the region of hundreds of pounds. If the following design is adhered to in detail and, assuming every component including the cabinet has to be bought, the total cost should not exceed £18

LOGIC BLOCKS

The major part of this equipment is therefore designed around standard ready made "logic blocks". Developments are now such that it is more economic, on component cost alone, for the amateur to use these new facilities. It also means that a great deal of the tedium of wiring multiple circuits is removed and the designer can spend more time and thought on the system rather than on the circuitry.

It is not intended to go into great details on defining the logic symbols or terms used in describing this unit, as these have already been extremely well covered in other articles. However, it is necessary to define the fact that wherever a reference is made to a "logical 1" (as opposed to a 0) this is a negative voltage of a magnitude between -4 and -8 volts. A "logical 0" is a voltage between $-0{\cdot}5$ and $+1{\cdot}0$ volts.

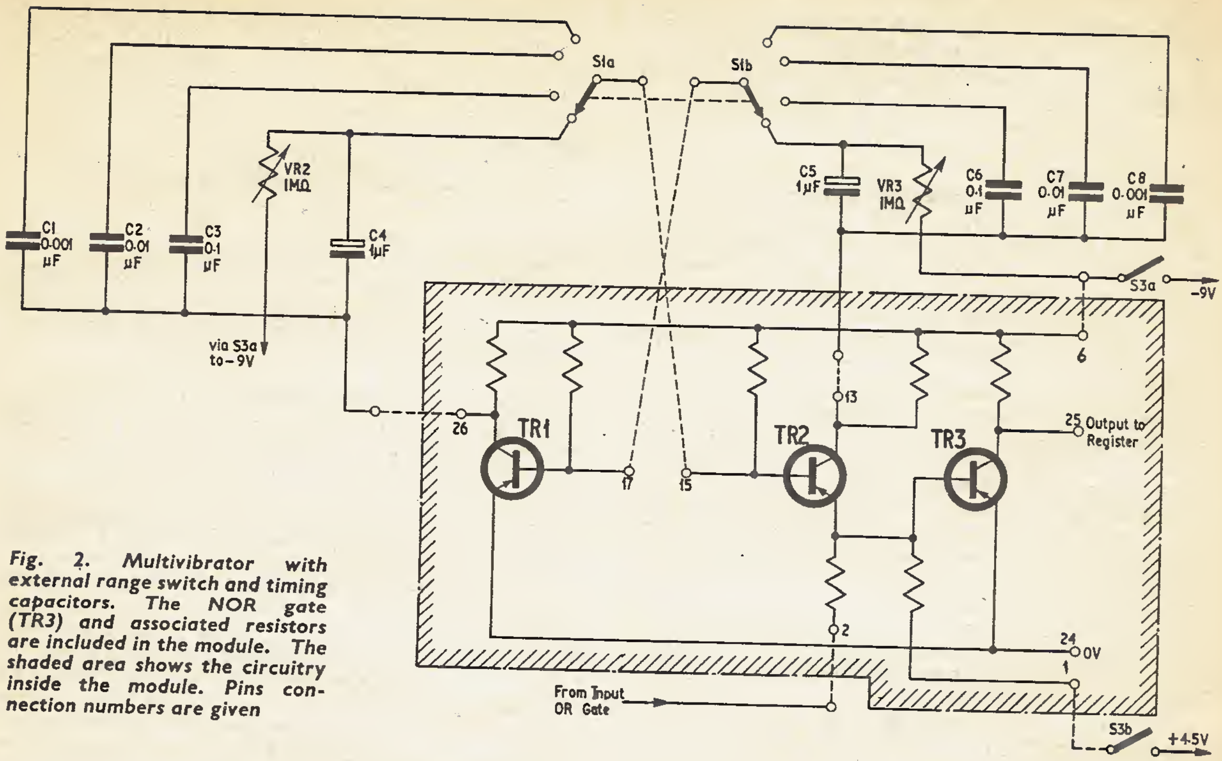


Fig. 2. Multivibrator with external range switch and timing capacitors. The NOR gate (TR3) and associated resistors are included in the module. The shaded area shows the circuitry inside the module. Pins connection numbers are given

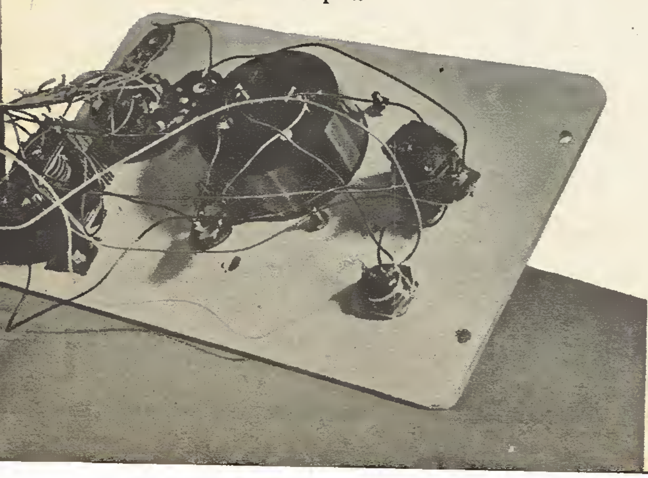
greater than one pulse less, and will only be significant at low counts.

The count of 24 or 25 will be displayed as an analogue output on the meter, which is directly calibrated in seconds and of course the reading would be 0·5 second. This figure is permanently held on the meter until the reset button is depressed, when the reading will once more return to zero.

If we allow the input to hold condition 0 for 1·5 seconds, we should count 75 pulses, but as soon as 60 is reached, the inhibit circuit comes into operation, and applies a level 1 on to the multivibrator NOR gate, thus preventing entry of any further pulses.

The meter will indicate that this has happened by reading full scale, which means that the pulse repetition frequency of the multivibrator must be reduced by means of the range switch, and the measurement repeated.

Various types of input transducers and circuits will be described later in this article, but of course, there are many possible ways of creating the correct input conditions and these will depend on the application to which the timer is to be put.



In Figs. 2, 4, and 5 the areas within the shaded boxes are the parts of the circuits contained within the modules.

If the home constructor so desired he could undertake the job of wiring up his own circuitry to cover that within the logic modules. Component values have not been included in this article, but the circuits used are fairly standard and equivalent circuits with component values can be found in several textbooks.

MULTIVIBRATOR AND CONTROL "NOR" GATE

Fig. 2 shows the basic module and the associated cross-coupling capacitors wired externally to the module. If one ignores TR3 the module is a simple multivibrator circuit with the cross-coupling left out. The circuitry is such that if a theoretically perfect capacitor is used to cross-couple, the dwell time for that side will be 1ms for every 0·01μF.

It must be realised though that to get continuous pulses, both sides must be cross-coupled to each other, and the same criterion for dwell time will apply. In this application it is most convenient to use a mark/space ratio between pulses of 1 : 1 and therefore it is necessary to use two identical capacitors for each range of frequency.

The actual time between identical points on output levels will therefore be 2ms per 0·01μF of coupling. In this design values of 1μF, 0·1μF, 0·01μF, and 0·001μF have been used; these give periods between pulses of 200, 20, 2, and 0·2ms respectively. For all the ranges except the slowest, using the 1μF electrolytic capacitor, these figures can be taken as accurate, and are controlled purely by the tolerance of the capacitors.

Due to the high leakage of electrolytic capacitors, the period on the slowest range will be found to be approximately 20 per cent longer than calculated, but this can be compensated for by including a preset 1 megohm

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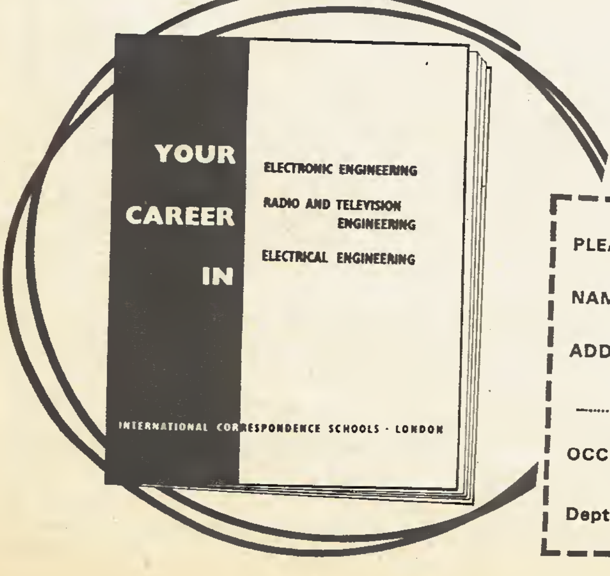

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+4·5V supply, so these have also to be linked externally. Pins 3 and 8 are what are called "direct entry points", or "set" and "reset" respectively.

If a logic level 1 is applied to, say, pin 8 this will cause the output point 15 to go to level 0 and this will override any signals which may still be entering the bistable by way of the capacitive inputs. Assuming that no signals are arriving on the capacitive clock entry point, the bistable will stay in the condition of output point 15 at state 0 after the "reset" pulse is removed.

Whatever state the output at pin 15 is at, the output at pin 17 will be the opposite; we therefore define in, this article, pin 15 as the "output" and pin 17 as the "complementary output".

When the final equipment is in operation and the "reset" button is pressed, all the binary divider outputs go to level 0, therefore, pins 8 on all the six stages are linked together so that the reset pulse is applied simultaneously to all the units. In order to achieve binary division down the chain, it is only necessary to couple the output (pin 15) of the first binary to the linked capacitive inputs (pins 25 and 26) of the following stage and this is repeated down the line.

At this stage it is worth showing part of the truth table for a divider network of this type, so that the state of the output points on each stage can be clearly defined for any number of entry pulses. This is extremely important here as it has a direct bearing on the function of the digital-to-analogue converter.

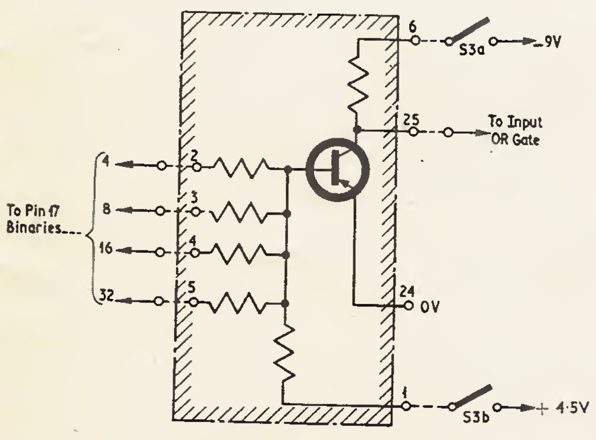


Fig. 5. Inhibit NOR gate

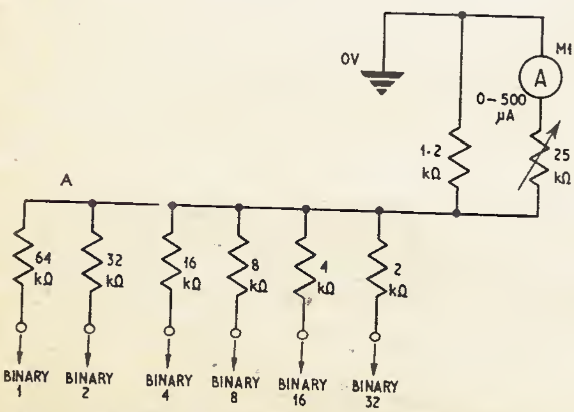


Fig. 6. Digital-to-analogue resistor network

Table 1: TRUTH TABLE FOR DIVIDER NETWORK

Mode	Pulse	State of Outputs Binary number 1	2	4	8	16	32
RESET	0	0	0	0	0	0	0
COUNTING	1	1	0	0	0	0	0
	2	0	1	0	0	0	0
	3	1	1	0	0	0	0
	4	0	0	1	0	0	0
	5	1	0	1	0	0	0
	and so on up to						
	57	1	0	0	1	1	1
	58	0	1	0	1	1	1
	59	1	1	0	1	1	1
STOP	60	0	0	1	1	1	1

At the count of 60 pulses the outputs of binaries 4, 8, 16, and 32 are all at level 1. This means that their complementary outputs are at level 0. This satisfies the condition which will operate the inhibitor NOR gate, and prevents any further pulses entering the register. It is for this reason that the *complementary* outputs of the last four stages are fed to the inhibit gate.

INHIBIT "NOR" GATE

The inhibit NOR gate is shown in Fig. 5. The four inputs are coupled to the complementary outputs of the last four binary dividers, and the output is coupled back to the simple diode OR gate of Fig. 3. The power requirements, as with all these modules, are again −9V and +4·5V.

DIGITAL-TO-ANALOGUE CONVERTER

The digital-to-analogue converter has a direct bearing on the accuracy and linearity of the instrument and although the circuit (as shown in Fig. 6) looks simple, it is perhaps too simple to be true.

Digital-to-analogue resistor networks are probably one of the biggest headaches the system designer has to contend with. In this application the problem is not too great as we are only dealing with a 6-bit register, however, with larger storage chains up to 10 bits the problems of designing these networks to operate with available components can be extremely difficult and can involve considerable component cost.

What are the hidden problems? The first is fairly obvious, and that is the fact that the resistor values called for are not standard and cannot therefore be obtained "off the shelf". It will also be noted that the values alter as a binary ratio, starting at 2 kilohms and ending at 64 kilohms. For a 10-bit register, the top value would be 1·024 megohms.

While the actual values of these resistors are not critical, the ratio between them is extremely important and this must stay constant to within a fraction per cent for perfect linearity of scale. They must also match each other under different temperature conditions, i.e. all have exactly the same temperature coefficient. In our case, where the equipment will probably only ever be subjected to room temperature, the latter problem is not critical, and as we are only working to 6 bits, the actual tolerance on ratio, while still important, is not too difficult to achieve.

is passed through the centre of a core, the direction of magnetisation can be changed by means of the current. The wire carrying the current is known as a "drive" or "co-ordinate" wire.

In a medium-size core store, however, there may be ¼–½ million cores, and this would need a large number of drive wires. The M.I.T. arrangement gets round this by setting the cores out in a matrix (see Fig. 4.1). This enables one drive wire to be used for several cores. When it is desired to switch a particular core, drive currents of approximately half that required to switch it are passed down each of the appropriate drive wires.

This does little more than disturb most of the cores on a wire, but where they cross at a core, they add up to sufficient drive to switch the core. By using this "coincidence" principle, the number of drive wires is considerably reduced. In the example drawn in Fig. 4.1, only eight wires are needed to switch sixteen cores.

It is possible to achieve a further saving in drive wires by breaking the "bits" up into words. If the sixteen bits were to be composed of eight words, each of two bits, the number of wires required could be dropped to six, by arranging the bits in "planes" (see Fig. 4.2). Now eight computer words are stored with one bit in each plane.

This is not the end of the story however. As the store stands, if a drive current is sent down the drive wires appropriate to a particular word, then all the bits in that word will switch.

To enable a word of any combination of bits to be written, a third wire is needed. This wire is known as the "inhibit" wire; each plane has its own inhibit wire, and this wire threads each core in the plane in the opposite sense to one of the drive wires. When a "0" is to be written into a core, an inhibit current is passed down the inhibit wire for that plane, and this prevents the drive currents from reinforcing each other, and hence stops the core from switching.

There is one further refinement to be added before the store is complete. It is all very well being able to write information into the store, but how is it to be read out again? This is where the fourth wire of the four wire system comes in.

A wire known as the readout wire is also threaded through each core in a plane. When a word is to be read out, the drive currents are reversed; hence, any core that was switched to a "1" originally, will now switch back to a "0". Those which were a "0" will not do anything. When a core switches back, the magnetic disturbance registers on the readout wire, and a "1" is recorded.

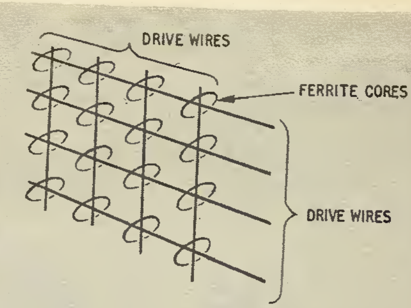


Fig. 4.1. Magnetic core store matrix

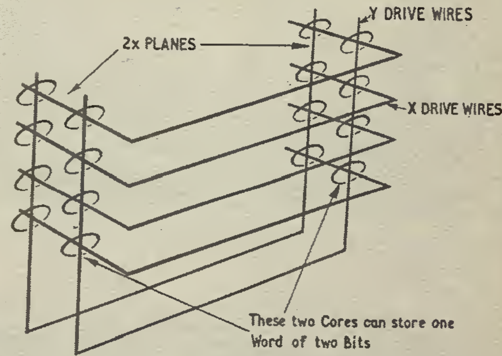


Fig. 4.2. Arranging "bits" in planes

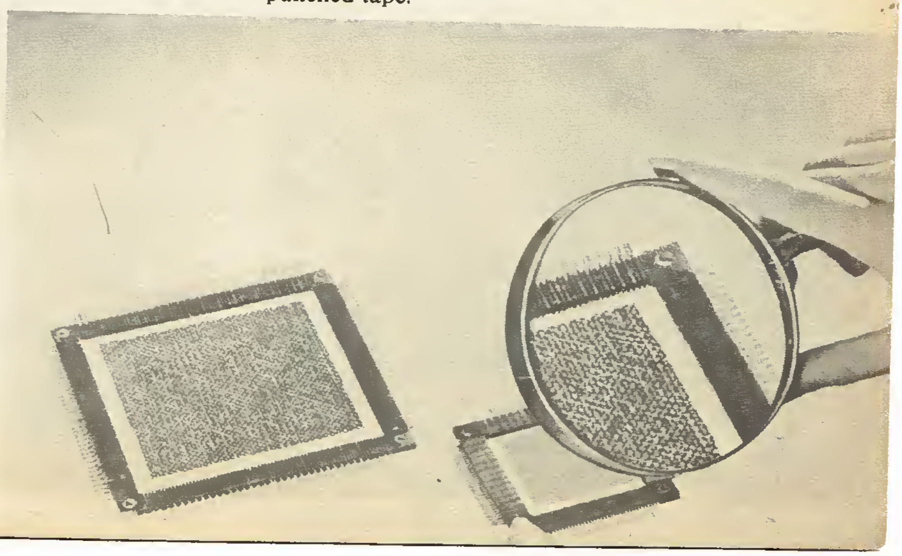
One disadvantage of this system is that when a word is read out of the store, the store is left empty. If it is required to save the word read out, then arrangements must be made for it to be written back again after it has been used.

Although this is a very popular type of store, it is not the only type. In general, a core store can be used, either as a "direct" store, to which the computer can gain access directly; or else as a "buffer" store for a slower type of storage such as magnetic tape.

A temporary store for use during an operation is known as a register. This usually consists of a string of bistables, which can store one word at a time.

Other forms of storage in common use are magnetic tape, magnetic discs and drums, punched cards, and punched tape.

Magnetic storage core matrix plane containing 4096 cores, manufactured by Mullard. Very fast switching times (0·17μs) are obtainable from the smaller matrix under the magnifying glass



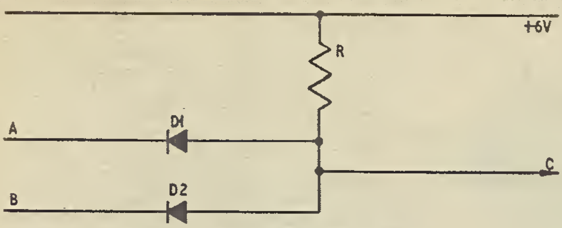


Fig. 4.6. Electronic AND gate

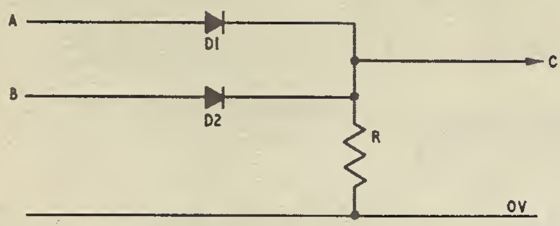


Fig. 4.7. Electronic OR gate

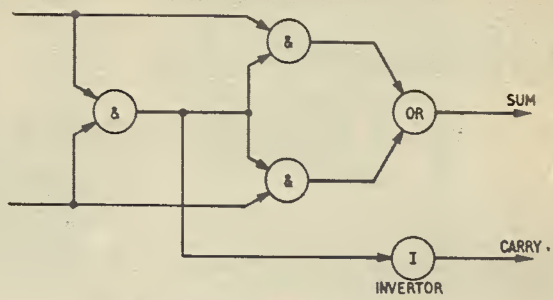


Fig. 4.8. Half-adder configuration

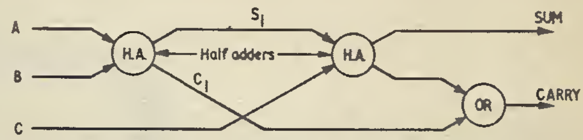


Fig. 4.9. Two half-adders make an adder

C can only be "1" when both A and B are "1".

The use of the "." and "+" signs for the AND and OR functions is deliberate, since Boolean equations can be manipulated in just the same way as the equivalent algebraic ones. For instance,

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

in both Boolean and ordinary algebra.

ELECTRONIC ARITHMETIC

Electronically, none of these Boolean functions is difficult to imitate. A transistor makes a very good invertor for a start, and it is partly for this reason that Boolean algebra is used at all.

An AND gate is shown in Fig. 4.6.

A "1" is defined as, say, +6V and a "0" as 0V. Then when both A and B sit at "0", current can flow through D1 and D2 to 0V. If either A or B rises to 6V, current can still flow through one of the two diodes to 0V. However, once both A and B have risen to 6V, there is no further path to earth for the current, and the output will rise to 6V.

The OR gate functions in almost an identical fashion and its circuit is given in Fig. 4.7.

Using these three logical functions and their negative counter parts, it is possible to perform arithmetic operations on binary numbers. Suppose, for instance, that two numbers A and B are to be added together. The truth table for this operation is given in Table 4.2.

When both A and B are 1, their sum is 2, which in binary is written as 10. This means that any logical circuit capable of adding the two numbers must also deal with the sum and the "carry" bits of the answer. A typical circuit that performs this function for just two binary numbers is known as a "half-adder". One such is shown in Fig. 4.8.

Table 4.2. TRUTH TABLE OF A PLUS B

A	B	C = (A plus B)
0	0	0
0	1	1
1	0	1
1	1	10

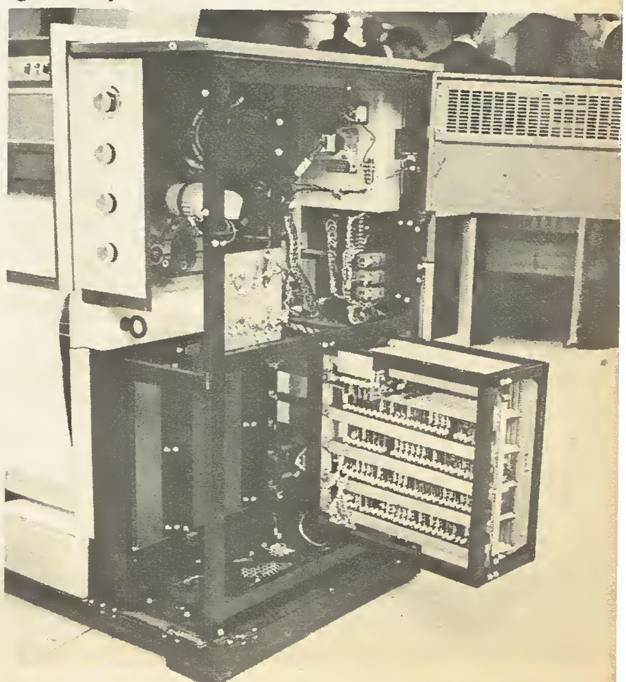
The reader may like to verify for himself, by means of a truth table, that this circuit really does work.

When two half-adders are connected as in Fig. 4.9, the result is known as a full-adder, and can add three binary numbers together.

This is just one of the many functions that logical elements can perform on binary numbers. It can probably be seen that the story does not end there, and that any arithmetic function, and quite a few non-arithmetic ones, can be performed by means of Boolean logic.

The next article will delve into the manner in which numbers are represented in different types of computer, and into the way negative numbers are taken care of.

The line printer opened for maintenance on the I.C.T. 1901 digital computer



calibration preset potentiometer (VR2) which is also intended for matching arbitrary samples of AC126 transistors within their manufacturing tolerance range.

Calibration checks should be made at monthly or quarterly routine overhauls of the equipment.

STARTING CONDITIONS

At the start of each session of photographic work, it is necessary to have some means of determining when the system has reached the selected nominal temperature and is ready for operation. In principle, the nominal temperature has been reached as soon as the circuit switches for the first time. However, this may take up to half an hour or even more, so that it is inconvenient to watch the panel lamps.

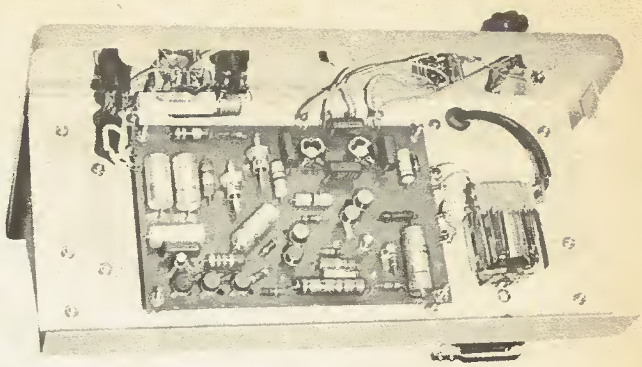
Fortunately this is quite unnecessary. The manual temperature selection control may also be used as search control to take readings of the actual temperature. If it is *slowly* turned to the point at which the circuit switches, then the scale reading at that point is the actual temperature of the liquid and feeler at the time. If the nominal control state has already been reached, displacement of the manual control through at most 0·2 degrees C in the appropriate direction causes the circuit to switch.

The switching time constant is about 0·5 seconds, so that response delays up to 2·5 seconds may result. These are essential to avoid spurious responses to mains voltage or water flow transients and to suppress hunting at critical hysteresis cancellation setting. Therefore move the manual control VR1 *slowly* and in *small steps* when using it to take a temperature reading.

The nominal control state is not significantly disturbed by a temperature read-off search adjustment of the manual control, provided the latter is returned to the nominal setting within 30 seconds. This allows adequate time to take a temperature reading. If continuous temperature indication is nevertheless desired, an ordinary mercury thermometer or some form of simple electronic thermometer should be suspended in the controlled liquid in addition to the Chemostat feeler.

THERMAL TIME CONSTANTS

In most cases, performance would be very disappointing if a haphazard plumbing system were to be used without due consideration. The accuracy of the electronic circuit in the Chemostat is beyond reproach,



since it proved possible to reduce its hysteresis to less than a fifth of the photographic bath temperature tolerance without undue circuit complication. The performance accuracy of the complete system is therefore determined entirely by the suitability of the plumbing system. The ultimate aim is to match the heating or cooling time constants of the plumbing system to the time constant of the temperature feeler in such a manner that corrections are not made so rapidly that overshoots beyond the tolerance range result, and not so slowly that random temperature drifts can again exceed the tolerance range.

Temperature adjustments always take place according to an exponential law which is of the same form as the discharge of a capacitor through a resistor. The so-called thermal time constant is the time taken for the temperature *difference* of a body with respect to its surroundings to drop to a fraction $1/e$ of its initial value. In the same way, the electrical time constant of a resistor–capacitance combination is the time taken by the capacitor to discharge through the resistor to a fraction $1/e$ of its initial voltage.

When this exponential law is expressed mathematically and differentiated to find the corresponding *rates of change*, we find that the rate of discharge of a capacitor (volts per second), or the rate of temperature change of a body (degrees per second), is always equal to the *existing voltage or temperature difference, divided by the time constant*. This simple rate law is of fundamental importance in the design of any thermostatic control system.

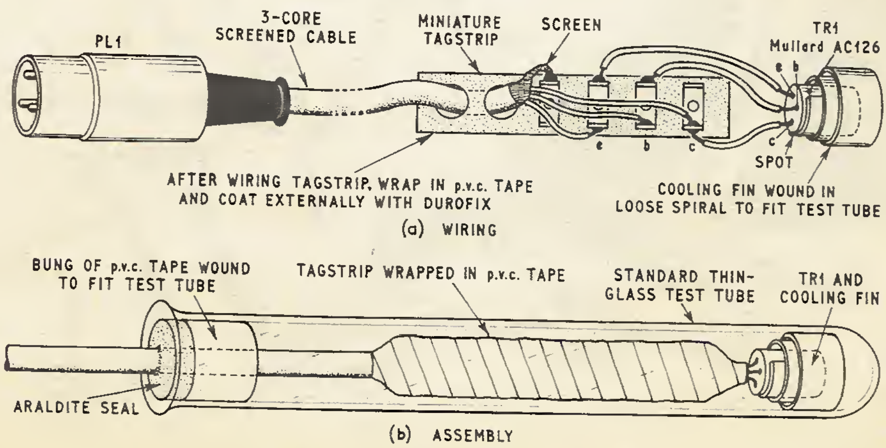


Fig. 6. Temperature feeler constructional details

MATCHING THE RATES

We will be using some form of heating or cooling device to apply continual corrections to the temperature of the photographic bath, according to the errors sensed by the feeler. The rate (degrees per second) of the temperature correction is given by the temperature difference impressed with respect to the photographic bath, divided by the thermal time constant of the bath with respect to the heater/cooler. The thermal time constant of the bath depends upon the manner in which heat is conveyed to or from the bath and thus differs profoundly for different physical arrangements.

The temperature feeler attempts to follow the heating or cooling of the photographic bath, but will thereby lag behind due to its own thermal time constant. The temperature lag will rise to a value enabling the feeler temperature to rise at the same rate as the bath temperature is increasing. Thus if the lag, which is the ultimate temperature error of the entire control system, is not to exceed the bath temperature tolerance, the rate of bath heating or cooling must not exceed the bath temperature tolerance divided by the feeler time constant. On the other hand, the rate of bath temperature correction should not be slower than this value, because disturbances are then not corrected as rapidly as inherently possible with a given system.

MEASUREMENTS

The feeler time constant is easily measured by keeping the bath temperature constant manually and plotting a graph of the rise or fall of feeler temperature against time. The feeler temperature is thereby measured with the help of the manual temperature control VR1, searching for the switch-point at successive intervals of time. Section (a) of Fig. 9 shows such a plot. The curve "in water" is the relevant one here. The thermal time constant is read-off from the graph as the time taken for the curve to drop to a fraction $1/e$ of its initial height. The temperature tolerance of the photographic bath is $\pm 0{\cdot}5$ degrees C and the thermal time constant of the Chemostat feeler was measured to be 100 seconds in water for the prototype. Thus the heating/cooling system should apply temperature corrections to the photographic bath at an optimum rate of 1/200 degree C/sec. A faster rate of temperature correction would lead to overshoot, whilst a slower rate would take longer than necessary to correct random disturbances.

AMBIENT VARIATION

Using variation of ambient air temperature as correction method, the relevant time constant of the bath is readily measured by filling the developer tray with water raised to a certain temperature above room temperature and then plotting the cooling curve *in the absence of draughts* (section (b) of Fig. 9). The same tray as will be used in the final system should be used, and the amount of water (or preferably actual developer) in it should correspond to the average amount which will be used in the tray during normal processing. The thermal time constant came out at about 2,000 seconds for prototype measurements with a light yellow plastic tray 7in × 9in containing 750cc of developer solution.

According to the rate law, we require an impressed temperature difference of 10 degrees C to obtain the required heating/cooling rate of 1/200 degrees C/sec with this thermal time constant of 2,000 seconds.

DESIGN PARAMETER

This is the nominal design parameter for the Chemostat plumbing system. As long as the feeler temperature is below the selected threshold, the photographic bath should be subjected to ambient air which is 10 degrees C hotter than the nominal bath temperature. When the feeler is above the threshold, the ambient air should be switched to 10 degrees C colder than the nominal bath temperature.

TWO-WAY CORRECTIONS

We have assumed that two-way corrections will be applied, i.e. heating if the temperature is too low *and cooling if it is too high.* This practice is indeed quite essential, because room temperatures normally tend to be above 20 degrees C, so that the Chemostat would lose positive control if only a heater were to be employed. Two-way corrections with positive heating and positive cooling make the system inherently insensitive to room temperature variations over a wide range and thus provide the only reliable method of working for all seasons of the year.

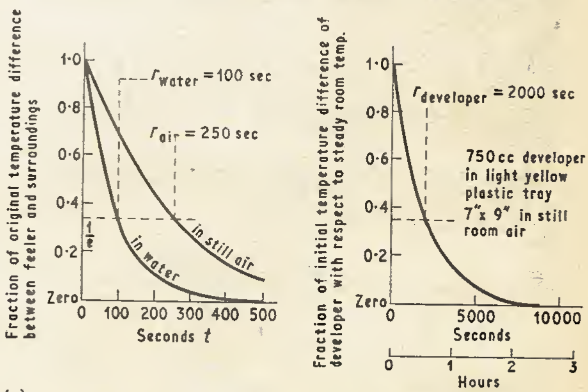
COOLING

Cooling is problematic when a good water main is not available. In such cases, electrical refrigeration equipment is essential. Commercial units are available for cooling running water. Experiments may also be carried out with adapted domestic refrigerators, with tepid tapwater running through folded tubing on the freezer plate. Such problems require individual attention in consultation with appropriate contractors.

We will assume that a cold water main connection is available, and that after an initial stabilising period, the steady temperature of the water issuing from it lies between 5 degrees C and 20 degrees C. This condition is normally satisfied for British and other temperate climates. Refrigeration equipment will then not be required.

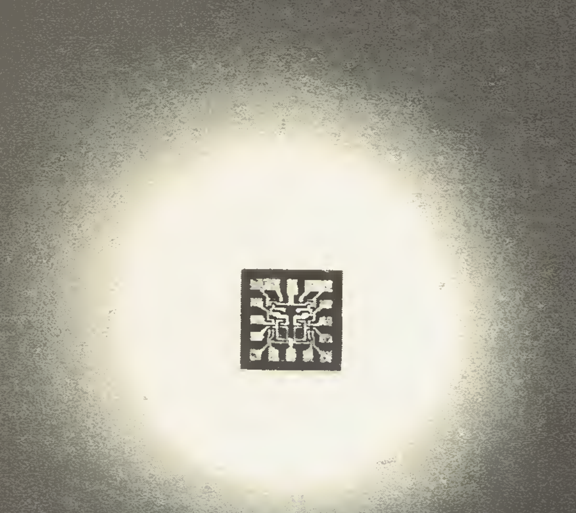
HEATING

A normal immersion heater dipping into the photographic bath would give far too short a time constant, resulting in greater overshoot errors than original random drift errors. Such a system would impair, not improve, the bath temperature stability. Suitable low-wattage immersion heaters with mechanical stirrers may be used in principle, but it is then difficult to apply a matched cooling cycle. Indirect heating methods are



(a) DETERMINING THE FEELER TIME CONSTANT (b) DETERMINING THE DEVELOPER DRIFT TIME CONSTANT

Fig. 9. These curves indicate how the optimum heating/cooling correction gradient for a given feeler and bath may be determined



microelectronics PART TWO

By M. J. HUGHES M.A.

THE first part of this article last month delved into the intricacies of thin film circuits. A glossary of terms was included which is completed this month. Now let us continue with a close look at silicon planar semiconductor integrated circuits.

SILICON PLANAR DEVICES

The concept of making integrated circuits from semiconductor materials stems back to the basic method of manufacturing conventional silicon planar transistors. It is worth describing the simple transistor before complicating the issue by introducing other types of components.

A planar transistor comprises three electrodes, the base, emitter, and collector. In the case of an *npn* device the emitter and collectors are of *n*-type silicon, while the base is *p*-type. The difference between *n* and *p*-type materials is the method by which current flows; in the former case by electron mobility, and in the latter case by hole mobility.

To obtain these two types of majority carriers, accurately controlled amounts of dopants have to be introduced to the silicon.

In the case of *pnp* germanium alloy diffused transistors, this is effected by alloying a small amount of doping material (e.g. indium) into each side of a sliver of *n*-type germanium. Under the action of heat the indium atoms diffuse into the germanium from both sides and form fronts, more commonly called junctions, between the indium pellets and the original germanium.

The two pellets of indium form the emitter and collector contacts respectively; the narrow band of original *n* type germanium left between them forms the base area. The gain of the transistor is roughly proportional to the width of this base region; the breakdown voltage is proportional to the quality and concentration of the doping material in the vicinity of the junction.

The same principle applies in making a planar transistor, except that, as the name implies, all diffusions are carried out in a single plane and from only one surface of the device.

DIFFUSION

To make an *npn* planar transistor, it is necessary to start with *n*-type silicon which will ultimately form the collector (see Fig. 4a). By forming a thin layer of silicon dioxide on the surface of this silicon—usually by heating to a high temperature in an atmosphere of steam—it is possible to passivate the surface, or protect it from chemical attack or contamination (Fig. 4b). If a small window is cut into this passivating layer by a photolithographic process using a powerful etch such as hydrofluoric acid, a *p*-type impurity such as boron can be diffused into this selected area (Figs. 4c and 4d).

The boron usually originates from boron tribromide, a gas, which is passed over the surface of the hot silicon. The length of time, and the temperature at which this operation is carried out controls the depth of penetration, and also the concentration of boron on the surface. The remaining passivating oxide prevents diffusion elsewhere on the surface. The boron diffuses sideways through the silicon as well as downwards; therefore the all important junction between the new *p*-type region and the original *n*-type material is under the surface of the oxide, thus being protected from outside influences.

The actual depth of penetration of this *p* material, or base region, is usually not more than 2 or 3 microns (a micron is a millionth of a metre). By regrowing a new layer of thermal oxide on top of the *p*-type material the window can be closed (Fig. 4e).

If now a smaller window is etched in this oxide exactly over the same centre as the first, it is possible to diffuse in an *n*-type impurity—for example phosphorus (again from a gas such as phosphorus oxychloride) (Figs. 4f and 4g). The protective covering of silicon dioxide again prevents diffusion taking place except over the window area.

Careful control of this second diffusion allows the *n*-type layer to penetrate the base region by an amount which must be less than the original base diffusion which in this case would be approximately 1 micron.

manufacture involving epitaxial isolation can be used to overcome this. We will deal with the subject of epitaxial deposition in detail a little later.

Although this has been an extremely rudimentary description of how a silicon planar transistor is made, a large number of production details have been omitted for the sake of clarity. The important feature of this method of manufacture is the fact that as all processes are carried out on one surface of the silicon, there is no reason why a large piece of silicon should not be used to fabricate several transistors simultaneously.

The only requirement for this would be to have photographic negatives carrying multiples of the base, emitter, and contact patterns, each negative being

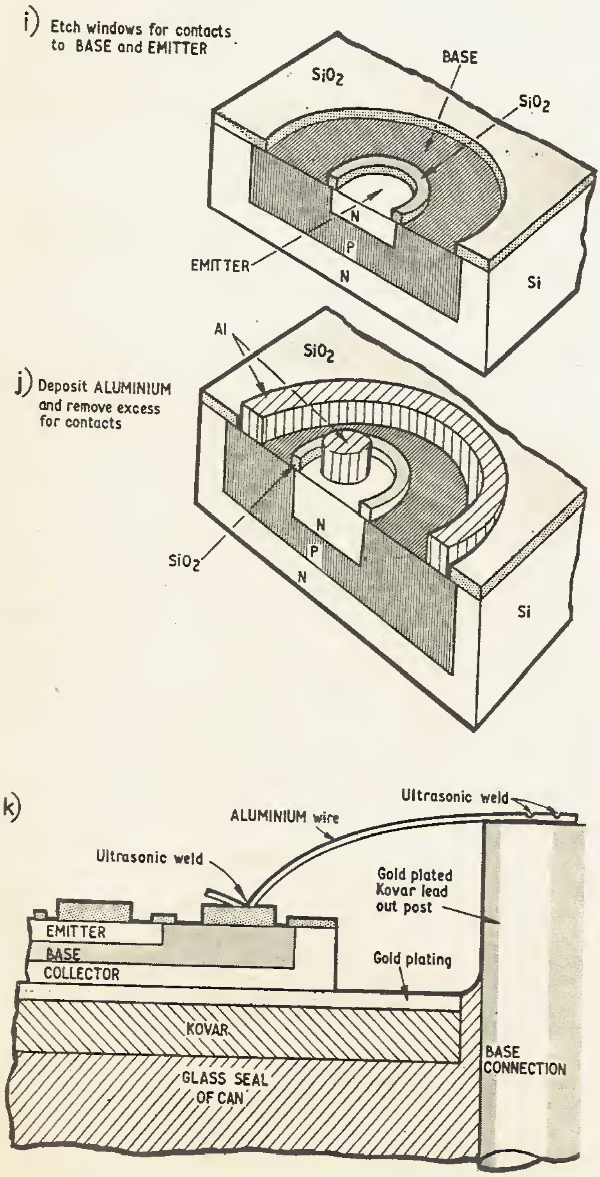


Fig. 4. Stage-by-stage process of making a silicon planar transistor from an n-type wafer to final connections

GLOSSARY

(CONTINUED)

Large scale integration—The process of fabricating complex circuits by interconnecting adjacent circuits on a wafer of silicon to form larger working circuits on a single substrate.

Logic family—A term used to define certain types of circuitry which are often ideal designs for making integrated circuits. Some typical family names follow:

CML—Current Mode Logic.
CTL—Complementary Transistor Logic.
DCTL—Direct Coupled Transistor Logic.
DTL—Diode Transistor Logic.
ECCSL—Emitter Coupled Current Steered Logic.
ECTL—Emitter Coupled Transistor Logic.
HLTTL—High Level Transistor Transistor Logic.
RCTL—Resistor Coupled Transistor Logic.
RTL—Resistor Transistor Logic.
TTL—Transistor Transistor Logic.

Mask—A very high quality photographic negative which carries a step and repeated pattern for use in photolithographic processes. The pattern could very well be of bases, emitters, or metallisation.

Stencil Mask—A thin piece of metal foil etched with windows which is used to define areas for metallisation in the thin film vacuum process.

Metallisation—The deposition of metal—usually aluminium—over the surface of a silicon wafer to form contacts and interconnections. Deposition is usually carried out by vacuum deposition.

Micromodules—Assembly of miniature components.

Micron—A millionth of a metre, or 0·001mm.

Monolithic—A monolithic integrated circuit is one in which all the components are fabricated from a single piece of material.

Mosaics—Registered trade mark for metal oxide silicon (transistor) array integrated circuits.

MOST—Metal oxide silicon transistor, a type of field effect transistor.

MTBF—Mean time between failures. This is a term used to define the reliability of a device, and is particularly used when referring to the reliability of intergrated circuits.

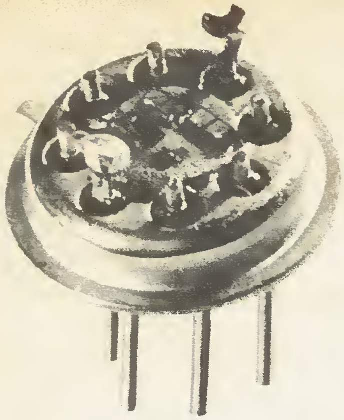
Multichip circuits—As opposed to monolithic circuits, these are made by using several different chips of silicon each containing independent circuit elements. The chips may be mounted on a conventional header, and interconnected by wire bonding, or they may be of the flip chip type, and can be mounted on to circuit board, or thin film circuits.

Ohmic contact—Any contact whether mechanical, soldered, or welded which does not have rectifying properties, and where the current through the contact is directly proportional to the potential difference across it. Simply a contact which obeys Ohm's Law.

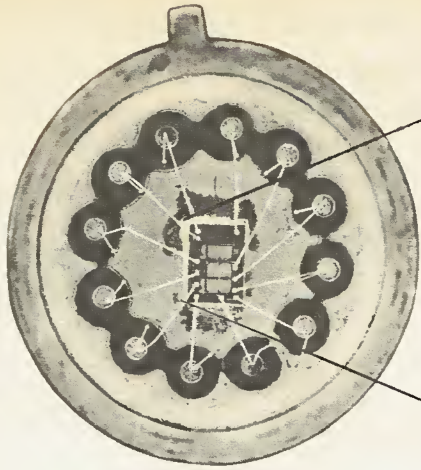
Parasitic—A parasitic is an undesirable stray capacitance, inductive coupling, resistance leakage, or similar effect such as undesirable transistor action. The first and last are the most serious in monolithic integrated circuits.

Passivation—The protection of a surface from chemical attack. Surface passivation is often used to describe the use of oxide layers which prevent diffusion in the planar process.

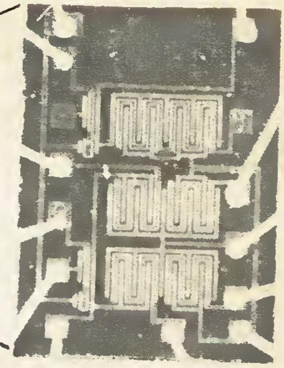
Photolithographic etching—A term used to describe the process by which materials can be etched preferentially in some areas and not in others by the use of photo-sensitive chemical resists.



A Marconi SCIC oscillator. The cover and gold electrodes on the circular crystal have been left out



A metal oxide silicon transistor circuit



An enlarged view of the MOST disc

material loses its semiconducting properties, and becomes "ohmic". By careful process control it is possible to produce regions of accurately controlled resistivity, and these areas form the basis of resistors in integrated circuits. If a controlled resistivity region is diffused to a known depth (T) and the region is in the shape of a rectangle with dimensions $W \times L$, the resistance along the length (L) is simply $(\rho \times L)/(W \times T)$ where ρ is the average resistivity of the region.

Increasing the length, decreasing the width, or decreasing the junction depth (providing the average resistivity stays the same) will all increase the value of resistance. A feature of a resistor produced this way is that its boundary comprises a *pn* junction (provided, of course, that the dopants are suitably selected). Under correct bias conditions this serves to isolate the resistor from the rest of the dice or wafer (Fig. 8).

As the dimensions of a resistor control its ohmic value, there are obviously some practical limits to possible values which can conveniently be used in miniature circuits. Usual resistance values which can be accommodated range from 10 ohms to 10,000 ohms.

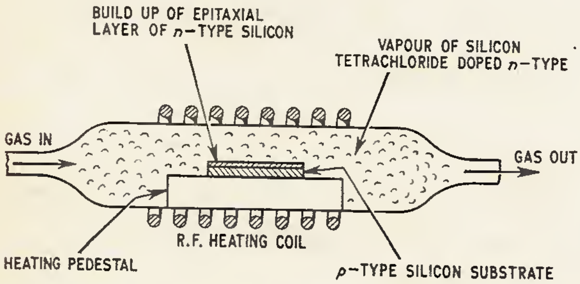


Fig. 5. Epitaxial deposition system. The glass envelope is heated by the coil, shown in section here for clarity

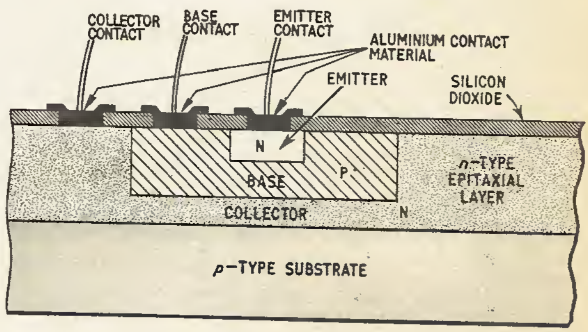


Fig. 7. Detail of a single epitaxially isolated planar transistor

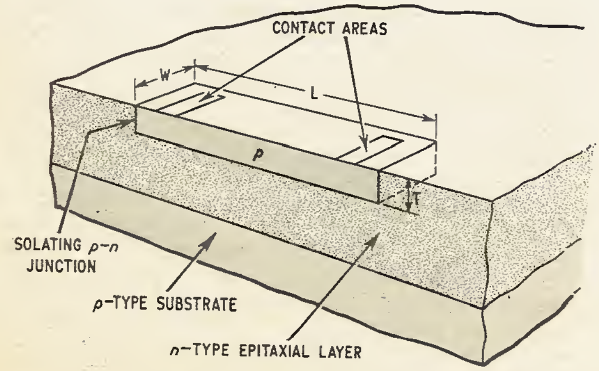


Fig. 6. Cross-section showing the basic structure of epitaxially related planar transistors

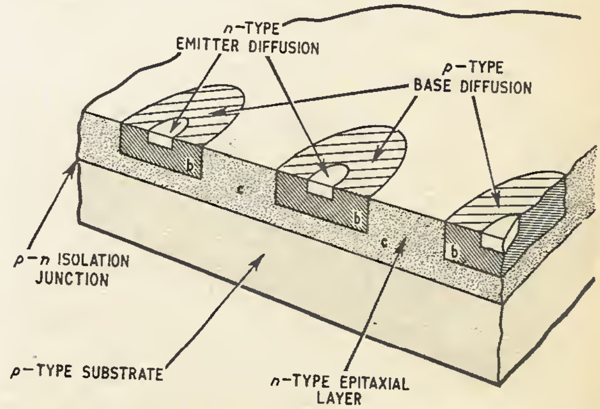


Fig. 8. Cross-section through a p-type resistor diffused into n-type material

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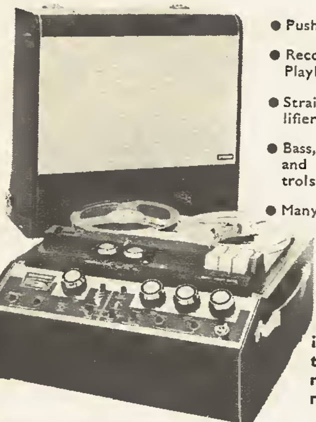

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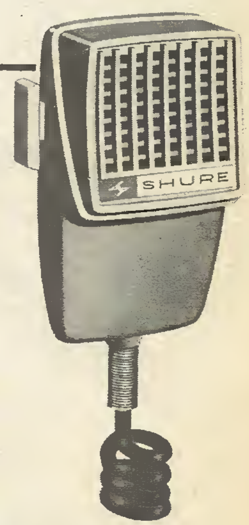

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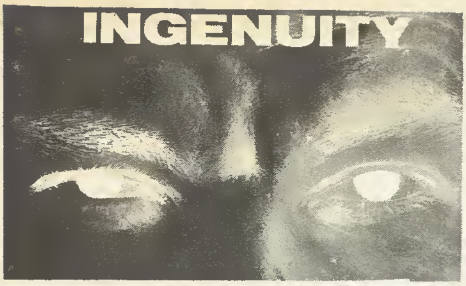


UNLIMITED!

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 individual requirements. The views expressed by readers are not necessarily those of the Editor.

NO-THUMP TREMOLO

I THOUGHT you might be interested in a "no-thump" electronic tremolo.

The flashing lights in the circuit cause the cadmium sulphide cell to alter its resistance.

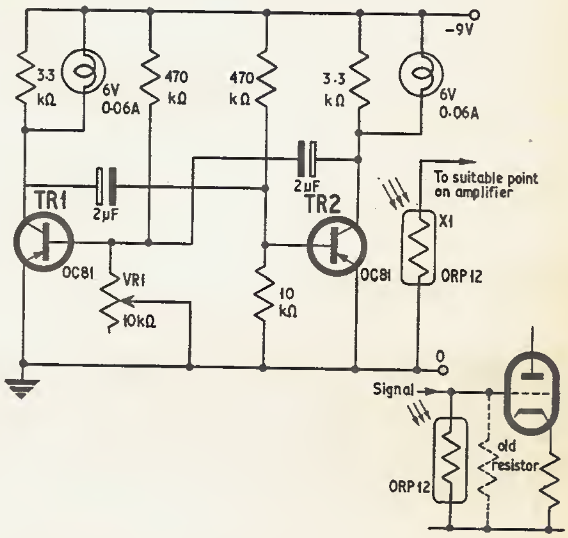
The cell is wired in place of the grid leak resistor in the preamplifier.

When illuminated the cell short-circuits the signal to earth and when no light is present the amplifier acts normally.

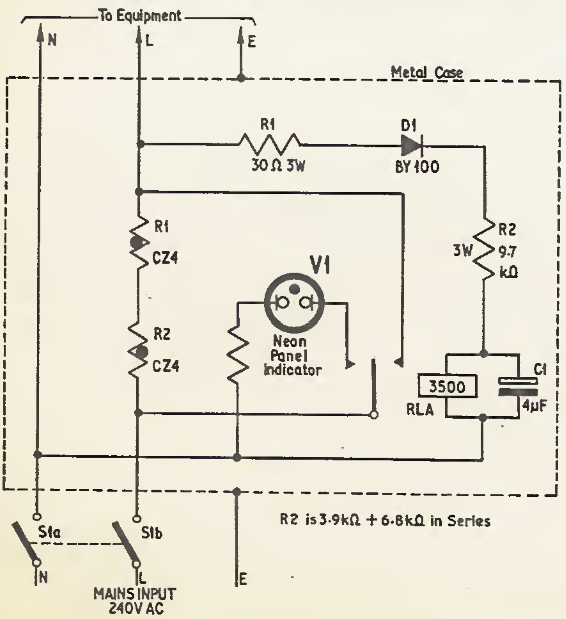
Thus a flashing bulb produces a tremolo effect.

One of the bulbs may be used as a flashing pilot to indicate that the tremolo is on.

H. Hughes,
Sheeffild 9.



ANTI-SURGE FOR PROJECTOR LAMPS



THE attached circuit was devised for automatic current surge limiting designed for slide or movie projectors up to 500 watts.

The unit was constructed inside a 6in × 4in × 2½in aluminium box type chassis.

All the components being mounted on an 18-way group board (except the relay), the thermistors are mounted vertically from the group board and away from other components. The relay is a surplus American P.O. type with its contacts adjusted to close at 6mA at 20 volts.

Heat-proof sleeving should be used on all wires near the thermistors.

It is essential that the equipment being used from the limiter should be switched on before operating the switch on the limiter.

P. G. Holland,
Castleford,
Yorkshire.

PARAMETERS AND SYMBOLS

Fig. 1 shows the symbols for transistors and diodes together with some typical physical outlines. The positive and negative signs show the normal biasing conditions. The small signal current gain for a transistor in the common emitter mode is defined as

$$h_{fe} = \frac{\text{the small change in collector current}}{\text{small signal change in base current which caused it}}$$

(ignoring the leakage current), and can be written mathematically as $\delta I_C/\delta I_B$.

This fraction varies with the absolute value of the collector current (I_C), and so when stating the h_{fe} of a transistor, the collector current at which it was measured must also be stated. The circuit described below allows h_{fe} to be measured for collector currents between 1 and 7mA.

Fig. 2 shows the I_C/I_B curve and Fig. 3 the variation of h_{fe} with I_C for the OC201 transistor. The slope of the I_C/I_B curve (called the transfer characteristic) varies with I_C. Now h_{FE} is defined as I_C/I_B, whereas

$$h_{fe} = \frac{\delta I_C}{\delta I_B}$$

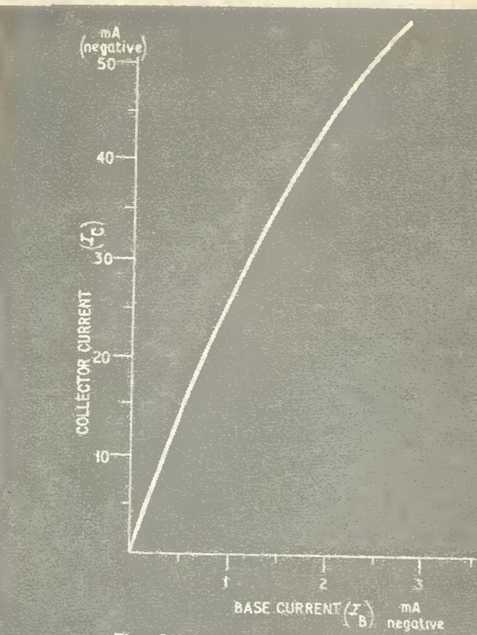


Fig. 2. A typical graph of I_C/I_B

If any transistor is connected so that its collector is correctly biased with respect to its emitter, but the base is left open circuit, it will be found that a very small residual collector current continues to flow, even though the base current must be zero. This current is known as the collector leakage current (I_{CEO}) and is temperature dependent. In general germanium transistors have a larger I_{CEO} than silicon, and the variation of this current may well effect the thermal stability of a circuit. For this reason it is useful to have a rough guide to the magnitude of this leakage, since a transistor which shows a good h_{fe} value but has a very high value of I_{CEO} should not be used.

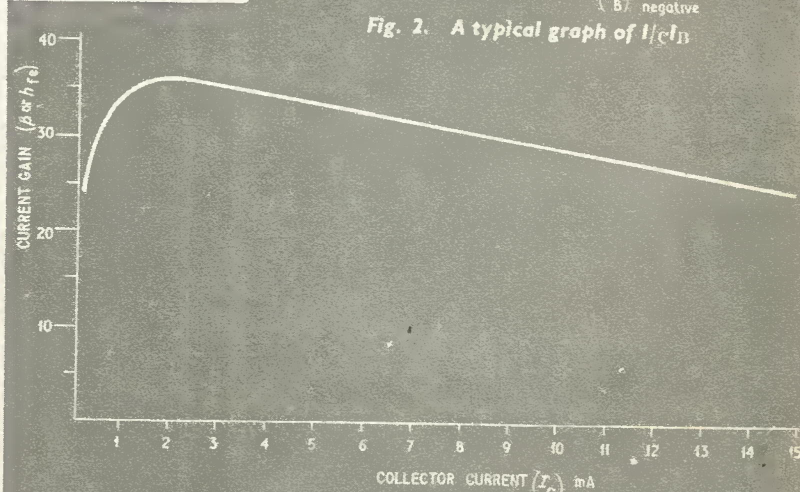


Fig. 3. Variation of h_{fe} with I_C for an OC201

A typical diode characteristic is given in Fig. 4. Note the change of current scale between forward and reverse bias conditions. The diode has a low forward resistance but high back resistance. This can be checked with the test set. For a diode which has broken down the resistance will be low in both directions.

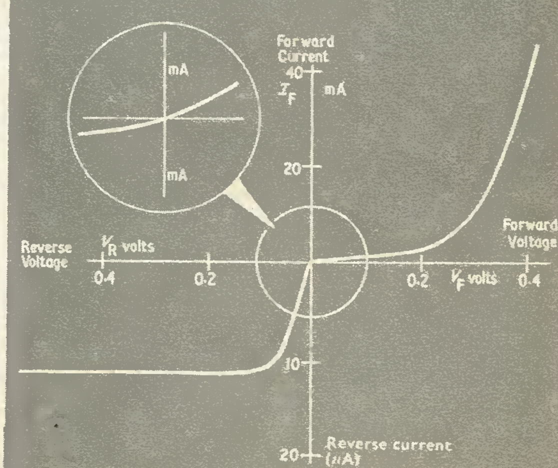


Fig. 4. Typical diode characteristic

NULL INDICATION

The circuit diagram is given in Fig. 5 and comprises three basic sections. Section A is a simple astable multivibrator. Each transistor is alternately switched hard on or hard off by the charge/discharge actions of the capacitors, and this results in the generation of a square wave. The frequency of oscillation is approximately $\frac{1}{0{\cdot}7\,(C_1R_2 + C_2R_3)}$

Section B includes the connection of the transistor under test. Switches S1a and S1b are two switches ganged together. S1a and b provides the polarity

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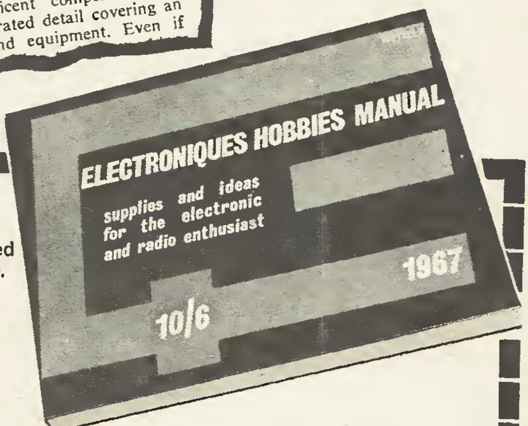

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R2	100kΩ	R9	47kΩ
R3	100kΩ	R10	47kΩ
R4	10kΩ	R11	82kΩ
R5	100kΩ	R12	4·7kΩ
R6	10kΩ	R13	1kΩ
R7	10kΩ		

All 10% ¼ watt except where stated

Potentiometers

VR1 50kΩ linear carbon
VR2 1MΩ linear carbon

Capacitors

C1 0·02μF polyester 150V
C2 0·02μF polyester 150V
C3 4μF elect. 12V
C4 0·1μF polyester 150V
C5 0·1μF polyester 150V
C6 100μF elect. 12V

Transistors

TR1, 2, 3 OC71 (3 off)
TR4 OC72 (1 off)

Switches

S1 Four-pole changeover (2 two-pole switches with toggles mechanically linked or rotary wafer switch)
S2 Single-pole on/off toggle
S3 Single-pole on/off toggle

Battery

BY1 9V type PP9 or equivalent

Meter

M1 0 to 10mA moving coil, 2½in diameter

Loudspeaker

LS1 3 ohm, 2½in diameter

Transformer

T1 11·5 : 1 (Ardente D3058)

Miscellaneous

Wood for case 10½in × 8¼in × 3in
Crocodile clips (3 off)
Knobs and dial plate for VR1

MAKING THE BOX

A simple wooden box may be constructed as in the photograph. It may be made with ¼in plywood or similar. Alternatively a metal box may be used provided no wiring connections are made to it. Strips of aluminium or other suitable material are required for making battery and transformer retaining clips.

The component mounting and wiring is carried out by using stand-off insulated terminal strips. Fig. 6 shows the front panel layout. Connection to the transistor under test is by suitable flying leads terminated with crocodile clips.

DIAL CALIBRATION

It is theoretically possible to calibrate VR1 by calculation corresponding to a given h_{fe}, but the arithmetic is rather protracted. Consequently it is much more convenient to calibrate practically from the scale given in Fig. 7. Trace the diagram and transfer it to white paper glued to the box front.

Turn the knob to its clockwise extremity (i.e. where the wiper is at the end nearest R5 corresponding to the * marked on the circuit diagram). Line up the $h_{fe} = 10$ mark with the pointer. This gives the position of fixing the scale.

MAKING TESTS

The following procedure should be carried out when making measurements. It must be noted that at no time should the connections to the transistor be touched during test, otherwise an incorrect reading may be obtained.

Make the required connections to the transistor using Fig. 1 as a guide if necessary. Switch on the set, and select the β (h_{fe}) position of S2. Select *pnp* or *npn* as appropriate. If you do not know which type of transistor is being tested, choose the *pnp* position first, and if no positive result is obtained, then switch to *npn* and try again.

Adjust the collector current by VR2 to a value between 1mA and 7mA and then vary VR1 until a minimum of audio output is obtained. This should quite easily be found by carefully adjusting the control about the "null" position. Read off the h_{fe} from the dial setting obtained.

I_{CEO}. The collector-to-emitter leakage current is normally very small, so it will not be possible to obtain a good reading on the meter used. However, if the transistor is faulty, a high leakage current (greater than, say, 0·1mA for small signal transistors, or 1mA for power transistors) will be directly detectable.

Select *pnp* or *npn* as before, and then I_{CEO} position on the function switch. The meter will then give a direct indication of the collector leakage current in common emitter mode, with a collector voltage of approximately 9V and with the base open circuit.

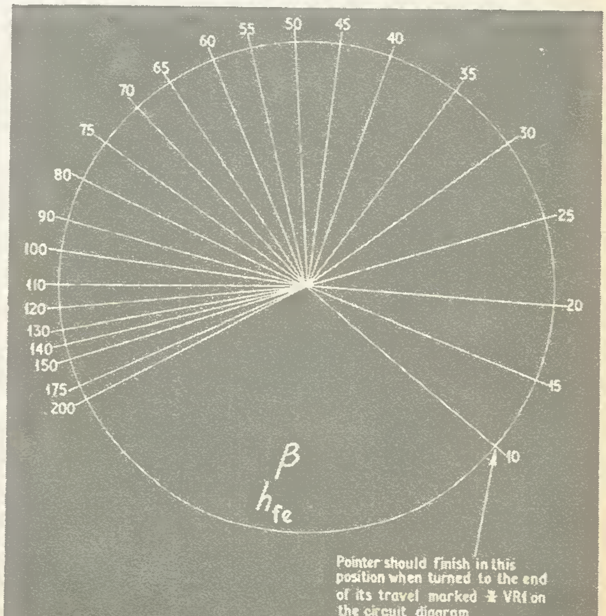

Fig. 7. Dial scale for VR1

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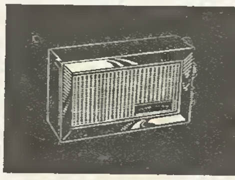

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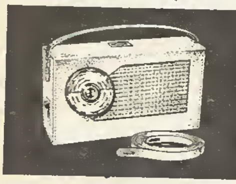

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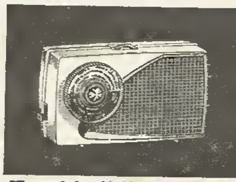

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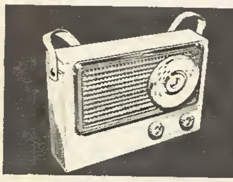

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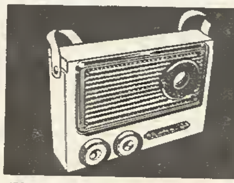
SUPER SEVEN



THREE WAVEBAND PORTABLE WITH 3in. SPEAKER

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JOHN VALENCE

COLOUR WITHOUT VALVES

The decision of the British Radio Corporation to develop an all-transistor colour receiver was obviously a shrewd, carefully deliberated business move. It must have been based on hard realistic thinking, as befits the launching of any large scale production.

It appears that some 18 months ago a small team of engineers were assigned to this project. In facing the many new problems of an all-transistor circuit, these designers knew they had a chance of gaining "a first" for British industry. Perhaps it is not altogether too fanciful to imagine that they were spurred towards this goal by the knowledge that in their Enfield laboratory they were working but three or four miles from Alexandra Palace, scene of that unique event in television history.

Be that as it may, the success of their efforts has certainly added another important chapter to the television story. And it has given this country a boost, I think, in a field which once we pioneered but in recent years have played but minor roles—that is colour wise.

Let us then applaud the B.R.C. The victory they have achieved is in no way diminished by the news that Motorola of U.S.A. were breathing hard down their necks in this race. The American firm (unfortunately for them) could not find the way to dispense with *one* remaining valve in the e.h.t. circuit!

LOW RANGE RADAR

One of the complexities of life is the fact that by solving one problem you then immediately create another one, or more. Road users are all too well aware that construction of a multiway flyover usually means merely the transfer of the bottleneck elsewhere. As Barbara Castle no doubt soulfully intones to herself "you can't win".

However, the particular transport problem I have in mind at the moment concerns her colleague the Minister of Aviation.

The success of the auto landing systems for aircraft seems assured. It is likely to be only a short time before this automated operation becomes quite standard at the larger airports, so permitting safe landings in conditions of zero visibility. But now the supplementary problem arises. How do the airport service vehicles find and reach aircraft under such conditions?

This matter has concerned the authorities for some time, and a study group has been set up at Birmingham University to investigate possible radar type systems for land vehicles. Various methods, including ultra-sonics, infra-red and "normal" radar are being considered for this particular application. Similar research is being undertaken in industry, sometimes in collaboration with this university group, and sometimes as a purely private venture.

Having read accounts of these activities during the past 12 months or so, I was pleased to have just recently the opportunity of seeing some tangible evidence of progress in this potentially important branch of applied electronics. This was at the Mullard Research Laboratories, Redhill, Surrey, where an experimental short range radar equipment was demonstrated. The function of this equipment is explained by the name AVOID (Airfield Vehicle Obstacle Indication Device). For obvious reasons the equipment is simple and compact; it operates in the X band, and uses frequency modulated c.w., and the range is 100 yards maximum, 3 yards minimum. An interesting feature is the electronic scanner, a 4ft length of horn-loaded waveguide, and thus there are no moving parts.

As the designers explained, the radar is still very much in experimental form. One of the important problems to be resolved is the method of display for the driver.

Quite unofficially of course, I offer my own opinion that with full use of microelectronic techniques this equipment might well provide the answer to the fog menace on public roads. Not tomorrow, I realise. But electronic technology moves on at such a pace that it seems a safe enough bet that some indicating device on the lines of AVOID will become available for the ordinary motorist before many years are past. And certainly before the M.O.T. have removed for good all those bottlenecks on our roads.

"I could be out there like a shot—if only I could find my coach"

SELF SERVICE DEPT

It is generally known of course that the good business enjoyed by supermarkets is explained by the open display and immediate accessibility to the shopper of a large variety of goods.

Such a system has its weakness and more and more supermarkets are having to devise ways and means for defeating the would be filcher. One idea that I believe has already been tried out involves the fitting of a magnetic tag to each article of merchandise on display. At the exit, the articles are de-magnetised by the cashier as she registers the amount. Should the shopper walk past this point without declaring some item, its presence will be betrayed by a sensitive pick-up device and a warning flashed to the cashier.

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MISCELLANEOUS *(continued)*

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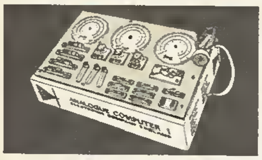

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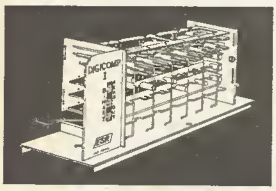

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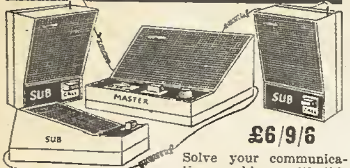

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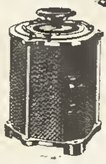

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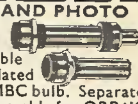

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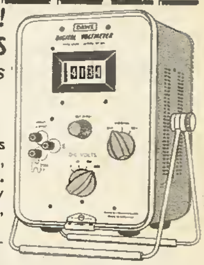

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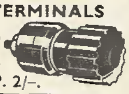

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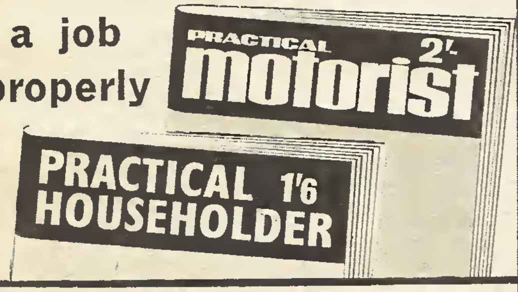

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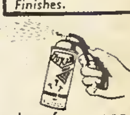

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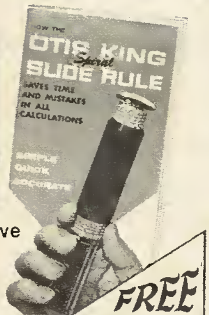

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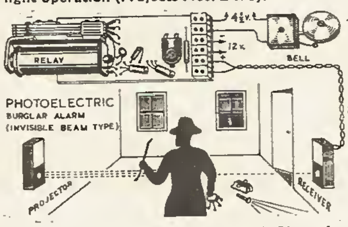

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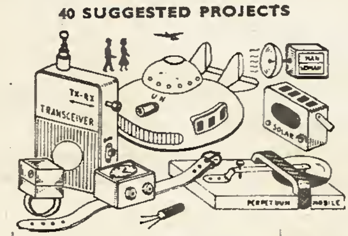

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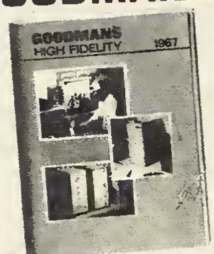

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Diodes. Set switch positions to "*pnp*" and "I_{CEO}". Short circuit the emitter lead to the collector lead on the test set, and note the meter reading, say I_1. Disconnect them and connect the anode of the diode to the emitter lead and the cathode to the collector lead. The meter should at once read another current, say I_2. The diode forward voltage and resistance at this current can then be found as follows:

Forward voltage = V_F

Diode resistance = R_d.

$$R_d = 9000 \left(\frac{1}{I_2} - \frac{1}{I_1}\right) \text{ ohms}$$

$V_F = R_d\, I_2$ millivolts

where I_1 and I_2 are in milliamps. It should be noted that this gives the "d.c." and not the small signal value.

Now change the switch S1 to *npn*. The current indicated by the meter should at once fall to a very low value; it may not be possible to detect any current at all. This shows that the reverse current I_R is very small when the diode is reverse biased with a voltage V_R of approximately 9V. If several milliamps of current flow is detected, the diode has broken down and is no longer useable.

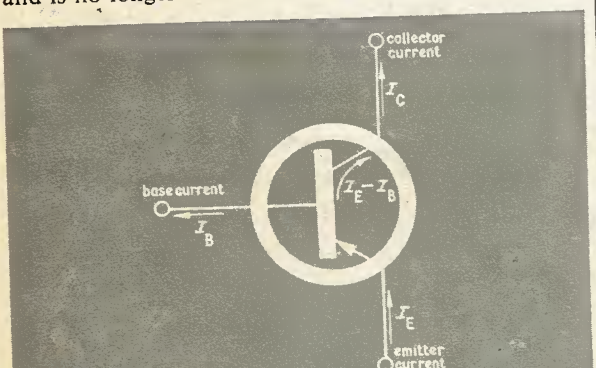

Fig. 8. Direction of current flow in a pnp transistor

Calculation of α. Fig. 8 gives an indication of the direction of the current flow in a *pnp* transistor, ignoring the leakage. It can be seen that $I_E = -(I_B + I_C)$ since, by convention, the current flowing into a transistor is positive, and that flowing out is negative.

Now α is defined as the current gain in common base, $= I_C/I_E$ assuming small current changes.

$$\text{Therefore } \alpha = \frac{-I_C}{-(I_B + I_C)} = \frac{1}{1 + \dfrac{I_B}{I_C}}$$

$$\text{But } \quad \frac{I_C}{I_B} = h_{fe}$$

$$\text{therefore } \quad \alpha = \frac{1}{1 + \dfrac{1}{h_{fe}}} = \frac{h_{fe}}{1 + h_{fe}}$$

Hence α may be found from the measured value of h_{fe}.

The value usually lies in the range 0·9 to 0·996, showing that the current gain of a transistor operating in common base is always less than unity. ★

THE CHEMOSTAT

continued from page 672

FLOW CONTACT

Fig. 11 sketches a simple flow contact for the blocking loop. This may be connected at the final water output, to monitor that water is actually flowing through the entire system. The screw cleat (3) on the flow contact cylinder should be adjusted to drain the cylinder at a rate slightly slower than the working flow rate through the system, i.e. considerably more water should be coming out of (3) than out of (2). Serious reductions of the water flow rate will then trip the blocking loop almost immediately, drawing the attention of the operator to the need for readjustment.

Under normal conditions, it should not be necessary to readjust the flow system during a working session. All adjustments are carried out during the initial preparatory half hour.

It is of advantage to maintain the ambient room temperature on the high side of the nominal bath temperature. This ensures stable air stratification above the jacket tray most of the time, and thus minimises convectional interchange between the developer liquid surface and the general room air. Avoid draughts.

SMALL FILM TANKS

When small tanks are used for film processing, these may be stood in a layer of water in the jacket tray, with the Chemostat feeler dipping into this water layer. Mixing takes place by convection on the heating cycle, but the water layer tends to assume stable stratification on the cooling cycle, so that it is advisable to fit a motor-driven stirrer in this arrangement.

ROOM AIR CONTROL

A structurally simpler method of working would be to use the Chemostat to sense the ambient room temperature and to switch forced convectional heaters accordingly. The relevant time constant for the Chemostat feeler is then 250 seconds (upper curve in section (a) of Table 1), so that the rate of change of room temperature should ideally be 1/500 degrees C/sec, i.e. just under 10 minutes for a change of 1 degree C. According to room size, this is a reasonable figure for small domestic turbo-heaters in the range 500W to 2kW. It is possible to fit series/parallel switching to a multi-element heater, to obtain a greater selection of wattages.

Faster rates of room heating are generally tolerable, because of the considerably greater thermal time constant of the developer baths. Indeed, this would give fastest correction of random disturbances of the developer temperature, but it necessitates two-way control with positive heating *and positive cooling*, since bath temperature fluctuations remain attenuated with respect to room air temperature fluctuations only on *cyclic* temperature variations.

The optimum cyclic amplitude would be given by the ratio of feeler and bath time constants multiplied by the bath temperature tolerance, which comes out to a temperature swing of 8 degrees C peak-to-peak for the room air. Such pronounced cyclic temperature variations of the room air are physiologically disconcerting, so that a proper plumbing system according to Fig. 10 is definitely preferable in the long run. ★

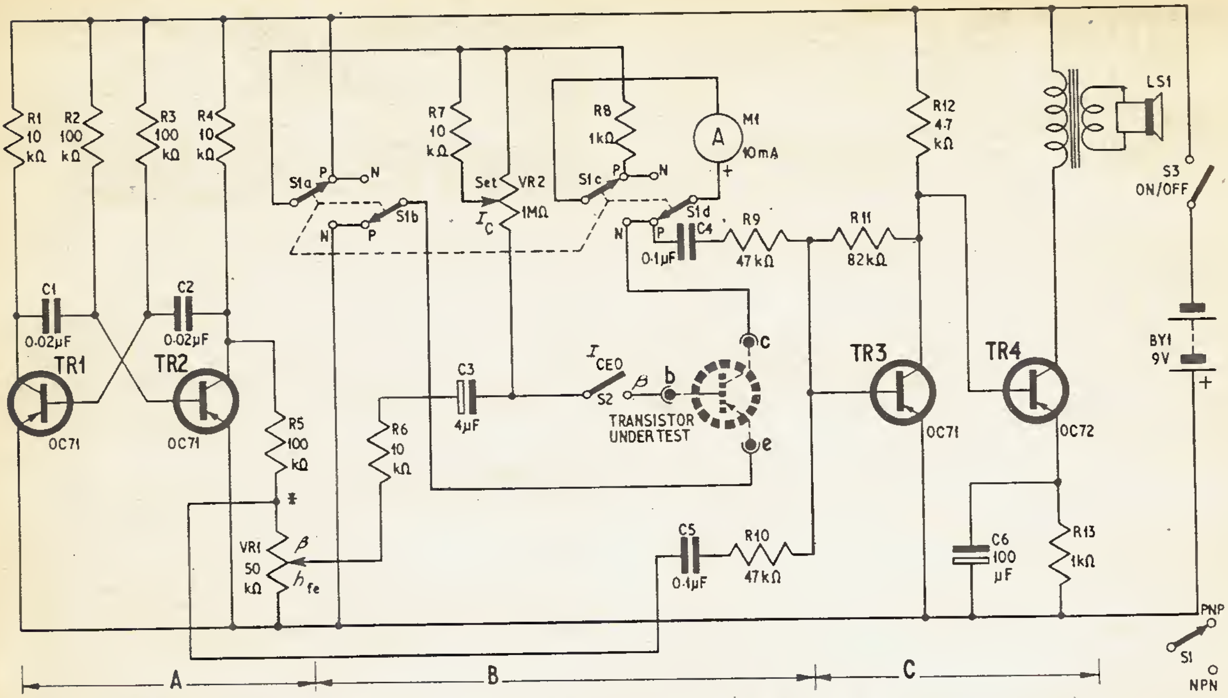

Fig. 5. Complete circuit diagram of the test set. The three sections A, B, and C are the different functional circuits as described in the text

reversal required for testing *pnp* and *npn* transistors, whilst Slc and d reverses the meter connection to cope with the changed direction of current flow. S2 removes the base current bias from the transistor when I_{CEO} is being checked. When closed, S2 provides the nominal d.c. bias condition necessary to fix the working point on the output characteristic of the transistor under test. Variable resistor VR2 varies the base current and hence the collector current of the transistor (as $I_C = h_{FE} I_B$).

A proportion of the oscillator voltage is selected by VR1 and applied through a series resistor to the base of the transistor under test. Current amplification occurs and a larger signal appears at the collector. The gain between the wiper of VR1 and the collector of the transistor under test is directly proportional to the transistor current gain, assuming that R6 effectively swamps any changes of input resistance to the transistor. Since

$$\delta I_B = \frac{\delta V}{R_6}$$

and $\delta I_C = h_{fe} \times \delta I_B$

$$= h_{fe} \frac{\delta V}{R_6}$$

where V = voltage at wiper of VR1 therefore, small change of collector voltage

$$= \delta V_C = h_{fe} \frac{\delta V}{R_6} \times R_L$$

R_L is the load resistance equal to R_8, therefore the voltage gain

$$A_V = \frac{\delta V_C}{\delta V} = h_{fe} \frac{R_L}{R_6}.$$

Hence if R_L and R_6 are fixed, A_V depends only on h_{fe}. This amplified voltage is added to a signal obtained directly from the oscillator. Since an inversion occurs between base and collector of the transistor to be tested, the two signals are added in antiphase, so that when they are of equal amplitude the resultant is zero. This state can be obtained by adjusting VR1 according to the h_{fe} of the transistor under test, since the proportion of oscillator voltage required will depend on the voltage gain and hence h_{fe} of the transistor. The summed signal is then applied to a simple audio amplifying stage for driving a loudspeaker. Hence, by adjusting VR1 until the audio output is a minimum, a direct reading of h_{fe} can be obtained by calibration of the potentiometer.

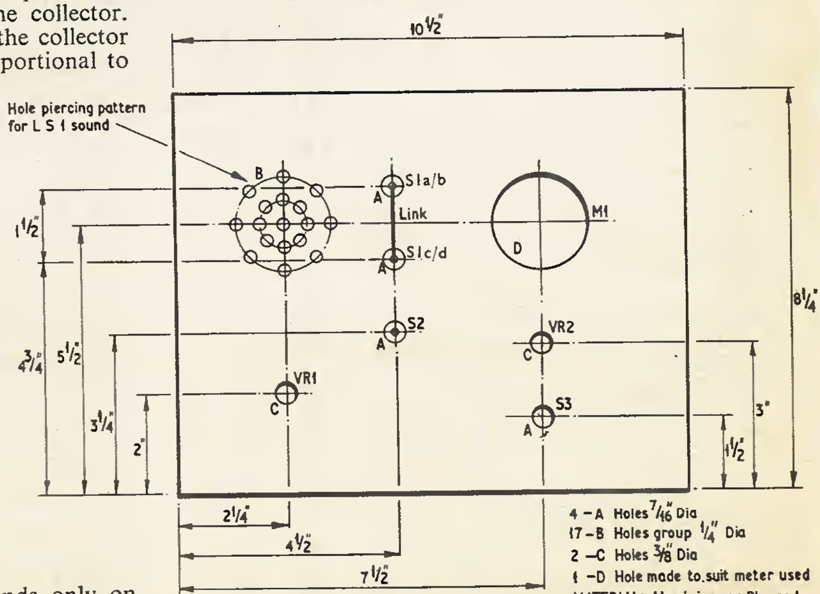

Fig. 6. Front panel drilling

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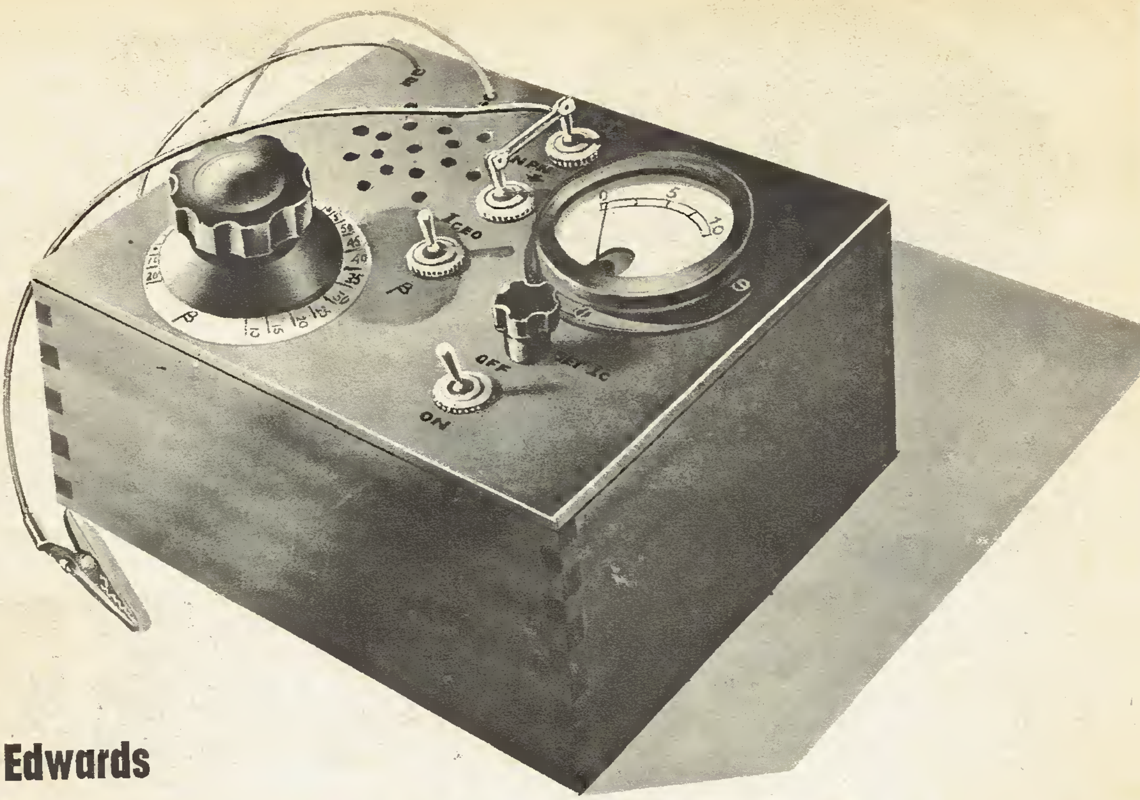

By P. Edwards

TRANSISTOR TEST SET

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The layout suggested is not obligatory, but the form shown was found to offer ease of operation. The following facilities are provided:

(a) Measurement of h_{fe} (also called β or α') for *pnp* or *npn* transistors with collector currents adjustable from 1 to 7mA;
(b) A check on I_{CEO} (or I'_{CO});
(c) Measurement of diode forward voltage (V_F) at a given forward current (I_F);
(d) A check on I_R diode reverse leakage current;
(e) Calculation of α from the measured value of h_{fe}.

The test set was designed in an attempt to eliminate some of the disadvantages experienced by the author when using commercially manufactured units. The most important of these were:

(a) The need for several knob adjustments and/or no direct reading of h_{fe};
(b) Adjustment of the h_{fe} control affected the preset collector current;
(c) No indication that the unit was switched on;
(d) D.C. systems where the actual parameter measured was h_{FE}, the large signal current gain rather than h_{fe} (β).

The set described here largely overcomes these difficulties and gives a direct dial reading of h_{fe} indicated by the null effect of an audio output.

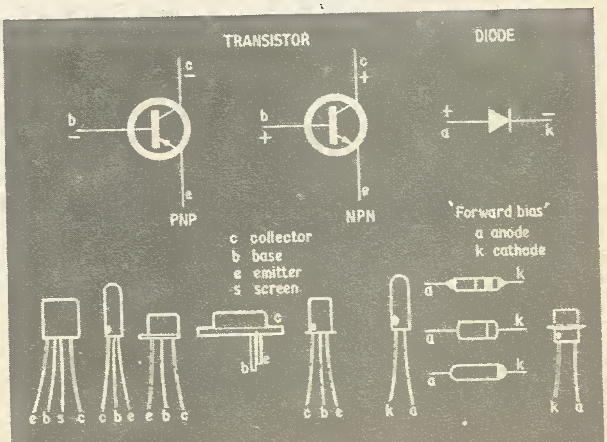

Fig. 1. Symbols and connections of transistors and diodes

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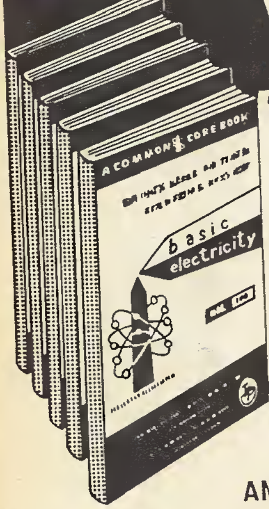

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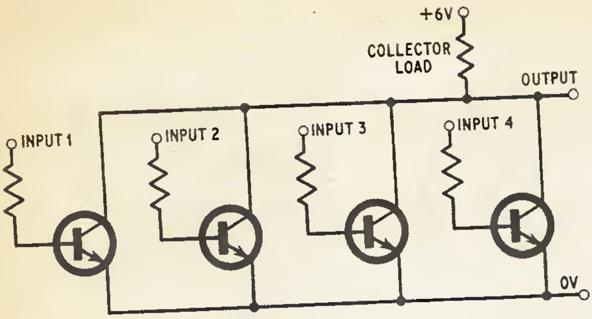


Fig. 9. A simple DCTL gate

INTEGRATION

Armed with the processes of making epitaxially isolated planar transistors and resistors, we can now consider a simple form of integrated circuit. Fig. 9 shows the schematic diagram of a very simple logic gate. This is a DCTL (direct coupled transistor logic) NOR gate. It comprises four inputs through resistors to the bases of four transistors, with common collectors coupled to a single collector load resistor. The output point is taken from the common collectors.

The circuit can be quite easily split into two discrete sections, one containing the transistors, and the other containing the resistors. As far as the transistor section is concerned we already have this part of the circuit as good as made from the wafer containing individual epitaxially isolated transistors, described earlier. Although the collectors of the transistors on this wafer are isolated from the bulk of the substrate through the epitaxial layer, all the collectors are commoned as they are actually formed from the epitaxial layer itself (Fig. 10a).

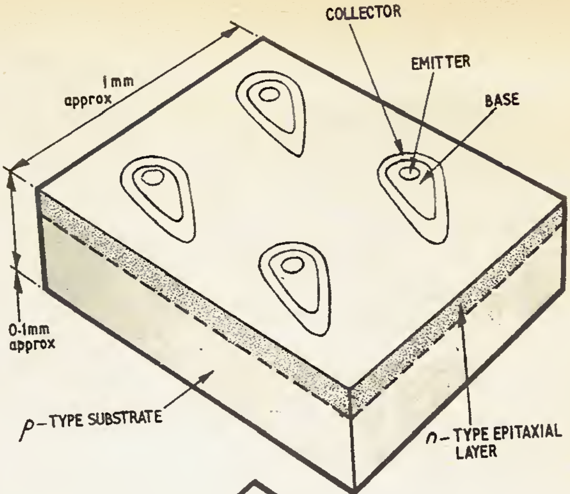
The transistor section can therefore be made merely by breaking the original wafer into groups of four transistors. A slight modification is needed; all the emitters also have to be commoned, but this can be done later on by interconnecting them with fine wire, using a process called "stitch bonding" (this operation is an extension of normal ultrasonic or thermo-compression bonding).

The resistor section can be formed by diffusing groups of five strips of *p*-type dopant into an *n*-type epitaxial layer on a completely separate wafer. The *pn* junction surrounding each of these resistors will isolate it from its neighbour (Fig. 10b). This wafer can then be broken into dice each dice containing a complete group of five discrete resistors. We can now take one dice of resistors, one dice of transistors, and mount them onto a header. All the individual components (apart from the collectors) are isolated from each other, even though the header may be of metal.

As a final operation before encapsulation, all that is necessary to complete the circuit is the interconnection of one end of each of the four base resistors to their respective bases, the collector load resistor to any one of the transistor collectors, the lead out connections to the other end of each resistor, and one from the commoned collectors.

Because this circuit is made from more than one chip of silicon, it is called a "multichip integrated circuit". The process is rather intricate and requires two completely separate types of wafer as starting points, thus causing complications in process control. Perhaps a worse problem with this sort of circuit is the large number of manual operations required to carry out the stitch bond interconnections. Although these circuits are still being made in quite large quantities, they are falling out of favour due to the rapid developments in "monolithic" circuits.

Next month: Monolithic circuits



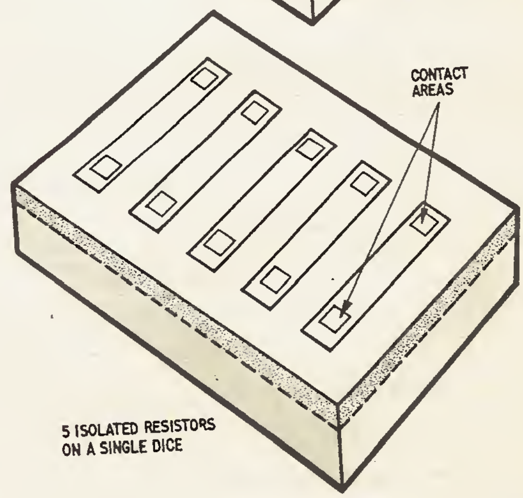


Fig. 10a. Four common collector transistors on a single dice

Fig. 10b. Five isolated resistors on a single dice

Probe testing a Plessey integrated circuit

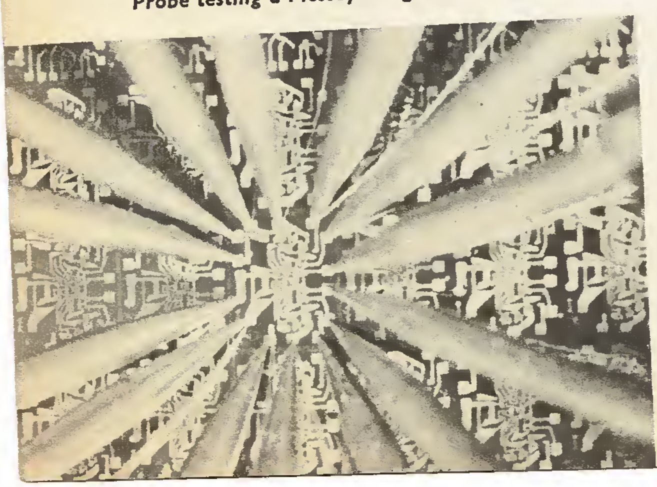


Photo resist—Light sensitive material usually applied in thin films deposited uniformly on a wafer or substrate. They are used to establish the patterns for controlled etching and diffusion.

Planar process—The planar process of forming integrated circuits and semiconductor components is based upon the use of a single surface for referencing each successive operation. The planar process depends upon the repeated use of silicon dioxide from one surface to control the location of diffusions.

Probing—A term used to describe testing techniques for checking the working quality of integrated circuits before the wire bonding operation. Several very fine tipped probes are accurately positioned over the metallised contact areas of the circuit to effect contact to the circuit.

Propagation delay—The finite period of time measured from the instant when the input signal is applied until the output has reached its final value.

Raw chips—Unmounted chips containing circuits or components.

Resistivity

Bulk resistivity—A constant value for a given material which is used to calculate the resistance of the material when engineered into various geometrics. It is measured in ohm centimetres.

Sheet resistivity—Effectively the resistivity of a material in a single plane of constant thickness. It is a term often used to determine the doping concentration in extremely shallow diffused layers—the higher the doping level the lower the sheet resistivity. As the thickness of the film or diffused layer is constant, sheet resistivity is only a function of surface area and is measured in ohms per square centimetre.

Resolution—The ability to separate between adjacent lines. It is a limitation often associated with photographic emulsion, lenses, and etching processes.

Saturation voltage—The voltage drop across a transistor—measured from emitter to collector—when a transistor is in a fully conductive state. It is proportional to the internal or collector resistance of the device and usually should be kept as low as possible.

SCIC—An abbreviation commonly used for semiconductor integrated circuit.

SIC—Silicon integrated circuit—a circuit formed entirely on a silicon chip.

Slice—Thin disc cut from a crystal and used in the fabrication of a multiplicity of circuits. Finally separated into chips.

Substrate—A piece of material used to support components.

Active substrates—All silicon wafers containing diffused components, upon which thin films are deposited.

Passive substrates—Glass, ceramic, or other insulating substrates upon which thin film components can be deposited.

Thermal SiO_2—Protective layer of silica, grown by the thermal oxidation of silicon.

Thick film circuit Silk screened circuit; cermet circuit; circuit made by depositing paint on an insulating substrate and burning off the organic matter to leave a purely mineral component.

Thin film circuit—A circuit in which all passive components are made by the process of depositing thin films cf various materials on insulating substrates.

Transistor base diffusion—Diffusion giving the base region of a transistor, e.g. boron into *n*-type silicon.

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capable of accurate superimposition over the image produced by the others. As the actual size of a small signal type of planar transistor is very small (rarely exceeding 500 microns (0·5mm) diameter) it is possible to make as many as 1,500 individual transistors on a piece of silicon no more than 1½in in diameter. This piece of silicon which is usually about 200 microns (0·2mm) thick is called a wafer. When all the diffusions and metallisation operations have been carried out it is cut into squares—or dice—each dice comprising an individual transistor.

ISOLATION

The bulk of the dice containing the planar transistor forms the collector region of the device. If the device was bonded into a metal can, the can would inevitably be directly coupled to the collector of the transistor. This may be perfectly acceptable for some simple types of transistors, but it is obviously desirable to produce a structure in which the collector may be isolated from the can.

Isolation is achieved in practice by using a process called "epitaxial isolation", which builds up a layer of silicon of opposite conduction type on to a conventional substrate of silicon. The "epitaxial growth" is carried out by heating the substrate in an atmosphere of hydrogen which contains the vapour of a chemical called silicon tetrachloride (Fig. 5). Without going into the complexities of the chemical reaction, the result is that the silicon tetrachloride decomposes at the surface of the silicon substrate and deposits silicon on the substrate at the rate of about 1 micron per minute.

An important feature of this process is that by introducing extremely small quantities of dopant vapour into the main hydrogen stream it is possible to control the type of conductivity as well as the value of conductivity of the deposited layer. The layer is usually grown to a thickness of 10 to 20 microns, but varies somewhat according to the application.

As one can control, at will, the conductivity type of the deposited layer, one could make a transistor similar to the one already described by first depositing a 20 micron thick layer of *n*-type silicon on to a *p*-type substrate.

If the rest of the diffusions are carried out in the same manner as before we can build up the same type of transistor except that there is now a *pn* junction between the collector and the bulk of the material. This junction has identical properties to a reverse biased diode, and therefore forms a very high resistance to current flow into the rest of the substrate, therefore giving effective isolation.

Obviously one cannot now make contact with the collector of the transistor from the rear of the dice through this high resistance; therefore it is necessary to etch a third window into the passivating oxide layer on the front surface to expose an area of the collector region. After breaking, this dice can be mounted into a metal can with the collector effectively isolated from the can itself.

This process of epitaxial isolation is the key to making complex integrated circuits, and will be referred to several times in this article. Important features of the diffused structure are the levels of doping and the depth of the junctions.

SILICON RESISTORS

Silicon that is 100 per cent pure is an extremely poor conductor of electricity at normal temperatures, but as impurities are added the conductivity increases until the

Again an oxide layer is grown over the window to passivate the surface completely (Fig. 4h).

MAKING CONNECTIONS

The transistor is now complete apart from making connections to the respective electrodes. This is carried out by opening up an annulus shaped hole in the oxide over the base region, and a small circular hole over the emitter (Fig. 4i). Aluminium is evaporated over the whole of the surface of the device by the same method as described for thin film circuits. Excess aluminium is removed by photolithographic methods leaving a contact annulus over the base and a spot over the emitter (Fig. 4j).

Contact to the collector is made in this case by welding the large area surface of the original starting material to a gold plated platform which will form part of the final transistor can. Wired connections to the base and emitter are made by ultrasonically welding very fine aluminium wires (perhaps 10 microns in diameter) to the evaporated aluminium and then to the more substantial lead out wires of the can (Fig. 4k).

The transistor produced by this method is called a double diffused transistor, and there are many types similar to this being made. A drawback with this type of transistor is that the collector connection is not insulated from the can, and this can present certain problems in use. A more sophisticated method of

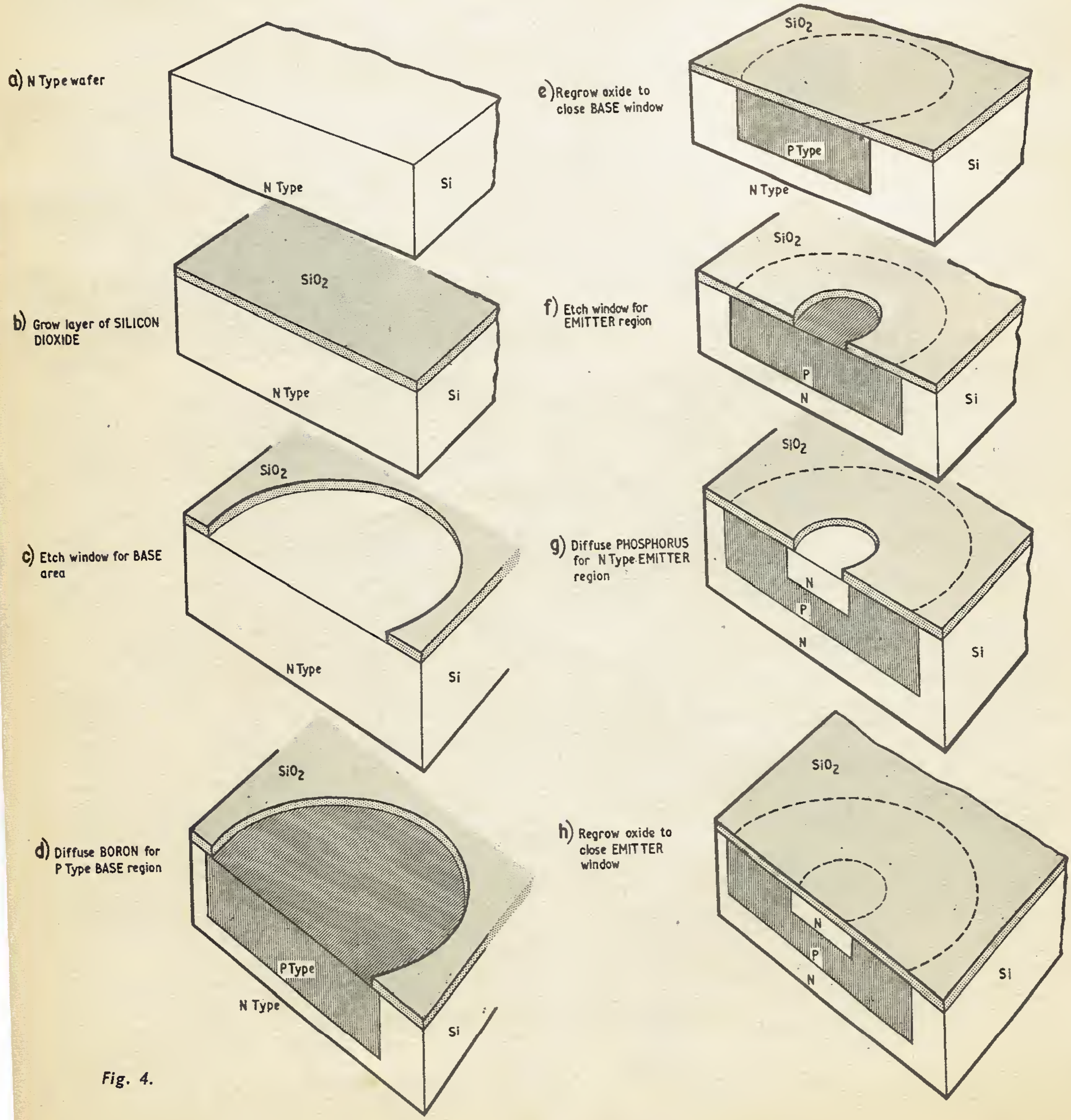


Fig. 4.

therefore preferable, since they may be integrated with the cooling cycle, and have inherently longer time constants.

PLUMBING SYSTEM

Fig. 10 sketches a complete system which is strongly recommended and relatively easy to install in a darkroom. A deep double-walled jacket tray (I) contains the photographic baths. The latter stand on wooden blocks, so that they are affected only by the temperature of the air in the tray, which in turn is determined by the temperature of the water flowing between the walls of the jacket tray.

With reference to Fig. 10, the following details require comment. The optimum input water temperature is 10 degrees C, and when the 2kW immersion heater is switched on, the optimum output water temperature is 30 degrees C. About 40 kcal are required to heat the (approximate) 2 litre contents of the heating vessel through the difference of 20 degrees C. An electrical rating of 2kW produces roughly 30 kcal/minute, so that the correction inversion time constant is approximately equal to the Chemostat feeler time constant. The simple arrangement of a transistor in an ordinary test tube as feeler, with its rather long time constant compared to a conventional mercury thermometer, is thus fully satisfactory.

It would be pointless to devise special mountings with shorter time constants, because inconveniently large electrical heating ratings would then be necessary to exploit them fully and the resulting short-period control cycles would be much more sensitive to inevitable departures from optimum conditions. (However, make sure to use a thin-walled test tube of the ordinary kind, not a thick-walled special type, and fit the feeler transistor with a small cooling fin bent to wedge against the glass in the bottom region of the tube, see Fig. 6.) The resulting thermal time constant should not differ too greatly from 100 seconds in water. The volume of water contained between the walls of the jacket tray (I) should be approximately equal to the volume of the heating vessel (E).

ADJUSTMENTS

For input water temperatures above 15 degrees C, the nominal photographic bath temperature must be increased above 20 degrees C accordingly, as shown in Fig. 10. It is convenient to fix an instruction scale behind the water input thermometer (D). This indicates the nominal setting of the Chemostat and the nominal output water temperature at (H) on the heating cycle, corresponding to each input water temperature reading of (D).

By the time the Chemostat has reached the steady control state, (D) and (H) will also have reached steady readings which remain tolerably set for several hours, i.e. throughout a normal working session. It normally suffices to switch on about 30 to 60 minutes before intending to commence processing. The screw-cleat (C) should be adjusted until the thermometer (H) reads the appropriate temperature on the heating cycle. Corresponding approximate water flow rates are also marked against (D) merely to permit rapid coarse adjustment at the start (collect output water for 1 minute in a measuring cylinder). Fine adjustments to (C) should be made only with reference to thermometer (H).

Thick-walled pressure-type rubber tubing should be used for all interconnections. This is largely unaffected by positioning and movements. A simple screw-cleat gives accurate and steady control of the flow rate when used on thick-walled rubber tubing. The flow rate should be adjusted coarsely to 3 litres/minute or a little more with the cleat fully open, by choosing an appropriate mounting height of the cistern (B) on the wall.

The ball-valve cistern (B) is quite essential because water-main pressures tend to fluctuate, and normal taps working straight from a high-pressure main into a low-pressure discharge circuit do not give steady flow rates even with constant main pressure. Such arrangements would be extremely unreliable.

The cistern (B) is readily made by adapting a w.c. cistern. Any watertight insert may be used for mounting the thermometers (D) and (H). The insert must be as small as possible. It is also possible to make a small hole in the rubber tube, push-in the thermometer bulb and seal with some watertight adhesive.

continued on page 690

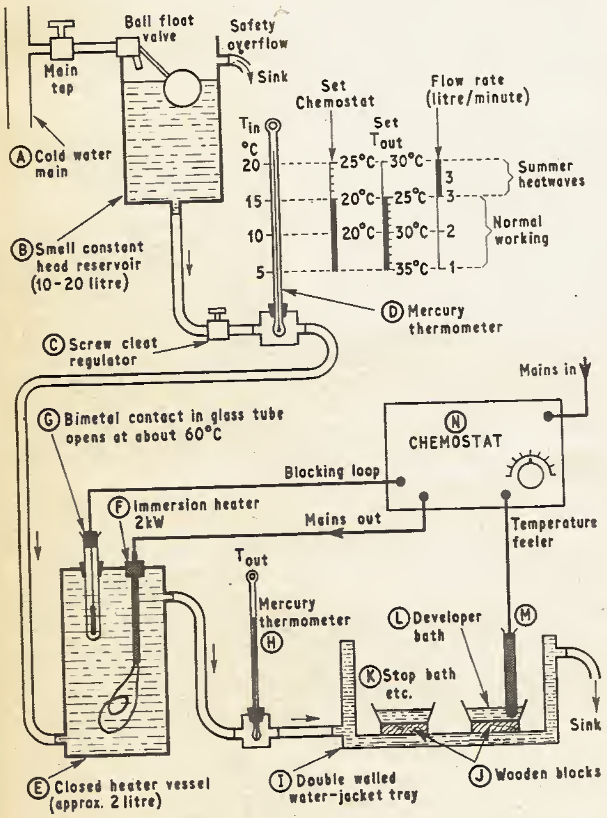


Fig. 10. A plumbing system for colour photographic processing

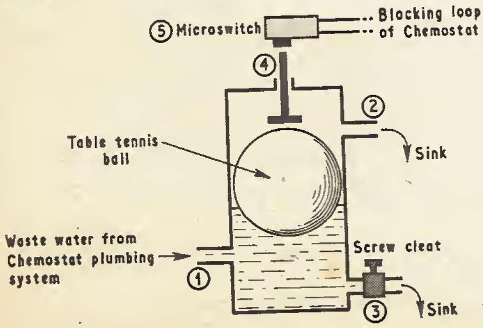


Fig. 11. Flow contact for blocking loop

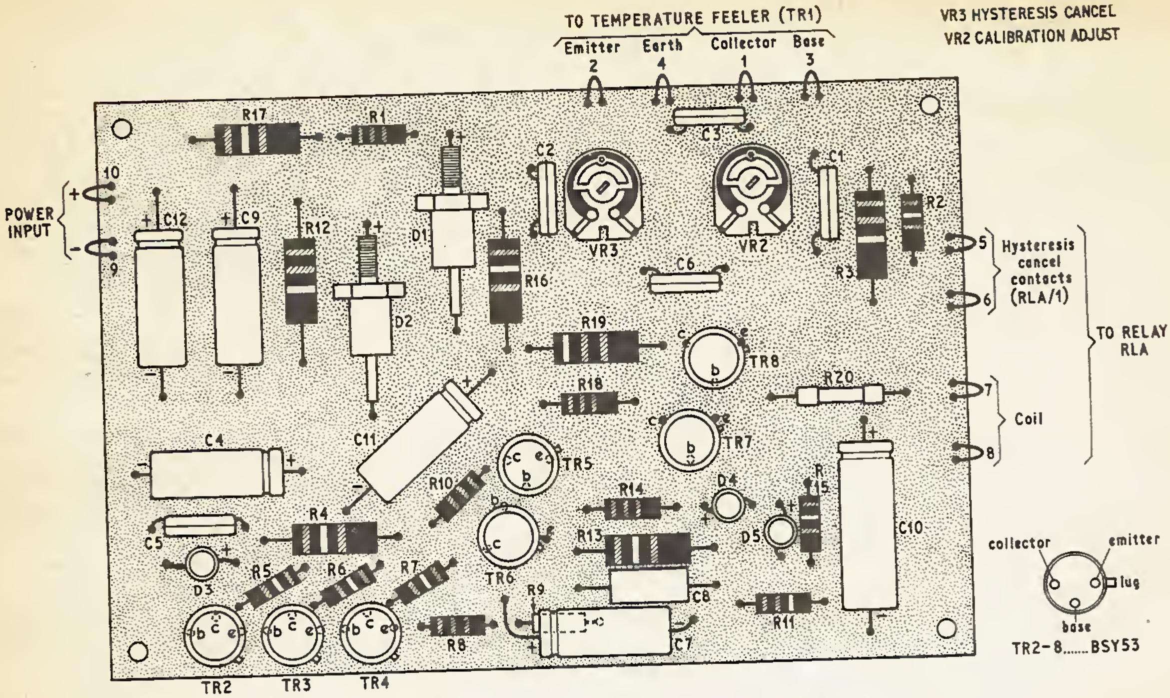


Fig. 7. Printed Circuit Board, component layout

Fig. 8. Printed Circuit Board (actual size)

MARKET PLACE

Items mentioned in this feature are usually available from electronic equipment and component retailers advertising in this magazine. However, where a full address is given, enquiries and orders should then be made direct to the firm concerned.

EQUIPMENT

As a result of experiments into the problems of designing battery chargers, specifically for the purpose of charging batteries used in ultrasonic aids for the blind, **Stoneleigh Electronics Ltd.**, Factory No. 8, Bridge Close, Romford, Essex, have produced a sub-miniature charger which has a mains isolated input circuit.

Called the "Stoneleigh" the constant current charger has a transistor stabilised circuit and will charge, without any switching, either one or two **Deac** Nickel Cadmium batteries (type 7/150DK) at a constant current of 15mA $\pm \frac{1}{2}$mA. The charger weighs only 5 ounces and measures 4in $\times$ $1\frac{3}{8}$in $\times$ $2\frac{1}{2}$in, including battery holder.

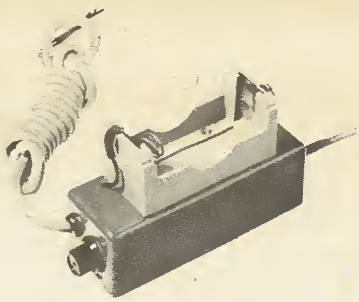
The charger can be modified to suit other batteries and with the increasing use of alkaline batteries in all domestic equipment it should save on the cost of battery replacement in such items as radios, tape recorders, and other portable appliances that are in constant use.

One excellent point about the **Photain** Burgalarm Kit is that it can also double as a fire alarm, and is claimed to provide a foolproof installation which can be fitted by the average handyman or any electrician.

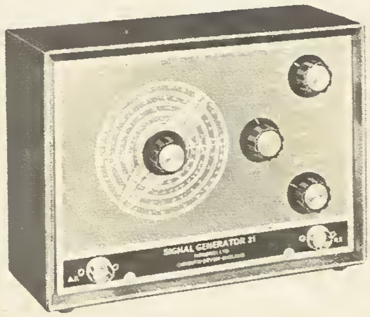
Obtainable from Photain Controls Ltd., Randalls Road, Leatherhead, Surrey, the kit cost £60 complete plus 15s for each fireswitch and comprises: control unit, three sets of encapsulated magnaswitches and magnets, two 6in gong 12V d.c. bells, Chubb Castle mortice dead lock, 100yd twin cable for loop circuit wiring and two 12V d.c. batteries.

The control unit is housed in a pressed steel case with hinged lid and contains the electronic circuit, operational relays, batteries, automatic a.c./d.c./a.c. changeover circuit, tamper-proof screw contact and key on/off switch.

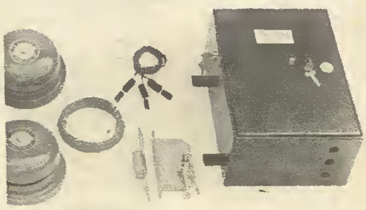
The magnaswitches and magnets are fixed to the door or window in such a position that when the door is closed the magnet is in close proximity with the magnaswitch which is screwed or stuck to the door frame.



Stoneleigh charger



Nombrex signal generator type 31



Burgalarm kit from Photain Controls

Hilka or QQQ soldering iron

The switches are wired in a double-pole loop system, a negative voltage being applied to one leg of the loop and a positive voltage to the other leg. This ensures that if any wire is cut or if they are shorted together in an attempt to override any switch then the alarm will sound.

The Chubb mortice dead lock is fitted with a switch which is operated by the bolt, and is wired in the loop circuit.

The alarm is powered by the mains supply with automatic changeover to the battery supply in the event of mains failure or interference, and reverts back automatically once the mains supply has been restored.

The fireswitches, if required, can be wired in the loop circuit and operate when the ambient temperature reaches 160 degrees Fahrenheit or 71 degrees Centigrade.

If correctly installed and maintained the "Burgalarm" will comply with insurance company specifications.

Test gear is another field where personal taste and pocket play important parts in stocking out the workshop. The **Nombrex Ltd.**, Exmouth, Devon, signal generator, type 31, is certainly reasonably priced at £12 10s 0d. The main features of this transistor signal generator are: frequency range from 150kHz to 350MHz in eight overlapping ranges with an accuracy better than 2 per cent. The signal unmodulated or modulated is approximately 3 per cent sine wave at 400Hz. A continuously variable r.f. signal attenuator. Directly calibrated frequency scales, discrimination within 1 per cent of the selected frequency. The average output is 100mV according to the frequency selected and the output impedance is 400 ohms maximum.

WARNING

The Home Office warns readers that soldering irons from Japan and sold in this country under the trade manes of **Hilka** and **QQQ** can be potentially dangerous. These names are printed in red on a small metal plate on the side of the handle which includes the iron rating 40W 220-240V and may also give the serial number 1513.

The trouble is that a protective spring surrounding the cord where it enters the iron can be pushed further into the handle than the manufacturers intended, and can make contact with a live terminal resulting in electrocution.

Trade associations representing importers, wholesalers and retailers have undertaken to warn their members of the defect and to advise them against selling any of the irons without first replacing the coil spring with a non-conductive flex protector.

It is recommended that members of the public should not use these irons unless they have been examined by a competent person and if necessary modified to make them safe.

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By world famous maker. Suitable for use in conversion of T.V sets to B.B.C.2 (625 line reception). OFFERED (less valves) AT THE BARGAIN PRICE OF ONLY 27/6. Post Paid. (The components are worth far more than our price for the complete unit and due to the very high value we regret that no correspondence can be entered into regarding this item.)

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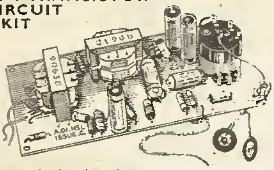

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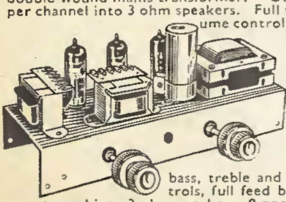

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A top-quality record player amplifier employing heavy duty double wound mains transformer, ECC83, EL84, EZ80 valves. Separate Bass, Treble and Volume controls. Complete with output transformer matched for 3 ohm speaker. Size 7in. w. x 3in. d. x 6in. h. Ready built and tested. **PRICE 69/6.** P. & P. 6/-.

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E.M.I. 13½ x 8 in. with high flux ceramic magnet, **42/-**. (15 ohm, 45/-). P. & P. 4" & 5" 2/-, 6½" & 8" 2/6, 10" & 12" 3/6 per speaker.

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VYNAIR AND REXINE SPEAKER AND CABINET FABRICS app. 54 in. wide. Usually 35/- yd., our price **13/6** per yd. length min. 1yd.) P. & P. 2/6. S.A.E. for samples.

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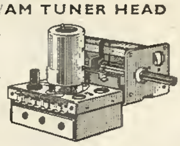

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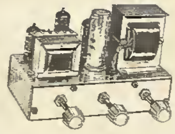
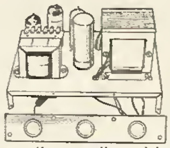


Designed for Hi-Fi reproduction of records. A.C. Mains operation. Ready built on plated heavy gauge metal chassis, size 7½in. w. x 4in. d. x 4¾in. h. Incorporates ECC83, EL84, EZ80 valves. Heavy duty, double wound mains transformer and output transformer matched for 3 ohm speaker, separate Bass, Treble and volume controls. Negative feedback line. Output 4½ watts. Front panel can be detached and leads extended for remote mounting of controls.

The HA34 has been specially designed for us and our quantity order enables us to offer them complete with knobs, valves, etc., wired and tested for only **£4.5.0** P. & P. 6/-.

HSL 'FOUR' AMPLIFIER KIT

A.C. Mains 200/250v., 4 watt, using ECC83, EL84, EZ80 valves

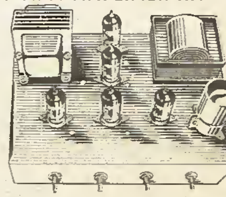


★ Heavy duty double-wound mains transformer with electrostatic screen. ★ Separate Bass, Treble and volume controls, giving fully variable boost and cut with minimum insertion loss. ★ Heavy negative feedback loop over 2 stages ensures high output at excellent quality with very low distortion factor. ★ Suitable for use with guitar, microphone or record player. ★ Provision for remote mounting of controls or direct on chassis. ★ Chassis size only 7½ in. wide x 4 in. deep. Overall height 4¾ in. ★ All components and valves are brand new. ★ Very clear and concise instructions enable even the inexperienced amateur to construct with 100% success. ★ Supplied complete with valves, output transformer (3 ohms only), screened lead, wire, nuts, bolts, solder, etc. (No extras to buy.) PRICE 79/6. P. & P. 6/-.

Comprehensive circuit diagram, practical layout and parts lists 2/6 (free with kit).

This kit although similar in appearance to HA34 employs entirely different and advanced circuitry.

10/14 WATT HI-FI AMPLIFIER KIT



A stylishly finished monaural amplifier with an output of 14 watts from 2 EL84s in push-pull. Super reproduction of both music and speech, with negligible hum. Separate inputs for mike and gram allow records and announcements to follow each other. Fully shrouded section wound output transformer to match 3-15Ω speaker and 2 independent volume controls, and separate bass and treble controls are provided giving good lift and cut. Valve line-up 2 EL84s, ECC83, EF86, and EZ80 rectifier. Simple instruction booklet 2/6. (Free with parts.) **All parts sold separately.** ONLY **£7/9/6**. P. & P. 8/6. Also available ready built and tested complete with std. input sockets, **£9/5/-**. P. & P. 8/6. Carrying Case for above **28/6**. P. & P. 7/6.

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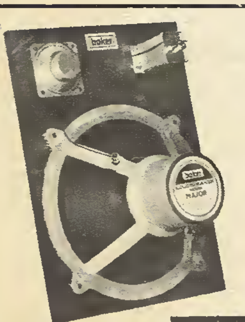

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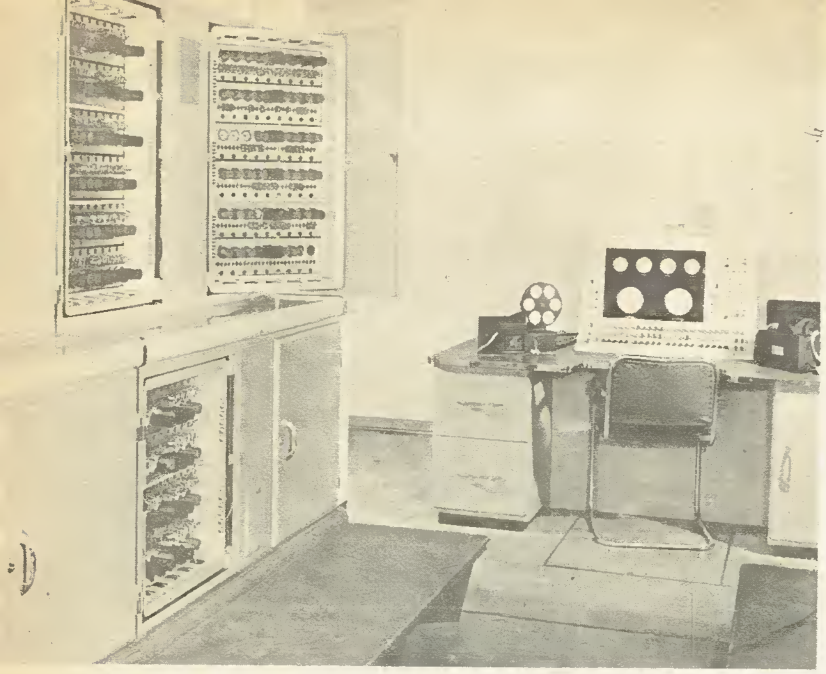


An early electronic digital computer—Ferranti Mk. I—using large valves

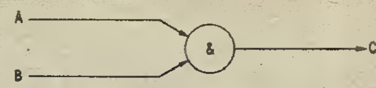


Fig. 4.3. Basic AND gate symbol

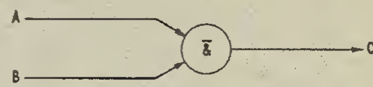


Fig. 4.4. Basic NAND gate symbol

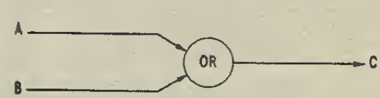


Fig. 4.5. Basic OR gate symbol

The use of the term "memory" for the computer store has been deliberately avoided until now. This is because it could be mistaken as being analogous to human memory. The store is the memory of the computer only in the sense that it can store numbers previously written there by the programmer.

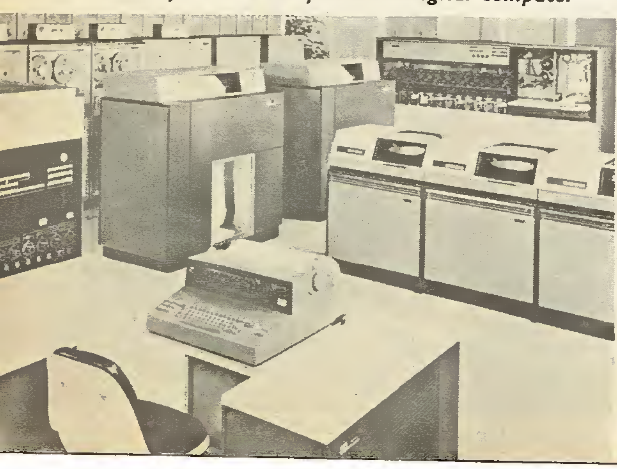
BOOLEAN ALGEBRA

Turning now to the other two sections of the computer, it is necessary to digress for a while into the realms of Boolean algebra. This is a most amusing algebra that produces such results as $1 + 1 = 1$.

Beneath a light-hearted exterior though, lurks a highly sophisticated and powerful tool for performing mathematical functions on binary numbers. It also has its applications in the control and routing of signals in the computer, so this is a convenient place to study it.

There are three main functions in Boolean algebra, the simplest being "inversion". This changes a "1" into a "0", and *vice versa*. In algebraic terms, if a binary number A is inverted, it becomes $\bar{A}$ (pronounced "not A" or "A bar").

Currently use I.B.M. System 360 digital computer



The second function is the AND operation. This can be represented in diagrammatic form (as in Fig. 4.3) or else in algebraic form by $C = A.B$ where the dot is used to mean AND.

All that this AND unit does is to give an output C of "1" only when both A AND B are "1". An extension of this unit consists of an AND followed by an invertor. In this configuration (known as a NAND element), the output C is only a "0" when both the inputs A and B are "1". At all other times the output is a "1".

A NAND unit is shown diagrammatically in Fig. 4.4; its algebraic form is $C = \overline{A.B}$

The third logical function is the OR operation (Fig. 4.5).

This is written algebraically as $C = A + B$, where the $+$ sign represents the word OR. In this case C will be a "1" if either A OR B becomes a "1". This unit also has its counterpart in "negative" logic in the NOR element, in which the output is the inverse of that of an OR unit.

These logical elements or "gates", as they are called, are very important in binary arithmetic, and control units of a digital computer. A useful way to keep track of the "1"s and "0"s in a Boolean expression is to use a "truth table", which sets out in tabular form all the possible combinations of "1"s and "0"s that will satisfy the expression. For example, the truth table of the AND element of Fig. 4.3 is as shown in Table 4.1.

Table 4.1. TRUTH TABLE OF FIG. 4.3

A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

COMPUTER EVOLUTION

S. A. HODSON B.Sc

BASIC DIGITAL CIRCUITS

PART FOUR

THE digital computer is the so-called "electronic brain" of today which is revolutionising our way of life. By applying its fantastic speed and accuracy to routine problems, it can take from our shoulders the burden of such things as accounting, book-keeping, payrolls, statistical analyses, ordering, and so on. The list is almost endless.

It may be remembered that in the first article of this series, it was explained that a digital machine could only work in terms of exact numbers. This is not such a great disadvantage as it may seem, especially in such fields as finance. The progress of the digital computer was left (in Part 1) at the stage where Babbage had to abandon development of his computer through lack of sufficient technical advance in his day. He did not, however, abandon it until he had formulated the basic layout of his machine. This layout is in use in modern computing machines.

Babbage's computer was to consist of three main units: the "mill", the "store", and the "control". Since it was envisaged that all the operations could be performed faster than a man could enter numbers, all data used had to be put into the store beforehand. Then the "mill", or "arithmetic unit", as it would be called today, would operate on the numbers in the store under the supervision of the control unit. The one difference between Babbage's machine and a modern one, is that his had to work with decimal numbers, whilst most modern computers work with binary numbers.

TWO STATES

With the advent of electronics, it is a common experience that electrical or electronic conditions come in pairs or duals; on/off, short-circuit/open-circuit, conducting/non-conducting, forward-biased/reverse-biased, and so on. Seldom, if ever, does an electronic device have more than two states.

Suppose now that the number 153 were to be represented using such two-state devices. Thirty would be needed (10 each for the hundreds, tens, and units). If, instead of units, tens, hundreds, and so on, the numbering system had columns of units, twos, fours, eights, etc. then the highest number in any column would be "1". Hence each column has only two states: "1", and "0", and can thus be represented completely by one electronic device. This numbering system is called "binary notation". Returning to the number 153, in binary this becomes 10011001. Therefore only eight devices are needed to represent it. These devices may be valves or transistors.

A number such as 10011001 is referred to as a computer "word", and is said to have eight "bits". The word "bit" is an abbreviation of "binary digit"; each "1" or "0" is a "bit".

Turning now to the three parts of the computer, the whole machine revolves about its store. There are many types of store; one that is quite widely used, and will serve as an example, is called a "four-wire, coincident current, core store", developed by the Massachusetts Institute of Technology (M.I.T.).

MAGNETIC CORE STORE

A magnetic core is a ring of magnetic material that can be magnetised in either a clockwise or an anti-clockwise sense. One core can store one "bit" of information, the "1" or "0" being signified by the sense of magnetisation of the core.

It is well known that a wire carrying a current generates a magnetic field around itself. If the wire

COMPONENTS . . .

Resistors
R1 64kΩ
R2 32kΩ
R3 16kΩ
R4 8kΩ
R5 4kΩ
*R6 2kΩ
R7 1·2kΩ
(See text for details)

Potentiometers
VR1 25kΩ skeleton preset
VR2 1MΩ skeleton preset
VR3 1MΩ skeleton preset
*VR4 5kΩ skeleton preset
*VR4 can be used in place of R6 (see text)

Capacitors
C1 0·001μF, C2 0·01μF, C3 0·1μF — polyester 400V
C4 1·0μF, C5 1·0μF — elect. 15V
C6 0·1μF, C7 0·01μF, C8 0·001μF — polyester 400V

Logic Modules
Register/bistable type 43A (6 off)
Multivibrator type 43D (1 off)
NOR gate type 40A (1 off)
All available from Electroniques (Prop STC) Ltd., Edinburgh Way, Harlow, Essex.

Diodes
D1, D2 OA81 (2 off)

Meter
M1 500μA moving coil type MR52P (Electroniques)

Switches
S1 Two-pole, 4-way rotary wafer switch
S2 Single pole, on/off, push button, normal open
S3 Double-pole, on/off, toggle switch

Plug and socket
PL1 and SK1 3-way panel mounting

Miscellaneous
Datum box type DD585 (Electroniques)
Veroboard, 61 × 44 holes, 0·1in matrix with copper strips (2 off) (Electroniques type VC695-44)
Batteries 4·5V flat pack (3 off)

The binary ratios are chosen so that for every single pulse into the register the current through the resistor chain will increase by one unit, two pulses would give an increase in current of two units and so on in linear steps. This can best be shown by a simple calculation.

RESISTOR NETWORK

Let us assume that the register is in the "reset" condition. This means that all the outputs will be at level 0, which is, to all intents and purposes, zero volts. As the other end of the resistor network is also held at earth potential no current will flow. On the entry of one pulse into the register, binary 1 will change its output to level 1, which is −6V. We will now have current flowing through the 64 kilohm resistor which can be simply calculated by Ohm's Law.

The total resistance between the output point on binary 1 and earth is made up from 64 kilohms plus the total effective parallel resistance of 32kΩ, 16kΩ, 8kΩ, 4kΩ, 2kΩ, and 1·2kΩ.

Total resistance = 64,000 + 554 = 64,554 ohms. (The parallel resistance of the meter can be neglected.) The total current flow is therefore

$$\frac{6 \times 10^3}{64{,}554} = 0{\cdot}093\text{mA}$$

The potential difference between point A and earth is therefore 0·093 × 0·554 = 0·051 volts.

If this same calculation is carried out for each combination of logical condition of register, it will be found that for every pulse input the potential at point A will rise by (to the first approximation) 0·05V increments.

To obtain the binary values of resistance necessary for this network, it is best to use conventional ½ watt solid carbon resistors, to the nearest preferred value below the value required. If the surface of the resistor is gently filed, so as to remove some conductive material, the value of the resistor will increase. This process can be done while monitoring the actual value on a good quality meter, or resistance bridge.

An alternative method is to use preferred values for the larger values, matching them to the binary ratios as accurately as is possible. (Remember that there is a tolerance associated with every resistor, and if you are lucky you may hit on a precise binary value.) It will almost certainly be necessary to adjust the lower values, particularly the 2 kilohms. To overcome this problem, the author used a preset potentiometer for the 2 kilohm resistor, and selected values for the rest of the chain.

The worst that can happen if there is a mismatch in the binary ratios is that the increments between voltages associated with the incoming pulses may vary, and in the worst case might even cause a drop back of meter reading, as the register steps from, say, binary 1111 (decimal 15) to binary 10000 (decimal 16).

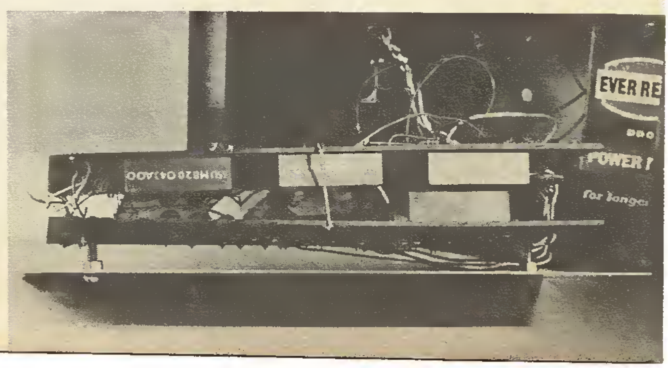
Although this network obviously controls the display accuracy of the instrument, it should be remembered that there is a certain amount of error associated with reading a meter, and as the full scale of the meter will display, in this case a total of 60 pulses, it will hardly be possible to detect any movement of the needle for a single pulse difference. (Normal accuracy of reading a moving coil meter is 2 per cent.)

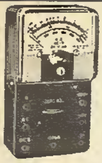
Next month constructional details will be given followed by suggestions of input circuits to make this stopclock suitable for:

(a) Camera shutter speed measurement;

(b) Human reaction timing;

(c) Velocity and acceleration measurement.





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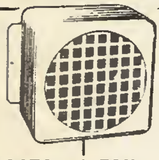

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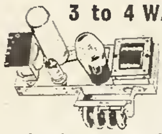

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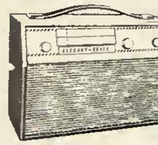

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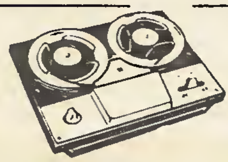

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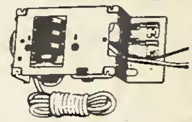

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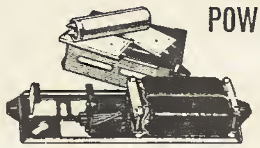

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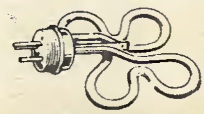

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potentiometer on each side of the unit. In practice, these can be used to calibrate the slowest scale when the equipment is completed. The ranges are selected by means of a ganged, double-pole, four-way switch.

On close inspection TR3, which is contained within the module, forms the active element of a double input NOR gate, one input being taken straight from the emitter of TR2, the second via a resistor from pin 2. This NOR gate is used to control the outflow of pulses from the multivibrator.

A logic level 1 on pin 2 will cause TR3 to go into conduction, or "bottom", and the output level at pin 25 will stay at level 0 irrespective of the state of the multivibrator. It should be noted that the gating operation merely controls the outflow of pulses and does not stop the multivibrator running.

Although only four ranges have been chosen for this instrument, there is no reason why this should not be extended in the "slower" direction with higher value capacitors. Rather than have ranges as multiples of 10 it might be better to have overlapping scales, which could lead to higher accuracies on the final instrument.

There is, however, a limit to the fastest speed of operation and this is set by the parameters of the modules. The manufacturer specifies a maximum pulse repetition frequency of 10,000 p.p.s. which means the shortest period would be 0·1ms, which would be obtained using cross-coupling capacitors of 500pF each.

The power requirements for this stage are −9V at 15mA, and +4·5V at 300mA. The preset potentiometers across the 1μF capacitors are taken straight to the −9V line.

INPUT "OR" GATE

The circuit shown in Fig. 3 comprises two germanium diodes. If both input points are in condition 0 the output will stay at 0; however, if either, or both the

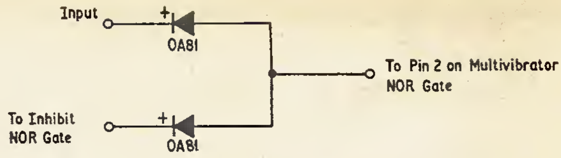


Fig. 3. Input OR gate

inputs go to level 1 the output will rise to level 1 and therefore block the output from the multivibrator. Although it is possible to buy this circuit ready made as a module, it was felt hardly worth while due to the simplicity of this particular stage.

BINARY STAGES AND REGISTER

The six stage binary register comprises six identical modules, the circuit of one being shown in Fig. 4.

The module used is a type 43A bistable/register element. Generally speaking, this module can be used as a "set", "reset" bistable, a shift register stage, or a binary divider, depending on which input points are used, and also on the interconnections between pins.

In this application, we wish to use the latter facility and, in order to achieve a complementary changeover on the entry of pulses from a single line, it is necessary to provide the internal pulse steering circuits which will route the incoming pulse to the correct side of the bistable. Without going into great detail, this is done by coupling the output of one side back to the capacitive input of the same side, this is then repeated for the complementary side of the bistable. Thus we have to link pin 7 to pin 2 on one side, and pin 4 to pin 9 on the other side externally.

As we have only single-line entry, it is also necessary to couple the two capacitive input points together (pins 25 and 26). Pins 1 and 10 both have to go to a

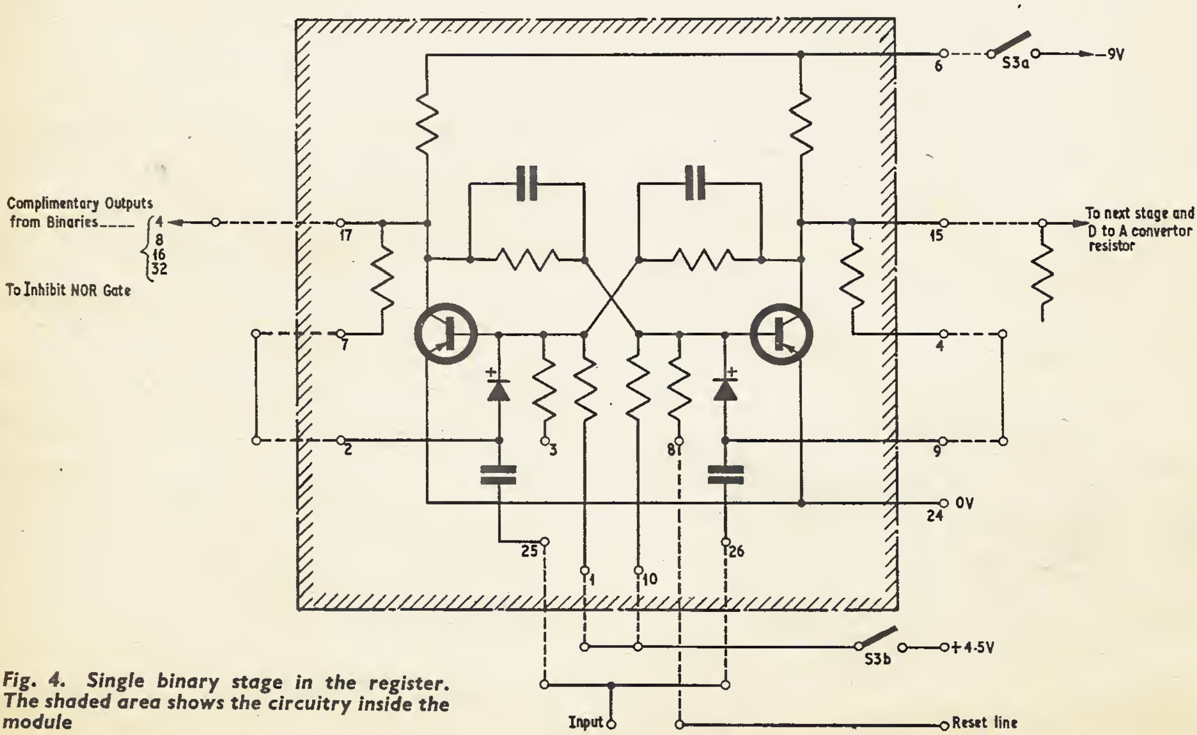


Fig. 4. Single binary stage in the register. The shaded area shows the circuitry inside the module

This is termed "negative logic" and all descriptions of operation will be based on these criteria. Germanium transistors are used throughout, and this in part accounts for the fact that negative logic is used in this system.

BASIC SYSTEM

Fig. 1 shows a block schematic diagram of the timer unit. Basically, it consists of a built-in "clock", the multivibrator, which can be switched to run at various pre-determined frequencies. The output from this clock is a series of square pulses having constant mark/space ratio. These pulses are fed through a NOR gate into a binary divider unit, sometimes called a ripple counter.

Each stage of the register is a clocked flip-flop with outputs coupled back to the inputs, thus on entry of each clock pulse, the stage will divide by a factor of 2. Each stage is cascaded to the next and, with six stages as in this unit, the final stage will divide by 32.

Assuming that the register starts in a "reset" state, i.e. all the binary outputs are at level 0, the register will accept a total of 63 clock pulses before it completes the full circle and returns to the condition when all outputs are at 0.

The NOR gate between the multivibrator and the register is present to allow the external stimulus to control the flow of pulses from the clock into the register. Assuming the input stimulus continued for more than 63 clock pulses, the register would return to the reset state, and continue counting on a second lap.

It would, therefore, be very difficult to tell what figure had been counted at the end of a period such as this. To prevent this "overflow" and recycling occurring, an "inhibit circuit" is incorporated which prevents any further pulses from the clock entering the register when the register is full, or, in this case, nearly full.

This "inhibit" circuit is simply a further 4 - input NOR gate coupled to the complementary outputs of the last four stages of the register. When the register has counted to 60, the complementary outputs of the last four stages will be in condition 0, then the output from the inhibit NOR gate changes from level 0 to level 1.

This signal is fed back through the input OR gate to the multivibrator NOR gate, which blocks the flow of any further pulses. Apart from preventing overflow, this simple arrangement allows us to work with a total register count of 60 which is a much simpler figure (arithmetically speaking) than 63.

It will be seen from Fig. 1 that the output of each binary stage of the register has associated with it a resistor which is commoned at one end, and taken via a 25 kilohm potentiometer to a meter. This simple resistor network is, in effect, a digital to analogue converter. This circuit converts the total count held in the register into an output current, which is displayed on the meter; the higher the count, the higher the reading on the meter.

OPERATING FUNCTION

Whenever a level 1 appears at the input point, clock pulses are prevented from entering the register, irrespective of whether or not the inhibit circuit has been brought into operation.

Let us assume that at the time of switching the instrument on, the input level is at level 1. When switched on, the register will take up a random condition depending on internal tolerances of the individual binaries, the output meter will therefore give a reading.

Before any measurement can be carried out, the register must be reset so that all the binary outputs are at level 0. This is done by applying a level 1 signal to all the direct "reset" entry points of the binaries simultaneously. In this instrument, this is accomplished merely by pressing the reset button. The output meter should now read zero.

Assuming that the multivibrator is generating pulses at the rate of 50 pulses per second, and we allow the input logic level to drop to state 0 and remain in this condition for 0·5 second before returning to level 1, we should theoretically allow 25 pulses to pass into the register.

There is, however, a chance that the multivibrator was already halfway through a cycle as the NOR gate was opened, therefore we may only count 24 pulses—this is one source of error in the equipment, but it can never be

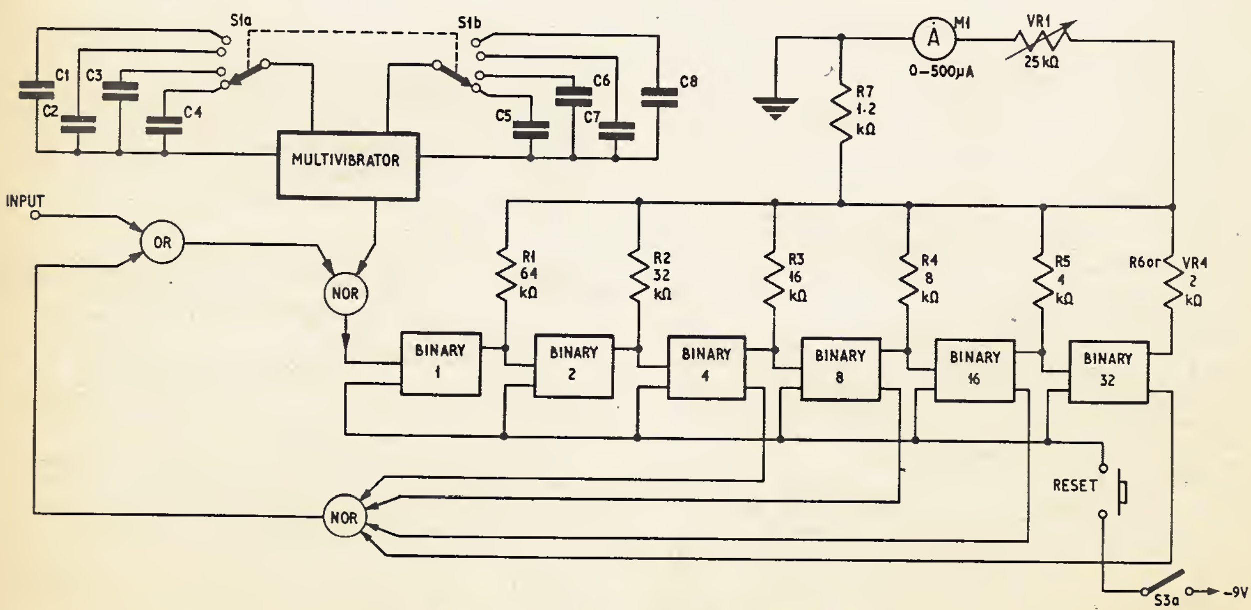
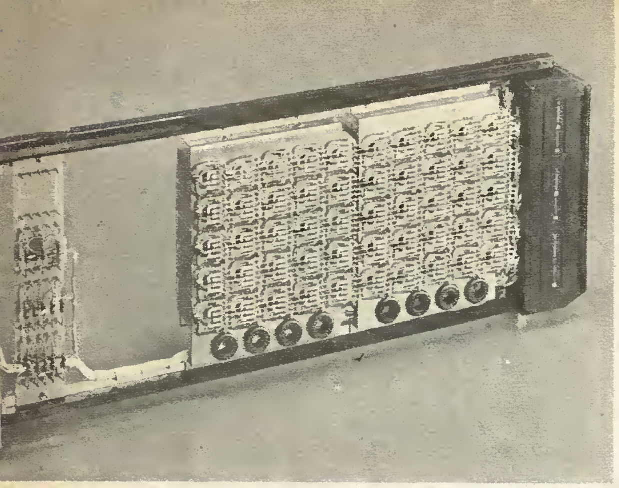


Fig. 1. Block diagram of the main timer unit



View of a typical switching unit incorporating fifty reed relay sets

quickly the faulty section. Test points on the front of the units then enable strategic parts of a circuit to be checked before the replacement of the faulty unit.

To eliminate any possibility of a fault remaining undetected for long periods, as could occur during a low calling rate period, test calls are passed through the system every eight minutes.

IN SERVICE

The modular design and use of registers and high speed electronic circuits combine to give an inherent flexibility to improve certain features and to introduce new services as the demand arises.

Among the improved features is the simplified method of barring outgoing and incoming calls, which is readily imposed by the appropriate threading of a lead through the class-of-service field.

An improvement in the private branch exchange (PBX) facility dispenses with the customary practice of reserving groups of numbers for possible PBX extensions; any directory number can be used for a PBX group of lines.

As the dial pulse counter can accept pulses at a greater rate than 10 pulses per second, a higher speed dial is now practicable. Even more useful in these days of subscriber trunk dialling (STD) when up to 10 digits are required on national calls and up to 15 digits on international calls, is the introduction of push-button telephones in place of dial telephones. In local calls within the exchange, the called subscriber will be rung by the time the last button is released.

On calls to exchanges of the electro-mechanical type, push-button signals have to be converted into 10 p.p.s. signalling until such time as multi-frequency signalling is introduced between exchanges.

Another new service is the ability for a subscriber to transfer incoming calls made to his directory number, to any of a specified group of subscriber stations, by dialling an appropriate code. This subscriber is also allowed an ex-directory number so that close associates having this private information are able to communicate with the subscriber, such as an off-duty doctor, while normal incoming calls are on transfer. A variant of this facility allows transfer of incoming calls to a recorded announcement to indicate that the subscriber does not wish to receive calls.

The Pentex system also makes it possible for a subscriber to dial the extension of a private automatic branch exchange without being routed through a switchboard operator.

A further facility is abbreviated dialling whereby a subscriber is allocated a list of short dialling codes representing directory numbers he frequently calls.

Other facilities which are being developed include 3-way conference calls, call-waiting, and an alternative transfer facility enabling calls to be transferred to any number rather than to an allocated group.

CONCLUSION

The exchange at Ambergate is currently serving 700 subscribers and by the end of 1967 a further six exchanges should be serving the public; thereafter new exchanges of this type will be put into service at a rate of more than one a week. This new system, embracing the use of the latest electronic techniques and components, and by virtue of the centralised control system, has exceptional flexibility in adapting to and providing new services and facilities.

With the progressive introduction of faster signalling in the national trunk network and the introduction of push-button telephones, the system will enable subscribers to enjoy "instant" switching and improved transmission performance. ★

The calling number generator and jumper frame of the Pentex electronic system

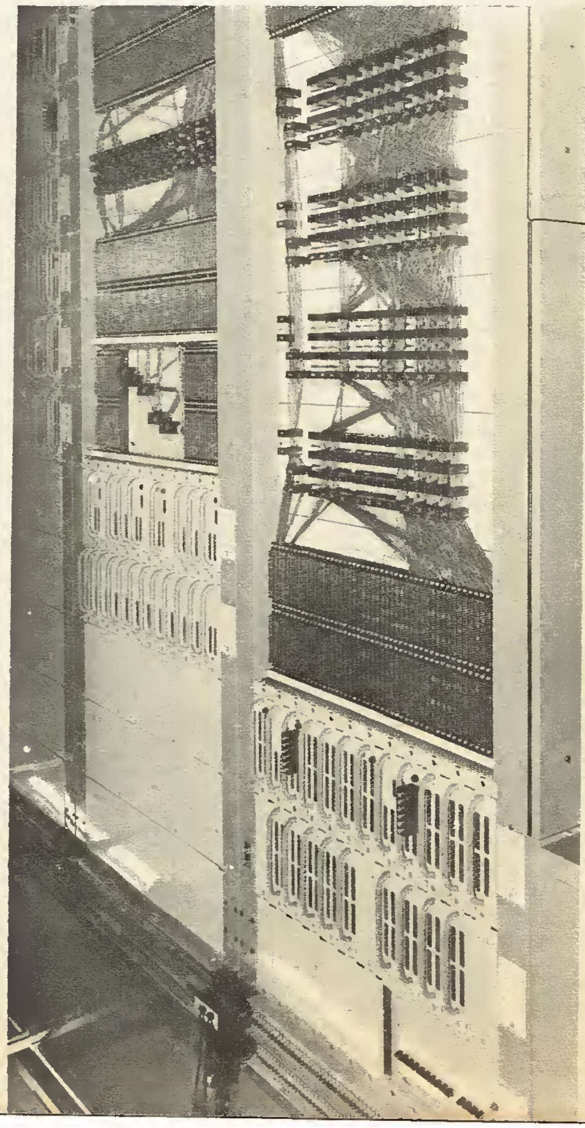
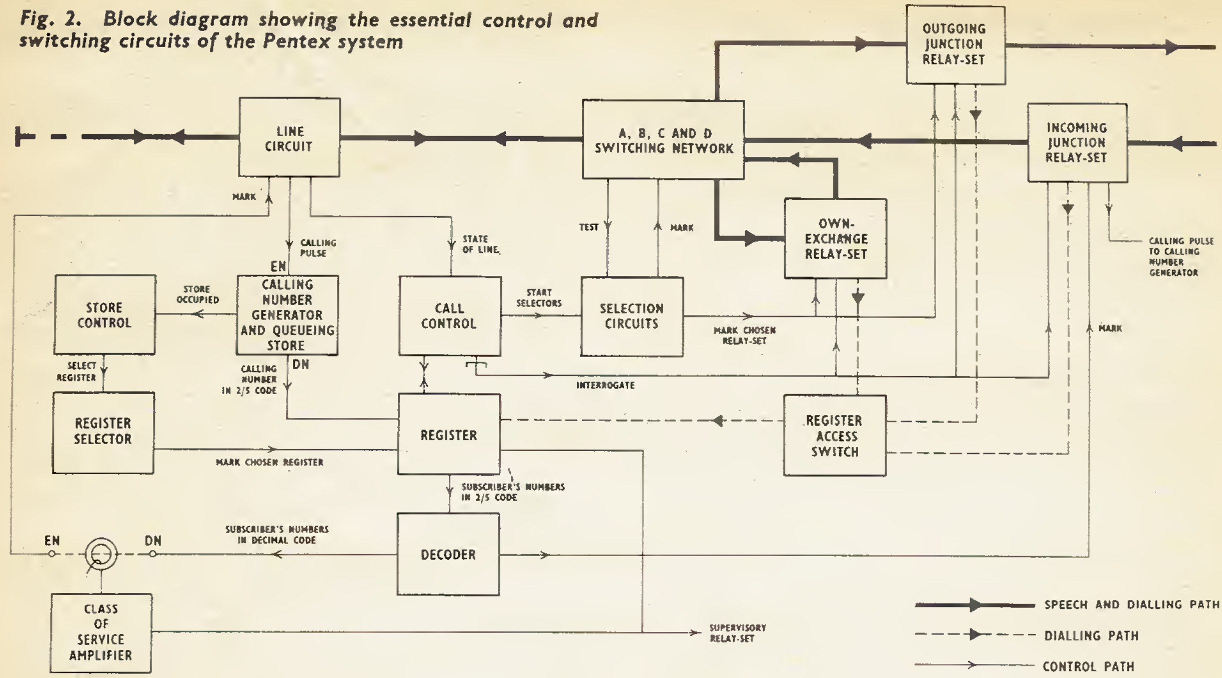


Fig. 2. Block diagram showing the essential control and switching circuits of the Pentex system



the register again requests access to the Call Control which instructs it to pass the called subscriber's number to the decoder, resulting in the marker relay of the called subscriber (2132) being operated.

Call Control checks over the test lead that the called subscriber is free, and then instructs the speech path selectors to choose a path from the originating exchange relay set, which is already connected to the calling subscriber, via the *D*, *C*, *B*, and *A* switches to the called subscriber's line circuit.

The establishment of this path is confirmed over the test lead by Call Control which then releases the register and itself from the call. This sequence also takes approximately 50 milliseconds. The "own exchange" relay set sends ringing tone to the calling subscriber and ringing current to ring the called subscriber's bell, and supervises the call throughout its duration.

LITTLE SIMILARITY

From these very brief descriptions of the two systems, it can be seen that there is little similarity. The step-by-step final selector and the "own exchange" relay set perform similar functions in that each supervises a call, giving ringing tone and ringing current, providing meter pulses, monitoring the end of the call and arranging release. Each must be provided according to the number of calls established in the exchange; a final selector can give access to 100 directory numbers and must be provided according to the probability of how many of these 100 subscribers will be making simultaneous calls. In Pentex, the "own exchange" relay set is available to all subscribers and must be provided according to the probability of the number of simultaneous "own exchange" calls.

In the step-by-step system the setting up of the path is geared in time to the pulses produced by the dial. The frequency (nominally 10 pulses per second) and duration of these pulses are critical. In the electronic system, it is not critical and the dial pulse counter has been designed to receive pulses at speeds up to 20 per second.

Having compared the two systems let us now take a closer look at the equipment used in Pentex.

REED RELAYS

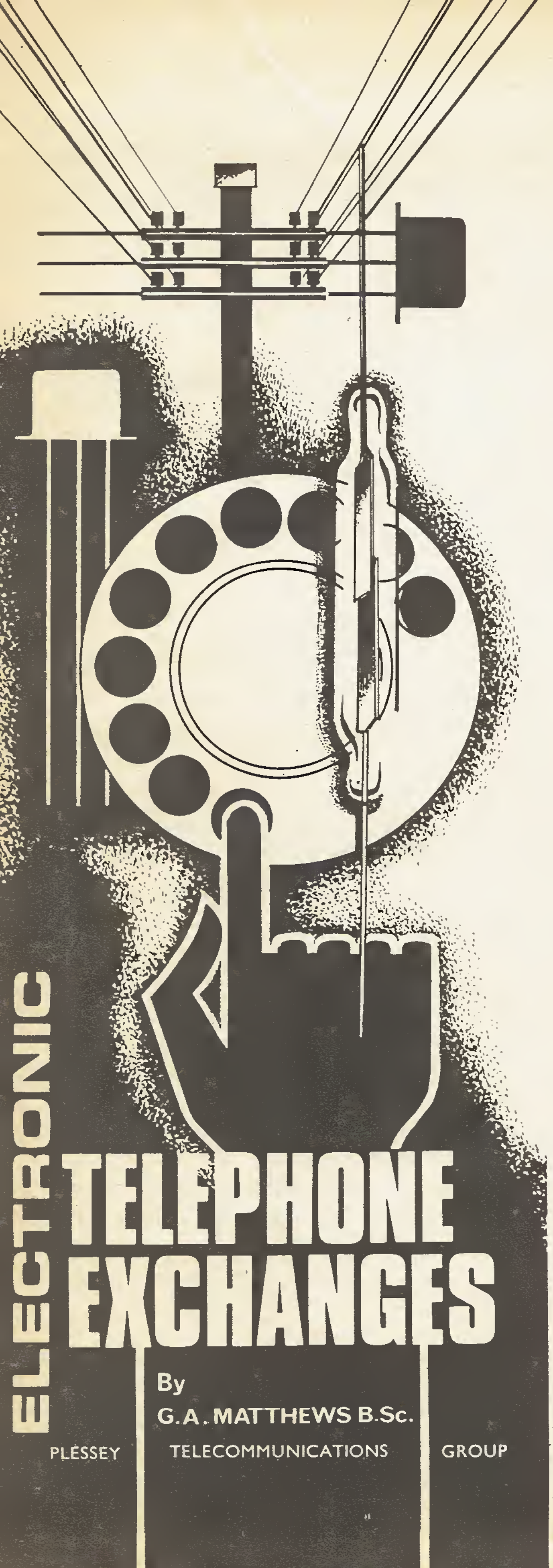
The whole of the speech switching network is made up of reed relays. Four reed contact units are mounted inside a screened coil which provides the required electromagnetic force to operate the reed contact units. The reeds, which are gold-plated over their contact areas, are sealed in a glass tube containing a gas mixture ensuring a long life free from contamination. The overall dimensions of the relay are 2in × 1in × 1in, which compares favourably with the conventional 3000 type of up to 4in × 2½in × 1in.

The reed relay is quite fast in operation, taking approximately 1ms to operate and 0·5ms to release. It is, therefore, suitable for many applications in the common control of the exchange. It is used exclusively for storing digits in a 2 out of 5 code, the four contacts per relay providing an easy means of decoding into decimal. Circuits which have to operate faster, such as the selectors and the calling number generator, use semiconductors.

CALLING NUMBER GENERATOR

In some types of electronic exchanges, the identity of a calling subscriber is discovered by scanning all lines in sequence. The Pentex system is too small to allow the cost of such scanning equipment, so the calling subscriber is identified in the following manner.

When the subscriber lifts his handset the line relay is operated. A contact on this relay discharges a charged capacitor producing a pulse of current approximately 1A in magnitude and 20μs in duration. This pulse is fed along a wire to the calling number generator (Fig. 3), which consists of an array of metal tape transformer cores arranged in rows of ten, each row



ELECTRONIC TELEPHONE EXCHANGES

By
G. A. MATTHEWS B.Sc.
PLESSEY TELECOMMUNICATIONS GROUP

THE END of 1966 marked the beginning of a new era in the field of telecommunications. A major step in Britain's aim to "go all electronic" with its telephone switching system was achieved with Europe's first production electronic exchange entering public service at Ambergate in Derbyshire.

Known as the Post Office TXE2, it was developed by Plessey in conjunction with the Post Office under the auspices of the Joint Electronic Research Committee. A similar system is marketed by Plessey under the name PENTEX. TXE2 is intended primarily for rural and small urban areas where subscriber demand lies in the appropriate range of 200 to 2,000 lines. It is the first full-scale electronic exchange to be integrated into the national network and the forerunner of many similar exchanges now in full production.

The new exchange at Ambergate operates on the space division principle with a sectionalised and duplicated common control.

CONVENTIONAL EXCHANGE

In order to appreciate the differences between electronic exchange systems and conventional electro-mechanical exchanges, let us first briefly look at the basic working methods employed in the conventional exchange.

The existing step-by-step electro-mechanical exchange is a sectionalised control system where individual switching stages are associated with and controlled by the pulses made by dialling particular digits of a telephone number.

Briefly, this system uses uniselectors and two-motion selectors for its switching stages. A uniselector is an electromagnetic rotary switch with wipers scanning 25 groups of outlet contacts; in the two-motion selector the wipers are stepped vertically by the dial pulses, past banks or levels of contacts to the selected bank or level; at this level the wipers make a rotary horizontal scan over ten groups of contacts in the bank.

ELECTROMECHANICAL ROUTING

The subscriber's telephone is connected to a subscriber's uniselector (Fig. 1) which, when the subscriber lifts his handset, searches for a free first group selector, which returns dial tone. If a subscriber (number 2114) dials 2132, the pulses representing the digit 2 lift the wipers of the first group two-motion selector to "level 2" bank of contacts, over which they hunt horizontally for a free second group selector connected to that level.

This group selector will respond in a similar way to the second digit 1, extending the subscriber to a free final selector connected to level 1. The third digit 3 will lift the wipers of the final selector to level 3, and the final digit 2 will step the wipers to the second outlet on that level. This outlet will be connected to telephone 2132 and the final selector will send ringing tone to the calling subscriber and ringing current to ring the called subscriber.

When the called subscriber answers, the ringing tone and current are removed and one pulse is recorded on the calling subscriber's meter for charging purposes. When the call is completed, the final selector detects this condition and releases all the switches held in the connection.

TWO ELECTRONIC GROUPS

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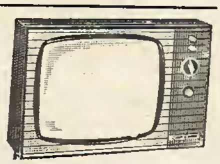

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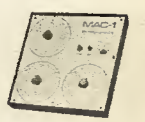

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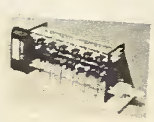

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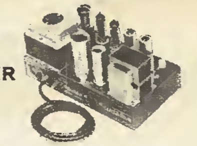

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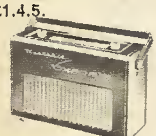

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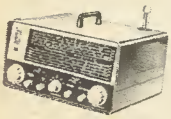

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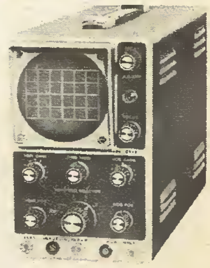

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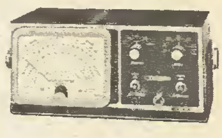

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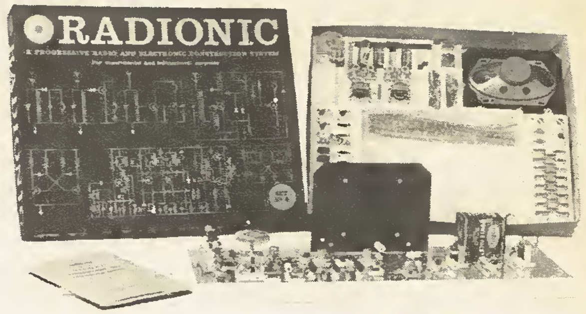

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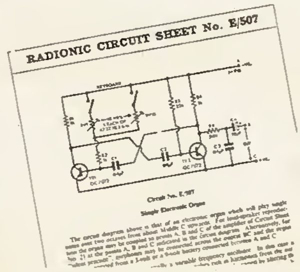

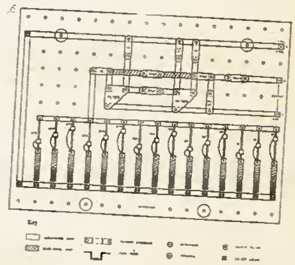

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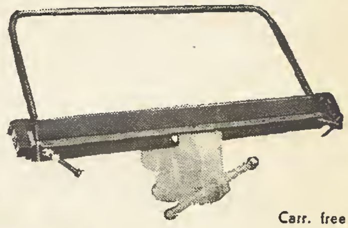

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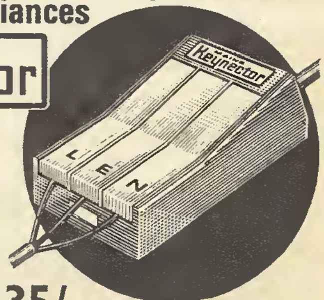

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