PRACTICAL

ELECTRONICS

MARCH 1968

PRICE 2/6

FLUORESCENT CAMPING LIGHT

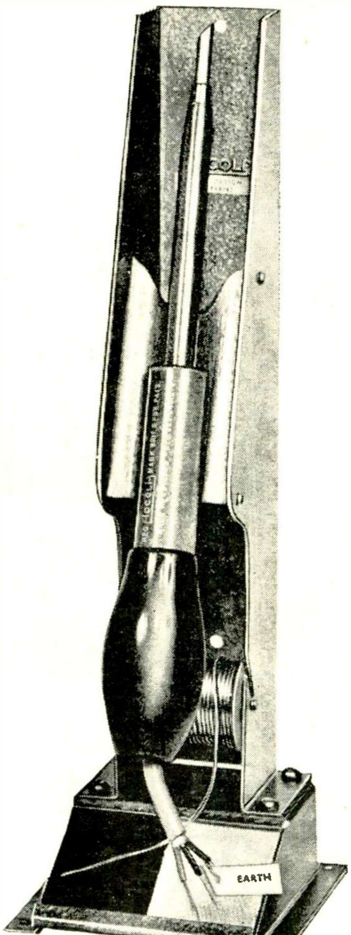
WITH

Transistor Inverter

Operates from 12v Car Battery

ALSO IN THIS ISSUE

* Rhythmic Sound Effects Unit
* Impact Counter



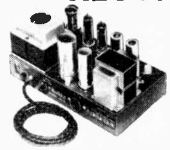
EARTH

HI-FI AMPLIFIERS — TUNERS — RECORD PLAYERS

FM TUNERS FM-4U

TFM-1S

10W POWER AMP. MA-12



20 + 20W STEREO AMP. AA-22U

HI-FI FM TUNER. Model FM-4U. Available in two units. R.F. tuning unit (£2.15.0 incl. P.T.) with I.F. output of 10·7 Mc/s and I.F. Amp. unit and valves (£13.13.0). Total Price Kit **£16.8.0**

HI-FI AM/FM TUNER. Model AFM-1. Available in two units which, for your convenience, are sold separately. Tuning heart (AFM-T1—£4.13.6 incl. P.T.) and I.F. amplifier (AFM-A1—£22.11.6). Printed circuit board, 8 valves. Covers L.W., M.W., S.W., and F.M. Built-in power supply. Total Price Kit **£27.5.0**

STEREO DECODER SD-1. Available as extra for above models. Self-powered. Kit **£8.10.0.** Ready-to-Use **£12.5.0**

Hear the BBC stereo FM programmes on the TRANSISTOR STEREO FM TUNER. Elegantly designed to match the stereo Amplifier, AA-22U. Available in two units, sold separately, can be built for a Total Price:
Kit TFM-1S (STEREO) **£24.18.0** incl. P.T.
Kit TFM-1M (MONO) **£20.19.0** incl. P.T.

20+20W TRANSISTOR STEREO AMPLIFIER. Model AA-22U. Outstanding performance and appearance. Kit **£39.10.0** (less cabinet). Attractive walnut veneered cabinet £2.5.0 extra. Ready-to-Use incl. cabinet, **£59.15.0.**

HI-FI MONO AMPLIFIER. Model MA-12. 10W output, wide freq. range, low distortion. Use with control unit.
Kit **£12.18.0** Ready-to-Use **£16.18.0**

HI-FI CABINETS. Full details available. MALVERN: Kit **£18.1.0.** GLOUCESTER: Kit **£18.10.0.**

DE LUXE STEREO AMPLIFIER. Model S-33H. De luxe version of the S-33 with two-tone grey perspex panel, and high sensitivity necessary to accept the Decca Deram pick-up.
Kit **£15.17.6** Ready-to-Use **£21.7.6**

HI-FI STEREO AMPLIFIER. Model S-99. 9+9W output. Ganged controls. Stereo/Mono gram, radio and tape inputs. Push-button selection. Printed circuit construction. Kit **£28.9.6** Ready-to-Use **£38.9.6**

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***Complete your motoring pleasure with this outstanding car radio,* Model CR-1**

Will give you superb LW and MW entertainment wherever you drive. Tastefully styled to harmonise with any car colour scheme. 8 latest semi-conductors (6 transistors, 2 diodes) for 12V positive or negative earth systems. Powerful output (4 watts) will drive two loudspeakers. Pre-assembled and aligned tuning unit. Available for your convenience in two units. Can be obtained for a Total Price: Kit (excl. L.S.) **£12.17.0** incl. P.T. 6″ × 4″ 3Ω loudspeaker £1.4.5.

Oxford

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

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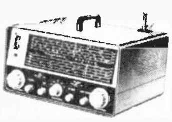
TRANSISTOR PORTABLE. Model UXR-1. Pre-aligned I.F. transformers, printed circuit. Covers L.W. and M.W. Has 7″ × 4″ loudspeaker. Real hide case. Kit **£12.11.0** incl. P.T.

JUNIOR EXPERIMENTAL WORKSHOP. Model EW-1. More than a toy! Will make over 20 exciting electronic devices, incl.: Radios, Burglar Alarms, etc. 72 page Manual. The ideal present! Kit **£7.13.6** incl. P.T.



GC-1U

"MOHICAN" GENERAL COV. RECEIVER for Amateur or Short Wave listening. Send for leaflet. Model GC-1U. Kit **£37.17.6** Ready-to-Use **£45.17.6**

Prices quoted are Mail Order, retail prices slightly higher

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3″ LOW-PRICED SERVICE OSCILLOSCOPE. Model OS-2. Compact size 5″ × 7¾″ × 12″ deep. Wt. only 9¾lb. "Y" bandwidth 2 c/s–3 Mc/s ±3dB. Sensitivity 100mV/cm T/B 20 c/s–200 kc/s in four ranges, fitted mu-metal CRT Shield. Modern functional styling.
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5″ GEN.-PURPOSE OSCILLOSCOPE. Model 10-12U. An outstanding model with professional specification and styling. "Y" bandwidth 3 c/s–4·5 Mc/s ± 3dB. T/B 10 c/s–500 kc/s. Kit **£35.17.6** Ready-to-Use **£45.15.0**

VVM, IM-13U

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

V-7A

AUDIO SIGNAL GENERATOR. Model AG-9U. 10 c/s to 100 kc/s, switch selected. Distortion less than 0·1%, 10V sine wave output metered in volts and dB's.
Kit **£23.15.0** Ready-to-Use **£31.15.0**

VALVE VOLTMETER. Model V-7A. 7 voltage ranges d.c. volts to 1,500. A.C. to 1,500 r.m.s. and 4,000 peak to peak. Resistance 0·1Ω to 1,000MΩ with internal battery. D.C. input resistance 11MΩ. dB measurement, has centre-zero scale. Complete with test prods, leads and standardising battery.
Kit **£13.18.6** Ready-to-Use **£19.18.6.**

RF-1U

MULTIMETER. Model MM-1U. Ranges 0–1·5V to 1,500V a.c. and d.c.; 150μA to 15A d.c.; 0·2Ω to 20MΩ 4½″ 50μA meter. Kit **£12.18.0** Ready-to-Use **£18.11.6**

R.F. SIGNAL GENERATOR. Model RF-1U. Up to 100 Mc/s fundamental and 200 Mc/s on harmonics. Up to 100mV output.
Kit **£13.18.0** Ready-to-Use **£20.8.0**

IG-82U

SINE/SQUARE GENERATOR. Model IG-82U. Freq. range 20 c/s–1 Mc/s in 5 bands less than 0·5% sine wave dist. less than 0·15μ sec. sq. wave rise time.
Kit **£25.15.0** Ready-to-Use **£37.15.0**

TRANSISTOR POWER SUPPLY. Model IP-20U. Up to 50V, 1·5A output. Ideal for Laboratory use. Compact size.
Kit **£35.8.0** Ready-to-Use **£47.8.0**

Prices and specifications subject to change without notice

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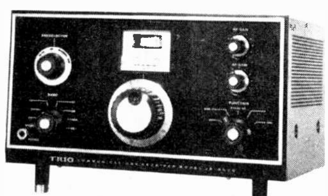
A MUST FOR EVERY ELECTRONICS HOBBYIST AND HI-FI ENTHUSIAST!

COMMUNICATION RECEIVERS

NOW AVAILABLE FOR THE FIRST TIME IN GREAT BRITAIN—TWO NEW TRIO RECEIVERS

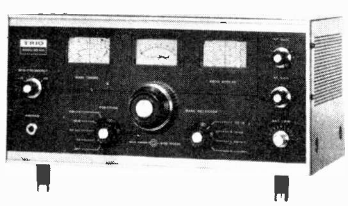


MODEL JR-500SE

This high performance receiver is made especially to cover the amateur bands and utilises a crystal controlled double heterodyne circuit for extra sensitivity and stability. **Brief spec.:** Covers all the amateur bands in 7 separate ranges between 3·5 and 29·7 Mc/s. Circuit uses 7 valves, 2 transistors and 5 diodes plus 8 crystals; output 8 and 500 ohm and 500 ohm phone jack. **Special features:** Crystal controlled oscillator ● Variable BFO ● VFO ● AVC ● ANL ● S meter ● SSB-CW ● Stand-by switch ● Special double gear dial drive with direct reading down to 1 kHz ● Remote control socket for connection to a transmitter. Audio output 1 watt. For use on 115/250V a.c. Mains. Superb modern styling and control layout—finished in dark grey. Cabinet size 7 × 13 × 10in. Weight 18lb. Fully guaranteed, complete with instruction manual and service data.

LASKY'S PRICE £61.19.0 Carriage and Packing 12/6.

MODEL 9R-59DE

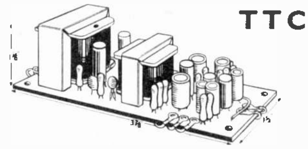


Brief spec: 4 band receiver covering 550 Kc/s to 30 Mc/s continuous and electrical band spread on 10, 15, 20, 40 and 80 metres. 8 valve plus 7 diode circuit. 4/8 ohm output and phone jack. **Special features:** SSB-CW ● ANL ● Variable BFO ● S meter ● Sep. band spread dial ● IF frequency 455 Kc/s ● Audio output 1·5W ● Variable RF and AF gain controls. For use on 115/250V a.c. Mains. Beautifully designed control layout finished in light grey with dark grey case, size: 7 × 15 × 10in. Weight 19 lb. Fully guaranteed, complete with instruction manual and service data.

LASKY'S PRICE £36.15.0 Carriage and Packing 12/6.

CONSTRUCTORS BARGAINS

TTC MODEL E1202



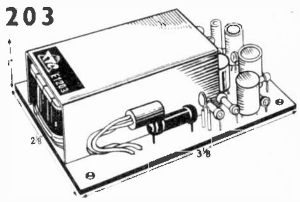
4 TRANSISTOR/PUSH PULL AMPLIFIER 12 WATTS

For use in general purpose and electronics projects. The amplifier utilises 2 × SB175 and 2 × SB178 transistors terminating in an 8 ohm output transformer. Powered by a standard 9 volt battery providing an output of 1·2 watts—sufficient for portable radios, tape recorders, intercom. small P.A. systems, etc.

Lasky's Price 47/6 Post Free

TTC MODEL E1203

4 TRANSISTOR—3 WATT

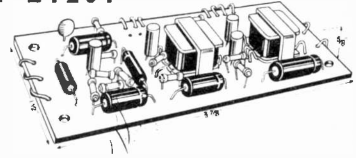


Brief Specification—Use: general purpose. Circuit: 4 transistor push/pull output. Output power: 2W 10% HD 3W max. Gain: 10mV for 2W output impedance 8 and 16 ohms. Frequency response: 150 to 10,000 c/s. Power source: d.c. 9 volts. Current consumption: 12mA at no signal: 500mA for maximum power. Dimensions: 3½ × 2½ × 1½in. Weight: 5¾oz.

Lasky's Price 57/6 Post Free

TTC MODEL E1201

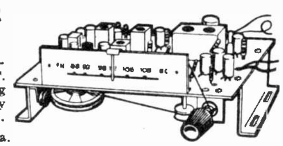
4 TRANSISTOR 200mW



Miniature audio push pull amplifier designed for use by experimenters and hobbyists. This amplifier utilises 2 × SB170, 2 × SB172 transistors terminating in a 3 ohm output transformer. Powered by standard 9 volt battery which provides an output of 200mW, sufficient for portable radios, tape recorders, intercoms and small P.A. systems, etc.

Lasky's Price 32/6 Post Free

TRANSISTOR FM TUNER CHASSIS



Fully tunable—range 88 to 108Mc/s. Completely wired on printed circuit. 10·3Mc/s. IF. 6 transistors and 3 diodes. Slow motion tuning drive. Size 6½ × 4 × 2½in. Operates from any 9V d.c. source. Full data and circuit supplied.

LASKY'S PRICE £6.10.0 Post 5/- extra.

MULTIPLEX ADAPTOR

Now you can enjoy stereo sound with the FM Tuner above. Brief spec.: MPX input sensitivity 100mV. Output 150mV. Self powered by a 9V battery. 4 transistor and 6 diode circuit. Size 5¼ × 2 × ¾in. Also suitable for use with other FM tuners with MPX input.

LASKY'S PRICE 99/6 Post 5/-

PACKAGE PRICE IF BOUGHT TOGETHER £11 Post 5/-.

SPECIAL TEST BARGAIN
TRANSISTOR CHECKER TTC MODEL C3022

For the engineer and experimenter. Uses include measuring Alpha, Beta and Ico factors of transistors, and for checking germanium and silicon diodes. Powered by 9 volt battery. Size 7 × 4½ × 3½in. Complete with connectors, battery and instruction booklet. Brief Spec.: Transistor Test-Alpha 0·7–0·9967; Beta 0-300 Ico 0-500uA-0-500uA. Diode Test: Forward and reverse internal resistance. Resistance: 200 ohms-Meg ohm.

Lasky's Price £6.19.6 Post 5/-

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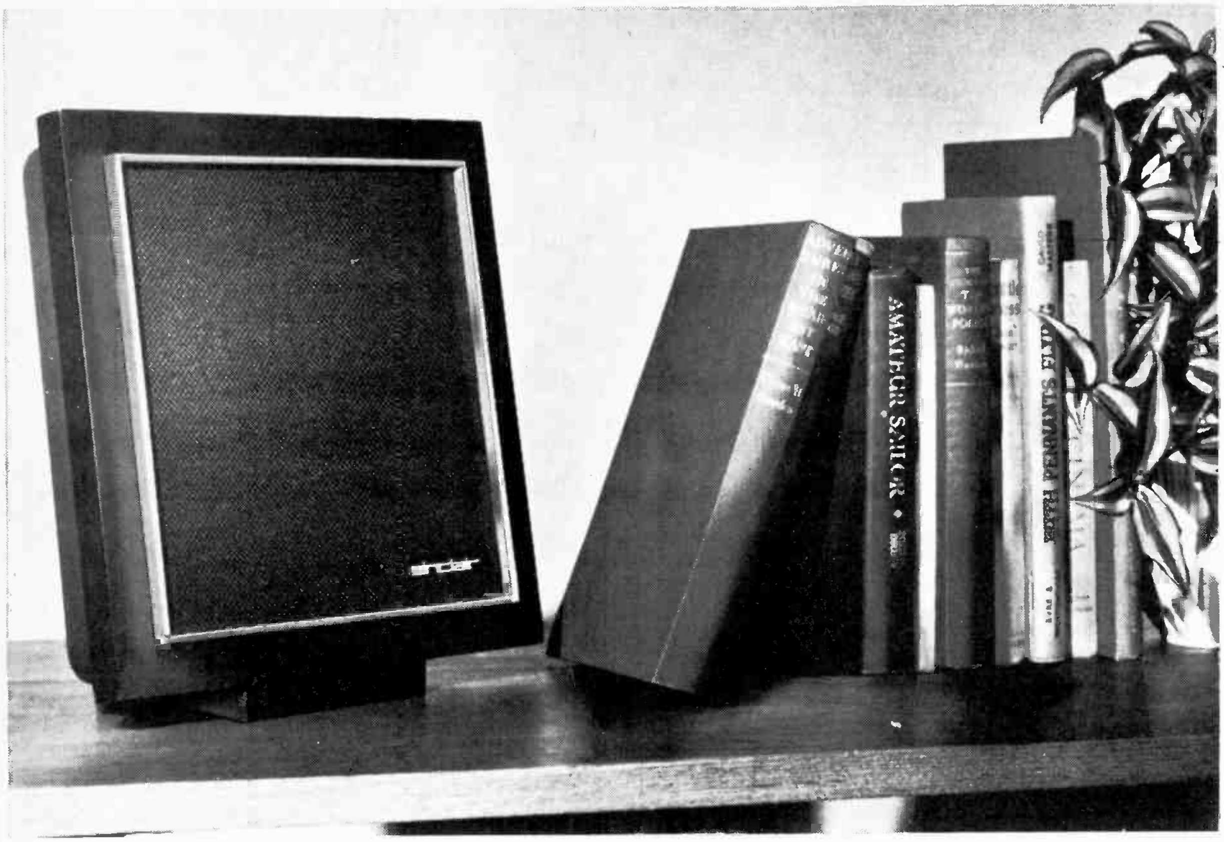

SINCLAIR Q.14 a truly superb loudspeaker

- **ACOUSTICALLY CONTOURED SOUND CHAMBER**
- **MAXIMUM LOADING IN EXCESS OF 14 WATTS**
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- **15 OHMS IMPEDANCE**
- **AN ALL-BRITISH PRODUCT**

Price need no longer stop you enjoying the best possible high fidelity loudspeaker reproduction, nor is size any longer a problem. These are considerations of the utmost importance to the stereo enthusiast. In the Sinclair Q.14 you will find a loudspeaker of such superb standards and so compactly and cleverly designed that you will want to change over to Sinclair the moment you see and hear it. At a recent trade show, experts and technical reviewers were amazed at the performance of this Sinclair speaker and agreed that for its size and price, the Q.14 was extraordinarily efficient. Tests made on a stock model by an independent laboratory specialising in acoustic research show the Q.14 to have an exceptionally smooth response between 60 and 16,000Hz with well sustained output both below and above these readings. The remarkable transient response ensures clean cut separation between instruments, voices, etc; the unusual contours of the Q.14 allow it to be conveniently positioned on bookshelf, wall corner or flush-mounted singly or in assemblies of two or more units.

The Sinclair Q.14 comprises a seamless, sealed assembly of special ultra-low resonant materials with detachable base and embellishment of solid aluminium bars.

J.R.H. of Blackpool, Lancs. writes:

The Q.14 is superior to the speakers that I have been using . . . every note from the lowest to the highest comes through perfectly.

Try the Q.14 in your own home without delay. Your money plus cost of postage back to us will be refunded in full in the unlikely event of your not being fully satisfied with the Q.14.

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● THE IDEAL LOUDSPEAKER FOR YOUR Z.12 HIGH FIDELITY SYSTEM

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SINCLAIR Z.12

COMBINED 12 WATT HI-FI AMP AND PRE-AMP

HIGH FIDELITY AT VERY LOW COST

RESPONSE FROM 15-50,000Hz ± 1dB

● **IDEAL FOR BATTERY OPERATION**

● **ULTRALINEAR CLASS B OUTPUT**

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.

"I have installed your Stereo 25 with two Z.12 Amplifiers. I have not heard anything better on sets costing four times as much."
W. R. M., Newcastle-on-Tyne.

"I am surprised and delighted with the reproduction (from two Z.12's in stereo).
R. H., Ayrshire.

Built, tested and guaranteed. With manual. **89/6**

SINCLAIR STEREO 25 DE-LUXE PRE-AMP AND CONTROL UNIT

For use with two Z.12's or any good hi-fi stereo system. Frequency response 25Hz to 30KHz ± 1dB connected to two Z.12's. Sensitivity Mic. 2mV into 50k Ω : P.U.—3mV into 50k Ω : Radio—20mV into 4·7 Ω. Equalisation correct to within ± 1dB on RIAA curve from 50 to 20,000Hz. Size $6\frac{1}{2}$in × $2\frac{1}{2}$in × $2\frac{1}{2}$in plus knobs. With elegantly styled brushed and polished aluminium front panel. Built, tested and guaranteed. **£9.19.6**

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PZ.4 Stabilised, heavy duty power pack for maximum operating standards from Z.12 assemblies. New circuitry, 18V D.C. at 1·5A from standard a.c. inputs.
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THE WORLD'S SMALLEST RADIO SET COSTS LESS, SOUNDS BETTER

SINCLAIR MICROMATIC

As easy to take with you everywhere as a wristwatch, the **Sinclair Micromatic** is the finest of all personal receivers ever. Brings in **Radio 1** and stations all over the medium waveband with fantastic power and better-than-ever quality now that a high-fidelity type magnetic earpiece is included as standard. Whether you build the **Micromatic** or buy it ready assembled, the cost of this set is now so low that there is nothing to stop you enjoying it straight away.

- MAGNETIC EARPIECE
- PLAYS ANYWHERE
- SIZE $1\frac{4}{5} \times 1\frac{3}{10} \times \frac{1}{2}$ in.
- TUNES OVER M.W.
- FANTASTIC RANGE AND POWER

Long life mercury cells (two required) each 2s. 9d.

Complete kit with mag. earpiece	**49/6**
Built and tested, with mag. earpiece	**59/6**

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THE MAGNIFICENT ROAMER 7 Mk. I

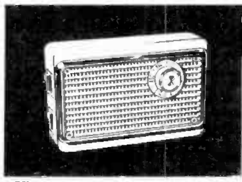
SEVEN WAVEBAND PORTABLE AND CAR RADIO WITH A SUPER SPECIFICATION

- 7 FULLY TUNABLE WAVE BANDS—MW1, MW2, LW, SW1, SW2, SW3 and Trawler Band.
- Extra Medium waveband provides easier tuning of Radio Luxembourg, etc.
- Built in ferrite rod aerial for Medium and Long Waves.
- 5 Section 22 in. chrome plated telescopic aerial for Short Waves—can be angled and rotated for peak S.W. listening.
- Socket for Car Aerial.
- Powerful push-pull output.
- 7 transistors and two diodes including Philco Micro-Alloy R.F. Transistors.
- Famous make 7×4 in. P.M. speaker.
- Air spaced ganged tuning condenser.
- Separate on/off switch, volume control, wave change switches and tuning control.
- Attractive case with hand and shoulder straps. Size 9×7×4 in. approx.
- First grade components.
- Easy to follow instructions and diagrams make the Roamer 7 a pleasure to build with guaranteed results.

Total building costs £5.19.6 P. & P. 6/6

Parts price list and easy build plans 3/– (FREE with parts).

TRANSONA FIVE

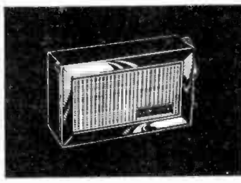


MEDIUM WAVE, LONG WAVE AND TRAWLER BAND PORTABLE

Attractive case with red speaker grille. Size 6½ × 4½ × 1½in. Fully tunable. 7 stages—5 transistors and 2 diodes—ferrite rod aerial, tuning condenser, volume control, fine tone super dynamic 3in. speaker, all first grade components. Easy build plans and parts price list 1/6 (FREE with parts).

Total building costs 42/6 P. & P. 3/6

POCKET FIVE



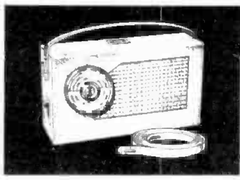
MEDIUM WAVE, LONG WAVE AND TRAWLER BAND PORTABLE

Attractive black and gold case. Size 5½ × 1½ × 3½in. Fully tunable over both Medium and Long Waves with extended M.W. band for easier tuning of Luxembourg, etc. All first grade components, 7 stages—5 transistors and 2 diodes—supersensitive ferrite rod aerial, fine tone 3in. moving coil speaker, etc. Easy build plans and parts price list. 1/6 (FREE with parts).

POCKET FIVE Medium and Long Wave version with miniature speaker ONLY 29/6. P. & P. 3/6.

Total building costs 39/6 P. & P. 3/6

MELODY SIX



TWO WAVEBAND PORTABLE WITH 3in. SPEAKER

Handsome leather-look case, size 6¾ × 3¼ × 1⅝in. with gilt trim and hand and shoulder straps. Fully tunable over both Medium and Long Waves. Incorporates pre-tagged circuit board, 8 stages—6 transistors and 2 diodes—ferrite rod aerial, push-pull output, wave change slide switch, tuning condenser, volume control, 3in. moving coil speaker, etc. Easy build plans and parts price list 2/– (FREE with parts).

Total building costs 59/6 P. & P. 3/6

MELODY MAKER 6

THREE WAVEBAND PORTABLE WITH 3in. SPEAKER

Smart pocket size case, 6¼ × 3¾ × 1½in. with gilt fittings. Fully tunable over both Medium and Long Waves with extra M.W. band for easier tuning of Luxembourg, etc. 8 stages—6 transistors and 2 diodes—top grade 3in. speaker, 2 R.F. stages for extra boost, high "Q" ferrite rod aerial. Easy build plans and parts price list 2/– (FREE with parts).

Total building costs 69/6 P. & P. 3/6

ROAMER SIX

SIX WAVEBAND PORTABLE WITH 3in. SPEAKER

Attractive case with gilt fittings, size 7½ × 5½ × 1½in. World wide reception. Tunable on Medium and Long Waves, two Short Waves, Trawler Band plus an extra M.W. band for easier tuning of Luxembourg, etc. Sensitive ferrite rod aerial and telescopic aerial for Short Waves. All top grade components, 8 stages—6 transistors and 2 diodes including Philco Micro-Alloy R.F. Transistors, etc. (carrying strap 1/6 extra). Easy build plans and parts price list 2/– (FREE with parts).

Total building costs 79/6 P. & P. 3/6

SUPER SEVEN

THREE WAVEBAND PORTABLE WITH 3in. SPEAKER

Attractive case size 7½ × 5½ × 1½in. with gilt fittings and carrying strap. The ideal radio for home, car or outdoors. Covers Medium and Long Waves and Trawler Band. Special circuit incorporating 2 R.F. stages, push-pull output, ferrite rod aerial, 7 transistors and 2 diodes, 3in. speaker (will drive larger speaker) and all first grade components. Price list 2/– (FREE with parts).

Total building costs 69/6 P. & P. 3/6

RADIO EXCHANGE Ltd

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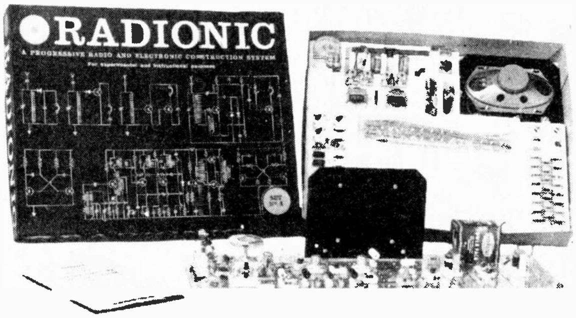

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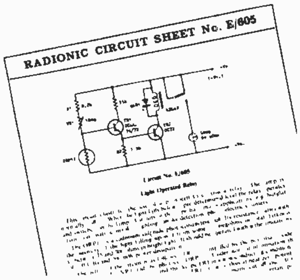
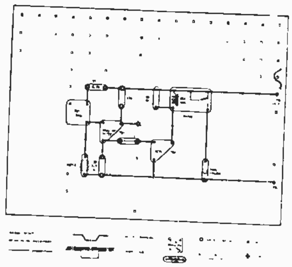


Theoretical Circuit



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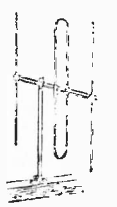

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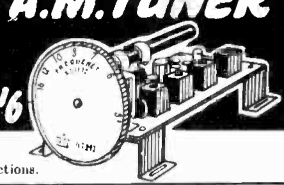

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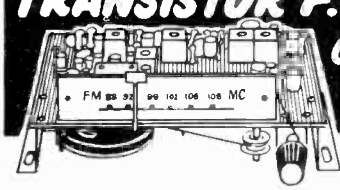

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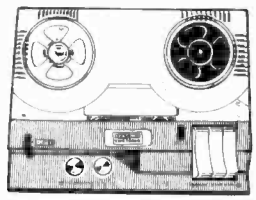

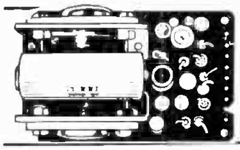

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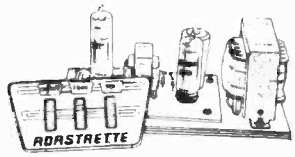
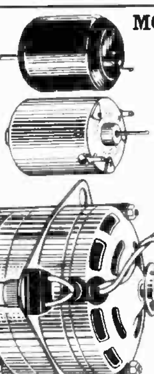


MOTOR BARGAINS



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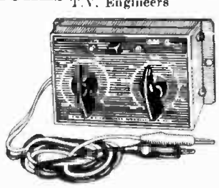

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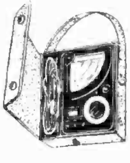

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J-Beam 4 element outdoor Band II VHF/FM Stereo Aerial. With mast, 87/-.
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VOL. 4 No. 3
March 1968

PRACTICAL ELECTRONICS

THE HUMAN ELEMENT

ONE of the great social problems of our time is how to come to terms with the machine. Not exactly a new problem, but one that now, as never before, demands close and urgent study as technology advances at an ever increasing rate and expands its influence over everyday affairs.

During the last months, this problem has been brought into sharp focus through a number of serious accidents at unmanned "Continental" type railway crossings. Much public concern has been expressed over the introduction of these automatically operated gates. Many suggestions have appeared in the national press, sent in by readers who proposed various electrical and electronic systems that would (it was claimed) prevent such disasters occurring in the future.

But in actual fact there is no technical problem involved. The problem is a social one, as one British Rail spokesman has said.

Nevertheless these "amateur systems designers" show a more enlightened attitude to current affairs than those other members of the public who join in the outcry against unmanned crossing gates. This is a defeatist attitude and totally ignores facts of life today. As we are constantly being told, the present economic plight of the country can only be solved by increasing productivity, and the only way this can be appreciably effected is by reinforcing existing manpower resources with all manner of automatic, and especially electronic, systems.

The electronic computer has often been referred to by some, in a rather patronising way, as a machine that cannot think for itself. Fair enough: but at least it is disciplined and can be relied on to react in a predetermined way to any given circumstance.

The driver of a road vehicle does have the capability to think; but how do we ensure he always thinks correctly! Impatient or impetuous, he may *think* he has time to beat the descending barrier.

Automatic control must, it seems, be extended wherever possible to eliminate such human weakness or misjudgement. For example, it may be the answer for road vehicles to come under the control of some electronic supervisor when approaching an unmanned railway crossing. If this sounds fanciful it should be noted that automatic control of vehicles travelling on major roads and motorways has been seriously proposed as an essential development in the future—for greater safety.

No, as we have already said, this particular problem is not technical but social. And this is true of many other situations, apart from railways, where the human encounters the "machine".

F. E. Bennett—*Editor*

THIS MONTH

CONSTRUCTIONAL PROJECTS

SPECIAL SERIES

GENERAL FEATURES

BEGINNERS

NEWS AND COMMENT

Our April issue will be published on Friday, March 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.

RHYTHMIC SOUND EFFECTS UNIT

By A.J. BASSETT

WITH the Rhythmic Sound Effects Unit coupled to a suitable audio sound source, one can easily generate a large range of effects. In particular, it will give an interesting and convincing demonstration of the scope of the *White Noise Generator* described in the January issue. Some of the effects that can be produced include steam locomotive sounds, heavy surf, or a marching army. Many other effects can be produced, according to the ingenuity and imagination of the operator.

The unit is powered by a supply of 18 to 24 volts d.c. (although it is possible to use a 9 volt battery) and the sounds may be heard by connecting it to an audio amplifier.

BASIC PRINCIPLE

The multivibrator (TR1, TR2) supplies bias control current to two other transistors (TR3, TR4) at regular intervals by way of the CR filter networks shown in Fig. 1. VR5, R7, and VR3 supply the base of TR3; VR6, R8, and VR4 supply the base of TR4. TR3 and TR4 then rhythmically modify the incoming audio signals, which reach these transistors by way of R9, R10, and C11. The modified signal, somewhat attenuated, passes via R11 to the output for amplification, recording or further processing.

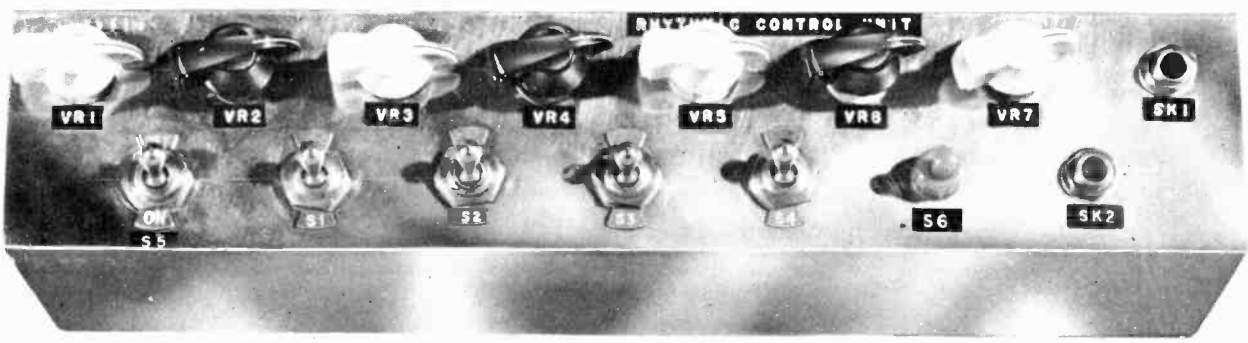
The third transistor (TR3) with its associated circuitry, acts as a voltage controlled filter, and when supplied with base bias current via VR3, it removes the upper frequencies from the signal, which then passes via R10 to TR4. This transistor acts as a voltage controlled signal shunt or attenuator, and when supplied with base bias current through VR4, shunts the audio signal to the common negative line, resulting in the lowering of the amplitude of the output from the unit.

MULTIVIBRATOR

The multivibrator is a fairly conventional circuit, with controls VR1 and VR2 allowing a wide variation of frequency and mark/space ratio. Transistors TR1 and TR2 are permanently cross-coupled by capacitors C3 and C4. A further pair of capacitors (C5 and C6) can be switched in by S1 and S2 to give a slower pulse repetition frequency, or to widen the mark/space ratio.

Base bias is supplied by the potential divider formed by R1 with diodes D1 and D2 which provide a useful degree of regulation. The d.c. applied to D3 and D4 is maintained at a steady value of just over 1 volt. Blocking diodes (D3 and D4) prevent a positive pulse being fed back to the common potential divider. So the voltage at the collector of TR1 will not be fed directly to the base of TR1. Similarly, the positive pulse at TR2 collector will not be fed directly to its own base.

Capacitors C3, C4, C5, and C6 must be low leakage types; a small leakage current will interfere with, or even stop, the multivibrator action. If the pulse repetition frequency is quite fast, even with VR1 and



Front panel view of the rhythmic sound effects units

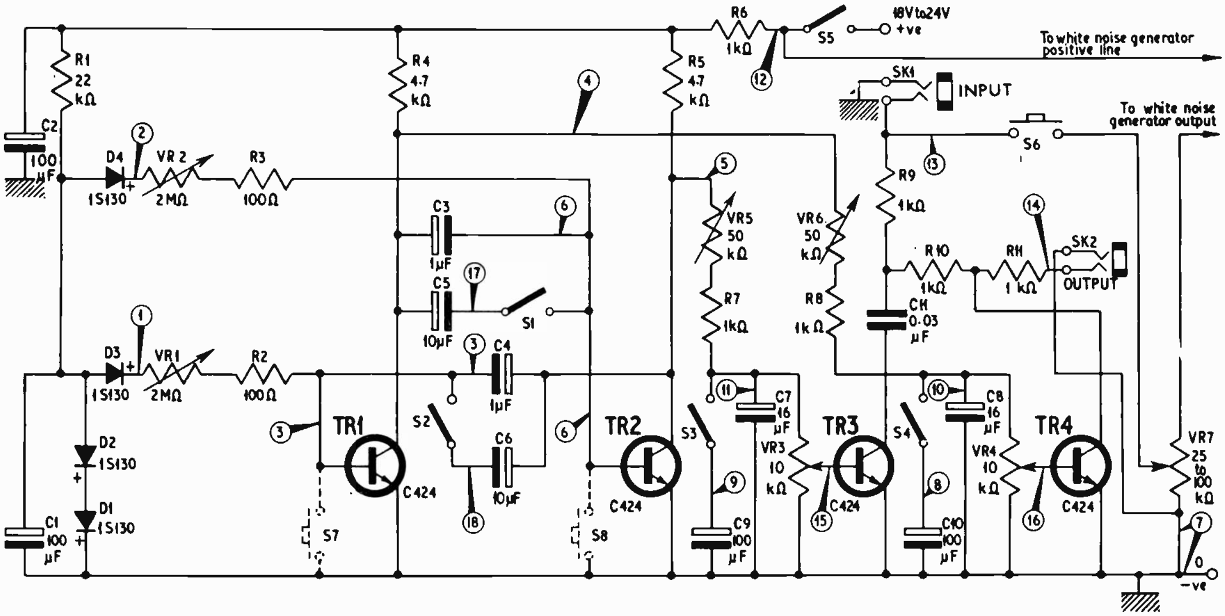


Fig. 1. Circuit diagram of the rhythm effects unit with leads for connection to the white noise generator. Circled numbers indicate the tag numbers on the printed circuit panel (see Fig. 3)

VR2 set at their maximum, or if the multivibrator does not start, and one or both transistors have a consistently low collector voltage, change the capacitors associated with the base of this transistor. It is best to use those having a low leakage dielectric, such as paper, Mylar or certain ceramics. However, tantalum foil electrolytic types are recommended for their low leakage properties.

Although the controls used to alter the speed of the multivibrator are also capable of giving a wide range of mark/space ratio, this entails the disadvantage that, as these controls are not ganged, the circuit may fail to oscillate at certain settings, especially where one transistor is receiving much more bias current than the other.

In these circumstances, it may be necessary to adjust the potentiometers until oscillation commences, or alternatively, "start-buttons" S7 and S8 may be installed. By pressing one of these for just a moment, oscillation can often be restored (press the button associated with the transistor having the lowest collector voltage at the time). If desired a twin ganged control (such as used for stereo amplifiers) can be used for VR1 and VR2.

VOLTAGE CONTROLLED FILTER

The third transistor TR3 in conjunction with R9, R10 and C11 acts as a voltage controlled filter. When the base voltage rises to about half a volt, thus allowing a base bias current to flow, the transistor conducts, and part of the audio signal on the collector is shunted to the negative line. Only the upper frequencies are lost in this way through C11; the lower frequencies are passed on via R10 to the following stage TR4. The effect is that of a top cut filter. When TR3 does not conduct, the entire audio spectrum is allowed to pass to TR4.

Conduction through TR3 and attenuation of the upper frequencies happens only when a positive bias current is fed to its base. The transistor receives this bias at regular intervals from the multivibrator (collector of TR2) through a bias control network.

When TR2 is cut off by the action of the multivibrator, its collector voltage rises, causing more current to flow through VR5 and R7. This current charges capacitor C7 (and C9 if S3 is closed), setting up a voltage gradient along the track of VR3.

If the wiper of VR3 is in such a position that it is 0·5V above the common line, current flows through the base of TR3 and the action of the voltage controlled filter commences.

When TR2 again begins to conduct, the supply of current through VR5 and R7 becomes too small to maintain TR3 in a state of conduction, and when C7 has discharged to a certain level, which depends on the setting of VR3, TR3 ceases to conduct. Thus a rhythmic action of the voltage controlled filter is produced, at the same frequency as that of the multivibrator.

This effect can be controlled, using VR3 and VR5, to give various degrees of action of the filter, from a point where it does not act at all, to a point where it acts strongly over most or all of the multivibrator cycle.

Capacitors C7 and C9 together provide a dual function: in removing the multivibrator switching transients from the bias supply to the base of TR3 (this would otherwise result in a loud ticking or buzzing sound) and in providing a suitable time constant for the flow of this base current.

In this latter function, they prevent the filter from acting too abruptly, whilst C7 on its own is best for the faster effects produced by rapid multivibrator action (e.g. quick march). For slower effects such as heavy surf it is better to switch C9 and C10 into circuit using switches S3 and S4.

VOLTAGE CONTROLLED ATTENUATOR

This function is carried out by transistor TR4, which acts in a manner similar to TR3. However, due to the absence of a capacitor in the collector circuit, the entire audio spectrum, including the low frequencies, is shunted to the common line when this transistor conducts. When TR4 conducts fully, there will be no audio output from the unit, and when TR4 does not conduct, its input signal will appear at the output.

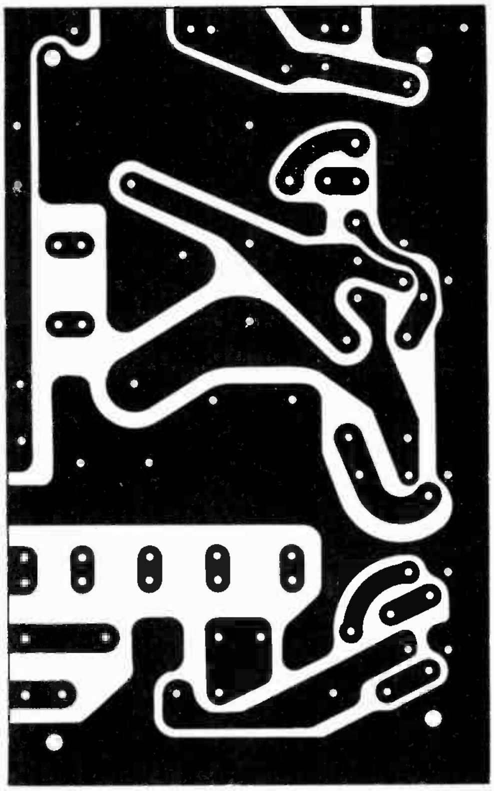


Fig. 2. Printed circuit pattern for the rhythm effects unit, shown full size

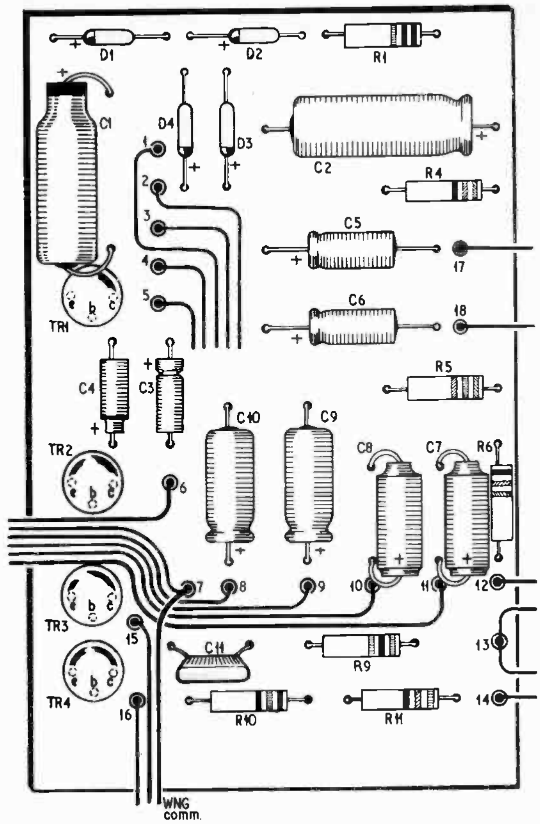


Fig. 3. Component positions and tags on the rhythm effects board. Connections for the lead-out wires can be found by reference to Fig. 4 (below) and Fig. 1. WNG refers to the white noise generator

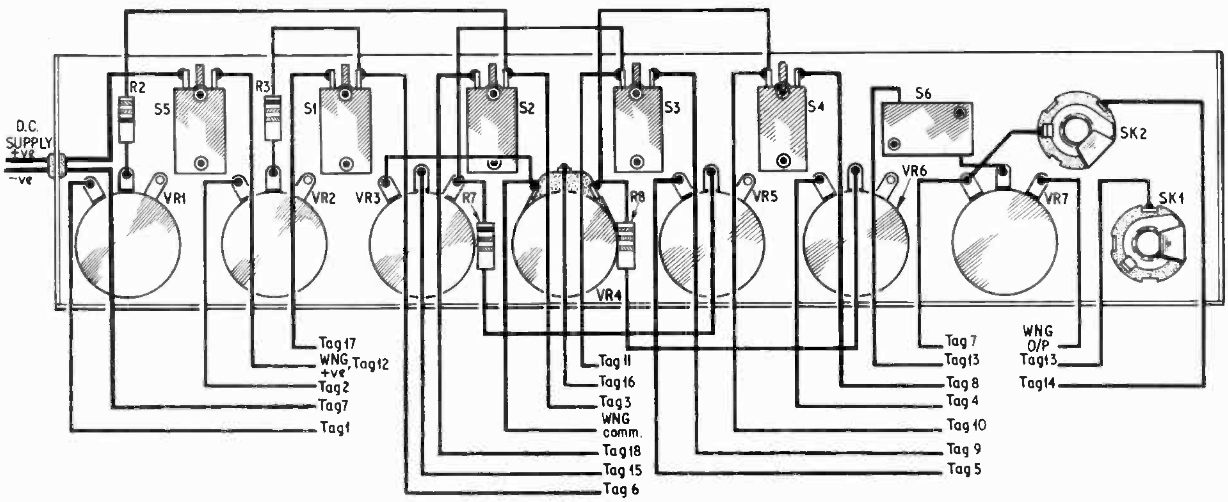


Fig. 4. Front panel wiring of the rhythm control unit with connections for the printed circuit board and white noise generator (published in January issue)

The bias control network associated with TR4 is similar to that used for TR3. However, the base bias for TR4 is derived from the collector of TR1, so that TR3 and TR4 conduct alternately from TR2 and TR1.

CONSTRUCTION

Make the printed circuit panel shown in Fig. 2 and fit components as shown on the printed board layout diagram in Fig. 3. There are 18 external connections to be made to this board and it is convenient to use turret tags in these positions, but they are by no means essential as the wires can be passed through the board. They are easily push-fitted to the board at points previously drilled with a suitable size drill.

Solder the components in place on the board in the following order: tags, resistors, capacitors, diodes, transistors. The switches, potentiometers, input and output sockets may be mounted next on an aluminium chassis; a suitable design is shown in Fig. 4. The white noise generator panel (January issue) is mounted in the same chassis box.

The two extra mounting holes are for switch S6 and a 25 kilohm potentiometer VR7, which control the output amplitude of the white noise generator and switch this noise signal to the input of the rhythmic control circuit when required.

Wire the switches, potentiometers, and audio sockets to the appropriate tags on the printed circuit board, according to the layout shown in Fig. 4. Check that the wiring is correct, and that the components are of the correct values (see earlier notes on the multivibrator capacitors).

TEST THE UNIT

Connect the unit to an 18 to 24V d.c. power supply, and switch on. Set VR5 and VR6 to the positions of highest resistance (clockwise) and check that the multivibrator is oscillating correctly. To do this, open switches S1 and S2 (up) and connect a crystal earphone to the collector of either TR1 or TR2.

If the multivibrator is oscillating rapidly, a buzzing sound or a rapid ticking will be heard. If, however, VR1 and VR2 are set to a high value, the oscillation will be much slower, with a "click" from the headphones every few seconds.

Correct operation of the multivibrator is indicated by rapid oscillation at low settings of VR1 and VR2,

COMPONENTS...

Resistors

R1	22kΩ	R5	4·7kΩ	R9	1kΩ
R2	100Ω	R6	1kΩ	R10	1kΩ
R3	100Ω	R7	1kΩ	R11	1kΩ
R4	4·7kΩ	R8	1kΩ		

Potentiometers

VR1, VR2 2MΩ log. carbon (2 off) or one twin ganged control
VR3, VR4 10kΩ linear carbon (2 off)
VR5, VR6 50kΩ log. carbon (2 off)
VR7 100kΩ log. carbon

Capacitors

C1 100μF elect. 25V
C2 100μF elect. 25V
C3 1μF tantalum 35V (Mullard)
C4 1μF tantalum 35V (Mullard)
C5 10μF tantalum 15V (Mullard)
C6 10μF tantalum 15V (Mullard)
C7 16μF elect. 10V
C8 16μF elect. 10V
C9 100μF elect. 10V
C10 100μF elect. 10V
C11 0·03μF paper 150V

Transistors

TR1, 2, 3, 4 C424 (S.G.S.-Fairchild) or ST141 (Sinclair) (4 off)

Diodes

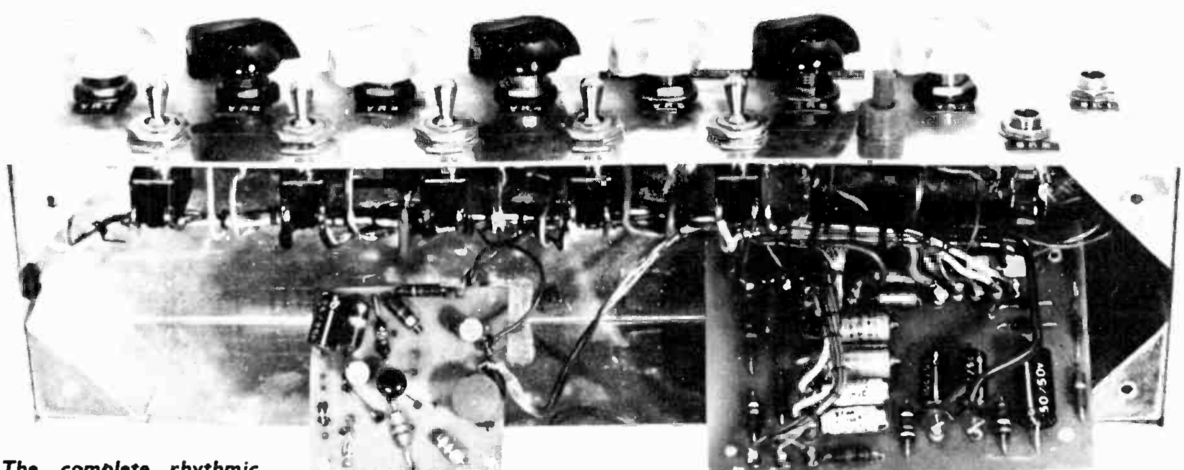
D1, 2, 3, 4 1S130 or DD000 (4 off)

Switches

S1 to S5 Single-pole, on/off toggle (5 off)
S6 Single-pole, on/off, push button or toggle
S7, S8 Single-pole, push on release off (2 off) (optional—see text)

Miscellaneous

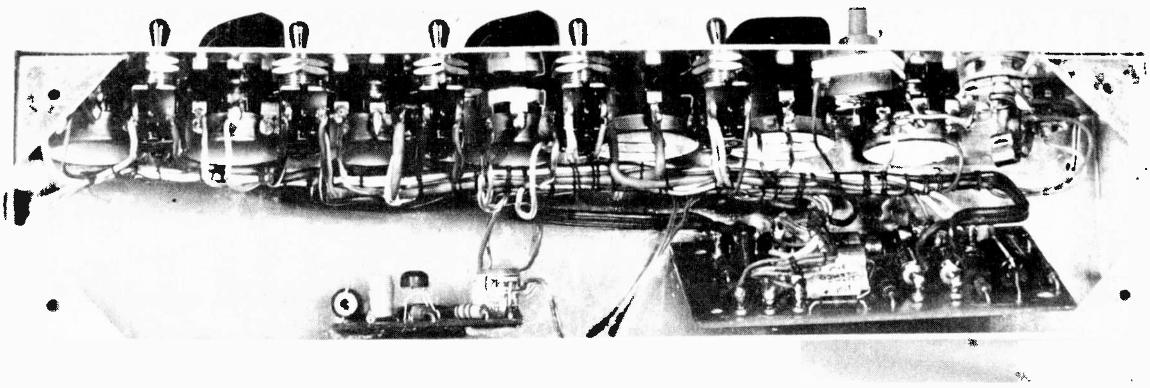
White Noise Generator (as in January issue)
Printed circuit kit with panel 4in × 2½in
Chassis or box 12in × 3in × 2½in
Jack sockets (2 off)
Turret tags (18 off)
Power supply 18 to 24 volts or four 6V batteries
Wire, knobs for VR1-7



The complete rhythmic sound effects unit

WHITE NOISE GENERATOR

RHYTHMIC EFFECTS BOARD



The controls and wiring form are shown; the two printed circuit boards are set in their final positions and fixed to the chassis by glueing small foam pads to the undersides. Make sure that the copper on the boards does not touch the chassis

gradually changing to the slow ticking at higher settings.

Multivibrator faults resulting in failure to oscillate, or in rapid oscillation even when VR1 and VR2 are set high, are most likely to be caused by a leaky coupling capacitor (which should be replaced) or to the use of transistors of widely different gain.

Once the multivibrator is working correctly, connect the output of the white noise generator to the input of the unit, and connect the output of the unit to an audio amplifier with loudspeaker. The tone controls on the amplifier should be set for a level response, and the volume control set for best output level.

PRODUCING RHYTHMIC EFFECTS

Steam Locomotive Sounds. Although this unit cannot generate all the mechanical sounds of a locomotive, the effects of rhythmic release of steam can be most startling.

Use switches S1, S2, S3, and S4 to disconnect capacitors C5, C6, C9, and C10 from the remainder of the circuit. Set VR1 and VR2 so that the multivibrator oscillates at about the rate you wish your "locomotive" to be going. Set VR3 and VR4 to a minimum, and adjust the volume control on the audio amplifier so that the output from the white noise generator comes as a steady hissing sound from the loudspeaker.

Now adjust VR4 carefully, and a point is easily found where the white noise periodically cuts off and returns, giving a sound which resembles that of rhythmic escape of steam. By adjusting also VR6, the "attack" of this effect is varied. For slow running, S4 may be closed, bringing C10 into action to give a more gradual "cutting-off" of the steam sound. For fast running, S4 should remain open.

Carefully adjust VR3, and a point will be found where the lighter, hissing sound will change to a deeper "Chuff-chuff" effect.

Further careful adjustment of all the controls will now vary the effects greatly. It should be noted that there is a considerable amount of interaction between the controls. This is due to the use of the simple circuit given here; to remove this interaction would require a somewhat more costly and complicated circuit.

Heavy Surf. Close switches S1, S2, S3, and S4 to bring capacitors C5, C6, C9, and C10 into circuit. Set VR5 to its minimum level and VR6 to maximum. Adjust VR1 and VR2 to give a multivibrator frequency of about one cycle in every 5 to 10 sec. Set VR3 to minimum (counter-clockwise) and adjust VR4 carefully, so that the noise fades out gradually, then returns after a short pause. Now by further careful adjustment of VR3, the sound can be made to commence with a roar and end with a hiss like sea spray. The repetition frequency, and impact of the sound effects can be varied further by adjustment of the controls.

Marching Feet. This effect is not quite so easily achieved as the other two, and may require a little patience. Switches S1, S2, S3, and S4 should be open. Set potentiometers VR5 and VR6 to their minimum settings. Set VR4 to the end of its track nearest R8 (clockwise). VR1 and VR2 are set so that the multivibrator runs slightly faster than one pulse per second. Carefully adjust VR3. As this will interact somewhat with VR1 and VR2 these should be reset accordingly.

By using VR3, you should be able to obtain a sound resembling that of marching feet, or an army on the move. Further adjustment of the other controls can then be used to vary the speed of your "army" from slow to quick march, and to add to the realism of the effect.

★

Meetings . . .

SOCIETY OF ELECTRONIC AND RADIO TECHNICIANS

HORNCHURCH

February 20, 7.0 p.m. *Automatic Landing Systems*, by F. J. Sullings, at Havering Technical College, 42 Ardleigh Green Road, Hornchurch, Essex.

EDINBURGH

February 23, 7.30 p.m., *Colour Television*, by J. C. Allen, at Napier Technical College, Room B44, Colington Road, Edinburgh.

THE SOCIETY OF ENGINEERS

LONDON

March 4, 6.0 p.m., *Progress in Radio Astronomy*, by F. W. Hyde, F.S.E., at The Geological Society, Burlington House, Piccadilly, W.1.

Transistor Amplifier DESIGN

2 POWER AMPLIFIERS

By A. Foord

LAST month's article considered small signal amplifiers, and the next logical stage is to deal with the last link in the chain before the loudspeaker—the power amplifier. We have come to expect a stringent performance from a modern hi fi power amplifier: a frequency response at full power from 20Hz to 20kHz, a power level of about 10 watts, and a distortion level in the order of 0·1 per cent. Many amateurs may not have the test equipment to make all these measurements at this level (a typical sinewave oscillator might have an inherent distortion greater than the 0·1 per cent we are trying to measure), and prefer to use one of the many published circuits.

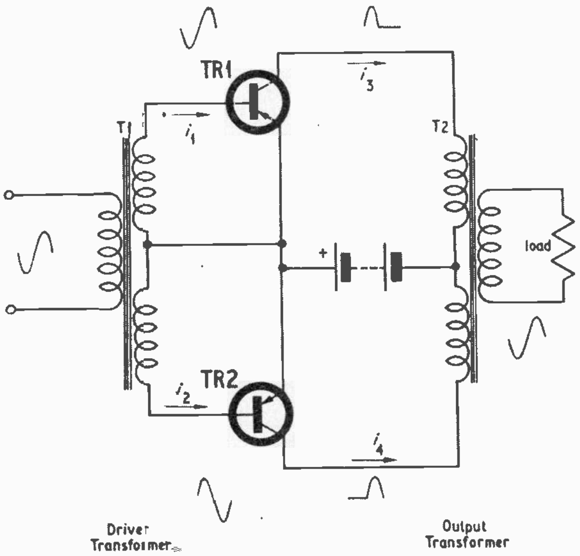


Fig. 2.1a. Basic class B output stage with phase indication

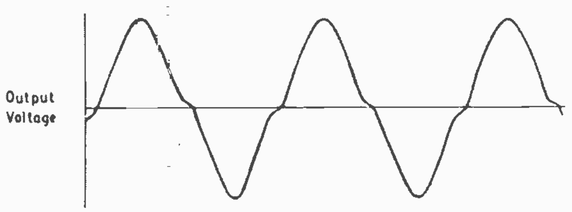


Fig. 2.1b. Typical example of crossover distortion

Amplifiers are defined as class A or class B depending on where the bias point is placed with respect to the total swing of the signal. For class A operation the bias point is placed so that the signal swing does not lie outside the region of normal transistor action; all the small signal amplifiers previously described were implicitly class A.

Generally, small signal stages use a standing current of about 1mA; with a signal applied to the input the current varies from about 0·5 to 1·5mA. If a class A stage is used for the power amplifier, it would be necessary to use a standing current of at least half the peak current we expect to handle, so that the maximum efficiency of a class A stage (transformer coupled) is as much as 50 per cent. Such a stage is easily recognised by having only one transistor and is often found in medium signal driver stages in front of an output pair. Here, only a relatively small current is required.

BASIC CLASS B CIRCUIT

If class B operation is used in a power amplifier, two transistors are connected back-to-back, each one conducting alternately. If a sine wave input is applied, one transistor amplifies the positive half of the wave and the other transistor amplifies the negative half. To accomplish this the transistor bias point is located at cut-off, any signal swing above the bias point will be amplified by the transistor and any swing below the bias point will not be amplified.

With two transistors in push-pull, one transistor amplifies positive signals and the other amplifies negative signals. In theory this arrangement can be 78 per cent efficient, in practice efficiencies of up to 70 per cent may be achieved.

The basic circuit of a class B amplifier is shown in Fig. 2.1a. Using a centre-tapped driver transformer, one output reproduces the signal 180 degrees out of phase with the other when referred to the common point, i.e. the centre tap. If both transistors are operating strictly in class B no forward bias is applied and the transistors will amplify only negative voltages.

Transistor TR1 will amplify the first half of the sine wave, then will remain cut off for the other half, while TR2 will amplify the second half of the sine wave only. The current waveforms appearing at the two collectors are shown in Fig. 2.1a, and the centre-tapped output transformer recombines these two waveforms to convert back to a full sine wave, the reverse action of the driver transformer. The load (loudspeaker) then "sees" a representation of the full sine wave in the secondary winding.

PRACTICAL AMPLIFIER

In a practical amplifier the transistors are not operated with absolute zero bias because of the non-linearity of the input/output characteristic, being worst near the cut-off region. This is the reason why the characteristics of both transistors should be "matched" as near identical as possible. If the two transistors are placed back to back (with zero bias) serious "crossover" distortion results when operation moves from one transistor to the other.

This distortion is shown in Fig. 2.1b. This effect can be offset by applying a small identical forward bias to each transistor, to allow a small collector current under no signal conditions. This "quiescent" current is about 20mA in power amplifiers in the 10 to 20 watt region, but may be only about 8mA in a 200mW amplifier. The bias is usually provided by a potential divider as shown in Fig. 2.2.

SINGLE-ENDED CLASS B CIRCUITS

In addition to the expense and physical size of a transformer, it is rather restricting to the overall frequency response of the amplifier, particularly at low frequencies. For these reasons an output transformer is often avoided (although the driver transformer may be retained since this is a low power component) and most modern amplifiers use a single-ended class B arrangement (Figs. 2.3a and b).

Fig. 2.3a uses a single power supply but requires a coupling capacitor of several thousand microfarads; such a high value is necessary to maintain low frequency response in this low impedance part of the amplifier. Fig. 2.3b does not require a capacitor but uses a centre-tapped power supply. Essentially the two transistors in Fig. 2.3a are placed in series across the power supply, but in parallel across the load.

Operation is easier to follow from Fig. 2.3b. Under no-signal conditions and equal quiescent currents through TR1 and TR2, the load current ($i_2 - i_1$) is zero and point X is effectively at earth potential as far as a.c. is concerned.

Under signal drive conditions i_2 becomes greater than i_1 (or i_1 becomes greater than i_2), therefore, the load current is only i_2 (or i_1). Under these conditions TR1 cuts off, TR2 supplies the load current i_2, and point X goes more positive.

For signals of the opposite polarity TR2 cuts off and TR1 supplies the load current i_1; point X goes more negative. A practical arrangement of this method is shown in Fig. 2.4.

The driver stage has the phase inverting transformer in its collector lead, so forming a class A driver. Note that the dots on the secondary windings indicate the phase sense. The two transistors in the output stage form a single ended class B arrangement. Base bias is provided by the resistor chain R1 to R4, while the emitter resistor for each transistor would be about 1 ohm to provide some measure of bias stabilisation.

Negative feedback is often provided from the output back to the driver stage; this aspect will be dealt with more fully in a later article in this series.

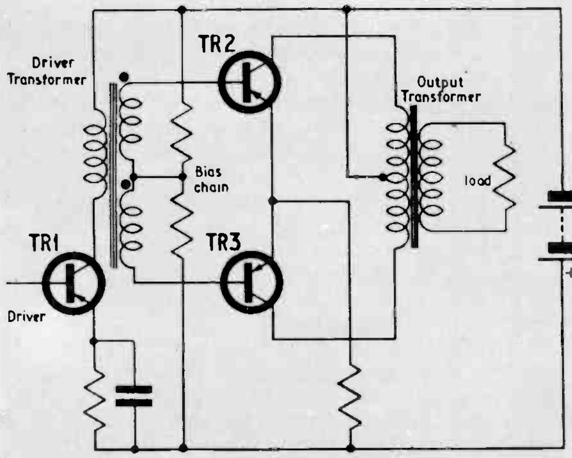


Fig. 2.2 Practical class B output stage and driver. Phase indication is shown by the dots on the driver transformer. TR1 forms a class A driver

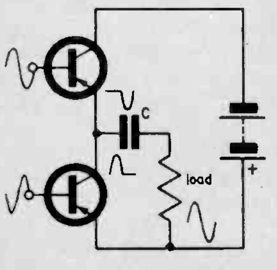


Fig. 2.3a. Basic single ended class B output stage using a single power supply. The load is capacitively coupled

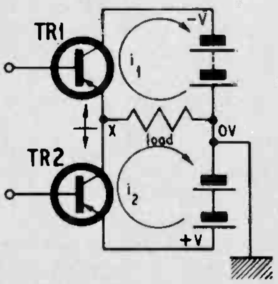


Fig. 2.3b. Load directly coupled to class B output transistors powered by two batteries

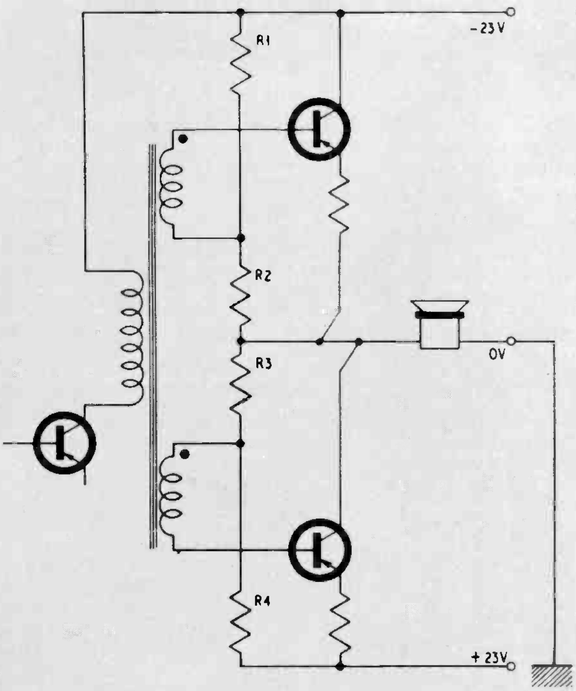


Fig. 2.4. Practical circuit of the output stages coupled to a class A driver. The dots on the driver transformer indicate phase sense. The load is directly coupled

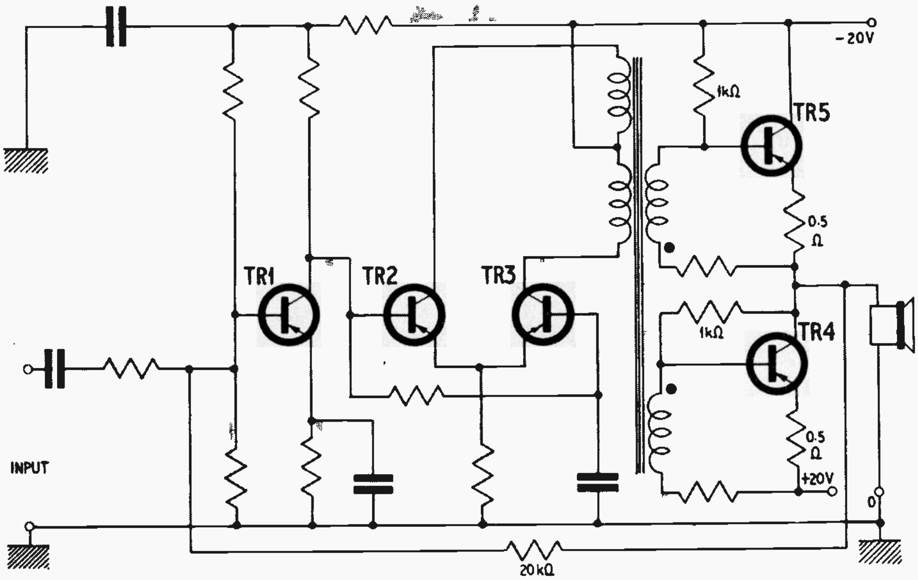


Fig. 2.5. The Bowes amplifier employs a long-tailed pair push-pull driver to run the output pair. The feedback loop via the 20 kilohm resistor is taken to the base of the previous stage

UNUSUAL AMPLIFIER

An unusual form of power amplifier (designed by Bowes) is shown in Fig. 2.5. Again a direct coupled class B output stage is used, but in this case the 1 kilohm base bias resistors are connected directly to the bases of the power transistors rather than to the lower end of the driver transformer as in Fig. 2.4. This method of biasing provides a.c. and d.c. feedback, reduces the current gain by four, and also reduces distortion in the output stages.

The driver transformer can be smaller than that used in the circuit in Fig. 2.4, because there is no d.c. polarisation as TR2 and TR3 feed the primary in push-pull. These two transistors form a long tailed pair with the base of TR3 grounded to a.c. by a capacitor. TR1 is directly coupled to the base of TR2 and overall feedback is applied from the load to TR1 base to form a virtual earth amplifier with a gain of 20 times. The amplifier gain without overall feedback is 60dB, with feedback it is 26dB, giving 34dB of feedback. This reduces the distortion to less than 0·1 per cent for 10 watts into 15 ohms at 1kHz.

Various resistors and capacitors can be used (but not shown) to shape the open loop frequency response to allow such a large amount of negative feedback. Small signal overall frequency response is 1dB down at 10Hz and 45kHz.

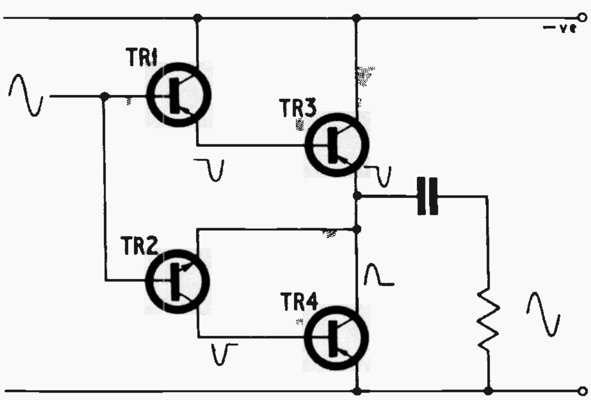


Fig. 2.6. Single ended class B output stage with complementary symmetry input pair

PHASE SPLITTER

Some amplifier designers prefer to use transistors to phase split, as shown in Fig. 2.6. Here the complementary drivers TR1 and TR2 also act in class B; when the input goes positive TR1 and TR3 are cut off, when the input goes negative TR1 and TR3 conduct. The situation is reversed for TR2, when the input goes positive TR2 conducts to produce an inverted (negative going) waveform on its collector, this turns TR4 on and produces a positive going signal on TR4 collector.

The signals from TR3 and TR4 combine in the usual way to form the load signal, this arrangement is usually used with a capacitive coupling to the load because of the difficulty of ensuring that the junction of TR3 and TR4 remains at exactly half the supply voltage.

A practical circuit of this nature is shown in Fig. 2.7. Quiescent current through TR4 and TR5 is set by adjustment to VR2. The diode D1 is clamped to the same heat sink as TR4 and TR5. If the temperature of the heat sink increases, the resistance of the diode decreases, to form a thermal feedback system, which then tends to reduce the current through the output transistors to a more reasonable value.

The preset potentiometer VR1 provides overall negative feedback and is adjusted until the junction of TR4 and TR5 is at approximately half the supply

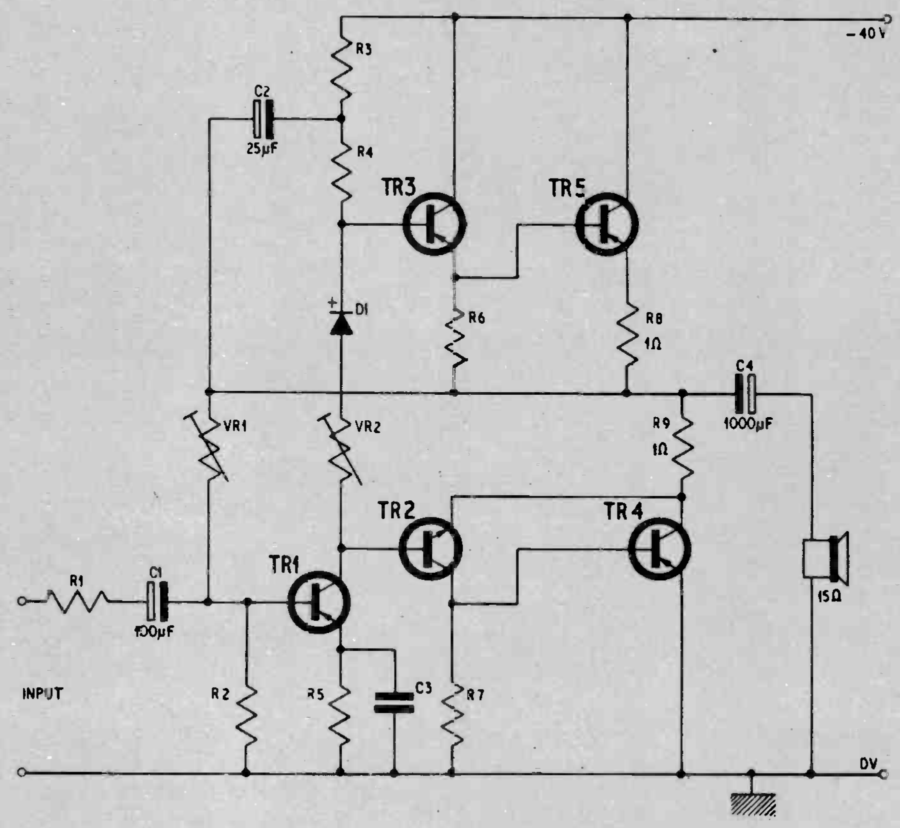


Fig. 2.7. Complementary symmetry driver and output stage

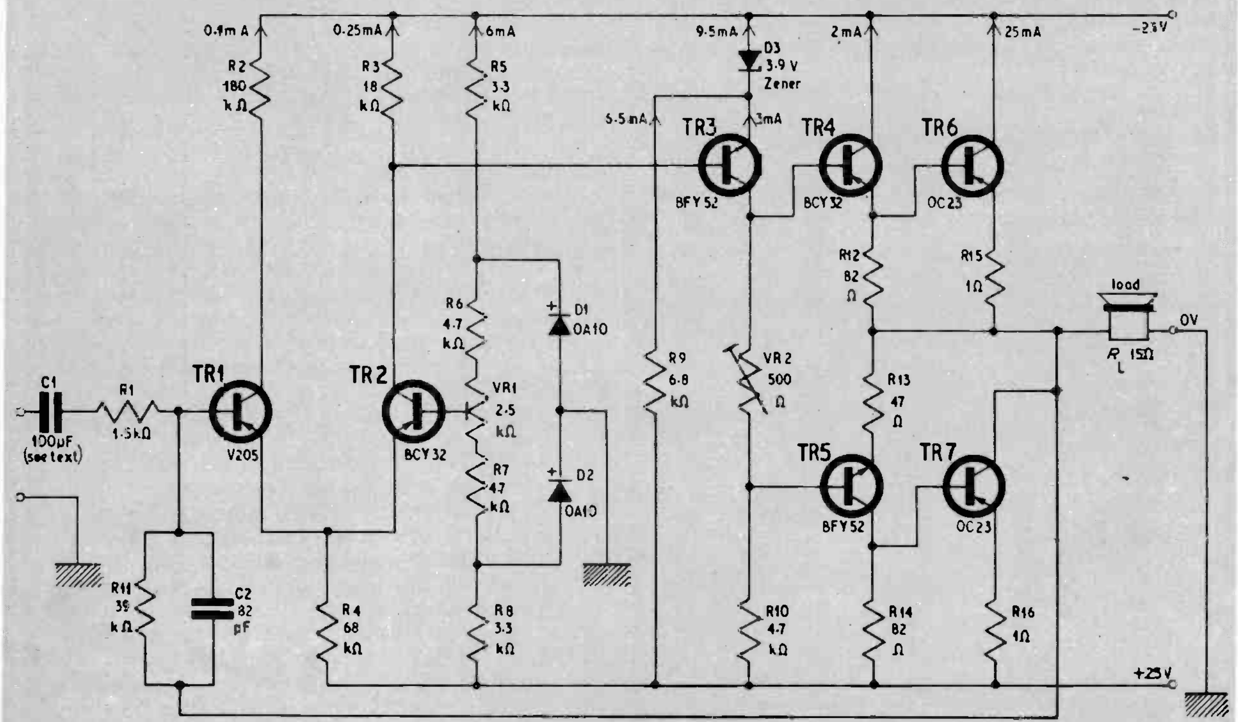
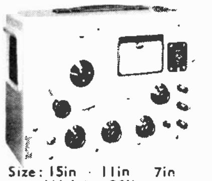


Fig. 2.8. Practical power amplifier using a differential input stage and direct coupling to the load

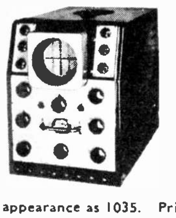
MARCONI AUDIO TESTER TYPE TF894



This directly calibrated AF oscillator from 50c/s to 12kc/s has a maximum output of 300mW into 600 ohm and is fitted with an output level meter and 600 ohm ladder attenuator of 0–50dB. An alternative 5,000 ohm outlet is provided and the level in each case is continuously variable. AF measurements: the voltmeter may be used for AF inputs (external) over the ranges of 0 to 80V in 4 ranges, providing a very useful facility. Supplied in excellent condition and working order for only **£18.10.0.** Power supply 240V a.c. (internal).

Size: 15in · 11in 7in
Weight: 20lb

COSSOR DOUBLE BEAM OSCILLOSCOPES TYPE 1035



An attractive end of contract run enables us to offer these fine professional scopes in perfect working order at only **£25** each plus 25/– P. & P. Brief technical spec.: 4in flat face C.R.T.; bandwidth 20c/s to 10Mc/s; time base repetitive, triggered or single stroke 15μsec to 150msec; size 16in × 11in × 19in. Also Cossor 1049 DC Coupled DB Scope same size and appearance as 1035. Price **£30** plus 25/– P. & P.

DIGITAL VOLTMETER

For the first time ever, we proudly present a three digit a.c./d.c. voltmeter for less than £100!
Manufactured by the world famous Hawker Siddeley Group at its Gloucester Works, the Digimeter Type B.I.E. 2123 is a fully transistorised multi-range instrument possessing the following distinctive features:

Electrical Characteristics:
D.c. ranges: 10mV to 400V in four ranges (1,000V for positive voltages).
Accuracy: the greater of ± 0·1% of ± 1 digit.
A.c. ranges: 100mV to 250V r.m.s. in three ranges.
Accuracy: the greater of ± 0·5% or ± 1 digit over the frequency range 30c/s to 10kc/s.
Range change is manual.
Input impedance: D.c.-15M Ω on two lower ranges, 1M Ω on two higher ranges.
A.c.–a.c. coupled, approximately equivalent to a shunt impedance of 8K Ω in series with the parallel impedances 180K Ω and 550pF.
Input characteristics: Single ended, floating. The potential between terminal connected to OV and earth should not exceed 400V d.c. or 250V a.c.
Input filter: 55dB attenuation at 50c/s.
Conversion time: 300msec.
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144 illustrations (including 50 new to this Edition and 14 cartoons).
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The first edition of *Aerial Handbook* was published in Oct. 1964 and the 5,000 copies were sold out in just over a year.

This second edition has been delayed until the plans for Colour Television and Multiplex Stereo had matured and could be dealt with from the angles of Transmission and Reception.

The activities of the BBC and ITA are well covered. Relay Systems, Eurovision, World Satellites and Colour Conversion, Post Office Tower, etc. also receive attention in non-technical terms.

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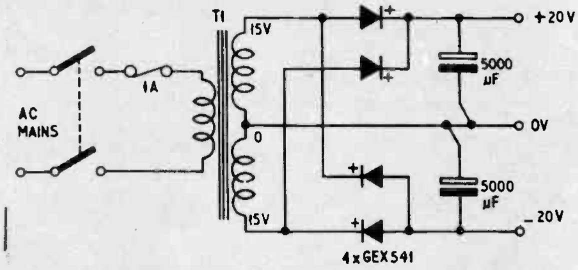


Fig. 2.9. A suggested circuit for providing plus and minus 20 volts

voltage. The adjustment of VR2 can be quite critical, a change of 10 per cent in the power supply voltage could increase the quiescent current from 20 to 100mA, so a simple stabilised supply is recommended for this type of amplifier.

There is always some difficulty in providing sufficient drive to TR3 base on large negative going signals (unless R3 is connected direct to a separate supply of −50V) the capacitor C2 provides "bootstrapping" from the output to help overcome this problem. Omitting C2 and combining R3 and R4 into one resistor slightly reduces the available power, but an oscilloscope would be needed to show the difference.

DIFFERENTIAL AMPLIFIER

We have already mentioned that the load is usually capacitively coupled in this form of amplifier because of the difficulty of maintaining the output point at exactly half the rail voltage. A drift at this point of one volt has no effect if the load is capacitively coupled, but there would be a standing current of over 60mA through a 15 ohm load if it is directly coupled.

Drift in the input stage (TR1 of Fig. 2.7) can be reduced by using a long-tailed pair differential amplifier in this position; such a circuit is shown in Fig. 2.8. TR1 and TR2 comprise the long-tailed pair and compare the load voltage (via the feedback resistor R11) with the bias voltage on VR1. Diodes D1 and D2 are forward biased to provide supplies of about plus and minus half a volt so that VR1 can be adjusted for zero d.c. across the load under no signal conditions.

Resistor R2 in the collector of the first transistor serves only to reduce its collector to emitter voltage to well below its maximum rated value. TR2 collector feeds the base of TR3; TR3 emitter is biased 4V away from the negative rail in order to permit a reasonable value for R3 and to aid d.c. bias stability. Resistor R9 increases the current in the Zener diode D3 in order to reduce its slope resistance to a small value.

The collector load of TR3 is split by VR2 which can be a 500 ohm potentiometer preset to about 330 ohms to give 25mA standing current in TR6 and TR7. It is important initially to switch on the amplifier with VR2 at zero resistance (minimum current through the output transistors). Then increase it in value (which "pushes" the two bases apart) until the desired quiescent current is obtained.

Transistors TR4 to TR7 act in the usual way, and overall feedback is taken from the load to the base of TR1 to make this a virtual point. Once set up there is no drift of the d.c. operating point, though it would be a good idea to use a simple stabilised supply for each rail.

The feedback capacitor value was chosen for no appreciable overshoot on a square wave.

Gain without feedback is 60dB, reducing to 28dB with feedback, giving 32dB of feedback. The frequency response at the lower end of the audio band is determined only by the time constant of the input resistor and capacitor, for 100µF polarity depends on d.c. level of pre-amplifier output since TR1 base is at zero volts. The bass response is 3dB down at 1Hz and the h.f. response is 3dB down at 20kHz. Power output is only 8 watts (due to the voltage across the Zener diode) but the distortion at this power should be less than 0·2 per cent.

This circuit must be regarded as experimental as, with the large amount of negative feedback applied to the circuit, variations in frequency response of the transistors might make it necessary to alter the value of C2 (or in an extreme case add internal frequency shaping networks). A square wave generator and an oscilloscope might be required.

A simple power supply suitable for Fig. 2.8 and for the Bowes amplifier Fig. 2.5 can be constructed using a mains transformer (type MT3AT) which has a 30V secondary with a centre tap. Fig. 9 shows a suggested circuit to provide the required supply without stabilisation.

Next month's article will look at some other audio circuits: emitter follower; 400Hz phase shift oscillator; times ten amplifier; preset fixed gains amplifier.

POINTS ARISING

SPRING LINE REVERBERATION UNIT
(December 1967)

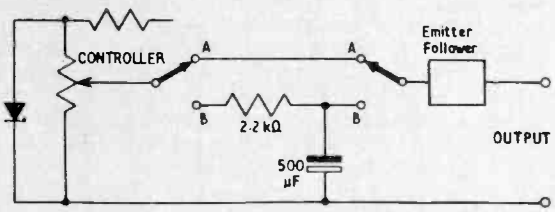
The size of the printed circuit panel (shown in Fig. 4b) is 3½in × 4¾in × 1/16in. The key diagram for TR3, TR4, and TR5 shows connections looking at the *top* of the transistor.

WHITE NOISE GENERATOR *(January 1968)*

The printed circuit panel should have another link wire so that C1 negative is connected to D1, R2, R4, and C3.

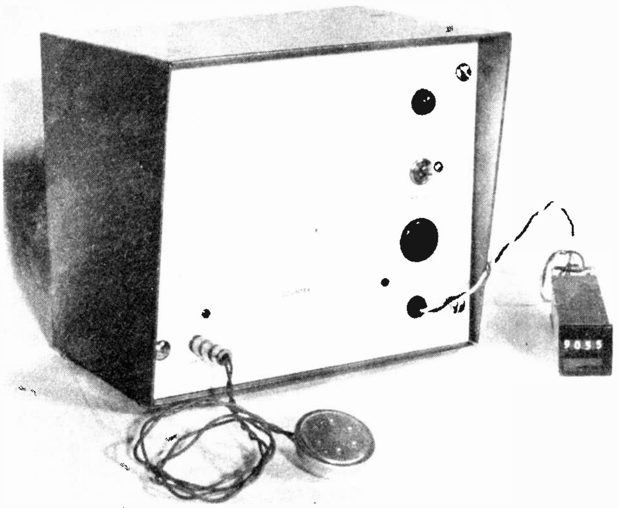
INGENUITY UNLIMITED *(January 1968)*

The diagram (below) shows how the switch is connected to give gradual acceleration with the "Model Trains" circuit.



The counting of small moving objects is a common requirement in manufacturing concerns and various electronic systems are employed for this purpose. Photo-electric detectors are often used, but in some applications an *impact* recording device has definite advantages over the former. This is especially so when the objects to be counted are gravity fed into some receptacle. If a dynamic transducer is suitably placed, the falling objects will bounce off the transducer diaphragm and into the receptacle provided. The impact made by each object will produce an electrical impulse and this can be processed by electronic circuitry to operate an electro-mechanical counter. This is the basis of the counting system to be described in this article.

Counting systems have, of course, other applications apart from industrial or commercial uses. Private individuals may sometimes find a need for an automatic counting system in connection with experimental work or in pursuance of a hobby. This counter may meet such needs.



IMPACT COUNTER

THE impact transducer employed in this equipment is an ordinary electro-magnetic earpiece (receiver). This is placed at an angle of 45 degrees so that objects drop a few inches on to the back of the earpiece and then bounce off into boxes. The diaphragm stays still whilst the body of the earpiece moves and so induces a voltage into the coil.

The signal from the earpiece is amplified by a single transistor TR1 and applied to a Schmitt trigger TR2, TR3. This is a two-state circuit where one transistor is always off and the other transistor is always on. The Schmitt gives a very steep wave front as it is triggered, and always produces a constant signal from the object falling on to the microphone. See Fig. 1.

The signal from the Schmitt is applied to the monostable circuit which is again made up of two transistors, TR4, TR5, one conducting and one not conducting. The input signal changes the stable state for a fixed period. This fixed period is decided by the C and R values of the circuit and should be longer than the object bounce time, but shorter than the repetition rate of the objects themselves. In the prototype equipment the monostable pulse length is held at about 100ms with the following values: R15=33 kilohm; C6=3μF.

The collector of TR5 is normally at about 1V and during the timing period rises to −6V. This negative going pulse is applied to a d.c. amplifier TR6, which in turn applies the signal to the output transistor TR7 which operates the electro magnetic counter RLA. The output transistor is held off by the 1·2 kilohm resistor R19 until the signal is received.

CIRCUIT OPERATION

The operation of the amplifier stage TR1 is straightforward and the input pontentiometer VR1 is adjusted to give the *lowest* gain that will always operate the electro magnetic counter, so as not to pick up noise. The amplifier is d.c. stabilised with the input potential divider and the emitter resistance.

The Schmitt trigger normally has TR2 conducting and TR3 turned off. When the input signal is applied to TR2 base it just turns this transistor towards off, which results in its collector rising and taking with it, through the "speed-up" capacitor C4, the base of TR3. This action is regenerative until the base of TR2 returns to its original voltage; this again takes place very fast irrespective of the speed of the base voltage change.

The monostable behaves in the same way but the diode D1 only applies the positive pulse which works through C6 to cut off TR5. This in its turn switches on TR4 which remains in this state until the charge of C6 is leaked away through R15.

The two amplifiers are standard and as the voltage on the base of TR6 rises quickly it starts conducting hard and the base of TR7 rises to −6V. This transistor is then bottomed very quickly and as a result dissipates very little power in operating the electro magnetic counter RLA.

The counter is shunted by a catching diode D5. This diode conducts when the counter switches off and the magnetic field reverses, thus preventing a reverse voltage being applied to TR7. TR7 is a 2G382 which will satisfactorily switch a 24V counter at 400mA if

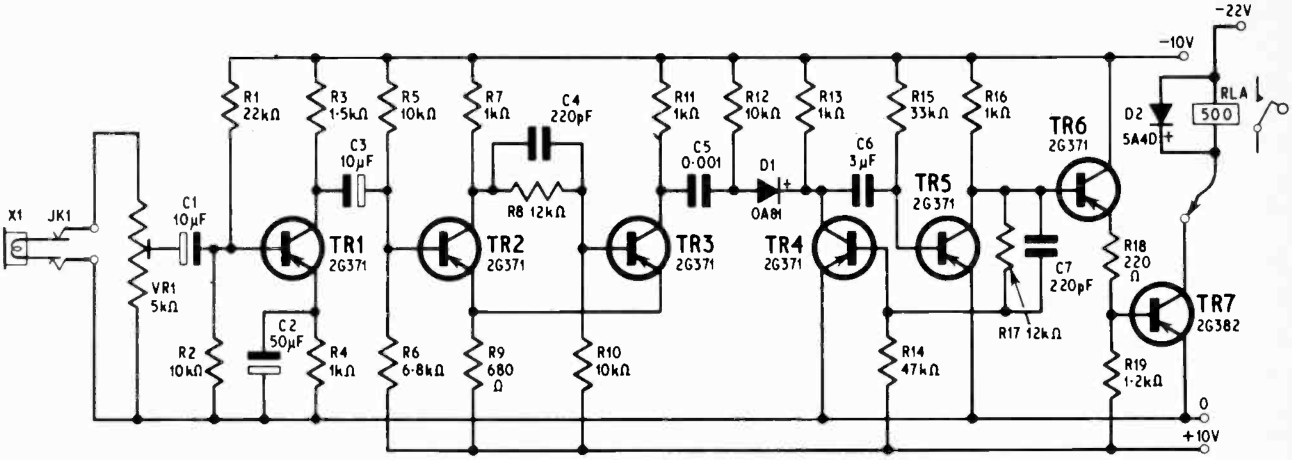


Fig. 1. Circuit diagram of the impact counter

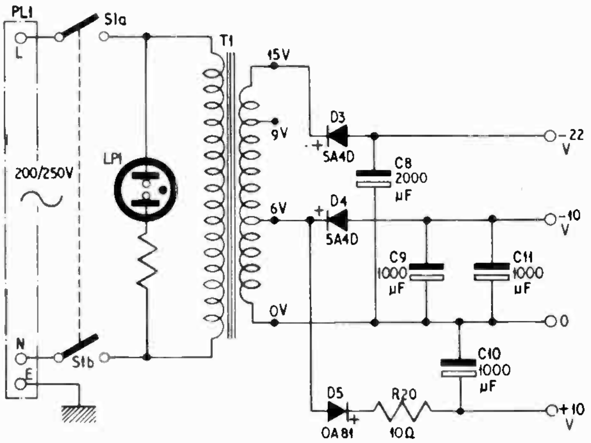


Fig. 2. Power supply circuit

these other components are used. In this particular device the counter is operated from a −24V rail. The power dissipated in TR7 is small due to the Schmitt and monostable giving short rise times.

POWER SUPPLIES

The mains operated power supply unit is built around the transformer T1, see Fig. 2. The tapped secondary of T1 supplies three separate half wave rectifier circuits, which deliver direct current at potentials of −22V, −10V—all with respect to the common 0V line.

A neon indicator lamp LP1 is connected across the mains input, and the supply is controlled by the double pole switch S1.

CONSTRUCTION

The details that follow describe the original prototype; other methods of construction may of course be employed according to personal choice and requirements.

The equipment is housed in a metal case of well-known commercial design. All the counter circuit components of Fig. 1 are mounted on a printed wiring board which plugs into a special connector. This connector is secured to the rear of the case front panel. Also mounted on this panel are the neon LP1, mains input plug PL1, mains switch S1, and jack socket JK1. A grommet hole is provided for the twin lead to the electro-magnetic counter RLA. ★

COMPONENTS . . .

Resistors

R1	22k Ω	R8	12k Ω	R15	33k Ω
R2	10k Ω	R9	680 Ω	R16	1k Ω
R3	1·5k Ω	R10	10k Ω	R17	12k Ω
R4	1k Ω	R11	1k Ω	R18	220 Ω
R5	10k Ω	R12	10k Ω	R19	1·2k Ω
R6	6·8k Ω	R13	1k Ω	R20	10 Ω ½W
R7	1k Ω	R14	47k Ω		

All ±10%, $\frac{1}{10}$W carbon, except where otherwise stated

Potentiometer

VR1 5k Ω linear, skeleton

Capacitors

C1	10μF elect. 15V		
C2	50μF elect. 6V	C7	220pF ceramic
C3	10μF elect. 15V	C8	2,000μF elect. 25V
C4	220pF ceramic	C9	1,000μF elect. 15V
C5	1,000 pF ceramic	C10	1,000μF elect. 15V
C6	3μF (3 × 1μF plastic)	C11	1,000μF elect. 15V

Transistors

TR1—6 2G371 (6 off) } Texas Instruments
TR7 2G382

Diodes

D1	OA81	D4	5A4D
D2	5A4D	D5	OA81
D3	5A4D		

Miscellaneous

- JK1 Miniature jack socket and plug (Radiospares)
- LP1 Neon mains indicator (Radiospares "miniature 200–250V panel neon" with self-contained resistor) or PP/A*
- PL1 Mains plug, panel mounting, 3 way 2A
- RLA Electro magnetic counter (ex. G.P.O.) L70546. 500 Ω coil
- S1 Double pole on/off toggle switch
- T1 Mains transformer. Standard primary. Secondary tapped at 6, 9 and 15V. 1A (Douglas type MT5 or similar)
- X1 Electro magnetic earpiece, approx. 10 Ω (ex telephone handset, or headphones)
- Printed wiring board, type A*
- Multi-way connector, with ten clips (Cinch)*
- Metal case, with front panel 8in × 7in × 6in. Contil type 876*
- 12-way tag strip. Grommet. Capacitor clip.

*Available from West Hyde Developments Ltd., 30 High Street, Northwood, Middlesex.

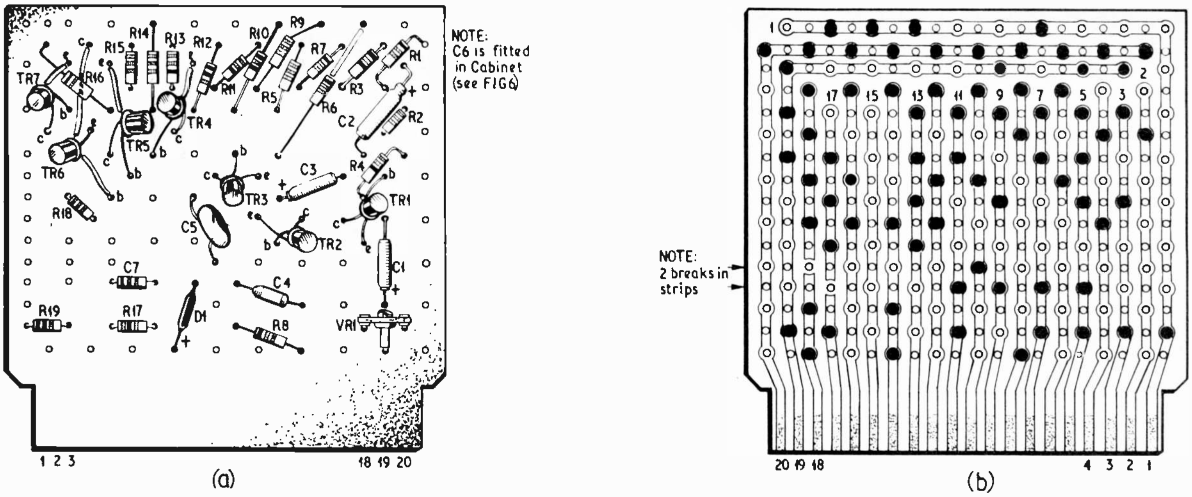


Fig. 3. Printed wiring board. (a) shows arrangement of circuit components, (b) shows underside of board and indicates where the metal strips are broken

PRINTED WIRING BOARD

Before mounting the components of Fig. 1 on to the printed wiring board, the latter must first be prepared by making one break in each of the metal conductor strips 17 and 18, see Fig. 3b. This operation is most effectively carried out with the aid of a $\frac{5}{16}$in. drill.

The components can now be fitted in position with their leads inserted into the correct holes and soldered to the conductor strips.

FRONT PANEL DRILLING

First take the front panel from the 867 Contil case and with the label TOP FRONT positioned in the front at the top, mark out as shown in Fig. 4. The lines should be drawn as shown and the centres of the holes marked with a centre punch. The protective coating is suitable for easy marking out and is also a help in holding the panel in a vice. It is important that the jaws have no loose particles attached, and that the teeth of the jaws are not too sharp as the coating will only protect from light pressures. Heavy pressures can however be used on a smooth faced or fibre jaws without marking the paint.

The drill used should be a $\frac{9}{64}$in and all the marked holes are drilled this size first. The $\frac{1}{2}$in holes at the top right are then punched out with an Osmor type punch. The $\frac{3}{4}$in hole is also punched after the $\frac{9}{64}$in hole has been increased with a drill for the cutter bolt. The $\frac{1}{4}$in hole has a small nick in it about $\frac{1}{20}$in high to prevent the neon rotating, and the $\frac{3}{4}$in hole has a $\frac{1}{8}$in diameter cut out as shown on the drawing, so that the mains plug does not rotate when the nut is tightened up.

After these holes are drilled, the coating is stripped off and a large drill used to de-burr the bottom four drilled holes. The next operation is to mount the components.

PRINTED CIRCUIT CONNECTOR

It will be noted that the printed circuit connector is a 10-way connector, and it is necessary to move two of the clips before use. The clip on position 8 is removed by carefully putting a screwdriver up the front at the bottom of the clip and springing it off with the back of the clip not being touched. This clip is then transferred to position 6. Likewise, the clip on position 12 is taken off and is put in position 17.

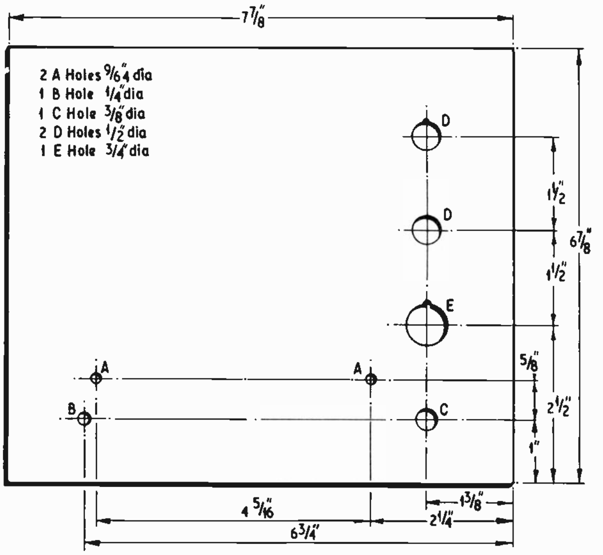
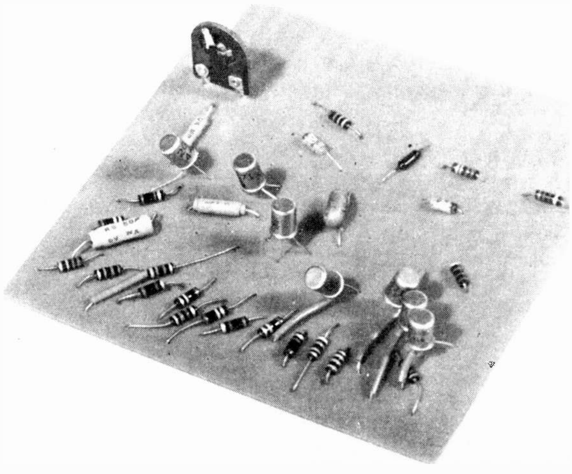
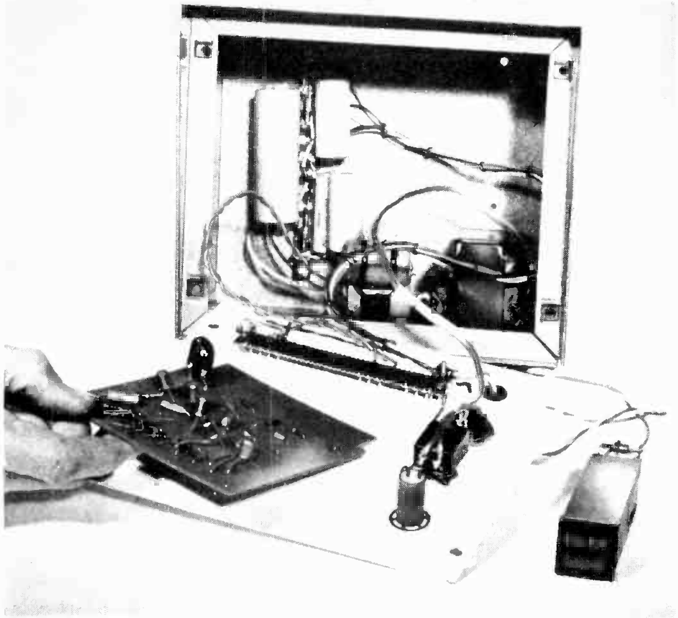


Fig. 4. Drilling details for front panel of case





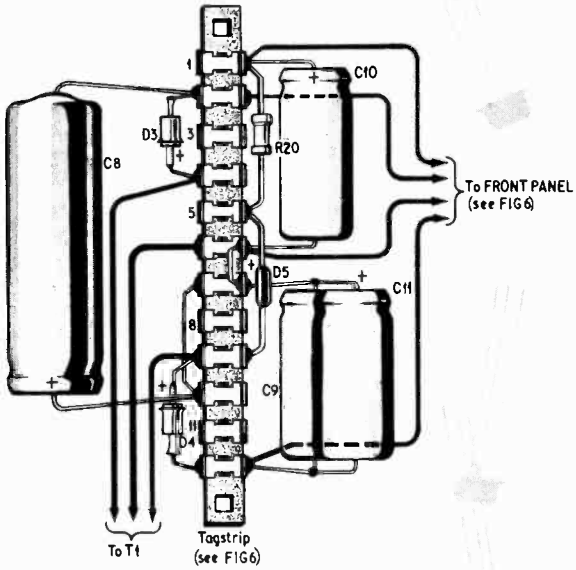


Fig. 5. Tag strip assembly with power supply components

The connector is then secured to the back of the panel with two 6B.A. screws. Three nuts should be fitted to each screw to act as spacers, before the connector is mounted. Finally a nut is fitted to each screw to secure the connector. Under one nut retaining the connector a solder tag should be placed for the earth connection from the mains plug.

A self-adhesive pad is placed on the rear surface of the front panel to prevent the printed circuit panel from being pressed accidentally against the front panel. The assemblied printed wiring board is plugged into the connector, no other fixing being required.

POWER SUPPLY COMPONENTS

The mains transformer T1 is secured to the bottom of the case with 4B.A. screws and nuts. The other power supply components are mounted on a tag strip secured to the back of the case. Fig. 5 shows the location and wiring of these components.

The timing capacitor C6 is mounted on the bottom of the case. Note: the actual value of C6 will depend upon circumstances; it may be necessary to make up the required value by connecting two or more capacitors in parallel. The prototype illustrated here employs three 1μF capacitors and these are mounted in a rubber clip fixed to the bottom of the case.

WIRING UP

The remaining connections can now be made. Details of the wiring between the front panel assembly and the components inside the case appear in Fig. 6. This diagram also gives the connections to the impact transducer and electro-magnetic counter.

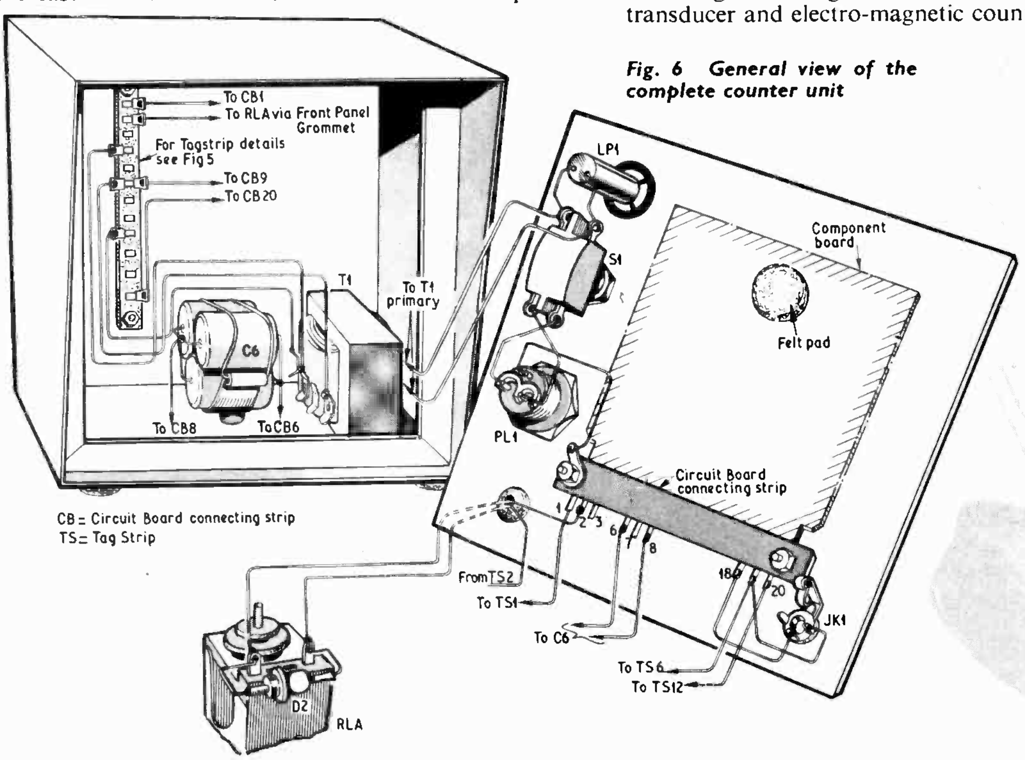
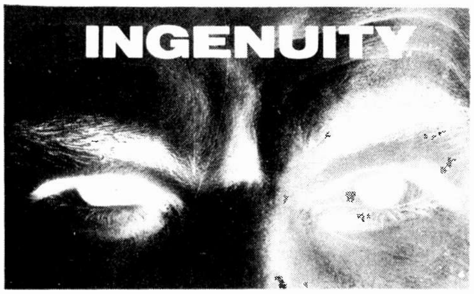


Fig. 6 General view of the complete counter unit



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.

REED SWITCH BUZZER

I HAVE been experimenting recently with the idea of using a reed switch as a vibrating reed relay for model control. This has not been very successful but some of the effects which I uncovered may be of interest to your readers.

Firstly if the reed switch is connected in series with the activating coil and a battery (Fig. 1) and the contacts are closed by bringing a magnet near, the system acts as a buzzer which can be made audible by inserting a speaker or earpiece in the circuit. By adjusting the position of the magnet a current as low as 1mA is all that is necessary to operate the buzzer.

Once the current is interrupted the action ceases and has to be restarted by bringing the magnet near again. This is like the function of the *Bite Indicator* printed in the August 1967 issue, but of course is a good deal simpler.

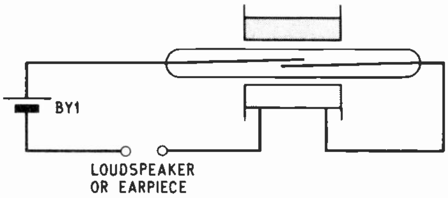


Fig. 1. Reed switch buzzer

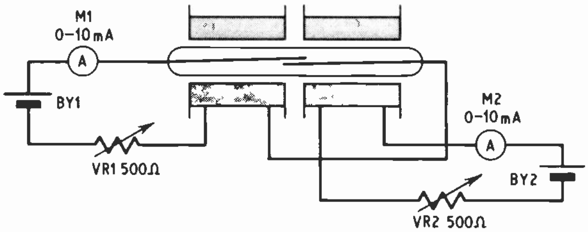


Fig. 2. Experimental arrangement for investigating action of controlling field

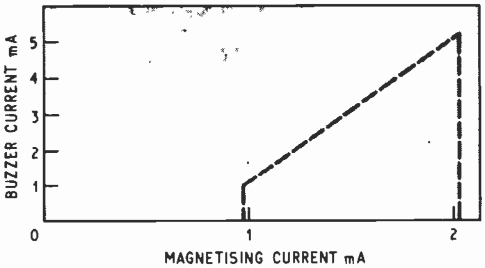


Fig. 3. Variation of buzzer current with magnetising current

An extension of this same idea is to put a second coil round the switch and pass a current through it to provide a magnetic field, Fig. 2. If this is done it is found that the current passed in the buzzer circuit is modulated by the current passing in the magnetising coil.

The results are shown in the accompanying graph (Fig. 3) and imply that the system has a gain of five. I may add that the buzzing action is still best started by using a magnet and that it is extremely sensitive to magnetic field, the current being affected by the movement of a magnet as much as two feet away.

My conclusions are that the reed switch and coil may sometimes be used as a source of a.f. more economically than a transistor and that with the development of more sensitive reeds applications may be found for the chopper action in the model control field.

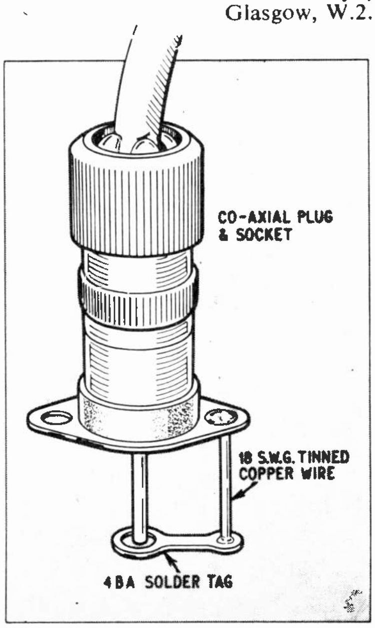
J. T. Lloyd,
Glasgow, W.2.

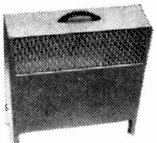
STEAM PRESENCE ALARM

Sir—I should like to say how useful I have found the Water Level Alarm published in your November issue, particularly because I discovered that it will also detect steam.

Perhaps I should explain that my wife is an incurable prolonged kettle boiler. Every time I went into the kitchen, there was a thick fog, well, at least twice a week anyway, that was until I fitted a "Steam" Level Alarm in the vicinity of the kettle. Now we get a "fog" warning which allows sufficient time to take evasive action. After some experiment, the arrangement shown in the sketch was found to be the best detector head for this purpose.

G. E. Dunning,
Morden, Surrey.

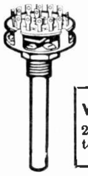




CONVECTOR HEATER

Just screw it together. Uses 1,250W copper clad element which gives off black heat. Will last a lifetime. Ideal for bedroom, it's so safe. Complete in stove enamelled case, 29/6, easily worth double. Carriage & ins. 8/6.

MINIATURE WAFER SWITCHES

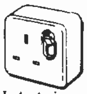


4 pole, 2 way—3 pole, 3 way—4 pole, 3 way—2 pole, 4 way—3 pole, 4 way—2 pole, 6 way—1 pole, 12 way. All at 3/6 each, 36/- dozen, your assortment.

WATERPROOF HEATING ELEMENT

26 yards length 70W. Self-regulating temperature control. 10/- post free.

G.E.C. 13 amp SWITCHED SOCKET



An excellent opportunity to re-equip your house or workshop, or if you are a contractor to restock for future ring main jobs. We offer 12 G.E.C. switch sockets, Brown Bakelite surface mounting. Latest ring main type listed at 6/6 each. You can have a box of 12 for 30/- only—thus showing you a saving of £2.8. Postage and insurance 4/6 extra.

FLUORESCENT CONTROL KITS

Each kit comprises seven items—Choke, 2 tube ends, starter, starter holder and 2 tube clips, with wiring instructions. Suitable for normal fluorescent tubes or the new "Grolux" tubes for fish tanks and indoor plants. Chokes are super-silent, mostly resin filled. Kit A.—15-20W. 19/6. Kit B—30-40W., 17/6. Kit C—80W., 17/6. Kit D—125W., 22/-. Kit E—65W., 19/6. Kit MF1 is for 6in., 9in. and 12in. miniature tubes 19/6. Postage on Kits A and B 4/6 for one or two kits then 4/6 for each two kits ordered. Kits C, D and E 4/6 on first kit then 3/6 for each kit ordered. Kit MF1 3/6 on first kit then 3/6 on each two kits ordered.

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Standard type and size with good length of spindle—made by Morganite. List price is 10/- each but if you act quickly you can have them at 12/- doz. (or 1/6 each if less than doz.). Following valves in stock all "lin" —100K +100K —500K +500K all new and unused. Post 2/9 on 1st doz. then 1/- per doz. 6 doz. or more post free.

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/-.

HI-FI SPEAKER BARGAIN

12in. High fidelity loudspeaker. High flux permanent magnet type with either 3 or 15 ohm speech coil. Will handle up to 10 watts. Brand new by famous maker. Price 29/6. With built-in Tweeter 35/-, plus 4/6 post and insurance.

MAINS RELAYS

Type A 210/250V a.c. coil, 2 types, one for single whole chassis mounting, has 3 pairs heavy duty changeover contacts, 8/6 each.

Type B in clear plastic case on tin base, plugs into octal valve holder. 2 pairs changeover contacts, 12/6 each.

COPPER CLAD ELEMENT

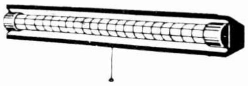
1,250W—4ft. long but bent to U shape ideal for overhead heater—just mount reflector above, 12/6 each plus 4/6 post. £6 doz. post paid.

MAINS TRANSFORMER. Upright mounting with primary tapped 200, 220, 240V. H.T. secondary is 250-0-250V at 80mA and it has two L.T. secondaries of 6.3V 1½A—unused (removed from equipment), 15/- plus 3/6 post and insurance.

PP3 Eliminator. Play your pocket radio from the mains! Save £s. Complete component kit comprises 4 rectifiers—mains dropper resistances, smoothing condenser and instructions. Only 6/6 plus 1/- post.

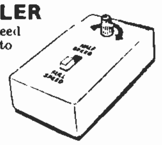
Where postage is not definitely stated as an extra then orders over £3 are post free. Below £3 add 2/9. Semiconductors add 1/- post. Over £1 post free. S.A.E. with enquiries please.

INFRA-RED HEATERS



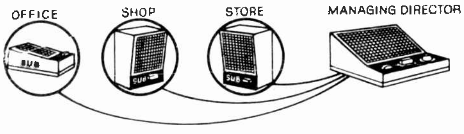
Make up one of these latest type heaters. Ideal for bathroom, etc. They are simple to make from our easy-to-follow instructions—uses silica enclosed elements designed for the correct infra-red wave length (3 microns). Price for 750W element, all parts, metal casing as illustrated, 19/6, plus 4/6 post and ins. Pull switch 3/- extra.

DRILL CONTROLLER



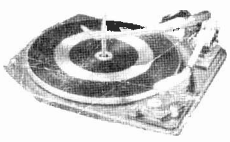
Electronically changes speed from approximately 10 revs. to maximum. Full power at all speeds by fingertip control, Kit includes all parts, case, everything and full instructions 19/6, plus 2/6 post and insurance. Or available made up 32/6.

THIS MONTH'S SNIP INTERCOM BARGAIN



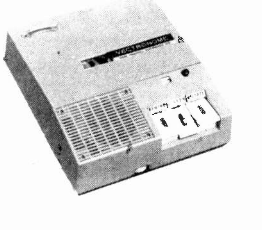
Will save time and improve efficiency. Ideal in home—office—shop—surgery, etc. Complete outfit comprises Master unit and three substations, each of which can call the master and have full two-way working. No wiring problems as subs fitted with 60ft. twin flex and they plug into sockets. Also included is packet of staples—and battery. Nothing else to buy—£4.19.6. plus 4/6 post and insurance.

GARRARD AUTO RECORD PLAYER Model 2000



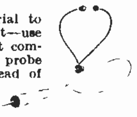
This is one of the latest products of the World's most experienced maker of fine record reproducers. Its superior features include—automatic playing of up to 8 mixed size records—stopping and starting without rejecting—manual playing—pick-up pivots to give low stylus pressure—large diameter turn-table for max. stability. Adjustments include pick-up height—pick-up dropping position and stylus pressure. Size is 13¼ 11¾in. clearance 4⅞in. above, 2¼in. below. Supplied complete with mounting template and service sheet. Offered this month at the Special Snip price of £6.19.6 plus 7/6 carriage 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 P.P. 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 flywheel driven capstan. Very portable in neat case with carrying handle, overall size of which is approximately 6¼ × 7¼ × 2 in. Price with tape, nickel cadmium rechargeable batteries and mains battery charger £9.19.6 (rather less than ½ original price). Postage and insurance 7/6. Unused and in perfect working order.

RADIO STETHOSCOPE



Easiest way to fault find—traces signal from aerial to speaker—when signal stops you've found the fault—use it on Radio, T.V, amplifier, anything—complete kit comprises two special transistors and all parts including probe tube and crystal earpiece 29/6—twin stetoset instead of earpiece 7/6 extra post and ins. 2/9.

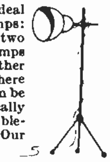
THE 'TECHNICAL' RECORD PLAYER

4 speed, gram. motor with lightweight pick up, motor electronically balanced and free from wow and flutter. Speed change by push button—16, 33, 45, 78 r.p.m. Price 39/6. 2 valve amplifier, 32/6. Elliptical Speaker, 9/6. Cartridge extra mono 10/6, stereo 15/- plus 4/6 post and insurance. DON'T MISS THIS TERRIFIC BARGAIN.

TUBULAR HEATERS

New and unused made by G.E.C.—rated at 60 watts per ft.—these are ideal in airing cupboards, bedrooms, offices, stores, greenhouses, etc., curtains or papers can touch them without fear of scorching or fire. Supplied complete with fixing brackets and available in the following sizes. Prices which are about ⅓ of list price include carriage by B.R.S. 8ft. 30/-; 10ft. 36/-; 12ft. 42/-.

FLOOD LAMP CONTROL



Our dim and full switch is ideal for controlling photo flood lamps: it gives two lamps in series, two lamps full brilliance and lamps off. Similar control of other appliances can be arranged where used in pairs or where circuit can be split exactly in half. Technically the switch is known as a double-pole change over with off. Our price, 4/6.

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, condensers and instructions. Real snip at only 16/6, plus 3/6 postage.

DOOR INTERCOM

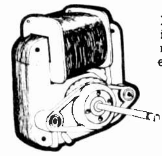
Know who is calling and speak to them without leaving bed, or chair. Outfit comprises microphone with call push button, connectors and master inter-com. Simply plugs together. Originally sold at £10. Special snip price, 79/6 plus 3/6 postage.

GEARED MOTOR

HALF REV. PER MINUTE

Made by famous Smith Electric, mains operated and quite powerful. Size 3¼ × 2¼ × 1½in. deep. Secondary use as process timer. Internal switch can be made to break circuit within a period up to 2 mins. 17/6. P. & P. 2/6 unless ordered with other goods.

MAINS MOTOR



Precision made—as used in record decks and tape recorders—ideal also for extractor fan blower heater, etc. New and perfect. Snip at 9/6. Postage 3/- for first one then 1/- for each one ordered. 12 and over post free.

RELAY SWITCHES. These enable micro switches, delicate thermostats or other low current devices to control up to 30A. Ideal to switch thermal storage heaters—motors, etc., made by the famous AEI group these are listed at £25 each—you can buy if you hurry at a very keen price of 39/6 each and we will include diagrams and data. Mounted on panel size approximately 6 × 7 × 2in deep.

THERMOSTATS

Type "A" 15A for controlling room heaters, greenhouse, airing cupboard. Has spindle for pointer knob. Quickly adjustable from 30-80°F. 9/6 plus 1/- post. Suitable box for wall mounting 5/- P. & P. 1/-.

Type "B" 15A. This is a 17in long rod type made by the famous Sunvic Co. Spindle adjusts this from 50-550°F. Internal screw alters the setting so this could be adjustable over 30° to 1,000°F. Suitable for controlling furnace, oven kiln, immersion heater or to make flame-start or fire alarm, 8/6 plus 2/6 post and insurance.

Type "D". We call this the Ice-stat as it cuts in and out at around freezing point. 2/3 amps. Has many uses, one of which would be to keep the loft pipes from freezing, if a length of our blanket wire (16 yds. 10/-) is wound round the pipes. 7/6. P. & P. 1/1.

Type "E". This is standard refrigerator thermostat. Spindle adjustments cover normal refrigerator temperatures. 7/6 plus 1/- post.

Type "F". Glass encased for controlling the temp. of liquid—particularly those in glass tanks, vats or sinks—thermostat is held (half submerged) by rubber sucker or wire clip—ideal for fish tanks—developers and chemical baths of all types. Adjustable over range 50°F to 150°F. Price 18/- plus 2/- post and insurance.

Simmerstat Heater Regulator

Suitable to control elements, heater, soldering irons and boiling rings up to 2,500W. Completely adjustable, normal price 55/- each. Special Snip Price 12/6 plus 2/- post and insurance.

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DAWE AUDIO SWEEP OSCILLATOR AND CONTROLLER TYPE 443B
20c/s to 20Kc/s in a Single Sweep Logarithmic Scale Calibration. Accuracy ±1% ±1c/s. Power supply 110V and 200-250V. Dimensions: 19 × 12 × 13in. Supplied Brand New with Instruction Manual. Less than half Maker's Price. **£125.** Send 6d. Stamp for Data Sheet.

DAWE AUTOMATIC L.F. SWEEP OSCILLATOR
Type 444C. 5c/s to 5,000c/s in a Single Range. 6-in. dia. dial with Logarithmic Calibration over 216° of Arc. Fre. Accuracy ±5%. Output continuously variable up to 10V. R.M.S. into a minimum Load Resistance of 10kΩ. Monitored on a Panel Voltmeter Power Supply. 110V and 200-240V. 50c/s. Dimensions: 19 × 18 × 9in. Supplied Brand New with Instruction Manual. Less than half Maker's Price. **£100.** Send 6d. Stamp for Data Sheet.

DAWE ANIMAL SONORAY TYPE 1803
Designed to give quick and accurate measurements of Back Fat Thickness, on live and dead pigs. Employs a Pulse Echo System, where High Freq. Vibrations, in the form of sound waves are transmitted into the animal by a Transducer and Reflected on a 5-in. C.R. Tube. Brand New with Instruction Manual. Less than half Maker's Price. **£150.** Send 6d. Stamp for Data Sheet.

VARIABLE D.C. SUPPLY UNITS TYPE S.E.4
0–48V 10A, continuous from 240V a.c. Silicon full wave bridge rectification, isolated transformer with Variac controlled primary. 3in. scale voltmeter and ammeter. Neon indicator. Housed in strong metal case. Size 17 × 7 × 6½in. **£29/10/0.** Carr. 15/-.

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A.c. input tapped 250-250V d.c. output. Tapped 24-26V. Very conservatively rated at 8A. Also a separate tapped a.c. output of 6-10·6V 18A. Completely enclosed in metal wall mounting case. Size: 15½ × 9 × 6½in. Brand new, **£9/10/0.** Carr. 15/-.

STABILISED L.T. SUPPLY UNITS
A.c. input 220-240V d.c. output two independent sections giving 24V 5A. Open unit built on Chassis. Size 26 × 7in. Brand new. Fraction of Maker's Price. **£25.** Ex Warehouse.

SPECIAL OFFER OF WODEN TRANSFORMERS BRAND NEW
No. 1. PRI tapped 200-250V E.S. Sec. Tapped 8-15-25-28-30-33-35V 15A. Tropically finished table top connects. **£5/17/6.** Carr. 10/-. No. 2. PRI 240V E.S. Sec. No. 1. 50V 4A. Sec. No. 2. 18-0-18V 1A. **55/-.** P.P. 7/6. No. 3. PRI tapped 200-250V E.S. Sec. 1. 315-0-315V 110mA. Sec. 2. 175-0-175 25mA. Sec. 3. 5V 1·9A. Sec. 4. 6·3V 3·1A. Sec. 5. 6·3V CT4A. Sec. 6·3V CT2A. Sec. 6·3V 1A. "C" Core table top connections. **50/-.** P.P. 7/6.

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Set of 4 for 16/9. DAF96, DF96, DK96, DL96, 4 for 24/6.

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6AL5	2/3	30C18	11/9	EBC33	7/-	EZ41	6/9	PY81	5/3	Z77	3/6
6AM6	3/6	30F5	12/-	EBC41	6/-	EZ80	4/6	PY82	5/-	**Transistors**	
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6V6GT	6/6	CCH35	9/-	EF39	3/9	PCF800	11/6	UB41	6/6	OC71	3/6
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FLUORESCENT CAMPING LIGHT

By R. B. HAYLE

THE fluorescent lamp is a very efficient producer of light, and can be relied upon to give at least four times as much light as a tungsten filament lamp of similar wattage rating. In fact, 10 per cent of the electrical energy used to power a fluorescent tube is actually converted into visible light, which compares very favourably with other light sources.

One drawback, when portable applications are considered, is that the fluorescent lamp requires a fairly high voltage to initiate and maintain a discharge within its tube; higher than can be conveniently obtained from batteries. However, if a simple transistor inverter of moderate efficiency is employed to step up the battery voltage and drive the fluorescent tube, the available light output will still be greater than the light output from a tungsten lamp drawing the same power directly from the battery, which results in a worthwhile gain in terms of running costs.

Designed for use in tent or caravan, the camping light described in this article may be powered economically from dry cells, or for long periods from a 12 volt car accumulator. As a guide to efficiency, the camping light consumes some 5·3 watts and yet has a light output of 160 lumens, equivalent to a 20 watt tungsten filament bulb.

FLUORESCENT TUBE

The fluorescent lamp itself consists of a glass tube coated on its inside surface with a suitable light emitting phosphor. The tube contains a small amount of mercury, with argon to assist in starting. At both ends of the tube there are filament heaters coated with an emissive material, similar to the filament in a directly heated valve.

To initiate a discharge within the tube, about 10 volts is applied to each filament and electrons are emitted to start the ionisation process. After a short warm-up period the full starting voltage is applied across the tube and it lights up. The mechanism of light production relies on the efficient generation of short wavelength ultra-violet energy within the tube, which in turn causes the phosphor to fluoresce and emit visible light. Typical voltages for a small tube are 150 volts to start and 50 volts to run.

In recent years preference has been given to "instant start" tubes with heaters strengthened to prevent stripping of the emissive material when a high voltage is applied direct to a cold tube. To achieve satisfactory instant starting, the tube should either be surrounded by a metal reflector or have a thin earthed metal strip running the full length of the glass envelope.

HIGH FREQUENCY SUPPLY

Since the main object is to get as much light as possible from the lowest level of input power, full consideration should be given to fluorescent tube characteristics. To begin with, a fluorescent tube will produce 20 per cent more light when run from a high frequency supply, above 10kHz.

Efficiency is further increased if a tube is under-run. For example, a tube run at 60 per cent input power will produce 70 per cent light output. Provided that there is enough voltage and power available to start the lamp, it can then be dimmed down to quite low levels of input without flickering or extinguishing.

With the above points in mind, the frequency of operation chosen was around 20kHz, high enough to give good efficiency, but not so high as to demand an expensive h.f. transistor and create severe interference with nearby radio receivers. Additionally, since the frequency is just beyond the audible range, there will be no annoying whistle from the transformer.

The smallest available tube is 6in long, rated at 4W. However, a 9in 6W tube, under-run at 4W, will emit 24 per cent more light than a 6in tube, by virtue of increased efficiency and greater tube wall area. A 9in tube was therefore chosen for this camping light, thus fixing the inverter power output at a nominal 4W.

CIRCUIT ACTION

The complete inverter circuit is shown in Fig. 1. Positive feedback is achieved by means of inductive coupling between the collector winding L2 and base winding L1. When the oscillator is first switched on, TR1 is class A biased by potential divider R1 and R2, and there will be a large d.c. standing current.

In the class A mode, efficiency is poor but there is maximum output. The secondary winding L3 will not be loaded until tube LP1 strikes, therefore a high voltage pulse is developed, sufficient to start the tube without pre-heating, even in cold weather.

Almost immediately after "switch on", base-emitter rectification of the oscillator waveform takes place, which tends to counteract the negative voltage at the junction of R1 and R2.

The amount of positive voltage developed by rectification is critically dependent on the value of C1, as this capacitor "stores" the rectified bias current. C1 is therefore selected to give a voltage which just cancels out the d.c. standing bias, so that the base is virtually at earth potential. TR1 is, therefore, operating in class B, with an overall conversion efficiency close to 60 per cent.

The transistor specified for TR1 has a 22·5W maximum collector dissipation, and a cut-off frequency of 2·5MHz. Although TR1 is generously under-run in the inverter circuit, and is provided with an efficient heat sink, R3 emitter resistor is included to give some measure of protection in the unlikely event of a thermal runaway, and will allow the lamp to be operated over a wider range of ambient temperatures.

Power transistors with a lower cut-off frequency will not work satisfactorily in the inverter circuit and care should be exercised if there is to be substitution of transistor types.

Capacitor C3 tunes the collector winding L2 to approximately 21kHz. C2 is switched into circuit by S1a to give a low consumption with reduced light output, enabling the lamp to be used for longer periods when working on dry batteries. The action of C2 increases the positive going potential on the base of TR1, thus biasing the transistor into the highly efficient class C mode. S1, therefore, provides an off position, a high, and a low output position.

The inverter will function satisfactorily, with instant start, from inputs ranging from about 9 volts up to 15 volts, although lamp brightness and current consumption will obviously depend on battery voltage.

Fuse FS1 is included to give protection against accidental short circuits and battery polarity reversal. Silicon diode reversal protection can be used, but this will spoil efficiency, due to the voltage dropped across the diode. C4 not only reduces radiation of interference by decoupling the battery leads, but also effectively lowers the dry battery impedance.

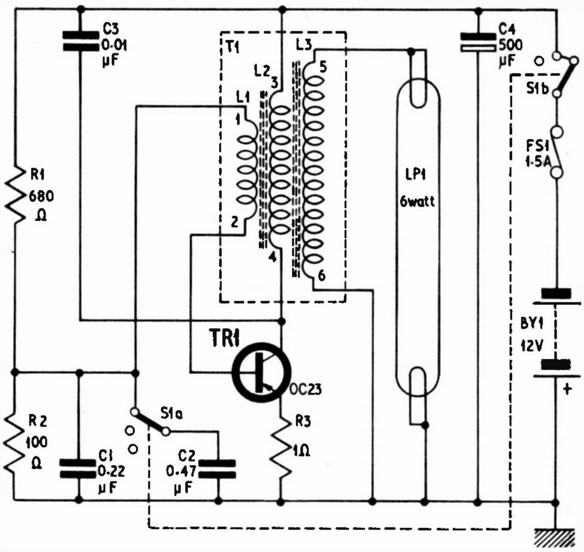


Fig. 1. Complete circuit of the camping light inverter

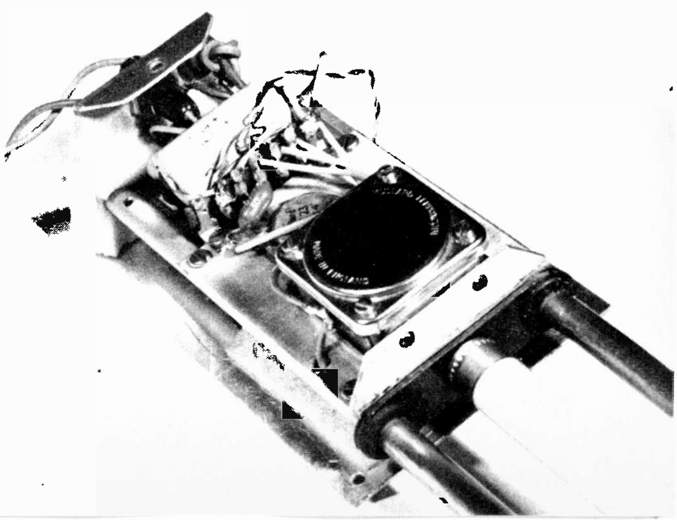
Nevertheless, even with C4 in circuit, some 20 millivolts of a.c. ripple will appear across the battery leads, suggesting that the leads should preferably be screened to reduce the likelihood of radio interference. The inverter and fluorescent tube are contained in an all-metal case which gives adequate screening of the lamp itself.

Remembering the 20 per cent bonus in light output when a fluorescent tube is operated on a high frequency supply, the actual power input to the tube is 4W less 20 per cent, or 3·2W. At an efficiency of 60 per cent the inverter input requirement is 5·3W, corresponding to a current of 440mA at 12 volts.

CONSTRUCTION NOTES

Fig. 2 gives a general view of the inverter layout and fluorescent tube mounting. The lamp chassis is based on two aluminium alloy—or plain aluminium—tubes 13¾in long by ⅜in outside diameter.

The power transistor, pot-core transformer, and a tag strip, are bolted to a 16 s.w.g. heat sink plate of aluminium, which is attached to the alloy tubes by four



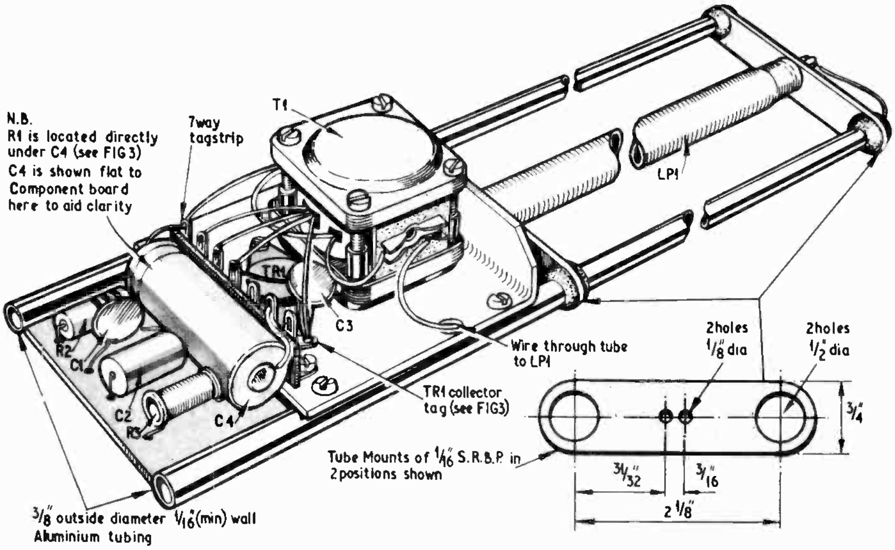


Fig. 2. General view of the inverter and fluorescent tube mounts

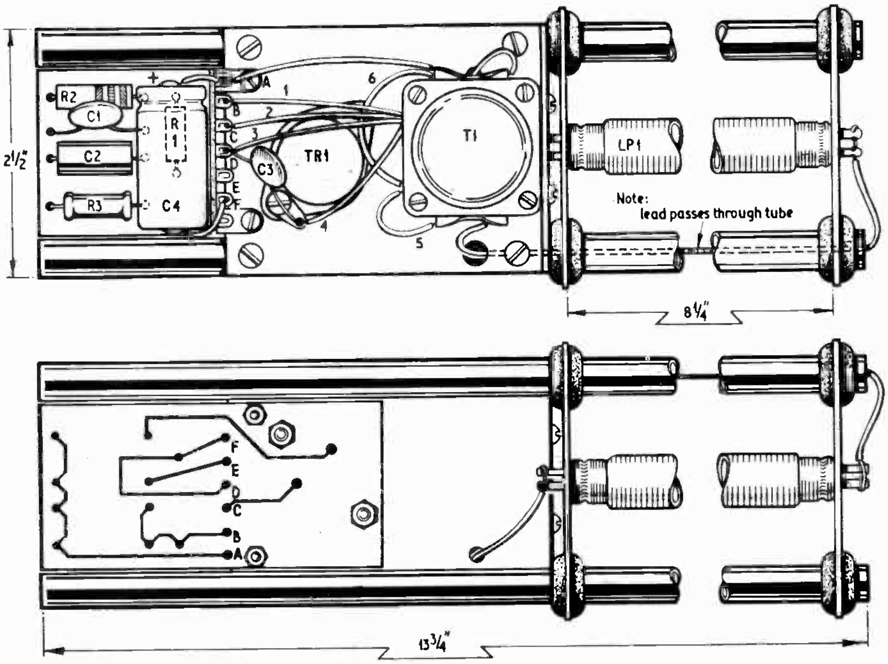
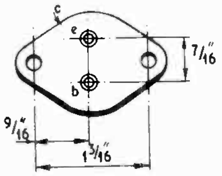


Fig. 3. Inverter layout and wiring (half scale)



Transistor connections looking at underside

COMPONENTS . . .

Resistors
- R1 680Ω 10%, $\frac{1}{4}$W carbon
- R2 100Ω 10%, 1W carbon
- R3 1Ω 5%, 3W wirewound

Capacitors
- C1 0·22μF disc ceramic 20V
- C2 0·47μF polyester 250V
- C3 0·01μF polyester 250V
- C4 500μF elect. 25V

Transformer
- T1 LA5 pot core with bobbin (Mullard) (see text)

Transistor
- TR1 OC23 with mica washer

Switch
- S1 2-pole 3-way midget rotary

Fuse
- FS1 1·5A 20mm cartridge and fuseholder

Lamp
- LP1 6 watt "natural" or "warm white" 9in fluorescent tube

Batteries
- BY1 12V heavy duty dry batteries or accumulator

Miscellaneous
- 18 s.w.g. sheet aluminium, 3$\frac{1}{2}$in × 3$\frac{1}{2}$in, 3$\frac{1}{2}$in × 8$\frac{1}{4}$in, and 7in × 14in
- 16 s.w.g. sheet aluminium 4in × 2$\frac{1}{2}$in, sheet s.r.b.p. 3in × $\frac{3}{4}$in (2 off), 1$\frac{3}{4}$in × 3$\frac{1}{2}$in
- Rubber grommets
- Two alloy tubes $\frac{3}{8}$in outside diameter by 13$\frac{3}{4}$in long
- 32 s.w.g. enamelled wire
- 38 s.w.g. double cotton covered wire

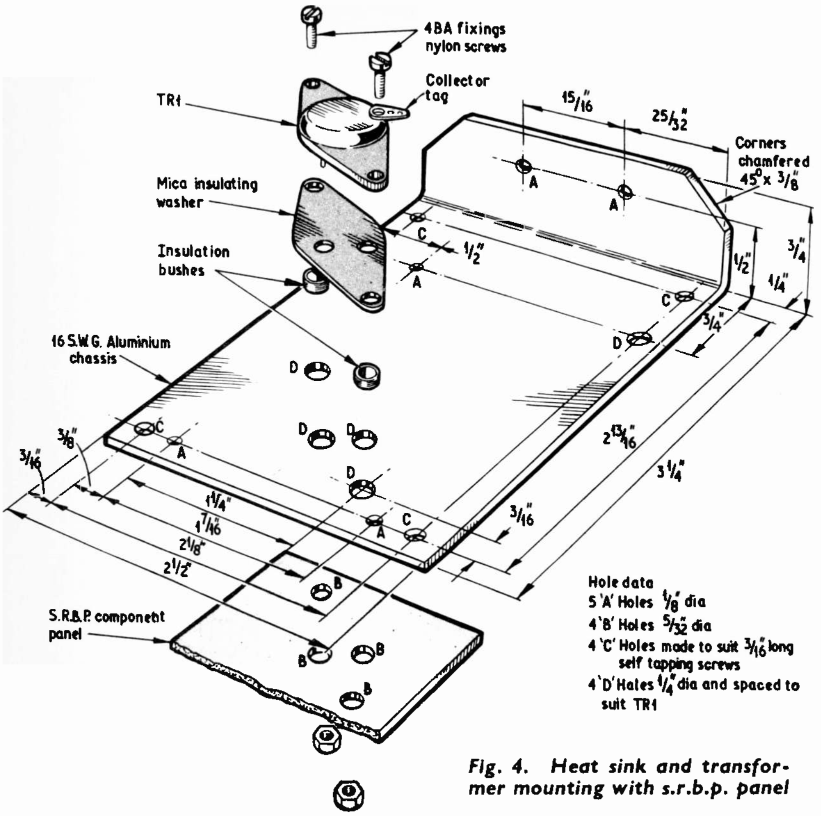


Fig. 4. Heat sink and transformer mounting with s.r.b.p. panel

self-tapping screws. The whole chassis acts as a heat sink about 18 square inches in area, with heat being dispersed from the plate along the tubes.

Fig. 2 also shows how the s.r.b.p. circuit panel, is bolted to the underside of the aluminium plate. The fluorescent tube is slung between the alloy tubes on two bearers of s.r.b.p., conveniently held on the alloy tubes by means of four rubber grommets. The miniature two-pin lamp terminals project through small holes in the s.r.b.p. bearers; the lamp leads are soldered to these pins.

More detailed views of the lamp chassis and component positions are shown in Fig. 3, together with the circuit panel drilling details and underside wiring. The screws and nuts holding the transistor also serve to mount the circuit panel; this is a useful method of electrically insulating the transistor from the underside of the heat sink.

The exploded view (Fig. 4) explains the transistor mounting method more clearly. Apart from the large mica washer (bought with the transistor), no other special washers are required. Portions cut from a length of ordinary insulated sleeving will prevent the 4B.A. screws from touching the metal plate, and the circuit panel isolates the nuts from the plate. A 4B.A. soldering tag acts as the transistor collector connection.

Also shown in Fig. 4 is the 16 s.w.g. heat sink plate, which is bent up at one end to form a transformer mounting bracket. The LA5 pot core is usually supplied with a small mounting plate, tapped with two 6B.A. holes, and held in place by the pot-core covers. The tapped plate holes correspond with the bracket holes.

Construction can commence by cutting and drilling the alloy tubes, heat sink plate, and circuit panel. The pot-core interior will be accessible after the transformer is mounted, so bobbin windings can be left until construction is well advanced.

After drilling the heat sink plate, the holes associated with the transistor should be thoroughly de-burred with a piece of sandpaper, to ensure that the anodised layer on the insulating washer is not pierced. During final assembly it is as well to check with an ohmmeter that the transistor case is electrically isolated from the heat sink.

As all external wiring is taken only to the tag strip, the circuit panel and chassis integral wiring may be completed, leaving the transformer leads, lamp leads, and S1 leads until last.

TRANSFORMER WINDINGS

Yet another advantage with a high frequency lamp supply is that transformer windings need consist of only a few turns, favouring hand-winding on the transformer bobbin. Winding instructions for the transformer are given in Fig. 5.

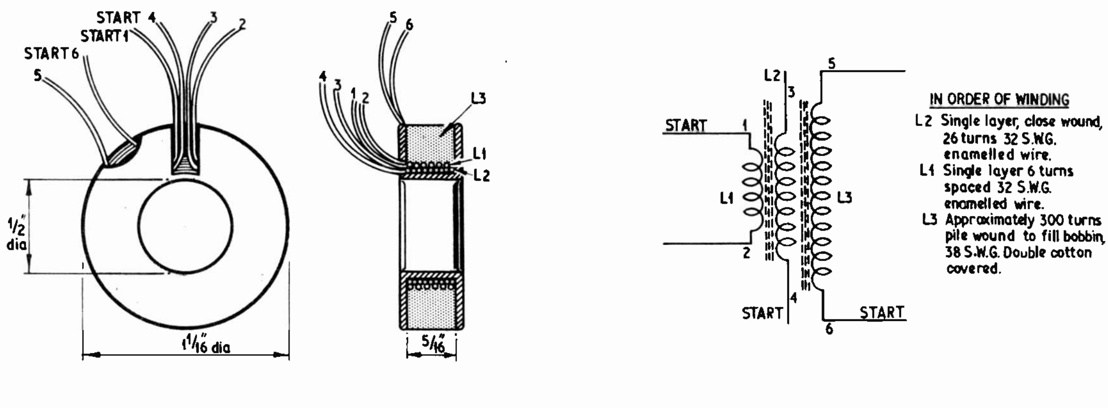


Fig. 5. Winding details of coils L1, L2, and L3 in transformer T1 (see text)

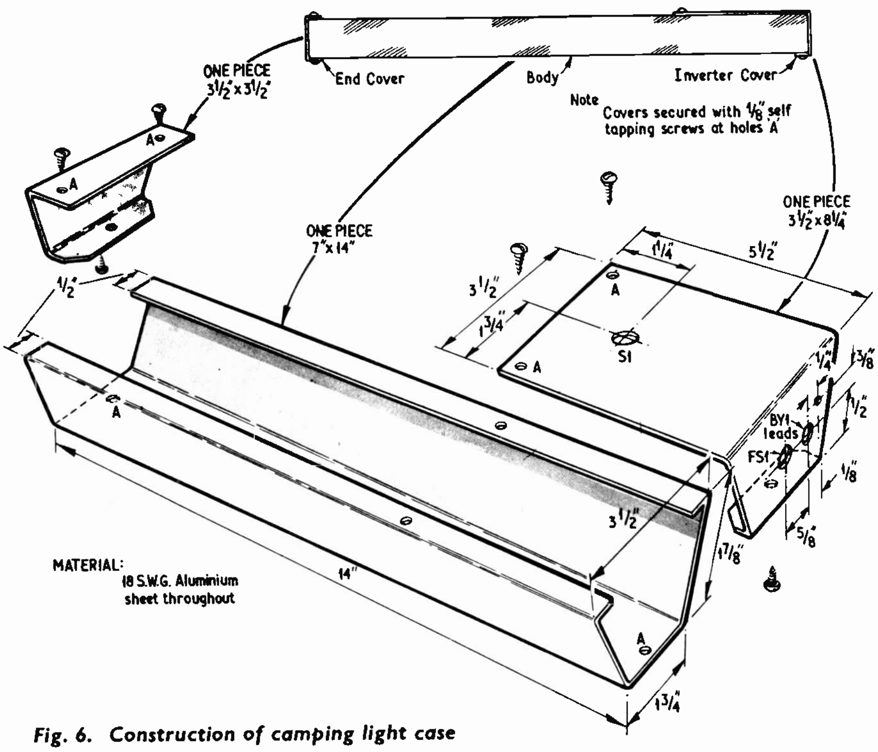


Fig. 6. Construction of camping light case

During the winding process the start and finish of each winding should be noted and it is helpful to apply dabs of different coloured paints to each lead as a means of later identification.

Before commencing winding of the bobbin, cut two strips of thin $\frac{5}{16}$in wide plastics insulating self-adhesive tape, which is to provide insulation between the layers L1 and L2 and hold the wire firmly in place. The LA5 bobbin is fairly fragile, so avoid exerting excessive pressure on the bobbin cheeks when winding or they will break.

Commence with L2; wind on one layer of 32 s.w.g. enamelled wire, leaving leads of about 3in in length at start and finish. The bobbin will accommodate 26 turns of 32 s.w.g. wire in a single layer. Wrap the insulating tape around the winding and interleave the "finish" lead where it is returned to the bobbin slot. Mark the start and finish leads of the L2 winding.

Next wind on L1, with a space between each turn, 6 turns in all of 32 s.w.g. wire as used for L2, and finish off in the same way as before. After marking, twist L1 and L2 leads together temporarily, and tuck them out of the way so as not to hinder the winding of L3.

Double-cotton covered wire is used for L3, to ensure good spacing between turns. Although enamelled wire could be employed for L3, it is easily scratched, and the effect of a single shorted turn would be serious. It is better to ensure that the insulation is adequate in the first place, rather than take a chance of having to rewind the secondary later in the event of damage to the enamel insulation.

If L1 and L2 have been neatly wound and terminated, it should be possible to accommodate the remaining 300 turns of 38 s.w.g. d.c.c. wire in the space left on the bobbin. However, there is no cause for worry if L3 has to have slightly fewer turns as the transformer ratio need not be exact. Note that both leads of L3 are taken to the small cut-out in the bobbin cheek, which will correspond with one of the two openings in the pot-core itself.

To complete the bobbin, slide 2in of thin sleeving on each of the six leads and secure the sleeving to the bobbin with spots of glue or wax. When the bobbin is installed in the pot-core, the cover will help to clamp the sleeving firmly in place, but must not allow the insulation to be damaged.

To complete the lamp chassis, solder the transformer leads to the tag strip and connect up the L3 secondary output to the fluorescent tube, as shown in Fig. 3, with one lead threaded through one chassis tube.

CHECKING TUBE OPERATION

The object of the following tests is to adjust lamp current to the required figure and, at the same time, to ensure that the lamp is operating efficiently. Connect a red battery lead to tag A, and a blue battery lead to tag F.

For the purposes of initial tests it is advisable to wire a 1·5 amp fuse in series with the blue battery lead, together with a 1A f.s.d. meter or suitably shunted milliameter. Connect the red and blue leads to a 12 volt battery of adequate capacity, and observe both current consumption and the glow of the fluorescent tube.

If all is well the tube will light dimly and a short-lived blue glow should be observed at one end of the tube just prior to starting. If the blue glow does not disappear, or the lamp does not light at all, quickly note the current and disconnect the battery. Battery current will probably lie somewhere between the extremes 200–600mA. If outside those limits, a fault should be looked for.

When an old fluorescent tube is used for tests the lamp current will probably be much lower than expected, as ageing tends to increase the impedance of the tube.

In the event of a fault, where the fluorescent tube refuses to strike properly, and the blue glow at the end of the tube does not disappear, the inverter output will probably be too low. The following examples could be the reason for an abnormally low output: TR1 sub-standard, incorrect or shorted transformer windings, too high a value for C1, or a battery which does not maintain sufficient voltage under load. Fluorescent tube faults are rare.

Assuming that the fluorescent tube will start readily and that there are no faults, but that the gain of the transistor is significantly high or low compared with the prototype (the original used a transistor with a d.c. current gain of 50) the battery current may be brought close to 440mA by adjustment of C1. To increase current, decrease the capacitance of C1, and vice versa.

Monitor the battery voltage to ensure that it is close to 12 volts. Next check the d.c. voltage across the base-emitter junction of TR1 with the lamp working, which should be within $\pm 0{\cdot}25$ volt. The inverter will be operating at maximum efficiency when the d.c. voltage across the base-emitter junction is close to zero.

With C2 brought into circuit the base should swing positive relative to the emitter, to about $+0{\cdot}5$ volt. It will be remembered that C1 and C2 determine the value of base voltage present.

With the lamp current correctly adjusted, check the dimming action of C2 by temporarily linking tags B and E. The fluorescent tube should dim—but not flicker or have a blue glow—and the current consumption can be expected to fall to about 150mA. The "dim" current may be adjusted, if necessary, by altering the value of C2, as previously with C1.

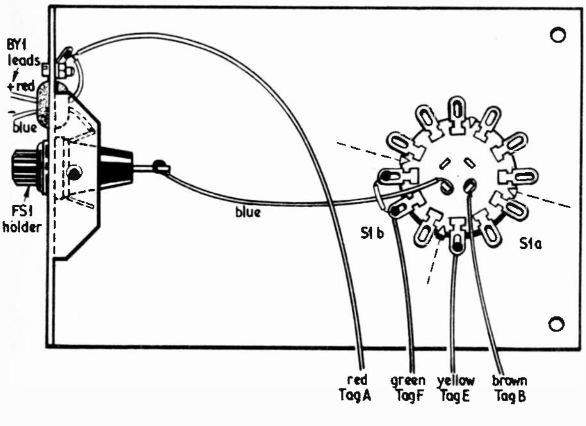


Fig. 7. Inside the inverter cover showing S1 connections

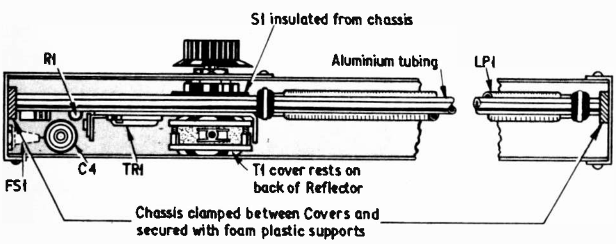
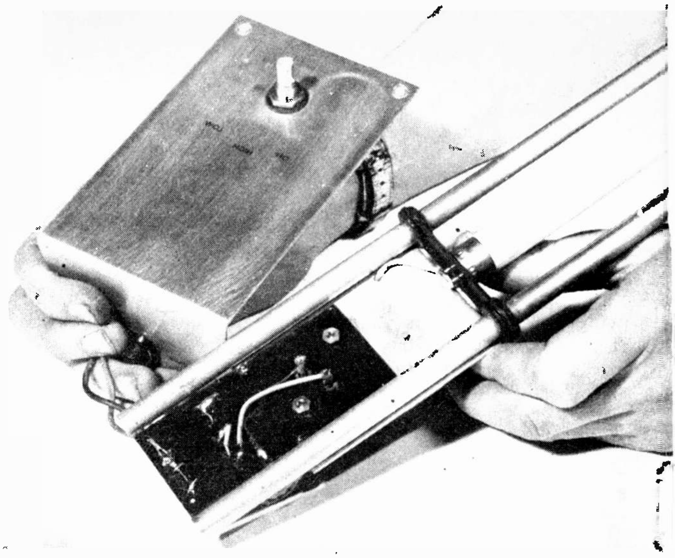


Fig. 8. Sectional view through the side showing the method of holding the lamp in the case



CASE CONSTRUCTION

Apart from giving a professional appearance, an all-metal lamp case is virtually essential, to prevent the radiation of harmonic interference. The case body, shown in Fig. 6, was bent to shape using two pieces of angle iron and two "G" clamps, as an improvised vice. This method gives neat, straight bends. To achieve maximum leverage, the angle iron vice can be clamped to a table top, otherwise very strong hands and wrists will be needed.

Avoid scratching the inside of the case body as this is polished later to act as a reflector. The end cover and inverter cover are bent and shaped as shown, and holes are drilled to take self-tapping screws, S1, FS4, and battery leads.

The case can be given a "brushed" appearance with fine flour paper, and is protected by a coat of clear laquer.

Mount S1 in the cover as shown in Fig. 7, together with fuse holder and battery lead grommet. The positive battery lead is taken through the grommet to an earthed solder tag and thence to the tag strip, to make certain that the aluminium case is adequately earthed.

Ordinary coaxial aerial cable can be used as a screened battery lead, with the outer braiding serving as the positive line. A screened battery lead will only be necessary where the lamp is situated close to a long and medium wave radio, inside a car for example.

COMPLETING ASSEMBLY

The lamp chassis can be held inside the case by pieces of foam plastics glued to the inverter cover and the end cover, to grip the alloy tube ends as shown in Fig. 8. The purpose of a foam plastics mounting is to minimise damage if the lamp is dropped or jarred. The chassis is insulated from S1 tags by a 2½in square of p.v.c. and a similar square of thin foam plastics, which helps to grip the chassis when the inverter cover is screwed on.

In use, S1 is switched to the HIGH position and the lamp is given a minute or so to warm up before switching to the LOW output position. If the lamp is intended for portable applications such as caving or as an inspection lamp, dry batteries may be contained in a separate case.

The battery type will depend on the required operating time. Two 996 or eight HP2 batteries will give approximately 9 hours of bright light or 30 hours of dim light. A VT1 battery is capable of better than 20 hours bright light. ★

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.

SOLDERING

Particularly interesting is the W range of temperature controlled soldering irons from **Weller Electric Ltd.**

These irons have interchangeable iron plated copper bits, with a built-in "magnastat". Heat can be controlled in three or four temperature settings from 260 degrees to 400 degrees C (500 to 750 degrees F).

A permanent magnet is attracted to the bit when it is cold. This switches the iron on and when it reaches a predetermined temperature the sensing element is no longer able to hold the magnet and switches off. When the bit cools the "magnastat" again attracts the magnet and resumes heating.

The tips are pre-tinned; it is claimed that they never need filing and outlast normal copper bits. The tips are easily changed when necessary, without battling against adhesion through corrosion, as the heat is concentrated at the tip and the iron shank remains cool. Any type of soldering from transistor to heavy electrical work can be undertaken by a single iron by simply selecting the required tip.

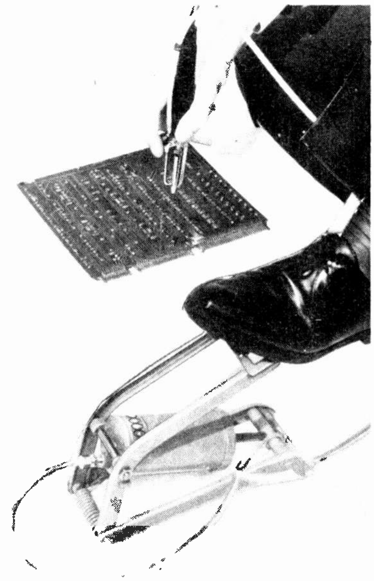
Full details and prices are obtainable from Weller Electric Ltd., Redkiln Way, Horsham, Sussex.

Enthoven Solders Ltd., Dominion Buildings, South Place, London, E.C.2, are now producing a special non-activated rosin cored solder. The rosin flux has been subjected to a refining process, which, by altering certain physical characteristics, is said to have a high insulation resistance and freedom from corrosive action.

The fluxing action of the rosin is said to be improved by this treatment. The cored solder is claimed to be free from any tendency to produce "dry joints", although this is usually a human failing during soldering.

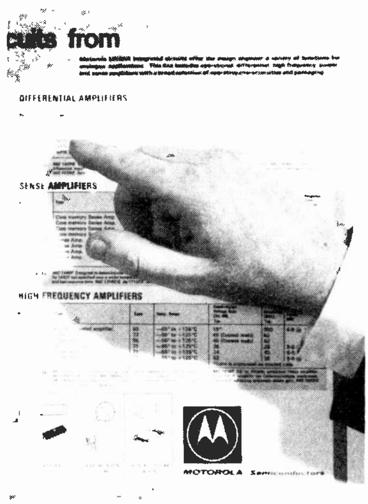
The Model ESS is a new version desoldering kit from **Antex Ltd.,** containing a footpump with patented moulded cylinder and a synthetic cup washer. Weight has been reduced to 3lb and a very high pressure is obtainable from the new footpump.

The ESS is available for 12, 24, 50, 110, 220 or 240 volt supplies. Price and address of nearest stockist can be obtained from Antex Ltd., Grosvenor House, Croydon, Surrey.



ESS desoldering kit from Antex Ltd.

Weller W60D 60 watt temperature controlled mains soldering iron



Part of the Linear Integrated Circuits wall chart from Motorola

Supplied to special order are four models from the Litesold range of soldering irons fitted with neon indicators to show when the supply is switched on. This feature reduces the risk of accidental burns to operators and equipment.

The neon indicators are mounted in moulded translucent nylon handles and can be fitted to the 10, 18, 20 and 25 watt models for all voltages from 100 to 250 volts a.c. or d.c. Prices of complete irons are from 35s 6d to 37s 6d each from **Light Soldering Developments Ltd.,** 28 Sydenham Road, Croydon.

RADIATION DETECTOR

A silicon semiconductor radiation detector type ND.7, has been introduced by the Nutronics Radiation Detectors, a division of **Solid State Nutronics Ltd.** The detector has been expressly designed for the use in educational establishments and by amateur experimenters.

The detector type ND.7, detects alpha, beta, and gamma radiation, X-rays, fission fragments and protons.

Further details can be obtained from Nutronics Radiation Detectors, Solid State Nutronics Ltd., 5 Voltaire Road, London, S.W.4.

LITERATURE

The first of a series of wall charts are now available from **Motorola Semiconductor Products Inc.**

The first wall chart is entitled "Linear Integrated Circuits from Motorola" and deals with operational amplifiers, audio amplifiers, differential amplifiers, sense amplifiers and high frequency amplifiers. Case types are illustrated and a glossary of linear IC symbols and definitions is included for quick reference.

Copies of the wall chart are available from the Technical Information Centre, Motorola Semiconductor Products Inc., York House, Empire Way, Wembley, Middlesex.

CLUBS NOTE

Finally, "Least Cost Feed Formulation Computer" is the title of a new 10 minute 16mm technicolour film produced by Kestrian Films Ltd., now available on free loan from **Electronic Associates Ltd.,** Victoria Road, Burgess Hill, Sussex.

The film describes the uses of a new feed formulation computer specifically designed for nutritionists engaged in feed formulation. The film makes good use of animation to describe what would otherwise be a very complex subject to put over, and the film should be of wide interest.

Another film of general interest is available from the **G.P.O.,** St Martins-le-Grand, London, E.C.1, entitled "The Post Office Tower of London".

The film was made by **AI Films Ltd.** in colour and runs for 20 minutes. It explains the Tower's place as the central point of the national microwave telephone network and as a television switching centre.

SEMICONDUCTOR BASICS

4—THERMISTORS

By G. J. KING

A THERMISTOR is a semiconducting resistance with a negative temperature coefficient. This simply means that its resistivity *decreases* as its temperature rises. Thermistors are used extensively as temperature compensating devices in transistor circuits by "turning down" the base current, and hence the collector current, as the temperature of the transistor rises.

The thermistor might be placed in thermal contact with a power transistor heat sink, thereby sampling its temperature, and arranged electrically in the base potential divider circuit to control base current. They are very well suited to many other applications in electronics, some of which are revealed in this article.

MANUFACTURE

A thermistor is made by mixing semiconducting oxides with a plastics binder to facilitate the formation of rods by extrusion or discs by pressing. A "firing" process dissolves the oxides evenly into the binder and causes the forms to harden into a black, ceramic-like material. Electrical connections are finally provided by electroplating, spraying with a conductive material, or by the "burning-in" of a silver paste.

Miniature bead-type thermistors, used more in electronic than "radio" applications, are made by drying and sintering a blob or bead of oxide paste between two parallel platinum alloy wires of very small diameter (about 50μm). The sintering hardens the bead and shrinks it over the wires, making good electrical connections. Protection is provided by coating the bead with a special enamel or even glass or by glass encapsulation.

PROPERTIES

While the thermistor has a negative temperature coefficient, most other ordinary conductors have a positive temperature coefficient, meaning an increase in resistance with temperature increase. This can easily be demonstrated by connecting an ohmmeter across the contacts of an electric light bulb when cold and then again just after it has been switched off. The filament resistance will be found to be far higher when hot than when cold.

A thermistor behaves in reverse fashion; the resistance will be found to decrease at the rate of about 3 to 6 per cent per degree C. At 20 degrees C a thermistor may have a resistance of about 200 ohms, depending on its type. The heat from an electric light bulb or soldering iron applied to a thermistor will cause the resistance to fall substantially. At about 100 degrees C, the resistance of a common "radio" type thermistor will fall to about 5 or 6 ohms.

PRACTICAL USE

The very basic thermistor application, therefore, is one of temperature measurement. For very accurate measurements the thermistor needs to be related to a known resistance in a bridge circuit, but the simple arrangement given in Fig. 4·1 is sufficient to demonstrate the idea.

The thermistor here is connected in series with a 10mA meter movement and a 1·5V battery (cell). A 200 ohm preset potentiometer permits the current in the circuit to be adjusted to provide, say, half-scale deflection (i.e. 5mA) at a room temperature of 20 degrees C. An increase in temperature then causes the current to rise, deflecting the pointer upwards, while a drop in temperature reduces the current and hence deflection.

The meter scale could thus be calibrated directly in terms of temperature, but not a very efficient thermometer would result because quite a large swing in temperature would be required to give a reasonable deflection on the meter. The current change, however, could be amplified by a transistor, causing the change in thermistor current to act as a change in base current, this then being translated to a much larger change in collector current by the action of the transistor.

Thermistor currents should generally be limited to low values to avoid the resistance falling due to the initial warming up period of the thermistor. This applies particularly to the simple thermometer just mentioned.

Another simple temperature measuring circuit is given in Fig. 4.2. Here it is the change in voltage across the thermistor, rather than the change in current through it, that is measured. The voltage across a resistor is proportional to its resistance and the current flowing through it. At low temperatures, therefore, the voltage will be towards maximum because the resistance will be high, and conversely at higher temperatures.

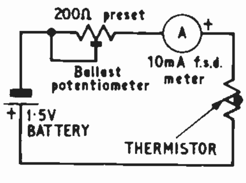


Fig. 4.1. A basic electronic thermometer circuit using a thermistor

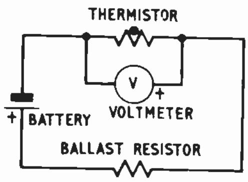


Fig. 4.2. Because the voltage across a transistor falls as its temperature rises, voltage can be used to indicate temperature as shown here

This principle can be extended to measure the temperature of a car engine, as shown in Fig. 4.3. A disc-type thermistor can be clamped to the rear of the radiator or to the engine somewhere, while an encapsulated thermistor must be used in the cooling liquid.

Current is limited by a resistor (selected to give about half-scale deflection on the voltmeter) and the thermistor itself tends to compensate automatically for increase in battery voltage when the dynamo or alternator is running. This is because the increasing current through the thermistor, brought about by the increasing "on-charge" e.m.f. of the battery, causes a slight rise in temperature and hence a fall in resistance, reflected as a tendency towards a lower voltage reading.

If a moving coil voltmeter is used, it should be connected to conform to the positive or negative earth (chassis connection) of the car. A moving iron meter, suitable for this application, deflects normally whichever way round it is connected to the supply.

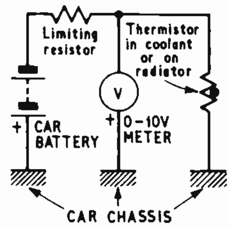


Fig. 4.3. This simple circuit can be used to record the temperature of a car engine

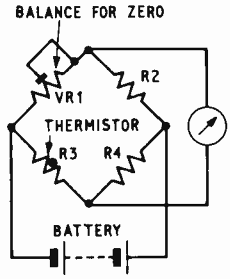


Fig. 4.4. Basic bridge-type thermometer, using a thermistor

WHEATSTONE BRIDGE

For greater sensitivity a bridge circuit is required, as shown in Fig. 4.4. For the highest sensitivity, a meter having a full-scale deflection of about 100μA is required with a d.c. supply of about 9V. This meter can be a centre-zero type calibrated for plus and minus indications relative to, say, 20 degrees C, or the bridge can be balanced to zero temperature using an ordinary end-zero scale.

The principle of operation is quite straightforward. The circuit forms a Wheatstone bridge, which is balanced for zero current through the meter by adjusting the preset potentiometer VR1 to balance with the thermistor at zero temperature. Any change in temperature from this setting thus unbalances the bridge due to the resistance change of the thermistor; the amount of unbalance is read off the meter in degrees C.

Bridge balance occurs when $VR_1/R_2 = R_3/R_4$ or when $VR_1 \times R_4 = R_2 \times R_3$. Because most thermistors possess a temperature coefficient which is roughly exponential, the temperature reading will not be truly linear. A linear deflection can be achieved by padding the arm of the bridge carrying the thermistor with series and parallel resistors. Such a refinement is included in the *Electronic Thermometer,* which is the subject of this month's beginners' constructional feature.

APPLICATIONS

Bridges incorporating a thermistor in one arm are often used to provide electrical control based on temperature. An illustration is given in Fig. 4.5. Here the thermistor controls the level of liquid in a tank.

The bridge components and d.c. supply are chosen to give appreciable current flow in the tank thermistor. This means that the thermistor will warm up (a typical value being 144 degrees C) when the water in the tank is not sufficiently high to immerse it.

However, when the water level rises to cover the thermistor, its self-generated heat is conducted away through the water and its resistance rises. It is under this condition that the bridge is balanced so that no (or very little) current flows through the relay winding. The relay contacts are then open.

When the level of liquid falls such that the thermistor is no longer immersed, the thermistor warms up, as just explained, and its rapidly falling resistance

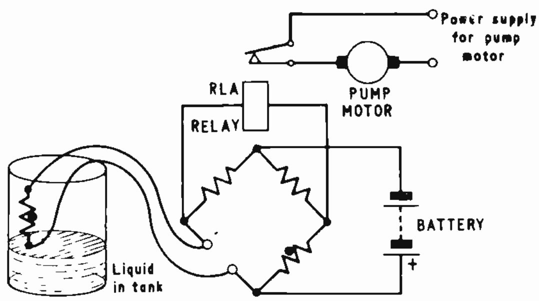


Fig. 4.5. A thermistor is used in this circuit for controlling the level of liquid in a tank

unbalances the bridge. This energises the relay, closes its contacts and switches the pump motor on, thereby refilling the tank. The pump ceases when the water rises sufficiently to immerse the thermistor.

The thermistor can even be used to measure vacuum! This is because the thermal conductivity of a gas is proportional to its pressure. By encapsulating the thermistor in the gas a transference of heat results, and the thermistor will alter in resistance with changes in gas pressure.

A similar arrangement is adopted in the Pirani vacuum gauge, but here a thin wire is incited to change in resistance (rather than a thermistor) with change in thermal conductivity brought about by change in gas or air pressure. Greater sensitivity, however, is given by using a thermistor.

Again a bridge circuit is used with the thermistor making one arm. Stabilised power supplies and d.c. amplification makes it possible to measure down to 10^{-4}mm of mercury.

CURRENT CONTROL

Direct use of the thermistor's negative temperature coefficient is to be found in many branches of electronics. In some television receivers, for instance, a thermistor is used to compensate for the positive temperature coefficient of the field scanning coils. Since these coils are made of many turns of copper wire, a substantial increase in resistance occurs due to the high ambient temperature within the set after it has been working for some time. The effect is a gradual reduction in picture height—very troublesome on early models.

The thermistor overcomes this problem when connected in series with the coils to sample the same

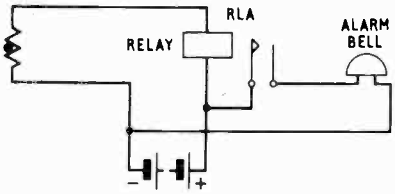


Fig. 4.6. A simple thermistor operated fire alarm

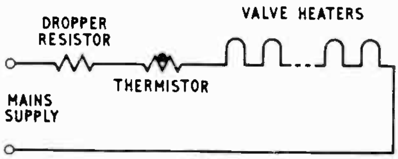


Fig. 4.7. Switch-on current surges in a series heater chain are avoided by using a thermistor in the circuit

ambient temperature. In this way the frame time base output stage is presented with a constant load over a wide temperature range. Resistive padding is sometimes necessary to balance the falling resistance of the thermistor with the rising resistance of the coils.

Temperature compensation of this nature is also found in bridges and test instruments which have to be accurate over a wide temperature range.

A simple "fire alarm" based on a thermistor is given in Fig. 4.6. Here the thermistor is set up in the area to be "monitored" and connected through cables to a relay winding. The relay contacts operate an alarm bell or siren when the thermistor warms up sufficiently for its resistance to fall to the value necessary to cause the relay to energise.

The sensitivity of the relay, the type of thermistor, and the supply voltage must be chosen with some thought, for if too great a current is permitted to flow through the thermistor when cold, it will warm up, pass more current, get even warmer and so on until the relay energises.

Indeed, a thermistor is sometimes connected in series with the winding of a relay to give just this action, as a delay for operation. Here relay operation is dependent on this "thermal inertia". A further application based on this principle is shown in Fig. 4.7, for the protection of series-connected thermionic valve heaters. If no thermistor is used a heavy current surge flows through the heaters on first applying the power owing to their initial low value (cold) resistance.

With the thermistor in series, however, the total resistance is initially quite high because of the relative high resistance of the cold thermistor. When the power is first applied the series current is low and a large ratio of the supply voltage is developed across the thermistor. This causes its temperature to rise and its resistance to fall at about the same rate as the resistance of the heaters is rising. The heaters are then allowed to warm up gradually and avoid being damaged.

Next month's article looks at photo-sensitive devices, including the photo-transistor and light dependent resistor.

THIS month's article explores the thermistor, and since this is a device concerned directly with temperature applications, we here describe appropriately a constructional item related to the thermistor's ability to translate temperature to electric current reasonably accurately over a wide temperature range.

The circuit of the "thermometer", given in Fig. 1, is based on a design by Mullard Ltd., using the miniature bead-type VA3700 thermistor. This has a very low heat capacity, which means that it is able to follow changing temperatures quickly. Moreover, it will respond to temperatures between −70 deg. C and +200 deg. C. However, the instrument in Fig. 1 is designed to read from zero to +100 deg. C (212 deg. F), but it can be preset to read below zero if required.

A Wheatstone bridge circuit is adopted with the thermistor X1 placed in one arm. Preset adjustments secure the condition of balance. Thermistor current is kept low to avoid self-heating by the small supply voltage and the low-current meter.

The idea is to balance the bridge at the lowest required temperature, so that when the temperature rises and the thermistor resistance falls the bridge unbalances and a forward (from zero) reading is given on the meter which is proportional to the rise.

Non-linearity of reading is minimised by the padding resistors R2 and R3. These reduce the sensitivity of the instrument to some extent, but they are necessary to counter the exponential temperature coefficient of the thermistor. They provide an overall linearity in the order of 2 per cent relative to full-scale deflection.

Preset potentiometer VR3 in series with the supply adds to the internal resistance of the battery, so that as this rises during its normal life, it can be countered by reducing the resistance due to VR3.

SWITCHES

To follow the method of construction described in this series, switches with screw terminals must be used. The type specified for S1 is a double pole switch, since this is readily available; only one pole is actually used however. Switches with solder tag terminals can be used but this will mean the use of additional crocodile clips, and is not recommended. Special care should be taken to ensure that crocodile clips do not short together.

Electronic Thermometer

CONSTRUCTION

The construction is a little more involved than the two previous articles in this series, but follows the same general procedure.

The first stage in construction is to measure and cut a baseboard 5in × 5in from any ½in thick softwood. The hardboard front panel measuring 5in × 5in is cut and drilled as shown in Fig. 2 and screwed to one edge of the baseboard with three ½in No. 6 countersunk wood screws. Three ⅜in holes should be drilled for VR3, S1, and S2. The size of cut out for the meter will depend on the type of meter used.

The meter M1, switch S2, and potentiometer VR3 should next be mounted on the front panel. S1 is not mounted on the front panel until the terminal strip has been first wired to it at a later stage.

Once the components have been mounted on the front panel, the next step is to wire the 8-way terminal strip before mounting on the baseboard. The terminal screws should not be tightened up until all components and wires for that particular terminal have been positioned. Each wire should be given a slight pull to ensure it has made contact and is held fast by the screw once it has been tightened. Refer to Fig. 1 and Fig. 2. Note the link wire between terminals 3 and 8.

When mounting VR1 and VR2 the centre or wiper lead should be carefully bent and joined to one of the outer leads and inserted in the appropriate terminal, see Fig. 2.

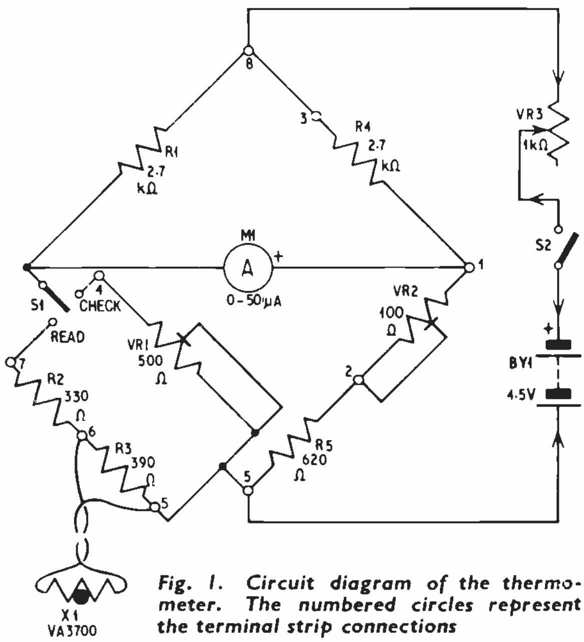


Fig. 1. Circuit diagram of the thermometer. The numbered circles represent the terminal strip connections

Before mounting the wired terminal strip on the baseboard, two leads from the strip should be screwed to the two outer terminals of S1, see Fig. 2. The switch S1 and terminal strip should then be fixed in position, the switch on the front panel and the strip screwed to the baseboard by two ¾in No. 4 countersunk wood screws. The battery clip should also be screwed in position with a ½in No. 6 countersunk wood screw.

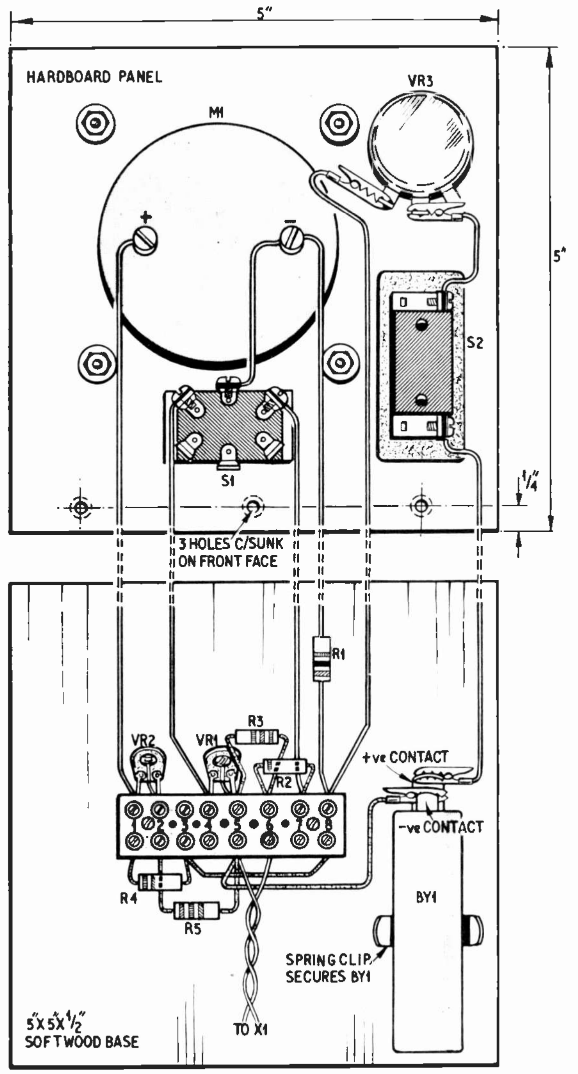


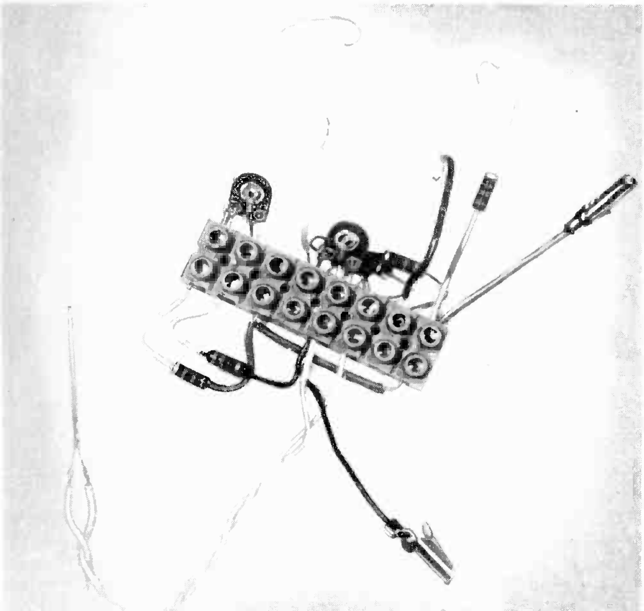
Fig. 2. Constructional and wiring details. The centre leads of VR1 and VR2 have been bent and joined to terminals 5 and 2 respectively

The thermistor is then taken up to +100 deg. C and VR3 adjusted to give full-scale deflection of the meter.

The above two adjustments should be repeated for the best tracking at the scale ends.

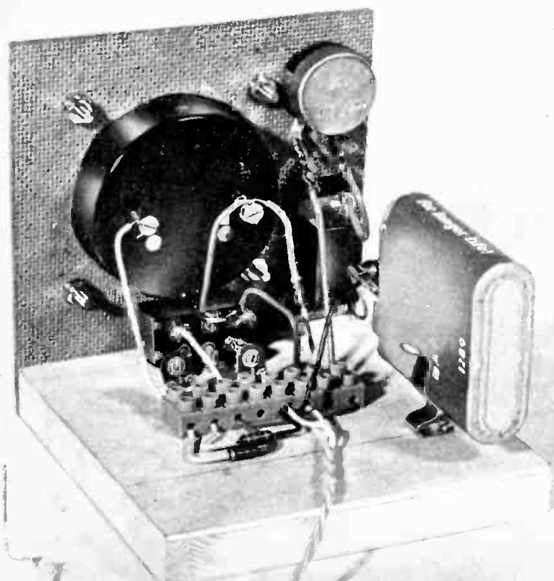
Once the terminal strip is fixed in position the lead from terminal 1 should be attached to the positive terminal of the meter M1. The free end of R1 should be connected to the negative terminal of M1. An additional lead is taken from the meter negative terminal and fixed to the centre screw terminal of S1. Also from terminal 8 a lead is taken to VR3 and attached by a miniature crocodile clip to the outer left hand tag of this potentiometer.

The negative battery lead from terminal 5 should be clipped to the negative connection of the battery by a miniature crocodile clip.



All components are wired to the terminal strip. The thermistor X1 is very fragile and great care should be taken when handling

The complete thermometer viewed from the rear



COMPONENTS . . .

Resistors
- R1 2·7kΩ, R2 330Ω, R3 390Ω, R4 2·7kΩ — All ½ watt 10%
- R5 620Ω Hystab 5% (Radiospares)

Potentiometers
- VR1 500Ω linear subminiature preset*
- VR2 100Ω linear subminiature preset*
- VR3 1kΩ linear midget wirewound (Radiospares)

* G. W. Smith & Co. Ltd., 3 Lisle Street, W.C.2

Thermistor
- X1 VA3700 (Mullard). Radio Crosland Ltd., 24 Foley Street, W.1

Switches
- S1 Double pole double throw
- S2 On/off toggle

Both with screw terminal connections

Meter
- M1 Moving coil meter. 0–50μA f.s.d. type MR65. G. W. Smith & Co. Ltd., 3 Lisle Street, W.C.2

Miscellaneous
- BY1 4·5 volt 1289 battery (Ever Ready)
- One 8-way plastics terminal strip
- One spring clip for holding battery
- Four miniature crocodile clips
- One knob
- Wooden baseboard 5in × 5in × ½in
- Hardboard front panel 5in × 5in
- Woodscrews for mounting front panel, terminal strip and spring clip
- Plastic covered, single core copper wire (Woolworths)

Total cost (approx.) £4 7s 6d

Finally, two leads with miniature crocodile clips screwed to one end should be taken from the screw terminals on S2 and clipped on VR3 centre tag and the positive connection of the battery respectively.

CALIBRATION

Calibration is established as follows. With the thermistor placed in an environment of 0 deg. C, as determined by a mercury or other kind of reference thermometer, switch S1 is set to the "read" position, and VR2 adjusted to zero the meter.

Now, to obtain a reference for subsequent checking of the battery voltage, S1 is set to the "check" position and VR1 adjusted to the full-scale position on the meter formerly given by the +100 deg. C calibration.

This makes it possible to check the accuracy of the instrument every now and again by switching to "check" and adjusting VR3 to give full-scale deflection on the meter (i.e. that deflection corresponding to +100 deg. C).

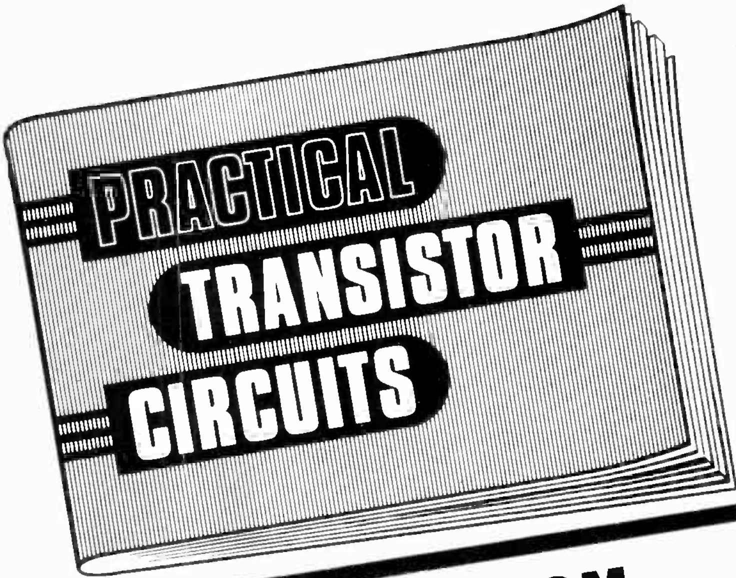
Since the meter deflection is essentially linear, it is possible to calibrate the meter scale between the zero and full-scale deflection marks in terms of degrees C.

If a lower than 0 deg. C reading is required, then the calibration for bridge balance (VR2) is made at the lower temperature (or higher if required).

Next month: A light operated switch

PRACTICAL ELECTRONICS

next month



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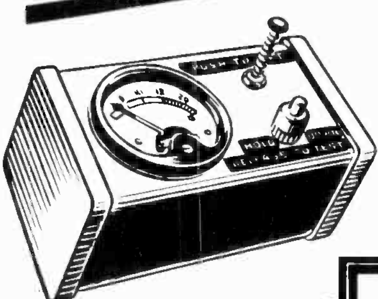

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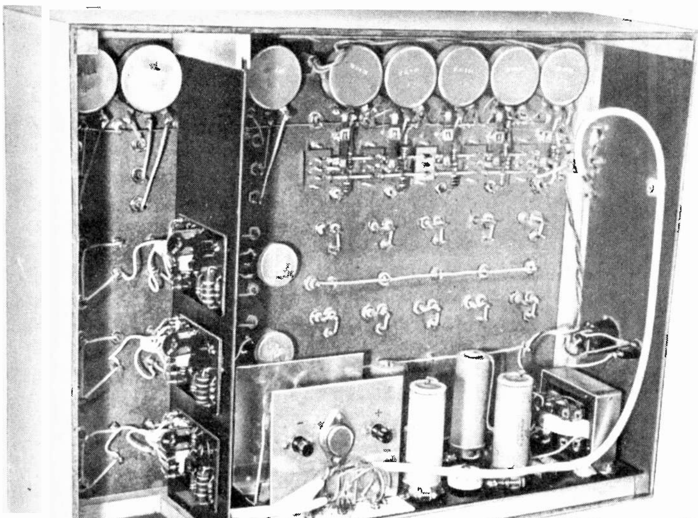


PEAC ANALOGUE COMPUTER

By D. BOLLEN

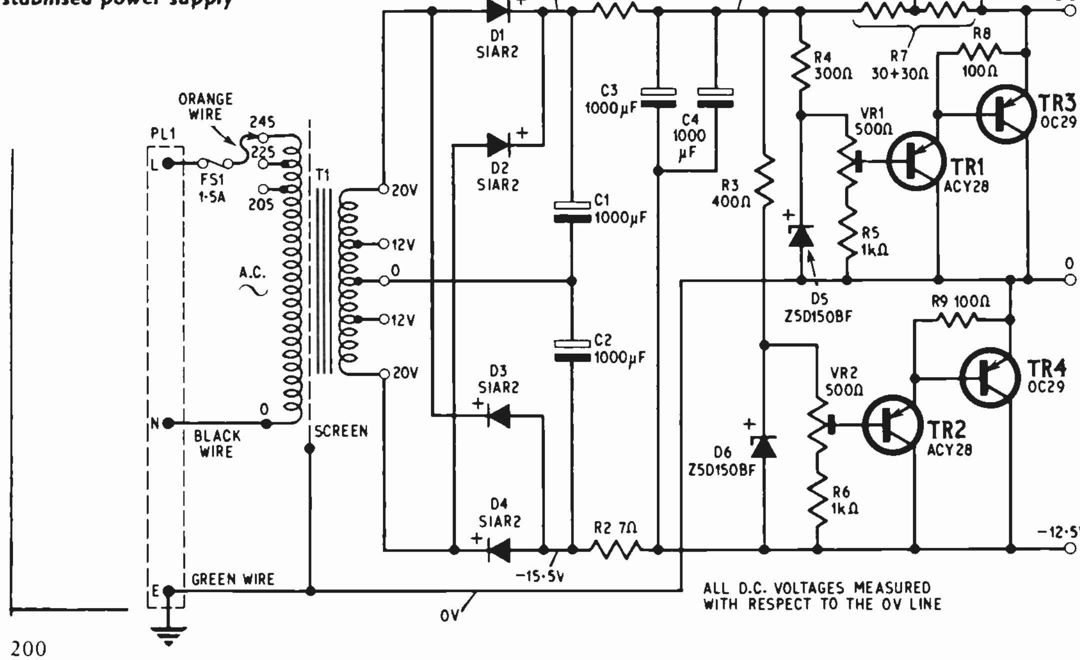
THE main design target for the PEAC power supply was a maximum voltage variation of not more than 1 per cent under all normal operating conditions. Several circuit configurations were tried, based upon either series or shunt regulation, but it was found that shunt regulation invariably gave the best performance for a given cost, plus the bonus of complete short-circuit protection. It was not considered to be a disadvantage for computer work, where nearly everything is switched on for most of the time, that a shunt regulated supply would be wasteful of power under no-load conditions.

The current reserve of the stabilised supply will just be sufficient to cater for the needs of UNITS "A to D". If further expansion of the computer is contemplated, beyond the inclusion of UNIT "D", a subsidiary unstabilised supply can be added to the computer at a late stage of construction, to power the relays of UNITS "B" and "D", and thus make available some extra current from the stabilised supply.

STABILISED POWER PACK

The circuit of Fig. 3.1 is based on a small, standard type of rectifier transformer, with bridge rectification

Fig. 3.1. Circuit diagram of the stabilised power supply



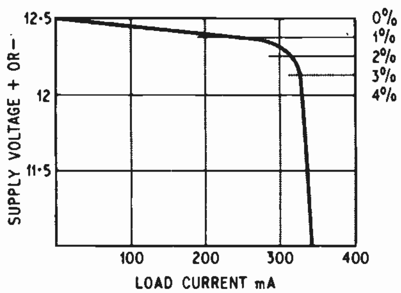


Fig. 3.2. Performance curve of stabilised power supply

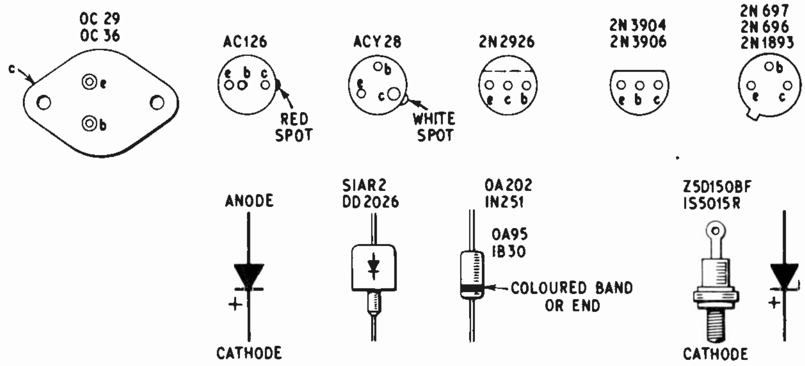


Fig. 3.3. Transistor and diode key

followed by two shunt regulators arranged in series to give positive and negative outputs relative to a zero voltage earthed centre-tap. Diodes D1–D4 provide full-wave rectification of the 40V r.m.s. nominal transformer output. Capacitors C1 and C2 are wired in series, with their common connection taken to the transformer centre-tap, and this doubles the capacitor voltage rating without the need for bleeder resistors. R1 and R2 achieve some measure of preliminary ripple smoothing while dropping the unregulated d.c. voltage to a safe value for C3 and C4.

COMPONENTS . . .

UNIT "A" POWER PACK

Resistors
R1, R2 7Ω 0·7A power resistors 5% (2 off)
R3 400Ω 5W wirewound 5%
R4 300Ω 5W wirewound 5%
R5, R6 1kΩ 2W carbon 10% (2 off)
R7 60Ω 0·7A power resistor 5% (two 30Ω in series, see text)
R8, R9 100Ω 1W carbon 10% (2 off)

Potentiometers
VR1, VR2 500Ω 3W panel mounting, wirewound (2 off)

Capacitors
C1–C4 1,000µF elect. 50V d.c. 900mA rippled (4 off)

Transformer
T1 Rectifier transformer. Standard mains primary. Secondary, 20V-0-20V 0·7A (Radiospares)

Diodes
D1–D4 S1AR2 (Westinghouse) *or* DD2026 (Lucas) (4 off)
D5, D6 Z5D150BF (STC) *or* 1S5015R (Texas) (see text) (2 off)

Transistors
TR1, TR2 ACY28 (STC) *or* AC126 (Mullard) (2 off)
TR3, TR4 OC29 *or* OC36 (Mullard) (2 off)

Miscellaneous
Four capacitor clips to fit C1–C4
S.R.B.P. panel 4in × 12in × $\frac{1}{16}$in or $\frac{1}{8}$in
4 B.A. and 6 B.A. assorted screws, nuts, washers, and solder tags
Insulated sleeving
20 s.w.g. tinned copper wire
16 s.w.g. sheet aluminium 2 off 4in × 4in, and 2 off $1\frac{1}{2}$in × $1\frac{3}{4}$in

SHUNT REGULATORS

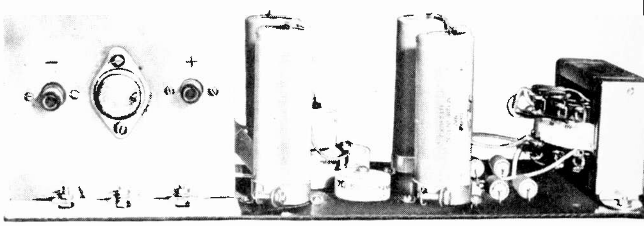
To understand the action of the twin shunt regulators, temporarily assume that the −12·5V output terminal is at zero voltage. The centre-tap and the positive outputs will then be positive in relation to the negative output. TR3 and TR4 collector-emitter voltages are both clamped at 12·5V, and the unregulated d.c. voltage is dropped across R7. Therefore, the voltage appearing at the junction of R7 and TR3 emitter is +25V relative to the assumed zero rail, with the centre-tap output at +12·5V. As all three output terminals are floating, it is a simple matter to connect the centre-tap output to an external earth and classify it as the zero voltage rail, with the other terminals forming positive and negative regulated outputs.

VR1 setting will determine the voltage across TR3, and VR2 the voltage across TR4. The range of adjustment of VR1 and VR2 is sufficient to allow for regulator diode (D5 and D6) tolerances on nominal voltage of ±15 per cent, and will therefore permit the use of manufacturers' rejects or "bargain" price regulator diodes. 10W diodes are specified for D5 and D6 in the Fig. 3.1 circuit, to achieve a low dynamic resistance, and reduce the short-term thermal changes which are inevitable when smaller regulator diodes are run at high temperatures.

Fig. 3.2 will give an idea of the capabilities of the regulated power supply, and maximum current limits. If an optional press-button switch is wired across one half of R7 (Fig. 3.1) output current can almost be doubled for short periods, and special purposes. The prolonged use of this extra current facility will, however, result in mains transformer overheating.

POWER PACK CONSTRUCTION

Low cost semiconductors were used throughout the prototype power pack. The diodes D1–D4 should have a p.i.v. rating of not less than 100V, and a maximum current rating of 1A or more. It is advisable to check all diodes with an ohmmeter, for high reverse resistance and correct polarity. The D5 and D6



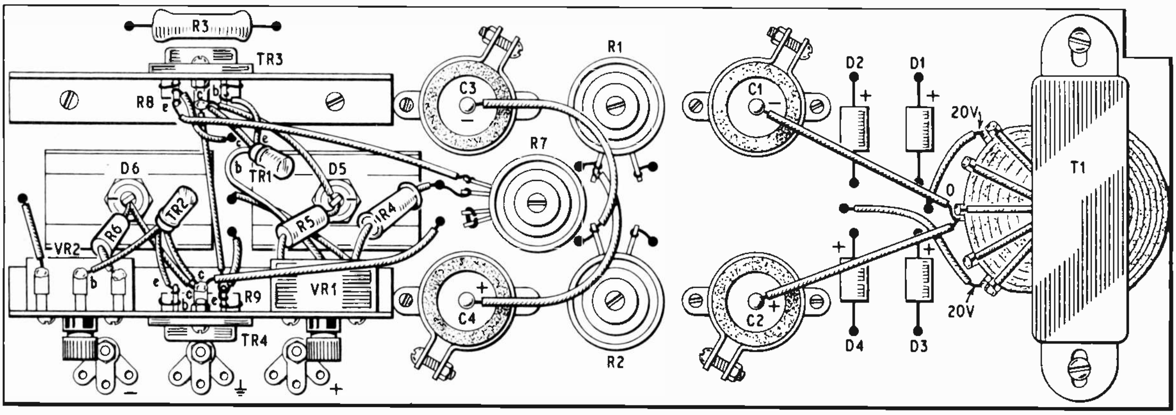


Fig. 3.4 Power supply component layout

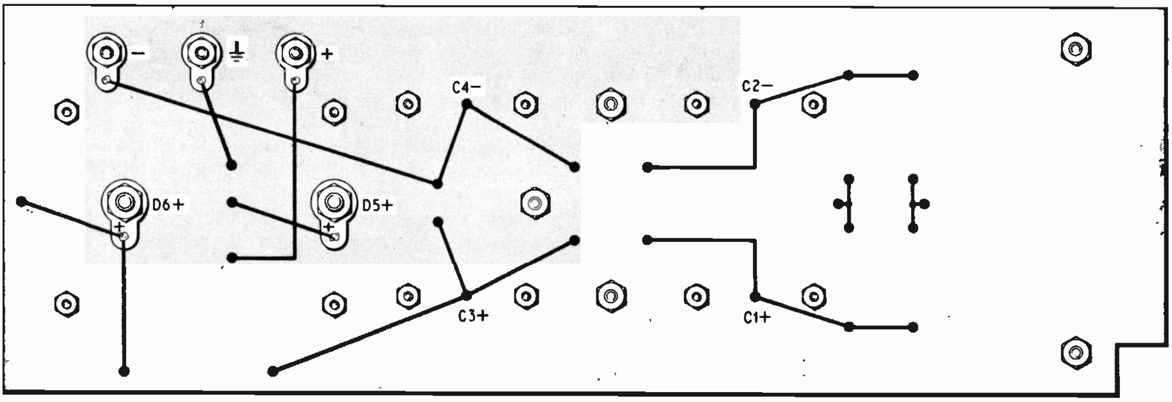


Fig. 3.5 Underside wiring of power supply panel

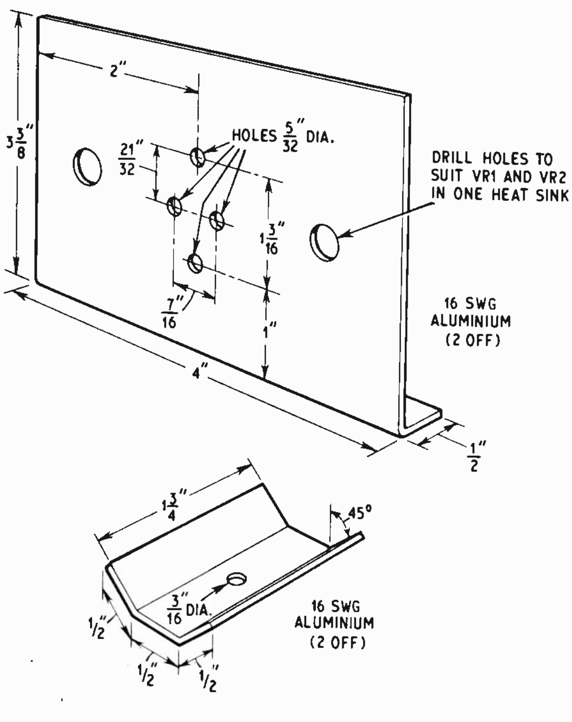


Fig. 3.6. Power supply heat sink details

measured voltage, when passing a current of about 100mA, can fall anywhere within the limits 12·5–17·5V.

If a choice exists, TR1–TR4 can be selected for highest *beta* gain, but matching is not necessary. Collector-emitter leakage currents of TR1 and TR2, with open circuit base, will preferably be below about 200μA at normal room temperature.

It is seriously recommended that the reader who intends to build PEAC should adhere closely to the semiconductor types specified here, and not consult other lists of equivalents. A key to transistor and diode connections appears in Fig. 3.3, and this covers all the semiconductors used in PEAC circuits.

Power pack components are assembled on a $\frac{1}{16}$in or $\frac{1}{8}$in s.r.b.p. panel measuring 4in × 12in. The panel sits on the wooden framework at the bottom of the UNIT "A" box. Component layout appears in Fig. 3.4, with the underside wiring in Fig. 3.5. Heat sinks for TR3, TR4, D5, and D6 are made up from 16 s.w.g. aluminium sheet, and measurements are given in Fig. 3.6.

First drill the s.r.b.p. chassis panel to accept hardware and wires, using Fig. 3.5 as a guide. Mount the mains transformer, capacitor clips, power resistors, and the three output terminal screws. Attach the regulator diodes, with their heat sinks and solder tags, to the panel, taking care not to damage the diode top terminals. Bolt TR4, VR1, and VR2 to the appropriate heat sink, solder R9 to TR4 emitter and base pins, and install the assembly on the s.r.b.p. panel. Similarly, bolt TR3 to its heat sink, complete with R8, and fix to panel.

Both power transistors should have a solder tag attached to their upper mounting bolts to make convenient connection to transistor collectors. Without insulating washers, TR3 and TR4 heat sinks will be "live", but damage is unlikely to result in the event of an accidental short-circuit.

Insert capacitors C1–C4 in clips, with polarity as indicated on Fig. 3.4. Also observe correct polarity when mounting diodes D1–D4. Before wiring up all components, insert R3 in the panel, alongside TR3 heat-sink.

COLOUR CODED WIRE

Wiring can start at the input end of the panel, with 6in lengths of orange, black, and green multi-stranded wire soldered to the live, neutral, and screen tags on the mains transformer. Red and blue wires are reserved exclusively for 12·5V d.c. positive and negative supply rails, with green wiring as the common earth throughout the computer.

Wire colour coding is almost essential for computer circuit interconnection, as it enormously simplifies fault tracing and assembly. However, the wiring of individual circuits, such as the power pack panel, can take the form of single colour sleeved 20 s.w.g. tinned copper wire.

It will be noticed (Fig. 3.4) that TR1 and TR2 are supported only by their leads, and this is to allow best positioning for good ventilation, well away from heat sinks. In the prototype R7 was made up from two 0·7A power resistor sections, to allow for the optional extra current facility mentioned earlier.

When power pack wiring is completed and checked, multiple solder tags can be fitted to the three output terminal screws.

TESTING THE POWER PACK

Connect the transformer input leads to the mains socket on the side panel of the UNIT "A" box, with the organge lead taken via FS1 (see Fig. 2.10 and Fig. 3.1), and, also join the neon indicator leads to the live and neutral mains socket screws.

Turn VR1 and VR2 fully anticlockwise and switch on. A quick check with a voltmeter will show if there is any serious departure from the voltages shown in Fig. 3.1. If any overheating of heat sinks or mains transformer seems imminent, switch off immediately and locate fault.

To set up the power pack, apply voltmeter leads to earth and positive output terminal, and advance VR1 for a reading of 12·5V. Repeat the procedure for the negative output and VR2. If it is impossible to bring an output to 12·5V, this will indicate a wiring fault or trouble with a regulator diode.

After the power pack has been left on for some time, VR1 and VR2 can be finally trimmed for exact outputs of $\pm$12·5V. With no external load on the power supply, TR3 and TR4 heat sinks can be expected to run fairly warm.

To ensure that power pack regulation conforms to the curve of Fig. 3.2, positive and negative outputs can be loaded by a selection of 5W resistors in series with an ammeter, while voltage is still being monitored. A worst case variation of 2 per cent change in voltage for 300mA change in current should be taken as an acceptable performance limit. When one half of R7 is temporarily shorted out, at least 50 per cent more current should be available before voltage drops beyond 2 per cent.

Locate the power pack inside the UNIT "A" box, and wire outputs to the main terminals TL1, TL2, and TL3. Voltage source dial alignment and setting up details will be discussed later, but a few rough checks with power on are in order, to see that all voltage source sockets and switches are functioning correctly.

OPERATIONAL AMPLIFIER

The most important analogue computing circuit is the operational amplifier; so named because it will perform a number of mathematical operations, such as addition, subtraction, change of sign, multiplication by a constant, division by a constant, and integration. All the thinking behind "op-amp" design is concerned with making the circuit as unobtrusive as possible, so that it can be regarded purely as an operational "black box".

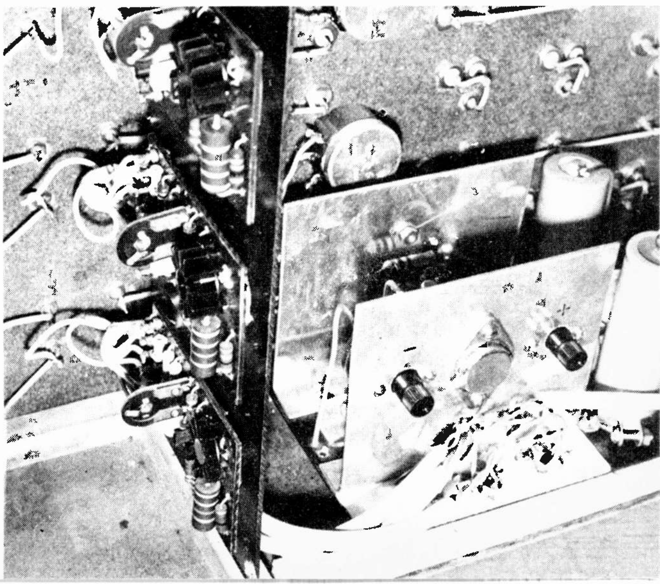
An analogue computer d.c. operational amplifier should comply with the following general requirements.

(a) Direct coupling between all stages to handle d.c. signals. Input and output terminals at earth potential in the absence of a signal, with 180 degree phase change (inversion) between input and output. Output voltage swings both positive and negative in relation to earth, and as large as the computer reference voltage ($\pm$10V).
(b) Large voltage gain in the open-loop configuration.
(c) Low output impedance.
(d) High input impedance.
(e) Very low input current.
(f) Sufficient bandwidth to cause negligible phase shift or attenuation of a signal up to the highest frequencies encountered.
(g) Insignificant output voltage drift over several hours.
(h) Good margin of stability when subjected to a wide range of different input, output, and feedback conditions.

Performance figures for UNIT "A" operational amplifiers are given in the Table 3.1, but to fully understand how some of the design problems are solved it is necessary to consult the actual "op-amp" circuit of Fig. 3.7.

OPERATIONAL AMPLIFIER CIRCUIT

The input stage of circuit Fig. 3.7 consists of a long-tailed pair (TR1, TR2), offering the advantages of high voltage gain, near zero input offset voltage relative to



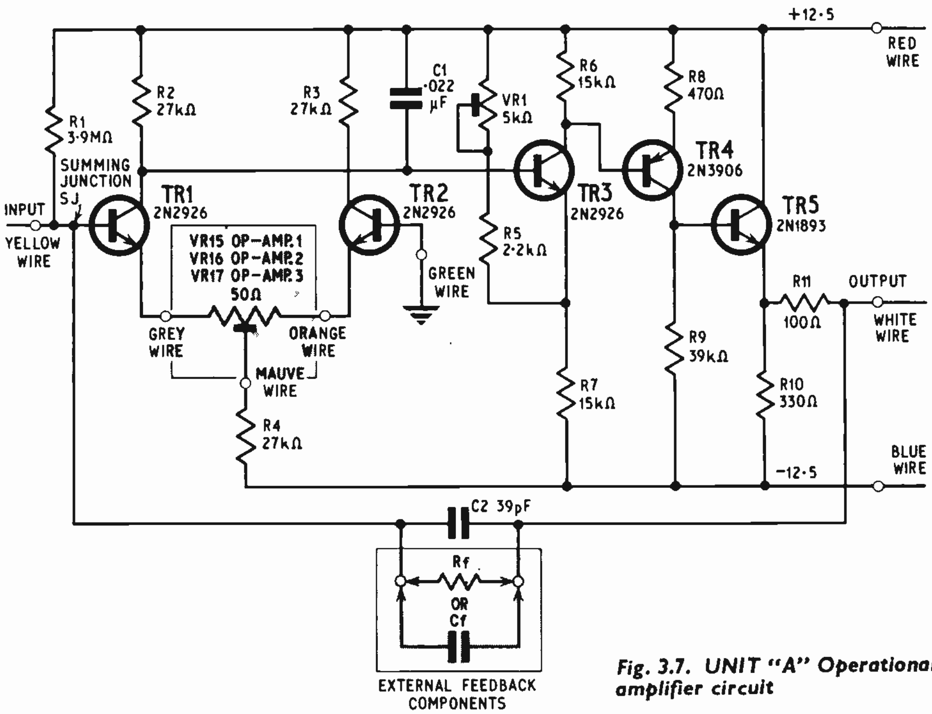


Fig. 3.7. UNIT "A" Operational amplifier circuit

COMPONENTS . . .

UNIT "A" OPERATIONAL AMPLIFIER

The following items are for a single amplifier, and are required in triplicate to cover the three amplifiers employed in UNIT "A".

Resistors
R1 3·9MΩ 5% carbon film
R2–R4 27kΩ 5% carbon film (3 off)
R5 2·2kΩ
R6, R7 15kΩ (2 off)
R8 470Ω
R9 39kΩ
R10 330Ω 2W
R11 100Ω
All ±10%, ½W carbon composition, except where otherwise stated

Potentiometer
VR1 5kΩ vertical skeleton pre-set

Capacitors
C1 0·022μF miniature polyester 250V d.c.
C2 39pF polystyrene 125V d.c.

Transistors
TR1–TR3 2N2926 orange (General Electric) *or* 2N3904 (Motorola) (3 off)
TR4 2N3906 (Motorola)
TR5 2N1893 (Bentron), 2N696, *or* 2N697 (General Electric).

Miscellaneous
S.r.b.p. panel 2in × 2¾in
Eight small turret tags
TO-5 transistor cooler Type BC105B (Bentron)
6 B.A. screws, nuts, and spacers
Stranded core p.v.c. wires; red, green, blue, orange, mauve, grey, yellow, and white
12in × 4in s.r.b.p. amplifier mount
Note: All transistors and cooler can be obtained from Rastra Electronics Ltd., 275–281 King Street, Hammersmith, W.6.

earth, and low drift with change in temperature when TR1 and TR2 are closely matched. The long-tailed pair also gives good rejection of drift induced by changes in supply voltage, and has a reasonably large input impedance at low collector current levels.

An input signal will undergo a phase change of 180 degrees between the base and collector of TR1, and the voltage datum level is shifted away from earth towards the positive rail voltage. Ignoring for the moment C1, the signal is passed straight to the base of TR3.

VR1, R5, and R7 form an adjustable potential divider across positive and negative supply rails, and the VR1 setting determines the working points of direct coupled stages TR3, TR4, and TR5. Front panel control VR15 sets the amplifier input at zero volts, while VR1 does the same for the output.

TR3, while contributing some voltage gain, also introduces another 180 degree change of phase, to bring the overall phase difference between the amplifier input and TR3 collector to zero. Obviously, the voltage at the collector of TR3 will be even closer to positive rail voltage than the collector of TR1, but this cumulative voltage shifting can be virtually eliminated by using a *pnp* transistor for TR4. At the same time, TR4 common emitter stage brings more voltage gain and another and final phase change of 180 degrees.

So, the situation at the collector of TR4, when VR15 and VR1 are at correct settings, will be no overall voltage shift, a total phase difference of 180 degrees, and a total voltage gain in the region of 5,000.

Finally, the addition of an emitter follower stage provides the low input impedance required for driving a variety of useful loads, without unwanted circuit complications. TR5 causes negligible further voltage shifting, adds no change of phase, and with a voltage gain very close to unity, will simply reduce the output impedance of the operational amplifier without modifying its other characteristics.

IMPORTANCE OF HIGH OPEN-LOOP GAIN

The ideal operational amplifier would have an infinite voltage gain when no feedback resistor was present, but since this is unattainable in practice, the effect of a finite open-loop gain on amplifier accuracy must be examined.

In Fig. 3.8, selected values of open-loop gain $-A$ are plotted against closed-loop gains $-G$, and percentage amplifier error. Closed-loop gains are normally restricted to 0·1–50 as this caters for almost all operational conditions, and it is seldom required to extend these limits. A different set of circumstances apply when the op-amp is used for integration, and these will be considered in detail later.

Very high $-A$ gains bring attendant drift and stability problems, and this in turn demands a larger number of components and more complicated circuitry to keep drift and stability within acceptable limits. At the opposite extreme, very simple amplifier circuits can be built to yield $-A$ gains in the region of 100–1,000, but when $-G$ approaches 50 the errors of such amplifiers would be near 10 per cent. Thus, if a low value for $-A$ was chosen, for the sake of simplicity, the range of available closed-loop gains would have to be restricted if the error was not to exceed one or two per cent, and this would place severe limitations on the operational flexibility of the amplifier.

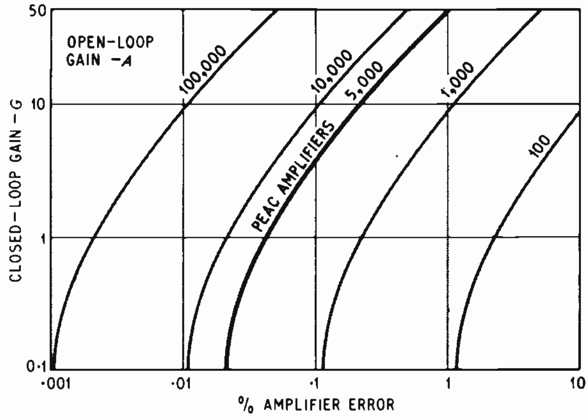


Fig. 3.8. Open-loop gain plotted against closed-loop gains and percentage amplifier error

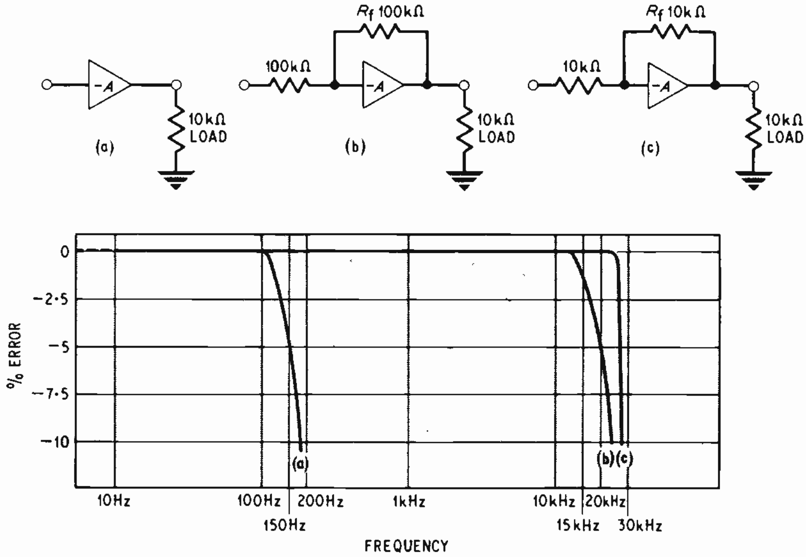


Fig. 3.9. Amplifier frequency response

It was assumed that PEAC operators would not wish to employ plug-in computing components with a selection tolerance better than, say, ±1 per cent. Therefore, the error contributed by the amplifier will preferably be less than external component errors, but not so small as to call for ridiculous extremes of circuit sophistication. The thickened curve of Fig. 3.8, corresponding to $-A = 5{,}000$, shows that the maximum error contribution of UNIT "A" amplifiers is 1 per cent or less for $-G$ gains of less than 50.

TABLE 3.1

UNIT "A" OPERATIONAL AMPLIFIER. TYPICAL PERFORMANCE

Supply voltage ±12·5V ±0·5%
Open-loop voltage gain 5,000 d.c.—100Hz. 200 at 10kHz
Maximum output voltage ±10V for loads >2kΩ
±5V for loads >300Ω
Input impedance 40kΩ approx.
Input current 0·005μA for 1V out
Closed-loop frequency response 0–10kHz within 1% when R_f = 100kΩ
Equivalent input drift ±0·5mV per hour
Input offset voltage and current almost zero when amplifier correctly balanced
R.M.S. noise, referred to input with input open circuit 200μV
Normal maximum range of plug-in components
R_{in} 2–100kΩ
R_f 10–100kΩ
C_f 1–0·01μF
Stability unconditional with all normal problem layouts

BANDWIDTH AND STABILITY

A direct coupled amplifier of the Fig. 3.7 type will display an almost constant phase change of exactly 180 degrees over a range of frequencies from d.c. to about 20kHz. Thereafter, with increasing frequency, the phase angle will begin to shift until, at several hundred kHz, and especially when the amplifier has a high gain, sufficient positive feedback is present to cause sustained oscillation. To counteract this instability, small capacitors are suitably situated in the op-amp circuit to reduce gain at critical frequencies, and it follows that the use of such capacitors will place a limitation on the available frequency response of the amplifier.

C1 of Fig. 3.7 will block the unwanted high frequency content of incoming signals, and plays a major role in determining the bandwidth of the amplifier. If C1 is reduced in value, bandwidth will be increased, but so will the likelihood of instability. Needless to say, any form of instability will be highly detrimental to accuracy, and must be avoided at all costs. C2 works in a different way, by introducing negative feedback and consequent loss of gain at very high frequencies. Both capacitors act together to combat instability under the very varied conditions of operational amplifier use.

The measured frequency response of a representative UNIT "A" amplifier is given in Fig. 3.9, and is very linear up to the well-defined break frequencies of (a) open-loop, (b) with feedback resistor of 100 kilohm, and (c) when R_f = 10 kilohm.

DRIFT

If a d.c. amplifier is adjusted so that its output voltage is zero when there is no input signal, over an interval of minutes, hours, or days—depending on the amplifier, its power supply, and its surroundings—a spurious voltage will begin to appear at the output. A poor amplifier in adverse conditions will require frequent manual adjustments to keep its output at zero. Fortunately, drift errors are very small when an operational amplifier is used for summing and sign changing, due to the presence of a feedback resistor, and no adjustment of the amplifier will be called for during intervals of perhaps several hours, except in applications requiring a very high degree of accuracy. However, when the operational amplifier is being used as an integrator, with a capacitor in its feedback loop, it is quite possible for drift errors to exceed 1 per cent within a space of less than an hour if suitable precautions are not taken.

The figure quoted in Table 3.1 for drift is the amount of input voltage, either positive or negative, required at the amplifier summing junction to reset the amplifier output to zero after it has been allowed to drift for one hour following a preliminary computer warm-up period. In practical terms, a drift of about $\pm 0{\cdot}5$mV

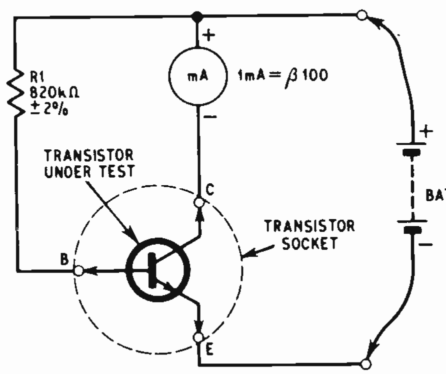
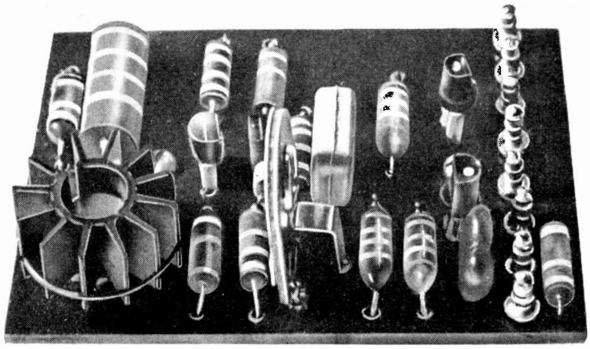


Fig. 3.10. Transistor test-rig. Note: reverse battery connections and milliammeter for pnp



per hour is not likely to prove to be too troublesome with most PEAC applications. Full scale analogue computers are sometimes installed in a temperature controlled computing room, and this considerably improves drift performance.

TRANSISTOR SELECTION

Several prototype UNIT "A" amplifiers were constructed using non-selected transistors, and about one third of the amplifiers failed to meet the specification of Table 3.1. Defects were due entirely to "spreads" in semiconductor characteristics, and disappointment will be avoided if all amplifier semiconductors are tested before use.

It has already been mentioned that the long-tailed pair input stage transistors (TR1 and TR2 in Fig. 3.7) should be matched. In all nine transistors of the same type will be required for TR1, TR2, and TR3 in the three operational amplifiers, and it will assist the matching and selection process if, say, one dozen transistors are purchased at the same time. No wastage will be involved as "spare" transistors can later be used up in other PEAC circuits.

A simple test-rig circuit is given in Fig. 3.10 to facilitate the matching of TR1 and TR2, and the circuit can also be quickly adapted for checking other transistors. The test-rig could take the form of a transistor socket and resistor mounted on an odd piece of s.r.b.p., or Veroboard, with a testmeter employed as a milliameter.

Select each TR1–TR2 pair for near identical *betas* of 100 or more; this will dispose of six transistors. Do not attempt to pair off transistors of different types even if they do have the same *beta*. From the remaining transistors, choose three with the highest *beta* for TR3.

Although TR4 is a *pnp* transistor, it must be of silicon construction for low leakage drift. The majority of *pnp* silicon types at present on the market are unsatisfactory for use in the op-amp circuit because they exhibit almost no gain at all at very low collector current levels. Of all the types so far tested only the 2N3906 was found to be consistently good at low currents, therefore a suitable equivalent cannot be quoted. To check TR4, reverse the battery leads to the Fig. 3.10 test-rig, and switch connections to the milliameter before plugging in the *pnp* transistor. TR4 should display a *beta* of about 50 or more.

When handling plastic encapsulated transistors, which tend to look alike, take note that lead connections do not necessarily conform to a common pattern. In particular, notice the lead differences between types 2N2926 and its equivalent 2N3904, and remember that the 2N3906 is *pnp*. To avoid mishaps, always refer to Fig. 3.3 before applying current to the transistor.

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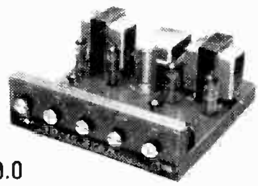

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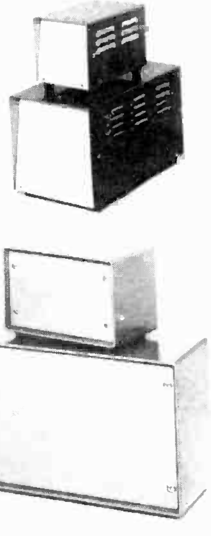

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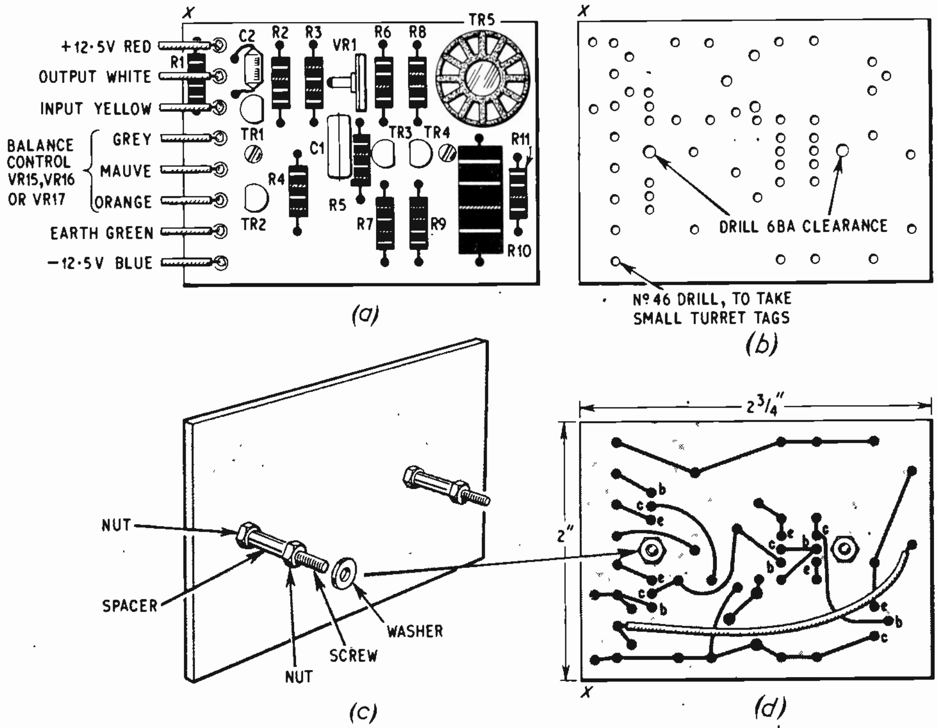


Fig. 3.11 UNIT "A" Operational amplifier constructional details. (a) component layout; (b) panel drilling; (c) mounting screws and stand-off spacers; (d) underside wiring (with 2N2926 used for TR1, TR2, and TR3)

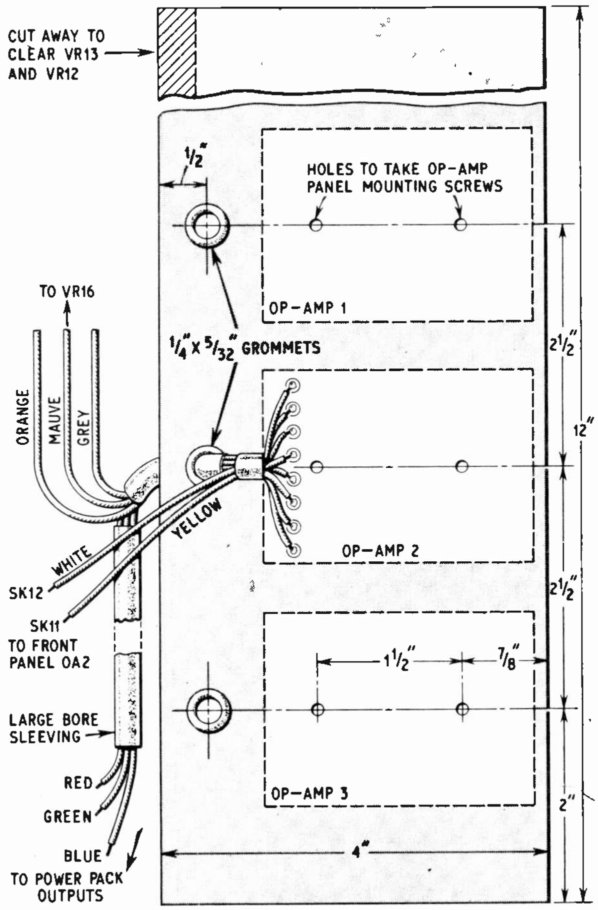


Fig. 3.12. Mounting and wiring details of operational amplifiers on slide-in mount

As a final check, insert all previously selected transistors into the Fig. 3.10 tester socket, but with their base leads not connected to R1, to see that there is little or no measurable leakage current.

UNIT "A" AMPLIFIER CONSTRUCTION

Cut three pieces of s.r.b.p. and finish to a size of 2in × 2¾in. Bind the panels together with Sellotape and drill according to Fig. 3.11(b). Separate the panels and remove drilling burrs, then rivet eight small turret tags in each panel in the positions shown in Fig. 3.11(a).

Starting with R1, components can be slipped into a panel and are soldered progressively in position on the underside. The underside wiring diagram of Fig. 3.11(d) applies to 2N2926 transistors for TR1, TR2, and TR3. The wiring will differ slightly when 2N3904 transistors are employed.

Before mounting each transistor, slip ⅛in of insulated sleeving on to the transistor leads to act as spacers. The output transistor TR5 is also fitted with a push-fit heat-sink before fitting to panel.

Try to avoid overheating components, and allow each soldered joint to really get cool before starting the next joint. When the wiring of each amplifier panel is complete, and checked, fit mounting screws with stand-off spacers as shown in Fig. 3.11(c).

Next prepare a slide-in mount for the amplifiers, made from 12in × 4in s.r.b.p. according to Fig. 3.12, and make sure that it will slide easily into the wooden slots provided in the UNIT "A" box (Fig. 2.11). The cut-away portion at the top of the mount should clear potentiometers VR12 and VR13. Insert rubber grommets and bolt the amplifiers to the mount.

WIRING HARNESS

Each amplifier is furnished with its own simple wiring harness. The harness for operational amplifier No. 2 is depicted in Fig. 3.12. Red, green, and blue wires will go from the amplifier turret tags through the nearest grommet, run down to the bottom of the mount, and cross to the power pack output solder tags. Orange, mauve, and grey wires pass through the same grommet to the appropriate balance control on the front panel which, for OA2, is VR16. Yellow and white wires go from the amplifier turret tags straight to OA2/SK11 and SK12 on the front panel (see Fig. 2.4).

Roughly estimate the required length of each group of wires belonging to amplifier No. 2, and allow a slight margin for error. Large bore sleeving can be used to contain the wires and form the harness. Repeat the above procedure for amplifiers No. 1 and No. 3. Solder harnesses to amplifier turret tags and pass through grommets. Slide the amplifier mount, complete with amplifiers and harnesses, into position in the UNIT "A" box, and connect and solder all orange, mauve, grey, yellow, and white wires. Do not yet connect up any of the red, green, or blue wires to the power pack.

TESTING AMPLIFIERS

Solder only the red, green, and blue harness wires belonging to amplifier No. 1 to positive, earth, and negative power pack output solder tags, respectively. Connect a 10V d.c. voltmeter to OA1/SK14 (earth), and OA1/SK7 or SK13 (amplifier output, see Fig. 2.9). A testmeter can be employed for setting up the amplifier but, because outputs may be positive or negative, a centre-zero ±10V d.c. instrument will be slightly more convenient.

Switch on the power pack. The voltmeter pointer will almost certainly go close to or beyond full scale. Adjust the pre-set control VR1, on amplifier No. 1 panel, for near zero volts output. Do not worry at this early stage if the adjustment seems to be critical, or if there is serious drift, as long as it is possible to momentarily attain a zero output. If the voltmeter shows no inclination to read zero volts, an amplifier fault will be indicated.

Assuming that it is possible to zero the amplifier output by means of VR1, insert a 10 kilohm resistor into miniature sockets OA1/SK11, SK12, whereupon the output voltage should drop to within 1mV or 2mV of zero. When OA1/SK10 is linked to any green socket, say VS5/SK4, by means of a length of wire terminated at each end with a plug to fit front panel sockets, the voltmeter will again display a positive or negative output voltage. Attempt to re-zero the amplifier output, this time by adjustment of front-panel control VR15; a failure to do so will again indicate an amplifier fault.

Repeat exactly the above procedures for amplifiers No. 2 and No. 3. To inspect individual amplifier panels, unscrew the nuts on the amplifier mounting screws to allow the amplifier to be swung away from the slide-in mount without disconnecting any wiring. It is possible to carry out minor component replacements without removing the amplifier from its harness or from the UNIT "A" box.

Next month: Instructions for setting up and using UNIT "A". Practical problem examples.

CONSTRUCTION KIT REPORT

Knight KG-668 Sine/Square Wave Generator

IF YOU'VE skipped through magazine constructional projects involving frequency conscious design or wished you could optimise that low fi amplifier or troubleshoot that tape recorder; and if you can couple these inclinations with a do-it-yourself enthusiasm, then we can readily recommend the purchase of the Knight KG-688 Sine/Square Wave Generator, one of the many construction kits now being marketed exclusively by Electroniques (prop. STC) Ltd. This piece of equipment combines an attractive specification with an all solid state design.

PERFORMANCE DETAILS

The sine wave frequency range covers 20Hz to 2MHz in five decade ranges with distortion in the audio range less than 0·25 per cent. The output voltages are 0–7·5V r.m.s. into loads of 10 kilohm or more and 0–6·5V r.m.s. into 600 ohms. The square wave frequency range extends from 20Hz to 200KHz in four ranges, the output voltage being 0–10V peak-to-peak into loads of 10 kilohm or more. The peaks are positive going with clamped reference to earth. Rise time is less than 0·1μsec at 20kHz. A six switch attenuator permits discrete 1dB steps up to a total of 41dB of attenuation of sine waves into 600 ohms.

ASSEMBLING THE KIT

All resistors and diodes were supplied on marked cards and colour coded connecting wires were precut to size with their ends stripped ready for soldering.

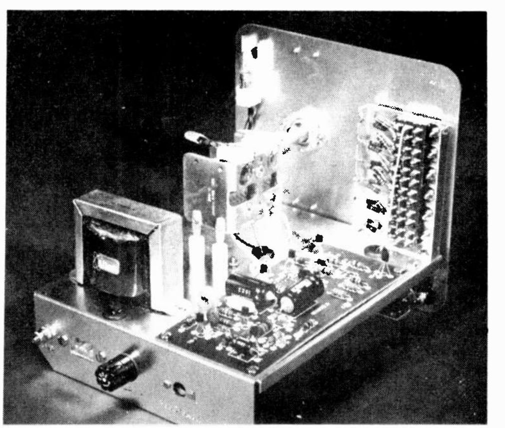
The only tools required were screwdriver, sidecutters, pliers, and soldering iron, and if you are a beginner there are liberal construction hints in using these both in wiring and soldering. Assembly instructions are extremely clear with step by step pictorials.

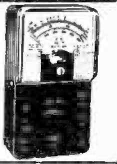
The time spent on construction of the Sine/Square Wave Generator was a leisurely 13 hours spread over a number of days. This period included calibration and a final check out to ensure that the generator fulfilled its specification.

TROUBLESHOOTING CHARTS

Any faults in the completed generator can be rapidly resolved with the troubleshooting charts contained in the operator's manual which also includes calibration notes and typical application procedures in the testing of amplifiers for phase shift, amplitude, and distortion.

Signal tracing techniques are outlined for the isolation of defective stages in television, radio and P.A. equipment. By using the attenuator amplification gains or losses can also be rapidly and accurately calculated in decibels.





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P. & P. on each 7/6.

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ONLY **£4.9.6** *Plus 7/6 Post & Packing*

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A superb high quality yet inexpensive stereo amplifier. Due to great demand we are now able to offer this precision made instrument at a fantastically low price. Its quality, reliability and styling has in no way been marred by its low price.

SPECIFICATIONS

Elegant styled cabinet (size 16in wide, 5in high, 8½in deep) in black rexine and woodgrained sides. Brushed aluminium front panel with contrasting black/silver knobs.

CONTROLS

Stereo/mono switch, gram/aux. switch, volume left, volume right, treble (cut and lift), bass (cut and lift), separate on/off switch, neon pilot indicator.

INPUTS AND OUTPUTS (PER CHANNEL)

Gram., aux., tape out and speaker out. A switched mains socket is also provided at the rear of unit. Employs Mullard valves throughout. ECC83 and 2 ECL 86 with a metal bridge rectification.

TECHNICAL SPECIFICATIONS

Gram. sensitivity 40mv at 1KHz, Aux. sensitivity 50mv at 1KHz (sensitivities are given for rated output). 4 watts R.M.S. per channel, 8 watts R.M.S. in mono position. Bass control at 100Hz lift +9db, cut – 10db. Treble control at 10KHz lift + 8db, cut – 13db. Total harmonic distortion 0·35% at 3 watts and 2% for rated output at 1KHz. Negative feedback 13db at 1KHz. Mains supply 220–250V A.C. 50–60H. Output matches into standard 3 ohms speaker system. Suitable 10in × 6in eliptical speakers are available at 29/6 ea. plus 5/- P. & P.

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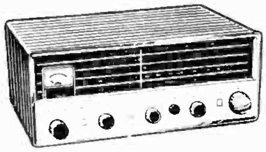

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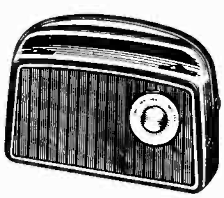

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- Simple connections to only 6 tags on the R.F./I.F. module, 3 I.F. stages, osc. coil and 3 transistors which with their associated components are completely wired.
- Only 4 connections on the A.F. module to complete the 4 transistor 600 milli-watt solid state amplifier.
- Pre-aligned R.F./I.F. module built and tested.
- A.F. module built and tested.
- Fully tunable over M.W. and L.W. bands. M.W. 540-1640 Kc/s (557-183 metres). L.W. 150-275 Kc/s (2000-1100 metres).
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- Finger tip controls.
- Class "B" modulised output stage with thermistor controlled heat stabilization. Class "B" output stage ensures long battery life. Current drain is proportional to the output level. Total current drain of the receiver under no signal conditions is 10-12mA. At reasonable listening level 20-30mA.
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2½ watt All Transistor Amplifier, AC mains 240v. Size 7″ × 4½″ × 1¾″. Frequency response 100 c/s—10 Kc/s. Semiconductors, two OC 75's, two AC 128's and two stabilisers AA129. Tone and volume controls on flying leads. £2.10.0. P. & P. 3/6. Suitable 8″ × 5″ 10,000 line high flux speaker 18/6. P. & P. 2/-.

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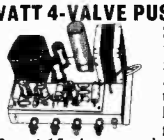

Size 9″×6″×1½″. A.C. Mains, 200-250 v. 4 valves. For use with Std. or L.P. records, musical instruments. All makes of pick-ups and mikes. Output 8 watts at 5 per cent of total distortion. Separate bass and treble lift control. Two inputs, with controls for gram. and mike. Output transformer tapped for 3 and 15 ohm speech coils. Built and tested. £4.4.0. P. & P. 11/-. 8″ × 5″ Speaker to suit. Price 14/6 plus 1/6 P. & P. Crystal Mike to suit 12/6 plus 1/6 P. & P.

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By M. L. Michaelis M.A.

5—SPECTROSCOPY; STRACE GAMMA RAY SPECTROMETER UNIT

In the first four instalments of this series, we learnt that *activity* determinations and *energy* determinations are two important types of measurements in studying nuclear radiation.

The activity of a radioactive substance is the number of atoms in the given amount of substance which disintegrate per unit time with the emission of nuclear radiation, irrespective of the type of disintegration or type and energy of emitted nuclear radiation.

The energy refers to the violence of emission of each particle or quantum of nuclear radiation, and is more or less specific for each species of radioactive atom.

Compared with an ordinary radio wave transmission, the activity is formally analogous to the transmitter power, and the energy is formally analogous to the transmitter frequency.

STRACE GAMMA RAY SPECTROMETER UNIT

MEASUREMENT OF ENERGY LEVELS

A simple G.M. counter is an activity measuring device, since it cannot distinguish nuclear radiations of different energies. All radiations which produce response pulses from the G.M. counter at all, produce electrically identical pulses. On the other hand, we have seen that the *Scintillation Detector* is a device which can be used to measure both activity and energy of a nuclear radiation, because the amplitude of its electrical output pulses is proportional to the energy of the detected nuclear radiation.

If two or more nuclear radiations of different energies, for example various species of radioactive atoms, are present simultaneously, the scintillation detector will produce a corresponding mixture of output pulses of different amplitudes. The number of pulses produced per unit time for each amplitude will be independent proportional measures of the activities of the respective species of radioactive atoms which are present.

The electronic process of sorting the pulses according to amplitude, and counting each amplitude class separately, is clearly an elegant and very important method for analysing mixtures of radioactive substances. It is analogous to measuring the field strengths of various radio transmitters operating within a frequency band of interest, or splitting a coloured light into its spectral components and measuring the relative or absolute intensities of the latter. Hence the name *spectroscopy*, which is applied to the process of selective activity measurement for different energy levels, in nuclear radiation studies too.

The entire electronic circuitry which is interposed between a scintillation detector (or any other spectroscopic nuclear radiation detector) and the radiation meter is commonly known as a *kick-sorter amplifier*. Its purpose is to sort the kicks or pulses according to amplitude, i.e. according to energy of the responsible nuclear radiation, feeding only those pulses in the range of interest to the radiation meter for counting.

GAMMA RAY SPECTROMETER UNIT

This month we describe the electronic principles of kick-sorter amplifiers, or nuclear radiation spectrometers. The questions of sample preparation, presentation to the detector, spectroscopic routine working and interpretation of results, will be taken up in a later instalment of this series, when we describe practical experiments with the equipment.

The description of electronic principles follows the details of the *Gamma Ray Spectrometer Unit* of our STRACE equipment, with appropriate reference to general features and alternative refinements found in professional equipment. (Reference should be made to Fig. 2.1

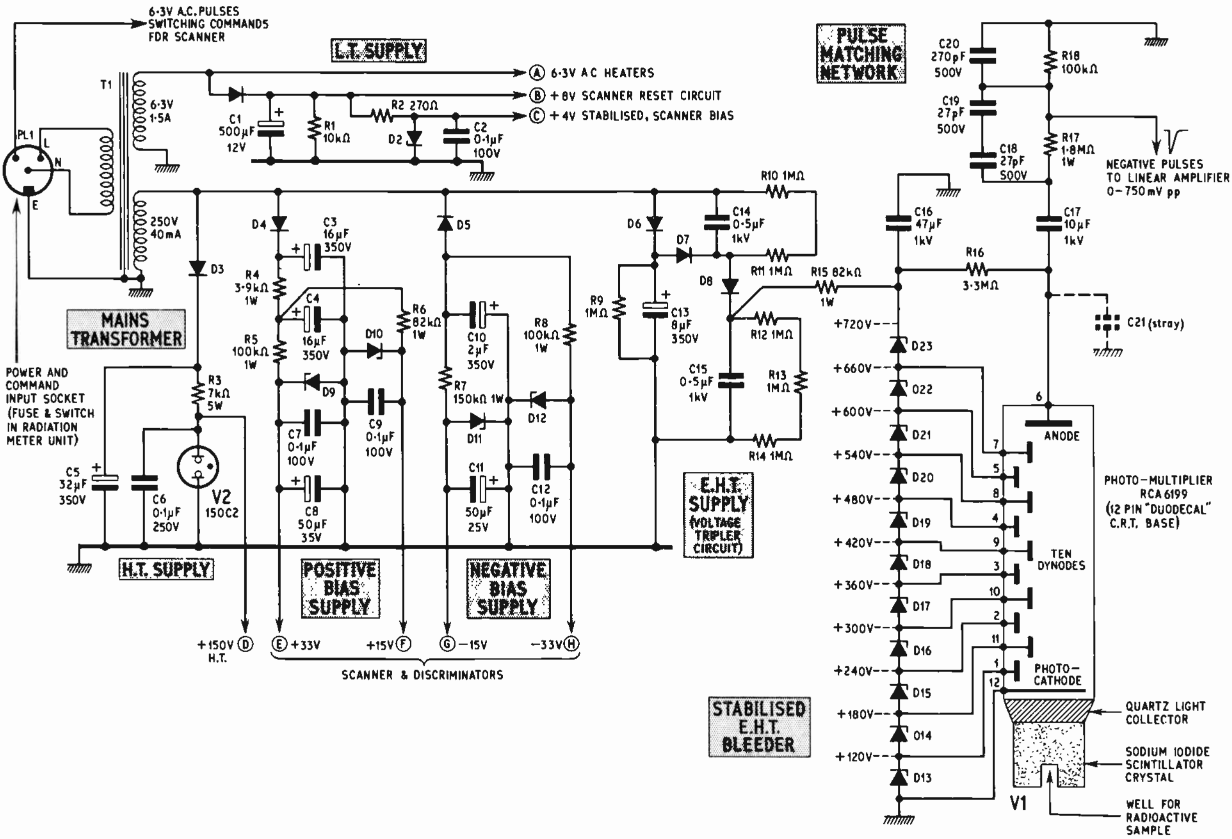

Fig. 5.1. STRACE Gamma Ray Spectrometer: Circuit diagram of the power supply and scintillation detector

block diagram of STRACE for an overall picture of the Gamma Ray Spectrometer Unit circuitry.)

POWER SUPPLIES

Fig. 5.1 shows the complete power supplies for the spectrometer, and also the scintillation detector.

Numerous features of general importance are illustrated here, notably the common practice of deriving the many different voltages required by the logical circuits from a single transformer winding of "conventional" rating. Optimum decoupling is achieved by using separate rectifiers for the various groups of supplies. Mixed polarities of the d.c. output voltages are readily available by connecting the rectifiers with differing polarities.

The rectifier and smoothing circuits as such, associated with D3, D4, and D5 in Fig. 5.1, are conventional. All supplies are stabilised, since supply voltage fluctuations would otherwise lead to intolerable drifts in the pulse amplitude sorting process. The circuit around D6, D7, D8 is a voltage tripler fed from the same transformer winding. In general, the use of such voltage multiplier rectifier circuits is at least as common as the adoption of true e.h.t. circuits (high voltage transformers), since the e.h.t. currents required by radiation detectors are usually very small.

VOLTAGE TRIPLER CIRCUIT

On the first half-cycle from T1, C13 charges to the peak level via D6. On the next half-cycle, D6 is cut off whilst C13 and T1 act as doubled source voltage in series, charging C14 to twice the peak level via D7. On the third half-cycle from T1, D6 replaces charge in C13, D7 is cut off, and charged C14 in series with T1 acts as tripled source voltage and charges C15 to the final voltage via D8. The sequence of events then repeats indefinitely.

The resistors R9 to R14 are included for safety, to discharge the circuit after switch-off. The diode/capacitor network may be extended according to the same ladder-symmetry, to produce any desired voltage multiplication factor, for feeding other radiation detectors which may require e.h.t. potentials of many kilovolts. The higher the multiplication factor chosen, the smaller the available output current for a given ripple factor, and the poorer the regulation and stabilisation. These considerations ultimately impose a limit, so that other types of e.h.t. power supply circuits are then resorted to in high-stability professional equipment.

Television-type circuits based on the line frequency oscillator principle with booster circuit are often found here, as well as high voltage mains frequency transformers. Portable equipment often uses transistor oscillators with a high-ratio step-up transformer, sometimes followed by a voltage multiplier rectifier circuit on the secondary side.

THE PHOTOMULTIPLIER

The photocathode of the photomultiplier (V1 in Fig. 5.1) is a very thin, translucent film of caesium/antimony deposited evenly on the flat front face. A piece of optically flawless quartz is in good optical contact with the photocathode on one side and the sodium iodide crystal on the other side, so that the light emitted in the crystal is guided as evenly as possible on to the entire area of the photocathode.

Photoelectrons emitted from the photocathode are accelerated to the first dynode (pin 1); there they knock-out a larger number of electrons by secondary emission. These are accelerated to the second dynode (pin 11), where more electrons again result by secondary emission. Since each one of the ten successive dynodes rests at a higher potential than its predecessor, the number of electrons increases cumulatively at each step, so that finally a large burst of electric charge reaches the anode

In the specified detector and with the circuit shown, about half a million times as many electrons reach the

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anode as departed from the cathode, so that large output signals are obtained in spite of the *extremely* feeble light intensity emitted by the sodium iodide crystal.

The dynodes are actually arranged in a complicated geometric manner, to prevent electrons bypassing certain stages, or feeding back to earlier stages to cause instability.

It is evident that the output signal is a *pulse of charge.* This is instantaneously deposited in the stray capacitance C21 at the anode. The *voltage* peak amplitude of the pulse at the anode is thus determined solely by the value of C21, and is quite independent of the load resistance R16. It is therefore most important to keep C21 as small as possible; otherwise the pulse voltage will not be sufficiently greater than the mains ripple voltage at the anode. It is not possible *under any circumstances* to operate the tube with grounded anode circuit and negative e.h.t. applied to the cathode: this would lead to immediate destruction of the photocathode.

LIGHT PROOF CASING

The photomultiplier would also be destroyed immediately if exposed to light of any intensity visible to the naked eye or even less, with the electrode voltages connected. The specified scintillation detector unit is thus fitted with a light-proof casing enclosing both the crystal and the photomultiplier. The casing also includes a mumetal shield around the photomultiplier tube, since the electron optics of the electrons travelling between the dynodes is otherwise disturbed by even quite small magnetic fields, leading to uncontrollable gain fluctuations.

Since the number of electrons in each pulse is multiplied in ten stages, and the secondary emission factor at each stage is a function of the applied voltage, the overall gain between cathode and anode varies with the tenth power of the applied voltage, i.e. it is *extraordinarily* sensitive to fluctuations of e.h.t. voltage. Any gain fluctuation of the photomultiplier would mean a fluctuation of the ratio of output pulse amplitude across C21 to energy of the incident nuclear radiation, and is thus most serious.

Professional equipment consequently uses the most refined devices for stabilising the e.h.t. voltage. For our purposes, however, the chain of Zener diodes, D13 to D23 in Fig. 5.1, provides adequate stabilisation and makes the ratio (pulse amplitude/radiation energy) constant to within about ± 2 per cent in this circuit.

DETECTOR OUTPUT PULSE

Optimum pulse uniformity is obtained by making the voltage between the first dynode and the cathode about twice as great as that between any two successive dynodes. The final multiplied burst of electrons lands abruptly in C21, so that the voltage pulse at the anode commences with a virtually instantaneous negative stroke of Q/C volts, where Q coulombs is the deposited electron charge and C farads is the value of the stray capacitance C21. This negative voltage then reduces exponentially, as the electrons leak away through the anode load resistor R16. The load resistor thus determines the duration, not the amplitude, of the pulse. The product of C21 and R16 (Fig. 5.1) is about 50μs, and the pulse amplitude is about —5V per MeV nuclear radiation energy deposited in the crystal.

Our pulses are thus of about the same duration as those from a G.M. counter, so that the circuit of Fig. 5.1 can not separate two successive pulses faster than a 20kHz interval. Whilst this is fully adequate for amateur purposes, it is not an inherent limitation of the scintillation detector, as it was for the G.M. counter on account of the gas de-ionisation time there required. If the anode load resistor of a scintillation detector is made sufficiently small, pulse rates of many MHz, or even in the u.h.f. range, can be handled.

It is not as much that professional studies demand such enormous counting rates, but rather that correspondingly small time intervals must be resolved. For example, the time taken by a particle of nuclear radiation in travelling from one detector to the next one can give important information concerning its trajectory and energy. These times are extremely short. Successive stages of decay of a radioactive atom may follow at u.h.f. time intervals. If these can be measured accurately, valuable inferences can be drawn concerning the nuclear structure of the atoms involved. Special scintillation detectors for such studies often match the anode directly into a 60 ohm coaxial cable, and very refined u.h.f. pulse amplifier techniques are employed to process the pulses.

LINEAR AMPLIFIER

Whilst sacrificing the time-resolution capabilities inherent in a scintillation detector, our pulse amplifier (Fig. 5.2) nevertheless gives very good performance and illustrates the basic principles involved.

The purpose of the amplifier is to raise the voltage range of the pulses to the optimum range of the amplitude discriminator, i.e. to levels much greater than the threshold fluctuation of the discriminator, yet within the linear range of the discriminator. The amplifier must be linear, i.e. it must amplify all relevant pulse voltages by the same amount, so that the energy relationship is not falsified.

In our case, we do not need much gain, because it is merely necessary to compensate the attenuation of the pulse matching network of Fig. 5.1, which was required to reduce loading and stray capacitance at the detector anode.

Low-output spectroscopic detectors, such as many barrier-layer semiconductor devices, often require high-gain amplifiers, aggravating the basic problems discussed now in respect of Fig. 5.2.

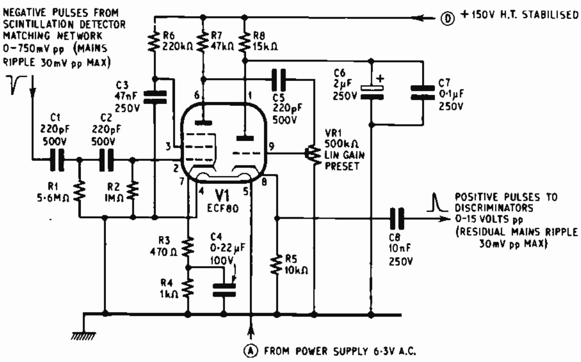

Fig. 5.2. STRACE Gamma Ray Spectrometer: Circuit diagram of the linear pulse amplifier

RESTRICTED BANDWIDTH

The type of linear amplifier required for nuclear radiation spectroscopy is always a *bandpass* amplifier, i.e. it is required to respond to a certain range of frequencies and to be insensitive to lower or higher ones. Restriction of the bandwidth to no more than the range necessary to handle the output pulses from the detector reduces random noise. Above all, rejection of low frequencies will remove even severe mains ripple components in the input signal mixture.

It is important to realise that the pulse repetition frequency is much less important than the pulse shape, for determining the optimum bandwidth and passband position of the amplifier.

For example, a train of 50μs pulses with a mean repetition frequency of 50Hz contains only a very small Fourier wave component of 50Hz frequency. The dominant component lies at the reciprocal of the pulse duration, i.e. around 20kHz in this example. The amplifier must therefore be designed to have peak response over a range around 20kHz, whereas gain should be negligible around 50Hz, and it is also undesirable to have significant gain at frequencies very much greater than 20kHz, since this would only increase susceptibility to noise and interference.

Amplifiers for use with fast resolution scintillation detectors mentioned earlier (low anode load values for detector) must have peak responses in the r.f. bands, or even in the v.h.f. or u.h.f. ranges, according to circumstances, but the principles remain the same. The actual figures in the above example apply approximately to our amplifier of Fig. 5.2.

GAIN STABILISATION

The small values of C1, C2 in relation to R1, R2 reduce gain at mains ripple frequency. C3 and C4 are also too small to act as effective bypasses for mains frequencies, so that strong cathode and screen negative feedback further reduces gain at mains ripple frequency. For frequencies around 20kHz, i.e. for the major Fourier components of the detector output pulses, the circuit possesses full gain, which is stabilised against valve ageing with the help of R3 providing cathode negative feedback.

Gain stabilisation is always effected with the help of negative feedback, although extremely complex circuits are often found for the purpose in professional amplifiers for high accuracy. The gain reduction at frequencies very much greater than 20kHz is obtained chiefly with the high value of R7 in conjunction with its stray capacitances.

The triode section of the ECF80 valve (V1b) is simply a cathode follower to establish low output impedance for feeding the scanner and discriminators without voltage collapse.

OVERLOAD PERFORMANCE

Apart from measures to be taken for establishing optimum bandwidth and for stabilising and linearising the gain, a third feature is of equal importance in the design of spectrometer amplifiers.

Isolated pulses will arrive with amplitudes enormously greater than the normal working range, for example, if a high-energy cosmic ray happens to be absorbed by the radiation detector. Such spurious large pulses must not result in amplifier blocking for a subsequent time, large compared to the mean interval between wanted pulses, since otherwise many of the latter will be lost.

In a simple amplifier like Fig. 5.2, blocking on excessive input amplitudes is due to grid capacitors charging-up on grid current. An excessive positive input pulse can not arise, because the detector gives negative pulses. Thus there is danger of blocking only at V1b grid (pin 9). But the triode is a cathode follower, so that very large amplitudes are necessary before grid current is drawn. The pentode (V1a) is cut off before R7 can develop enough pulse voltage to draw grid current at pin 9 of the triode.

In general, if grid current is drawn in any stage on excessive pulse amplitudes, the recovery is adequately fast if the product of grid capacitor and gridleak (grid circuit time constant) is at most equal to a few times the pulse width. Since the pulse interval is normally much greater than the pulse width, the amplifier will then most likely have recovered by the time the next wanted pulse arrives.

The demand to make grid circuit time constants comparable to the pulse width is equivalent to rejection of low-frequency components and restriction of the amplifier response to the principal Fourier components of the pulses. This underlines even more clearly, why the amplifier must be a bandpass and not a low-pass type.

There are other ways of avoiding overload blocking, apart from correct dimensioning of grid circuit time constants. These are based on various forms of negative feedback, balanced amplifiers, diode traps, and all manner of other devices.

THE SCANNER

The scanner is the actual heart of the kick-sorter. It sorts out all pulses falling within a narrow range of amplitudes, and passes only these to the radiation meter unit for counting (activity determination). As soon as the activity reading has been established for this amplitude range (energy level), the scanner moves on to the next adjacent small amplitude range for the next reading. This process is repeated until all amplitude levels of interest have been covered successively.

More advanced professional equipment, especially if entirely digital, often employs numerous amplitude discriminators with threshold levels staggered progressively

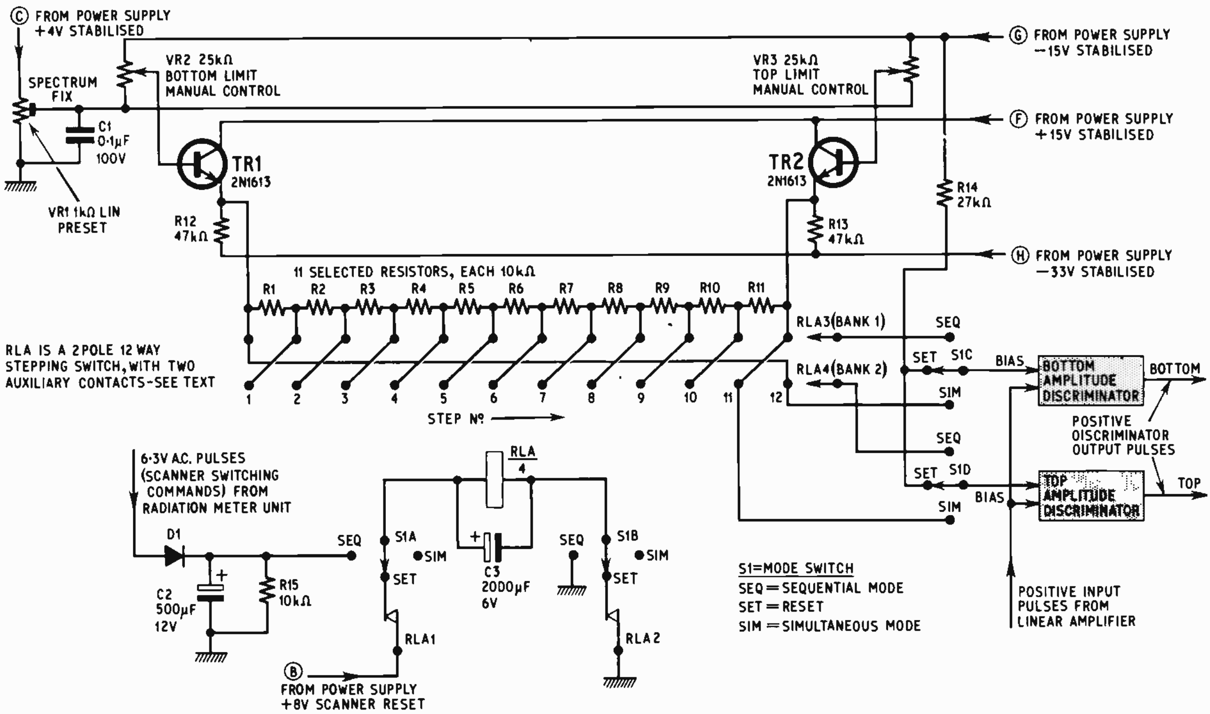

Fig. 5.3. STRACE Gamma Ray Spectrometer: Circuit diagram of the sequential scanner

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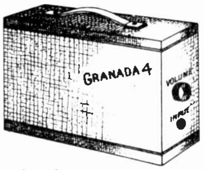

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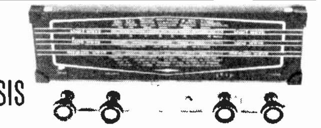

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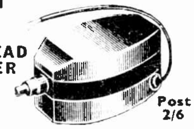

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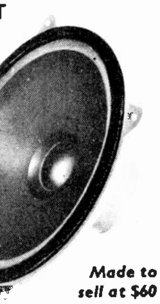

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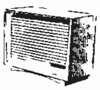

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Many hundreds of channels are operated simultaneously in this manner in some advanced equipments. Their complexity and cost is clearly quite beyond amateur resources, but the rapidity with which a complete spectrum is obtained therewith makes them professionally economical propositions.

SEQUENTIAL METHOD

The scanner in our STRACE equipment is *sequential*, i.e. its selection channel is moved successively to the various energy levels.

The pulse amplitude discrimination process itself is very simple, and most professional circuits, however much they may differ in detail, employ essentially the same principle. A diode (in general, the grid/cathode path of a valve or the barrier-layer of a semiconductor) is biased with an adjustable inverse d.c. voltage. The pulses to be discriminated are applied at the same time. Only those pulses whose amplitudes exceed the standing inverse d.c. voltage can briefly open the diode and pass on to the next stage.

According to the d.c. voltage setting, different threshold levels can be selected. However, the function remains a mere "cut" into two classes, one greater than and one less than the threshold.

For true energy level selection, i.e. selection of pulses with amplitudes within a narrow range, to the exclusion of all others greater or smaller, we need *two* threshold cuts. One of these is set to the bottom limit, and the other one to the top limit of the range to be selected. A further logic circuit is then interposed to reject all pulses from the lower-limit discriminator which are simultaneously accompanied by a pulse from the upper limit discriminator. The remainder consists of pulses lying between the two limits.

SCANNER CIRCUIT

Fig. 5.3 shows the scanner circuit of the STRACE spectrometer. VR2 and VR3 select the two threshold bias voltages, which are decoupled by the respective buffer emitter followers TR1 and TR2, to prevent mutual interaction of the potentiometer settings. The voltage range between the two threshold limits is divided into 11 equal intervals with the precision resistors R1 to R11. These resistors are connected sequentially to the two wafers of a 2-pole 12-way stepping switch driven by the solenoid RLA. Each time RLA is briefly energised, wipers A3 and A4 advance one contact, in the direction of increasing numbers. After step 12, the wipers return to step 1 on the next cyle. The contacts are, in fact, arranged in a circle and are drawn in a line only for clarity in Fig. 5.3.

INTERVAL LOGIC

With the four-wafer function switch S1 set to "SEQ", the actual threshold levels of the two amplitude discriminators differ by the voltage drop across successive resistors, i.e. by one eleventh of the difference between the settings of VR2 and VR3.

On step No. 12, the entire voltage difference is applied between the discriminators, but in the reverse sense, so that the top discriminator then always fires when the bottom one does, and no pulses appear in the difference channel, whatever the potentiometer settings. This writes a brief zero line in the radiation meter unit and gives visual separation between successive repeated recordings of the 12-step spectrum when the equipment is left running.

The command pulses for proceeding to successive steps are derived from the timebase in the radiation meter unit. The 12-step spectrum is repeated indefinitely and automatically, until switched off.

In the setting "SIM" of S1, the threshold voltages from the potentiometers VR2 and VR3 are fed directly to the respective discriminators, and the stepping switch mechanism is inoperative. The potentiometers may then be set directly to an amplitude range of interest. This mode is required when the aim is not to scan a complete spectrum or part thereof, but rather to observe a particular species and the decay of its activity with time, i.e. to study the lifetime of a particular component in a radioactive mixture.

The third setting of the mode switch S1, "SET" blocks the discriminators and resets the stepping mechanism to step 1. R14 feeds maximum bias to both discriminators, thus muting the outputs entirely. RLA is energised internally at the same time, via contacts A1 and A2. A2 opens as soon as RLA armature attracts, so that it immediately drops off again, but A2 then closes again, so that the armature attracts once more. Contacts A3 and A4 thus rapidly advance to successive steps, until position 1 has been reached via position 12. At position 1, the cam-contact A1 opens and brings the mechanism to rest.

The entire assembly of RLA with A1 to A4 is available from model control shops. The units are usually 12-way, which fact has determined the circuit details chosen here.

Professional equipment employs very similar relay circuits, or equivalent arrangements with semiconductor switching devices and electronic ring counters.

SETTING UP THE SPECTRUM RANGE

VR1 in Fig. 5.3 is adjusted such that the bottom-end stops of VR2 and VR3 on the front panel correspond to 0·1MeV nuclear radiation energy. VR1 of Fig. 5·2 (amplifier gain) is adjusted such that the top-end stops of VR2 and VR3 of Fig. 5.3 correspond to 3·6MeV nuclear radiation energy. The two adjustments must be repeated alternately until no further improvement is possible.

The procedure is as follows. Set VR1 of Fig. 5.2 and VR1 of Fig. 5.3 both mid-way. Record spectrum of standard samples of Caesium-137 (strong spectrum line at 0·66MeV) and of Cobalt-60 (two strong lines at 1·17MeV and 1·33MeV respectively, as well as the sum-line at 2·5MeV). Determine the settings of VR2 and VR3 of Fig. 5.3 for maximum counting rate at each of these four energy levels in the "SEQ" mode by extrapolation on a 12-step recorded spectrum.

Set the potentiometers to the extrapolated positions and measure the actual voltage at the slider with an electronic voltmeter (e.v.m.). Plot a linear graph of the four known energy points against the measured voltages. Read-off on this graph the energy value corresponding to −15V.

In the same ratio as this energy value bears to 3·6MeV, change the resistance of the track portion of VR1 in Fig. 5.2 (amplifier) between grid pin 9 and chassis (use ohmmeter). Then re-scale the energy axis of the graph to make 3·6MeV correspond to −15V at VR2/VR3 sliders (Fig. 5.3).

Now read-off on the graph against the new scale the potentiometer slider voltage corresponding to 0·1MeV. This will be some small positive value, since the graph crosses the X axis at about 0·25MeV due to silicon threshold levels of the diodes and transistors in the discriminators.

Adjust VR1 in Fig. 5.3 such that an e.v.m. connected between its slider and chassis reads the small positive voltage read-off on the graph for 0·1MeV.

Repeat the entire procedure at least once.

CALIBRATION

Now calibrate the scales of VR2 and VR3 of Fig. 5.3 on the front panel. For this purpose, read-off the correct slider voltages on the graph for successive tenths of a MeV from 0·1 to 3·6, adjust the potentiometer for corresponding e.v.m. reading between slider and chassis, and make mark on the scale against the pointer knob. This procedure is *essential*, because it is not possible to rely upon linear potentiometers being linear and thus calibrating geometrically with a protractor once the end-points have been fixed.

Next month: The remaining circuitry for the STRACE gamma ray spectrometer; this includes the amplitude discriminator and the pulse channel amplifiers. Some practical points for those who wish to build this unit will also be included.

Readout—
A SELECTION FROM OUR POSTBAG

Closed circuit

Sir—I have been a regular reader of your excellent magazine since its inception. My main interest is in model control systems, with an occasional gadget or piece of audio equipment.

I am particularly interested in inductive loop systems. They seem to have many potential applications: short range model control, and wireless intercoms being the most obvious.

An article on this subject would be most welcome.

J. B. Strugnell,
Hayling Island,
Hants.

Inductive Loop Systems come under the Wireless Telegraphy Act, and therefore a G.P.O. licence is required. Furthermore, only the frequency allocated by the G.P.O. can be used. It is also doubtful whether the authorities would grant a licence to a private individual; these systems are usually used for commercial purposes and other establishments such as hospitals, etc.

Haw-haw!

Sir—I have always been interested in the special effects circuits described in past issues of your magazine, such as the *Fuzz Box* and *Treble Booster*. These are a great help to people like myself who wish to use these effects but are thwarted by the price of the commercial units.

The latest development in this field is the "Wah-Wah" which has aroused considerable interest despite its price. I was wondering if you had any details or planned to publish a similar circuit in the near future. If not, perhaps one of your readers could supply me with any details.

P. Brewer,
Bury,
Lancs.

Patience, please.

Electronic exchange

Sir—I would like to obtain a copy of Practical Electronics for January 1965.

An OC29 is offered as a reward for the first copy I receive.

C. Garratt,
10 Laighstonehall Road,
Hamilton,
Lanarkshire.

Once bitten . . .

Sir—In class recently a number of questions were asked about the *Bite Indicator* featured in the August 1967 Issue. These were disposed of satisfactorily but the following discussion raised a number of other points that I was unable to answer.

Reference was made to a device which was said to be used by Japanese fishermen to attract fish to their vicinity. I gather that this was featured in a recent television programme.

I hazarded a guess that it was done by the emission of sound waves, probably outside audio frequency. This prompted a series of questions as to the frequency used, whether particular types of fish responded to particular frequencies, whether use of the wrong frequency could have the opposite effect and so on.

I should be grateful if you would pass on any information you may have which is relevant, or if you could refer me to a reliable source of information.

W. Field,
Science Dept.,
Southborough Boys' School,
Surbiton,
Surrey.

Unfortunately being one of the elementary fishermen of the string, pin, and worm variety, I can venture no suggestions as to the method that may be employed in attracting fish via a frequency system. It has been shown that Dolphins react strongly to various types of frequency variation on the basis of an echo sounder.

The Department for Underwater Studies at London University may be able to help as one of the establishments uses "pingers" and "boomers" for underwater survey of old wrecks—R.T.

PEAC response

Sir—I should like to offer my appreciation of the value of your magazine. As a university research worker in biology I particularly welcome the policy of explaining *Microelectronics, Nucleonics, Colour TV* and the new devices to broaden my own understanding of the tools I may be using tomorrow. Thank you.

Regarding PEAC, this the first device I plan to build from Practical Electronics but owing to the large number of parts which will be required it would be much appreciated if P.E. could negotiate with one or two component dealers to have all parts available in packs. The alternative is terrifying! I shall have to write off to several dealers with requests for a few dozen of this from one and a few dozen of that from another. It will take weeks to assemble the kits before any building can take place.

Dr P. J. Walker,
Exeter,
Devon.

Sir—I have read with considerable interest your article on the *Analogue Computor (PEAC)*, which appears in the latest issue. I feel that the construction of the computer would be an ideal subject as a project for apprentice training since it would have considerable up-to-date interest.

In order to programme such a project, however, it would be necessary to have the complete literature on the subject available at the outset. Is it possible, at all, to obtain pre-publication copies of this particular article?

T. H. Gill,
Co. Londonderry,
N. Ireland.

Sir—For several weeks now, I have been looking for a project which would be suitable for inclusion in my "A" level course (Elements of Engineering Design).

On reading the article in the January 1968 issue concerning the P.E. *Analogue Computor*, I decided that this would be the ideal project. Once completed, I am sure the computer would find immediate application at school. I am sure that this would be a most worthwhile project.

J. C. Hinchliffe,
Huddersfield,
Yorkshire.

We are quite sure that PEAC is an excellent project for apprentice and school training schemes. This computer lends itself to group work since it is based upon unit construction, and certain items such as the amplifiers are built in triplicate or more. There would, therefore, be plenty of work to keep a number of persons actively engaged.

There should be no great difficulty in obtaining components since these are, generally speaking, quite ordinary, readily available items. If there are certain difficulties in obtaining items locally, then it is suggested that readers get in touch with one or more of the firms advertising in our magazine.

We regret that it is not possible to provide information in advance of publication.

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Date: March 11-14
Title: 1968 Physics Exhibition
Time: 10 a.m.-6 p.m.
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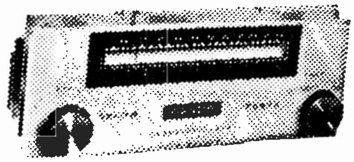

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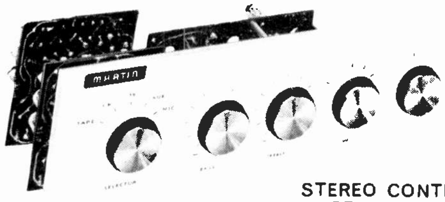

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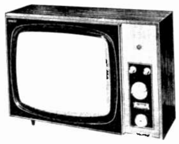

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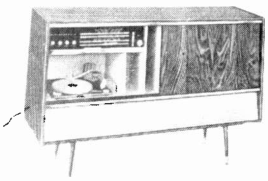

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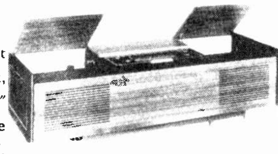

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OC44	1/6	NKT214 ..	3/6
OC45	1/9	NKT215 ..	3/6
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OC71	2/–	NKT217 ..	7/9
OC72	2/–	NKT218 ..	4/1
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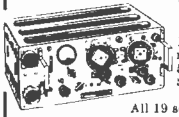

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Polystyrene: ±5%. 160V: 5pF, 10pF, 15pF, 22pF, 33pF, 47pF, 56pF, 68pF, 100pF, 150pF, 220pF, 330pF, 470pF, 680pF, 820pF, **5d.** 1,000pF, 1,500pF, 2,200pF, **6d.** 3,300pF, 4,700pF, 5,600pF, **7d.** 10,000pF, **8d.** 15,000pF, 22,000pF, **9d.**
JACK PLUGS (Screened): Heavily chromed, ¼in. Standard: **2/9** each. Side-entry: **3/3** each. Standard (Unscreened): With black, grey, white, red, blue, green or yellow covers, **2/3** each.
JACK SOCKETS (¼in Plug): With black or white bezel and chrome nut, **2/9** each. Available with: Break/Break, Make/Break, Break/Make, Make/Make contacts.
POTENTIOMETERS (Carbon): Long life, low noise. ¼W at 70°C. ±20% ≦ ¼M, ±30% > ¼M. Body dia., ⅞in. Spindle, 1in × ¼in. **2/-** each. Linear : 100, 250, 500 ohms, etc., per decade to 10M. Logarithmic: 5k, 10k, 25k, etc., per decade to 5M.
SKELETON PRE-SET POTENTIOMETERS (Carbon): Linear: 100, 250, 500 ohms, etc., per decade to 5M.
Miniature: 0·3W at 70°C. ±20% ≦ ¼M, ±30% > ¼M. Horizontal (0·7in × 0·4in P.C.M.) or Vertical (0·4in × 0·2in P.C.M.) mounting, **1/-** each.
Submin. 0·1W at 70°C. ±20% ≦ 1M, ±30% > 1M. Horizontal (0·4in × 0·2in P.C.M.) or Vertical (0·2in × 0·1in P.C.M.) mounting, **10d.** each.
RESISTORS (Carbon film): High stability, very low noise. ¼W at 70°C. Body ⅝in × ⅛in. Values in each decade: 10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91 from 4·7Ω to 1M. ±5%, **2d** each. 1·2M, 1·5M, 1·8M, 2·2M, 2·7M, 3·3M, 3·9M, 4·7M, 5·6M, 6·8M, 8·2M, 10M. ±10%, **2d.** each.
SEMI-CONDUCTORS (All new): OA5, OA81, **1/6.** OA44, OA45, **1/9.** OC71, OC72, OC73, OC81, OC81D, OC82D, OC170, OC171, **2/3.** OC140, AF115, AF116, AF117, **3/-.**
SILICON RECTIFIERS: 0·5A at 70°C. 400 P.I.V., **3/-.** 800 P.I.V., **3/3.** 1,250 P.I.V., **3/6.** 1,500 P.I.V., **4/-.**
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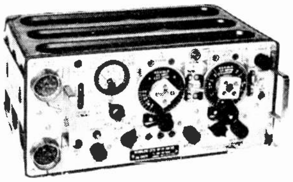

This set is made up of 3 separate units: (1) a two valve amplifier using a 6V6 output valve: (2) (some only, not built in the very latest models) a V.H.F. transreceiver covering 229–241 Mc/s using 4 valves; (3) the main short wave transmitter/receiver covering, in two switched bands, just below 2–4½ Mc/s, and 4½–8 Mc/s (approx. 160–37·5 metres) using 9 valves. For R.T., C.W. and M.C.W. The receiver is superheterodyne having 1 R.F. stage, frequency changer, two I.F. (465 kc/s) signal detector, A.V.C. and output stage. A B.F.O. included for C.W. or single side-band reception. T.X. output valve 807, other valves octal bases. Many extras, e.g. netting switch, quick flick dial settings, squelch, etc. Power requirements L.T. 12 volts, H.T. receiver 275 volts d.c., H.T. transmitter 500 volts d.c., size approx. 17½ × 7½ × 11ins. Every set supplied in new or as new condition in carton with book including circuits, only **£4.10.0**, or Grade 2 slightly used **50/-** carriage both 15/-.
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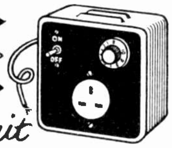

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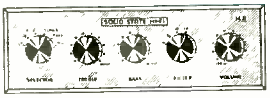

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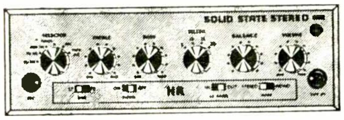
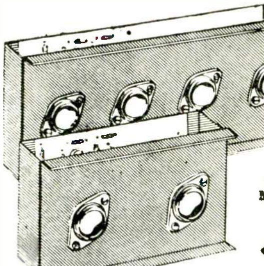
SP6-2





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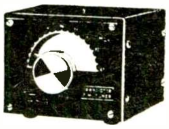

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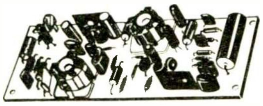

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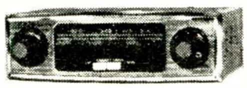

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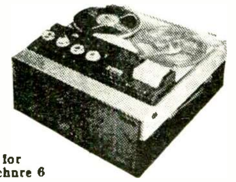

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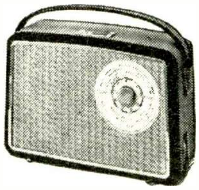

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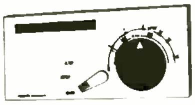

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