Wireless World

October 1968 Three Shillings

Domestic receiver review
Amateur solid-state transmitter

Wireless World

Electronics, Television, Radio, Audio

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This month's cover *montage includes one of the Murphy "coloured" television receivers, the Ultra 6702 colour receiver, G.E.C. portable G832 and below it the Pye 'Piccadilly', and on the left the Ferguson Futura II (upper) and G.E.C. G832 table receivers.*

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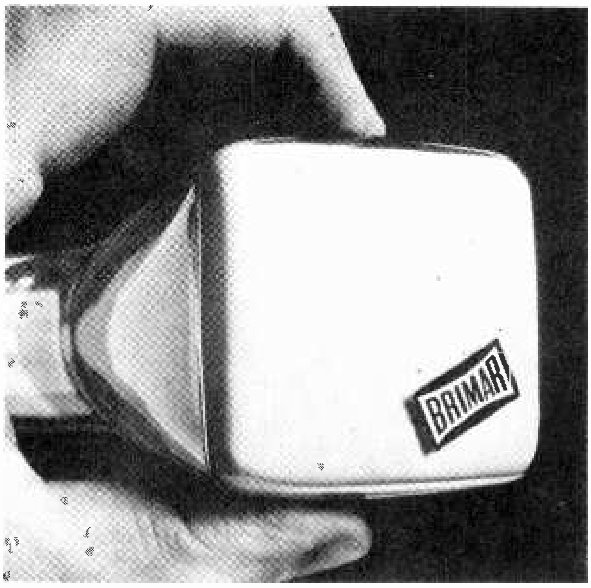
Square?



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Wireless World

The Poor Relation?

Almost annually since the first British National Radio Exhibition was held in 1923 we have devoted a section of one or more issues at the time of the show to a review of the latest developments in domestic receivers. Our excuse, if any was needed, was that, for the benefit of those of our readers unable to attend the London Show we should publish a digest of the latest techniques. Indeed, even when there was not a show we endeavoured, after discussing with designers and manufacturers their latest products, to give a "state of the art" survey. Now, of course, in place of a public show there is the annual plethora of trade shows held in London's West End hotels. As is our custom we have again devoted several pages in this issue to a survey of domestic receivers, but in doing so we have had some serious heart searchings, in fact had we not announced this in the last issue we would in all probability have omitted it as, on reflection, there seems little worth reporting—at least in technical design matters.

What has happened to the British radio industry? It now appears to be the poor relation of its now affluent offspring—the electronics industry. Whereas in the radio industry's hey day the cream of the country's radio engineers were engaged on the development of broadcasting equipment and domestic receivers, we get the impression that the calibre of the average engineer/technician now working on domestic equipment design is a good deal lower than in the field of professional electronics (e.g. radar, computers, communications). Is this the cause or the effect of the industry's unsatisfactory situation? Although each of the major electronics groups has a domestic receiver section, division or subsidiary company it is in each case little more than a gap-filling production activity.

All too often we find that, instead of British designs being copied overseas (as in the past), manufacturers in this country are content to follow overseas competitors and even go so far as to unashamedly use foreign-made chassis in so-called British receivers. Perhaps their motto is "if you can't beat 'em, join 'em"! Incidentally imports of complete receivers and parts for the first seven months of this year were £7M (45% above the figure for the same period last year), while exports were less than £3M.

We have found, on the whole, very little evidence of real initiative in design thinking. Is this because set makers have got used to waiting for the active device manufacturers to take the initiative and provide circuit designs based on their latest products which they can then adapt or adopt? One wonders when last a set designer told a device manufacturer what he wanted in terms of new components to perform particular functions. Because of this attitude of taking what is provided by the device manufacturers we find there is technically little, if any, difference between the products of the various groups, hence our dilemma as to the justification for devoting space to a survey of the latest techniques. In fact, had it not been for the imported sets that were displayed by agents we would have had little of technical interest to report. The only encouraging sign is that one or two British manufacturers have been bold enough to start using integrated circuits in their sets. In passing it is significant that, whereas Japanese, German, American and Scandinavian manufacturers design their products for world markets, those in this country seem to be content with the home market.

In spite of what we have said we hope readers will find the technical survey and the accompanying pictorial review of new receivers of interest, and of assistance in choosing new equipment or influencing the choice of others.

Domestic Receiver Survey

Developments in television and sound receiver design, as seen at the recent trade shows in London

Although there is no longer a general radio and television exhibition open to the public, most of the receiver manufacturers and suppliers get together in late August and hold simultaneous private trade shows in various hotels in London, at which they introduce their latest models. This provides a suitable occasion for *Wireless World* to take a general look at the technical design of domestic receivers. The following report, compiled by members of the editorial staff, is pictorial in approach, comprising mainly photographs of new sets and items of circuitry sketched on the spot, with commentary which aims to be descriptive but may also be to some extent explanatory.

Television

All of the British manufacturing groups were displaying colour television receivers with tube sizes varying from 48cm through 59cm to 64cm. Apart from one or two notable exceptions the circuitry followed what has become a conventional pattern. In the monochrome television receiver field, technical innovations were few. There was an impression given throughout the whole of the exhibitions that last year's design would do for the present and that any development effort would be reserved for the commencement of the u.h.f. single-standard era starting in 1969. Most manufacturers professed to having a single-standard receiver "ready" but only one working model was displayed. This was a 64cm colour receiver introduced by Bang & Olufsen that will retail for about £400. In justifying the high price, claims are made for better picture quality and a high standard of circuit stability throughout. A quick look through the service manual illustrates the performance that B and O hope to achieve with this receiver in which the service engineer is asked to align the receiver north/south and to inspect various portions of the screen with a microscope during purity adjustments.

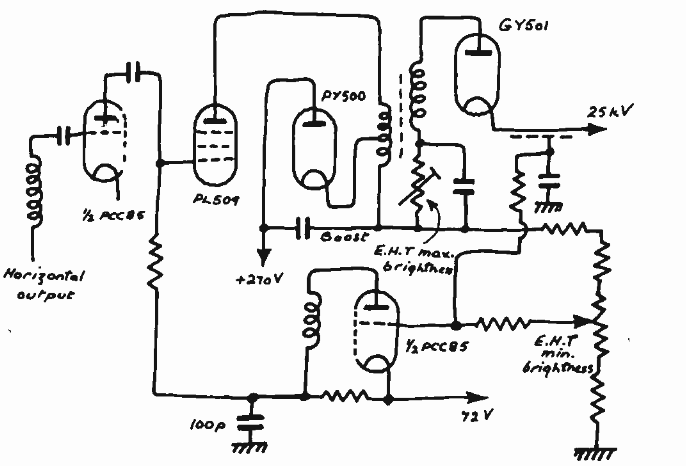


Fig. 1. Simplified circuit diagram of the e.h.t. generator employed in the Bang & Olufsen single-standard colour tv receiver, Beovision 3000.

In order to make the task of static convergence easier and to make the adjustment less susceptible to mains voltage changes permanent magnets are not employed. A d.c. voltage, obtained by rectifying pulses from the line output stage during the scan period, is applied to the convergence coil unit. The same coils are also used for dynamic convergence so that it has been necessary to insert blocking capacitors in the circuit to prevent the d.c. from interfering with the operation of the dynamic convergence circuits. The amount of d.c. flowing is controlled by a potentiometer accessible from the front of the receiver, as are all the convergence adjustments. No e.h.t. over-wind is included on the line output transformer, instead a separate e.h.t. generator is employed, a skeleton circuit of which is shown in Fig. 1. Line pulses from the line output stage are amplified and shaped in one half of the PCC85, which operates as a controlled rectifier. In operation a negative charge is developed across the 100-pF capacitor which supplies the bias for the PL509 which in turn provides the high level pulses which are applied to the e.h.t. coil, the output being rectified in the GY501 to provide the required 25kV.

Low-frequency power consumption variations are fed to the grid of the other half of the PCC85 via the two e.h.t. brightness controls whilst higher frequency variations are coupled to the same grid via the capacitance of the e.h.t. output screened cable which is in the region of 270pF. If the mean current through the picture-tube increases, the voltage at the grid of the PCC85 will fall (this voltage is equal to the boost voltage minus the voltage drop across the e.h.t. max. brightness control) resulting in the PCC85 taking less current. The charge across the 100-pF capacitor will become less negative and more drive will be applied to the PL509 resulting in the e.h.t. voltage being restored. The receiver employs a total of 14 valves, 53 transistors and 52 diodes.

In the non-stop quest for optimum tube dimensions there was the inevitable change in shapes and sizes and this year saw the widespread use of a new 51cm tube, near a true rectangle in shape and with the correct aspect ratio of 4:3, a logical introduction which was long overdue. It is something of a mystery that the industry had established the anomaly of receiving a 4:3 aspect ratio picture on a 5:4 aspect ratio tube for so many years.

Greater simplicity has been the main design trend in the Philips colour television receivers on show this year. Last year this company introduced sets with a number of "extras"—an "Autowhite" system to give automatically the familiar bluish-white picture when the set was receiving monochrome transmissions, a "colour-off" button to assist the user to adjust brightness and contrast correctly, a tuning indicator to show when the set was correctly tuned on colour transmissions, and a

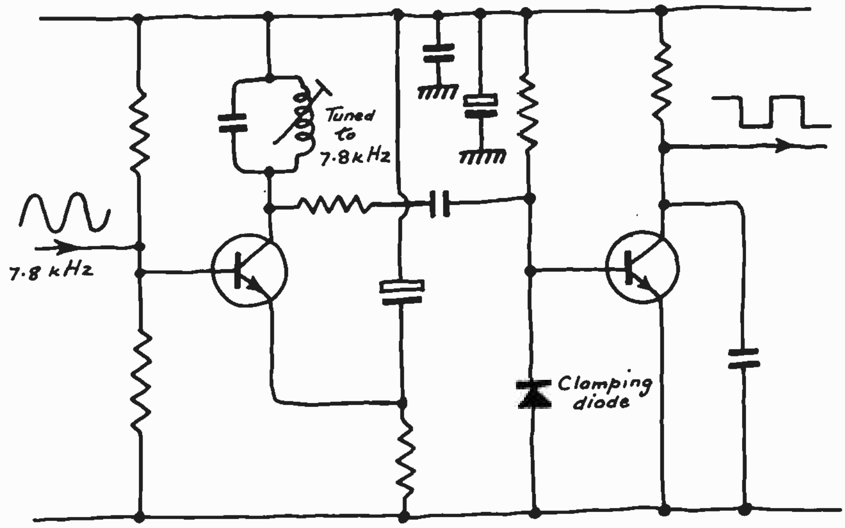


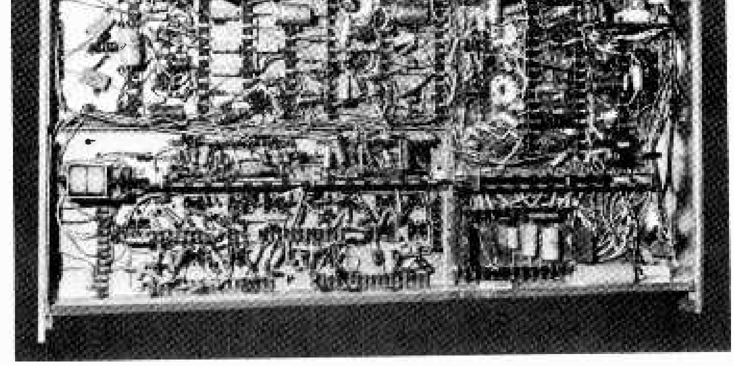
Fig. 2. An outline of the 7.8kHz switching wave generator employed in the Baird colour television model 718.

tone control. This year the basic circuitry is substantially the same but these extra facilities have been deleted in the interests of economy. A preview of new Philips colour receivers due to come out in January revealed that these will have 56cm shadow-mask tubes with the "squarer"-looking screen.

Also using the 56cm "squarer" shadowmask tube are the latest colour television sets from the Rank Bush Murphy group, the Bush CTV174D and Murphy CV2210D. These are, in fact, the receivers that have a section of the colour decoder in the form of an integrated circuit, as reported in our August issue (p. 263). The integrated circuit, a 20-lead flat pack, replaces 65 discrete components, and provides the functions of two synchronous detectors, two inverters, four matrices, and three output circuits giving respectively *R*, *G* and *B* signals. As explained in the earlier report, the purpose of using an i.c. in this position is not to save space or reduce cost but to achieve an improvement in picture quality by using the superior *R,G,B* type of c.r.t. drive without the extra complication and cost that this normally brings when constructed from discrete components. A block schematic of the integrated circuit was shown in the August report.

Baird's 48cm colour television Model 718, shows some departures from circuit convention. An R.C.A. integrated circuit is employed in the a.f.c. section. A 39.5MHz signal from the last stage of the vision i.f. amplifier supplies a control potential to the oscillator section of the u.h.f. tuner to correct for tuning errors and drift (a.f.c.).

Underside view of the ITT/KB colour receiver chassis illustrating the proliferation of cable runs resulting from a hand-wired assembly. The system switch and operating solenoid are clearly visible.



Instead of using a bistable in the 7.8kHz switch generator, a sine wave is fed from a master oscillator through a single-stage tuned amplifier to a bottoming transistor, which delivers a squared waveform as shown in Fig. 2.

To achieve 180° line-by-line phase change of the *R–Y* demodulated signal, required by the PAL system, the phase of the *R–Y* signal itself is switched instead of switching the reference generator phase to the *R–Y* demodulator stage.

ITT/KB have just released details of their first colour TV receiver, model CK400. This is a 48cm dual-standard version which is unique among present generation colour sets in that the chassis is virtually hand-wired throughout, only a small printed panel being used to support the components located round the tube base connector. The circuitry is of hybrid design with transistors occupying all of the signal processing stages except for the v.h.f. tuner, sound output stage and chrominance output stages. Both field and line timebases are valve-operated and a solid-state tripler provides e.h.t. One departure from accustomed hybrid practice is the use of a transistor (type BD119) for the luminance output stage. In common with most other colour receivers the CK400 has a monochrome capability if the decoder chassis is removed for servicing. The usual number of colour setting-up controls are provided, accessible from the front by removing a wooden cabinet panel. A customer "tint" control, in addition to the normal saturation control, allows the user to exercise a preference for a particular colour balance by varying the differential gain of the colour-difference pre-amplifiers.

The circuit incorporates an electronically operated device which automatically adjusts the reference white temperature from illuminant "C" required for colour reception to the bluish-white of monochrome pictures. A 15-V pulse derived from the l.o.p.t. is applied to Tr_8 which bottoms, generating positive and negative-going squared pulses at its emitter and collector respectively. Suitable proportions of these pulses are added via R_7 and R_8 to the emitters of the *R–Y* and *B–Y* pre-amplifiers Tr_9 and Tr_{10}, and are thus added to the *R—Y* and *B—Y* signals at their collectors. When these modified signals after further amplification reach the c.r.t. grids and triode clamps, the latter now operate on the tips of the inserted pulses, so that their effect is to change the bias on the tube grids by an amount equal to their amplitude (see Fig. 3). When the colour-killer Tr_{11} is cut-off on a monochrome transmission, Tr_9 and Tr_{10} are disabled, the colour-difference signals disappear, and the bias on the c.r.t. grids reverts to its normal value. If the c.r.t. anode voltages are adjusted for the correct shade of white (illuminant "C") with the pulses present on a colour transmission, the picture will move towards the usual bluish monochrome shade when the pulses are not present.

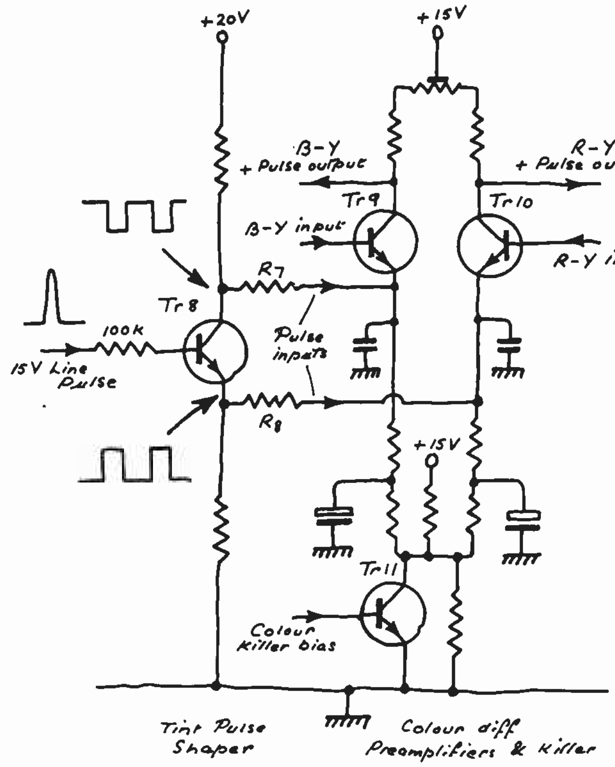
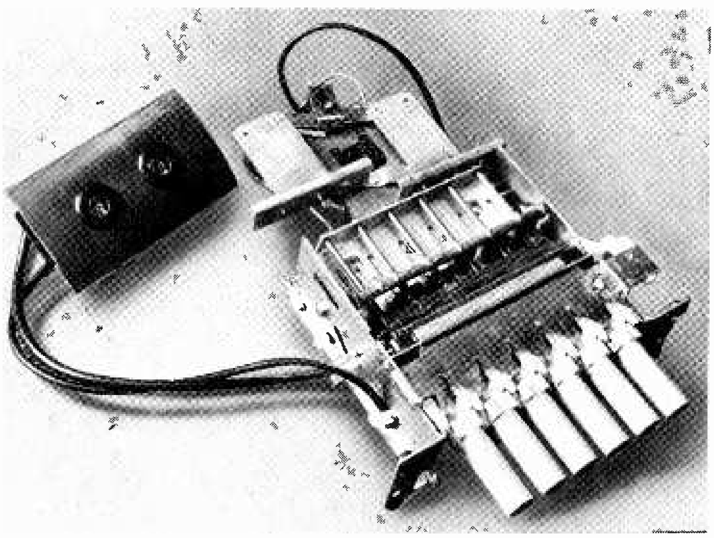


Fig. 3. Circuit diagram of part of the ITT/KB colour decoder panel showing the principle of operation of the automatic reference white correction circuit.

In apparent contradiction of the generally adopted policy of marking-time on dual-standard receiver designs and in spite of the near approach of the time when all television broadcasts will be radiated in the u.h.f. bands, G.E.C. have just introduced an integrated u.h.f./v.h.f. television tuner unit which was developed at their Slough laboratories and is manufactured in their own plant. This is a solid-state unit which is virtually two parallel sets of tuning circuits (one set for Bands I and III; the other for Bands IV and V) operating in conjunction with common r.f. amplifier and mixer transistors and a common tuning gang capacitor. A separate transistor stage is employed for the v.h.f. oscillator making a total of three transistors. A sliding switch assembly located along the centre of the unit provides u.h.f./v.h.f. changeover switching. Six press-buttons provide mechanical selection of six channels in any combination of bands and systems. Each press-button incorporates a memory-type fine tuner and claims are made for high reset accuracy, ensured by designing-in a large mechanical tolerance.

G.E.C's new u.h.f./v.h.f. integrated tuner unit as shown in this photograph is more of a mechanical endeavour than an electronic one. The electronic components are contained in a screened box on the underside.



Sound receivers

Radio receivers were divided generally into two categories; (i) portable battery-operated models and (ii) tuner/amplifiers with separate loudspeaker units for stereo reception, or with an additional loudspeaker used in conjunction with the receiver integral loudspeaker. The latter type of equipment was invariably described as "hi-fi", which could be a misnomer in the absence of a standard reference for hi-fi equipment such as the D.I.N. standard in Germany.

Techniques from high-fidelity sound reproduction equipment are gradually infiltrating into the field of ordinary receiver production. (We are now seeing, for example, the big manufacturing groups offering the public pseudo hi-fi in the form of separate units as an alternative to the radiogram.) An instance of this infiltration in circuit design was noted in the latest British Radio Corporation stereo radiograms (the H.M.V. "Stereomaster" models 2401 and 2402). The chassis includes quite an elaborate voltage stabilizer circuit following the power unit, the purpose of which is to ensure that the full required current will be delivered to the two audio amplifiers on signal peaks. These amplifiers are each capable of giving 7 watts output—quite large for a radiogram—so the maximum instantaneous current demand can be considerable. Without the stabilizer the power supply would have a high internal impedance and this would limit the current delivered on peaks and so cause waveform distortion. The circuit of the stabilizer is shown in Fig.4. Another function performed by it is to provide a constant voltage of −15V for the varicap diode tuning system shown in Fig.5.

Tuning by varicap diodes has been established for some time in v.h.f./f.m. tuners and in some of the more advanced imported receivers, but it is still rather unusual in the ordinary run of British-designed sound receivers. The tuner in H.M.V. models 2401 and 2402 has a five-pushbutton station selector, and each of the five buttons incorporates a variable control for tuning. As can be seen from the simplified circuit diagram in Fig.5, each variable tuning control is a 100kΩ potentiometer, which is used

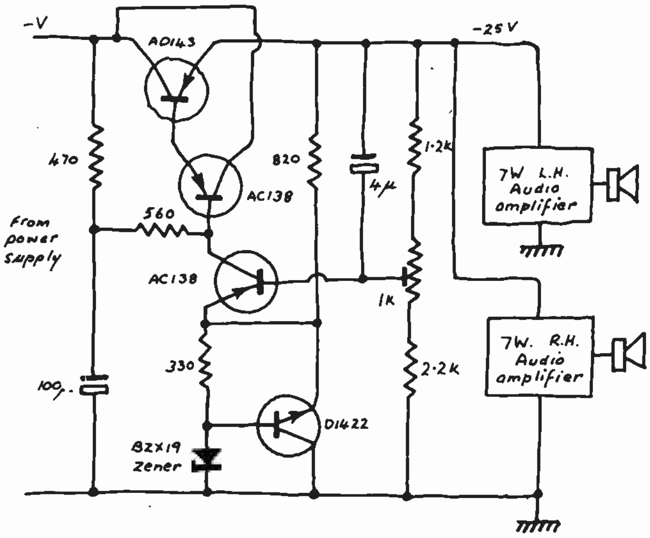


Fig. 4. Voltage stabilization circuit used in H.M.V. stereo radiograms. A 15-volt source for the varicap tuner is provided from the junction of the 820 Ω resistor and the emitter of the D1422 transistor.

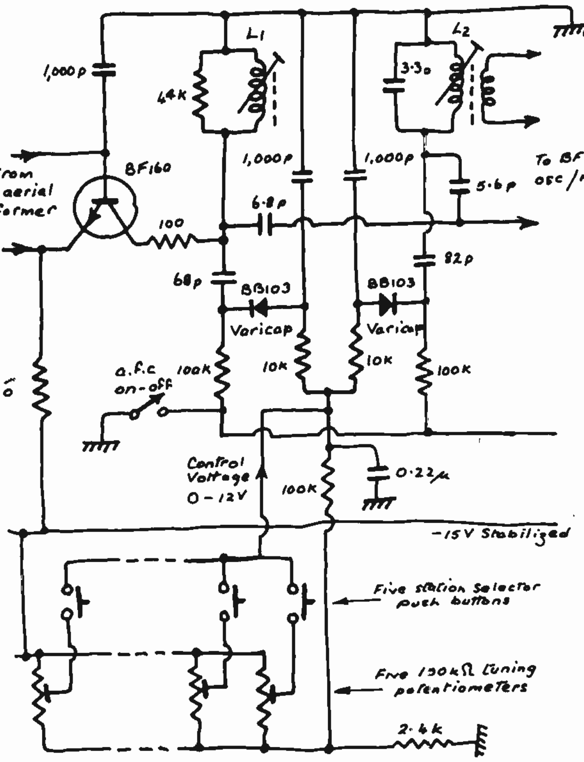


Fig. 5. Section of v.h.f./f.m. tuner in British Radio Corporation stereo radiograms, showing use of varicap diodes for tuning between the r.f. amplifier and the mixer/oscillator.

for applying a variable negative voltage (total range 0-12V) through a pair of 10kΩ resistors to the anodes of two BB103 varicap diodes (which are thereby reverse-biased). As a result the capacitance between the two electrodes of the diode varies in proportion to the control voltage. Each varicap diode is connected in series with fixed capacitors across a pre-set inductor (L_1 and L_2), thereby forming a tuned circuit. The first tuned circuit tunes the output of the BF160 r.f. amplifier while the second tunes the following oscillator/mixer stage (not shown). The tuning range available from the varicap diodes is limited but is sufficient for the v.h.f./f.m. broadcasting band.

A 5W amplifier fabricated on a single monolithic chip has been announced by Sinclair Radionics. Performance figures claimed for the unit are: a frequency response $\pm$1dB from 5Hz to 100kHz, a power gain of 110dB and 1% distortion at 1kHz. The distortion figure is no worse than a number of other amplifiers that carry the high-fidelity label and the amplifier should find a number of useful applications particularly when the low price, 59s 6d, is considered. The amplifier employs a class AB, "totem pole", output stage using two n-p-n transistors.

The integrated circuit is manufactured by Plessey and is very similar in design to the a.f. stage of an integrated experimental radio receiver described by M. J. Gay and M. C. Sucker of Plessey in a paper given at the Radio Receiver Conference at the University College of Swansea about a year ago. This conference was covered in the November 1967 issue of *Wireless World*. The receiver described had a 40dB conversion gain, 90dB of a.g.c. control and 3W a.f. output. All components, with exception of the coils, being on a single chip. What happened to this prototype receiver, we wonder? The Sinclair amplifier contains a pre-amplifier with a sensitivity of 5mV into 2.5MΩ and requires that an external volume control and tone control circuitry be added. The power supply voltage can be between 8 and 18V.

A pioneering step in portable radio design has been taken by Roberts' Radio who use the Mullard TAD 100 integrated circuit in their new receiver, model RIC.1. This i.c. is a directly-coupled wideband amplifier which is capable of being connected in a number of configurations. In the Roberts design it performs the functions of the mixer/oscillator, i.f., detector and audio pre-amplifier stages including most of the discrete passive components as well as the transistors normally employed to provide the above functions. The r.f. tuning circuits follow normal practice but i.f. coupling is carried out by a tuned crystal filter. Because of the limitations of producing large values of capacitance and restricted resistor values, the a.g.c. and decoupling components are wired externally. The whole is combined on a printed circuit board. Integrated circuit amplifiers have the advantage of showing only a small spread in characteristics so that with a few simple precautions taken in manufacture of the receiver, it should prove to be very reliable. The RIC.1 covers the long- and medium-wave bands and costs 15gn.

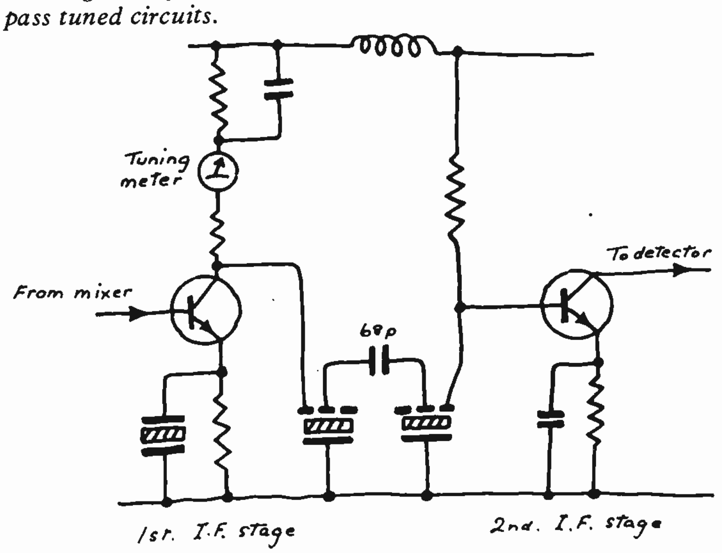
Sony are using piezo-electric ceramic filters in one of their latest transistor receivers in place of conventional i.f. transformers and tuned circuits. The relevant part of the circuit is shown in Fig.6. The main advantage of this technique is, of course, that since the filters are fixed components with known response/frequency characteristics, the time-consuming manufacturing process of lining up the i.f. section is avoided. The receiver is the TR1000, a 10-transistor superhet giving coverage of the medium- and short-wave bands.

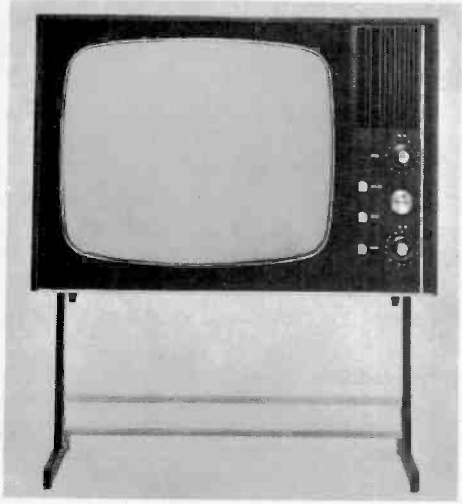
The f.m. tuner front-end design employed in Hacker's "Sovereign" portable radio is also used in their stereo audio radio SAR 1000, a combined stereo f.m. tuner-amplifier with optional a.m. waveband. The automatic mono-to-stereo radio switching system has a single tuning point. A low-level stereo signal, which would give a poor performance, does not cause the automatic switching to occur. At the output of the tuner the 19kHz carrier signal cancels itself. The tuner front-end is tuned by a triple-ganged variable capacitor.

An integral f.m./a.m. radio receiver allowing direct broadcast recording is a feature of the Tobisonic cassette tape recorder TCR52. During recording from microphone or radio a monitor output is available. The tape transport system includes fast-forward winding. Pressing a button on the top of the recorder causes the cassette to be ejected, thus simplifying cassette changing. The microphone is equipped with an on-off switch. Also, a mains power unit is built into the recorder.

Automatic switch-over to battery operation in the event of a failure of the a.c. mains power supply is a feature of the Interceptor 1858, marketed by Elsworthy Electronics. One of the five wavebands covered by this portable is the amateur 2-metre band between 142 and 150MHz.

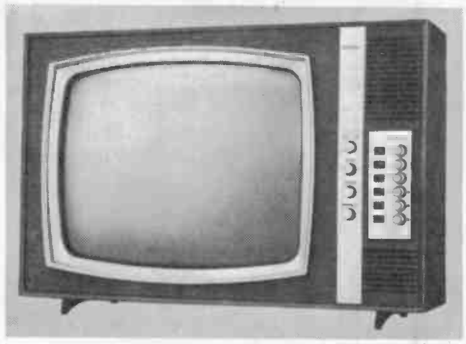
Fig. 6. Part of circuit of Sony TR1000 a.m. transistor receiver showing use of ceramic filters in place of conventional band-pass tuned circuits.





Decca 59cm monochrome TV receiver model DR23 with v.h.f. and u.h.f. coverage. Forward facing 13cm diameter loudspeaker. Mains operation. Price: 84gn, stand extra.

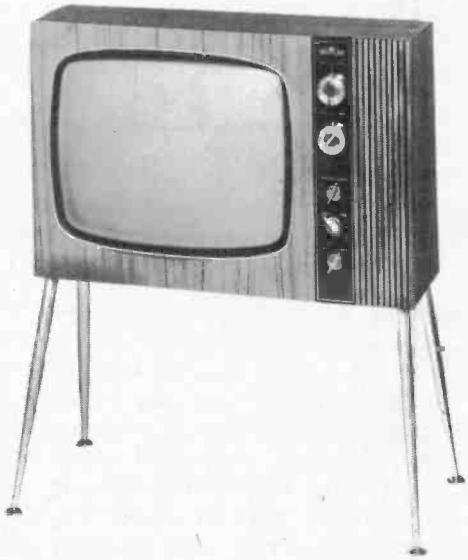
Telefunken Bajazzo de luxe a.m./f.m. transistor portable radio receiver with facilities for use as car radio. Output 2.5W (portable), 5W (car) driving 13 × 18cm loudspeaker. Price: 55gn.



Sobell 48cm monochrome TV receiver model 1032. Features u.h.f./v.h.f. transistor tuner incorporating six press-buttons, each with memory fine tuner. Price: 72gn.

Ferranti 48cm colour TV receiver model CT1167 employing hybrid dual-standard chassis. Rotary-type multiband tuner and forward facing 18 × 10cm loudspeaker. Price: £299.

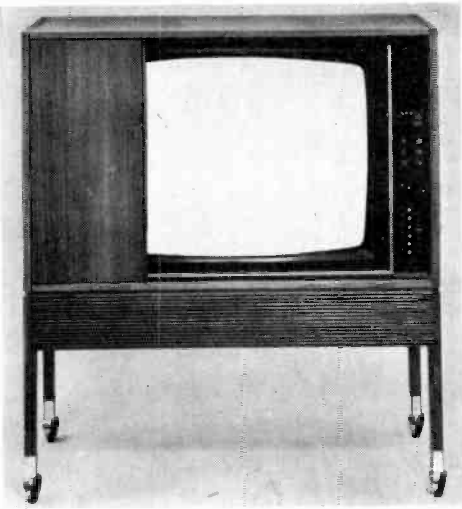
Pye model 6000 "Piccadilly" multi-band transistor portable radio receiver. Long, medium and four short wave-bands plus v.h.f. coverage. Also extended l.w. band and marine band. Built-in aerials for all bands. Visual tuning indicator, a.f.c. and variable a.g.c. Socket facilities provided. Chassis of stainless steel. Price: £100 plus.



RGD model RV235 48cm monochrome television receiver. S.T.C. VC52 series dual-standard chassis and transistor u.h.f. tuner. Forward facing speaker. Price: 75gn.

National model SC140F four-waveband radio receiver with stereo record player and separate speaker units. Price complete with speakers: £102 18s.

Unitra model DG204 radiogram from Poland covers five wavebands including v.h.f./f.m. B.S.R. UA25 record changer. Socket for tape recording. Price: £46 4s.



Bang & Olufsen model 3000 single-standard 625-line u.h.f. colour TV receiver with 63cm tube. Available in teak or rosewood finish with tambour doors. Price: 398gn.

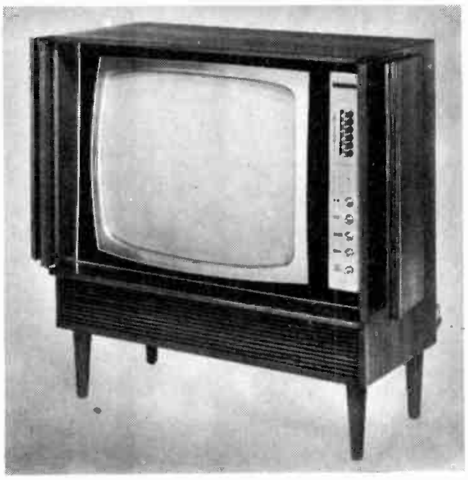
Fidelity RAD14 three-waveband a.m./f.m. portable radio receiver with 18 × 10cm loudspeaker. Wooden cabinet 30 × 23 × 7.5cm. Weight: 2kg. Price: 17gn.

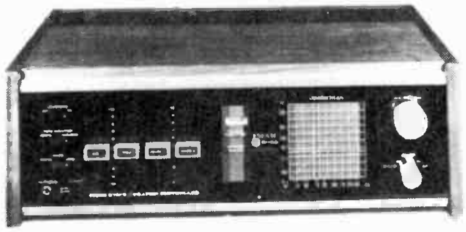
Standard model SR-K466F a.m./f.m. pocket radio receiver employing 11 transistors, and featuring a.f.c. on f.m. Output 200mW; speaker 4.5cm diameter. Power source: three mercury batteries. Dimensions: 79 × 62 × 31mm. Price: 23gn.

Hacker model RP25 "Sovereign II" transistor portable radio receiver. Features 16 transistors and 5 diodes, a.f.c. and quiet tuning on v.h.f. Power output 1.5W; 20 × 13cm loudspeaker. Price: £44 14s.

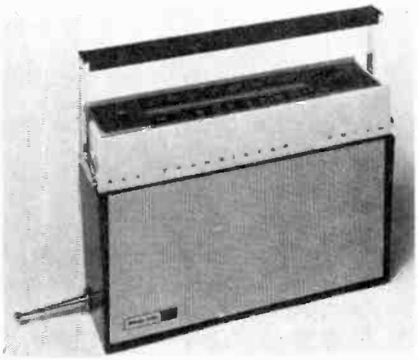
Teleton model 12-T 203U portable TV receiver with 31cm c.r.t. Power source 220/240V a.c. or 12V d.c. All v.h.f. and u.h.f. channels covered, 300-Ω balanced input. Eighteen transistors and four diodes employed. Weight 7kg. Price: about £79.

Decca 64cm colour TV receiver model CTV25CE. Dual-standard hybrid chassis with press-button tuning. Two 18 × 10cm loudspeakers. Price: 342gn or 345gn according to cabinet finish.

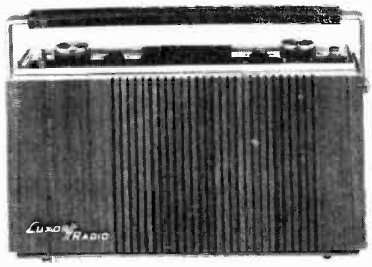




Nivico model AST140E a.m./f.m. stereo radio receiver with unusual crossdial tuning indicator. Automatic stereo switching. Total output 66W. Separate bass and treble controls; frequency response 20Hz to 20kHz. Mains operation. Price: 129gn.

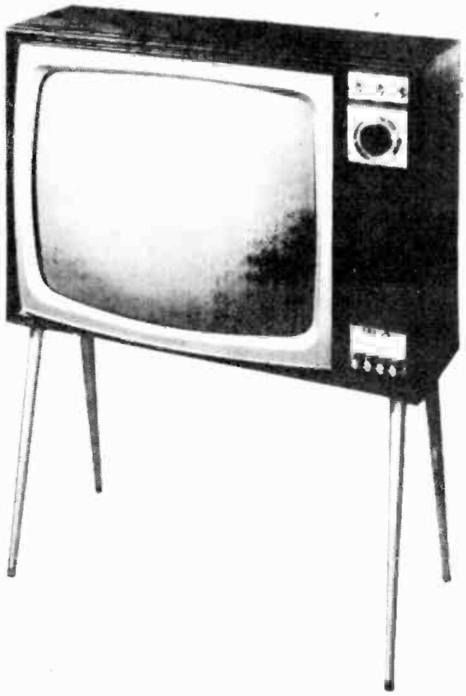


Philco-Ford model T993 portable radio receiver covering medium-wave and v.h.f. Ten transistors and eight diodes employed. Features include a.f.c. on v.h.f. Price: 14gn.



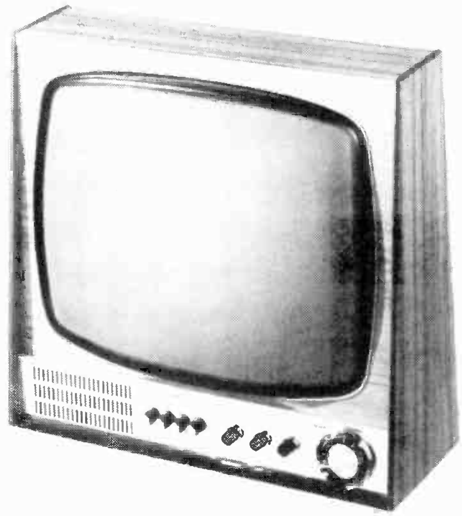
Luxor model B4773 a.m./f.m. transistor portable radio receiver featuring a.f.c. and pretuned press-buttons on f.m. Audio output 2W. Socket facilities include input for battery eliminator. Price: 41gn.

Ferguson model 3163 combines a 7-transistor radio receiver with a battery-operated electric clock. Long- and medium-wave coverage with internal aerial. Audio output 140mW; 7.5cm diameter loudspeaker. Price: £17 10s.



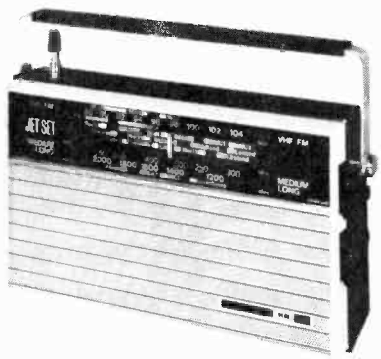
H.M.V. 59cm monochrome TV receiver model 2648. Incorporates B.R.C. 1400 series dual-standard chassis embodying rotary v.h.f. tuner and press-button u.h.f. tuner. Low wattage heater circuit. Price: £82 4s.

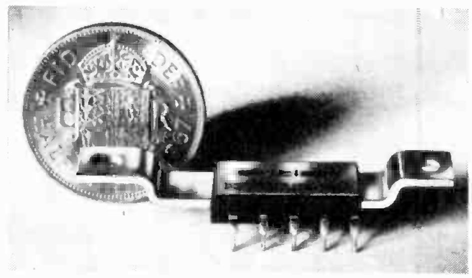
Roberts model RIC.1 long- and medium-wave portable radio receiver employs a Mullard TAD100 linear integrated circuit in an advanced design. Crystal filter i.f. coupling also featured. Audio output in excess of 1W driving 18 × 9cm loudspeaker. Price: 15gn.



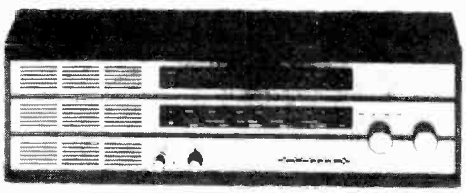
Ferguson 48cm monochrome TV receiver model 3652 incorporating B.R.C. 1400 series chassis. Price: £75 10s.

K.B. model KR607 a.m./f.m. transistor portable radio receiver covering long, medium and v.h.f. wavebands. Audio output 400mW driving 13 × 8 cm loudspeaker. Features two-position tone control. Price complete with earpiece and wallet: 14½gn.

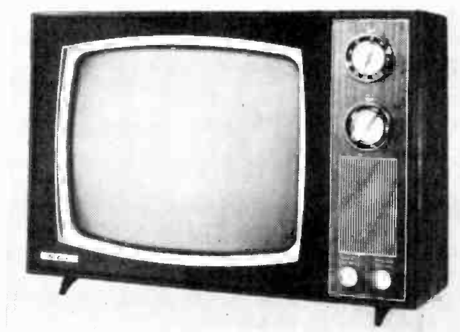




Sinclair IC-10 monolithic integrated circuit power- and pre-amplifier in dual-in-line package measuring 2.5 × 1 × 0.5cm. Output of 5W r.m.s. (continuous) is claimed. Price: £2 19s 6d.



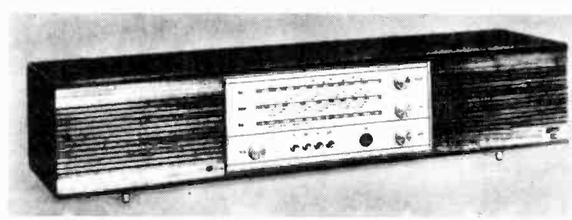
Stella model ST4311 a.m./f.m. mains table radio receiver covering the long-, medium- and short-wave bands and v.h.f. A valve chassis is employed. Price: 32gn.



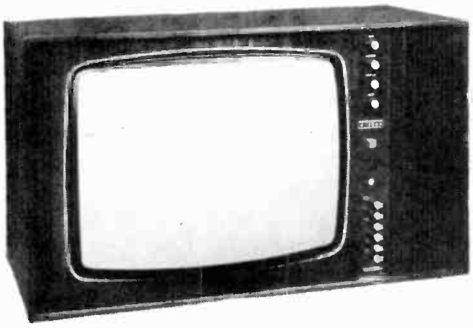
G.E.C. 48cm monochrome TV receiver model 2038 designed specially for rental. Continuously tunable u.h.f. tuner and rotary type v.h.f. tuner. Price 70gn.

Grundig Nymphenberg stereo radiogram in period style. Transistors: 26, diodes: 23. Waveband coverage; v.h.f., s.w., m.w. and l.w. Output power: 10W per channel. Stereo decoder fitted. Record changer: four-speed unit with manual or automatic record selection. Mains operation. Price: 437gn.

Ekco model A410 transistor stereo radio receiver with built-in stereo decoder and visual stereo indicator. Long-, medium- and short-wave coverage plus v.h.f. Two 20 × 13cm loudspeakers; output 4W per channel. Price: £53 10s.



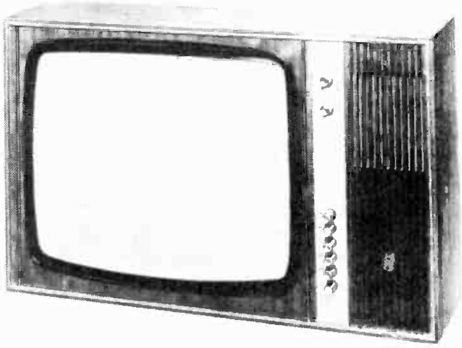
KB model CK 400 colour TV receiver employing 48cm type tube. Hybrid chassis featuring manual tint control. Removable decoder board. Solenoid-operated system switch. Solid state e.h.t. unit. Price: 275gn.

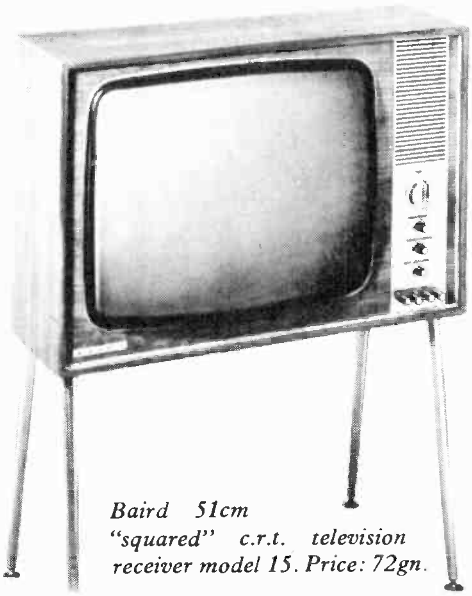


Philips model 503 colour TV receiver incorporating a 56cm "square" tube mounted in a "push-through" presentation. Available next January.

Marconiphone 59cm monochrome TV receiver model 4626 incorporating B.R.C. 1400 series chassis. Price: £114 10s.

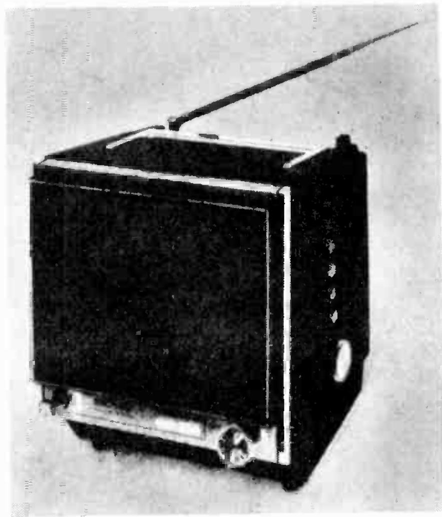
Pye model 63 monochrome TV receiver with 51cm "squared" tube. Incorporates the 368 series hybrid chassis featuring solenoid-operated system switch. Forward facing 20 × 13cm loudspeaker. Price: £83.



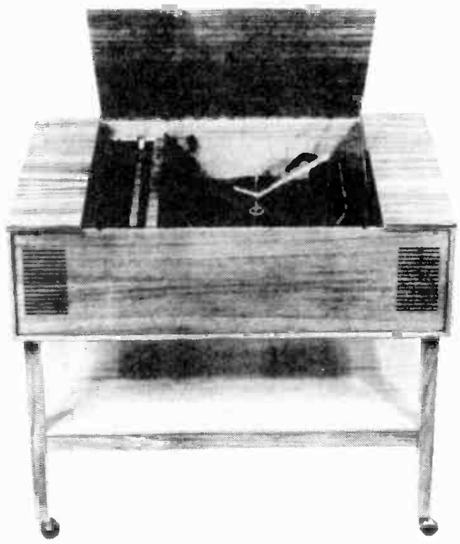


Baird 51cm "squared" c.r.t. television receiver model 15. Price: 72gn.

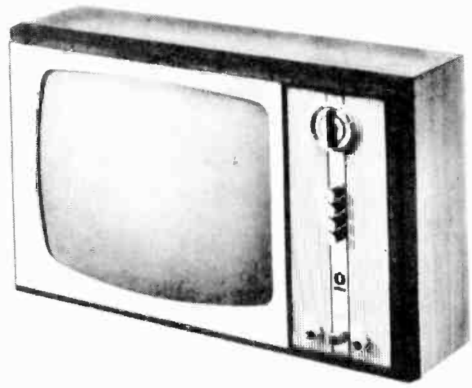
Bush model CTV174D colour TV receiver using 56cm tube with 4:3 aspect ratio. Also features integrated circuit colour decoder and R,G,B drive to c.r.t. Price: 299gn. The Murphy CV2210D is similar.



Sony 23cm battery/mains portable TV receiver Model TV9-90UB covers all v.h.f. and u.h.f. channels. Thirty transistors and fifteen diodes employed. Weight 5.5kg. Price: £79.



Dynatron model HFC4 "Geneva" transistor stereo radiogram with decoder fitted. Long- and medium-wave and v.h.f. coverage, 20W power output. Bass reflex speaker enclosures. Record changer with diamond stylus. Price: £111 8s 8d plus stand.



Ultra 48cm monochrome TV receiver model 6636 incorporating B.R.C. 1400 series chassis. Price: £73 15s.

Low-power Transistor Transmitter

A 7-MHz 3-W solid-state design of very small size

by G. R. Kennedy

The basic design requirement was for a small transmitter which could be carried in a large pocket or an ordinary brief-case, able to run for a reasonable period off dry batteries, yet with enough power output to ensure at least a reasonable chance of a contact and which used readily available transistors not costing more than 10s each. These requirements were met by the basic circuit shown in Fig. 1.

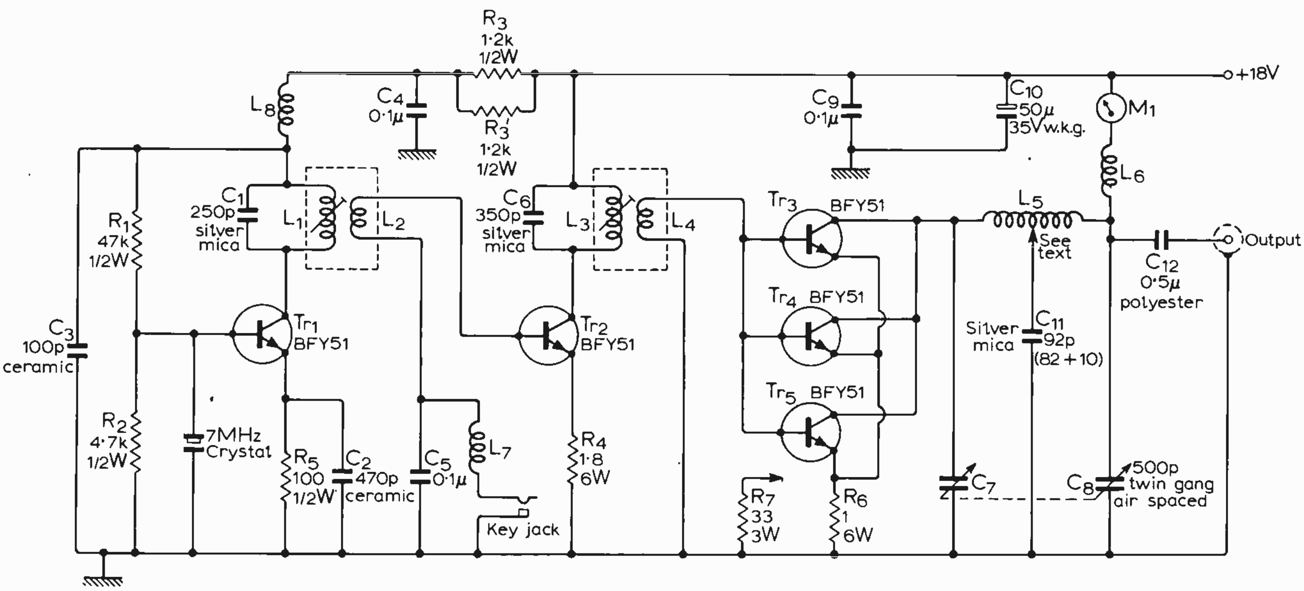
For an r.f. amplifier stage the f_T of a transistor should be at least twice the signal frequency, and for a stable oscillator it should be several times the oscillation frequency. For the BFY51, $f_{T(min)}$ is 50 MHz, which is seven times the signal frequency. The voltage rating of the transistors in a transmitter should be at least three times the supply voltage: $V_{CE(max)}$ for the BFY51 is 60 V and the supply voltage used in the transmitter is 18V. The power dissipation of transistors is linked to the maximum and working junction temperatures. For a BFY51, $P_{TOT(max)}$ is 5 W at 25°C and 2·8W at 100°C, the temperature being that of the case. The oscillator and driver are run at lesss than 1 W, and the p.a. runs at a maximum of 1 W per transistor, with the transistors in a heat sink. The BFY51 is, therefore, a suitable choice for the transmitter.

Circuit description

The first BFY51 stage is a negative impedance crystal oscillator. In this type of circuit when the emitter bias resistor is bypassed by a capacitor of a certain value and when the collector circuit is on the inductive side of resonance, a negative impedance appears between the base and the common line. A quartz crystal is placed between the base and the common line, so that the circuit oscillates at the crystal parallel frequency. The tuned circuit in the collector must be tuned to slightly higher than the resonant frequency of the crystal to present an inductive impedance. The d.c. bias conditions are set by R_1 and R_2 in a potential divider. The temperature compensation is not as good as would be devised for a straight class A amplifier stage since R_2 shunts the crystal, and the low value required for good temperature compensation would have damped the circuit considerably. However, more than adequate stabilisation against thermal run-away is provided over the normally expected ambient temperature range. To further help short term stability, the first transistor is placed in a heat sink. The supply voltage of 18 V is dropped via R_3 to 12 V at the collector of the first transistor. The filter network, L_8 C_4, isolates the oscillator supply rail as regards r.f. The oscillator output is taken via the step-down transformer, L_1 L_2, which matches the oscillator collector impedance into the base impedance of the next stage.

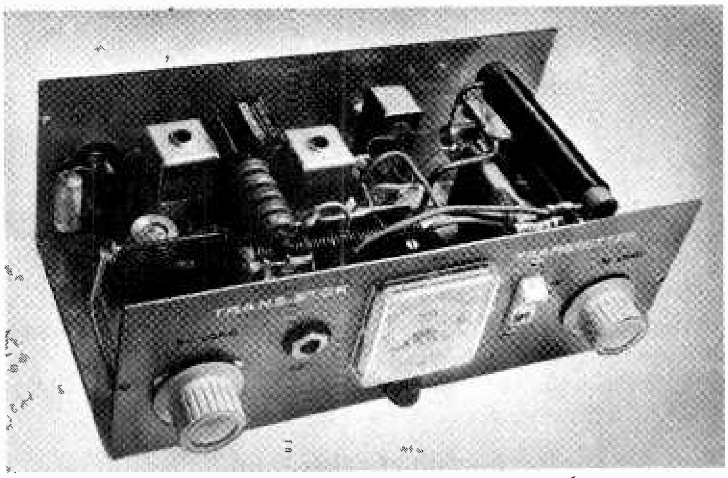
The buffer transistor, Tr_2 a BFY51, operates in class B, with a tuned collector load adjusted to resonate at the crystal frequency. Negative feedback is applied by means of the un-bypassed emitter resistor R_4. The transistor base input is transformer coupled from the oscillator stage, with the cold end of drive winding interrupted by a key jack. This provides a suitable method of d.c. keying the transmitter, since the buffer transistor is silicon, with an extremely small leakage current when the base is open circuited. The efficiency of the keying is also increased by the negative feedback, since this lowers the operating point of the transistor. Keying the buffer stage means, of course, that the oscillator is free-running whilst the transmitter is switched on, and oscillator frequency shift

Fig. 1 The circuit diagram of the transmitter. The R_3, R_3' combination is used to obtain the required 600 Ω.



with keying ("chirp") is obviated. The filter, L_7 C_5, prevents r.f. from appearing on the key leads.

The p.a. stage consists of three BFY51s operating in parallel single-ended class B. The input is transformer coupled and matched by the transformer L_3 L_4. The output is taken via a π coupler network C_7 L_5 C_8 to the output capacitor C_{12}. The combined collector currents of Tr_3 Tr_4 and Tr_5 are monitored on the meter M_1, and r.f. isolation is given by the r.f. choke L_6. The common emitter resistor R_6 is of a low value but for tuning up purposes, a higher resistor, R_7 is inserted at this point to limit the collector current and increase the negative feedback. No thermal compensation has been provided in the p.a. stage, and consequently the three transistors are mounted on a common copper heat sink. Since the BFY51 has the collector connected to the TO5 can, the heat sink has to be isolated from the transmitter case. The 18 V rail to the p.a. and buffer amplifier is decoupled via C_9 and C_{10}, to prevent instability.



A view of the transmitter showing the front panel.

Oscillator stage

A compromise has to be found in the oscillator circuit between high stability with no self-heating of the components, and sufficient output to drive the following stage. Since a power transistor is being used in both the oscillator and buffer, the oscillator output and buffer drive are more than with small signal transistors. Hence, let the input power to the oscillator transistor be 0·25 W: then $I_c \approx 13$ mA. The available voltage swing at the collector, taking into account the voltage drop across the emitter resistor, the series dropper and the r.f. choke is $18 - 1{\cdot}3 - 7{\cdot}8 - 0{\cdot}4 = 8{\cdot}5$ V r.m.s. Assume two turns for L_2 (see later), then the number of turns required at the collector is $n_1 = (n_2 V_c) V_{IN}$.

Now V_{IN} will vary with the gain of the transistor, the collector load and the loop gain. However, an r.m.s. voltage of less than 1 V r.m.s. is advisable across the quartz crystal for stability. So taking V_{IN} as 0·85 V r.m.s.,

$$n_1 = \frac{2 \times 8{\cdot}5}{0{\cdot}85} = 20 \text{ turns}$$

L_1 is then 20 turns of 20 s.w.g. enamelled copper wire close wound on a 0·635 cm diameter former with an iron dust core. Reference to standard wire tables gives an inducatance of 2 μH

$$L_1 = 2\ \mu\text{H and for resonance } C = \frac{1}{\omega^2 L}$$

where L is in henrys, C is in farads, f is in Hz and ω is $2\pi f$.

The parallel tuning capacitor for 7 MHz is:

$$C_1 = \frac{10^{12}}{4\pi^2 \times 7^2 \times 10^{12} \times 2 \times 10^{-6}} = 257 \text{ pF}$$

Coil winding details

coil	value	turns	wire	remarks
L_1	2μH	20	20 s.w.g.	close wound, 0·635-cm former
L_2	0·5μH	2	20 s.w.g.	on cold end of L_1
L_3	1·5μH	13	20 s.w.g.	close wound, 0·635-cm former
L_4	0·5μH	2	20 s.w.g.	on cold end of L_3
L_5	See text			
L_6	20μH	100	24 s.w.g.	close wound, 1·27-cm former
L_7	2mH } Pi-wound r.f. chokes			
L_8	2mH } Pi-wound r.f. chokes			

Buffer stage

Input inductor L_2: The measured drive was 29 mW at 2·5 V r.m.s. The average input impedance $R_{IN} = V_{IN}^2/P_{IN}$.

$$\therefore R_{IN} = \frac{2.5^2 \times 1000}{29} = 216\ \Omega$$

Let the inductor working Q be 10 for good harmonic suppression, then $L_2 = R_{IN}/\omega Q_w$

$$\therefore R_{IN} = \frac{216 \times 10^{-6} \times 10^6}{14\pi \times 10} = 0{\cdot}5\ \mu\text{H}$$

Referring to standard copper wire tables gives L_2 as two turns of 20 s.w.g. enamelled copper wire. This is wound over the "cold" end of L_1 and the whole assembly is mounted inside a screening can.

The value of the collector inductor L_3 will depend on the p.a. drive inductor L_4. Assuming for the moment that this is two turns, then

$$n_3 = \frac{n_4 . V_c}{V_{IN}} = \frac{2 \times 16}{2{\cdot}5} = 13 \text{ turns.}$$

L_3 is, therefore, 13 turns of 20 s.w.g. enamelled copper wire close wound on an 0·635 cm diameter former with an iron dust core giving an inductance of 1·5 μH.

$$\therefore C_6 = \frac{10^{12}}{4\pi^2 \times 49 \times 10^{12} \times 1{\cdot}5 \times 10^{-6}} = 345 \text{ pF.}$$

P.A. stage

For the drive inductor L_4. The input impedance of the output transistors at higher emitter currents is approximately equal to the extrinsic base resistance $r_{bb'}$ (also known as the base spreading resistance of the hybrid-π equivalent circuit). Here $r_{bb'} \approx 120\ \Omega$. Then

$$R_{IN} = \frac{120}{3} = 40\ \Omega$$

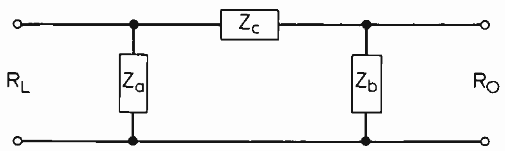
Now the Q of the p.a. drive inductor need not be high, since the collector circuit Q will be high. Let the working Q of the inductor be 2, then

$$L_4 = \frac{R_{IN}}{\omega Q_w} = \frac{40 \times 10^6}{2\pi \times 7 \times 10^6 \times 2} = 0{\cdot}5\ \mu\text{H}$$

L_4 is 2 turns of 20 s.w.g. enamelled copper wire wound over the cold end of L_3, the whole enclosed in a screening can.

For the output inductor L_5. The design of the p.a. π network will depend on the stage following the p.a. If a high Q conventional aerial tuning unit is used, then a single low Q π network can be used. If it wished to couple the p.a. directly into an aerial, then the Q of the π network will have to be raised. The simplest method of doing this is to add two π networks in series.

Single π network



For the p.a. stage

$$R_L \approx \frac{V_{cc}^2}{2P_{OUT}} - R_E$$

where V_{cc} is the supply voltage, P_{OUT} is the r.f. output power and R_E is the emitter resistor.

Assuming an 80% transfer efficiency $P_{OUT} = 2{\cdot}4$ W

$$\therefore R_L = \frac{18^2}{2 \times 2{\cdot}4} - 1 = 66\ \Omega$$

now

$$Z_a = R_a + \mathrm{j}\,\frac{R_L\,R_O \sin\beta}{R_O \cos\beta - \sqrt{R_L\,R_O}}$$

where R_a is the pure resistive component fo Z_a, and β the phase shift (+ or −) between input and output of the network.

Assume the components to be ideal (i.e. no R_a term), and let the phase shift β be 90°. Then

$$|Z_a| = -\frac{R_L . R_O}{\sqrt{R_L . R_O}} = -\sqrt{R_L\,R_O}$$

Similarly

$$Z_b = R_b + \mathrm{j}\,\frac{R_L\,R_O \sin\beta}{R_L \cos\beta - \sqrt{R_L\,R_O}}$$

and making the same assumptions

$$|Z_b| = -\frac{R_L\,R_O}{\sqrt{R_L\,R_O}} = -\sqrt{R_L\,R_O}$$

Also

$$Z_c = R_c + \mathrm{j}\sqrt{R_L\,R_O}\sin\beta$$

$$|Z_c| = +\sqrt{R_L\,R_O}$$

So $-X_a = -X_b = +X_c$, where the sign indicates capacitive (−Ve) or inductive (+Ve) reactances. For a 50 Ω output.

$$R_L\,R_O = 66 \times 50 = 57{\cdot}5\ \Omega$$

then

$$C_a = C_b = \frac{1}{\omega X_a} = \frac{10^{12}}{14\pi \times 10^6 \times 57{\cdot}5} = 400\ \text{pF}$$

$$L_c = \frac{X_c}{\omega} = \frac{57{\cdot}5 \times 10^6}{14\pi \times 10^6} = 1{\cdot}3\ \mu\text{H}$$

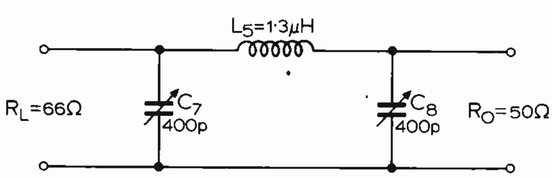


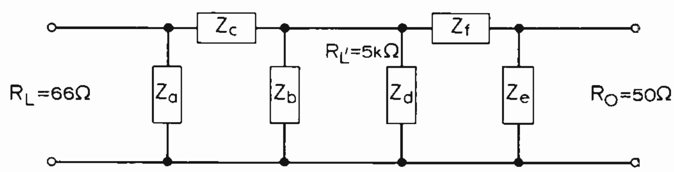
Fig. 3 Single π-network circuit.

The output π network for feeding a 50 Ω input high-Q aerial tuning unit is shown in Fig. 3. The Q is

$$\sqrt{\frac{R_L}{R_O}} = \sqrt{\frac{66}{50}} = 1{\cdot}15$$

This value is too low for the network to adequately suppress harmonics. In practice higher value variable capacitors may be used at C_7 and C_8. This enables different aerial tuning unit loads to be used, and also allows experiment in different output network configurations to be carried out for optimium results with a given aerial. If the following circuit is to be used, however, the minimum capacity of each variable capacitor should be less than 40-pF.

Double π network



From the formulae given and from the assumptions made in the previous section:

$$|Z_a| = -\sqrt{R_L\,R_L'} = |Z_b|$$

$$|Z_c| = +\sqrt{R_L\,R_L'}$$

$$|Z_d| = -\sqrt{R_L'\,R_O} = |Z_e|$$

$$|Z_f| = +\sqrt{R_L'\,R_O}$$

Then

$$-X_a = -X_b = +X_c$$

$$= \sqrt{66 \times 5{,}000} = 575\ \Omega$$

$$C_a = C_b = \frac{1}{\omega X_a}$$

$$= \frac{10^{12}}{14\pi \times 10^6 \times 575} = 40\ \text{pF}$$

$$L_c = \frac{X_c}{\omega} = \frac{575 \times 10^6}{14\pi \times 10^6} = 13\ \mu\text{H}$$

$$-X_d = -X_e = +X_f$$

$$= \sqrt{5{,}000 \times 50} = 500\ \Omega$$

$$C_d = C_e = \frac{1}{\omega X_d}$$

$$= \frac{10^{12}}{14\pi \times 10^6 \times 500} = 46\ \text{pF}$$

$$L_f = \frac{X_f}{\omega} = \frac{500}{14\pi} = 11\ \mu\text{H}$$

The circuit of the double π network is given in Fig. 5. The value of

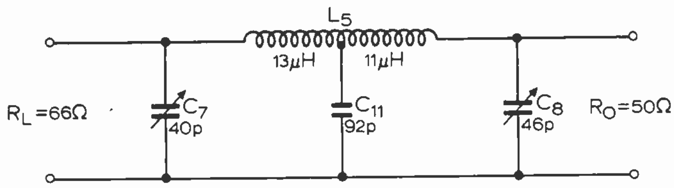


Fig. 5 Double π-network circuit.

R_L', 5,000 Ω was chosen to give the required Q

$$Q = \sqrt{\frac{R_L'}{R_O}} = \sqrt{\frac{5{,}000}{50}} = 10$$

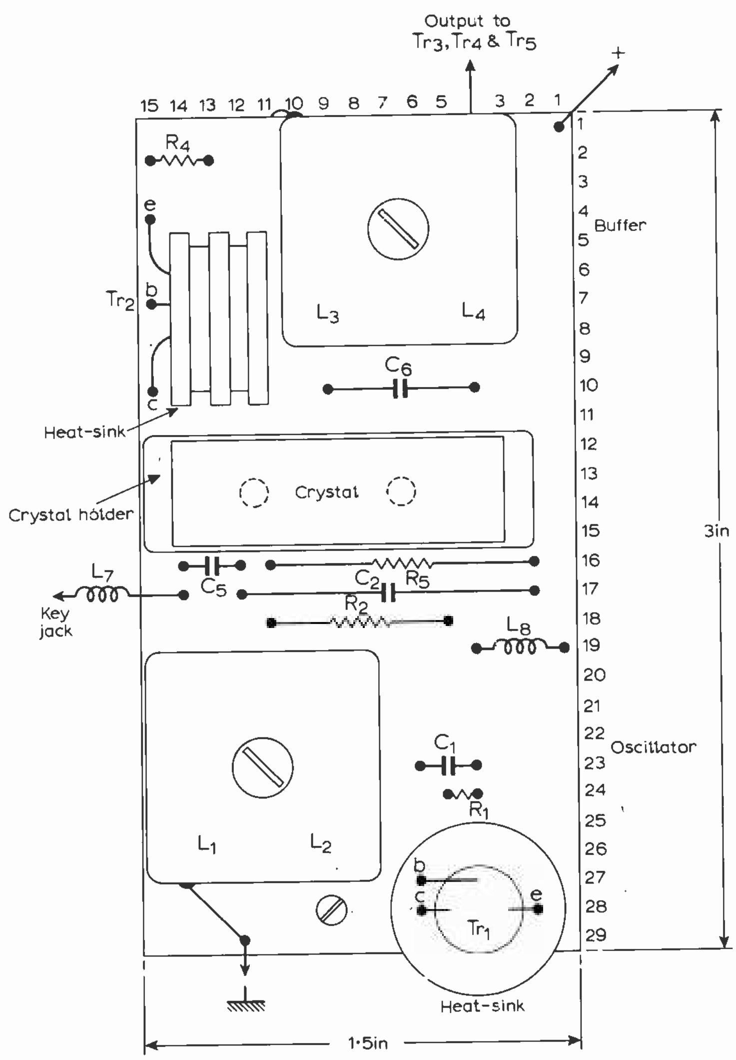
A Q of 10 is a good compromise between efficient harmonic suppression and inductor resistive loss. The coil winding details for the single π network, $L_5 = 1{\cdot}3\ \mu$H, are 6 turns of 18 s.w.g. enamelled copper wire close wound on an insulating tube of 1·5 cm diameter. Alternatively (for different loading values), 54 turns as above tapped at 6, 10, 14 turns etc. For the double π network, $L_5 = 13 + 11\ \mu$H, 100 turns 18 s.w.g. enamelled copper wire close wound on an insulating tube of 1·5 cm diameter, tapped at 54 turns.

Thermal design of p.a. heatsink

The thermal resistance of the p.a. heatsink is given by

$$\theta_h = \frac{T_j - T_{amb}}{P_c} - \theta_m - \theta_i$$

Fig. 6 Layout of components in the case.



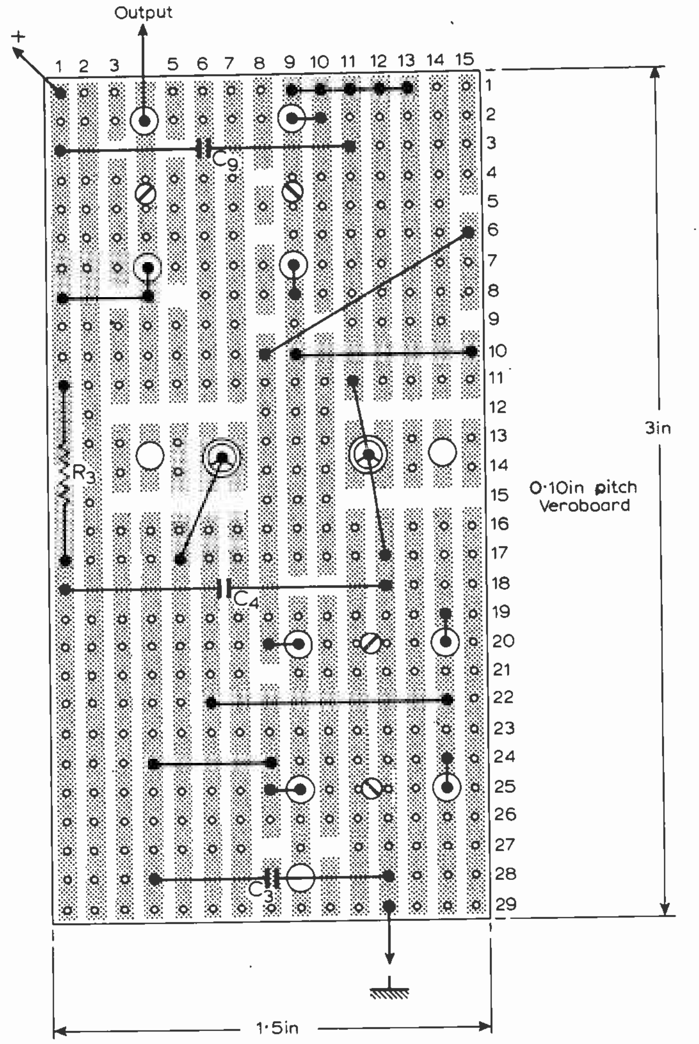


Fig. 7 Underside of the Vero circuit board.

where

θ_h = thermal resistance of the heat sink (heat sink/ambient)
θ_i = thermal resistance between transistor case and heat sink
θ_m = thermal resistance between collector junction and transistor case
T_j = collector junction temperature
T_{amb} = ambient temperature
P_c = total power dissipated at the collector junction

For the BFY51,

$$T_{j(max)} = 200°\text{C};\ \theta_m = 35°\text{C/W};\ P_{c(max)} = 1\ \text{W}$$

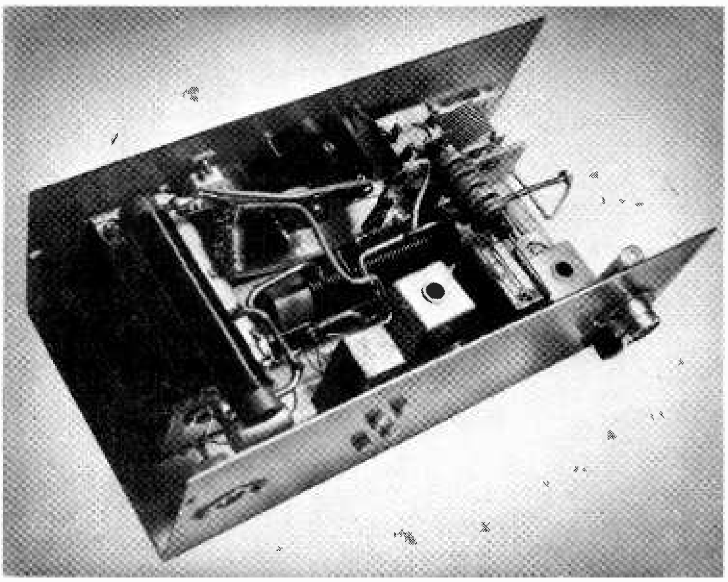
The highest ambient likely to be met is 45°C. If the transistor is mounted in a copper block, with silicon grease at the interface, then θ_i may be taken as 0·2°C/W

$$\theta_h = \frac{200 - 45}{1} - 35 - 0{\cdot}2 = 120°\text{C/W}$$

The thermal resistance between the transistor case and air is approximately 220°C/W. A heat sink is therefore required. A copper block of minimal dimensions to accomodate three TO5 transistor cases should be adequate.

Construction details

The original transmitter was built into a small aluminium box 20 × 10 × 6 cm made from a sheet of 18 s.w.g. aluminium bent



This photograph can be related to the practical layout drawings to give a clean picture of the layout employed.

into a squared off "U", with a hooded lid of the same metal fitting over the top. This prototype contained a single p.a. π network, but a second model was rearranged to accomodate a double π network. No special care was taken in the layout, apart from the usual precautions of using rigid wiring, and making sure that unwanted coupling and consequent feedback did not occur. The internal layout of the first prototype is shown in Fig. 6.

The oscillator and buffer were constructed on a sub-unit of 0·25 cm pitch Veroboard 3×6 cm in size (Figs. 6 and 7). This was mounted on two pillars attached to the base plate.

The heat-sink for the three p.a. transistors is made out of solid copper. The dimensions are $4 \times 1{\cdot}6 \times 1{\cdot}6$ cm. The block is drilled at three places using a drill suitable for the BFY51 TO5 case ($\frac{5}{16}$ in, 8mm or Letter O), and the transistors are inserted into the holes after being smeared with silicon grease to improve heat transfer. The heat-sink is then drilled and tapped 6BA in four places on the reverse side and retained in the case by nylon screws and insulators. The other transistors in the circuit are fitted with standard round heat-sinks.

In the prototype the single p.a. π network inductor L_5 was of 54 turns, tapped along its length to aid the original setting-up. It might well be more useful to use such a winding, instead of the calculated 6-turn inductor, to help in matching into other loads. Modulation of the transmitter has not been tried—the reader is referred to Larsen (*R.S.G.B. Bulletin,* Oct. 1966, p. 639) for information and references.

Other frequency bands may be tried. Doubling in the buffer stage can be accomplished, with reduced drive to the p.a. and reduced p.a. output. The buffer inductor values and π network component values will have to be re-calculated using the method given. The efficiency of the p.a. in these calculations should be taken as about 50%. Other transistors could be tried in the p.a. or the p.a. could drive a further stage. Cheaper high power r.f. transistors might give interesting results.

The transistor transmitter that has been described is capable of giving a stable and clean c.w. signal. Reports received on the air have been most encouraging. It has been found to be very economic on power requirements, and the batteries specified seem quite adequate. Construction of the basic circuit should give those new to semiconductor transmitters a footing from which to try further developments of the original idea.

It is planned to show the transmitter at this years Radio Society of Great Britain Exhibition to be held at the Royal Horticultural Society's New Hall in Westminister between October 2 to 5. Other equipments to be shown are the r.f. signal generator by Nelson Jones, P. J. Baxandall's Loudspeaker and the Wireless World Computer and Crosshatch Generator.

Less e.m.f. for the Volt

In the near future all readings on voltmeters in Britain are likely to be slightly low. An e.m.f. indicated as 1 volt will in fact be slightly higher than 1 true volt. The reason will be that the standard volt in Britain is probably going to be changed, in such a direction that in future it will represent a smaller electromotive force than it does at present. In October the International Committee on Weights and Measures (B.I.P.M.) will be meeting at Sèvres, France, and is expected to make recommendations for bringing the differing volt units of ten countries into agreement. But engineers and technicians need not worry too much, for the probable change in each case is not likely to be more than a few parts in a million—in Britain about 10 p.p.m. Nevertheless it is the increasing importance of precision electrical measurements in engineering, to which electronics has greatly contributed, that has made necessary this more accurate definition of the standard volt.

A significant factor in this need to regularize the volt is the general adoption of the SI system of units, in which electrical units are defined in terms of the units for mass, length and time. For example, the volt is defined first in terms of the ampere and the watt. The ampere is in turn defined in terms of force and length (force produced between wires carrying current), while the watt is defined in terms of the joule and thence also derives from force and length. Force, of course, is defined in terms of mass, length and time. Unfortunately the absolute volt determined in this way is different from the volt as given by the standard cells kept by national standards laboratories, so the purpose of the October B.I.P.M. meeting will be to bring the units maintained by the various countries into conformity with the absolute SI volt.

New measurements of the ohm and the ampere in terms of the basic SI units have been made in various national laboratories. The ohm determinations show that the values of the standard resistors used to maintain the unit of resistance are substantially correct (to better than 1 p.p.m.). On the other hand the recent ampere determinations indicate that the absolute ampere is smaller by about 11 p.p.m. than the ampere determined by the standard cells and standard resistors used to maintain the standards for the volt and ohm, respectively, at B.I.P.M. Since these measurements indicate that no adjustment in the ohm is called for, an adjustment in the base of reference for the volt is needed to account for the results obtained in the ampere determinations.

Fortunately, it will be a long time before the average voltmeter used by electronics people is accurate enough to be affected by these minute adjustments to the standard.

News of the Month

High Power m.o.s.ts.

One has become accustomed to thinking of the m.o.s. field-effect device as a small-signal amplifier often used in input stages. It is therefore a surprise to learn from Associated Semiconductor Manufacturers Ltd., of Wembley, London, that they have a research programme aimed at developing high-power m.o.s.ts for use as linear amplifiers in single-sideband h.f. transmitters (operating from 2 to 30 MHz). Next year, in fact, they hope to produce a device giving an output of more than 100 watts peak envelope power. Meanwhile, they have actually developed an experimental m.o.s.t. with an output of 30 watts p.e.p., and as we go to press this device will probably be on show at the International Broadcasting Convention in London.

A feature which makes the m.o.s.t. particularly suitable for single-sideband amplification is that its output current is proportional to the square of the input voltage, so that the level of odd-order intermodulation products is low. In contrast to the bipolar transistor, the m.o.s. device is thermally stable and requires no complex bias circuit to prevent thermal runaway. Also, of course, the m.o.s.t. has the advantage of a higher input impedance than that of a bipolar transistor and an exceedingly low gate current. A.S.M. state that two factors in the development of the high-power amplifier are raising the breakdown voltage to increase the output and arranging the construction to minimize feedback capacitance. They claim that with the 30-watt device a stable performance with little distortion is maintained over a wide frequency range.

Goodbye red, black and green in 1970?

New regulations made under the Consumer Protection Act 1961 require that the colour coding of the power cable of domestic electrical appliances offered for sale in Great Britain complies with the code recently recommended by the International Commission on Rules for the Approval of Electrical Equipment (C.E.E.). The new coding is as follows:

LIVE—BROWN
NEUTRAL—LIGHT BLUE
EARTH—GREEN AND YELLOW STRIPED.

Up to a date to be specified in the regulations—January 1, 1970, has been proposed—the present British standard code will also be permitted. At one time during the discussions, but for the intervention of the U.K., the C.E.E. was likely to choose black for the live cord. If this had been done a great deal of confusion between the present black for neutral and the new standard could have occurred in this country.

Airborne audible warning system

Monitoring all the equipments contained in a modern aircraft is a time-consuming business which adds to the crew work-load. Most aircraft contain some form of central warning system whereby a failure in an essential service or the onset of a dangerous condition actuates some sort of primary indicator. The pilot on seeing the warning then scans a secondary set of warning indications to find out which system has failed so that the necessary action can be taken. If the fault is cleared all warnings are also cleared, but if the fault persists the primary warning indication can be cancelled so that the system is prepared for any other failure that may occur.

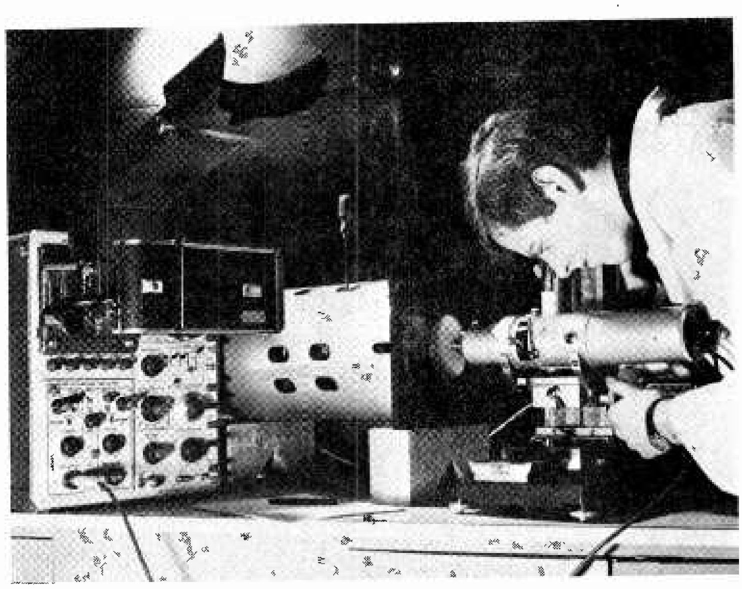
As a logical development of the above technique Ferranti have produced an audible warning system, called type FAW.3, that plays back a recorded message, via headphones or a loudspeaker, giving details of any failure that has occurred or any dangerous condition that has developed. The tape section of the device employs a 16 track head, fifteen of the tracks are for messages, the remaining one being used for control purposes. The normal message length is three seconds; this can be extended if desired, and the message is continuously repeated while the fault exists or until cancelled by the pilot. Of the 15 messages which can be accommodated six are considered to be priority warnings and would be restricted to conditions affecting the immediate safety of the aircraft. If a priority warning is called for during the replay of a non-priority warning the non-priority warning is interrupted. In the event of two warnings occurring simultaneously they are repeated sequentially.

Space research spin-off aids heart patients

An instrumentation system developed by the National Aeronautical & Space Administration Flight Research Center, Edwards, California, for use by pilots of research aircraft, is being used as an emergency ambulance aid. The system enables an ambulance attendant to transmit to a hospital the electrocardiograms of a patient whilst en route to that hospital. The hospital being forewarned of the patient's coronary condition—in detail—can make all the necessary preparations in advance. In the system slim bare wires replace ordinary clinical electrodes. These wires are applied to the skin using a quick drying conductive silver-glue eliminating the need for shaving the skin. Information obtained in this way is relayed over a conventional radio link. The system is at present being used in California and Los Angeles.

Nigeria communications contract for GEC-AEI

The Nigerian Ministry of Communications and GEC-AEI Telecommunications have recently signed a contract in Lagos worth £9.6m. Under the contract GEC-AEI will supply and install a 2,500-mile microwave and v.h.f. network which will complete stage three of Nigeria's national telecommunications plan. Intelligence will be transmitted at 450MHz and 2 and 6GHz using f.d.m. while supervisory information will employ t.d.m.



A technician using the microspot analyser announced by Ferranti. The instrument which is for c.r.t. resolution measurement can be used in any one of four modes, spatial frequency, two slit line width, half power line width and intensity distribution across spot. In addition the instrument can be used to measure deflection linearity, phosphor noise, phosphor build-up and persistence.

techniques. The supervisory channels make it possible to monitor remote stations and to display any fault occurring at such a station at one of the maintenance control centres. In some cases where the traffic is expected to be heavy auxiliary narrow-band radio links will carry the supervisory information. A total of 17 maintenance control centres will be established to service the network; each will carry trained staff, spares and the necessary test equipment.

VASCA officers

At a recent meeting of the General Management Committee of the Electronic Valve & Semiconductor Manufacturers' Association, Dr. F. E. Jones was elected chairman of the Association in succession to P. H. Spagnoletti, who has held that office for the past two years. V. A. Cheeseman (managing director of the M-O Valve Company) was elected vice-chairman. G. P. Thwaites has been elected chairman of the group concerned with industrial valves and tubes and J. C. Akerman was re-elected the chairman of semiconductor devices group. The British Radio Valve Manufacturers' Association and V.A.S.C.A. also announce that the Post Office has changed the address of their headquarters at Mappin House, Oxford Street, as follows: Mappin House, 4 Winsley Street, Oxford Street, London. WIN ODT.

Wired standard frequencies

Many laboratories may wish to follow the example of the United States National Bureau of Standards Laboratories in Gaithsburg, Maryland, and wire standard frequencies direct to working positions on test benches, in much the same way as the mains is at present. In the American set-up a tuned loop aerial picks up a standard frequency transmission at 60kHz from station WWVB at California, Colorado. Using standard techniques the received 60kHz is used to control a local 100kHz crystal oscillator and a pen recorder keeps a record of the local oscillator's performance. The 100kHz is divided down to provide outputs at 100, 10 and 1kHz, and 400, 100, 60 and 1Hz and amplified to provide seven spot frequencies with a stability of one part in 10^{10} over 24 hours at 30V r.m.s. The seven outputs are then connected via balanced lines to the various working positions; one of these is half a mile away from the source.

The advantages of such a system are obvious, no need for a large number of separate frequency standards, one person only responsible for the installation and, of course, convenience. An article on standard frequency transmissions by J. McA. Steele in *Wireless World* September 1967 would provide a starting point for anyone wishing to adopt this technique.

Defence message switching system

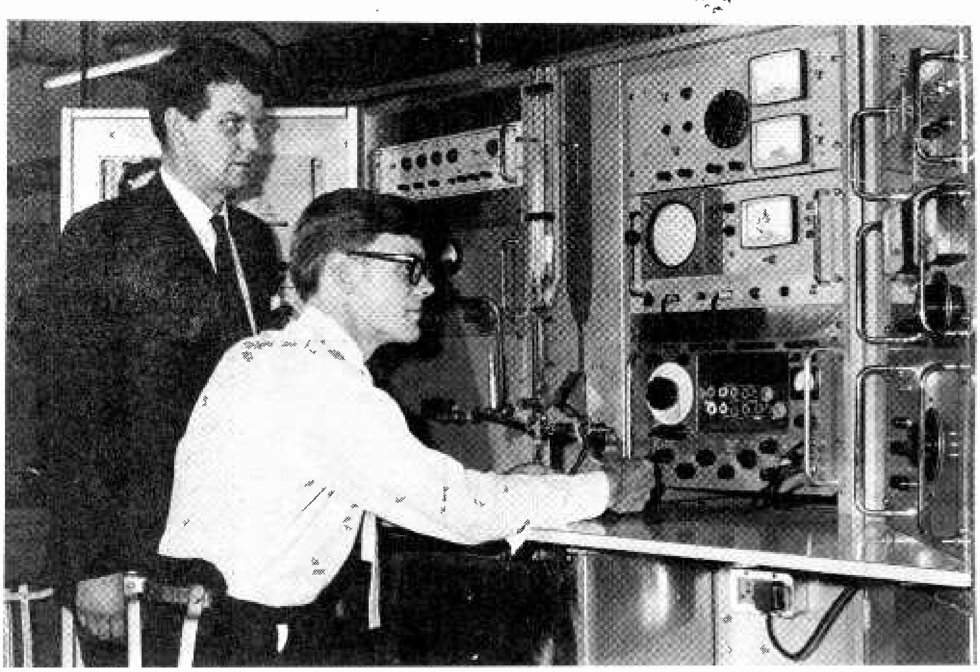
The Ministry of Defence is to have the largest, fully automatic message switching system yet ordered by the British Government. A £1m contract has been awarded to The Marconi Company by the Ministry of Technology, to supply a message switching and distribution system for the Defence Communications Centre under central London.

The system will be used for switching military teleprinter messages and data traffic and will handle internal communications between the separate branches within the Ministry, it will also form the hub of the military services network in the U.K. and overseas. Manual routeing, or handling of messages will be completely eliminated, and all messages will be accepted immediately and stored on magnetic discs, to be transmitted automatically to the appropriate destination as lines become free. The system will accept a simple destination code at the start of each message, which defines a single address, or any one of a large number of circulation lists.

The preparation of messages on paper tape at the terminals is entirely eliminated, the messages being compiled on-line, directly into the system. The usual complex communications message format is reduced to a very simple plain-language form, suitable for use even by inexperienced operators. This is accepted by the computer system, and expanded into the full communications format required by the networks to which the system is connected. Messages can be monitored on electronic tabular displays, and edited, without the need to extract them from the magnetic store, thus reducing transit delays previously experienced in manual systems.

The picture shows the auxiliary power supply, a Deac rechargeable battery, being installed in a Wayne Kerr universal bridge model B221 Mk. III. The battery enables the instrument to be used in areas where no power supply is available and enables measurements to be made on in-situ components where a mains common link would be embarrassing.

The millimetre-wave magnetron and klystron production department formerly at Elliott Electronic Tubes factory at Borehamwood, Herts, has been transferred to the English Electric factory at Chelmsford. The present frequency range of these components is from 18 to 80 GHz with peak power handling capabilities of up to 50 kW and mean powers up to 50 W. The photograph shows A.B. Cutting, now manager of the department, in the millimetre wave tube laboratory.



Television sets on roller-skates!

A new product designed to make life easier for the harassed housewife has been introduced by a Birmingham company—Harrison P.O. Box 233, Birmingham 12. The product, called Telemove, consists of four castors on extendible arms that are attached to the legs of any television set. The assembly is completed by adding a magazine rack. The television set can now be easily moved for household cleaning purposes.

Radio blackout test

A space flight to study methods for preventing the loss of radio signals from spacecraft returning to Earth has been carried out under the control of the National Aeronautics and Space Administration from Wallops Island, Vancouver.

The eight-minute ballastic flight test,

RAM C-B, was a continuation of the N.A.S.A. radio attenuation measurement project to study the problem of communicating through the ionized gas (plasma sheath) created when a spacecraft re-enters the Earth's atmosphere at great speeds. The test is the second in the RAM C series.

Unlike the previous RAM test, in which water was ejected into the plasma stream to restore radio communications, this test will be confined to measuring the amount of electrons and ions which build up around the spacecraft.

The results of the flight will be used with information from the water-ejection experiment, laboratory tests, and theoretical studies to provide a better understanding of the problem of communicating through the plasma sheath.

Digital displays for A.T.C.

An order worth about £170,000 has been placed with the Marconi Company by the Board of Trade for 36 type X2000 graphical display systems. The equipment will be used by the Board of Trade College for Air Traffic Control at Hurn airport, near Bournemouth, to study some of the problems associated with the large flight plan processing system currently being installed at West Drayton near Heathrow airport, London. The equipment will also be used to study better ways of presenting information to air traffic controllers.

L.F. telemetry and broadcast interference

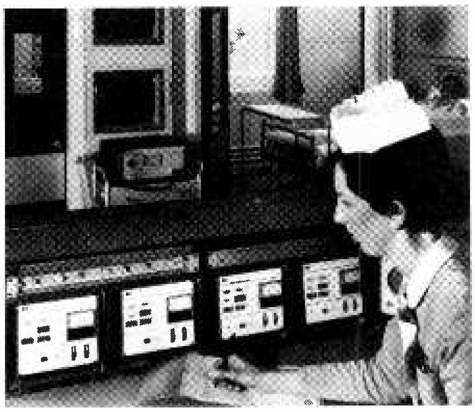
Tests conducted by the Electronic Industries Association, Washington, has led to a formal 'Objection' being filed with the Federal Communications Commission concerning a proposal to permit a.m. broadcasters to use the 20 to 36Hz band for telemetry purposes. If the proposal is adopted broadcasters will be freed from the necessity of maintaining expensive land lines. Listening tests carried out with the co-operation of local radio stations have shown that the l.f. telemetry produces noticeable interference and distortion on broadcast material particularly where voice modulation and music passages with sustained pauses are concerned.

Americans choose Decca for inter-city flight trials

A seven-week evaluation programme is to be carried out in America to demonstrate the feasibility of using STOL (short take-off and landing) aircraft for inter-city passenger services. The aircraft to be used is the McDonnell Douglas model 188, known in Europe as the Breguet 941. Due to the steep climb and descent characteristics of this aircraft accurate navigation in three dimensions is essential and a Decca/Omnitrac installation has been installed for this purpose.

New British computer

International Computers (Holdings) Ltd have announced a new large computer called the 1908A that is compatible with the earlier 1906A. The new computer can be supplied with a thin film store with a capacity of up to one million words with a cycle time of 330 ns. The form of construction is similar to that of the 1906A, twelve-layer printed circuits and emitter coupled logic being employed. I.C.L. also announced its intention to enhance the ex. Leo-Marconi System 4 range with the introduction of a new processor with at least twice the power of the 4-70.



An electronic monitoring system for coronary patients has been installed at the Royal Victoria Infirmary, Newcastle-upon-Tyne by Hewlett Packard. Changes in a patient's condition are recorded and a warning signal alerts hospital staff. As well as watching for distress conditions the equipment also includes an electrocardiograph and a pace-maker.

Navigation and the SRN4

British Rail's Seaspeed SRN4 hovercraft now in service as a cross-channel ferry is equipped with Decca navigational aids. At the high operating speeds, 50 to 70 knots, it is essential that some quickly assimilated readout of position be provided. A pictorial display coupled to a Decca Mk. 8A receiver provides an instantaneous positional readout and a moving chart records the craft's track.

Other Decca equipment fitted to the Hovercraft are true- and relative-motion radar displays.

Stereo-radio extended to Northern England

The BBC announce that stereophonic programmes on Radio 3 have been extended to a large part of Northern England from 10th August. The transmissions are from the Holme Moss station on 91.5MHz. Good stereophonic reception is to be expected within the existing service area of the Holme Moss v.h.f. transmitter.

S.E.R.T. and R.T.E.B. discuss merger

Successful launching and rapid growth of the Society of Electronic and Radio Technicians has culminated in discussions for a possible merger with the Radio Trades Examination Board, the body which promoted the society in 1964. Such a move would give S.E.R.T. access to a body promoting courses and examinations in radio and electronics, and R.T.E.B. examinations would be conducted under a joint body providing membership of a professional society to successful entrants. S.E.R.T. and R.T.E.B. have recently moved to new premises at Faraday House, 8-10 Charing Cross Rd, London W.C.2.

Educational television seminar

A Royal Television Society seminar entitled "Television in Educational Technology—what is its role?" is being held in London at the Institution of Electrical Engineers, Savoy Place, W.C.2 on Friday, October 11th 1968 at 3 p.m. Admission is free. Applications for tickets should be made to the secretary, Royal Television Society, 166 Shaftesbury Avenue, London, W.C.2.

"The Fuel Cell"

In the article by G. Beardmore in the September issue there are two errors. Fig. 1 showing the percentage efficiency of energy converting devices and systems has its key missing. Cross-shaded areas represent the present range, and solid areas the projected range. In Fig. 3. (a) both electrodes have been labelled as cathodes, whereas the left-hand electrode, into which passes the hydrodgen gas, should be labelled "anode".

Courses

A course of twenty-seven lectures on **colour television engineering** will again be given at the Northern Polytechnic, Holloway Road, London N.7, on Monday evenings, commencing October 7th. Fee 51s. A parallel laboratory course, requiring attendance one additional evening every four weeks, has been introduced this year. Fee 30s.

An educational course of eight lectures on **"sound for film and television"** is being organized by the British Kinematograph, Sound and Television Society for Monday evenings beginning October 7th at the Royal College of Arts, Queens Gate, London S.W.7. Registration forms are obtainable from the B.K.S.T.S., 110/2 Victoria House, Vernon Place, London W.C.1. Fee £6.

Among the special courses arranged by the Department of Electrical Engineering, **Hendon College of Technology**, London N.W.4, for the 1968/9 session are six-lecture courses on thyristor applications (commencing October 17th) and colour television (October 24th) and another, of 10 lectures, on principles of feedback control (October 14th).

Eight lectures on **high-fidelity sound reproduction** will be held at Wolverhampton College of Technology on successive Wednesday evenings commencing October 16th. Further details may be obtained from the College Registrar. Fee £2.

Two short courses of lectures on **solid state physics** will be held at Barking Regional College of Technology, Longbridge Road, Dagenham, Essex. Commencing October 23rd are eight lectures on electrical properties of semiconductors and commencing January 22nd there will be eight lectures on optical properties of solids. The fee for each course is 2gn. Application forms are obtainable from the college.

Personalities

The new president of the Institute of Physics and Physical Society is **M. R. Gavin,** M.A., D.Sc., F.I.E.E., principal of Chelsea College of Science and Technology. Until his appointment three years ago to the College, of which he will be vice-chancellor when it becomes a university of technology, Dr. Gavin had been professor of electronic engineering in the University College of North Wales, Bangor, for ten years. He received his doctorate from Glasgow University for work on valves for decimetric waves and spent eleven years at the G.E.C. Research Laboratories, Wembley, before entering the academic world. His first appointment was as vice-principal and head of the department of physics and mathematics of the College of Technology, Birmingham. Dr. Gavin, who is 60, has been head of the department of electronic engineering at Bangor since it was set up in 1958.

Roger P. Towell, F.I.E.R.E., chief engineer of the recently formed Marconi-Elliott Microelectronics Ltd., has been with Marconi for about a year having previously spent 17 years with E.M.I. After seven years in the E.M.I. Engineering Dept. he transferred to the Research Laboratories and for several years was primarily concerned with the development of airborne radar. For a year prior to joining Marconi, Mr. Towell, who is 41, was manager (technical) of the E.M.I. Microelectronics Division.

R. P. Towell

Martin J. L. Pulling, C.B.E., M.A., F.I.E.E., who retired from the post of deputy director of engineering in the B.B.C. fifteen months ago, has joined the board and has been appointed chairman of the Ferrograph Company in succession to **R. W. Merrick** who remains on the board. Mr. Pulling, graduate of King's College, Cambridge, spent five years in industry before joining the B.B.C. in 1935. He became superintendent engineer, recording,

M. J. L. Pulling

in 1941 and was at one time controller, television engineering.

W. E. C. Varley, O.B.E., F.I.E.R.E., the B.B.C's chief engineer, transmitters, has retired and is succeeded by **M. J. Crawt,** F.I.E.R.E. Mr. Varley joined the Corporation in 1933 and after serving at Daventry and Droitwich he joined the headquarters staff of the Transmitter Department in 1935. During 1943 and 1944 Mr. Varley was chief broadcasting engineer at Allied Forces Headquarters in North Africa. He was appointed assistant superintendent engineer, transmitters, in 1958 and two years later superintendent engineer, transmitters, later re-designated chief engineer, transmitters. Mr. Crawt joined the B.B.C. in 1940. Since 1964 he has been superintendent engineer (transmitters I) with responsibility for all v.h.f. and u.h.f. television and sound broadcasting stations. Mr. Crawt is succeeded by **D. East,** M.I.E.R.E., his assistant, who joined the B.B.C. in 1943. Except for three years when he was in the valve section, he had been in the transmitter section of the planning and Installation Dept. since 1954.

D. A. V. Williams, B.A., M.I.E.E., has become chief engineer, B.B.C. external broadcasting in succession to **Dr. K. R. Sturley,** who, as announced in July, has accepted an invitation to the Chair of Communications at the Ahmadu Bello University, Zaria, Nigeria. Mr. Williams, who was educated at Marlborough College and Trinity Hall Cambridge, joined the B.B.C. in 1950 at Alexandra Palace. For two years from 1962 Mr. Williams was the B.B.C's senior engineer in New York and on his return from the United States he became head of the external services unit in the Transmitter Planning and Installation Department. For the past 18 months he has been superintendent engineer (transmitters II) with responsibility for the operation and maintenance of all the B.B.C's low-, medium- and high-frequency transmitters at home and overseas. Mr. Williams' successor is **C. C. Butler,** M.I.E.E., who has been his assistant since 1964. Mr. Butler joined the B.B.C. at Daventry in 1940.

Martin H. Oliver, Ph.D., B.Sc., D.I.C., A.C.G.I., M.I.E.E., head of the Radio Department of the Royal Aircraft Establishment, Farnborough, for the past three years has become superintendent of the Services Electronics Research Laboratory, Baldock. Dr. Oliver, who graduated in 1926 at Imperial College, London, received his Ph.D. in 1939 for a thesis on "Measurements in connection with electrical surge phenomena". He spent the early war years in the Radio Department at the National Physical Laboratory and in 1943 joined the Telecommunications Research Laboratory. In 1956 Dr. Oliver became superintendent of microwave electronic research and in 1960, superintendent, offensive radar at the Royal Radar Establishment.

The Independent Television Authority has announced the following three appointments to the new post

H. French

H. N. Salisbury

of Regional Engineer in the Operations and Maintenance Department in preparation for the Independent Television colour service which will start early in 1970. **H. French,** Regional Engineer South, has been engineer-in-charge of the Chillerton Down, Isle of Wight, transmitting station since 1959. Before joining the I.T.A. in 1956 at the Winter Hill station, Mr. French was for 14 years with the B.B.C. as a

G. W. Stephenson

transmitter engineer. He served in the Royal Navy for four years. **H. N. Salisbury,** M.I.E.R.E., Regional Engineer North, joined the I.T.A. in 1958. The following year he became assistant engineer-in-charge of the Chillerton Down station. In 1961, he was promoted to engineer-in-charge of the Caldbeck, Cumberland, transmitting station and was transferred to Winter Hill in 1965. Before joining the I.T.A. Mr. Salisbury was for 14 years with the B.B.C. During this period, he spent two years seconded as chief engineer to the Forces Broadcasting Service in Cyprus. **G. W. Stephenson,** M.I.E.E., Regional Engineer Midlands, joined the I.T.A. in 1958 at Emley Moor and in August 1959 was appointed assistant engineer-in-charge at the Mendlesham transmitting station. Since 1961 he has been engineer-in-charge of the Stockland Hill, Devon station. Mr. Stephenson was with the B.B.C. as a transmitter engineer for 13 years and served in the Royal Navy for three years.

Measuring Delays Accurately

Technique using recirculation of pulses through network under test offers accuracy of ±0.2% or better

by L. E. Weaver, B.Sc., M.I.E.E.*

The problem of accurately measuring the time of transmission of waveforms through delay lines and similar networks arises in a number of branches of electronic engineering and physics. The author's particular requirement has been to measure the delays introduced by timing elements and filters used in the signal paths in colour television studio and outside broadcast equipment. For example, the delays in the R, G, B or Y, R, G, B outputs of a colour camera must be matched within very close limits. The maximum tolerance on a $1\mu s$ delay might be 5ns, which would mean a measurement of the delay to appreciably better than $\frac{1}{2}\%$. Since the tolerance is a fixed time rather than a percentage delay, the accuracy required increases with the delay.

The direct measurement of the delay of a waveform through the network by the use of the calibrated sweep circuits of an oscilloscope can be ruled out immediately since even a true accuracy of $\pm 2\%$ is not easy to achieve by this method and this is far from adequate for the purpose.

The technique favoured hitherto has been to make use of the "pi-points", that is, the frequencies at which the phase shift through the network is 180°, which occur at frequencies equal to $n/4t_p$, where t_p is the phase delay through the network. Provided an oscilloscope is available which has comparable gains on both X and Y amplifiers the network under test can be measured on an insertion basis. The delays through the two paths are initially adjusted to equality, so that the cathode-ray tube displays a straight line Lissajou figure at all frequencies when a common signal generator is fed into the two paths.

The unknown network is then inserted into one path assumed to have a good 75 ohm impedance, and the first frequency at which the straight line figure is again obtained is measured by means of a digital frequency meter. This is equal to $1/4t_p$ where t_p is the phase delay at the frequency of measurement and does not necessarily coincide precisely with the pulse delay of the network since a certain variation in delay over the band is always allowed. The permissible variations increase as the frequency increases, so it is important to keep the measured delay high, if necessary by inserting a fairly large calibrated delay in series.

The pi-point method is very reliable and easy to carry out, but uncertainties in the measurement make it less attractive where the highest absolute accuracy is required. It is, however, excellent for matching the delays of samples of the same network, where the absolute values of delay are less important, and delays equal within 1ns are not difficult to obtain.

A technique which the author has used with some success in his work is based on recirculation of a test pulse through the delay network and measurement of the period corresponding to an integral number of the resultant pulses by means of a digital frequency meter. The achievable accuracy is believed to be better than one or two parts in 10^3. The circuit is essentially very simple and can probably be improvised by most laboratories without great difficulty. The important part is the loop in Fig. 1 to the right of the two splitting pads SP_1 and SP_2; it consists of a pair of video delay networks in series, one of which is the unknown delay, an adjustable attenuator, a high-grade, wideband amplifier, and the two splitting pads already mentioned. The latter take the usual form of three 75-ohm resistors in a delta connection or, alternatively, three 25-ohm resistors in a star connection. The input and output impedances of the amplifier must provide satisfactory terminating impedances for the delay networks, assumed to be nominally 75 ohms.

The total attenuation around the loop is adjusted so that the net loop gain is a little less than unity, so that any pulse impressed upon the loop via the splitting pad SP_1 will initiate a train of pulses which will circulate around the loop, the interval between the successive pulses being equal to the total transmission delay around the loop, and the decrement of the train being a function of the net loop gain. Input 2 of the double-beam oscilloscope is used to view these pulses, while input 1 is used to view the initiating pulse. These two waveforms can be clearly seen in the photograph of Fig. 2 (a), where for convenience the lower trace has a reduced gain compared with the upper. In order to prevent mutual interference between successive pulses of the train the width of the initiating pulse must be sufficiently short in relation to the interval between the pulses, and it is also useful to include a Gaussian or similar filter in series with the output of the pulse generator in order to give the initiating pulse a good shape, although this is by no means indispensable.

After an interval which may be varied by means of a control on the pulse generator the next initiating pulse arrives, and adds linearly to the waveform existing at that instant at the input to the loop. By choosing the pulse spacing suitably the initiating pulse in each instance may be made to fall precisely upon the nth recirculated pulse following the previous initiating pulse. This is an adjustment which may be carried out with great precision by adjusting the pulse generator p.r.f. to set the nth pulse to its maximum amplitude—all the more obvious since the whole pulse train changes in amplitude and shape during the adjustment. This is clearly shown by a comparison of Figs. 2 (a) and 2 (b), and also of Figs. 2 (c) and 2 (d). In each instance twenty

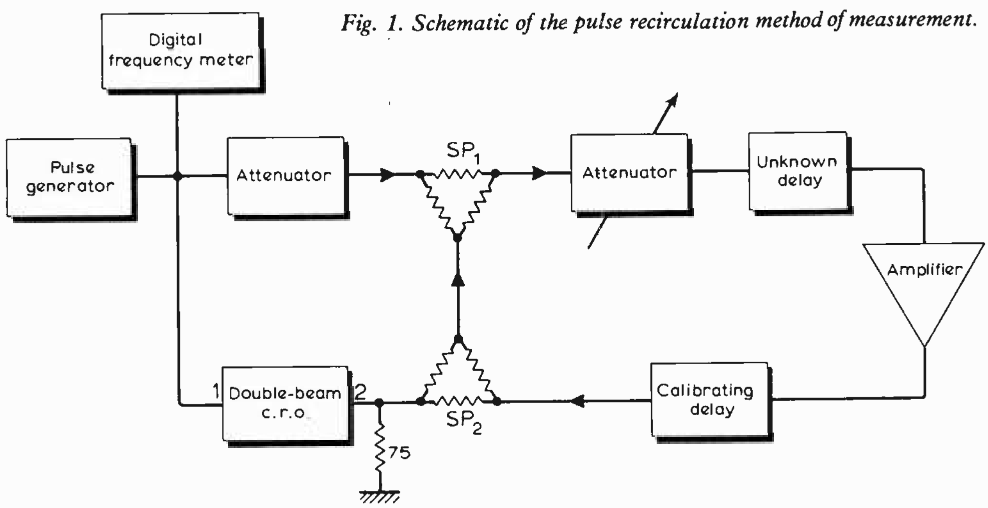


Fig. 1. Schematic of the pulse recirculation method of measurement.

*Designs Department, British Broadcasting Corporation

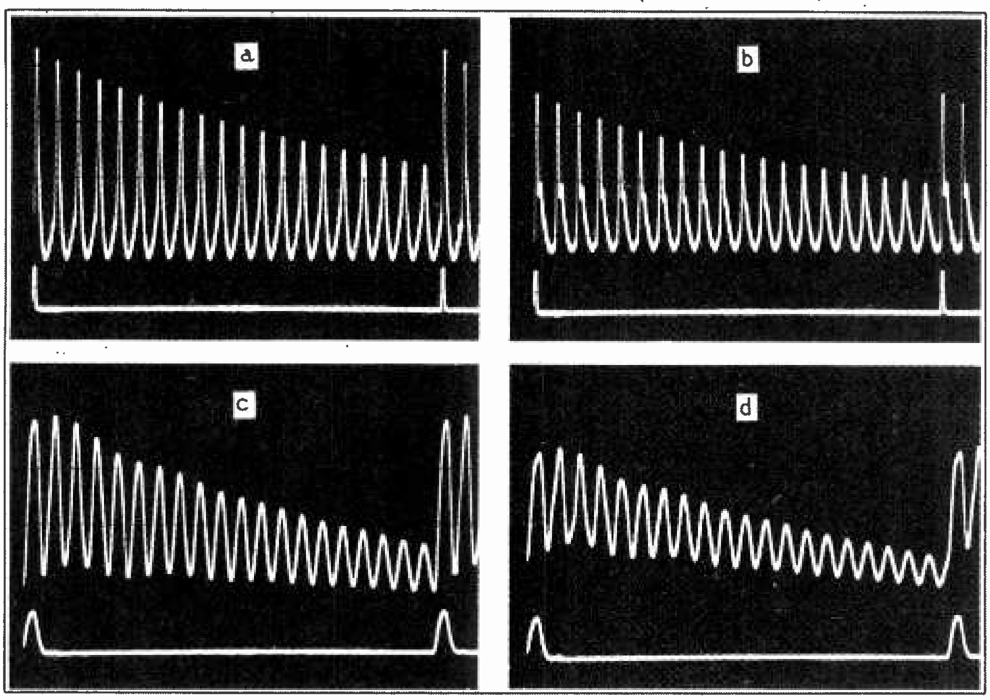


Fig. 2. Oscillograms from the double-beam c.r.o. (Fig. 1). Each shows the initiating pulse on the lower trace and the train of pulses resulting from recirculation on the upper trace.

recirculated pulses were used and the setting in the right-hand photograph is deliberately misaligned by less than 1% of the initiating pulse period.

When this adjustment has been made the pseudo-period of the continuous sequence of recirculated pulses is evidently equal to the total delay around the loop, so that the apparent repetition frequency of the recirculated pulses is nF, where F is the reading of the digital frequency meter. The total delay round the loop is the reciprocal of the pulse pseudo-frequency, that is $1/nF$. The counter is preferably connected as shown outside the loop to reduce the possibility of errors from its shunt capacitance.

A single measurement of this kind, however, does not measure the value of the unknown, since the delay in the other circuit elements of the loop and the wiring are all included in the measurement. It is not in general practicable to measure the residual delay when the unknown delay has been removed because it is too short, so a fixed high-grade delay element, known as the calibrating delay, has been added. The total delay with the unknown removed can then be measured once and for all and the value retained as a correction for any subsequent measurements. As will be seen from Fig. 1, care has been taken to insert the calibrating delay into the circuit in such a way that it is buffered from the unknown delay by the video amplifier and the attenuator, so there is no possibility of interaction between the two as a result of impedance mismatching.

Accuracy

The accuracy is determined by the width of the initiating pulse and the number of recirculated pulses. The former has a strong bearing on the sensitivity of setting, and the latter sets a limit upon the possible inaccuracy for a given number of pulses. For example, if twenty pulses are used, a number which has been found convenient in practice, the maximum setting inaccuracy before the twentieth pulse has obviously been passed is one-half a pulse width, say $\pm 3\%$. In fact, the sensitivity is such that a very marked change occurs in the appearance of the waveform for a variation in the initiating pulse period of less than 1%, as is attested by a comparison of Figs. 2 (a) and (b), where the initiating pulse had a half amplitude duration of 200ns and 20 recirculated pulses were used. The change in period was measured by means of a digital frequency meter. Tests showed that the setting accuracy in this particular instance was better than $\pm 0.2\%$.

A difficulty can occur in measuring very short delay lines when the initiating pulse is too wide, or when the bandwidth of the delay element is unusually small by comparison with its delay. In each such instance it is possible for successive pulses to interfere with one another, resulting in a deformation of the base-line of the train of recirculated pulses which is quite characteristic. If taken to an extreme it can result in the conversion of this train of pulses into an approximate staircase waveform. This effect can just be seen to appear on the left-hand side of Figs. 2 (c) and (d). It can always be removed by increasing the length of the calibrating delay.

Example

In the measurement photographed in Fig. 2 (a) the counter indicated a frequency of 39.99 kHz, so that the period corresponding to the train of recirculated pulses, that is the total delay around the loop including the unknown and calibrating delay, was the reciprocal of 799.8 kHz or 1,250ns.

With the unknown delay removed and still using twenty recirculated pulses, the pseudo-frequency of the pulse train was 3.998 MHz, that is, a residual delay of 251.1ns. The delay of the unknown was therefore $1{,}250-251=999$ns: it had previously been adjusted by the pi-point technique to be 1,000ns. The agreement is excellent, due in this instance to the flatness of the group delay characteristic of this particular network, which improves the accuracy of the pi-point method.

Acknowledgements. The author's thanks are due to the Director of Engineering of the B.B.C. for permission to publish this article.

Announcements

Underwater Acoustics. The Institute of Physics and Physical Society have announced the establishment of a new award to be known as the A.B. Wood Medal and Prize. The award, which will be annual, will be made for distinguished work in physical sciences associated with the sea, particularly underwater acoustics.

A travelling exhibition, **Analytex 68,** of analytical, measuring and recording instruments, will be visiting several towns between October 21st and November 1st. Techmation Ltd., will be exhibiting at hotels in Birmingham, Bristol, Cambridge, Edinburgh, Gateshead, Glasgow, Manchester and Southampton. Invitations are available from Techmation Ltd, 58 Edgware Way, Edgware, Middlesex.

Hirschmann Aerials. Electroustic Ltd, of 73b North Street, Guildford, Surrey, have been appointed sole U.K. agents for the complete range of products manufactured by the West German aerial company, Richard Hirschmann.

Ultra Electronics (Components) Ltd., Microelectronics Division, 35/37 Park Royal Road, London N.W.10, have been appointed sole U.K. agents for **Melco** semiconductor and integrated circuit products.

Environmental Equipments Ltd, of Denton Road, Wokingham, Berks, are now marketing in the U.K. the range of **Tenpac** semiconductor strain gauges manufactured by Toyota R & D Laboratories in Japan.

Data Recognition Ltd, 7 Loverock Road, Battle Farm Estate, Reading, Berkshire, have been appointed U.K. distributors for the range of punch-tape perforators and readers used in data control applications manufactured by Ohr-tronics Inc., of America.

An agreement has been reached between the **Wayne Kerr Company Ltd.**, New Malden, Surrey, and the Comtel Corporation, of Michigan, U.S.A., for the latter to market Wayne Kerr products in the United States.

A range of **coaxial connectors** manufactured by Star-Tronics Inc., of Georgetown, Mass., U.S.A., are now available in Europe and the British Commonwealth through G. & E. Bradley Ltd, Electral House, Neasden Lane, London N.W.10.

B. & K. Instruments Ltd, 59 Union Street, London S.E.1, will in future distribute and provide an after-sales service for the products of **Eldorado Electronics,** Concord, California, U.S.A.

B. H. Morris & Co (Radio) Ltd., of 84/88 Nelson Street, London E.1, have been appointed sole U.K. distributors for the **Teac Corporation** of Japan. The Teac range of products was previously handled by C. E. Hammond.

U.S.S.R. Radio Imports. Technical & Optical Equipment (London) Ltd, 15/17 Praed Street, London W.2, have been appointed sole importers and distributors for all Russian transistor radio receivers.

Advance Electronics Ltd., Roebuck Road, Hainault, Essex, have acquired the Wrexham company, **Filmcap Ltd.,** manufacturers of film capacitors.

The Ministry of Technology have placed an order worth more than £250,000 with **G. & E. Bradley,** of Electral House, Neasden Lane, London N.W.10, for electronic multimeters for use by the Armed Forces.

WESCON 1968

New devices revealed at the Western Electronic Show and Convention, Los Angeles

by Aubrey Harris

An overwhelming amount of technical information is presented for consumption by some 50,000 electronics engineers every year at the WESCON (Western Electronic Show and Convention). At Los Angeles this year (August 20th-23rd) approximately 130 papers were read, at 32 sessions; at certain times as many as five sessions were being conducted simultaneously. The show is sponsored jointly by the I.E.E.E. and the Western Electronic Manufacturers Association. If one has not had one's fill of information from the papers, there are one or two other events provided to remedy this deficiency: for example, a Science Film Cinema where 22 scientific and engineering films were shown in a continuous programme daily; the Future Engineers' Competition at which twenty-one outstanding high school students exhibit their electronic experiments and compete for $3,400 (approx. £1,400) in prizes; the Industrial Design Award Exhibit, at which the twenty leading electronic designs are shown; not to forget the main exhibition by some 650 companies of their latest designs of electronic equipment, components and products.

At the technical sessions solid-state devices generated much interest, not surprisingly, as with the 1969 domestic-U.S. production estimate of some ten million (colour and monochrome) television receivers and sixteen million radio sets there is a potentially tremendous market for integrated circuits in home-type electronic equipment. However, there are very few new designs of this equipment incorporation i.cs just yet.

Linear i.cs in domestic and communications equipment

C. H. Klasing (Mallory Co., Inc.) in his paper "Integrated Circuits for the Entertainment Industry" stated the aim of the i.c. manufacturer is to design units providing in one package replacement for the largest possible number of discrete components. Present-day technology has not yet reached the stage where i.cs can be substituted for existing, well-proven, discrete-component circuitry and still maintain the performance and reliability required at competitive pricing.

The prediction was that the incorporation of integrated circuits into domestic equipment will be a slow, evolutionary process taking perhaps 5—10 years. Particular discrete circuit functions will be replaced as i.cs become available which compare favourably in performance and price.

One aim is to design i.cs to replace high cost components such as transformers and electrolytic capacitors, although these items themselves cannot be constructed in monolithic form. However, their *functions* can be performed by i.c. devices; for example, zener diode regulators can replace smoothing capacitors, audio driver stages using complementary or quasi-complementary transistor design can be substituted for driver transformers and a discrete amplifier stage with an emitter by-pass capacitor can be replaced by a multi-stage amplifier (with emitter resistor degeneration) at less cost.

The question of price should not only be considered as the cost of the i.c. itself; some early attempts at designing integrated circuits for entertainment equipment necessitated more complexity and cost in decoupling components, biasing resistors and power supply changes than the circuitry they were intended to replace.

In an attempt to reduce the cost of incorporating i.cs into home equipment circuit packages are being produced which include both an i.c. and a transducer. These packages may contain a tape head, pickup cartridge or microphone together with an associated built-in pre-amplifier. These devices are capable of providing outputs of up to one volt or so, at low impedance, simplifying the task of isolating motor noise and power supply hum from low-level transducer leads.

In the field of communications systems, the adoption of integrated circuits, it seems, will not be as rapid nor as easy as was the case with the incorporation of digital i.cs into computing systems. This is partly because there is more functional diversity in communications equipment and also because communications designers are more concerned with the relationship between the system and the circuit elements than are computer designers. The latter have been working with "functional block" principles prior to the introduction of microcircuits.

During the transition period, before the complete adoption of m.s.i, or l.s.i, it is felt that versatile, low-cost, high-performance single-function circuits will be employed. Robert A. Hirschfeld (National Semiconductor Corp.) described one unit, the LM171, which can be used as either a tuned or untuned r.f./i.f. amplifier, a limiter, a detector, a mixer or an oscillator (Fig. 1). The LM171 has improved performance over its transistor equivalent and because of the fact that one type of unit can perform many functions, manufacturing procurement problems are simplified.

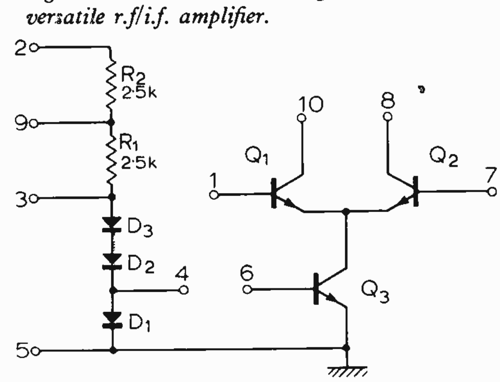
Another unit, the LM172, uses a "sub-systems" approach and can be used as a complete a.m. i.f. strip including detector. It replaces all components in a superhet between the output of the mixer and the input of the power amplifier.

In current discrete-component practice, the most efficient utilization of available power gain, from a limited number of active devices, is obtained by matched, tuned interstage networks. Because of the limited a.g.c. range obtainable by varying, for example, d.c. emitter current in a conventional common-emitter stage, several stages must receive a.g.c. voltage from the detector, and consequently require d.c. decoupling, to eliminate effects of changing d.c. operating points with a.g.c.

Economics usually dictate the simplest diode detectors, biased from tuned transformer secondaries, in present strips, while the large tuned gain and often marginal stability force power supply decoupling for each stage. Attempts to simulate conventially tuned strips by using a number of monolithic amplifiers on one chip, with each input and output brought out to the interstage network, have functioned, but have neither been easy to stabilize nor economical.

The approach used in the LM172 gives a much more efficient arrangement, shown in Fig. 2. All gain is attained in a single, lumped gain stage, which is direct coupled. To avoid a.g.c. disturbance of the high gain amplifier, it is left running at maximum gain at all times, with a.g.c. performed by a single, efficient gain control stage, a voltage variable

Fig. 1 Schematic LM171 integrated-circuit versatile r.f./i.f. amplifier.



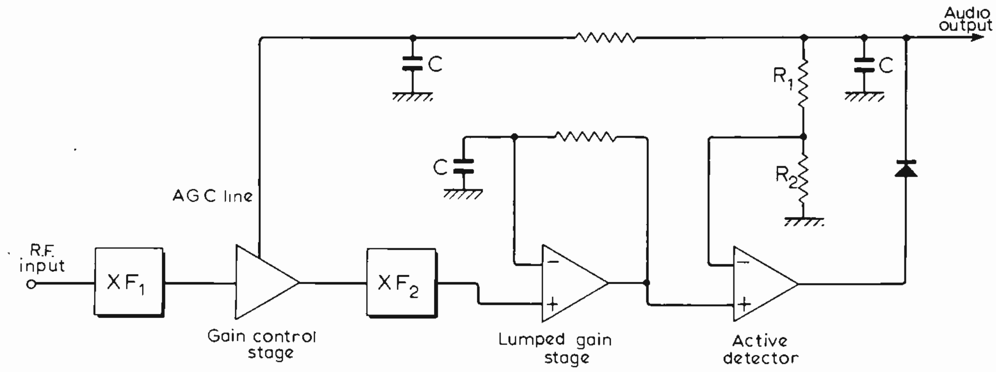


Fig. 2 Block diagram of the LM172—a complete a.g.c. stage, i.f. amplifier and a.m. detector. The capacitors and ceramic filters (XF_1, XF_2) are external to the chip.

attenuator, with a single decoupling capacitor (or ceramic filter) taking the place of individual stage decoupling elements in conventional strips. Bandpass shaping is done by an external filter, ahead of the strip, which also serves to couple the strip to the receiver tuner. The lumped gain stage is designed for maximum r.f. effectiveness, and stabilized by a d.c. feedback loop, which sets all bias points at optimum level, regardless of variations in the monolithic process. Finally, an a.m. detector is used which can be directly coupled to the gain stage output which is insensitive to d.c. bias. This reliably provides the correct a.g.c. voltage, and, by virtue of its "active detector" construction, is capable of audio voltage gain, unlike the loss characteristic of simple diode detectors.

With an active detector operational amplifier the audio output voltage is equal to the modulation envelope times the ratio $(R_1+R_2)/R_2$. In the LM172 the audio output is set to about 1 volt peak-to-peak from a 100% modulated signal.

I.C. voltage regulator

A linear i.c. medium power voltage regulator was described in a paper by W. H. Williams and J. H. Parker (Westinghouse). The device contained in a TO-5 can was designed to be used as a regulator, one per circuit card, for supplying operating voltages to such items as operational amplifiers and digital logic modules.

Among the advantages of such a small sized regulator are that one (or more) can easily be accommodated on a printed circuit card; a single, large regulator for powering many cards is not therefore necessary. Further benefits are that due to the large degree of isolation between individual cards using the regulators, there is a minimum of interaction and mutual interference between cards.

The performance of the unit is truly remarkable. With a regulated output voltage of between four and 16 volts, a change from no load to 150mA is accomplished with 0.5% regulation in the temperature range 0 to 75°C. The output impedance is 0.05 ohms and the input ripple attenuation is 40dB at frequencies up to 20kHz. The maximum power dissipation is 2 watts (with a heat sink) at temperatures up to 25°C.

The chip itself consists of seven transistors, three diodes, two zener diodes and one s.c.r. (Fig. 3). The design of the unit allows for its application in a variety of circuitry, apart from the "normal" regulator connection using external resistor sampling it may be connected for current limiting (constant current output when overloaded), "foldback" current limiting (reduced current output when overloaded), s.c.r. overload protection (a built-in s.c.r. drops load voltage and output current to zero when overloaded).

The usefulness of the regulator may be increased by the addition simply of (a) one transistor (load regulation increased from 150mA to 5A, and/or (b) one resistor and one zener diode (input voltage capability raised up to 24V), as shown in Fig. 4.

New display device

Much work has gone into the investigation of various means for producing high brightness, inexpensive, flat display devices suitable for digital displays and as a successor to the c.r.t. for television screens. Dr. R. H. Willson gave details of an experimental unit developed by Westinghouse for the display of digital information. It uses a gas discharge technique and is known as the plasma display panel.

It is a matrix display made with a sandwich of three thin plates. The centre plate is honeycombed with either etched or ultrasonically drilled holes and thin film electrodes are deposited on the outside surface of the outer plates (see Fig. 5). Air is evacuated from the panel, and the array is filled with a neon-nitrogen gas mixture. Specific plasma display elements can be lit by applying coincident voltages of appropriate magnitude to selected crossed grids. Alphanumeric characters are generated by writing a specified sequence of elements (dots). The voltages applied to the electrodes are capacitively coupled into the cell so only a.c. excitation voltages are required. The display is viewed through one set of highly transparent electrodes and the gas discharge is totally confined to the cylindrical cavity formed by the three sheets of glass. The external electrodes are not subject to ion bombardment so problems of cathode sputtering, which would decrease both the lifetime and the brightness of the cell, are avoided.

A single voltage source, capacitively coupled to the array, supplies the sustaining voltage for the whole array. Plasma discharge elements which are initially on are maintained in the on state by the sustaining voltage, while elements which are initially off, remain off. Elements are turned on (written), or turned off (erased) by the application of appropriate voltages to select x and y co-ordinates. The device has an inherent memory much like a magnetic core.

The gas used is a neon-nitrogen mixture although experiments have been made with krypton, xenon, carbon monoxide, water vapour and helium gases both with and without phosphor added.

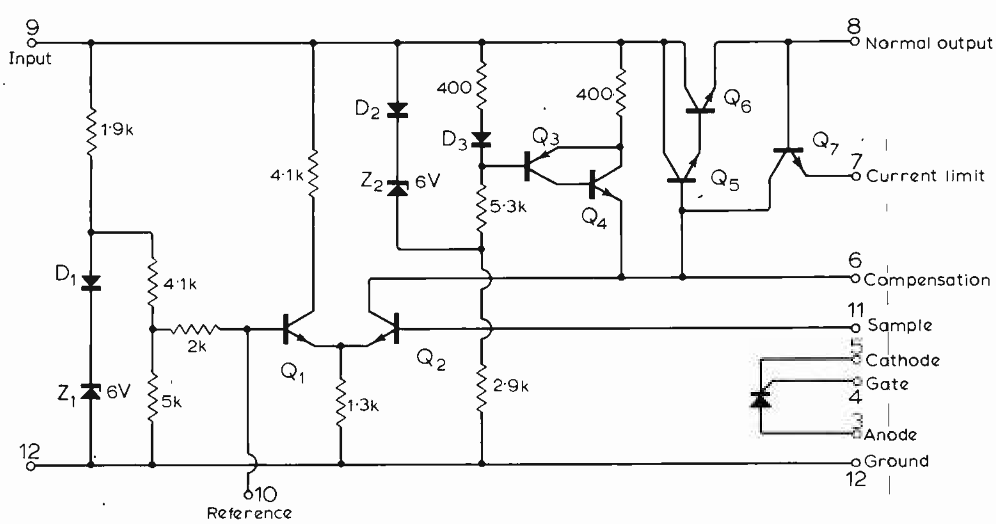
Cell sizes have been produced between 6- and 85-thou; a typical unit with 0.015-inch cells uses a cell density of 40 per inch and gives an average spot brightness of 2056 cd/m^2. Spot brightnesses of 3426 cd/m^2 have been measured; there is no flicker on the display, as with a c.r.t. because the picture does not have to be continuously scanned.

Panel lifetime is estimated at 100,000 hours, and the power consumption is in the region 2.5 to 3×10^{-4} watts per cell. The cost at this time (in production quantities) is said to be about $10,000 (approx. £4,200) for a unit 2 ft × 5 ft.

Digital coding

There are many methods of coding picture information for transmission purposes, rang-

Fig. 3 The WC109 integrated circuit regulator schematic.



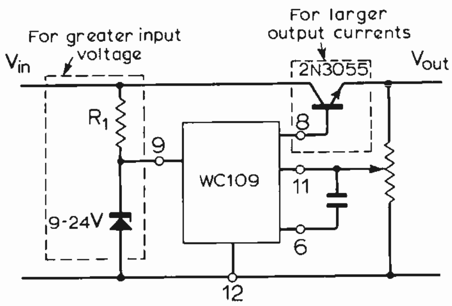


Fig. 4 Additional external components for increasing regulation range of WC109 device.

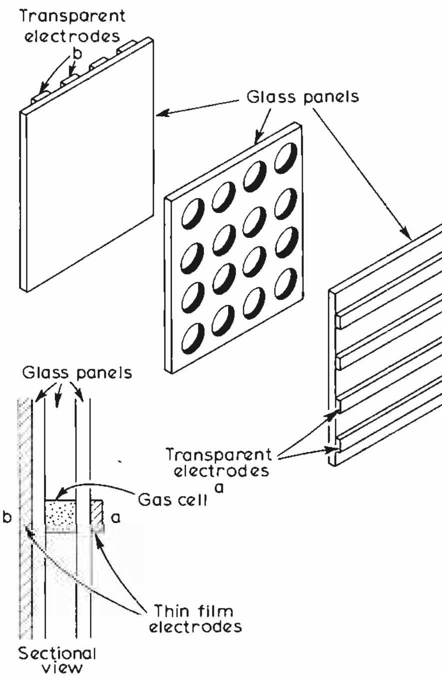


Fig. 5 Plasma display panel. A rectangular array of gas cells with external X and Y addressing electrodes.

ing from conventional television line-by-line scanning to character recognition in which the specific shape of the object is determined and a special code transmitted for each object (or partial object) shape. The most efficient system transmits all required information with a minimum channel capacity. A technique intermediate between those cited above, in both complexity and efficiency, known as contour coding was the subject of a paper by W. F. Schreiber, T. S. Huang and O. J. Tretiak (M.I.T.).

In the reconstruction of images from outlines it is obvious that in the case of graphical, i.e. two-level data, the image may be recreated exactly from the outline information since all that is necessary is to fill in the spaces between the outlines with black. It turns out that continuous-tone images may also be recreated exactly from the outlines provided that they also contain information about the spatial gradients of the image. Just as a function of a single variable can be reproduced to within an additive constant from its derivative, a function of two variables, i.e. an image, can be recovered from its gradient. The outlines are generally found to consist of connected series of points having gradients significantly different from zero. Thus if all the significant outlines are transmitted all the significant gradient information will be available for picture reproduction.

The information which needs to be transmitted about the outlines or contours in an image consists simply of the location of the contour points in the case of graphical data or the location plus gradient information or area brightness levels in the case of continuous tone images. A series of coding techniques is available for transmitting this type of information, ranging from simple and inefficient to complicated and highly efficient. Simple in this context refers to the amount of logic required for the coding and decoding and most importantly to the amount of storage required, especially at the receiver.

Four possible systems were described.

The co-ordinates of all the points along all of the contours may be transmitted without taking advantage of the fact that the points are connected. In the special case where a random access picture device is available at both transmitter and receiver no storage is required. This system gives useful savings only for graphical data consisting mostly of blank paper.

Alternatively, instead of locating each point individually, they may be located with respect to previous points on the same line. Similar transmission efficiency can be obtained by tracing the contour directly. Each contour point is located with respect to another which is only one picture element distant, except for the initial point of each contour. One may thus transmit all the points on one contour before proceeding to the next contour. This obviously substantially increases both the storage and processing requirements but it also permits greatly improved efficiency. The most straightforward way of transmitting the contour information is to give the co-ordinates of the initial points of the contour plus incremental information from which the remaining points may be found. Since each contour point is adjacent to the previous contour point it takes only a limited amount of information (a maximum of 3 bits) to indicate the direction of the next point. In the case of continuous-tone images where gradient information must also be transmitted, one may also transmit the value of the gradient at the initial point and incremental information permitting the calculation of the gradient at the rest of the points.

A more advanced method is to fit each contour with the most nearly matching mathematical curve, starting with a series of straight line segments and then where required bringing into use higher order curves—quadratics or exponential.

Conferences and Exhibitions

Further details are obtainable from the addresses in parentheses

LONDON

Sept. 30-Oct. 2 — Savoy Place
Tropospheric Wave Propagation
(I.E.E., Savoy Pl., London, W.C.2)

Oct. 2-5 — R.H.S. New Hall
R.S.G.B. Radio Communications Exhibition
(P. A. Thorogood, 35 Gibbs Green, Edgware, Middx.)

Oct. 15 & 16 — St. Ermins Hotel
Ultrasonics for Industry
(*Ultrasonics*, Dorset House, Stamford Street, S.E.1)

Oct. 30 & 31 — Middx. Hosp. Medical School
Electronic Weighing Conference
(I.E.R.E., 9 Bedford Sq., London, W.C.1)

BRIGHTON

Oct. 8-10 — Hotel Metropole
Intersolidus—Nepcon—Electronics Packaging Conference
(Gordon Saville Exhibitions, 21 Victoria Rd, Surbiton, Surrey)

KENILWORTH

Oct. 16-17 — Chesford Grange
Metrication . . . the problems of change
(Inst. of Prod. Eng., 10 Chesterfield St., London, W.1)

MANCHESTER

Oct. 22-24 — Hotel Piccadilly
Electronic Instruments Exhibition
(Industrial Exhibitions Ltd., 9 Argyll St., London W.1)

OVERSEAS

Sept. 30 & Oct. 1 — Philadelphia
Computer Impact on Engineering Management
(Instrument Soc. of America, 530 William Penn Pl., Pittsburgh, Pa)

Oct. 2-4 — Monticello, Ill.
Circuit and System Theory
(I.E.E.E., 345 East 47th St., New York, N.Y. 10017)

Oct. 5-14 — Bordeaux
Intl. Radio & Television Exhibition
(Foire de Bordeaux, 12 Plac de la Bourse, Bordeaux)

Oct. 8-11 — Los Angeles
Telemetering Conference
(B. E. Norman, P.O. Box 56, White Sands Missile Range, New Mexico 88002)

Oct. 9-15 — Düsseldorf
INTERKAMA—Instrumentation & Automation Congress & Show
(NOWEA, 4 Düsseldorf 10, Postfach 10 203)

Oct. 10 & 11 — Washington
Applications of Ferroelectrics
(H. L. Stadler, Phys. Elec. Dept., Ford Motor Co., Dearborn, Mich.)

Oct. 14 & 15 — Framingham, Mass.
Thermionic Energy Conversion
(J. E. Kemme, Los Alamos Sci. Res. Labs., P.O.B. 608, San Diego, Cal.)

Oct. 14-16 — San Francisco
System Science & Cybernetics
(H. Mays, Fairchild Semiconductor R. & D. Labs., 4001 Junipero Serra Blvd., Palo Alto, Cal.)

Oct. 15-17 — Schenectady
Switching and Automata Theory
(S. B. Akers, Electronics Lab., General Electric Co., Syracuse, New York 13201)

Oct. 15-18 — Budapest
Reliability in Electronics
(Mrs. A. Valko, Scientific Soc. for Telecom., Technika Haza, Szabadsag Ter 17, Budapest V)

Oct. 17-27 — Bucharest
British Industrial Exhibition
(Ind. and Trade Fairs, Commonwealth House, New Oxford St., London W.C.1)

Oct. 19-27 — Genoa
Intl. Communications Fair
(Ente Autonomo Fiera Internazionale, Pizzale J. F. Kennedy, Genoa)

Oct. 20-22 — Tel Aviv
Electrical & Electronic Engineers Convention
(I. Cederbaum, Israel Inst. of Tech., P.O.B. 4910, Haifa)

Oct. 23-25 — Washington
Electron Devices
(D. A. Chisholm, Bell Telephone Labs, Murray Hill, New Jersey 07974)

Oct. 28-30 — Gatlinburg
Applied Superconductivity
(Dr. W. F. Gauster, Oak Ridge National Laboratory, Bldg 9201-2, P.O. Box Y, Oak Ridge, Tennessee)

Oct. 28-Nov. 1 — Amsterdam
Fiarex—Electronic Components Exhibition
(Vereniging F.I.A.R., Minervalaan 82hs, Amsterdam)

Oct. 30-Nov. 1 — California
Circuits & Systems
(Prof. Shu-Gar Chan, Dept. of Elec. Eng., Naval Postgraduate School, Monterey, Cal.)

Wireless World Colour Television Receiver

5. Convergence circuits and adjustments

Because the three guns of the cathode-ray tube cannot occupy the same physical position the red, green, and blue rasters produced by them and the common deflection fields are displaced from each other on the screen. The so-called convergence coils, magnets and circuits are necessary to bring the three rasters into register with each other.

The mains deflection fields for scanning are produced by a deflection-coil assembly of the usual form which carries the sawtooth currents at field and line frequencies. These fields act simultaneously on all three electron beams. To obtain register of the rasters subsidiary deflecting fields are needed which act separately on the three beams.

The convergence assembly is fitted to the tube neck behind the main deflector-coil assembly; that is, between the guns and the deflector coils. Three sets of pole pieces are built into the tube and have internal screens between them so that the field produced by one does not affect the other beams. Magnetic screening is, of course, far from perfect and the screening reduces interaction between the fields rather than eliminates it.

The convergence assembly comprises three sub-assemblies mounted radially with 120° between them, one for each electron beam, and they are denoted by the colours which the beams excite on the screen. Each sub-assembly has two coils and one permanent magnet. One coil carries current at field frequency, the other at line frequency. Usually, each coil has two windings which may be connected in series or parallel as required by the circuitry used.

The windings are on two strips of magnetic material and across them at one end is mounted a disc-shaped magnet which is magnetized across a diameter and which can be rotated so that the strength of the magnetic field in the cores can be adjusted. The cores at the other end come near to the internal pole-pieces in the tube. Thus by turning the magnet a static deflection can be given to the beam, and by passing currents through the coils the beam can be deflected at line and field frequencies. The two are usually known as static and dynamic convergence.

The blue components are mounted vertically on top of the neck of the tube and provide a field which deflects the blue beam vertically. The red and green sub-assemblies are mounted at 120° to each other and to the blue and they provide deflections along the same angles. Viewed from the front, red is on the left and green on the right. Thus if a certain current in the blue coils gives a certain deflection of the blue beam downwards, the same current in the red coils will deflect the red beam by more or less the same amount but at an angle of 120° to "downwards". The deflection can be resolved into two components, one vertically upwards and the other horizontally to the right. The same thing happens with the green beam; deflection is 120° from the blue but the other way, and it can be resolved into a deflection vertically upwards combined with one horizontally to the left.

Because of the combined vertical and horizontal movements obtained for the red and green beams nothing further is needed. Convergence can be obtained by adjusting the currents and waveforms in the two assemblies. An additional coil and magnet are needed to give a horizontal movement to the blue beam, however, and these are provided in what is called the blue lateral assembly. This is a small assembly which is mounted on the tube neck behind the main convergence assembly.

In addition to all this, the convergence assembly carries two purity magnets. These are mounted at the back of the main convergence-coil assembly and comprise two flat rings which can be rotated around the neck of the tube. They are each magnetized so as to produce a magnetic field which acts across a diameter of the tube. The strength of the field can be varied by turning one magnet relative to the other; when like poles are together the field is a maximum, when unlike poles are together it is a minimum. The direction of the field across the tube can be altered by turning both together.

The purpose of these magnets is to ensure that the red beam excites only the red phosphor dots of the screen, the green beam only green dots, and blue only blue.

Adjustment of the two purity magnets in conjunction with the position of the deflector-coil assembly enables a red, green, or blue raster of substantially uniform colour to be obtained when the appropriate gun is operating alone. The adjustments are not usually very difficult.

Adjustment of the three convergence magnets and the blue lateral magnet readily enables perfect convergence to be obtained at the centre of the screen. For all convergence adjustments a crosshatch pattern generator must be regarded as an essential piece of equipment, and a suitable generator was described last month.

Static convergence adjustments readily give substantially perfect convergence within a circle of some 2 inches diameter at the centre of the screen. Outside that it gradually deteriorates and towards the edges of the screen the red, green and blue bars of the crosshatch pattern will be quite separate instead of being merged to produce white.

To correct for this it is necessary to pass currents at line and field frequencies of the proper amplitudes and waveforms through the convergence coils. The usual practice is to limit the waveform to a combination of a sawtooth and a parabola. Nothing more elaborate than this is normally attempted and because of this perfect convergence over the whole of the screen is rarely obtainable

The need for convergence arises mainly because the three guns do not occupy the same position. However, the amplitudes and waveforms of the convergence currents which are needed to achieve perfect convergence are affected in some degree by many other factors. For example, manufacturing tolerances in the tube and in the deflector-coil assembly, to mention only two things, affect the perfection of convergence

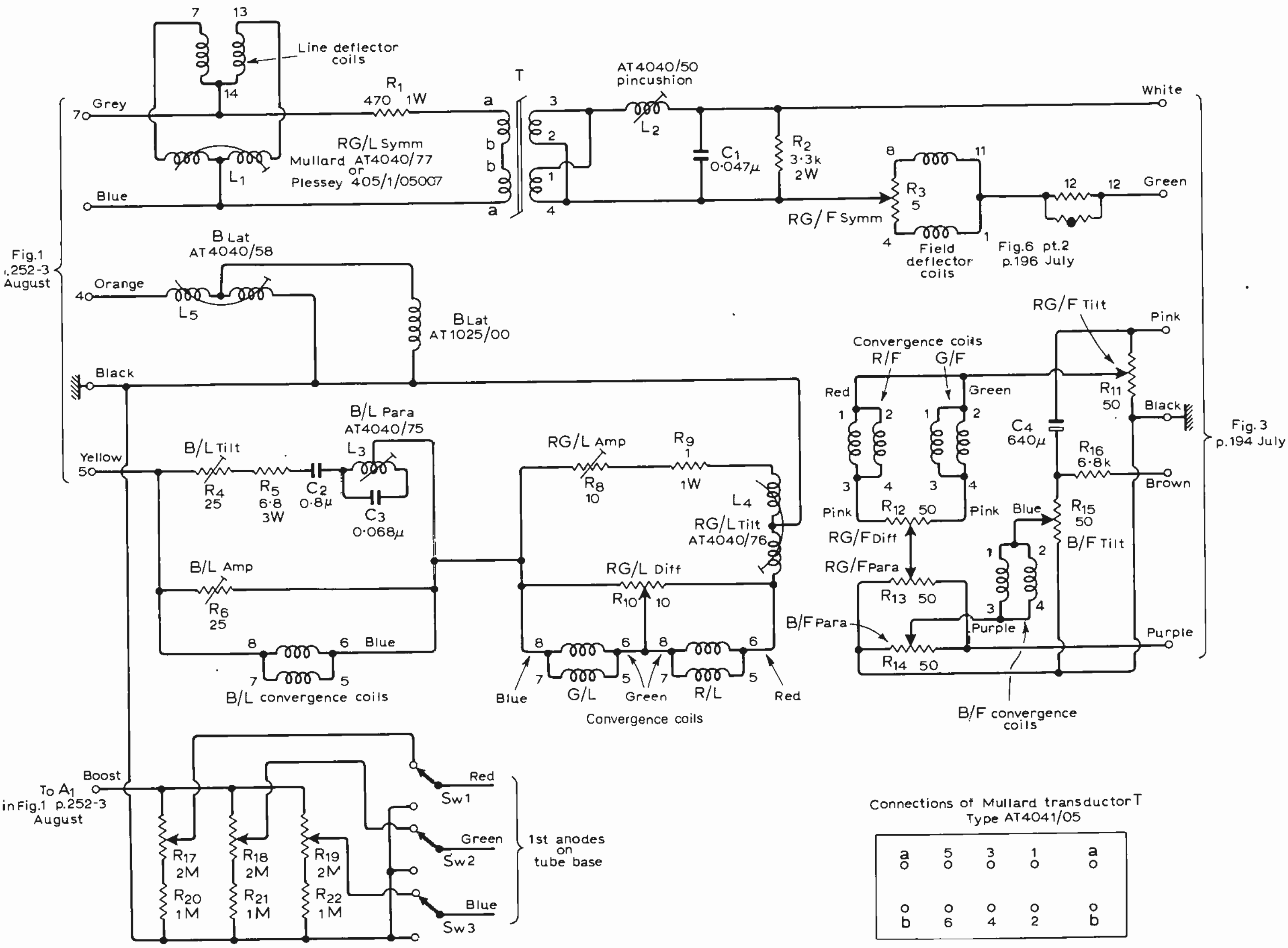


Fig. 1. Complete circuit diagram of the convergence unit. The switches employed are Rendar Instruments miniature slide type, model R 53005 (Electroniques stock number 168F27391D). They are d.p.d.t. switches, but only one pole in each is used.

obtainable with given convergence circuitry. In any given case it would no doubt be possible to devise circuitry which would give substantially perfect convergence over the whole screen. The cost and difficulties of adjustment would rise considerably, however, and the usual practice is to use an arrangement which theoretically allows perfect convergence only along the vertical and horizontal centre-lines of the screen. This is usually adequate.

It must be understood that imperfect convergence does not show at all in uniform areas. It shows only on edges where there is a change of colour or brightness and it is evident then as a colour fringe on the edge.

It is a fact of observation that a degree of imperfection in convergence that looks intolerable on the cross-hatch pattern is much less evident on Test Card F, is not at all intrusive on a black-and-white programme picture and may be almost unnoticeable on a colour picture. It can always been seen if it is looked for, of course, but it often passes unnoticed when watching a programme. The reason is, of course, that the main interest of the picture is usually towards the centre and it is there where one's attention is concentrated. However, as well as this, there is often less detail in the picture towards the edges, especially towards the top, which may be partly a sky area.

There are a great many controls needed for convergence and they have to be adjusted while watching the screen closely. It is very desirable, therefore, that all the controls should be so mounted that they are readily accessible while watching the screen. The convergence panel is therefore mounted immediately over the tube. In addition to the actual convergence controls the panel also carries voltage controls for the three first anode voltages of the tube and switches for rendering any guns inoperative at will.

The circuit diagram of the unit is shown in Fig. 1. The upper part of the diagram shows the interconnections between the deflector coils. At the top left a lead from terminal 7 of the line-scan transformer and one from the linearity coil, both in the line timebase unit, are brought in. The lead from 7 is taken out again to the junction of the two line-deflector coils, while the other ends of these coils are brought back as two separate leads to the coil L_1, which is RG/L Symmetry. This enables the relative amplitudes of the currents in the two line-deflector coils to be adjusted. If, for example, the current is made a little greater in the top coil of the pair than in the bottom, then the length of the scanning lines at the top of the picture will be a little greater than that of those at the bottom.

Connected in shunt with the deflector coil and the symmetry control is a 470-Ω resistor R_1 in series with a winding of a transductor. This is a special transformer having a readily saturable core, the secondary of which is connected, with some modifying components, in series with the field-deflector coils. The effect of the non-linear core is to cause some intermodulation of the line and field scanning currents. This reduces the amplitude of the line scan at top and bottom of the picture, and of the field scan at left and right to correct for pincushion

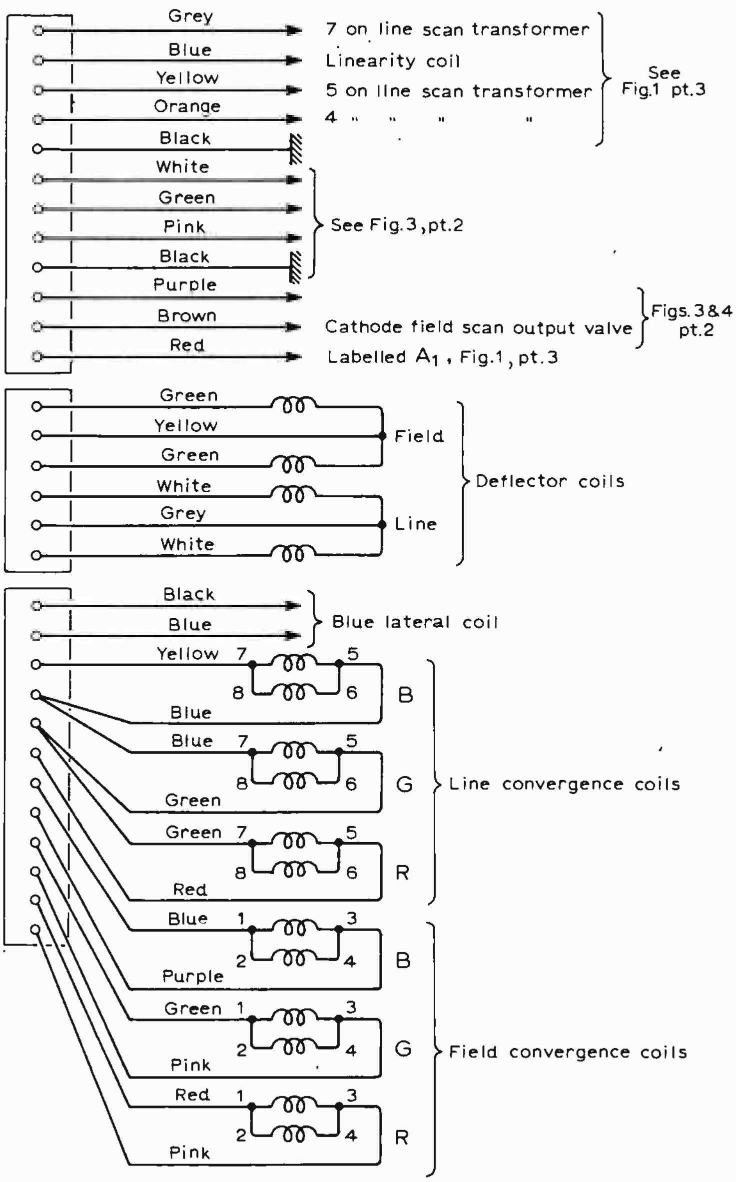


Fig. 2. External connections of the connector blocks are shown in this diagram.

distortion of the raster. The coil L_2 provides an adjustment of the magnitude of the effect.

At the top of the diagram, leads from the field-scan output transformer are brought in from the timebase unit. One immediately goes out again to the junction of the two field-deflector coils, the other ends of which come back as separate leads to RG/F Symm, R_3. This serves the same purpose in the field circuit as L_1 does in the line.

These two symmetry controls are used as two of the convergence controls.

The convergence circuitry proper is in the lower part of Fig. 1. On the right are the field circuits. The connections on the right are all from the timebase unit. A sawtooth waveform is brought in at 'pink', which is from terminal 5 of the field output transformer, and a parabolic waveform is brought in at the bottom terminal, 'purple'. This is actually connected to the field output-valve cathode through a large capacitor in the timebase unit. (C_{10}B shunted by R_{19}B of Fig. 3, Part 2.) At this point the parabolic waveform is developed naturally.

The amplitude of the sawtooth applied to the red and green convergence coils is controlled by R_{11} RG/F Tilt, while the amplitude of the parabolic current is controlled by R_{13}, RG/F Para. The relative amplitudes of the currents in the red and green coils is controlled by R_{12} RG/F Diff.

For blue convergence the sawtooth is fed to R_{15}, B/F Tilt, through C_4 which actually comprises two 320-μF capacitors in parallel. The parabolic component of current is controlled by R_{14}, B/F Para.

The phase of the parabolic waveform is fixed, being derived from the valve cathode. The relative phase of the sawtooth component can be reversed by connecting to the other end of the tapped convergence winding on the field output transformer. Additionally, the effect on the tube can be changed by reversing the convergence-coil connections. The connections given later are the normal ones, but it cannot be guaranteed that with some tube-deflector coil combinations some such changes to connections may not be desirable.

On the line side, matters are a little more complex because the inductance of the convergence coils becomes important. As a result, the circuit is more complex. All the coils are basically in series between 5 on the line-scan transformer and chassis, which means that they are in series with the deflector-coil circuit. The potentiometer R_{10}, RG/L Diff, enables the relative amplitudes of the currents in the red and green coils to be adjusted. RG/L Tilt, L_4, controls the relative amplitudes of sawtooth and parabolic components of the current, and RG/L Amp, R_8, the amplitude.

In the blue part of the circuit B/L Amp, R_6, is a shunt across the blue convergence coils. The network R_4, R_5, C_2, C_3 and L_3 enables the waveform to be adjusted.

The B Lateral coil is fed from terminal 4 of the line output transformer through the controlling coil B/Lat.

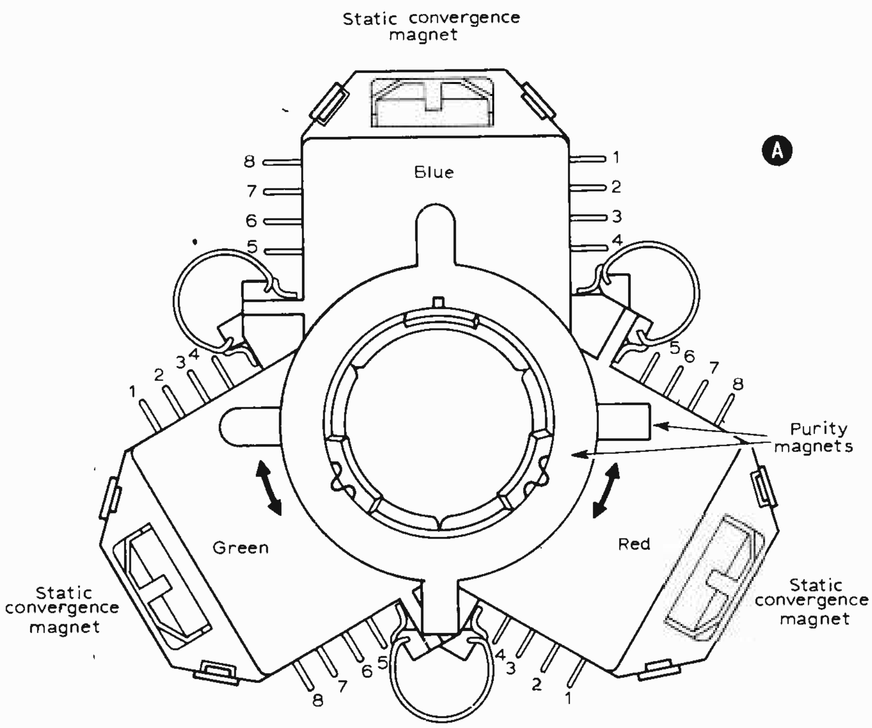
Included in the convergence unit, but electrically quite separate are the first anode controls for the tube. Good insulation for all these is necessary.

The various convergence controls tend to require operation in pairs and so as far as practicable they are grouped physically in pairs in order of adjustment. It is unfortunate, however, that all the convergence controls without exception interact to some degree and late adjustments in the sequence throw out early ones in some degree. It is this which accounts for the greater part of the difficulty of convergence adjustment and which makes it very much an art and a skill to be acquired by practice. At a first trial some of the controls may well appear to have no effect. This does not necessarily mean that there is anything wrong. When other controls are properly adjusted they will be found to have an effect, perhaps small but sufficient.

With the exception of the three connections for the first anodes of the tube, which are soldered directly to the switches, all connections are via connector blocks. There are three of these, one 6-way and two 12-way. The diagrams give the arrangement and the colour-coding adopted; this last need not be adopted, of course. However, some colour coding is almost essential to keep track of so many leads and to adopt the same one facilitates reference to the diagrams.

An insulating material panel is used to carry all the controls. The use of a metal panel at chassis potential is dangerous because the chassis is live unless an isolating transformer is employed. If at all possible this should be used when making adjustments to parts on the tube neck, for one can hardly do this without coming into contact with some part of the chassis. Watch it.

Before starting to adjust convergence it is necessary to have at least the luminance output stage working, because the output of the cross-hatch generator is injected into its grid circuit. It is desirable to have the whole receiver working so that proper adjustments to picture width and height and linearity of the scans can be made, as well as to the e.h.t. supply. These things affect the scanning waveforms and their amplitudes and so the precise waveforms available to the convergence circuits. While making these adjustments, the core of the raster-connection or pincushion coil L_2 is adjusted to make the raster as rectangular as possible.



The diagram shows a rear view of the Plessey convergence assembly. For series coil connection, connect to tags 1 and 4 and join 2 and 3 for the field circuit and connect to tags 5 and 8 and join 6 and 7 for the line.

For parallel coil connections, connect to tags 1 and 4 and join 1 and 2 also 3 and 4 for the field circuit and connect to tags 5 and 8 and join 5 and 6 also 7 and 8 for the line.

For series connection, the field coils have a resistance of 168Ω and an inductance of 1.18H while the line coils have a resistance of 2.9Ω and an inductance of 0.5mH.

Parallel connection is normally used but sometimes series connection of the blue line coils may be needed.

Purity

Assuming these to have been done, the first step is the adjustment of purity. The following is the proper sequence:

(1) Slack the wing nuts holding the deflector coils in their housing. Move the coils as far back as they will go.

(2) Switch on the cross-hatch generator. Switch off the blue gun. Adjust the red and green static convergence magnets so that at the centre of the screen the red and green rectangles of the pattern become superimposed to provide a single yellow pattern. Remember that the patterns can only move at 120° to each other; that is, at 30° to the horizontal. Alternate small adjustments to each control are needed, and remember that if vertical (or horizontal) bars are superimposed exactly by one control and horizontal (or vertical) bars are not, then no adjustment to the other control will superimpose both.

(3) Switch on the blue gun and adjust the blue convergence magnet and the blue lateral magnet to superimpose the blue reactangles at the centre of the screen on the yellow to produce white. This is much easier to do, for the blue convergence magnet moves the blue raster vertically, and the blue lateral moves it horizontally. Unfortunately, there is some interaction, and the blue adjustment will slightly upset the red and green adjustments. At this stage this does not matter for only rough static convergence is necessary. At a later stage, however, it will be necessary to return to the red-green adjustments with the blue gun off and then to turn on the blue gun and re-adjust the blue magnets, repeating the process until all three beams have been made to converge at the centre of the screen.

(4) In the early stages of (2) and (3) operate the picture-shift controls to make the edges of the rasters plainly visible to make quite sure that one is attempting to align the same rectangles in each raster at the screen centre. With everything out of adjustment it is possible to try to align the wrong rectangles, although it is unlikely that one will succeed in doing so.

(5) Switch off the cross-hatch generator. Turn off both green and blue guns and adjust brightness and red 1st anode voltage for a reasonably bright raster. This will have a red patch surrounded by variously-coloured patches. Adjust the two purity magnets to get the best red patch possible in the centre of the screen. The patch will be very ill-defined and is likely to be far from circular.

Each magnet has two tabs, one with a rounded end and the other with a square end. When two similar tabs are together the field is at its strongest, and when dissimilar tabs are together it is at its weakest. The effect of turning them together is readily seen and spreading them apart weakens or strengthens the field as the case may be.

When satisfied that the best red patch has been obtained, slide the deflector coils forward until the whole screen is a uniform red. If the coils have to come fully forward and the screen is still not uniform re-adjust the purity magnets in an endeavour to obtain a completely uniform red screen.

(6) Switch the green gun on and the red gun off. Check that the raster is a uniform green.

(7) Switch the blue gun on and the green gun off. Check that the raster is a uniform blue. Adjustments to the green and blue 1st anode voltages may be needed to make these rasters visible.

(8) There are no extra adjustments for the purity of the green and blue rasters separately from the red. Normally, none is needed. If the green and/or blue rasters appear less pure than the red it usually means that the assessment of red purity has not been good enough and one must try to get the red purity better.

Convergence

We now come to convergence. The cross-hatch generator is now kept on permanently, and for about half the stages the blue gun is switched off. Adjust the anode voltages so that red and green bars are of about equal intensity and so that they give a clear yellow wherever they are superimposed.

(1) Adjust the red and green static convergence magnets so that red and green rectangles near the centre of the screen are superimposed.

(2) Look at a vertical bar near the centre. It will be a single yellow line near the centre where the static convergence holds good, but above and below it will spread into separate red and green lines. The aim is now to adjust RG/F Tilt and RG/F Para to make these red and green lines coalesce throughout their lengths into a single yellow line. Both controls affect

things throughout the length of the lines, but Para has a major effect at the bottom, whereas Tilt appears to twist the line about a centre pivot. Adjust the controls alternately and only a little at a time. Do not worry if the adjustments separate the lines in the centre, but then concentrate upon obtaining parallel red and green lines.

(3) Now adjust RG/F Diff and RG/F Symm to obtain equal separation of horizontal bars of the pattern where they cross the vertical centre bars. If it is possible to superimpose the horizontal bars where they cross the vertical centre bars well and good. If it is not, concentrate upon obtaining equal spacing of the red and green bars, making quite certain that all the red bars are on the same side of the green bars.

(4) Re-adjust static convergence for a yellow centre rectangle.

(5) Repeat (2) and (3), this time endeavouring to superimpose the red and green vertical centre bars to obtain a yellow bar, and to superimpose the horizontal red and green bars at the points where they cross the vertical centre bar. From time to time slight re-adjustment of static convergence may be needed.

(6) Next adjust RG/L Amp and RG/L Tilt; The first affects the separation of vertical bars on the left-hand side of the raster, the second does the same on the right. The two interact and also have some effect on the separation in the middle. The aim is, therefore, to obtain equal separation of all vertical bars with all green bars on the same side of the red, so that they can be superimposed by an adjustment of the static magnets, which then do.

Comment. There is usually little difficulty in obtaining almost perfect convergence of all the vertical bars and of the horizontal bars where they cross the centre vertical bar, by adjustment of these six controls plus the red and green static magnets. The controls may have to be gone over three or four times in succession before this is obtained. The cross hatch pattern will then be substantially yellow but horizontal bars away from the centre will probably be out of register.

(7) There are two controls which act to bring the horizontal bars into register, RG/L Diff and RG/L Symm. These are adjusted alternately to bring the horizontal bars as nearly as possible into register. In doing this, the earlier adjustments may be adversely affected, in particular RG/F Diff and RG/F Symm, so it is best to work these four controls together for the best register of horizontal bars. The other controls affecting the registration of vertical bars need be re-adjusted only if it is found that they have been upset by the later adjustments.

Comment. Never attempt to correct any defect completely by the operation of one control. If it can be done, then that setting of the control is almost certainly wrong and will prevent the proper adjustment of some other control. Aim at adjusting each control only to improve matters somewhat, and then by repeatedly going over the whole process one can gradually arrive at an optimum condition. Perfect registration over the whole pattern is unlikely to be achieved. The best that can be achieved may well be that horizontal bars go out of register at diagonally opposite corners, and the extreme left and right vertical bars may not be perfectly superimposed. Only experience will tell whether a given result is the best that can be achieved with particular equipment or whether one can do better with more adjustment.

(8) Now switch on the blue gun and attempt to converge the blue pattern with the yellow. Start with the blue static magnets to converge the blue centre rectangle on the yellow to obtain white. Then adjust BF/Tilt and BF/Para for the proper separation of blue horizontal bars where they cross the yellow vertical bar in the centre of the screen. Tilt has a more or less uniform affect throughout, whereas Para affects mainly the top of the picture. As in the case of other adjustments, the aim should be to obtain uniform spacing of the blue and yellow bars with the one always on the same side of the other, rather than superposition, for the latter can then always be obtained by adjusting the blue convergence magnet.

(9) Adjust B/L Amp for maximum droop of the horizontal blue bars. The control will be fully one way. Then adjust B/L Tilt and B/L Para to make the shape of the horizontal bars roughly symmetrical about the vertical central line of the tube. The waveform is mainly parabolic and Para adds a second-harmonic component which has the effect of flattening the droop of the blue bars around the centre. Complete symmetry will not be obtained, and maximum droop will be to the left of centre.

(10) Adjust B/L Amp so that the shape of the horizontal blue bars is as nearly as possible the same as that of the yellow.

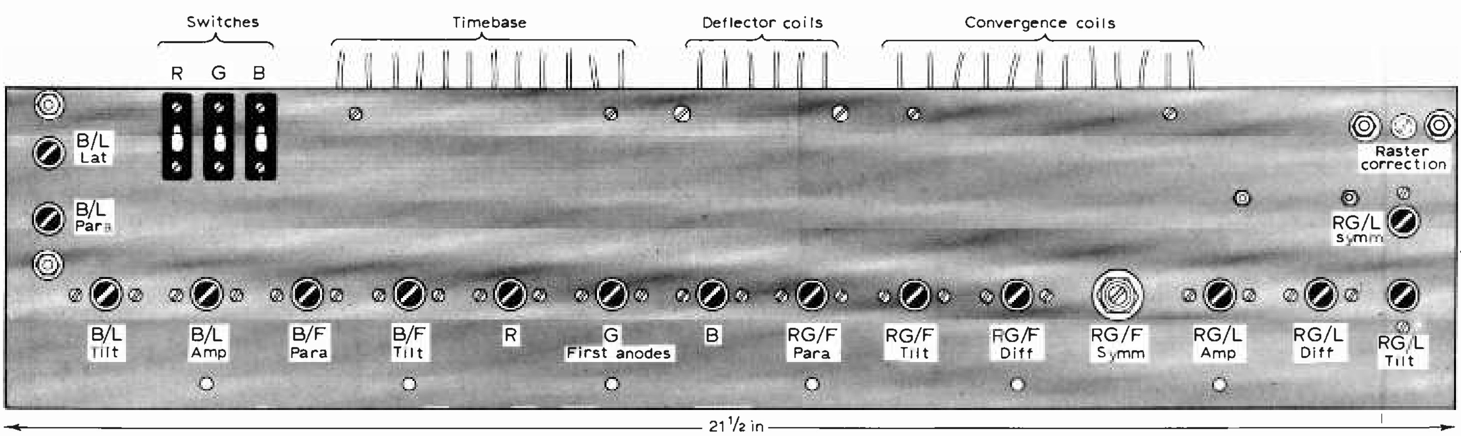
(11) Re-adjust B/F Tilt, B/F Para and the vertical blue magnet to superimpose the blue horizontal bars on the yellow where they cross the vertical centre line. Then re-adjust B/L Amp, B/L Tilt and B/L Para to get the horizontal bars superimposed as far as possible everywhere. Repeat as necessary.

(12) Adjust the static B Lat magnet to superimpose vertical blue bars on yellow at the centre. Adjust B Lat to align vertical bars at left and right; the connections to the coil may need reversing. In effect this alters that amplitude of the blue line scan so that the blue raster can be made of the same width as the yellow. The control must thus be used in conjunction with the static B Lat magnet.

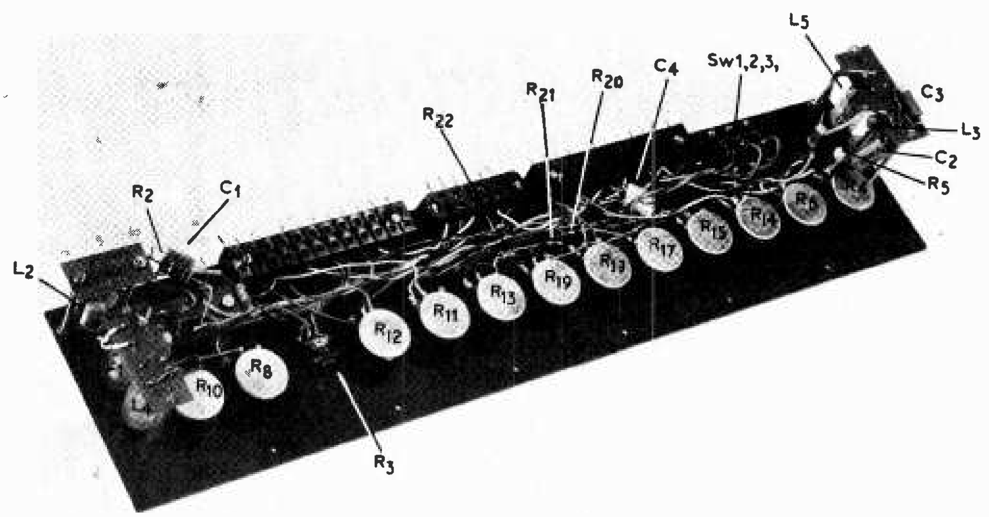
When all this has been done, do not be disheartened to find that the red-green convergence has deteriorated. Because of interaction this is inevitable and it is necessary to go through the whole procedure again.

To save space, the foregoing description has been written as a complete drill, and the warning not to attempt to adjust any control for perfection should be heeded, even if it seems hard to do so. In practice, it is best initially to go through the whole procedure of convergence adjustment quite roughly, and then

The layout adopted for the convergence controls is shown in this drawing. The panel is screwed to the top edge of the panel which holds the cathode-ray tube.



This photograph shows the underside of the convergence panel and indicates the positions of some of the chief components. The layout is far from critical.



to repeat it a little more carefully. This will bring all the controls to somewhere near their proper settings and so will reduce the magnitude of interaction between the controls at the later stages.

If this is done, then it is likely that going over the full procedure twice more, very carefully, will suffice. The main practical difficulty is knowing when to stop! Perfect convergence over the whole screen is theoretically impossible and it is a matter of individual judgement whether or not the optimum condition has been reached in any given case. It is not possible to indicate how much misconvergence will be found, for it depends very much on component tolerances, including the c.r. tube. Since the convergence waveforms are derived from the scanning waveforms, clearly anything which affects the linearity of scan will affect convergence, hence the need for making the timebase adjustments first.

The cross hatch pattern shows up misconvergence very clearly, much more clearly than an average television picture. When one has reached a stage in the adjustments at which it seems hard to get the convergence any better, it is helpful to replace the pattern by a television picture, which need not be a colour picture. The newcomer will be surprised how little noticeable is a degree of misconvergence which, from the cross hatch pattern, he would expect to be intolerable. In general, the noticeable effect of misconvergence is judged to be bad on the cross hatch pattern, fair on monochrome test card F, easily tolerable on a monochrome moving picture and still less noticeable on a colour picture.

The reason is, of course, that misconvergence only shows where there are changes of luminance or colour. It thus appears only on the edges of objects in the picture and its magnitude depends on the amount of the change of luminance or colour. Then misconvergence normally appears only towards the edges of the picture, whereas the main interest of the picture is usually the central area, so that one's attention is concentrated on the part where the convergence is good.

More elaborate circuitry with extra controls would certainly enable improved convergence to be obtained but it is not generally considered that the improvement is worth the extra complication and expense. We have done no work on such circuitry and so cannot recommend anything of this nature.

The interaction between the convergence controls could also be reduced by more complicated and expensive circuits, but it would not eliminate it completely because some of it arises in the tube itself, and this seems to be inevitable. It does not, therefore, seem worth while to go to a lot of trouble merely to reduce the interaction.

It is, of course, necessary that the tube and any iron-work near it be demagnetized before any of these adjustments are made, including the purity adjustments. The automatic degaussing circuit will normally take care of this. However, it will not deal with metal-work outside the tube shield and sometimes other measures will be needed.

A separate degaussing coil can be wound on a circular former of 12-inches inside diameter with a winding length of $\frac{1}{2}$ in. and a depth of 1 in., so that the outside diameter is 14 in. Some 800 turns of No. 24 enam. wire are needed and the coil will take 4.1 lb. The resistance is $60\,\Omega$ with an inductance of 0.43H, and the coil take 1.5A on 240-V, 50Hz mains.

In use the coil is connected to the mains and moved about slowly in front of the tube and round the sides and top with its side parallel to them. It is then withdrawn slowly to a distance of some 6 ft. before it is switched off. Avoid getting the coil near any permanent magnets; it is not desirable that these should be demagnetized! It is unlikely that this degaussing coil will be needed, and almost certain that it will not be if the purity adjustments can be carried out to obtain rasters of uniform colour.

Corrections

In Fig.1, Pt.4, p.322, September, C_1 is drawn as an electrolytic capacitor. In view of its voltage rating it is obvious that it should be a paper-dielectric type. On p.323, the mains transformer secondary was inadvertently given as 35-0-35V; it should be 35 V, C.T., that is 17.5-0-17.5 V. On the same page, the 12-way connector type number appeared as B751 instead of BTS1.

Wireless World Digital Computer

The series of articles describing the *Wireless World* digital computer which appeared in the August to December 1967 issues is being reprinted. The 36-page reprint, which will be ready at the beginning of October, will cost 10s and can be obtained from Dorset House, Stamford Street, London S.E.1.

A Segmented Fit Squaring Circuit

A design technique for developing a circuit with an accurate square-law transfer function.

by R. J. Lamden, M.Sc., M.I.E.E.

A circuit with an accurate square law transfer function, that is,

$$V_o = kV_i^2 \quad . \; . \; . \; . \; . \; (1)$$

when k is a constant and V_i, V_o are the input and output voltages, has many important uses. For example, this type of response is required for the measurement of mean power levels. Often circuits using square-law diodes or lamp-brightness measurements are used, but these are of uncertain accuracy and liable to variations with temperature and time. Moving-coil wattmeters are low-frequency devices and assume that their input waveforms are sinusoidal. But given an accurate squaring circuit, a number of other possibilities appear. For instance, two voltages can be multiplied in analogue fashion. If the voltages are V_A, V_B, they can be added and subtracted in operational amplifiers, and a voltage proportional to the product can be formed using the equation,

$$4V_AV_B = (V_A + V_B)^2 - (V_A - V_B)^2 \quad . \; . \; . \; (2)$$

Square-root function can be obtained using feedback techniques, and many functions may be approximated by using the first few terms of their Taylor series expansion

$$f(V) = A_0 + A_1V + A_2V^2 + A_3V^3 \quad . \; . \; . \; (3)$$

As A. E. Crump has recently pointed out[1], any non-linear single valued function can be approximated by a series of linear segments. The analysis of the squaring circuit is particularly simple, and the accuracy of the approximations can be calculated without recourse to graphical matching of the curve by straight-line segments.

The way in which a segment of the transfer function can be approximated is shown in Fig. 1. For purposes of explanation suppose that the curve is to be matched

$$V_o = V_i^2 \quad . \; . \; . \; . \; . \; . \; (4)$$

for V_i between -1 and $+1$ volt; the alterations necessary for any magnification of this range can easily be obtained. If the maximum error is to be E_m then, from Fig. 1, this is the amount by which the segment is below the parabola at its beginning and end. If we suppose that this is to be the nth segment of an approximation, the diode break-points will be called

$$V_i\,(n-1) \text{ and } V_i\,(n).$$

Suppose that the straight line segment follows the characteristic

$$V_o = A_nV_i + V_c \quad . \; . \; . \; . \; (5)$$

Then at input voltage V_i the error will be

$$E = V_o - A_nV_i - V_c$$
$$= V_i^2 - A_nV_i - V_c \quad . \; . \; . \; (6)$$

This equation is also that of a parabola, and it is plotted in Fig. 2. The graph has been made more recognisable by re-labelling the input voltage co-ordinate,

$$V_i' = V_i - \frac{A_n}{2} \quad . \; . \; . \; . \; . \; (7)$$

Then

$$E = V_i'^2 - \left(\frac{A_n^2}{4} + V_n\right) \quad . \; . \; . \; (8)$$

Fig. 2 shows that the maximum error is also present, at the centre of the segment, $V_i' = 0$, in the opposite sense to the error at the ends. So from equation (8)

$$E_m = \frac{A_n^2}{4} + V_c \quad . \; . \; . \; (9)$$

or rewriting equation (8)

$$E = V_i'^2 - E_m \quad . \; . \; . \; . \; (10)$$

If we apply this equation to the ends of the segment, V_1, V_4, where $E = E_m$, we see, from equation 10 that the length of the segment is

$$V_4 - V_1 = 2\sqrt{2\,E_m} \quad . \; . \; . \; (11)$$

This shows that for a fixed maximum error, a parabola will be fitted by segments with a constant spacing between the break-point voltages. This is true for all except the first segment. Here the usual requirement is that there shall be no output for no

R. J. Lamden did post-graduate research in radio astronomy at Manchester University before joining Ferranti to work on aircraft radar. Moving to U.K.A.E.A. in 1959, he now works on detection of earthquakes and nuclear explosions.

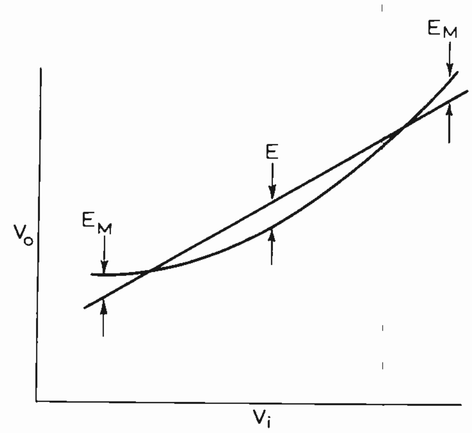
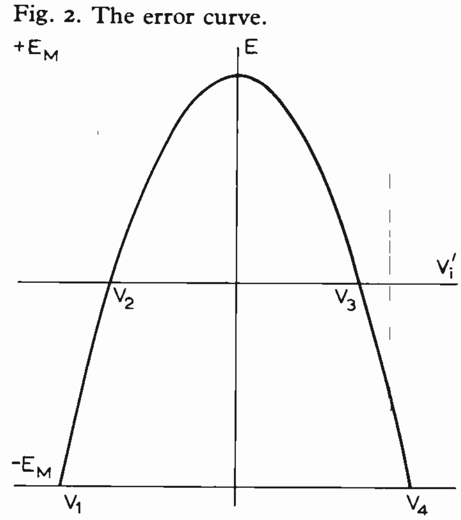


Fig. 1. A single segment.

Fig. 2. The error curve.



input, that is, zero standing error. So, referring to Fig. 2, this segment must stretch over an input range V_2 to V_4, since the error must be zero at an input voltage of V_2[1]. Substituting again in equation 10 shows that the length of this segment will be

$$\Delta V_1 = \sqrt{E_m}(1 + \sqrt{2}) \ . \ . \ . \ (12)$$

So to cover the input voltage range from 0 to 1 with N segments,

$$\sum_1^N \Delta V_n = 1 \ . \ . \ . \ . \ (13)$$

Or

$$1 = \sqrt{E_m}(1 + \sqrt{2}) + 2\sqrt{2}(N - 1) \ . \ . \ . \ (14a)$$

Or

$$\sqrt{E_m} = \frac{1}{1 + \sqrt{2}\,(2N - 1)} \ . \ . \ . \ (14b)$$

Using this equation the number of segments needed for a given accuracy can be found, and Fig. 3 shows the result graphically.

This graph neglects the effects of diode imperfections, and even apart from the errors inherent in adjusting large numbers of break-point potentiometers, the assumption involved would probably fail for accuracies better than 0·1%. An interesting point of this graph is the quite good accuracy obtainable with a few segments. Since the first segment goes through zero, and the segments join each other, the standing voltage V_o for each segment, is automatically inserted by the effects of the earlier segments. The gain for the nth segment can be found from the equations

$$A_n = \frac{V_o(n) - V_o(n-1)}{V_i(n) - V_i(n-1)}$$

$$= \frac{(V_i^2(n) - E_m) - (V_i(n-1)^2 - E_m)}{V_i(n) - V_i(n-1)} \ . \ . \ . \ (14a)$$

$$= V_i(n) + V_i(n-1) \ . \ . \ . \ . \ . \ (14b)$$

$$= 2\,\frac{1 + 2\sqrt{2}\,(n-1)}{1 + \sqrt{2}\,(2N - 1)} \ . \ . \ . \ . \ (14c)$$

when $V_i(n)$, $V_o(n)$ are the input and output voltages at the nth break-point.

Practical circuits based on this theory have been built and the outline details are shown in Fig. 4. An accuracy of 1% of full scale was required, that is, a total output harmonic content more than 40 dB down on the second harmonic when the circuit is used for squaring a one-volt peak sine-wave. It is necessary to have the same output polarity for an input of either sense so a unity-gain inverting amplifier A_1 was used. Both conventional operational amplifiers and monolithic types have been used in both positions in this circuit. A capacitor C_1 has been inserted in the feedback path of the second amplifier to ensure an adequate stability margin.

The direct input is applied through diodes $D_{1,4,7,10}$ while the inverted input goes through $D_{3,6,9,12}$. The break point voltages are fed through diodes $D_{2,5,8,11}$, which provide compensation for the effect of temperature on the diode forward-conduction voltage, as pointed out by A. E. Crump. This balancing out of the voltages also means that the break-points can be set up by connecting an accurate voltmeter, most conveniently a digital type, to the sliders of the potentiometers, and adjusting these to the calculated break point voltages.

The effect of the diode non-linearity at the break-points, which although generally favourable are somewhat uncertain, can be reduced by making the input voltage swing large in comparison with the non-linear region. An input voltage range of ± 5 volts was chosen, since this is conveniently obtainable from both monolithic and discrete component operational amplifiers. For an accuracy of better than 1% four segments are required, and the calculated break-point voltages are given in Table 1.

Gold-bonded germanium junction-diodes have been used to keep the switch-on region as small as possible; the effects of diode leakage-current can be reduced by making the input resistors as small as possible. The values of these resistors can be found, once the value of the feedbacks resistor R_5 has been settled, by reference to equation 14c. For unity overall gain, if the operational amplifier gain can be considered very high, then with the nth diode conducting the gain will be

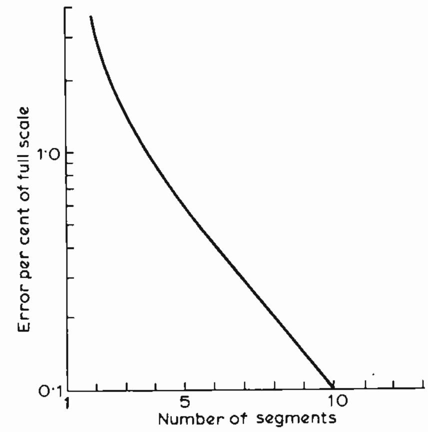


Fig. 3. A curve showing the accuracy of segmental fit.

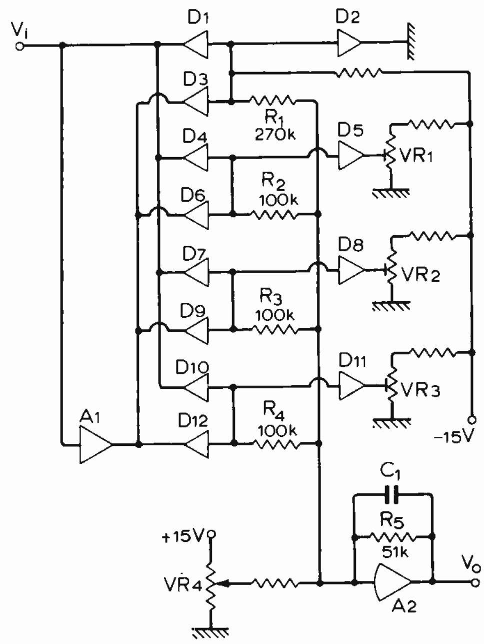


Fig. 4. A practical squaring circuit.

TABLE 1

4 Segments, Break-Point Voltages. No.	Input Range 0·5 volts. Voltage
1	±1·108
2	±2·405
3	±3·703

$$A_n = R_5 \sum_1^n \frac{1}{R_n} \ . \ . \ . \ . \ . \ . \ . \ (15)$$

Comparing 15 with 14c

$$R_1 = R_5 \frac{1 + 7\sqrt{2}}{2}$$

$$R_2 = R_3 = \frac{1 + 7\sqrt{2}}{4\sqrt{2}}$$

Using $R_5 = 47$ kΩ gives $R_1 = 100$ kΩ, $R_2 = R_7 = R_4 = 270$ kΩ. These values were made up from 1% metal oxide resistors, and the potentiometer voltages were properly adjusted, using a digital voltmeter. After these had been set RV_4 was adjusted to give an output level of zero for zero input.

This is a circuit reliably capable of attaining accuracies better than 1% of full scale at any point on the characteristic, as a number of units using different amplifiers have shown. It has a frequency response up to at least 10 kH$_2$ with a suitable choice of C_1. The long term stability is good, and the characteristics can be accurately reproduced.

REFERENCE

1"Diode Function Generators", by A. E. Crump. *Wireless World* Dec. 1967.

Transistor Usurps Transmitter Valve

An experimental solid-state device built in the U.S.A. has finally disposed of the old idea that transistors would never supersede high power thermionic valves such as those used in transmitters. Developed by R.C.A., it is a transistor of laminated construction capable of generating r.f. energy at 1 MHz with a power of 800 watts. The device is formed from two separate silicon wafers, an emitter-base wafer and a base-collector wafer, which are subsequently fused, or laminated, under heat and pressure into a single structure and finally sealed in glass. The construction makes accessible both an emitter contact area and a collector contact area for heat sinking.

Electronics and the Artist

Cybernetic Serendipity, at Nash House, The Mall, London S.W.1, is an international exhibition sponsored by the Institute of Contemporary Arts "exploring and demonstrating relationships between the arts and technology". Open until October 20th, it has, amongst its specific aims that of presenting "an area of activity which manifests artists' involvement with science, and the scientists' involvement with the arts", and that of showing "links between the random systems employed by artists, composers, and poets, and those involved in the use of cybernetic devices".

The term 'cybernetic' refers to "systems of communication and control in complex electronic devices like computers, which have very definite similarities with the processes of communication, and control in the human nervous-system". 'Serendipity' here refers to "the facility of making happy chance discoveries". Thus we find amongst the exhibits cybernetic devices themselves, in which stimulus from the changing environment, human or machine, evokes a response in terms of sound, light or movement; and the products of computer systems in the shape of line drawings, films, poems, etc.

An element of superficiality and consequent naivety permeates the exhibition. Upon entering the hall you are drawn into a magical scene of prevailing gloom, strange noises, flashes and sparkles. It's all a bit like an amusement arcade on a wet afternoon at the seaside.

One of the first exhibits to be seen is rather like a one-armed bandit combined with a 'what-the-butler-saw' machine. Clapping the hands and screaming causes pictures with pop-art motifs to change in rapid sequence under intermittent illumination. It is not very interesting and there's no pay-off so one moves on disgruntled. There are a number of devices that can be described as simple stimulus-and-response systems, besides the one just described. One with large blue lamps set in three rows responds to voices of different pitch. Different rows light up. A more sophisticated unit incorporating a cathode-ray tube produces diagonal striations of different colours. The most engaging of the sound-stimulated exhibits is a simple four-petal flower on a stalk of plastic tubes. A high-pitched sound emitted to one side causes the flower to swing round and face the source in a manner much like that of the little weed when talking to Bill and Ben.

However, it will already be apparent that nothing essentially new in any respect has been described. When the technology behind the exhibits is reduced to block diagrams the results are very simple indeed. Thus, to talk about the "artists' involvement with science" is an inflated way of saying that an artist abandons certain tools and techniques, possibly because they are only associated with the immobile non-kinetic art-forms of orthodox painting and sculpture, and reaches out for the dynamic possibilities of simple electronic and electro-mechanical feedback systems. In a curious way, fascination with the tools of a possible new means of expression has resulted in a regression of aesthetic expressiveness with the creation of oversize toys. Bruce Lacey, in his wall-fitting "Owl", has used a panel of selenium cells to supply current to ruffle a small array of feathers on each side of the creature's square body. Two Crookes radiometers have become eyeballs: strikingly simple and equally ineffective. The prize for the most ingenious non-happening must go to John Lifton for his "Analogue Feedback Projection System", which was designed to involve the observer. A rectangular image is projected on to the centre of a hemispherical screen, and secondary images oscillate towards and away from the centre.

Leaving aside the giant mobile, the numerous mechanical and electrical displays of harmonic relations, the programmed analogue computer reconstructing a drawing, and the computer poetry samples, we turn to the musical offerings. A computer is described as producing music by probability and chance. By definition the sounds being generated are random, having no points for harmonic reference and no sequential pattern. Very different however is an experimental suite for string quartet, composed by a computer according to a programme by Hiller and Isaacson of Illinois University. 'Experiment 4' in the Illiac Suite is a very satisfying, closely written piece of counterpoint. It seems quite clear that this, composed as it was in 1957, is nevertheless by far the most advanced contribution to the exhibition.

Whatever new art works result from the impact of technology on the artist, this exhibition can hardly claim to present any point for further growth. Elaborate cybernetic systems are very expensive. They can be large, especially if discrete electronic components are used extensively. Such systems do not do new things all on their own, but require careful programming and maintenance. Last but not in any way least there is a requirement for new forms of display. Music can be transcribed into readable form, but how can other electronic signal patterns, obeying newly conceived rules, be displayed other than by flashing lamps or on large colour cathode-ray tubes? The artist-engineer of the future is certainly not going to be short of challenging problems.

J. G.

Books Received

A Guide to Amateur Radio, twelfth edition, by J. P. Hawker is "intended to assist the newcomer to learn more about the hobby, and to help him or her to obtain a transmitting licence". Each chapter is thick with information. A selection of questions that any novice might ask is printed in the first chapter and given clear and encouraging answers. In this way the confidence of a would-be amateur is built up. Following chapters introduce the reader to more and more general facts along with details of circuitry of communication receivers and transmitters. Valves still predominate in the more powerful designs but several transistor receiver circuits are described with full constructional details. A chapter is devoted to explaining the licence examination, and several useful tables appear, including technical abbreviation and symbols, radio circuit symbols, amateur abbreviations, morse code, and frequency bands for amateur transmission and reception. Pp. 86. Price 5s. Radio Society of Great Britain, 28 Little Russell Street, London, W.C.1.

a b c's of Radio and TV Broadcasting by F. J. Waters is a basic non-mathematical survey of transmitter equipment and its operation. The opening chapter explains the fundamentals of electromagnetic radiation, ending with a block diagram of a superhet receiver. Audio and video modulating signals, and the electronic and electrical devices for their production, amplification, and recording, are considered in the second and third chapters. The origin, amplification and modulation of radio-frequency carrier waves is investigated and explanations are accompanied by very frequent and simple diagrams. The last third of the book deals with power supplies, transmission lines, broadcasting and receiving aerials (considered functionally), and remote transmitter operating. Each chapter ends with several review questions, the answers to which are at the end of the book. The index allows the book to be used as an encyclopaedia. Pp.128. Price £1. W. Foulsham & Co. Ltd., Slough, Bucks.

Letters to the Editor

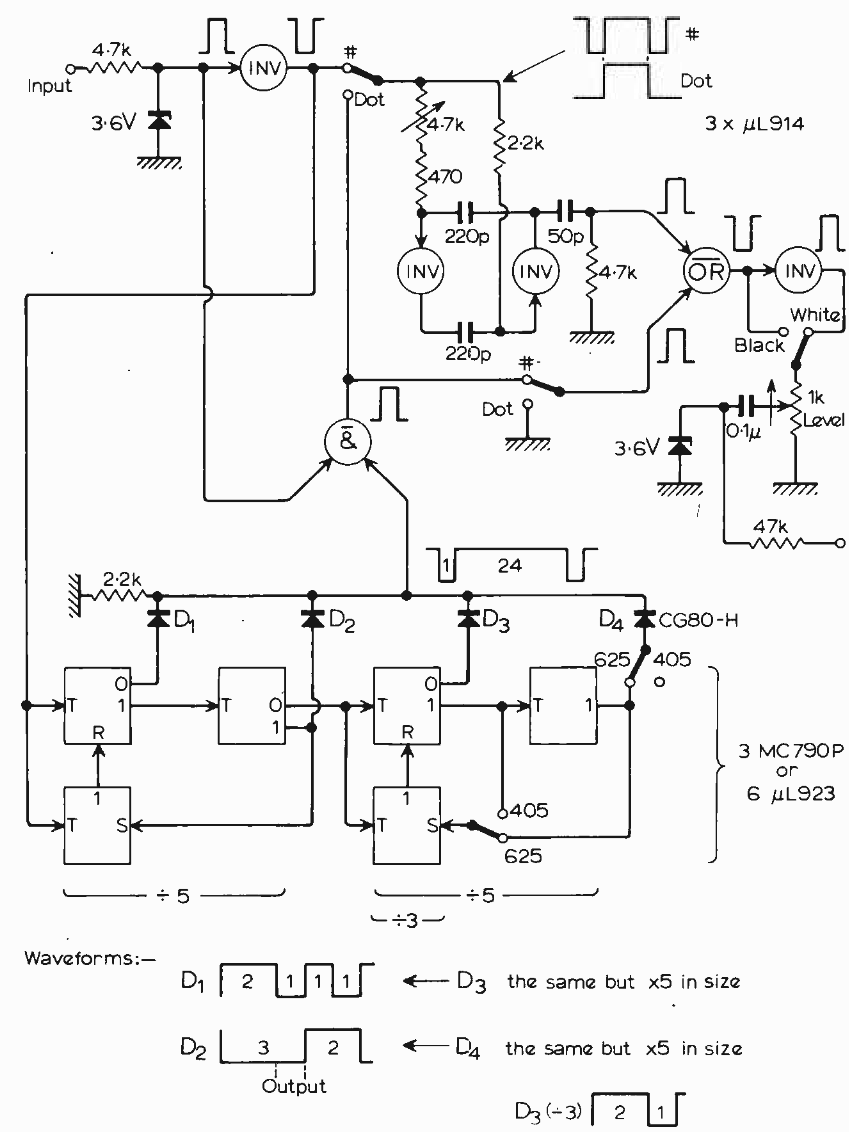
The Editor does not necessarily endorse opinions expressed by his correspondents

Crosshatch and dot generator

I read with considerable interest the article in the September issue describing an integrated circuit pattern generator, as I have made one very similar in design. However, I have achieved the same result in a more economical way and think that your readers may be interested.

A saving of some 33% of the cost of integrated circuits can be made by using Motorola dual-in-line MC790P and MC724P in place of 2 × μL923s and 2 × μL914s respectively as they are electrically interchangeable.

The first simplification to the generator is to remove the buffers between the i.cs 6, 7 and 9, and likewise 10, 11 and 13 and to use the form of counter shown in the drawing. This does not require any gating but it will not produce a single output pulse like the dividers in the article but a two to three mark-space ratio pulse. A divide-by-five stage like this will drive an identical divider without any buffer between. I.C.14 can be eliminated in the article by using a two-input AND gate (fed from the 0-outputs of i.cs 9 and 13). Also some means must be provided to ensure that the counters start from the zero position.



In my version a four input AND gate is required in order to achieve a one-line-wide pulse every twenty-five lines due to the odd waveforms.

This could be a 4-input integrated circuit or two 2-inputs in parallel, but it is much cheaper to use four diodes and a resistor.

Finally, the output logic can be simplified as shown to include crosshatch/dot and black/white switching with simple switches.

Thus the complete generator now uses only six μL923s and three μL914s—or three MC790Ps and 2½ MC724Ps and a few extra discrete components.

Two possible further simplifications would be to remove the half μL914 feeding the dividers as in my version, and also the buffer after the multivibrator by making the multivibrator generate the correct mark-space ratio. However, this short time constant is right on the upper limit of oscillation and is not really reliable even with selected μL914s.

A modification can be performed to my counter chain to enable it to be used for 405-line working, this is shown in the drawing; the counter divides by 15 to give 27 horizontal lines—some 25 being visible. This could be arranged on a switch as shown for dual standard 405/625.

For dots only, the input to the multivibrator can be the 1-line wide output of the divider chain, so that the m.v. gives dots directly with no further gating!

A. W. CRITCHLEY
Uxbridge, Middx.

"Long-tailed pair"

In his helpful article 'Balanced Transistor D.C. Amplifiers' in your August issue, T. D. Towers says that the long-tailed pair circuit using transistors is sometimes known as the Slaughter circuit, and then proceeds himself to use that name. I can see no justification for this. Merely substituting transistors for valves in 1956 is hardly an achievement that deserves special recognition. The credit should go to the inventor of the long-tailed pair circuit, who was not F. F. Offner in 1937 as stated by Mr Towers, but A. D. Blumlein in his patent 482,740 of 1936.

The name 'Blumlein circuit' would not do, because it would apply to about half the really important basic circuits we use, so I urge that his own very apt name, 'long-tailed pair', should be the one used for it, whether in valve or transistor version. We already have the injustice of the name Miller (instead of Blumlein) integrator, which I have been doing my best for the last 22 years to correct*. Why are we so fond of giving to Americans the credit for British inventions?

*E.g., *W.W.*, June 1946, p. 203.

M. G. SCROGGIE
Bromley, Kent

F.E.T. a misnomer?

It is regretted that the printers made nonsense of equation (3) in Mr. Hart's letter on p. 304 of the September issue. Here is the correct expression:

$$\left|\left(\frac{\partial I}{\partial \phi_1}\right)_{\phi_2}\right| \gg \left|\left(\frac{\partial I}{\partial \phi_2}\right)_{\phi_1}\right| \qquad \ldots\ldots\ldots\ldots (3)$$

Switched-mode D.C. Regulators

How semiconductors are used to obtain a constant voltage from an unregulated supply by periodic switching of a series pass transistor

by T. D. Towers, M.B.E., M.A.*

Last month we looked at "linear" constant-voltage d.c. supplies, in which, in effect, transistors are used as feedback-controlled variable resistors continuously dissipating exactly the amount of power necessary to keep the output voltage constant under varying input voltage and output load conditions. When it comes to high volt-amp requirements or high step-down voltage between input and output, the major problem of design in linear regulators becomes largely a mechanical one of providing an adequate heat sink for the dissipating transistors. This is the same problem that faces designers of high power audio amplifiers, who have been turning in recent years to class D (pulse-width-modulated) designs. A similar trend is developing in d.c. power supplies, and this article gives some account of the basic circuits that have been used in discrete-component, and more recently, in micro-circuit designs.

Switching regulators can be more compact than equivalent linear ones because of the reduction in heat-sink size for the same output power. To the higher efficiency of the switching mode we can add the use of economical wide tolerance semiconductors. Finally switching regulators are of paramount importance in battery driven equipment, particularly where the output voltage required is much lower than the supply voltage. They have found a special place in missiles and space vehicles where power has to be carefully conserved.

On the other side of the coin, the greater heat-sink simplicity has to be paid for with greater circuit complexity. In general, also, switching regulators do not suppress input ripple as well as linear ones. Also, the feedback of switching transient spikes into the supply rail can sometimes present quite a problem. Finally in the switching regulator the response to load transients (sudden changes in load current) tends to be slower than in the linear case.

Switched voltage regulator principle

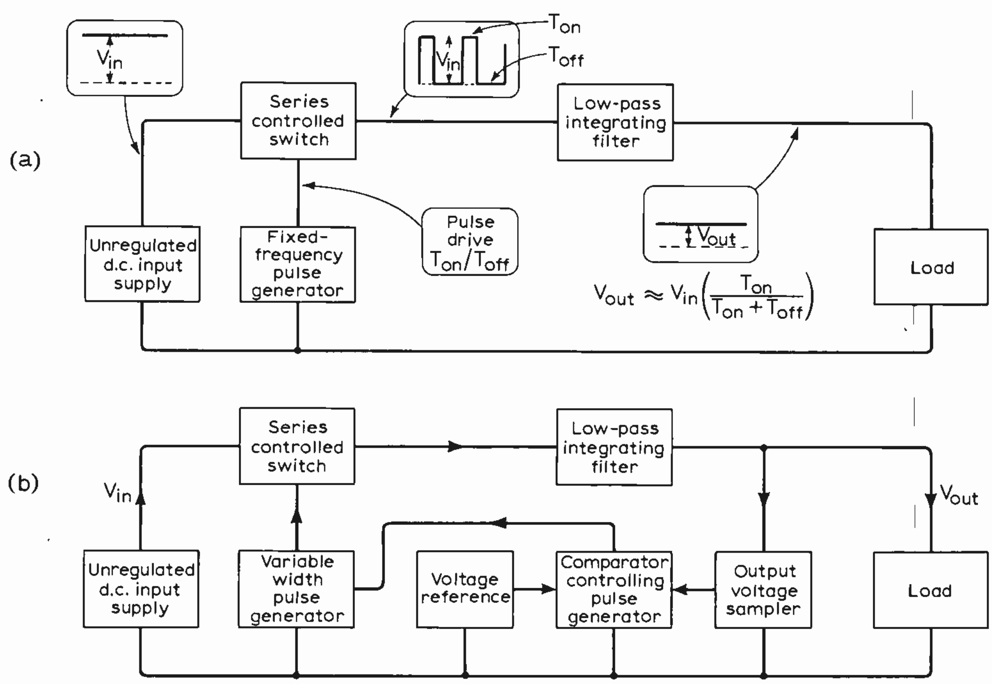
Fig. 1(a) shows the basic arrangement for obtaining a low voltage outpu from at higher voltage input by switching on and off a series controlled switch at a fixed pulse repetition frequency and passing the resultant "chopped" voltage through a low-pass filter. A d.c. output of current, I_{OUT}, at voltage, V_{OUT}, calls for a continuous power output $P_{OUT} = V_{OUT} \times I_{OUT}$. If we assume lossless switching and filtering, this means that the input line must supply the same average power. Now the input voltage source supplies current (and therefore power) only during the "on" period, T_{ON}, while the load takes current (and power) during the whole period $T_{ON} + T_{OFF}$. If $\bar{I}_{IN}$ is the mean input current during the "on" time, then $P_{IN} = V_{IN} \times \bar{I}_{IN}$ is the input energy during T_{ON}. Now during T_{OFF} the series switch is cut off and no current (or power) is drawn from the input. Thus $V_{IN}\ \bar{I}_{IN}$ is the mean energy taken from the source over the whole switching period and must be equal to $V_{OUT} \times I_{OUT}$. With a suitable design of filter for low output ripple, the input current during T_{ON} can be made relatively constant and equal to the constant output current, I_{OUT}, i.e. $\bar{I}_{IN} = I_{OUT}$. Thus the input energy in one period $T_{ON} + T_{OFF}$, given by $V_{IN} \times I_{OUT} \times T_{ON}$ must equal the output energy $V_{OUT} \times I_{OUT}\,(T_{ON} + T_{OFF})$. From this,

$$V_{OUT} = V_{IN}\, T_{ON}/(T_{ON} + T_{OFF}),$$

as the illustrative waveforms in Fig. 1(a) show. By the arrangement of Fig. 1(a) we can therefore, by suitable selection of the switching mark-space ratio, set the output voltage at any level from 0V up to V_{IN}. However, the output level will vary if V_{IN} varies, which can happen either from independent variation of the input line voltage or from changes in the current taken by the load.

The output voltage can be regulated by the circuit arrangement of Fig. 1(b). Here a feedback circuit samples the output voltage and compares it with a reference voltage by means of a comparator circuit. In the comparator, the difference (error signal) between the two voltages produces a control signal which is fed into the pulse

Fig. 1. Basic blocks illustrating operation principle of switched d.c. voltage regulators. (a) Producing lower output voltage by periodically switching input through to output load via smoothing filter; (b) additional regulating of output voltage by controlling "on" time of series switch by comparing output with fixed reference.



* Newmarket Transistors Ltd.

generator controlling the series-switch. The feedback signal from the comparator controls the on-off duty cycle of the pulse generator in such a way that if the output voltage across the load tends to fall below the preset level, the duration of the "on" time of the pulses increases. The series-pass switch then conducts for longer periods of time, and the output voltage returns to the desired level. Equally, if the output voltage tends to rise, the feedback shortens the "on" time of the pulse generator to reduce the output level.

Later we will examine the various circuit blocks in detail, but at this point the main advantage of the switched regulator over the linear regulator can be seen. The series switch, nowadays usually a transistor, operates either fully cut-off or fully saturated ("bottomed"). Both of these states are low dissipation, so that dissipation losses in the series element are very much lower than in the linear regulators discussed last month. For any required output power from the regulator, therefore, much less heat-sinking provision is required for the transistor, permitting much more compact equipment design.

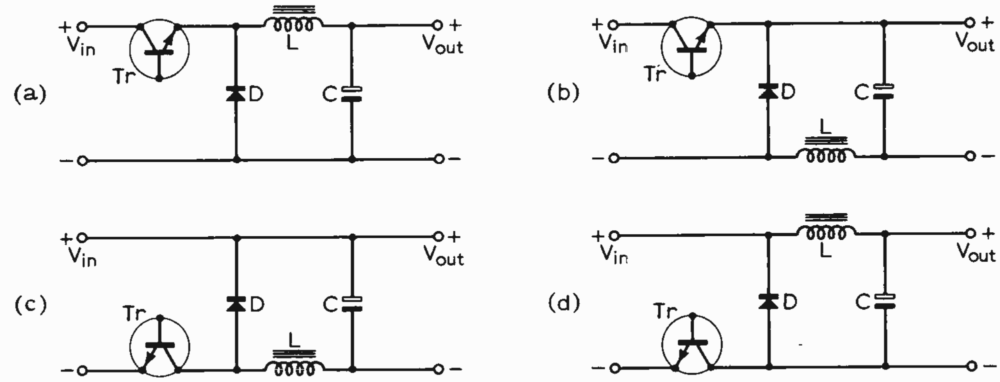


Fig. 2. Types of filters used after series switching transistor in switched d.c. voltage regulators: (a) In emitter circuit with choke in positive lead; (b) as (a) but with choke in negative lead; (c) in collector circuit with choke in negative lead; (d) as (c) but with choke in positive lead.

Low-pass filter design

The low-pass filter to ensure a smooth d.c. in the output line of the switched regulator is a critical part of the circuitry. In the interests of efficiency, no lossy elements should be included, and this rules out a simple *RC* filter. Common practice is to use an *LC* filter of which various forms are shown in Fig. 2. The actual arrangement depends on whether p-n-p or n-p-n transistors are used as the series switch element. The configurations of Fig. 2 are for n-p-n only, as the tendency nowadays is to use silicon power transistors (which are most commonly n-p-n) and the configurations for p-n-p can be derived simply by reversing the d.c. polarities.

In Fig. 2(a) the load, fed from V_{OUT}, is in the emitter circuit of the series transistor. The low-pass filter has three essential elements, *L*, *C* and *D*. The diode, *D*, is to protect the transistor against destructive reverse voltage spikes that may be produced when the transistor rapidly switches off the current flowing through the inductance, *L*. This diode acts as an energy-recovery diode, transferring the energy stored in the inductor during the "on" time of the transistor into the load when the transistor is turned off. It operates much the same as the efficiency or damping diode in a television line output stage. It substantially increases the efficiency of the circuit, and prevents the transistor emitter voltage rising materially above the positive supply line when the transistor switches off. Because of the fast rise and fall times involved, the diode must be a fast switching one to perform the required function.

As to the *LC* components of the filter, the inductance is usually designed to be large enough to ensure that the stored energy, $0{\cdot}5LI^2$, is sufficient to provide a relatively constant current flow into the load under maximum load conditions when the series switch is off, and the capacitance, *C*, is chosen to be large enough to provide the constant output under light load conditions when the energy in the inductance would be too low on its own. A low *L/C* ratio is aimed at to reduce output voltage transients and to reduce the supply voltage transients arising from sudden changes in load current. Typical values of *L* in practice are 0.5–5.0mH. With the pulse repetition rates of 30–100Hz commonly used, a value of 50–1000μF will be found used for *C*.

More specifically, to keep output ripple low, *C* is usually chosen much greater than $1/(4\pi^2 f^2 L)$, where *f* is the switching pulse repetition frequency. As for *L*, to keep the input current I_{IN} relatively constant during T_{ON}, *L* is selected to make dI_{IN} small in the formula $dI_{IN} = T_{ON}(V_{IN} - V_{OUT})/L$.

The arrangement of the filter elements in the emitter circuit of the switching transistor shown in Fig. 2(a) may in practice be varied as shown in Figs. 2(b)–(d), all configurations being shown for positive rail. In Fig. 2(b) the inductance is transferred to the earth rail. In Figs. 2(c) and (d), the filter is connected in the collector circuit of the transistor, with the inductance in the negative and positive rails respectively.

Series switch transistor requirements

There are some very special requirements for the series-pass transistor as it has to switch substantial currents at repetition frequencies, f_R, up to 100Hz without undue internal losses.

Firstly the transistor should have a high current gain at the maximum load current, so that there are no substantial losses in its base-emitter circuit. Secondly it should have an open-circuit-base avalanche voltage rating higher than the input supply voltage. Thirdly it should have low reverse collector leakage current, to avoid undue dissipation in the cut-off condition. Fourthly it should have a low collector-emitter saturation voltage in the "on" condition, again to keep internal dissipation losses low. Finally, it should have "on" and "off" switching times short compared with the minimum "on" pulse width [typically $1/(10f_R)$]; i.e. switching times should be of the order of $1/(100f_R)$ (=200ns for a 50Hz drive). When you add up all the above requirements, you find that only silicon diffused transistors are really suitable. Germanium alloy transistors cannot switch fast enough and have too high a leakage.

Variable mark-space ratio pulse generators

Referring to Fig. 1(b), we see that the output voltage is regulated by varying the on-off time of the series pass element. This is achieved by varying the on-off time of the variable mark-space ratio pulse generator driving the series element, the ratio being controlled by a d.c. feedback signal from the comparator stage. There are many possible circuits for constant-frequency pulse generators with the mark-space ratio controlled by a d.c. signal. Fig. 3 illustrates a few typical arrangements.

Fig. 3(a) is a unijunction *RC* relaxation oscillator, the output of which is resistively added via R_2 with the external control voltage, $V_{CONTROL}$. When the combined voltage at the base of the 2N1308 exceeds its forward base-emitter starting voltage, the transistor turns on and produces a square wave output. The p.r.f. is set by the CR_3 time constant, and the mark space ratio can be varied from 0 to 100% by varying $V_{CONTROL}$ from 0 to 12V. R_3 should be kept much smaller than R_2 to keep the p.r.f. independent of the mark-space ratio, and R_1 should be made equal to R_2.

In Fig. 3(b), we find a different approach. Tr_1 is a fixed-frequency *LC* feedback oscillator, the output from which is applied via winding L_3 to the emitter of a modulator transistor, Tr_3. A control voltage, $V_{CONTROL}$, governs via Tr_2 the d.c. level at the base of Tr_3. When $V_{CONTROL}$ is high, the voltage at the base of Tr_3 is low and the transistor switches on early in the cycle, producing a high mark-space ratio in its output. When $V_{CONTROL}$ is low, correspondingly the mark-space ratio is low.

Another approach to a d.c. controlled mark-space ratio is given in Fig. 3(c). Here, Tr_3, Tr_6 is an astable multivibrator, with C_1 and C_2 its timing capacitors. The usual base-drive timing resistors have been replaced by the output resistances of the collectors of transistors Tr_4, Tr_5. These output resistances are controlled by base drive from resistors R_1, R_3 in the collectors

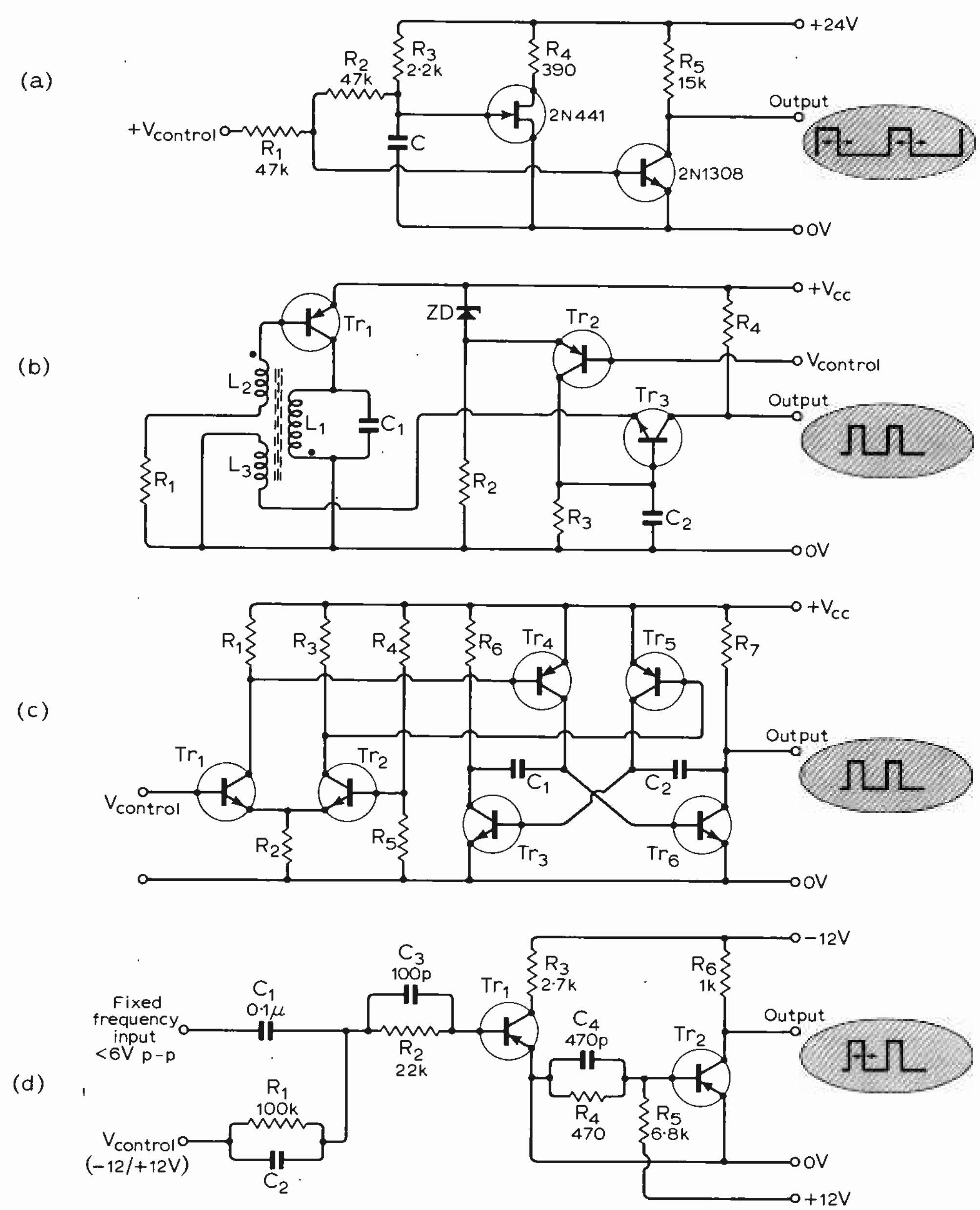
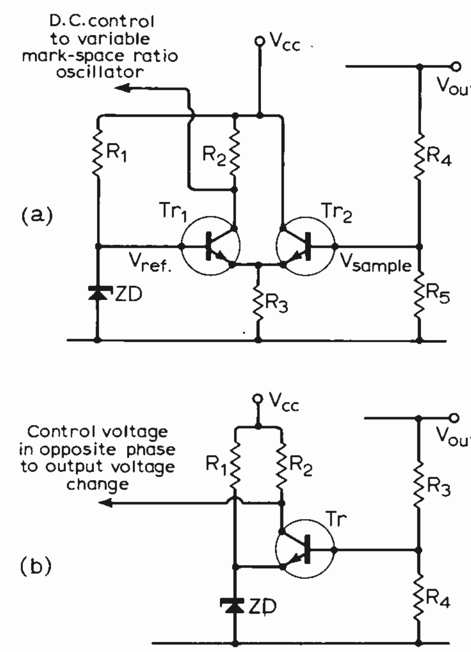


Fig. 3. Examples of constant-frequency pulse generators with mark-space ratio controlled by d.c. signal (a) Unijunction oscillator; (b) LC oscillator with output modulator transistor; (c) Astable multivibrator with long-tail control pair; (d) Schmitt trigger control with fixed frequency input.



of the long tailed pair, Tr_1, Tr_2. The base of Tr_2 is held at a fixed potential by the potentiometer R_4, R_5. A variable d.c. voltage applied to the base of Tr_1 alters the collector voltages of Tr_1 and Tr_3 in opposite directions. This in turn varies the output currents of Tr_4 and Tr_5 in opposite directions while keeping the total constant. As a result, the astable multivibrator, Tr_3, Tr_6 keeps a constant p.r.f., while its mark-space ratio changes.

A final example of a d.c.-controlled mark-space ratio pulse generator uses a fixed input frequency from an external source as shown in Fig. 3(d). In this circuit, varying $V_{CONTROL}$ varies the switch-on point of the Schmitt trigger Tr_1, Tr_2 under the fixed frequency input drive, thus varying the mark-space ratio of the resultant output, while keeping the p.r.f. constant.

Fig. 4. Basic comparator circuits (a) Long-tail pair which feeds back a voltage to control series-pass transistor switching mark-space ratio to keep output voltage constant (b) Simpler single-transistor version.

Feedback control loop

The remaining elements in the basic circuit of Fig. 1(b) form the feedback loop control comprising a circuit sampling the output voltage, a voltage reference and a comparator circuit. Usually the sampler is merely a potentiometer across the output and the voltage reference a zener diode. The comparator is often some variant of a long-tailed pair of which the basic circuit is shown in Fig. 4(a). In this the control voltage from the collector of Tr_1, moves in phase with the output voltage change as sampled by R_4, R_5.

Where the 2mV/degC temperature variation of Tr_1 and Tr_2 need not be balanced out, we find a simpler single transistor comparator as in Fig. 4(b). Here the emitter of the transistor Tr is clamped to the zener diode reference voltage, and, if the output voltage tends to rise, the control voltage from the collector of Tr tends to fall and controls the oscillator mark-space ratio to bring the output voltage back to the regulated level.

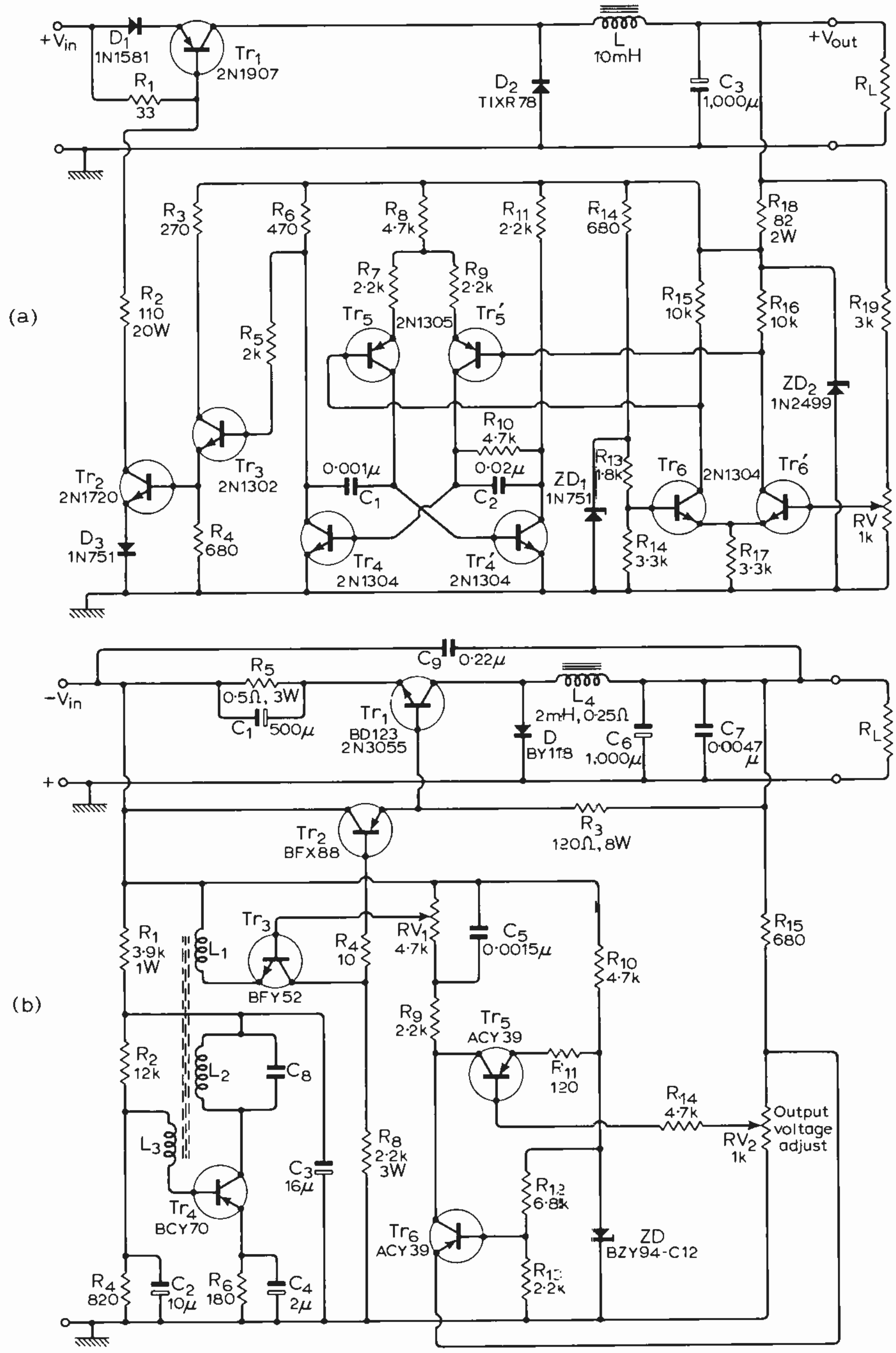
Practical switched regulator circuits

One practical design for a switched regulator (by Texas Instruments Ltd.) capable of giving a regulated 20V ($\leqslant \pm$ 0.2V) for 0 to 5A output from an unregulated 30 to 60V input is given in Fig. 5(a) as an illustration of the design points discussed above, using germanium transistors.

The series-pass transistor, Tr_1, is a 2N1907 alloy-diffused p-n-p power device capable of switching sufficiently fast at the relatively low p.r.f. of 10kHz adopted. The on/off drive to Tr_1 is provided by Tr_2 with its input buffer Tr_3. Tr_3 is driven in turn by the left hand collector of the astable multivibrator Tr_4, Tr_4'. The multivibrator mark-space ratio is controlled from the collectors of the long-tailed pair comparator transistors Tr_6, Tr_6' via the base-current-controlling transistors Tr_5, Tr_5'. In the comparator Tr_6, Tr_6', one base is tied through the potentiometer R_{13}, R_{14} to a oxed reference voltage zener ZD_1, while the other base samples the output voltage via the potentiometer $R_{19} - RV$. The low pass filter D_2, L, C_3 between the switch transistor and the output is a p-n-p version of Fig. 2(c).

Fig. 5(b) illustrates a recent design (by Mullard Ltd.) using modern faster diffused silicon transistors in a circuit with a switching rate of 40kHz with an output capable of being preset between 25 and 30V at 50W into the load for any input voltage between 40 and 65V with a regulation of better than $\pm$0.3V. The overall efficiency of the circuit is around 80% with only 2.2W dissipated in the series transistor Tr_1. The circuit uses the combination of an LC oscillator (Tr_4) with a variable mark-space modulator Tr_3 as already outlined in simplified form in Fig. 3(b) above. The turn-on level of the modulator Tr_3 is

Fig. 5. Practical circuits of switched d.c. voltage regulators (a) Multivibrator-controlled 20V/5A from 30 to 60V input (Texas) (b) LC oscillator controlled 25 to 30V/50W from 40 to 65V input (Mullard).



controlled through RV_1 and R_9 by the comparator transistor Tr_5, whose emitter is clamped via R_{11} to a fixed zener voltage ZD, and whose base is connected to the output via potentiometer R_{15}, RV_2. A buffer driver transistor, Tr_2, is interposed between the modulator Tr_3 and the series switch Tr_1. The transistor Tr_6 provides a safeguard against accidental output short circuit. When a short circuit occurs, Tr_6 turns hard on and biases Tr_3 so that the series transistor Tr_1 is cut off. The series transistor requires only a minimal heatsink of some 15°C/W by contrast with a conventional linear regulator where a very large and efficient heatsink would be necessary for the same regulated output power capability.

Integrated circuit switched regulators

A reader faced with designing a d.c. voltage regulator may find the account of the basic circuitry given above of some interest, but hitherto, because of the considerable circuit complexity, ninety-nine times out of a hundred he would fall back on the "good old" well-tried linear regulator with its large "hot plate" heatsink. The coming of monolithic silicon integrated microcircuits has changed all this.

Fig. 6(a) sets out the circuit of the National Semiconductors Type LM100 monolithic voltage regulator, which in its entirety is fabricated in a square chip of silicon less than 0·1cm square, and is comparable in size with a single silicon transistor. Fig. 6(b) shows the external connections to the eight-lead TO5-outline can in which the circuit is encapsulated. The single chip of the LM100 contains the voltage reference, the feedback amplifier and other circuits necessary to form a switched regulator with the exception of the series-pass transistor, the efficiency diode, the choke inductor, and the smoothing capacitance. The availability of such prepacked complex circuitry must mean that in the future we will see many more designers turning to switching regulators.

In the circuit of Fig. 6(a), ZD_1 is the basic zener voltage reference, current-supplied from the lowest collector of Tr_2. Tr_2, a single transistor with three independent collectors, reflects the wide capabilities of the monolithic diffusion techniques now available. The network Tr_4, Tr_6, R_1, R_2, Tr_7 is designed to convert the temperature dependent zener voltage of ZD_1 to a temperature-independent constant reference voltage of 1.8V at the base of Tr_8. The transistor pair, Tr_8, and Tr_9 form the input

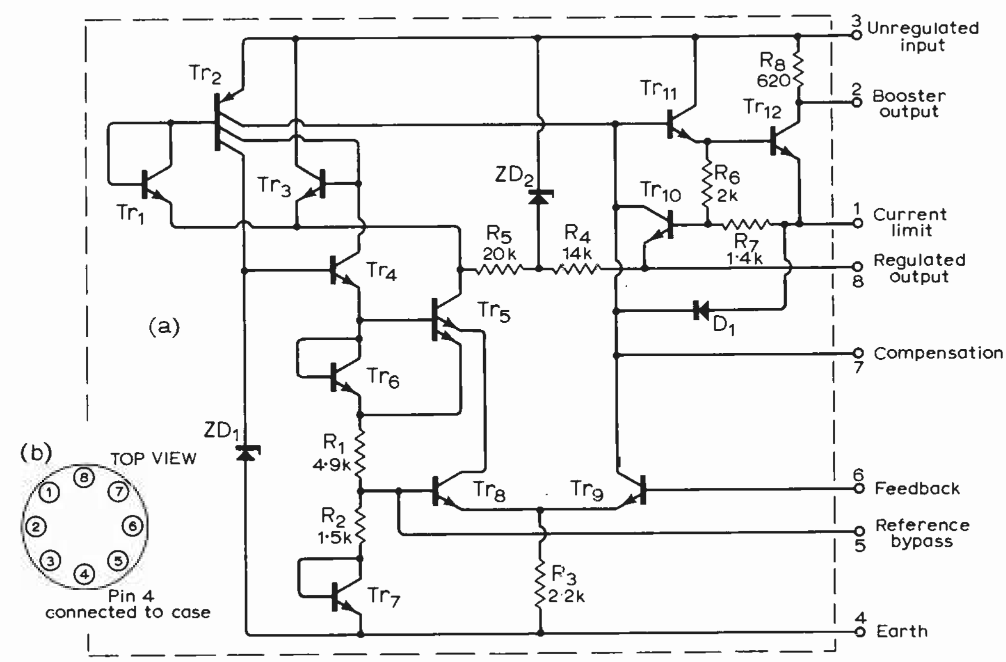


Fig. 6. Some details of monolithic integrated circuit d.c. voltage regulator (National Semicondictor Type LM100). (a) Internal circuit; (b) Lead connections.

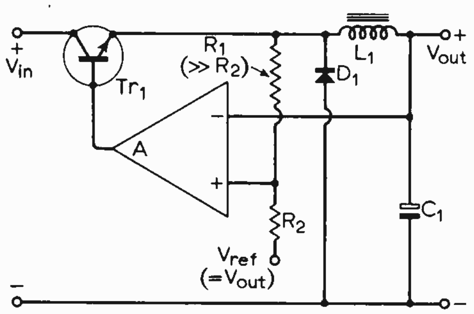


Fig. 7. Basic principle of self-oscillating switching d.c. voltage regulator using monolithic i.c.

stage of an operational amplifier, whose stage gain is made high by using one of the collectors of Tr_2 as a current-source load. The output of this amplifier, from the collector of Tr_9, drives a compound emitter-follower, Tr_{11} and Tr_{12}. The output from the collector of Tr_{12} at pin 2 is available as the drive for an external series switch transistor, which must be p-n-p. The transistor Tr_{10} is used to limit the output current drive from Tr_{12} to the external p-n-p transistor to prevent overloading the integrated circuit. The current is set by an appropriate external resistor connected between terminal 1 (current limit) and 2 (regulated output.)

In the remainder of the circuit of Fig. 6(a), Tr_1, Tr_3 and Tr_5 provide bias stabilization for Tr_2 to hold its collector currents at the required values. R_4, R_5 and ZD_2 are included to ensure that the regulator starts up on switch on. Finally, D_1 is a clamp diode to keep Tr_9 from saturating when it is switching.

Fig. 7 shows the principle of operation of the LM100 as a switching d.c. regulator. From the internal circuit details given above it will have been seen that the device itself comprises essentially an operational amplifier and a reference voltage. In Fig. 7, a reference voltage equal to the required output voltage is applied to one input of the operational amplifier, *A*, the output of which drives a separate switch transistor, Tr_1. A resistive divider R_2 and R_1 ($\gg R_2$) provides small positive feedback at high frequencies to make the circuit oscillate. At lower frequencies, the feedback is negative. When the circuit is first turned on, V_{OUT} is less than V_{REF}, and the switch transistor is turned on. When this happens, current flowing through R_1 raises the voltage on the non-inverting input of the operational amplifier to just above the reference voltage. The circuit remains switched on until V_{OUT} rises to V_{REF}, when the amplifier goes into the active region and turns the switch transistor off. The output voltage then drops back until the voltage on the amplifier non-inverting input returns to V_{REF}, when the amplifier switches on again. Hence the output voltage oscillates about the reference voltage, giving a ripple on the d.c. The amplitude of this output ripple, being nearly equal to the voltage fed back through the attenuator R_1, R_2, can be made quite small.

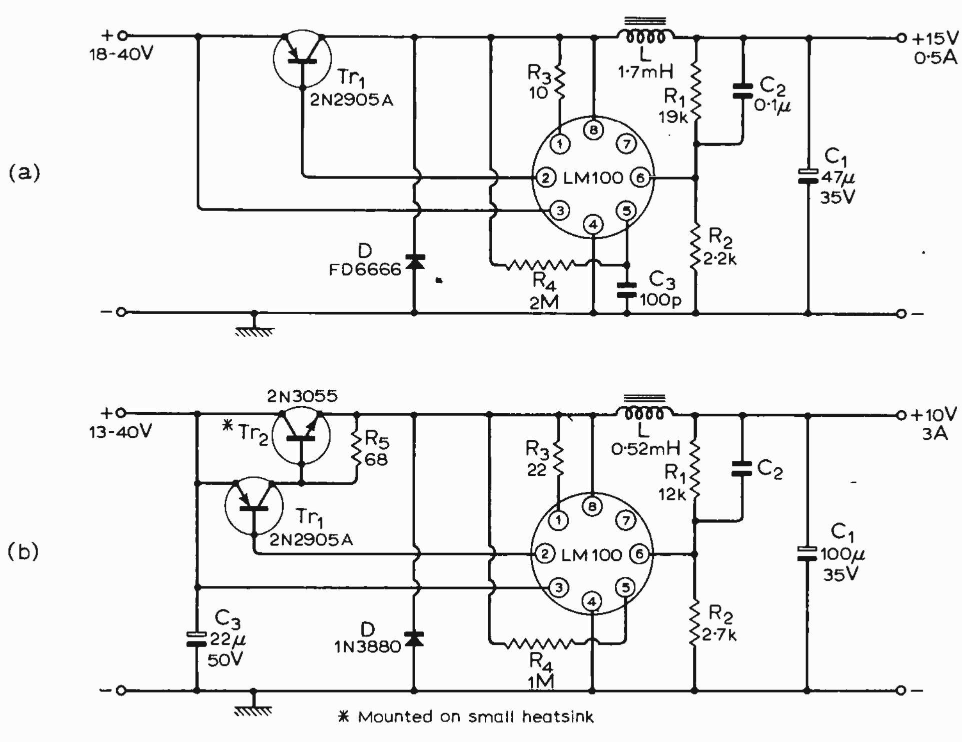
Practical circuits using monolithic switching regulators

Fig. 8(a) illustrates the use of the LM100 as a switching regulator to give a regulated output of 15V at 0·5A from an 18 to 40V input, using a small TO5-outline silicon, 2N2905A, p-n-p transistor as the series switching element. In this arrangement, *D*, *L* and C_1 comprise the usual clamped smoothing circuit, fed from the series switch transistor Tr_1. Feedback to the inverting input of the operational amplifier (Pin 6) is obtained via a resistive divider, R_1, R_2, from the output. The resistance values shown are to provide the required 15V regulated output, but with different resistance values the output can be set anywhere between 2 and 30V. R_3 is the resistor which limits the output drive current from pin 2. R_4, connected from the output to the approximate 1kΩ input resistance of the reference terminal 5 [see Fig. 6(a)], corresponds to R_1 in Fig. 7 and provides the necessary feedback for oscillation. C_2 is an extra capacitor to minimise the output ripple by causing the full ripple to appear on the feedback terminal. The remaining capacitor, C_3, removes the fast-rise time transients which would otherwise be coupled into pin 5 through the shunt capacitance of R_4. This circuit can give output currents up to 500mA, the limit being set by the selected value of the protective resistor R_3. The optimum switching frequency lies somewhere between 30 and 100kHz.

Fig. 8(b) shows a higher powered arrangement of the LM100 as a switched regulator set to give 10V output at up to 3A from a 13 to 40V input. Basically the arrangement is the same as Fig. 8(a), except that the single p-n-p 2N2905A is replaced by a composite connection of a 2N2905A driving an n-p-n 2N3055 power transistor to produce in effect a very high gain p-n-p power transistor. The capacitor C_9 across the input is to help to prevent switching transients being fed back into the supply line.

Many other circuit arrangements of the LM100 are possible, such as its use in a regulator with external fixed frequency drive, with separate current limiting, or with continuous short circuit protection. Any interested reader should consult a copy of an Applications Note, *"Designing Switching Regulators"* by R. J. Widlar, available from National Semiconductor Corporation, Santa Clara, California.

Fig. 8. Typical practical self-oscillating switched-mode d.c. voltage regulators built round monolithic LM100 microcircuit. (a) 15V, 0·5A from 18 to 40V using small, TO5-outline series switch transistor; (b) 10V, 3A from 13 to 40V using TO3-outline power transistor.



Satellite switch-off

After more than three years of successful operation the three Pegasus satellites launched by the National Aeronautics & Space Administration in 1965 have been turned off. The primary task of these satellites was to study the density of near-earth meteoroids, a meteoroid strike being registered by the discharge of a capacitor detection panel. For some months past the satellites, having fulfilled the primary role, have been used to collect engineering data in general and details of the reliability of electronic sub-assemblies in space in particular. It is understood that a good deal of valuable information on this later subject has been obtained. Initially the satellites had a design life-time of only eighteen months but were working perfectly right up until the switch off.

Simplified Design of Schmitt Trigger Circuits

A method relying on the high gain and low leakage of readily available silicon transistors.

by G. E. Marshman B.Sc.*

Using silicon transistors with high gains and low leakage currents, the design of many circuits become greatly simplified. The design of a Schmitt trigger is complicated and lengthy if the effect of base currents and leakage must be considered. The considerable spread of these characteristics may also cause variations in performance if their effect is at all significant. A method will be evolved which reduces the effect of base currents to a minimum and permits rapid and simple design.

The Schmitt trigger circuit is drawn in Fig. 1(a) in its usual form. In Fig. 1(b) it has been redrawn to show it as a long-tailed pair amplifier, with positive feedback from the collector of Tr_1 to the base of Tr_2. The state of the circuit depends on the voltage on the two bases. The transistor whose base is more negative is turned on, and the other transistor off.

Consider the base of Tr_1 to be at 0 volts. Tr_1 is held off, and the base voltage of Tr_2 is set by the voltage divider chain R_1, R_2 and R_3. Emitter current flows through R_4 via the transistor into R_5 the collector resistor.

Now imagine that the base voltage of Tr_1 is increased until it is very nearly equal to the base voltage of Tr_2. This voltage is V_{on}. At this point Tr_1 starts to turn on. Emitter current flows via R_4 and into the collector resistor R_1. The resultant voltage drop across R_1 reduces the base voltage on Tr_2 so switching the circuit into the other state.

When Tr_1 is turned off:

$$Tr_2 \text{ base voltage} = V_{on}$$

$$= \frac{V_{cc} R_3}{R_1 + R_2 + R_3}$$

$$R_3 = \frac{V_{on}}{V_{cc} - V_{on}} \cdot (R_1 + R_2) \qquad (1)$$

The current through Tr_2, I_{c2}, is given by:

$$I_{c_2} = \frac{V_{on} - V_{be}}{R_4}$$

$$R_4 = \frac{V_{on} - V_{be}}{I_{c_2}} \qquad (2)$$

And the output voltage V_o will be given by:

$$V_o = I_{c_2} R_5$$

$$R_5 = \frac{V_o}{I_{c2}} \qquad (3)$$

When the input voltage is such that Tr_1 is on (and Tr_2 off) then as the input voltage is reduced so the current in Tr_1 decreases, raising its collector voltage. This causes the base voltage of Tr_2 to rise also. When the input voltage reaches V_{off}, the base voltage of Tr_2 is also at V_{off} and Tr_1 will turn off, the circuit reverting to its other state.

Just before the circuit switches, the base voltage of Tr_1 is V_{off} and therefore the transistor current, I_{c_1}, will be given by:

$$I_{c_1} = \frac{V_{off} - V_{be}}{R_4} \qquad (4)$$

And Tr_2 base voltage $= V_{off}$

$$= \frac{(V_{cc} - I_{c_1} R_1) R_3}{R_1 + R_2 + R_3}$$

$$R_3 = \frac{V_{off}}{V_{cc} - I_{c1} R_1 - V_{off}} \times (R_1 + R_2)$$

Comparing this equation with equation (1) we can see that:

$$\frac{V_{on}}{V_{cc} - V_{on}} = \frac{V_{off}}{V_{cc} - I_{c_1} R_1 - V_{off}}$$

$$R_1 = \frac{V_{cc}(V_{on} - V_{off})}{V_{on} I_{c_1}}$$

In actual practice the circuit will switch when the voltage on Tr_1 base is within 0·1 volt of the voltage on Tr_2 base. To compensate for this effect a figure of 0·1 is added to the above expression:

$$R_1 \frac{V_{cc}(V_{on} - V_{off} + 0{\cdot}1)}{V_{on} I_{c1}} \qquad (5)$$

Equation (1) states that:

$$R_3 = \frac{V_{on}}{V_{cc} - V_{on}} \cdot (R_1 + R_2)$$

R_2 may now be given any value such that the current in the divider chain will be large compared to the base current of Tr_2. In most cases it will be satisfactory if we put R_2 equal to R_1. R_3 may now be calculated from equation (1).

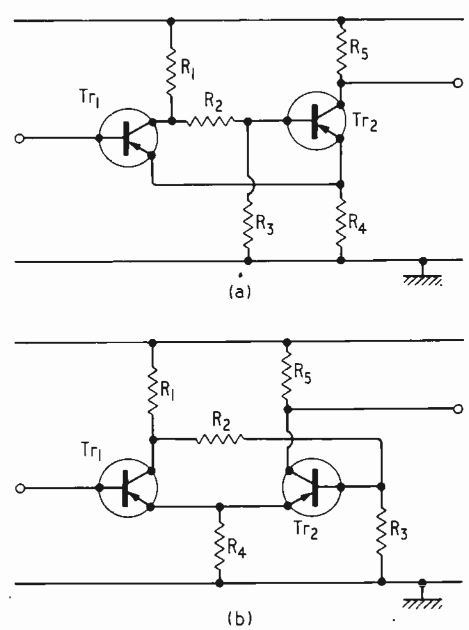
From the design values of supply voltage, output voltage and current, and the two switching voltages, the circuit may now be designed in the following manner.

(a) From equation (2) determine R_4.
(b) From equation (3) determine R_5.
(c) From equation (4) determine I_{c_1}.
From equation (5) determine R_1.
(d) Choose a value for R_2.
(e) From equation (1) determine R_3.

Example

Using the derived equations we will design a trigger circuit with a required output of 4 volts at 1 mA, a turn-on voltage of 4·5 volts and a backlash of 2 volts. The transistors used are Mullard BCY70, minimum current gain at 1 mA is 50. The supply is 12 volts. Thus $V_{cc} = 12$, $V_o = 4$, $I_{c_2} = 1$ mA, $V_{on} = 4{\cdot}5$, $V_{off} = 2{\cdot}5$.

Fig. 1 (a) Usual form of Schmitt trigger circuit. (B) Trigger circuit redrawn as a long tailed pair amplifier with positive feedback.



*Muirhead & Co Ltd.

(a) $$R_4 = \frac{V_{on} - V_{be}}{I_{c_2}}$$

$$= \frac{4\cdot5 - 0\cdot6}{1}\ \text{k}\Omega$$

$$= 3\cdot9\ \text{k}\Omega$$

(b) $$R_5 = \frac{V_o}{I_{c_2}}$$

$$= 4\ \text{k}\Omega \text{ say } 3\cdot9\ \text{k}\Omega$$

(c) $$I_{c_1} = \frac{V_{off} - V_{be}}{R_4}$$

$$= \frac{2\cdot5 - 0\cdot6}{3\cdot9}\ \text{mA}$$

$$= 0\cdot48\ \text{mA}$$

$$R_1 = \frac{V_{cc}(V_{on} - V_{off} + 0\cdot1)}{V_{on}I_{c_1}}$$

$$= \frac{12(4\cdot5 - 2\cdot5 + 0\cdot1)}{4\cdot5.(0\cdot48)}\ \text{k}\Omega$$

$$= 11\cdot6\ \text{k}\Omega \text{ say } 12\ \text{k}\Omega$$

(d)

Put $R_2 = 12\ \text{k}\Omega$

(e) $$R_3 = \frac{V_{on}}{V_{cc} - V_{on}}\cdot(R_1 + R_2)$$

$$= \frac{4\cdot5}{12 - 4\cdot5}\cdot(12 + 12)$$

$$= 14\cdot4\ \text{k}\Omega \text{ say } 15\ \text{k}\Omega$$

A trigger circuit was constructed to this design. The turn-on voltage was 4·4 volts, the turn-off voltage 2·5 volts. There was negligible change in performance up to an ambient temperature of 40°C.

October Meetings

Tickets are required for some meetings: readers are advised, therefore, to communicate with the society concerned

LONDON

2nd S.E.R.T.—"Colour television maintenance" by E. Dixon at 19.00 at the London School of Hygiene & Tropical Medicine, Keppel St., W.C.1.

2nd B.K.S.T.S.—"Sound in Longshot", Symposium at 19.30 at the Royal Overseas League, Park Pl., St. James's St., S.W.1.

7th. I.E.E.T.E.—"Lasers – light for the engineer" by Dr. E. Eastwood at 18.00 at Savoy Pl., W.C.2.

9th I.E.E.—"Omega" by F. Stringer at 17.30 at Savoy Pl., W.C.2.

9th I.E.R.E.—"Large scale integration—its effects on logic design" by K. J. Dean at 18.00 at 9 Bedford Sq., W.C.1.

11th R.T.S.—Seminar on "Television in educational technology—what is its role?" at 15.00 at I.E.E., Savoy Pl., W.C.2.

14th I.E.E.—"Propagation in a random one-dimensional medium" by Dr. H. E. Rowe at 17.30 at Savoy Pl., W.C.2.

16th I.E.E.—"Thin film transistors" by Prof. J. C. Anderson at 17.30 at Savoy Pl., W.C.2.

16th I.E.R.E.—"Airborne collision avoidance systems" by S. S. D. Jones at 18.00 at 9 Bedford Sq., W.C.1.

16th B.K.S.T.S.—Demonstrations of new professional equipment at 19.30 at the Royal Overseas League, Park Pl., St. James's St., S.W.1.

17th I.E.R.E. & I.E.E.—Colloquium on "System structures of modern computers" at 10.00 at Middx. Hospital Medical School, Cleveland St., W.1.

17th I.E.R.E.—"P.C.M. for point-to-point music transmission" by E. R. Rout and A. H. Jones at 18.00 at 9 Bedford Sq., W.C.1.

17th Inst. Electronics.—"Teaching digital computers to technologists and technicians" by G. H. Stearman at 18.45 at London School of Hygiene and Tropical Medicine, Keppel St., W.C.1.

17th R.T.S.—"Ultrasonic delay lines for television" by R. W. Gibson at 19.00 at I.T.A., 70 Brompton Road, S.W.3.

22nd Soc. Relay Engineers.—Symposium on "Experence of colour TV on wired systems" at 14.30 at the I.T.A., 70 Brompton Rd., S.W.3.

23rd I.E.E.—Discussion on "Electro-optics" at 17.30 at Savoy Pl., W.C.2.

23rd I.E.R.E.—"Are examinations really necessary?" by Roy Cox at 18.00 at 9 Bedford Sq., W.C.1.

24th I.E.E.—Coloquium on "Transmission-line properties of interconnections and their measurement" at 14.30 at Savoy Pl., W.C.2.

24th I.E.R.E. & I.E.E.—Colloquium on "Recent advances in the design of biological amplifiers" at 14.30 at 9 Bedford Sq., W.C.1.

25th R.T.S.—"A new lightweight colour camera" by S. C. Tan at 19.00 at the I.T.A., 70 Brompton Rd., S.W.3.

28th I.E.E.—Colloquium on "Solid-state displays" at 14.30 at Savoy Pl., W.C.2.

29th I.E.E.—Discussion on "Increasing the reliability of electrical and electronic equipment under high ambient temperature conditions" at 17.30 at Savoy Pl., W.C.2.

30th I.E.E.— "Science and profit in the electronics industry" by R. J. Clayton, Electronics Division chairman, at 17.30 at Savoy Pl., W.C.2.

30th B.K.S.T.S.—Discussion on "Why educational TV?" at 19.30 at Royal Overseas League, Park Pl., St. James's St., S.W. 1.

BATH

23rd. I.E.R.E. & I.E.E.—"Recent advances in mobile communications" by D. A. S. Dryborough at 19.00 at the Technical College.

BELFAST

23rd. I.E.R.E.—"Management, methods and media in electronic training at the School of Electronic Engineering, R.E.M.E., Arborfield" by the Commandant, Col. H. G. Frost, at 18.30 the Ashby Inst., Queen's University, Stranmillis Rd.

BIRMINGHAM

25th. S.E.R.T.—"Colour television—the decoder" by W. J. Anderson at 19.30 at the University of Aston, Gosta Green.

BOURNEMOUTH

31st. I.E.R.E.—"Tunable coherent sources" by Dr. E. L. Thomas at 19.00 at the College of Technology.

BRISTOL

16th. I.E.R.E.—"Integrated circuits, the present and future" by D. W. Roberts at 19.00 at the Technical College.

CARDIFF

2nd. R.T.S.—"A solid-state colour receiver" by S. C. Jones, R. E. Gray and J. W. Bussell at 18.30 at Llandaff Technical College, Western Avenue.

9th. I.E.R.E.—"M.O.S.F.E.T. in integrated circuits" by Prof. W. Gosling at 18.30 at the University of Wales Inst. of Science and Technology.

11th. S.E.R.T.—"Integrated circuits" by M. Williams at 19.00 at Llandaff Technical College, Western Avenue.

16th. R.T.S.—The 1966 Fleming Memorial Lecture, "The strange journey from retina to brain" by Dr. R. W. G. Hunt at 19.00 at the B.B.C. Centre, Llandaff.

CHELMSFORD

7th. I.E.R.E. & I.E.E.—"Electronics in medicine" by Dr. D. W. Hill at 18.30 at the Lion and Lamb Hotel, Duke St.

DURHAM

16th. I.E.E.T.E.—"Laser physics and developments" by Dr. D. Balfour at 19.30 at the University, Science Labs., South Road.

EVESHAM

15th. I.E.R.E.—"Pulse code modulation and its application to sound and television" by Dr. C. J. Dalton at 19.00 at the B.B.C. Club.

GLASGOW

18th. S.E.R.T.—"Airport telecommunications" by W. A. S. Aitken at 19.30 at the Y.M.C.A., 100 Bothwell St., C.2.

LEEDS

3rd. I.E.R.E.—"Digital logic and its application" by P. McLennon at 19.00 at the University, Dept. of Electrical and Electronic Engineering.

LEICESTER

8th I.E.R.E.—"Telemetry and communications systems in the oil industry" by A. C. W. Bedwell at 18.30 at the University Physics Lecture Theatre.

LIVERPOOL

16th. I.E.R.E.—"Pulse code modulation" by P. Tyler at 19.00 at the University Dept. of Electrical Engineering and Electronics.

MANCHESTER

17th. I.E.R.E.—"The use of thin films in electronic engineering" by R. Naylor and R. Fairbank at 19.00 at Renold Bldg., Inst. of Science and Technology, Altrincham St.

31st. S.E.R.T.—"Colour television servicing" by T. M. Robinson at 20.00 at John Dalton College.

MIDDLESBROUGH

29th. S.E.R.T.—"Microelectronics" by T. M. Ball at 19.30 at the Cleveland Scientific Inst., Corporation Rd.

NEWCASTLE-UPON-TYNE

9th. I.E.R.E.—"Special applications of lasers" by D. Tuck at 18.00 at the Inst. of Mining and Mechanical Engrs., Neville Hall, Westgate Rd.

NEWPORT, I.O.W.

18th. I.E.R.E.—Discussion on "Production management" at 18.30 at the Technical College.

READING

15th. I.E.R.E.—"Frequency synthesizers" by K. R. Thrower at 19.30 at J. J. Thomson Physical Lab, the University.

SOUTHAMPTON

22nd. I.E.R.E.—"Circuit design by computer" by E. Wolfendale at 18.30 at the Lanchester Theatre, the University.

SWINDON

15th. I.E.R.E. & I.E.E.—"Research on control techniques for railways" by Dr. L. L. Alston at 18.15 at the College.

ESRO 1 Cleared for Launching

Flight unit no. 1 of the ESRO I satellite has been cleared for launching on October 2, 1968—the date decided upon several months ago. At a recent meeting attended by representatives of the European Space Research Organization and the American National Aeronautics and Space Administration the readiness state of the satellite and the launching and orbital control facilities was assessed and the go-ahead was given.

The satellite will carry eight experiments for the study of ionospheric and auroral phenomena which will measure the flux and energy of high-altitude particles. The satellite will be stabilised along the lines of magnetic force so that when over the northern polar region auroral photometers point towards earth and most of the particle detectors will be directed towards incoming particles.

U.K. experiments forming part of the payload include measurement of auroral luminosity (Queen's University, Belfast), ionospheric electron and positive-ion temperature measurement (University College, London), and measurement of the electron and proton flux and energy spectrum from 40 to 400keV and 5 to 30 MeV (Radio and Space Research Station).

Test Your Knowledge

*Series devised by L. Ibbotson,** *B.Sc., A.Inst.P., M.I.E.E., M.I.E.R.E.*

5. Transmission lines

1. A sinusoidal generator drives a travelling wave along a transmission line. The phases of voltage and current each
(a) lag increasingly with distance from the generator
(b) lead increasingly with distance from the generator
(c) do not vary with distance
(d) have two values at different parts of the line.

2. A line, driven by a sinusoidal generator, as a result of its termination supports a total standing wave. The phases of voltage and current on the line each
(a) lag increasingly with distance from the generator
(b) lead increasingly with distance from the generator
(c) do not vary with distance
(d) have two values at different parts of the line.

3. The wavelength of a sinusoidal signal on a transmission line is
(a) directly proportional to the phase change coefficient
(b) inversely proportional to the phase change coefficient
(c) proportional to the phase change coefficient plus a constant
(d) independent of the phase change coefficient.

4. For a sinusoidal input signal the characteristic impedance of a transmission line is
(a) the impedance of a unit length of it
(b) the impedance which when connected to the end of the line does not reflect back any energy
(c) the impedance seen at the input of the line when the output is short circuited
(d) the impedance seen at the input of the line when the output is open circuited.

5. The characteristic impedance of a transmission line
(a) is always resistive
(b) always has a significant reactive component
(c) is in general effectively complex at high frequencies and real at low frequencies
(d) is in general effectively real at high frequencies and complex at low frequencies.

6. A line carries a single sinusoidal travelling wave. The propagation constant indicates
(a) the change of phase per unit length of the line
(b) the natural log of the ratio of voltage amplitudes unit distance apart on the line
(c) the natural log of the phasor ratio of voltages unit distance apart on the line
(d) the natural log of the ratio of signal powers unit distance apart on the line.

7. If a transmission line is non-dispersive one of the following is independent of frequency:
(a) the phase change coefficient
(b) the attenuation coefficient
(c) the propagation constant
(d) the phase velocity.

8. The group velocity of a signal on a transmission line is:
(a) the velocity with which the energy travels
(b) the velocity with which the waveform travels
(c) the velocity of electrons in the conductors
(d) the velocity of sound in the conductors.

9. For an ideal transmission line the equation

$$\frac{\partial^2 V}{\partial x^2} = K \frac{\partial^2 V}{\partial t^2}$$

holds. The value of the constant K allows us to deduce
(a) the characteristic impedance of the line
(b) the velocity of propagation of a signal on the line
(c) the largest amplitude of signal which the line can transmit
(d) the attenuation per unit length of line.

10. Several sinusoidal waves are travelli simultaneously in both directions on a tran mission line. At the same point on the li the voltage and current associated with a one wave have a ratio which is
(a) always Z_0
(b) Z_0 unless one of the other waves is the same frequency
(c) generally not Z_0
(d) Z_0 at some points on the line but n at others.

11. The input impedance of a transmissi line of length l terminated by a load Z_L quoted in the textbooks as

$$Z_0\left(\frac{Z_L + Z_0 \tanh \gamma l}{Z_0 + Z_L \tanh \gamma l}\right)$$

A sinusoidal generator is switched to t input of the line at time $t = 0$. T impedance which the line presents the generator at $t = 0$ is:
(a) the above impedance
(b) Z_0
(c) Z_L
(d) an impedance of a value whi depends on the phase of the generator $t = 0$.

12. On a mismatched transmission line t reflection coefficient at a given point defined as the complex ratio of voltage of t incident wave to voltage of the reflect wave. The reflection coefficient is:
(a) real at all points
(b) complex at all points
(c) real at nodes and antinodes of the vo age standing wave pattern
(d) imaginary at nodes and antinodes the voltage standing wave pattern.

13. On a mismatched transmission li the distance between adjacent standi wave nodes is:
(a) one wavelength
(b) half a wavelength
(c) a quarter of a wavelength
(d) an eighth of a wavelength

14. On a mismatched lossy transmissi line
(a) there is no standing wave
(b) the voltage standing wave ratio small but uniform
(c) the v.s.w.r. is greatest near generator
(d) the v.s.w.r. is greatest near the lo

15. A loss-free transmission line $1\frac{1}{4}$ wa lengths long is terminated in a short circ The input impedance is:
(a) zero
(b) infinite
(c) Z_0
(d) a small resistance.

Answers and comments, page 383

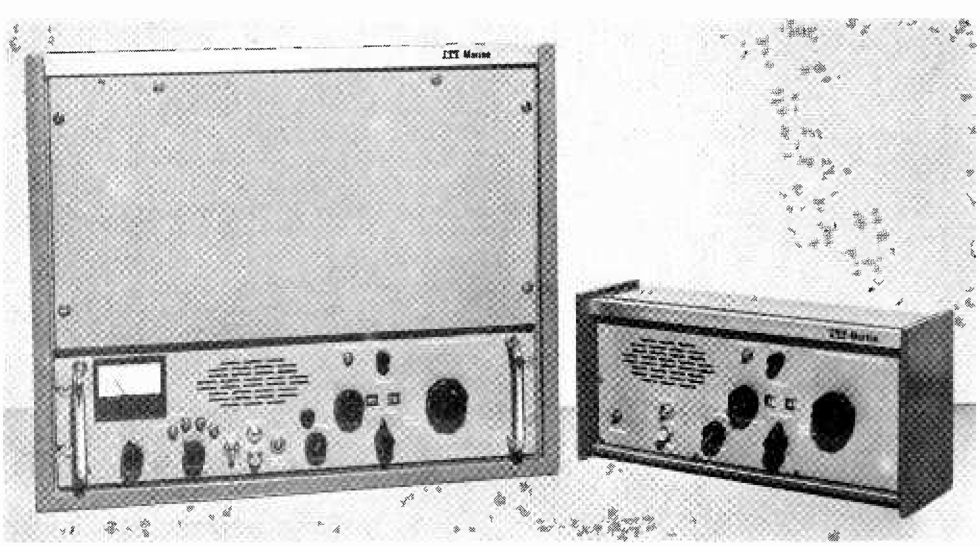
* West Ham College of Technology, London, E.15.

New Products

41-channel Marine Radio-telephone

The STR 60-A by International Marine Radio Co, a 41-channel 20W marine radiotelephone capable of working on the 156-161MHz marine v.h.f. band, is semiconductor-built throughout. It is capable of simplex or duplex operation and employs a channel spacing of 50kHz. A built-in diplexer permits simultaneous transmission and reception using a single dipole aerial, with a loss in both transmit and receive directions of only 0.7dB. The basic version has the transceiver and main control unit mounted in a cabinet (shown left in the photograph) measuring approximately 52 × 43 × 14cm. A rack-mounting version with transceiver behind the control unit is available. In addition, the transceiver may be operated from any one of up to four remote locations. Sub-control units for this purpose (shown right in the photograph) measure approximately 36 × 18 × 11cm and are also available in rack versions. A main and an auxiliary selector on the control unit allow for dual watch facilities. One channel is set up on each, and, with an associated switch set to "dual watch", the receiver dwells for 1/10th second on the auxiliary and 9/10th second on the main channel. When a signal is present on the auxiliary channel the receiver locks on to it and switching stops. The receiver, with a sensitivity of 1.2μV for 20dB signal-to-noise ratio, and the transmitter are built in the Ministac system, giving high shock and vibration resistance and high reliability, simple maintenance and minimum spares stocking. A handset with the usual press-to-talk button mutes the loudspeaker when taken off its rest. Provision is made for the connection of the STR 60-A to the ship's telephone exchange. The transceiver consumes 130W from normal ship's supplies on full transmit power. A special version designated STR-60-T is available for tankers where the additional oil-refinery frequencies are required. International Marine Radio Company Ltd., Peall Road, Croydon, Surrey.

WW 321 for further details



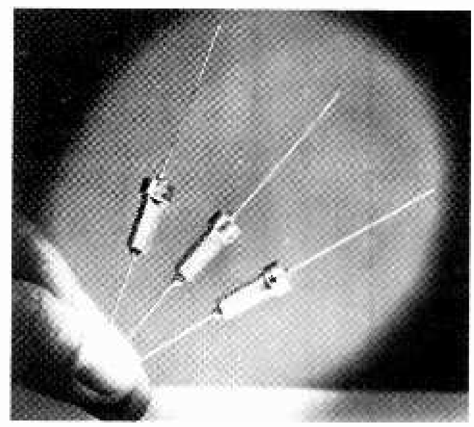
Crystal Filters

Salford Electrical Instruments are now marketing quartz crystal filters with centre frequencies of 21.4 and 37.3 MHz. These units were developed primarily for the high-frequency communications market, as the present trend indicates a need for intermediate frequency selectivity at frequencies at the higher end or outside the normal operating range of the system. The QC 1062L standard filter at 37.3MHz, has a 6dB bandwidth of 12kHz and a 6/60dB shape factor of 2:1. Another version is also available having an ultimate attenuation of 80dB. Spurious passbands in the stop-band are almost eliminated within the frequency range ±1MHz of the centre frequency. The QC 1062K filter at 21.4MHz has a similar shape factor but has been designed for systems having a bandwidth of 30kHz. The filters are housed in a hermetically sealed metal can and have a high resistance to vibration. Salford Electrical Instruments Ltd., Peel Works, Barton Lane, Eccles, Manchester.

WW302 for further details

High Current Tantalum Capacitors

Dage (G.B.) Ltd., are producing a series of miniature tantalum feed-through capacitors for high current and high frequency applications. The capacitors are capable of effective filtering beyond 1000MHz with low self-inductance; and have a feed-through d.c. current rating of 5A at 85°C. Each unit is hermetically sealed with glass-to-metal solder seal terminations. The leads are of tin and lead coated nickel, and can be soldered or welded. Voltage and capacity ratings extend from 60μF at 6V to 3.9μF at 75V. The dissipation factor at 120Hz is given as 6% maximum



at 25°C. The leads are positive and the cases negative. Dage (G.B.) Ltd., 1 Penn Place, Rickmansworth, Herts.

WW 329 for further details

Desk Calculator

An easy-to-use desk calculator primarily intended for scientific applications has been announced by Hewlett Packard. The calculator will operate either in a fixed or floating point mode as required and has a capacity of 1×10^{-98} to $9.999999999 \times 10^{99}$. A full range of trigonometrical functions can be carried out by pushing single buttons, namely sin, cos, tan, arcsin, arcos, arctan in all four quadrants, a further single key stroke will convert the result from rectangular to polar co-ordinates or vice-versa. The usual arithmetic keys, addition, subtraction, multiplication, division and square root are included as well as keys for log x, In.x and e^x. A useful key among the group for numerical input is one that sets in the value of π.

Up to 196 keystrokes may be programmed by selecting "Programme" and pressing the required keys sequentially, no code conversion is required. Programming keys available include the functions if $x>y$, if $x<y$, if $x=y$, if flag, set flag and go-to. A programme, once assembled may be run automatically or step-by-step for error detection, it may also be recorded on a small magnetic card on the

integral recorder for automatically reading-in again for use of a later date. Peripheral equipment that will be available shortly include a printer and an *xy* plotter. The calculator costs under £2,500. Hewlett Packard, 224 Bath Road, Slough, Bucks.

WW 315 for further details

Vibrating Capacitor for Sensitive Electrometers

Developed by Mullard, vibrating capacitor type XL7900 contains a membrane that can vibrate at high frequencies, and offers a new means of measuring small voltages and currents. Electrometers using it have measured currents as small as 8×10^{-17}A, or 500 electrons per second. The XL7900 contains four metal plates in parallel, the two outer being fixed. The two inner plates are mechanically linked so that the distance between them is constant. They can, however, vibrate as a rigid pair with respect to the outer plates. This movement is achieved by applying an alternating voltage between one of the vibratory plates and a fixed plate. The d.c. supply is connected to the other two plates, one fixed and one vibratory. Consequently, when the middle plate vibrates, the capacitance across the d.c. supply changes and modulates the direct voltage at the frequency of vibration. The alternating voltage so produced is easily amplified to produce a signal that is directly proportional to the voltage across the capacitor. When measuring currents, a high resistance of known value is connected across the input capacitor of the XL7900. The voltage produced across the resistance by the direct current through it is then modulated and

amplified to give a signal proportional to the current. The membrane is driven at its resonant frequency by a signal at approximately 6kHz to give an output (d.c. converted to a.c.) at the same frequency. The maximum overall length is 64.7mm and the maximum diameter 30.2mm. Mullard Ltd., Mullard House, Torrington Place, London W.C.1.

WW308 for further details.

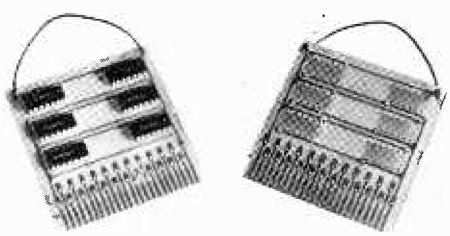
Switching Transistors

Particularly suitable for switching circuits incorporating inductive loads are three n-p-n silicon planar epitaxial transistors, type BSW66, BSW67 and BSW68 from Mullard. The energy rating of these TO-39 encapsulated transistors is 5mW. They will all switch 1A. The only difference between the transistors lies in the supply voltage ratings. The V_{CBO} and V_{CEO} is 100V, 120V and 150V for the BSW66, BSW67 and the BSW68 respectively. V_{EBO} is 6V and V_{CEsat} 0.15V. Mullard Ltd., Mullard House, Torrington Place, London W.C.1.

WW 322 for further details.

I.C. Mounting Board

A new circuit mounting card to mount up to 6 dual-in-line (14- or 16-lead) integrated circuits now forms part of A.P.T's Lektrokit system. The new card, part number LK-3111, is constructed of copper-clad epoxy

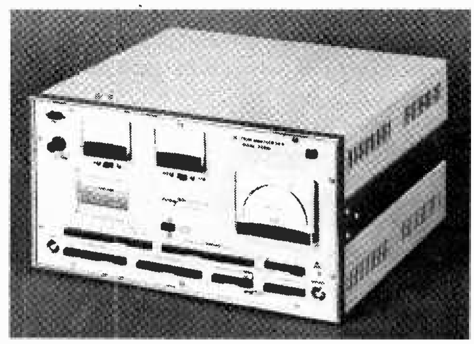


glass laminate with printed power supply tracks to each i.c. It is fitted with 24 input /output edge-connector terminations at 2.54mm (0.1in) pitch and provision is made for the attachment of a nylon cord loop to assist card removal. Size of the card is 68mm (2.7in) square and the price is 7s. 6d. Cards are also available as part of the components for a complete 6-way mounting framework. A.P.T. Electronic Industries Ltd., Chertsey Road, Byfleet, Surrey.

WW 320 for further details

Low-frequency Spectrum Analyser

Fenlow Electronics have recently produced a low-frequency spectrum analyser type SA4 incorporating integrated circuits. Operational amplifiers at the output provide a range of smoothing times and a true integration facility. A neat panel layout allows any operation whether the instrument is used manually or with the Fenlow Automatic Plotter type MP1. The analyser operates on a heterodyne principle using a homodyne detector with a low-pass filter to define the bandwidth of the instrument. This means that analysis is carried out at a constant band-



width, which is particularly advantageous when dealing with random noise. After squaring and smoothing, the result is plotted as spectral power density against frequency. Frequency accuracy is ±1% over seven ranges, the lowest being 0.3 to 1.66Hz and the highest 4.69 to 26kHz. Smoothing times are 1, 10, 25, 50 and 100 seconds, and integrator scaling is X1 and X10. Fenlow Electronics Ltd., Springfield Lane, Weybridge, Surrey.

WW311 for further details.

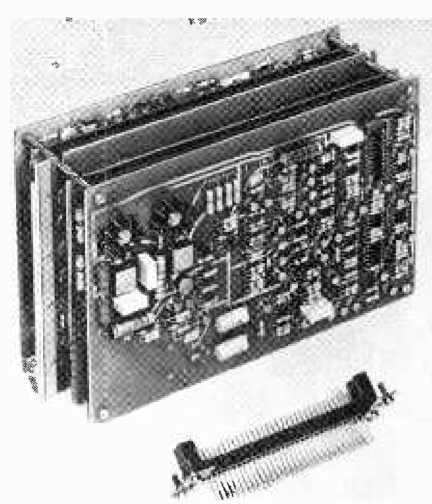
Modular Pulse Generating System

Farnell Instruments Ltd., have produced an inexpensive generator which can be assembled in either single or double output configuration. The modules are mounted side by side in a 19-inch case. Power and signal interconnections appear in the form of patching leads at the rear of the assembly. A pulse repetition frequency of 1Hz to 10MHz is available with width and delay times variable between 0.1 μs and 1s. The component modules include a power supply adequate for a full double pulse generator, a trigger module with an output of 1 volt maximum up to 10MHz, a pulse repetition frequency generator, a delay generator, a pulse width unit, and an output amplifier giving 10V at an output impedance of 50Ω. Farnell Instruments Ltd., Sandbeck Way, Wetherby, Yorkshire.

WW314 for further details.

Ferrite Memory Stacks

Mullard offer two ferrite memory systems for use in process control equipment, machine tools and communications systems. The first is a standard memory system, type MM1500,

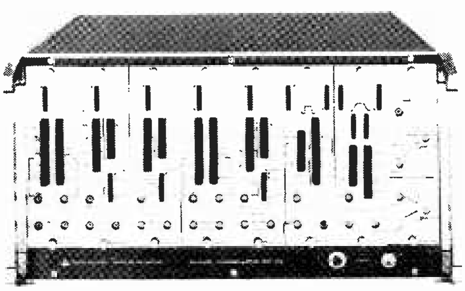


with a capacity of 1024 words of 1 bit. It has a cycle time of 2 μs. Operation is possible over the ambient temperature range 0 to +50°C. The overall dimensions are approximately 9×28×13cm. The second standard system, type MM1501 (shown in the photograph), has a capacity of 1024 words of 8 bits. Its cycle time is 4μs and access time 0.6μs. Operation is satisfactory over the ambient temperature range 0 to +55°C. The approximate dimensions are 7.5×10.75×20cm. Power requirements are +6V at 2A and −6V at 1A for the MM1500 and +12V at 3A for the MM1501. Mullard Ltd., Mullard House, Torrington Place, London W.C.1.

WW 325 for further details

Modular Pulse Generator

The Advance Instruments Division of Advance Electronics Ltd., has produced a new modular pulse generator, the PG52, which is assembled from the range of five signal generating and processing units available. Repetition frequencies up to 20MHz, and output pulses of up to 20V into 50Ω with rise and fall times of 5ns can be obtained from the system, and its versatility enables complex pulse and ramp waveforms to be



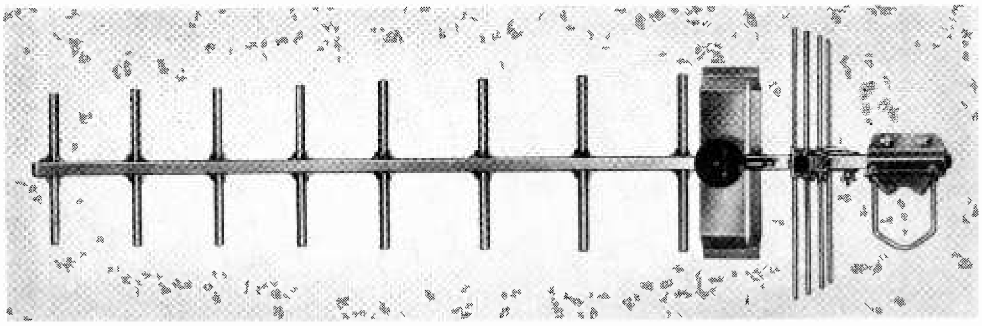
produced. The five plug-in units are all self-contained, and require only d.c. power supplies, which are obtained from the main frame. Signal paths are made externally, through BNC/BNC connectors, to ensure maximum flexibility in interconnection. The majority of functions are selected by push-buttons. The output modules are protected against damage due to short-circuit. The clock generator uses integrated circuits, and silicon transistors are employed in all units. Advance Instruments, Hainault, Essex.

WW310 for further details.

U.H.F. Television Aerials

Antiference has introduced a new range of wideband u.h.f. television aerials which replaces all existing Antiference and Belling-Lee u.h.f. aerials following the fusion of the aerial interests of these two companies. To be known as the Trucolour range, the folded dipole of the new aerials is of "fat" sectional dimension (relative to its length) which, it is claimed, is a design feature giving even response and accurate matching over a frequency band of at least 88MHz. Besides offering an increase in gain over existing types employing the same number of elements, the gain does not vary by more than 3dB over the band and by no more than 1dB over adjacent channels. Trucolour aerials are designed to match a 75-Ω feeder without the use of a balun and are available for channel groups A(21-34), B(39-51) and CD(49-68). Aerials are supplied in assemblies of 6, 10, 13 or 18 elements and 10- or 18-element broadside arrays. Prices range from £1 17s to £7 17s. Antiference Ltd., Aylesbury, Bucks.

WW 323 for further details



Insulated Stand-offs

Thirty-two new moulded diallyl stand-off insulators for mounting and supporting electronic equipment have been added to the range of stand-offs by Cambion Electronic Products. Made in four families of mounting styles and a wide range of thread sizes, diameters and lengths, the new insulators can be used in temperatures up to 160°C. They provide a reliable way of supporting metal panels, separating boards and similar applications. Cambion Electronic Products Ltd., Castleton, near Sheffield, Yorkshire.

WW317 for further details.

Gate-protected M.O.S.Ts

Six p-channel enhancement type m.o.s.ts having a new type of gate protection circuit consisting of a diffused resistor-diode network, that protects each device gate from accidental damage due to voltage transients, are available from SGS-Fairchild. The resistor coupled with the input capacitance forms an *RC* network that slows down the incoming pulse so that the protection diode has time to break down. The *RC* time constant (150ns) is insignificant compared with the normal operating speed. Gate leakage is typically less than 50pA. The simplest of the new devices are the single-channel types BSW95 and BSW95A. Intended for fast low-current switching and high input impedance linear amplifiers, these are low capacitance units. The BSW95 and BSW95A are the gate protected equivalents of the BSX83 and BSX84. Very low "on" resistance is characteristic of the BSV20 and BSV20A, being the gate-protected equivalents of BSW30 and BSW31. The remaining two new devices, the BSV34 and BSV34A are both dual-monolithic and suitable for low and high level choppers, multivibrators and analogue switches. The "on" current is 22mA. The BSV34 and BSV34A are the gate-protected equivalents of the BSX85 and BSX86. SGS-Fairchild Ltd., Planar House, Walton Street, Aylesbury, Bucks.

WW 328 for further details

Pulse Generator

A repetition rate continuously variable from 0.1Hz to 10MHz and width and delays variable from 35ns to 10 seconds are claimed for the A100 pulse generator introduced by Datapulse of California, U.S.A. Other features include single or double pulses, <5ns rise time, simultaneous ± 10V output, ± 400mV triggering sensitivity, and synchronous and non-synchronous gating. Triggering features oscilloscope-type polarity and level controls. Multiple decade switches plus × 100 multipliers provide extended range capabilities, useful in biological and geophysical research, for educational purposes, television circuit design, etc. Dimensions of the generator are

6 × 22 × 28cm deep and the price is $470. European Officer: Systron-Donner International, S.A. 447, Avenue de Tervueren, Brussels 15, Belgium.

WW 319 for further details

40-ampere Triacs

Low switching losses, low on-state voltage at high current, low thermal resistance, uniform gate current density, rapid electrical conduction, and efficient heat dissipation—all these features are claimed for four new 40A triacs from RCA Electronic Components. These are designed to switch from an off-state to an on-state for either polarity of a 2.5V 80mA maximum gate signal. Types 2N5441 and 2N5444 are designed for 120V r.m.s. line operation and they can control a 5kW load. Types 2N5442 and 2N5445 are designed for 240V r.m.s. line operation and can control a 10kW load. The 2N5441 and 2N5442 are press-fit types and the 2N5444 and 2N5445 are stud-mounted. RCA Electronic Components, 415 South Fifth Street, Harrison, N.J.07029, U.S.A.

WW313 for further details.

Monolithic Crystal Filters

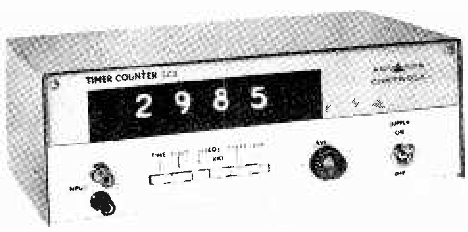
Monolithic crystal filters, type MXF, manufactured by the Collins Radio Company, California, U.S.A., are now available in the U.K. from G. A. Stanley Palmer Ltd. The centre frequency range of these filters is from 3.5 to 20MHz with bandwidths of

).005 to 0.02% of centre frequencies. Basically the filters are frequency selective devices, consisting of coupled resonators in which both the resonators and the coupling medium are embodied in a single quartz plate which, in turn, carries electrode pairs on its top and bottom surfaces; the electroded regions become resonators, and the regions between the electrodes, coupling elements. When an electrical signal is fed to the input electrode pair, the piezo-electric property of the quartz creates an acoustic displacement in the first electroded region. Part of this acoustic energy, which is in the form of a shear wave, tunnels in an exponentially decaying manner across the unelectroded region to the second resonator, thereby creating an acoustic displacement. The energy continues in a similar manner through the array, until the piezo-electric effect of the last resonator turns it into an output signal. The filters come in four case sizes—TO-5, TO-8, 'C' type and flat pack housing different numbers of resonators. In all instances passband ripple can be held to 0.25dB over an operating temperature range of −40°C to +65°C. G. A. Stanley Palmer Ltd., Island Farm Avenue, West Molesey Trading Estate, Surrey.

WW309 for further details.

Timer Counter

Advance SC3 is a four-decade instrument with clear in-line numerical display which can be used as a frequency meter, counter or timer, the function being selected by front panel pressbuttons. In the count mode, regular or random signals in the frequency range 10Hz to 1MHz can be totalled during any arbitrary interval determined by either press button, external contact openings or closures, or external applied voltage. Frequency is measured over the same range as on count, a time-base is provided with alternative gate times of 0.1 and 1 second,

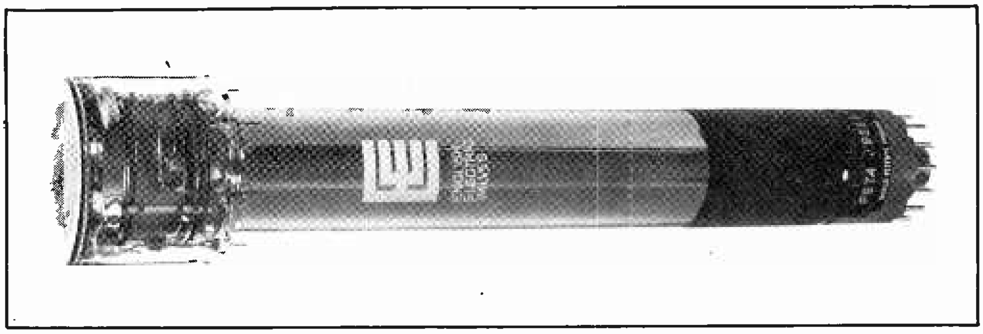


allowing measurements to be made to an accuracy of typically 0.1%. When used as a timer or "electronic stop watch" the instrument displays in units of 0.01 sec. up to a maximum of 99.99 seconds. Integrated circuits are used in this lightweight instrument. Advance Electronics Ltd., Hainault, Essex.

WW306 for further details

New TV Camera Tube

The English Electric Valve Co. Ltd. has produced a new type of 3-in image orthicon TV camera tube which can give pictures of a quality approaching that of a standard 4½-in tube. It is available in two versions; the P874 which directly replaces the 8093B, and the P875 which replaces the 7293B. In these new



tubes the basic features of an ordinary Elcon image orthicon are combined with a special electron-optical design which reduces the noise in the output signal and eliminates the dynode background effect. English Electric Valve Company Ltd., Chelmsford, Essex.

WW 318 for further details

High-surge Mains Switch

A high-surge double-pole on/off mains switch, specifically designed for modern TV receivers, ahs been introduced by the Resistor Division of the Plessey Components Group. The outstanding feature of the switch, type R, is its ability to sustain instantaneous current of about 60A. Also, it has low contact resistance. Type RS is fitted with a steel spindle and type RIS has an insulated spindle. The independent unit can be combined with one of Resistor Division's range of moulded carbon track potentiometers, or supplied to fit other manufacturers' potentiometers. Plessey Components Group, Resistor Division, Cheney Manor, Swindon, Wilts.

WW305 for further details.

Chopper-stabilized Operational Amplifier

Analog Devices Ltd., have encapsulated their model 230 chopper-stabilized operational amplifier in a package measuring approximately $3.75 \times 3.75 \times 1.5$cm. In the bandwidth d.c. to 1Hz, peak-to-peak voltage noise is 1μV maximum. Stability is claimed to be better than 10μV per year, and voltage drift better than 0.1μV/degC. Open-loop gain is 10V/V, and the minimum output current at ± 10V is 4mA. The power fall off is 6dB/octave which limits full power response to about 10kHz. The amplifier will work from ± 12V to ± 18V. The unit weighs approximately 22g. Analog Devices Ltd., 38/40 Fife Road, Kingston-upon-Thames, Surrey.

WW 327 for further details

Smaller M.O.S.Ts

Mullard have introduced two new m.o.s. transistors, types BFW96 and BSV22. Both are electrically similar to types already available but, because of their smaller encapsulation (TO-72 instead of TO-5), they are particularly useful where space is limited. Because of its very high input impedance (typically $10^{-12}\,\Omega$) and low output impedance (typically $31\,\Omega$ with additional bipolar transistor), the BFW96 is specially suited for use as an impedance converter. The BSV22, however, has a low offset voltage and negligible offset current. Therefore, in chopper circuits it will give a superior performance to that of a bipolar transistor. The maximum dissipation at 25°C is 200mW for both types. Mullard Ltd., Mullard House, Torrington Place, London W.C.1.

WW312 for further details.

Miniature Coaxial Switches

A range of miniature coaxial switches, the CCM series, are available from Radiall Microwave Components Ltd. Single pole, with a choice of 3, 4 or 6 ports, they are available in manual control or electrically operated versions. Fitted with 3mm precision coaxial connectors they are said to have excellent performance up to 12 GHz, with a characteristic impedance of $50\,\Omega$ and a peak power handling capacity of 2kW. Radiall Microwave Components Ltd., Station Approach, Grove Park Road, Chiswick, London W.4.

WW303 for further details

Analogue/digital Convertor

A versatile 10-bit analogue-to-digital, digital-to-analogue convertor, type APR-800-AD/DA, is available from Lotus Electronics of Norwich. The module is able to convert analogue signals, in the range 0-4 V positive, into serial or parallel digital information, and conversely it is able to convert serial or parallel digital information into analogue signals from an i.c. output amplifier with a slew rate of 10V per μsec. The module contains binary counter/store, resistor ladder network, reference supply, clock and input and output amplifiers. Lotus Electronics, 41 Thunder Lane, Norwich, Norfolk.

WW 324 for further details

Versatile F.E.Ts

Motorola's two plastics encapsulated versions of the 2N4416 junction field effect transistor have unusually low noise figures (2.0dB max. at 100MHz and 4.0dB max. at 400MHz) and will work equally well from d.c. to above 400MHz. The power gain is 18dB min. at 100MHz and 10dB min. at 400MHz. The MPF106 and MPF107 are both n-channel devices with input and output capacitance of 5.0pF max. and 2.0pF max. respectively. The casing is TO-92 pattern. Motorola Semiconductors Ltd., York House, Empire Way, Wembley, Middx.

WW 326 for further details

1kW Solid State Power Amplifier

The Derritron amplifier described under this heading in last month's issue was erroneously illustrated by a photograph of a dissociated product.

World of Amateur Radio

I.A.R.U. Region I Conference

The Belgium National Society (U.B.A.) are assuming responsibility for making the arrangements for a triennial conference of I.A.R.U. Region I societies to be held during the period May 5-9, 1969, at the Hotel Metropole, Brussels. Visitors to the conference will be entertained by U.B.A. members during the weekend preceding the opening when receptions will be held at the Martin Club, Brussels and, possibly, at the Hotel de Ville (Town Hall) by courtesy of the burgomaster of the city. Since the 1966 conference was held in Opatija, Yugoslavia, in May of that year, the number of member societies in Region I Division has increased from 20 to 31.

70 cm Band Changes

The G.P.O. has intimated that changes are to be made shortly to the existing 427—450 MHz band allocated to radio amateurs in the United Kingdom. On the effective date, to be announced, the frequency limits will be changed to 425—429 MHz and 432—450 MHz. The channel 429—432 MHz is to be allocated to a new service which is due to come into operation in this band. Footnote 319 to article 5 of the Geneva Radio Regulations 1959, allocates frequencies in the 70 cm band on a primary basis to the radiolocation service and on a secondary basis to the amateur service. Amateur televison takes place on frequencies in the 70 cm band (currently 427—445 MHz) but under the re-arrangement, presumably, this will now become 432—450 MHz.

Slow-Scan T.V. Authorized in U.S.

The United States Federal Communications Commission has authorized slow-scan television in the high frequency and very high frequency amateur bands. On 3.5 MHz and higher, the operating mode is restricted to bandwidths no greater than a properly operated single sideband telephony transmission. On 50 MHz and higher bandwidths equal to a double sideband standard amplitude modulated signal will be permitted.

Italy Curbs Transmitting Equipment

In order to keep a check on the sale of transmitting equipment to the general public and in particular the sale of 27 MHz Japanese-made walkie-talkies, the Italian government has introduced legislation which requires manufacturers and retailers to furnish certificates to the purchasers of all types of transmitters. Radio amateurs in Italy are anxious that this new regulation should not restrict the construction and use of home-made transmitters.

Diplomatic Wireless Service at R.S.G.B. Exhibition

The Diplomatic Wireless Service, modern version of a highly secret war-time organization is to exhibit some of its latest communication equipment on the centre stage at the R.S.G.B. Amateur Radio Exhibition to be held in the New Hall of the Royal Horticultural Society, Greycoat Street, Westminster, London, S.W.1, from October 2 to 5, 1968. The exhibition is due to be opened at 12 noon on the 2nd by the Postmaster General (Mr. John Stonehouse, M.P.).

Convention in Ireland

A national convention for radio amateurs in Northern Ireland and Eire will be held at the Ballymascanian Hotel, Dundalk, on Sunday, October 6, 1968. The event will open at 10 a.m. with an exhibition of amateur radio equipment, followed at 2.30 p.m. by a business meeting. The convention dinner is due to commence at 7 p.m. Tickets and full details are available from S. H. Foster (GI3GAL), 31 Belmont Park, Belfast 4. (Complete day £1.15.0; dinner only £1.7.6.)

New Orleans 250th Anniversary

In commemoration of the celebration of the 250th anniversary of the foundation of the city of New Orleans, Louisiana, in 1718 by Jean Baptiste Le Moyne, Sieur de Bienville, the Greater New Orleans Amateur Radio Club is offering an attractive commemorative certificate to any radio amateur who submits a log extract indicating two-way communication on any bands, in any modes with three amateur stations located within the metropolitan area of New Orleans. Claims, together with a stamped addressed envelope, should be sent to the secretary of the club at 2935 International Trade Mart Tower, 2 Canal Street, New Orleans, La, 70130.

Amateur Radio Growth in Germany

Membership of the German National Amateur Radio Society (D.A.R.C.) had by July 9, 1968 increased to 18,717, and of that total 10,408 were licensed amateurs. At the same date there were 13,985 transmitting licences current in Germany, distributed as follow DJ, DK, DL calls, 11,997; DL4 and DL5 call 497, DM calls, 1,491. The current annu membership fee of D.A.R.C. is 40DM. Re procal arrangements exist between Germa and a number of European countries includi Austria, Belgium, France, Luxembourg, t Netherlands, Spain, Switzerland and t United Kingdom with agreements propos with Denmark, Norway and Sweden. Inform tion concerning the issue of short-term licenc can be obtained from D.A.R.C. Internation Affairs Office, Muehlenstrasse 27, D-560 Doenberg, Germany.

Real DX on Top Band

Doyen of Top Band operation Stewart Perry (W1BB), of Winthrop, Mass, in h summer 1968, 160 Metre DX bulletin, recor that Robert Denniston (WDX, president the A.R.R.I.), recently worked a station Japan and on the next morning worked G6B in England 6,500 miles westward, th 4,500 miles eastward: an achievement whi would not have been thought possible a fe years ago. During the past few months ma parts of the world have been linked for t first time on Top Band. When Stewart Per himself worked CE3CZ (Chile), on May 1 he achieved a century of countries worked that band. Another outstanding result stan to the credit of Roger Parsons 5Z4L (G3RBP), in Kenya who succeeded in maki numerous contacts with the United Stat on 1827 kHz. Earlier in the season Mr. Parso made the first ever contact on Top Ba between Tanzania and the U.S. when operated as 5H3KK. He has also made number of Top Band contacts with statio in the U.K.

Wirral Society's New Headquarters

Wirral Amateur Radio Society, with 1 licensed amateurs in the peninsula and known to be active, has solved its hea quarters problem by successfully negotiati for the acquisition of the local Civil Defen building upon disbandonment of the corp With a permanent headquarters the socie now enters a new era which will enable a wid range of activities to be enjoyed by member Gordon Lee (G3UJX), was chiefly responsib for bringing about the acquisition of the ne building.

Indonesian Licences Issued

At long last, the Indonesian governme has decided to issue amateur licences using t prefix YB but no official information has y been received from I.T.U. headquarters Geneva that Indonesia has withdrawn i previous objection to international commun cations by its amateurs.

New Operating Aid

A new operating aid, obtainable free charge from A.R.R.L. Communications Dep 225 Main Street, Newington, Connectic 06111 U.S.A., sets out the RST system, a ti conversion chart, ending signals, the ARR and ICAO phonetic alphabets and steps t take in an emergency.

JOHN CLARRICOATS G6C

Answers to "Test Your Knowledge"—5

Questions on page 377

1. *(a)*. Propagation of any travelling wave is always associated with a lag of phase proportional to distance in the direction of propagation.

2. *(d)* All points between a pair of adjacent nodes support oscillations with the same phase. Adjacent antinodes are in antiphase.

3. *(b)*. The wavelength is the distance between adjacent points supporting oscillations with the same phase for a travelling wave. Hence wavelength = 2π /phase change coefficient.

4. *(b)*. The basic definition of characteristic impedance is the input impedance of an infinite length of the line. Such an impedance terminating a finite line absorbs all the incident power.

5. *(d)*. For a line with primary constants resistance per unit length R, leakance per unit length G, inductance per unit length L, capacitance per unit length C, $Zo = \sqrt{(R + j\omega L)/(G + j\omega C)}$
At low frequencies, because of the normal ranges of values of R, G, L, and C it generally has a capacitive component, but at a high enough frequency $\omega L \gg R$ and $\omega C \gg G$ so that $Zo \simeq \sqrt{L/C}$ which is resistive.

6. *(c)*. If points 1 and 2 are separated gy distance l on the line, 2 being nearer to the load than 1, $V_2 = V_1 \exp - \gamma l$ where γ is the propagation constant. *(a)* and *(b)* are the phase change coefficient and attenuation coefficient respectively.

7. *(d)*. The term "non-dispersive" means sinusoidal signals of all frequencies travel with the same phase velocity. If this is the case the phase change coefficient must be proportional to frequency.

8. *(a)*. Answer *(b)* is the phase velocity. On a non-dispersive line the group and phase velocities are equal, but on a dispersive line they are not.

9. *(b)*. $K = 1/\sqrt{\text{phase velocity}}$. A line for which this equation holds would be non-dispersive so that phase and group velocity are the same.

10. *(a)*. Although the steady state input impedance of a mismatched line is not generally Zo, this is due to the fact that currents and voltages in the forward and reflected waves add in a manner which depends on the length of the line in wavelengths and the phase change at reflection.

11. *(b)*. The impedance quoted is the steady-state value ultimately presented to the generator when the standing wave has established itself by multiple reflections at load and generator.

12. *(c)*. At antinodes the reflected wave voltage is in phase with the incident wave voltage, at nodes the two are in antiphase.

13. *(b)*.

14. *(d)*. Near the generator the reflected wave has suffered the attenuation of its journey to the load and back, and hence its amplitude is a smaller fraction of that of the incident wave than is the case near the load.

15. *(b)*. A quarter wavelength of loss-free line transforms a short circuit into an open circuit. The input impedance at points any multiple of a half wavelength apart is the same.

Literature Received

"**Reliability of Electronic Equipment**" Pt.5 is a three-page leaflet produced by the British Standards Institution. It is intended to establish uniform criteria for an equipment reliability programme. Some of the aspects covered include: reliability prediction; the evaluation of parts, materials and processes; and the testing of sample equipment during development and production. The leaflet is available from the B.S.I. Sales Office, 101/113 Pentonville Road, London N.1, at 5s plus 6d postage.

Electronic Components, Equipment and High-fidelity Catalogue (9th Edition) from Henry's Radio lists more than 6000 items in 280, or so, pages. The usual balance of kits, test equipment, components, tools, etc is maintained and Henry's comprehensive crystal list is included. The catalogue costs 7s 6d from Henry's Radio Ltd., 303 Edgware Road, London W.C.1.

Engineering publication 25-45 from Westinghouse Brake & Signal Company describes a range of **silicon diffused 1.5A avalanche diodes** which will withstand surge reverse voltages of up to 2kV and are encapsulated in resin. Westinghouse Brake & Signal Company Ltd., 82 York Way, Kings Cross, London W.1.
WW 362 for further details

The **Capsule Catalogue Selection Guide** lists the range of special purpose d.c. power supplies available from Hewlett Packard. The folding guide classifies each power supply in terms of regulation, 0.1 0.01 and 0.001%, in the first instance and then according to voltage and current ratings. Hewlett Packard Ltd., 224 Bath Road, Slough, Bucks.
WW 363 for further details

We have received from the Spectral Electronics Corp., Italy **(1) a trimming potentiometer** short-form catalogue listing a comprehensive range of trimmers of various shapes and sizes; **(2)** two leaflets describing a range of miniature **printed circuit switches** typically 1-pole 10-way or 2-pole 5-way and **(3)** a leaflet describing the company and some of its products. The U.K. agents for Spectral are: Guest Electronics Ltd., Nicholas House, Brigstock Road, Thornton Heath, Surrey.
(1) WW 364 for further details (2) WW 365 for further details (3) WW 366 for further details

Switches, signal lamps and signal lamp holders are the main subjects of the latest catalogue (No. 137) from Arcolectric Switches Ltd., Central Avenue, West Molesey, Surrey. Each component is illustrated and described in some detail.
WW 367 for further details

Two catalogues describing **(1) r.f. coaxial cables** and **(2) coaxial connectors** are available from Radiall Microwave Components, Station Approach, Grove Park Road, London W.4. Both catalogues are well produced and give comprehensive technical information.
(1) WW 371 for further details (2) WW 372 for further details

Marconi-Elliott Microelectronics is the title of a brochure that describes the facilities available at the new microelectronics plant at Witham, Essex. The brochure is well illustrated and some of the manufacturing processes peculiar to integrated circuits are explained.
WW 373 for further details

An instrument that checks the **speed accuracy of tape recorders** when used in conjunction with a test tape is described in a leaflet from Calan Electronics Ltd., 6 Croft Street, Dalkeith, Scotland. The instrument can be used for speed checking at 19 or 9.5cm/s and has full-scale deflections of ± 10, 3, or 1%.
WW 374 for further details

An unusual method of **selecting power supplies** is provided by a cardboar slide rule being distributed by A.P.T. Electronic Industries Ltd., Chertse Rd., Byfleet, Surrey. The rule enables data on power supplies coverin voltages up to 500 and current up to 10 amps to be quickly determinec Prices and dimensions are also given on the rule.
WW 375 for further details

Electronic bread-boarding aids of novel design for both educational an industrial use are described in leaflets produced by Howard Electroni Industries, Manor Way, Boreham Wood, Herts. A typical board consists of 14 connectors, each connector being capable of accepting up to twelve com ponent lead out wires of widely varying diameter plus a 4mm wander plug i desired. The boards are available in a number of configurations for discret components or integrated circuits.
WW 376 for further details

Product Data (1) is published by Technical Indexes Ltd., Index House Cross Lane, Marple, Cheshire, and performs three main functions: It act as an accurate buyers' guide, it is an index for the Electronic Engineerin Index **(2)** and it also acts as an index for the Electronic Micro Data Servic **(3)**. The product data book is reprinted three times a year and costs 250s pe annum. Product data supplies names and addresses of manufacturers of large number of components and test equipment.
(1) WW 377 for further details (2) WW 378 for further details (3) WW 379 fo further details

H. F. Predictions—October

The predicted value of the Ionospheric Index (IF2) used for the charts is th same as that predicted and later measured for October 1967.

The trans-equatorial routes show little change from the previous fev months except that the effect of shortening northern hemisphere daylight i becoming apparent. Hong Kong promises much improved working (0600–1200 G.M.T.) compared with the previous six months. The Montrea daylight MUF is up to 30MHz so operation above 20MHz should now become consistently good.

The LUFs shown were drawn by Cable & Wireless Ltd. for reception in the U.K. of commercial telegraphy; curves for high-power broadcasting would be similar.