Wireless World

ELECTRONICS, RADIO, TELEVISION

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Transistor 200mW Amplifier for 6V Supplies

The circuit below shows an amplifier, suitable for use with high-output crystal pick-ups, capable of giving 200mW output. It consists of three Mullard OC72 transistors, the stages being transformer-coupled. Negative feedback is applied to the driver stage, reducing the transistor input and output impedances, improving the base response of the driver and input transformers, reducing transistor spread effects, and reducing harmonic distortion.

The input is coupled to the OC72 driver stage by a 30 : 1 input transformer, which provides sufficient sensitivity for use with high-output crystal pick-ups. If the primary inductance of the input transformer is 500H the frequency response will be good down to 100c/s.

The output stage is transformer-coupled to the driver stage. It uses a matched pair of Mullard 2-OC72 transistors in common-collector Class B push-pull. The main advantages are reduced cross-over distortion, and the ability to use the resistance of the primary of the output transformer to obtain the required thermal stability.

For 250mW into the output transformer primary, an output of 200mW into a 3Ω load is obtained. The average sensitivity for this output is 1·7Vr.m.s. (minimum is 2·0Vr.m.s.). The frequency response is good from 160c/s to 6kc/s. This is obtained by placing a capacitor across the feedback resistor, to limit the high-frequency gain and partly compensate for the loss in low-frequency gain, arising from the transformers.

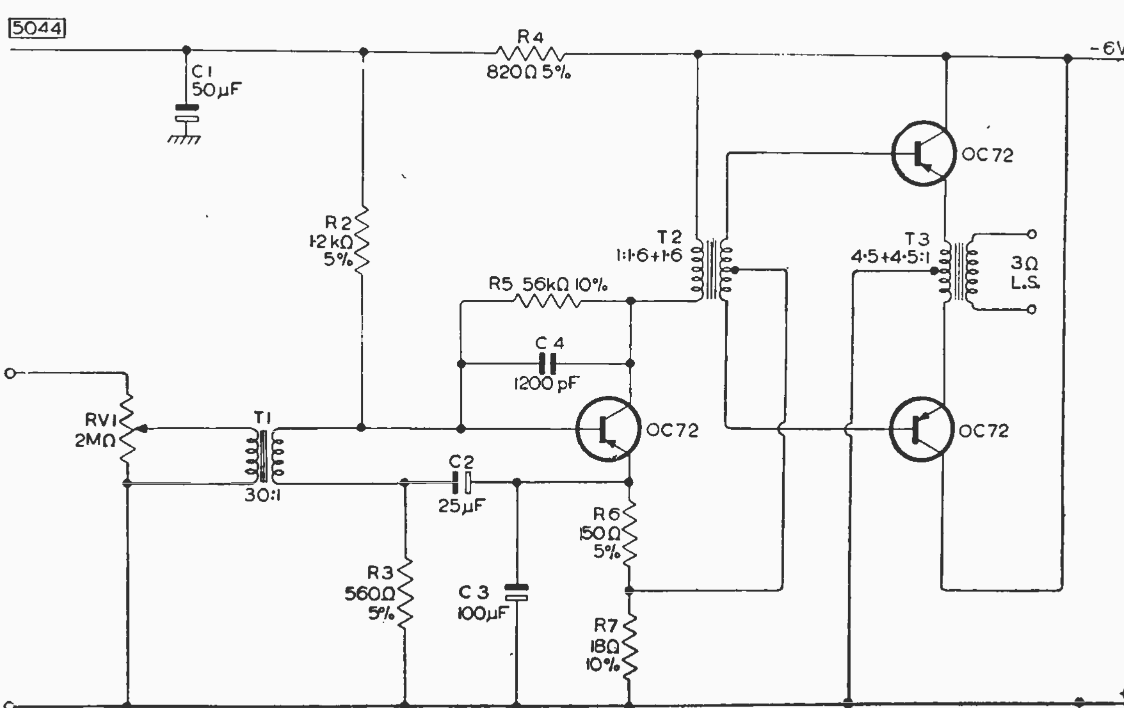
The quiescent currents of the driver and output resistors are, respectively, 6·5mA and 1·0mA. The maximum collector current of the transistors is 83mA.

Total amplifier current consumption is:

Zero drive	10mA
Average speech and music	32mA
Sinewave full drive	83mA

Transformer Details

Input Transformer	
Turns ratio	30 : 1
Primary inductance	>500H
Primary resistance	<10kΩ
Secondary resistance	<100Ω
Driver Transformer	
Turns ratio	1 : 1·6+1·6
Primary inductance	>4·5H at 6·5mA
Primary resistance	<70Ω
Secondary resistance	<200Ω per half winding
Output Transformer	
Turns ratio	4·5+4·5 : 1
Primary inductance	>0·5H total
Primary resistance	=6Ω±1Ω per half winding
Secondary resistance	<0·3Ω



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A Tax on Thrift

THE ruling by H.M. Customs and Excise that reconditioned television tubes may in certain circumstances incur liability to Purchase Tax has touched off a wave of indignation and much heated argument.

The official statement "clarifying" the position, was given in last month's issue of this journal (page 314). In essence it says (1) that reconditioned tubes may be sold as such without further payment of purchase tax if the treatment is external and has not involved the opening of the tube, and provided that secondhand tubes are segregated physically and in the trader's accounts from new tubes; (2) that extensive repairs involving the opening of the tube will not incur tax provided that the customer's own tube including all its principal component parts is returned to him; but (3) that if a fresh, not necessarily new gun is fitted or the work is such as to amount to the manufacture of a virtually fresh tube, the transaction is a sale and is liable to a tax at the same rate (60%) as on a new tube.

The general indignation which was first aroused by this pronouncement seems subsequently to have channelled itself into two main criticisms: first, that there is no precedent for demanding Purchase Tax twice on the same goods and, second, that the cost of a new gun is such a small part of the total cost of a tube that its introduction cannot by any stretch of the imagination amount to the manufacture of a new tube.

The resolution of this paradox is simple. In fact there is literally nothing in it, for the main item, and the most expensive, in a cathode-ray tube is the vacuum. This is the "commodity" on which most of the tax is levied, and it is difficult to avoid the conclusion that when air is let into a tube it is destroyed, and that when it is pumped out again a virtually new tube is created. To those who retort that it is the same vacuum which has been restored, the answer would be that a new cost has been incurred and that it is mainly on this new value that *tax is to be levied.*

While we are sorry to have to disappoint those who may look to us for support in fighting this latest detail ruling, we are glad of the opportunity it gives us of returning to the question of Purchase Tax in general and the anomaly of its incidence on radio valves and cathode-ray tubes in particular.

No one likes to pay taxes, least of all Purchase Tax which has borne heavily and unpredictably on the radio industry and its customers in the home market. No two people will agree on what is a fair and equitable distribution of the burden of taxation, but we say that it is a gross injustice that a television viewer should have to pay tax on valves and cathode-ray tubes to keep his receiver in commission while a motorist gets an exchange replacement of his car engine tax free.

For the time being the radio industry, having failed to get the tax abolished by representations through all available channels, is compelled to accept this anomaly. That being so we cannot complain if those charged with the duty of administering the law take steps to anticipate the many possible means of evasion which ingenious and unscrupulous people will always find. The higher the rate of taxation the more intensive will be the search for loopholes, and the higher the dissipation of tax receipts in salaries and expenses of the customs officers detailed to the task of enforcement. (H.M. Customs and Excise will need no reminder of the work involved by the phenomenal increase in the stocks of repaired and secondhand jewellery which appeared in the shops during the period when P.T. was standing at 100%.)

As many man-hours and as large a proportion of the tax receipts could well be expended on establishing the borderline between "minor" and "extensive" repairs to cathode-ray tubes on the basis of case-law built slowly by a succession of arbitrary rulings by authority. Since arguments founded on justice and equity seem to have fallen on stony ground it is to be hoped that this tax may be abandoned on grounds of expediency, as no doubt it was decided to give up the idea of taxing the potentially more lucrative trade in motor car spares.

Guided Weapon Techniques

A Review of Possible Systems of Guidance

By ***LIEUT. P. CAVE,*** *Grad.I.E.E., R.N.*

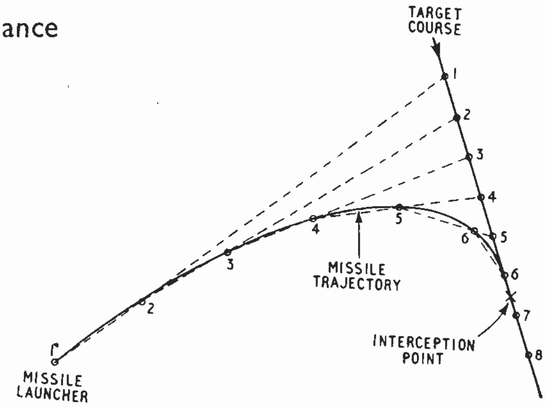


Fig. 2. "Curve of pursuit" trajectory. The dotted lines indicate the line of sight of each successive position of missile and target.

IT is not generally realized that there is a wide variety of established guidance techniques, each one with its own application in the guided weapon field. This review will compare the different systems that are available and establish the limitations in each case.

If guided weapons are to be classified by the guidance system that is used, then they fall readily into two main groups. In one group are those systems where the target position data is continuously available and hence moving targets may be dealt with, whilst the other group contains systems which use pre-determined target data. The range of the target will determine which system is to be used, and as the first group is to be preferred from the point of view of accuracy, it would be quite possible for a long-range missile to be launched on pre-determined information, but to have a terminal guidance system using instantaneous target data.

Reference to the "family tree" of guidance systems in Fig. 1 shows that these two main groups may each be sub-divided into two groups, the first into homing and command systems and the second into ballistic and "flat top" or constant-altitude systems. The difference between homing and command guidance may be summarized by defining a homing missile as one where the flight path required to effect an interception is determined within the missile itself, whilst in a command system the flight path is computed at a point external to the missile and steering orders are then transmitted to the missile by radio or other means. A ballistic trajectory system is one where the missile is uncontrolled for a large percentage of its journey and the shape of the trajectory is parabolic or elliptical, whilst a "flat top" system is similar to a fast, high flying, pilotless aircraft which is continuously controlled. It is interesting to note that the first guided weapon brought to the public notice in this country, i.e., the German V1, was of this latter group, whilst the V2 was a ballistic missile.

Homing Missiles.—One method of producing a homing missile would be to arrange that the missile points continuously at the target, i.e., that the missile heading changes at the same rate as the line of sight from missile to target. This trajectory may be expressed mathematically by the equation

$$\dot{F}=\dot{\theta} \qquad (1)$$

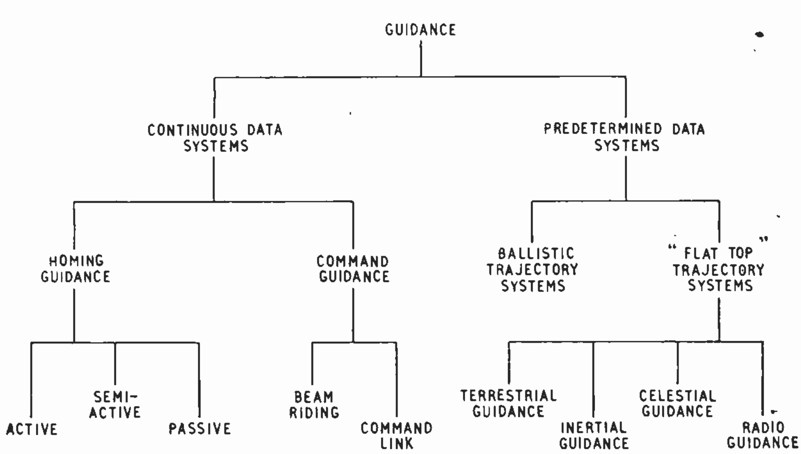
where F is the missile heading and θ is the line of sight, both with respect to the same reference in space, and $\dot{F}$ and $\dot{\theta}$ are the first time derivatives $\frac{dF}{dt}$ and $\frac{d\theta}{dt}$.

This system will produce a "curve of pursuit" trajectory as shown in Fig. 2 and a consideration of this trajectory will show that it is uneconomical and that it will always result in a stern chase. Furthermore it can be shown that an infinite lateral acceleration is required at the end of the course. As this is impossible to produce in practice, a definite miss distance is inherent in this system.

The homing trajectory may be improved by making the missile head for a calculated interception point and this method reaches its ideal when the missile flies in a straight line between the launcher and the interception point. The method most commonly used in G.W. is called proportional navigation where equation (1) is extended to a general case of

$$\dot{F}=K\dot{\theta} \qquad (2)$$

Fig. 1. Family tree of guidance systems.



where K is the "navigation constant." The advantage of this system is that no knowledge of range is required, other than that the target must be within the range capabilities of the missile.

If the missile is to fly in a straight line from launcher to target then $\dot{F}=0$ and to satisfy equation (2) either $\dot{\theta}=0$ or $K=\infty$. The former case will involve aiming the missile at the interception point before launching, as in the case of normal predicted gunfire, while the second case will require an infinite rate of turn and hence an infinite lateral acceleration as soon as the missile is launched. A very reasonable compromise may be obtained by giving K a value between 3 and 10 and allowing the missile to turn through the initial error in aim in a finite time. When this has been achieved the missile will fly along an interception course and K must be chosen as a compromise between the acceleration that may be applied to the missile and the time available for the turn. Fig. 3 illustrates the change of trajectory with different values of K.

The functions of the instrumentation of this system may be summarized in the following stages:—

(1) Establish the sight line in space (θ).

(2) Measure the sight-line rate ($\dot{\theta}$).

(3) Make missile heading change by $K\dot{\theta}$.

With small variations in technique the major differences between homing weapons lie in the methods used to establish the sight line.

Active Homing.—In this class of missile the sight line is established by a lock-follow radar set mounted in the missile. This systems leads to some enginering difficulties but the maximum range of such a set is severely limited by the size of aerial reflector that may be used, as this must be smaller than the diameter of the missile.

Semi-active Homing.—Here the sight line is still established by radar but an improvement in range capabilities and a reduction in weight of electronic equipment in the missile is effected by installing the transmitter of the radar set on the ground and arranging for it to illuminate the target continuously. Reflected energy is then used by the receiver in the missile to auto-follow the target. The improvement in range over active systems may be as much as five times, since the power transmitted and the size of the transmitter aerial dish may both be greatly increased when the equipment is mounted on the ground. This makes the missile suitable for the surface-to-air role and a salvo of missiles may be fired without mutual interference taking place.

Passive Homing.—No transmitter is used in this system and the missile uses energy radiated by the target to establish the sight line. For missiles which use infra-red radiation there is a limit to the range at which targets can be detected.

A special feature of the lock-follow systems in use in homing missiles is that they must establish the sight line with respect to a space reference and not with reference to any missile axis. This calls for gyro stabilization of the reflector and hence the misalignment signals from the radar or infra-red receiver must be arranged to precess this gyro.

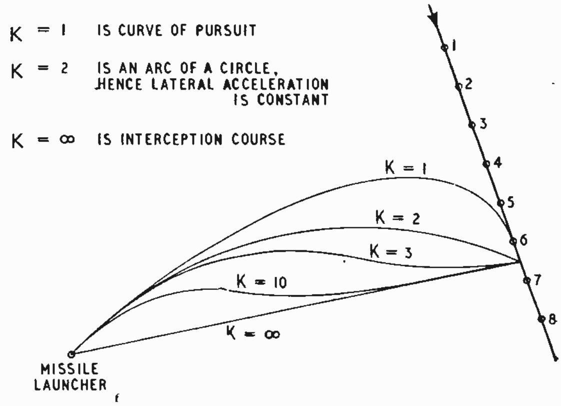


Fig. 3. Homing trajectories for different values of K.

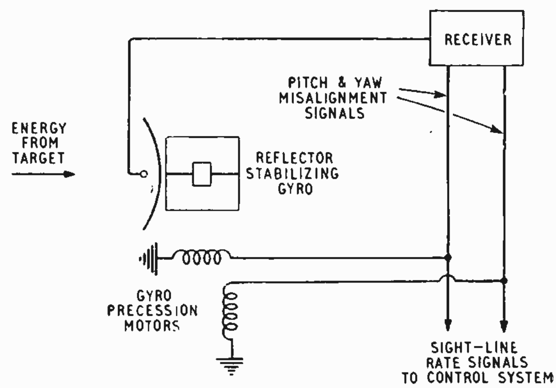
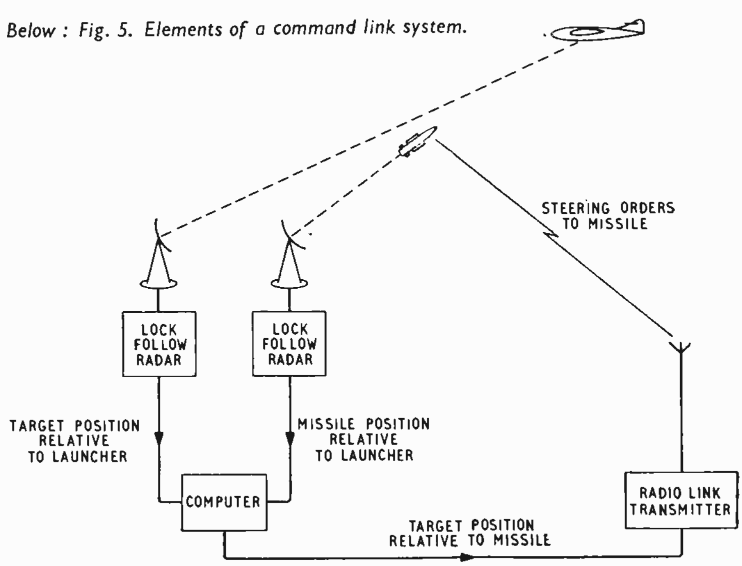


Fig. 4. Basic arrangement in a homing missile to measure sight-line rate.

Below: Fig. 5. Elements of a command link system.



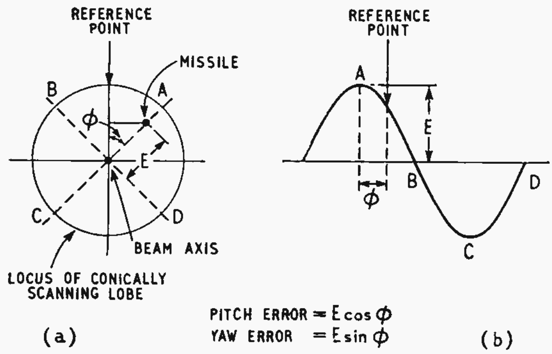


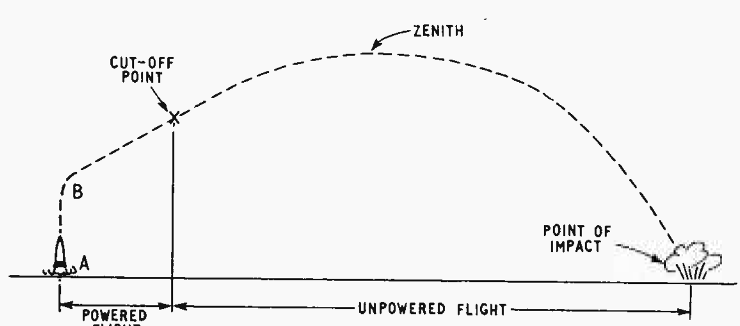
Fig. 6. Beam-riding system. (a) Cross-section of beam and (b) resultant error measuring signal.

Since the gyro precession rate, i.e., the sight-line rate, is proportional to the applied signal, this signal may be used as a measure of sight-line rate. This is shown diagramatically in Fig. 4.

Command Systems.—The basic command link system is shown in Fig. 5 and from this it will be seen that the required missile course is computed continuously from two lock-follow radars, measuring missile and target positions with respect to the launcher. From this a computer gives target position relative to the missile and the required course is converted to steering orders which are transmitted to the missile by a radio link.

This system is capable of many variations ranging from the system as shown to the manually guided missile where the radars are replaced by optical sights and the computer by a human operator. Only the radio link remains and even this may be replaced by a wire trailed from the missile! The main disadvantage of this system is that only one missile can be fired at a time and if a salvo of two is required then all the ground equipment except the target following radar must be duplicated. Among the advantages are those of a very simple missile equipment and a longer range compared with some of the present homing systems. However, the guidance accuracy decreases as the missile approaches the target as against a homing system where the reverse is true. A method which can be adopted in medium range missiles where the miss distance required is beyond the computation capabilities of the system, is to fit the missile with a short range homing system to control the missile in its terminal phase.

Fig. 7. Typical ballistic trajectory.



Beam-Riding Systems.—In a beam-riding or line-of-sight guidance system, the missile is made to fly in the centre of a conically scanning radar beam similar to that used by a lock-follow radar set, and this beam is made to point at the target. If the missile is within the cone but not in the centre, then the signals received by the missile from the radar will be amplitude-modulated at the conical scan rate. This modulation signal is indicative of the error in position of the missile from the centre of the beam, the amplitude being proportional to the distance, and the phase having a direct relationship to the direction of the error with reference to a fixed point in the conical scan. This reference point (generally the pitch or yaw axis) may be transmitted independently from the ground to the missile by pulse position modulation of the guidance radar transmission. The error modulation may then be resolved along the pitch and yaw axes and used as steering orders to the missile's control system. This is shown diagramatically in Fig. 6. It will be noted that a salvo of missiles may be fired without any increase of ground equipment since, whilst this is still a command system, it is the flight path which is transmitted to the missile, rather than the actual steering orders required. The disadvantages of this system are that its accuracy decreases with range and its trajectory is not very economical, as too much time is spent at low altitudes where aerodynamic drag is large.

Ballistic Missiles.—The trajectory followed by a ballistic missile is similar to that of a long range shell and the same factors control the range in both cases, i.e. the angle of elevation and the velocity at the end of powered flight. In the case of the shell the powered flight is short—from the breech to the muzzle of the gun—and range is controlled by the angle of elevation. The ballistic missile may be powered for 60 seconds or more before it reaches the required velocity; this velocity is controllable in order to vary range, whilst the elevation angle is held constant. As will be seen in Fig. 7 the ballistic trajectory may be divided into three parts. In the first, AB, the missile is launched vertically. This is done to allow the missile to accelerate slowly and thereby economize on the strength and weight of the missile airframe. This is highly desirable since the maximum velocity that the missile can attain is governed by the "mass ratio," i.e.

$$\frac{\text{Mass of missile when launched}}{\text{Mass of missile when fuel all burnt}}$$

Due to the low velocities attained during the first few seconds of flight, the missile cannot be stabilized by control surfaces and is maintained in a vertical position by such a method as moving the direction of the jet stream from the motors. This may be accomplished by gyro-controlled swivelling rocket motors or by the use of deflecting plates in the jet stream. When the missile has attained sufficient velocity, the vertical control gyro is precessed by about 45° and the missile continues to accelerate at 45° elevation until the required "cut off" velocity has been reached. This will depend on the required range and for a missile at 45° launching elevation,

Range $= u^2/g$ for the unpowered section of the flight where u is the cut-off velocity if air resistance is neglected and g is acceleration due to gravity. From this it will be seen that the velocity must be determined accurately if large errors in range are to be avoided. Measurement of velocity may be made (1) inside the missile by integrating the output of an accelerometer, or (2) outside the missile by measuring the Doppler frequency shift of the signal from a transponder unit.

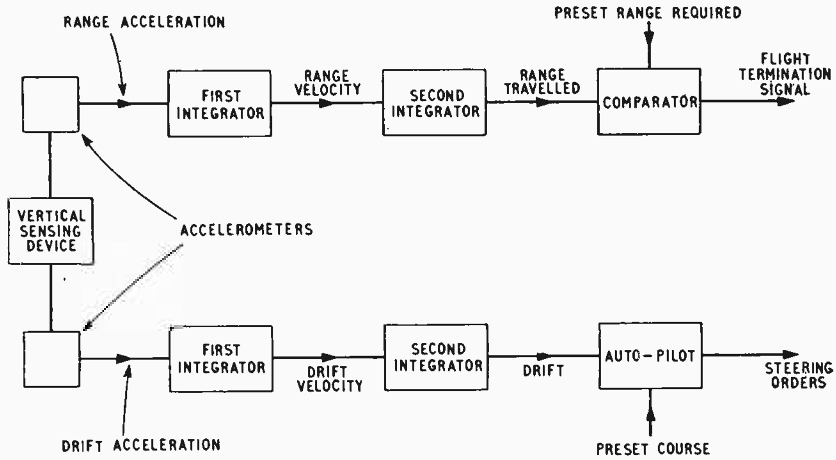


Fig. 8. Elements of an inertial guidance system.

When the correct cut-off velocity has been reached, the fuel supply is cut off and the missile follows a ballistic trajectory. The other main problem in launching a ballistic missile is to ensure that it is launched on the correct bearing to the target. The missile will be maintained on course by a gyro-controlled auto-pilot and in the V2 missile the correct bearing was ensured by lining up the axis of this gyro before launching. This method did not permit any adjustment after launch but later methods, such as automatic alignment with a radar beam or one of the methods used to steer "flat top" trajectory missiles, permit corrections to be made after launch.

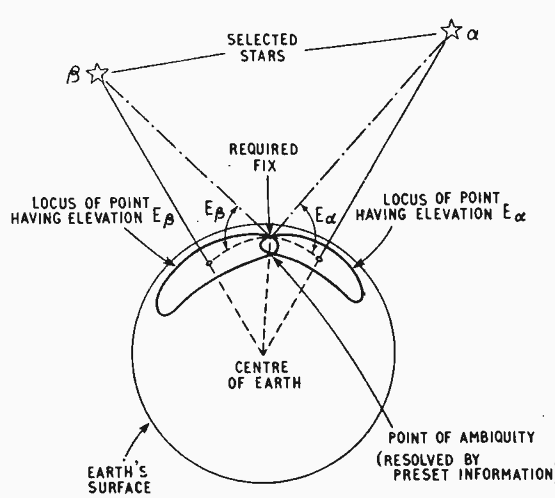
"Flat Top" Trajectory Missiles.—In contrast to the ballistic missile which is powered for a short time only and attains a high velocity, the "flat top" missile is powered throughout the flight and travels at a relatively slow speed. As its trajectory is all within the earth's atmosphere an air breathing motor can be used, e.g. turbo-jet, ram-jet or pulse-jet engine, but this advantage in the amount of fuel to be carried is offset by the fact that continuous guidance is required to control the missile's behaviour in the earth's atmosphere.

Terrestrial Guidance.—The simplest form of direction indicator that will function satisfactorily in a fast-moving missile is a magnetic compass, and indeed this forms the basis of navigation in most aircraft. Thus a missile could have a pre-set magnetic course set before take off and deviations from this course used as steering orders. A refinement in this system would be to use a gyro magnetic compass and this was the system used in the V1, range being determined on a dead reckoning basis by counting the revolutions of a small propellor. The best accuracy obtainable is of the order of 1° to 2° and this only if the magnetic deviations along the route are known and compensated in the missile. A further refinement might be to correlate the variations in the vertical component of the earth's field, but again an accurate magnetic survey would be needed.

Inertial Guidance.—The range through which a missile has travelled from the launching point may be measured by double integration of the acceleration of the missile along the line of flight and normal to the local vertical, the first integration converting acceleration to velocity and the second converting velocity to distance. The accelerations may be measured quite accurately with an accelerometer, but accurate integration over long periods of several hours' duration is difficult, due to drift. A more difficult problem still is the determination of the local vertical. This may be measured by a pendulum in the case of a body that is not accelerating, but accelerations will render a pendulum system useless. A suitable pendulum can, however, be simulated by a specially controlled gyroscope. Such a missile must be launched on the correct course, but once this is done it may be kept on course by a similar measurement of the distance travelled *across* the line of flight, i.e., drift, and arranging for this to be brought to zero by appropriate steering of the missile. A block diagram of this arrangement is shown in Fig. 8.

Celestial Guidance.—The techniques of celestial navigation are well established in the marine and aeronautical fields, but the application to missile guidance is a complicated matter. A "fix" may

Fig. 9. Method of obtaining a position fix from the observation of the altitude of two stars.



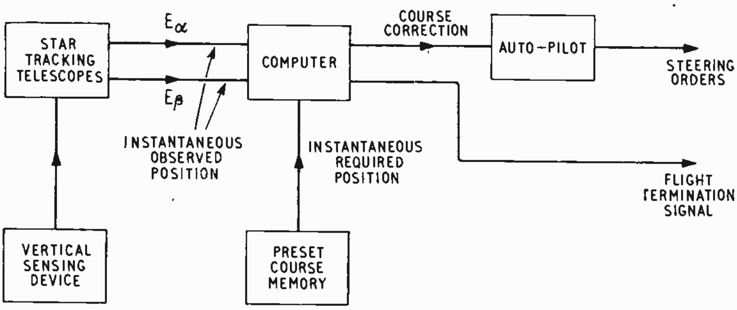


Fig. 10. Celestial guidance system.

be obtained by observing the altitude of two stars, as shown in Fig. 9, and hence for continuous guidance, constant observation of two selected stars is necessary. To measure the altitude, an artificial horizon must be provided and since this must be independent of missile accelerations, a device similar to that mentioned in the preceding paragraph would be suitable. Arrangements must now be made for two automatic star-tracking telescopes to be mounted on this platform. These will measure the altitude of the selected stars continuously and their auto-following action is accomplished by a similar system to that used in passive homing missiles to establish the sight line to an infra-red source of energy. Hence a continuous position fix of the missile may be calculated and compared with an instantaneous, pre-determined position which may be stored in the missile on tape or in a magnetic store. Errors between "observed" and "required" position are then used as corrections to the setting of the missile auto-pilot.

The system is shown in block form in Fig. 10, from which it will be seen that the computer, having "observed" and "required" star altitudes as its input, will produce the course corrections for the auto-pilot and also the flight termination signal when the observed position coincides with the target position. In a missile using celestial guidance it will be most important to correct for time and the system must either be continuously corrected or launched at the precise instant for which the system is pre-set.

Radio Guidance Systems.—Systems employing radio guidance may be divided into two main categories, those deriving range along and drift across a pre-determined course and those relying on a radio field derived from static transmitters. All radio systems are liable to jamming, a disadvantage when compared with inertial and celestial guidance systems, but this need not be as serious as it might be thought, especially in the first type of system mentioned. This system relies on the measurement of the ground speed of the missile by a radio Doppler system. Speeds are measured along and across the missile heading and integration of these speeds will give range from launcher and drift. A comparison of the block diagram in Fig. 11 with the inertial system as shown in Fig. 8 will illustrate the parallels between the two systems.

The radio field systems work on similar principles to the "Gee" and "Oboe" blind bombing systems employed in World War II. Radio position lines are established from fixed transmitters. The co-ordinates of the target are established with reference to these position lines and the missile's position is measured continuously with respect to the same reference. The missile course in terms of the radio position lines is pre-set and stored in the missile. Hence continuous comparison of the desired and observed positions may be made and differences used as correction signals to the auto-pilot. Radio position lines are of three types:—

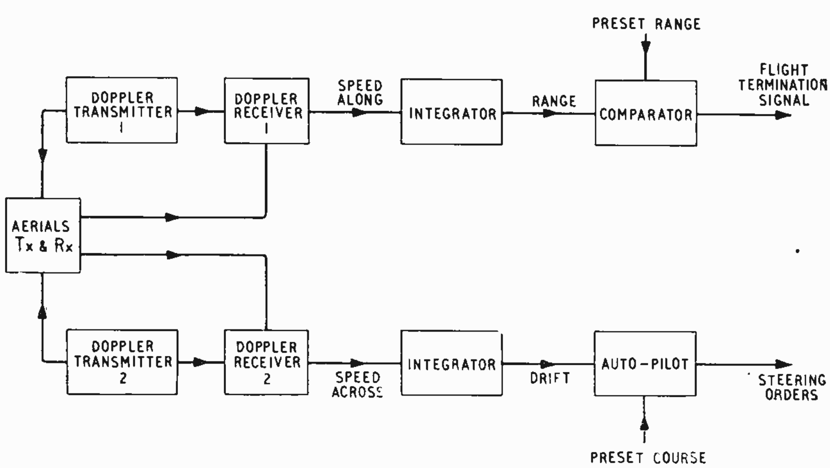
(a) Orbital lines at a constant range from the launcher generally determined by a transponder system between the missile and a fixed station near the launcher.

(b) Radial lines on constant bearings from a fixed point determined by a directional aerial system. It is interesting to note that a beam-riding missile might be considered to come under this heading.

(c) Hyperbolic position lines determined by a comparison of the arrival at the missile of two signals known to have been radiated at the same instant from two fixed stations. This is the basis of the Decca and Loran navigation systems.

To obtain a fix, two position lines will be necessary and whether they are both of the same type or not will depend on the ease of getting a good intersection. The greatest accuracy will be obtained by the hyperbolic lines since these do not depend on the transmission speed, but it must be also noted that orbital and radial position lines from the same reference will always give an intersection at right

Fig. 11. Radio guidance system using the integrated velocities measured by Doppler radio.



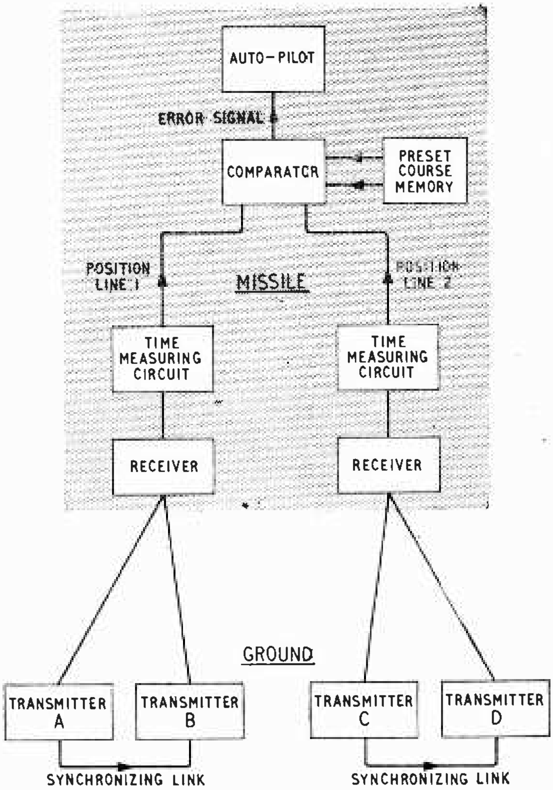


Fig. 12. Radio field system using two hyperbolic position lines.

angles and hence a choice must be made to suit each case.

Another advantage of this radio system is that there need not be a close liaison betwen the stations launching the missiles and those providing the guidance field. Once the field is set up missiles may be launched into it from a number of points. In general, a parallel between radio field guidance and celestial guidance may be observed and this will be shown by a comparison betwen Figs. 10 and 12.

Security regulations will not permit description of the missiles that are in current production or under development. Such information that has been released, however, shows that this country has concentrated its first efforts on defence weapons against aircraft attacks, as this is the main threat against our islands, and that the majority of attack weapons have been developed in the U.S.A. or in Russia, though we may be quite sure that defence weapons have not been neglected in these countries. The author's view is that future developments in guidance systems should be directed towards the extension of detection ranges of radar and infra-red systems, together with the development of increasing accuracy in manufacturing techniques for such pieces of equipment as gyros, accelerometers and actuating systems. Moreover, the ability of manufacturing processes to "produce the answer" in smaller and smaller packages is of prime importance. These are essentially engineering problems and as such present a vital challenge to the engineers of to-day.

Transistorized V.H.F. Airborne Equipment

A NEW range of airborne v.h.f. equipment for use in modern civilian aircraft and embodying the latest design techniques with printed circuits, transistors and sub-miniature valves where applicable, was shown at the 75th Anniversary Exhibition held by Standard Telephones and Cables at the Waldorf Hotel during the first week of July.

Known as the STR23/34/35/36 it is a complementary and comprehensive VHF/ILS/VOR airborne communications and navigational equipment approximately half the weight, half the size and consuming half the power of the earliest sets it replaces. It will be fitted in the B.E.A. Vanguard and Comet fleets of aircraft.

The STR23 provides two-way v.h.f. communication in the band 118 to 135.95Mc/s, with remote selection of 360 channels of 50-kc/s spacing and with a transmitter power output of 20 watts. The modulator is fully transistorized and embodies speech clipping. The companion receiver is a 560-channel, 50-kc/s spacing, double-frequency changing superhet with transistors and crystal diodes in all stages from the second i.f. amplifier to the output stage inclusive. It covers the band 108 to 135.95Mc/s and is remotely controlled. Transmitter and receiver each weigh 16lb.

This equipment can be used either as a separate self-contained v.h.f. airborne radio telephone or in conjunction with the complementary VOR/ILS localizer receiver, SR34, and glide path receiver, SR35. The former is a combined 100-channel, 100-kc/s spacing receiver and instrument drive unit and is interchangeable with the receiver part of STR23. It provides navigational and glide path approach information with instrument presentation and covers the band 108 to 117.9Mc/s. Three valves only are used in this set, the remaining stages being transistorized. It weighs 30lb.

The complementary glide-path receiver, SR35, provides 20 channels spaced 300kc/s apart in the band 329.3 to 335Mc/s. It is a double superhet and all stages from the second mixer to the output use transistors and the set weighs 8lb.

Each of these units has a built-in power pack for operation from the 115-V, 400-c/s a.c. supply found in the most up-to-date civil aircraft, but 28-V transistorized power packs are under development for each of these sets.

The final unit, the SR36, is a 75-Mc/s marker beacon receiver and uses one valve only the remaining stages being either transistors or crystal diodes. This receives the vertically radiated signals which fix pre-determined spot distances from the end of the landing runway. The unit weighs 6lb only, has a built-in power pack and the information is given by three lamps included in the display unit.

NATIONAL RADIO EXHIBITION

(Earls Court, Aug. 27th—Sept. 6th, 11 a.m.—10 p.m.)

WIRELESS WORLD SHOW NUMBERS

September: **Show Guide** (publication date August 26th). Plan of the stands with stand-to-stand guide to the exhibits.

October: **Show Review** (publication date September 23rd). An assessment of trends in the design of television and sound receivers.

French Components Show

THIS year the 21st Exhibition of the French components industry, held at the Parc des Expositions, Porte de Versailles, Paris, was distinguished by its title of 1st International Components Exhibition—which it justified by the presence of 37 foreign firms amongst the 314 exhibitors. Apart from this the Salon is different in a general way from our own components show in that it places much more emphasis on electro-acoustic equipment and test and measuring instruments—hence the greater number of stands.

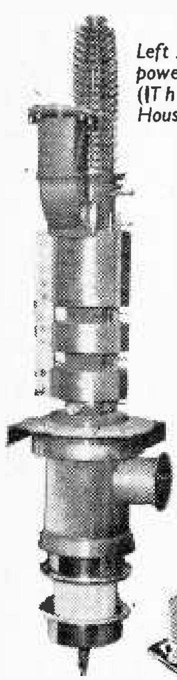
Many other differences were, of course, observed in the detailed things—for example, the large number of a.c. voltage regulators for television sets on display (evidence of the fact that the mains supply voltage in France can vary as much as $\pm 30\%$). And in the electro-acoustics section one became accustomed to seeing amplifiers and tuners with variable response curve indicators on their front panels. A horizontal wire representing the curve behind a transparent graticule is automatically moved up or down at either end when the bass or treble controls are operated.

The electro-acoustics section was actually dominated by large numbers of portable record players in mock leather attaché cases, most of which had the loudspeakers in the detachable lids. One model, the Teppaz 336, had two 7½-inch speakers and a piezo-electric "tweeter" in its lid. Another multiple loudspeaker system, intended for "hi-fi" and called the Armad "acoustic screen," had two loudspeakers mounted back-to-back in a cube of expanded polystyrene. One side of the cube is open to the listener while the opposite side is closed by a large sheet of the same material (see photo.). The two speakers work in phase, so that the cones compress the air in the cube during their backward movement and the air outside during their forward movement. This arrangement is said to improve the acoustic loading and response curve of the speakers, to propagate the sound laterally over an angle of 180 degrees, to attentuate standing waves on the cones and to avoid spurious cabinet vibrations.

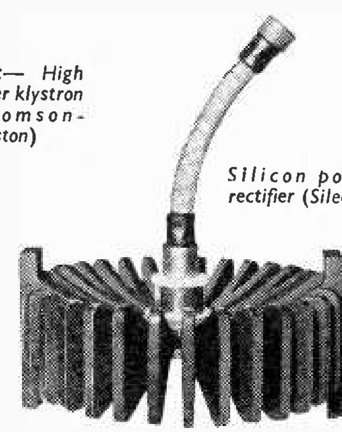
Also in the "hi-fi" category was an unusual pickup for long-playing records, shown by Avialex, which combined a piezo-electric element with an electromagnetic element. The first, giving a voltage proportional to the amplitude of the stylus movement, covers reproduction of low frequencies, while the second, responding to the velocity of movement, deals with the high frequencies.

Tuning-coil packs with push-button or piano-key station selection seem to be very popular in France (see photo.), and many of the examples on show were designed for portable transistor sets. Many transistor receivers are intended for use inside motor cars, and to cater for this several detachable car aerials were on display. One type clips on the top edge of a lowered window glass while another is a rod fixed horizontally on the inside of the windscreen by suckers. Aerials in general were fairly conventional, except perhaps for one "skeleton slot" v.h.f. type with its feeder branches in the

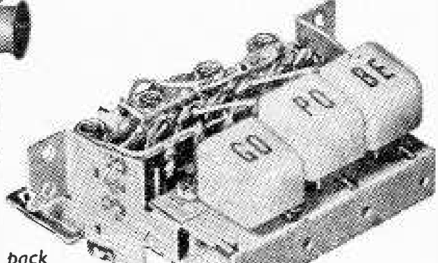
Automatic mains voltage regulator (Voltam)



Left :— High power klystron (Thomson-Houston)

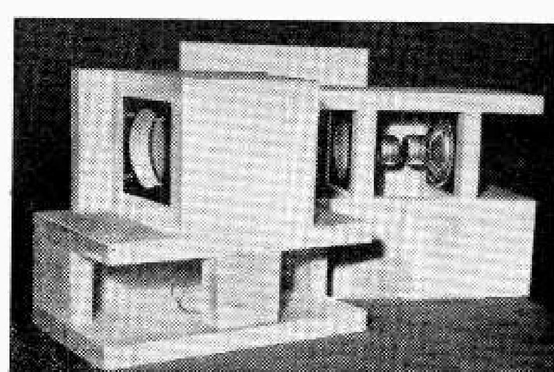


Silicon power rectifier (Silec)



Right :— Coil pack with piano-key switching (Alvar)

Two versions of the Armad "acoustic screen" (S.A.T.I.)



same plane as the "slot" structure and two reflectors fixed behind on the mounting bracket.

Semiconductor devices—germanium, silicon and selenium—appeared to be in much the same state of development as in Britain. Some of the more advanced devices noted were n-p-n high-speed switching transistors (La Radiotechnique), sensitive Hall-effect elements (Siemens & Halske) and a selenium "solar battery" of 20 cells working a transistor receiver (Westinghouse).

An interesting item in the test gear section was a portable transistorized capacitance meter, shown by Chauvin Arnoux, capable of measuring capacitances from 2pF to 0.1μF directly on a pointer indicator. The capacitor under test is charged repetitively by a transistor square-wave generator and the resultant discharge waveform is rectified to give the mean discharge current, which is indicated on the meter in terms of capacitance.

Amongst the oscilloscopes, one unusual model had its c.r.t. external to the main cabinet in a horn-shaped enclosure which was mounted on a ball joint so that the tube could be swung to any viewing angle. Another c.r.o. was capable of superimposing four waveforms from different sources on the screen for comparison purposes. This was done by an electronic commutator sampling each waveform 10^4 times per second. Yet another instrument had electronic commutation (for two channels) in a detachable Y amplifier which could be interchanged with a standard (single channel) Y amplifier.

The new 110-degrees scanning angle for television c.r. tubes was represented by new deflector-coil assemblies, and a complete receiver chassis with a 110-degrees tube and appropriate e.h.t. and deflection components was demonstrated by Cicor. For small television camera tubes of the photo-conductive type, Telco were showing a compact coil assembly called the "Vidibloc" which contained three separate elements—one coil for focusing, another for deflection and a third for aligning the electron beam on the tube axis. Matched groups of three "Vidiblocs" are available for colour television.

In the realm of high power operation, two exhibits of particular interest were an S-band amplifying klystron capable of giving 30 megawatts peak output (Thomson-Houston), and a silicon junction rectifier which would deliver 150 amps mean current with 200 volts peak inverse (Silec).

Among new connecting devices a notable exhibit from America was the "Interlock" system, in which the plug has a hook on its end and is locked firmly into the socket cylinder by pressure from a spring-loaded ferrule. The two parts are separated by pulling on the ferrule.

Medical Electronics Conference

AN experimental ultrasonic "telescope" for producing "radiographic" type pictures of internal biological structures was perhaps the most technically advanced device described at the recent Paris conference on medical electronics (see page 364). Constructed by Dr. C. N. Smyth, of University College Hospital, London, it depends on the varying opaqueness of different body tissues to ultrasonic waves and displays the pictures by a television type of scanning system.

In the present early state of the work the biological subject is represented by a test object immersed in a tank of water. Low power ultrasonic waves of 12Mc/s frequency are directed from a transducer at one end of the tank on to the test object. The pattern of energy transmitted through the object is then focused by a plastic lens on to a 0.5mm thick quartz plate at the other end of the tank. This plate also forms the target of a television pick-up tube outside the tank. Because the plate is mechanically damped by the water the ultrasonic waves do not spread over its surface and vibration is confined effectively to the points of impact of the beam. Consequently the voltage pattern set up in the plate by the piezo-electric effect corresponds to the ultrasonic energy distribution. This charge pattern is scanned by the electron beam of the pick-up tube and the resultant signal is displayed as a television picture. To allow more than one image to be displayed the charge pattern on the plate is removed by ion bombardment.

The definition is limited by the thickness of the quartz crystal plate, but this thickness cannot be reduced too far because of the atmospheric pressure resulting from the vacuum in the pick-up tube.

Direct stimulation of the auditory nerves of deaf people by pick-up coils enclosed in the skull has already been mentioned in *Wireless World* (Sept. and Dec. 1957 issues, p. 457 and p. 613). Details of these experiments were given by Dr. A. Djourno at the conference and X-ray pictures were shown of the embedded coils. When signals were induced in the coils by magnetic induction the patients could discriminate between low frequencies below about 100c/s. At 15c/s they reported "noises" like motor-cycles, and anything above this gave the effect of sheets being torn up. Words were generally unintelligible, but "Papa" could be distinguished from "Mama" and rhythms and code patterns could be recognized. It was suggested that voice frequencies might be heterodyned down to the low frequencies which could be perceived, or possibly converted into pulse codes.

A topographical method of displaying the distribution of e.g. potentials on the scalp, described by Dr. A. Rémond, involved scanning a line of pick-up electrodes in turn and integrating the voltages obtained from each. The resulting "contour" of voltage against position was displayed on a c.r.t. repetitively at 7-ms intervals and recorded photographically to show the changes taking place with time. Dr. Rémond was also working on a two-dimensional system of plotting potentials with interpolation between scanning points. This gave a record on a diagram of the scalp rather like height contours on a map.

The presence of lung cancer cannot always be detected by ordinary X-ray examination, but Dr. M. Marchal described an auxiliary radiographic technique based on the fact that a cancer inhibits the normal blood pulsation in the lung it infects. Photocells are placed on the patient's chest during fluoroscopic examination in such positions that the blood pulsations appearing in the image are detected and converted into electrical signals. According to the shape of the recorded signal waveforms, it is possible to see whether the blood pulsations are normal or not.

Other communications dealt with low-noise transistor amplifiers, integration methods on biological traces to overcome noise, X-ray image intensifiers with television display, intracardiac pressure measurements and statistical diagnosis using electronic computers.

Video Tape Recording

DEMONSTRATION OF THE AMPEX VR1000 EQUIPMENT

RECENTLY Associated-Rediffusion took delivery of a modified Ampex video tape recorder and *Wireless World* was given the opportunity of seeing it put through its paces.

The principle used in the Ampex machines*, which are modified to British 405 line standards by Rank-Cintel Limited, is to provide the equivalent of a very high tape speed by recording across a 2in-wide tape with a set of rotating heads whilst it is moving past the head assembly at 15in/sec. Four video heads are used, spaced at 90° intervals round a drum rotating at 1500 r.p.m. and the effective tape speed is about 1550in/sec past the head. The heads "overlap" so that no signal is lost during the changeover from one head to the next: this is arranged to fall during a line blanking period so that any disturbance is not seen on the picture. A servo-control system is used to maintain tape and head speed at the correct values and the block diagram shows the main features of this. The theoretical horizontal resolution on a 405 line standard is about 380 picture elements per line, ten lines being recorded as one transverse "stripe" by each head in turn. Signal-to-noise ratio (picture) is better than 30dB and some machines have provided a ratio as high as 50dB. (26dB is accepted as being the minimum desirable figure for a television picture.)

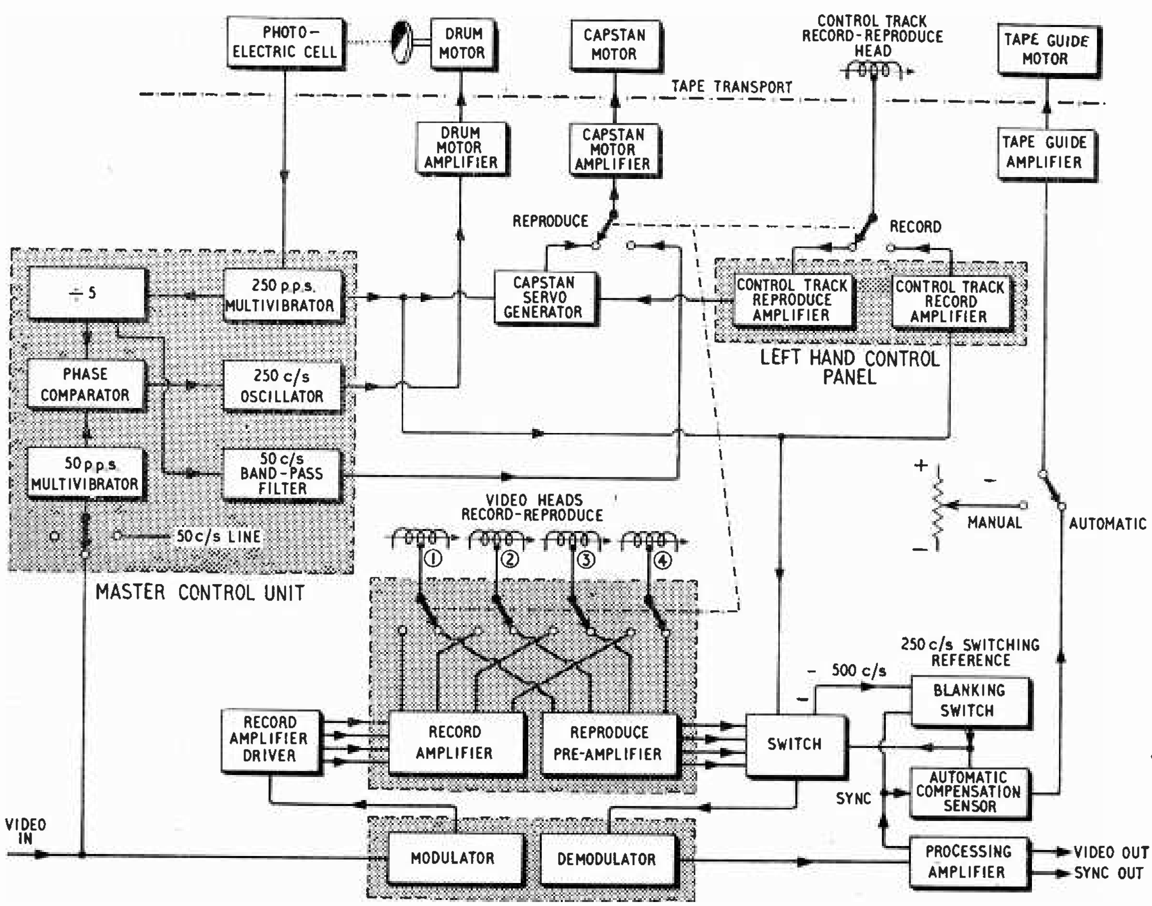
Joins in the tape could lead to instability of frame synchronization if the splice comes in such a place that one field is shortened or lengthened.†

Editing facilities are provided by recording longitudinally, on one edge of the tape, a control track (this is similar to the sprocket holes in a cine

* Technical Notebook, Sept. 1957.

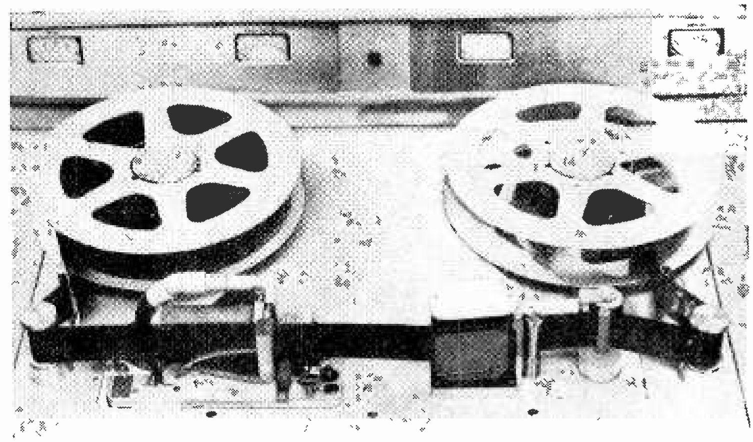
† Technical Notebook, April 1958.

Block diagram of the Ampex recorder video system. The processing amplifier (bottom right) removes the "syncs" from the playback and substitutes "clean" ones.



film) which includes pulses marking the frame blanking periods and 250 p.p.s. sync. These are rendered visible by applying a finely divided magnetic powder to the tape: this sticks to the magnetized parts and thus enables the modulation to be seen so that a cut can be made during the frame blanking period. Once the splice has been made the particles are wiped away. The sound track is also longitudinally recorded; but on the opposite edge of the tape to the control track pulses.

Associated-Rediffusion provided for the demonstration a studio performance which was first seen "live" on monitors placed about the studio and then as a replay from the Ampex machine. It would, of course, be an exaggeration to say that the magnetically-recorded picture is indistinguishable at close quarters from the original. It is, however, quite hard to say whether the picture is a playback or not when looking at a monitor from such a distance that the line structure disappears. Watching a 21in monitor about four or five feet away it was obvious that the signal-to-noise ratio was worse and the definition was not quite so good as on the "live" transmission. Synchronization of the line time base was fairly good; some slight "wander"—about one tenth of an inch in amplitude—was visible. This, on a 21in tube, represents a timing error of about half a microsecond which is a quite good performance. Unfortunately it is not possible to comment on frame synchronization and black level retention because the monitors provided showed either an inability to interlace correctly, or a loss of d.c. component, on the "live" programme. One rather disconcerting feature was that one head seemed to have rather better performance than the other three, so that thirty lines of picture exhibited a lower signal-to-noise ratio than the next ten. When questioned, one of the technicians in charge said that this could have been caused by dirty or worn heads and, in fact, the recorder demonstrated had been in use for many hours for the training of operational staff.



Tape transport mechanism of the Ampex recorder. The pipe on the back of the video head (left) evacuates the space between the tape and the rotating head so that air pressure maintains an intimate tape-to-head contact. The large right-hand assembly contains the control track and sound record and erase heads.

A few "drop-outs" appeared on a second run-through of the tape; these take the form of white dots rather like extremely well-limited ignition interference. On a third run-through of part of the tape drop-outs were even more evident, but again these were blamed on dirt on the head assembly. Overall, the performance of the machine can be considered very satisfactory and the slight defects noted above under critical comparative examination probably would not be noticeable under domestic conditions.

The recording system consists of three main units —the recorder itself and two racks containing the power supplies and control equipment. The recorder weighs 1,350 pounds, costs £20,000 and plays for 65 minutes from a 12½ inch reel of tape, which costs about £100 and can be used at least 100 times. This tape is imported from the U.S.A. and it is coated with a special fine-grain oxide mix. One head assembly will normally last for at least 100 hours running time (three "spares" are provided with the machine) and there is a "trade-in scheme (operated by Rank-Cintel, Limited) for servicing worn heads.

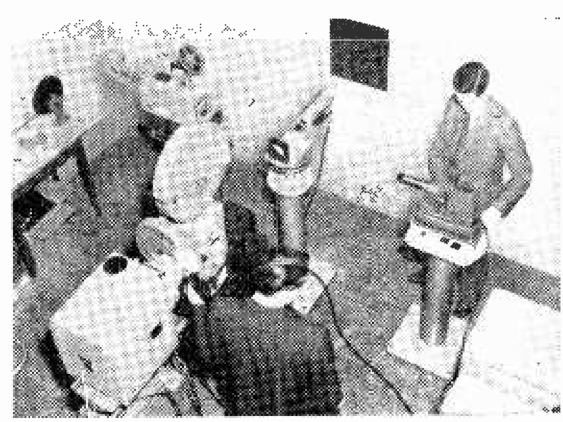
TV Aids TV Advertising

A LARGE closed-circuit television system is to be installed by Marconi's Wireless Telegraph Co., Ltd. for L.P.E. Television, Ltd., the advertising agents, to enable executives in 43 offices and 3 conference rooms to judge the merits of films and to see the performances of artistes as they would appear to television viewers.

Marconi's have developed new cameras (BD871) with pedestal mounting so that they can be swivelled to pick up the output from either of three projectors (two 35mm and one 16mm) or stills from a slide projector.

Distribution is by modulated crystal-controlled r.f. in a cable system supplied by Belling & Lee, Ltd., and the film projectors and associated sound systems are by R.C.A. (Gt. Britain), Ltd.

A four-position switch at each viewing point gives the choice of two internal circuits as well as the B.B.C. and I.T.A. broadcast programmes.



WORLD OF WIRELESS

N.T.S.C. Colour in Europe

DEMONSTRATIONS of N.T.S.C. colour television working on 625-line standards were witnessed by *Wireless World* recently at the laboratories of Hazeltine-Aga in Paris. This organization is a fairly new one, formed by Hazeltine, of America, and Aga, of Sweden, with the intention of making available American technical experience and patents to Continental radio manufacturers if the N.T.S.C. colour system is established in Europe.

The demonstrations were conducted on a closed circuit, using N.T.S.C. coding equipment built by Aga, with an RCA 21-inch colour receiver adapted to work on 625-line standards. A flying-spot scanner provided the picture source and was used on both still colour transparencies and "live" material in a small studio. The displayed pictures were of excellent quality but were not superior to the 405-line colour demonstrations we have seen recently in Britain, except perhaps in lack of "lininess".

Colour Television Training

TECHNICAL education almost invariably tends to lag behind the work being undertaken in industrial research and development laboratories. This, however, will hardly be true of those studying colour television at the Northern Polytechnic (London, N.7) during the coming session. John Gilbert, head of the Polytechnic's Department of Telecommunications, with the co-operation of V. J. Cooper, Marconi's Chief Television Engineer, has set up colour demonstration apparatus and test gear for an evening course of lectures covering the fundamentals of colour transmission and reception.

Entry qualifications for the course, which presupposes some knowledge of monochrome principles, are at least the C. & G. Radio III level, or the R.T.E.B. Television Servicing Certificate.

The syllabus covers the perception of colour, colour synthesis, photometry, and a résumé of monochrome transmission techniques. Possible colour transmission systems are compared, the N.T.S.C. system being dealt with in detail, leading to considerations in receiver design.

Telecommunications Technicians

DESIGNED to meet the needs of employees of the Post Office Engineering Department and of organizations engaged in the manufacture of telecommunications equipment, the City and Guilds telecommunications engineering course is one of the most successful run by the Institute. Experience has shown, however, that the complete five-year course is beyond the capacity of the majority of students, many of whom fall out after the third year, while a number of the entrants in the fourth and fifth years are found to be graduates and those already possessing advanced qualifications of various kinds.

It has, therefore, been decided to introduce a four-year telecommunication technicians' course with supplementary studies covering, for instance, microwave techniques, sound and television broadcasting and radar and radio navigational aids. This new four-year course is roughly equivalent to the first three years of the existing five-year scheme which it will eventually replace.

The Full Technological Certificate, now awarded at the end of the fifth year, will, in the new scheme, be awarded to those holding a Telecommunication Technicians' Certificate who pass in two of the examinations in the group of supplementary studies.

Examinations covering the first two years of the telecommunications technicians' course will be introduced in 1959.

Medical Electronics Conference

TWO British representatives were elected to the executive committee of a new international organization on medical electronics formed recently at a planning conference in Paris. Dr. C. N. Smyth, of University College Hospital, becomes a vice-president, while B. Shackel, of the Psychological Research Laboratory of E.M.I. Electronics, becomes the treasurer. Dr. V. K. Zworykin, the well-known television pioneer, now at the Rockefeller Institute for Medical Research, New York, was elected president. The purpose of the organization is to promote international co-operation and co-ordination in medical electronics, through existing national organizations, with the immediate aim of arranging another conference, probably next year in Europe.

The planning sessions were followed by two days of technical sessions, consisting of 34 short and informal communications on work in progress. Some of the topics discussed are summarized on page 361.

Sandwich Courses

THE popularity of sandwich courses leading to higher qualifications in engineering and technology, consisting of alternate periods (usually about six months) of study in a technical college and experience in industry, has increased considerably over the past few years. This is borne out by the latest list of approved sandwich courses in technical colleges in the U.K.* which includes details of 263 courses—65 more than were approved in 1957/58.

The definitions "works based" and "college based" are used in the list; the first denoting a course for employees of a particular firm who gain their practical experience with that firm, and the second a course for which students enrol at a college and gain their works experience with a variety of firms under the guidance of the college.

The courses are listed both under subjects and colleges. Three electronics courses are quoted:—a four-year course at East Ham Technical College (leading to the H.N.C. and Grad. Brit. I.R.E.); a four-year physics and technology of electronics course at the Northern Polytechnic (Dip. Tech. and Grad. Inst.P.) and a four-year course in physics with electronics at Glamorgan College of Technology (College Diploma and Grad. Inst.P.). There is also a light-current electrical engineering course at Salford Royal Technical College and a number covering

* List 182 (1958) H.M.S.O. (1/6)

telecommunications and electrical engineering generally.

Whilst on the subject of sandwich courses mention should be made of the list of full-time and sandwich degree and diploma courses in London and the Home Counties issued by the Regional Advisory Council for Technolgical Education.

"Oboe" Awards.—For their war-time development of "Oboe"—the radar blind-bombing device—whilst at T.R.E., Alec H. Reeves and Dr. Frank E. Jones have been jointly awarded £3,000 on the recommendation of the Government Departmental Awards Committee. Mr. Reeves was with Standard Telephones and Cables before the war and in 1946 joined the Standard Telecommunications Laboratories where he is now head of a division. Dr. Jones, who was at T.R.E. from 1940 until 1952 when he went to the R.A.E. as deputy director of equipment, retired from Government service two years ago and is now a director of Mullard.

U.K. Radio Backbone.—Nearly three years ago it was announced by the Post Office that a chain of radio relay stations extending through the country from north to south was to be built to carry some thousands of telephone circuits and two television circuits. This was to be completed by 1960. It is now learned from the annual report of the Telecommunication Engineering and Manufacturing Association that this work has not yet been put in hand and, says the report, "it would appear to be one of the projects to have fallen under the axe of the Chancellor of the Exchequer."

Receiving Licences.—Combined television and sound licences in the U.K. increased by 53,765 during May, bringing the total to 8,201,098. Sound-only licences totalled 6,425,530, including 343,085 for car radio, bringing the overall total to 14,626,628.

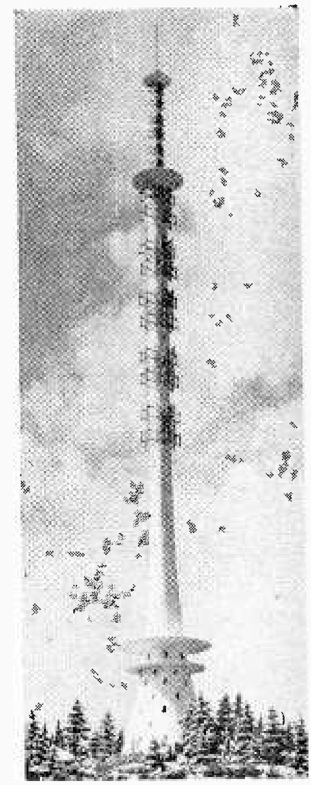
TV in Australia.—Production of television receivers in Australia rose from 49,000 in 1956 to 208,000 last year. At March 31st there were just over 220,000 television licences in force in the country. They are concentrated in Victoria and New South Wales, the only states in which there are stations.

Receiver Manufacture.—Instead of the summary of estimated sales of domestic receiving equipment issued in the past by **B.R.E.M.A.**, the Association is compiling a monthly survey of "estimated despatches to the home market by all manufacturers." The first figures to be issued (April) are: television receivers 73,000, sound (including car radio) 83,000 and radio-gramophones 12,000. Compared with the estimated average for April in the previous two years, the television figure is up by 3,000 but sound receivers are down by 6,000 and radio-gramophones by 4,000.

Information Processing.—An International Conference on Information Processing sponsored by U.N.E.S.C.O. will be held in Paris next June. Assistance will be given by a new organization, the Provisional International Computation Centre, established in Rome by agreement between U.N.E.S.C.O. and the Italian Institute of Higher Mathematics. The main function of this Centre is to ensure mutual assistance and international collaboration between existing computation and information processing bodies. Its Bulletin No. 1 was published in April, 1958, from the Secretariat, Palazzo degli Uffici, Zona dell'Eur, Rome.

Computer Conference.—The first conference of the British Computer Society will be held in Cambridge from 22nd to 25th June, 1959.

Air Traffic Control.—Plans are being made by the Guild of Air Traffic Control Officers to hold a convention on October 23rd and 24th at Southend-on-Sea. Information on the convention is obtainable from the Guild, 118, Mount Street, London, W.1.



NOVEL TV TOWER.—This model shows the novel construction of the tower built by the Bayerische Rundfunk on the summit of the Ochsenkopf, north east of Bayreuth, to carry the aerials for a television and v.h.f./f.m. station. The transmitting equipment is housed in the eight stories in the lower part of the tower. The first of the four platforms carries the parabolic reflectors for the radio links and the second platform is provided to protect the reflectors from falling ice. The Band II aerials are mounted above the third platform below which are the Band I television aerials. Provision is made to extend the height of the tower from 166 m to 180 m to accommodate the arrays for a Band IV television transmitter. The base of the tower is 1,013 m above sea level.

Institute of Physics.—The Institute's report for 1957 shows that during the year the membership rose to close on 6,000. Of the 68 candidates who took the recently established graduateship examination only 21 passed.

S.I.M.A. Council.—New members elected to the council of the Scientific Instrument Manufacturers' Association for 1958/59 are G. C. Fairbanks, representing Elliott Brothers, H. R. A. de Jonge (Rank Precision Industries), E. R. Ponsford (Solartron), and J. Rock Cooper (Oertling).

Plastics Travel Scholarships.—Two £500 European travel scholarships have been given to the British Plastics Federation by the Iliffe Associated Press. Nominations for the scholarships, which are open to men and women in the plastics industry, should be submitted to the Federation, 47-48, Piccadilly, London, W.1, by August 31st.

Norwood Technical College.—The 1958/59 prospectus of the Norwood Technical College, London, S.E.27, includes details of full-time, part-time and evening courses in telecommunications engineering, v.h.f. techniques, electronic instrumentation, radar maintenance, radio and television servicing and advanced radio operating.

S.E. London Technical College, Lewisham Way, S.E.4, is running a six months' full-time course starting in October in preparation for Part III of the I.E.E. Examination. Provision is made for specializing in industrial electronics and radio communication.

Amateurs' Courses.—The East London Group of the R.S.G.B. is again organizing in conjunction with the Essex County Council a course in preparation for the radio amateurs' examination. The eight-month course will be held at the Ilford Literary Institute, High School for Girls, Cranbrook Road, Ilford, Essex, on Wednesday evenings commencing September 24th (fee 30s). A morse class (fee £1) will be held at the Institute on Monday evenings.

I.E.E. Radio Section.—The chairman of the Radio and Telecommunication Section of the I.E.E. for 1958/59 is G. Millington (see Personalities). Two new vice-chairmen have been elected; they are: R. J. Halsey, C.M.G., B.Sc. (G.P.O.); and T. B. D. Terroni, B.Sc. (A. T. & E.). The five new ordinary members of the committee are: D. A. Barron, M.Sc. (G.P.O.); G. G. Gouriet (B.B.C.); C. G. Mayer, O.B.E. (R.C.A.); J. Moir (B.T.H.); and A. J. Young (English Electric Valve).

Television Convention.—The British Amateur Television Club will be holding its fourth amateur television convention on September 6th from 10.0 to 7.0 in the Conway Hall, Red Lion Square, London, W.C.1. There will be displays of amateur-built television equipment in operation, including demonstrations of colour television. The charge for admission of non-members is 5s (2s 6d after 2.0 p.m.). Further particulars are obtainable from D. S. Reid, 27, Rose Valley, Brentwood, Essex.

Research Fellowship.—The Committee representing the Royal Society and the Armourers and Brasiers' Company has appointed Dr. T. E. Faber, of Corpus Christi College, Cambridge, as Armourers and Brasiers' Company Research Fellow from October 1st, to work at the Cavendish Laboratory, Cambridge, on the electronic properties of liquid metals.

American films previously distributed in this country through the U.S. Embassy are now available from the Film Library of the Central Office of Information. Among the 150 American films listed in a supplement to the Library's main catalogue are two 16-mm films on the diode and triode and another (running for 31 minutes) on the life of Edison.

E.F.F.I.—The first name in the list of organizations participating in the Electronic Forum for Industry given in our last issue should have been the British Electrical and Allied Manufacturers' Association, and not B.R.E.M.A., as inadvertently stated.

QSL cards have in the past been issued free to amateurs by Mullards, but owing to the increased cost of production it has been necessary to make a nominal charge for supplying and overprinting. The charges are:—250 cards, £1; 500 cards, £1 10s; and 1,000 cards, £2.

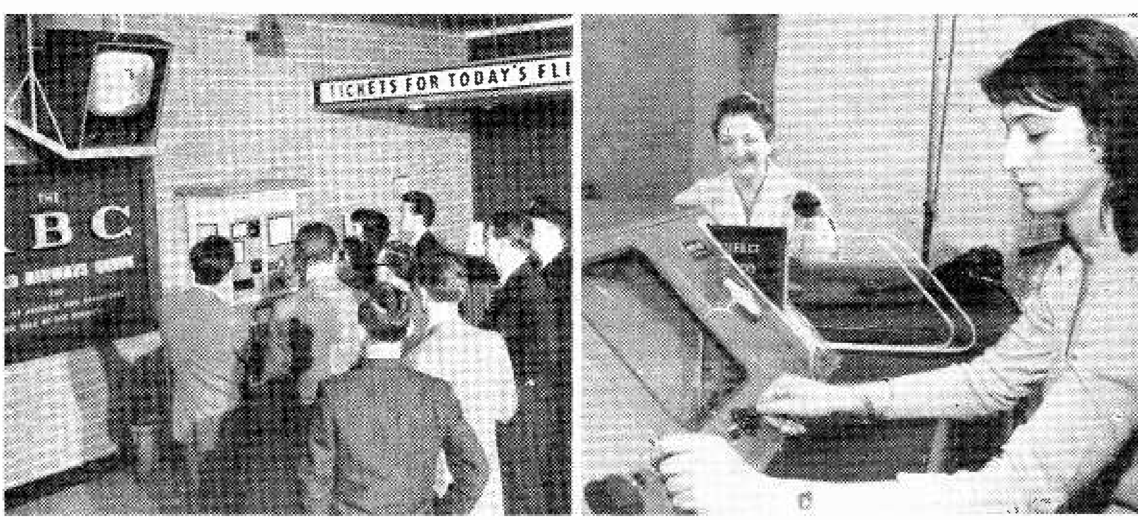
Evening Courses for the Radio Amateurs' Examination and in radio and television servicing will be conducted at the Brentford Evening Institute, Middlesex, commencing September 22nd. Particulars are obtainable from the Education Office, Town Hall, Chiswick, London, W.4. A radio and television maintenance course will be conducted at the Wesley Evening Institute, Stonebridge Road, London, N.W.10, commencing in September. At the Northwood Evening Institute, Potter Street, Northwood Hills, Middx., two radio courses will be held next session. One covers the Radio Amateurs' Examination syllabus the other being a more advanced course. Classes commence on September 23rd.

Courses for Overseas Trainees.—Home and overseas distributors of Pye equipment have for some time been able to send their technical staff for factory training at Cambridge, and for this purpose Pye have now set up a training school. Three training courses—elementary radio, advanced radio and television servicing—will be held each year for overseas trainee engineers. At present 30 students are attending these courses.

Capitol Radio Engineering Institute, which has been established for some years in Washington, D.C., where it provides both residential and postal courses in radio and electronic engineering, is establishing an overseas headquarters in London. Arthur F. R. Cotton, who went to the United States 11 years ago, has been appointed Director of European Operations for the Institute.

"**Science Recorded**" is the title of the tape recorded magazine issued monthly by Science for the Blind, a subsidiary of the Philadelphia Association for the Blind. According to a note in *General Radio Experimenter*, one source from which radio material is extracted, over 4,000 tapes were dispatched during the 12 months ended last October.

For the DXer.—"World Radio Handbook for Listeners," now in its 12th edition, includes not only frequencies of transmitters but also tuning signals, times of regular transmissions, names of broadcasting personalities and other useful information on the broadcasting organizations of the world. Although published in Denmark it is printed in English and is available in this country from Surridge, Dawson & Co., Ltd., 136, New Kent Road, London, S.E.1, price 13s 6d.



AIR TERMINAL TELEVISION.—Closed-circuit TV equipment has been installed at the West London Air Terminal as an aid to making announcements. The announcement is spoken once only, the announcer appearing on the screens of eight 21-in Pye receivers in various parts of the building, then a "caption" giving the details is screened. The equipment uses a standard Pye Staticon tube camera which covers both the announcer and the bilingual captions, which are inserted in a carrying cradle in the control panel (right). The total cost of the equipment, installed by Audio and Video Rentals, was in the region of £2,000.

Personalities

G. Millington, M.A. (Cantab.), B.Sc., the new chairman of the Radio and Telecommunication Section of the I.E.E., has been with Marconi's since 1931 specializing in theoretical and experimental studies relating to wave propagation. He has headed the company's propagation section since the retirement of T. L. Eckersley in 1946. A native of Southwark, London, he was a pupil of St. Olave's grammar school and later graduated at Clare College, Cambridge, For two years Mr. Millington was engaged in research work on beta-rays at the Cavendish Laboratory. In 1953 he was appointed international vice-chairman of the C.C.I.R. study group investigating the problems of ground-wave propagation.

G. MILLINGTON

D. H. Black, M.Sc., Ph.D., who for the past two or three years has been principal director of electronics research and development in the Ministry of Supply, has been appointed director of the Ministry's Armament Research and Development Establishment at Fort Halstead. Dr. Black has been in the Civil Service since 1939, before which he spent 14 years in industry, the last seven being with Standard Telephones & Cables. He was at R.R.D.E. (now R.R.E.), Malvern, for two years before being appointed in 1947 director of electronics research and development (defence) in the M.o.S. He held this post until 1953 when he went to Australia for two years as head of the United Kingdom Ministry of Supply staff in the Commonwealth.

C. H. Banthorpe recently became technical director of Central Equipment, Ltd., of which Derwent Television is a part. He joined the company in 1936 as a radio service engineer. Throughout the war he was at the Telecommunications Research Establishment, after which he returned to Central Equipment to take charge of radar production and test, transferring to television shortly before the B.B.C. transmissions recommenced. For several years he has been works manager of the Derwent factory at Perivale, Middlesex, and has been responsible for the designing of their television receivers since 1951.

W. E. C. Varley, Associate I.E.E., has been appointed by the B.B.C. assistant superintendent engineer (transmitters) on the retirement of **C. W. Skinner,** M.B.E., after more than 33 years' service. Mr. Varley joined the Corporation in 1933 as an assistant maintenance engineer at the Daventry transmitting station. In 1935 he was appointed assistant to the superintendent engineer (transmitters) in London. In this capacity he was responsible for the development and maintenance of precision equipment for the control of frequency of medium- and short-wave transmitters. He has carried out a number of broadcasting surveys in Africa and elsewhere on behalf of H.M. Government.

W. J. Phillips, for the past 18 years with Siemens Edison Swan in charge of their cathode-ray tube and valve life test department, has joined Perth Radios, Ltd., as works manager.

R. W. Addie, M.A., who joined E.M.I. Electronics six months ago as export manager, has been appointed to the board as marketing director.

P. G. A. H. Voigt, B.Sc., the well-known loudspeaker designer, who has lived in Canada since 1950, has been elected chairman of the Canadian Society of Music Enthusiasts, the aim of which is "to provide its members with a better understanding of both music and the technical means to attain its reproduction in high fidelity." Mr. Voigt's tape-recorded address given at the 21st anniversary celebration of the B.S.R.A. was repeated at a recent meeting of the Canadian S.M.E.

A. H. Dickinson, A.M.Brit.I.R.E., who was an assistant engineer in the B.B.C. research department during the war and since 1945 has been with Broadcast Relay Services as chief engineer in their overseas branches, has left the company to join the broadcasting section of the Colonial Office as chief engineer, Department of Information and Communications, British Honduras. He is well known for his work on the development of vertical incidence broadcasting.

D. L. Phillips, M.M., M.Inst.B.E., A.M.Brit.I.R.E., has resigned his appointment as works manager of Technograph Electronic Products, Ltd., the development and manufacturing company of Technograph Printed Circuits, Ltd. He will be undertaking consulting work and has been appointed consultant to Mills & Rockleys, Ltd., of Coventry. During the war he served as a technical signals officer in the R.A.F. Prior to joining Technograph he was in Plessey's components division at Swindon.

OUR AUTHORS

J. N. Prewett, M.A., Grad.I.E.E., author of the article describing a transistor test set, obtained-his degree in natural sciences at Clare College, Cambridge, and after serving for two years in the Royal Signals joined the Central Electricity Research Laboratories in 1953. At the laboratories he has been mainly concerned with electronic circuit designing.

S. Welldon, who in this issue discusses the use of the Zener diode as a voltage stabilizer for small motors, joined the research laboratories of the G.E.C. in 1947 where he initially worked on the development of equipment for the London-Birmingham television link. He has more recently been working on semiconductor evaluation and applications.

J. H. Jowett, B.Sc.(Eng.), who describes a photographic timer on page 385, recently joined the J. Langham-Thompson organization at Bushey Heath, Middlesex, as a trials engineer. After graduation at Bradford Technical College in 1952 he took a two-year graduate apprenticeship course with the G.E.C. at Coventry, and from 1954 until March this year was on the staff of the G.E.C. applied electronics laboratories. His interest in photography is purely as a hobby.

OBITUARY

Reginald Charles Bulgin, a director of A. F. Bulgin & Co., died on June 6th at the age of 52. He had been with the company since its inception in 1923, and was in charge of the Purchasing Department.

News from the Industry

75th Anniversary.—An exhibition to mark the progress of design in telecommunications over the past 75 years was organized last month by Standard Telephones & Cables who started business with a staff of three in Moorgate, London, in 1883 as agents for telephone apparatus. They now employ 25,000 at eight major factories throughout the United Kingdom.

B.T.M.-Powers-Samas Merger.—The British Tabulating Machine Company and Powers-Samas Accounting Machines have reached agreement in principle for a merger of their businesses. A new operating company will be formed to take over the undertakings of both companies.

Mullard.—A new division to be known as the Government and Industrial Valve Division has been formed, which will mainly embrace the former Communications and Industrial Valve Department and the Government Radio Valve Department. Head of the new division is H. St. A. Malleson. Within the new division four product groups have been established with a commercial manager in charge of each: electron optical devices (J. V. S. Tyndall), receiving valves (D. R. Rolinson), special industrial valves (K. F. Gimson), and transmitting and microwave valves (P. S. Britton).

Heath Kits, which cover receivers, amplifiers, test equipment, etc., are to be marketed in this country. Daystrom, Ltd. has been set up over here by Daystrom Inc. (Murray Hill, N.J.), of which the Heath Company is a subsidiary. Temporary factory accommodation has been secured in Gloucester and production is planned to start before the end of this year. George Tillett, formerly chief engineer and a director of Armstrong Wireless and Television, has been appointed chief engineer.

Ultra's turnover for the year ended last March was a record for the company with a net profit of £114,191, nearly double that of the previous year. In his report the chairman, Edward Rosen, said that "the diversified activities of the special products division are now larger than that of the company's founder business, radio and television."

Ever Ready.—The annual report of the Ever Ready Company (Great Britain) records that the net profit before taxation for the year ended March 1st was £1.926,303 compared with £1.797.810 for the previous period. Taxation will absorb nearly £1M. The report also states that 355 members of the staff have received gold watches for twenty-five years' continuous service with the company.

Evershed & Vignoles, Ltd., have established a Scottish area office at 13, Rutland Street, Edinburgh, 1. (Tel.: Fountainbridge 3058.) R. M. Wardrop, who for some years prior to joining the company in 1955, was in the G.E.C. Research Laboratories, is in charge of the office.

Cosmocord, Ltd., have set up a stereophonic test laboratory at their works at Waltham Cross, Herts. The company is producing a stereo cartridge (Acostereo) and is developing a combined cartridge for stereo, L.P. and standard records.

Winston Electronics, Ltd., have been appointed U.K. distributors of the Beckman-Berkeley (Richmond, Cal., U.S.A.) range of electronic equipment for industry.

Air Surveillance Radar.—The new Decca long-range air surveillance radar announced last month, was inadvertently quoted as operating in the 3-cm band. The D.A.S.R.1 operates on a wavelength of 10 cm.

Electronic Rentals Association, Ltd., has been formed by a number of sound and television receiver rental concerns "to promote the consideration and discussion of all questions affecting rental services . . .". The registered office of the association is at 75, Cannon Street, London, E.C.4.

Jason (France) has been formed by the Jason Motor and Electronic Company to manufacture high-fidelity equipment in France. The offices are at 19 Boulevard des Capucines, Paris, 2e. The company's first products will be the Jason J10 amplifier and the CQ speaker, which is being made under licence from CQ Audio, Ltd.

Vibration and shock testing service for potential users of isolating mountings is one of the activities of the new engineering laboratory of Cementation (Muffelite), Ltd., Molesey Road, Hersham, Surrey, who manufacture anti-vibration mountings under licence from Barry Controls Inc. (U.S.A.).

Simon Equipment, Ltd., has supplied a multichannel recording installation for the Central Electricity Generating Board in Manchester. It is capable of eighteen hours uninterrupted recording on four channels simultaneously and incorporates a time injection unit which superimposes time signals on all channels at one-minute intervals. The company also announces the appointment of J. A. Wright, previously with Ericsson Telephones and Siemens Edison Swan, as works manager.

Plessey's chemical and metallurgical division, at Towcester, Northants, has recently moved a section of its plant engaged in the production of ferromagnetic memory planes to a new factory at Water Lane, Towcester.

Philips' North-East Regional Headquarters are now at 72, Wellington Street, Leeds. The building includes a large lecture room, a showroom and a trade advice centre.

Murphy Radio v.h.f. mobile radio equipment was used by motor cycle travelling marshals during the Tourist Trophy races in the Isle of Man this year.

OVERSEAS TRADE

Britain in Europe Committee.—An organization under this title has been set up with offices at 61, Catherine Place, Palace Street, London, S.W.1 (Tel.: Victoria 4165) to promote interest in the proposed European Free Trade Area. Among the 50 or so members of the committee, of which Sir David Kelly is chairman, is C. O. Stanley, chairman of Pye, and D. Maxwell Buist, export director of B.E.A.M.A.

V.H.F. radio-telephone equipment has been supplied by Marconi's for the port of Karachi. Ten-watt f.m. transmitter-receivers have been installed in five harbour craft and there are three base stations.

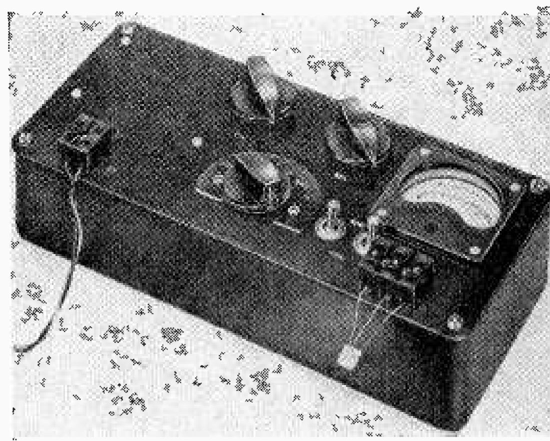
Data control system suitable for use with large skin-milling machines of the type used for manufacturing large aircraft components has been developed by E.M.I. in collaboration with the Cincinnati Milling Machine Co., of Ohio. Equipment for the system is being manufactured at Hayes for the Air Materiel Command of the U.S. Air Force.

V.H.F. equipment valued at £15,000, including 15 f.m. radio links, is being manufactured by A.T.E. (Bridgnorth), Ltd., for connecting the administration headquarters of the Bahrein Petroleum Company at Awali, Bahrein Islands, with the refinery, wharf and other locations.

Transistor Test Set

Measurement of Collector Leakage and Current Gain

By *J. N. PREWETT**, *M.A., Grad. I.E.E.*



External view of test set.

WHEN designing or maintaining transistor equipment, some means of measuring the "goodness" of a transistor is required. Ideally, six or more characteristic curves should be plotted and compared with the manufacturer's data. Since this operation is lengthy and involves the use of a lot of expensive equipment, a simpler means of testing transistors was devised.

The parameters measured are I_{cbo}, the collector leakage current with the base open circuit (also called I'_{co}), and β, the common emitter current gain with short-circuited collector (also called α'). The majority of transistor faults will show up on these two measurements. To avoid accidental damage to transistors under test, the measurements are made at fixed low values of current and voltage.

The following measurements may be made:

(a) I_{cbo} from 0 to 1 mA (V_{ce}=2·5 to 1 V depending on leakage current)

(b) β from 5 to 100 (V_{ce}=2·5V, I_c=1.3 to 2·3mA).

The equipment is suitable for testing p-n-p or n-p-n germanium junction transistors with up to about 200 mW dissipation. Silicon units may also be tested, but the measured value of β will be rather lower than the true value.

Measurement of I_{cbo}—The collector leakage current is not very dependent on voltage until the collector breakdown voltage is approached. For convenience, the measurement is made at a supply voltage of between 1 and 2·5 V, depending on the value of the leakage current. The basic measuring circuit is shown in Fig. 1. Should the transistor have a short circuit fault, R_5 will limit the meter current to 1·65mA.

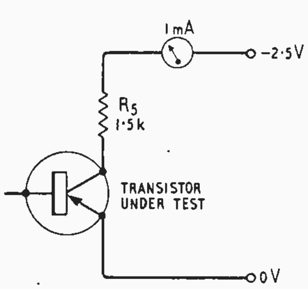


Fig. 1. Measurement of I_{cbo}.

Measurement of β—The method employed is to set up the transistor in a common emitter circuit, so as to pass 1·3 mA collector current. If the base current is now increased by i, the collector current will increase by βi, assuming that the value of β does not change when the collector current is increased. In practice there is a small variation of β, but this does not greatly affect the measurement. If we make i=10 μA, and allow for a maximum value of β of 100, then βi = 1 mA when β = 100. Provided the initial 1·3 mA collector current can be backed off, the increase in collector current may be displayed on a 0 to 1 milliammeter calibrated 0 to 100, so that β may be read directly.

Fig. 2 shows the circuit used to measure β. With S1 open, the collector current is controlled by RV_1 which adjusts the base current. When I_c = 1·3 mA, the voltage drop across the collector load R_3 is such that V_c = 2·5 V. Since both sides of the milliammeter are now at the same potential, no current can flow through it, and it will read zero.

When S1 is closed, an additional 10μA (2·5V/R_1 approximately) will flow into the base, increasing the collector current by 10β μA. If the meter resistance is very much less than the collector load resistance, all the additional collector current will flow through the meter. Since the meter has a 1-mA movement, and is calibrated 0 to 100, the meter reading now gives the value of β.

When using this method of measurement, there are a number of small errors, most of which can be eliminated or reduced. The sources of these errors are: (a) the meter, (b) the current i through R_1, (c) the fraction of i injected into the base of the transistor due to finite base resistance, (d) the fraction of the increase in the collector current which passes through the meter, determined by the meter resistance and internal resistance of the 2.5 V source and (e) the variation of β with collector current.

If a small ex-Government meter is used, there may be up to 10% error on the full scale reading of the meter. This error may be eliminated as follows. The meter, in series with a 2·5-kΩ, 1% tolerance, high-stability resistor is placed across the 2·5-V and 0-V points, and the voltage of the 2·5-V source adjusted for full scale deflection. If the meter reads 10% high, say, the 2·5-V source will be 10% below its nominal value (neglecting the meter resistance compared with 2·5 kΩ). Reverting now

* Central Electricity Research Laboratories.

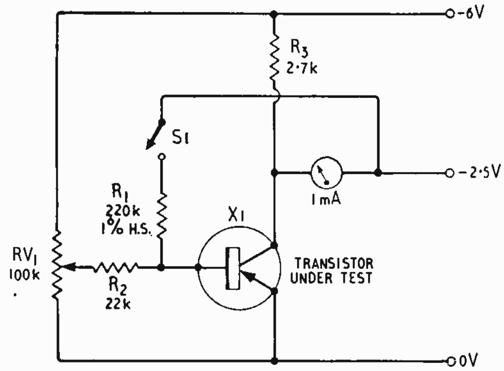


Fig. 2. Measurement of β.

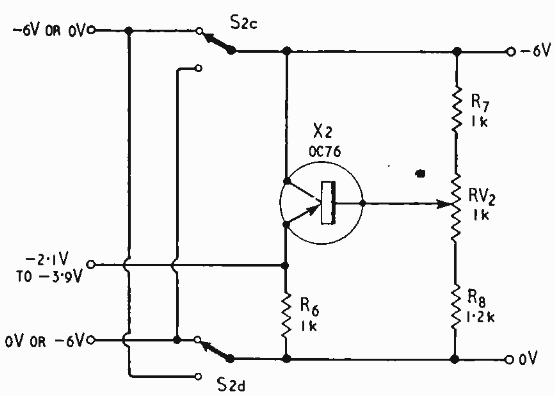


Fig. 3. Voltage supplies.

to Fig. 2, the current flowing through R_1 will be 10% low, and the additional collector current will be 10% low. But as the meter reads high by the same amount, the error will be corrected.

For the majority of transistors under test, the base-emitter voltage will be approximately 0·15 V, and the input slope resistance of the order of 1,000 Ω. Thus the current flowing through R_1 is only $(2{\cdot}50-0{\cdot}15)/R_1$ instead of $2{\cdot}5/R_1$. Also a small percentage of this current flows up R_2 instead of into the transistor base, the amount depending on the position of RV_1. Furthermore, at the collector, the meter plus source internal resistance will be about 100 Ω (meter resistance about 80 Ω), so that a small percentage of the additional collector current flows up the load resistor R_3 instead of through the meter. The error due to these three causes gives a meter reading which lies between 10 and 14% low for most transistors. Therefore, the value of R_1 should be reduced by, say, 12% of its value calculated from the simple theory. The simple theory requires 10μA to flow with 2·5 V across R_1.

i.e. $R_1 = 2{\cdot}5/10 = 0{\cdot}25\text{M}\Omega$

The corrected value is therefore given by 88/100 × 0·25 MΩ = 220 kΩ. This is a preferred value and a 1% tolerance, high-stability type should be used.

The error due to variation of β with collector current can only be estimated from published data on the transistor type under test. The error should be negligible for small amplifying types having a maximum collector current of 10 mA. In the case of transistors designed for class-B audio output stages or for switching, such as the OC72 and OC76, the maximum value of β occurs at about 4 mA collector current, and the value of β measured on this test set may be 10 or 20% below the maximum.

Supplies.—The supply voltages required for testing a p-n-p transistor are:

Collector load supply = −6 V
Meter supply = − 2.5 V
Emitter supply = 0V

The corresponding voltages for an n-p-n transistor are:—

+ 6 V, + 2·5 V, 0 V } which may be expressed as { − 0 V, − 3·5 V, − 6 V

Therefore, to be able to test both p-n-p and n-p-n transistors, it is necessary to be able to change over the polarity of the supply to the collector load and the emitter, and to adjust the meter supply between, say, −2.1 and −3.9 V. The extra range of adjustment allows for battery voltage deterioration and the setting up procedure for eliminating meter errors described above. The meter supply may be obtained from a low-resistance (100 Ω) potentiometer passing 60 mA, or from an emitter follower having a total circuit drain of about 5 mA. For the same low output impedance of about 25 Ω, the latter system has the obvious advantage of very much lower current drain.

The basic circuit is given in Fig. 3. The base potential of transistor X2 is controlled by the CALIBRATE potentiometer RV_2. The emitter potential of X2 remains a small fraction of a volt more positive than the base for tens of milliamperes change in emitter current. The emitter of X2 is therefore a low impedance source, and is ideal for supplying the meter. With the circuit values shown, the emitter output impedance is about 25 Ω.

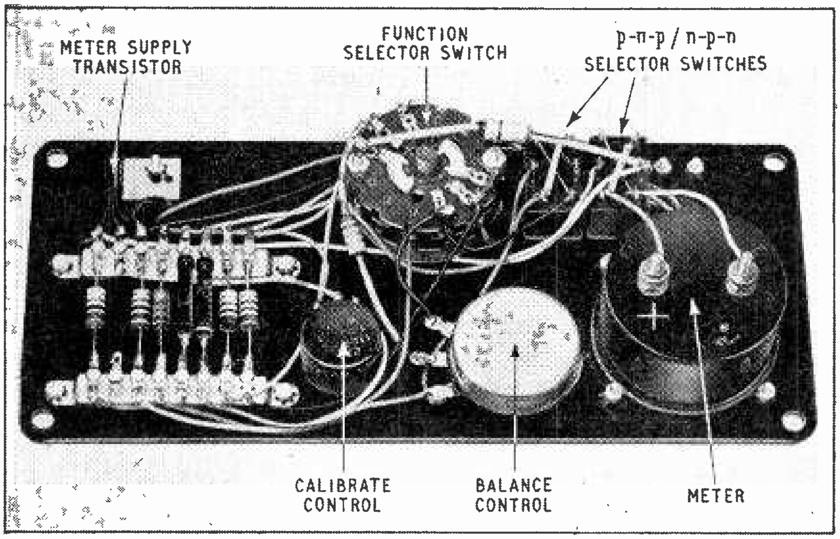
S2 is a reversing switch. Since the meter supply current flows in opposite directions for p-n-p and n-p-n transistors, a reversing switch must also be provided for the meter.

Complete Test Set.—Fig. 4 shows the circuit diagram of the test set, which incorporates the circuits of Figs. 1, 2 and 3, with additional switching.

S2 is a 4-pole change-over switch whose position is selected for p-n-p or n-p-n transistors. S1 is a combined on/off and function selector switch. It was considered that the set would be less likely to be left on after use if the on/off switch was combined in this way. The functions of the switch positions are as follows:—

Position 1: Battery off.
Position 2: Meter supply voltage can be set up by RV_2 (marked CAL. or CALIBRATE).
Position 3: Circuit of Fig. 1 is set up, and I_{cbo} can be read from the meter.
Position 4: Circuit of Fig. 2 (with S1 open) is set up, and RV_1 (marked BAL. or BALANCE) is adjusted for zero meter reading.
Position 5: An additional 10 μA is injected into the base of the transistor being tested and the value of β can be read directly from the meter.

Where it is intended to operate the test set from a 4½-V battery, the value of R_3 should be reduced to 2.2 kΩ. β will now be measured in the collector



Layout of components on underside of panel.

current range 0.9 to 1·9mA if the meter supply voltage is still fixed at 2.5 (i.e. 2V ac-oss R_3).

Materials and Construction.— The test set was built on the underside of the lid of a box 9in × 4in × 2in as shown in the photographs. The layout may be varied to suit the size and shape of box used. If the set is likely to be standing idle for long periods it is best to use an external battery, since a burst cell in the same compartment as electronic equipment may cause considerable damage.

The function selector switch S1 is a 4-pole 5-way Yaxley switch. The wiper of S1a must be double width, so that when it is in position 5, number 4 contact is still made. The wiper of S1c should preferably be non-shorting when changing switch positions. The p-n-p/n-p-n selector switch S2 may either be two adjacent double-pole change-over toggle switches, or a Yaxley switch. If the latter, the wipers must be non-shorting, to avoid damaging the battery when changing from p-n-p to n-p-n. Alternatively, a three-position Yaxley switch may be used with a dummy middle position (in which the battery will still be on).

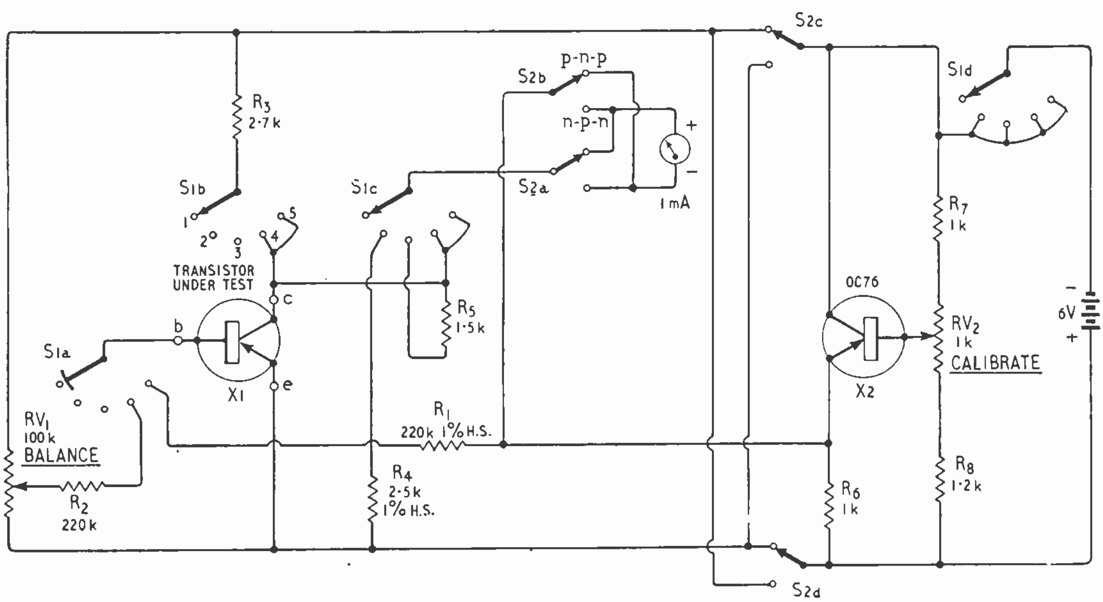
The meter may be a small robust ex-Government meter calibrated 0 to 1 mA. It is so easy mentally to sub-divide the scale into 100 parts, that it is barely worth marking it specially to read β.

An OC76 has been chosen for X2 because at the time of writing it is one of the most suitable transistors on the market, and is also reasonably priced. An OC72 is equally suitable if one is available, but any small transistor (other than a sub-miniature type) whose β is greater than 30 will be satisfactory.

R_1 and R_4 should be 1% tolerance high-stability carbon resistors. Selected 5% or 10% tolerance resistors may be used instead, but the accuracy of the set may be affected as the resistors age. All the remaining resistors are ¼-watt, 10% tolerance.

5-amp terminal blocks are used to bring in the battery supply and for connecting the transistor under test. The physical connections to emitter, base and collector are the same, whether a p-n-p or n-p-n transistor is being tested. The battery used is type

Fig. 4. Circuit diagram of test set. All resistors ¼ watt, 10% unless otherwise marked.



L15 Drydex hand-lamp battery or equivalent.

Operation of Test Set.—Connect the battery with the correct polarity to the test set. Incorrect connection will not damage the test set, but will be made obvious by the negative reading on the meter when the function selector switch is turned to CALIBRATE.

Set the polarity switches to p-n-p or n-p-n as required. Incorrect setting will not damage the transistor under test, but the current measured will be the emitter leakage current I_{ebo}, which is usually very much less than I_{cbo}. In addition, it is unlikely that the meter will be able to be set to zero when the function selector switch is turned to BALANCE.

Insert the transistor to be tested into its socket. Changing over emitter and collector connections will not damage the transistor, but due to the very low value of β when the transistor is operated in this connection, it is unlikely that the meter will be able to be brought to zero.

Turn the function selector switch to CALIBRATE, and adjust the CALIBRATE potentiometer RV_2 for full scale deflection on the meter.

Turn the function selector switch to I_{cbo}, and read off the value. For most transistors at room temperature it will lie between 10 and 400 μA. If the meter goes off scale, short together the emitter and base leads. If the meter reading falls to a very low value, the transistor is a satisfactory amplifying device, but care should be taken only to use it in circuits incorporating a high degree of d.c. stabilization of the transistor working point. If the meter remains off scale, the collector-base junction has been damaged and the transistor is useless.

Turn the BALANCE control fully anti-clockwise to avoid damaging the meter and the transistor at the next stage of testing. Turn the function selector switch to BALANCE, and adjust the meter to zero with the BALANCE control RV_1.

Turn the function selector switch to β, and read off the value of β on the meter (f.s.d. corresponds to $\beta = 100$).

Turn the function selector switch back to OFF, and remove the transistor under test.

Results.—A V10/30 and an OC72 had their β values measured both on this test set, and on an a.c. test rig. In the latter case, a 1-μA, 1,000-c/s current was injected into the base of the transistor under test, and the voltage across a 330-Ω resistor in the collector circuit was measured to obtain the a.c. collector current. The measurement was made with the d.c. conditions as close as possible to those in the test set, i.e. $V_{ce} = -2.5$ V, $I_c = -1.5$ mA. The estimated maximum error of the value of β measured by the a.c. method is 4%.

TABLE 1

Transistor	Measured value of β	
	D.C. Test Set	A.C. Test Set
V10/30 ...	45	43
OC72 ...	72	70

The values of β obtained by the two methods are given in Table 1.

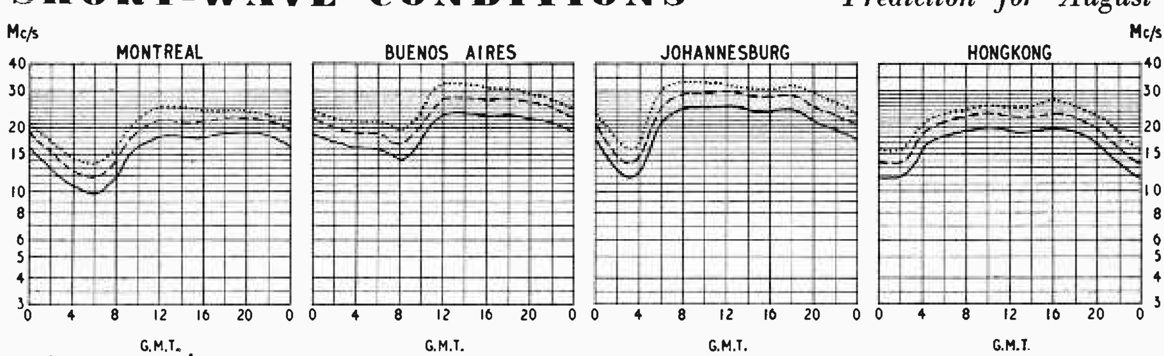
The agreement between the two methods is considered to be quite satisfactory, especially as the primary purpose of the d.c. test set is to check transistors rather than to make accurate measurements of their characteristics.

To test the sensitivity of the test set to battery voltage changes, several transistors were tested using a 4½-V battery, and the values of β compared with those obtained with a 6-V battery. It was found that the former values were less than 5% low for small transistors, and less than 10% low for low-power transistors. This lowering of the measured value of β is caused by the lowering of the actual value of β due to the fall of the initial value of collector current from 1.3 mA to 0.75 mA.

Conclusions.—The test set described in this report will measure the collector leakage current and current amplification factor of transistors with up to 200 mW collector dissipation with sufficient accuracy to determine their suitability for a particular circuit. It can be constructed quite cheaply, is simple and virtually foolproof in use, and has proved its worth over the last eighteen months.

SHORT-WAVE CONDITIONS

Prediction for August



THE full curves given here indicate the highest frequencies likely to be usable at any time of the day or night for reliable communications over four long-distance paths from this country during August.

Broken-line curves give the highest frequencies that will sustain a partial service throughout the same period.

·········· FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE FOR 25% OF THE TOTAL TIME

— — — PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY

——— FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE ON ALL UNDISTURBED DAYS

Doppler Effect in Radio and Radar

2.—Practical Applications

By N. M. RUST

THE determination of velocity by Doppler effect has been in the news recently as a result of its use by the traffic police in Britain, America and on the Continent for detecting violations of the speed limits. In this application the direction of motion is self-evident, so no special means of directional discrimination, as discussed last month, is required.

Another topical application in which the direction of motion is self-evident is the measurement of the velocities of artificial satellites of the earth. The author is not aware of any published information on this, but it is presumed that coherent pulse methods would be used. This means that the radar pulses, instead of being "self-oscillating," are derived from, or locked to, a drive of very stable frequency. The oscillations in each transmitted pulse are thus coherent with this drive, and the received pulses form a group of oscillations that can be made to beat with the drive oscillations, forming a Doppler note when the target is moving. If the Doppler and pulse repetition frequencies are integrally related, interference effects take place that result in "blind spots" at the corresponding radial velocities.

Range information can be obtained with c.w. Doppler radar by several different methods. The most obvious way would seem to be to combine Doppler indication with f.m. radar. D. C. G. Luck describes a use of this in "Frequency Modulated Radar" (McGraw-Hill, 1949). A triangular frequency sweep cycle is employed, and use is made of the fact that the Doppler shift raises the f.m. beat frequency on one stroke of the triangular frequency sweep, say the upward, and lowers it on the other, say the downward, or vice-versa according to the direction of motion. The principle is illustrated in Fig. 1. This method was actually used in apparatus developed for the American air force in the war as a bomb-release device. It was set up in accordance with the speed and height of the aircraft, and was claimed to be effective in securing a high percentage of hits.

Another method* is applied with a sawtooth frequency modulation sweep. In principle this is very similar to a coherent pulse system. A small section of the beat note is examined with a short gating pulse recurring at the sawtooth repetition frequency. Stationary targets produce steady signals, whilst moving targets give an output that is amplitude modulated at the Doppler note frequency.

Fig. 2 illustrates this method: (a) shows successive sawtooth frequency sweeps, and the position of a short gating pulse which occurs at exactly the same part of the sawtooth sweep on every stroke; (b), (c) and (d) show what happens stroke by stroke, to a very much larger scale. At (b), for fixed targets, exactly the same part of the beat note cycle is intercepted each time, and there is no output component within the range of the Doppler frequency filters used. At (c), owing to approach motion there is a progressive advance in phase of the beat note part intercepted by the gating pulse and there is consequently an a.c. output acceptable to the Doppler filter. The filtered output is shown at (e) by the full line. At (d) is shown a similar stroke-by-stroke phase shift for a receding target: the gating pulse sees a progressively retarded beat note phase. The filtered Doppler output is now of opposite phase, as shown by the dotted line in (e).

The range is defined by the beat note frequency. As the beat note will in practice be much higher in frequency than the Doppler note, the Doppler

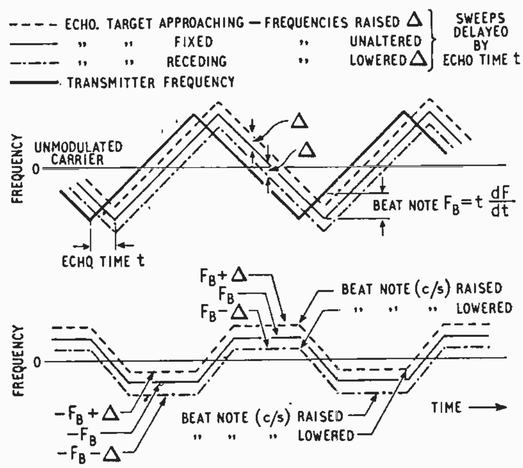


Fig. 1. Principles of a system combining Doppler indication with f.m. radar for range measurement. Above is the triangular frequency sweep and below is the variation of beat note on the same time scale.

shift of beat note is not sufficient to affect the accuracy of the range display. Range can therefore be displayed in the manner normal for frequency modulated radar. Analysis of the Doppler note defines the target velocity. This method produces "blind spots" when the Doppler note is a multiple of the frequency modulation repetition frequency, in the same way as a coherent pulse system does in relation to the pulse repetition frequency.

Amongst other methods which might be mentioned, two are of special interest as illustrating general principles that may find useful application. The first may be described as the two-frequency method. Going back to the illustration used in last month's article on general principles, the phase indicator can record radial distance in half wavelengths. If it is impracticable or inconvenient to count the number of turns representing half wavelengths, there is no means of determining the radial motion if it is over one half wavelength. Furthermore, even if the distance moved radially could be recorded in this way, in most cases the initial conditions would remain unknown, and hence the absolute range cannot be defined.

* British Patent 660,631.

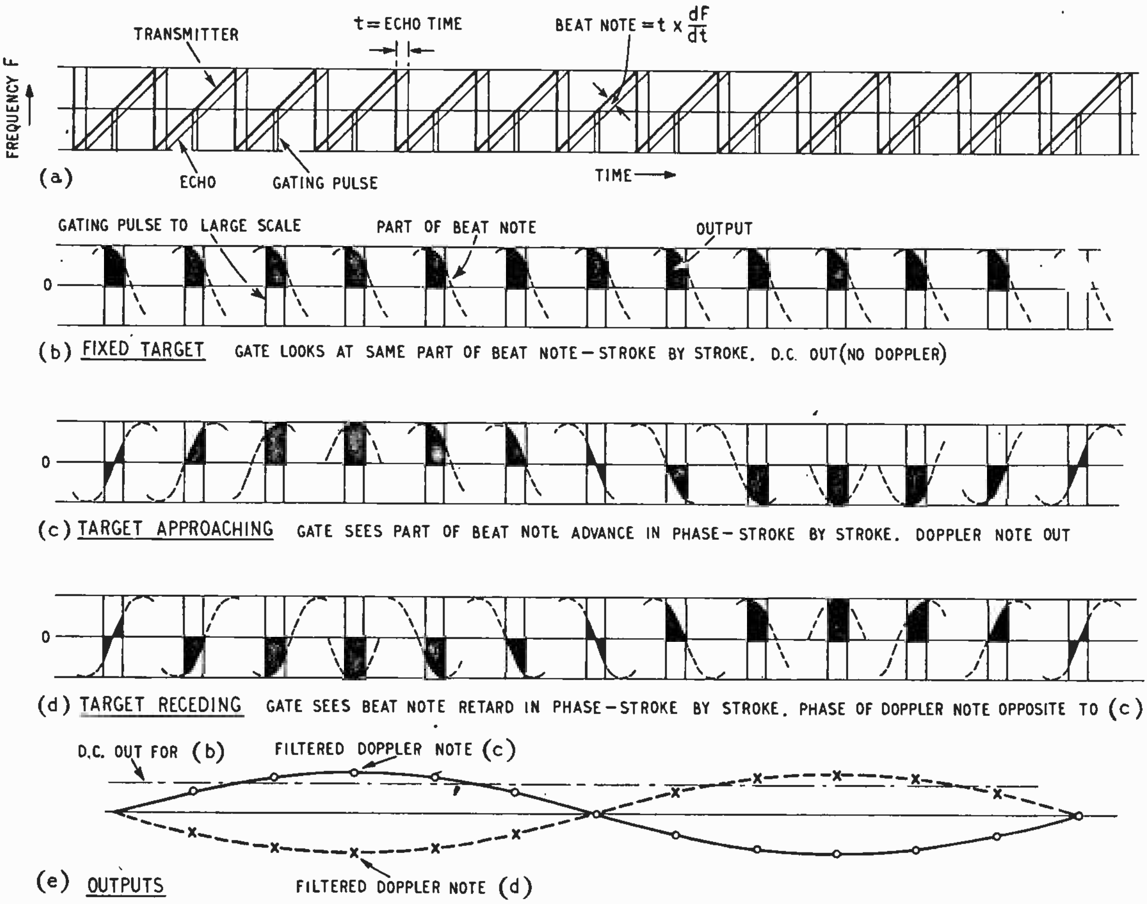


Fig. 2. Another system for range measurement combining Doppler with frequency modulation. Diagrams (a), (b), (c), (d) and (e) are explained in the text.

Both these objections can be overcome by radiating a second, slightly different frequency. As the relationship between Doppler phase and range is linear for all transmitted frequencies, it is apparent that the differences of phase between the Doppler notes from a double frequency source must also be linear with respect to range. Fig. 3 illustrates this. Now if frequencies are chosen so that this difference of phase just reaches one complete phase cycle at a given radial distance of the target, we can make radial measurements within this range by extracting the Doppler note for each frequency separately and then measuring the phase difference between these Doppler notes. The range is then proportional to the phase difference.

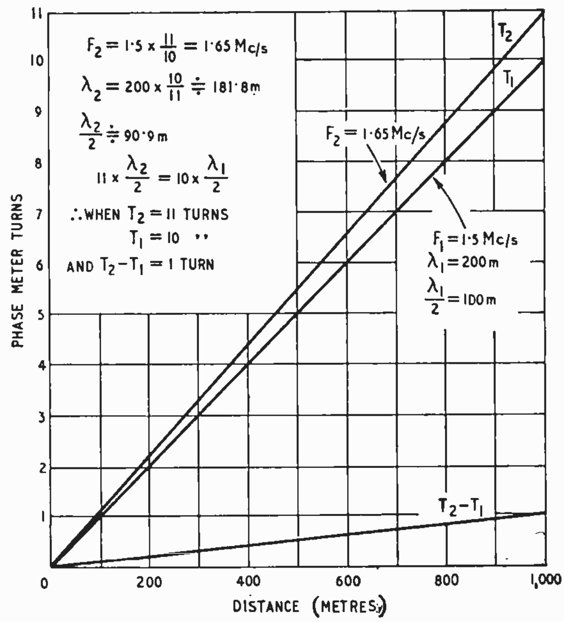
There is a very simple numerical relation which gives the correct range scale factor. The fraction of a cycle difference in phase between the Doppler notes directly represents the fraction of one half-wave radial distance moved, for the wavelength corresponding to the frequency difference between the transmitted frequencies. Thus if we wish to measure ranges up to 15km without ambiguity, we must make the frequency differences correspond to a wavelength of 30km. The frequency difference must then be 10kc/s, and the phase meter will read to a scale of one turn equals 15km radial distance.

The other method was originally proposed by the late E. H. Armstrong, and was tried experimentally for long-range radar. He adapted his f.m. radar station at Alpine, New Jersey, for the purpose. It has subsequently been developed in this country by Marconi's*. This method of range determination goes back to Newton, but was used by him in the opposite sense to determine the velocity of sound. It is related that in a college quadrangle at Cambridge he clapped his hands at a steady rate which he adjusted until he could not hear the return echo from the quadrangle wall, as it synchronized with the direct clap sound. The time interval between the hand claps was thus made equal to the time taken for the clap to reach the wall and return. As the distance from the wall was known, the speed of sound was directly calculated. If he had known the speed of sound he could equally well have calculated his distance from the wall.

Armstrong's experiment was carried out by frequency modulating his transmitter, sinusoidally, with an oscillation whose frequency he could control. Moving targets then gave a clear, uninterrupted Doppler note (corresponding to the radial target velocity and the wavelength radiated) when the modulation frequency was adjusted so that the radar return arrived exactly one modulation period later than the transmitted cycle. The range was then equal to half of the wavelength corresponding to the modu-

* British Patent 620,568.

Right:—Fig. 3. Doppler range measurement using two frequencies, f_1 and f_2. This graph shows that the phase difference between the Doppler notes (T_2-T_1) is also linear with respect to range.

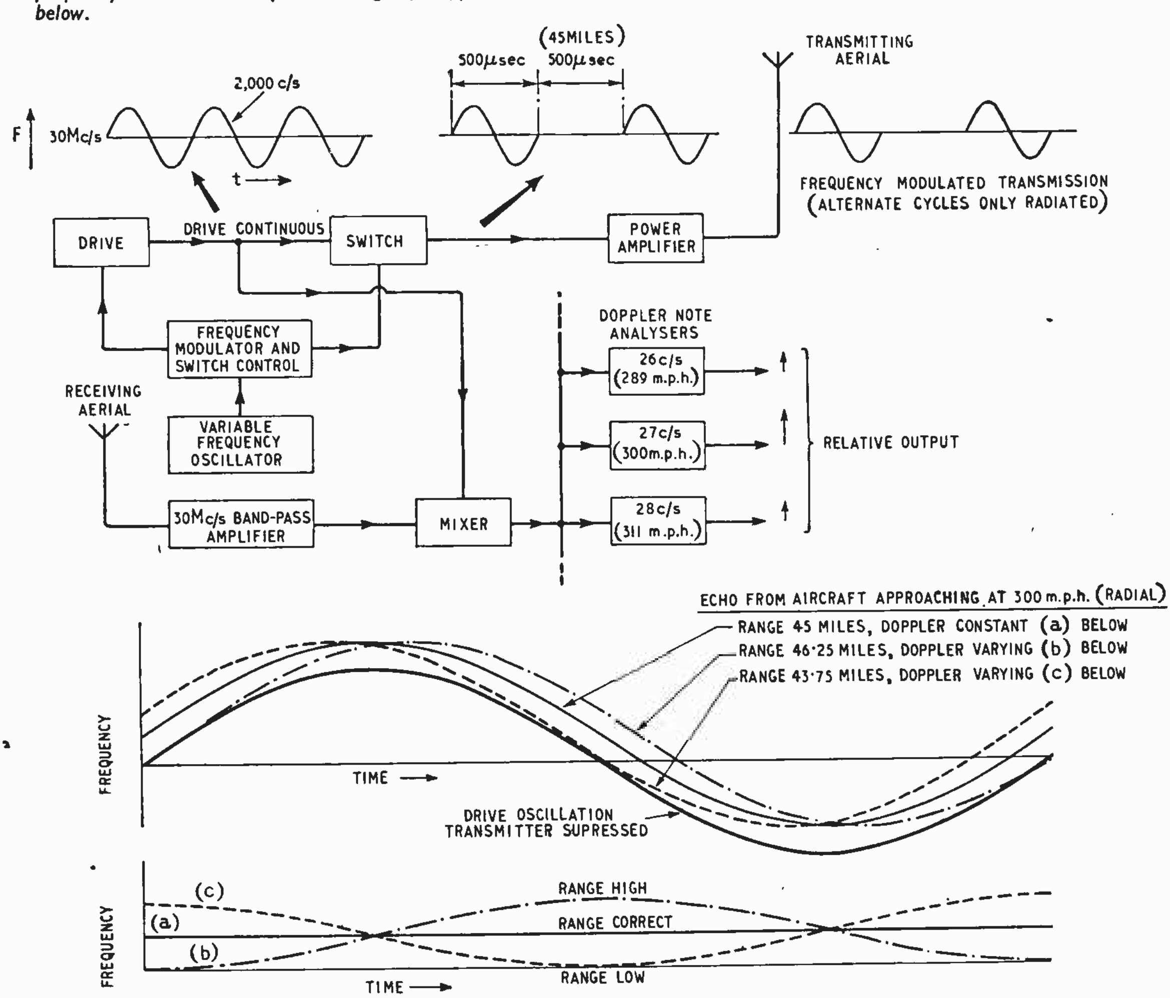


lation frequency. The Doppler note determined the target radial velocity in the normal manner.

Fig. 4 shows, in principle, how Armstrong carried out his experiment. To avoid difficulties due to the transmitter blotting out the echo signal, only alternate frequency-modulated cycles were transmitted, although the drive circuit carried on without interruption. Adjustments of modulation frequency were made until the echo signal from a transmitted cycle just fell on top of the next non-radiated drive cycle. When correctly synchronized, as the diagram shows, the Doppler note is steady. When not correctly synchronized the beat note is wobbled, and the response from the Doppler analyser is therefore greatly reduced.

An interesting point about this method is that, so long as each frequency modulation cycle is made the same as the preceding one (whatever modulation waveform is used), the Doppler note is exactly the

Below:—Fig. 4. E. H. Armstrong's radar system involving Doppler indication. A block schematic of the transmitting and receiving equipment is shown above, with the frequency modulation sweep and change of Doppler notes below.



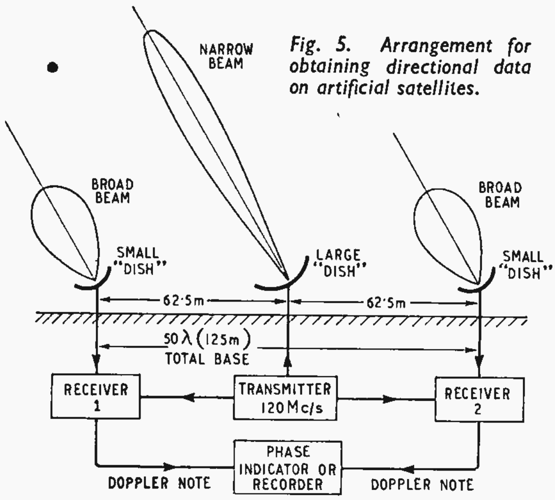


Fig. 5. Arrangement for obtaining directional data on artificial satellites.

same as if the carrier had not been frequency modulated, if the repetition frequency is correctly synchronized. Any alteration from synchrony tends to break up the Doppler note. The sensitivity to the break-up effect is dependent principally upon the frequency deviation of the modulation. As a result of this the range selectivity can be controlled by varying the deviation.

A very simple, single-target radar system can be devised, in which, when a Doppler response is heard, the frequency is modulated with a small deviation cycle (at first). After the approximate range has been found (by increasing the modulation frequency from the value representing the maximum range until the Doppler note is uninterrupted), the deviation is increased to measure the range more precisely. Finally, with the full deviation available, a setting will be obtained in which a very slight alteration of frequency to one side or the other will obliterate the Doppler note. The main practical difficulty in the use of this principle is to adapt it to multi-target use. Velocity and range resolution have to be performed simultaneously, and the design of a practical method of displaying the information clearly becomes difficult.

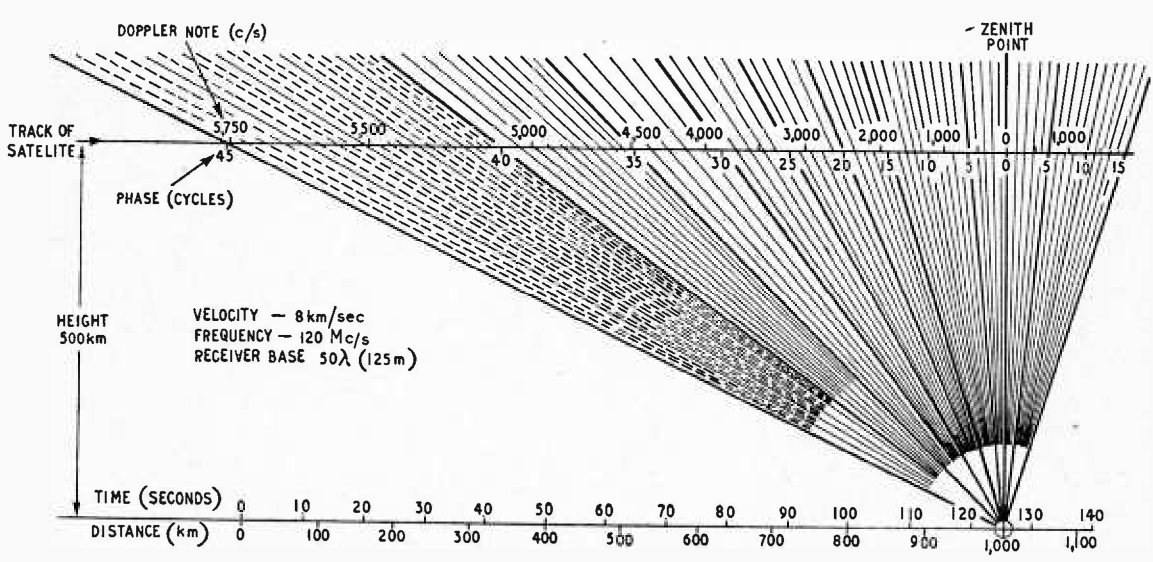
A principle that can be employed for the very precise discrimination of direction is that the instant-by-instant phase of the Doppler beat note is determined by the instant-by-instant relative phase of the transmitted and received oscillations. This enables the phase comparison of two Doppler notes, originating from the same transmitter and received at points separated in space, to be used as a very convenient means of determining the corresponding high frequency phases. This provides very precise directional information when the receiving points are many wavelengths apart.

By the use of u.h.f. or microwaves very high discrimination can be obtained with quite short bases, and when necessary ambiguities can be resolved by the use of auxiliary shorter bases. Moreover, the results obtained have an advantage over the ordinary multi-lobe interferometry technique as applied, for example, with the Cambridge interferometric aerial for tracking the "sputniks." This advantage lies in that not only does the phase comparison define the position of the lobe maxima and nulls (by noting the in-phase and anti-phase positions), but also the exact position in any part of a lobe may be determined by the measurement of relative phase at intermediate points.

The possible application of this principle to provide accurate data for the determination of satellite orbits is interesting enough to warrant an illustration. Fig. 5 shows an arrangement that could be used, and in Fig. 6 the track of a satellite is plotted in relation to the lines that indicate the relationship of phase of the Doppler notes. Fig. 5 shows a big "dish" for the transmitter (radiating 120 Mc/s c.w.). Smaller "dishes," giving relatively broad beams in order to facilitate tracking, are used at the spaced receivers. The transmitter oscillation is fed to the receiving points, and the Doppler note obtained by beating it with the signals is fed back from both receivers to

(*Continued on page* 377)

Fig. 6. Track of a satellite plotted in relation to lines indicating phase relationship of Doppler notes.



the centre of the base. The notes are then compared in phase, either by a Lissajous figure method using a c.r.t. display, or preferably by a Decometer* type of phase-meter. With the arrangement shown, and a satellite flying at 8km/sec at a height of 500km, one complete cycle of phase change between the Doppler notes takes just over a second when the phase is changing at the fastest rate, so that such an arrangement should be practicable. It would be of advantage to record and count the beats of the interacting Doppler notes on a tape recorder, with auxiliary time markings.

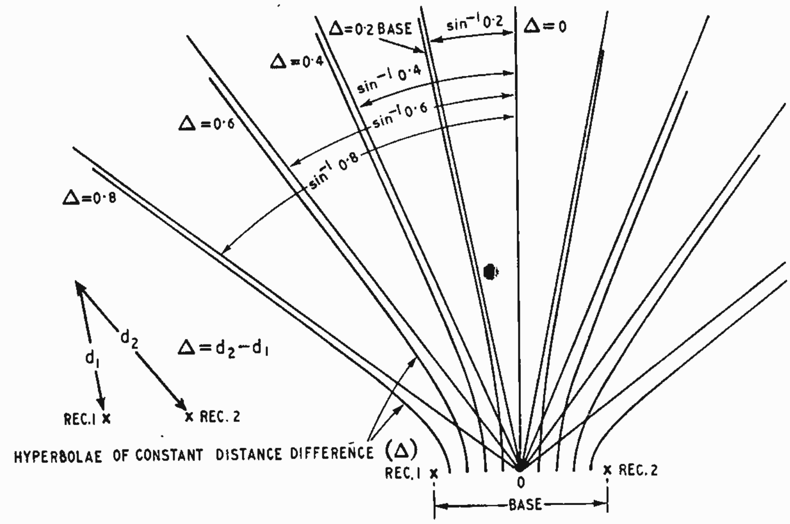


Fig. 7. The hyperbolæ of Fig. 6 shown in more detail at the base between the two receivers (Fig. 5).

The grid lines of Fig. 6 are really hyperbolæ of similar nature to those used for hyperbolic navigation systems. As the distance of the track from the base is very big compared with the base, the hyperbolæ have, for all practical purposes, merged into straight joining at the centre of the base. This is illustrated in Fig. 7, which shows the slope of the grid lines near the base to a very big scale compared with Fig. 6. In Fig. 6 the Doppler notes for a straight line track of constant height are shown above the track. The phase difference between the two notes is marked cycle by cycle under the track line, starting from the zenith point as a reference. It will be seen that in moving from a distance of 1,000km to the zenith point 45 beat cycles are swept through. It would be quite practicable to record or note the quadrature points in these cycles up to about 500km from the zenith.

Velocities can be determined by analysis of the beat notes before mixing. A complete set of data could thus be obtained for orbit calculation. This could easily be supplemented by very precise range data, obtained at definite intervals (using the Armstrong method) by frequency modulating the transmitter with a very accurately known frequency, using a relatively big frequency deviation, and noting the very sharply defined instants at which the Doppler note was pure. It should be added that, for the purposes of the illustration, the curvature of the earth was not taken into account although it would affect matters considerably in practice.

The *Wireless World* article by G. E. Beck referred to last month ably deals with an aeronautical application in which Doppler effect is used to determine the true ground speed and drift angle of an aircraft in flight. An interesting application of the method described might prove possible for marine navigation in coastal waters, by using underwater echo-sounding technique. Barium titanate transducers make it possible to produce the requisite sharp beams, but as relatively high frequencies for echo-sounding purposes would have to be used, the depth of range would be restricted. Certain extreme conditions which induce the production of layers of warm or cold water might cause errors at times due to ray bending effects.

Such a system would provide a ship's log that gave valuable data for coastal navigation. Besides true distance run, "ground" speed, drift velocity, true course, and drift angle could be indicated.

Towards the end of the last war the Germans used a secondary radar application of Doppler for the control of V2 missiles. A continuous wave signal was radiated from the ground control station. This was received by the missile in flight, doubled in frequency and re-radiated. These signals were then picked up by the ground station and mixed with a signal derived from the signal transmitted from the ground by frequency doubling. The Doppler note thus obtained, as a little consideration will show, was exactly the same as if the doubled frequency signal had been radiated and returned as an echo. The signal-to-noise ratio was very much better than for primary radar because of the detection and re-radiation at the missile, and allowed the Doppler beats to be counted without errors. As has been pointed out above, the "integrated Doppler" obtained in this way gives a direct method of measuring the radial distance traversed by the missile—this being directly proportional to the number of beats counted. Controls were set so that when the missile reached the required height in its take-off track, as defined by the number of beats counted, the missile was set off on its target course.

A German concern has exploited the same principle for harbour and river echo depth sounding surveys. In this case the transmitter and beat recorder are placed on the vessel carrying out the survey. The repeating station, which can be portable, is set up at a convenient place ashore. The distance-moved data is supplemented by d.f. bearing information obtained from the repeater signal. An accurate position fix of the vessel is thus obtained at each sounding position.

It seems obvious that this secondary radar method could be adopted for air navigation purposes. It has the advantage over most other navigational methods of giving a direct indication of velocity.

The writer gratefully appreciates permission given by the Marconi Company to refer to work carried out whilst in their employment.

* As used in the Decca Navigator system.

Servicing American Car Radios

By *JACK DARR**

NATIONAL characteristics seem to differ widely in the way in which each ethnic group meets adversity: the British confront their daily difficulties with the impassive countenance and the world-renowned "stiff upper lip"; the French shrug them off with an insouciant "C'est la vie". The Yank, on the other hand, loves to "maximize" his troubles. "So you think *you* got troubles? Boy, lemme tell you what happened to *me* the other day. Why, I . . .", etc., etc. The following is a typical example of this national characteristic. In defence of countrymen and self, I must contend that one segment of the American radio maintenance industry really seems to have an undue amount of troubles. I refer, of course, to those inverted brethren who make what they laughingly refer to as a living servicing, or attempting to service, the modern automobile radios. A situation which was fairly bad in the beginning has rapidly grown worse: from the merely difficult, we have gotten to the improbable stage, and in some cases, to the entirely impossible! We are apparently faced with an organized conspiracy to render it as difficult as possible for us to do a service job! (The reference above is to an old saw of these parts, which reads, "only acrobats and auto-radio mechanics have to stand on their heads to make a living!")

A DIFFICULT JOB MADE IMPOSSIBLE!

As concisely as possible, the subject of this diatribe will be the difficulty we find in removing the radios from modern U.S. automobiles. Although the writer is comparatively inexperienced with respect to English cars, having encountered only the ubiquitous M.G., Triumph, Morris Minor, and a few others, mostly in the sports-car class, he is quite certain, in the good old American tradition, that no vehicle, British or any other, could possibly offer as much trouble as any American product, selected purely at random!

Auto-radios have been quite troublesome for years past. In the beginning, about 1928, they consisted of a large box (the radio) on the firewall, or, as you would say, the bulkhead, another large box (the speaker), a control head on the dash, connected with a variation of the Bowden shaft and, finally, another larger box, usually beneath the chassis or seat, which held the h.t. batteries! Later models developed into one box, including speaker, on the firewall, with the control head on the dash. After this came the single-unit models mounted in the instrument panel, containing all the parts. It was at this point in history that the devil reared his ugly head!

Cleverly designed to fit into the restricted space available, they were marvels of performance, sensitivity etc. (if you could just get the ignition noise out of the little beasts!), but they were becoming just a touch hard to get in and out. Now, the fiendish intent of the designers began to dawn upon an unsuspecting group of technicians: with forebodings, they glumly studied the future, appalled by what they could foresee! If they had been blessed with *accurate* foresight, only 10 short years ago, there would be *no* old-timers in the auto-radio business today! They would have resigned *en masse* and gone back to raising rhubarb! Not being endowed with the giftie, however, they remain, hopelessly striving to wrest a pittance from one of the most cantankerous and infuriating mechanical devices ever invented!

Allow me to state, at this point, that the target of my slings and arrows is absolutely *not* the gentry who design the sets themselves: the quarry I am baying is that group of unco-operative idiot-savants, in Detroit and elsewhere, who "design" the instrument panels and dashboards of the vehicles! Let us, as briefly as possible, set forth a few indisputable facts in the case: even the most ardent partisan of said fiends in human form cannot disput their veracity!

Question: Of the many gadgets festooning the instrument panel of the modern car, which one requires the most frequent service attention, many times more than all other parts together, during the life of the car?

Answer: The radio, of course.

Question: Of the above-mentioned units, which is the most difficult and inaccessible for servicing?

Answer: The radio, of course!

(Proof: the radio is installed firmly in the centre of the dash, as near the top as possible. Below it are the glove pocket, heater controls, ashtray and as many pieces of ductwork, levers, Bowden shafts, dash-braces (of heavy metal), brake levers, etc., as can be crammed into this restricted space. In a normal car, about 75% of these must be either removed completely or loosened and swung aside in order to allow very limited access to the radio.

Question: But surely these chaps have allowed enough room for the radio to be removed easily, after these impedimenta have been loosened up?

Answer (by many thousands of disgruntled U.S. servicemen): HAH!

Question: But isn't it possible to change tubes, vibrators, and so forth, by taking a lid off the case, without havin' to pull the whole bloomin' set?

Answer (by same group): You're joking of course.

(Author's note: Once upon a time, it was. This seems like the Golden Age of auto-radio, to those few survivors who still remain limber enough to participate in this contortionistic sport. We can still dimly remember those halcyon days when one could take the bottom lid off the radio and see inside the thing! Alas, those days are gone for ever.)

In addition to the facts outlined above, the design

* Ouachita Radio-TV Service, Mena, Arkansas.

of the vehicles themselves has contributed greatly to our difficulties. In common with other of Dame Fashion's caprices (The Sack!), car-styling has introduced new hazards, such as the "wrap around" windscreen, to complicate matters further. There not being sufficient room for this mobile picture-window on the front of the car, the designers have bent it around until the lower corners of it come out as a large triangular protrusion in the opening previously used for the front door! This is extremely convenient for the radio technician. As he arises from the prone position necessary to work with the radio, it is in exactly the right place to catch him a stunning crack on the forehead, resulting in a still further addling of what few brains he has left after struggling with the radio for an hour!

Instrument panels also partake of this trend; instead of being straight up and down, they now slant steeply back and inward toward the firewall: this was the only way they could find to reduce the limited space behind it!

In The Beginning.—We survivors of that bruised and battered group of old-timers have some remarkable memories. Of one 1937 model which had a factory-installed radio: we firmly believed that the set was installed and the car built around it, because we couldn't get it out! Of the 1938 model which required draining of the radiator and removal of the heater. Of another which had the radio and all instruments mounted on a panel, open on the front side, so that they were actually in the engine compartment! By the expedient of leaving off the splash-pans on the bottom of the engine, this resulted in the radio and other gear acquiring a thick coating of mud, oil, grease, and anything else thrown up by the front wheels. This was the first completely encapsulated radio; after a few months, it resembled a large cocoon. To service, the mud was chipped off with screwdrivers, wire-brushes, etc.; one irate technician is reported to have turned a high-pressure hose on it! Another car required removal of not only the hand-brake but the steering column, in order to install the radio. This one was also equipped with a mounting bolt fixed to the very top of the tuner chassis, easily accessible, if one happened to be an octopus; for those still using the standard human arms, with only one elbow, it was rather difficult. We remember the maker who mounted the set with the speaker plug on the back of the set, exactly 1⅛in from the firewall, 2in up from the bottom. The year after, this was further complicated by the addition of another speaker: a dual socket was used, with both plugs alike: it was simple to insert the plug into the wrong one. A two-piece set in which the units were connected with a very small, completely "ambiguous" plug, which could be inserted into the socket easily in any position. The socket in question was, of course, located on top of the radio chassis, entirely invisible from the serviceman's viewpoint. Incorrect insertion of this plug resulted not only in the radio refusing to work, but in blowing the fuse and burning up a small resistor, necessitating the removal of the radio once again!

It has long been a cherished belief of American servicemen that the car manufacturers maintained special, underground groups of designers, whose only function was the designing of dashboards. These groups are rated on an Inaccessibility Quotient: the more difficult the radio to remove, the higher the I.Q. for that year. They are paid on a bonus system, we believe. The higher I.Q. they can achieve, the more they make. Each year, they receive from the builders of the "custom-built" radios the dimensions of the sets for that year's cars. Their job is to work out a set of specifications which will enable the body department to accommodate the radio within the dashboard. The set must go into this space during manufacture, but leave no room for getting it out! This is achieved by adding heater-ducts, etc., to block access paths. Catastrophe was narrowly averted during one year's production by a large heavy brace which was added at the last moment, under the dash, to block up an overlooked opening through which the radio could have been removed easily!

Heads fell in bunches some years ago in Detroit. Some novice designers so far forgot themselves as to design a radio for a 1951 model which was mounted in its entirety on a metal panel, speaker and all. This panel was fixed to the dash by four small metal screws: it could be removed in less than *one minute* with a pocket screwdriver, while sitting upright in the front seat! Needless to say, the luckless wights responsible for this tragic blunder were summarily executed, after a whole year's production had slipped through. Next year, things were well in hand again: the same radio was used, in the same place, but now the dash was the usual immovable mass, and the radio had to be taken down, back and out, over heater controls, ashtrays, etc., in the usual manner. Two completely inaccessible fixing-bolts were added, at the very top of the chassis, in an effort to get revenge for the previous model.

Some of the very late models have I.Q.s which are simply wonderful. Some have reached the ideal of 100%, by adding air conditioners. These consist in the main of a great hulking cabinet, squatting on the floorboards between driver and passenger, in such a position as to render the radio (incidentally, all the dashboard instruments, too) entirely, absolutely inaccessible! To remove this unit, it is necessary to call in an air-conditioning mechanic, who closes valves, etc., and pumps down the unit, so that the blower cabinet may be disconnected and removed. One historic job recently performed by one of my associates resulted in a total of 11 hours, to replace a defunct r.f. amplifier valve. Removal of air-conditioner, 6 hours; replacement of valve, 6 minutes: Replacement of air-conditioner, 4.8 hours. Total charge, $1.80 for tube, $37.50 labour!

Transistorized Radios.—With the advent of transistorized radios in the early 1957 and 1958 cars, servicemen felt a faint surge of hope. "Surely," they said, wistfully, "they'll make the sets smaller, and they'll be easy to get out!" Alas, their hopes were dashed. Instead of the tiny chassis they had hoped for, the sets were built into cases of the same dimensions, to allow for a large impressive dial scale and a multitude of ornate knobs. Inside, of course, was a plenitude of unoccupied space, but outside they were the same as ever. In addition, there was a great lump protruding from the back of the set with several aluminium cooling fins, making the newer sets even more troublesome to remove! To add insult to injury, these sets did not use vibrators: thus, they were deprived of even this slight clue to possible troubles by listening to the tone of the vibrator!

Mountings.—Most sets use at least three-point suspension, some four or even more. In front the control knobs protrude through threaded bushes, which are held to the dash by large, thin nuts. In the early sets, these were flush with the dash, and could be removed with ease by an adjustable wrench, of the type known as a "Crescent," "Mexican Speed-Wrench," or knuckle-buster. When this was discovered, the designers took immediate steps to correct it. Now, these nuts are found at the bottom of very deep, special fittings, making it utterly impossible to remove them without a very special socket wrench indeed.

The back end of the set is held in place by one or two bolts, fixed to braces, etc. These used to screw into threaded holes in the cases. Now they fit special brackets and other added attractions. Extreme ingenuity is displayed by some designers in the location of these brackets. In one recent model it is necessary to remove the heater vent-control arm, and a large chrome-plated cover, 8 by 16 inches, the ashtray, and part of the glove pocket. This is an exquisite example of Applied Technological Stupidity: if the bracket on the set had been moved back exactly 1 *inch*, it would have been possible to fix them to the exposed lower edge of the dash! However, by placing these pitfalls in our path, the designer made it possible for us to spend an added 15 minutes each in removing and replacing the radio. The additional charge necessitated by this is deeply appreciated by our customer of course; so much so that he seeks out our competitor the next time the radio goes out! (Of course, he finds that competitor charges the same price as we do; hence, after making the rounds, he generally returns to the fold in a few months!)

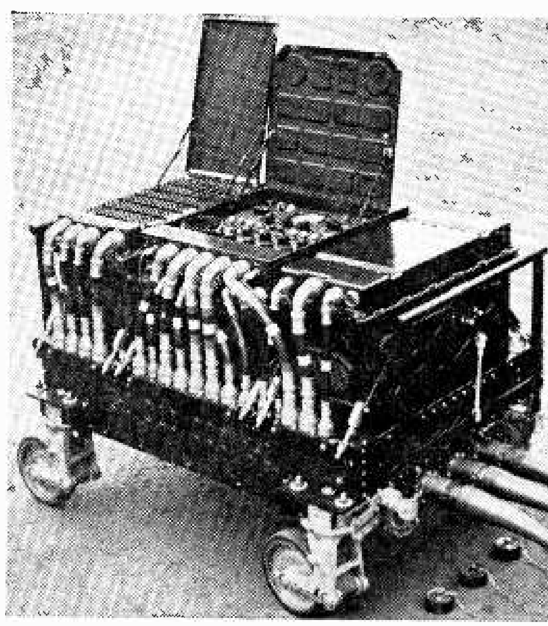
Constructive Criticism Department.—Never having been one to grouse merely for the sake of hearing one's own teeth rattle, the writer is hereby prepared to offer a set of suggestions for the boffins in Detroit, which should, but probably will not, carry a great deal of weight in the design of next year's cars! He feels, having been engaged in this contortionistic trade since its inception in 1928, more or less qualified.

General Design.—Why not affix the sets in the dash so that they would be removable from the front? The only disadvantage to this would be that there would be four small screwheads visible. For some reasons, designers seem to have an utter horror of leaving screwheads showing. Just why, I've never been able to discover. I have conducted a survey among my customers on this point over a period of at least five years, and I have yet to hear a negative answer! Not one of them would object to screwheads! Front-mounting, for one thing, would remove the major obstacle to the installation of the popular air-conditioners. To secure the back of the sets, a large metal pin, about ½ to ⅝in in diameter could be fixed to the back of the cabinet; this would slide into a mating hole in the firewall, possibly cushioned with a heavy rubber bush. Alternatively, the sets could be held by special braces for the dash, no more complicated than the ones already in use today: by forming them so that they provided grooves, the sets could be slid into place like desk-drawers, held by a few very small screws on the front.

Plugs and Sockets.—These must be mounted on the backs of the sets, to allow clearance at the sides for the set to be slid in and out. Interconnecting plugs should be slightly larger, and very definitely polarized, so that there is no possibility of inserting them into the socket wrongly.

Fuses.—These should be mounted in accessible places. Present cars use very short leads on very obstreperous holders, requiring a minimum of two hands to open. In their present location, only one hand can reach them—stalemate. Only Pontiac has taken cognizance of this problem, Allah bless them: they include the radio fuse in a fuse-panel, in an easily accessible location on the firewall! May their tribe increase!

So, in summation, although we, with other Americans, take an insular pride in Detroit's accomplishments, both in quantity and quality, we feel that there is still much, much room for improvement in this one particular section. For some reason, though, they have failed to seek our expert advice on the subject, and are muddling along in their own profitable way! We would dearly love to see an automobile radio that we could remove without feeling as if we had removed the largest speaker from a folded corner horn the hard way, by crawling up the bell after it! The very latest development of the 12-volt valves, for automobile radios, led one serviceman at a recent meeting to a bitter comment. After hearing the lecturer advise against attempting to test the low anode voltage valves, he said, "Well, that makes it complete. Now, after making radios we can't get out of the cars, they've finally made valves we can't test!"



***Automatic Radar Mechanic:**—This equipment, designed and developed by the General Electric Co., tests automatically 300 inter-unit radar system voltages and waveforms at high speed. For instance, four d.c. measurements are made in one second, to an accuracy of $\pm 0{\cdot}2\%$, a "no go" signal appearing if the limits $\pm 1\%$ are exceeded. G.E.C. state that the machine is easily adapted to testing practically any equipment and it can be provided with recording facilities.*

Zener Diode Voltage Stabilizer

APPLICATION TO SMALL BATTERY MOTORS

By S. WELLDON*

THE advent of the transistor has stimulated interest in the use of miniature portable equipment for sound recording and reproduction. Incorporated in much of this equipment, for example in record-players and tape and wire recorders, are electric motors designed to be operated from small batteries. This type of motor is usually driven from a 4.5, 6, or 9V battery. The "dry" Leclanché cell, however, has neither a constant terminal voltage, nor a constant value of internal resistance, with life. A typical curve of the terminal p.d. of a 1.5-V cell is given in Fig. 1; this shows a sharp fall at the beginning of life, followed by a more gradual decline. In fact, it is often advisable to design apparatus on the assumption that the battery supplying the power will have a working voltage rather less than 1.5V per cell. A value of 1.35V per cell is often chosen, since the terminal p.d. of a cell having intermittent use tends to "level off" at this voltage.

*Research Laboratories of the General Electric Co. Ltd.

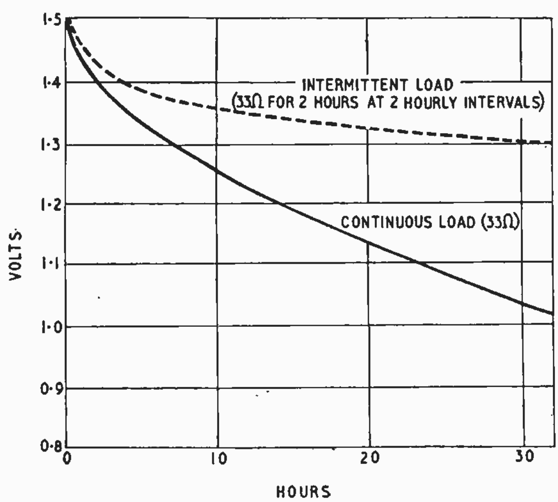


Fig. 1. Typical variation of terminal p.d. of a 1.5V dry Leclanché cell with life.

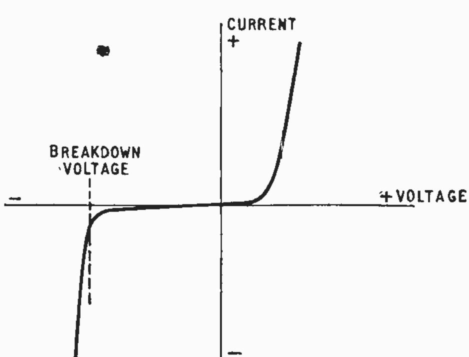


Fig. 2. Characteristic of a typical Zener diode.

The value of internal resistance is rather indeterminate. It increases with the age of the cell, and it also varies with the amount of current drawn. Also to be considered is the effect of polarization which will occur momentarily if the battery is required to deliver a relatively large current pulse.

Battery Motors.—The terminal voltage variations caused by the above effects may become embarrassing when a stable voltage is required to drive a recorder or record-player motor. Such a motor usually has a permanent-magnet field, and is provided with a centrifugal, friction-controlled governor. The regulating efficiency of the governor is generally made rather low to keep power losses low. In addition, the associated flywheel or capstan is often quite small, and may not have sufficient inertia to compensate adequately for short-term variations in battery voltage. The motor is similar to a shunt-wound motor in that a constant voltage rather than a constant current source is required, and a fairly large surge current is drawn when starting. If the motor *is* operated from a constant current source, it will take an appreciable time to reach its final speed and in some cases may not start at all.

If an attempt is made to run the motor in conjunction with a class-B audio amplifier, and a common battery of small capacity is used, the fluctuations in supply voltage caused by current changes in the output stage can be sufficient to vary the motor speed. Even where separate batteries are employed, the initial high voltage may overload the governor and raise the speed of the motor. The usual solution here is to place a variable resistor in series with the armature winding; but the disadvantage of this system is the need for fairly constant adjustment of the resistor during the life of the battery. There is also a tendency to over-run the motor, because the voltage applied to it is not known exactly.

Zener Diode Stabilizer.—A method of providing a stabilized voltage makes use of the breakdown characteristic of a Zener diode. This is a p-n junction diode, made from silicon and having a well-defined reverse breakdown voltage. By careful choice and control of the materials used in its manufacture, the voltage at which breakdown occurs can be decided within fairly close limits, and this voltage is stable with life. Currently available Zener diodes have breakdown potentials ranging from 3 to 15V. The shape of the characteristic is indicated in Fig. 2.

After the breakdown voltage has been exceeded, the characteristic has a very steep slope. The voltage/current gradient of this part of the characteristic is known as the Zener slope resistance R_s, and, for optimum regulation, should be as small as possible. It is not a constant, however, and there can be significant variations from one device to another. The slope resistance also depends to a great extent on the diode breakdown voltage and tends to a minimum value of 5Ω or less at breakdown voltages between 6 and 7V. At the present time there appears to be no generally accepted method of accurately defining breakdown voltage for a particular diode. For convenience here we will assume it to be the voltage across the diode when the reverse current is 5mA, since this usually ensures that the beginning of the linear portion of the voltage/current characteristic has been reached.

A suitable stabilizing circuit is given in Fig. 3.

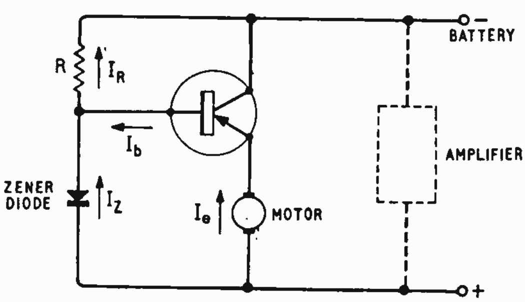


Fig. 3. Voltage stabilizing circuit using a Zener diode.

The load is placed in series with the emitter of a transistor in the common-collector arrangement; and the Zener diode is placed in the base circuit. A limiting resistor R in series with the diode across the supply is made greater than the Zener slope resistance. The diode should have a breakdown voltage slightly in excess of the voltage required for the load, to allow for the voltage drop across the base-emitter junction. The transistor serves to isolate the load from the diode, and must, of course, be capable of handling the required load current.

Numerical Example.—It is useful to examine the method of operation by considering a practical example. A miniature record-player and a transistor class-B push-pull audio-amplifier were to be operated from a small, common, battery. The record-player needs at least 4.5V at about 60mA, and the amplifier was intended to be operated from 6V. It was envisaged that four small unit cells could provide the power. An experimental EW77* diode having a breakdown voltage (as defined above) of 5V was selected.

It will be assumed that the Zener slope resistance is 20Ω, this being a typical value for a 5V diode. It will also be assumed that the slope resistance is linear beyond the breakdown voltage point indicated in Fig. 2.

Referring to Fig. 3, the minimum current through the diode should not be less than 5 mA, since the slope resistance increases appreciably at lower values of diode current. The maximum current in the diode is determined by the maximum dissipation allowed in the device. With an EW77 rating of 150mW for ambient temperatures of up to 40°C, the maximum current for a 5V diode will be 30mA. For reasons of power economy, however, it may be advisable to limit this current to a slightly lower value. If, for example, it is limited to 25mA, the diode current I_Z can change by a maximum of 20mA, and with a (linear) slope resistance of 20Ω, this will cause the voltage across the diode to vary from 5 to 5.4V. The voltage drop across the base-emitter junction is about 300mV, so that the corresponding variation in motor voltage is from about 4.7 to 5.1V. This variation should be easily controllable by the motor governor.

The current I_b in the base of the transistor is equal to $I_e/\bar{\alpha}_{cb}$ where I_e is the emitter current and $\bar{\alpha}_{cb}$ the d.c. or large signal current gain of the transistor. Since the load is inductive and the current is commutated, the final value of I_e is not readily calculable. However, assuming it to be about 60mA, and using a transistor with a current gain of 30, I_b will be 2mA. The current I_R ($= I_b + I_Z$) in the limiting resistor R will therefore have a minimum value of 7mA, and a maximum value of 27mA.

The value of R required depends on both the Zener slope resistance and the supply voltage chosen. If the latter is 6V, the maximum p.d. across R will be $6 - 5.4 = 0.6$V, and therefore R will be $600/27 = 22\Omega$. The minimum voltage across R is equal to $22 \times 7\text{mA} \approx 150$mV, so that the minimum battery voltage required for the stabilizing action to occur is 5.15. In this case, operation from a 6-V supply would give a very short battery life, and it would be more economical to increase the supply to, say, 7.5V (e.g. five unit cells). The value of R should then be increased to 82Ω (to the nearest preferred value), and the minimum battery voltage becomes 5.57. If R is reduced to its limit to allow a maximum current of 30mA through the diode, the minimum battery voltage is lowered. However, since the initial current drain is higher, the life of the battery will tend to be reduced rather than extended.

If the 7.5-V supply is chosen and the same battery used for both stabilizer and amplifier, the latter must, of course, be capable of operating at the increased voltage. Such an arrangement, however, should present no difficulties.

The power dissipated in the transistor is $I_e \times (V_{battery} - V_{motor})$, so that its value will depend on the supply voltage and the load current. The former will vary during the life of the battery, and the latter will change with variations of torque. With a 7.5V supply, the power in the transistor with the motor running normally will be about 140mW, dropping to 50mW towards the end of the life of the battery. The transistor must have a higher dissipation rating than the former value, however, because of the high starting current, and it should be borne in mind that this would be a continuous rating if the motor were accidentally or deliberately prevented from rotating while switched on. For most of these surge conditions, the GET15 transistor is a suitable choice, since it has a dissipation rating of 250mW at ambient temperatures up to 40°C, increasing to 500mW if mounted on a 3in × 3in cooling fin. The peak emitter current for this transistor is 350mA. In practice it is unlikely that the motor will be left in a " seized up " condition for any length of time, and the starting pulse is not long enough to raise the junction temperature excessively.

Stabilizing Factor.—The amount of stabilization

*A more recent commercial near equivalent with a greater allowable dissipation is the 5.6V, 300mW SX56.

that can be achieved will depend mainly on the Zener slope resistance and the value of the limiting resistor. However, because of the many other variables involved, it is difficult to predict the degree of regulation exactly, though a simple description will give a useful indication.* Suppose in the above example, the battery and diode voltages stand at 7.5 and 5.4V respectively. The current through the limiting resistor ($R = 82\Omega$) is 25.6mA. Now if a reduction in supply voltage is sufficient to decrease the diode current by 1mA, the voltage across the diode will drop by 20mV, and this will in turn produce a drop of 20mV in the motor voltage. The current through R is then 24.6mA, and the p.d. across it is 2.02V. This gives a battery potential of 2.02 + 5.38 = 7.4V. There is, in fact, also a change in I_b, due to the change in I_e, but this is very small compared with the reduction in the current in the Zener diode. Thus a battery voltage variation of 100mV is required to produce a 20mV change in load voltage, giving a stabilizing factor of 0.2.

As mentioned earlier, the slope resistance increases at very low values of diode current. Thus, when the battery voltage falls below the minimum values given earlier, the stabilizing action becomes rapidly poorer, though it does not immediately cease.

Apart from the short-term voltage regulation afforded by the use of this circuit, there is also the advantage that no voltage adjustment whatever is required during the life of the battery. This is particularly useful where tape and wire recorders are concerned.

It is possible to obtain superior stabilization with more elaborate circuits, but the circuit given in Fig.3 is adequate for most small motors of the type described here. It is simple and compact, and reasonably economical in power consumption.

Thermal Stability.—The thermal stability of a Zener diode depends on several factors, including the value of the Zener voltage, and the operating current. The temperature coefficient tends to be negative at the lower ranges of breakdown voltage, and positive at the higher. With a typical 5V diode, the temperature coefficient is negative, and has a value between 0.01% and 0.02% per °C (i.e., between − 0.5mV and − 1mV per °C rise in ambient temperature). The transistor base-emitter voltage also varies with temperature, typically between − 2mV and − 2.5mV per °C. The variation in motor voltage with temperature is therefore typically equal to

− 0.5mV − (− 2mV) per °C = + 1.5mV per °C.

This is a small, and relatively long term, variation and as such is insignificant in this application.

*It can be shown that $\frac{\delta V_{in}}{\delta V_{out}} \approx 1 + \frac{R}{R_s} + \frac{(1-\alpha)R}{R_L}$ where R is the limiting resistor, R_s the Zener slope resistance, R_L the load resistance, and α the emitter-to-collector current gain of the transistor. The third term is very small compared with the first two, so that $\frac{\delta V_{in}}{\delta V_{out}} \approx 1 + \frac{R}{R_s}$ and the stabilising factor $\approx \frac{R_s}{R+R_s}$.

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Design of a Linear Phase-shift Low-pass Filter by L. E. Weaver, B.Sc. B.B.C. Engineering Monograph No. 17 dealing with the choice of circuit and practical realization of a 3-Mc/s cut-off filter for removing noise from a television camera control unit. Supplementary note by R. D. A. Maurice, Ing Dr., A.M.I.E.E., on random fluctuation noise in image orthicon camera tubes. Pp. 23; Figs. 14. Price 5s. B.B.C. Publications, 35, Marylebone High Street, London, W.1.

The Use of Electronic Valves. British Standard Code of Practice CP 1005: Part 4: 1958. Section 9 gives additional recommendations on magnetrons relating to special characteristics, heater operation, h.t. supply, magnet design, stray field, cathode and output connections, installations, dangerous radiations, storage and transit. Section 10 deals with special quality valves, their ratings, choice of type and circuit, heater surges, effects of interface impedance growth, mounting and temperature considerations, handling and preventive maintenance. Pp. 20. Price 5s. British Standards Institution, 2, Park Street, London, W.1.

The Radio Amateur's Handbook, 1958 edition; by the headquarters staff of the American Radio Relay League. A recognized standard manual of amateur radio, it explains basic theory, design and construction of all types of amateur equipment and the latest developments in suppressed-carrier, single-sideband and teletype (teleprinter) techniques for amateur communications. Pp. 616 including 32 pp. of valve and semiconductor data with over 1,350 illustrations. Obtainable from the Modern Book Co., 19-23, Praed Street, London, W.C.2, or from the Radio Society of Great Britain, New Ruskin House, Little Russell Street, London, W.C.1; price 32s 6d (34s 3d by post).

Proceedings of the Third National Conference on Tube Techniques (New York, September, 1956). Selection of 29 papers on details of the design and manufacture of valves (principally receiving). Pp. 128; Figs. 149. Price $5.

Proceedings of the Transistor Reliability Symposium (New York, September, 1956). Selection of 19 papers dealing mainly with the performance of transistors in military applications. Pp. 128; Figs. 140. Price $5. Both the above are published by the New York University Press, Washington Square, New York, 3.

Practique Electronique by J. B. Oehmichen. Survey of transducers available for industrial measurement and control systems, basic circuit elements and their integration to form complete systems. Pp. 302; Figs. 162. Price 1,350 Fr. Editions Radio, 9, Rue Jacob, Paris, 6.

The Ionosphere by Karl Rawer. Survey of existing knowledge of the physics of the ionosphere, regular and irregular changes in its constitution and their influence on radio propagation. Translated from the German by Ludwig Katz. Pp. 202; Figs. 72. Price 42s. Crosby Lockwood & Son, Ltd., 26, Old Brompton Road, London, S.W.7.

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Divided Output Transformers

Use of Separate High- and Low-Frequency Units

By R. GUELKE*, Ph.D., M.I.E.E., F.Inst.P.

THE design of the output transformer for an audio-frequency amplifier of wide-frequency range presents a number of problems. The self-capacity of the primary winding can be high enough to interfere with the working of the transformer at high frequencies. Leakage inductance can also be troublesome at these frequencies, particularly if a considerable amount of negative feedback is to be applied.

It is therefore not surprising that suggestions have been made that the audio-frequency range should be divided into two regions and two transformers used, one for the high- and the other for the low-frequency region; similar to the well-known use of two loudspeakers. For example, P. W. Klipsch has described[1] a parallel dividing network for separating the two frequency ranges just prior to the output transformers, greater freedom from low-frequency distortion and its intermodulation products being claimed. A well-known manufacturer (Philips) has used two output stages driven by separate valves.

It is well known that thermionic valve amplifiers are capable of dealing with the entire audio-frequency range without difficulty. It would therefore appear to be unnecessary to divide the frequency range prior to the output valves.

In this paper a circuit is put forward in which the audio-frequency spectrum is divided into two sections prior to the output transformers, but subsequent to the output valves of the amplifier. The output from the secondaries of the transformers can be combined for purposes of overall feedback.

* Cape Town University.

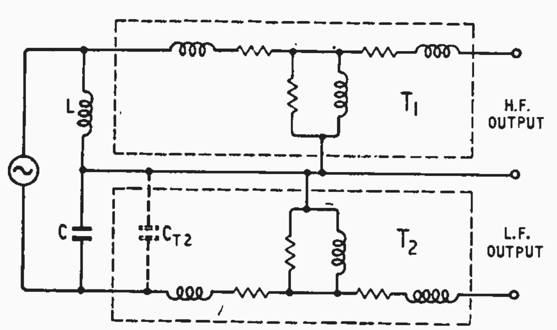

Fig. 1. Theoretical frequency dividing circuit.

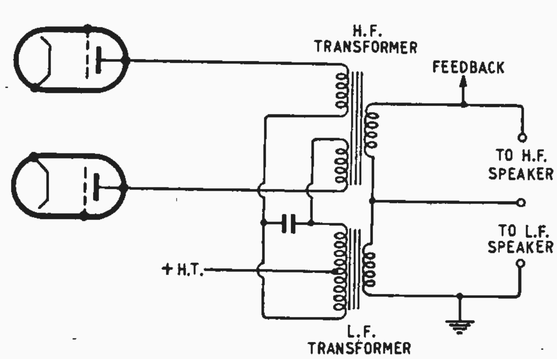

Fig. 2. Practical application of Fig. 1.

Circuit Details

Fig. 1 shows the principle of the circuit. A generator is followed by a simple dividing network consisting of an inductance L and a capacity C in series. This is followed by the equivalent circuits of the transformers, T_1 (high-frequency), and T_2 (low-frequency). The capacity C_{T2} represents the self-capacity of the winding of the low-frequency transformer. L and C can be calculated from the following formulæ:—

$$L = \frac{R}{2\pi f}, \quad C = \frac{1}{2\pi f R}$$

where R is the load resistance, and f the dividing frequency.

If it is possible to connect two transformers in series, the primary inductance of the high-frequency transformer could be used in place of the inductance L, and the self-capacity of the windings of the low-frequency transformer absorbed into the capacity C. Because the high-frequency transformer would have few turns and also be much smaller than the low-frequency transformer, the self-capacity of this transformer would not be important. The leakage inductance would also be comparatively small. For the low-frequency transformer leakage inductance and capacity would not be of any consequence, because at the higher frequencies where they become significant the high-frequency transformer would take over. This means that the low-frequency transformer need not be specially wound to reduce this self-capacity. Thus simpler (and cheaper) methods of winding can be used; and as these require less space, the size of the transformer is reduced.

In order to test the possibilities of this scheme an audio-frequency amplifier was constructed to the specification of D. T. N. Williamson[2] but with the output modified as shown in Fig. 2. It was found that this output stage gave the same frequency response and power output as a standard high-quality transformer if the following conditions were observed:—

1. Any transformer having a sufficiently high primary inductance could be used as the low-frequency transformer. Even standard mains transformers were found adequate using the h.t. windings as the primary and tappings on the mains or l.t. windings as the secondary.

2. The high-frequency transformer had to be

constructed of low-loss core material, and the primary inductance adjusted to a suitable value by means of an air gap.

For the high-frequency transformer Ferroxcube was found very suitable as a core material. A core having a cross-sectional area of about 1 sq cm and a "window" for the windings of about 2.5 sq cm was wound with a total of 2,400 turns on the primary (1,200 each side) to make a suitable transformer. This transformer was able to deliver 15 watts at frequencies above 2000 c/s. With a cross-over frequency of 1000 c/s and a suitable low-frequency transformer 15 watts could then be obtained over the full audio range.

The cost of the two transformers is considerably lower than that of a single high-quality transformer because the method of winding is not critical. Furthermore, the high-frequency transformer takes the place of an inductance in the dividing network. The frequency division is carried out at high impedance so that the condenser for the dividing network is smaller and less expensive than usual.

Care has to be taken to obtain the correct polarity for the addition of the two outputs in the feedback circuit. The two primary windings on the high-frequency transformer must also be well insulated because they are subjected to the full primary a.c. output voltage from the low-frequency transformer.

For an amplifier which is to be used with a frequency dividing network the use of two output transformers is both economical and satisfactory.

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[2] Williamson, D. T. N. "Design for a High-Quality Amplifier," *Wireless World*, Vol. 53, Nos. 4 and 5, Pp. 118 and 161, April and May 1947.

Inexpensive Photographic Timer

Simple Compensation for Variations in Enlarger-Lamp Supply Voltage

By J. H. JOWETT, B.Sc. (Eng.)

AN excellent design for a precision photographic timer was given in *Wireless World* for February, 1955, by J. G. Thomason. Compensation was provided, through the use of Atmite discs, against the differing exposure periods required with variation of mains voltage, in this way improving the operational use of such a device for professional work.

In the circuit suggested below sufficient compensation is obtained for the average experimenter's purposes, and possibly also for some professional purposes. This is accomplished by the use of a single-valve assembly which may be quickly constructed within a very small space. Many readers will consider that the advantage of simplicity outweighs the more elaborate, if more accurate, arrangement of J. G. Thomason. No apologies are therefore offered for a further design.

The basic circuit used in the timer to be described is that of the "bootstrap" amplifier*, as shown in Fig. 1, a device which is commonly used for the generation of linear sawtooth waveforms. It consists of what is virtually a cathode follower, the anode being at h.t. potential and the cathode returned to earth through a resistor R_k. One end of a d.c. voltage source V is connected to the cathode, while the opposite pole is connected to the grid through a charging resistor R and charging capacitor C.

As this is a cathode follower, for valves of short grid base

$$V_k \simeq V_c$$

Then, the voltage across R is given by $(V+V_k-V_c)$, i.e., V approximately, independent of other potentials. Hence, as the voltage drop across R is V volts, the current through the resistor has a constant value of V/R amps.

* F. E. Terman, "Electronic & Radio Engineering", 4th edition p.651

This is the basis of the operation of the "bootstrap" circuit. The capacitor C is charged at a constant rate and the potential across it rises linearly with respect to time. As the output voltage and capacitor voltage are raised simultaneously, the two poles of the externally applied d.c. source, V, are both raised in potential together, as if by their own bootstraps. The time taken for C to charge to a given potential V_1 is given by the rate of charge multiplied by the value of final potential, or,

$$t = \frac{CR}{V}.V_1$$

If R were connected directly between grid and cathode, i.e., V made equal to zero in the above expression, from this theory C would only be charged within an infinite time. In practice, however, a small potential difference exists between grid and cathode, depending on the grid characteristic of the valve. Capacitor C would therefore be charged at a low rate from this voltage difference, and the cathode current would rise until limited by the valve.

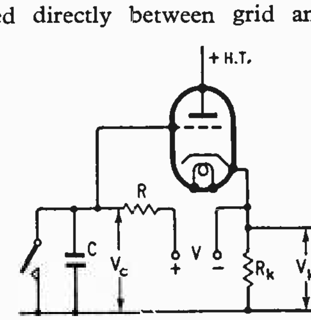


Fig. 1. The basic "bootstrap" circuit.

The full circuit of the practical design is shown in Fig. 2. It can be seen that this circuit differs from the standard bootstrap arrangement in that the anode supply is taken directly from the 240-V

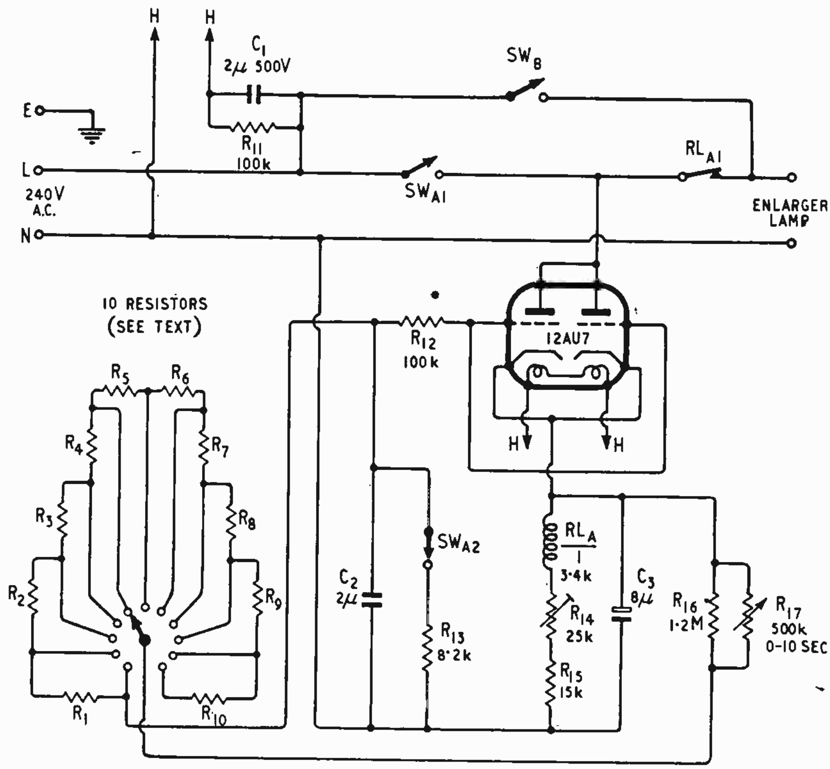


Fig. 2. Circuit of the complete timer.

a.c. mains. Not only does the valve operate as a bootstrap amplifier (with the charging resistor directly between grid and cathode), but it also acts as a rectifier with load $R_{14}+R_{15}$ and relay $\frac{RL_A}{1}$ and reservoir capacitance C_3. It will be appreciated that this dual function complicates considerably the previous arguments, and in fact makes a rigorous mathematical expression of the circuit conditions somewhat involved. The basic principles of operation will nevertheless be clear from the foregoing explanation.

In the initial condition, capacitor C_2 is short-circuited by one contact of SW_A, and the anode voltage is removed by means of the second contact. When this switch is operated, the cathode current rises quickly to a small value determined by the grid characteristic, in the region of 1mA for the valve used. It then begins to rise much more slowly, until, when a suitable value of cathode current is reached (in this case 3.5mA) the relay contacts open, concluding the timing period. Switch SW_A may be returned to its original position at any later time to reset the cycle of operations; thus a simple double-pole toggle switch is satisfactory for this application.

It was found that the circuit, as described above, was sensitive to mains voltage changes to an extent shown in the curve of Fig. 3. As the mains voltage rises or falls from the nominal, so the nominal timing period decreases or lengthens. On the same graph is plotted the theoretical curve showing the variation of timing period necessary to compensate for a fourth power law between enlarger lamp output and mains voltage, as suggested by J. G. Thomason. These two curves show a fair measure of agreement over part of the range, indicating that a certain amount of mains voltage compensation would be obtained without further measures being necessary. As stated previously, a full mathematical analysis of this circuit is difficult and uncalled for in an article of this kind, so a simple qualitative test was carried out to verify the source of the variation of timing period.

The anode voltage was first held constant and the heater voltage varied; only small changes were noted. From 200 volts to 260 volts, the change in period due to heater variations was from 19 to 21 seconds, on the 20-second range. Thus the major variations occur, as was also verified, through the change in anode voltage. The effect of increased voltage at the anode is of course an increase in the rectified output at the cathode, and consequently greater voltages in general throughout the circuit. Capacitor C charges more rapidly and the point at which relay RL_A operates occurs in a shorter time interval. The law is not linear owing to the curvature of the valve characteristics, particularly at the lower voltages, and the variation of r_a with anode current.

To investigate the suitability of the time-voltage characteristics for photographic work, the following short experiment was carried out. First, a sheet of bromide paper was exposed to the enlarger for 10 seconds, timed by a stop-watch, with the values of mains voltage between 210V and 250V as marked in Fig. 4. The variation of density between successive strips of the paper is quite noticeable. In the second part of the experiment, the timer was set to the 10-second range and the strips were again

(*Continued on page 387*)

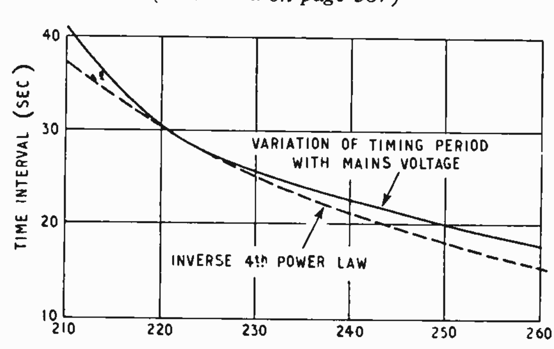
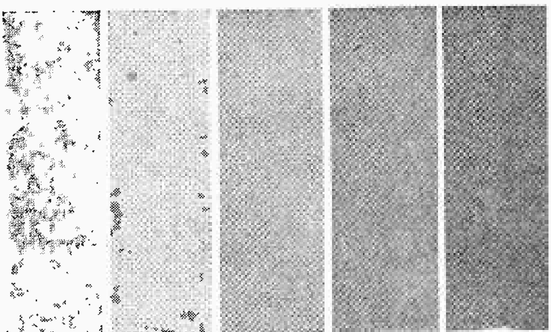
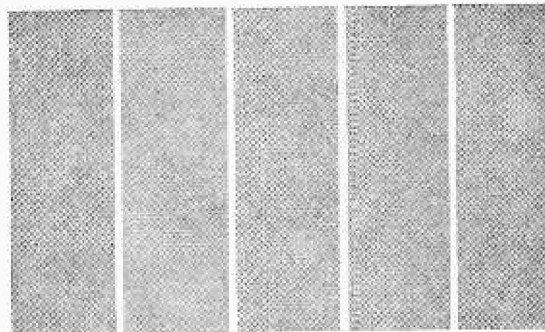


Fig. 3. Variation of timing period with mains voltage, compared with a theoretically desirable fourth power characteristic.



210V 220V 230V 240V 250V

Fig. 4. Test exposures on normal paper at 10-volt increments of mains voltage. Constant exposure of 10 seconds on each voltage, timed by a stop-watch.



210V 220V 230V 240V 250V

Fig. 5. Test exposures again at 10-volt mains voltage increments as in Fig. 4, but using the timer, on the 10-second range, throughout.

exposed at the 10-volt intervals, as in the first part, between 210 and 250 volts. The results of this second test are shown in Fig. 5, and it can now be seen that the difference in densities between the 210-V and 250-V strips is much reduced—only of approximately the same order as between 10-volt intervals without the use of the timer. This variation in exposure is negligible under mains voltage fluctuations likely to be encountered in practice.

The aim of the circuit design has been simplicity, and the only complication introduced is the necessity for a multiplicity of timing period ranges. These are selected by means of an 11-way Yaxley switch which introduces the correct values of charging resistors. In series with these resistors is a variable resistor, which is calibrated up to 10 seconds, allowing a wide variety of times to be selected up to a maximum of 200 seconds. The values of the range resistors are given in the accompanying table, but no tolerances are given as their accuracy will depend upon the requirements of the user and also upon the exact value of C_2. The last-mentioned should be a good quality paper capacitor of about 200 volts working, with high insulation resistance; if the insulation is poor, it will be found that operation of the circuit is affected on the higher ranges. The operating period of the timer with all controls at minimum is about 0.2 second.

The selection of valve type 12AU7 (CV491) was made first because the heater is suitable for operation from the mains supply through a 2-μF capacitor, allowing further simplification and space reduction. Secondly, the permissible heater-to-cathode potential is 200 volts, which gives an ample margin of protection. Resistor R_{11} in parallel with C_1 allows the last-mentioned to discharge on withdrawal of the mains plug, for safety reasons.

As previously mentioned, relay $\frac{RL_A}{1}$ operates with a current of 3.5 mA, and if any other relay is used it is recommended that a more sensitive type be selected and that it be shunted if necessary to operate at this current. If this cannot be arranged, the circuit values given will have to be altered to provide the correct ranges, and some experiment will undoubtedly be called for. The relay contacts should have voltage and current ratings adequate for the enlarger lamp; if not, a back-up relay must be used, possibly energized from the mains via a half-wave rectifier. The switch SW_B by-passes the unit when adjustments of the enlarger are desired for an indefinite time period. If a metal chassis or case is used it should be isolated from the rest of the circuit and preferably earthed.

The variable resistor R_{14} was provided to allow initial setting-up in spite of circuit component tolerances. The 20-second range is recommended as a suitable range for this purpose, as adequate accuracy is obtainable without the expenditure of too much time. When the adjustment has been made on this range the other ranges will be found to be in their correct proportions and no further adjustments should be necessary, except for the calibration of the variable resistor controlling the 0-10 second range.

TABLE OF RANGE RESISTORS

Resistor No.	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Time Interval Seconds ...	10	20	30	40	50	60	80	100	150	200
Nearest Prefd. Resistor Value	330k Ω	330k Ω	330k Ω	330k Ω	330k Ω	330k Ω	560k Ω	750k Ω	1.5M Ω	1.0M Ω

Consistent and accurate results are obtainable through the use of this timer, even for exposure periods of 0.5 second. Such short exposures are, of course, impracticable by manual methods, and a consequent speeding up of operations is therefore possible when a number of prints are being made. Certainly the use of the timer transforms the most tedious part of an otherwise interesting hobby.

Thanks are due to M. A. Newman, B.Sc., for helpful suggestions in preparing this article.

"Electrical Who's Who."—The 1958-59 edition of this valuable directory of people in the electrical and radio industry, research organizations, the Services and Government Departments, includes about 8,000 brief biographies. These entries are supplemented by an index in which the names are classified under companies and organizations. Compiled by *Electrical Review* it is obtainable from Dorset House, Stamford Street, London, S.E.1, price 27s 6d (postage 1s 6d).

LETTERS TO THE EDITOR

The Editor does not necessarily endorse the opinions expressed by his correspondents

Direct-coupled Transistor Amplifier

MR. OWENS is right in stressing the severe temperature dependence of the circuit shown in Fig. 2 of my article (May issue). It is unfortunate that this figure should have been labelled as a "practical amplifier" since it was mainly intended to show the conditions of measurement when plotting Figs. 3 and 4. For example, the 1 MΩ resistor in series with the first base was included solely to provide a constant-current drive to the amplifier and the 1 MΩ resistor in the feedback loop was selected to give the correct class-A operating condition, and only incidentally gives a small measure of d.c. stabilization.

The practical amplifier which was modified to yield Fig. 2 did in fact have a battery in the feedback loop, allowing the d.c. feedback resistor to be reduced to 100 kΩ, and thus giving a useful measure of a.c. and d.c. feedback whilst maintaining an absolutely flat low-frequency response. Unfortunately this arrangement did not allow the adjustments of feedback ratio necessary to yield the curves of Fig. 4.

Where a floating battery is an embarrassment, Mr. Owens' Fig. A provides a convenient alternative. His Figs. B and C are interesting in their own right, but depart somewhat from the principle of direct-coupling *without bias adjustment or loss of available current swing.*

Hounslow. D. A. G. TAIT.

[In Fig. B which accompanied Mr. Owens' letter in last month's issue the connection between the top of R_3 and the right-hand end of R_9 should be deleted.—ED.]

Variable Transformer Windings

MR. H. E. STYLES' transformer (p.262, June issue) requires considerable arithmetical effort on the part of the user. This could be greatly reduced if secondaries of 1, 2, 4, 7, 10, 20, 40, 70 and 100 volts were used, giving virtually the same maximum output (254V) and requiring the addition of only one switch.

Ewell, Surrey. J. S. SINGLETON.

The Author Replies

THE modified series of windings proposed by Mr. Singleton certainly offers the advantage of somewhat simplified addition although, in practice, my original series is not found to offer any particularly difficult arithmetic.

Apart from necessitating the use of an additional switch for voltages up to a maximum of 254, the modified series proposed by Mr. Singleton has other drawbacks which might militate against its use in some circumstances.

In the first place, with my own series any particular voltage can only be obtained by one particular combination of windings whereas the modified series permits alternative combinations of windings to be employed for quite a number of values of voltage. Thus, for example, a voltage of 14 can be achieved either by a combination of the 10 and 4 volt windings or by a combination of the 1, 2, 4, and 7 volt windings. The same voltage can only be attained in one way with the original series i.e. by a combination of the 2, 4, and 8 volt windings.

Bearing in mind the inevitable minor differences which must arise between differently disposed transformer windings, it is likely that two combinations giving the same nominal output voltages will in practice yield slightly different actual values. For many purposes this may not matter but in some circumstances such possibility of inconsistency might be undesirable.

A second minor objection arises from the same cause. Starting at the low-voltage end, the original series of windings provides a steady progression of voltages by working successive switches in a regular manner (left-hand columns below).

With the modified series, however, one is apt to run into repetition, as indicated in the right-hand columns.

Switch Combination	*Output Voltage*	*Switch Combination*	*Output Voltage*
1	1	1	1
2	2	2	2
1, 2	3	1, 2	3
4	4	4	4
1, 4	5	1, 4	5
2, 4	6	2, 4	6
1, 2, 4	7	1,2, 4	7
8	8	7	7
1, 8	9	1, 7	8
2, 8	10	2, 7	9
1, 2, 8	11	1, 2, 7	10
4, 8	12	4, 7	11
1, 4, 8	13	1, 4, 7	12
2, 4, 8	14	2, 4, 7	13
1, 4, 8	15	1, 2, 4, 7	14
16	16	10	10
		1, 10	11
and so on		2, 10	12
		1, 2, 10	13
		4, 10	14
		1, 4, 10	15
		2, 4, 10	16

Finally, if auto-connection is employed to achieve higher maximum voltage, the modified series necessitates a primary tapping at 200 volts and gives a maximum of 454 volts compared to the value of 511 volts obtainable with the original series.

It is thus evident that a choice between the two must largely depend upon the precise purposes for which it is desired to use the transformer and, in particular, the importance attached to the somewhat greater ease of adding together numbers from the second series.

Pinner, Middlesex. H. E. STYLES.

"TV DX"

SOME observations on the reception of Channel 2—ABN Sydney (64-70Mc/s) Australian television in Auckland, New Zealand, during the period 18th November, 1957 to 24th January, 1958, may be of interest. Distance approximately 1,250 miles.

Receiver untouched, standard, domestic, 17in fringe model. Aerial 5-element Yagi, at a height of approximately 200 feet above sea level, but in a comparative dish compared with adjacent hills.

Reception has been accomplished some 17 times, the periods being a maximum of four hours and a minimum of just a few minutes. On at least three occasions the signal could hardly have been better, even close to the transmitter. Times of reception were completely unpredictable and varied from 3 p.m. to 12 p.m. This would of course coincide with transmission times (New Zealand 2 hours forward.) Vision without sound was quite common, but rarely the other way round. Fading and ghosting were sometimes severe, and at other times non-existent. The longest period without any fading of either vision or sound was of 45 minutes on the evening of 24th January, 1958—(6 p.m. to 6.45 p.m.) During one evening when an experimental local transmitter was testing, it was possible to make a direct comparison of the pictures (405 as opposed to 625) and there could be no doubt as to which was superior. Incidentally, it was also possible to appreciate f.m. sound even though it was heard through a poor loudspeaker system. Once the receiver was adjusted no attempt was made to improve results as it was found that a minimum signal would "hold" if it was sufficient to modulate the tube to a grey level, fading then varied the contrast level.

Auckland, New Zealand. C. A. ROUSE.
Bell Radio Television Corporation.

Optical Illusion

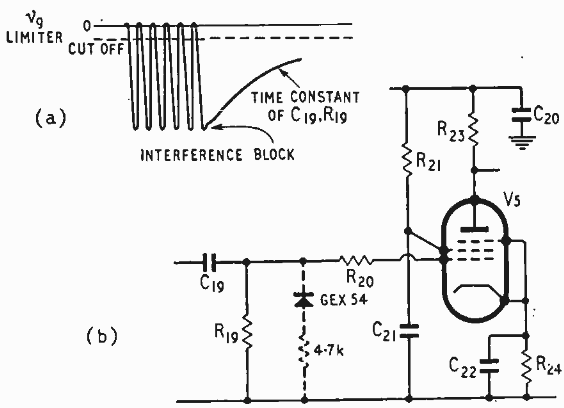
READERS with access to a double beam oscilloscope may be interested to observe an unusual optical effect which I discovered by chance the other day.

Set a presentation on the tube face of any waveform to hand and lock it with about 4 complete waves showing. Now set another wave shape on the second beam at a few cycles short of the second harmonic of the former so that it is on a slow shift. If you now look at the tube face but endeavour to focus your eyes at a point some three feet past the screen then the four waves on beam one can be made to overlap and show as five waves. When this is achieved the two presentations will be floating on different planes some distance inside the tube.

Leeds. TERENCE JOHN HALL.

Swamp Interference Stopper

THIS is written for the benefit of all those who have built the "Unconventional (Pulse Counter) F.M. Receiver" described by M. G. Scroggie,* and enjoyed



excellent results until they found themselves (as I did) receiving violent jamming. One hundred yards away from the receiver is the main local police transmitter which caused receiver paralysis. The likeliest place for this to occur is at the grid of the limiter, as indicated in diagram (a).

As can be seen, this is effectively negative d.c. restoration in which the positive excursion of the waveform is clamped to the cathode potential. At the end of the interference block the grid is left greatly negative and the valve cannot conduct for some time, i.e., it is paralysed. There are several ways of curing this:—

(a) By stopping the grid current which produces d.c. restoration.

(b) By using d.c. coupling.

(c) By counteracting the negative d.c.r.

Methods (a) and (b) aim at getting rid of any d.c.r. effect.

Method (a) could be practically achieved only with a cathode-coupled limiter (see for example, G. G. Johnstone, *W.W.*, August, 1957).

Method (b) is impracticable because of attenuation.

Method (c) entailed building-in positive d.c. restoration.

(c) was tried since only a diode and a resistor needed to be added to the existing circuit (see diagram (b)).

* *Wireless World*, April and June, 1956, April 1958

Ideally the diode should have been returned to a potential corresponding to cut off for the limiter. However, the diode was taken to earth as a reasonable compromise and was left there after it was found that the clamping potential was not very critical. This modification should cure all except very bad cases: these could very well have the same trouble occurring on the grid of the last i.f. valve. If this is so, similar measures will prevent paralysis there also.

On a conventional receiver with a 10.7-Mc/s i.f. strip a diode would probably effect an improvement, although it would lower the Q of the last i.f. transformer for large inputs, due to the grid current of the limiter and the diode current. As a simple, inexpensive remedy, however, it would probably be worth a trial.

Bristol. G. J. ANDRIESSEN.

Tape Spools

I HAVE read with interest the letter from D. J. Kidd in the May issue. There can be no doubt that with the type of reels available at the moment much undesirable fiddling is necessary in order to thread them up.

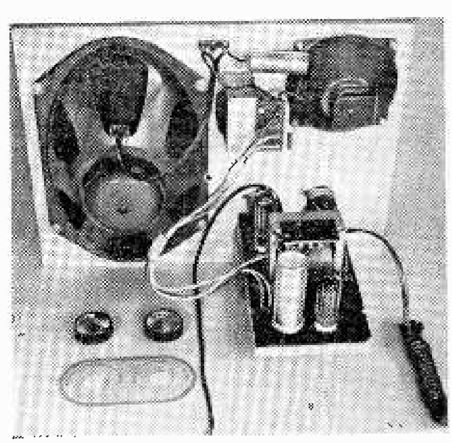
To my knowledge, only one manufacturer has made any effort to improve matters by providing a reel with a novel form of spring clip which nips the end of the leader. Apart from this, most of the others seem content to plod along, marketing the same old reels which appear to be designed to waste the maximum time when one is frantically endeavouring to thread up for a recording.

In contrast, the many ingenious reels available to the cine film enthusiast make me green with envy. I realise that improvements cost money, but feel sure that most tape recordists would gladly pay a little extra in order to obtain easy-to-handle reels.

London Tape Recording Club. JOHN WEIR.

"Do-it-Yourself" Amplifier

THE first of a new series of Cossor kits, Model 562K, comprises a three-watt, two pentode amplifier to feed two loudspeakers, a 10×6in elliptical and a 4in tweeter; the same equipment being used in the factory-made 562 record player. The sensitivity is 240mV with a signal to hum and noise ratio of 45dB. The frequency response is 2dB down at 50c/s and 13kc/s with the treble cut control turned to minimum. Detailed assembly instructions are given, and most of the components are already soldered into position on a printed circuit board. The price of a complete kit is £9 15s.

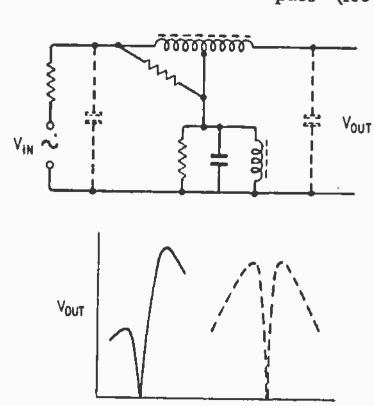


Completed Cossor 562K Amplifier

Technical Notebook

Solid "Electrolytic Tank" was described by Rowe and Martin at the I.E.E. Microwave Valve Convention. Instead of filling the volume round the metal electrode analogues with a liquid electrolyte, a solid conductor is used. The main advantage of using a solid is that, since there are no polarization effects, d.c. fields can be used instead of a.c. fields to measure the equipotentials between the electrode analogues, and errors due to a.c. pick-up are avoided. Another advantage is that the conductivity is less liable to vary with time. The solid is made by mixing conducting amorphous graphite (40 per cent by weight) and insulating gypsum plaster, these proportions giving the desired volume resistivity of about 10^5ohm-cm. Errors due to imperfect mixing can be kept below 2 per cent.

Modified Bifilar-T Traps.—The bifilar-T trap shown in the upper diagram (full lines) is widely used in television receivers to secure adequate sound rejection. This is obtained by making the sound i.f. fall in its "rejection notch" (lower diagram, full line). The network may also be used at audio frequencies for such purposes as harmonic rejection in fixed-frequency measuring instruments, and some practical results are described by A. Hendry and A. G. McIntosh in the July, 1958, issue of *Electronic & Radio Engineer*. The authors show how the basic network may be modified, e.g., by adding the capacitors shown dotted in the upper diagram, to produce a number of variant frequency responses such as low-pass (frequency of maximum response on low side of rejection notch) and symmetrical characteristics (dotted line, lower diagram). The insertion of such networks into negative-feedback loops can produce sharp band-pass responses.

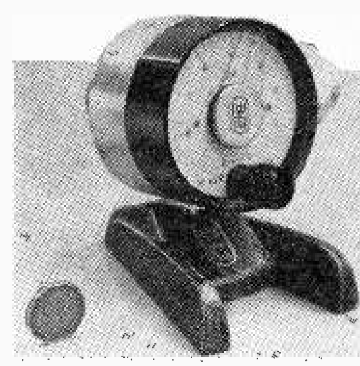


Two-State Indicator Tube for computer circuits introduced by Mullard is notable for its high sensitivity and low power requirements, making it suitable for transistor and other circuits where only small signal voltages are available. It is essentially a triode valve in which the anode serves as a fluorescent screen, giving a blue-green glow about 20 sq mm in area. Working with an anode voltage of 50V, the tube light output can be switched from maximum (anode current 0.5mA) to minimum (anode current less than 5μA) with a grid voltage swing of only 3V. The DM160, as the tube is designated, is very small, being mounted in a 5-mm diameter bulb with flying-lead connections.

Semiconductors at R.R.E.: Indium antimonide is used as the sensitive element in an infra-red-seeking guided missile, but for "good definition" and high sensitivity the sensitive area must be very small. The element actually takes the form of a strip less than 5×10^{-4}in thick, this thickness being achieved by electro-etching (the reverse of electroplating). Another process in semiconductor preparation demonstrated recently at the Royal Radar Establishment is the zone refining of silicon. Molten germanium is sufficiently non-reactive to allow this process to be carried out in a boat-shaped crucible which is passed through an r.f. field; but unfortunately silicon is so reactive at its melting point that this is impossible. Another feature of molten silicon is that it has a very high surface tension—several times that of mercury. This allows a rod of silicon to be passed vertically through an r.f. heating coil, in a vacuum, and as long as the molten zone does not exceed 1cm in length the rod remains in one piece. The rod is revolved and gradually drawn through the field, by pushing from below and pulling from above, so that a bent rod (provided it is not bent to such a degree that it cannot enter the vacuum chamber) is straightened, and, by "seeding" the leading end of the rod with a small crystal, the whole rod can be made into one single crystal structure.

—100°F Primary Cells.—*Electronic News* for 17th March reports that the Yardney Electric Corporation have produced a primary cell efficient down to temperatures as low as −100°F. The cell uses a silver chloride cathode, a calcium anode and acetonitrile as the electrolyte solvent. The efficiency of the cell is 4 watt hours/pound at −100°F and 18 watt hours/pound at 75°F with an e.m.f. of 2.55V.

Potentiometer-like Attenuator usable up to 3000Mc/s is made by the German firm Wandel and Golterman. The input is taken as usual to one end of the track, but, unlike a normal potentiometer, the earth connection is taken to the whole of the side of the track opposite to the wiped portion. This arrangement



produces a resistively loaded line in which the series resistance is provided by the track length and the shunt resistance by the track width between the wiped and earthed sides. The output is taken from the tapping on this line made by the sliding contact. The output impedance would be incorrect near the ends of the line, so the sliding contact is prevented from reaching right to these ends. Thus there is a minimum insertion loss of 10dB in this attenuator. The maximum possible attenuation is 70dB, and the accuracy ±0.2dB. In this country the attenuator is available from Solartron.

Doppler Radar Using Transistors.—The Doppler navigational radar put into service with the R.A.F. in 1954 consists of four electronics units and weighs over 100 lb. Subsequent development for civil and military use has reduced this weight and has produced a smaller aerial system. Another version, using transistors as far as possible, is now under development at the Royal Radar Establishment. This consists of only two units, and will weigh considerably less than 100 lb.

PHOTOCELLS

By "CATHODE RAY"

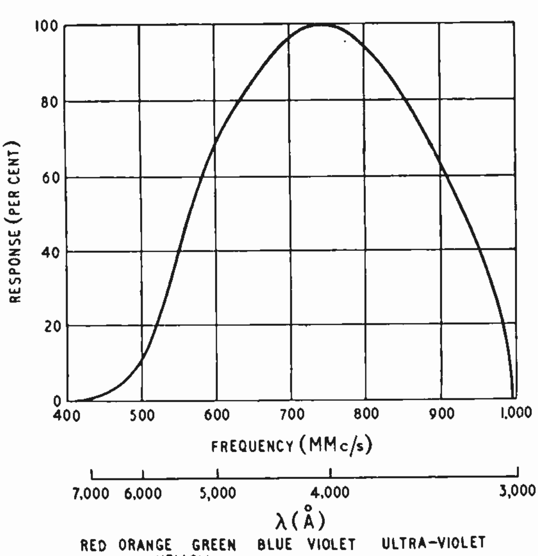
Including Some Recent Semiconductor Devices

WE are all familiar with valves and perhaps transistors, but my guess is that only a minority of us habitually handle even one of the many varieties of photocell. Probably most of that minority are owners of photographic exposure meters. Yet in spite of the fact that so few people ever see them, photocells are used in a staggeringly large number and variety of ways. If I were to do no more than mention them by name I doubt whether it would leave me room for anything else, so I won't start. But partly because there are so many uses there are many different kinds of photocell, and because they are seldom seen most of us are probably rather vague about them. It isn't my intention to say much about their construction or methods of use, but to follow up our recent ventures into electronic theory by seeing how the chief kinds work.

If you followed the series from the beginning you may remember that the photo-electric effect played a very important part in triggering off the modern ideas about matter. It was discovered that when light is shone on certain metals they emit electrons, and (contrary to what nineteenth-century physics led one to expect) the force with which the electrons are emitted increases with the frequency rather than the intensity of the light. This was, however, quite in keeping with the revolutionary quantum theory that had just been introduced to a sceptical world by Planck. It is now accepted that light consists of something like small particles, called photons, each having an amount of energy equal to the frequency f of the light in c/s multiplied by a constant, h (Planck's constant), equal to 4.15×10^{-15} if one's unit of energy is the electron-volt (eV).

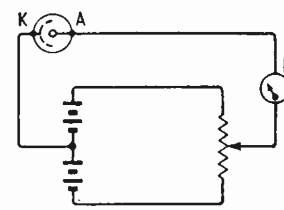
The obvious query on this is what, if light consists of particles and not waves, is f the frequency of? Well, we went into this to some extent in the March issue, and I can only repeat that both light and electrons do in fact have some of the properties both of waves and of particles, and if you don't like that idea you must, I am afraid, lump it.

Fig. 1 Response curve of antimony-cæsium photo-emissive cathode.



As we found in the June issue, metals and other solids have vast numbers of valency electrons circulating throughout them energetically, even at the absolute zero of temperature (0°K). Additional

Fig. 2 Circuit for examining current/voltage characteristic of photo-emissive cell just above and below zero voltage.



energy, usually amounting to several eV, is needed by any of these electrons to enable it to break surface and get clear—to be emitted, as we say. This quantity of energy is known as the work function, denoted by ϕ. One way of increasing the energy of the electrons is by means of heat. This is the method adopted in valves and cathode-ray tubes. Another method is to shed light on the cathode surface. Either way, the amount of energy imparted per electron must be at least equal to ϕ.

If the energy is derived from light, we know it is in packets of size hf. Since h is known, the lowest frequency needed to obtain emission from any metal follows. The ϕ for tungsten, for example, is 4.5eV, so the minimum f is $\phi/h^* = 4.5/(4.13 \times 10^{-15})$ c/s = 1,090 MMc/s.

The frequency of light runs from about 400 MMc/s at the red end to a little over 800 MMc/s at the violet, so no visible light is effective with tungsten; ultra-violet is needed. By contrast, the ϕ for cæsium is only 1.8eV, so practically the whole range of visible light has sufficient energy to overcome it.

It might seem, then, a simple matter to choose a metal suitable for emitting electrons when illuminated by radiation of any particular range of frequency. In practice it is much less simple, because the effective ϕ depends very largely on the condition of the surface. The thinnest possible coating of impurity or tarnish, for example, may quite alter its emissive properties, for better or worse. Details can be found in any good book on photocells.

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*I have just been looking up some books on this, and several of them give the equation for minimum frequency as $hf \times e\phi$ instead of $hf \times m$. Not one of these explains how hf (which is energy) can be equal to ϕ (which is energy) *multiplied by electric charge*. Anybody checking this equation by seeing whether the dimensions were the same on both sides would conclude that it was wrong. The explanation is that if the two sides are not in the same system of units a constant must be introduced to make them so. If hf is in conventional units, ϕ (usually in electron-volts) must be brought into the same system by multiplying by the number of conventional units of energy equal to one eV of energy. But to represent this by e, which stands for the amount of negative electric charge of one electron, is as muddling as making a change from British to metric units in an equation by introducing a factor l, denoting the length of an inch in metres.

In valves, heat is used to make the cathodes yield a constant emission for control by the other electrodes. Light is not a convenient alternative to this. The purpose of photo-emission is to detect or measure the light. And so we have the innumerable applications in television cameras, sound films, photometers, burglar alarms, etc., etc.

We have seen how to calculate the *minimum* frequency for emission from a surface of given φ; how about the maximum frequency? The surplus energy imparted by light of higher frequency than the minimum appears as kinetic energy of the emitted electrons. So if white light is shone on cæsium, the red part of it causes electrons merely to stagger out, with no spare energy, while the violet part, having double the frequency, makes them emerge with an energy of about 1.8eV; that it to say, with the speed they

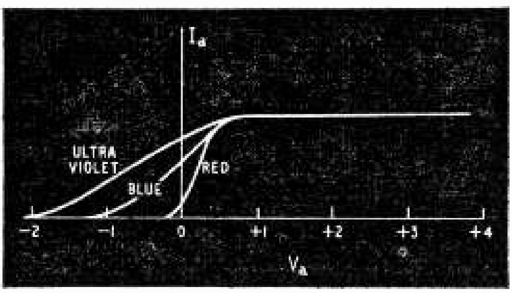


Fig. 3 How the current/voltage characteristic is influenced by colour of light.

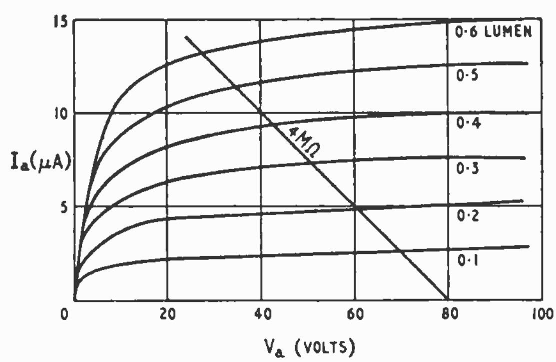


Fig. 4 The used part of a vacuum photocell's characteristic curve sheet resembles a pentode's.

would be given by a positive e.m.f. of 1.8V†. Of course, this speed is not necessarily at right-angles to the surface, so even when the light used is monochromatic—which means that it is all concentrated on one frequency—the speeds of emission directly away from the surface vary over a range from zero to the maximum as just calculated.

Under suitable conditions there is hardly any top limit to the maximum frequency that causes emission, and enormous velocities can be imparted to the emerging electrons; but ordinary photocells are enclosed in glass bulbs, which cut off most of the ultra-violet frequencies. If a cell is needed specifically for that range, a quartz window is fitted to admit it. There are other things affecting the band of frequencies for which the cell is effective; for example, surfaces absorb or reflect certain frequencies selectively. Fig. 1 shows a typical colour response curve for an antimony-cæsium cathode.

The fact that light frequencies higher than the minimum make electrons come out with speeds that can be reckoned in eV means that those electrons can land on another electrode *against* an e.m.f. up to that limit. Fig. 2 shows an arrangement for applying a controllable voltage to what we will call (by analogy with a valve) an anode, though it can be made either positive or negative. K is the photocathode, and the two electrodes are enclosed in the usual glass bulb so that the air between them can be removed. Although what is reckoned to be a high vacuum leaves about as many air molecules in every cubic centimetre as the entire population of the United States, they are so small that practically all the electrons get through without obstruction.

Let us suppose that we illuminate the cathode with various monochromatic lights, and that the cell has the characteristic shown in Fig. 1. Then a red light will just make a few electrons emerge with almost no speed, so a zero or slightly positive voltage will be needed at the anode to attract them there and make them show a deflection on the microammeter M. A blue light will bring some of them out with a velocity corresponding to a frequency difference of about 240 MMc/s, or say 1eV. They will just be able to reach the anode if it is made 1V *negative*. Making the anode gradually less negative brings in more and more of the emitted electrons—those emerging other than directly towards the anode—until finally, when all are gathered in, even a highly positive potential cannot increase the number. With near ultra-violet light, some electrons have even higher velocities, and a still more negative voltage is needed to ensure that none reaches the anode.

If the brightness of the three lights is adjusted to be effectively the same at the cathode, the results of these experiments will be as in Fig. 3. Increasing the brightness would proportionately increase the number of electrons emitted, so the current readings would all be multiplied everywhere by that factor. But the "starting voltage" for any one colour would be the same as before.

When a current flows *against* an e.m.f., as indicated by the left-hand region of Fig. 3, it possesses energy, which can be utilized. Suppose the battery and potential divider in Fig. 2 is abolished and simply a resistor is connected between K and A. Then the electrons flowing through it will set up a p.d. across it, making the anode negative. The cell will in effect be a generator driving current through the resistor. This corresponds exactly with the current that flows through a resistor between anode and cathode of an ordinary diode, the energy in that case coming from heating of the cathode instead of light shining on it. The same thing is familiar in other types of valve, where some grid current flows even when the grid is slightly negative.

Although there are rumours that direct conversion of heat to electrical energy in this way may become a practical source of power, the efficiency would seem too low to be attractive; and the power available from an ordinary emissive photocell is even more insignificant. The usual way of using the cell is to apply something of the order of +100V to the anode through a high load resistance, the relation-

†For voltages lower than about 10,000 (so that the relativity correction is negligible) the velocity is $594\sqrt{V}$ km/sec, so with V = 1.8 it is 800 km/s or 1,800,000 m.p.h.

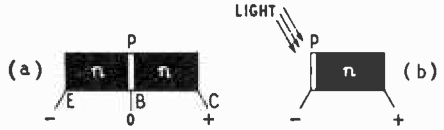


Fig. 5 An n-p-n transistor (a) and the corresponding photo-transistor (b).

ship between voltage drop across this resistance and brightness of light being very similar to that between load voltage and grid voltage in a pentode —see Fig. 4. The voltage drop is used as a measure of the light, or for actuating something by light.

I must just mention that the anode current can be multiplied considerably if a small amount of inert gas is admitted to the tube. The characteristics of these tubes are similar to Fig. 4 up to about 20V; above that, the electrons get up enough speed to knock electrons out of the gas atoms (ionize them, to use the technical term) and these swell the crowd. Which type is the better to use depends on the circumstances. In general, the vacuum type is used for measurement (quantitative) and the gas type for detection (qualitative).

We must press on, for we have covered only the first of the three points in the sermon—photo-*emissive* cells. As we have seen, one could also classify these as photo-*voltaic*, in that they are capable of generating an e.m.f. directly from the power of light, but as it is only to a very limited and insignificant extent one does not. Before coming finally to the cells which are photo-voltaic enough to be so used, let us take a look at the photo-*conductive* class. If you wanted to be awkward you might point out that the emissive type could also be regarded as photo-conductive—and in its normal mode of use, too—but for convenience the term is confined to solid conductors.

Selenium is the substance everyone thinks of here, because its light-sensitive properties were discovered as long ago as 1873, and for most of the time since it has remained supreme. But recently there has been considerable development of other semiconductors, notably compounds of lead and thallium with sulphur, selenium and tellurium. What is likely to interest us most is that still more recently transistor technique has become involved.

Semiconductors, you may remember, are substances in which there is a small energy gap between the energy band filled with valency electrons and a conduction band into which they have to be raised if the material is to conduct at all. The smallness of the gap means that the energy of heat at ordinary temperatures is sufficient to raise a small but significant proportion to the conduction band. In transistors and most other semiconductor devices this heat conduction is just a nuisance, because it is a sort of leakage, not under the control of the input signal. The useful current carriers, introduced by impurities, are under control. Light is another form of energy, and more effective than heat because of its higher frequency. That is why semiconductors tend to conduct better in the light than the dark. It is also why transistors are enclosed in opaque containers, but where control by light is desired they can be modified accordingly; hence the photo-transistor.

In general, a photo-transistor has one electrode

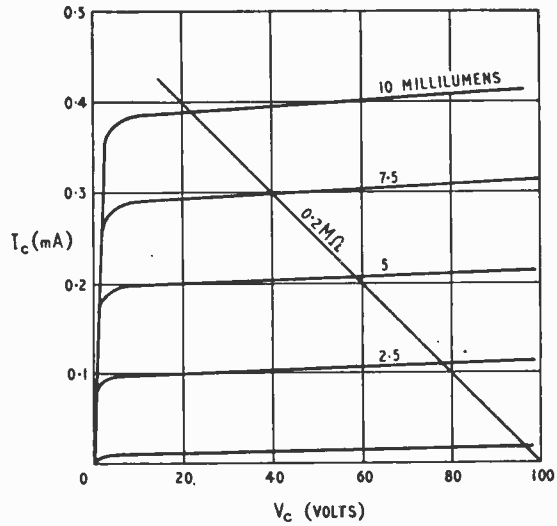


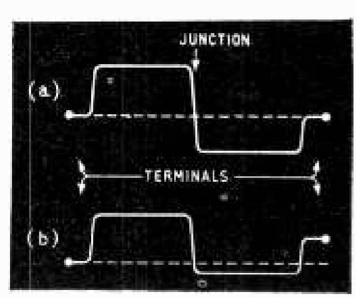
Fig. 6 The characteristic curves of a photo-transistor closely resemble those of a transistor triode.

fewer than the corresponding signal transistor, because the current carriers are introduced directly by the impact of light instead of from the usual emitter. Fig. 5(a) shows an *n-p-n* junction transistor in which the emitter functions as the source of free electrons, thanks to the donor impurity therein. Their flow into the base—whence they are snapped up by the positive collector voltage—is controlled by the signal voltage between emitter and base. Alternatively, electrons already in the base can be freed by the direct impact of light, as in Fig. 5(b). The characteristic curves (Fig. 6) are of exactly the same type as for the transistor triode, except for light taking the place of base voltage as the controlling parameter.

It is not essential to have a junction; the resistance of a simple strip of germanium goes down when it is exposed to light. The semiconductor compounds mentioned are also used simply as light-variable resistors. Some are remarkably sensitive and some respond to a very wide spectrum, embracing ultra-violet, visible and infra-red. At ordinary temperatures the current carriers released by light have to compete with those released by heat, so for extreme sensitivity they are cooled. A lead sulphide cell cooled by liquid air, for example, is sensitive to 10^{-13} watts per sq cm. Without this refinement, or any means of concentrating or directing the radiation, the Mullard 615V lead sulphide cell is stated to detect the heat from an ordinary soldering iron at 100 yards.

Lastly, photo-voltaic cells, which generate their

Fig. 7 Potential diagrams of a junction photo-transistor, (a) in the dark, and (b) illuminated.

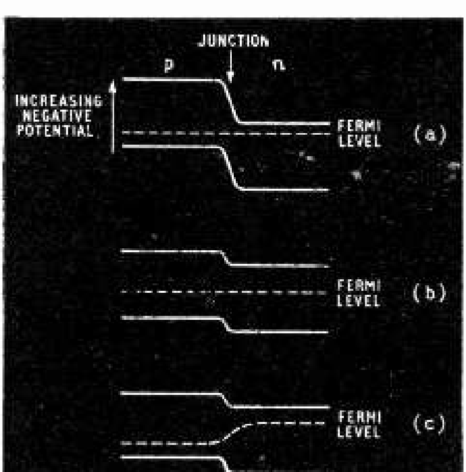


own power. We noted in passing that emissive cells qualify also as photo-voltaic, but so slightly as to be of no practical value in that role. Semi-conductor junctions (*n-p*), as all treatises on them explain, develop a difference of potential between the two sides of the junction. Nearly all the said treatises fail to explain why no trace of it can be found when even a highly sensitive voltmeter is connected to the terminals. The reason, after one wrong guess, was given last month as the counteracting p.d.'s of the metal-to-semiconductor junctions at the terminals. But just as heating one of the junctions between different metals in a complete circuit upsets the balance and sends a thermo-electric current around the circuit, so the impact of light on a suitable junction enables it to act as a current generator. This is shown very simply in Fig. 7, where (a) is the balanced condition in the dark (or equal illumination throughout), whereby there is no p.d. between the terminals. The quite large p.d. at the junction, you remember, is caused by the superfluity of electrons in the *n* material and holes in the *p* material; these diffuse across the boundary, the electrons charging the *p* side negative and the holes charging the *n* side positive. The process ceases when this p.d. just balances the diffusive tendency. Heat—or light—dilutes the effect by creating hole-and-electron pairs in either or both regions. Neither electrons nor holes will diffuse into regions where there are already plenty of their own kind, and so the p.d. tends to be lower, as in Fig. 7(b), with the result that a net p.d. appears between the terminals.

If you like the Fermi level idea you may prefer to think of the thing on that basis. You remember that making pure semiconductor material into *p* or *n* displaces the Fermi level from the middle of the energy gap downwards or upwards respectively. So where the two kinds are in contact a p.d. is created as in Fig. 8(a). Heating the material tends to bring the Fermi level back to the middle again, the two opposite kinds of impurity conduction being (as it were) swamped by the increased intrinsic conduction. The p.d. is thereby reduced as shown at (b).

Light, if it could get to all the material represented, would have a similar effect. Since these

Fig. 8 Fermi diagrams of a p-n junction, (a) normally, (b) heated throughout, and (c) exposed to light at the junction.



materials are not particularly transparent, it is as much as one can do to illuminate a thin section at or about the junction. A transition from decidedly *p* or *n* type to near-intrinsic conduction at the junction due to strong illumination there can be represented by a shifting of the Fermi level in the gap,

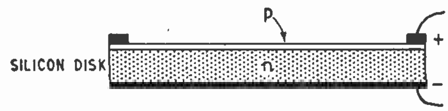


Fig. 9 Section of junction photo-voltaic cell used in Bell Telephone tests.

as shown at (c). The drop in p.d. as compared with (a) appears again.

Selenium, although somewhat outmoded for photo-conductive cells, is a favourite material for the photo-voltaic kind, and electric exposure meters usually consist of a suitable metal-to-selenium junction feeding a microammeter. These instruments are taken for granted now, but a year or two ago some excitement was created by tests carried out by the Bell Telephone Laboratories, in which a special battery of photo-voltaic cells mounted on a rural telephone pole provided the power for a repeater station from sunlight alone. On a bright day the power developed was 10 watts—more than was needed by the repeater, so that there was a surplus to charge an ordinary battery to keep things going at night and during dull days. (Whether there would be enough surplus to ensure continuous operation in this country seems open to doubt!)

Fig. 9 gives some idea of the construction of the cells used. The semiconductor is silicon (presumably germanium would have rather an excessive intrinsic conductivity at the temperature it could reach in full American sunlight). Most of it is *n*-type due to arsenic "impurity," but an extremely thin layer of *p* is formed on one surface by diffusion of boron. The junction is only 0.0001in below the surface. In bright sunlight, the e.m.f. generated was about 0.5V; polarity as marked in Fig. 9. As many as 432 cells were used for the test, mounted in a flat aluminium case with glass lid. The efficiency was about 10%, which was a considerable advance on conventional photocells. Since it is estimated that in two days the earth receives more energy from sunlight than could be provided by all its known reserves of fuel, you may begin to wonder why we are bothering about nuclear power stations. There are, of course, many snags in solar energy, chiefly financial (capital costs, and so forth). But for special applications, such as this telephone idea, it has interesting possibilities.

One of these special applications has been demonstrated more recently, also by the U.S.A., giving their earth satellites at least one advantage over the first two sputniks,‡ which went dead (together with the dog) as soon as their batteries ran out. One of the American satellite's radio transmitters is energized by photo-voltaic cells, and since the sun at that altitude is not only unobscured by clouds but also by the atmosphere the radiation is much more intense and (except when eclipsed by the earth) continuous.

‡ Since writing, Sputnik III has gone up, energized partly by solar batteries.

Wide-Band Oscilloscope

By G. H. LEONARD*, B.Sc.

THE techniques used in oscilloscope Y amplifiers have made considerable advances during the past few years and instruments are commercially available having direct coupled amplifiers with a 3dB bandwidth of the order of 30Mc/s together with a rise time of the order of 10-15mμsec and a high sensitivity. These instruments are usually complex, making use of very accurate multivalve timebases, calibrators, etc., and the latest distributed p.d.a. tubes. They are excellent multi-purpose instruments but are very expensive.

Being faced with requirements for an oscilloscope having a rapid rise-time (with negligible overshoot) and wide bandwidth, it became apparent to the writer that provided certain limitations were accepted the distributed amplifier normally found in expensive instruments could be dispensed with. Using modern valves with a high figure of merit in conjunction with low anode loads, and cathode followers to reduce the effects of input capacitance, the design of a wide-band amplifier having a suitable gain appeared to present few problems, provided a.c. coupling were accepted together with considerable restriction of the usable Y deflection.

MODIFYING AN EXISTING COMMERCIAL INSTRUMENT

The use of a.c. coupling was not considered to be a serious drawback; the occasions when one is interested in examining rise-time and d.c. level together are, in the writer's experience, comparatively rare. When they do arise, it is frequently possible to make a separate observation of the d.c. level by the use of a simple chopper consisting of a pair of resistors and a high-speed relay energized from a 6.3-V, 50-c/s, supply to obtain a "double-beam" presentation of d.c. level. With this in mind, it was decided that the l.f. response of any amplifier must be such as to give negligible droop on a 50-c/s square wave.

Vertical Deflection

The minimum acceptable height of display is very much open to debate. For design purposes a minimum display of one centimetre for short pulses of either polarity (with the mean d.c. level roughly corresponding to the undeflected trace) was considered sufficient provided an adequate synchronizing signal could be obtained. This presupposed a display of 2cm for a sine wave or other symmetrical phenomena. To obtain such a display on a 4EP1 cathode-ray tube (commonly used in reasonably priced oscilloscopes) a peak-to-peak voltage swing of approximately 20V must be applied across the Y plates if the final anode voltage is 1kV and the p.d.a. voltage 2kV. This implies an output swing of 10 volts peak-to-peak from each half of a push-pull output stage, which is within the capabilities of a wide-band amplifier pentode with a high figure of merit, such as the Mullard E180F, even if the anode load is as low as 680 ohms, provided that negative feedback is used to retain good linearity.

With these facts in mind, it was decided to modify an existing oscilloscope to incorporate a wide-band amplifier. After examining the alternatives and contacting the manufacturer as to the h.t. current available for the Y amplifier, a Telequipment 720 was chosen.

The most important stages in a wide-band oscilloscope amplifier are the final paraphase output stage and the preceding stage, as it is here that large signals must be handled with reasonable linearity. It is therefore proposed to examine the design considerations for these stages in some detail. The effective input capacitance of each Y plate of the 4EP1 is 6pF, which consists of 3pF to the earthy electrodes plus the inter-plate capacitance, 1.5pF, which must be multiplied by 2 to allow for the anti-phase voltage applied to the other plate. Add to this a minimum of 4pF for strays, and a rough calculation shows that even with a resistive source impedance of 500ohms the 3dB point would be about 30Mc/s.

Since the cut-off of other stages would also have some effect, this frequency is too low and a lower source impedance must be obtained. This can be obtained by using a cathode follower, but it must be remembered that for large outputs the cathode CR must be kept sufficiently short for the C to be able to discharge through the R more rapidly than the fastest negative-going transient to be handled, otherwise the cathode will be unable to follow, the valve will cut off, and the output impedance will rise to the value of the cathode load. Again taking 500 ohms and 10pF, we have a time constant of 5mμsec which should be short enough. The mutual conductance of an E180F is 16.5 as an amplifier, but if the screen current is considered a higher figure is obtained. Calling this 18, we have that the output impedance of the stage is approximately 1/18kΩ or 55 ohms, which is low enough to ensure that up to the frequency where the cathode ceases to follow, the drop in output will be small.

It is quite common practice in modern oscilloscope amplifiers to utilize a cathode-coupled pair, d.c. coupled to the Y plates, for the output stage, the Y shift potential being applied to the "earthy" grid. This arrangement ensures that the full grid base of the valves can be utilized when asymmetrical pulses are examined. Such a stage also has considerable gain, the push-pull (anode to anode) out-

* Ultra Electric.

put being equal in amplitude to the output which would be obtained from one valve operating as a simple amplifier with the same anode load. At first sight, it would therefore appear that the ideal arrangement is a cathode-coupled pair d.c. coupled to a pair of cathode followers which are d.c. coupled to the Y plates; any shift bias voltage, applied when examining asymmetrical waveforms, would bias the cathode followers to a suitable operating point to fully utilize their grid bases.

This arrangement suffers, however, from the following disadvantages. First, great care must be taken in the design in order to ensure that no valves are over-run if the Y shift potentiometer is left at one end of its travel, so that a "safe" design must have a restricted shift range which will in turn restrict the asymmetrical handling capacity. Secondly, an extra h.t. supply must be provided so that the cathode followers may be directly coupled to the preceding anodes whose potential is virtually h.t.+ if low loads are used. Thirdly, the stage requires four valves. Finally, the input impedance is not very high. This last point applies to both resistive and capacitive components. Since the cathode of the input valve has an a.c. voltage approximately equal to half of the input and in phase with it, the apparent input capacitance of the valve is halved, but as the grid is normally returned to a steady d.c. potential there is no feedback effect on the resistive component.

Phase Splitter Output

An alternative arrangement, which was the one chosen, is the "split anode load" phase splitter, which has effectively equal anode and cathode loads with a.c. coupling to the Y plates. This circuit, V5 in Fig. 1, gives anti-phase outputs at anode and cathode which are substantially equal to the input so that the stage gain is approximately two. Since the anode load, R_{25}, is kept low the output impedance at the cathode is substantially that of a similar cathode follower so that another valve is eliminated. The input capacitance is low and as the grid leak, R_{27}, is tapped into the cathode load the input resistance is high. This means that a smaller coupling capacitor can be used for the same l.f. response, reducing strays and thereby improving the h.f. response of the preceding stage. The handling capacity for symmetrical inputs is the same as for the cathode coupled pair, but for asymmetrical inputs, since the standing bias is not variable, it is limited by the grid swing available in each direction.

At first sight, it might appear that the anode of the stage could be coupled to a Y plate without interposing a cathode follower and that the stage would then be perfectly cathode compensated, the anode and cathode time constants being equal. In practice, however, these ideal conditions are not met. As the screen current increases the cathode current swing, the anode resistor must be larger than the cathode resistor to obtain equal outputs. Also the anode capacitance increases the anode time constant. The input capacitance of the cathode follower V6 is only about 2pF so that with the strays assumed as before to be 4pF and the anode capacitance of the valve (3pF) we have 9pF. This appears of the right order for ideal compensation.

The values derived above and earlier in the text are of course very approximate, being based on estimates of the stray capacitances. In practice, it was found that the stage was slightly over-compensated and it was necessary to add a small capacitance at the anode to eliminate a small overshoot.

The amplifier preceding the output stage, V4, is designed to give an output which is sufficient to fully load it without introducing distortion and for this reason the anode load, R_{20}, is higher than would at first seem desirable.

The undecoupled cathode resistor R_{23} helps, of course, in linearising the stage, introducing 6dB of negative feedback. Nevertheless, the theoretical stage gain is 6. Experiments were made with a view to applying cathode compensation to this stage, but in the layout used the improvement in rise-time which could be obtained without introducing overshoot was negligible.

As the input capacitance of the stage is relatively high, being of the order of 5pF, a cathode follower, V3, is used to isolate it from the preceding amplifier.

(*Continued on page* 397)

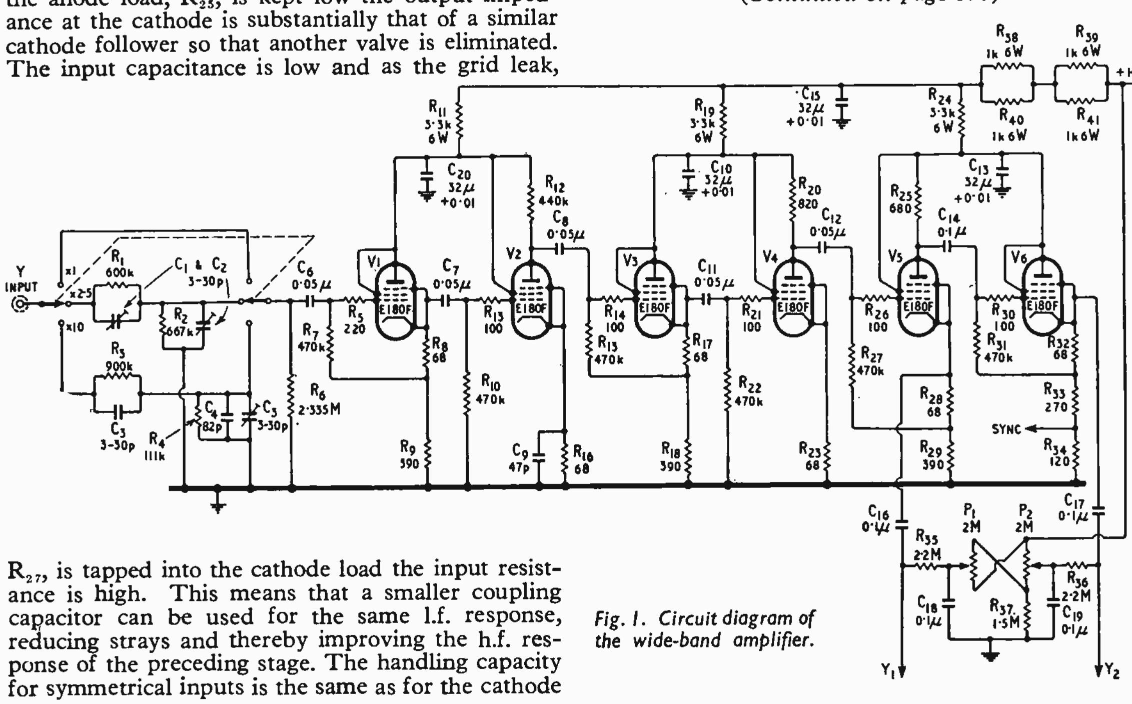


Fig. 1. Circuit diagram of the wide-band amplifier.

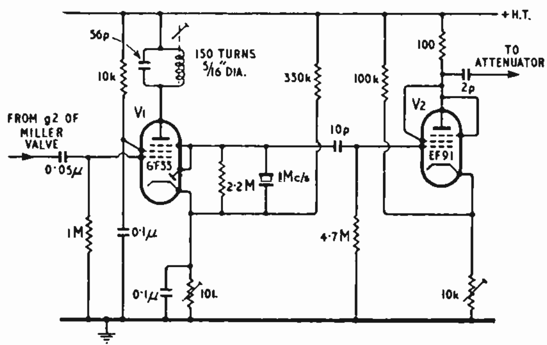


Fig. 2. Time calibration oscillator for the timebase, using a 6F33 and an EF91

The cathode CR of this valve, and the input cathode follower, is unlikely to introduce any distortion as the voltages handled are smaller.

The first amplifier, V2, is designed to give some gain (approx. 3) without noticeably affecting the frequency response, while the input cathode follower, V1, presents a high impedance to the attenuator or the circuit under test.

The various decoupling components shown in the circuit serve to reduce the h.t. voltage to 180 volts, the normal voltage for the E180F, and also give a small measure of anode compensation so that the 50-c/s square-wave response is adequate.

The input circuit and attenuator deserve special mention, being the only high impedance circuits associated with the amplifier. With the modern tendency to employ synthetic resin-bonded fibre switch panels at 200Mc/s the need for low-loss materials is easily overlooked. It was found, however, that an attenuator built on standard wafers introduced sufficient loss at higher frequencies to completely spoil the rise-time of the instrument. Only when a ceramic wafer switch was used and the anchoring points for the input capacitor were mounted on Polythene was the attenuator satisfactory. Similar considerations applied to a high-impedance probe, and in view of the cost of design and manufacture of this item the input impedance of the instrument was arranged to be similar to the well known Tektronix instruments for which probes can be purchased. To facilitate the use of this probe, capacitors are provided across both series and parallel elements of the attenuator so that the input capacitance is independent of the attenuator setting.

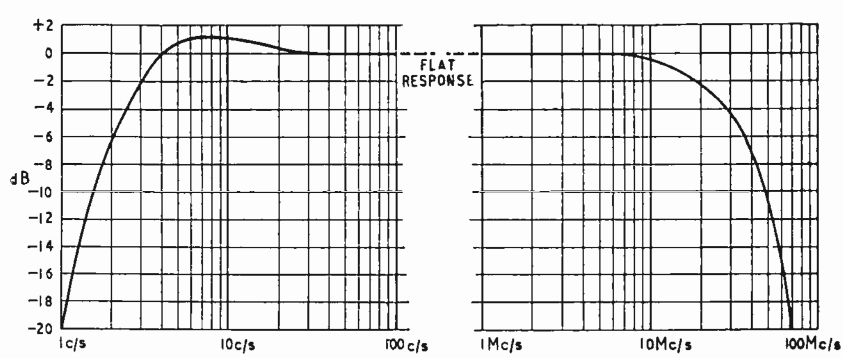
The Telequipment oscilloscope modified has available a 1-V peak-to-peak calibrating signal and a graticule of 6-mm squares. When the amplifier was built it was found that the maximum deflection obtainable was approximately 4 squares and it was felt desirable to increase this to 5 squares (the attenuator includes a ×2.5 position) and also to provide a fine gain control for setting up. Since the inclusion of such a control in the amplifier was liable to introduce long leads, variable time constants or other complications likely to lead to either a poorer rise-time or instability, the e.h.t. circuit was examined. It was found possible to insert a variable resistor in an a.c. circuit so as to reduce the final anode potential of the c.r. tube without unduly affecting the p.d.a. voltage so that sufficient variation in sensitivity could be obtained. Space was found on the front panel for a "Set e.h.t." control, which is normally set up, together with the focus and astigmatism, at the start of any measurements.

Unfortunately, adjustment of the e.h.t. also affects the sensitivity of the X plates, which means that the calibration of the timebase is affected. The oscilloscope incorporated a sweep speed control, intended as a semi-preset, mounted at the rear of the instrument; this was moved to the front panel. The time calibration oscillator circuit had been removed with the original Y amplifier but room was found to mount a small sub-chassis on which was mounted the circuit shown in Fig. 2. This consists of a short suppressor grid base pentode, V1, with the anode and suppressor arranged as a crystal oscillator, the grid being fed from the unblanking circuit so that the oscillations are keyed on at the start of the sweep and a locked display obtained. The second valve, V2, is a clipper so biased that it only passes current on the peaks of the sine wave and hence produces short pulses at the anode. To save controls, the front panel space being limited, the time calibration and voltage calibration circuits are connected to spare positions on the attenuator switch. This also avoids the need for a second low-loss switch.

High Frequency Sync

The need for a further facility became apparent when the amplitude response of the amplifier, Fig. 3, was being plotted. Many signal generators of quite reputable make do not give a pure sine wave output, so that great care must be taken in comparing the peak-to-peak voltage displayed on an oscilloscope with any meter indicating peak or r.m.s. Examination of the brightness of the display with quite low timebase speeds gave some indication of the presence of distortion, but at frequencies above 3Mc/s a locked display of the actual waveform was very difficult to obtain. To improve the timebase performance an extra (high speed) position was incorporated on the "time multiplier" switch; this position gives approximately 10 times increase in sweep speed of the timebase with the risk that the rated grid

Fig. 3. Frequency response of the wide-band oscilloscope.



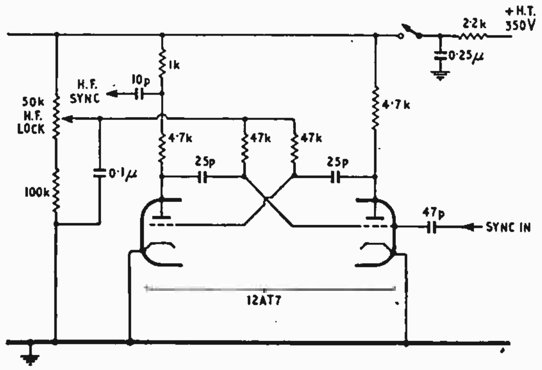


Fig. 4. Multivibrator for improving synchronization of the timebase at high frequencies.

current of the associated valve will be exceeded.

To overcome the limitations of the triggering circuits, which have a reduced performance at high frequencies, the arrangement shown in Fig. 4 is used. An "H.F. Sync" position is provided on the sync selector switch which feeds the output of the sync amplifier to the multivibrator, the output of which is switched to the timebase. The "H.F. Lock" control is adjusted to obtain a suitable division ratio, the multivibrator frequency (of the order of 1Mc/s) being within the limits at which the timebase will trigger. With this arrangement, it has been found possible to obtain a locked presentation of 20-Mc/s sine waves.

The instrument has obvious limitations in respect of brilliance etc. but nevertheless has many uses; the amplitude response being useful up to 40Mc/s, it has, for example, been found possible to use it to check television i.f. amplifiers for amplitude non-linearity under actual signal conditions with the a.g.c. in operation. It is also invaluable for pulse work, the Y amplifier rise and fall times being of the order of 15mμsec.

The writer wishes to acknowledge the part played by F. Woodrow and J. Mosely, who assisted in the development of the instrument.

Colour Receiver Development

IN last month's issue (p. 323) we published a picture of an experimental 21-inch colour television receiver for N.T.S.C. type signals developed at the G.E.C. Research Laboratories. As stated in the caption, the main feature of this set is its small size, which is obtained mainly by the use of a.c./d.c. technique for the power supplies. There are, however, several other interesting features and refinements in the circuit. In general the aim has been to provide accurate registration of the three images on the shadow-mask tube; adequate bandwidth and definition with correctly shaped frequency response characteristics in both luminance and chrominance channels, together with full d.c. maintenance; and stable and noise-free reference signal generation from the colour sync burst.

On the signal side, sound rejection and sound i.f. take-off conform to usual monochrome practice, but in the vision circuits two separate crystal detectors are used to provide isolation between the luminance and chrominance channels. This arrangement enables a high definition luminance signal to be maintained, and when this is fed to the ferrite-loaded delay line (for correct phasing of luminance and chrominance) small reflections in the line are prevented from disturbing the smooth and symmetrical chrominance channel frequency response.

The luminance signal is amplified by two video stages in a "bootstrap" circuit and is ultimately fed in the correct drive ratios to the three cathodes of the c.r. tube. Master brightness is controlled by a bias arrangement in one of the video stages, and the d.c. component of the signal is maintained to within about 1dB.

Two chrominance amplifiers with a 6dB bandwidth of ±500kc/s supply two "clamping" triodes for high-level demodulation along the red and green difference axes, R-Y and G-Y. After filtering, these difference signals are fed to the red and green grids of the tube, and also to a matrix amplifier which forms the B-Y signal for the blue grid of the tube. A reference frequency amplifier provides the two appropriately phased reference signals for the triode demodulators.

The continuous reference signal required for synchronous demodulation is obtained from an LC oscillator which is frequency and phase locked by a two-mode automatic phase control loop, or d.c. quadri-correlator, so that both fast pull-in and good noise performance are achieved. One of the two detectors in the automatic phase control loop provides a d.c. voltage only when a burst signal is present and when the oscillator is phase locked. Since this is a synchronous detector it provides an accurate indication of the presence of a burst even under adverse signal-to-noise conditions, and is used as a colour "killer" control for switching off the chrominance channel automatically when a burst signal is absent. The output of this detector is also fed as an automatic chrominance control signal to bias the chrominance amplifier from which the burst output is taken.

The colour burst is separated from the chrominance waveform and amplified before being applied to the automatic phase control detectors. The separation is carried out by a gating circuit which switches on the burst amplifier only during the burst period of about 4μsec. In order to be quite independent of line timebase synchronization, the gating circuit operates from the back edge of the line sync pulses appearing in the sync separator output.

The c.r. tube e.h.t. supply of 23kV at 1mA is obtained directly from the line flyback without voltage doubling, and a triode shunt regulator is used to stabilize the supply and thereby minimize the effect of e.h.t. changes on the convergence of the three electron beams. Passive convergence circuits, fed from the line and frame timebases, supply the appropriate current waveforms to the dynamic convergence coils mounted round the neck of the tube. Direct currents are also applied to these coils for static convergence adjustments.

AWARD OF I.E.E. PREMIUMS

TWENTY-ONE of the twenty-eight major premiums awarded by the Institution of Electrical Engineers for contributions read during 1957 are for papers on radio and electronic subjects.

The Institution Premium (£50) is awarded posthumously to Dr. E. C. S. Megaw for "Fundamental radio scatter-propagation theory".

The Kelvin Premium (£25) goes to Dr. G. H. Metson for "The conductivity of oxide cathodes".

G. G. Gouriet receives the Blumlein-Browne-Willans Premium (£20) for his contribution "Bandwidth compression of a television signal".

R. G. Medhurst and his three co-authors G. F. Small, H. D. Hyamson, and Muriel Hodgkinson share the Fahie Premium (£15) for their four papers covering various aspects of frequency-modulated systems.

The Coopers Hill War Memorial Prize and Medal (£20), which is awarded triennially in turn by the I.E.E., the School of Military Engineering, Chatham, and the School of Forestry, Oxford, goes this year to L. R. F. Harris, for his paper "Time sharing as a basis for electronic telephone switching".

The premier award of the Radio and Telecommunication Section, the Duddell Premium (£20), is shared by Professor A. L. Cullen and Dr. H. A. French for their paper "An instrument for the absolute measurement of low-level microwave power in the 3-cm band".

Professor H. E. M. Barlow and H. G. Effemey share the £15 Ambrose Fleming Premium for "Propagation characteristics of low-loss tubular waveguides".

Eleven £10 Premiums have been awarded this year for Radio Section papers. A number of them go to authors of papers read at the Ferrites Convention.

Two of the three premiums of the Measurement and Control Section are for papers on digital computers. Dr. T. Kilburn, Dr. G. R. Hoffman and R. E. Hayes share the Silvanus Thompson Premium (£20) for "An accurate electroluminescent graphical-output unit for a digital computer", and Dr. M. V. Wilkes, W. Renwick and Dr. D. J. Wheeler receive the Mather Premium (£15) for "The design of the control unit of an electronic digital computer". The third Measurement Section Premium (£10) goes to Dr. G. B. B. Chaplin and A. R. Owens for their papers on transistor d.c. amplifiers.

EXHIBITIONS AND CONFERENCES

FURTHER details of the exhibitions and conferences listed below are obtainable from the addresses given in brackets. British manufacturers can obtain information regarding exhibiting at overseas shows from the Board of Trade, Export Publicity and Fairs Branch, Lacon House, Theobalds Road, London, W.C.1.

UNITED KINGDOM

National Radio Show, Earls Court, London, S.W.5 .... Aug. 27-Sept. 6
(Radio Industry Council, 56 Russell Sq., London, W.C.1.)

Farnborough Air Show .... Sept. 1-7
(Society of British Aircraft Constructors, 29 King St., London, S.W.1.)

Autumn Audio Fair, Grand Hotel, Harrogate .... Oct. 24-26
(Audio Fairs, Ltd., 42 Manchester Street, London, W.1.)

Convention of Scientific Instrument Manufacturers, Majestic Hotel, Harrogate .... Nov 6-9
(S.I.M.A., 20 Queen Anne St., London, W.1.)

Symposium on Mechanization of Thought Processes, N.P.L., Teddington, Middx. Nov. 24-26
(National Physical Laboratory, Teddington.)

Radio Hobbies Exhibition, Royal Horticultural Society's Old Hall, London, S.W.1. Nov. 26-29
(P. A. Thorogood, 35 Gibbs Green, Edgware, Middx.)

Electronic Computer Exhibition and Business Symposium, Olympia, London, W.14. Nov. 28-Dec. 4
(Electronic Engineering Association, 11 Green St., London, W.1.)

OVERSEAS

International Conference on Semi-conductors, Rochester, N.Y., U.S.A. .... Aug. 18-23
(G.E.C. Research Lab., P.O. Box 1088, Schenectady, N.Y., U.S.A.)

Western Electronic Show and Convention, Los Angeles, U.S.A. .... Aug. 19-22
(Wescon, 1435 South La Cienega Boulevard, Los Angeles 35, Cal., U.S.A.)

Swiss Radio, Television and Recording Show, Zurich, Switzerland...... Aug. 28-Sept. 2
(W. Von Liliencron, 15 Strassburg Strasse, Zurich.)

International Analogy Computation Meeting, Strasbourg, France .... Sept. 1-9
(F. H. Raymond, 138 Boulevard de Verdun, Courbevoie (Seine).)

International Congress on Cybernetics, Namur, Belgium .... Sept. 3-10
(International Assoc. for Cybernetics, 13 rue Basse-Marcelle, Namur.)

Instrument-Automation Conference and Show, Philadelphia, U.S.A. .... Sept. 15-19
(Instrument Society of America, 313 Sixth Ave., Pittsburgh 22, Pa.)

International Symposium on Nuclear Electronics, Paris, France .... Sept. 16-20
(Société des Radioélectriciens, 10 av. Pierre-Larousse, Malakoff (Seine).)

International Radio-Television-Electronics Fair, Amsterdam, Netherlands.. Sept. 22-29
(H. J. Kazemier, Emmalaan 20, Amsterdam Z.)

Irish Radio and Television Show, Mansion House, Dublin, Eire .... Sept. 23-27
(*Irish Radio & Electrical Journal,* 14-15, Dame Street, Dublin, Eire.)

British Components Exhibition, Stockholm, Sweden.................. Sept. 29-Oct. 3
(R.E.C.M.F., 21 Tothill Street, London, S.W.1.)

I.R.E. Canadian Convention and Exposition, Exhibition Park, Toronto...... Oct. 8-10
(Grant Smedmor, 1819 Yonge Street, Toronto 7, Canada.)

National Electronics Conference, Chicago, U.S.A. .... Oct. 13-15
(N.E.C., 84, East Randolph St., Chicago, Ill., U.S.A.)

International Radio and Telecommunications Fair, Ljubljana, Yugoslavia.. Oct. 31-Nov. 9
(Gospodarsko Razstavisce, Titova 48, Ljubljana.)

Conference on Magnetism and Magnetic Materials, Philadelphia, Pa., U.S.A. Nov. 17-20
(C. J. Kriessman, Remington Rand Univac, 1900 W. Allegheny Ave., Philadelphia.)

RANDOM RADIATIONS

By "DIALLIST"

Repaired C.R.T.s

MY best thanks to the numerous readers who have kindly written to tell me of their experiences with repaired c.r. tubes. Without exception, their reports are favourable—provided that the work is expertly done by a well-equipped firm. A good many of those who wrote are wireless and television dealers. One said that he has been having tubes repaired during the past three years by the firm whose methods and equipment were described recently in *Wireless World*. "In that time," he wrote, "I have had all makes repaired and have received wonderful service from the tubes. In my opinion they are as good as new ones and so far as I know most of those I had repaired so much as three years ago are still going strong." Another wrote that the only trouble he had ever had concerned a tube which developed a cathode-heater short within six months. "But that," he said, "was put right without question under the guarantee and is still giving good service after 12 months' use." Well, you can hardly say fairer than that, can you? With c.r.t.s costing what they do, the call for re-gunning services is bound to increase. My only fear is that mushroom firms without the necessary equipment or knowledge will spring up with the idea of making money while the going's good.

A Cathode-Grid "Short" Tip

A Scottish dealer sends me an interesting tip for coping with cathode-grid shorts. "Except in the case of triode c.r.t.s," he writes, "the fault can be successfully overcome by strapping the grid permanently to the cathode." The boost h.t. supply is then disconnected from the first anode, to which the lead previously going to the grid is connected. This done, the first anode is used as a control grid and the tube, now converted into a triode, works, he claims, quite satisfactorily. Some adjustment of the focusing and ion-trap magnet and of the brilliance control will probably be found necessary. "When this has been done the picture is very nearly as good as it was before the short developed." I can't claim to have tried out the suggestion, for I don't possess a c.r.t. with a cathode-heater short. But it's certainly an ingenious idea, and I'd be glad to hear from anyone else who has put it into practice with success.

Colour Television

THE B.B.C.'s report on its colour television tests carried out up to the spring of last year shows that on the whole these have been very satisfactory and that results are promising. Myself, I hope that when a colour TV service comes it will break away completely from the 405-line, or 625-line standards, and won't bother its head about compatibility. My idea is that colour television should take place in, say, Band V and that the black-and-white pictures with the 405-line standard should continue to use Bands I and III. If the same programmes were broadcast in colour as in black and white, there'd be no hardship to anyone. Existing receivers could continue to be used in Bands I and III until their owners felt inclined (or could afford) to go in for colour sets. In Band V a standard of the order of 1,000 lines could be adopted and then we'd have some really fine colour pictures. With the smaller rooms of modern homes an increase—a big increase—in the number of lines would be a very great advantage. It's often not easy to sit far enough from a 17-in screen (to say nothing of a larger one) to get rid of lininess; and it seems that the man-in-the-street doesn't care about spot wobble or spot astigmatism. If only more of our folk could see the beautiful French 819-line pictures, with their freedom from lininess even on 21-in and 24-in screens, I'm sure there'd be a demand that when colour comes its transmissions should be of an equally high order of definition.

Why Valves?

PROFOUND as is my respect for W. T. Cocking's erudition in the realm of electronics, I must join issue with him when he accuses me of falling into "the common error of supposing that the word 'valve' means only a one-way device." *Pace* W. T. C., the idea couldn't be too common, for it really isn't an error. This he would have found had he consulted a large reference book such as the Shorter (not the Concise) Oxford English Dictionary, which runs to 2,494 large pages. Coming from the Latin *valva* (one leaf of a double door), it is quoted as having been used to denote a sluice. After the discovery of the circulation of the blood the name "valve" was given to "a membrane or fold in veins, arteries or the heart, which close to prevent any reflux of the blood." Similar arrangements, again called valves, were at one time believed to exist in plants to prevent a backward flow of the sap. In mechanical uses the dictionary defines the word as "a device of the nature of a flap, lid, plug, etc., applied to a pipe or aperture to control the passage of air, steam, water and the like, usually acting automatically by yielding to pressure in one direction only." I can't offhand think of any true valve, anatomical, hydraulic, pneumatic or mechanical which doesn't serve as a one-way controller.

Inadequate

But my chief objection to the use of "valve" to denote a "bottle" containing three or more electrodes is that it is almost as inadequate as the French "lampe" or the American "tube." Surely the outstanding feature of triodes, pentodes and so on is their ability to amplify. It is on this account that simple tubes can also be made to act as oscillators. I'd like to see a name adopted which did more than refer to just the unidirectional current-controlling powers of one of the most useful inventions that Man has ever made. The Fleming diode was called a valve because, like the crystal detector (though this doesn't entirely prevent reflux), it allowed current to flow in one direction only. The name was passed on to Lee de Forest's triode and its successors and, despite its hopeless inadequacy, it has stuck. Can't we find a worthier and more descriptive name? Or has its use now become so firmly rooted that nothing will change it? I'm rather afraid that that's the case.

The Doppler Cop

THE new Marconi radar speed checking equipment, which makes use of the Doppler Effect, is most ingenious and if it becomes widely adopted by the police, I can foresee that some of our "sporty boy" motorists will have to watch their speedometers while driving on roads where there's a speed limit. PETA (portable electronic traffic analyser) uses a very narrow horizontal beam. It can give separate readings on vehicles as little as eight feet apart and can be made to lock automatically on to any selected target. Accuracy of better than ±1 m.p.h. is claimed. PETA has other possible uses besides aiding the traffic cop. A camera attachment will soon be available and an analyser unit. Using these gadgets it will be possible to record the speed and traffic density at any point of a road at such periods as may be desired.

UNBIASED

By FREE GRID

The Debagged Wavelengths

IN an article in the July issue describing a wavemeter for use on the "ultra-shorts," H. B. Dent calls attention to the fact that he designed a similar instrument 23 years ago which was also for "ultra-shorts," but this arbitrary expression then meant an order of wavelengths 10 times longer than it does today.

It would not surprise me if he designed another such instrument 23 years hence but I very much doubt whether the "ultra-shorts" of those future days will be only a mere 10 times shorter than they are now. We seem to be rushing down the slippery slope of wavelength shortness so rapidly nowadays that in 23 years' time the "ultra-shorts" will be so short that they may well be called the debagged wavelengths.

Thus in 1981, the five metres of 1935, which became the five decimetres of 1958, will not have become five centimetres nor yet five millimetres. As I see it, the techniques of radio communications in 1981 will have changed so radically that wavelengths will have descended far below that part of the spectrum occupied by heat and light and we shall be measuring our wireless wavelengths in micro-Angstrom units.

It is all very well for so-called experts to point out to me that such wavelengths would be impracticable for use in radio communication. I seem to remember hearing the same thing about 100-metre wavelengths in 1920 or thereabouts.

Outward Bound

SCIENCE fiction has been with us for a very long time even if we go back only to the days of Jules Verne. Since the end of the last war the writing of it has become a major industry, especially in the U.S.A.

I have often thought of trying my hand at it myself as it seems to be very remunerative, but unfortunately for me it needs a quality in which I am singularly deficient, namely, a very lively imagination. Also, judging by the efforts of certain American science-fiction writers, it does not seem to be necessary to stick too closely to the rules of science, and that would go against the grain with me.

Naturally, our own science of electronics and wave propagation plays a large part in the type of literature under discussion; in fact it plays the major part, and that is the only excuse I have for discussing science fiction in these columns.

Many writers of science-fiction stories use a very large canvas in that a recurrent theme is a journey to a distant planet or star by space ship. There are even stories in which a journey is being made to a very distant star which it would take many centuries to reach, so that provision has to be made on the space ship for generation after generation to be born and die of old age during the period of travel. Despite this, the thought never seems to have occurred to the writers of these stories, as it has to me, that the whole cosmos of stars, including our own solar systems with its inhabited earth, is merely a cluster of giant space ships which started on its journey many thousands of millions of years ago. For evidence it is only necessary to study the writings of the late Sir James Jeans—to say nothing of Mr. Fred Hoyle—about the expanding universe.

Apparently all the stellar systems, including our own, are receding from each other at high speed which suggests to my mind that they are flying fragments of a cosmic explosion. What does this suggest but a cosmic accident which occurred long ago when the universe was indeed one body as its name implies, and not merely the mass of fleeing fragments it is to-day?

Probably the inhabitants of the original universe reached a very high degree of scientific knowledge but a moment's carelessness on the part of a trigger-happy physicist, showing his blonde around the laboratory, led to a nuclear explosion of unparalleled intensity and the fragments are still flying asunder. Only in recent æons has life started to reappear on some fragments, including the earth.

When, how and where will the journey end? What a subject for a science-fiction writer!

Stereo or Anti-Stereo?

IT is getting increasingly difficult to know whether we are coming or going in the matter of stereophonic reproduction. No sooner do I tell you (July issue) that, if we are to believe the best authority, stereo will be impracticable in my humble living-room owing to the large amount of space required, than a well-known manufacturer leads me to believe the opposite.

Pye Group Records have done this by bringing out an arrangement whereby the public can listen to stereo discs in the necessarily confined space of a record dealer's listening booth. I have seen a photograph of it complete with its two loudspeakers, but unfortunately it is not to be sold to the public despite the fact that it ought to sell like hot cakes.

I have not yet had an opportunity of testing this arrangement on a dealer's premises, but a superficial examination of the photo I have seen might lead an untutored ignoramus like myself to suppose that it tended to blend the sound rather than the opposite, somewhat in the same manner as did those famous male-voice quartets of Victorian days.

Anti-stereophonists in 1889.

Maybe most of you are too young to have heard one of these anti-stereophonic quartets and so I have tried in the accompanying sketch to show how they *looked*. With regard to how they *sounded* I can only say it was the very reverse of stereophonic. Their object was to blend the sound or, as a musician would say, to obtain a good ensemble, a very important thing in harmony.

I'm sure this new close-quarters stereo listening arrangement isn't like that and I am looking forward to hearing a demonstration.

Mechanizing Art

IT IS reported in the press that at the National Gallery in Washington visitors who want to know something about the pictures they are looking at can hire a pocket wireless set with earphones which enables them to pick up a commentary made by the Director of the Gallery or one of his assistants.

This is a praiseworthy effort but there is nothing new in the basic idea. Well over twenty years ago I reported in these columns (27.12.35) that I had been in a picture gallery in Prague in which a commentary was given on any picture by a concealed loudspeaker immediately a visitor stopped in front of it. The commentary was a recorded one, the mechanism was set in motion by a visitor cutting an invisible ray as he took his stance in front of the picture.

This American idea is an improvement in many ways but no mention is made of the provision of recorded commentaries in several languages using a separate channel for each language. I suggested an improvement of this kind in my original pre-war note on the Prague installation.