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COMMUNICATION VIA SATELLITES

THE idea of long-distance communication by reflection from or relay by artificial earth satellites has been with us now for at least 15 years. At first it was treated as a rather pleasant exercise in speculation, and even today it is often difficult not to regard it as still part of science fiction. But the hard facts are that commercial interests in all parts of the world are putting teams of engineers and scientists to work on the detailed design of systems which are now feasible, thanks to advances in rocket propulsion, u.h.f. and s.h.f. generation and the techniques of noise reduction in receivers. In America ground stations have been built and satellites of both the passive ("Echo") and active ("Score" and "Courier") kinds have been put into orbit to prove the merits of alternative methods.

Quite apart from the natural reaction of those nations who can afford to meet the scientific and technological challenges of space exploration, the military advantage of reliable communication and the commercial gains awaiting increased traffic handling capacity are sufficient justification for the present expenditure on satellite communications.

In the band width available a million telephone channels could in theory be provided for about the same cost (£88 M) as the proposed Commonwealth round-the-world cable, which has a capacity of only 80 telephone (3kc/s) channels. That is not to say that the Commonwealth telephone cable project should be scrapped. It is based on a proved system and one which will fit into any future scheme of world communications.

Before satellite communication systems can carry the load of daily traffic, many years of testing and development lie ahead. There is no lack of feasible ideas and many have been worked out in considerable detail. The case for one type of active satellite system is stated in an article published in this issue, and equally detailed analyses of other proposals can be read in *Proc.I.R.E.* for April 1960. No doubt fresh ideas will appear in the Brit. I.R.E. Communications and Space Research Convention, which is to be held in Oxford next July.

Everything is in a state of flux but, as things stand at present, passive satellites in 24-hour orbits, and thus apparently fixed 22,300 miles above points on the equator, would seem to offer the best solution. The reflection process is linear and no problems arise from cross-modulation; but a large structure, preferably spherical, is required to return an adequate and constant signal. No one yet knows whether such a reflector can be placed exactly in the right orbit, and if so how long it will stay there under the influence of sun and moon gravitational perturbations, radiation pressure or meteor impacts. A better short-term policy would seem to be to use several lower-altitude, shorter-period reflectors spaced so that at any time at least one was above the horizons of both transmitting and receiving stations. Such reflectors can be placed in orbit (with relatively few misfires) by rocket vehicles at present in quantity production, but the system presents difficulties in location and tracking, in following Doppler frequency shifts and in smooth transition from one satellite to another to maintain a continuous service.

Active satellites simplify problems of signal-to-noise ratio and, being more solid and compact structures, are probably less vulnerable to meteor damage than thin metallized balloon reflectors. Being equipped with solar cells they can no doubt find the energy for position and attitude correction under ground control, if enough ejection matter can be included in the payload to provide the necessary reaction. Attitude stabilization can be neglected or reduced if less directional aerials (of lower gain) are employed—but at the price of high transmitter power and more weight. In low-altitude active satellites, which travel for a large part of their time in the earth's shadow the problem of energy storage is important and there is room for the development of batteries of even higher capacity/weight ratio which will work for long periods when sealed.

Thanks to parametric amplifiers and masers, noise in receivers is no longer a limiting factor and a limit to performance in this respect is now set by cosmic background noise. The selection of suitable modulating systems under the guidance of information theory has further extended the distance at which reliable signals can be exchanged. Much has been learnt from experience with telemetry, and the successful communication with Pioneer V out to a distance of 23 million miles gives the measure of present-day performance.

Looking to the future and assuming that one or more of the available communication systems is put into service, there still remains the very big problem of interference. Passive reflectors are aperiodic and will return to earth any u.h.f. and s.h.f. signals which would otherwise have penetrated the ionosphere and been lost in space. Active satellites will add their quota to a rising interference level and will themselves be vulnerable to interference. The whole future of satellite communications will depend more than anything else on the decisions of an Extraordinary Administrative Radio Conference of the International Telecommunication Union to be called in 1963, and on the readiness of all concerned to abide by the decisions then to be taken on frequency allocation.

ACTIVE SATELLITES

By L. POLLACK *

PROSPECTS FOR WORLD-WIDE COMMUNICATION SYSTEMS

Paper presented at the U.R.S.I. XIII General Assembly, London, September, 1960

THE subject of earth satellites as radio relays has received great attention in the communication industry during the past several years. The need for such satellites to extend the capacity of commercial long-haul systems has been well documented, and it is now a generally accepted fact, to we who are close to the subject at least, that the capacity of international communication routes may be most economically increased by an artificial satellite relay system.

Various systems of satellites such as passive and active, at low altitude orbit and synchronous altitude orbits, have been analysed for application as multichannel communication relays, by several authors, e.g., Pierce and Kompfner in *Proc. I.R.E.*, March, 1959. As a result of similar studies at I.T.T. we have concluded that an active satellite repeater in a synchronous orbit will prove to be the most economical system.

Development of this active system, however, will probably progress from the low-altitude type to the synchronous orbit "real time" repeater.

General System Constraints

Factors such as choice of operating frequency and modulation scheme apply with equal weight to all satellite relay systems. With respect to the operating frequency, operation must be in the 1 to 10 kMc/s band as determined by cosmic noise and atmospheric absorption, considerations which have been described elsewhere† and are summarized in Fig. 1. In active systems where weight of the satellite is so important, two further factors are considered in determining the optimum frequency: (a) satellite r.f. components, particularly power amplifiers, diplexers and antennæ decrease in size and weight with increasing frequency; and (b) the efficiency (d.c. power input, r.f. output) of radio-frequency amplifiers seems to improve with the number of applications for such amplifiers; at present substantially higher efficiency is available at lower frequencies.

This question of transmitter efficiency is the more important in determining the weight of the satellite and the cost of placing it in orbit. Improvement in efficiency decreases the weight of power supplies rapidly, particularly in present supplies using solar cells and rechargeable batteries. In addition, with increased efficiency, the problem of heat dissipation is ameliorated and the weight of heat sinks or radiators will be less.

The selection of an operating frequency, then, becomes a matter of determining which of the frequencies between 1000 and 10000 Mc/s can be generated and transmitted most efficiently. At the present state of the art this seems to be in the 2000 to 4000 Mc/s band.

Since satellite power is limited, the modulation method that will yield the desired channel signal-to-noise ratio, say 50 to 55 dB, with the least transmitted power is preferred. Therefore, a type of modulation is indicated which will yield substantial improvement of the channel signal-to-noise ratio over the carrier-to-noise ratio at the expense of bandwidth.

For the active relay the choice of modulation is further limited by the peak-to-average ratio of the multichannel modulated carrier or carriers, particularly if a beam type amplifier such as a travelling-wave tube is used in the output stage of the satellite.

System Description

Let us consider two systems which may illustrate the instrumentation that will be used:

(a) **Delay Repeater Type.**—The first system, a delayed repeater type known as project Courier, has been in operation since the launching of the satellite on Oct. 4, 1960.

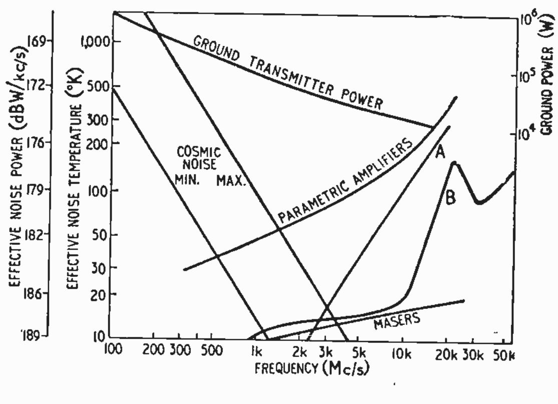


Fig. 1. "Noise"-frequency curve. The effective noise power scale is in decibels referred to 1 watt per kc/s bandwidth. Curves A and B show respectively absorption during heavy rains and clouds, and oxygen-water vapour absorption above 10° antenna elevation.

The programme (directed by the U.S. Army Research and Development Laboratory) brought together the efforts of the I.T.T. Corporation for the ground stations, the Philco Company for the satellite, and Radiation, Inc., for the tracking antennæ. Two stations were linked during the first experiments, one

* I.T.T. Laboratories, Nutley, N.J., U.S.A.
† Radio Communication Using Earth-Satellite Repeaters. L. Pollack, *Electrical Communication*, Vol. 36, No. 3, 1960.

at Ponce, Puerto Rico, and the other at Deal, New Jersey.

In the Courier concept, each ground station can accommodate the output of 20 teleprinter machines operating continuously at 100 w.p.m. The messages are recorded at slow speed on magnetic tape (about 1.6in/sec) during the time the satellite is not in view. When the satellite, which is in a 650 nautical mile orbit at 28° inclination, comes into view, the ground station transmits the recorded signals at higher speed, 60 in/sec, and the satellite stores them on magnetic tape. Simultaneously, previously stored messages are transmitted to the ground, on another frequency, and later played back at the 1.6in/sec speed to a paper tape punch for eventual teleprinter machine read-out. The klystron recorder and control console are shown on the right of Fig. 2. Each of the four digital types of satellite tape machines can record 15 million bits. A fifth machine is an analogue recorder.

Fig. 2. Control console, klystron recorder and tape machines in the control van for the Courier project.

The satellite normally transmits a 50 mW v.h.f. beacon signal for acquisition and tracking. When it comes within range of a ground station, a coded command from the v.h.f. ground transmitter to the v.h.f. receivers in the satellite will activate the satellite u.h.f. transmitters and receivers.

Operating in the 1700 to 2400 Mc/s band, the four satellite message transmitters permit reception at the ground of horizontal and vertical polarization at two frequencies. The H- and V-polarized transmissions at each frequency are combined prior to detection in the ground receiver at i.f. The two base band outputs are further combined, yielding a fourfold diversity system which will resist signal variations caused by satellite tumbling and nulls in the antenna pattern.

The 1-kW ground transmitter, through orthogonal illumination of a 28-foot parabolic reflector, directs a circularly-polarized signal to the satellite receivers. The 4-watt satellite transmitter output and ground receiving system noise figure of 3 dB should yield a signal-to-noise ratio of better than 21 dB at the maxi-

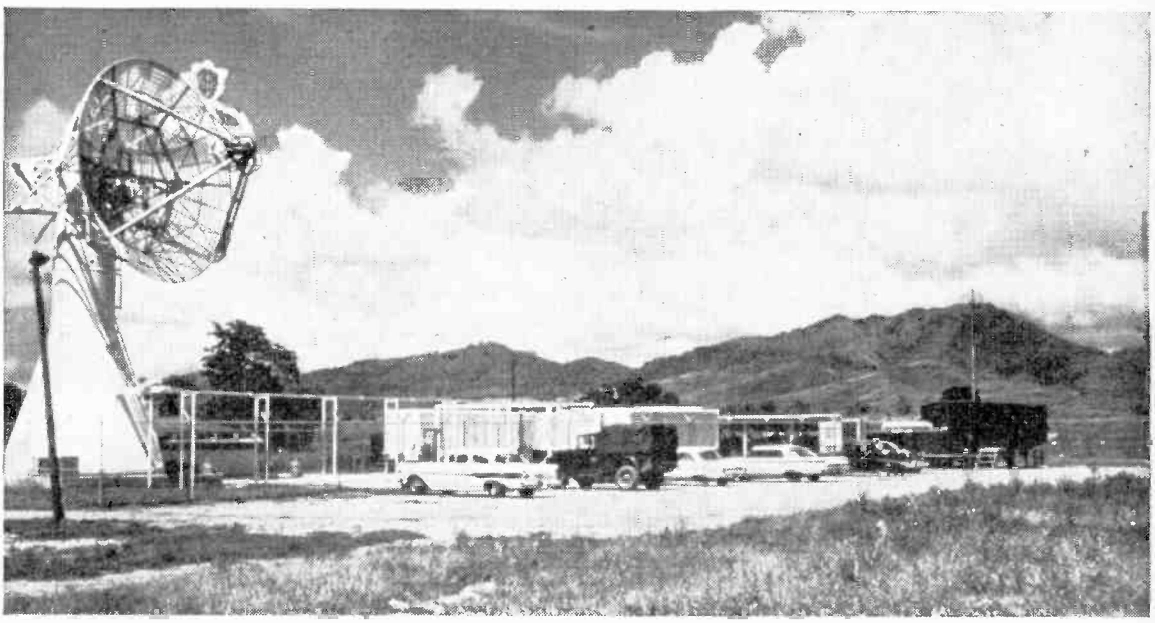


Fig. 3. The Ponce, Puerto Rico, ground station for " Courier."

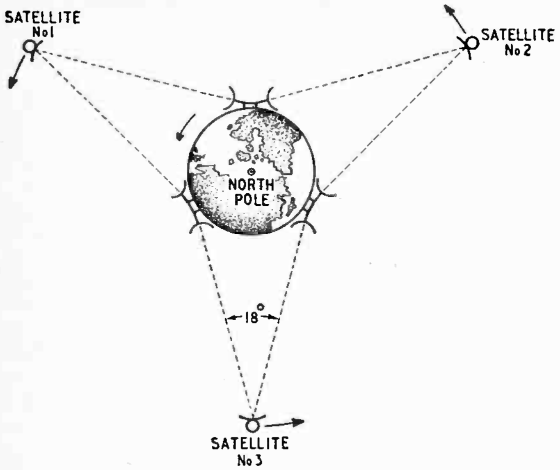


Fig. 4. Synchronous-orbit satellite system. The vehicles are in an equatorial orbit at 22,300 miles. Their orbital speed and the rotational speed of the earth are 2π radians per 24 hours so that they maintain a constant position relative to the earth.

mum slant range. This corresponds to an error rate of better than 1 part in 10^5 at 2700 miles. A photograph of a complete ground station is shown in Fig. 3.

(b) **Synchronous Orbit Real Time Repeater.**—The single delayed repeater satellite may be the economical method for teletype or other digital transmission when a delay of as much as 12 hours can be tolerated. However, it is the synchronous orbit repeater which is expected to meet economical telephone standards.

The commercial system that we have designed for early implementation would operate in the 2 to 4 kMc/s band. The satellite would weigh less than 450lb to use available booster rockets, e.g., the Atlas-Agena, and would carry a simple wideband repeater with an assured operating life of at least one year.

A three-satellite synchronous-orbit system, shown in Fig. 4, would furnish communication to most of the inhabited areas on earth.§

The satellite vehicles would be attitude and position controlled to keep station at points in space above the mid-Atlantic, mid-Pacific and Indian Oceans.

The maximum gain satellite antenna has a beam width of 24° which allows a margin of ±3° for attitude control error in addition to the 18° required for hemispherical coverage. The radio repeater block diagram shown in Fig. 5, is a simple ultra-high frequency translator using all solid state components except for a single travelling-wave tube which will amplify the translated signal and simultaneously generate the translating frequency.

The command and control signals, for operating the propulsion system and turning on a spare u.h.f. translator, should this be required, plus the telemetry signals, which indicate operating conditions in the satellite, will be radiated over a separate v.h.f. transmitter.

By frequency-modulating the carrier with the multi-channel information in pulse code form, the travelling-wave tube can be operated at power output saturation with good efficiency (perhaps 25-30%).

The ground station would use 60-ft diameter reflectors and parametric converters, with a receiving system noise temperature of 95°. If we take, for example, the usual p.c.m. case of a 6-bit code at a voice channel sampling rate of 8 kc/s the base-band bandwidth for the assumed 960 channel system is 2.3×10^7 c/s. To transmit the information with the least power, a gaussian shaped band-pass response is used.

The 3-dB bandwidth of the overall system would be 46 Mc/s to obtain an acceptable inter-channel cross-talk ratio. Since the pulse information frequency-modulates the f.m. threshold, the r.f. carrier must be exceeded. In addition, there is a p.c.m. threshold below which noise improvement fails; this point is reached when the pulse signal cannot be separated from noise with great certainty. An r.m.s. base-band signal to r.m.s. noise of 9 dB is an acceptable threshold value.

The carrier power required (in dB referred to 1

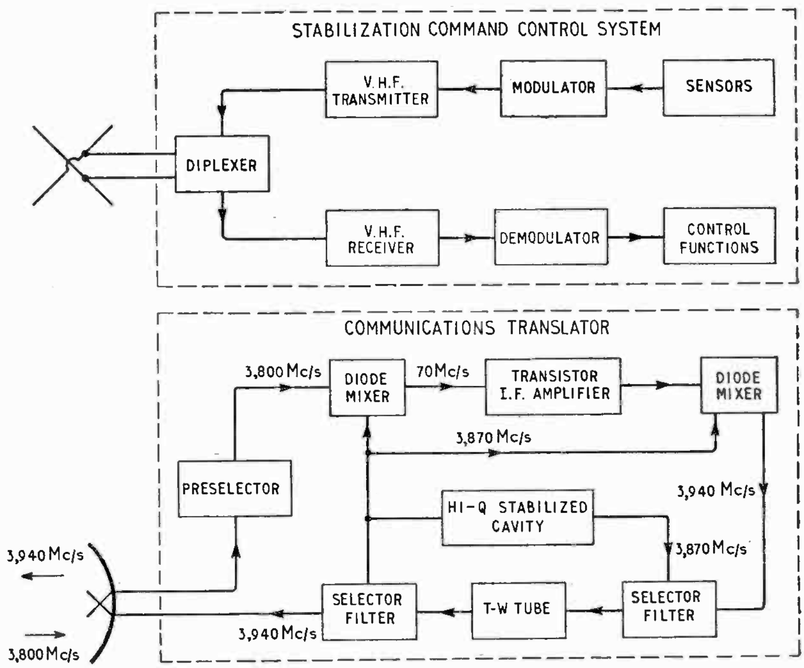


Fig. 5. Schematic of satellite communication equipment using solid-state components and one travelling-wave tube.

§ This system was first suggested by A. C. Clarke in *Wireless World*, October, 1945.—Ed.

watt), neglecting for the moment the f.m. threshold, is:

$$P_{tr} = -10 \log \frac{1}{KT} + 10 \log B - 20 \log \frac{\sqrt{3}\Delta f}{f} + 9 + L$$

B = I.f. bandwidth

L = Path loss in dB (the sum of receiving and transmitting antenna gain and free space loss)

K = Boltzmann's Constant 1.38×10^{-23}

T = Effective temperature of the receiving system, i.e., receiver noise temperature + antenna temperature.

If in addition we use a synchronous demodulator, the p.c.m. threshold of 9 dB will determine the system breaking point.

With such a receiving system a satellite power output of five watts would allow a 9 dB margin above the system threshold. The satellite's overall dimensions are:—length 5ft and diameter 3ft. The major portion of the weight of 450lb is due to the station-keeping propulsion equipment, the control system, and the vehicle frame. The electronic equipment weighs only 80lb. The 5-watt translator, operating on 3.7-4.2 kMc/s, with a bandwidth of 50 Mc/s, has a capacity of 500 channels.

In the particular case considered here, small solid fuel rockets such as used in the Tiros weather satellite will correct initial orbit injection velocity and position errors. Once the satellite is in proper orbit propulsion along the three axes for station keeping will be accomplished with gas jets.

The satellite attitude reference system consists of an infra-red horizon sensor to determine the earth vertical and horizontal. A sun sensor will provide orientation of the solar collectors and the third plane of reference. Corrective torques are applied whenever the satellite attitude or position drifts beyond specified limits. Thus, the satellite will slowly oscillate about a nominal position between pre-set limits.

Traffic Requirements

Initially, a world-wide system channel allocation could be arranged as shown in the Table. The Atlantic satellite would link Western Europe, Africa, all of South America and Eastern United States. This satellite would handle the greatest traffic, with a total of 960 voice channels. These allocations are based on traffic studies for the immediate future rather than long-term estimating. The channel allocations for the Pacific and Indian Ocean satellites are based on linking small as well as large countries where growth in communications has been hampered by natural barriers.

By initially designing a wide-band system with sufficient channel capacity to apportion traffic to all interested countries through international agreement, it is hoped the problem of unauthorized use of the satellite will be avoided.

Problems

It is recognized that several factors in the ultimate establishment of the satellite system require development to achieve a fully operational commercial system. The life of the satellite repeater has been mentioned. The life of components can reach ten to twenty years, as demonstrated by submerged repeater experience. We have proposed a time division system; however, the synchronization accuracy required has not been achieved. The launching vehicles and the space tracking networks to control orbit injection have been developed to a high state of perfection by the Defense Department and National Aeronautical and Space Administration as part of our weapons and space science programme. Attitude control devices which must cycle on and off many thousand times during a one-year life must be proved. The operating frequencies for the satellite system must be allocated and international agreement obtained.

VOICE CHANNEL ASSIGNMENTS

Atlantic Satellite		Pacific Satellite	
England	144	Hawaii	48
Germany	96	New Zealand ...	36
France	72	Australia	72
Italy	24	Japan	72
Switzerland ...	24	Philippines ...	48
Belgium	12	Eastern U.S.S.R. ...	48
Denmark	12	New Guinea ...	12
Netherlands ...	24	Alaska	12
Norway	12	Inter-Sector ...	36
Sweden	12		
U.S.A.	288		384
Cuba	24		
Bahamas	12		
Puerto Rico ...	24	**Indian Ocean Satellite**	
Argentina	24		
Brazil	24	Central U.S.S.R. ...	96
Venezuela	36	China	36
Colombia	24	Borneo	12
Bermuda	12	Saudi-Arabia ...	6
Dominican Rep. ...	6	Turkey	6
Ethiopia	6	Israel	6
South Africa ...	6	Greece	6
Belgian Congo ...	6	India	36
Morocco	6	Pakistan	6
Nigeria	6	Afghanistan ...	6
Egypt	6	Iran	6
Inter-Sector ...	18	Inter-Sector ...	18
	960		240

A 960 channel system, such as envisaged for the Atlantic satellite, would occupy a 50 Mc/s band for the duplex transmitting and receiving channels.

The useful bands available for a common carrier system under present F.C.C. allocations are 2110-2200; 3700-4200; 5925-6425; and 10700-11700 Mc/s.

If for the moment we assume we can share frequencies with common carrier line-of-sight stations, the bands 3700-4200 or 5925-6425 Mc/s would appear attractive since these fall close to the optimum frequency for communications through a satellite radio repeater and a 500-Mc/s band, well in excess of our requirments, is available.

The line-of-sight transmitters in common carrier service operate at less than 10 watts output with antenna beam widths of less than 10°. At the synchronous orbit altitude the interference of these line-of-sight transmitters with the satellite is certainly negligible. Similarly, the 10 watts or less radiated by the satellite will not interfere with the line-of-sight receiver by a margin of 30 to 40 dB. The problem then is with the satellite system ground transmitter possibly interfering with the line-of-sight receiver and alternately the line-of-sight transmitter interfering with the satellite system ground receiver. It has been shown that by restricting the elevation angle of the satellite system antenna to *not* less than

10° above the horizon, a prerequisite to avoid noise due to the hot earth, and the choice of site to areas where low man-made noise conditions prevail, will avoid, ground-terminal-to-ground-terminal interference. A calculation of a typical system at 3 kMc/s would show that a separation of 30 miles between competing stations would assure that the interference level is 20 dB below the desired signal.

These thoughts consider the immediate future, perhaps the next ten years; however, thinking of the long-range growth of communication requirements, several common carrier trunks will be required across the oceans. To accommodate the expansion ten to twenty additional 50-Mc/s bands will be required. The provision of a frequency allocation for the exclusive use of these earth-space-earth relaying services will indeed be a difficult problem.

The time delay in transmitting from one ground station through the satellite to another ground station is about 0.5 sec. Operational tests of the disturbance caused by this delay to the conversing parties indicate that it is not serious. In fact, the observers participating in the tests were not aware of the delay until it was called to their attention. Delays longer than 0.5 sec, with appreciable echo present, were annoying. Increased attention to echo suppression at the subscriber terminals will be necessary.

It is interesting to consider the economic potential of the 24-hour satellite system. The estimated cost of a small ground station (6-12 channels) is $400,000 and that of a large station (70-280 channels) $1M. The first cost of the ground system and operation for ten years allowing for twenty high-capacity and twenty low-capacity stations is estimated at $50M, based on an annual operating cost of $1M for the large stations and $500,000 for small stations. Assuming four misfires in placing the first satellite in orbit and using existing government launching facilities, the cost of the first satellite in orbit is expected to be $30M. With time, misfires should decrease, and in a ten-year period, the satellites would be replaced four times at an approximate total cost of $130M. The over-all cost of the system, then, is $180M—an average of $18M per year over the ten-year period. F.C.C. statistics for communication carriers for the year 1957 indicated a gross revenue per overseas telephone channel of approximately $85,000. Considering the trans-atlantic satellite with 960 channels, with the present channel utilization factor and the same message charges, the gross income would be in excess of $80M per year.

Comparing this income of the single Atlantic satellite with the estimated cost of $18M per year for the system indicates that it would certainly pay for itself and suggests the strong possibility of a substantial reduction in the tariff charge per message. With this note of optimism I conclude.

Electronic Railway Signal-Interlocking

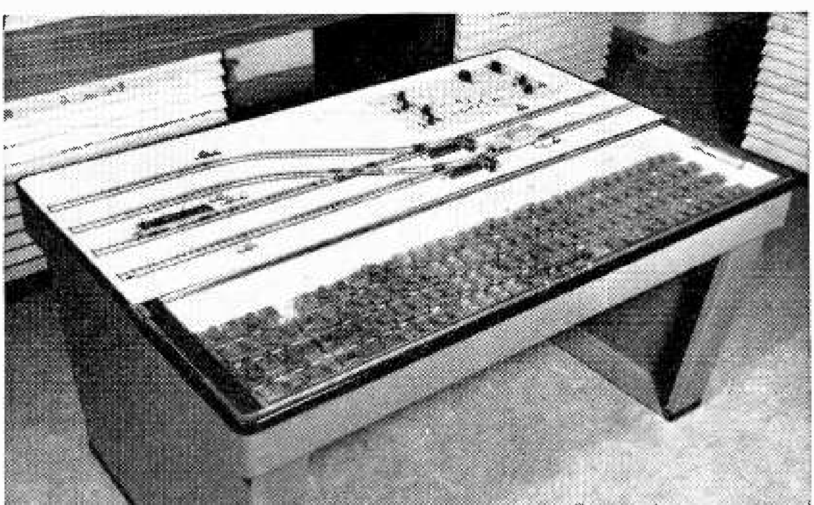
THE Western Region of British Railways are to install at Henley-on-Thames what they believe to be the first electronic signal-interlocking system in the world.

The plant, developed by Mullard Equipment, Ltd., employs solid-state circuitry exclusively, the avoidance of mechanical components introducing great economies in maintenance costs.

The logic of the system is composed, in the main, of "AND" gates with inputs from the track circuits. The signal controls are of the "switch entrance, push-button exit" type, and the state of each route is indicated by appropriately coloured lights in the signal-box. Inputs from all track circuits and points are required by a succession of "AND" gates before the exit push-button can conclude the logical sequence initiated by the entrance switch. If any part of the route is in the wrong state, the route cannot be cleared, and the signals remain at red. When a train has passed the first track circuit of its cleared route, the entrance signal is automatically returned to red, and the route cannot be used again until the logical sequence has been repeated.

The system is arranged to "fail safe"; any fault occurring in the logic circuitry causes all signals to return to red. In addition, a route set up incorrectly by the signalman may not be corrected immediately. All signals must first be set to red, and the route set up correctly after a sufficient time-delay to allow the train to stop has been imposed automatically.

The plug-in logic units, employing semiconductors and ferrites, are capable of operating reliably over a wide temperature range.



Simplified demonstration model of the signal-interlocking system to be installed at Henley-on-Thames signal-box.

Applications of Frequency-Sweep Oscillators

1.—DIRECT TEST AND MEASUREMENT

By R. BROWN

The basic principle of the frequency-sweep oscillator is that its r.f. output, whilst remaining constant in amplitude, is changed in frequency at an a.f. rate. This variation of frequency may be accomplished, in the electrically-simplest units, by a motor-driven tuning capacitor or some other form of mechanical modulation. In more recent instruments, however, the wide-band frequency modulation or sweep is accomplished electrically, typical means being a back-biased semiconductor junction, a reactance valve or a section of ferrite material whose effective permeability is varied by an a.c. passed through a winding. These devices are connected in the frequency-determining circuits of an oscillator and the voltage or current used to vary the frequency of the oscillator also deflects a c.r.t. spot, so forming a line. Points along this line then represent frequencies, rather than times, as they would on the* x*-trace of a normal c.r.o.*

ONE of the most time-consuming and boring tasks that have to be carried out in the construction or repairing of electronic equipment is the adjustment and measurement of frequency-response curves. It is here that the frequency-sweep oscillator, wobbulator, or sweep generator, as it is variously called, comes into its own. Its use always brings about a very great saving in time, and in most of its numerous applications the skill required is very much less than would be required were other types of instrument or techniques used.

Perhaps the best known application of this instrument is the alignment of intermediate-frequency amplifiers. The block diagram of apparatus set up for displaying the response curves of such amplifiers and similar equipment is shown in Fig. 1. A time-base is used to sweep the frequency of the oscillator across the passband of the equipment under test. The output from the tested equipment is detected and displayed as y-axis deflection of an oscilloscope. The oscilloscope timebase is synchronized with the sweep of the oscillator, so that distances along the horizontal axis of the display are a function of oscillator frequency. Distances along the vertical axis of the display will, of course, be proportional to the output of the equipment, that is to the gain or response. The trace thus represents curve of the gain/frequency characteristic of the tested equipment.

Calibration

This displayed response curve is very informative; but if the aim is accurate alignment some means of calibrating the x and y axes, that is frequency and gain scales, must be included in the instrument. The first necessity is a datum or horizontal line corresponding to zero gain and, therefore, no output from the equipment under test. This datum line can be produced by pulse modulation of the frequency-sweep oscillator, so that it is switched off during each alternative oscilloscope scan. The oscilloscope will thus display the response curve on one scan, and the datum line on the next scan.

Frequency calibration can be carried out by mixing the output of the frequency-sweep oscillator with the output from a separate marker oscillator: or, alternatively, by connecting an absorption-type wavemeter to the output of the frequency-sweep oscillator. The markers produced by the first method are known as " active " markers, whilst

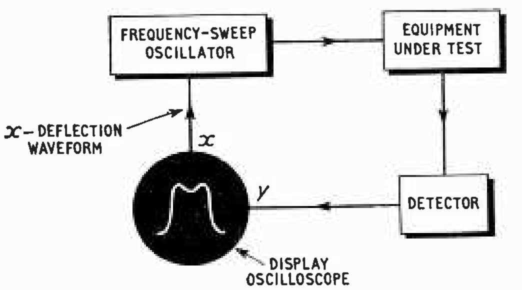


Fig. 1. Typical arrangement of apparatus for displaying amplitude/frequency response curves.

those produced by the second method are described as " passive " The source of markers can be a variable-frequency calibrated oscillator—a signal generator for example—or it can be a crystal oscillator. The output from the frequency-sweep oscillator will beat with the marker oscillator and when their frequencies approach synchrony, this beat will show up on the displayed response curve. If a crystal is used, its frequency can be chosen so that the frequency-sweep signal will beat with the individual harmonics of the crystal and produce a series of markers at fixed intervals.

Active markers would, if produced as described above, be required to pass through the equipment; but some may well occur at frequencies outside the

* See, for instance, *Wireless World*, Vol. 62, p. 252 (June, 1956).

equipment's passband and thus not visible: they might also be difficult to see on the skirts of the response curve. This defect can be avoided if part of the swept-frequency signal is tapped off and mixed separately with the output from the marker oscillator; the beats so produced can, after passing through a low-pass filter to limit their width, be mixed with the detector output and displayed.

The beats produced by both of these methods of producing active markers do distort the trace to some extent. A better approach is to shape the beat produced by this secondary process into a narrow pulse. This narrow pulse is then used to modulate the intensity of the oscilloscope beam so that the spot is extinguished when a beat occurs. The blank point produced can be made very sharp, and it gives a very distinct marker which does not distort the response curve.

Passive markers are produced, as has been said, by connecting an absorption wavemeter across the output of the frequency-sweep oscillator. The wavemeter will absorb some of the energy in the signal when the signal frequency coincides with the wavemeter frequency, so a dip will appear in the displayed response curve. This type of marker is sometimes difficult to see, particularly on the skirts of the response curve or near the cross-over point of an f.m. demodulator. If the equipment under test includes an efficient limiter, the marker may not appear at all.

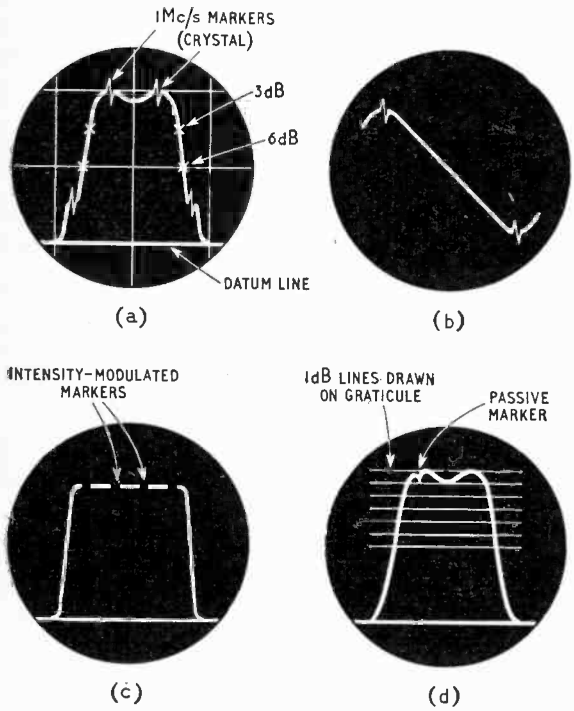


Fig. 2. Typical displays: (a) response curve of bandpass amplifier showing active crystal markers at 1Mc/s intervals and datum or zero-output line. —6dB and —3dB points are estimated on the display, —6dB being half way (half output) between zero and top of curve. (b) F.m. discriminator showing crystal markers. (c) Wideband amplifier response curve with intensity modulation of c.r.t. beam for markers. (d) Bandpass amplifier curve with passive (absorption wavemeter) marker. Lines drawn at 1dB intervals enable amplitude measurements to be made.

Relative amplitudes within the response curve can be roughly estimated from the display. If, however, an attenuator is fitted to the frequency-sweep oscillator the oscilloscope graticule can be calibrated accurately. This can be done in the following manner:—

A horizontal line is first drawn on the graticule at the height of the top of the response curve; the oscillator output is then reduced by a convenient amount, say 1dB, and a second line is drawn at the new position of the top of the response curve. The oscillator output is then reduced in level in further steps of 1dB, a horizontal line being drawn at the height of the top of the response curve at each step. When the oscillator output is restored to its maximum level, the relative levels of the different points on the displayed response curve can be accurately determined by making use of the series of 1dB lines that have been drawn.

Some typical response curves are shown in Fig. 2. The various types of frequency marker are shown, and also two methods of assessing relative levels within the displayed response curve.

In some applications such as equipment alignment on a production line a large number of similar items have to be aligned and checked. A considerable saving in time and skill can be achieved by displaying the response of the equipment under test and a correctly adjusted equipment simultaneously. Fig. 3 shows a suitable arrangement. Two detectors and a double-beam oscilloscope are used: on one beam of the oscilloscope is displayed the response curve of the equipment under test, while on the other beam is displayed the response curve of the standard correctly-adjusted equipment. All the operator has to do is adjust the components in the equipment under test until the two response curves are identical. There is no need then to refer to any frequency or amplitude calibration.

Sources of Error

There is a tendency for the frequency-sweep generator to be used only for the initial alignment of amplifiers, filters etc. and reliance to be placed on well proved point-by-point methods for making the final adjustments and for carrying out precise measurements on the equipment under test. Yet, if reasonable precautions taken, sweep-generator measurements will be found to yield results which are quite as accurate as point-by-point measurements.

Sweep Rate.—One of the most important points over which care should be taken is the rate at which the frequency of the generator is swept[1]. It is essential that the sweep rate is slow enough to allow the voltages in all the circuits in the network under test to reach their full amplitude. The circuit time constants are not important when making measurements at one frequency, for there is then ample time for all the circuits to reach their steady-state condition; but if these time constants are not taken into consideration when using sweep-generator techniques serious errors can occur. The effects of having too fast a sweep rate are unfortunately not easily recognizable except in extreme cases, and these cases are not often met in practice.

In the event of the sweep rate being too high

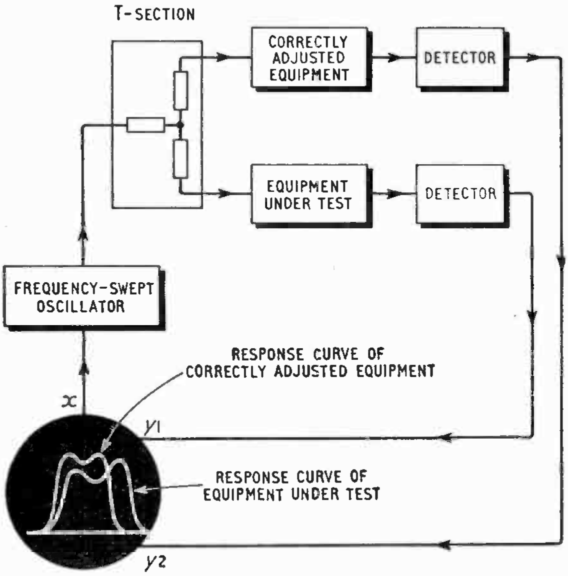


Fig. 3. Arrangement of equipment for use on repetitive work. Double-beam c.r.o. displays, superimposed, both desired (from previously adjusted equipment) curve and that obtained from equipment under test.

there will not be sufficient time to allow the voltages in the circuit to reach their normal maximum value, the response curve displayed will have a lower amplitude than the actual response curve. Also, even after the frequency of the sweep generator has been swept past the top end of the passband of the network under test there will still be some output from the network as the circuits slowly return to the no-signal condition. These effects produce in addition to a reduced amplitude, an apparent increase in bandwidth, a displacement of the displayed response curve in the direction of the sweep, and an asymmetrical response curve with the trailing edge stretched out more than the leading edge (Fig. 4). In extreme cases a damped oscillation can be produced after the trailing edge of the response curve; but long before this effect becomes apparent the other effects will have produced very serious errors.

There is luckily a very simple method which can be used to determine approximately, for any given circuit, the maximum permissible sweep rate. This is based on the response, to a swept-frequency signal, of a resonant circuit of bandwidth B_g which has an amplitude characteristic approximating to a gaussian error-distribution curve. The relationship between the sweep time t(sec), the sweep width w (c/s), and the bandwidth B_g (c/s) of such a circuit can be expressed by the following formula:—

$$A = 1 + 0.195\,(w/tB_g^2)^2 - \tfrac{1}{4} \quad \ldots\ldots (1)$$

where A is the ratio of the displayed amplitude to the amplitude that would be measured were point-by-point methods of measurement used. From this it would appear that correct results will only be obtained with point by point measurements; but small errors can be accepted and for most purposes an error of less than 5% is not serious. This allows the simplification of Equation (1):—

$$B_g = \sqrt{(w/t)} \quad \ldots\ldots (2)$$

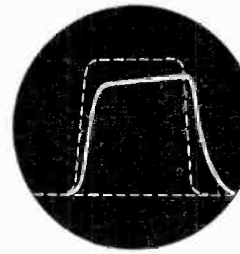


Fig. 4. Effect of sweep rate too high. Dotted curve is true response, full line shows display with asymmetrical, low-amplitude curve displaced in direction of sweep.

B_g now gives the minimum bandwidth that can be correctly displayed for any given sweep rate.

These two equations are correct where the rate of change of frequency is linear with time—a condition which holds when the waveform of the voltage used to control the sweep is a sawtooth. In some sweep generators, however, the sweep-control voltage is sinusoidal as it is obtained from the a.c. mains supply. Thus the rate of change of frequency will vary throughout the sweep and, where this is the case, it is necessary to use the maximum sweep rate as the basis for obtaining the minimum bandwidth that can be correctly displayed. A sine wave is steepest at the point where it crosses the zero axis and, at this point, the frequency will be swept at 1.57 times faster than would be the case were a sawtooth waveform used. Hence for a sinusoidal sweep waveform Equation (2) must be changed to:—

$$B_g = \sqrt{1.57w/t} \quad \ldots\ldots (3)$$

In many cases the shape of the response curve of networks does not conform to a gaussian error-distribution curve, and there does not seem to be any simple means of determining directly with the fastest permissible sweep rate. The most common type of response curve which does not conform to a gaussian error curve is shown in Fig. 5. This has a flat top with very steep sides, and is typical of the response curves of many filters and wideband amplifiers. The critical portions of such a response curve, as far as maximum sweep rate is concerned, are the leading and trailing edges, the width of the flat top being of no importance. One way out of the difficulty is to draw the expected response curve, and then draw the response curve of a resonant circuit (with a gaussian error-distribution curve) which has the same steep side as the response curve of the equipment under test. The sweep rate must then be chosen so that it is slow enough to display correctly the response curve of this equivalent resonant circuit.

In generators using a sinusoidal sweep from the mains supply the duration of the sweep is fixed at 10msec—the time of one half cycle of the mains frequency—and this is the period used in almost all commercial instruments. Alterations in the

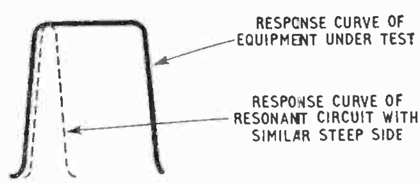


Fig. 5. Determination of maximum permissible sweep speed for circuit with response other than that of gaussian error curve.

sweep width are then achieved by altering the rate at which the frequency is swept. Fig. 6 shows a graph relating sweep width to minimum bandwidth for a generator with a sweep duration of 10msec. As an example of the use of this graph, consider a wideband i.f. amplifier having steep sides and a passband of three-and-a-half megacycles. A sweep width of, say, 5Mc/s would have to be used in order to display completely the skirts of the response curve. The graph shows that for such a sweep width the sides of the response curve will be displayed correctly provided that they are not steeper than the sides of the response curve of a resonant circuit which has a response curve corresponding to gaussian error distribution curve and a bandwidth of 28kc/s.

Harmonic Distortion.—Harmonics of the frequency-swept signal, produced either in the sweep generator itself or by non-linearities in the characteristic of the equipment under test can be a serious source of error. This is particularly so when testing equipment which has a response in which the passband is very wide compared with the centre frequency. With a response curve of this type the second and third harmonics of the frequency-sweep signal may well be within the passband for part of the sweep. Fig. 7 shows the response curve of an equipment which has a passband extending from 500kc/s to 3.5Mc/s, the full line shows the actual response while the dotted line shows the effects of the presence of the second and third harmonics. From the leading edge of the response curve at 500kc/s to 1.17Mc/s the second and third harmonics, as well as the fundamental, are within the passband of the equipment and the displayed response has an amplitude which is the sum of the three components. At 1.17Mc/s the third harmonic passes outside the passband of the equipment, and the displayed amplitude is then the sum of the second harmonic and the fundamental. At 1.75Mc/s the second harmonic passes outside the passband of the equipment and the true amplitude is displayed. The harmonics will also produce a response on the display at frequencies below 500kc/s, where the fundamental is outside the passband.

Perhaps the most serious type of error encountered as a result of harmonics being present is that which occurs when measurements are made on the response of the high-selectivity trap circuits which are often included in broad-band equipment. These circuits are designed to suppress unwanted signals, often by as much as 40 to 50dB. With a correctly-adjusted trap the fundamental of the frequency-swept signal will be suppressed by this amount, but if there are any harmonics present which fall within the passband of the main equipment, they will be passed through without any suppression and will be displayed.

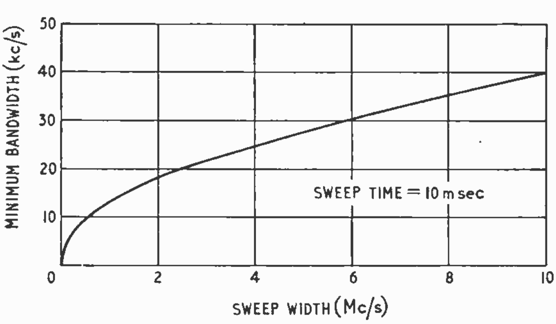


Fig. 6. Relation between sweep width and minimum bandwidth that can be displayed correctly, for a sweep time of 10msec.

Matching.—It is most important that the cable connecting the sweep generator to the equipment under test is correctly matched. The result of any mismatch will be that some of the energy from the sweep generator will be reflected at the input of the equipment under test and standing waves will be set up on the cable. As the frequency is being varied continuously, the number of standing waves in the cable will vary throughout the sweep. This results in the voltage at the input to the equipment under test varying throughout the sweep—if the sweep width is wide enough this voltage will pass through a number of maxima and minima.

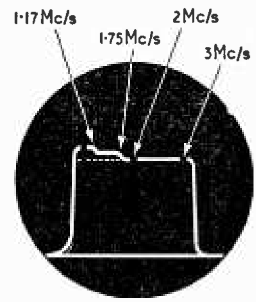


Fig. 7. Effect of harmonic distortion in generator when harmonics fall within passband of equipment under test.

The actual errors produced will depend upon the degree of mismatch, the electrical length of the cable and the width of the frequency sweep. The maximum possible error will occur when the sweep width and the electrical length of the cable are such that the voltage at the equipment under test varies at least from one voltage maximum to the next voltage minimum.

Oscillator-output Variation.—Even with the most careful work, it is practically impossible to build a frequency-sweep oscillator in which the output level remains constant throughout the sweep. With any of the methods commonly used to sweep the frequency—reactance valve or ferrite modulator, motor-driven tuning, etc.—the sweep voltage has some effect on the oscillator output. 0.25 to 0.5dB is a common variation and the output change can be even greater. This, however, can be reduced considerably by including in the instrument some form of automatic level control. One way of doing this is to connect a detector across the output of the swept oscillator. The detector output, which will be proportional to the sweep-oscillator output, is used to control the gain of one of the amplifier valves in the instrument, and so tends to reduce the variations in oscillator output. With such an automatic level control in circuit, the variations in oscillator output can be reduced to something like ± 0.1dB.

Applications

The frequency-sweep oscillator has a multitude of applications additional to the direct display of the amplitude/frequency curve. Much greater accuracy of amplitude/frequency alignment, for instance, can be achieved if, instead of displaying the amplitude/frequency characteristic, the first derivative of the amplitude/frequency is displayed; or the difference between the input and output of the equipment under test, instead of simply the output, can be displayed. These two applications, together with several others, will be described in later parts of this article.

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2. D. G. Haley. 20Mc/s Sweep Generator Type TF 1099. *Marconi Instrumentation*, Vol. 6 (1958), p. 166.

(To be continued)

Electronic Nerve Cell

FOUR-TRANSISTOR CIRCUIT ANALOGUE

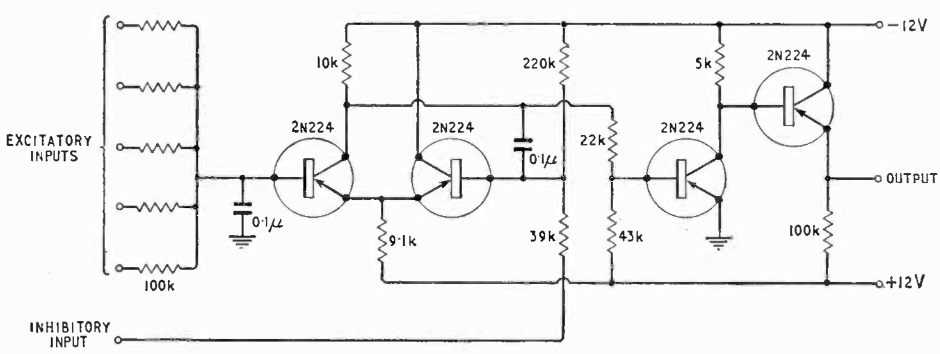
By MICHAEL LORANT

SCIENTISTS of the Bell Telephone Laboratories in the United States have recently developed a new and simple electronic circuit that simulates some functions of the individual biological nerve cell, or neuron. Numbers of these artificial cells are being combined into experimental networks that are roughly analogous to the nerve systems of the eye or ear.

The main function of the nerve cell which has been simulated by this circuit is the transmission of electrical pulses in response to those stimuli that meet certain conditions. The neuron circuit fires electrical pulses of standard amplitude and duration, just as a biological cell usually does. If the circuit is driven by a constant stimulus trains of pulses are emitted, simulating receptor cells as in the eye or ear. A higher intensity of excitation increases the frequency of pulsing. When the neuron circuit is excited continuously the frequency of the pulses can be made to decrease with time, exhibiting accommodation like a living nerve cell. Input excitation must, as in a biological cell, surpass a threshold value, and the circuit will integrate two or more input pulses below the threshold value to cause firing. A particular input connection can also, while energized, inhibit firing of the neuron circuit by other inputs. Similarly, immediately after firing, the electronic neuron's threshold rises to a very large value and for a few milliseconds no input signal can fire the neuron circuit again.

The circuit includes four transistors, thirteen resistors, and two capacitors. The pulse length it delivers, about six milliseconds, is considerably longer than that of a biological nerve cell, but can be shortened if desired. The circuit has an integrating time constant of two milliseconds and a refractory time constant of about ten milliseconds, approximating the time constants of the biological neuron. Because the electronic inputs and outputs are compatible, the circuits can be assembled into chains and networks.

Electronic neurons can be combined with photo-resistive cells to simulate simple functions of nerves in the retina. Some receptors, known as "on" receptors, fire only when the light intensity they receive is increasing; "off" receptors fire only when the light is decreasing; and "during" receptors fire only while they receive a steady light. Flicker-fusion phenomena have also been produced. In the human eye, these can cause a sequence of flashes to be seen as continuous illumination; this property of vision is exploited in motion pictures and television. Mutual inhibition of cells in an array has also been demonstrated experimentally. Some animals have been observed to possess this arrangement, in which a cell receiving a greater light intensity inhibits the firing of nearby cells that receive less light. This results in local sharpening of image boundary detail.



Circuit diagram of electronic nerve cell analogue developed at Bell Telephone Laboratories.

WORLD OF WIRELESS

R.I.C. Backs 405 Lines

THE Radio Industry Council, which speaks for the set-making industry, has come out strongly against a change to 625-line television standards in this country in its representations to the Pilkington Committee, which have now been made public. The difficulties of planning receiver production over the next 15 or 20 years, when the demand for v.h.f. and u.h.f. sets of either or both 405- and 625-line standards would fluctuate unpredictably, are emphasized. It is pointed out that new dual-standard sets with v.h.f. and u.h.f. to cover the transition period would cost from £15 to £20 more than at present, and that the 405-line components would ultimately become redundant. Such sets would have no export value.

The advantage of 405 lines in allowing in the available bandwidth at least one more alternative programme than would be possible with a 625-line standard* is underlined and the Council concludes that "... because it would appear that if a change were made to 625-line standards a period of 15/20 years would be required to give National coverage to more than three programmes, during which the public would suffer confusion and additional cost, the Council can do no other than recommend the maintenance of 405-line standards in Bands I and III and their extension into Bands IV and V."

The Council would like to see the introduction of a colour TV service, but supports the T.A.C. report in saying that this should be deferred until the question of line standards is settled. It would also welcome an extension of sound broadcasting to cater for local interests, and the introduction of stereo sound broadcasting provided that this can be transmitted over single radio channels.

*See *Wireless World*, July 1960, pages 322 and 313

Westward TV

FULL-POWER test transmissions will begin from the I.T.A. Caradon Hill station near Liskeard, Cornwall, on February 1st. They will consist primarily of Test Card C and will begin at 10 a.m. daily except Sundays. The station will radiate vertically polarized signals in Channel 12.

Caradon Hill, which will have a vision e.r.p. varying from 10kW to 200kW according to direction, is the first U.K. station to operate in this channel. The actual carrier frequencies will be 209.74325Mc/s (vision) and 206.23Mc/s (sound).

It is planned to bring the station into service toward the end of April. The programme contractors for this station and the sister station being built at Stockland Hill, near Axminster, Devon, are Westward Television Ltd.

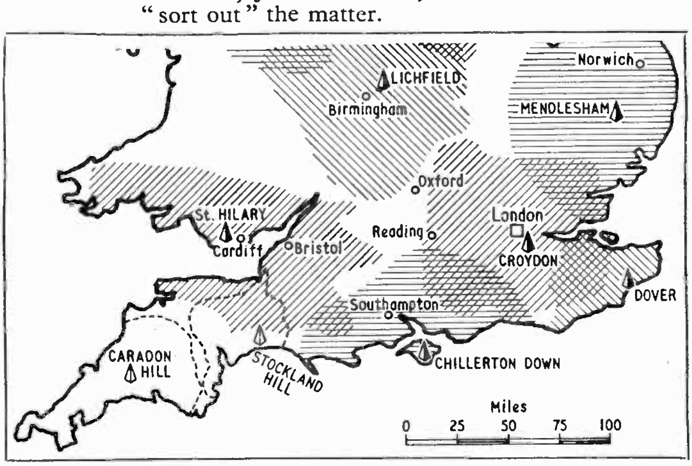
Research Council

THE appointment of three new members of the Council for Scientific and Industrial Research gives an opportunity to publish a list of the present members of the council which was set up in November, 1956, under the "Department of Scientific and Industrial Research Act" to be in executive charge of the D.S.I.R. The newly appointed members are Professor B. Bleaney, F.R.S., Professor of Experimental Philosophy at the University of Oxford since 1957 prior to which he was for ten years Fellow and lecturer in physics at St. John's College, Oxford; Dr. J. W. Cook, F.R.S., the research chemist who has been vice-chancellor of the University of Exeter since 1955; and Frank Cousins, general secretary of the Transport and General Workers Union.

The present constitution of the Research Council, of which Sir Harry Jephcott is chairman and Sir Harry Melville secretary is:—Prof. C. E. H. Bawn, Prof. B. Bleaney, Prof. C. F. Carter, Dr. J. W. Cook, F. Cousins, Sir Walter Drummond, Sir Willis Jackson, Vice-Admiral Sir Frank Mason, Sir Harold Roxbee Cox, Dr. C. J. Smithells and L. T. Wright.

Licensing Anomalies

A CLAUSE in the licence granted to operators of relay exchanges makes it obligatory for them to make a return to the Post Office of particulars of the broadcast receiving licence held by each subscriber. This, they feel, is unreasonable as no such demand is made upon the ordinary radio retailer when supplying a sound or television receiver irrespective as to whether the set is purchased outright, is on hire purchase or rented. At the annual luncheon of the Relay Services Association, at which Miss Mervyn Pike the Assistant P.M.G. was a guest, the chairman, J. W. Kinsman, asked the Post Office to "sort out" the matter.



Estimated service areas of the two transmitters to serve S.W. England are shown dotted on this map, giving the service areas of existing I.T.A. stations in Southern England and Wales.

Hirst Research Centre

THE reorganization of the General Electric Co. Ltd. has now extended to the Wembley Research Laboratories which will in future be known as the Hirst Research Centre as a tribute to the memory of the founder of G.E.C. A number of research units will be formed. The first, dealing with fundamental research, will be known as the Central Research Laboratories and the other groups will have a call on its advice and services. The second will be the Telecommunications and Engineering Research Laboratories and later the five operating groups of G.E.C. (Domestic, Installation, Lighting and Heating, Osram, and Radio and Television) will have the opportunity of setting up their own research units, thus securing a closer integration of applied research and technical development with production and sales.

O. W. Humphreys, C.B.E., continues as Director of Research, V. J. Francis will be deputy director in charge of central Research and R. J. Clayton, O.B.E., deputy director in charge of Telecommunications and Engineering.

Technical Education

BETTER educational opportunities for technicians are foreshadowed in a Government White Paper (Cmnd 1254) which the Minister of Education has described as "a charter for technicians." The White Paper sees the last years of school and the first years of work as a continuous period of co-ordinated education. It is planned to "broaden" the courses in technical colleges by including more mathematics, more scientific principles and more English.

It was recently stated by the Minister of Labour that the proportion of technicians to other employees was higher in the electrical and electronics industry (11.6%) than in any other.

Phys. Soc. Prize Winners

EACH year a competition to encourage craftsmanship and draughtsmanship in the scientific instrument industry is held in connection with the Physical Society Exhibition. John S. Palmer (Marconi's W/T) has won the Silvanus P. Thompson prize and the first prize in the senior section for scientific instruments and components with his reset motor assembly. Other prize-winners include:—

V. S. Marcham (Cambridge Insts.), reflecting electrostatic voltmeter
R. Croucher (Mullard), vernier measuring microscope
Peter Shrives (Hilger & Watts), measuring microscope workstage unit
J. Carrier (Elliot Bros.) rotary standing-wave indicator
Allan E. Pembroke (Mullard) impedance for 3-cm waveguide
Peter J. Perry (R.R.E.) simple oscilloscope
John Cross (Marconi's W/T) blanking and sync. mixer
John G. Wray (N.P.L.) transistor audio oscillator
Jack L. De'ath (Marconi's W/T) translator
William G. Payne (Hilger & Watts) pre-amplifier
Stephen S. Martin (Hilger & Watts) signal generator.

"Beam Indexing Tubes".—On page 7 of the first part of this article in the January issue it is regretted that a line of type was dropped. The sentence starts on line 7 and should read "This idea is based on the fact that whilst the phase of the chrominance signal is proportional to hue, the amplitude is proportional to saturation."

R.I.C. Appointments.—J. W. Ridgeway, O.B.E., commercial director of A.E.I. (Woolwich), has been elected chairman of the Radio Industry Council in succession to E. E. Rosen (chairman of Ultra Electric Holdings). Mr. Ridgeway was chairman of the Council from 1948 to 1952 and has also served for some years as chairman of the British Radio Valve Manufacturers' Association (B.V.A.). The new vice-chairman in succession to H. V. Slade (Garrard Engineering) is A. L. Sutherland (director of Philips Electrical) who is also chairman of the British Radio Equipment Manufacturers' Association. R. Kelf-Cohen, C.B., acting-director of the Council since the death of Sir Raymund Hart last year, has been appointed director and secretary.

Components Show.—Over 240 manufacturers have already booked space at the Components Show which will be held for the first time at Olympia from May 30th to June 2nd. It is being organized on behalf of the Radio and Electronic Component Manufacturers' Federation by Industrial Exhibitions Ltd.

International Instruments Show.—B & K Laboratories are once again organizing an international instruments show in which 50 exhibitors will participate. It will be held at their premises in Park Lane, London, W.1, from June 19th to 23rd.

TV Translators.—An experiment in the use of a very low-power translator to improve the television service in areas of unsatisfactory reception is being conducted by the B.B.C. in Hastings. The translator, of a new type developed by B.B.C. engineers, picks up the Crystal Palace Channel 1 transmissions and re-radiates them with horizontal polarization in Channel 4. Higher-powered equipment is being used at the new Sheffield station which re-radiates the Holme Moss Channel 2 transmissions in Channel 1 using horizontal polarization.

Television Centre.—The second of the large studios (No. 4) at the B.B.C. Television Centre in West London was brought into use on January 8th. It is equipped with E.M.I. cameras which, like the Marconi cameras in Studio 3, employ the English Electric 4½in image orthicon tube.

Space Electronics.—Decca Radar, Ltd., have formed a space electronics group to inaugurate the company's research and development effort in this field. The group will be set up in new laboratories at Somerton Airport, Cowes, Isle of Wight.

Licence Figures.—The November 30th figure for combined television-sound licences in the U.K. was 11,027,821. The month's increase was 64,954. Sound-only licences totalled 4,147,310 including 461,726 for car radio sets. The figures for West Germany (including West Berlin) on December 1st were 4,497,936 television sets and 15,854,319 sound radio receivers. Sweden reached her millionth television licence in the middle of December.

Computor Memories.—The Information Systems Branch of the U.S. Navy is holding a symposium on large-capacity memory techniques for computing systems in Washington, next May. Further details and a preliminary programme are obtainable from Miss J. Leno, Code 430A, Office of Naval Research, Washington 25, D.C.

Electronic Digital Computers.—A course of six lectures on the application of electronic digital computers to control problems will be given at the Norwood Technical College, Knight's Hill, London, S.E.27, on Tuesday evenings, commencing Febrary 14th (fee 10s).

Personalities

Dr. Lloyd V. Berkner, the new president of the Institute of Radio Engineers, is immediate past president of the International Scientific Radio Union. After graduation in 1927, Dr. Berkner, who is 56, joined the first Byrd expedition to the Antarctic (1928/30) and then served for three years on the staff of the National Bureau of Standards. From 1933 to 1941 he was in the department of terrestrial magnetism of the Carnegie Institution of Washington. In 1941 he headed the radar section of the Bureau of Aeronautics. After holding other Government appointments he became in 1951 president of Associated Universities Inc., New York, an educational institution operating a number of research establishments including the National Radio Astronomy Observatory. A few months ago Dr. Berkner was elected president of the Graduate Research Centre, Dallas.

A. G. Wray, M.A., A.M.Brit.I.R.E., who has been chief of Marconi Instruments' advanced development group since 1956, is appointed deputy chief engineer. A graduate of Emmanuel College, Cambridge, he joined the company in 1944 and in 1952 became company physicist. For the past four years he has been responsible for the design and development of multi-channel microwave test equipment and atomic power instrumentation. Mr. Wray has also been a joint editor of the company's technical house journal, *Marconi Instrumentation,* since 1952.

A. G. Wray.

Marconi Instruments have announced three other engineering appointments. **R. L. Gilbert,** Ph.D., M.A., who joined the company in 1958 after three years as a geophysicist in the Dominion Observatory, Ottawa, becomes advanced product engineering manager. **A. Haviland** and **D. R. Willis,** A.M.Brit.I.R.E., have been appointed Proprietary Engineering Managers. Mr. Haviland has been with the organization since 1931. In 1943 he was made chief of the development test section. Mr. Willis, who has been with the organization 21 years, was for part of the war responsible for the engineering and production of radar test equipment.

N. Elson, technical director of Cossor Communications Co. which he joined a few months ago, has been appointed general manager in succession to **K. P. Wood,** B.Sc., A.M.I.E.E., who has resigned. Mr. Elson was chief engineer of the instrument division of Racal prior to joining Cossor. Other appointments to the boards of Cossor companies are **B. C. Scott** (Cossor Radar & Electronics Ltd. and Cossor Instruments Ltd.) and **J. S. Gilks** (Cossor Communications Co. Ltd.), Lea Bridge Cabinet Works Ltd., and Best Products Ltd.)

N. L. Lupton, M.A., A.F.R.Ae.S., is the new contracts manager of Plessey's Electronics and Equipment Group which embraces the domestic equipment, electronics, and telecommunications divisions at Ilford and the subsidiary Hagan Controls Ltd. In 1941 he joined the Sperry Gyroscope Company as a service engineer and since 1958 has been with Microcell Ltd.

L. Gosland, B.Sc.(Eng.), M.I.E.E., research manager of the British Electrical and Allied Industries Research Association (E.R.A.) has also been appointed to the post of deputy director. He joined the Association in 1925. Mr. Gosland is chairman of the Commission Mixte Internationale pour la Protection des Lignes de Telecommunications et des Canalisations Souterraines (C.M.I.) and also of the C.I.G.R.E.* study committee on radio and telephone interference. The appointment of two assistant directors of the E.R.A. is also announced; they are **C. G. Garton,** M.I.E.E., F.Inst.P., who is head of the Materials Department, and **E. W. Golding,** O.B.E., M.Sc.Tech., M.I.E.E., head of the Rural Electrification Department, and also overseas liaison officer. They will each continue in their present positions. Mr. Garton, who joined the E.R.A. in 1937 after four years with the All-Union Electrotechnical Institute, Moscow, is this year's chairman of the Measurement and Control Section of the I.E.E. Mr. Golding joined the E.R.A. in 1945 prior to which he was senior lecturer in electrical engineering at Nottingham University.

* Conférence Internationale des Grands Réseaux Electriques.

J. A. Mason, C.B.E., M.M., M.I.E.E., C.G.I.A., production director of Automatic Telephone & Electric Co. since 1950, has been appointed deputy managing director. He joined the company as a draughtsman in 1911. After military service in the First World War he went into the company's electrical engineering department where he subsequently became assistant chief engineer. Mr. Mason, who is 63, is also director of the associate company British Telecommunications Research Ltd. He is succeeded as production director by **F. O. Morrell,** B.Sc., M.I.E.E., who has been director (engineering) since 1956.

Barry Rogel, B.Sc.(Eng.), A.M.I.E.E., who led the microwave design team of Wayne Kerr Laboratories, has gone to America to become managing director of a recently formed subsidiary of Rosemount Engineering Company, of Minneapolis. He will, however, act as a consultant to Wayne Kerr and as such joins Dr. A. L. Cullen, Professor of Electrical Engineering at the University of Sheffield, and Dr. V. S. Griffiths, reader in spectroscopy at the Battersea College of Technology.

Anthony S. Pudner, M.B.E., A.M.I.E.E., A.M.Brit.I.R.E., has been appointed an additional assistant engineer-in-chief by Cable & Wireless. He joined the company in 1934 at the age of 17. Four years later he went to the company's Bermuda station as assistant engineer. He went to Korea in 1950 to be assistant engineer in charge of the company's field wireless unit. Since 1958 he has been area engineer, West Indies.

L. A. Sawtell, Comp.Brit.I.R.E., since 1945 manager of the valve division of Mullard's, which he joined in 1929, has retired. Mr. Sawtell, who is a past chairman of the Radio Industries Club, has been over 38 years in the radio industry.

George H. Russell, Assoc.Brit.I.R.E., a former senior development engineer with Bush Radio who has been with Arks Publicity for several years, has joined Taylor Advertising Ltd. as an associate director. Mr. Russell, who has contributed a number of articles to *Wireless World,* handled the publicity for several radio and electronics companies whilst with Arks.

Victor Thomas, press officer for Philips Electrical Ltd. since 1952, has taken up an appointment with N. V. Philips Gloeilampenfabrieken, Eindhoven. Among other duties he will be concerned with the editing of the company's international house magazine *The Announcer,* which is printed in English. He has been with Philips since 1948.

S. E. Allchurch, O.B.E., secretary of the British Radio Equipment Manufacturers' Association since 1946, has been appointed to the newly created post of director of the Association. For the time being he will combine the duties of director and secretary. Before joining B.R.E.M.A. he was assistant director of a department in the Ministry of Aircraft Production concerned with the fitting of radar and communications equipment to Service aircraft.

In announcing in our last issue **B. M. Lee's** appointment as manager of Belling and Lee's industrial group it should have been made clear that he is responsible to, but has not actually joined, the executive board.

OUR AUTHORS

L. Pollack, whose paper on active satellites for world-wide communications presented at the London meeting of U.R.S.I. we reproduce in this issue, has been with I.T.T. Laboratories, New Jersey, since 1943. Mr. Pollack, who is 40, is now project manager of space communication systems and communication systems for anti-submarine warfare.

R. Brown, the first part of whose article on frequency sweep oscillators begins on p. 57, recently joined Leland Instruments where he is responsible for Government contracts and technical liaison with Government departments. Immediately prior to joining Leland he was for four years with Marconi Instruments. After completing his National Service in 1950 he spent five years as a marine radio officer.

OBITUARY

Sir Godfrey Ince, G.C.B., K.B.E., chairman of Cable and Wireless Ltd. and its associated companies since 1956, died on December 20th. He was 69. Sir Godfrey had an outstanding career in the Civil Service from which he retired in 1956. He was Director General of Manpower from 1941 to 1944 when he became permanent secretary to the Ministry of Labour.

W. R. Metcalfe (G3DQ), president of the Radio Society of Great Britain for 1960, died on Christmas Day. He had been a member of the Council since 1955.

NEW YEAR HONOURS

Among the recipients of Knighthoods in the New Year Honours List are the following:—

Gerald C. Beadle, C.B.E., Director, Television Broadcasting, B.B.C.;

Cecil Dannatt, O.B.E., M.C., D.Sc., M.I.E.E., Vice-chairman, Associated Electrical Industries, Ltd., and also a director of a number of companies in the A.E.I. Group;

Edward R. Lewis, chairman, Decca Navigator Company and Decca Radar Ltd.; and

Alfred C. B. Lovell, O.B.E., F.R.S., Professor of Radio Astronomy, University of Manchester and director of the Nuffield Radio Astronomy Laboratories. Professor Lovell is a member of the National Committee on Space Research and is chairman of the U.R.S.I. commission on radio astronomy.

W. H. Stephens, Director-General of Ballistic Missiles, Ministry of Aviation, is appointed a Companion of the Order of the Bath (C.B.). He was head of the Guided Weapons Department, R.A.E., Farnborough, where he later became deputy director (equipment).

Among those appointed Commanders of the Order of the British Empire (C.B.E.) are: **F. E. McGinnety,** M.Sc., M.I.E.E., Director General of Inspection in the Ministry of Aviation, who was at the Signals Research and Development Establishment of the Ministry of Supply from 1929 to 1954; **J. R. Pheazey,** vice-chairman and joint general manager of Standard Telephones and Cables, who has just completed 50 years with the company and is also a director of Kolster Brandes; and **A. J. Young,** B.Sc.(Eng.), M.I.E.E., managing director of the English Electric Valve Company.

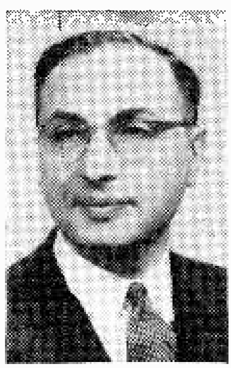
Newly appointed Officers of the Order of the British Empire (O.B.E.) include: **H. W. Baker,** Superintendent Engineer, Television, London Studios, B.B.C.; **S. J. Giffen,** senior assistant telecommunications controller, Northern Ireland, G.P.O.; and **C. W. Sowton,** assistant staff engineer, G.P.O., who is secretary of the technical sub-committee of the Television Advisory Committee.

Among the new M.B.E.s are: **R. B. Dickinson,** executive engineer, G.P.O.; **F. J. G. Haines,** engineer-in-charge (sound), Cardiff, B.B.C.; **J. F. Lucas,** principal station radio officer, Government Communications Headquarters; **J. W. Murray,** chief engineer, Nigerian Broadcasting Corporation; and **L. S. Pinder,** chief engineer, Nuffield Talking Book Library for the Blind, who played a major part in the development of the tape-reproducer for the blind.

Recipients of the British Empire Medal include:— **O. C. Baldock,** radio operator, Government Communications Headquarters, Foreign Office; and **W. F. Young,** radio technician, Royal Air Force, North Weald.

E. R. Lewis (Knighthood)

A. C. B. Lovell (Knighthood)



A. J. Young (C.B.E.)

C. W. Sowton (O.B.E.)

L. S. Pinder (M.B.E.)

E

News from Industry

G.P.C. Record Year.—The Gas Purification and Chemical Co. announce a group profit before taxation of £811,034. This is over £300,000 above the previous year's figure and the highest in the history of the group, which includes A.B. Metal Products, B. & R. Relays, Grundig (Great Britain), E. G. Irwin and Partners, Greencoat Electronics (formerly Staar Electronics) and Wolsey Electronics. Since the a.g.m. the chairman, Vice-Admiral Sir Charles Hughes Hallett, and a director, W. J. Arris, have resigned.

Radio Rentals announce a group trading profit for the year ended last August of £2.3M after allowing £3.4M for depreciation. Taxation absorbed a further £728,000 leaving a net profit of £1,573,987 compared with £1,098,616 the previous year.

Marconi Instruments are to manufacture in this country transistor electronic counters to the design of Computer-Measurements Company, of Sylmar, Cal. The 10-year agreement under which M.I. has world selling rights outside North America and Japan, also provides for the exchange of engineering information.

Blue Spot.—The agreement with A. Prince Industrial Products Ltd. for the marketing in this country of Blue Spot sound and television receivers has been terminated by Blaupunkt Werke G.m.b.H. The sale and service of Blue Spot receivers will now be handled by Bosch Ltd., 205/207 Great Portland Street, London, W.1.

U.K. Agents.—Among the eight "exclusive foreign representatives" appointed by Stoddart Aircraft Radio Co., Inc., of Hollywood, Cal., is Aveley Electric Ltd., of South Ockenden, Essex, for England.

British-made Tektronix 'Scopes.—Livingston Laboratories announce that two types of Tektronix oscilloscopes (515A and 545A) are now being made in Guernsey, Channel Islands, and are therefore duty-free under the Commonwealth Preference regulations.

Mullard's component division has been sub-divided, under its divisional head, A. F. T. Marner, into four commercial product groups. These groups, and the managers, are:—Permanent Magnets (B. C. Foreman); Ferrites (W. A. Everden); Computers (K. R. Patrick) and Radio & Television (W. K. Bailiff).

Furzehill Laboratories Ltd., of 57 Clarendon Road, Watford, Herts., have taken over the production, sales and service of the range of stroboscopes previously manufactured by Watford Instruments under the trade name of "Strobolyser." Paul D. Tyers will continue to be associated with the design of the "Strobolysers."

M.F. beacon/telegraph transmitters have been supplied (in duplicate) by the International Marine Radio Company for each of three new ocean weather ships.

United Mercantile Company Ltd., U.K. distributors of Zenith receivers, have moved to Sovereign House, 13-14 Queen Street, London, W.1 (Tel.: Grosvenor 4901).

Magnavox have opened a service department at 20/22 Corsica Street, London, N.5 (Tel.: Canonbury 5041).

Texas Instruments Ltd. have moved from Dallas Road to Manton Lane, Bedford (Tel.: Bedford 67466).

Ultra-Miles Link.—Ultra Electronics Ltd. have purchased a one-third share in Miles Electronics Ltd. A. V. Edwards and L. R. Crawford, Ultra directors, are joining the board of Miles Electronics. The two companies jointly designed and manufactured the aircraft and radar simulator for the de Havilland Sea Vixen and are now developing similar equipment for the Blackburn Buccaneer.

Derritron.—Three more companies, making a total of 10, have joined the Derritron group which was formed in January, 1960, under the chairmanship of V. G. P. Weake. The newcomers are Beulah Electronics Ltd., Direct TV Windings Ltd., and Direct TV Replacements Ltd. Alfred Rose, who previously headed these companies, will be managing director.

British Electronic Industries Ltd., is the name of the company formed to acquire the shares of Pye Ltd. and E. K. Cole Ltd. The chairman of the company is C. O. Stanley, chairman and managing director of Pye, with Eric Cole as deputy chairman.

Wolsey Electronics have recently entered the closed-circuit television system field. The equipment operates on either a video or r.f. camera output, and in the case of a video output will employ an r.f. modulator to enable standard receivers to be used. A system has been installed at Goodwood Racecourse.

Air Navigation Equipment.—Orders worth over £650,000 have been placed by the Ministry of Aviation with Marconi's for the supply of Doppler navigators and automatic direction finders. The equipment, which includes ancillary gear and spares, is for use in Argosy C. Mk. 1 aircraft of R.A.F. Transport Command.

Telecommunications Test Equipment.—Contracts worth £100,000 have been awarded to Marconi Instruments Ltd. by S.H.A.P.E. for test gear for use on the "Ace High" radar project. It comprises white noise test sets, signal generators, and universal bridges.

EXPORTS

Television transmitting equipment for Mexico and Venezuela has been ordered from Marconi's. The Venezuelan equipment comprises three vision and three sound transmitters and the Mexican eleven Mk. IV camera channels, with associated equipment.

High-altitude u.h.f. airborne emergency transmitter-receivers to the value of £50,000 are to be supplied by W. S. Electronics to the Danish Government. A fully-transistorized power supply and extremely light weight are features of the equipment. It is intended to provide emergency contact between pilot and ground in the event of aircraft electrical-system failure.

Decca weather radar is being installed at five airports in Western Germany. Equipments are nearly complete at Frankfurt and Hamburg, and will, in addition, be installed at Hanover, Munich and Schleswig.

High-power radio communication equipment has been ordered from Marconi's by the British Government on behalf of the Pakistan Posts and Telegraphs Department. The equipment, consisting of two 30-kW h.f. i.s.b. transmitters, their drive units, and five telegraph h.f. receivers, is to be installed near Karachi.

TRANSISTOR SIGNAL GENERATOR

DESIGN COVERING 100kc/s TO 25Mc/s

By C. BAYLEY

MANY advantages are gained from the use of transistors, particularly in test equipment, where the major points are that it can be small, portable and independent of mains supplies, although a mains power unit, simpler than the conventional valve supply, can be used. Lack of dependence on mains, small size and low weight are a great benefit to the field service engineer. Isolation from the mains improves performance as far as both hum and interference are concerned and is also an advantage when working on "live" equipment. Waste power dissipation is very low: the economy in running such equipment is obvious and deterioration of components by heat is reduced to the minimum. Also the equipment is ready for use immediately after switching on—a wait whilst temperatures and thus frequency become stable is not necessary. The radiation from oscillator circuits is reduced considerably and therefore screening precautions might not be so severe.

The signal generator is one of the most commonly used pieces of test equipment and it is one in which the benefits accruing from the use of transistors are most marked. It was thus decided to design a transistor signal generator.

Choice of Basic Circuit

There are many circuits for transistor oscillators, so it would be as well to consider carefully the factors affecting their use in signal generators.

Firstly, transistors are current-operated devices having low impedances, thus matching is more critical than in a valve circuit where the valve is often regarded as having such a high impedance that its effect can be ignored. Most h.f. oscillators use an L-C tuned circuit whose dynamic impedance is high, usually of the order of a fraction of a megohm. Thus a low-impedance transistor, although capable of producing large currents at low voltages, could be so mismatched that it could not drive sufficient current into some tuned circuits to keep them oscillating (Fig. 1 (a)). Improvement of the matching of transistor and tuned circuit can be achieved by reducing the L-C ratio or by tapping the coil, as in Fig. 1 (b).

In the first case, though, the tuning capacitor becomes inconveniently large—too large for a standard variable type to be used—and in the second case the circuit impedance varies too widely to enable a good match to be achieved over the tuning range of the capacitor. The dependence of circuit impedance on tuning capacity (and therefore frequency) is clear from an examination of the expression for impedance at points A and B in Fig. 1 (b): $Z=(L/r-(1/C)+\omega^2L_2$. The approximate formula for the dynamic impedance of the circuit in Fig. 1 (a) is $Z=L/Cr$, i.e., there is no direct dependence on frequency. Thus version (b), although convenient from the point of view of tuning capacitance, has to be limited in frequency range.

Beat Oscillator Techniques

The use of two oscillators whose frequencies beat together to produce the desired output has advantages for lower radio, supersonic and higher audio frequencies. For higher radio frequencies a straight oscillator is preferable; also a lower ratio of maximum to minimum frequency is acceptable, thus the matching problem can be successfully solved by the limiting of the frequency swing.

In the conventional b.f.o. the fixed and variable-frequency oscillators usually operate at frequencies

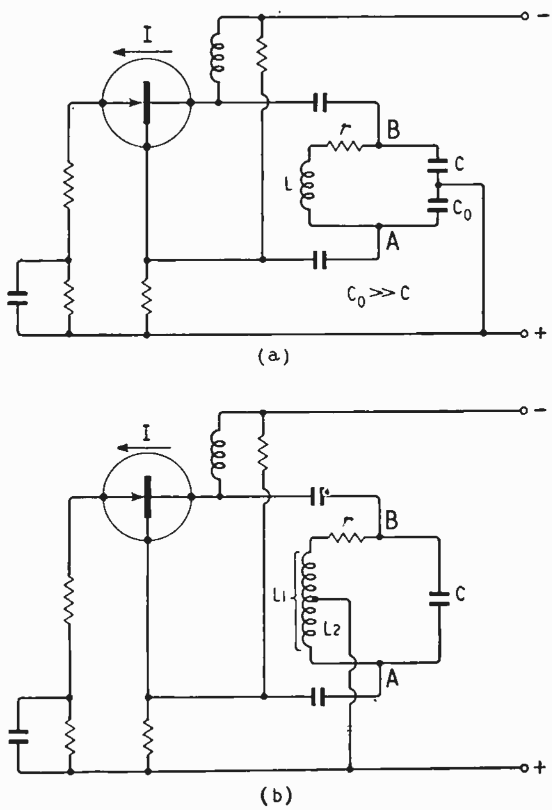


Fig. 1. Two oscillator circuits. In (a) the current I may be insufficient to maintain oscillation, but in (b) I is three or four times greater when $L_1 = 4L_2$.

five to ten times those of the beat. This makes easy the filtering out of the unwanted frequencies after detection of the beat and would also satisfy the requirement that the frequency range should remain small. However, this would, for our purposes, demand the beating of frequencies above a reasonable maximum figure for f_α, the alpha cut-off frequency.

Generally the best solution seems to be to design a b.f.o. for the lower band of frequencies—say 50 to 500kc/s—and above that to use a straight oscillator. For the higher frequencies the desired lower L/C ratio can be obtained conveniently by using the same tuning capacitor. The best choice of b.f.o. frequencies seems to be rather close to the beat frequency, e.g., for an output at 500kc/s the fixed-frequency oscillator (f_1) could be at 1,200kc/s and the variable (f_2) at 700kc/s. As the top limit of frequency f is to be 25Mc/s (for short-wave band coverage) it might be thought that it would be possible to use higher beating frequencies, but this would demand that both oscillators use transistors with high f_α. If, of course, short-wave coverage is not required then this section could be dropped and transistors of lower f_α used. Table 1 lists some high alpha-cut-off transistors.

Naturally the use of low beating frequencies makes their filtering from the output more difficult, but this can be achieved satisfactorily by the proper design of low-pass filters. Unwanted components could occur on some ranges but in practice these are quite harmless.

Further important considerations when choosing an oscillator circuit are good frequency and amplitude stability. To achieve both these ends care must be taken with biasing and stability measures. Looking at the circuit of Fig. 2 it will be seen that the base-biasing resistors, R_1 and R_2 are of much higher values than are commonly used*. High values for these resistors are necessary to prevent excessive damping of the tuned circuit. The collector-to-emitter potential should be chosen as high as possible to reduce internal capacitance and maintain collector current at a low value. This reduces internal power dissipation and, hence, avoids effects due to a rise in temperature. Amplitude modulation is not applied directly to the oscillator because here it can cause frequency modulation.

* See: The Junction Transistor and its Applications, by E. Wolfendale, pp. 123-135

Some slight modifications from the Colpitts valve oscillator circuit have to be made: for instance, the base-emitter coupling capacitor C_1 has to be several times larger than the collector capacitor, C_2. This is understandable as C_1 has to pass a large current into the tuned circuit whilst C_2 is in a position where the impedance is much higher.

The oscillator output is taken from the tap on the emitter resistor R_3 R_4. Provided that R_3 is high in relation to the impedance at the tap the frequency of oscillation is not affected by changing the load at the tap. However the output is reduced to about 30 to 50mV and an amplifying stage is essential to obtain sufficient input to the attenuator.

The amplifier is a conventional common-base circuit and its output is taken from the step-down transformer to the low-pass filter which matches the 75-Ω attenuator. This attenuator is arranged to give six 20-dB steps of attenuation and "fine" continuous variation of the output over a 20-dB range is obtained by variable negative feedback to the base of the amplifier stage.

If short-wave operation is desired the amplifier transistor would, of course, have to be of the high alpha-cut-off variety. A type with an f_α no lower than 100Mc/s would be suitable. Alternatively the output could be taken directly from the tap on the oscillator emitter resistor but this would preclude the use of modulation, and, of course, result in a much lower maximum output.

Modulation

Three methods of applying modulation to the amplifier were considered:—

1. In a Class-C amplifier high-level modulation can be applied in the common-base or common-emitter circuits by varying the collector supply. This is similar to the Heising method of modulating a valve amplifier.
2. Low-level modulation can be achieved by placing the source in the emitter-base circuit.

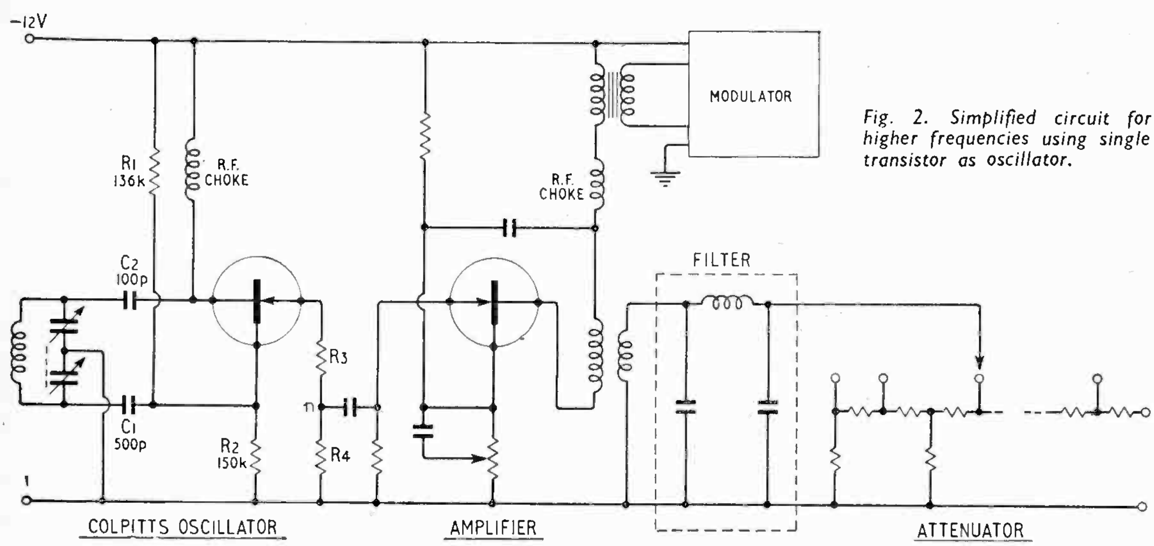


Fig. 2. Simplified circuit for higher frequencies using single transistor as oscillator.

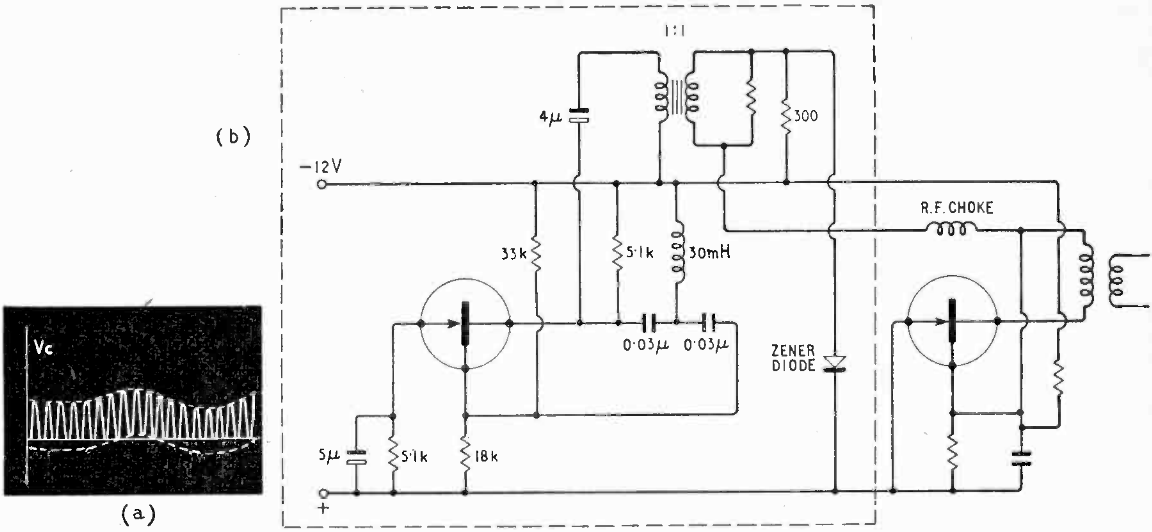


Fig. 3(a). Result of applying modulation by chosen method. Note " clipping " of sine wave. (b) shows simple 1 kc/s oscillator and connections to amplifier stage.

3. By adjusting the bias and r.f. drive voltage the modulating current can be made, in an arrangement similar to that described in (2), to change the input impedance of the stage. This is analogous to square-law modulation of Class-B valve circuit.

In our case, deep modulation is not required—30% is normal for a signal generator—and the amplifier does not necessarily have to work in " pure " Class C. The method given in (1) was thus chosen, and Fig. 3(a) shows the output when modulated by a sine wave. In Fig. 3(b) a simple 1-kc/s oscillator is shown. This is a convenient circuit as the 1:1 modulation transformer could be employed as the output transformer of an a.f. stage should modulation from an external source be desired.

It is clear from Fig. 3(a) that distortion of the output takes place and, to avoid the presence of harmonic frequencies in the output some form of filtering is essential. Another tuned circuit ganged with the oscillator could be used but this would demand an extra section on the tuning capacitor. Thus low-pass filters, switched from range to range, are employed.

To obtain proper modulation in the amplifier the initial collector bias has to be chosen carefully. Correct operation is achieved when this is approximately equal to half the supply, i.e. about −6V with a 12-V supply.

TABLE I

Makers	Type	f_α (Mc/s)	Description
Associated Transistors	AP11	30	Germanium alloy p-n-p diffused base
Mullard	OC 170	70	Germanium alloy p-n-p diffused (graded) base
Newmarket	V15/20R	30	Germanium alloy p-n-p drift transistor
Semi-conductors	MA 393	60	Germanium p-n-p " micro-alloy "
Texas Instruments	2N1142	600	Germanium p-n-p diffused-base mesa type
	2N1143	480	Germanium p-n-p diffused-base mesa type
	2S005	30	Silicon n-p-n grown diffused
	2S014	20	Silicon n-p-n grown diffused

B.F.O. Signal Generator

Remembering that a b.f.o. design is advantageous for the lower r.f. bands we may arbitrarily choose the b.f.o. output ranges as within, say, 100 to 500kc/s.

With the variable-frequency oscillator (v.f.o.) ranging from 800 to 1,000kc/s it is possible to achieve the chosen coverage with fixed-oscillator frequencies of 1,100kc/s and 1,300kc/s. Thus the first range is 1,100-1,000=100kc/s to 1,100-800=500kc/s, and this satisfies the requirement that the tuning range of the v.f.o. should be kept small.

The low-pass filters following the frequency-changing circuit have to be multi-range types if it is desired to employ modulation. It would be inconvenient to have a separate switch for these, so the number of positions of the range switch depends on the design of this part of the circuit. Thus our

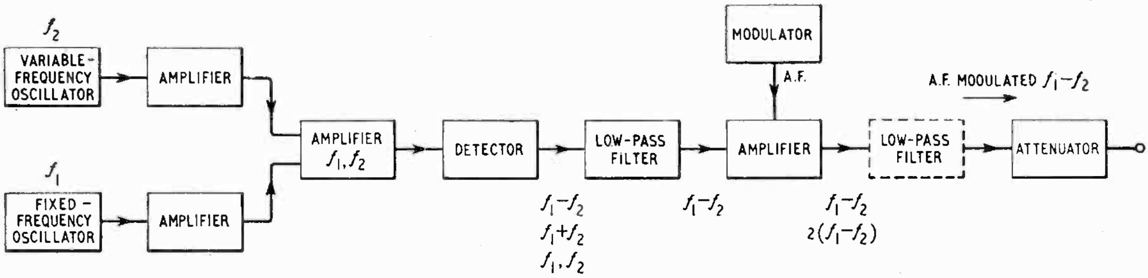


Fig. 4. Block diagram of signal generator when operating as a beat-frequency oscillator.

signal generator when operating as a b.f.o. takes on the outline shown in Fig. 4.

Complete Design

At the left-hand end of Fig. 5 are shown the oscillators: they are basically similar to ensure good frequency stability. The mixing of the beat oscillator outputs is carried out in the triple-wound step-down transformer T_1 (impedance ratio about 3,000Ω to 100Ω), then both signals are amplified by V5. Sum and difference frequencies are produced at the detector V6 which is a mixer-type diode with a low forward resistance and capacitance. The output passes into the first low-pass filter which removes the original fundamental and sum frequencies. S_{1-4} selects the output from either the b.f.o. (V1 to V4) or the v.f.o. (V1). Two positions are provided in the v.f.o. position so that, on short waves, the coupling transformer T_1 and the amplifier V5 are switched out of circuit and are replaced by the short wave coupling transformer T_3.

V7 is the final amplifier, and, it will be remembered, this produces second-harmonic distortion when modulation is applied. Thus another low pass filter follows the output transformers T_4 and T_5.

So that the input to the step attenuator may be set accurately (0.1V r.m.s. is the chosen level) a level-monitoring meter can be connected at this point. For convenience a second gain control R_{21} is fitted for setting-up: this, of course, is done with the normal "fine" output control R_{23} at maximum output.

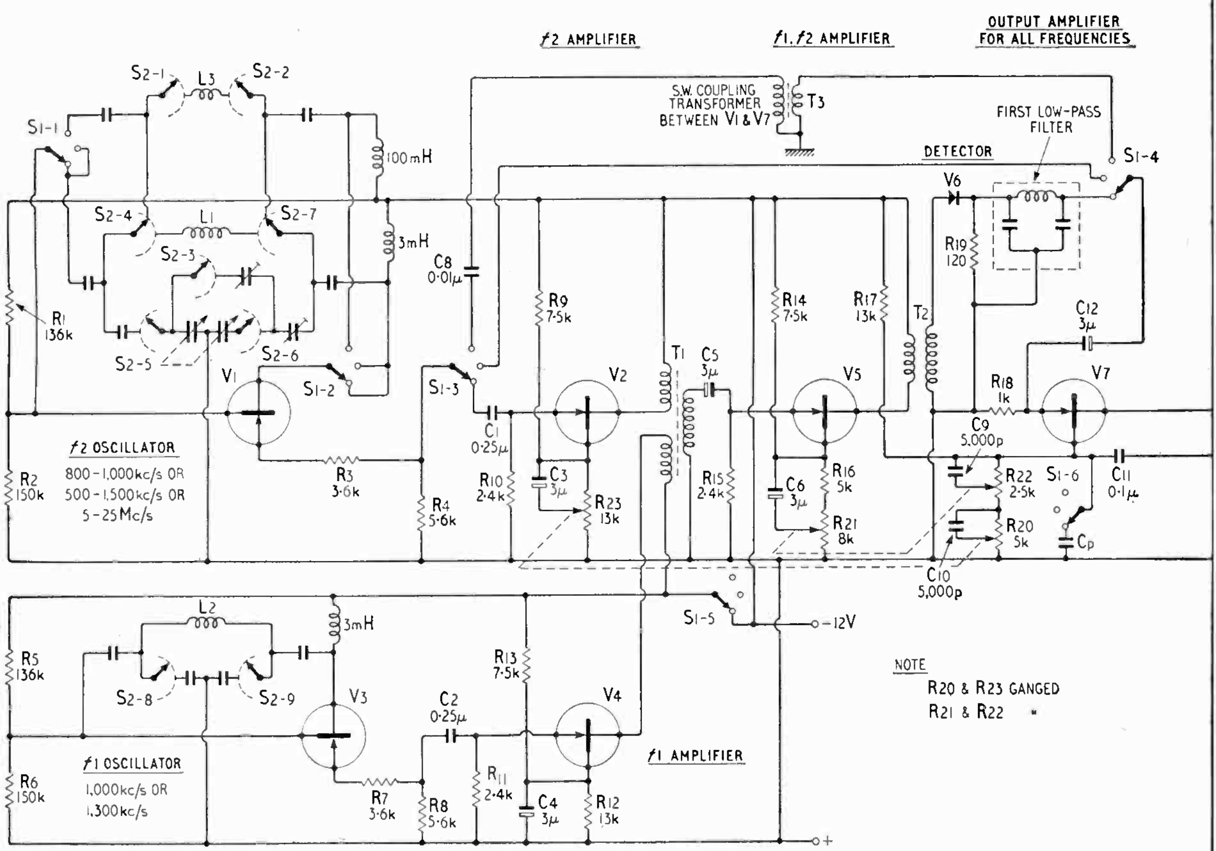


TABLE 2

Oscillator Frequency (kc/s)	Cut-off frequency f_c (kc/s)	Frequency Bands on Tuning Capacitor
800-1,300	650	B.f.o. filter
100-170	185	100-300 kc/s
170-300	320	
300-500	550	300-500 kc/s
500-850	925	500-850 kc/s
850-1,500	1,600	850-1,500 kc/s
5-9, 8-15, 14-25 Mc/s	No filter used	5-9 Mc/s, 8-15 Mc/s, 14-25 Mc/s

$L = 10^3 2R_t/2\pi f_c$ mH
$C = 10^6/2\pi f_c R_t$ μF
$R_t \approx 75\Omega$ (terminating impedance).

The range switch S_2 has eight positions, three of which cover the b.f.o. ranges 100 to 170kc/s, 170-300kc/s and 300 to 500kc/s. No change is made in the v.f.o. circuit between the 100 to 170kc/s and 170 to 300kc/s ranges—only the low-pass filters are switched. For clarity the coils associated with the v.f.o. are shown separately in Fig. 6 (a) and that for the b.f.o.—Fig. 6 (b).

For frequencies higher than 500kc/s a straight oscillator is used as the source, so that the supply to the beat oscillator V3 and V4 is interrupted by $S_{1\cdot5}$. Other sections of S_1 change the coupling transformer, r.f. chokes and capacitors to appropriate values for the low, medium and high-frequency ranges. It is not important to use an output low-pass filter on short waves as the harmonics are suppressed sufficiently by stray capacities in the attenuator network. On short waves only V1 and V6 (apart from the modulator) are operating, thus only these two transistors need to be of high f_α type. R_{22} and R_{20} perform the "set level" and "fine output" control functions, but as these are ganged to R_{21} and R_{23} respectively only two knobs are required on the front panel. R_{22} and R_{20} have no effect when the b.f.o. section is in use as they are by-passed by Cp, say 0.1μF, switched in by $S_{1\cdot6}$.

Monitoring Unit

At the h.f. end of the s.w. band the maximum oscillator output falls to about 50mV. Thus, when using the 14 to 25Mc/s band the meter has to give a clear indication at 50mV. At all other frequencies the output is set at 100mV. A sensitive meter (50 or even 25μA f.s.d.) is thus required and two diodes are connected in parallel as the rectifier.

This combination, shunted by a 270-Ω resistor has an impedance of about 150Ω and is substituted for the first 150-Ω shunting resistor in the attenuator so that maximum power is available to work the meter without causing a mismatch. The output level should be set with the step attenuator switched to 1μV and, of course, the "fine" control set to maximum output. For 50-mV level the current flowing through the meter is 4.5μA and for 100mV, 15μA. The frequency response of the unit is practically flat up to 30Mc/s.

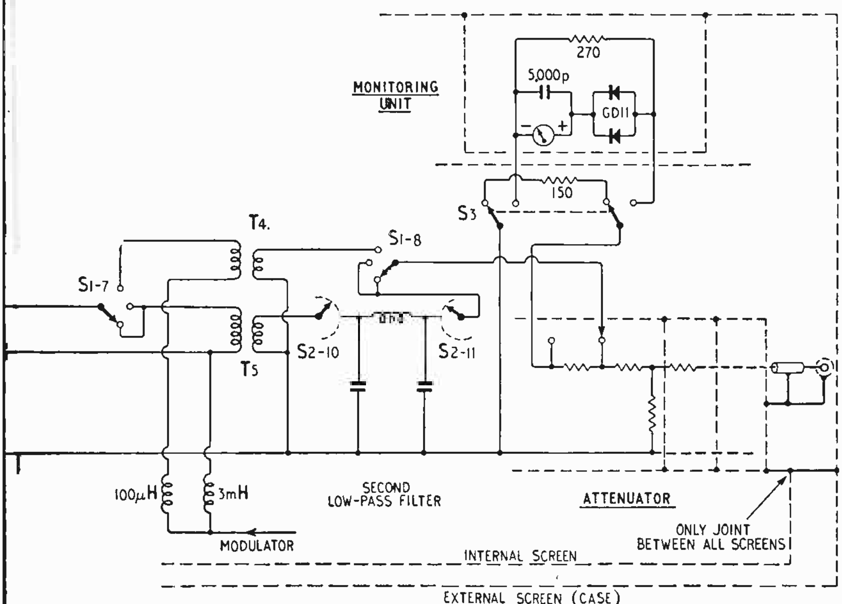
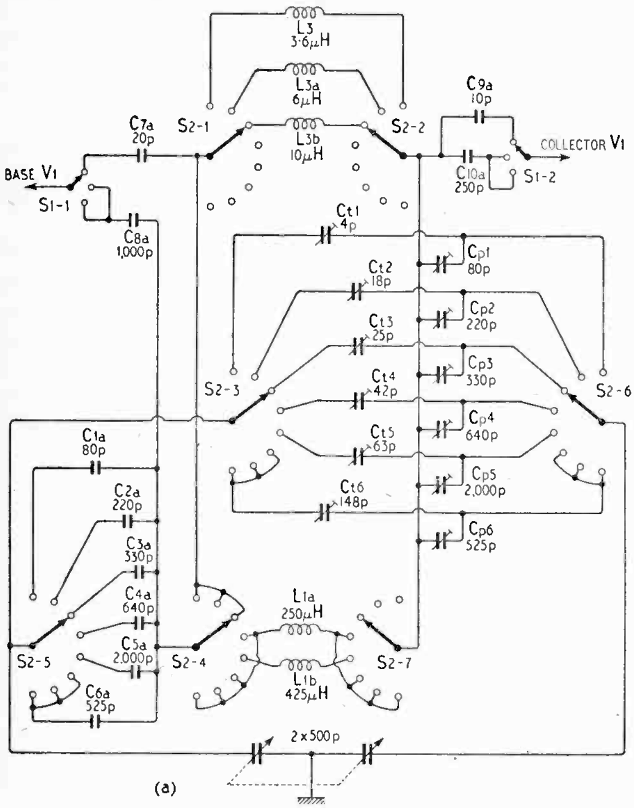


Fig. 5. Signal Generator: Detail of modulator is shown in Fig. 3(b), attenuator, Fig. 8, coil details and switching, Fig. 6(a) and (b); filters, Fig. 7. Transformer details: T_1, $\frac{5}{16}$in dia. former pri $\approx$ 30μH, 100 turns, spaced to 0.5in; sec $\approx$ 3μH 30 turns spaced to 0.5in; dust core of former fully in. T_2, T_5, pri 80mH; sec 3mH; impedance ratio 2000:75. T_3, pri 6.5mH; sec 0.5mH. T_4—as T_1 but without dust core.

Low-Pass Filters

A π-network has been used for the low-pass filters and the terminating impedances are, for the first filter 50 to 150Ω (input impedance of V7) and for the second 75Ω. Thus the value of 75Ω can be assumed for both filters; but it is advisable to check the input impedance of V7 under operating conditions. Table 2 and Fig. 7 show data needed for the calculation of the values for the low-pass filters, f_c being the cut-off frequency. On the lower ranges, using the b.f.o., the highest frequency to be passed by the first filter is 500kc/s and the lowest to be cut is 800kc/s, thus 650kc/s is a suitable frequency for design purposes. The other filters are the second or output filters, which remove the second harmonic generated by modulation; consequently these have to cut off below twice the lowest frequency on each range and this limits the ratio between mini-



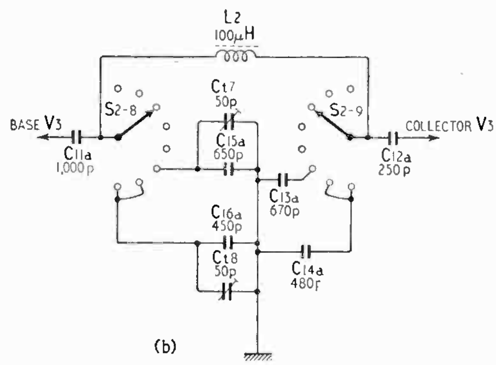


Fig. 6 (a). Variable-frequency oscillator (f_2) coil switching; (b) beat frequency oscillator (f_1) coil switching.

mum and maximum frequencies to less than 1:2. Thus the first b.f.o. range has to be divided into two, i.e., 100-170kc/s and 170-300kc/s and provided with the appropriate filters.

Some adjustment of the filters may be necessary after construction; for instance, if it is found that a filter is reducing output at the high-frequency end of its band, then the inductance of the coil should be reduced. This obviously calls for adjustable iron-dust cores, and, to achieve high efficiency, Litz wire and low-loss capacitors, such as polystyrene-dielectric types, should be used.

It will be noticed that the range switch (Figs. 5 and 6) has eight positions, although seven continuous-tuning ranges are provided—this extra position changes the first low-pass filter halfway through the lowest-frequency tuning range.

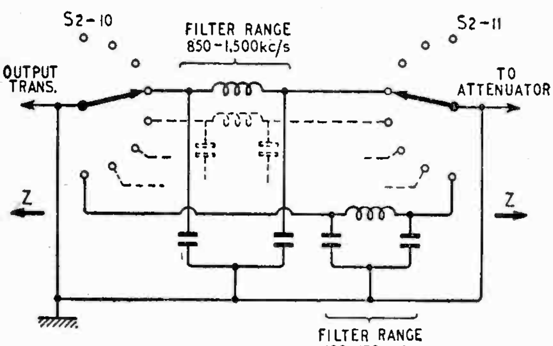


Fig. 7. Low-pass filter switching.

Attenuator

100mV is usually sufficient signal for testing purposes, and it is convenient to use 20dB steps, thus the attenuator steps run: 100mV, 10mV, 1mV, 100μV, 10μV, 1μV.

Fig. 8(a) shows the attenuator circuit and the way in which the values given for R_1 and R_2 are calculated. The use of a single-wafer switch would be convenient, but the capacities between the rotor and stationary contacts would shunt the attenuator resistors and render the whole useless for the higher ranges. Thus several wafers, individually screened and connected so that stray capacities do not bypass the resistors, have to be used and Fig. 8(b) shows how these are arranged. Assuming that the stray capacities C_p are about 0.1pF and the capacity to earth, C_s, is 3pF, the leakage attenuation will be 30 times per stage, i.e., three times the loss in the resistor. At the high-level end of the attenuator C_s is deliberately increased by adding small capacitors to improve the performance further.

The accuracy of attenuation should be reliable down to say 10μV at 5Mc/s. Outside these limits the screening of the oscillator must be very good if the calibration is to be within ±10%. The transistor signal generator has a very definite advantage here as no ventilation is needed (it is always difficult to screen holes!) and the power supply (battery) can be screened with the generator. Even so, careful construction is necessary.

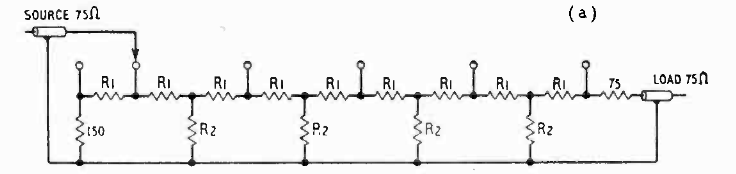
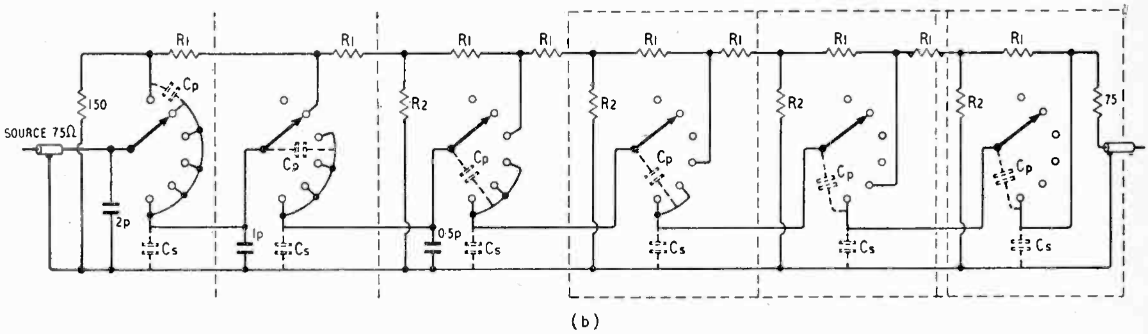


Fig. 8 (a). Attenuator theoretical circuit; (b) practical arrangement to reduce stray couplings.

$$R1 = 75\left(\frac{P+1}{P-1}\right) - R2$$

$R2 = 2.75 \sqrt{P} / (P - 1)$
where P is the power ratio of input to output per section. In this case P = 100, so values for R1 and R2 will be :—
$R2 = 150.10/99 = 15.15\Omega$
and $R1 = 75 - 15.15 = 59.85\Omega$



Construction

The front-panel controls are:—
1. Tuning (for ranges see Table 2).
2. Range switch (S_2).
3. Function switch (b.f.o., m.w., s.w.) (S_1).
4. Monitor meter and switch (S_3).
5. Level set (R_{21} and R_{22}, ganged).
6. Coarse attenuator (20-dB steps).
7. Fine attenuator (20-dB variation) (R_{23} and R_{20}, ganged).

Fig. 9 shows a suggested layout and the position of internal screens. It is essential to avoid loops or double paths between points on the screens; thus the internal screens are insulated from the case proper and are connected to the case and each other at only one point—the earthy connection of the output socket. The monitor or level-set meter circuit is enclosed in a screen which is secured only to the front plate, this forming its sole "earth" connection. The tuning dial should be outside the case, the front panel continuing behind it. Similarly no cut-outs should be made in the internal screening. The components are mounted on tags on a sheet of insulating material placed behind the front piece of the internal screen: the wiring should naturally be point-to-point, as short as possible, and in general follow roughly the theoretical circuit.

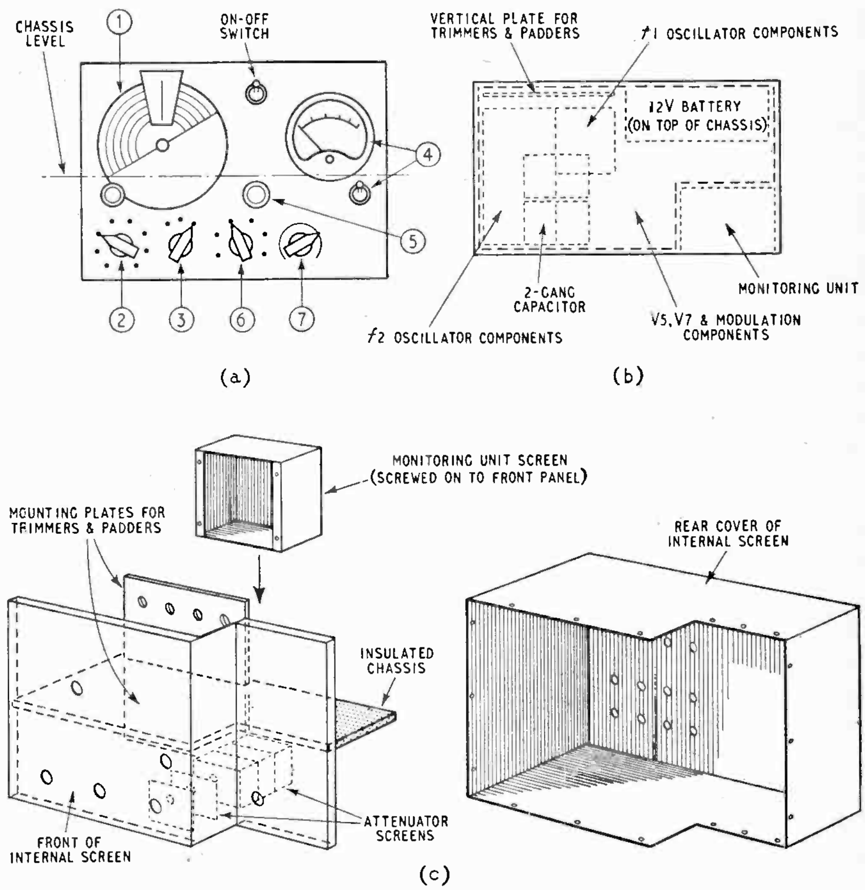
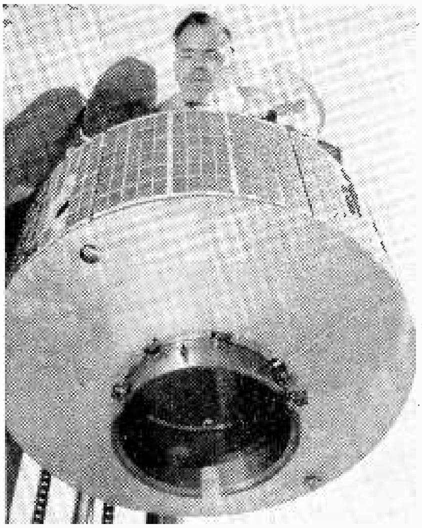
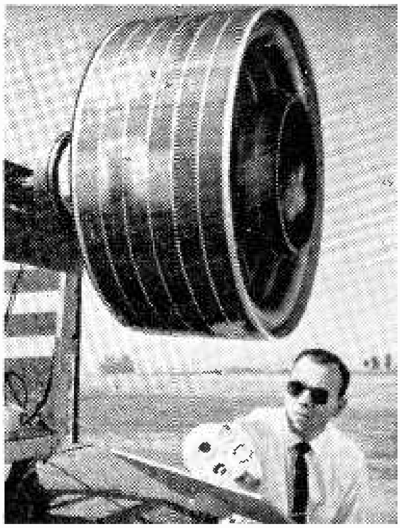


Fig. 9. (a) Front panel; (b) layout; (c) screening arrangements.





(Left) The Hughes spin-stabilized communication satellite is powered by 2,700 solar cells and is seen (right) undergoing centrifugal tests.

"FIXED" SATELLITE

HUGHES Aircraft Company in the United States have developed a communication satellite designed to orbit at a radius of 22,300 miles, and so to appear "fixed" above any selected point on the earth. Over the mouth of the Amazon, for instance, it would be "visible" to ground communication stations throughout most of North and South America, Western Europe and the Western half of Africa. The new design is 29 inches in diameter and weighs only 32 pounds, of which a mere 5 pounds is accounted for by the "electronics." It can be launched economically by a Scout rocket and weight has been reduced by adopting spin stabilization, with the axis parallel to that of the earth. Auxiliary nitrogen jets are used for final trim.

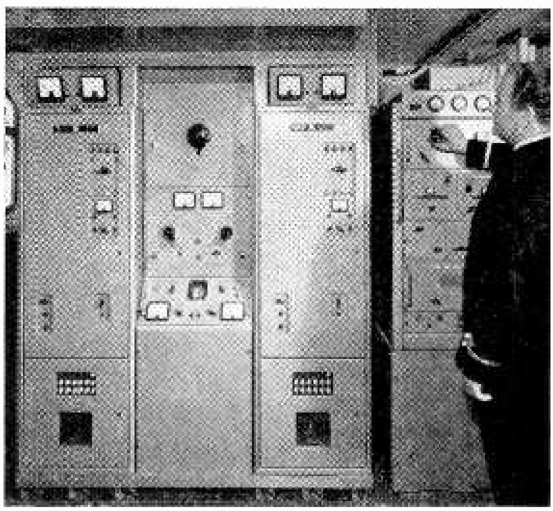
Since a pencil beam is not feasible with spin stabilization the aerial system is arranged to give a circular radiation pattern. The repeater consists of a transistorized u.h.f. receiver and L-band (2kMc/s) transmitter using a travelling-wave tube with a power output of 2.5 watts. Single-sideband is used to increase the number of available channels and the repeater also serves as a command receiver and telemetering transmitter.

Wideband Transmitter Output Amplifier

PART of the Marconi radio equipment installed in the G.P.O.'s cable-laying ship H.M.T.S. "Monarch" consists of two wideband transmitter output amplifiers, Type NT203, covering 1.5Mc/s to 24Mc/s and which do not require retuning whenever the transmitting frequency is changed. These can be used singly in conjunction with suitable drive units, such as the low-level drive stages of the NT201 independent-sideband transmitters included in the "Monarch's" equipment, or in parallel to give a peak envelope power output of 2.8kW (s.s.b. operation).

The NT203 is a linear distributed amplifier consisting of a penultimate stage and a power output stage. The former has 9 pairs of E180F valves in push-pull with anode and grid circuits consisting of "lumped-impedance" type transmission lines, while the final amplifier has 8 push-pull pairs of 4X250B air-cooled tetrodes, also with transmission-line circuits. The output impedance is 50Ω.

Although no tuned circuits are employed the discrimination against second harmonics throughout the frequency band covered is said to be generally better than −40dB and inter-modulation products are of about the same order. Included in these equipments are p.e.p. output indicators, feeder s.w.r. meters and facilities for remote control. Further details can be obtained from Marconi's Wireless Telegraph Co., Ltd., Chelmsford.



Marconi Type NT203 transmitter amplifiers in G.P.O. cable-laying ship "Monarch."

Electricity Direct from Heat

By "CATHODE RAY"

As I said only the time before last, a main aim of power engineers is to generate electricity direct from heat, instead of going through the tiresome sequence of using the heat to boil water and making the steam impinge upon blades in a turbine, causing it to move strong magnets past an array of conductors. This procedure is particularly irksome in nuclear power stations, where it looks incongruously old-fashioned alongside the modernity and scientific elegance of the nuclear part of the system. I am sure many people who know roughly how electricity is generated in ordinary fuel-burning stations imagine that steam-raising and turbines have been abolished in nuclear stations, and are surprised when they find them still in use. Even boilers are there, only they are called "heat exchangers."

Now I know that this sort of thing is none of our business, but—transistors notwithstanding—we rely upon it for most of our business. Besides that, we are finding ourselves moving closer to the successors of the old heavy electrical power engineers as we both converge towards a common centre—atomic physics. At the moment, the generation of electricity direct from heat looks like having more impact at first on our light electronic applications than on large-scale supplies.

The thing itself is nothing new. My last two instalments have been on undesired electrical manifestations of heat—as "noise" in valves and transistors. But electricity has been usefully generated direct from heat for ages. The fact that heating a joint between wires of different metals generated an electric current was discovered by Seebeck as long ago as the year Napoleon Bonaparte died. That electricity can be generated in a single piece of metal by heating one end of it (Thomson effect) is less familiar. But I suppose we all know that an ordinary diode valve acts as an electric generator when its cathode is heated. We may not all know that we know it, but it follows from the familiar fact that the characteristic curve of a diode extends slightly into the negative voltage region, as in Fig. 1(a). A load line can be drawn from the zero voltage point, representing a resistance R connected to the diode without any applied voltage; and the point at which it cuts the curve marks the current that will flow (I_0) and the voltage (V_0) across R. As the circuit diagram (b) shows, the generator of this current is indeed the diode, and of course its power output is I_0V_0 watts.

Fig. 1 (a) Enlarged view of the part of a diode characteristic curve near zero anode voltage, showing that some current flows even when the voltage is negative. (b) Basic circuit of a diode as a heat-to-electricity converter, the load resistance R being represented in (a) by the line marked R.

The issue here is perhaps confused by the fact that the heating of the cathode, without which no anode current would flow, is invariably done electrically. In the days when the cathode was always a directly-heated filament, there was some excuse for assuming that this anode current was somehow directly due to the filament battery. With an indirectly-heated cathode, that is impossible, and precisely the same result would be achieved in the anode circuit however that cathode was heated, so long as it was brought to the same temperature. It could for example be done with a bunson burner, or by focusing the sun's rays on it with a lens.

The fact that (purely for convenience) cathodes are heated electrically does at least mean that the input and output power are both of the same kind so that it is easy to calculate the efficiency. And it is not impressive. Typically, for an input of 1.4V, 0.15A (210,000 microwatts) the output might be 0.5V, 0.5μA (0.25 microwatt), or an efficiency of 0.00012%. Even heat from the sun is not so plentiful—in Britain, anyway—that it can be thrown away like that. All the same, the principle is established, and one must remember that normally this generator effect is discouraged by the valve designer. It is a major nuisance in low-reading valve voltmeters, because it shifts the zero to an extent that varies steeply with the cathode temperature. Can this despised weed be cultivated into a valuable plant?

Intensive cultivation has certainly been going on, and reports emerge from time to time claiming progressively higher efficiencies. Whatever I quote will probably be out of date by the time you read it, but an experimental efficiency of 12% has been claimed and 30% confidently predicted.

Even granting these figures are reliable, some readers (aware that electric generator efficiencies are in the upper nineties) may still not be impressed with their practical value, remarkable though the progress must be admitted to be. If so, then they must be confusing the efficiencies of the electrical machines alone (i.e., mechanical to electrical) with the overall efficiencies of generating stations, and the latter are subject to a serious limitation at the heat-to-mechanical stage. Any sort of heat engine is presented with a fluid, such as steam or burnt gas or oil, at a relatively high temperature. The energy the fluid possesses by virtue of this temperature drives the engine, and at the exhaust the fluid is cooler and therefore has less energy. The difference is energy available for useful mechanical work. Naturally there are some losses, such as heat radiated from the engine and mechanical work lost in friction. But the efficiency of the engine, reckoned as the ratio of useful work to the drop in fluid energy between inlet and exhaust, can be quite high. This basis of reckoning takes no account of by far the biggest loss of energy—that thrown away in the fluid at the exhaust. The greater the ratio of maximum to minimum absolute temperature, the greater the amount of mechanical work theoretically

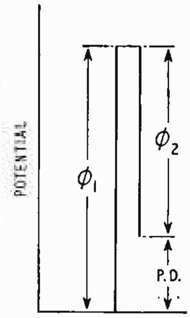


Fig. 2. When electrons pass from a conductor having a work function ϕ_1 to one with a work function ϕ_2, a potential difference is set up between them equal to ϕ_1-ϕ_2.

available. So in power stations the temperature at which the steam enters the turbines has been pushed steadily higher as engineering techniques have progressed. But even in the most modern power stations only about one-third of the heat energy of the fuel is utilized And of course the overall efficiency of small electric generating units, such as those used in country houses, is far lower. So the 12% of the " thermo-electron engine " begins to look more significant.

Note the rather surprising name, for a device with no moving parts—" engine." This has been given to it by Dr. Kaye and Dr. Hatsopoulos of U.S.A., leading workers in this field. They did so because they regard it as essentially a heat engine, like a steam or petrol engine. Just as steam flows from a hot body (the boiler) to a relatively cold body (the condenser) and back as water, so an electron " gas " flows from the hot cathode to the relatively cold anode and back via the load circuit. Only in doing so it gives (instead of mechanical energy) electrical energy. This analogy could no doubt be profitably followed into greater detail if we were mechanical engineers, well up in the theory of thermodynamics and heat engines. But I for one am not, so it would be a case of explaining the obscure in terms of the still more obscure. I just drop the hint in case any A.M.I.Mech.Es reading this would like to approach from that angle. As for the rest of us, we would probably be safer to stick to our electronics.

One of the facts thereof is that any electron requires a certain amount of energy to make it emerge from a conductor. This energy is curiously named the " work function " and denoted by ϕ, and is conveniently specified in electron-volts (eV) because that indicates the potential difference in volts that has to be overcome. If two pieces of exactly the same metal are brought into contact, their work functions—being the same—cancel out when an electron current flows out of one into the other. So (apart from any resistance drop) there is no difference of potential between the two sides of the contact. If however two metals with different work functions are brought into contact, a potential difference will be set up between them, equal to the difference between the work functions, as shown in Fig. 2. If you attempt to measure this with a voltmeter you will not succeed, even if you take the precaution of using a valve voltmeter drawing negligible current. That is because somewhere in the circuit there is bound to be at least one other junction between different metals, the net work function of which will cancel out the p.d. set up at the first junction.

Fig. 3 is a potential diagram for a diode connected as in Fig. 1(b). Beginning at the cathode, there is first a p.d. due to the cathode work function, ϕ_K. Because the direction of the electrons at the anode is inward, instead of outward as at the cathode, ϕ_A is set off downwards. But not from the level where ϕ_A left off. There is the p.d. caused by heating the cathode, which gives many of the electrons greater energy than is barely necessary to emit them. They are therefore able to climb a potential hill between ϕ_K and ϕ_A. In an ordinary diode the space charge due to the electrons between the electrodes makes this hill steeper, so that the number with enough spare energy to climb over it is a mere trickle—often less than 1 μA.

The difference of potential between cathode and anode is marked V_A, and this is the voltage available for driving the anode current through a load. To make it as large as possible, not only should the difference between cathode and anode temperatures be as large as possible but ϕ_K should be as much larger than ϕ_A as possible. And the space-charge hill (δ) should be reduced—preferably eliminated altogether. Unfortunately, increasing the current increases it! So the cure must be pretty drastic.

In a vacuum diode, the obvious but by no means easy way is to get rid of the gap. No space, no space charge. Of course, there must be some gap, otherwise cathode and anode would be at the same temperature and all one would get would be the thermo-electric e.m.f. Experimentally, it has been made as small as 0.01 millimetre—an impressive achievement with an emitting surface.

Another way in which the " engine " differs from an ordinary diode is that for the latter one wants as large an emission at as low a temperature as possible, an aim that is promoted by using an oxide coating to reduce ϕ_K. But here one wants a high temperature, which looks after the emission without the need for a low ϕ_K. So tungsten, which has a high ϕ and high melting point, is indicated.

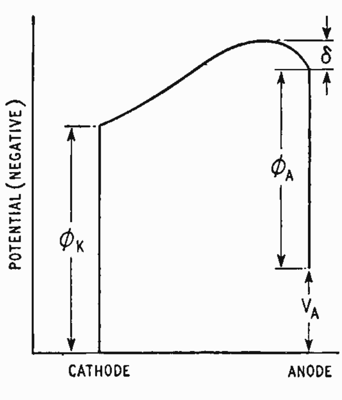


Fig. 3. In a diode the cathode and anode have their work functions, ϕ_K and ϕ_A; there is also a p.d. due to the heating of the cathode. The net p.d. between anode and cathode is marked V_A. A crowd of electrons between cathode and anode constitutes a space charge, which raises a potential barrier δ, severely restricting the flow of current.

There are obvious difficulties in maintaining such a minute gap, especially with such large temperature changes, and alternative solutions have been looked for. One of them is the control of the electrons by a third electrode, as in Fig. 4. Although the names "cathode" and "anode", meaning the electrodes where the electrons respectively leave and arrive, are correct by definition even when the anode is negative relative to the cathode, the inventor of this tube evidently felt they weren't altogether appropriate and substituted the transistor terms "emitter" and "collector". The accelerating plate is held at a positive potential of the order of 100V. By itself this would obviously draw off all the electrons and cause a heavy current to flow through the battery—not at all what is wanted. So a permanent magnet is also fitted, to provide a magnetic field B, at right angles to the electric field E. Directly the electron starts off towards the positive plate, it crosses the magnetic field, and in accordance with the right-hand rule is whisked around into a curved path that takes it (if everything has been correctly calculated) to the collector, and thence through the load R to the starting point. So, although a relatively high voltage is needed for the accelerator, there should be no current in that circuit and therefore no expenditure of power in providing the two fields.

It has been calculated that a device of this kind is potentially capable of a higher efficiency than the diode "engine", but a snag is that if the current density in the tube is large the field strengths have to be large—perhaps impracticably so.

I am more impressed with the possibilities of a third variety, which is analogous to the gas-filled diode, the great advantage of which is the neutralizing of the negative space charge by positive gas ions, so that the voltage drop between cathode and anode is greatly reduced. This, of course, is just the sort of thing we want, and allows of a reasonable engineering clearance between cathode and anode. In fact, it can be more than that, allowing the designer better scope for keeping the heat where it is needed.

In order to be of any use for neutralizing the electronic space charge, the gas atoms have to be ionized, by knocking away at least one electron from each. In the ordinary "soft" rectifier this is done by the applied anode voltage accelerating the emitted electrons to a velocity that renders them capable of inflicting this bodily harm on the gas atoms. But in the "engine" there is no applied voltage, and the velocity of emission is not enough. One idea is to provide an auxiliary ionizing electrode held at an appropriate voltage. But there are obvious objections to that. It has been found possible to ionize them with the work function voltage of the cathode, if that exceeds the ionizing voltage of the gas. With most combinations it doesn't, but with the exceptionally high work function voltage of tungsten (4.52V) and the exceptionally low ionizing voltage of caesium vapour (3.89V) it does. The voltage is brought to bear when the caesium atoms hit the cathode.

Besides performing this essential duty, the caesium has the convenient effect of reducing the work function of the anode to 1.81V. So the difference between ϕ_K and ϕ_A is exceptionally large, and consequently so is the output voltage—in an experimental "engine", 2.5V at 1A. This quite high output current required a very high cathode temperature, 2,910°K (=2,637°C), and yielded an efficiency of 10.4%.

In this experiment, with 2½ watts output, the load resistance was 2.5Ω. Much higher power would mean correspondingly lower load resistance. Even in these days of transistors there isn't very much call for such low-voltage d.c. as that. It is possible to step up the voltage to some extent by arranging several diodes in series. But often one wants a.c. A very ancient joke was to send some sap to buy an a.c. battery. One might think it equally naïve to ask for an a.c. version of the kind of current generator we have been considering. But their developers have no such inhibition and have pointed out that by suitably modulating their output in accordance with known techniques they can be made to provide a.c.

In experimental work so far reported, the cathodes have for convenience been heated electrically, the idea presumably being to established the essential principles before complicating the issue by the practical problems of applying non-electrical heat. That these problems are rated by the developers as mere routine can be guessed from the confidence with which they have announced that thermo-electron engines can be built to use conventional, nuclear or solar heating. In view of the exponential relationship between output and temperature (this is yet another place where $e^{1/kT}$ comes in; see "k" in the last November issue) I would expect control of temperature to sufficiently narrow limits to be quite a formidable problem on its own. But they know more about what they are doing than we do.

The thermo-electric effect has already been mentioned. Has it been considered as a source of

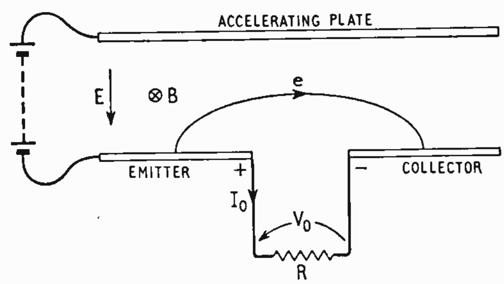


Fig. 4. In this diagram, E represents an electric field from accelerator to emitter, and the conventional symbol marked B is the rear of an arrow pointing into the paper, indicating the direction of a magnetic field. Under the influence of these fields, electrons leap across to the collector without causing space-charge effects.

power, as distinct from instrumental applications such as thermometry? It has not only been considered but actually used, I believe on a commercial scale, a good many years ago. One form, if memory serves me (if it doesn't, "Free Grid" will no doubt come to the rescue) was seen in this country, for bringing the offerings of the B.B.C. to the considerable proportion of British citizens who at that early date had a gas supply but no electricity. Another recollection of about the same period concerns a paraffin powered radio for bringing news of the exploits of stahkanovites and similar inspiration to dwellers in the remoter parts of the People's Republics. There would seem to be scope for more and smaller

"WIRELESS WORLD" INDEX

The index to Volume 66 (1960) is now available price 1s (postage 3d). Cloth binding cases with index cost 9s including postage and packing. Our publishers will undertake the binding of readers' issues, the cost being 25s per volume including binding case, index and return postage. Copies should be sent to Associated Iliffe Press Ltd., Binding Department, c/o 4 Iliffe Yard, London, S.E.17, with a note of the sender's name and address. A separate note, confirming despatch, together with remittance should be sent to the Publishing Department, Dorset House, Stamford Street, London, S.E.1.

devices of this kind now that transistors have displaced valves, for situations (if any) where batteries are not readily obtainable. (What about a combination radio and petrol lighter?) Compared with thermo-electron engines, they are less efficient at high temperatures, say about 1,000°K, but more efficient at lower temperatures. Their maximum efficiency is lower. And the voltage per thermo-junction is much lower even than that per diode, but it is rather easier, I would think, to arrange a lot of them in series, as in fact is usually done.

Development of semiconductors is having its impact on thermo-electric devices, as on so much else, but that is a subject (and a very involved one) of its own.

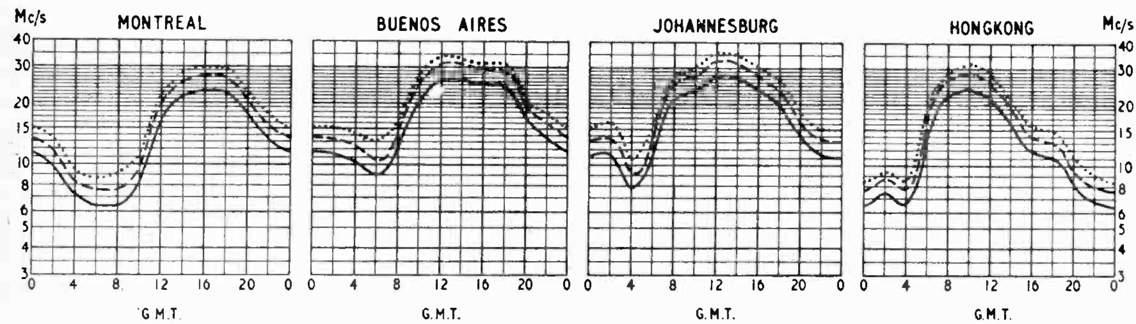
Another kind of generator altogether is the magnetohydrodynamic, considerately abbreviated to mhd. It makes another whole subject, but perhaps I can just indicate the broad idea by saying how it compares in principle with the conventional power station. In a turbo-generator set, a fluid (steam) is used to generate mechanical energy, which in turn generates electrical energy by causing relative motion between conductors and magnetic fields. In the mhd generator these two stages are telescoped into one by using a conducting fluid. The possibilities would seem to be very big indeed. But a great deal of development will be needed before they can displace such highly developed and well established units as turbo-generators.

Another kind of device that is sometimes included under our title, though it would be more correct to call it a generator of electricity *instead* of heat, is the fuel cell. If a supply of hydrogen gas is ignited it will burn, just like commercial gas, by combining with the oxygen of the air to form water vapour. This is simply a rearrangement of the electrons in the hydrogen and oxygen atoms. When rearranged, their total energy at their original temperature is less, so the surplus is given off as heat. However, by arranging a sort of middleman to keep the two parties to the transaction separate, this surplus energy can be made to come in potential form, as an excess of electrons at one electrode and a deficiency at another, these electrodes therefore becoming negative and positive respectively.

This is precisely what happens in an ordinary chemical battery cell, the only difference in a fuel cell being that the materials can be fed in continuously instead of being used up irreplaceably. In the Bacon cell—which we heard a lot about, over a year ago—hydrogen and oxygen are fed in through porous electrodes in a solution of caustic potash, and the chemical reactions cause electrons to accumulate on the hydrogen electrode and be withdrawn from the oxygen electrode—which therefore becomes about 1 volt positive. The efficiency is much higher than in the best heat engine, and the possibilities are tremendous.

All this may seem to have been a maximum hotch-potch of information for a minimum of accomplished practice. We have so often been let down by popular news of what was "just round the corner." And however promising the experimental results, the new methods of generating electricity will have a tough fight before they can displace the firmly established methods. Perhaps at first they will be limited to exotic applications such as satellites. But I shall be surprised if some of the conventional sources of electricity are not seriously challenged before many more years have rolled.

SHORT-WAVE CONDITIONS *Prediction for February*



THE full-line curves 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 February.

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 MEDIAN STANDARD MAXIMUM USABLE FREQUENCY

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

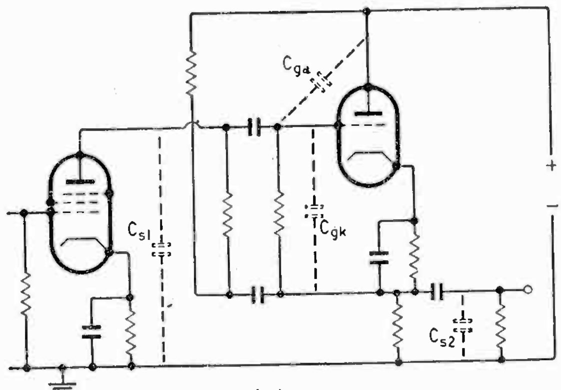
The Bootstrap Follower

2.—MEASUREMENTS IN PRACTICAL CIRCUITS

By G. W. SHORT

IN the first part of this article the properties of the "bootstrap follower" were discussed and a high-gain cascade amplifier combination of a pentode and bootstrap follower was analysed. We now pass to a consideration of practical design details and some measurements of performance.

Effect of Output Capacitance.—The effect of the capacitance c_{s2} across the output of the amplifier has so far been ignored. One reason for this is that c_{s2} is unknown—it depends on what you connect to the amplifier. Another is that the effect is complex, because c_{s2} affects the load seen by the pentode. Clever people could no doubt calculate the performance with c_{s2} included, but the writer gave up at this point, and made some measurements instead.



(b)

Fig. 8(b).—Bootstrap follower combination showing stray capacitances. (Repeated from Part I of this article).

The circuit used is shown in Fig. 9, which is based on Fig. 8(b). Care was taken to keep the anode strays of V1 down to a minimum. R_4 and R_5 were connected "close up," coupling capacitor C_2 was a small type (TCC Metalmite) and the valve holders were just far enough apart to accommodate it. A small earthed screening plate was put between the grid and anode tags of the triode valve holder, which are adjacent. The rest of the circuit was arranged so that it could quickly be changed from a bootstrap follower amplifier to a cascade amplifier and vice versa. For the cascade amplifier, C_3 was disconnected, R_8 was shorted, and R_6 was unshorted. The output was taken to a voltmeter via another bootstrap follower stage, made up from the other section of the ECC81 double triode. The meter was calibrated by applying the output of the audio oscillator used for measuring frequency responses directly to this second bootstrap follower stage.

The cascade amplifier had a gain of 6000 at 1 kc/s, and a − 3dB bandwidth of about 10 kc/s. The gain of the bootstrap follower amplifier at 1 kc/s was 1700. Some reduction was to be expected, because, first, in the circuit used only half the pentode load is subject to impedance multiplication, and, second, the triode gain (V_{ou}/V_{gk}) is reduced because the load is halved. Despite the lower gain, the high-frequency response was poorer than that of the cascade circuit (see Fig. 10) because of the ill effects of c_{s1}. This stray capacitance is made up of the output capacitance of the EF86 (5.5pF) plus strays, which might be expected to add up to 10 pF in a carefully wired-up circuit. In the cascade circuit, the triode should have a gain of 38, and in the bootstrap follower circuit a gain of 32. The value of c_{ga} is 1.6 pF, while c_{gk} is 2.2 p.F. These values yield a calculated ratio of gain-bandwidth products of 6, which agrees with the measurements (ignoring the l.f. responses).

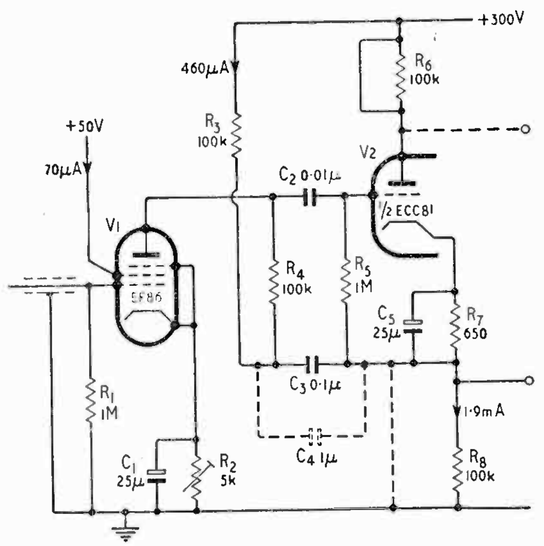


Fig. 9.—Practical pentode—b.f. combination circuit, based on Fig. 8(b). This can be turned into a cascade amplifier by disconnecting C_3, shorting R_8, and unshorting R_6. R_2 was adjusted to provide 1.5 V bias for V1.

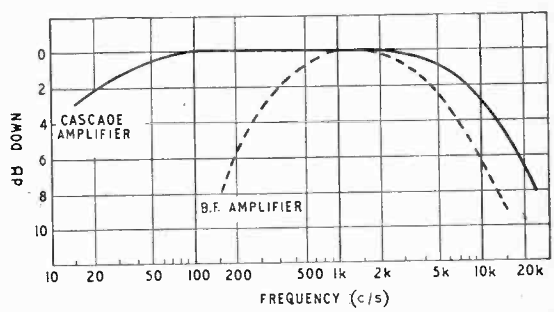


Fig. 10.—Frequency responses of the cascade and bootstrap follower amplifiers.

The effect of a capacitive triode load is shown in Fig. 11, which shows how the cut-off frequency (– 3dB) varies with this capacitance. As might be expected, the effect is worse for the cascade amplifier, which has a higher output resistance, but it is not very serious for normal values of load capacitance.

Low-Frequency Response.—The falling-off of l.f. response in the cascade amplifier due to the $0.01\mu F$, $1\ M\Omega$ interstage coupling should produce a 3dB loss at about 16 c/s, and this will be made slightly worse by the triode cathode-bias circuit. The measured response agrees with this. In the bootstrap follower amplifier, however, the lower cut-off frequency is about 330 c/s, which is twenty times greater.

Why should there be such a great discrepancy between the two circuits? The obvious difference between them is that the bootstrap follower amplifier

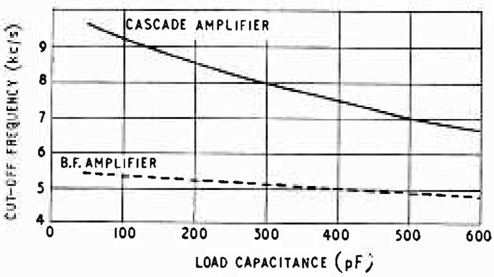


Fig. 11.—Effect of load capacitance on upper cut-off frequency.

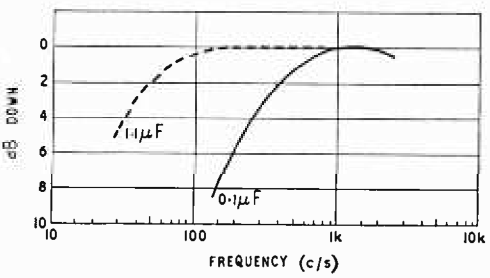


Fig. 12.—Effect of lower coupling capacitance on l.f. response of bootstrap follower amplifier.

has *two* couplings, C_2R_5 and C_3R_3, instead of one. In Fig. 9, these have equal time-constants, so on the face of it one would expect merely a further 3dB loss at 16 c/s compared with the cascade amplifier. Indeed even this would be pessimistic, since R_5 is impedance-multiplied to about $33\ M\Omega$ in the bootstrap follower.

It seemed reasonable to leave the upper coupling network C_2R_5 as it was, and make measurements with an increased C_3R_3. An extra $1\mu F$ capacitor C_4 was strapped across C_3 and the response measured again. The result, shown in Fig. 12, was to bring down the cut-off frequency to 40 c/s, which is a marked improvement, though the cascade amplifier is still superior. The best thing to do would be to make C_3 infinitely large by connecting the lower end of R_4 directly to the other end of R_a. This kind of direct connection is used in Bailey's circuit.* Unfortunately, a direct coupling of this kind puts the two valves in series across the h.t. line and so imposes restrictions on their d.c. operating conditions. The h.t. voltage must be shared between the two stages, and the anode currents of the valves must be equal. An a.c.-coupled circuit is more versatile in this respect and, fortunately, adequate l.f. response can be ensured by using a suitable electrolytic capacitor for the lower coupling. A small leakage current is permissible since it does not seriously affect the operating conditions of the triode.

In a circuit like that of Fig. 9, there are signal-voltage drops across C_2, R_7 and C_5, and C_3. All of these reduce the voltage fed back to the lower end of R_4, and so reduce the amount by which R_4 is multiplied by bootstrap action. If, for example, the transmission of each coupling were 0.9, then the overall transmission would be 0.9 cubed or 0.73, which would result in nearly 3dB loss of gain. At lower frequencies the transmission of each coupling would be smaller and the situation would get rapidly worse. The loss of l.f. signal across the triode cathode-bias network is particularly bad, since any signal-frequency voltage lost here reduces the impedance multiplication of the grid resistor R_5, which in turn reduces the response of the C_2R_5 coupling; so once the rot sets in it spreads rather rapidly. Moreover, it is only the in-phase part of the fed-back voltage which produces impedance multiplication. Because of this, in a CR network such as C_3R_3, the effective part of the output voltage is $1/(1 + X^2/R^2)$ times the input, X being the reactance of the capacitor. Thus when $X = R$, which is the normal condition for a 3dB loss, the actual loss is 6dB.

Single-Ended Bootstrap Follower Amplifiers.—The foregoing results show that, as a single-ended amplifier, the pentode-bootstrap follower combination is inferior in gain to a normal cascaded amplifier. Another disadvantage is that it cannot deliver as great an output voltage.

There may be circumstances in which these disadvantages are unimportant, and there may be reasons why the bootstrap follower combination is still an attractive proposition. Possible grounds for preferring the bootstrap follower combination to a normal cascade amplifier are component economy, stability, and greater suitability for use in feedback circuits. Let us see if there is a niche in which the bootstrap follower circuit fits.

An examination of Fig. 9 shows that, in this particular bootstrap follower combination, there is no component economy compared with a cascade amplifier. Indeed, one extra resistor and one extra capacitor are required. To reduce the number of components some degree of direct coupling must be resorted to. A completely direct-coupled circuit would look very like Fig. 7 (Part 1). The trouble with this is that the pentode load R_a is also the cathode-bias resistance for the triode. It must therefore be small (no more than a few thousand ohms) and the gain is therefore small. Readers will recognize this kind of circuit as one variety of "single-ended push-pull" output stage. In a power output stage one does not look for high gain so much as high output power, and the comparatively low gain is not important. Somewhat similar arrangements have also been used in video-frequency amplifiers which must work into low-impedance loads. The load R_l is connected via a block-

* *Wireless World*, January, 1960

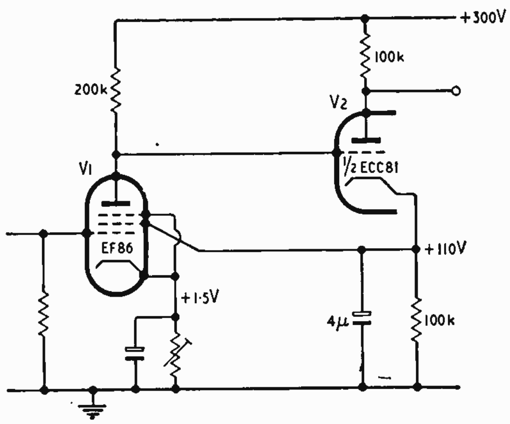


Fig. 13.—Partially direct-coupled cascade amplifier designed for economy in components.

ing capacitor, or returned to a tap on the h.t. supply such that there is no direct current through it.

A circuit which is not completely direct-coupled and is capable of furnishing much more gain has already been mentioned in connection with low-frequency response. Naturally, it uses fewer components than an a.c.-coupled circuit. But if direct coupling is to be permitted, one must compare like with like: that is to say, one must compare a bootstrap follower combination having some degree of direct coupling with a cascade amplifier also with some degree of direct coupling. Such a cascade amplifier is shown in Fig. 13. Astute readers will realize that the circuit of Fig. 9 can be converted into that of Fig. 13 with the minimum of trouble on the part of the experimenter! With this circuit the gain was about 8000, with an upper cut-off frequency of 8.5 kc/s. The lower cut-off frequency was 110 c/s: this indicates that the triode cathode capacitor was too small. Although this circuit is very economical in components, it does not represent quite the limit in economy. With some combinations of valves it should be possible to do without the triode cathode resistor. To be able to do so, the anode current of the triode must be the same as the screen current of the pentode, and the pentode must be capable of working satisfactorily with a screen voltage slightly in excess of its anode voltage. The best bet is to use a high-slope pentode such as the EF91, but unfortunately this kind of valve is not really suitable for use in low-level a.f. stages, because of hum and microphony. In general, it is much better to use a proper audio valve like the EF86 and stand the expense of the one extra resistor.

Readers who like using unorthodox-looking circuits may care to experiment with a combination of valves such that the screen current of the pentode is *greater* than the anode current of the triode. The triode cathode resistor must then be returned to h.t. positive.

The bootstrap follower combination does possess one characteristic which sometimes makes it more suitable than a normal amplifier. This is that there is only one phase reversal, so that the input and output voltages are in anti-phase. This can be useful in feedback circuits for getting the polarity right.

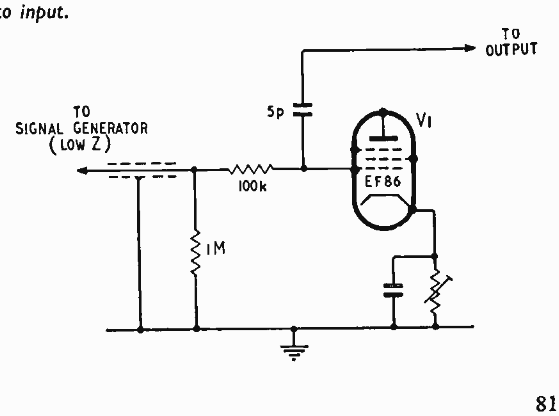
In certain circumstances, the bootstrap follower combination may produce less phase shift than a cascade amplifier. This is because the triode has a lower output resistance in the bootstrap follower circuit and so the high-frequency phase shift caused by capacitance across the output will be less than in the triode stage of the cascade amplifier. The writer suspects, however, that claims about reduced phase shift for this kind of circuit are usually based on an assumption that the output resistance of the triode is as low as that of a true cathode-follower. If this were so, then for audio applications the high-frequency phase shift introduced by load capacitance would be negligible. Unfortunately, as we have seen, this is not true of circuits in which the triode is driven from a high-impedance source, and these are the very circuits which produce high gain. In such circuits there are two important h.f. cut-offs, as in a cascade circuit. While Fig. 11 suggests that there may well be more h.f. phase shift in the cascade circuit, one could always reduce it in the latter by using a smaller triode load and possibly still end up with a high overall gain.

On the matter of stability, it is obviously true that stray coupling from output to input of the bootstrap follower combination is not likely to cause oscillation, since it completes a negative feedback loop. Such coupling could only give trouble of this kind if phase shifts elsewhere in the loop were large enough to bring the total phase shift to 180°. It does not follow that the effect of stray coupling is harmless. Since such a coupling takes place by way of a capacitance of, at the most, a few pF, it is in itself frequency-selective and introduces considerable phase shift. It can therefore affect the frequency response considerably.

To illustrate this the frequency response was measured with a 5-pF capacitor connected from output to input. Measurements were made on the Fig. 9 bootstrap follower combination with the input circuit modified as shown in Fig. 14. Since the 1-MΩ grid resistor was virtually shorted by the signal generator, the effective signal-source resistance was 100 kΩ.

The effect of the 5-pF feedback capacitance was to change the frequency response to that shown by the solid-line curve of Fig. 15. The gain at the peak was 1200, and the response was 3dB down at about 1.5 kc/s. Even this is better than might be expected on simple theory. If one regards the boot-

Fig. 14.—Modification of bootstrap follower amplifier input circuit to measure the effect of stray coupling from output to input.



strap follower combination as a sort of composite single-valve amplifier, then the 5-pF capacitance is its anode-grid capacitance and gives rise to Miller effect. Since the gain without feedback was previously found to be 1700, a 5-pF capacitance must look like 8500 pF between the input grid and earth, and with this value of capacitance one would expect a 3 dB drop at about 200 c/s.

The 100-kΩ grid stopper by itself, without the 5-pF feedback capacitance, has some effect on the high-frequency response. This is shown by the dotted-line curve of Fig. 15.

Bootstrap Follower Phase Splitters.—In general, then, the single-ended bootstrap follower combination is inferior to ordinary cascaded stages. In phase-splitting circuits of the "concertina" type, however, it can be used with advantage to obtain a higher overall gain than one would get from a straight pentode followed by a normal triode concertina phase-splitter.

Fig. 16 shows the frequency response of a modified Fig. 9 circuit. The modifications consisted of adding a 50-kΩ anode load resistor and using a 4-μF electrolytic capacitor for C_3. The gain to either output was 1250. The deterioration in h.f. response is probably the result of Miller effect in the triode, which approximately doubles the effect of the grid-anode capacitance.

This type of circuit is clearly very useful. The h.f. response could be improved by reducing the load of the pentode. The gain would fall, but it would still be greater than that of a normal circuit with no impedance multiplication. One way of reducing the gain is simply to remove C_5. This reduces the impedance multiplication and introduces some local negative feedback. Another method is to reduce R_4, and yet another is to use a low-μ triode for V2.

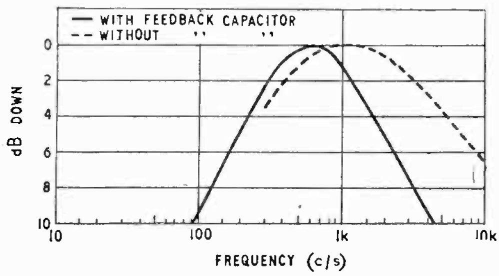


Fig. 15.—Effect of 5pF coupling capacitor (solid line). The dotted line shows the response without the capacitor but with a 100-k Ω grid stopper.

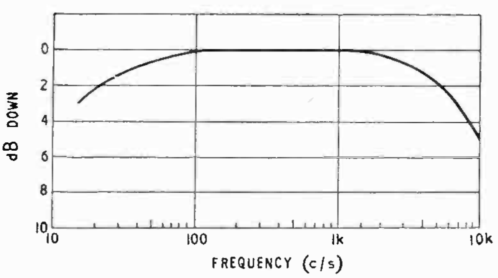


Fig. 16.—Frequency response of bootstrap follower phase-splitter combination.

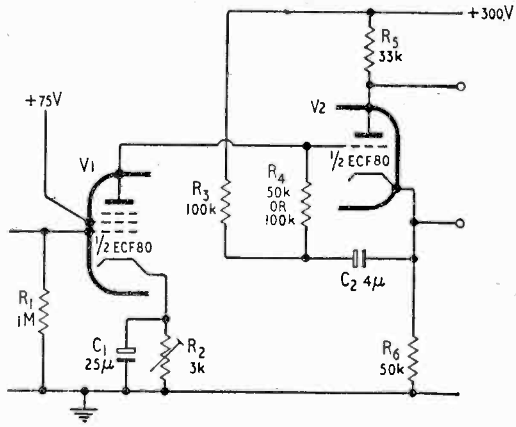


Fig. 17.—Experimental high-gain phase-splitting circuit using a triode-pentode valve. R_2 was adjusted to provide a bias of 1.5V. R_4 is the only component which adds stray capacitance to the sensitive part of the circuit.

In many cases, an impedance multiplication of 10-20 will be as much as can be made use of without running into h.f. response difficulties, and almost any triode will provide this amount. It then becomes an attractive proposition to use a triode-pentode of the television frequency-changer type as a single-valve bootstrap follower phase-splitter combination, to give high gain together with adequate bandwidth.

Whichever circuit is used, care should be taken to minimize the wiring stray capacitance in the pentode anode and triode grid circuit. The best way of doing this is to connect these two electrodes directly, since a short piece of wire has a lower capacitance to earth than a coupling capacitor. In addition, the number of components in the vulnerable part of the circuit should be kept as small as possible, since each one adds its quota of stray capacitance. The components should be soldered to the valve-holder tags, using short leads, and not mounted on tag boards some distance from the valve holders.

These considerations lead to the kind of circuit shown in Fig. 17. With $R_4 = 50$ kΩ, this had a gain of 750 to each output, 3 dB down at 14 c/s and 30 kc/s, and provided about 25 V peak from either output into a 300-kΩ load. With $R_4 = 100$ kΩ, the gain was 1000, the bandwidth was 15 kc/s, and the peak output was about 35V. No attempt was made to optimize component values (this applies to all the circuits used in making measurements for this article) and it may well be possible to do a bit better than this.

A valve designed for r.f. applications is not likely to have very low hum and microphony, but it should still be possible to use such a valve where the signal level is fairly high. The usual high-slope output pentodes require round about 10V grid drive, so that the input to a typical pentode bootstrap follower phase-splitter would be about 10 mV. This is a bit too low for comfort, but in many amplifiers 20 dB of negative feedback is used, and the required input would then be 100 mV. Under these conditions one might hope to get away with it. However, the writer would like to emphasize that the circuit of Fig. 17 has not been tried out by him in an actual audio amplifier. It may be full of hidden snags, and, as this article has endeavoured to illustrate, with these types of circuit you can't be too careful.

Symbolic Circuit Description

A USEFUL FORM OF SHORTHAND FOR COMPLEX SYSTEMS

By P. RAILTON and H. JEFFERSON, M.A.

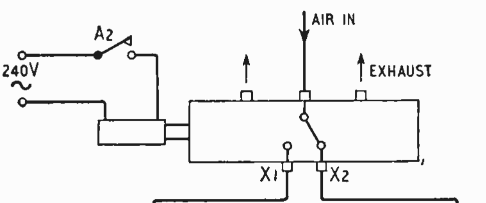
THE increasing complexity of electric and electronic circuits has brought in its train an increasing mass of paper describing the operation of the circuits. Where the descriptions are intended to be used for maintenance and fault-finding they are of necessity detailed and as the equipment grows in size the study of the handbook becomes itself a task of formidable proportions. This is especially true of switching circuits. In the linear circuits, amplifiers, modulators and the like, there is commonly a single path to be followed throughout the units of the system with perhaps an entrant side chain from an oscillator to a modulator or a separation into a number of parallel and similar tracks at a filter system. In switching circuits we no longer have this simplicity. The operation of a relay may close six circuits and open half-a-dozen more. Sometimes, though this is usually deprecated, two circuits may race against each other and the designer's skill becomes his skill as a handicapper. As each stage in the operation is completed a whole new set of functions is initiated. All this must be described.

To facilitate the understanding of repetitive but non-linear circuits a practice has developed of showing a small diagram at important points of the circuit diagram to indicate the waveform which will be seen on an oscilloscope connected to any of these points. This practice, not surprisingly, is very frequently adopted by the manufacturers of oscilloscopes, but it has also been found useful by others whose judgment can be assumed to be free of any trace of special interest. It is a clear admission that a lengthy description of the functioning of the device is not really sufficient.

An interesting method of dealing with the circuit description of switching circuits has been suggested by M. M. Bonell in the official journal of the Spanish Posts and Telecommunications, *Revista de Telecomunicacion* (Vol. 12, No. 53, pp 2-7, September 1958). The author is concerned with the functioning of automatic telephone exchanges and his paper is devoted to a description of a symbolic method of cataloguing the stages involved in setting up a call. He claims that on four pages of normal size he has provided all the information normally requiring a book of more than one hundred pages. Obviously the information has become much more accessible: at the same time it has become easier to understand and in consequence easier to remember.

Bonell's diagrams appear to be of much wider application than he suggests and they deserve wider publicity. This article has been prepared to ensure the latter and to encourage the former. Its merits are those of Bonell, its defects must be attributed to the authors.

In order to demonstrate the method we have



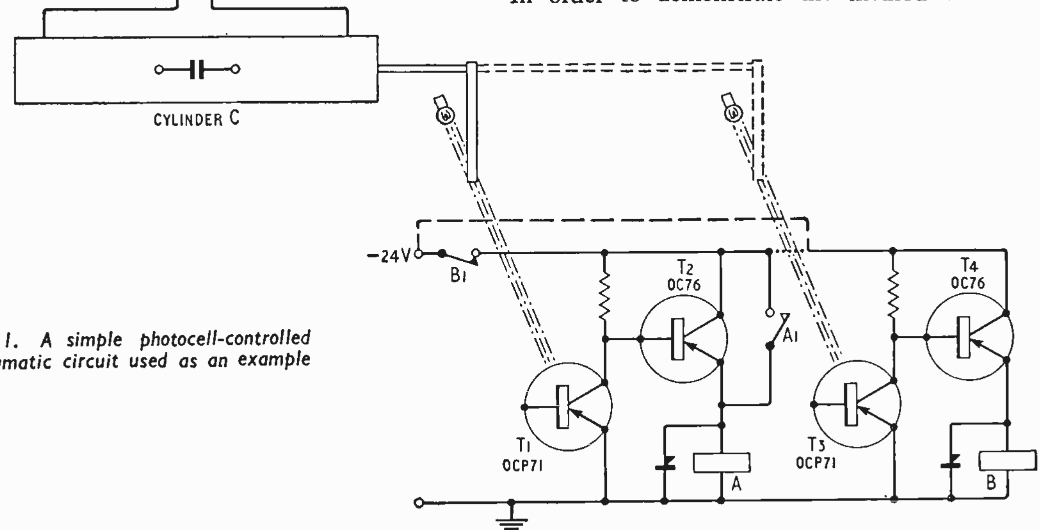
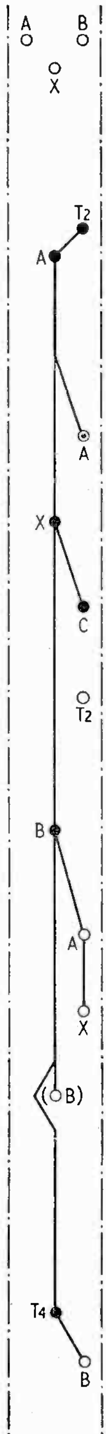
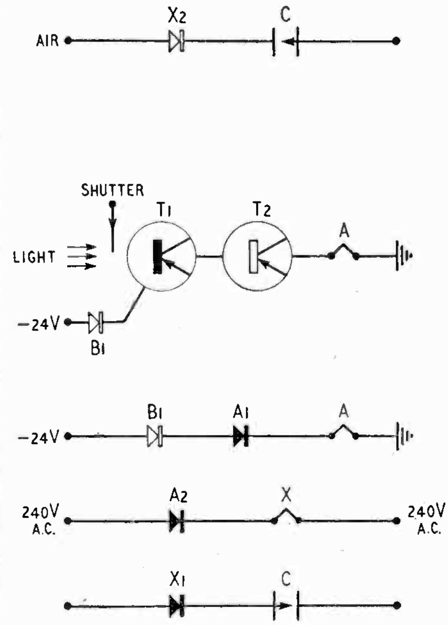


Fig. 1. A simple photocell-controlled pneumatic circuit used as an example

devised a simple reciprocating circuit in which air pressure is used to drive a shutter to the point at which it intercepts the light falling on a photo-transistor. A second transistor then operates a relay to reverse the motion which continues until the shutter reaches a second light beam. The complete arrangement is shown in Fig. 1. It will be seen that in this relatively simple system we have on-off



(1) *When first switched on with the piston in some arbitrary central position light will fall on both phototransistors which will then conduct, cutting off the second transistor of each pair. Neither relay will be operated. The air valve X will not be energized so that pressure will be applied through the path X2 to the cylinder and the piston will be driven to the left.*



(2) *When the piston has travelled far enough to the left the shutter will intercept the light falling on the normally conducting phototransistor T1. In consequence T1 will be cut off, bringing the normally non-conducting transistor T2 into conduction and operating relay A. The −24 volt supply for this action is provided through the normally closed contact B1.*

(3) *Relay A now locks on through its own holding contact A1.*

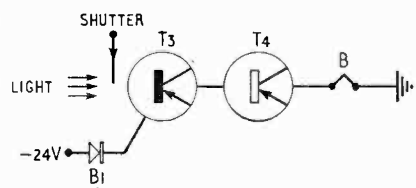
(4) *Contact A2 is operated and applies the 240 v a.c. mains supply to the solenoid of air valve X.*

(5) *When the solenoid is energized air pressure is applied through the path X1 to the cylinder, while the other end is opened to atmosphere through X2. The piston is driven to the right.*

(6) *As soon as the piston moves light again falls on the photo-transistor T1, cutting off the transistor T2 but leaving A operated through the holding contact A1.*

As this is the reversal of step 2 no other notation is needed.

(7) *On the completion of its stroke the piston causes the shutter to intercept the light reaching phototransistor T3. As in step 2 transistor T4 conducts and relay B is operated.*



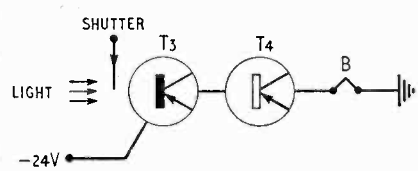
(8) *The operation of B opens contact B1 so that relay A releases.*

(9) *The release of relay A opens the holding contact and also contact A2, so that X releases.*

(10) *The operation of contact B1 also releases B*

(11) *The release of B closes contact B1.*

At this point we find that we are redrawing the diagram of step 7. Investigation reveals that relay B will oscillate until transistor T4 is cut off. The circuit of Fig. 1 is therefore altered by deleting the dotted line and inserting the dashed line. Step 7 is then changed to:



With the change thus made necessary steps 10 and 11 disappear. A new stage in the centre indicates the re-illumination of T3 and consequent events.

The system is now in the original state with relays A and B and solenoid X all de-energized. This is the opening condition of step 1 and the cycle will now be repeated

Key to Symbols

Contact normally made or air path normally complete

Contact made or air path completed when device is energized

Relay or solenoid coil

Non-conducting transistor

Conducting transistor

Relay energized

Relay de-energized

Relay held

actions in light paths, air paths, electric circuits through transistors and electric circuits through relay contacts. It is now necessary to describe in detail the functioning of the circuit. This is done in the table, which contains in parallel columns the conventional description in words and the symbolic description of the Bonell diagram.

As will be seen the Bonell diagram is in two parts, the one on the left indicating the successive operations, for example the energizing of relay A in step (2), while on the right the skeleton of the circuit which produces the operation is given in a form which tells us what happens without excessive detail.

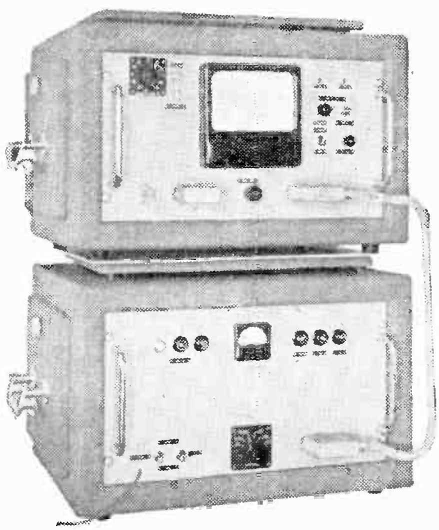
We do not, at this stage, require to know just how much light must be cut off from the phototransistor in order that the second transistor emitter current will rise to the operate current of the relay. This is a matter which must always be referred back to the original and detailed circuit.

The preparation of the Bonell diagram is in itself a useful tool in the detection of circuit errors. Such an error which results in a race between the piston movement and relay B has been introduced into the symbolic circuit, in order that it might be detected at step (10). It is probably always more difficult to gloss over racing sequences and similar circuit aberrations in a highly formalized language, which is what the diagram in fact is, than in a flow of words.

In the manuscript a conservative estimate is that the Bonell diagram occupies only one-third of the length of the conventional description. This is a much smaller improvement than is claimed by Bonell. There are two reasons for this: the circuit itself is simpler than Bonell's circuits and the conventional description is rather abbreviated. For example, in step 3 no mention is made of the -24V supply, nor of the fact that the normally made B1 contact is in the holding path of relay A. This sort of abbreviation becomes much less pardonable in complex circuits.

The symbols used for relays are those introduced by Bonell, while the others are those which we have found convenient. It is, of course, vital to the success of a symbolic form such as this that a uniform system should be adopted and that once adopted it should be protected from the hands of the improvers who can produce a maximum of confusion for a minimum of merit.

Permanent Noise Factor Measurement



A METHOD of centimetric radar receiver noise measurement, which provides a permanent meter indication of noise factor under true working conditions has been developed by C.S.F. (Compagnie Générale de Télégraphie Sans Fil, 79, blvd. Haussmann, Paris 8).

The limited output of a noise discharge-tube, pulsed at half the recurrence frequency of the radar equipment, is fed to the transmission waveguide via a directional coupler. The noise pulses are employed as a standard, and are delayed to avoid interference from clutter.

The amplitude of the receiver output is proportional, during "even" pulses, to receiver noise added to that of the noise diode, and to receiver noise alone during "odd" pulses. The two outputs are compared in a differential amplifier, the output of which is proportional, after standardization, to the difference in amplitude of the two inputs. A meter connected to the output of the amplifier gives noise factor in decibels.

An additional rack enables measurement of noise factor to be made on one or more radars, readings being presented on separate meters.

CLUB NEWS

Bradford.—"Transistors, Pirates, and Direction Finding" is the title of the talk to be given by A. R. Bailey (G3IBM) at the February 14th meeting of the Bradford Amateur Radio Society. The club meets on the second and fourth Tuesdays of each month at 7.30 at Cambridge House, 66, Little Horton Lane, Bradford 5.

Cleckheaton.—Dr. N. H. Chamberlain, of Leeds University, will deal with industrial electronics in a lecture to the Spen Valley Amateur Radio Society on February 1st. Meetings are held on alternate Wednesdays at 7.30 at the Labour Rooms, Cleckheaton.

Halifax.—Transistors is the subject of the lecture to be given by E. C. Bell, of Bradford Technical College, at the February 7th meeting of the Halifax and District Amateur Radio Society. Meetings are held at the Sportsman Inn, Ogden, at 7.30.

Leeds.—The February programme of the Leeds Amateur Radio Society includes a transmitting evening (1st) and a lecture by D. Watson on amateur television (15th). The club meets each Wednesday at 7.45 at 3 Woodhouse Square, Leeds 3.

Elements of Electronic Circuits

22.—Multiplication and Division

By J. M. PETERS, B.Sc. (Eng.), A.M.I.E.E., A.M.Brit.I.R.E.

ARITHMETIC multiplication and division form an important part of mathematical operations on wave-forms and a variety of methods for achieving these functions have been devised.

Multiplication

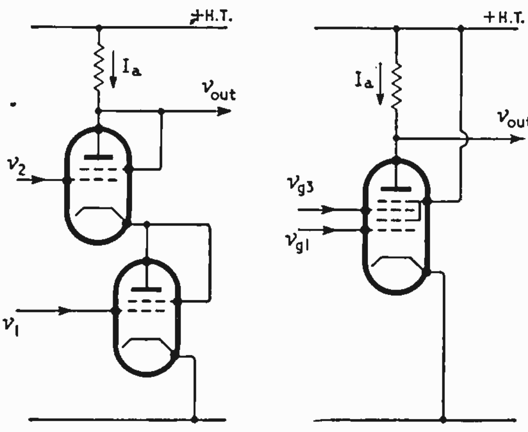
Three common methods of achieving multiplication use the characteristics of valves, "take logarithms" almost as one would using log. tables or employ a pulse generator of variable width and amplitude.

Valve Characteristics.—If it is desired to achieve multiplication with valves at least two inputs should each, independently, be proportional to the output. With a triode, this means that the anode characteristic (I_a/v_a) must be linear. In other words the output current must be proportional to the anode voltage and the grid voltage:

$$I_a = k\, v_a v_g$$

Although this relationship is very difficult to achieve in practice, if some types of output tetrodes or pentodes strapped as triodes are used and the range of variables is restricted, an output approximately proportional to the product of two input voltages may be obtained. Fig. 1(a) shows a circuit using two tetrodes strapped as triodes. V2 is a cathode follower with V1, the multiplier valve, as the cathode impedance. $v_{k2} = v_{a1} = v_2$ by cathode follower action. As the valves have been arranged to have linear I_a/v_a characteristics, variation of v_2 causes a linear variation in current through the valves; as does v_1. Thus the common valve current I_a and consequently v_{out} is proportional to $v_1 v_2$.

A similar method uses a multi-grid valve, with the voltages to be multiplied applied to different grids (Fig. 1(b)). This is the process commonly known as "multiplicative mixing" nearly always used in a.m. superheterodyne radio receivers, where the anode current $= k\, v_{g1} v_{g3}$. Here v_{g1} is the signal voltage applied to the first (control) grid and v_{g3} is the local oscillator voltage applied to the third grid of the mixer valve.



(a) (b)

Fig. 1

A similar process occurs in amplitude modulation where the carrier amplitude after modulation is proportional to the modulating signal and to the amplitude of the carrier input.

Logarithmic Devices.—Let us consider the expression $\log a + \log b = \log ab$. Some forms of diode can be operated under conditions which produce a practically logarithmic voltage/current characteristic; hence this can lead to their use for multiplication purposes. After converting the inputs, the two logarithms are added and the antilogarithm derived, either directly from an exponential characteristic or by methods which involve the use of feedback circuits. Rectifiers of the copper-oxide type have a forward-impedance law which is approximately logarithmic (of the form $v = R \log I$) and can be used for multiplication. Fig. 2 shows a simple circuit employing a rectifier.

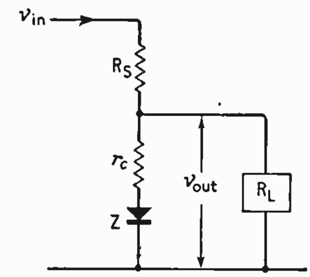


Fig. 2

Z— the dynamic-forward or "characteristic" resistance of the rectifier.

r_c— the ohmic resistance of the rectifier—this represents the resistance of the assembled component parts of the device and is quite small.

R_S—the resistance of the source—this is made large compared with Z.

R_L—the load resistance which is also made large compared with Z.

An improvement on this simple circuit is the non-linear bridge circuit employing identical rectifiers (Fig. 3). First of all let us consider what happens when R_1 and R_2 are fixed and R_3 and R_4 are varied. For low values of R_3 and R_4 it is possible to balance the bridge, i.e. $v_{out} = 0$. As the values of R_3 and R_4 are increased the

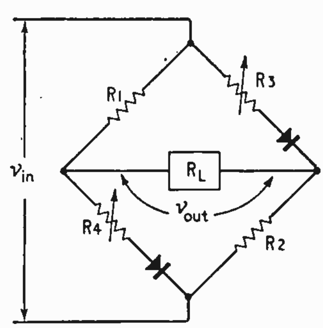


Fig. 3

input voltage v_{in} must be made larger in order to balance the bridge. Ultimately a condition is reached when v_{out} can no longer be zero, regardless of the value of v_{in}, and when $R_3 = R_4 = R_1 = R_2$ the output current (and hence v_{out}) rises logarithmically with an increasing v_{in}.

Variation of Waveform.—The average value of a waveform is proportional to the product of its amplitude and duration, provided that the negative excursion is clamped to zero. This is pressed into service by making the amplitude of the waveform follow one input and the duration the other. Methods based on this principle are quite often used in computers with a comparatively high degree of accuracy.

Division

Naturally, circuits carrying out this function are sometimes required and the simplest of these need not use valves or semi-conductors.

Passive Circuit Elements.—A very common example of potential division is the arrangement of resistors, capacitors or inductors in simple potential-divider configurations. The volume control is perhaps the most familiar divider; with this the input represents one variable, the rotation another. Of course, for "mathematical" use the potentiometer must have an accurately-known law.

Logarithmic Division Devices.—The expression $\log a - \log b = \log (a/b)$ enables us to use the logarithmic devices which were described in the section on multiplication.

Suppose we wish to find the quotient of two voltages $v_1 \div v_2$. We apply these voltages to two non-linear bridges and connect the bridges in series. The output currents are fed to a meter which records their difference $I_1 - I_2$. Then since $I_1 = k \log v_1$ and $I_2 = k \log v_2$, $I_1 - I_2 = k \log v_1 - k \log v_2$ which by definition is $k \log (v_1/v_2)$ therefore the difference in output currents is proportional to the logarithm of the ratio of the two inputs.

Feedback Techniques.—With the aid of a high-gain amplifier together with a subtractor circuit it is possible to convert any multiplying circuit into a dividing circuit. Let us examine the block diagram of Fig. 4.

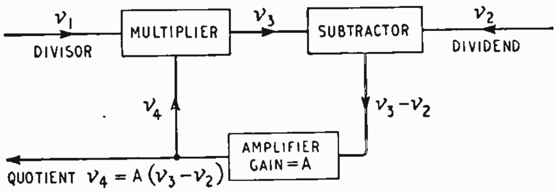


Fig. 4

It is required to derive the result $v_4 = v_2/v_1$. The equations to be considered are:—

$$v_3 = kv_1 v_4 \ldots\ldots\ldots\ldots \quad (1) \text{ (from the multiplier)}$$

$$v_4 = A(v_3 - v_2) \ldots\ldots\ldots \quad (2) \text{ (from the amplifier)}$$

substituting in (2) for v_3 we have

$$v_4 = A(kv_1 v_4 - v_2)$$
$$v_4 - Akv_1 v_4 = -A v_2$$
$$v_4 (1 - Akv_1) = -A v_2$$
$$v_4 = A v_2/(Akv_1 - 1)$$
$$= v_2/(kv_1 - 1/A)$$

If we make the gain (A) of the amplifier very high $1/A$ becomes very small. Then $v_4 = v_2/kv_1$ which is the required ratio (k can be made equal to one).

TECHNICAL NOTEBOOK

Tunnelling through Insulators has recently been demonstrated by Ivar Giaever of the American General Electric Research Laboratories. The quantum tunnelling process by which electrons can pass through an energy barrier which they have insufficient energy to surmount has already been demonstrated and made use of in semiconductor tunnel diodes, but had not so far been observed in insulators. In Giaever's experiments the insulator was only ~ 10-100 atoms thick and was sandwiched between two metal plates. Giaever also found that, if both of the metals were made superconductive, then the tunnelling voltage/current characteristic exhibited a negative-resistance region. Since superconductivity can be removed by applying a magnetic field, this offers a method of controlling the characteristics of such a device. It could in fact be made to function as a capacitor, resistor, diode, negative-resistance diode, switch or triode. The device can be made simply by depositing the metal and insulating layers on a suitable substrate. It could thus be made extremely small and with a very low power consumption and dissipation. Since the tunnelling current depends on the electron density in the energy levels in the two metal plates, information about these levels can be obtained from measurements of the tunnelling current.

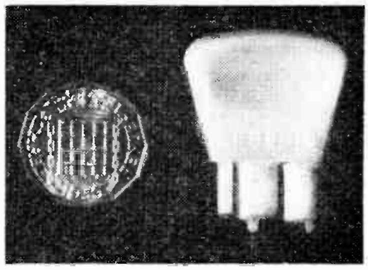
Photographic Memory has been recently developed by Bell Telephone Laboratories for an experimental electronic telephone switching system. In this memory switching instructions and directory information are permanently stored in the form of many small clear spots in an otherwise opaque photographic film. Each store contains over 2×10^6 spots or "bits" of information. This is read out by a flying-spot scanner, a 68-bit word taking only 2.5μsec to read. The flying-spot electron beam is also used to initially develop the film by stopping the beam briefly at positions where a spot is desired. A photographic emulsion is used which is fast enough to be exposed when the beam is stopped, but slow enough not to be exposed by a moving beam. Two million spots can be exposed in about ten minutes in this way. The photographic developing process—which may involve as many as fifteen steps and which takes in all about half an hour—has been made completely automatic in this equipment.

Thermoelectric Cooling Unit—the BT4—has been introduced by Salford Electrical Industries. This unit utilizes the Peltier effect in which heat is absorbed or generated when an electric current is passed across the junction of two dissimilar metals or semiconductors. (This effect occurs only at the junctions, and is in addition to the normal Joule electrical heating in the metals or semiconductors.) In this unit four pairs of junctions formed between p- and n-type bismuth telluride are used since this semiconductor exhibits a large Peltier effect. In use the unit is clamped between the object to be cooled and a heat sink (for absorbing the heat produced from four of the junctions). The cooling power increases with decreasing temperature difference between pairs of junctions up to a maximum, for this unit, of about 3W for a 10°C junction temperature difference. The cooling power can also be continuously varied or even reversed simply by varying the value or direction of the input current, so that such units can readily be incorporated in automatic control systems. Other advantages of this cooling unit over conventional units are that the actual junctions occupy only about a ½-in cube, it is silent and reliable (since no moving parts are used) and finally, it is unaffected by vibration or attitude.

Microwave Modulator using n-type germanium diodes has been developed by E. T. Harkless and R. Vincent of the Bell Telephone Laboratories. The operation of the device depends on the fact that such diodes, when suitably mounted in a waveguide, can be changed from nearly perfect absorbers to almost complete reflectors simply by switching the d.c. bias on them. The modulator uses a pair of such suitably-mounted diodes combined with a hybrid junction. With a reverse bias of about 7V on the diodes they reflect nearly all of the radiation incident on them and the microwave signal is transmitted with an attenuation of only 1 to 2dB. When the bias is switched to about 40mA in a forward direction nearly all of the radiation incident on the diodes is absorbed and the microwave signal is attenuated by 30 to 40dB. In this way up to 1W of 35kMc/s radiation has been successfully switched on and off at a repetition rate of 10Mc/s and with pulse rise and fall times of less than 2mμsec. Pulse lengths as short as 5mμsec have also been achieved.

High-Voltage Line Fault Locator introduced by Ferranti detects faults by means of the signal reflections these faults produce. The locator produces signals at a frequency of 1Mc/s in the form of 400V peak-to-peak 5μsec pulses spaced at 5msec intervals. These pulses are capacitively coupled to the 132 or 275kV high-voltage line. Any discontinuity in the electrical characteristics of the line due to a fault or the proximity of a tower then produces reflections of the pulses which are detected in the locator. The reflections produced by faults are larger and so may be distinguished from the reflection produced by towers. The delay between a pulse and its reflection determines the distance along the line to the discontinuity to an accuracy of 1% or 3000 ft, whichever is the greater, and faults can be detected at distances from 1 to 100 miles. This new locator should replace the old time-consuming method of visually searching the line for faults.

Tape Cleaning Attachment for use with the Grundig TK24 four-track recorder on fast forward or rewind is shown (with a threepenny bit to indicate its size) in the photograph. The attachment has three prongs which are fitted into three corresponding holes on the tape deck when it is desired to clean the tape. Dust and other foreign particles are removed from the tape as it bears on the felt pads which cover two of the attachment prongs. Such cleaning



reduces the number of "drop outs" and this can be particularly beneficial with four-track reproduction.

TRANSISTOR BATTERY TAPE RECORDER

MARKETED in this country by E.M.I. Sales and Service, the German Protona "Minifon Attaché" dictation tape recorder measures only 7in by 4in by 1⅝in and weighs only 2 lb 6 oz. With the tape magazine used with this recorder, an overall playing time of 2×15 minutes can be obtained. The response is within ±3dB from 200c/s to 3000c/s at the single tape speed used (1⅞in/sec). Fast rewinding is at 30 times this record/playback speed. A useful dictation facility is that the last few syllables can be repeated. This recorder is transistorized and runs from a 12V battery.

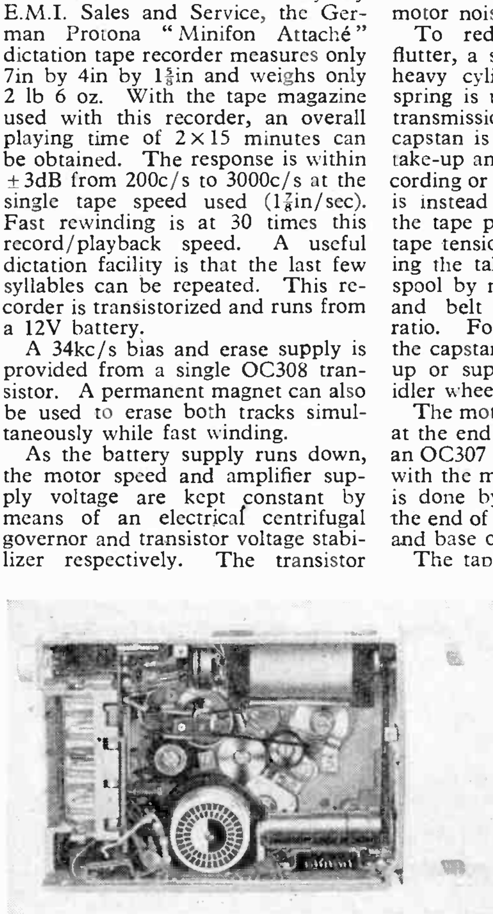
A 34kc/s bias and erase supply is provided from a single OC308 transistor. A permanent magnet can also be used to erase both tracks simultaneously while fast winding.

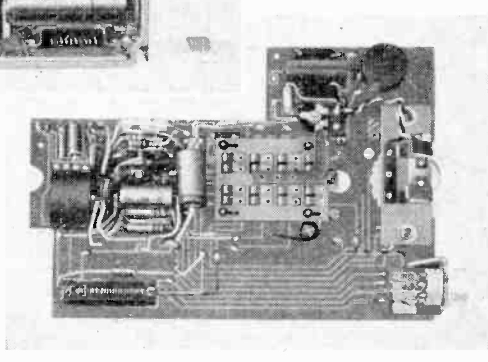
As the battery supply runs down, the motor speed and amplifier supply voltage are kept constant by means of an electrical centrifugal governor and transistor voltage stabilizer respectively. The transistor stabilizer also suppresses electrical motor noise.

To reduce possible sources of flutter, a structure consisting of two heavy cylinders joined by a spiral spring is used to connect the motor transmission belt to the capstan. The capstan is not connected to the tape take-up and supply spools during recording or replaying; the supply spool is instead driven by the motion of the tape past the capstan. Take-up tape tension is provided by connecting the take-up spool to the supply spool by means of a slipping clutch and belt of suitable transmission ratio. For fast forward or rewind the capstan is connected to the take-up or supply spool via one or two idler wheels respectively.

The motor is automatically stopped at the end of each reel by cutting off an OC307 transistor which is in series with the motor battery supply. This is done by using the metal foil on the end of the tape to join the emitter and base of the OC307.

The tape is housed in a magazine which automatically positions it correctly relative to the tape-deck drive mechanism. This magazine may be removed and replaced regardless of how much of the tape has been played.





The Protona "Minifon Attaché" dictation recorder is constructed on two chassis: that shown on the left contains the mechanics and that on the right the electronics.

LINEAR PASSIVE FOUR-TERMINAL NETWORKS

By G. de VISME*, B.Sc.

USE OF SUPERPOSITION AND RECIPROCITY TO DETERMINE ELECTRICAL CONSTANTS

ASSOCIATED with linearity, either in the field of mechanical, electrical, magnetic, or even electromagnetic systems, there are two quite fundamental and—but for special cases—unprovable axioms: Superposition and Reciprocity.

The first principle asserts that the effect of a number of independent causes acting together within a linear system is the sum of the effects produced by each cause acting on its own.

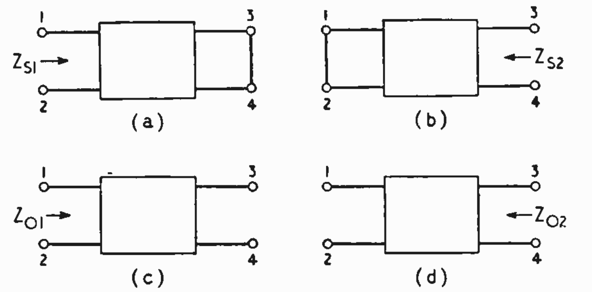


Fig. 1. Definition of short-circuit and open-circuit impedances of a four-terminal network.

The second principle states that if a cause at one point in a linear system produces an effect at another point, then the same cause acting at the second point produces the same effect at the first. In a sense, this principle expresses the fact that a linear system behaves in the same way in both directions.

The linear passive four-terminal network is a very important type of linear network. It can be represented as a box with four terminals, 1, 2, 3 and 4, between which some form of coupling exists. The box itself contains no separate sources of voltage or current, and the elements coupling the four terminals are all linear.

Using only the principles of superposition and reciprocity, and without specifying the contents of the box, we derive the coupling between any two pairs of terminals in terms of externally measurable properties of the four-terminal network, namely the open- and short-circuit impedances measured across these two pairs of terminals.

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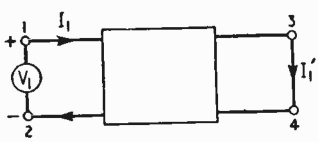


Fig. 2

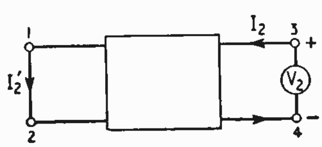


Fig. 3

Figs. 2 and 3. Four-terminal networks with one pair of terminals short-circuited and a generator connected to the other pair.

Define short-circuit and open-circuit impedances Z_{S1}, Z_{S2}, Z_{O1} and Z_{O2} as in Fig. 1(a), (b), (c) and (d).

1. Let us short-circuit terminals 3 & 4 and connec, to terminals 1 & 2 an a.c. generator of zero impedancet whose voltage is representable by the complex number V_1.

Sinusoidal currents, representable by complex numbers I_1 and I'_1, will flow in the left-hand and right-hand circuits respectively, as in Fig. 2.

The signs and arrows in this diagram, as in all subsequent diagrams, indicate the positive directions of voltages and currents.

We have therefore, by definition,

$$V_1/I_1 = Z_{S1} \quad \text{(i)}$$

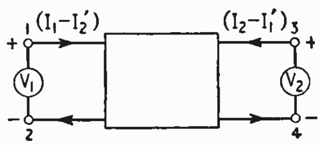
The ratio V_1/I'_1 also has the dimensions of impedance; let us call this ratio Z_{T1}.

2. Now let us short-circuit terminals 1 & 2 and connect to terminals 3 & 4 an a.c. generator of zero impedance, whose voltage is representable by the complex number V_2.

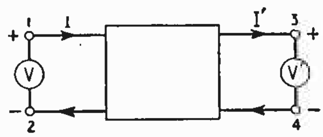
Sinusoidal currents, representable by complex numbers I_2 and I'_2, will flow in the right-hand and left-hand circuits respectively, as in Fig. 3.

As before, we have, by definition,

$$V_2/I_2 = Z_{S2} \quad \text{(ii)}$$



Left: Fig. 4. Superposition of Figs. 2 and 3.



Right: Fig. 5. Relabelled version of Fig. 4.

And we may define an impedance Z_{T2} equal to V_2/I'_2.

The principle of reciprocity then requires that $Z_{T1} = Z_{T2} = Z_T$, say. Thus we have

$$V_1/I'_1 = V_2/I'_2 = Z_T \quad \text{(iii)}$$

3. Suppose we now connect the generators V_1 and V_2 at the same time to terminals 1 & 2, and 3 & 4 respectively. Then the principle of superposition requires that the currents flowing in the left-hand and right-hand circuits be respectively $(I_1 - I'_2)$ and $(I_2 - I'_1)$, as in Fig. 4.

For convenience, let us relabel the voltages and currents, calling V_1 V, V_2 V', $(I_1 - I'_2)$ I, and $(I'_1 - I_2)$ I', as in Fig. 5.

Then,

$I = V/Z_{S1} - V'/Z_T$, from (i) and (iii) . . . . . . (iv)

$I' = V/Z_T - V'/Z_{S2}$, from (ii) and (iii) . . . . . . (v)

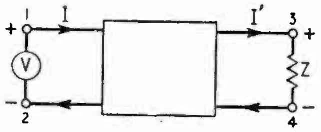
These equations are entirely general, irrespective of the values of V and V′. They relate the currents flowing in the input and output circuits with the voltages *actually present* across terminals 1 & 2 and 3 & 4.

Suppose we now adjust the voltage of the generator across terminals 3 & 4 so as exactly to prevent any current from flowing in the right-hand circuit. To do this we have to make $V' = (Z_{S2}/Z_T)V$, from (v).

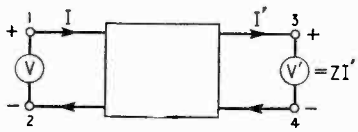
As a result, V/I becomes

$$\frac{V}{(V/Z_{S1}) - (Z_{S2}/Z_T)V/Z_T}, \text{ from (iv)}$$
$$= Z_{S1}Z_T^2/(Z_T^2 - Z_{S1}Z_{S2})$$

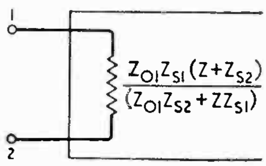
As far as the network is concerned, it is conscious only of an open circuit across terminals 3 & 4 and



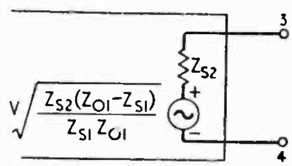
Left: Fig. 6. Four-terminal network terminated in an impedance Z.



Right: Fig. 7. Substitution of a suitable generator for the impedance Z in Fig. 6.



Left: Fig. 8. Equivalent input circuit of a four-terminal network terminated in an impedance Z.



Right: Fig. 9. Equivalent output circuit of a four-terminal network.

hence presents to the generator V the impedance Z_{01} by definition, so that,

$V/I = Z_{01} = Z_{S1}Z_T^2/(Z_T^2 - Z_{S1}Z_{S2})$,

Therefore,

$Z_T^2 = Z_{S2}/(1/Z_{S1} - 1/Z_{01})$ . . . . (vi)

Now, instead of adjusting V′ to make I′ zero, we will adjust the voltage of the generator connected to terminals 1 & 2 to make the current I zero. To do this we have to make $V = (Z_{S1}/Z_T)V'$, from (iv).

As a result, V′/I′ becomes

$$\frac{V}{(Z_{S1}/Z_T)V'/Z_T - (V'/Z_{S2})}, \text{ from (v)}$$
$$= Z_{S2}Z_T^2/(Z_{S1}Z_{S2} - Z_T^2)$$

By the same reasoning as before, the impedance presented to the generator V′ is Z_{02}, so that, noticing the direction of I′ in Fig. 5,

$-V'/I' = Z_{02} = Z_{S2}Z_T^2/(Z_T^2 - Z_{S1}Z_{S2})$

Therefore,

$Z_T^2 = Z_{S1}/(1/Z_{S2} - 1/Z_{02})$

Comparing this with (vi), we see that

$Z_{S1}/Z_{01} = Z_{S2}/Z_{02}$ . . . . (vii)

Although we defined *four* impedances Z_{S1}, Z_{S2}, Z_{01}, and Z_{02}, we see that they are not independent, but are related in a simple way as shown in equation (vii).

We are now in a position to calculate the behaviour of the four-terminal network when terminated in a general impedance Z, as in Fig. 6.

In this case the voltage V′ is produced by the current I′ flowing through Z, and is therefore related to I′ by the equation $V' = ZI'$. We can substitute this value of V′ into equations (iv) and (v) without further ado, but for the benefit of readers who have not fully grasped the idea of generator substitution I repeat that, *as far as the network is concerned,* the impedance Z may be replaced by a generator of zero impedance and voltage $V' = ZI'$, as shown in Fig. 7, without in any way affecting the currents I and I′.

(a) Input Impedance Z_{in}.

This is the ratio V/I which in this case equals

$$\frac{V}{(V/Z_{S1}) - (ZI'/Z_T)} \text{ from (iv)}$$

Z_T is given by (vi), and I′ is given by (v) as follows

$I' = V/Z_T - ZI'/Z_{S2}$

$= V/[Z_T(1 + Z/Z_{S2})]$ . . . . (viii)

Therefore,

$$Z_{in} = \frac{V}{(V/Z_{S1}) - ZV/[Z_T^2(1 + Z/Z_{S2})]}$$
$$= Z_{01}Z_{S1}(Z + Z_{S2})/(Z_{01}Z_{S2} + ZZ_{S1})$$

The input circuit is therefore as in Fig. 8.

Using equation (vii), we could express this impedance in terms of Z and *any three* of the four impedances Z_{01}, Z_{S1}, Z_{02} and Z_{S2}.

Notice in passing that $Z_{in} = Z_{S1}$ for $Z = 0$ and $Z_{in} = Z_{01}$ for Z = infinity, as we would expect.

(b) Output Circuit.

Substituting for Z_T from (vi) into equation (viii), I′ becomes

$$\frac{V}{(1 + Z/Z_{S2})\sqrt{Z_{S2}/(1/Z_{S1} - 1/Z_{01})}}$$
$$= V\sqrt{\frac{Z_{S2}(Z_{01} - Z_{S1})}{Z_{01}Z_{S1}}} \Big/ (Z + Z_{S2})$$

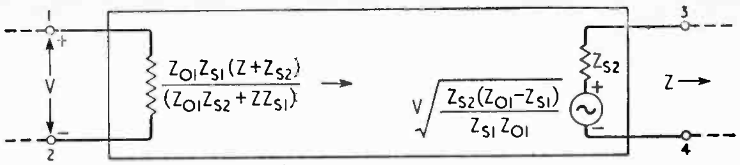
This suggests the output circuit shown in Fig. 9, which is of course none other than that indicated by the well-known "Helmholtz-Thevenin" theorem. Z_{S2}, as we saw, is the impedance measured across terminals 3 and 4 when the source of voltage V is short-circuited.

Once again, the output e.m.f. could have been expressed in terms of V and *any three* of the four characteristic impedances of the network.

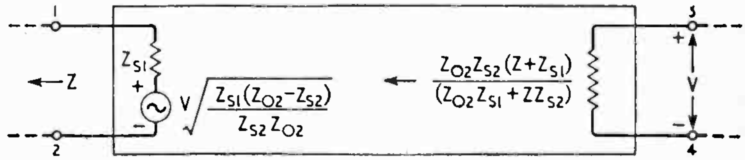
(c) Combined Equivalent Circuit.

Combining the results (a) and (b) into one circuit, we can express the whole of the left-to-right behaviour of the network as in Fig. 10.

The dotted lines suggest other circuitry. The circuitry connected to terminals 1 and 2 *results in*



Left: Fig. 10. Left-to-right equivalent circuit of a four-terminal network obtained by combining the input and output circuits of Figs. 8 and 9.



Right: Fig. 11. Right-to-left equivalent circuit of a four-terminal network obtained by interchanging suffixes 1 and 2 in the left-to-right circuit of Fig. 10.

a voltage V across these terminals—it is not, of course, necessary to suppose an actual generator of zero impedance and voltage V connected directly to these terminals.

To derive the right-to-left behaviour, we do not need to go through all these calculations again. We only need change all suffixes 2 into 1 and all suffixes 1 into 2. Fig. 11 shows the result.

Application to the T-network.

Fig. 12 shows the circuit of the general T-network. Its open- and short-circuit impedances are:

$$Z_{01} = Z_1 + Z_3,\ Z_{02} = Z_2 + Z_3$$
$$Z_{s1} = Z_1 + Z_2Z_3/(Z_2 + Z_3),\ Z_{s2} = Z_2 + Z_1Z_3/(Z_1 + Z_3)$$

If a voltage V is applied to terminals 1 and 2, and an impedance Z is connected to terminals 3 and 4, the voltage appearing across Z is

$$VZZ_3/(ZZ_1 + ZZ_3 + Z_1Z_2 + Z_1Z_3 + Z_2Z_3)$$

And the input impedance across terminals 1 and 2 comes to

$$(ZZ_1 + ZZ_3 + Z_1Z_2 + Z_1Z_3 + Z_2Z_3) \div (Z + Z_2 + Z_3)$$

The reader may check for himself that the equivalent circuit of Fig. 10 gives exactly the same results.

If we solve for Z_1, Z_2 and Z_3, we get

$$Z_1 = \sqrt{Z_{01}}(\sqrt{Z_{01}} - \sqrt{Z_{02} - Z_{s2}})$$
$$Z_2 = \sqrt{Z_{02}}(\sqrt{Z_{02}} - \sqrt{Z_{01} - Z_{s1}})$$
$$Z_3 = \sqrt{Z_{01}(Z_{02} - Z_{s2})} = \sqrt{Z_{02}(Z_{01} - Z_{s1})}$$

It follows therefore that a given network having open- and short-circuit impedances Z_{01}, Z_{02}, Z_{s1} and Z_{s2} will behave, as far as coupling between input and output is concerned, exactly like a T-network

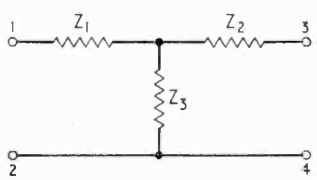


Fig. 12. General T-network.

whose series arms have impedances $\sqrt{Z_{01}}(\sqrt{Z_{01}} - \sqrt{Z_{02} - Z_{s2}})$ and $\sqrt{Z_{02}}(\sqrt{Z_{02}} - \sqrt{Z_{01} - Z_{s1}})$, and whose shunt arm has impedance $\sqrt{Z_{01}(Z_{02} - Z_{s2})}$.

The above treatment is quite general for sinusoidal voltages and currents. In so far as Z and the four characteristic impedances Z_{01}, Z_{02}, Z_{s1} and Z_{s2} can be expressed as Laplace coefficients Z(p), $Z_{01}(p)$, $Z_{02}(p)$, $Z_{s1}(p)$ and $Z_{s2}(p)$, the results obtained express the transient behaviour of the network just as well as its steady-state behaviour.

Another point to be emphasized is that the treatment supposes nothing about the four-terminal network beyond its linearity, and the results therefore hold for any form of coupling from input to output, e.g., the coupling existing between two aerials.

Imperial College

SELECTED in 1953 as the spearhead of the national attack on the problem of providing more university-trained scientists and engineers, the Imperial College of Science and Technology, London, is in the process of doubling its size to provide for 3,000 students. The college, which has been a school of the University of London since 1908, is itself a federation of three institutions—Royal College of Science, Royal School of Mines and City & Guilds College. Since 1953 the number of students has increased by 1,000 and there are now some 2,600. There have also been established over 40 new posts as professor or reader. Sir Patrick Linstead, C.B.E., F.R.S., is Rector.

The work of Imperial College is divided between the three constituent colleges; the R.C.S. covering pure sciences (chemistry, physics, mathematics, botany, zoology, geology and meteorology), the R.S.M. mining, mineral dressing, metallurgy, mining geology, oil technology and applied geophysics, and the C. & G. the main branches of engineering (aeronautical, chemical, civil, electrical and mechanical).

The normal undergraduate honours degree course is of three years leading to the B.Sc. or B.Sc.(Eng.) of London University and the Associateship of the particular college (A.R.C.S., A.R.S.M. or A.C.G.I.). Advanced study or research leads to the Diploma of Membership of Imperial College (D.I.C.) and/or a higher degree.

The Dean of the Royal College of Science is Professor H. Jones, F.R.S. The head of the physics department is Professor P. M. S. Blackett, F.R.S., with Dr. M. Blackman and Dr. C. C. Butler professors of physics, Dr. J. D. McGee, O.B.E., professor of instrument technology, Dr. A. Salam, F.R.S., professor of theoretical physics and Dr. W. D. Wright professor of technical optics. Dr. R. W. B. Stephens is reader in acoustics and Drs. J. A. Clegg, H. Elliot, O. Klemperer and C. E. Wynn-Williams readers in physics.

The Dean of the City & Guilds College is Professor O. A. Saunders, F.R.S. The teaching staff of over 40 includes Dr. E. C. Cherry (professor of telecommunications), Dr. D. Gabor (professor of applied electron optics), A. Tustin (professor of electrical engineering), Dr. A. R. Boothroyd (reader in electronics) and Drs. B. Adkins, J. Lamb and D. G. O. Morris (readers in electrical engineering).

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Beam Indexing Tubes

2.—CIRCUIT DETAILS OF THE COLOUR TELEVISION DISPLAY UNIT

By IAN MACWHIRTER,* A.M.I.E.E.

(Concluded from page 7 of the January 1961 issue)

HAVING considered the matching of a beam index tube to an N.T.S.C. type colour signal, the next step is to examine the problem of beam position indexing and the synchronizing of the chrominance signal with the phosphor strips. A simple method of determining the position of the beam on the screen, would be to have a photomultiplier cell, optically filtered to receive light from one primary colour, say blue, and to use the repetitive series of blue light pulses to generate rectangular gating pulses for switching on the appropriate colour video signal.[11] However, this arrangement suffers from the disadvantage of requiring extremely fast rise-time amplifiers and expensive artificial delay lines. In practice the method is best suited to laboratory development work where the possible errors of signal translators and the loss of saturation occasioned by comparatively wide angle sampling of the chrominance signal by the display screen may be completely obviated. Moreover, small departures from linearity in the line time base will not cause objectionable colour errors, provided that such departures are small, compared with one colour triplet of width, say, 60×10^{-3} in.

A complete circuit diagram for a gated display is shown in Fig. 9(a) and (b).

The indexing pulses generated in the photo pick-up are amplified in a wideband amplifier and limiter. No afterglow correction is provided since the indexing strips are made of P16 phosphor whose afterglow is down some 20 dB in 100 mμsec, whereas the pitch of the indexing pulses is approximately 240 mμsec. The pulses are fed from the wideband amplifier to an earthed grid stage (V1) which raises the pulse level to about 5 V. This is sufficient to be differentiated and to trigger the transistor (T1) in the avalanche mode.[12] The triangular output of some 20 V p-p and rise time of 4 mμsec is applied to the grid of V2 in whose anode circuit is a short-circuited delay line. The line can be a lumped-constant one, but the cut-off frequency should be not less than 50 Mc/s and preferably higher. The line has a delay of 20 mμsec which provides a rectangular pulse at the anode of V2 of width 40 mμsec (this width was chosen as being suitable for one application of the circuit). This pulse is injected via a polarity inverter (V3); (a) into the lower valve (V7) of a series pair which constitute part of the gate; (b) into a further delay line which is centre-tapped and whose delay is equivalent to twice the phosphor pitch. Again, the cut-off frequency of the delay line should be at least 50 Mc/s.

In one application the pulse at the input to this line feeds the " red " gate, the centre tap feeds the " green " gate and the end of the line feeds the " blue " gate; the delay between adjacent colours is 80 mμsec, so that the total line delay is 160 mμsec.

Referring now to the gate proper, it consists of V5, V6 and V7 which are therefore triplicated. Video signals of the appropriate colour are fed into the grid of V5, from a preceding stage (V4) where the direct component is re-inserted.

The video signal appears at the anode of V7 and is periodically " lifted up " by the gating pulse so that the black portion (if any) of the " lifted " video signal is greater in amplitude than peak white level of the " unlifted " video signal. The remaining valve of the gate (V8) is biased well beyond cut-off so that only the " lifted up " video signal appears at the anode. This point is connected directly to the anodes of the other two gates (V9 green), (V10 blue). The peak signal here of some 20-25 volts is polarity inverted by (V11). The rectifier restorer in the grid circuit works sufficiently well to prevent V11 from passing grid current when the signal amplitude is large. The signal from V11 is then fed to the output stage V12 in whose grid is a d.c. clamp of conventional design.

It is possible to obtain a signal of just 100 V p-p at the anode of V12. The video pulse rise time at this point is 10 mμsec, the pulse base width is 40 mμsec, and the repetition rate is about 4.25 Mc/s in one particular application. The overall linearity is good, and the differential non-linearity between channels is negligible. (See Appendix 3).

Ultra-violet Indexing Strips

A better method for beam position indexing in a domestic receiver still employs light pulse pick-up, preferably from a low visibility ultra violet phosphor which may be conveniently mixed with the visible blue primary phosphor. From this pulse is derived a sinusoidal signal which is used to heterodyne the incoming equi-angle chrominance signal up to the colour switching frequency of the screen, which can then sample directly the chrominance information, as outlined earlier in this article.

If the manufacturing technology of the screen structure allowed indexing pulses to be generated whose rise times are very short i.e. less than 5 mμsec, and a wideband amplifier followed the photo pick-up, it should be possible to limit the amplitude of the indexing signals at the level corresponding to the 1% minimum beam current. From these limited rectangular pulses there may be derived the sinusoidal indexing signal. Provided that the maximum negative excursion of the approximately sinusoidal chrominance signal does not allow the beam current to drop below 1% of its maximum value (i.e. pulse

* Associated Electrical Industries Ltd.

limiting level), no crosstalk will be caused by any change in phase of the chrominance signal.

In practice, it has been found difficult to make a screen structure of indexing phosphor strips of sufficient sharpness to allow this simple method to be used completely free from phase crosstalk. For example, for one experimental display tube, an indexing pulse rise time of 40 mμsec was measured. Whilst the use of *rectangular* chrominance pulses, as employed in the gated display, does not provide objectionable crosstalk, it has been found that the use of an approximately sinusoidal chrominance signal aggravates crosstalk. This happens even if the maximum negative excursion of the signal is kept above the indicating pulse limiting level.

There is an additional source of crosstalk when approximately sinusoidal chrominance information is applied directly to the screen structure, irrespective of indicating strip shape i.e. whether ideally rectangular or trapezoidal as found in practice. Consideration of Fig. 10 will explain this point.

It is seen that the ultra-violet indexing strip is placed behind the blue phosphor strip. The chrominance signal *c*, sitting on top of some luminance pedestal, will be approximately sinusoidal in shape. Let the colour shown be a saturated blue, then the indicating pulses will be generated as shown at *p*; from these pulses an indicating sinusoid *s* may be formed. Now let the phase of the chrominance sub-carrier be shifted in order to reproduce a

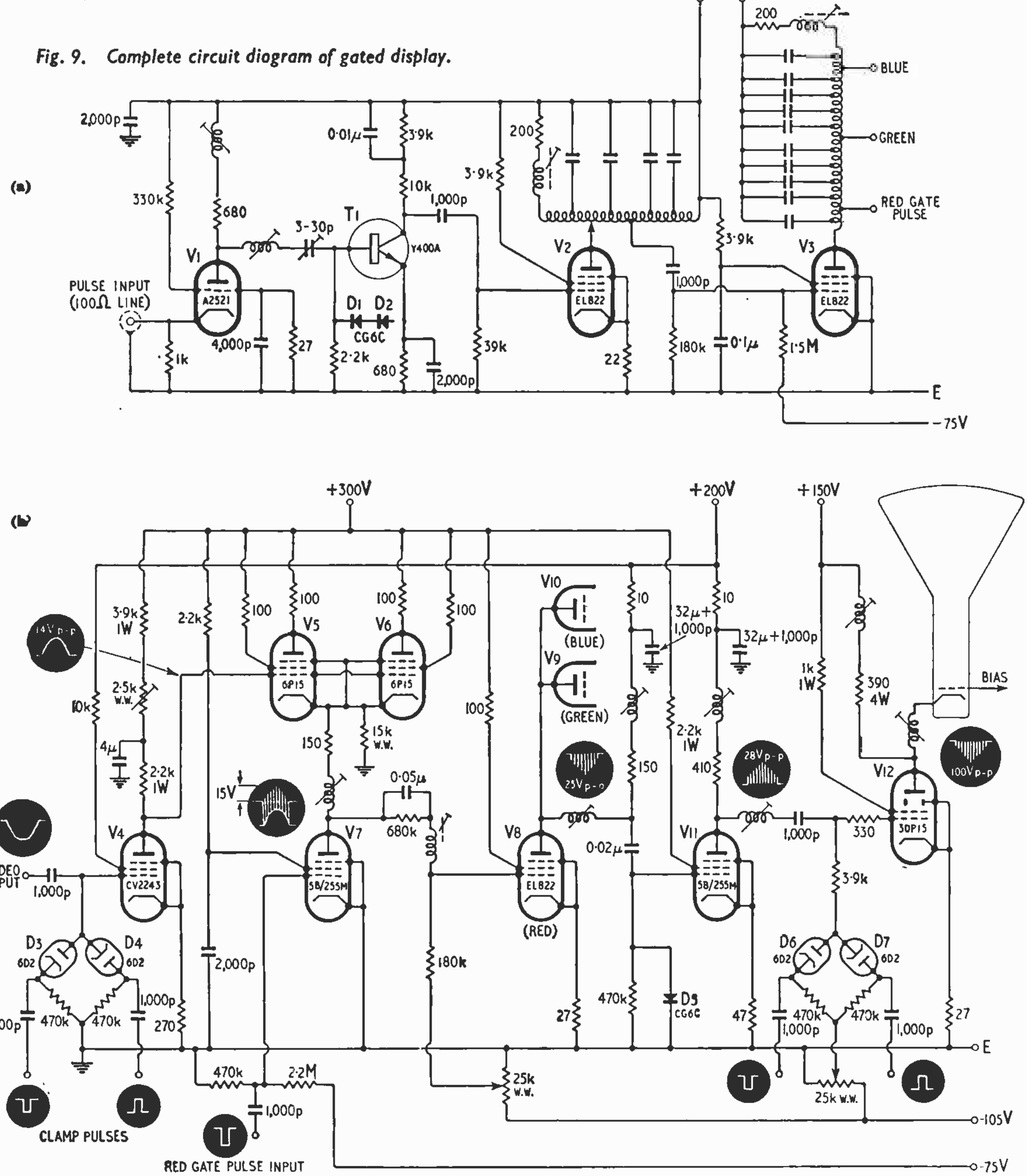

Fig. 9. Complete circuit diagram of gated display.

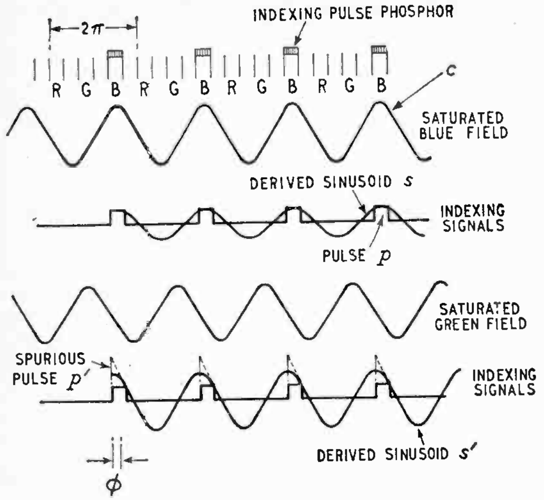

Fig. 10. Illustrating the development of crosstalk when using sinusoidal chrominance information. For diagrammatic clarity a point spot size has been assumed.

saturated green field. Assuming the green drive voltage to be the same as for the blue, we can see that part of the green sinusoid will generate a spurious indicating pulse p' as well as the regular indicating pulse p which is generated by a pre-set minimum beam current. Thus the sinusoidal indicating signal s' formed by both p and p' will be displaced in time as shown by ϕ (See Appendix 1).

Further colour errors may be introduced by unwanted changes in indexing frequency. If the transverse scanning of the phosphor strips should be non-linear, or if the pitch of these strips should vary as a result of manufacturing inaccuracies, then the frequency of the sinusoidal indicating signal will vary. It is essential that the phase of this signal be preserved if colour errors are to be avoided. In general, the phase response of a normal amplifier over a limited pass band is such that the phase angle ϕ varies more or less linearly with frequency, i.e., the envelope delay D is constant since $D = d\phi/d\omega = K$. In amplifying the sinusoidal signal the requirement is that $D = d\phi/d\omega = 0$ and this is satisfied by combining the indicating sinusoid amplifier with a suitable phase corrector (see Fig. 16)

Slow variations in line time-base linearity (e.g., a normal " exponential " sweep) and scan amplitude will be accommodated by this method, colour synchronization remaining good. It is possible, however, that apparent changes in linearity of a transient nature will result in areas of local colour errors. Such transients may be caused by flaws in the evenness of the display tube face plate.

In order that the colour synchronizing circuits shall not become inoperative in areas of picture black it is necessary to run the display tube with a minimum beam current of about 1% of the peak white value.

The chrominance signals illustrated in Fig. 10 have, in fact, been squared by the transfer characteristic of the display tube gun, but similar spurious signals are generated.

For the reasons given, it appears prudent to adopt a screen layout which might minimize the crosstalk and of many possible solutions to the problem of layout, two are here described.

Case I.—(Using regular R, G, B, sequence phosphor strips).

Fig. 11 shows a phosphor strip structure in which there is an indexing strip in every gap between the R, G, B, strips. When scanned, the frequency of the indexing signal will be three times the colour repetition frequency and it can be shown that although the indicating signal may be modulated in amplitude by the luminance and chrominance signals it is not phase modulated (see Appendix 2). This indexing signal, after amplitude limitation and after a frequency division by three, may be used directly to control the colour circuitry of the receiver, provided that the frequency divider starts off in the correct phase at

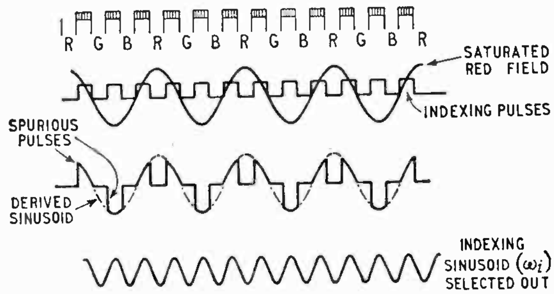

Fig. 11. Use of intermediate ultra-violet indexing strips.

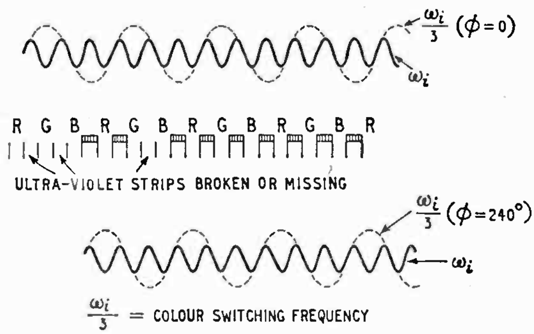

Fig. 12. Effect of broken or missing indexing strips.

the beginning of each line. Referring to Fig. 12 it can be seen that if the first ultra-violet strips at the beginning of the line sweep are unbroken, i.e., missing, this would be true; however, a broken ultra-violet strip would cause a phase error in the frequency division. In order to avoid this triple phase ambiguity of 0°, 120°, 240°, it is necessary to have at the beginning of each line a further set of strips which, on scanning, generate a frequency whose possible phases with reference to the indexing frequency uniquely determine the phase of frequency division. A suitable frequency for the second set of scanned strips would be at triplet repetition frequency, only two possible phases for frequency division would then be possible 0°, and 360°. It should be clear that these " run-in " strips should only exist at the beginning of the line sweep when no chrominance signals are applied to the tube, in this way there will be no cross modulation between the " run-in " signal and the video signal.

Fig. 13(a) shows a suitable layout for a practical

(Continued on page 95)

screen structure, and Fig. 13(b) shows a way in which a control signal may be derived. However, it should be pointed out that it may not be desirable to generate both signals by the same means, i.e., photoelectrically, and it is possible to pick off the "run-in" signals from secondary-electron emitting strips and a suitable collector within the display tube bulb.

The photocell P_1 will generate two signals, one at a frequency f_r i.e. "run-in" frequency, and one at $3f_r$. Component f_r will be present only at the beginning of scan where there is no video modulation. The filter F separates the two components and will have band-pass characteristics to allow for variations in scanning speed, etc. Component $3f_r$ is presented to a normally "closed" gate, this gate will be "opened" by a signal f_r. When the gate opens, the frequency divider provides an output of $\frac{3f}{3} = f_r =$ colour switching frequency f_c. The component $f_r = f_c$ is then applied (a) back to the gate via a suitable equalizing delay, so that the divider will continue to work when the run-in signal has stopped, (b) to the chrominance control circuits of the receiver.

Since the component $3f_r$ is not cross-modulated by the video signal the phase of the output control signal f_c will also be unaltered.

Case II.—(Using an alternating sequence strip structure.[13])

Fig. 14 shows a different screen structure which will directly generate an indexing signal of correct frequency and free from cross-modulation effects.

It will be seen that red phosphor borders each side of the combined blue and ultra-violet indexing strip. Let the colour shown be a saturated blue, then the indexing pulses will be generated as shown at p; from these pulses an indexing sinusoid may be formed.

Now let the phase of the sub-carrier be shifted to reproduce a saturated green field. Assuming the green drive voltage to be the same as for the blue, we

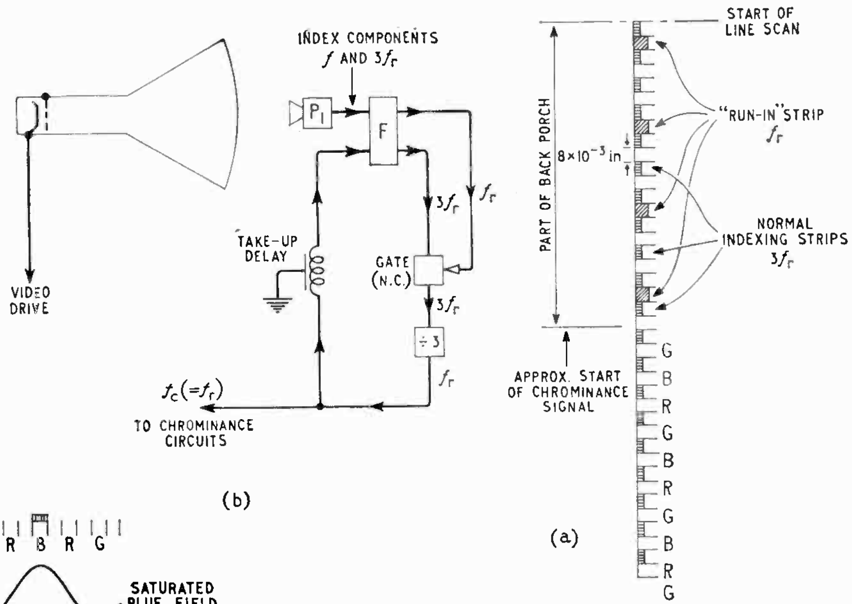

Fig. 13(a). Section of practical screen structure and (b) derivation of control signal.

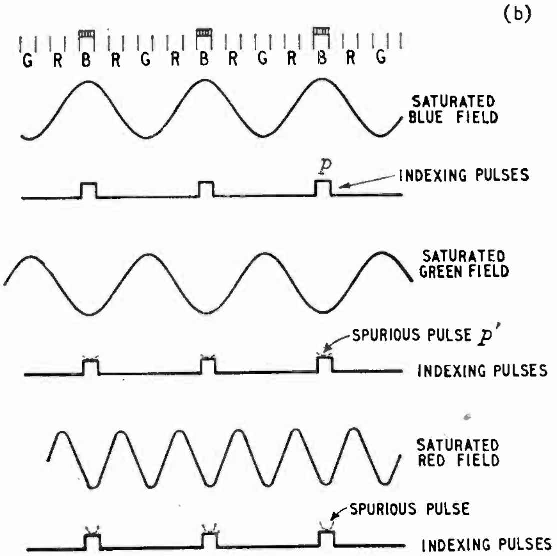

Fig. 14. Alternative screen structure with red-bordered combined blue and ultra-violet strips.

can see that the contribution of the green signal to a spurious indexing signal p' is not only small but symmetrical about the true indexing pulse. When the phase of the sub-carrier is shifted again to show a saturated red field, the spurious indexing pulse is larger in amplitude than before, but is again symmetrically placed about the true indexing pulse. These small, symmetrically placed, spurious signals will not phase-modulate the indexing signal.

A block diagram for a receiver using this screen structure is shown in Fig. 15. Because there are two red phosphor strips per unit group of white forming strips, it is necessary to gate the red signal at twice the indexing signal frequency.

A screen with this structure has the additional advantage of producing more red light than from a simple colour triplet. Therefore, less inert material need be mixed with the green and blue phosphors and the maximum brightness for a given beam current, will increase. However, it would not be easy to use

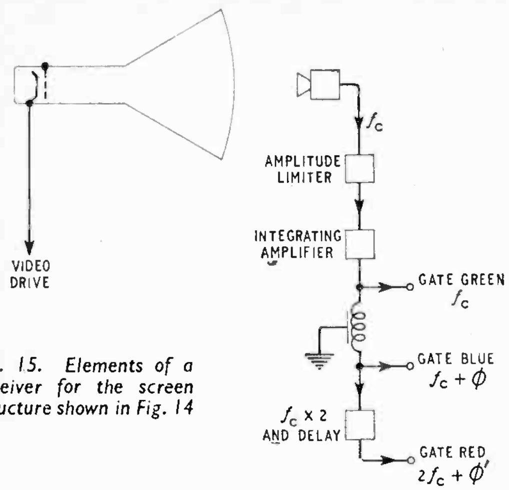

Fig. 15. Elements of a receiver for the screen structure shown in Fig. 14

a tube with this screen structure in a non-gating receiver and it is doubtful whether the extra complexities in the video circuitry would cost less than the extra circuitry used for handling the "run-in" signals.

A complete colour receiver using a beam position indexing cathode ray tube and the N.T.S.C. proportioned signals is shown in block form in Fig. 16.

It has been shown that the formulation of the N.T.S.C. signal is not suited for direct application to the beam indexing tube. The question now arises whether it would be advantageous to modify the transmitted signal to the form suggested earlier in this report. Before making any recommendations on this it must be borne in mind that the formulation of a compatible band-shared colour television signal should never be designed for the requirements of any particular type of display tube to the exclusion of all others. With the exception of contrast-law correction problems the N.T.S.C. formulated signal uniquely satisfies these general requirements:

(i) *Compatibility.* Compatibility on black and white display tubes is potentially good since the luminance composition of the colour signal is similar to the photoptic visibility curve of the eye, i.e., the luminance of colours shown by a black and white display would be the same as if seen direct by the eye and the subjective effect of this is to observe pleasing tones of grey in the picture.

A change to an equi-weighted luminance signal will adversely affect this compatibility. Moreover, the colour receiver would no longer obey the constant luminance principle unless some deficiencies in colour reproduction are tolerable.

(ii) *Constant Luminance Principle.* The composition of the luminance signal is inevitably involved with the relative contributions of the reproducing phosphors to white, if constant luminance operation is considered necessary with a simultaneous display.

The effectiveness of these two concepts is restricted by the present form of contrast-law correction and it is outside the scope of this article to comment further on this. However, it should be recognized that as permanent colour television standards are still unformed in the United Kingdom the possibility of re-scaling the luminance signal to match any new developments in phosphors ought not to be excluded. It is possible to modify the angular positions of the N.T.S.C. chrominance vectors to make them more suitable for use with a beam indexing display, but one attraction with the present formulation is that the two colour differ-

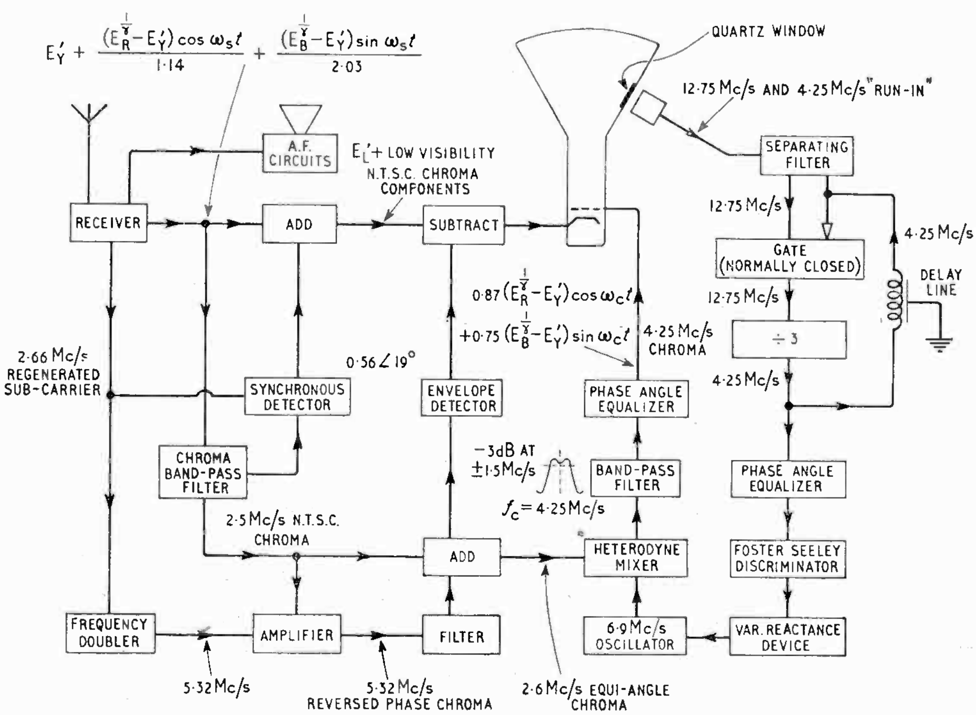

Fig. 16. Block diagram of complete beam index tube colour receiver working from an N.T.S.C. colour signal.

ence components are in exact quadrature. This fact alone provides such operational advantages that the benefit from the change would have to be proved significant.

Conclusions

The "beam indicating" or "beam index" display tube of the kind described can provide superior pictures, both in colour and black and white, to the shadow mask cathode ray tube. Whilst the former tube is relatively cheap to make, it must appear disappointing that, at the present state of the art, the costing estimate of a receiver with such a tube and all the refinements necessary to produce correct colour reproduction, is not significantly less than the ordinary three-gun shadow mask receiver. Whilst certain economies may be effected in the exactness in operation of the signal translating apparatus already described, it appears necessary to employ line time bases with non-linearities of the order of 1% if objectionable colour errors are to be avoided.

It can be said that if this figure for line time base non-linearity is considered impracticable for cheap, mass produced receivers, and the subsequential colour errors are accepted, the remaining advantage in using the beam indexing display is the superiority in the reproduction of black and white pictures. Therefore, until simple circuitry can be devised which permits the use of line time base non-linearities of some 7% and yet secures satisfactory colour reproduction, the single-gun beam indexing display cannot be considered as a potential successor to the well-established, three-gun shadow mask display.

Acknowledgements

The above review of some of the problems of beam indexing tubes formed part of a programme on colour television displays carried out at the Applications Laboratories of the Radio & Electronic Components Division of Associated Electrical Industries Ltd. and the author wishes to thank the company for permission to publish these results. In particular, the author thanks the Divisional Engineering Manager, Mr. C. L. Hirshman for helpful criticisms of the review's contents and Mr. D. W. Furby for his design of the pulse generator using an avalanche transistor.

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APPENDIX I

The generation of the spurious indexing signal is not only dependent on cross-modulation caused by the non-linearity of the display tube gun but on the simple scanning of the indexing phosphor structure. An attempt to illustrate this graphically has already been made in the text relevant to Fig. 10; a simple equation is derived below which identifies the relative magnitudes of the cross-modulation parameters.

If the display tube has a linear transfer characteristic (i.e. contrast = unity) then the light output L from the whole screen can be expressed by

$$L = k\left[E_y' + E'_c \cos(\omega_c t + \phi)\right]$$

where E_y' is the luminance signal.

E_c' is a measure of saturation

ϕ is a measure of hue

The generated indexing signal S is of the form $L(a_0 + a_1 \cos \omega t + a_2 \cos 2\,\omega t + \ldots\ldots. a_n \cos n\,\omega t)$

Thus $S = Lk\left[E_y' + E'_c \cos(\omega_c t + \phi)\right]\left[a_0 + a_1 \cos \omega_c t + \text{etc.}\right]$

$= Lk\left[E_y'\ a_0 + a_0\ E_c' \cos(\omega_c t + \phi) + a_1\ E_y' \cos \omega_c t + a_1\ E_c' \cos \omega_c t \cos(\omega_c t + \phi) + a_2\ E_c' \cos \omega_c t\ \cos(2\,\omega_c t + \phi) + \ldots.. a_n\ E_c' \cos \omega_c t \cos(n\,\omega_c t + \phi)\right]$

Extracting components at the fundamental frequency (ω_c) S becomes $Lk\left[a_0\ E_c' \cos(\omega_c t + \phi) + \frac{a_2 E_c'}{2} \cos(\omega_c t + \phi) + a_1\ E_c' \cos \omega_c t\right]$

which shows that the amplitude and phase of S will be affected by the phase ϕ of the chrominance signal.

APPENDIX II

It has been stated in the text that with the use of an indexing strip between each colour phosphor an indexing sinusoid may be generated which is not affected by the phase of the chrominance signal. The key point in understanding this is that the generated indexing pulses are of equal mark/space ratio and therefore the even harmonic components are zero.

As in Appendix 1,

$L = k\left[Ey' + E_c' \cos(\omega_c t + \phi)\right]$

The generated indexing signal S is of the form $L\left[a_0 + a_1 \cos 3\,\omega t + a3 \cos 5\,\omega t + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots a_n \cos(n + 2)\,\omega t\right]$

where n is not an even integer.

Thus $S = Lk\left[Ey' + E_c' \cos(\omega_c t + \phi)\right]\left[a_0 + a_1 \cos 3\,\omega_c t + a_3 \cos 5\,\omega_c t + \text{etc.}\ldots\ldots\right]$

$= Lk\left[a_0\ Ey' + a_0\ E_c' \cos(\omega_c t + \phi) + a_1\ Ey' \cos 3\,\omega_c t + a_1\ E_c' \cos 3\,\omega_c t \cos(\omega_c t + \phi) + a_3\ Ey' \cos 5\,\omega_c t + a_3\ E_c' \cos 5\,\omega_c t \cos(\omega_c t + \phi) + \text{etc.}\right]$

extracting the components at a frequency ($3\,\omega_c$), S becomes $Lk\,(a_1\ Ey' \cos 3\,\omega_c t)$ which shows that the generated indexing sinusoid will be unaffected by the phase (ϕ) of the chrominance signal.

It should be pointed out, though, that any manufacturing inaccuracies of the strip structure, or any sudden change in scanning linearity can cause even-harmonic components to appear; this will be accompanied by a colour error in the reproduced picture.

APPENDIX III

The actual figures for the linearity of the complete gate circuit are not stated because the overall linearity (i.e. picture contrast or "gamma") including the display tube, depends on:—

(a) The shape of the gating pulses entering the gate. Fig. A illustrates the formation of a simple gated step wedge by the gate circuit as shown in Fig. 9

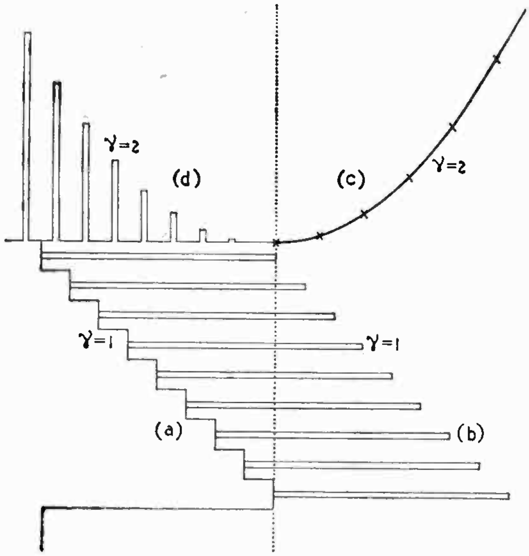


Fig. A

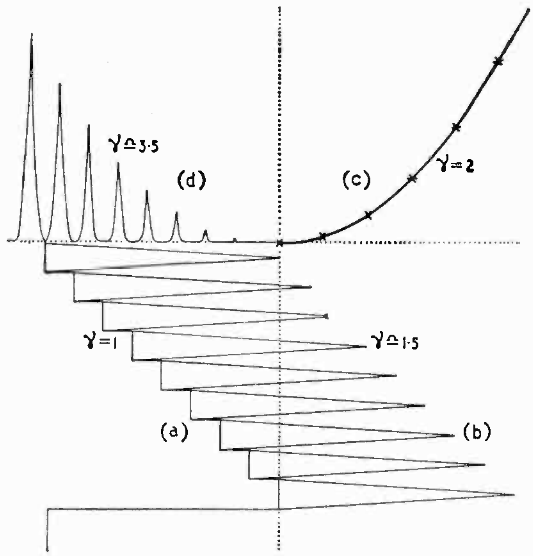


Fig. B

when ideal rectangular gating pulses are available. It will be seen from (b) in Fig. A that the overall contrast of the reproduced picture is that of the display tube (for which adequate correction is usually made in the formulation of the video signals at the transmitter).

Fig. B illustrates the reproduction of the same step wedge when only bandwidth-limited gating pulses are available. In practice trapezoidal pulses are used, although triangular pulses are shown in the figure. Now the phosphor excitation is proportional to the area under the pulses as shown in (d), it can be seen that there will be a considerable reduction in low level excitation. (Notice the reduction in base width.) For the triangular pulses a calculation showed that the picture contrast may be increased by 1·5. This clearly establishes the need for maintaining a good pulse shape, at least until the gate proper. Such residual contrast in excess of unity can be corrected by means of judiciously introduced non-linearity in the main amplifier.

(b) Subsequent integration of the pulses in amplifier following the gate. In practice, the effect of integration has not been proved detrimental to picture quality, because the bandwidth of the main amplifier is quite adequate to handle the trapezoidal gate pulses.

(c) Spot modulation defocusing. No measurements on this possible source of contrast change are available.

BOOKS RECEIVED

Phototubes, Edited by Alexander Schure. A mainly non-mathematical survey of the field of photoelectricity. The history of the photoelectric effect is discussed and the theory behind the operation of modern devices is explained. A chapter is included on the design of phototube-operated amplifiers designed to perform a variety of functions. Pp. 88; Figs. 40. John F. Rider Publisher, Inc., 116, West 14th Street, New York 11, N.Y.

Electronics and Nucleonics Dictionary, by Nelson M. Cooke and John Markus. This second edition contains over 12,000 definitions of terms. Attention has been paid to modern practice in hyphenation and usage. The range has been extended to cover the related field of nuclear energy technology and new developments in electronics. Where American usage is at variance with British, this is noted. Pp. 543; illustrated. McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, London, E.C.4. Price 93s.

Fundamentals of Semiconductors, by M. G. Scroggie. The level of treatment is at an intermediate stage between the simplified layman's guide and the advanced textbook. The whole field is covered, from basic electron theory to short descriptions of electroluminescence, Hall effect, and masers. Pp. 160; Figs. 129. Gernsback Library, Inc., 154, West 14th Street, New York 11, N.Y. Price $2.95.

A Simple Approach to Electronic Computers, by E. H. W. Hersee. Concerned with principles rather than practice, the book explains to the layman the operation of simple digital and analogue computers. Non-mathematical in treatment, it deals with most of the basic computing-circuit elements and methods in general terms. Pp. 104; Figs. 27. Blackie and Son, Ltd., 16-18, William IV Street, Charing Cross, London, W.C.2. Price 12s 6d.

How to Install and Service Auto Radios, by Jack Darr.. A practical book on car radios. Well known to readers of *Wireless World* for his humorous articles on radio servicing, Mr. Darr writes in a readable style, giving helpful advice to servicemen in all phases of their dealings with car radio installations, including transistorized and hybrid types. Pp. 154; Figs. 101. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 26s.

Radar and Collision—A Handbook for Mariners, by L. Oudet. A discussion of the principles and practice of the avoidance of collision between radar-equipped ships. Seeks to impress the concept of intelligent use of radar facilities, rather than reliance on its capabilities as a "magic box." Examples of actual collisions are used to illustrate the arguments. Pp. 89; Figs. 36. Hallis and Carter, 25, Ashley Place, London, S.W.1. Price 15s.

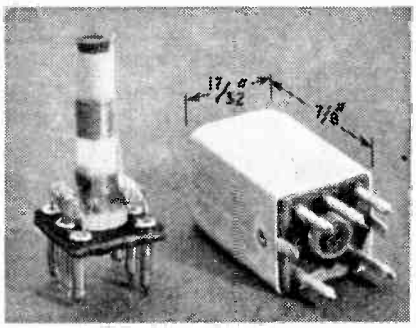
MANUFACTURERS' PRODUCTS

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Transistor I.F. Transformers

SHOWN in the illustration is a new miniature 10.7-Mc/s i.f. transformer introduced by Denco for use in transistor v.h.f./f.m. receivers. The transformer (IFT15) consists of two coupled circuits with tapped primary and secondary windings each tuned by polystyrene-foil fixed capacitors. Adjustment is by means of the customary dust-iron core. The unloaded "Q" of each winding is said to be approximately 70 at 10.7Mc/s and the working bandwidth 250kc/s (−6dB points).

There is a companion ratio-detector transformer



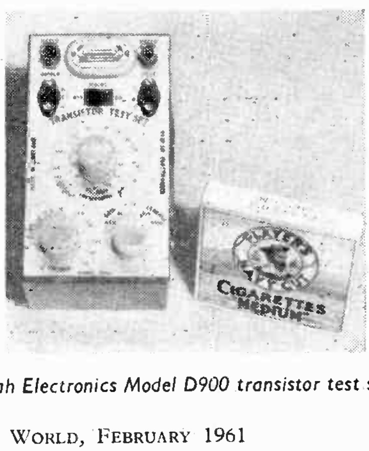
Denco 10.7-Mc/s i.f. transformer for transistor v.h.f./f.m. receivers.

(RDT2) having a bifilar secondary winding and an effective bandwith of 220kc/s.

I.F. and discriminator transformers are provisionally priced at 10s 6d each and the makers are Denco (Clacton), Ltd., 357-359, Old Road, Clacton-on-Sea, Essex.

Transistor Test Set

IN the compact mains-operated Beulah Electronics Model D900, variable input currents (up to 1mA) and collector voltages (up to 25V) are provided for measuring transistor direct-current gains and leakage currents

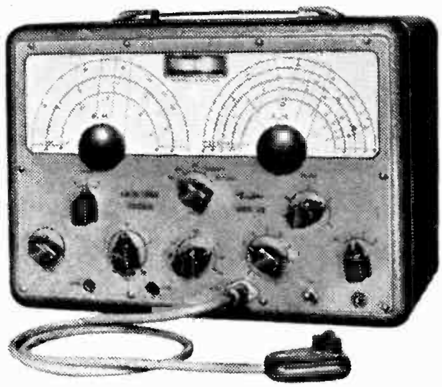


Beulah Electronics Model D900 transistor test set.

with the aid of an external meter. This instrument can also measure the a.c. gain of a transistor *in situ*. To do this the transistor is connected in an oscillatory circuit in the test set and the feedback decreased until oscillations as indicated by a flashing neon just cease. The degree of feedback then gives a measure of the current gain. The oscillations have a high harmonic content which also allows them to be used as an a.f. and r.f. signal tracer source. The model D900 costs £10 and is available from Beulah Electronics of 138 Lewisham Way, New Cross, London, S.E.14.

A.M./F.M. Signal Generator

THE Taylor Model 61A contains both an a.m. and a f.m. (or sweep) generator. C.w., a.m., f.m. or swept signals or, alternatively, a combination of a swept and a c.w. or a.m. signals can be obtained. The a.m. (or c.w.) generator covers from 4 to 120Mc/s on fundamentals: the f.m. (or sweep) generator covers from 4 to 12Mc/s as well as from 70 to 120Mc/s (also on fundamentals). The f.m. deviation is at 400c/s and can be continuously varied up to ±100kc/s; the sweep deviation is at 50c/s and can be continuously varied

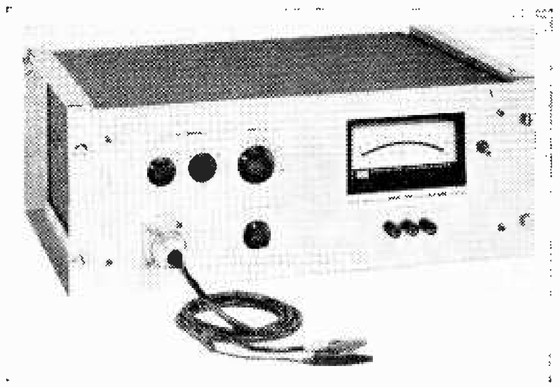


Taylor Model 61A a.m./f.m. signal generator.

up to ±1Mc/s. The r.f. output is 100mV, and a 0 to 120dB attenuator is provided. Up to three crystals can be mounted internally for calibration purposes. This generator costs £55 and is manufactured by Taylor Electrical Instruments Ltd., of Montrose Avenue, Slough.

D.C. Milli-microvoltmeter

THE Keithley Model 149 has 13 overlapping ranges with full-scale deflections extending from as low as 0.1μV up to 100 mV (d.c.). The stability after an hour's warming up is within 0.01μV per hour or 0.03μV per 8 hours: the noise with the input short circuited is less than 0.003μV peak-to-peak. The response speed is within one second except on the 0.1μV f.s.d. range where it is within two seconds. The input resistance is 10^5MΩ/V on the ranges up to 100μV f.s.d. and 10MΩ on all ranges above this. On many of the scales (but not the 0.1 or 0.3μV f.s.d. ranges) zero suppression up

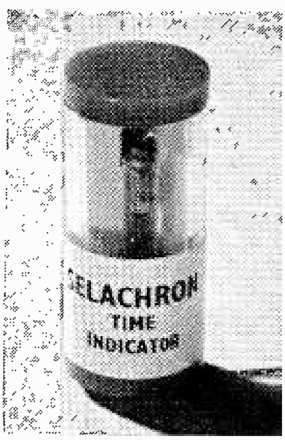


Keithley Model 149 d.c. milli-microvoltmeter.

to 100 times full scale is possible. A 10V, 5mA output for feeding a recorder is also provided. This instrument utilizes a 100 c/s mechanical chopper followed by a resonant amplifier and synchronous detector. It costs £352 and is distributed in the U.K. by Livingstone Laboratories, Ltd., of Retcar Street, London, N.19.

New Elapsed-time Indicators

EACH indicator in the new Industrial Instruments "Selachron" range contains a small replaceable electrochemical cell. As current is passed through the cell the anode is consumed so that its remaining length indicates the elapsed time. Each indicator is $2\frac{5}{8}$in long, has a diameter of 1in and weighs less than 2oz. Different models cover maximum elapsed times from 100 to 10,000 hours and a.c. or d.c. inputs from 6 to 300V. Different input voltages and a.c. are catered for by the use of suitable dropping resistors and semiconductor half-wave rectifiers respectively. The current consumption of these



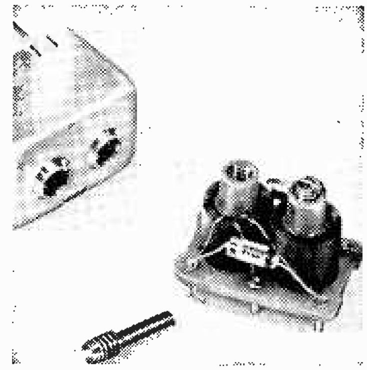
Electro-chemical elapsed-time indicator by Industrial Instruments.

units ranges from a maximum of 4.7mA for a 100-hour indicator down to 0.065mA for a 10,000-hour indicator. These indicators cost £2 5s each and the address of their manufacturer is Industrial Instruments Ltd., of 9 Paved Court, Richmond, Surrey.

Miniature I.F. Transformers

THE Wireless Telephone Company (one of the Plessey group) has introduced a new range of miniature i.f. transformers for portable transistor receivers with intermediate frequencies within the range 450-480kc/s. Chief feature of the new transformers is the parallel mounting of the coils which gives stable coupling and compact assembly. The ferrite-cup cores are potted in an epoxy resin which ensures good mechanical rigidity and resistance to vibration. Can size has been reduced to $1\frac{1}{16} \times \frac{3}{8} \times \frac{11}{16}$in high.

Double-tuned transformers are used in the first two stages and a single-tuned unit in the third with diode and i.f. by-pass capacitor included in the can. Alignment is carried out by adjustable dust cores mounted



Wireless Telephone Co.'s new miniature i.f. transformers for transistor receivers.

in a novel way. In place of the usual threaded core a plain core is bonded to a polystyrene screw working in a threaded hole in the coil former. This provides a robust screw for adjustment by an ordinary metal-bladed screwdriver, and it also allows the cores to be wax sealed after final trimming.

Of special interest to production engineers is the use of a colour coded indent to identify each transformer type. The indent enables an operator to orient the transformer correctly when assembling a receiver chassis.

Further details can be obtained from the Wireless Telephone Co. Ltd., Hallamgate Works, Crookes Road, Sheffield 10.

Multi-band Short-wave Aerial

THE SWL7 wire-trap aerial, as it is styled, is intended to provide efficient reception on the seven short-wave broadcast bands of 11, 13, 16, 19, 25, 31 and 49 metres. Briefly the principle involved is that if a tuned circuit, or its electrical equivalent, is inserted at each of two points along a random length of wire they behave as insulators at the frequency to which they are tuned and the section of wire between them behaves as an efficient half-wave dipole at that frequency. Like an orthodox dipole its efficiency is well maintained over a limited range of frequencies either side of the resonant frequency.

By inserting a number of traps along the aerial on either side of the centre point and with pairs adjusted to "look like" insulators at one of the above short-wave broadcast bands, a single-wire can be made to function as a number of separate half-wave dipoles with a single low-impedance feeder connected to the electrical centre of the system. And the feeder will be satisfactorily matched to the aerial on all bands. This is the basic design of the SWL7. Practically it covers seven short-wave bands. It costs £7 complete and including 100ft of 75Ω twin-wire feeder.

Aerials functioning on any desired combination of bands can also be supplied and further details are obtainable from Mosley Electronics Ltd., 15 Reepham Road, Norwich, Norfolk.

FEBRUARY MEETINGS

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

LONDON

1st. Brit.I.R.E.—"A fast electronically scanned [radar] receiving system" by Dr. D. E. N. Davies at 5.30 at the London School of Hygiene, Keppel Street, W.C.1.

2nd. I.E.E.—"Silicon power rectifiers" by A. J. Blundell, A. E. Garside, R. G. Hibberd and I. Williams at 5.30 at Savoy Place, W.C.2.

7th. Brit.I.R.E.—"Tunnel diodes", joint meeting with Institute of Physics and Physical Society, at 2.15 at 47 Belgrave Square, S.W.1. (Members only.)

7th. I.E.E.—"Magnetic properties of thin films for computing devices" by E. M. Bradley at 5.30 at Savoy Place, W.C.2.

8th. Brit.I.R.E.—"Perseus, a medium-scale data processing system" by G. Emery at 5.30 at the London School of Hygiene, Keppel Street, W.C.1.

8th. Women's Engineering Society.—"Space flight" by a member of the British Interplanetary Society at 7.0 at 45 Great Peter Street, S.W.1.

8th. British Kinematograph Society.—"Past, present and future trends in sound recording techniques" by F. W. Rennie at 7.30 in the Mezzanine Cinema, Shell-Mex House, Strand, W.C.2.

9th. Radar & Electronics Association.—"Digital computers" by A. St. Johnston at 7.30 at the Royal Society of Arts, John Adam Street, W.C.2.

10th. Television Society.—"Transistorized distribution amplifiers" by B. Marsden at 7.0 at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.

13th. I.E.E.—Discussion on "The road to corporate membership: what is the responsible experience required?" opened by A. H. Mumford and D. S. Rolfe at 6.0 at Savoy Place, W.C.2.

14th. Brit.I.R.E.—"Some psychoacoustic and engineering aspects of hearing aid design" by J. Jessop at 5.30 at the London School of Hygiene, Keppel Street, W.C.1.

14th. I.E.E.—Discussion on "Technical teacher training" opened by Dr. F. T. Chapman at 6.0 at Savoy Place, W.C.2.

16th. I.E.E. — Faraday Lecture "Transistors and all that" by L. J. Davies at 6.0 at Central Hall, S.W.1.

17th. B.S.R.A.—"Organ pipes and reeds" by H. Willis at 7.15 at the Royal Society of Arts, John Adam Street, W.C.2.

22nd. Brit.I.R.E.—Discussion on transistorized medical and biological electronic equipment at 5.30 at the London School of Hygiene, Keppel Street, W.C.1.

22nd. British Kinematograph Society.—"Carbon in motion picture engineering and electronics" by A. C. Conford at 7.30 at the Central Office of Information, Hercules Road, Westminster Bridge Road, S.E.1.

23rd. Television Society.—"Programme problems and possibilities associated with Monitor by Huw Wheldon at 7.0 at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.

28th. Society of Instrument Technology.—"Three terminal bridge measurements and automation" by Dr. V. S. Griffiths at 7.0 at 26 Portland Place, W.1.

BIRMINGHAM

22nd. Television Society.—"Television on Royal occasions" by T. H. Bridgewater at 7.0 at the College of Advanced Technology, Gosta Green.

BRISTOL

14th. Television Society.—"Television advertising—the first five years" by D. Ingram at 7.30 in the Colston Room, Hawthorns Hotel, Woodland Road, Clifton.

15th. Brit.I.R.E. — "High speed digital applications of transistors" by M. L. N. Forrest at 7.0 at the College of Science and Technology.

CARDIFF

8th. Brit.I.R.E.—"The principles of analogue to digital computer conversion" by J. L. W. Churchill at 6.30 at the Welsh College of Advanced Technology.

CHELTENHAM

24th. Brit.I.R.E.—"Design aspects and characteristics of long-distance waveguide communication systems" by Dr. A. E. Karbowiak at 7.0 at the North Gloucestershire Technical College.

CHESTER

23rd. Society of Instrument Technology.—"The atomic clock" by J. V. L. Parry at 7.0 in the Lecture Theatre, Administration Building, The Associated Ethyl Co., Oil Sites Road, Ellesmere Port, Wirral.

EDINBURGH

8th. Brit.I.R.E.—"Measuring stability and spurious modulation spectra of high-quality oscillators" by A. L. Whitwell at 7.0 at the Department of Natural Philosophy, The University, Drummond Street.

FAWLEY

3rd. Society of Instrument Technology.—"Instrumentation in radio astronomy" by Dr. H. P. Palmer at 5.30 at the Administration Building, Esso Refinery.

GLASGOW

9th. Brit.I.R.E.—"Measuring stability and spurious modulation spectra of high-quality oscillators" by A. L. Whitwell at 7.0 at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent.

LIVERPOOL

15th. Brit.I.R.E.—"Inertial navigational systems" by Wing Cdr. E. W. Anderson at 7.0 at the Adelphi Hotel.

MANCHESTER

2nd. Brit.I.R.E.—"The manufacture of television tubes" by P. Funnell at 7.0 at Reynolds Hall, College of Technology.

SOUTHAMPTON

22nd. Brit.I.R.E.—"The application of computers to commercial problems" by N. D. Hill at 7.0 at the Lanchester Building, the University.

WOLVERHAMPTON

8th. Brit.I.R.E.—"Computers and mathematics" by R. Wooldridge at 6.15 at the College of Technology, Wulfruna Street.

RANDOM RADIATIONS

By "DIALLIST"

Colour Television

MYSELF, I'm glad that the Postmaster-General hasn't approved the starting of a colour television service by the B.B.C. There's no doubt that the B.B.C. could make a good job of it with satisfactory and completely compatible transmissions; but I don't feel that the time is yet ripe, or that it will be until much cheaper receivers have been developed. And they must be such that their adjustments stay put and don't call for constant, or at any rate frequent, fiddling with delicate controls; otherwise they'd be of little use to the man-in-the-street, and he'd quickly be put off buying by tales of tribulations of his friends who had taken the plunge and gone in for colour receivers. The very fact that a service was in being would in all probability give him the idea that prices of colour sets would quickly come down to his sort of figure and would have a distinctly harmful effect on the sale of black-and-white receivers. Much better—don't you think?—that people shouldn't be led to believe that colour television is just around the corner.

It'll Come

Colour television will undoubtedly come, but I don't think that when it does it will be done by any of the systems so far developed. Something much less complicated and fiddly is needed and I think there's no question that it will come along in time. Till then let's be content with the monochrome system and put money and brains into improving that. The TV receiver, when you come to think of it, is now vastly better than it was only a few years ago. The number of outside-the-cabinet knobs has been steadily reduced by increasing the number of inside pre-set controls and by introducing refinements such as automatic brightness control. And there are other similar improvements. Anyhow, we mustn't put on colour TV until we're certain that it won't be a flop.

U.S. Television DX

AN American reader tells me that there is a strong body of enthusiasts for long-distance v.h.f./f.m. and television reception in his country and in Canada. They have formed The American Ionospheric Propagation Association which now has members all over the world. Should any DX-minded reader of *Wireless World* wish for particulars, the address of the association is: c/o 68 Amber Street, Buffalo 20, N.Y., U.S.A. I've often seen accounts in American magazines of long-distance reception of television programmes and I know that London has been received in or near New York under freak conditions. My correspondent doesn't appear to have picked up any of our TV stations, but he says he is going "to keep his eyes peeled for London this winter." Here's wishing him success. I don't suppose that a standard American receiver would answer unless it were specially adapted. For one thing, their images are negative, the sync and the intervals being not blacker than black, but whiter than white. I wonder if the real enthusiasts get British sets.

Some Telescope!

THE Americans, I see, are to build a gigantic radio telescope in the Allegheny Mountains of West Virginia. Our own at Jodrell Bank, with its reflector bowl 250 feet in diameter, is a pretty sizeable affair; but the new American 'scope will quite dwarf it, for it is to have a bowl no less than 600 feet in diameter. Carried by 256 railway wagon wheels, this can be revolved on a circular rail track. It is stated that its range will be 38,000 million light years—and a light year is quite some distance, being in round figures six million million miles. Our Jodrell Bank telescope has made some remarkable discoveries about outer space and the bodies existing in it. Still more astonishing results are to be expected from the device in the Allegheny Mountains when it gets to work. It should also be of great value for tracking space vehicles launched by man and for obtaining data transmitted from them to earth. The cost is estimated at £29M!

Television in Eire

A TELEVISION service is due to start in the Dublin area before the end of this year. From this beginning TV will be extended gradually over the whole of Southern Ireland. Since there are already the best part of 100,000 405-line sets in use in the country for the reception of B.B.C. and I.T.A. transmissions in Northern Ireland, a 405-line standard is to be adopted, to begin with at any rate. What standard will finally be used hasn't yet been decided, but presumably it will be governed by the decision taken in this country. It won't be an easy business to provide a service giving national coverage, for there are many mountainous districts and they always mean headaches for planning engineers. The solution may well be similar to what we have developed in Wales, Scotland and other hilly districts, a few high-powered stations and the gradual building up of a network of low-powered relays. I don't suppose that the system will ever be so com-

CONFERENCES AND EXHIBITIONS

We regret the omission of the dates of the British National Radio and Television Show from the list of conferences and exhibitions in our January issue. Since going to press with that issue we have also obtained details of other forthcoming events. The following should therefore be added to the list given in our last issue:—

Mar. 5-14	**Leipzig Spring Fair** (Leipziger Messeamf, Post Box 329, Leipzig C1)	Leipzig
Mar. 20-25	**Radio & Electronic Engineering Convention** (Institution of Radio Engineers (Australia), 157 Gloucester Street, Sydney, N.S.W.)	Sydney
Aug. 23-Sept. 2	**National Radio and Television Show** (Radio Industry Exhibitions Ltd., 59 Russell Square, London, W.C.1)	Earls Court, London
Sept. 1-8	**Firato—International Radio Show** (Firato Secretariat, Emmalaan 20, Amsterdam)	Amsterdam
Sept. 14-25	**French Electronics, Radio & Television Show** (Fédération Nationale des Industries Electroniques, 23 rue de Lubeck, Paris XVI)	Paris

plete as our own, for that would cost a great deal of money and Southern Ireland's population is scattered.

Not Dead Yet

FOR some time there have been those who say that the valve is on the way out; but it's still a very long way from being a back number, for there are so many things that it can do and that transistors can't—not yet, at any rate. It's difficult, for instance, to imagine the output stage of a high-powered transmitter being worked by any sort of semiconductor devices. That may come, but it's still a long way off. Meantime, interesting developments continue to be made in the world of valves. For example, the compactrons, tiny multiple valves, each containing several sets of electrodes within its small envelope. I confess that I've never been very keen on multiple valves myself, largely because if the single heater goes west you may lose the equivalent of a pair or a trio of valves at one blow. But that may be an old-fashioned idea, for people today don't seem to fight shy of them.

Components on Show

THE 1961 Radio and Electronic Components Show will be held in Olympia and it will be at least three times as big as those of yesteryear which were somehow fitted into one big room at Grosvenor House, with latterly a small overflow into a nearby building. To me the Components Show has always been one of the highlights of the year. It'll go on being a highlight, but it's now to be held every other year. This year's will be of special interest because it is to include components for computers, for the controlling mechanisms of machine tools, for man-made satellites, for guided missiles and for apparatus used in nucleonic engineering.

UNBIASED

By "FREE GRID"

Diary Worry

WE have had our *Wireless World* Diaries in use for a few weeks now, and many of us have had occasion to use the information on one or more of the eighty data-packed pages which precede the actual diary.

I received my Diary as a gift from the Editor and I am, therefore, a little worried about a recent decision of the High Court in which it was laid down that for income-tax purposes such a gift should be rated at its second-hand value. To unthinking people such a value in the case of a diary—even a *Wireless World* one—would be a small fraction of the few shillings at which it was priced when new.

But some diaries, unlike a suit of clothes which was actually the test-case gift dealt with by the court, have a habit of increasing in value enormously when second hand. This is obvious when one considers what the original diaries of Pepys, Evelyn or even Nell Gwynne would fetch on the open market today. As was recently pointed out, parts of Pepys diary were so severely critical of certain personalities of his day that they have never been published, and this greatly enhances their potential value.

Naturally my own year-by-year diary contains many references to famous names in the world of wireless, and in some cases critical remarks which could bring me a tempting offer from certain sensational newspapers, as any income-tax inspector would quickly realize. I hope, therefore, that next year the Editor will make it a suit of clothes (vital statistics 40-in × 38-in × 29-in) and I will buy my own diary.

As for the *Wireless World* Diary, I have nothing but praise for the data pages and it is only the actual diary section for which I have any criticism. I can't grumble at being told such an obvious thing as that Christmas Day falls on December 25th, as *Wireless World* has many readers in non-Christian countries who would not necessarily know this.

All the same, I do feel that rather than be told that Lammas falls on August 1st, I should have been informed of when the National Radio Show opens its doors. But maybe the show date was not known when the diary went to press.*

* It was not; but it was when the calendar of conferences and exhibitions in the January issue went to press. We regret the omission. The dates are Aug. 23 to Sept. 2.—ED.

C.I.D. Censured

WHEN a person as important as the chief of the C.I.D. writes his memoirs I always feel that he ought to take the utmost care to be meticulously accurate, especially when dealing with a technical subject like wireless. The late Sir Basil Thomson who was chief of the C.I.D. in the first world war rather let Scotland Yard down in that respect; at least that is my opinion.

In his book entitled "Queer People," which I recently picked up, he discusses the great German spy scare of 1914 when it only needed the flimsiest reason for reports to reach the C.I.D. that somebody was sending wireless messages across the North Sea to the enemy.

Such a wireless spy scare was in evidence before the war started and I recalled a striking instance of it when writing on this subject in the issue of *Wireless World* for June 4th, 1937, although a natural modesty made me omit to mention being a witness of it.

It happened that an unfortunate girl was paying a visit to her brother in a certain naval dockyard where there was a powerful radio transmitter. By chance, she was standing within a few feet of the aerial mast when the operator started transmitting. The field strength was so great that the metal ribs of her "stays"—a commonplace appliance in 1914—were forced into electrical oscillation, they apparently resonating to a harmonic of the wave being radiated. The result was that sparks were observed to be leaping from her person to some earthed iron railings against which she was leaning, and she was promptly arrested.

This incident led to patriotic young men following girls in the interests of national security, especially the younger girls whose trailing tresses could so easily have concealed a primitive dipole. In my illustration it can be clearly seen that an alert young man's attention has been attracted by the suspicion-rousing coiffure of a young girl in the grounds of the old White City on which the B.B.C.'s new TV headquarters now stands. This patriotic following of girls led so frequently to the altar—or should be say halter—that the whole idea was later suspected to have been initiated by the wiles of women.

Sir Basil seems to dismiss the feasibility of spies using a radio transmitter in those days because, to quote his own words, "a Marconi transmitter needed a 4 h.p. engine to generate the wave." In actual fact with a standard Marconi 10-in spark coil and a couple of 12-volt car batteries with an aerial suspended down a chimney, I should be very surprised indeed if a spy could not have sent a message from the East Kent coast to the nearest point of the Belgian coastline occupied by the Germans, a distance of 40 to 50 miles; even if the enemy were using the—by modern standards—relatively insensitive magnetic detector.

Such a transmitter as I have described, using a 12-cell 80 AH capacity storage battery, was the basic emergency transmitting equipment of a British ship in those days. The maximum current taken by the coil just before the make-and-break did its stuff was between 7 and 8 amps, which is, of course, not at all beyond the capabilities of a car battery of large capacity. Ships' emergency transmitters were expected to—and did—have a much greater range than 40-odd miles.