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THE TUNNEL DIODE - IN THEORY AND PRACTICE

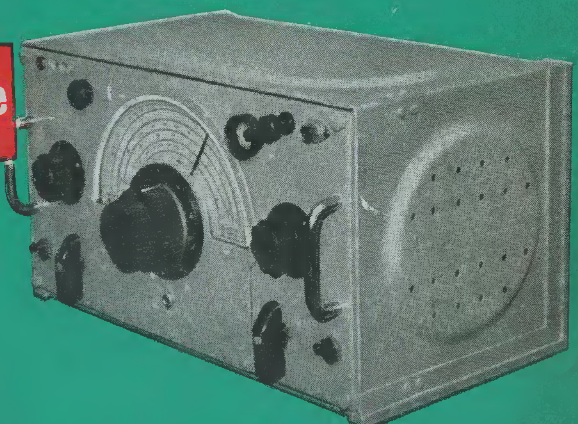
VOLUME 14
NUMBER 4
NOVEMBER
1960

The RADIO Constructor

RADIO · TELEVISION · AUDIO · ELECTRONICS

LONG DISTANCE TV

R1155 General Purpose Receiver



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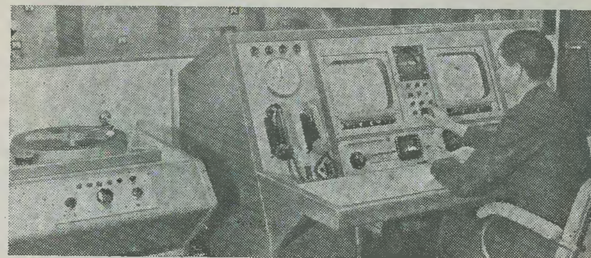

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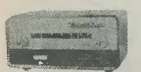

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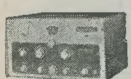

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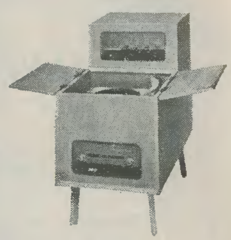

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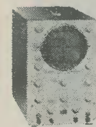
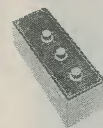
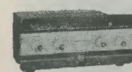


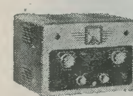
O-12U



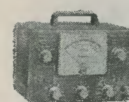
DC-1U



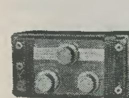
S-33



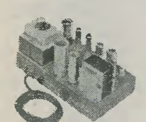
DX-40U



AG-9U



UJR-1



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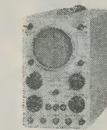
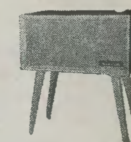


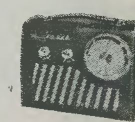
OS-1

V-7A

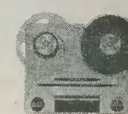
S-88



SSU-1



UXR-1



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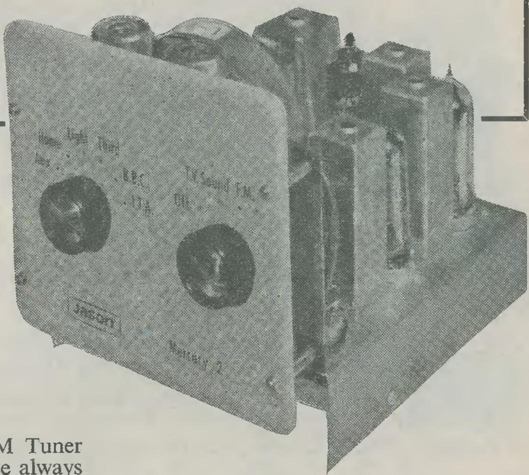

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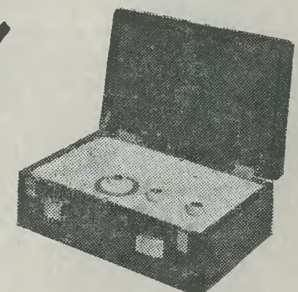

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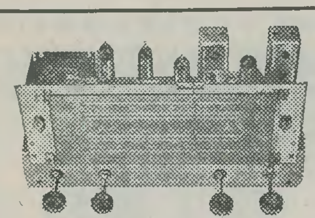

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3S4	7/6	6SA7	6/–	EBC41	8/6	MU14	9/–
3V4	7/6	6SJ7M	6/6	EBF80	10/–	P61	3/6
5U4	7/6	6SN7	6/6	ECC84	9/6	PCC84	9/6
5Y3	7/6	6V6G	6/6	ECF80	9/6	PCF80	9/6
5Z4	9/6	6X4	7/6	ECH42	10/6	PCL82	11/6
6AM6	5/–	6X5	6/6	ECL80	10/6	PEN25	6/6
6B8	5/–	12A6	7 6	ECL82	10/6	PL81	12/6
6BE6	7/6	12AT7	8/–	EF39	5/6	PL82	10/6
6BH6	9/6	12AU7	8/–	EF41	9/6	PY80	7/6
6BW6	9/6	12AX7	8/–	EF50	5/6	PY81	9/6
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6H6	3/6	12Q7	6/6	EF92	5/6	UBC41	9/6
6J5	5/6	35L6	9/6	EL32	5/6	UCH42	9/6
6J6	5/6	35Z4	7/6	EL41	9/6	UF41	9/6
6J7G	6/6	80	9/6	EL84	8/6	UL41	9/6
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16/450V	3/–	8+8/500V	5/–	32+32/350V	5/–
16/500V	4/–	8+16/450V	3/9	32+32/450V	6/–
32/450V	3/9	8+16/500V	5/6	32+32+32/350V	7/–
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CONTRIBUTIONS on constructional matters are invited, especially when they describe the construction of particular items of equipment. Articles should be written on one side of the sheet only and should preferably be typewritten, diagrams being on separate sheets. Whether hand-written or typewritten, lines should be double spaced. Diagrams need not be large or perfectly drawn, as our draughtsmen will redraw in most cases, but all relevant information should be included. Photographs should be clear and sharp. Details of topical ideas and techniques are also welcomed and, if the contributor so wishes, will be re-written by our staff into article form. All contributions must be accompanied by a stamped addressed envelope for reply or return, and should bear the sender's name and address. Payment is made for all material published.

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TRADE NEWS. Manufacturers, publishers, etc., are invited to submit samples or information of new products for review in this section.

TECHNICAL QUERIES must be submitted in writing. We regret that we are unable to answer queries, other than those arising from articles appearing in this magazine; nor can we advise on modifications to the equipment described in these articles.

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ten YEARS OF Suggested Circuits

One of the most popular features in *The Radio Constructor* has been the "Suggested Circuit" series written by G. A. French. "Suggested Circuit No. 1" appeared in December 1950, and subsequent articles have followed, without a break, in every issue since that date. This month sees the publication of No. 120 in the series, and we have asked our contributor to write a few words, not only to mark the event but also to announce the publication, in late November, of an important new addition to our Data Book range: "*Suggested Circuits* 1 *to* 20".

I MUST CONFESS THAT I EXPERIENCED A little touch of pride when, several days ago, I mailed "Suggested Circuit No. 120" to the Editor of *The Radio Constructor*. As I left the Post Office I recalled an occasion, in 1950, when I similarly mailed the first article in this series: "Suggested Circuit No. 1". On the former occasion, however, my emotions consisted more of trepidation!

I had conceived the idea of a series of articles which would illustrate interesting and unusual circuit designs in addition to basic techniques some time previously, and the Editor had given it a provisional blessing. After the series had been launched, we were gratified to find that readers were very keen on the approach used, and that they appreciated articles in which working circuits were presented with essential data only. Since that initial article was published, "Suggested Circuits" has appeared at the front of every issue, and has covered subjects ranging from electronic laboratory equipment to the simplest of periodic switches. Due to my being in the fortunate position of having access to the latest developments in the commercial field, many of the articles have had considerable topical value. Too topical in one case: "Suggested Circuit No. 72, A Phototransistor Light-Operated Switch" appeared, in November 1956, several months before the phototransistor concerned was released to the market!

Readers have been extremely kind and helpful, and have passed on many suggestions for future articles. Such suggestions have always been valuable and are of considerable help in predicting and mapping reader interests. Criticism has also been helpful. For instance, letters from several readers who reported overheating of a power-dissipating resistor in one circuit resulted in the specification, in all subsequent articles, of "nominal" power ratings for resistors instead of the R.C.S.C. ratings previously applied. "Nominal" ratings (approximately twice R.C.S.C. ratings) appear to be those most frequently employed, nowadays, by home-constructor component stockists.

In order to mark the 10th year of "Suggested Circuits" and, also, to meet the many requests received, a book–"*Suggested Circuits* 1 *to* 20"–is to be published during the later part of this month. This book will contain in fully up-to-date manner, and with a new and attractive layout, the complete "Suggested Circuits" from 1 to 20 inclusive. The subjects covered include a simple and inexpensive Two-Valve Capacity Bridge, a Short Wave Regenerative Preselector, a one-valve Speech Operated Switching Circuit, a Transformer Ratio Analyser, a Series Noise Limiter, a Receiver Remote Mains On-Off Control, a high-accuracy and foolproof Electronic Timer, and many others. Every circuit is presented in the manner with which readers are familiar, and the book will provide a permanent record to be kept by all experimenters and enthusiasts.

And, now, I must get down to work on "Suggested Circuit No. 121"!

No. 120 | An Electronic "Watch-Dog" for Intermittent Faults

WHAT IS PROBABLY THE MOST INFURIATING and time wasting aspect of radio and television servicing is given by the intermittent fault. A fault can, of course, only be located accurately when it is actually in existence. Equipment with an intermittent fault has, therefore, to be left switched on for considerable periods of time until the fault occurs. Waiting periods may extend up to several days or more, and a continual watch has to be maintained.

The device described in this month's article provides automatic indication of the appearance of an intermittent fault by giving loud audible warning whenever the equipment under test fails. The device is controlled by a negative voltage, of 1 volt or more, derived from the equipment, and it provides the warning when this voltage ceases. The control voltage may, to take an example, be obtained from the grid of a television sync separator whereupon cessation of signals, due to a fault in the preceding stages, would cause that grid to drop to chassis potential. A warning that signals had ceased would at once be given. Alternatively, the device may be connected to the grid of a line output valve whereupon failure of the line sawtooth generator would once more cause a drop to zero potential of the control voltage and the sounding of the audible warning. Yet again, the control voltage could be obtained from the output of a sound receiver, this being done by rectifying the a.f. voltage present on the speaker transformer primary. If a constantly modulated signal is applied to the aerial terminals of the receiver, the control voltage would drop to zero when the receiver failed, and the audible warning would once more be given.

The device may also be used to provide audible warning of cessation of voltage in applications other than servicing. All that is required is that the voltage should be capable, when present, of providing a negative potential of 1 volt or more for application to the input terminals of the unit.

The warning device employs rather novel techniques. There are no relays, and the circuit is designed around a single double-triode valve. One of the triodes is an audio oscillator coupled to a loudspeaker, and it is the sound given by this loudspeaker which provides the warning signal. The components in the immediate valve circuit consist of six resistors, three condensers, a speaker transformer and the loudspeaker. Apart from one of the resistors, which has a tolerance of 5%, none of these components are critical in value and should, in most instances, be readily available.

The Circuit

The circuit of the "Watch-Dog" appears in Fig. 1. The double-triode, $V_{1(a)}$ and $_{(b)}$ can be an ECC84 or a PCC84, these types being approximately equivalent valves (apart from heater voltage) which are normally employed as cascode r.f. amplifiers in television tuners. In combination with the speaker transformer and C_2, C_3 and R_4, $V_{1(b)}$ forms an a.f. oscillator. The speaker transformer may be of any type intended for operation with a valve output stage, but it must have a tap in its primary winding. This tap enables feedback to be applied to the grid of $V_{1(b)}$. The values of C_2 and C_3 are selected experimentally to ensure that oscillation occurs at the desired amplitude and frequency.

When the grid of $V_{1(a)}$ has no voltage applied to it, it assumes chassis potential via the grid leak, R_1. In consequence, this triode draws a relatively high current through R_2 and $V_{1(b)}$. The cathode of $V_{1(b)}$ then takes up a potential which is lower than that at the junction of R_5 and R_6, and the resulting bias conditions are such that it oscillates.

When a negative voltage of 1 volt or more, relative to chassis, is applied to the grid of $V_{1(a)}$, its anode current decreases. Because of this the cathode of $V_{1(b)}$ rises to a potential higher than that at the junction of R_5 and R_6, and it becomes cut-off. Oscillation in $V_{1(b)}$, therefore, ceases.

Design Points

A number of points concerning the basic design of the circuit need to be discussed.

Valve types which are normally employed as cascode r.f. amplifiers are specified in this circuit instead of one of the more familiar a.f. double-triodes because they have higher cathode-heater voltage ratings. It is possible, should $V_{1(a)}$ become cut-off, for the cathode of $V_{1(b)}$ to rise to full h.t. potential, and high cathode-heater ratings simplify h.t. power supply requirements. The ECC84 has a maximum limiting cathode-heater voltage of 200 and the PCC84 one of 250 when the heater is negative of cathode (as occurs here). It becomes possible, therefore, to specify a maximum h.t. supply voltage of 180 for the circuit when an ECC84 is used, and one of 230 when a PCC84 is used, and still have a comfortable margin in hand. It is important to note that the cathode-heater ratings just quoted apply only to one of the triodes in the valve (actually the "upper" triode when the valve is used as a cascode amplifier). The valve pin numbers in Fig. 1 should, therefore, be followed, as these ensure that the correct triode is employed in the $V_{1(b)}$ position.

Apart from their different cathode-heater ratings and, of course, their different heater requirements, both valves specified should give identical results in this circuit. The PCC84 has a slight advantage, however, because its higher cathode-heater rating places less restriction on h.t. potential. On the other hand it requires a heater voltage of 7, as opposed to the ECC84 heater voltage of 6.3, and such a voltage is not immediately available from a standard mains transformer.[1] It will be noted that an internal screen is connected to the grid of $V_{1(b)}$. This screen is employed when the valve functions as a cascode amplifier and has no bearing on circuit operation in the present application.

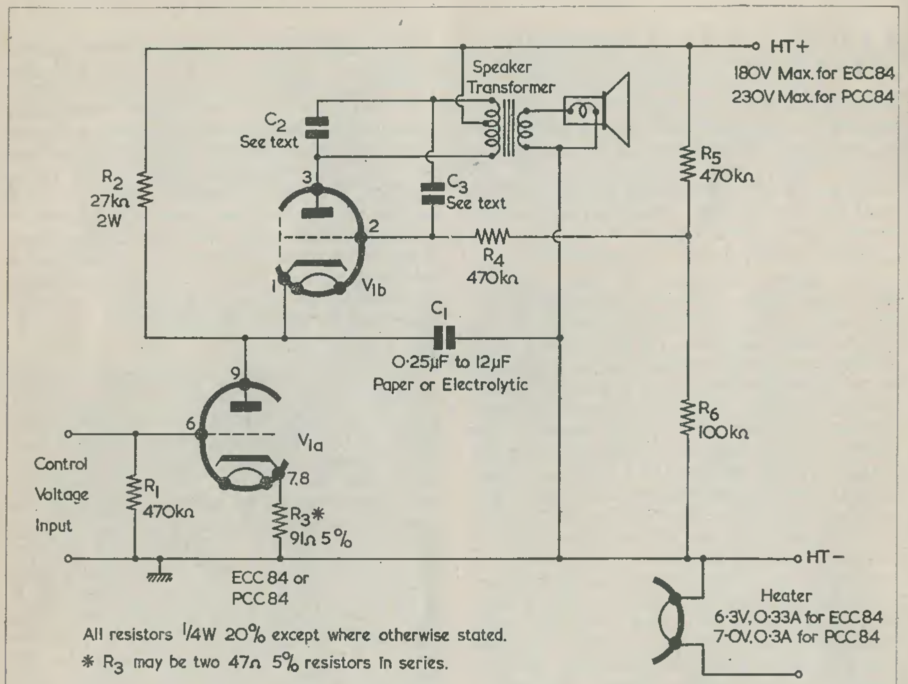


FIG.1.

The 27kΩ resistor R_2 provides a bleed current when negative voltage is applied to the grid of $V_{1(a)}$. If this resistor were not in circuit the cathode of $V_{1(b)}$ could never rise higher than cut-off potential above its grid, and the device would lose sensitivity.

[1] It may be worth pointing out, nevertheless, that if the 210 volt primary of a mains transformer is connected to a 230 volt supply, a 6.3 volt secondary winding gives an output at 6.9 volts. Other similar methods of connecting standard mains transformer primaries may also give heater secondary voltages close to 7 volts.

When zero voltage is applied to the grid of $V_{1(a)}$ the cathode of $V_{1(b)}$ goes negative of the potential at the junction of R_5 and R_6. This does not result in the grid going positive of the cathode, however, because $V_{1(b)}$ is an oscillator whose leaky-grid bias maintains an average grid potential which is negative of cathode. There is, also, a compensatory action which prevents the cathode of $V_{1(b)}$ from going *heavily* negative of the junction of R_5 and R_6. Low anode current in $V_{1(a)}$ (due to a negative potential on its grid) flows through R_2 only. High anode current in $V_{1(a)}$ (due to zero potential on its grid) flows through R_2 *and* $V_{1(b)}$.

The function of condenser C_1 is that of maintaining the cathode of $V_{1(b)}$ at a steady potential so far as a.f. is concerned. Without C_1, $V_{1(b)}$ would not oscillate. C_1 also helps to reduce the effects, in $V_{1(b)}$ circuit, of any a.c. voltages which might be impressed on the grid of $V_{1(a)}$. Experimental work with the prototype indicated that C_1 should have a minimum value of 0.25μF. Since paper condensers having values of this order may not be readily available, it might be found more convenient to employ an electrolytic condenser having a higher value in the C_1 position.

A small amount of cathode bias for $V_{1(a)}$ provided by the 91Ω resistor, R_3. This sistor prevents excess anode current when $V_{1(a)}$ grid is at chassis potential.

It is assumed in Fig. 1 that the smoothing condenser in the associated power unit provides a bypass capacity of some 8μF or more between the h.t. positive rail and chassis.

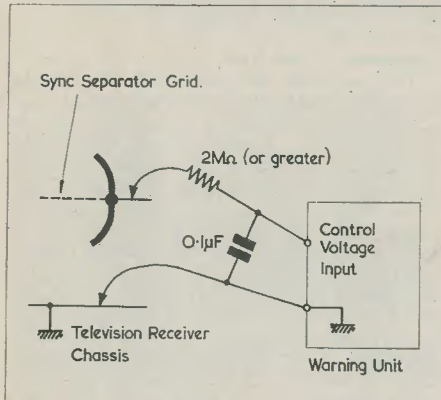


FIG.2a

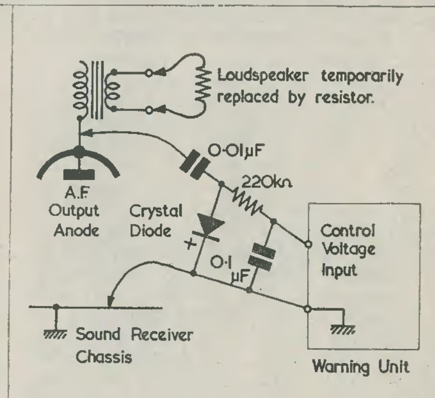


FIG.2b

M857

Results with the Prototype

It was found, with the prototype, that for negative control voltages relative to chassis from zero to 0.4 there was no significant change in tone or volume of the oscillation heard from the loudspeaker. As negative voltage was increased, from 0.4 to 0.8 volts, oscillation gradually reduced in volume, ceasing completely at 0.8 volts. Reducing voltage gave the reverse effect, with oscillations commencing at 0.8 volts. There was a slight change in oscillator frequency for input voltages between 0.4 and 0.8 volts, this being probably due to the changing potential relationship between the cathode of $V_{1(b)}$ and the junction of R_5 and R_6.

Oscillation frequency was liable to vary, also, according to the nature of the applied control voltage. Thus, if the grid of $V_{1(a)}$ were touched with the finger, the note from the oscillator became subject to shallow but perceptive modulation at 50 c/s. (This effect continued even with a relatively high value electrolytic component in the C_1 position.) The effect does not detract from the efficiency of the device, but it would be advisable to filter out high amplitude a.c. when coupling the input terminal to the equipment under test.

Whilst little difficulty was experienced in getting $V_{1(b)}$ to oscillate reliably, the writer formed the opinion that component values in the oscillator circuit had to be selected with a little more care than would be needed if a conventional a.f. triode had been employed. The process of selecting oscillator components is discussed later.

The note obtained from the loudspeaker with the prototype was extremely loud, and was quite capable of breaking through the background noise given in a servicing workshop.

H.T. current consumption was measured on the prototype at an applied h.t. voltage of 200, and with a PCC84 in circuit. With zero voltage applied to the input terminal, current consumption was 10mA. With 1 volt negative applied to the input terminal, consumption was 6.5mA.

Construction

The construction of the unit should raise little difficulty, because few components are needed and layout is unimportant.

It is necessary to put the oscillator into working order before construction is finalised. The circuit should be made up as shown in Fig. 1 but with R_2 omitted and R_4 returned to the cathode of $V_{1(b)}$ instead of to the junction of R_5 and R_6. The grid of $V_{1(a)}$ should be temporarily short-circuited to chassis. Under these conditions values for C_2 and C_3 should be selected which allow the generation of a clean high-amplitude note from the loudspeaker.

As an aid to putting the oscillator into operation, the following information may be of assistance. If the tap in the speaker transformer primary is not a centre-tap, the winding with the greater number of turns should be that which connects to the anode of $V_{1(b)}$. It is advisable to commence with a 0.01μF condenser in the C_2 position as such a value will almost certainly ensure that oscillation frequency falls into the audible range. A suitable value for C_3 may then be found by experiment. It is advisable to start here with a value around 100pF and increase this in steps of 100pF or 200pF until oscillation commences. The oscillation may then be brought to the desired frequency by adjusting the value of C_2, after which the optimum value of C_3 may be finally found. Too low a value in C_3 will prevent oscillations commencing, whilst too high a value will cause the triode to block. The oscillator should operate immediately h.t. is applied, and it should continue to operate at h.t. voltages considerably lower than that initially applied.[2] During the setting-up process, h.t. should not be applied for long periods of time when oscillations are obviously not present. This is because a relatively heavy current may be drawn when $V_{1(b)}$ is not oscillating, and because high a.c. voltages may be applied to its grid if it is blocked. To give a guide to what is required it was found in the prototype, which employed a fairly large centre-tapped transformer, that C_2 needed a value of 0.01μF and C_3 one of 400pF.

After $V_{1(b)}$ has been made to oscillate satisfactorily, R_4 may be connected to the junction of R_5 and R_6, and R_2 inserted into circuit. It should then be found that $V_{1(b)}$ oscillates when $V_{1(a)}$ grid is at chassis potential, and that it ceases to oscillate when $V_{1(a)}$ grid has a potential of 1 volt negative relative to chassis. Should oscillations not commence when $V_{1(a)}$ grid is at chassis potential R_6 may be increased in value. If a control voltage higher than 1 volt negative is needed to cause oscillation to cease, R_6 should be reduced in value.

Equipment Under Test

Two methods of connecting the unit to equipment under test are shown in Fig. 2.

In Fig. 2 (*a*) the unit is connected to a sync separator grid. Under normal signal conditions this grid will be negative of chassis by a potential equal to average signal level. The series resistor in Fig. 2 (*a*) forms a potentiometer with the internal grid leak (R_1 in Fig. 1) and allows sufficient negative control voltage to appear on the input terminal for the oscillator to cease functioning. Also, the value of the series resistor is sufficiently high to prevent alterations to sync separator operation. The resistor should be mounted close to the sync separator valve pin. The 0.1μF condenser connected across the input terminals prevents video frequencies from being applied to the grid of $V_{1(a)}$.

In Fig. 2 (*b*) the a.f. signal on the output anode of a sound receiver is detected and applied, via a resistor and bypass condenser, to the input terminals of the unit.

In both instances illustrated in Fig. 2, cessation of signals will cause the input voltage of the device to fall to zero, whereupon audible warning is at once given.

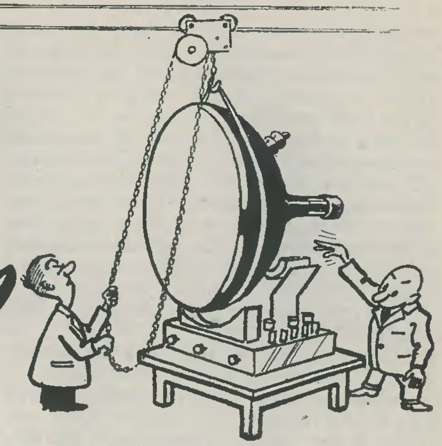
[2] This last requirement may be checked by the simple process of switching off the associated power supply. Oscillations should continue as the h.t. electrolytic condensers discharge.

Trade Review

The SWL-7 Short Wave Aerial

The SWL-7 is a wire trap type dipole aerial specifically designed for reception of the Short wave broadcast bands. Due to the unique design, the aerial operates on the 11, 13, 16, 19, 25, 31 and 49 metre broadcast bands with a single coaxial line feed to the receiver. The SWL-7 is supplied complete with coaxial line feed and provides a relatively compact aerial operating effectively over these bands without the need for complex array systems. Considerable interest from monitoring professional organisations as well as Short wave listeners has already resulted. The SWL-7 is available from Mosley Electronics Ltd., 15 Reepham Road, Norwich, Norfolk.

In your Workshop



This month Smithy the Serviceman, and his able assistant, Dick, discuss matters ranging from transistor v.h.f. receivers to polystyrene condensers

IT WAS AS THE WORKSHOP CLOCK WAS ticking its way round to the end of the lunch period that Smithy, looking up suddenly from his completed crossword puzzle, realised that his assistant Dick was behaving in a very unusual manner.

"Well, this is a bit of a change, isn't it?" said Smithy. "Normally at lunch time you're lost to the world in one of those lurid paper backs your depraved tastes cause you to indulge in."

A little self-consciously Dick put the service manual he had been avidly studying down on the bench.

"You only noticed", he remarked, "because you've managed to finish your crossword earlier than usual. Normally about this time you're calling upon the heavens to descend on the compiler whilst you try to think of three letter words beginning with E and ending with U and meaning 'bird'."

"Whatever birds I encounter in my crossword", the Serviceman replied coarsely, going into the attack, "have nothing on those which appear in your literature. How the police allow the front covers, even, baffles me!"

"People", replied Dick airily, "are not so hypocritical nowadays as they used to be. Present day books describe *real* life."

For a moment Smithy's mind focused on the cover of one of Dick's recent selections which, by the sheer dramatic vividness of the violent action it portrayed, had indelibly stamped itself on his memory; and he shuddered a little at the "real life" which Dick so readily accepted. Looking around, his familiar surroundings came into focus and he gratefully returned to the safe and comfortable groove provided by the Workshop.

Transistor V.H.F. Receivers

"Ah, well, everyone to his taste," he remarked, "however dissolute it may be! Besides, it's time to get down to a spot of work."

"Fair enough," said Dick.

He picked up his service manual and glanced at it.

"As a matter of fact", he continued casually, "this manual I've been reading is quite interesting."

"Yes?"

"It's for one of these new transistorised a.m./f.m. sets. I'm surprised to find that they don't seem to be all that much more complicated than valve sets after all."

"There's no reason why they should be," commented Smithy. "Transistor radio designs don't differ much from their valve counterparts. Usually, there is an extra stage somewhere or other to make up for the loss of gain, and most r.f. and i.f. stages have simple neutralising circuits. But, apart from that sort of thing, valve and transistor sets are pretty much the same."

"Transistor f.m. receivers are rather new, aren't they?"

"They were introduced at the Radio Show", said Smithy, "and quite a few manufacturers are in production with them. Let's have a look at that manual."

Dutifully, Dick handed it over.

"Well, it all seems very straightforward to me," said Smithy, examining the circuit.

"When you switch to a.m. you have an r.f. amplifier, an oscillator/mixer, and an i.f. amplifier before you hit the a.m. detector. Three transistors in all, working from a ferrite rod aerial and having an i.f. in the 465 kc/s region. On f.m. the r.f. transistor, oscillator/mixer transistor and i.f. transistor all switch over to 10.7 Mc/s, giving you a three-stage i.f. amplifier. Two new transistors, working at v.h.f., then come into circuit and work into that little lot. The new transistors being an r.f. amplifier and another oscillator/mixer."

"But not into the same detector," Dick reminded him.

"Oh no, of course not," said the Serviceman. "The last i.f. stage is now coupled to a straightforward ratio discriminator with two crystal diodes. The outputs of the a.m. detector and the f.m. discriminator are then switched to the a.f. section of the receiver by part of the wavechange switch. Very neat!"

"It *is* neat," agreed Dick. "I suppose that the transistor types may be a wee bit newish to us servicing types. OC171's for the two new transistors switched in on f.m., and OC170's for the transistors which double up as r.f. and i.f. amplifiers on a.m. and 10.7 Mc/s i.f. amplifiers on f.m."

"They aren't all *that* new," commented Smithy. "Although I must admit I haven't personally handled these particular types myself. You may note that they have an extra lead-out wire for a screening connection, in addition to the usual emitter, collector and base wires."

"So they have," said Dick. "Well, I hope that one of these new a.m./f.m. sets goes wrong soon so that we can get our hands on it!"

"That's a very unkind thought," reproved Smithy. "Although, to be quite frank, I'm rather looking forward to playing around with one of these sets myself, when I get the chance."

Tuner Unit Contacts

"They had transistor t.v. sets at the Show too," remarked Dick.

"I know they did," chuckled Smithy, "but I haven't had any detailed gen on these yet. Apart, that is, from the number of transistors and diodes employed."*

The Serviceman chivvied Dick back to his bench and indicated that Question Time was over for the moment.

Peace descended upon the Workshop for as long as half an hour, this period being punctuated only by the heavy clattering of a television turret tuner as Dick cleaned and adjusted its contacts. After he had completed his task, Dick checked the tuner on aerial signals. His face fell as he examined the results of his work.

"Smithy!"

The familiar wail carried across the Workshop.

"Hullo!"

The Serviceman kept his head bowed over his work.

"It's this turret," continued Dick, to Smithy's unresponsive back. "I've cleaned and adjusted its contacts, but it's just as bad now as it was when I started."

"Dear, *dear* me," sighed the Serviceman, as he laid down his soldering iron. He walked to Dick's bench and looked at the offending receiver.

"Here you are," said Dick. "Look! The receiver came in with crackly contacts in the turret which I've now cleaned up and adjusted. Yet I've only got to waggle the knob a little and the picture goes right off the screen!"

Smithy noticed that the tuner was set to a Band III channel.

"Try Band I," he advised.

Dick ratchetted the turret to the local Band I channel and moved the knob experimentally.

"Well, that's funny," he said, surprised. "However much I waggle the knob the picture's rock-solid!"

"I think I know what's wrong," said Smithy, grasping the channel selector knob. "It's probably poor indexing. It seems a bit loose, even by feel. (Fig. 1 (*a*).) Let's have a look at Band III again." Smithy turned the tuner knob. "Right; now here's our Band III channel again. And, as you say, if you waggle the knob you lose the picture. What makes me think that this isn't a case of crackly contacts is that, when we waggle the knob, we don't get a shower of flashes on the screen, nor are there any snaps, crackles and pops from the loudspeaker."

Smithy experimented with the channel selector knob and the fine tuner.

"Ah," he said, after a moment. "I think I can now demonstrate to you just what's happening. As I guessed just now, the indexing has mildly ascended the wall. With the result that, when you select the channel, there's still a little rotational play on the channel selector knob and, in consequence, on the turret drum inside the tuner. Now, watch what happens! I've selected the channel and I'm very slowly moving the turret knob through the few degrees of rotation allowed by the faulty indexing mechanism. Can you see what's happening?"

"Yes, definitely," said Dick. "It's just as though you're adjusting the fine tuner. You start off with a low definition picture which gets better and better, then it finally breaks up and you've gone into the sound channel. At the same time the sound level goes up and down, reaching maximum at about the same time as you get the best picture."

"Well?" prompted Smithy.

"Which means", continued Dick, "that, if you're repeating the effect of the fine tuner you're obviously altering oscillator frequency as you move the knob."

"Exactly," confirmed Smithy. He drew a sketch on Dick's pad. "The contacts in this tuner are the sort of thing that's often encountered, and they consist of studs on the turret drum wiping across leaf contacts fixed to an insulated mounting on the chassis. (Fig. 1 (*b*).) At the same time, the tuner contains the regulation Colpitts oscillator circuit which connects, via two of our contacts, to the oscillator coil in the turret drum. (Fig. 1 (*c*).) Now the length of metal in the two contacts forms part of the oscillator tuned circuit and provides a small amount of series inductance. At Band I, where the turret coils may have some 20 to 50 turns, the inductance provided by the contacts is comparatively negligible. At Band III, on the other hand, where the turret coils may consist of a couple of turns only, the inductance inserted by the contacts is comparatively high."

"I'm with it now," exclaimed Dick. "In this tuner the wonky indexing mechanism allows enough play for the stud contact to move over quite a considerable length of the fixed contact. (Fig. 1 (*d*).) When the stud contact is closest to the fixed contact lug, the inductance inserted by the two is at minimum, and, when the stud contact is furthest away from the fixed contact lug, the inserted inductance is at maximum."

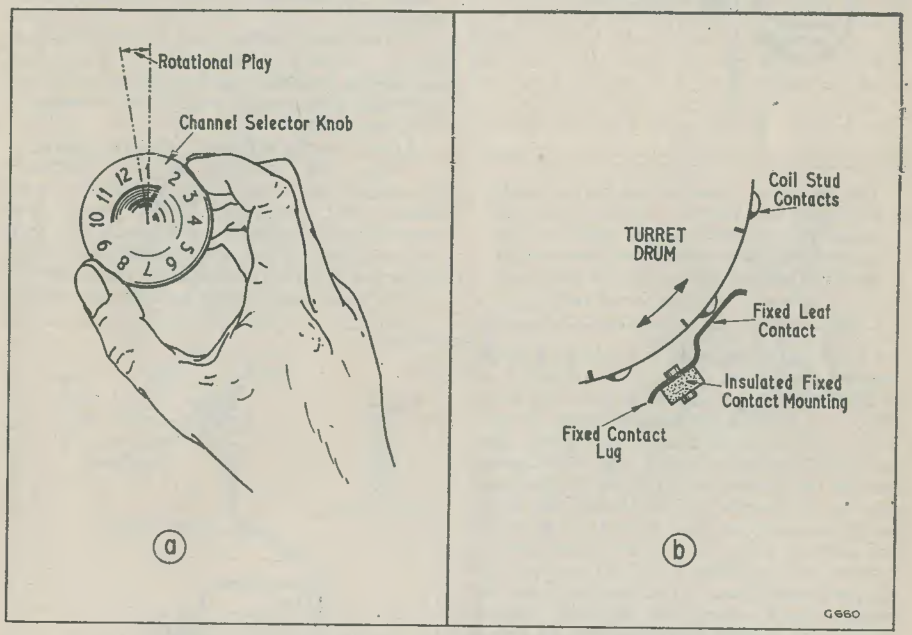


Fig. 1 (a) When Smithy checked a tuner with faulty indexing the first thing he noticed was rotational play of the channel selector knob
(b) In a typical tuner, stud contacts on the coil segments wipe across fixed leaf contacts, as shown in this sectional view

"You've got it," said Smithy. "And the difference in inductance for the two positions in our case is equal, at Band III, to some 2 Mc/s of oscillator frequency! Which is why I obtained the fine tuning effect. Don't forget that the same detuning effect happens on the aerial and r.f. tuned circuits as well but this is not, of course, likely to cause so noticeable an effect on the screen."

"Do all turret tuners suffer from this detuning business?"

"To a certain extent, yes," said Smithy, "depending, amongst other things, on the type of contacts employed. The leaf spring

* Brief advance details of transistorised television receivers were given last month in our report on the Radio Show and the Pye Group Exhibition.—*Editor.*

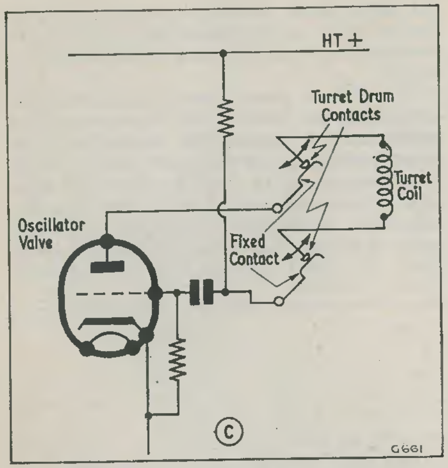


Fig. 1 (c) A conventional turret tuner oscillator employs a Colpitts circuit in which two connections are made to the turret coil. The inductance inserted by the fixed and moving contacts is effectively in series with the turret coil

we have just considered is liable to give the greatest trouble on this score. Another type of fixed contact is made in the form of a loop. (Fig. 1 (*e*).) The detuning effect as the stud wipes across this contact is slightly less, because the loop provides two inductances: one via the direct path from lug to stud, and one via the indirect path around the loop. As the stud moves away from the lug end of the contact more and more inductance is inserted via the direct path and less and less via the indirect path. The two don't exactly balance each other out by any means, because the indirect path is quite a lot longer than the direct path, but there is some alleviation.

"Probably the best type of turret tuner unit contact is the knife type. (Fig. 1 (*f*).) If either the fixed or moving contact is made wider than its opposite number you can have quite a lot of rotation without seriously affecting the inductance inserted by the two contacts. (Fig. 1 (*g*).)"

"Phew!" said Dick. "It shows the sort of thing you've got to look out for in this game, doesn't it?"

"It does," agreed Smithy. "Whilst we're on the subject, I should point out also that you can seriously alter the frequency of a Band III tuned circuit in a turret merely by careless soldering at its contact lugs! Let's assume that a particular fixed contact in a tuner is connected into circuit by a nice neat solder connection which employs little solder. (Fig. 2 (*a*).) If, in the course of servicing, you apply a whacking great blob of solder on the lug of that contact (Fig. 2 (*b*)), you may reduce the inductance it inserts so much that Band III coils may need readjustment to get them back on frequency again."

Indexing

"Ah, well," said Dick, looking affectionately at his little 10 watt Litesold. "That wouldn't happen to me. I'm one of the types who whispers 'dainty' every time I apply the iron!"

The Serviceman raised an incredulous eyebrow.

"Now, there's no point in nattering further about contacts," he said, ignoring his assistant's remark. "So let's carry on to the real fault in this tuner, which is its indexing."

"I'm all ears."

Again, Smithy refrained from comment.

"Now, the function of the indexing mechanism on a tuner", he continued, "is to ensure that the turret clicks firmly into position when a channel is selected, and that it stays there. There are, roughly, two main species of indexing mechanism. One employs a dirty great wheel which is really part of the turret drum and which has serrations around its edge corresponding to the channel positions. (Fig. 3 (*a*).) Against this wheel presses a roller on the end of a spring, the other end of the latter being fixed to the tuner chassis. Everything is of a solid and hefty nature, the spring being a lusty descendant of those lethal things which used to lurk in hand-wound gramophones. The second type of indexing mechanism, found in tuners where the coils are mounted radially on a disc instead of in a drum, is of a much lighter nature; and it consists of a smallish cog-wheel against whose teeth rests a spring-loaded lever and roller. (Fig. 3 (*b*).) Both indexing mechanisms have the same principle.

"Now, the cause of poor indexing such as we have here is usually a tired indexing spring. Whereupon the normal solution consists of removing the spring, bending it a bit in the desired direction and replacing it. You have to be rather careful about the bending operation because some indexing springs are brittle and tend to snap. So try and bend it over its entire length, rather than at any particular point. If the spring is past its useful life then it's necessary to fit a new one, which should be available from the manufacturers of the tuner. Alternative solutions consist of wedging the spring over in some manner so that it applies greater pressure, or of getting the portable blast furnace out and doing a spot of de- and re-tempering. However, these last two solutions seem to me to be rather more trouble than the repair is worth."

"Could other troubles cause poor indexing?"

"Now and again," said Smithy. "If you have a lot of friction between the turret spindle and the points on the chassis against which it bears, the indexing spring may be unable to overcome it and the turret won't click smartly into position."

"What about wear and tear on the turret spindle itself?"

"Well", said Smithy thoughtfully. "You *are* liable to get mechanical wear in some tuners when these have seen plenty of service. The wear is not always on the spindle, however. In a lot of tuners you have a mild steel turret shaft which rotates in V slots in the mild steel chassis. (Fig. 4 (*a*).) There are no true bearings as such and the consequence is that, after a considerable amount of use, the chassis slots tend to wear away. (Fig. 4 (*b*).) This wear is mainly in the same direction as the pressure applied by the indexing spring and it *could* be so bad as to cause the drum to be completely out of mechanical alignment with the tuner chassis; whereupon the only cure is to go out shopping for a new tuner unit. Mild wear must obviously reduce indexing pressure, if only for the reason that it allows the drum to shift that much further away from the indexing spring."

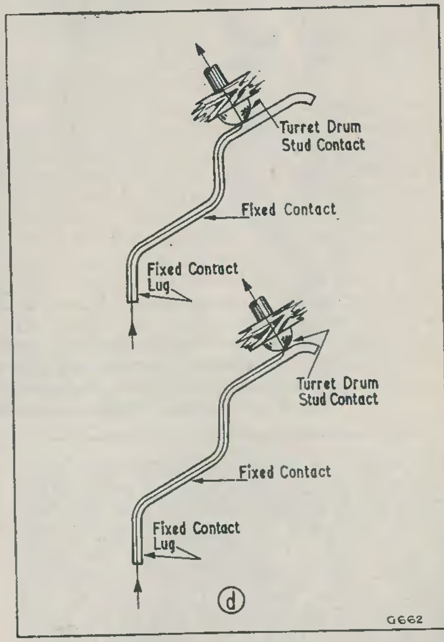


Fig. 1 (d) When poor indexing occurs in a turret tuner the coil stud contact may take up either of the two positions shown here. The arrowed line passing through the two sets of contacts demonstrates the differing amounts of inductance inserted

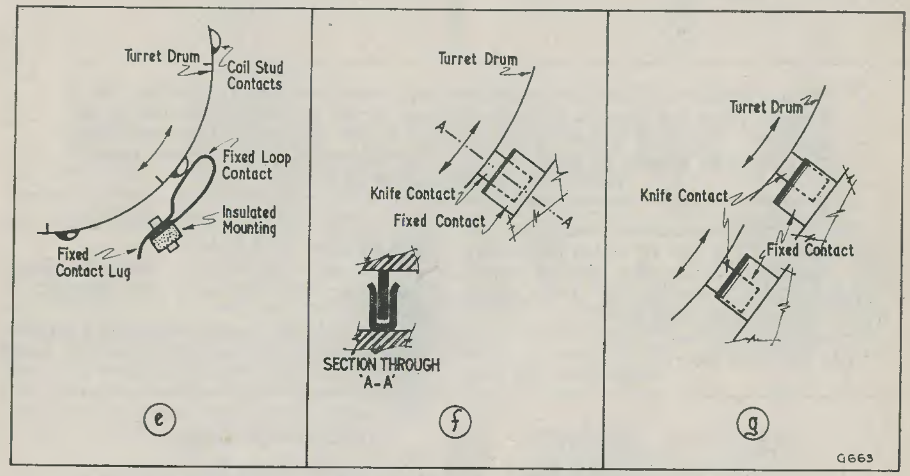


Fig. 1 (e) An alternative type of fixed contact which slightly reduces inductance changes as the stud wipes across it
(f) A knife contact, as employed in some turret tuners
(g) Despite the large difference in relative positions between fixed and moving contacts shown here, the inductance inserted by the contacts suffers little change

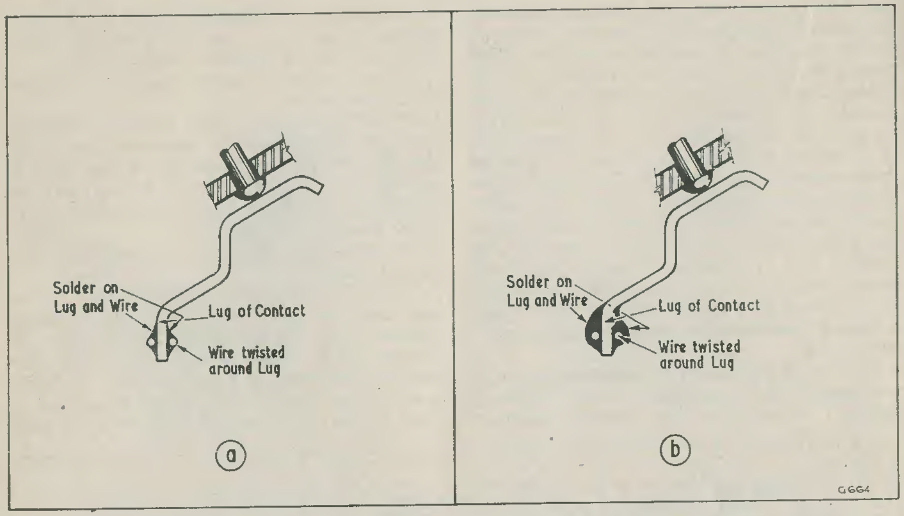


Fig. 2. Excessive differences in the quantity of solder on the fixed contact lug of a turret tuner can cause a significant change in the inductance inserted by the contacts. The small amount of solder in (a) results in a higher inductance than does the large amount of solder in (b). Both (a) and (b) show sections through the contact and its soldered connection

"Spindle friction and chassis wear," mused Dick slowly. "The first of which may cause poor indexing, whilst the second could eventually lead to the demise of the tuner. What's the solution, Smithy?"

"Lubrication, my lad!"

"Yes, but with *what?*"

"The best I can offer", replied Smithy, "is molybdenum disulphide."

"Ask silly questions", remarked Dick, "and you have no one but yourself to blame!"

"I'm perfectly serious," chuckled Smithy. "For bearing surfaces like those in tuner

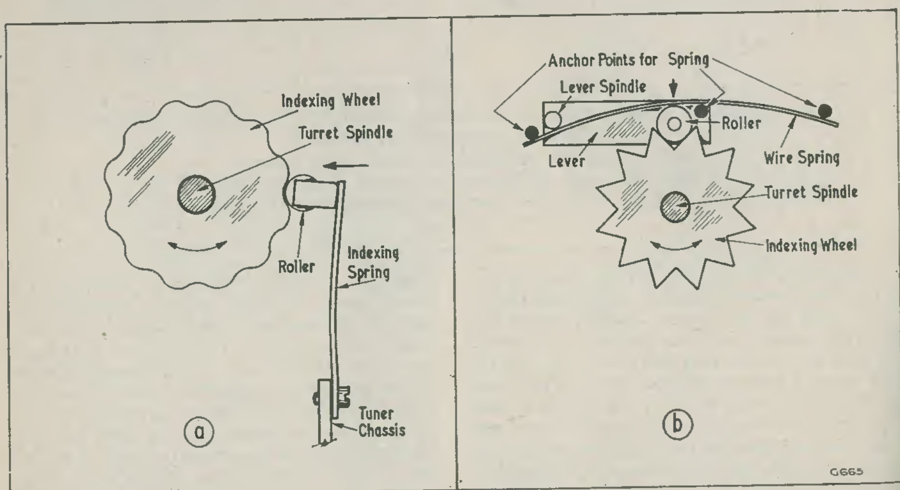


Fig. 3. Two types of turret indexing mechanisms. That shown in (a) is usually employed when the turret coils are fitted in a drum. The mechanism of (b) is used in tuners where the coils are mounted radially on a flat disc

units there's nothing to beat molybdenum disulphide. It's the slipperiest stuff known to man!"

"Perhaps so," protested Dick. "But you can't just go into the self-service and pick up a jar of moly-whatever-you-called-it straight off the shelf!"

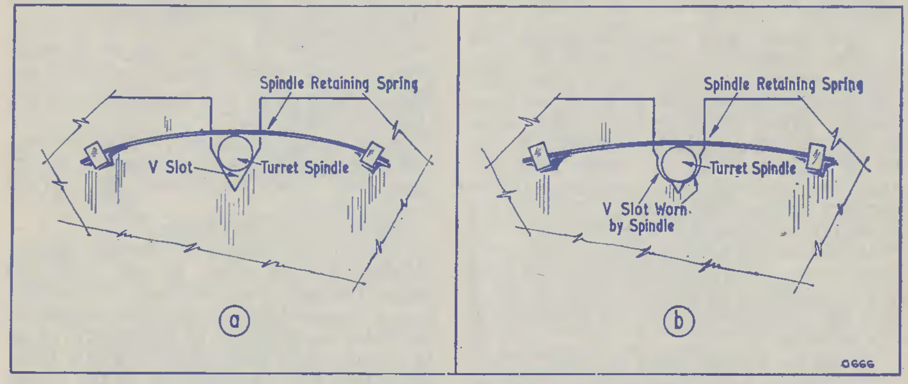


Fig. 4 (a) In most tuners the turret spindle fits into V-slots on the chassis, as shown here. The spindle-retaining spring normally applies light pressure, the heavy indexing spring elsewhere in the tuner providing the main pressure which keeps the spindle in the slot

Fig. 4 (b) After considerable use, the sides of the V-slot can become worn, causing displacement of the spindle

"You can get it in most large garages," said Smithy, "in a very convenient form known as anti-scuffing paste. You only want a tiny quantity because, for applications like tuner unit bearing surfaces, the merest smear gives complete lubrication. But you must make certain, when you buy the paste that it *is* a molybdenum disulphide compound."

Change of Subject

The Serviceman decided that he had dispensed enough information and prepared to return to his bench.

"Just a moment," said Dick, "I've got one more query only."

"Carry on."

"Well," said Dick. "What about striped slugs?"

"*Striped slugs!*"

"That's right," continued Dick, coolly. "Striped slugs. You referred to them the other day when we were talking about i.f. transformers, and I forgot to ask you what they were."

"That was a serious omission on your part," commented the Serviceman, his mind painfully making the change from turret tuners to i.f. transformers. "You know, you're certainly the boy for drastic changes of subject!"

"I've been curious about them for quite a little while now," Dick prompted him gently.

"I have no doubt," said Smithy drily. "Anyhow, there isn't very much to tell you about them.

"For many years," Smithy continued, "manufacturers have been attempting to find a coil former and dust core combination in which the latter can be adjusted easily without, in the first place, being so tight that it breaks, and without, in the second place, being so loose that it can fall out of adjustment due to vibration."

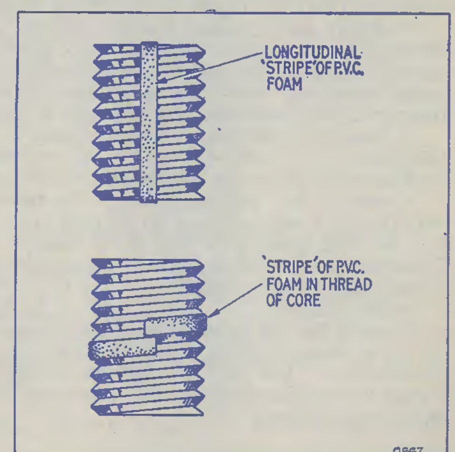


Fig. 5. A recent technique with dust core manufacture consists of fitting a bulky 'stripe' of p.v.c. foam either longitudinally or in a thread of the core

"It doesn't seem a very hard problem to solve," commented Dick.

"It isn't," replied Smithy, "until you start dealing with high speed coil assembly methods on production lines. And, don't forget that, like every other instance where one piece fits into another, acceptable dimensional tolerances have to be applied to both parts.

"The latest idea for overcoming this problem consists of 'striped' cores, or slugs. These are conventional dust cores with hexagonal adjusting holes to which are fitted narrow 'stripes' of p.v.c. foam either longitudinally along the length, or laterally in one of the threads. (Fig. 5.) These cores can then be inserted into moulded plastic formers with internal threads. The core and former dimensions and tolerances are such that, without the 'stripe', the core is always a loose fit in the former. The 'stripe' of foam p.v.c. then takes up the slack with the result that the core cannot slip due to vibration. It's as simple as that!"

"Why the different types of stripe?"

"So far as I know," said Smithy, "the first type to be tried out were the longitudinal ones. However, the inside of a former may not necessarily represent a perfect circle. With a non-circular internal section the torque needed to turn a core with a longitudinal 'stripe' tended to vary as the core rotated. This effect is irritating and doesn't occur with the lateral 'stripe'. So the lateral 'stripe' cores are those which have proved most popular amongst manufacturers in practice."

"I haven't seen any striped cores yet," remarked Dick.

"Probably not," replied Smithy. "If my information is correct they've only just started, in the last few months, to be used in large quantities. You'll be seeing them in mass-produced receivers soon, though."

"A funny thing happened to me recently," said Dick.

"On your way to the Workshop?"

"Come off it," protested Dick. "*In* the Workshop! I was adjusting an i.f. core in a t.v. set and thought it felt a bit funny. I unscrewed it out of the former and found it was made of aluminium."

Smithy nodded.

"Quite a few t.v. sets," he remarked, "use ali cores these days in some of their i.f. transformers. It's just one of the minor trends in component design you bump into from time to time."

Polystyrene Condensers

Once more Smithy prepared to leave Dick's bench, only to be forestalled.

"There's another component trend I've noticed for some time", remarked Dick, "and that's the increasing use of polystyrene condensers."

The Serviceman sighed.

"Dash it all," he said irritably. "How on earth am I going to get any work done this afternoon? What *about* polystyrene condensers?"

"Only that they seem to be used rather a lot these days," replied Dick lamely.

"That's perfectly true."

"And also," continued Dick, thinking quickly, "they seem to be used at higher and higher frequencies. I've found them in t.v. i.f. strips and so on."

"Polystyrene condensers", said Smithy, non-committally, "have a number of advantages over other condensers, and certain disadvantages."

"What are the advantages?"

"Their main advantage", replied Smithy, deciding that he might as well carry the subject through to its bitter end, "is that they have a fantastically high insulation resistance; this being in the region of 500,000MΩ or so. In consequence, when they were first introduced they were considered to be the answer to a hi-fi enthusiast's prayer for applications such as grid coupling condensers. Since that time, however, the prices of the lower capacity polystyrene condensers, say from 20 to 200pF, have become commensurate with those of silver-micas and ceramics. And that is why you find them used pretty extensively in t.v. i.f. coil assemblies and things like that where very high insulation resistances are not all that important."

Dick assumed his puzzled expression.

"What I don't understand," he remarked, "is how you can use polystyrene condensers in i.f. tuned circuits. They have a 'rolled' construction which must, surely, present a lot of inductance to the tuned circuit."

"They *do* have a 'rolled' tubular construction", affirmed Smithy, "in more or less the same manner that a paper condenser is made. That is to say, you start off with a long sandwich consisting of metal foil, dielectric film, metal foil, and dielectric film. When you roll this sandwich up you get a tubular condenser in which one metal foil constitutes one plate and the other metal foil the other. So far as I know, polystyrene condensers overcome the inductance snag by having the lead-out wires connect to the metal foils at a near-central point which is so positioned that the inductance between the connecting point and the centre balances out the inductance between the connecting point and the outside. At any rate, small polystyrene condensers are perfectly O.K. to use in tuned circuits up to at least 40 Mc/s or so. If they weren't, manufacturers wouldn't use them in t.v. i.f. strips! My own experience has been that, due to their high insulation resistance, they're a wee bit better, even, than silver-micas or ceramics. On a tuned circuit running around 38 Mc/s I've found that a polystyrene condenser gives an increase in Q of about 15% as compared with a ceramic or silver-mica of the same value."

"What about other advantages?"

"Well," said Smithy. "The lower capacity polystyrene condensers can be made very small in physical size, smaller even than ceramics or silver-micas of the same value—although not necessarily of the same voltage rating. Also, they have a low temperature coefficient—round about N120."

"Which means," said Dick dutifully, "that the capacity drops by 120 parts in a million for each degree rise in temperature."

"Centigrade."

"Centigrade. What about disadvantages?"

"Well, their main disadvantage is that they cannot stand up to high temperatures. It's inadvisable to operate them above, say, 65° C."

"I see," commented Dick. "Any special precautions whilst using them?"

"Not really. You should keep them away from sources of heat on a chassis, such as heater droppers and things like that. Don't touch their bodies with a soldering iron, as they're liable to melt with the heat. They're by no means so delicate, however, that they need heat shunts on the lead-out wires when you connect them into circuit, or anything like that. Oh, yes, and don't splash any polystyrene dope on to them, or you'll find that they dissolve!"

Catching Up

Yet again Smithy turned away. He was surprised, this time, to find his progress unimpeded. This was because his assistant, after a hasty glance at the clock, had started to clatter busily about the few utensils which constituted the Workshop's culinary effects.

"Ye gods," said the Serviceman wrathfully. "Here I've been half the afternoon wasting time nattering to you, and you rush into tea break as though you haven't a moment to spare!"

"Sorry, Smithy," said Dick, hastily opening a tattered book he had drawn from his pocket. "But I must catch up on the reading I missed at lunch time."

Smithy gazed at the book's cover but the scene, a kaleidoscopic complex of bludgeons, blood, bodies and barbed wire, caused him to hastily avert his eyes.

Sighing a little at his assistant's unsociable reading habits, Smithy took a sober, hard-cover, book from the drawer of his own bench and opened it at a page neatly indicated by a book-mark. Quietly, the Serviceman composed himself to read *Lady Chatterley's Lover*.

THE INSTITUTION OF ELECTRICAL ENGINEERS

FARADAY LECTURE 1960/1

The Faraday Lecture for 1960-1 is to be given by Mr. L. J. Davies, C.B.E., M.A., B.Sc., M.I.E.E., entitled "Transistors and All That".

Mr. L. J. Davies is Director in charge of Research and Education of Associated Electrical Industries (Rugby) Ltd., and a Director of Associated Electrical Industries Lamp and Lighting Co. Ltd. He is Chairman of Governors of the Rugby College of Engineering Technology, a Member of Council of the Electrical Research Association and a Past President of the Illuminating Engineering Society.

A list of the places and dates at which the lecture will be given is produced below. In each case admission is free, by ticket, obtainable from the address shown. A stamped and addressed envelope should accompany the request for tickets.

Rugby (Temple Speech Room), 16th November, 1960—J. Richmond, M.B.E., B.Eng., A.M.I.E.E., 53 Vernon Avenue, Rugby.

Bristol (Colston Hall), 8th December, 1960—D. Stephens, A.M.I.E.E., 7 Clovelly Crescent, Llanrumney, Cardiff.

Swansea (Brangwyn Hall), 13th December, 1960—C. Evans, A.M.I.E.E., 38 Old Road, Llanelly, Carmarthenshire.

Manchester (Free Trade Hall), 24th January, 1961—H. Diggle, B.Sc.Tech., M.I.E.E., Transformer Division, Associated Electrical Industries Ltd., Southmoor Road, Wythenshawe, Manchester 23.

Leeds (Town Hall), 26th January, 1961—J. Woodhouse, c/o Brush Electrical Engineering Co. Ltd., Scottish Union Building, 26 Park Row, Leeds 1.

Portsmouth (Guildhall), 14th February, 1961—H. W. Housley, A.M.I.E.E., 15 Southdown Road, East Cosham, Portsmouth, Hants.

London (Central Hall, Westminster), 16th February, 1961—The Secretary, The Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Birmingham (Town Hall), 28th February, 1961—J. C. Pyatt, A.M.I.E.E., Nechells "B" Power Station, Nechells, Birmingham.

Leicester (De Montfort Hall), 2nd March, 1961—W. L. Passant, A.M.I.E.E., Sales Specialist Switchgear Division, Brush Electrical Engineering Co. Ltd., Loughborough.

Edinburgh (Usher Hall), 21st March, 1961—D. R. Rollo, B.Sc.(Eng.), A.M.I.E.E., Bruce, Peebles & Co. Ltd., 26 Blythswood Square, Glasgow, C.2.

Newcastle (City Hall), 23rd March, 1961—R. Bruce, M.Sc., M.I.E.E., C. A. Parsons & Co. Ltd., Heaton Works, Newcastle-on-Tyne 6.

UNDERSTANDING TELEVISION

PART 34

By **W. G. MORLEY**

The thirty-fourth in a series of articles which, starting from first principles, describes the basic theory and practice of television

In last month's article we introduced the subject of line flywheel circuits. We saw that control of line sawtooth generator frequency by a d.c. voltage can be achieved by applying the control voltage to the appropriate grid leak of a blocking oscillator or multivibrator. An alternative method, wherein the control voltage is applied to a reactance valve in combination with a sine wave oscillator (whose output is later shaped to make it suitable for application to the grid of the line output valve) was also described. We further discussed the manner in which a control voltage may be obtained by comparing sawtooth generator frequency with sync frequency.

In this month's contribution we start by considering the manner in which a control voltage is obtained by comparing sync pulse frequency with that of a sine wave oscillator. After this we carry on to further aspects of television deflection circuits.

Obtaining a Control Voltage from a Sine Wave

The process of obtaining a flywheel sync control voltage by comparing the frequency of a sine wave with that of the line sync pulses is somewhat similar to that employed with sawtooth waveforms. In both instances, the control voltage is derived from the potential held by the waveform during the period when sync pulses are present.

Fig. 207 illustrates, partly in block form, a sine wave oscillator running approximately at line frequency, whose frequency is directly controlled by a reactance valve. The reactance valve functions in the manner already discussed[1] and it applies, effectively, a varying capacity across the oscillator tuned circuit. A control voltage is applied to the grid of the reactance valve. When this control voltage goes positive the effective capacity offered by the valve increases, causing oscillator frequency to drop; and *vice versa*.

Loosely coupled inductively to the oscillator tuned circuit is a secondary tuned circuit. This is adjusted to resonate at line frequency, and the outside terminals of its coil are connected to the cathodes of two diodes. High amplitude negative-going sync pulses, available, normally, at the anode of the sync clipper, are applied to the centre-tap of the coil. The anodes of the two diodes connect to the two equal-value resistors, R_5 and R_6, the junction of these resistors being returned to the centre-tap of the coil (to provide a d.c. circuit for the diodes) via the high-value resistor R_4. The anode of the lower diode is kept at a relatively steady potential by reason of the large value condenser C_5 in parallel with the resistance inserted between the slider of R_8 and chassis. The control voltage for the reactance valve is obtained from the anode of the upper diode.

In the presence of sync pulses the diodes conduct, allowing whatever sine wave voltage is present on their cathodes to appear at their anodes (less the small voltage dropped in the diodes themselves). Between sync pulses the diodes do not conduct, as their cathodes are caused to go positive by the positive-going sync clipper anode. (Conduction in the diodes causes the coupling condenser C_4 to take up a charge such that, whilst the diode cathodes follow the potential changes on the sync clipper anode, the most negative potential held by the cathodes is slightly negative of that on the anodes.)

In Fig. 208 (*b*), the sine wave has a higher frequency than that of the sync pulses. Because of this the sync pulse period corresponds to a later part of the waveform, and the potential appearing on the anode of the upper diode is positive of zero potential, and that on the anode of the lower diode negative of zero potential. Since the anode of the lower diode is held at a relatively steady potential, the anode of the upper diode goes positive of that potential by the sum of the two voltages appearing on the anodes.

In Fig. 208 (*c*) we have the case where sine wave frequency is lower than sync pulse frequency. This time the period of diode conduction occurs at an earlier part of the sine wave than it did in Fig. 208 (*a*), with the result that a negative voltage appears on the anode of the upper diode and a positive voltage on the anode of the lower diode. The anode of the upper diode now goes negative of the relatively steady potential on

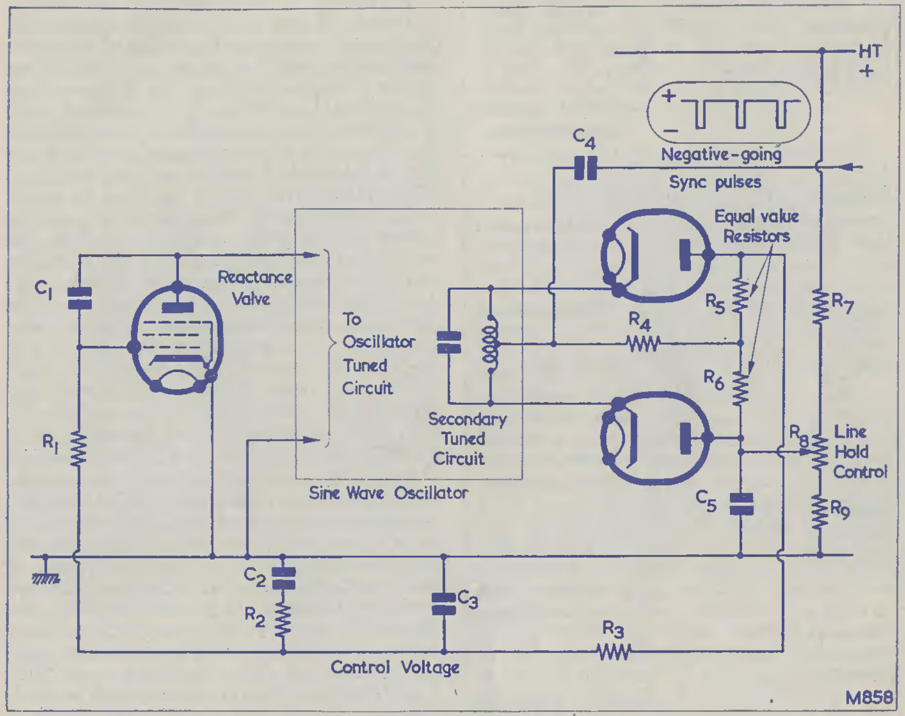


Fig. 207. A typical flywheel sync circuit incorporating a sine wave oscillator. The secondary tuned circuit resonates at line frequency and is loosely coupled inductively to the oscillator tuned circuit. The control voltage appears on the anode of the upper diode and is passed to the reactance valve grid via the time delay and "damping" circuit offered by R_3, C_3, R_2 and C_2

The waveforms in Fig. 208 illustrate the manner in which the circuit functions, Fig. 208 (*a*) representing the desired, central, instance. In Fig. 208 (*a*) the period in which the diodes conduct coincides with the time when the two sine waves applied to the cathodes have zero potential with respect to the centre-tap in the coil. In consequence, the anode of the upper diode holds the same potential as does the anode of the lower diode.

[1] In last month's article.

the anode of the lower diode by the sum of the two voltages.

Summing up the results given in Fig. 208 it may be stated that, when sine wave frequency is higher than sync pulse frequency the anode of the upper diode goes positive of the anode of the lower diode, and that when sine wave frequency is lower than sync pulse frequency, the anode of the upper diode goes negative of the anode of the lower diode. The control voltage is taken from the anode of the upper diode; and it is in the correct sense for application to the grid of the reactance valve of Fig. 207. When sine wave frequency increases the control voltage goes positive, with the result that the reactance valve offers increased effective capacity to the oscillator tuned circuit and oscillator frequency drops. The reverse effect takes place when sine wave frequency increases.

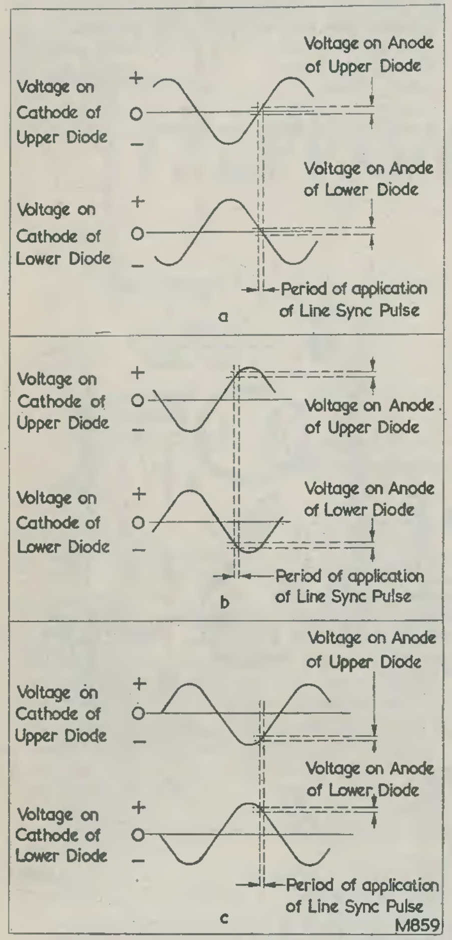


Fig. 208. *Waveforms illustrating the action of the circuit of Fig.* 207. *In* (*a*) *the sync pulse and sine wave frequencies are similar and the resultant phase relationship gives zero control voltage. In* (*b*), *sine wave frequency increases, resulting in a positive control voltage; whilst, in* (*c*), *a decreased sine wave frequency results in a negative control voltage. All waveform voltages are with respect to the centre-tap of the secondary tuned coil of Fig.* 207

According to the frequency relationship between the sine wave and the sync pulses, the control voltage on the anode of the upper diode goes positive or negative of that on the anode of the lower diode. At the same time the potential on the anode of the lower diode is that provided by the slider of potentiometer R_8. R_8 may, in consequence, be made the line hold control for the complete circuit. The flywheel sync circuit can then be set up initially by putting the slider of R_8 to the centre of its track and by adjusting the oscillator tuned circuit such that this resonates at line frequency. Under these conditions the reactance valve will be in the centre of its range of effective capacity change, and variations of control voltage will occur above and below the potential selected by R_8[2]. When, with time, valve characteristics and component values shift due to ageing, R_8 may be re-adjusted to bring the circuit back to the desired relationship of Fig. 208 (*a*).

It will be noted that, although the cathode of the reactance valve in Fig. 207 is returned to chassis, the potential offered by R_8 is always positive of chassis. At first sight, the impression might be given that the grid of the reactance valve is, therefore, always positive of chassis. In practice, however, the sine wave developed across the oscillator tuned circuit is applied to anode and cathode of the reactance valve and a leaky-grid effect (due to the anode-grid condenser C_1 and the resistance in the grid circuit) takes place at the grid, causing this electrode to take up a negative bias. The amplitude of this negative bias is then varied by carrying the positive potential applied by R_8 to the series resistors R_3 and R_1.

As is the case with flywheel sync circuits employing multivibrators and blocking oscillators, variation of the line hold control of Fig. 207 can cause alterations in phase relationship between the frequencies of the line sync pulses and the sine wave. The visible effect on the reproduced picture is the same as that which occurs in the previous instances: as the hold control is adjusted within the range over which flywheel sync is effective the reproduced picture moves bodily from left to right or right to left. An important point of the circuit of Fig. 207 is that differing phase relationships between the sine wave and the line sync pulses may also be caused by variations in the resonant frequency of the secondary tuned circuit coupled to the diodes. This is because the voltage across the tuned secondary of a loosely coupled transformer (as is given here) is only in phase with that across the primary when it is resonant at exactly the applied frequency.

[2] This assumes that component values in the circuit are such that the range of potentials offered by R_8 corresponds to the range of effective capacity variation of which the reactance valve is capable.

Line Hold Adjustment

The fact that adjusting the hold control of a line flywheel sync circuit causes alteration in the phase relationship between sawtooth generator and line sync pulse frequencies represents a slight disadvantage. This is because it is possible for line hold adjustments to mask the effects of incorrectly set-up picture centring devices. Before picture centring is attempted on a receiver with flywheel sync the line hold control should first be adjusted such that the picture is bounded on either side by equal amounts of signal at blanking level, the latter being made visible on the cathode ray tube by advancing brightness. (It may also be necessary to reduce width to bring the sides of the raster within the edges of the screen.) The picture centring device may then be set up, at normal brightness (and width) settings, in the conventional manner. When a receiver is set up in this manner the line hold control becomes capable of correct adjustment by a non-technical person, who merely adjusts it for a locked, centralised, picture.

As an aid to correct adjustment of the line hold control push-button switches are fitted to some receivers which temporarily disable the flywheel sync circuits. Such push-buttons may be used with diode comparator circuits and they function by short-circuiting the control voltage to a point at central potential. Thus, in Fig. 203,[3] the control potential could be short-circuited to chassis, or, in Fig. 207, to the slider of R_8. The line hold control is adjusted with the push-button depressed for correct line frequency (as shown by a properly resolved picture on the screen), after which the button is released. The flywheel sync circuit then takes over, providing the desired phase relationship between sawtooth generator and line sync pulse frequencies.

Pull-In

The term *pull-in* defines the ability of a flywheel sync circuit to come into synchronism when a signal, whose sync pulse frequency differs from that of the sawtooth generator, is suddenly applied to it. Speaking in very general terms, the pull-in range of a flywheel sync circuit is inversely proportional to its susceptibility to impulsive interference. However, pull-in range must not be made too small or the flywheel sync circuit is liable to fall out of synchronism due to sudden shifts in sync pulse frequency in the received signal (caused by shifts at the transmitter or on changing channel to an alternative transmitter). Also, a circuit with a low pull-in range may not be capable of coming into synchronism when the associated receiver is switched on after a period of disuse. It is usual to design for a compromise, and pull-in ranges of some 400 to 800 c/s on either side of sawtooth generator frequency appear to be fairly typical of current British practice.

[3] Published in last month's issue.

Time Constant

The time delay offered in a flywheel sync circuit, and which provides the essential flywheel action, is usually described as its *time constant*. The time constant offered in different flywheel sync circuits may vary between the period occupied by several lines and several hundred lines. Whilst flywheel sync circuits having long time constants are somewhat less susceptible to impulsive interference than those having short time constants, they suffer from the disadvantage that they cannot adapt themselves as quickly to sudden changes in line sync pulse phase and frequency at the transmitter. This effect is especially noticeable with programmes recorded, as video signals, on tape. Such tapes carry complete synchronising information, and slight discrepancies in line sync pulse spacing and the associated lines of picture information are liable to occur due to small mechanical irregularities in the recording and playback processes. The effect on receivers employing flywheel sync circuits with long time constants is the occasional displacement of groups of lines to left or right of their correct position in the reproduced picture. This effect is usually described as "line jitter".[4]

Frame Flyback Suppression

Frame synchronising signals are transmitted at the end of each frame in the television signal in order to initiate flyback in the frame sawtooth generator of the receiver. At the same time, the video signal amplitude drops to a level which is at no time higher than blanking level. The result is that, in a perfect receiver, the cathode ray tube beam should always be cut-off during the frame flyback period, and no visible signal should appear on the screen.

[4] "Line jitter" also describes the case where, due to fault conditions, the receiver sawtooth generator output suffers intermittent changes in frequency or phase.

In practice it is difficult to design an economic receiver such that the cathode ray tube beam is completely cut-off at blanking level. One reason for this is that blanking level is only a little lower than black level (in the British 405 line system it is only 5% of peak white level below) and it is difficult for non-technical people to obtain a brightness control setting which enables signal levels very slightly above black level to appear on the screen whilst allowing blanking levels to result in cut-off of the beam. If a.c. coupling is employed in the video circuits of the receiver a brightness control setting meeting the requirements just mentioned becomes impossible to achieve, because the blanking level on the signal applied to the modulating electrode of the cathode ray tube varies according to the average voltage of the complete video waveform. Partial d.c.

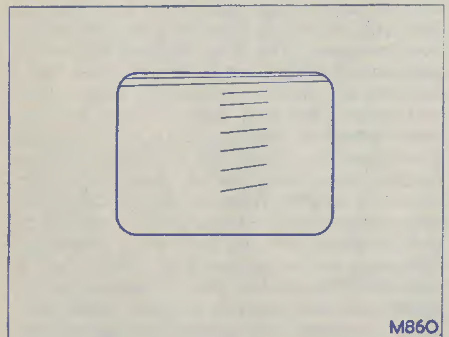


Fig. 209. If the cathode ray tube beam does not cut-off at blanking level, the frame blanking period may cause lines similar to those shown here to be formed during frame flyback. This diagram is intended to be illustrative only; practical examples may have fewer or more lines as well as different spacing and positioning

couplings in the video circuits may similarly make the requisite brightness control setting difficult, if not impossible, to achieve.[5]

Unless special precautions are taken, therefore, it is possible for the cathode ray tube not to be cut-off during at least part of the frame flyback period. A typical instance of what may then occur is given in Fig. 209, which illustrates the results possible on the screen of a receiver working in the British 405 line system. It is assumed, in this diagram, that the cathode ray tube is not cut-off at blanking level, but is cut-off at synchronising signal level (30% of peak white level lower, at the sync pulse tips). It is also assumed that frame retrace is quicker at the beginning of the flyback period than at the end. In the lower part of Fig. 209 we see a number of short lines positioned, approximately, in the centre of the screen. These lines are given by the short periods at blanking level which occur between broad frame pulses, and their sloping nature is due to the fact that the frame deflection circuits cause the beam to be deflected upwards whilst the still-running line deflection circuits cause it to be deflected from left to right. Higher up the screen, the short lines give way to complete lines. The latter are given by the complete lines at blanking level which are transmitted after the broad frame pulses. It is interesting to note that both the short and long lines are provided alternately by the even and odd frame blanking periods. The number of short lines which can appear depends upon whichever broad frame pulse causes the actual initiation of frame flyback, whilst the number of complete lines which can appear at the top of the screen depends upon the time when the retrace period comes to an end. It will be seen that the line spacing reduces as the beam moves upwards, this being due to the fact, assumed above, that retrace is quicker in the earlier part of the flyback period.

In order to overcome the possibility of lines such as those shown in Fig. 209 appearing on the screen of a television receiver it is conventional practice to apply *frame flyback suppression pulses* to one of the modulating electrodes of the cathode ray tube. Almost always, the pulses are applied to an electrode other than that used for video signal modulation. Therefore, should the cathode ray tube be cathode modulated, as is normally the case, such pulses are usually applied to the grid.[6] The pulses have a polarity which causes the cathode ray tube to be completely cut-off during the frame flyback period. Thus, frame flyback suppression pulses applied to the grid of a cathode are negative-going. Also, they should have a duration which is equivalent to the flyback period of the frame deflection circuits. Too short a duration may allow some of the lines shown in Fig. 209 to appear on the screen, whilst too long a duration may result in suppression of the first lines carrying picture information in the subsequent frame.

It is usual to derive frame flyback suppression pulses from the frame output transformer, where high-amplitude pulses of the desired duration normally appear. Since the anode of the frame output stage goes positive during the flyback period, negative-going pulses are normally obtained by means of an additional winding on the transformer, as in Fig. 210 (*a*), or by means of suitably connecting the secondary, as in Fig. 210 (*b*). The pulses are applied to the cathode ray tube electrode by a resistance-capacity network which provides attenuation and some shaping. Such a network also provides a low impedance between the cathode ray tube electrode and chassis at the higher video frequencies in order to prevent attenuation of such frequencies due to the internal capacity between that electrode and the modulating electrode.

[5] A.C. and partial d.c. couplings were discussed in "Understanding Television" part 21, October 1959 issue.

[6] Occasionally, they are applied to the first anode of a cathode modulated tube.

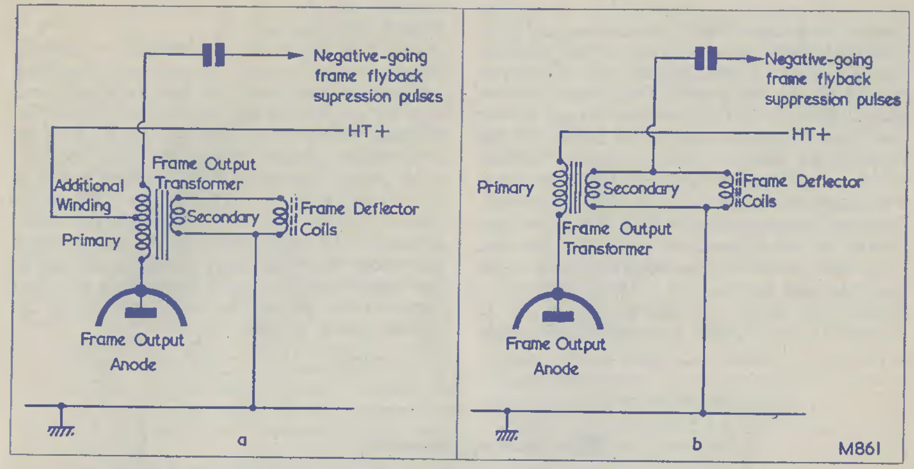


Fig. 210. Frame flyback suppression pulses are usually derived from the frame output stage. Two typical basic methods of obtaining negative-going suppression pulses are shown here

Line Flyback Suppression

During the line flyback period the transmitted signal changes from synchronising signal level to blanking level when the line sync pulse comes to an end, and it remains at this level for an appreciable period before the commencement of the following line of picture information. The end of the line sync

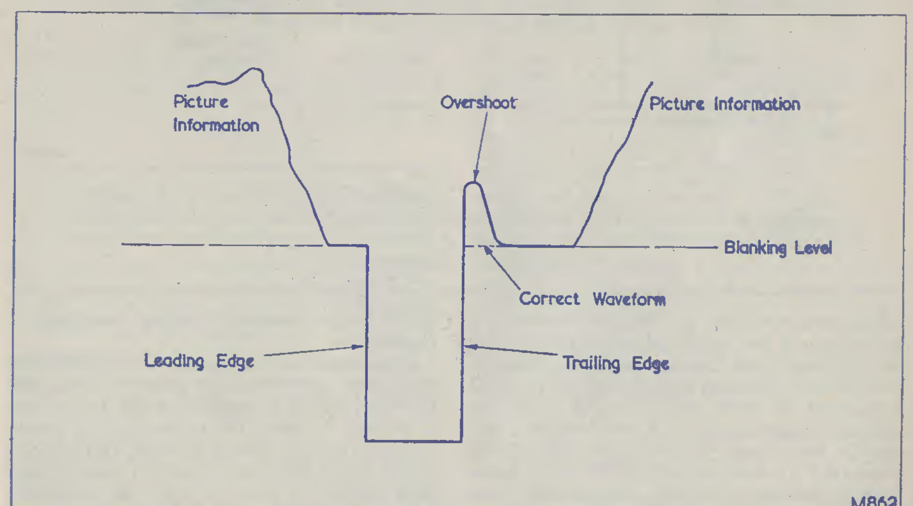


Fig. 211. Illustrating overshoot after the trailing edge of a line sync pulse. (The shape of the pulse is idealised)

pulse will normally occur during the retrace period at a time when the beam has been deflected some two-thirds of its way back to the left. Even if the cathode ray tube is not cut-off at blanking level, the resumption of blanking level during the line retrace period does not cause any noticeable effect on the reproduced picture. This is mainly because of the high speed with which the beam traverses the screen. A visible effect can, however, appear on the screen if, due to conditions at the transmitter or in the receiver, overshoot occurs at the end of the sync pulse, as illustrated in Fig. 211. The overshoot, if sufficiently large and sharp (i.e. short in duration) may cause perceptibly increased brightness, resulting in the appearance of a faint vertical line visible when pictures of low overall brightness are reproduced. The line is especially noticeable because, due to small variations in sync pulse length and line sawtooth generator flyback initiation, it is not steady but tends to fluctuate slightly in position.[7] In order to obviate the effect some recent British receivers incorporate line flyback suppression in addition to frame flyback suppression.

In line flyback suppression circuits, suppression pulses may be obtained from any convenient point in the line timebase and may be applied to the same electrode of the cathode ray tube as are the frame flyback suppression pulses. Since the only requirement of the line flyback suppression pulses is that they cause the cathode ray tube to be cut-off when the overshoot occurs, their duration and shape are relatively unimportant provided that they have good amplitude at the time when overshoot takes place and that they do not extend beyond the end of the line blanking period.

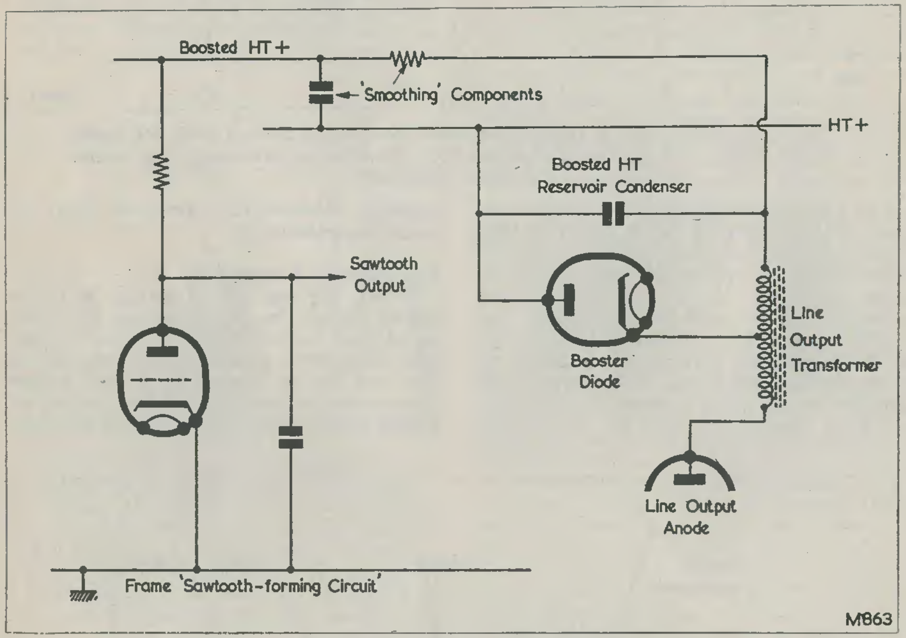


Fig. 212. The resistor of the frame "sawtooth-forming circuit" is frequently returned to the boosted h.t. positive supply instead of to the normal h.t. positive rail. This method of connection provides a measure of compensation for variations in picture height due to changes in e.h.t. voltage

[7] The term "rope" has been applied to this effect in some laboratories, since the appearance of the line is reminiscent of a wavering hanging rope.

"E.H.T.-Compensated" Frame Sawtooth Generators

If, whilst constant line and frame deflecting forces are applied to the beam of a cathode ray tube, the e.h.t. potential at the final anode is caused to drop, the raster on the screen increases in size. This is because the electrons in the beam travel at a reduced velocity and take longer to pass through the deflecting field, whereupon they suffer greater deflection. The effect is sometimes described as "blooming", and it is especially noticeable when the e.h.t. voltage falls below the minimum figure specified for the cathode ray tube.

Since e.h.t. voltage tends to drop as e.h.t. current increases, it becomes possible for a reproduced picture to perceptibly expand in size when the depicted scene changes from a low to a high brightness level, and vice versa. This effect is not very troublesome in receivers having reasonably well-regulated e.h.t. supplies. Nevertheless, it is fairly common practice to provide some simple form of compensation. Such compensation is employed in the frame timebase only, as the line timebase automatically provides a degree of compensation on its own account. In the latter case, increased e.h.t. current loading on the line output stage causes a drop in boosted h.t. voltage and, in consequence, a drop in the deflection current in the line deflector coils.

Compensation of the frame timebase is achieved by the simple process of returning the resistor in the "sawtooth-forming circuit" of the frame sawtooth generator to the boosted h.t. positive supply instead of to the normal h.t. positive rail.[8] (See Fig. 212.) When, due to an increase in e.h.t. current, e.h.t. voltage drops, the consequently reduced boosted h.t. voltage causes a drop in frame sawtooth amplitude and a compensatory reduction in frame deflection current. The reverse effect takes place when e.h.t. voltage increases.

Connecting the resistor in the frame "sawtooth-forming circuit" to the higher potential offered by the boosted h.t. positive supply has the secondary advantage of providing improved sawtooth linearity.[9]

It is important to ensure that the "smoothing" components in Fig. 212 have a relatively high time constant. Otherwise, abrupt changes in boosted h.t. voltage can cause momentary shifts of the frame scan up or down the screen of the cathode ray tube until the "sawtooth-forming circuit" settles down to its new supply potential.

Next Month

We have now completed our consideration of the deflection circuits employed in the television receiver. In next month's article we shall carry on to automatic gain control circuits.

[8] This method of connection was briefly referred to in "Understanding Television" part 26, March 1960, on page 590.

[9] This point was shown in "Understanding Television", part 22, November 1959 issue.

CAN ANYONE HELP?

Requests for information are inserted in this feature free of charge, subject to space being available. Users of this service undertake to acknowledge all letters, etc., received and to reimburse all reasonable expenses incurred by correspondents. Circuits, manuals, service sheets, etc., lent by readers must be returned in good condition within a reasonable period of time

Receiver Type BC348Q.—F. Inglis, 39 Melville Street, Kilmarnock, Ayrshire, would like to borrow, or preferably purchase, the official manual of this American Army Signal Corps receiver, or any information on its circuitry. Also required is the manual for the Army WS18 set, Mk. III, walkie-talkie.

* * *

Oscilloscope Type TS34-AP.—J. R. Tilsley, "Penwartha", Hafodty Lane, Upper Colwyn Bay, N. Wales, requests the loan or purchase of the handbook or circuit diagram for this ex-Govt. oscilloscope. Also details of any modifications.

* * *

Elon JC20 Tape Recorder.—H. Wright, 7 Kempton Street, Cantley, Doncaster, requires the circuit diagram for the above recorder. This was published in the September 1959 issue (now out of print) of *Tape Recording and Hi-Fi Magazine*.

* * *

H.M.V. TV Model 5806 (or 1806 or 2806?).—L. Robson, 3 Lambaurn Avenue, Forest Hall, Newcastle on Tyne 12, wishes to obtain, and will gladly purchase, the circuit and/or service data of this televisor.

* * *

Geloso G255 Tape Recorder.—AB. R. T. Winter, C/J942466, 4 Mess, H.M.S. *Eastbourne*, c/o G.P.O., London, would urgently like to purchase or borrow the circuit diagram.

* * *

Beam Echo Stereo Amp. SPA21 and Beam Echo Tuner BM611.—B. Chappelow, 36 Woodlands Road, Willerby Road, Hull, would like to obtain the manuals of these equipments, borrow or purchase.

Armstrong TV5 14-inch Televisor.—R. F. Gilbert, 1 Hillside, Kingstamerton, Plymouth, Devon, would like to buy or borrow the service sheet or any information on this model by Armstrong Radio.

* * *

Receiver Type R1224A.—W. J. Mullarkey, 59 Brompton Road, Manchester 14, would like to receive any information, circuit, etc., of this receiver.

* * *

Bendix Radio Compass MN26C.—R. K. Lloyd, Box 1164, Lusaka, Northern Rhodesia, urgently requests any data, or the circuit diagram, of this equipment.

* * *

"Major-Seven" Transistor Portable Receiver.—W. H. Rees, 57 Belmont Road, Bushey Grove, Watford, Herts., would like to hear from anyone who has had experience with this kit.

* * *

Receiver 1355.—G. A. O'Dowling, 28 Kylemore Lane, Greenock, Renfrewshire, would like details of h.t. and detector modifications to this receiver for mains input and audio output using RF Units.

* * *

Collins TCS Receiver.—A. Jaques, 185 Bispham Road, Blackpool, would like to borrow, hire or purchase, the manual for this receiver.

* * *

"Universal" Televisor.—E. H. Atkins, 46 Old Farm Road, Mancetter, Atherstone, Warks., would like to trace a retailer currently stocking the line output transformer LOT/1, Denco (Clacton) Ltd. now having ceased production of this component. Alternatively can any reader advise a rewinding service.

LONG DISTANCE TV A Report on Exceptional DX Reception

IT MIGHT BE THOUGHT THAT, TO RECEIVE television signals regularly from the Continent, it would be necessary to employ a specially designed ultra-sensitive receiver together with a multi-element aerial sited in as high and advantageous a position as possible. But this does not seem to be so. In Buckingham, Mr. I. C. Beckett, an 18 year old service engineer, receives pictures regularly from Spain, Portugal, Italy, Hungary, Czechoslovakia, Russia, West Germany and Sweden. He achieves this with a standard domestic receiver modified for 625 line reception in the simplest of manners, and with a standard Channel 1 "H" aerial.

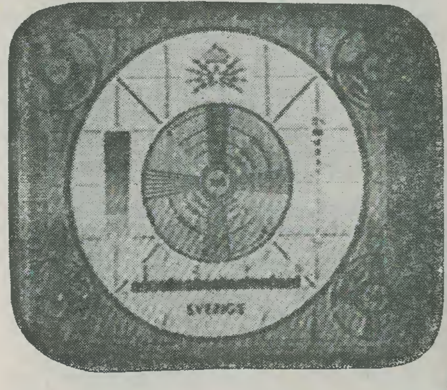
As the result of a report received from Mr. Beckett, the writer went to Buckingham recently to investigate the results obtained. During the afternoon of the visit Mr. Beckett switched on his receiver, to reveal a blank screen displaying noise only, together with black spots and lines given by interference from vehicles in the street outside. After some ten minutes, faint information became visible. "There's something coming in now", said Mr. Beckett confidently. And so there was. Within another five minutes the signal strengthened and locked in, and the writer found himself looking at Test Card G with the word BUDAPEST along the bottom. This faded shortly afterwards only to reappear again at such strength that contrast had to be backed off by a considerable amount. Later on in the afternoon the Budapest signal faded out, to be followed by an Italian picture at lower strength.

Heading illustration
Caption Spain, 19th July 1960. 48.25 Mc/s. Programmes received from 3.10 to 4.11 pm BST.

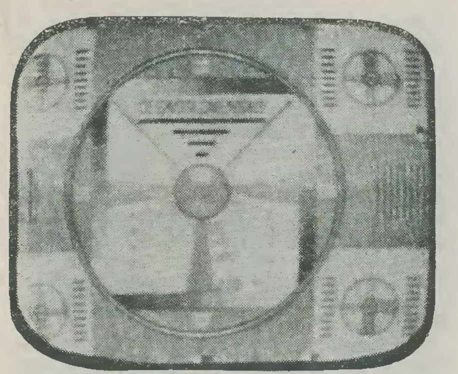
Reception of this type has occurred on almost every day that Mr. Beckett has switched on his receiver since he initially modified it on 15th May, 1959. Mr. Beckett says that signals appear at any time, although 10 to 12 o'clock in the morning and 3 to 6 o'clock in the afternoon appear to be slightly more favourable than other times. These facts are fully borne out in the careful log which has been kept by Mr. Beckett and by Mr. J. Barge, who helped with the original experiments.

Equipment

The receiver used is a standard Philips domestic model type 1768U modified for 625 line reception. This employs the following line-up to the video detector: PCC84 cascode r.f. amplifier, PCF80 oscillator and mixer,



Test Card, Sweden, 7th June, 1960. 62.25 Mc/s

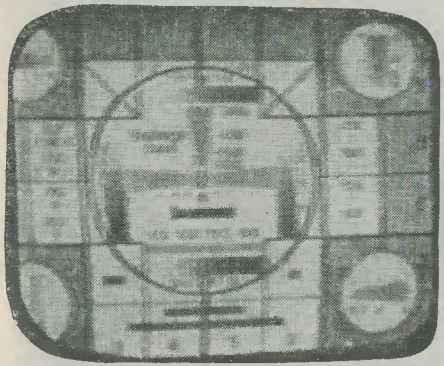


Test Card, Czechoslovakia. 3rd June, 1960. 49.75 Mc/s

EF80 first video i.f. amplifier, and EF80 second video i.f. amplifier. The first two valves are in the turret tuner unit, which is set up for British channels. The second video i.f. amplifier feeds into a conventional OA81 video detector, the detected signal being applied to the video output valve and, thence, to the c.r.t. and sync separator. A.G.C. is taken from the grid of the sync separator.

One of the modifications to the receiver consists of the reversal of the video detector diode, thereby enabling negative modulation pictures to be correctly resolved on the screen and allowing sync pulses of correct polarity to be fed to the sync separator.

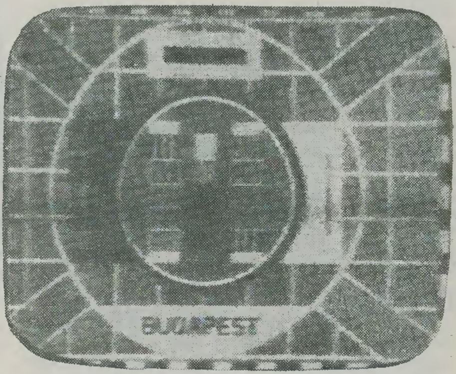
The line timebase of the receiver employs a PCF80 triode with a PL36 line output valve in a multivibrator arrangement, feedback from the PL36 anode to the triode grid being obtained from a tap in the line output transformer anode winding. Line frequency is controlled by a variable leak in the triode grid circuit, this consisting of a 1MΩ potentiometer and a 330kΩ fixed resistor in series. The frequency of the line timebase has been increased for operation with 625 line signals by the simple expedient of shunting a second 330kΩ resistor across the existing fixed resistor of the same value.



Test Card, Russia. 1959. 49.75 Mc/s

These are the only circuit modifications carried out on the receiver. All tuned circuits in the i.f. strips and in the turret tuner have been left as they are. Since the fine tuner in the turret does not have sufficient range to bring in signals which are roughly central between British channels, Continental transmissions are tuned in by adjustment of the oscillator core. Such adjustment is available through holes in the channel selector knob, this being a standard setting-up facility with the receiver.

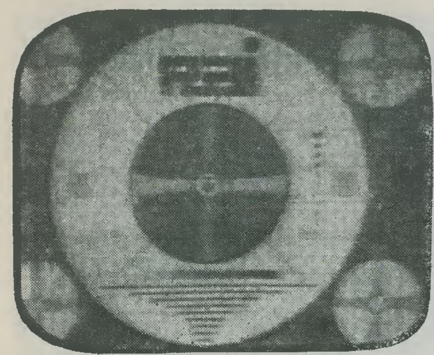
The modified Philips receiver is installed on the premises of Messrs. A. C. Marriott, radio dealers, of Castle Street, Buckingham. Mr. Beckett has also received Continental signals at his home at Twyford several miles away. In this case the receiver is an Ultra



Test Card, Hungary. 19th July, 1960. 49.75 Mc/s

model W80MF modified for Band I and Band III reception by having its front end replaced by a Cyldon turret tuner. Mr. Beckett picks up all his signals on Band I and this tuner contains all Band I coils. The video detector in this Ultra receiver is one half of an EB91, and negative modulation signals are received by reversing this diode with the aid of an adaptor. The line timebase has been modified for 625 line operation by selecting a value for the line hold control series resistance which enables both 625 and 405 line signals to be synchronised. Again, signals lying between British channels are tuned in by adjustment of the oscillator core.

The aerial employed at Buckingham is a standard Belling-Lee Channel 1 vertical "H", mounted some 10 feet above roof level of the 3-storey premises of Messrs. A. C. Marriott. The aerial at Twyford is a standard Belling-Lee Channel 4 vertical "H". This is



Test Card, Italy. 1960. 53.75 *Mc/s*

fitted approximately 8 feet above chimney level on a 2-storey house.

Camera

Photographs of received pictures are taken direct from the c.r.t. screen. The camera used is an Ilford "Sportsman" with "Vario" lens. Aperture and shutter speed settings are 2.8 and 1/50 sec. respectively. Focus is set to 3½ feet, from which distance all photographs are taken. The film is Ilford HP3. The camera is held in the hand whilst photographs are being taken, no tripod being employed. It is found convenient to have the room in which photographs are taken as fully blacked out as possible.

Picture Quality

The photographs accompanying this article have been chosen from a very large selection held by Mr. Beckett. Test and caption cards, rather than programme material, have been singled out, as these allow ready identification of source.

It will be seen that, in all the photographs

Programme, Italy. 9th July, 1960. 53.75 *Mc/s*

reproduced here, horizontal definition is rather low, this being obviously the result of employing an unmodified 405 line i.f. strip. There is, also, foldover on the left hand side. This latter is due to the simple nature of the line time-base modifications. (A retrace time suitable for the British blanking period, after the leading edge of the line sync pulse, of approximately 16.5μS is too long for the equivalent 625 line blanking period of approximately 10μS.)

Patterning is evident on some of the pictures. The cause of this is not known.

Sound Reception

Although his receivers are not modified for f.m. sound reception, Mr. Beckett has still obtained reception of the sound accompanying the Continental video signals. The quality of such signals is surprisingly acceptable, discrimination presumably taking place on the skirts of the sound i.f. response

Caption, Spain. 19th July, 1960. 48.25 *Mc/s*

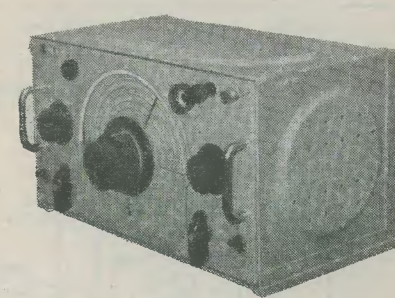
curve. Since the Continental sound carriers are above the vision carriers in each channel (whereas British sound carriers are below), it is impossible to receive the sound and vision signals of a single channel simultaneously on the modified receivers.

Television DX

This report has given details of what seems to be almost phenomenally good television Dx. And yet none of the equipment employed is in any way unconventional. Indeed, one of the receivers can be modified from 625 line back to 405 line operation merely by removing an adaptor.

The Radio Constructor would be interested to hear of any other instances of long distance t.v. reception. Where possible, brief details of such reception may be published in future issues.

The R1155 as a General Purpose Receiver



By D. Easterling **Part 1**

THE R1155 RECEIVER IS A COMPREHENSIVE communications set, used by the R.A.F. during the last war with some probably still in service. After the war many came on to the surplus market, rapidly becoming popular with Short wave listeners and filling a gap until new and more specialised equipment was available. Fifteen years later R1155's are still obtainable at various prices according to their condition, and although less suited to amateur band operation than the specialised types now in favour among enthusiasts, they are still a good buy for a workshop receiver; or, for the serious broadcast listener who wishes to supplement f.m., as a means of receiving foreign stations through all the clatter now inhabiting the bands, when conventional broadcast receivers fail miserably.

Unmodified, the R1155 receiver is a superhet having ten valves including the magic eye tuning indicator. The line up is as follows:

- Pentode r.f. stage.
- Triode-hexode frequency changer (oscillator-mixer).
- Two pentode i.f. stages.
- Double diode triode detector and a.f. output stage.
- Double diode triode a.g.c. and b.f.o.
- Three stage direction finding circuit.

No internal power supply unit is fitted, and the output stage is suitable for headphone use only; thus usual modifications concern the removal of the unwanted d.f. stages, and the introduction of suitable power and output stages. The simplest method of overcoming these problems is to construct a separate external unit which provides both the required facilities and which can be plugged into one of the Jones sockets on the front of the receiver, the unwanted d.f. circuits being simply ignored. This scheme was originally used by the writer, but recently some maintenance had to be carried out and it was then decided to remove all unwanted circuits (a source of spare components), using the space provided to mount the power and output sections. At the same time, the receiver's general appearance was improved by fitting a new front panel over the existing one and drilling only the required control apertures, some of these controls being moved to produce a more symmetrical layout. On completion of this work, results exceeded expectations, and it was decided that although the subject has been covered by other writers in the past, the modification might be of interest to constructors who have missed these previous articles.

Before proceeding with the process of modification it may be as well to discuss general circuit details.

Fig. 1 shows the circuit after modification. It will be seen that the aerial socket is connected to two leads, each going via a condenser to a separate wiper in the wavechange switch assembly. Originally, these leads were kept completely separate, with the lead from C_1 going to a fixed aerial on the aircraft, and used for the top three frequency ranges; while that from C_2, used with a long trailing aerial, connected to the two low frequency ranges. Connecting them together, therefore, enables one aerial system to be used for all bands. In addition to the above there was also provision for a low impedance d.f. loop, but this is now ignored.

Focusing attention to the tuning heart (shown enclosed by the broken line), it will be realised that in the receiver this is contained in the long rectangular metal housing below chassis at the rear, with associated valves and r.f. transformers mounted ir mediately above. The tuning heart ci illustrated is, of course, a simplified with the coils of only one range show with certain filters and coil shorting ci

rrange-
the

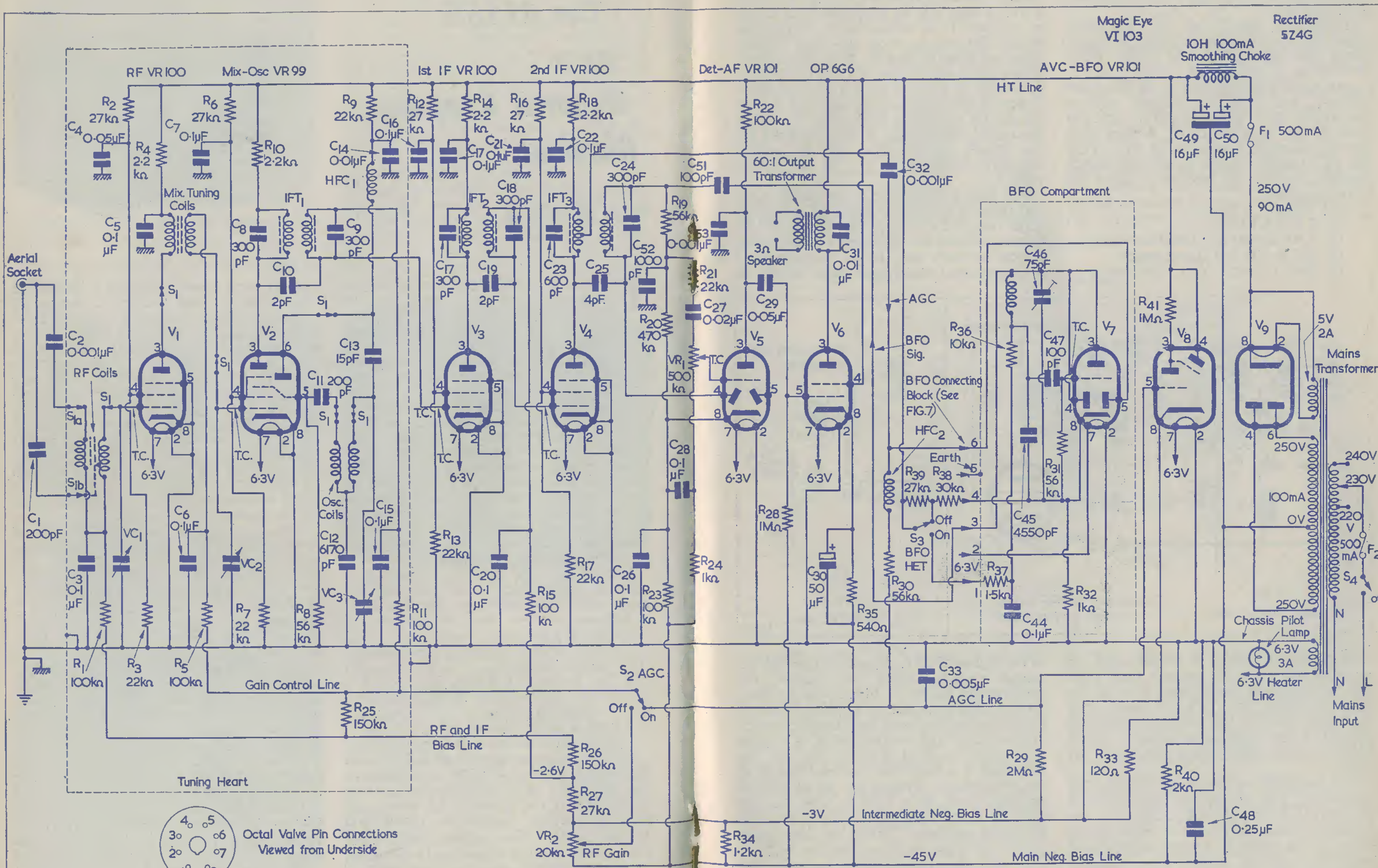


FIG.1.
Circuit of the R1155 after modification

Prog

...d. It is felt that a simplified circuit is justified in this case, as the interior of the unit plays no important part in the modification procedure.

Transformer input on low frequency ranges, and tapped grid coils on the higher ranges are features of the aerial input connections to V_1, the r.f. stage. The r.f. stage is transformer coupled to the frequency changer, V_2; with the hexode section functioning as a mixer-amplifier and the triode as the local oscillator. A three-gang tuning condenser, consisting of VC_1, VC_2, and VC_3, together with a wavechange switch assembly, enables the receiver to cover the following ranges:

(1) 18.5 to 7.5 Mc/s.
(2) 7.5 to 3.0 Mc/s.
(3) 1,500 to 600 kc/s (Medium wave).
(4) 500 to 200 kc/s (Long wave).
(5) 200 to 75 kc/s (Very Long wave).

being applied to the grid of V_5 triode acting as the first a.f. amplifier. The original system, however, is shown in Fig. 2, where it will be seen that an additional filter could be switched in to reduce audio frequencies below 300 c/s in order to limit locally generated noise in aircraft. With the original arrangement, also, the output was taken from the anode of V_5 via a small 1:1 transformer to one of the Jones sockets, and had a level suitable for headphone operation. The above mentioned transformer is now replaced by the anode load resistor R_{22} to permit capacitive coupling via C_{29} to the output valve V_6.

The 6G6 output stage is completely new, and replaces the double triode d.f. switching stage originally occupying the position. Output suitable for operating a loudspeaker is now available and, for an impedance of 3Ω, the output transformer ratio should be

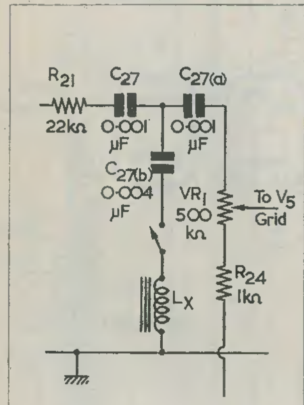


FIG.2
Bass Filter Circuit

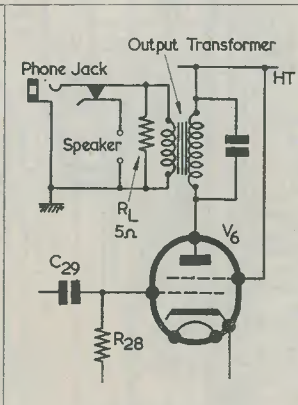


FIG.3
Fitting a Phone Jack

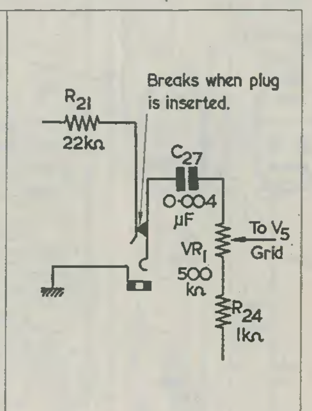


FIG.4
Inserting P.U. Jack

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Of particular interest to constructors are receivers with the suffix letters L (steel case) and N (aluminium case) since, in these, the frequency range 200 to 75 kc/s which is of very little use to the average listener is omitted, a new range covering the 3 to 1.5 Mc/s (Trawler Band) being inserted in its place.

The remainder of the circuit is illustrated completely, and shows two i.f. amplifiers (V_3 and V_4) feeding, via i.f.t.3, the demodulator circuit of V_5 and the a.g.c. circuit of V_7. In the case of V_5 a single diode is used since the second diode was originally associated with the d.f. system. The a.f. output is developed across the filter circuit R_{19}, R_{20} and R_{21}. In the circuit illustrated in Fig. 1, the a.f. is fed via C_{27} direct to the volume control VR_1; the controlled output

in the region of 60:1. In order to provide an output socket suitable for phones, the arrangement shown in Fig. 3 was adopted. Here it will be seen that a resistive load is always across the output transformer secondary, so that the output valve is always reasonably matched whether or not the loudspeaker is connected (a useful feature in the workshop). Phones or an alternative speaker fitted with a jack plug can be connected, thereby automatically cutting out the main speaker. Cheap low impedance (about 50Ω) phones may therefore be used, and while the mismatch does not effect the output stage due to RL the decrease in volume is compensated by the gain of the additional output stage.

While on the subject of additional connections, reference to Fig. 4 shows how a pick-up

jack may be inserted. Of course, the a.f. stages cannot be considered hi-fi, nor does the inclusion of this facility turn the receiver into a radiogram; nevertheless the facility does prove useful on occasion for test purposes.

Valve V_7 is another double diode triode, and is mounted with some associated components inside a screened box located above chassis to the left of the tuning dial. The double diodes, wired together, rectify the carrier to produce a d.c. voltage suitable for a.g.c. purposes. The triode section, in conjunction with the tuned circuit using L_{22}, operates as a series fed Colpitts oscillator, and when switch S_3 (HET) is on, a c.w. signal of about 280 kc/s is applied to the final i.f.t. Its second harmonic, beating with the signal

only. Incidentally, in the original arrangement the r.f. gain control was ganged to the volume control VR_1 but, in the rebuild, separate controls are used, following normal communication receiver practice. As with the previous system, the a.g.c. voltage is also used to control the Magic Eye shadow; thus the reception of a signal will produce an a.g.c. voltage and close the shadow.

The power supply unit is a conventional transformer-fed full wave rectification h.t. arrangement; the mains transformer also containing two low voltage windings to provide current for the rectifier filament, and other valve heaters. Notice that the negative h.t. line from the centre tap on the transformer secondary is taken to a negative bias rail, not direct to the chassis. The potential

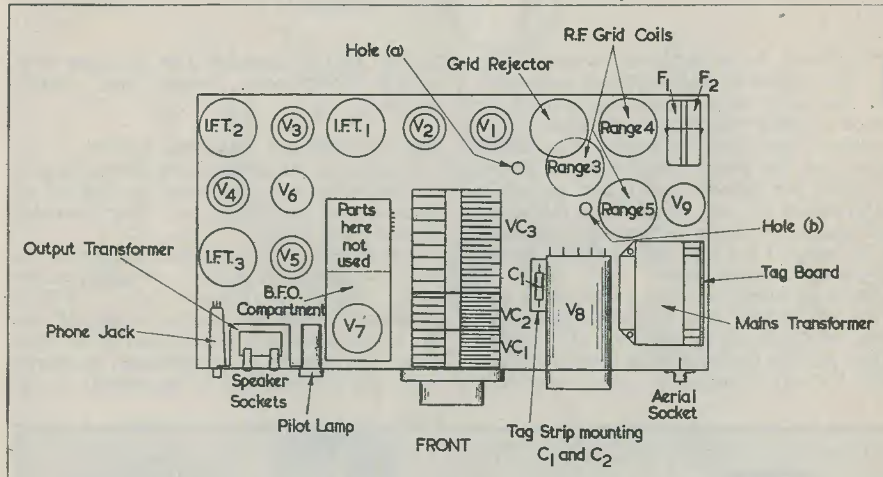


FIG.5.
Above-chassis Component Positioning

M834

carrier (converted to i.f. at 560 kc/s), produces an audible note. The tone can be adjusted by the pre-set capacitor C_{46}.

The b.f.o. facility described above enables an unmodulated c.w. signal to be easily read. Even if the constructor is not interested in c.w. reception, however, the device is worth retaining since it is often useful when calibrating a signal generator or other r.f. oscillator.

The R1155 receiver is very sensitive, consequently the gain control circuits need to be fairly comprehensive. In the original arrangement, the master control switch allowed for two possible systems: automatic volume control, and manual control from the r.f. gain control VR_2. These alternatives were a part of the master control switching, but in the modified arrangement a simple two-way switch provides these two facilities

difference across resistors R_{40}, R_{34} and R_{33} is used for the gain control and biasing circuits.

From the above circuit description it will be seen that the modification incurs the use of very few additional components; these being the mains transformer, rectifier and output valves, smoothing choke, output transformer, plugs and sockets, front panel; and condensers shown marked on the drawing as C_{49}, C_{50}, C_{30}, C_{48} and C_{29}. The last two condensers are paper tubular types, replacing the bulky canned types originally installed.

The insertion of a power output stage and power supply unit raises the operating temperature of the receiver. This problem is overcome by providing two rows of ¼in ventilation holes, spaced 1in apart, at the top and bottom of each side panel.

Morse Tape Recorder

by **R. M. Quaile**

This article describes an instrument which is capable of recording morse signals directly on to paper tape. Provision is made for automatically switching off the tape drive in the absence of signals

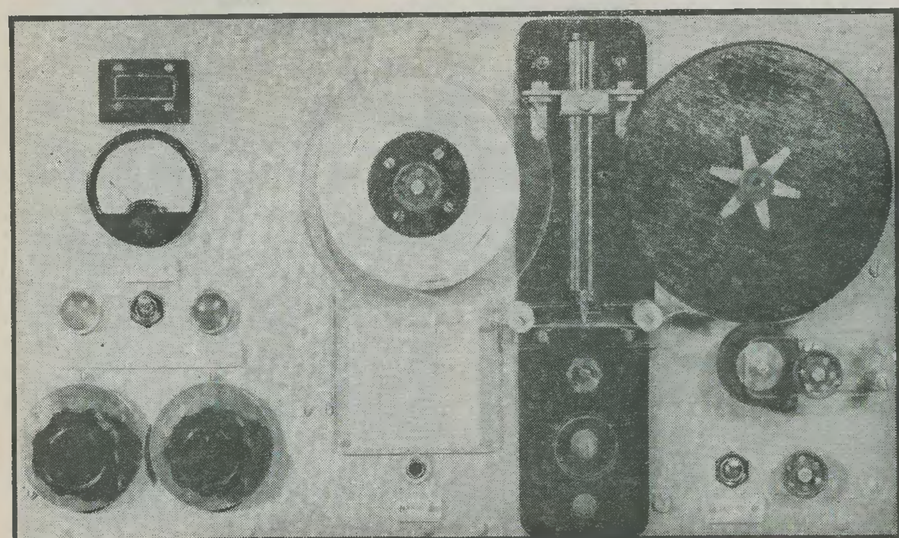
The morse tape recorder which forms the subject of this article is a unit which can be of considerable use to both the novice and the advanced enthusiast. It is capable of recording, by means of a pen on paper tape, any morse signal between 10 and 28 words per minute, and it can provide a useful record not only of character formation and spacing (a factor of considerable value to the learner) but also of c.w. QSOs carried out on the amateur bands.

The instrument employs components and parts which were found in the spares box. None of these are in any way of a critical nature and the design may be copied successfully by any handyman. The electronic section of the recorder also employs non-critical components which are readily available.

The Amplifier and Switching Section

In order to understand the functioning of the recorder it is necessary to first of all discuss the amplifier and the switching section.

The circuit of the amplifier and switching section is given in Fig. 1. In this diagram the morse signal is obtained via a 0.01μF condenser from the output stage of the associated receiver and is applied in the form of an interrupted a.f. tone (present, of course, when the sending key is depressed) to the



Morse Tape Recorder constructed by the author

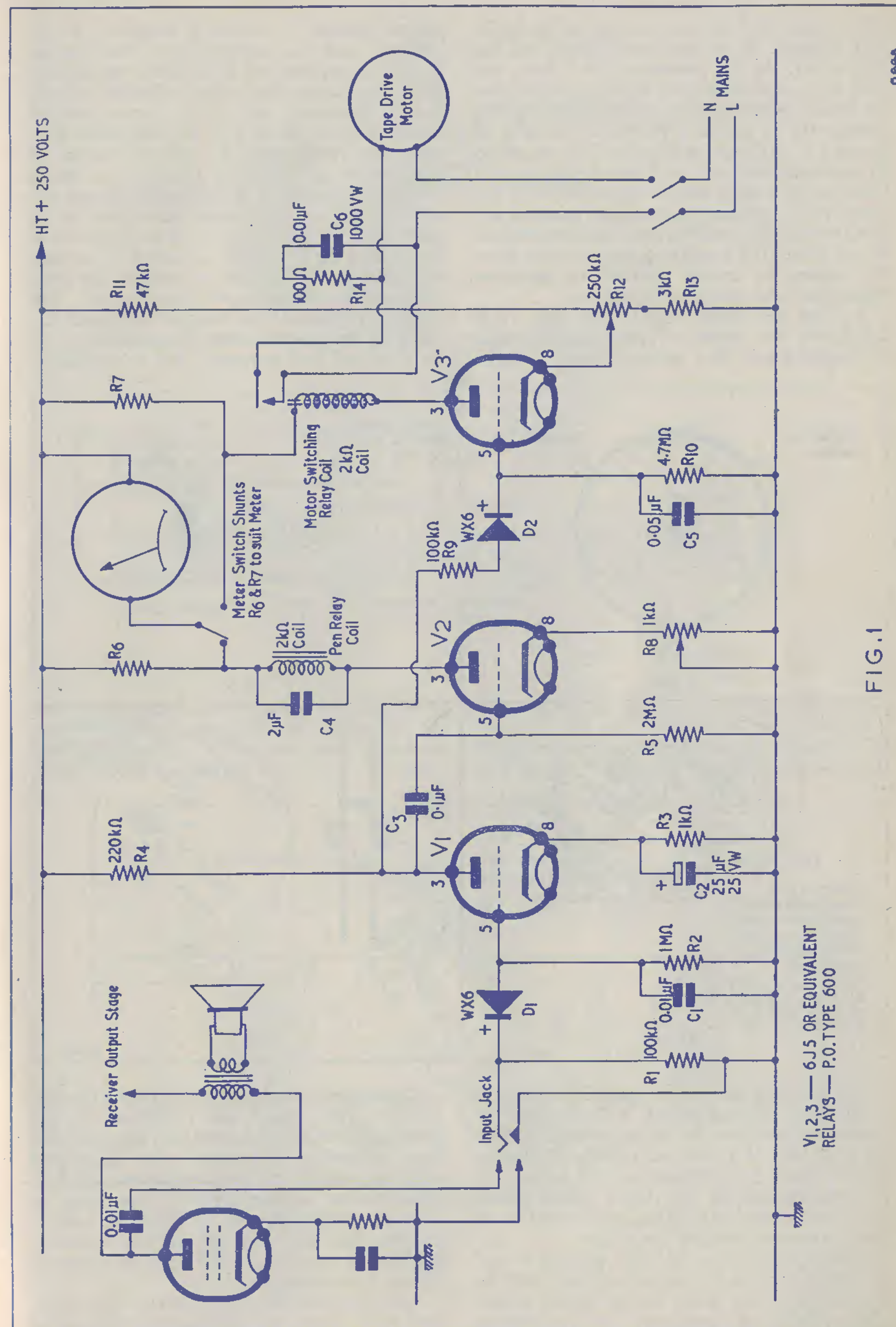


FIG. 1

input jack. The tone is rectified by diode D_1 and appears, as a negative voltage, on the grid of V_1. In the presence of a.f. tone, the grid of V_1 goes negative, with the result that its anode goes positive. The positive-going voltage on V_1 anode is passed to the grid of V_2 via C_3. Adjustable bias for V_2 is provided by potentiometer R_8, and this is set up such that the valve does not, in the absence of a.f. tone, pass sufficient current to operate the pen relay in its anode circuit. In the presence of a.f. tone, the positive-going voltage from V_1 causes V_2 anode current to increase, whereupon the pen relay operates.

As has just been noted, bias for V_2 is adjustable by means of potentiometer R_8. In consequence, this potentiometer is fitted

morse signals V_1 passes a relatively heavy current and its consequently low anode voltage is applied, via R_9 and the conducting diode D_2, to the grid of V_3. The cathode of V_3 is, however, held at a more positive potential than the grid by potentiometer R_{12}, with the result that V_3 anode current is insufficient to cause the relay in its anode circuit to energise. When morse signals are applied to the input jack the anode of V_1 goes positive and this positive potential is applied to the grid of V_3, causing V_3 to pass sufficient anode current to energise the relay and switch on the tape drive motor. The positive potential also charges condenser C_5. Between morse characters V_1 anode drops to its previous low potential, but the presence

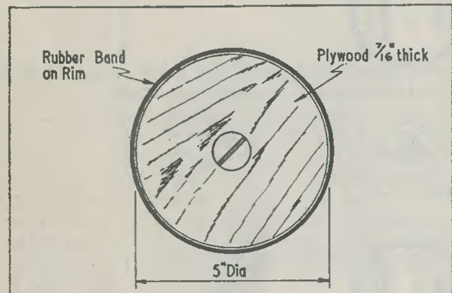


FIG.2

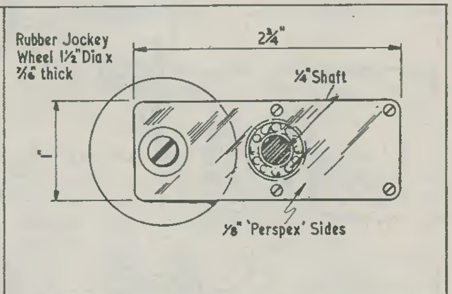


FIG.3

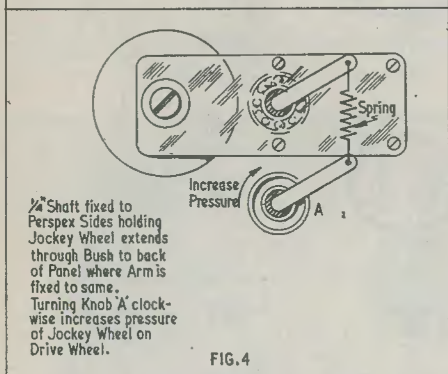


FIG.4

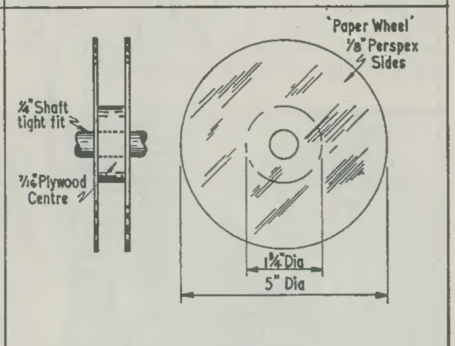


FIG.5

G669

to the recorder as a front panel control. It is adjusted, in conjunction with the receiver volume control, to the setting which enables the pen relay to follow accurately the morse signals from the receiver output stage. In the photograph of the front panel which accompanies this article R_8 is the right hand potentiometer beneath the meter.

Another function of the amplifier and switching section is that of switching off the tape drive motor when morse signals cease. This effects an economy by preventing wastage of paper tape. In the absence of

of D_2 prevents discharge of C_5 into V_1 anode circuit. The overall effect is that, in the presence of morse characters C_5 charges; and that, between characters, it discharges relatively slowly into its parallel resistor R_{10}. When morse signals cease C_5 continues to discharge relatively slowly; so that, after a period, the grid voltage of V_3 becomes sufficiently negative for the relay in its anode circuit to de-energise.

Potentiometer R_{12} controls the bias on V_3 and it is made an adjustable front panel control. It should be adjusted such that the

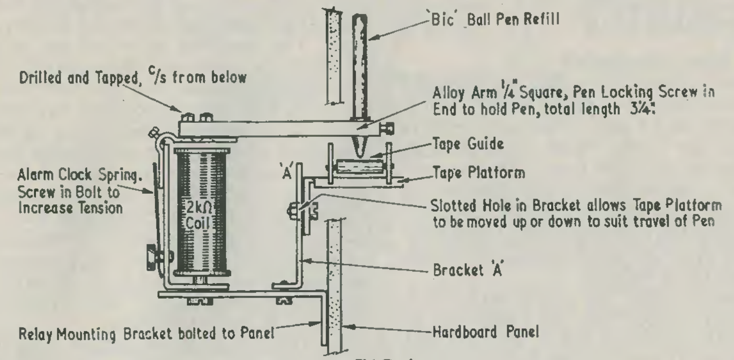


FIG.6

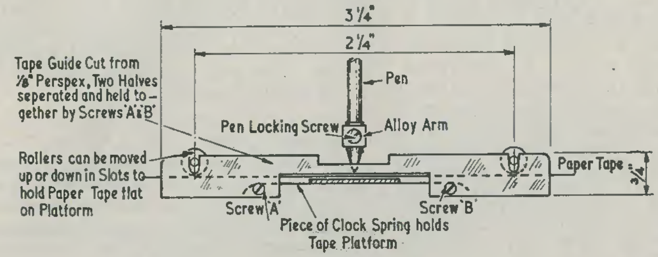


FIG.7

G670

tape drive motor starts and stops reliably as morse signals commence and cease. In the photograph, R_{12} is the left hand potentiometer below the meter.

A meter is included in the circuit to monitor the anode currents of V_2 and V_3. The shunts, R_6 and R_7, have values which enable the meter to read 12mA full-scale

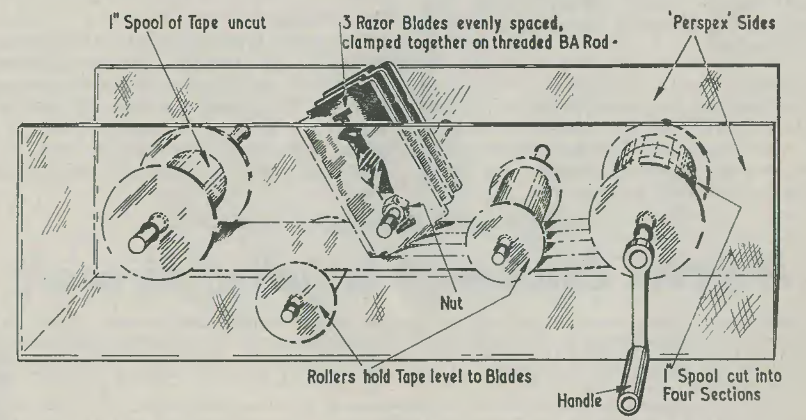


FIG.8

G671

deflection with R_6 and 8mA full-scale deflection with R_7.

The Tape Drive Mechanism

The motor which drives the tape consists of a 230 volt clock movement from which a drive is taken at 4 r.p.m. The movement is coupled to the drive wheel illustrated in Fig. 2. This wheel is cut from $\frac{7}{16}$in plywood and it has a rubber band fitted around its rim to provide friction for pulling the tape. In the photograph the drive wheel is on the right of the recorder front panel, the motor (not shown) being behind.

Immediately below the drive wheel is a rubber jockey wheel. This has a diameter of approximately $1\frac{1}{2}$in and has a bush pressed into its centre to enable it to revolve freely. It is mounted between two Perspex strips as shown in the photograph and in Fig. 3. A $\frac{1}{4}$in shaft is secured to the Perspex strips and this passes through a bush in the panel. Behind the panel an arm is fixed to the shaft and is coupled, via a spring, to an arm on a similar shaft immediately below, as shown in Fig. 4. The second shaft passes through a tight-fitting bush to the front of the panel and is fitted with a knob. Turning the lower knob clockwise then applies a clockwise force to the jockey wheel mounting assembly, whereupon the latter presses up against the drive wheel. In consequence, adjusting the setting of the lower knob varies the pressure of the jockey wheel against the drive wheel and the consequent driving friction on the paper tape which passes between them.

Fig. 5 illustrates the paper wheel which is mounted, in the photograph, to the left of the drive wheel. As may be seen, this consists of two circular Perspex sections with a plywood central section. The Perspex sides are screwed to the plywood centre as shown in the photograph.

The Relays

Both the relays employed in the instrument are Post Office type 600 models with 2kΩ coils, that employed for motor switching having a pair of make contacts and being used in conventional manner.

The pen relay is modified to make it capable of lowering a pen on to the paper tape. The modified relay and its mounting to the front panel are illustrated in Fig. 6. The existing contact sets are removed from the relay and are replaced by two strips of alarm clock spring. These press against the armature, adjustable pressure being given by the securing bolt near the base of the relay. An alloy arm is fitted to the armature as shown, this carrying a ball pen refill. The lower end of the pen refill is passed through a vertical hole in the arm and is secured by a locking screw at the end of the arm. The pen refill employed is a "BIC" type, and is available at most stationers.

For the sake of appearance a $\frac{1}{2}$in diameter chromium-plated tube passes over the pen refill and is secured to the front panel at the top. This tube is clearly visible, between the paper wheel and the drive wheel, in the photograph. The pen refill is completely free to move inside the tube.

The Tape Guide

The tape guide is mounted immediately below the pen, and its construction is shown in Fig. 7. It consists of two Perspex sides whose inside surfaces are separated from each other by $\frac{5}{16}$in. The heights of the two rollers are adjustable and may be set such that the tape runs level on top of the tape platform. This latter consists of $\frac{1}{16}$in mild steel plate, $1\frac{1}{4}$in wide and $3\frac{1}{4}$in long. A length of clock spring passes underneath the tape platform and projects over the spacing bolts of the tape guide. Adjustments to the height of the platform may be made as illustrated in Fig. 6.

Paper Tape

The paper tape employed with the recorder should be $\frac{1}{4}$in in width. If tape of this width cannot be obtained a suitable alternative consists of splitting 1in tape with the aid of the simple device illustrated in Fig. 8. 1in paper tape may be obtained from W. H. Smith & Son Ltd., Bridge House, Lambeth, S.E.1.

Marconi Equipment in Indian Aircraft

Avro-748 twin turbo-prop aircraft being built by the Government of India will be fitted with the Marconi sub-miniature automatic direction finder, Type AD.722. The AD.722 is one of the Marconi equipments being manufactured by Bharat Electronics Ltd. in Bangalore, under the terms of a general manufacturing agreement recently concluded between the Government of India and Marconi's Wireless Telegraph Company Ltd. of Chelmsford, England.

The AD.722 is an outstanding example of modern techniques in airborne direction finding. It was originally developed for the R.A.F. to meet the requirement for a radio compass of exceedingly small weight and size, suitable for unpressurised operation at high altitudes. Intended primarily for pilot operation in high speed aircraft, it has an all-up weight of less than 10 kg, while maintaining a high degree of operational efficiency.

The direction finding system is of the Bellini-Tosi type, with the goniometer embodied in the bearing indicator. The directional receiving aerial is a fixed crossed loop system moulded in plastic which is hermetically sealed inside a shallow casing. When fixed to the aircraft's fuselage the loop provides a low-drag installation with a maximum projection of less than 2 cm. or $\frac{3}{4}$in.

The Tunnel Diode in Theory and Practice

by **J. B. DANCE M.Sc.**

The tunnel diode, already in production in this country and in the United States, represents what is probably the most exciting break-through in semi-conductor research since the transistor. This article is the first of a series of three which presents an extremely comprehensive treatment on the theoretical and practical aspects of the tunnel diode, and great care has been taken to outline the tunnelling process (actually a phenomenon of quantum mechanics) in terms which may be understood by those familiar with simple transistor operation. Some of the material in these articles is a little more specialised than that which normally appears in our pages, but we feel certain that readers will appreciate that this is inevitable if all the facts on this very important new device are to be covered concisely.

We wish to offer grateful acknowledgments to Standard Telephones and Cables Ltd., and to General Electric Company (U.S.A.), for assistance and advice in the preparation of these articles.—*Editor.*

Electrical devices which will amplify and oscillate are essential parts of almost all electronic apparatus. For many years the thermionic valve was the only type of amplifier available, but transistors have gradually become more widely used and are now a serious rival to the valve. A few other types of amplifier are known such as the parametric amplifier (the mavar), the travelling wave tube, the maser, the klystron and the magnetic amplifier. Some of these are suitable only for industrial and laboratory use, e.g. the maser must be cooled to a temperature of about −268°C in a bath of liquid helium and also requires a powerful magnet. The ordinary constructor of simple radio equipment usually has only two types of amplifier to choose from—the valve and the transistor; both of these have their limitations, especially at very high frequencies. Any simple device which is capable of amplifying at high frequencies would therefore be extremely useful.

The invention of the so-called tunnel diode in 1958 by Dr. Leo Esaki, a young Japanese physicist, gives us a completely new form of amplifying device which may well be of enormous assistance in solving some of the problems of modern electronics. Many companies are carrying out intensive research into the manufacture of tunnel diodes (or Esaki diodes) and they will probably be appearing in industrial equipment—especially computers—very soon; although some time yet may elapse before they are developed far enough for them to be available to ordinary radio amateur experimenters. They should eventually become quite cheap.

The tunnel diode, like the transistor, is a semi-conductor device. It can be made much smaller than the transistor and gives good low noise amplification at very high frequencies. It can amplify, detect, oscillate, act as a frequency converter, or as a very high speed switch in computers, etc. Unlike the transistor and amplifying thermionic valve, the tunnel diode is a device with only two connecting wires. Current production diodes have dimensions similar to the typical example shown in Fig. 1, and it is probable that future diodes will be fitted into even smaller and smaller cases as development progresses. The tunnel diode may well be the last word in micro-miniaturisation.

Theory

In the tunnel diode electrons "tunnel" their way through an electrical potential energy barrier which is present at the junction of certain p and n types of semi-conductor—hence the name tunnel diode. The electrons do not have enough energy to jump over the barrier. To give an idea of a potential energy barrier, Fig. 2 illustrates a gravitational potential energy barrier. The ball is moving towards the barrier and would like to fall from level A to level B. The ball does not possess enough energy (i.e. is not travelling fast enough) to roll over the top of the barrier. Therefore the only way it can fall to level B is by passing through a tunnel underneath the barrier. Similarly it is possible for electrons to tunnel their way beneath an electrical potential energy barrier which they cannot surmount. Such tunnelling cannot be explained by the classical laws of physics and, for a full understanding of the mode of operation of tunnel diodes, it is necessary to study the quantum mechanics of solid state semi-conductors. Whilst a full quantitative discussion is far outside the scope of this article, it is nevertheless possible

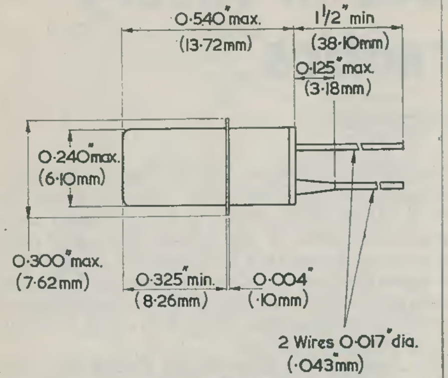


FIG.1.
Outline dimensions of tunnel diodes in the Standard Telephones and Cables JK range.

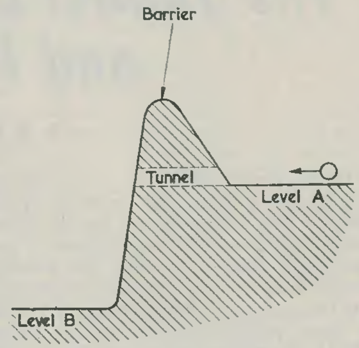


FIG.2.
A mechanical analogy of electrical tunnelling.

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to understand the functioning of the tunnel diode by reasonably simple considerations.

Quantum Mechanics—Simplified

Calculations showing that tunnelling effects were possible had been made as early as 1929 by means of a quantum mechanical approach. The electrons were considered to have a wave nature and from this it was shown that there is a certain probability that they can penetrate a potential energy barrier although they do not possess enough energy to surmount it. (We always speak of the probability of a thing happening in quantum mechanics—nothing is certain.) This probability is diminished as the barrier gets thicker and as the energy (the height) of the barrier is increased. Whilst it has been known for a long time that tunnelling through energy barriers can take place, it is only recently that tunnelling has been observed in semi-conductors.

In order to really understand the process of conduction through a tunnel diode, it is first necessary to learn something of the mechanism of ordinary conduction, especially through semi-conductors. Electrons in a solid material may either be free to move or they may be fixed in close proximity to certain atoms. In a metal some of the electrons are attached to particular atoms, but others are free to move about. The fixed electrons are said to be in the valency energy band because they are held in position by chemical or valency forces. The free electrons enable a metal to conduct electricity and are therefore said to be in the conduction energy band; they have more energy than the valency electrons and therefore the conduction band is shown above the valency band in the electron energy level diagram of Fig. 3 (*a*). The dots represent electrons. In

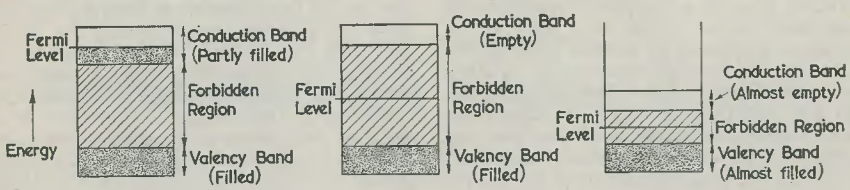

FIG.3(a) Metal

FIG.3 (b) Insulator

FIG.3(c) Pure Semi-conductor

Diagrams showing the electron energies in various solids.
The greater the height, the greater the energy.

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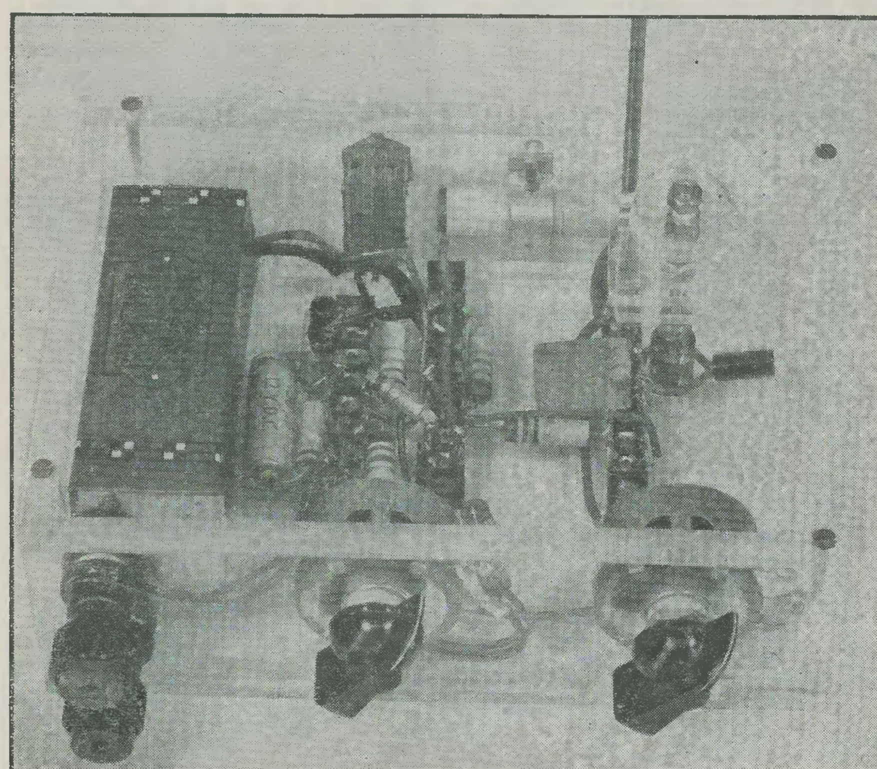
between the two energy levels is a space known as the "forbidden" region because it is impossible for an electron to have an energy represented by a level within this band. The Fermi level—which we shall require later—may be defined as the level which has a 50% probability of being occupied by an electron. In the case of a metal it has the maximum energy level of any electron in the metal.

The electron energy level diagram of an insulator is even simpler. The valency states are completely full and the conduction states are completely empty—otherwise the insulator would have a small conductivity. The hotter any material becomes, the greater the energy associated with its molecules. At ordinary temperatures, however, the probability of a valency electron acquiring enough energy from heat to jump into the conduction level is quite negligible. The energy of the conduction band is several electron volts above the valency band and it therefore remains empty. The Fermi level for an insulator is in the middle of the forbidden region as shown in Fig. 3 (*b*).

Semi-conductors

Semi-conductor elements such as germanium and silicon have four valency electrons per atom and all four are held fairly firmly in position. As shown in Fig. 3 (*c*), however, the energy which an electron requires to move from the valency level into the conduction level is much less than is the case with insulators; the actual value is about one electron volt. A few electrons will therefore acquire enough energy at room temperature (from collisions) to move into the conduction band. When this happens, an electron-hole pair is said to have been formed. The electron can carry charges in the conduction band and the hole can carry charges in the valency band. Thus semi-conductors have a small conductivity. The conduction band is almost empty and the Fermi level lies half-way between the two bands as in an insulator.

A semi-conductor need not be an element;



A tunnel diode synchrodyne receiver (80–100 *Mc/s*).—*Standard Telephones and Cables Ltd.*

for example gallium arsenide and indium antimonide are very useful semi-conductors which form the usual p and n types to be discussed.

"Doped" Semi-conductors

Let us now imagine that an extremely small percentage of an impurity element such as arsenic is mixed with the pure semi-conductor ("doping"). An arsenic atom has one valency electron more than a semi-conductor atom and therefore each arsenic atom in the semi-conductor provides an electron which is comparatively free to move; the conductivity is thus increased. Such a semi-conductor containing atoms which have extra electrons (donor atoms) is known as an n type semi-conductor (n for negative) because negative electrons act as carriers for the electric current.

If an impurity atom with three valency electrons (such as gallium) is introduced in a very small quantity into the semi-conductor, there will be a deficiency of electrons. An extra electron will tend to flow into the impurity atom leaving a hole elsewhere. This hole is in turn filled up leaving another hole. The hole may thus pass through the material. The movement of a hole is equivalent to the passage of an electron in the opposite direction, i.e. the passage of an electric current. Such a semi-conductor with a deficiency of electrons is known as p type (positive carrier), since the current is carried by holes which may be considered the opposite of electrons, i.e. positive charges. As a hole can be filled by an electron (i.e. accept an electron), atoms such as gallium are said to be "acceptor" atoms.

The energy level diagrams for p and n type semi-conductors containing moderate amount of impurity atoms are shown in Figs. 4 (*a*) and 4 (*b*). In Fig. 4 (*a*) a new acceptor level is formed just above the valency band; the Fermi level is half-way between this and the valency band at low temperatures. Fig. 4 (*b*) shows that a new donor level is formed just under the conduction band in n type semi-conductors; this is because the additional electrons in the n type have this energy. At ordinary temperatures there is a reasonable probability that an electron in this donor level will gain enough energy to pass into the conduction level. The Fermi level is half-way between the filled donor level and the empty conduction level. The height of the acceptor and donor levels depends on the amount of impurities in the semi-conductor.

The Tunnel Diode

Figs. 4 (*a*) and (*b*) refer only to the normal p and n types of semi-conductor which contain about 10^{15} impurity atoms per c.c. and which are used for transistors and ordinary diodes. A tunnel diode consists of a junction between p and n types of semi-conductor, but the amount of impurities is about one hundred thousand times greater than in the normal p and n types. In such highly doped semi-conductors, the donor band of the n type shown in Fig. 4 (*b*) and the conduction band become one; the states at the bottom of the conduction band are therefore occupied. The Fermi level is no longer in the forbidden region but has moved up with the donor band into the conduction band. Similarly in the p type the acceptor band shown in Fig. 4 (*a*) has moved down into the valency band with the addition of the extra impurities. The states at the top of the valency band are therefore empty and the Fermi level lies in the valency band. Such highly doped semi-conductors are therefore said to be degenerate.

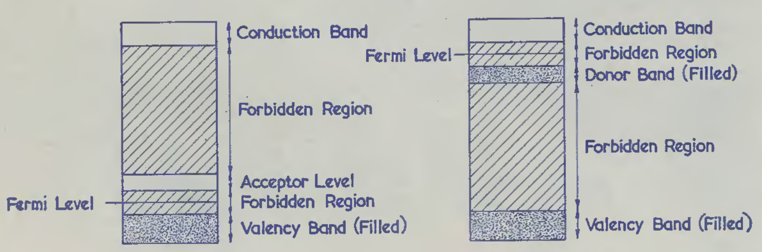


FIG.4 (a)
P-type

FIG.4 (b)
n-type

Electron Energy Level diagrams for p and n types of 'moderately doped' semi-conductors.

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Fig. 5 shows the energy level diagram for an unbiased tunnel diode, the highly doped p and n types being placed side by side with a small barrier region in between. In an unbiased junction the electron density at any energy level must be the same on each side of the barrier. The importance of the Fermi levels can now be seen because the heights of the n and p types in Fig. 5 must be adjusted until the Fermi levels are the same on each side of the barrier when the bias is zero.

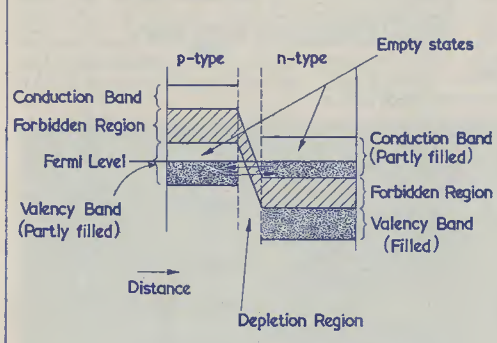

FIG.5.
Energy diagram for an unbiased tunnel diode.

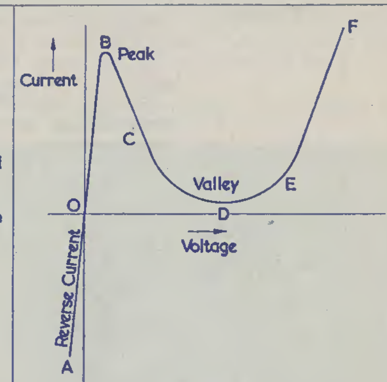

FIG.6.
Current-voltage graph for a tunnel diode.

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What Is The Barrier ?

When a p–n junction is made, the excess holes in the p type will diffuse into the n type and electrons from the n type will diffuse into the p type. This results in a net positive charge on the n side of the junction and a net negative charge on the p side. This charge stops further diffusion by electrostatic attraction. The charges are fixed and the junction does not contain any holes or electrons. It is therefore known as a "depletion region". As this region contains nothing to carry charges, it is a potential energy barrier. In a highly doped tunnel diode this region is very thin (about a millionth of a cm.) and this fact increases the probability of tunnelling.

An electron striking the barrier is, more often than not, reflected back into the region from which it came. It can be shown, however, that there is a certain probability that the electron will not be reflected but will tunnel through the barrier. Although this probability is small, such an enormous number of electrons strike the barrier per second that very high current densities (of the order of 1,000 amps per sq. cm.) can be achieved by the tunnelling process. The tunnel must normally be horizontal on the energy level diagrams. If no bias is applied (Fig. 5) electrons will be able to tunnel through the barrier, but equal numbers will pass across in each direction as shown by the arrows. No net current will therefore pass. It is important to note that the electron flow occurs between the valency electrons of the p type and the conduction electrons of the n type material.

If the corresponding edges of the forbidden regions are joined as shown in Fig. 5, it can be seen that the electrons must tunnel their way through the forbidden region. Thus the forbidden region may be said to constitute the barrier.

Explaining The V-I Curve

The way in which the current changes with changing voltage across the tunnel diode is shown in Fig. 6. The shape of this curve can be explained by means of the energy level diagrams. We have already seen that the current is zero when the voltage is zero (point O in Fig. 6).

If a small reverse bias is applied across the diode, the electron energy level diagrams will be displaced in height as shown in Fig. 7. The reverse current will be increased by the bias, but the forward current will remain roughly the same as when no bias was applied. For small values of reverse bias, the current increases with increasing bias. This explains the part of the voltage-current graph (Fig. 6) from O to A.

If a small forward bias is applied to the diode, the energy levels are displaced in the opposite direction as shown in Fig. 8. The

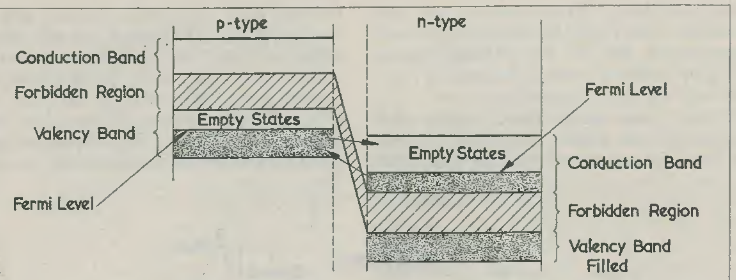

FIG.7.
Energy diagram for a tunnel diode with a small reverse bias.

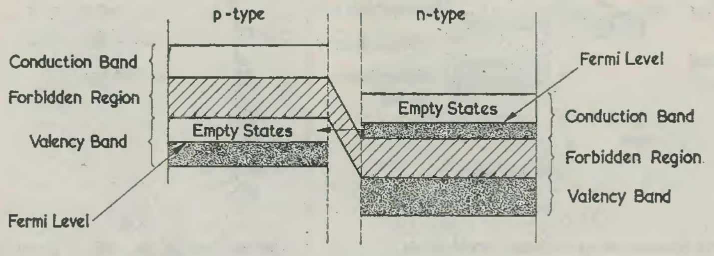

FIG.8.
Energy diagram for a tunnel diode with a small forward bias.

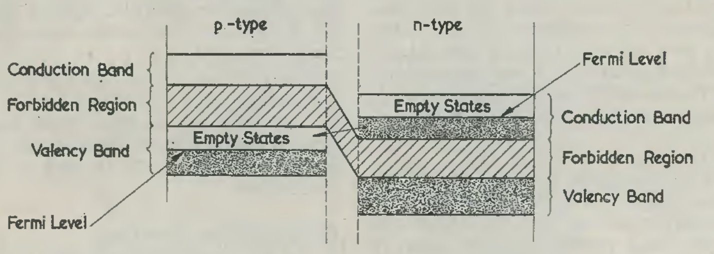

FIG.9.
Energy diagram for a tunnel diode with a slightly larger forward bias (negative resistance region).

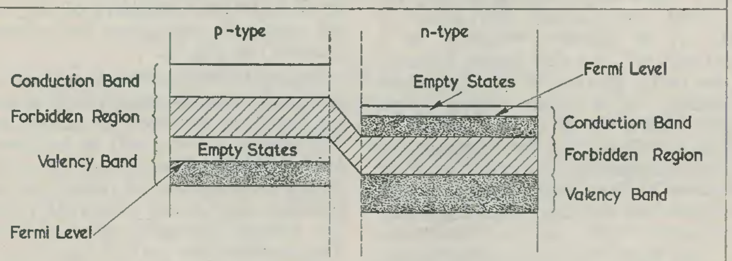

FIG.10.
Energy diagram for a tunnel diode biased into the valley region.

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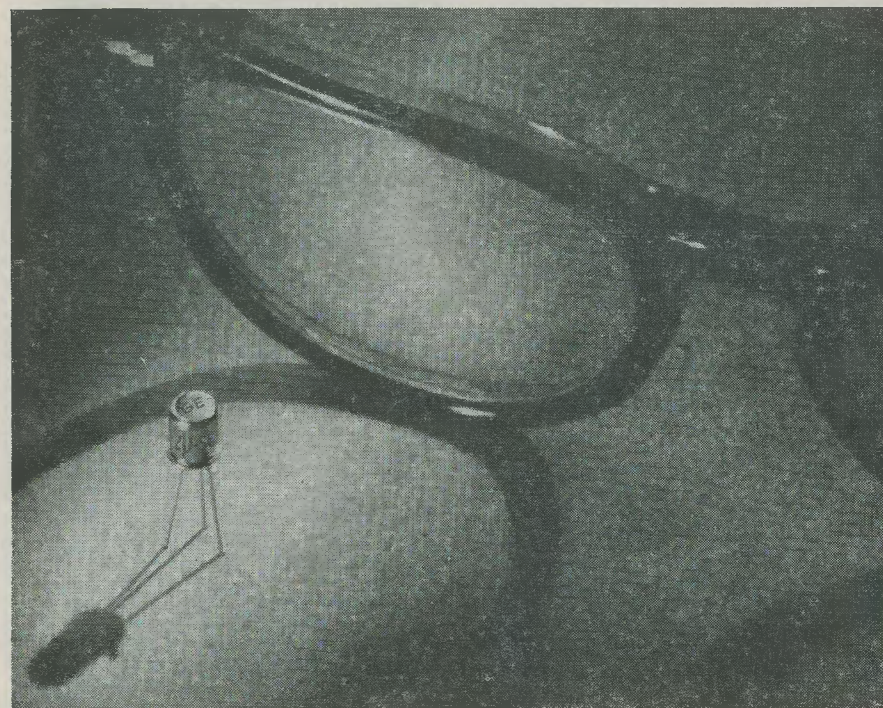
electrons in the n type semi-conductor are raised in the diagram and they tunnel into the empty state region of the p material. Within the range from O to B (Fig. 6), the current increases with increasing bias. It obeys Ohm's law to a first approximation.

If a slightly larger forward bias is applied, the electrons in the n type are raised still more as shown in Fig. 9. The number of electrons in the n type conduction band which are opposite empty states in the p type valency band is now gradually becoming less and consequently the current decreases from B to D as the voltage increases. The differential or incremental resistance of the tunnel diode in this region is therefore negative. It is the most important region of the voltage-current curve because it is the part of the curve which allows the tunnel diode to amplify, oscillate, etc.

Further increase of the forward bias leads us to the energy level diagram of Fig. 10. Here all of the electrons in the n type material conduction band are opposite the forbidden region in the p type material. Normally only horizontal tunnelling is allowed and therefore no electrons can pass from the n type to the p type material by tunnelling. Theoretically only a very small current, the valley current of Fig. 6, should pass through the diode when it is biased in this region, this current being due to diffusion effects. In actual practice the valley current is in excess of this diffusion current, but no satisfactory explanation of this excess current has yet been offered. The excess current can give rise to poor peak/valley current ratios and seems to be connected with a noisy region of the diode.

If the forward voltage is increased still further into the region E to F in Fig. 6, the current through the diode again increases because the electrons can now surmount the much smaller barrier. In other words the two conduction bands come opposite to each other and ordinary conduction can occur without tunnelling (see Fig. 11). It can be clearly seen from Fig. 11 that the electrons do not have to pass through the forbidden region at such forward biasing. In addition holes carry current between the two valency bands.



A General Electric tunnel diode compared with a spectacle lens. The third lead is an earth connection to the case.—General Electric Co., U.S.A.

It has been stated that normally any tunnelling must be horizontal. Experiments carried out at liquid helium temperatures have shown that some peaks which form on the voltage–current curve of silicon diodes are caused by very high frequency ultrasonic vibrations. These vibrations, known as phonons, are due to energy interactions in the tunnelling process and occur at ordinary temperatures. They can assist tunnelling by allowing the electrons to tunnel at a slight angle in the energy level diagrams.

occurs in all transistors and generally limits the high frequency use of these devices.

The passage of a current through a tunnel diode, however, is similar to its passage through a wire. The current flowing at any time depends only on the electric potential at that time. If the potential across a tunnel diode is instantaneously reduced to zero, the electrons in the diode at that instant do not continue to flow in the circuit, but merely come to rest and become a part of the material of which the diode is made. To be

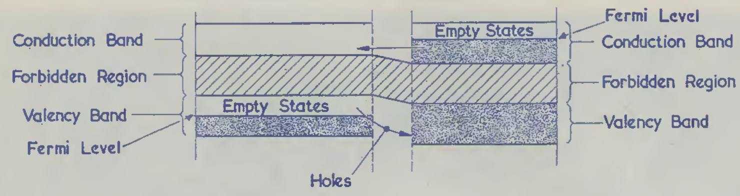


FIG.11.
Energy diagram of tunnel diode biased so that ordinary conduction occurs.
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Summary

In order to understand the operation of the highly doped tunnel diode, it is necessary to study the electron energy band diagrams of the materials. Tunnelling occurs when electrons pass from the n type conduction band through the forbidden region into vacant states in the p type valency band. It does not occur between two conduction bands. Tunnelling occurs in all parts of the Fig. 6 curve except that from D to F. The Fermi levels are reference levels. They line up at zero voltage, but, at other biasing, the difference between the Fermi levels in the p type and the n type is equal to the bias voltage. The bias voltage always appears across the junction.

Tunnelling Speed

In an ordinary thermionic valve a stream of electrons flows from the cathode through the grid to the anode. If a negative voltage large enough to cut off the valve anode current is suddenly applied to the grid, the electron stream is not immediately cut off owing to transit time effects. The electrons which have already passed the grid continue on their journey to the anode and take an appreciable (but short) time to reach it. A signal therefore takes an appreciable time to pass through a valve. A very similar effect

correct it should be pointed out that the signal in a tunnel diode moves at a speed similar to that with which it would move in a copper wire. The response is therefore not quite instantaneous, but is very much quicker than that which can be obtained with either valves or transistors. In fact the signal (not the electrons themselves) travels through a tunnel diode at about the speed of light —186,000 miles per second. As in a wire, each electron in a tunnel diode moves only a microscopic distance and the electrons leaving it need not necessarily be the same ones as those which entered it. An actual electron moving with its usual velocity at room temperature would take about 10^{-13} seconds to pass through the barrier region. A better way of calculating the response speed, however, is to find the time taken for the electrons to adjust themselves to a change in the applied voltage. From the dielectric constant and resistivity of the semi-conductor it can be shown that this time is also about 10^{-13} seconds (i.e. one ten million millionth of a second!)

It is for this reason that the tunnel diode possesses advantages over the valve and transistor at very high frequencies. It is almost as though we had found a very small piece of wire which could amplify!

(To be continued)

PART 1

A Comprehensive Pre-Amplifier Design

By **Peter J. L. Binns, M.Sc.**

(The author wishes to acknowledge with grateful thanks information received from the General Electric Co. Ltd., Tannoy Ltd., and Electrical & Musical Industries Ltd.)

THE PURPOSE OF THESE ARTICLES IS TO examine more closely than usual the factors peculiar to the accurate reproduction of older gramophone records, culminating in the design of a comprehensive monophonic pre-amplifier circuit which may be simplified to suit individual taste. It is not proposed to consider in detail the other items in the reproduction chain—pick-up, power amplifiers, loudspeakers—as these have received adequate treatment in the literature. The pre-amplifier here described is intended to operate from a linear monophonic pick-up of the moving coil or variable reluctance type. It is not suitable for use with high output crystal types, nor is it intended for stereo.

The earliest comprehensive pre-amplifier to be described fully was that due to D. T. N. Williamson. Since then, developments have been rapid, and commercially produced pre-amplifiers now offer every refinement for the reproduction of gramophone records. However, details of these are not generally available. After studying commercial pre-amplifiers, the writer noted the following features:

(1) Switched inputs for gramophone pick-up, microphone, radio (frequently two or more positions), tape recorder, etc.

(2) Switched compensation for recording characteristics, ranging from a few to a large number.

(3) Variable bass and treble controls, giving both boost and cut, to cover room acoustics, listener's taste, etc.

(4) Steep cut low-pass filters to remove surface noise from records, heterodyne whistle on a.m. radio, etc. The frequency of cut is generally variable from 10 or 12 kc/s down to 5 kc/s or even lower. The rate of attenuation ("slope") of the filter is sometimes variable also.

(5) A main volume control.

(6) Various additional refinements peculiar to the particular manufacturer.

Merits

Let us consider these items in turn, and try to assess their merits, not just as extra "knobs to twiddle", but aids to the enjoyment of recorded music, and radio reception.

(1) Switched inputs are clearly desirable, to avoid changing connections, and also because inputs at widely different levels may be encountered. It is better to avoid switching in very low level stages whenever possible. A minimum of three positions is necessary, one each for gramophone, f.m. radio and tape recorder.

(2) Switched record compensation is absolutely necessary, as no amount of fiddling with infinitely variable bass and treble controls will give satisfactory results. The ear is not always an infallible judge in this respect! However, the degree of complication worthwhile in providing accurate playback characteristics must be decided by the individual. This is considered in detail in a later part of this article.

(3) In the opinion of the writer, the bass and treble controls usually fitted to commercial equipment tend to be misleading and confusing. Under ideal circumstances they are unnecessary, and in practice can at least be simplified, if not dispensed with altogether. The argument about compensating for room acoustics is futile—how many concert halls are similar acoustically to one another? Bass cut should never be necessary with gramophone records (a reduction in bass compensation for very old records is allowed for in the compensation stages). It is occasionally useful with radio programmes for talks, but this can be incorporated in the input selector switch. The advantage of this is that the variable bass cut control can be eliminated and cannot be subject to misuse. Bass boost, on the other hand, is valuable as a variable control (in addition to fixed record correction) because many people prefer (or are forced by circumstances) to listen to music at a lower volume than that demanded

by complete realism. Owing to the non-linear characteristics of the human ear, additional bass, and to a less extent treble, compensation is necessary to restore natural sounding balance. This is a well known acoustic principle known as the Fletcher-Munson effect. For this same reason, some variable treble boost is desirable as well. A further reason is that if the pre-amplifier is used to feed a tape recorder, a little treble boost will frequently improve the quality of

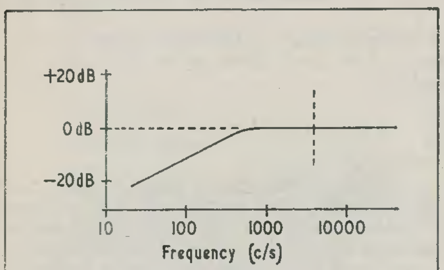


FIG. 1

the recording, as some "top" is often lost in the recording process. A treble cut control (the most popular of all "tone controls") has no place at all in a high fidelity pre-amplifier. All necessary treble cut is obtained from the steep cut filter in conjunction with the treble de-emphasis circuit in the record compensation section (unless the steep cut filter is omitted—see later).

(4) The steep cut filter is now accepted as essential but unfortunately there is no easy way of designing such a filter. The simplest circuits to construct use a tuned choke, and are very effective, but it is not easy to vary the rate of attenuation. The frequency of turnover should be variable from not less than 9 kc/s down to 5 kc/s, or even lower if really old records are to be played.

(5) The volume control calls for no comment, except that it should be capable of silencing the programme completely. Normal listening volume is conveniently about half maximum. The output from the pre-amplifier should be at least 1.5 volts.

(6) The only additional refinement which the writer considers desirable is that the output from the pre-amplifier should be via a cathode follower. This minimises the risk of hum pick-up, and allows a long cable to be used without loss of high frequencies.

To summarise, we have arrived at the specification of a monophonic pre-amplifier to satisfy the most exacting requirements. It will incorporate the following features:

(*a*) Switched input for (at least) gramophone, tape, and radio positions. No switching in low level stages.
(*b*) Switched compensation for a variety of recording characteristics (to be considered later in this article).
(*c*) Bass boost and treble boost variable controls.
(*d*) Steep cut filter, with adjustable turnover frequency.
(*e*) Volume control.
(*f*) Cathode follower output.

We shall now consider recording characteristics and correction circuits for these.

Recording Characteristics

We have considered the design details of a comprehensive monophonic pre-amplifier for gramophone, tape, and radio programmes, and noted that it was desirable to incorporate switched compensation for a variety of types of record. Assuming a pick-up with linear characteristics, the compensation needed will be the inverse of the recording characteristic used when the particular record was made. Let us examine these recording characteristics in some detail.

As most readers will know, the early 78 r.p.m. records were made with a characteristic approximating to that shown in Fig. 1.

The overall frequency response before 1939 was quite restricted, but since the war has been much extended. This type of curve was used until recently by EMI for their 78 r.p.m. records, and the high frequency response was maintained to well over 10 kc/s.

The reason for using this type of curve was that below about 300 c/s the amplitude of the recording stylus was becoming great enough to break down the walls of the record grooves. Hence the amplitude of the cutting stylus was kept constant below the turnover frequency, with a resultant loss in

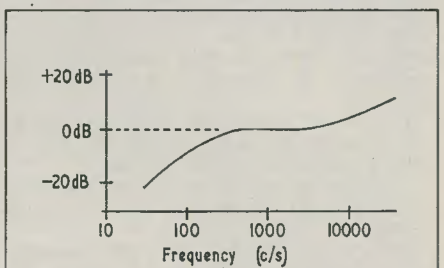


FIG. 2

bass. This loss must be corrected in the reproducer.

After the war, Decca introduced "ffrr" (full frequency range recording). These records, in addition to the falling bass characteristic, had a rising treble characteristic above 3,000 c/s. (Fig. 2.)

This treble pre-emphasis, when corrected in the reproducer, reduces the surface noise at the same time. In America this principle was carried much further, with the result that recording characteristics were no longer flat at any point, but became as shown in Fig. 3.

This type of characteristic was adopted for long playing records, both 45 r.p.m. and 33⅓ r.p.m. in addition to 78 r.p.m., but unfortunately no standard was laid down, with the result that a very large number of different characteristics were used. All were of the same form, but differed in the amount of bass and treble correction required, and in the turnover frequency. A final compromise was reached with the universal adoption of the R.I.A.A. characteristic in 1955.

Reviewing briefly the various characteristics which have been used for LP records since their introduction, the pre-1955 American Columbia requires least bass (13dB at 50 c/s) and most treble (16dB at 10 kc/s) correction. The RCA (old), on the other hand, needs most bass (at least 20dB and 50 c/s) and least treble (12.5dB at 10 kc/s).*

These two cover the extremes of American practice, but between them are the important A.E.S., R.I.A.A., and N.A.B. characteristics. (See Fig. 5.) The A.E.S. curve was evolved as a standard playback characteristic, and was more recently followed by the R.I.A.A. curve. This latter is substantially the same as the N.A.R.T.B. curve, and is sometimes also called the "new A.E.S." curve. It is necessary to provide correction for all these characteristics if American records made over the last 15 years are to be played.

In this country, precise information about recording characteristics was difficult to obtain. The intermediate Decca LP curve approximated to A.E.S., though a flatter characteristic was used for very early Decca LP's. The EMI Group (Columbia, HMV) now use the R.I.A.A. curve for LP's, but prior to 1954 it was nearer the American Columbia. Nixa records used the A.E.S.

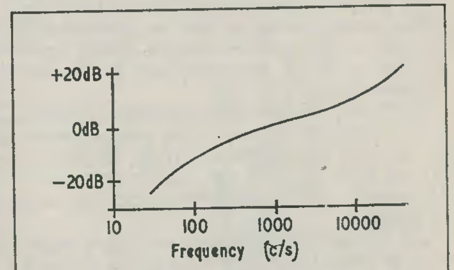


FIG. 3

curve, but Westminster recordings issued under the Nixa label may be either A.E.S. or R.I.A.A. D.G.G. used a characteristic of their own, with −10dB at 50 c/s and +13.3dB at 10 kc/s.

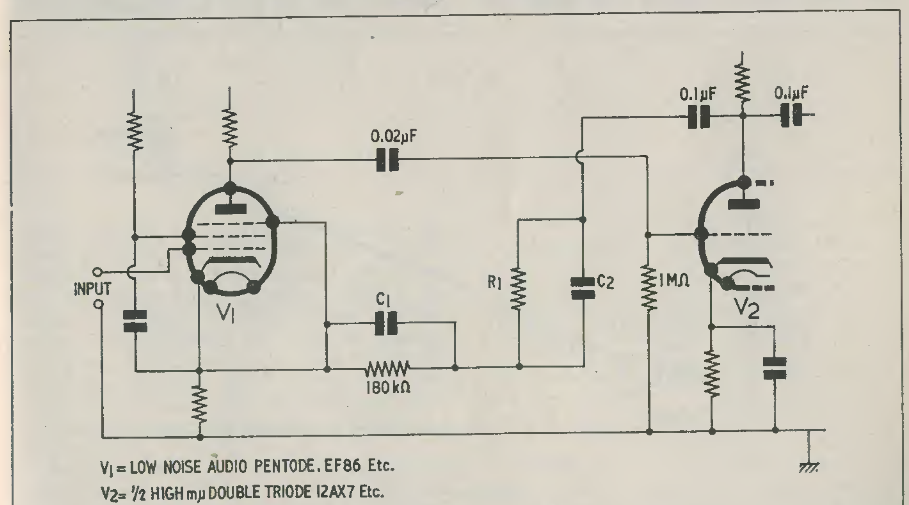


FIG. 4

Fortunately, the R.I.A.A. curve was adopted as standard, both in this country and America. It is pleasant to realise that today the would-be record collector needs only one playback correction, only one pick-up head,

* All recording characteristic levels quoted are with respect to level at 1,000 c/s.

and only two turntable speeds (45 and 33⅓ r.p.m., mono or stereo).

Pre-amplifier Compensation

It should by now be clear that the switched compensation for records old and new specified in our pre-amplifier design is not very simple, and we must consider the degree of complication which is worthwhile. The writer suggests three alternatives which should cover all requirements.

(1) For a simple pre-amplifier, or for those whose main interest is not in gramophone records, a two position switch giving compromise or R.I.A.A. corrections for 78 and LP records.

(2) For all but the most advanced circuits, a four position switch giving compensation for (*a*) EMI 78, (*b*) Decca ffrr 78, (*c*) A.E.S., (*d*) R.I.A.A. If many pre-war records are to be played, a fifth position for old 78s may be added.

(3) For advanced circuits, and those whose records come from both sides of the Atlantic and include many different labels, a comprehensive scheme covering all characteristics ever used or likely to be used. This circuit is conveniently controlled by two switches. The first controls only treble de-emphasis, and has four positions, giving a loss at 10 kc/s of (*a*) 10dB, (*b*) 12dB, (*c*) 14dB and (*d*) 16dB. This switch is used in conjunction with, and controlled by, the second switch. This latter switch controls bass boost and turnover frequency, and also provides two complete characteristics without reference to the first switch, which is automatically disconnected for these two settings. The two complete characteristics are EMI 78 and Decca ffrr 78, and the bass characteristics American Columbia, R.I.A.A., A.E.S., and RCA. By making use of the four bass and four treble positions, all possible characteristics are covered. There is also a position for old 78s, which makes use of the variable treble de-emphasis.

This arrangement sounds complex, but it has advantages over any other. Use of a single switch would require a large number of positions; and two completely independent switches would make setting up rather difficult. With the present arrangement, the treble de-emphasis control can be set at 12, and all selection done on the other switch, without introducing any serious errors—a useful feature when the circuit is used by other members of the family!

The basic circuit for all these corrections is a negative feedback loop from the anode of the second stage to the cathode of the first. (Fig. 4.)

The beauty of this circuit is that its response can be easily tailored to fit the characteristic required. With C_1 omitted, and R_1 and C_2 short circuited, the response is level (a purely resistive feedback network). Hum and noise are greatly reduced by the feedback, but the gain is still sufficient for most pick-ups. Condenser C_1 controls the treble de-emphasis, and C_2 the bass turnover frequency: the larger the capacity the lower the frequency in each case. Resistor R_1 across C_2 controls the point where the bass curve begins to flatten off. If R_1 is omitted, the bass will continue to rise until the maximum possible boost (about 20dB at 50 c/s) is reached. By varying these three components, any desired characteristic can be matched.

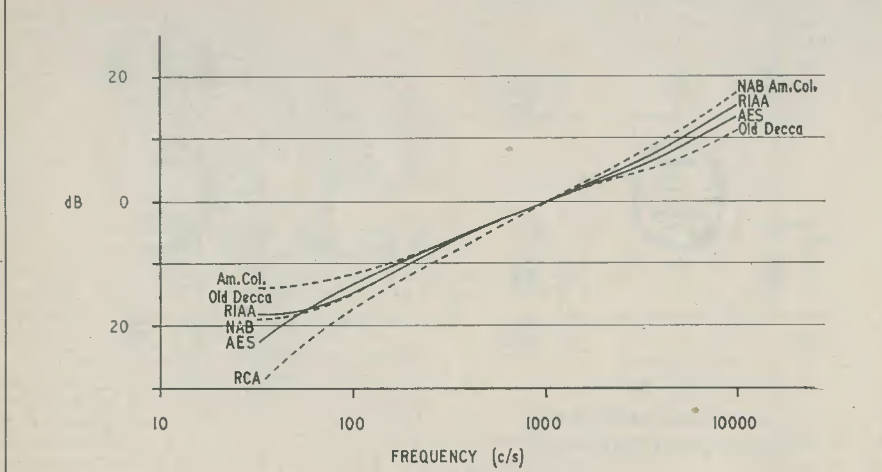


FIG.5

Pre-1955 and RIAA Recording Characteristics
(The RIAA Characteristic appears as FIG.3 in British Standard B.S.1928:1960)

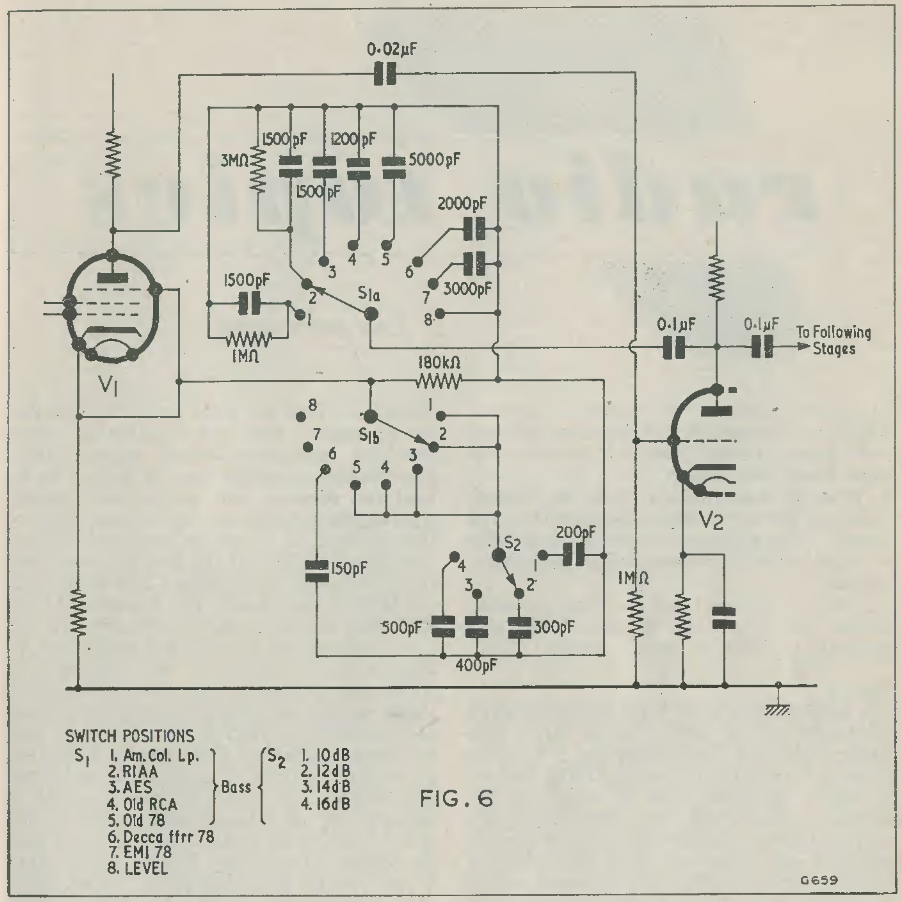


FIG. 6

Returning now to the three suggested arrangements mentioned earlier, for the first two circuits the switching should be obvious. With the simple two position circuit, for 78 r.p.m. records C_1 is 200pF, C_2 is 3,000pF, and R_1 is omitted. For LP records, C_1 is 300pF, C_2 is 1,500pF, and R_1 is 4MΩ.

With the four position circuit, which requires a two-band four-way switch, the values are as follows:

Characteristic	C_1	C_2	R_1
EMI 78 ..	Omit	3,000pF	Omit
Decca ffrr 78	150pF	2,000pF	Omit
R.I.A.A. LP	400pF	1,500pF	3MΩ
A.E.S. LP ..	220pF	1,500pF	Omit

For the third circuit, the complete diagram is given in Fig. 6. Reference to Fig. 4 should make it quite clear, though at first sight it looks somewhat complex.

Next Month

This series will conclude with a consideration of the remainder of the pre-amplifier circuit.

radio topics

BY RECORDER

As an aftermath to the Radio Show a conversation I had with a non-technical friend affords a useful introduction to *Radio Topics* this month.

"What I liked mainly," said my friend, "were the glossy wooden cabinets of some of the sets. They really *were* worthwhile looking at. Far better than those rough old plastic finishes."

Gently, I explained that the shiny polyester surface used on most wooden radio and television cabinets is, *itself*, a plastic!

Plastics

It is surprising how little attention, even nowadays, is paid to the great part which plastics play in our everyday life. For instance, many of our clothing fabrics include or consist of plastics such as nylon, the filaments from which the fabric yarns are built up having been extruded out of nozzles in rather the same way that toothpaste is squeezed out of a tube. The electrical wiring in recently built houses, and in our radio and television sets, is plastic covered; the plastic consisting of p.v.c. extruded over the central conductor. P.V.C., in plain sheet form, is used also in the cheaper plastic mackintoshes. Polyethylene, more usually called polythene (or Alkathene, which is the I.C.I. brand name), also finds many applications, these ranging from food bags to high voltage insulation. The e.h.t. lead to the final anode in a TV set is polythene covered as, also, is the centre conductor of the coaxial down-lead which connects to its aerial socket. Polythene is very much in evidence in London's West End these days; not only is it the staple raw material for the suitcase-sited retailers in Oxford Street who (whilst keeping a sharp look-out for the Law) sell polythene clothes protectors, it also covers the traffic wardens' notices on your windscreens if you park in the wrong area!

The examples I have just mentioned, nylon, p.v.c. and polythene, are thermoplastic materials. They are given this name because, when heated, they are capable of being moulded into any desired shape. Thus, thermoplastic material may be forced, under heat and pressure, into an injection mould, whereupon it takes up the internal shape of that mould; or it can be extruded, as was mentioned earlier. If the plastic is extruded from a slot instead of from a hole it becomes available in sheet form. If it is extruded from a circular slot it appears in tubular form.

It is interesting to note that some thermoplastics have a "memory", this causing them to attempt to resume their original moulded shape if they are distorted from this shape at a temperature which is just sufficiently high to cause softening. Commercial advantage is taken of this effect by means of the following process. A length of p.v.c. tubing is slipped over a thinner metal tube having many holes in its surface, and the two ends are sealed. The tubing is then heated until it just reaches softening point. Compressed air is next blown into the metal tube, causing the outside diameter of the p.v.c. tubing to increase by as much as two to three times. The temperature is then reduced and the compressed air released. The expanded p.v.c. tubing now has stable dimensions at normal temperatures and it can be despatched in this form for use elsewhere. At another factory it may, for instance, be slipped over the handles of pliers and similar tools. The expanded p.v.c. tubing is re-heated, its plastic "memory" causes it to shrink to its old diameter again, and it forms an extremely tight covering on the handles. Alternatively, the expanded p.v.c. tubing may be slipped over metal tubes of the type used as handles on bus doors. Under heat the plastic shrinks on to these tubes, providing a very tightly fitting outer covering.

Thermosetting Plastics

A different category of plastic materials appears in the thermosetting range. Thermo-

setting plastics undergo a chemical change at high temperatures which causes them to "set" into their final shapes and dimensions; they cannot then be re-moulded into any other shape. The most usually encountered thermosetting plastic is phenol formaldehyde (popularly known as Bakelite). Phenol formaldehyde is fed into the mould in the form of powder. The two halves of the mould then come together under pressure, heat is applied, and the powder is caused to change its chemical composition. When the mould is opened, the powder has been converted to a hard homogeneous object whose dimensions are those dictated by the mould. Frequently "fillers", consisting of wood-flour, asbestos fibres, particles of nylon, etc., are introduced into the basic phenol formaldehyde powder to modify the properties of the final moulded material. Such fillers also reduce the cost of the moulding, as they are cheaper per unit volume than the phenol formaldehyde they displace.

There is a popular misconception that phenol formaldehyde mouldings can be turned out at a very high rate. In practice, this is not so. With small mouldings, for instance, it takes some 90 seconds for the powder to change into its final form. In consequence, it is usual for small mouldings to be produced on completely automatic presses. These, fed with sufficient powder for several hours' running, automatically shake the required amount of powder into the bottom half of the mould, bring down the top half of the mould, and apply pressure for the requisite amount of time. They then open the mould, eject the moulded article into a container, and start all over again. In such presses the mould is maintained at operating temperature all the time.

Another frequently encountered material which falls into the thermosetting category is that which is known popularly as Paxolin. Paxolin consists usually of what is more correctly called synthetic resin bonded paper (s.r.b.p. for short). In sheet form s.r.b.p. is made up of many sheets of paper impregnated with a plastic (or "resin") such as phenol formaldehyde. The whole is then raised in temperature under pressure, resulting in the production of a solid material consisting of the sheets of paper bonded together by the hardened resin. Early s.r.b.p. production used phenol formaldehyde as the resin but this required heavy pressures. More modern resins have since been developed for this application, and these require much lighter pressures. S.R.B.P. tubes, such as are used for coil formers, are made up in much the same way. The paper used is treated on one side with the resin, and it is rolled up under heat on a circular mandrel in the form of a swiss roll. The roll and mandrel are then baked in an oven to provide complete hardening, and the tube is finally pushed off the mandrel.

Names

You may note, in the last few paragraphs, that I have skated a little around the names employed for some of the plastics. This is because many plastics are known, not by their chemical names, but by brand names. Few people know what phenol formaldehyde is, and yet everybody is fully at home with the word Bakelite. Similarly, the term s.r.b.p. usually results in an uncomprehending stare from the average radio enthusiast, but he knows exactly what is meant by Paxolin. Bakelite is, in fact, a brand name employed by the company: Bakelite Ltd. Paxolin is another brand name which, despite its general usage amongst radio enthusiasts, has now, if my information is correct, been discontinued by the manufacturer concerned. Both Bakelite and Paxolin, when used in print, should be given a capital letter. So also should another old friend of ours —Perspex. Perspex is the brand name given by I.C.I. to their product, methyl methacrylate.

Noise

Changing the subject rather abruptly, I had the misfortune some years ago to live in an apartment underneath that of a lady who had the most resonant console radio in all the world. This radio burst forth at its full 10% distorted output power on all the bass notes given by any orchestral music it reproduced. Whilst my upstairs neighbour revelled in the relatively full audio range of the pop music she loved to hear I, downstairs, heard the bass section only. When I felt like a change I used to go up to her landing and give myself a treat by listening to the rest of the orchestra through her door.

I was frequently tempted to steal up one dark night with a soldering iron and change all her a.f. 0.01μF's to 500pF's. Somehow, I never got round to it.

It is, perhaps, because of this formative experience in my life that I record with qualified approval the latest venture by the Noise Abatement Society. The Society is organising a competition in which either professional or amateur cartoonists may submit a cartoon depicting a typical I.S.U. I.S.U. stands for "Intellectually and Sensitively Under-privileged" (they won't get the Elephant and Castle boys in if they use words like that) and is exemplified by "a person who does not realise he is making a noise and wonders what all the fuss is about, like . . . a motor-cyclist revving up at traffic lights"; and, I presume, people playing thumpy radios.

I'm all for the Noise Abatement Society, because most of us *do* suffer from far too much unnecessary noise. But it merits my personal zero marks out of ten for that silly, precious, I.S.U. phrase.

Talking of noise, do you ever hear a continual, low-pitched, steady hum? Apparently quite a few *Daily Mail* readers have; so many, indeed, that this paper carried out an investigation. So far as can be judged from the outcome, the hum seems to emanate from television aerials or their supporting masts. These vibrate in the wind, giving an effect rather like that of wooden telephone poles. In any event, it was stated that one case was cleared by filling the supporting mast with sand, thus damping down the vibration. The latter would give the impression that the particular masts concerned were *resonant* at the hum frequency.

Michaela and Armand Denis

If, like me, you listened to *Desert Island Discs* on the 19th of September, you no doubt shared with me a fascinating little item of information.

Armand Denis who, with his wife, Michaela, form the well-known exploring and filming team, spoke of his earlier life. At one time he was a radio engineer, and he invented a device whose proceeds financed him sufficiently to enable him to embark on his later career.

The device? Automatic volume control for receivers.

Really Tiny

And, now, a little piece of news for those who like building really tiny receivers.

Currently available from Technical Suppliers Ltd., 63 Goldhawk Road, W.12, is a new subminiature loudspeaker measuring $1\frac{3}{4}$in in overall diameter. The speaker has a depth of $\frac{3}{4}$in, and is listed as TSL-Lorenz type LP45F. To achieve sufficient acoustic output from the speaker at low signal levels, a new type of ferrite magnet has been used. This gives the high field strength of 9,500 gauss. Leaflets describing the speaker are available from Technical Suppliers Ltd.

S.T.C. Display

Should you be in Aldwych, next time you're in the West End, you might find it interesting to take a look at the Standard Telephones and Cables Ltd. window display in this company's headquarter building at No. 63.

The main item in the display is a $\frac{3}{4}$ ton steel pendulum. This is kept swinging by the power of a single transistor. Also to be seen is an electronic crystal-controlled clock which displays the time on gas tube indicators, together with a model of a submerged repeater of the type which will be used next year in the U.K.-Canada telephone cable.

A telemetering panel destined for the Kariba power project has been taken from the production line to show the extensive use of S.T.C. relays, resistors and condensers in this equipment.

There is also a multi-channel aircraft radio receiver, as supplied by S.T.C. for the latest Comets; and a power panel from S.T.C.'s 4,000 Mc/s microwave system which handles 960 simultaneous telephone calls on each of its six radio channels.

Quite a Radio Show in miniature, in fact.

RADIO HOBBIES EXHIBITION

23rd to 26th November, 1960

Exhibitors List as at 20th October, 1960

1 Radio Society of Great Britain.
1 London UHF Group.
2 Royal Air Force.
3 British Amateur Television Club.
4 Data Publications Ltd. *Radio Constructor.*
5 Associated Electrical Industries (Woolwich) Ltd.
6 K.W. Electronics Ltd.
7 Tiger Radio Ltd.
8 Sound Vision Service (Electrical).
9 Associated Iliffe Press Ltd. *Wireless World* and *Electronic Technology*.
10 Enthoven Solders.
12 Taylor Electrical Instruments Ltd.
13 James Scott & Co. (Electrical Engineers) Ltd. (Hallicrafter)
14 The Jason Motor & Electronic Company.
15 & 16 Mullard Ltd.
17 Electroniques (Felixstowe) Ltd.
18 Daystrom Ltd. (Heathkit)
19 Short Wave Magazine Ltd.
20 Webbs Radio.
21 Minimitter Co. Ltd.
22 Avo Ltd.
23 Royal Naval Reserve.
24 Hennings Musical Industries.
28 65th Signal Regiment R. Signals Territorial Army.
29 Features of Radio Transmitting & Receiving Communication Rooms (Trade & Amateur)
30 Aveley Electric Ltd.
31 Bridge Electronics.

A Signal Injector for RF, IF and AF Testing

By D. TETLOW

This signal injector was devised for use in a Technical Training Establishment to fulfil the following requirements:

(i) to exercise students in elementary workshops practice;
(ii) to instruct students in the operation of L–C and R–C oscillators;
(iii) to produce a simple testing instrument to aid in the service and repair of all types of receivers and transceivers.

The signal injector is basically a harmonic generator whose fundamental frequency is 465 kc/s. Harmonics of this frequency are produced covering the h.f. and lower part of the v.h.f. Band. The principle of operation is the modulation of a sinusoidal r.f. by a non-sinusoidal a.f. In this particular circuit the a.f. is a sawtooth waveform but an advantage would be gained by modulating with a square wave audio frequency since this proves most useful for distortion testing in a.f. amplifiers. Any double triode may be used set up as an astable multivibrator.

Designing the Circuit

The main problem which had to be overcome with the design of the injector was the limitation, both in quantity and variety, of all types of components. Thus the design had to be fitted around those items of which there was an abundance. This immediately precluded the use of a double triode which could be used as a free running multivibrator giving a square wave a.f. at a frequency of 1,600 c/s. The only valve in sufficient quantity was the 6K7 and as can be seen this has been utilised for both r.f. and a.f. stages.

It can be seen that, in normal circumstances, the construction of this circuit makes few demands on the pocket, most readers finding the necessary components in the "spares box". Moreover, modification of the circuit to suit the availability of components is a relatively easy matter and this is, of course, of great importance if a number of these signal injectors are required.

Outputs

The signal injector produces the following outputs:

(i) r.f. signals, modulated at 1,600 c/s and consisting of harmonics at 465 kc/s up to 30 Mc/s.
(ii) i.f. signal at 465 kc/s modulated or unmodulated.
(iii) a.f. signal at 1,600 c/s.

The magnitude of the signals depends on the h.t. supply used but in general an r.f. and i.f. output of not less than 1 volt peak and an a.f. output of not less than 5 volts peak will be obtained.

Circuit Description

V_1 uses a 6K7 in a fairly conventional oscillator circuit. An i.f. transformer of non-miniature pattern is used for the anode and grid circuits of the oscillator, frequency alignment being carried out with the adjustable dust-iron cores.* The output is taken from the screen via an isolating condenser and potentiometer.

V_2 uses a 6K7 in a modified transitron relaxation oscillator circuit. The waveform produced is a sawtoothed wave whose frequency is determined by C_5, C_4, R_8. Two outputs are taken from the anode. The first output is the modulating voltage which is applied to the suppressor of V_1 via the potentiometer R_5. This controls the depth of modulation. The second output is that which feeds a.f. to the potentiometer R_9 via C_6. A switch, S_2, is included in the suppressor circuit of V_1, enabling the modulation output to be switched off and giving access to unmodulated i.f. at the r.f./i.f. terminals. It should be noted that, when S_2 is closed, V_2 operation will be affected unless the slider of R_5 is at the lower end of its track.

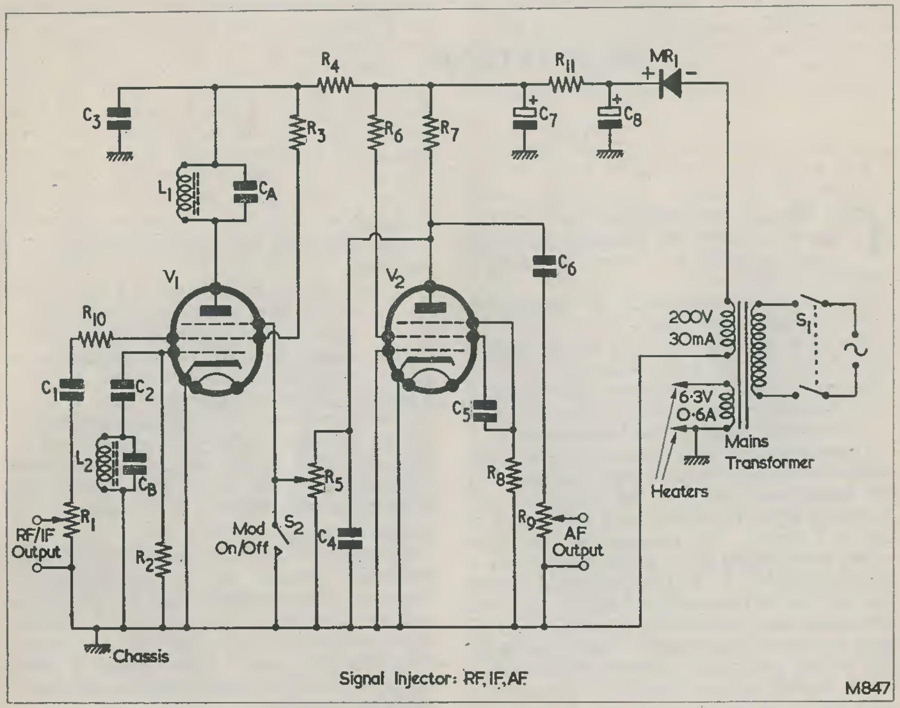
Adjustments

Few adjustments are required. The L–C oscillator will be found to oscillate very readily. If a wavemeter or signal generator

* If excessive feedback is obtained it might be desirable to delete either C_A or C_B.—*Editor*

is available the stage can be brought on to frequency by adjustment of the dust-iron cores. Failing this a receiver capable of receiving c.w. may be used, especially if its scale calibration is accurate.

The transitron oscillator is also simple to adjust. The frequency of oscillation is not critical and depends solely on the preferred test tone. A frequency of 1,600 c/s was chosen but this may be increased by decreasing the value of C_4 or decreased by increasing the value of C_4.



Components List

Resistors

- R_1 50kΩ potentiometer
- R_2 47kΩ ½ watt ±20%
- R_3 27kΩ 1 watt ±10%
- R_4 240kΩ ½ watt ±%20%
- R_5 50kΩ potentiometer
- R_6 47kΩ ½ watt ±10%
- R_7 100kΩ ½ watt ±10%
- R_8 500kΩ ½ watt ±10%
- R_9 50kΩ potentiometer
- R_{10} 25kΩ ½ watt ±%20%
- R_{11} 3kΩ 2 watt ±20%

Mains Transformer

- Primary 230V a.c.
- HT sec: half-wave 200V, 30mA
- LT sec: 6.3V 0.6mA

Condensers

- C_1 0.1μF, 350V wkg.
- C_2 100pF, mica
- C_3 0.1μF, 350V wkg.
- C_4 0.05μF, 350V wkg.
- C_5 0.01μF, 350V wkg.
- C_6 0.1μF, 350V wkg.
- C_7 8μF electrolytic, 350V wkg.
- C_8 8μF electrolytic, 350V wkg.

Valves

- V_1, V_2 6K7

Rectifier

- MR_1 Metal or contact cooled, 30mA, 200V
- L_1, C_A, L_2, C_B 465 kc/s i.f. transformer

Switches

- S_1, S_2 On/Off toggle

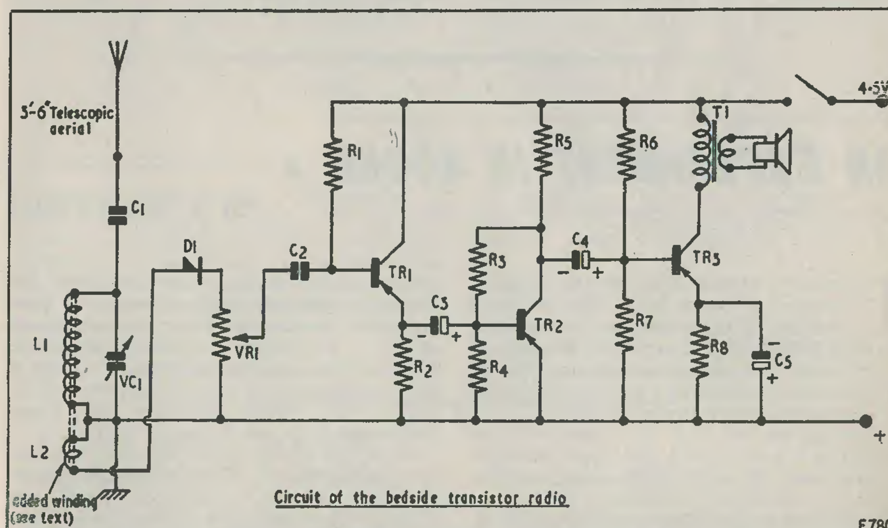
A Bedside transistor Radio

By A. H. STRANGE

A BEDSIDE RADIO SET, AS THE TITLE TENDS to suggest, need not have an output power approaching that of a normal set, although this does not mean that distortion has to be tolerated to a greater extent for a given sound level. The simple circuit about to be described has been used, in conjunction with a time switch, as an alarm for some while. The time switch has open contacts and for this reason it was advisable to employ battery power, which automatically prescribed the use of transistors.

An OC72 is used as a class A output stage, this producing a lower power output than would be obtained with a class B push-pull stage taking the same average current. However, it delivers sufficient power for the purpose and is economical, since the circuit requires no driver transformer and one less transistor. A five-inch speaker is employed to maintain efficiency. Since space is unimportant an even larger speaker may be used, together with standard size components, should this be desired. The output transformer is a valve type modified by removing ⅓ of the primary winding to obtain a ratio of 10–1, using resistance measurement as an approximate guide. A degree of temperature stabilisation is provided on all stages, its use not only being advisable in order to reduce the chance of thermal runaway, but also to help maintain the transistors on the correct working point of their curve and therefore offset the risk of distortion that may otherwise be incurred. It was unintentional that the stabilisation employed in the second stage also introduced a.c. feedback, but this method, although not wholly efficient, does reduce the number of components required by an emitter condenser and resistor.

The first stage has a grounded collector and is preceded by a high value diode load VR_1, which also serves as a volume control. The high value of VR_1 helps to maintain the Q of the tuned circuit. With such simple tuning arrangements, as high a Q as possible must be obtained, this mainly being achieved by adding a diode winding, L_2, to the earthy end of the tuned aerial coil, L_1. The diode winding consists of eight turns, and the wire gauge employed is not im-



Circuit of the bedside transistor radio

portant as it does not form part of the tuned circuit. The diode winding should be placed as close to the tuned winding as possible. The tuned coil is a single layer of Litz wire wound on a former just large enough to fit over a $\frac{3}{8}$in Ferrite rod which is 7in long, and it consists of 100 turns although 80 might be more appropriate for the Medium waveband when higher frequency stations are required. Unless constructors are familiar with terminating Litz wire, they would be well advised to purchase a similar ready-wound rod, then adding the diode winding described above. The diode winding is, of course, a single conductor and not Litz. In order to still further maintain the Q, the tuning condenser should be air spaced with ceramic insulation. With a good earth only a short telescopic aerial is required, but the condenser C_1 should not be omitted. All the above points add up to good selectivity. No claims are made concerning the sensitivity, but it is satisfactory in the locality in which the set is used* for the purpose of receiving both Home and Light programmes.

A 4.5 volt battery is employed, the total current drain being about 11mA. Satisfactory operation takes place with a battery voltage of between 3 and 4.5 volts; therefore, if the flat type of torch battery is used it should be some months before it need be discarded, assuming occasional use of the set.

* London, N.1.

Components List

Resistors

R_1	150kΩ ±10%
R_2	3.3kΩ ±10%
R_3	100kΩ ±10%
R_4	22kΩ ±10%
R_5	2.7kΩ ±10%
R_6	5.6kΩ ±5%
R_7	1.8kΩ ±10%
R_8	68Ω ±5%
VR_1	100kΩ pot.

Condensers

C_1	47pF
C_2	0.1μF
C_3	12μF, 6 W.V.
C_4	12μF, 6 W.V.
C_5	100μF, 6 W.V.
VC_1	500pF variable

Miscellaneous

T_1	Output transformer, 10:1 (3Ω speaker). See text.
L_1, L_2	See text
D_1	Crystal diode
TR_1	OC71
TR_2	OC71
TR_3	OC72

AN EXPERIMENT IN SOUND

By B. GOODWIN

Feeding a microphone into an oscilloscope has long been the favourite method of presenting to the beginner an idea of the sine wave and the similarity of sound and alternating current wave forms. Taking this combination a step further brings an interesting phenomenon to light.

The set-up (see Fig. 1) consists of two reflectors of the bowl fire type mounted facing each other approximately four feet apart. In the centre of reflector A is a moving coil earpiece connected to an audio oscillator. At reflector B a similar earpiece acts as a microphone, feeding the sounds transmitted from reflector A to the Y plates of an oscilloscope.

The X plates of the scope are now connected to the oscillator. Since the X and Y voltages are identical in frequency the resulting waveform will, according to their respective phases, be similar to those shown in Fig. 2. For example, should the Y voltage be maximum positive, when the X voltage is max. negative, then the waveform is that of Fig. 2 *(e)*, which illustrates 180° phase difference.

Now, the action of the reflectors is to set up standing waves. Thus, if the microphone is moved towards the earpiece, it will pass through the successive compressions and decompressions of air, corresponding to positive and negative peaks of the standing wave (see Fig. 3). This causes a variation of the oscilloscope trace owing to the change in phase of the sound wave incident on the microphone.

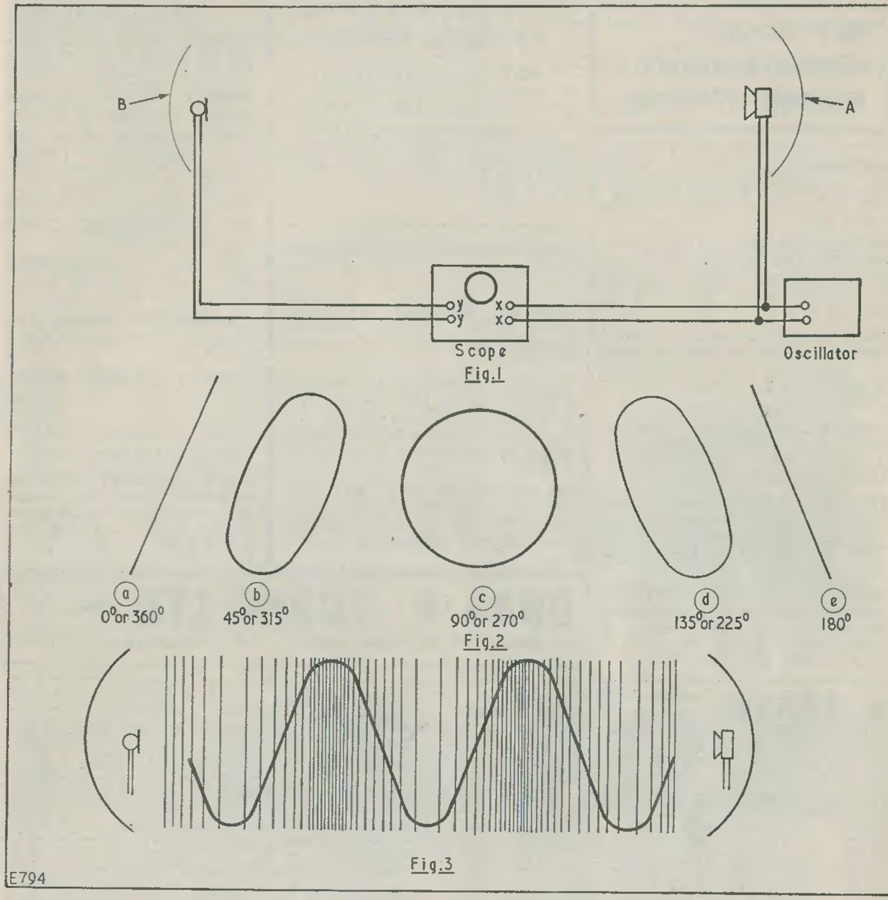


Fig. 1

Fig. 2

Fig. 3

Using this phenomenon, the position of positive and negative peaks can be pin-pointed in space, giving rise to a possible application. This is that, if the distance is measured between one positive peak and the next, we have, using the formula for wavelength, a possible method of frequency determination.

The wavelength measured with the author's equipment was 31.5 cms. Thus, since $V=f\lambda$ where V=the velocity of sound=3.3×10^4 cms/sec. and λ=wavelength, then $f=\frac{3.3 \times 10^4}{31.5}=1,080$ c/s.

Since the oscillator frequency was 1 kc/s, the error is 8%. Not very good, but after all this is only an experiment.

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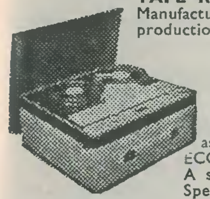

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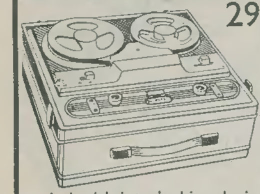

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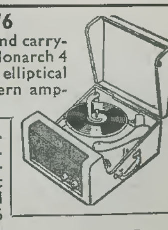

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