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TRANSISTOR CIRCUITS MANUAL No. 5

by
Clive Sinclair

Transistorised Tape Recorder Circuits.

Supersensitive Reflex Receiver.

Practical Construction Data.

Matchbox Superhet Receiver.

**Tunnel Diode F.M. Transmitter with full
building instructions.**

**14-Plans and diagrams of tested circuits for
the constructor.**

Electronic Transistorised Photoflash Unit.

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TRANSISTOR CIRCUITS

MANUAL

No. 5

by

CLIVE SINCLAIR

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INTRODUCTION

The transistor circuits manual series has proved so popular that in this, the fifth in the series, the page size has been doubled. This makes it possible to give larger and clearer circuit diagrams than before and it also means that only the very largest circuits have to be split into two parts.

The circuits included in this edition are those which readers asked for most in their letters. A large part of the book is devoted to tape recorder circuitry since this is a field now ripe for transistorisation. The circuit for a complete record/playback amplifier is included which will give a performance quite up to professional standards unlike most of the transistor tape recorders on the market at the moment. The amplifier was designed by G.E.C. and readers who have built circuits designed by this company before will know what excellent results they can expect.

Readers have often asked for the circuit of a high performance photoflash and one has been included here. The design is a comprehensive one, again by G.E.C., which can be used for a wide range of tube sizes.

Radio receivers have always been, and still remain, the most popular constructional projects. Four new circuits are given here. They will appeal to those readers who are devoted to the construction of miniature sets. In the past many of the tiny sets described have been severely lacking in performance mainly because of the limitations imposed by the components available. It has not been possible in the past to build a matchbox sized superhet, for example, because the twin-gang tuning capacitors, I.F. transformers and ferrite rod aerials on the market were far too large. Now, at last, this has all changed; T.S.L. can now supply a complete range of subminiature superhet components, all precisely matched to one another, which are the smallest in the world. These are used in the circuits in this book and will provide a considerable stimulus to the experimentally minded constructor.

The last circuits in the book are built around an amazingly new semiconductor device, the

tunnel diode. The circuits given are more experimental than those usually included in these books because the tunnel diode is really still a very new device, as it has not yet been applied in any large numbers, not much circuitry experience has been built up. Most of the development work so far done has been devoted to computer circuitry since this is likely to be one of the biggest markets for the T.D.'s.

Those readers who have not yet read about the tunnel diode, and there will be many as remarkably little has been written, may well be asking what is so interesting about this device. The most obvious advantage it has over existing semiconductor components, such as the transistor, is that it can amplify and oscillate at amazingly high frequencies. Tunnel diode amplifiers have been made which operate at 5,000Mc/s and oscillators have been built to work at twice this figure. Even the ordinary commercial tunnel diodes which are now readily available have cut-off frequencies of around 1,000Mc/s which compares very favourably with the transistors available 7 years ago which had reached about the same stage that the T.D. has now but which could only operate up to about 10Mc/s.

The oddest thing about the tunnel diode is that it has only two terminals or electrodes. Its ability to amplify and oscillate depends entirely on the fact that, between certain voltages, an increase in the voltage applied across the diode results in a decrease in the current flowing through it. In other words, the diode exhibits negative resistance on part of its characteristic curve. It is mainly because of this unusual means of obtaining amplification and oscillation that the large scale use of the tunnel diode has been delayed. Completely new techniques are having to be evolved and engineers are having to learn to think along new lines. The possibilities are so exciting, however, that a great deal of work is being done and the results are worth waiting for.

It is hoped that future Bernards publications will include an increasing number of tunnel diode circuits as these components become cheaper to buy and as experience is gained in their use.

2 WATT TAPE ERASE AND BIAS OSCILLATOR

In battery operated tape recorders which have any pretensions towards high quality reproduction a high frequency erase system must be used. The power required has to be at least $1\frac{1}{2}$ watts to overcome losses in the erase head and this unit fulfils all the requirements. The circuit is shown in Fig. 1. Two GET116 transistors are used as a class C oscillator operating from a 12 volt supply. The transistors should be a matched pair.

The erase head is coupled to the oscillator by a tuned transformer and the power output is 2 watts at 60kc/s. Bias for the record head is also supplied. The total power consumption of the unit is about 3.5 watts which represents an efficiency of around 60%.

The description of the circuit given by G.E.C., who designed the unit, is as follows:— The two GET116 transistors are used in a class C push-pull oscillator, the positive feedback and operating bias being provided by two identical RC networks (R_1, C_1 and R_2, C_2). The erase and record heads are coupled to the oscillator by a high efficiency transformer using a pot core assembly and the turns ratio is arranged to reflect a load impedance of 30 ohms to each collector (120 ohms collector to collector). The output circuit is tuned by capacitor C_4 , the value of which depends both on the type of erase head used and the value of Q chosen for the transformer. A small capacitor, C_5 , is connected in series with the record head to prevent the applied audio signal from being shunted by the transformer secondary winding. The voltage across the latter must therefore be somewhat greater than that required by the record head. The value of C_5 may then be adjusted to give the optimum value of H.F. bias.

The behaviour of the circuit may be conveniently examined by assuming that it is already oscillating at a frequency determined by the tuned circuit presented to the collectors. Then the voltage at each collector varies between 0 and $-2 V_{cc}$ with respect to earth. At the instant the voltage of Tr1 collector is zero and that at Tr2 collector is $-2 V_{cc}$ then the latter voltage is across R_1, C_1 in series with the base emitter diode of Tr1. Since the resistance of this junction is small, the voltage developed across R_1, C_1 is approximately $2 V_{cc}$ and in this condition Tr1 is conducting while Tr2 is biased off. As the voltage swing continues, the voltage at 'A' begins to decrease and that at 'B' rises. The time constant of R_1, C_1 is made large compared with the period of oscillation, hence the voltage across C_1 does not follow the reduction at 'A' and Tr1 is cut off. However, due to carrier storage a reverse base current then flows in Tr1 and the base input circuit does not immediately become a high impedance. C_1 , therefore, discharges through the transistor until the carrier storage pulse has ceased, after which it discharges through R_1 in the normal manner. During this time Tr2 is conducting and Tr1 remains cut-off until the point is reached in the next cycle where the voltage at 'A' becomes greater than that remaining across C_1 . The time constant of the feedback network is made two or three times the period of oscillation so that the residual charge in the capacitor is large enough to maintain class C bias conditions, this being essential to avoid exceeding the power rating of the transistors.

The characteristics of the circuit using typical GET116 transistors and standard erase and record/playback heads are as follows:—

	Collaro Heads	Truvox Heads	
Total input current (supply voltage = 12V)	290	290	mA
Input power	3.5	3.5	W
Output voltage across erase head	26	250	Vrms
Power into erase head	2	1.9	W
H.F. bias current in record head	0.8	0.8	mA
Operating frequency	60	60	kc/s
Peak emitter current	0.5	0.5	A
Power dissipated in each transistor	about 330	about 330	mW
Operating temperature range with each transistor on 3" x 3" fin	- 40 to + 65	- 40 to + 65	°C
Supply voltage range for complete erasure	9—12	9—12	V

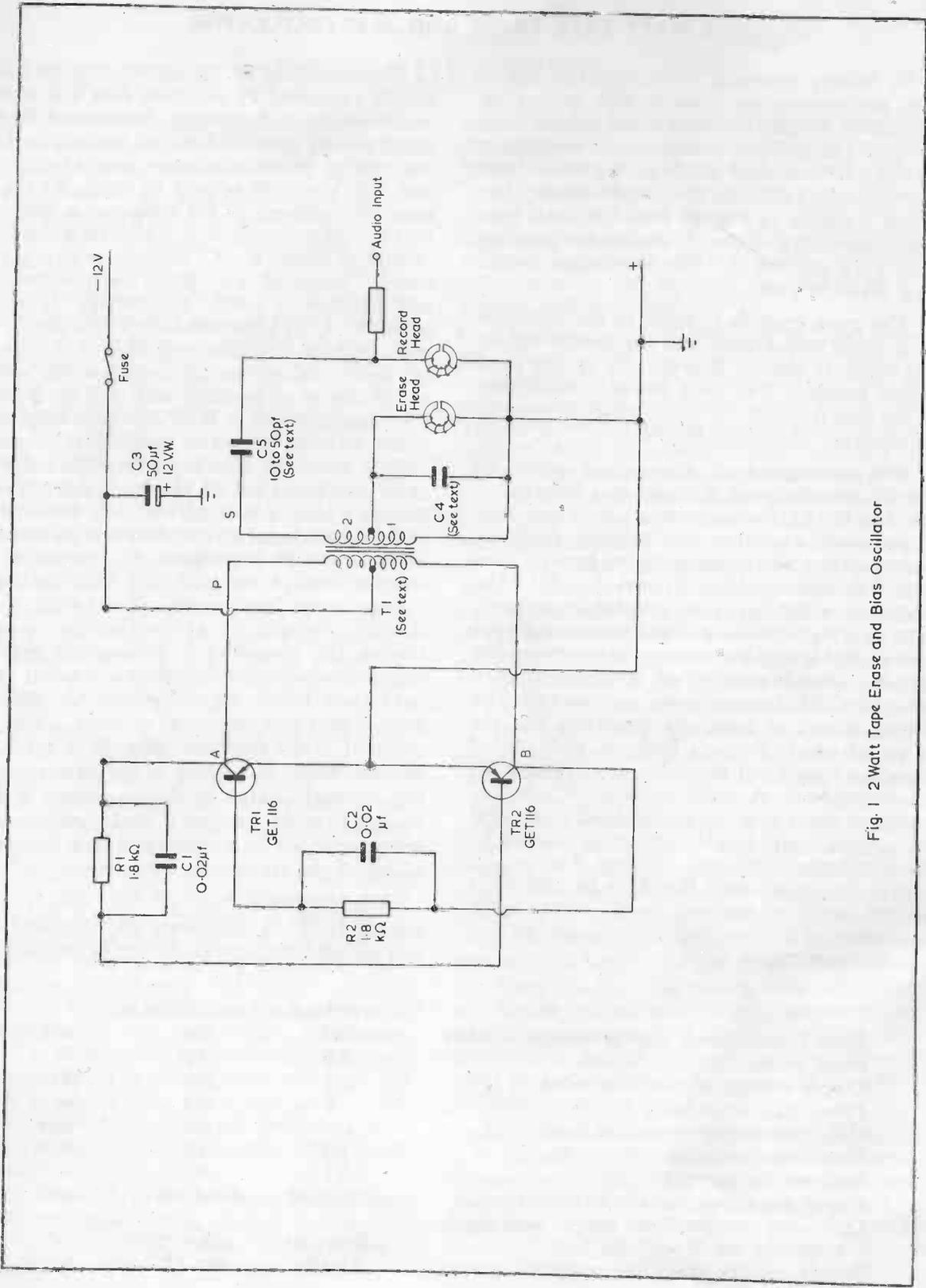


Fig. 1 2 Watt Tape Erase and Bias Oscillator

The transformer details given below are typical high (Table 1) and low (Table 2) impedance heads respectively.

Table 1

Transformer and output circuit details for Truvox heads.

Erase head inductance approximately equal to 80mH.

T1 (A) QL approximately equal to 2.

"Gecolite" ferrite core assembly GA110A.

Primary: 10 + 10 turns of 30 s.w.g. enamelled copper wire, bifilar wound.

Secondary (1): 340 turns of 36 s.w.g. enamelled copper wire.

Secondary (2): 190 turns of 36 s.w.g. enamelled copper wire.

(The two secondaries are connected in series.)

Primary inductance (each half): 37 microH.

Primary d.c. resistance: 9.5 ohms.

Secondary (1) d.c. resistance: 9.5 ohms.

Secondary (2) d.c. resistance: 6.5 ohms.

C_4 : 180 pf.

Overall efficiency approximately equal to 58%.

T1 (B) QL approximately equal to 10.

"Gecolite" ferrite core assembly GA110B.

Primary: 6 + 6 turns of 30 s.w.g. enamelled copper wire, bifilar wound.

Secondary (1): 200 turns of 32 s.w.g. enamelled copper wire.

Secondary (2): 100 turns of 32 s.w.g. enamelled copper wire.

(The two secondaries are connected in series.)

Primary inductance (each half-section): 8.5 microH.

Primary d.c. resistance (each half-section): < 0.1 ohm.

Secondary (1) d.c. resistance: 2.5 ohms.

Secondary (2) d.c. resistance: 1.8 ohms.

C_4 : 680 pf.

Overall efficiency approximately equal to 52%.

Table 2.

Transformer and output circuit details for Collaro heads.

Erase head inductance approximately equal to 1mH.

T1 (C) approximately equal to 2.

"Gecolite" ferrite core assembly GA110A.

Primary: 12 + 12 turns of 30 s.w.g. enamelled copper wire, bifilar wound.

Secondary (1): 40 turns of 30 s.w.g. enamelled copper wire.

Secondary (2): 600 turns of 36 s.w.g. enamelled copper wire.

(The two secondaries are connected in series.)

Primary inductance (each half-section): 53 microH.

Primary d.c. resistance (each half-section): < 0.2 ohm.

Secondary (1) d.c. resistance: < 0.2 ohms.

Secondary (2) d.c. resistance: < 45 ohms.

C_4 : 0.015 microfarad.

Overall efficiency approximately equal to 58%.

T1 (D) QL approximately equal to 10.

"Gecolite" ferrite core assembly GA110B.

Primary: 6 + 6 turns of 30 s.w.g. enamelled copper wire, bifilar wound.

Secondary (1): 19 turns of 30 s.w.g. enamelled copper wire.

Secondary (2): 300 turns of 36 s.w.g. enamelled copper wire.

(The two secondaries are connected in series.)

Primary inductance (each half-section): 8.5 microH.

Primary d.c. resistance (each half-section): < 0.1 ohm.

Secondary (1) d.c. resistance: < 0.2 ohm.

Secondary (2) d.c. resistance: 10 ohms.

C_4 : 0.08 microfarad.

Overall efficiency approximately equal to 53%.

Suitable commercial transformers: —

	T1 (A)	T1 (B)	T1 (C)	T1 (D)
Colne Electric	—	06044	—	06042
Parmeko	—	P3009	—	P3007
Belclere	TF2544	TF2545	TF2546	TF2547

The high Q transformers above produce a more sinusoidal output than do the low Q ones but they are rather less efficient.

The output terminals of the oscillator must

not be short circuited during operation since this will cause very large collector currents in the transistors; sufficient to damage them.

50 mW BIAS OSCILLATOR FOR USE IN MINIATURE TAPE RECORDERS

In miniature recorders, such as those used for dictating purposes or as "electronic notebooks", quality of reproduction and freedom from noise are not of prime importance. A considerable amount of refinement of detail can be sacrificed in fact, in the interests of small size, light weight and long playing time. Thus the use of an erase oscillator, consuming as it does, a considerable amount of power, is hardly justifiable and a permanent magnet may be used instead. The high frequency oscillator under these circumstances, only has to provide the bias voltage for the record/playback head. The power required for this purpose is only a matter of a few tens of mW and this can readily be provided by a small pocket radio type of battery such as the PP3.

Unfortunately, there are no small, battery operated tape decks yet on the market and some enterprising manufacturer might do well to produce one along the lines of those used by the Japanese. The enterprising constructor, however, might well build one for himself. Although this would be no simple task I have seen one or two such units which worked beautifully. Far better, in fact, than some of those now being imported into the country. The main requirements are a suitable electric motor, which should be shielded and possibly suppressed and some means of speed regulation. If the unit is intended only for speech a tape speed of only $1\frac{7}{8}$ " per second or possibly even $15/16$ ths i.p.s. should be sufficient as long as wow and flutter are kept to a minimum and a narrow gap head is used. At these speeds and with double play tape a small reel of tape, possibly just a 2" reel, will be needed to provide adequate recording time. Both tracks, or all 4 tracks if 4 track recording is used, will have to be erased at the same time since with permanent magnet erase it is not easy to erase selectively. On a miniature machine of the type envisaged this is unlikely to matter very much, however.

Circuit Details.

Fig. 2 shows the circuit diagram of a 50mW bias oscillator using one of Newmarket's small audio transistors. It operates from a 9 volt battery and is designed to feed into a 180 ohm load. The current consumption is about 12mA.

The transistor, Tr1, is operated in the common emitter mode with the tuned circuit in the collector. Feedback to the base emitter circuit

is by means of a secondary winding, matched to the transistor input impedance, on the collector coil. The output is taken directly from the collector circuit.

The degree of feedback is controlled by R_3 . The larger the value of R_3 the lower the total positive feedback becomes because R_3 being un-bypassed, provides negative feedback. Adjustment is made for minimum distortion which should occur when the amount of positive feedback in the circuit is just sufficient to maintain stable oscillation within current swing limits of the transistor.

When the output from the oscillator must be isolated from the load, i.e. the head, as far as d.c. is concerned, the output may be taken via a 5 microfarad capacitor. A third winding on the transformer may also be used and this has the advantage that the output impedance can be altered to suit the head by altering the number of turns.

Since the transistor is dissipating quite an amount of power for its size it should be modulated in the clip provided with each unit. When a higher output power is required a Newmarket V15/201P may be used to provide up to 600mW. The component values must then be altered as follows:—

R_1	150 ohms	C_1	2 microfarad
R_2	30 ohms	C_2	2 microfarad
$R_{3,4}$	5 ohms	C_3	0.002 microfarad

The load will then be 25 ohms.

The frequency of oscillation is 40kc/s which is high enough for speech recording.

Components.

Transistor: TR1 Newmarket type V10/50A.

Transformer: T_x Core—Ferroxcube LA7 pot core, grade A2.

Windings: Primary (P) 80 turns of 30 s.w.g. enamelled copper wire, inductance 900 microH.

Secondary (S) 8 turns of 30 s.w.g. enamelled copper wire, inductance 9 microH.

Resistors

R_1 820 ohms

R_2 680 ohms

R_3 25 ohm potentiometer

R_4 150 ohms

Capacitors

C_1 25 microfarad

C_2 2 microfarad

C_3 0.002 microfarad

All 10% tolerance $\frac{1}{4}$ watt types.

G.E.C. TRANSISTORISED RECORD/PLAYBACK AMPLIFIER

The modern high quality tape recorder is a fairly complex device using very high gain audio amplifiers. Since reasonable size is required for domestic use considerable problems arise in the design. The major difficulties with conventional units are generation of too much heat, which reduces component life, microphony, which is usually due to vibrations being picked up by the valves from the tape deck motors and A.F. instability caused by lack of adequate screening. All these problems, which make the design and production of recorders using valves so difficult, are easily overcome by the use of transistors. Too much heat is avoided because of the considerably reduced power consumption, microphony becomes impossible and A.F. instability far less likely due to the far lower input and output impedances of the transistor. Besides these there are the usual advantages of reduced weight and size.

From the above it is clear that there is much to be said for the transistorisation of the tape recorder even when 'mains only' operation is

intended. The increased reliability obtained should, in fact, be sufficient justification alone because high quality recorders are notoriously poor from this point of view. The only disadvantage with transistors is the higher cost but, considering the total cost of a recorder, this is not really very significant.

The design of a completely transistorised record/playback amplifier is by no means an easy matter but G.E.C. have made an extremely thorough job of it. Equalisation is closely to C.C.I.R. specifications at either $7\frac{1}{2}$ i.p.s. or $3\frac{3}{4}$ i.p.s. The audio output power is 1 watt and the signal to noise ratio is better than 50dB. The total harmonic distortion at maximum output is less than 3%. On record the signal to noise ratio is again better than 45dB and the total distortion less than 0.5% for an input recording current of 150 microA. All in all the performance is comparable with the best valve units.

To simplify explanation of the circuit functions the unit has been divided into two circuits

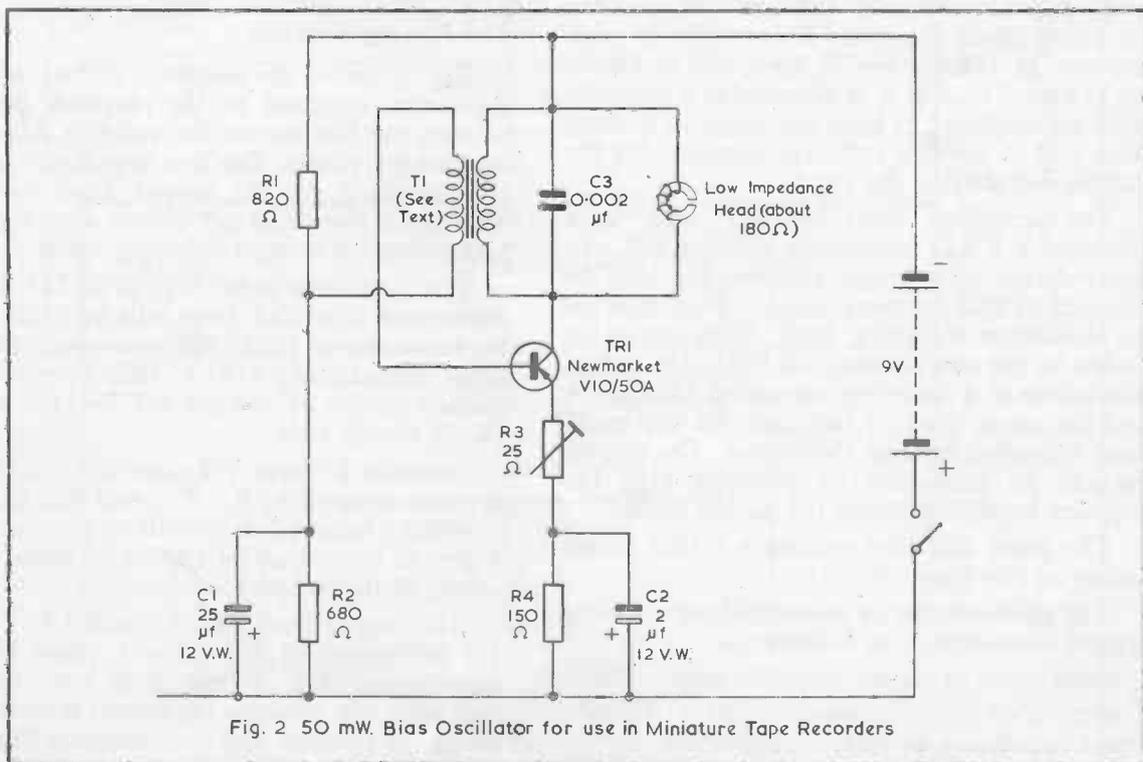


Fig. 2 50 mW. Bias Oscillator for use in Miniature Tape Recorders

showing the record and playback parts separately. A circuit of the complete unit is also given.

The Record Circuit.

The record circuit is shown in Figs. 3 and 4. Three inputs are provided. Input 1 is the high impedance low level input and input 2 is the low impedance low level input. Both of these feed into Tr1 which has an input impedance of 200 ohms. When R_2 is 1Megohm the input into socket 1 for peak recording level is 150mV., this being an appropriate level for many ceramic and crystal pick ups. The input should not exceed 500 microV into the base of Tr1 (2.5V into socket 1) as more than this will overload the stage.

For larger signals socket 3 should be used. This feeds into Tr2 which requires a voltage of 1.5mV on the base for the maximum recording level. With a value of 100K ohms for R_1 the input sensitivity will be 300mV. The voltage applied to the base of Tr2 must not exceed 30mV.

L_1 and C_{13} , between Tr3 and Tr4, provide the treble boost required. This results in peak response at 12Kc/s for $7\frac{1}{2}$ i.p.s. and at 6Kc/s for $3\frac{3}{4}$ i.p.s. Tr5, Fig. 4, is operated as a common collector amplifier to keep distortion to a minimum and to provide sufficient damping for the transformer driving the head.

The recording level monitor used is a 100microA F.S.D. miniature moving coil ammeter driven by a bridge rectifier. R_{27} may be adjusted so that the meter reads 100microA for the maximum recording level. With the value shown in the components list full scale deflection occurs at a recording current of 200microA and the meter reads $\frac{3}{4}$ full scale for the maximum recording level of 150microA. The recording can be monitored by plugging high impedance headphones into the socket shown.

The erase and bias oscillator is that shown earlier in this book (Fig. 1).

The performance of the record circuit using typical transistors is as follows:—

Current drain of record amplifier only: 20mA.
Current drain including erase oscillator: 320mA.
Input impedance at 400c/s: 200 ohms.
Input voltage at 150microA recording current: 30microV.

Input impedance of 2nd stage at 400c/s: 470 ohms.

Input voltage to 2nd stage for 150microA recording current: 1.5mV.

Total noise output, with volume control at maximum: -45dB.

Signal to noise ratio, with 100microV input (500mV into 1Mohm) and volume control adjusted to give 150microA recording current: 55dB.

Total harmonic distortion at 150microA level: < 0.5%.

At 200microA level: < 1%.

At 350microA level: < 3%.

The signal to noise ratio can be increased at the expense of treble response by reducing the amount of treble boost. To increase the signal to noise ratio by 3dB R_{16} should be reduced to 3.9K ohms and C_{13} and C_{14} increased to 820pf and 0.005microfarad respectively. This will limit the high frequency response at $7\frac{1}{2}$ i.p.s. to 9Kc/s. For a similar increase at $3\frac{3}{4}$ i.p.s. C_{12} should be 2200pf.

The Playback Circuit.

Fig. 5 shows the amplifier circuit with the transistors switched to the playback position, as with the last circuit the switches have been omitted for clarity. The first two stages provide compensation for the output from the head. This latter rises 6dB per octave until the head losses cause it to start dropping again.

For a constant input voltage to Tr1 the output voltage from Tr2 drops 6dB per octave until the reactance of C_4 , C_6 becomes lower than the input impedance of Tr2. This crossover frequency occurs at 14Kc/s for $7\frac{1}{2}$ i.p.s. and at 7Kc/s for $3\frac{3}{4}$ i.p.s.

Between Tr3 and Tr4 there is a treble boost network comprising R_{17} , C_{15} , and R_{18} , C_{16} . This provides a boost of about 3dB on playback. The degree of boost may be altered by changing the values of the network components.

The output from Tr4 is coupled to Tr5 and Tr6 by means of a 2 : 1 + 1 phase splitting transformer. The output stage uses the split load principle whereby the output is divided between the emitters and the collectors thus combining the advantages of both common emitter and common collector amplification, that is high

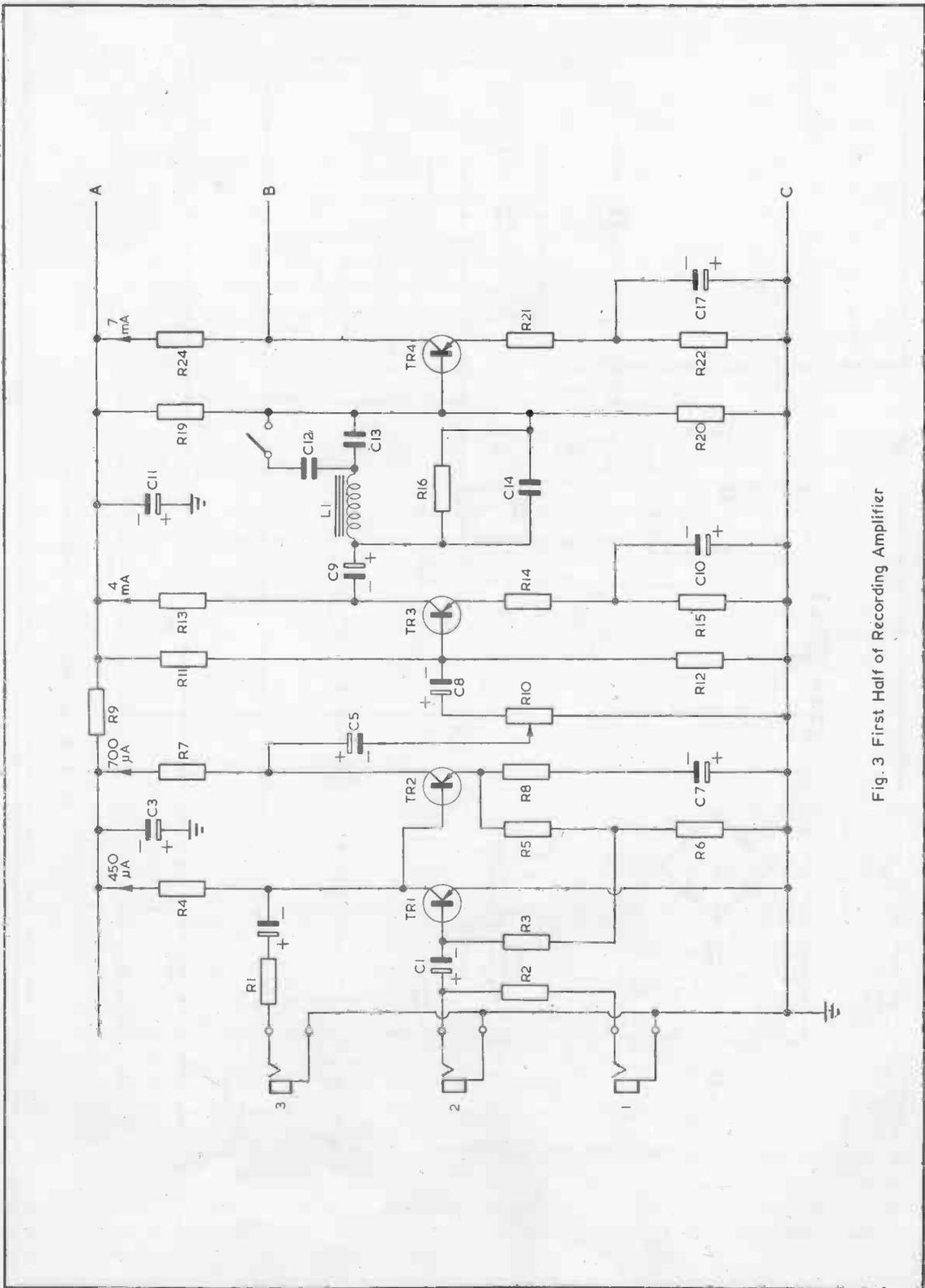


Fig. 3 First Half of Recording Amplifier

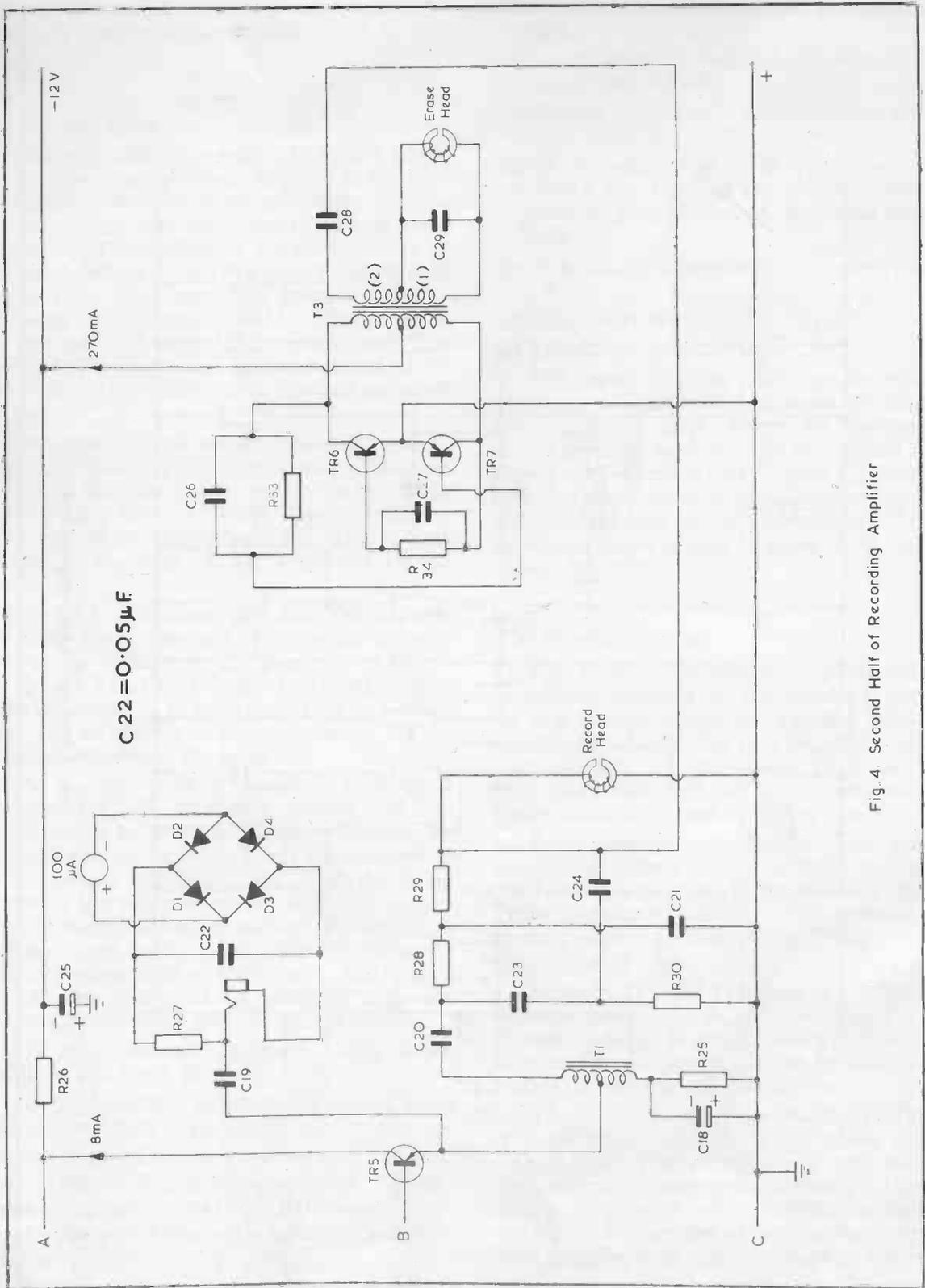


Fig. 4. Second Half of Recording Amplifier

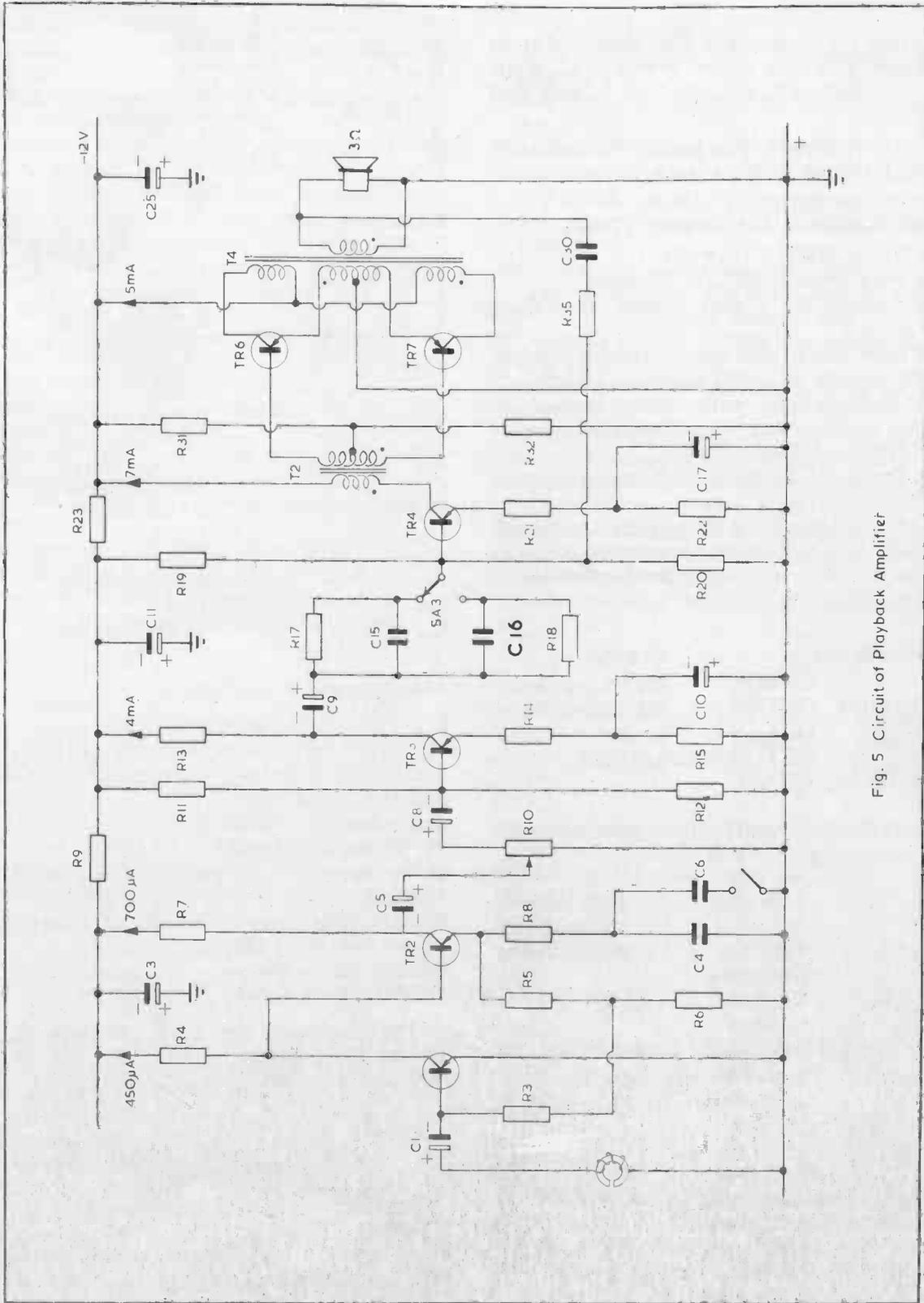


Fig. 5 Circuit of Playback Amplifier

gain from the former and low distortion from the latter. The peak output power is 1.2 watts with less than 3% distortion at 1 watt and 400 c/s.

The performance of the playback circuit using typical playback resistors is as follows:—

Quiescent current drain: 25mA.

Current drain at 1 watt output: 170mA.

Peak output power: 1.2 watts.

Input impedance at 400c/s: 30 ohms.

Input voltage for 1 watt output at 400 c/s: 30 microV.

Total noise output with volume control at maximum relative to 1 watt output: -45dB.

Signal to noise ratio, with volume control adjusted to give 1 watt output from tape recorder at 150microA level: 55dB.

Total harmonic distortion at 1 watt output at 400c/s: < 3%.

The complete circuit of the record/playback amplifier, with switching arrangement, is shown in Figs. 6 and 7. The components used are as follows:—

Semiconductors

Tr1,	GET106	SA 3-pole 2-way
Tr2, Tr3, Tr5	GET114	SB 12-pole 3-way
Tr4,	GET103	
Tr6, Tr7	GET116 (matched pair)	
D ₁ , D ₂ , D ₃ , D ₄	GEX34	

Switches

Resistors ($\pm 10\%$ $\frac{1}{4}$ watt unless otherwise stated).

R ₁ , R ₂	See text
R ₃	4.7K ohm $\pm 5\%$ high stability
R ₄	18K ohm $\pm 5\%$ high stability
R ₅ , R ₆	220 ohm $\pm 5\%$ high stability
R ₇	10K ohms
R ₈ , R ₂₃ , R ₂₆	47 ohms
R ₉ , R ₁₃	1K ohm
R ₁₀	100K ohm volume control
R ₁₁ , R ₁₉	15K ohm
R ₁₂	3.3K ohms
R ₁₄ , R ₂₁	22 ohms
R ₁₅	330 ohms
R ₁₆	5.6K ohms
R ₁₇	3.9K ohms
R ₁₈	4.7K ohms
R ₂₀	2.2K ohms
R ₂₂	120 ohms
R ₂₄ , R ₂₅	680 ohms

R ₂₇	12K ohms
R ₂₈ , R ₂₉	39K ohms
R ₃₀	18K ohms
R ₃₁ , R ₃₃ , R ₃₄	1.8K ohms $\pm 5\%$
R ₃₂	27 ohms $\pm 5\%$
R ₃₃	22K ohms

Capacitors

C ₁	50microfarad 3v.w.
C ₂ , C ₅ , C ₈ , C ₉	8microfarad 12v.w.
C ₃ , C ₁₁ , C ₂₅	500microfarad 12v.
C ₄ , C ₆	0.25microfarad
C ₇ , C ₁₀ , C ₁₇	250microfarad 3v.
C ₁₂	1500pf.
C ₁₃	470pf.
C ₁₄	0.003microfarad
C ₁₅	0.01microfarad
C ₁₆	0.02microfarad
C ₁₈	100microfarad 6v.
C ₁₉ , C ₂₀ , C ₃₀	0.1microfarad
C ₂₁	150pf.
C ₂₃ , C ₂₄	68pf.
C ₂₆ , C ₂₇	0.02microfarad
C ₂₈	47pf.
C ₂₉	0.08microfarad

Inductors and Transformers

L₁ Treble boost inductors.
 "Gecolite" ferrite core assembly GA110A.
 1,000 turns of 40 s.w.g. enamelled copper wire.
 Inductance - 370mH.
 d.c. resistance - 60 ohms.
 T₁ Head Transformer.
 Turns ratio - 1:8 (windings connected in series).
 Primary inductance > 200mH at 50c/s with 8mA polarising current.
 Primary d.c. resistance - 50 ohms.
 Total d.c. resistance < 700 ohms.

The transformer used in the prototype amplifier had the following construction:—
 $\frac{5}{8}$ " stack of 0.014" laminic stampings M, and E.A. pattern No. 36. Cross sectional area of core 0.27 sq. in. laced joint.
 750 turns of 36 s.w.g. enamelled copper wire + 5250 turns of 40 s.w.g. enamelled copper wire. No interleaving between layers.
 T₂ Driver Transformer.
 Turns ratio 2 : 1 + 1 (secondary bifilar wound).
 Primary inductance > 4H at 50c/s with 7mA polarising current.

Primary d.c. resistance < 150 ohms.
 Secondary d.c. resistance (each section) < 20 ohms.

The transformer used in the prototype had the following construction:—

$\frac{5}{8}$ " stack of 0.014" laminic stampings, M. and E.A. pattern No. 36. Cross sectional area of core 0.27 sq. in. laced joint. Primary windings 1200 turns of 40 s.w.g. enamelled copper wire. Secondary winding 600 + 600 turns of s.w.g. enamelled copper wire, bifilar wound. No interleaving between layers.

T₃ Oscillator Transformer.

"Gecolite" ferrite core assembly GA110B.

Primary winding 6 + 6 turns of 28 s.w.g. enamelled copper wire bifilar wound.

Secondary winding (1) 19 turns of 30 s.w.g. enamelled copper wire.

Secondary winding (2) 300 turns of 36 s.w.g. enamelled copper wire.

The two secondary windings are connected in series.

Total primary inductance 34microH.

Total primary d.c. resistance < 0.2 ohms.

Secondary (1) d.c. resistance < 0.2 ohms.

Secondary (2) d.c. resistance 10 ohms.

T₄ Output Transformer.

Turns ratio 3.8 + 3.8: 1 (primary bifilar wound).

Turns ratio of collector to emitter windings 3:1.

Total primary inductance > 800mH.

Total d.c. resistance of collector windings < 3 ohms.

Total d.c. resistance of emitter windings 2 ohms.

Secondary d.c. resistance < 0.2 ohm.

The transformer used in the prototype amplifier had the following construction:—

$\frac{5}{8}$ " stack of 0.014" laminic stampings M. and E.A. pattern No. 36.

Cross-sectional area of core 0.27 sq. in. laced joint.

Collector windings 150 + 150 turns of 26 s.w.g. enamelled copper wire, bifilar wound.

Emitter windings 50 + 50 turns of 28 s.w.g. enamelled copper wire, bifilar wound.

Secondary winding 52 turns of 22 s.w.g. enamelled copper wire, bifilar wound. No interleaving between layers.

The following commercial transformers are suitable:—

	L ₁	T ₁	T ₂	T ₃	T ₄
Belclere	TF2549	TF2550	TF2551	TF2547	TF2552
Colne Electric	06039	06040	06041	06042	06043
Parmeko	P3004	P3005	P3006	P3007	P3008

The constructor who undertakes this rather ambitious project should be able to build himself a tape recorder in many ways superior to those at present on the market and at much

lower cost than most. The care and effort required are considerable but are more than justified by the results.

G.E.C. ELECTRONIC PHOTO-FLASH UNIT

Fig. 8 shows the circuit diagram of a transistorised electronic photo-flash suitable for battery operation. The unit is suitable for tubes having maximum ratings up to 100 joules and the maximum operating voltage is 500 volts.

The range of power output possible is, therefore, 25 to 100 joules. For the lowest power level four 1.5 volt dry cells may be used as the power supply but for higher powers a set of three 2 volt, 8 ampere-hour accumulators is preferable. The time required for the capacitor to

recharge after firing is between 8 and 15 seconds depending upon the size of the capacitor and the type of power supply used.

The Circuit.

The complete circuit diagram of the unit is shown in Fig. 8. The transistors, Tr1 and Tr2, and the transformer T₁, form a square wave oscillator operating at about 500c/s. Oscillation is maintained by feedback windings on the

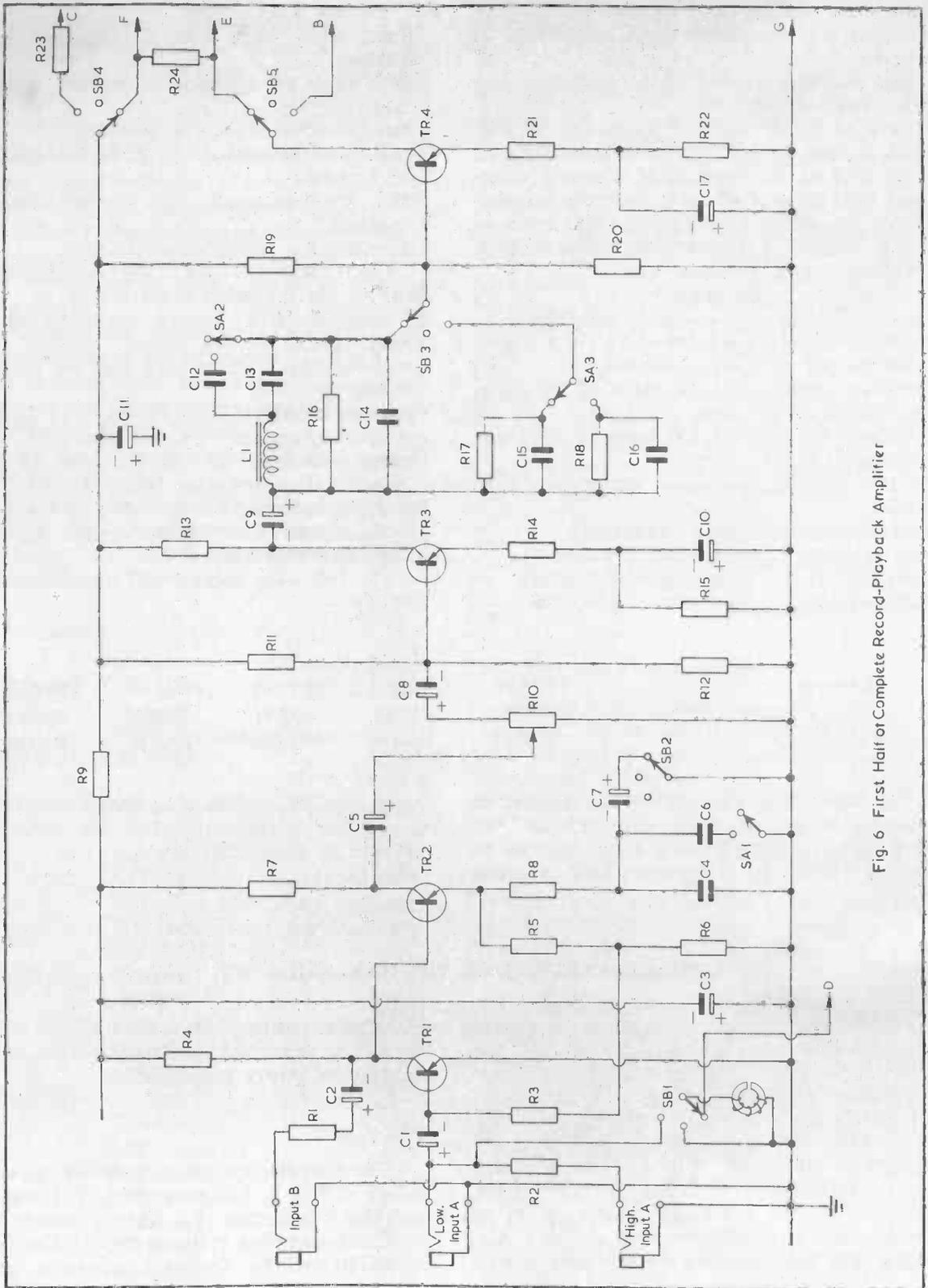


Fig. 6 First Half of Complete Record-Playback Amplifier

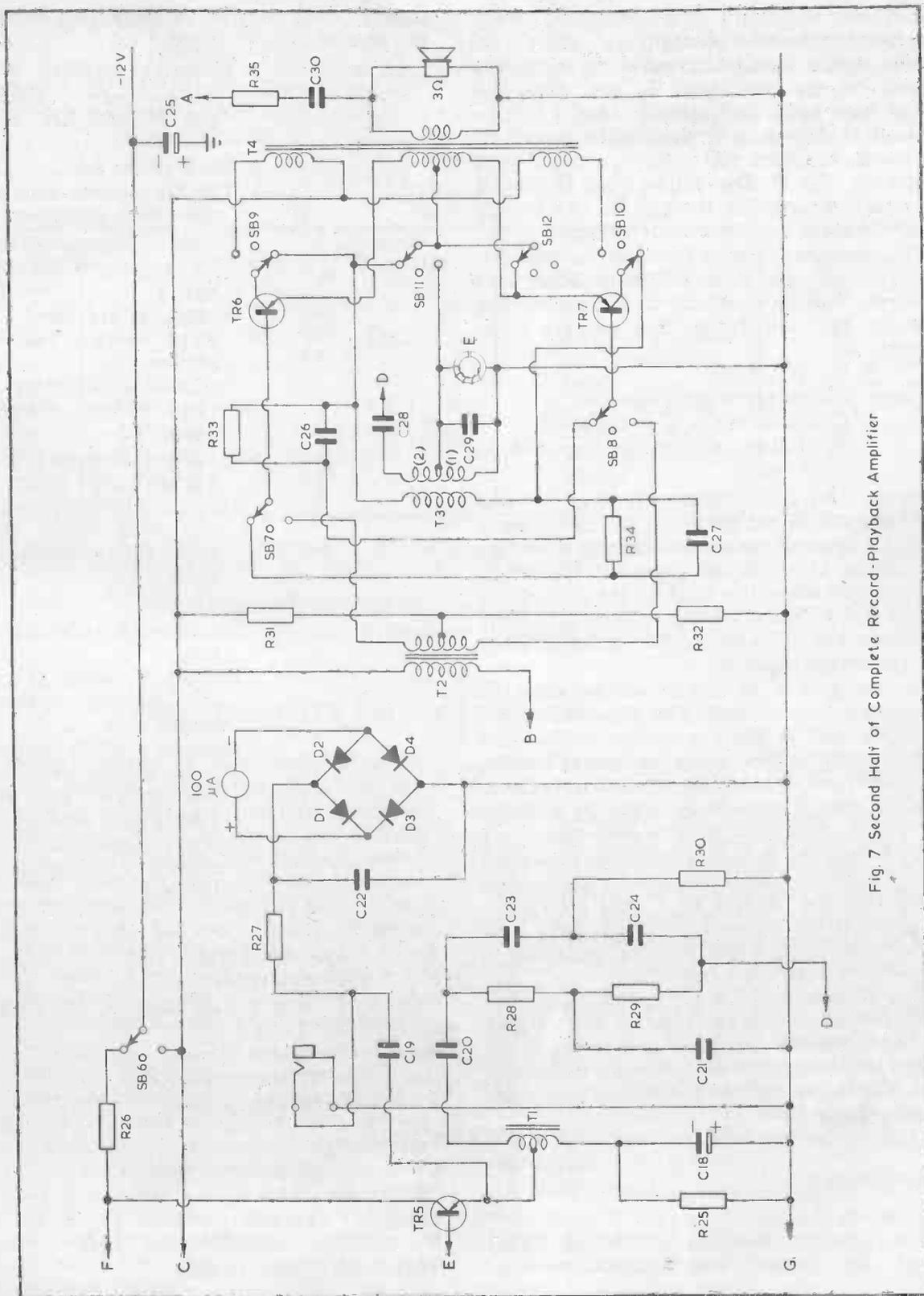


Fig. 7 Second Half of Complete Record-Playback Amplifier

transformer which are shown separately in the diagram for the sake of clarity.

The square wave generated by the transistors appears in the primary of T_1 and, since this transformer has a high step-up ratio, a voltage some 40 times greater appears in the secondary. This voltage, about 500 volts, is rectified by a bridge rectifier D. The output from D charges the reservoir capacitor, through R_4 , to a voltage approximating its own output voltage.

The amount of energy stored in the capacitor depends upon the value of the capacitor and upon the voltage to which it is charged. The formula for calculating this energy is as follows:—

$$E = \frac{1}{2} CV^2 10^{-6}$$

where E = energy stored in joules
 C = capacitance in microfarads
 V = voltage across the capacitor in volts.

Since the lamp extinguishes at between 100 and 150 volts not all the energy in the capacitor is used. To obtain a reasonable amount of energy the voltage to which the capacitor is charged must be well above this level. In the case of this design one, or more, 200 microfarad capacitors are charged to 500 volts and the energy obtained is 25 joules per capacitor.

A neon bulb V_2 is used to indicate when the capacitor is fully charged. The potential divider R_6 , R_7 is used to apply a voltage to the neon bulb such that it glows when the voltage reaches a level between 450 and 500 volts and not before. In some cases it may be necessary to alter the value of R_7 slightly to achieve this end.

To trigger the flash tube a voltage of around 5KV is required. This is obtained by discharging C_3 through the primary of T_2 and taking the voltage from the secondary. Since T_2 has a high step-up ratio the voltage from the secondary is sufficient to trigger the tube.

The purpose of R_3 is to control the limit to which the current drawn from the battery may rise. An ammeter connected in series with the battery may be used to adjust this for the correct level. The levels required for various energy are given in Table 1.

Components.

Transformer T_1 .

The primary windings should be bifilar wound. The primary and feedback windings

should be sandwiched between two halves of the secondary.

Laminations Mumetal material 0.004" thick.

Type M and EA pattern No. 36.

Stack height 0.65".

The laminations should be assembled interleaved.

Windings

Primary 22 turns + 22 turns, 19 s.w.g. enamelled copper wire.

Secondary 915 turns + 915 turns, 38 s.w.g. enamelled copper wire.

Feedback — 10 turns + 10 turns, 30 s.w.g. enamelled copper wire.

Insulation between layers— 1 layer 0.001" paper.

Insulation between windings — 1 layer 0.001" paper and 1 layer 0.005" empire cloth.

Transformer T_2 .

Core

Ferrite rod 5/16th" dia. \times 5/8" long.

Primary 83 turns 34 s.w.g. silk covered enamelled copper wire.

Secondary 1,500 turns 38 s.w.g. silk covered enamelled copper wire wave wound over primary.

Primary inductance: 150 microH measured at 1Kc/s.

Resistors.

R_1 100 ohm $\frac{1}{2}$ watt.

R_2 10 ohm $\frac{1}{4}$ watt.

R_3 47 ohm 1 watt variable wirewound.

R_4 See Table 1.

R_5 3.3M ohm $\frac{1}{4}$ watt.

R_6 4.7M ohm $\frac{1}{4}$ watt.

R_7 1.8M ohm $\frac{1}{4}$ watt.

Capacitors.

C_1 100 microfarad 6v.

C_2 See Table 1.

C_3 0.1 microfarad 500v.

V_2 Neon indicator G.E.C. LH1.

Transistors See Table 1.

Battery See Table 1.

Rectifiers D_1, D_2, D_3, D_4 . Each diode may be two SX632's in parallel or a single SX635.

Flash tubes Any of the following tubes may be used—Mazda FA8 for units up to 75 joules; "Sief flash" SF11, SF12, SF15 or SF18 for all units up to 100 joules.

Table 1.

Value of R_4 (ohms)	* C_2 (mfd.)	Energy (Joules)	Transistor Type	Battery	Maximum Supply Current
2,200	200	25	GET115	4 × 1.5v dry cells the photoflash type.	1A
1,000	400	50	GET571	3 × 2v, 8 A/hr portable accumulators Exide MFB9.	3A
560	600	75	GET571		4A
560	800	100	GET571		5A

* Built up from T.C.C. "Lectroflash" capacitors type SCE60PE (200 microfarad, 500v. d.c.). The larger capacitance values being obtained by connecting single units in parallel.

WARNING.—The charge on C_2 is quite large enough to be lethal. The unit must therefore be handled with greater care and only used when in an insulating container.

HIGH SENSITIVITY DOUBLE-TUNED REFLEX RECEIVER

The performance of very small or simple radio sets described before has often been disappointing for one reason or another. The selectivity was almost invariably inadequate and the sensitivity was frequently less than one would have liked. This was rarely the fault of the designers who made the best use they could of the facilities available but the difficulty remained that the components they really needed were just not made. The art of miniaturisation of components had not gone far enough to satisfy the demands of the miniature radio designers.

This is now changed. The designers will not be satisfied of course because they will now want something else (3" 110° cathode tubes for pocket television sets, no doubt) but the fact remains that all the components needed for really high performance pocket sets are now available. The most important perhaps, is the 'Babyvar' tuning capacitor which is less than $\frac{5}{8}$ " square and yet is a twin gang unit complete with trimmers. Since the two gangs have the capacity range the capacitor is suitable for use

in T.R.F. receivers as well as in the superhets for which it was intended.

Fig. 9 illustrates one of the most interesting possibilities of the 'Babyvar'. It is a reflex receiver with Tr1 acting both as an R.F. and an A.F. amplifier. This, of course, is now quite a common arrangement but what is not so common is the fact that the output from Tr1 is tuned as well as the input. This not only increases the selectivity of the set considerably (a major failing of earlier reflex receivers) but it also increases the sensitivity because the R.F. load in the collector of Tr1 can be made much larger in impedance and this impedance can be matched accurately to that of the diode circuit. The resultant improvement in gain is considerable.

A third advantage that this set has over its predecessors is the improved A.G.C. circuit. This is the same as that used in superhet receivers and, whilst these latter, being more sensitive, have greater need for adequate A.G.C.

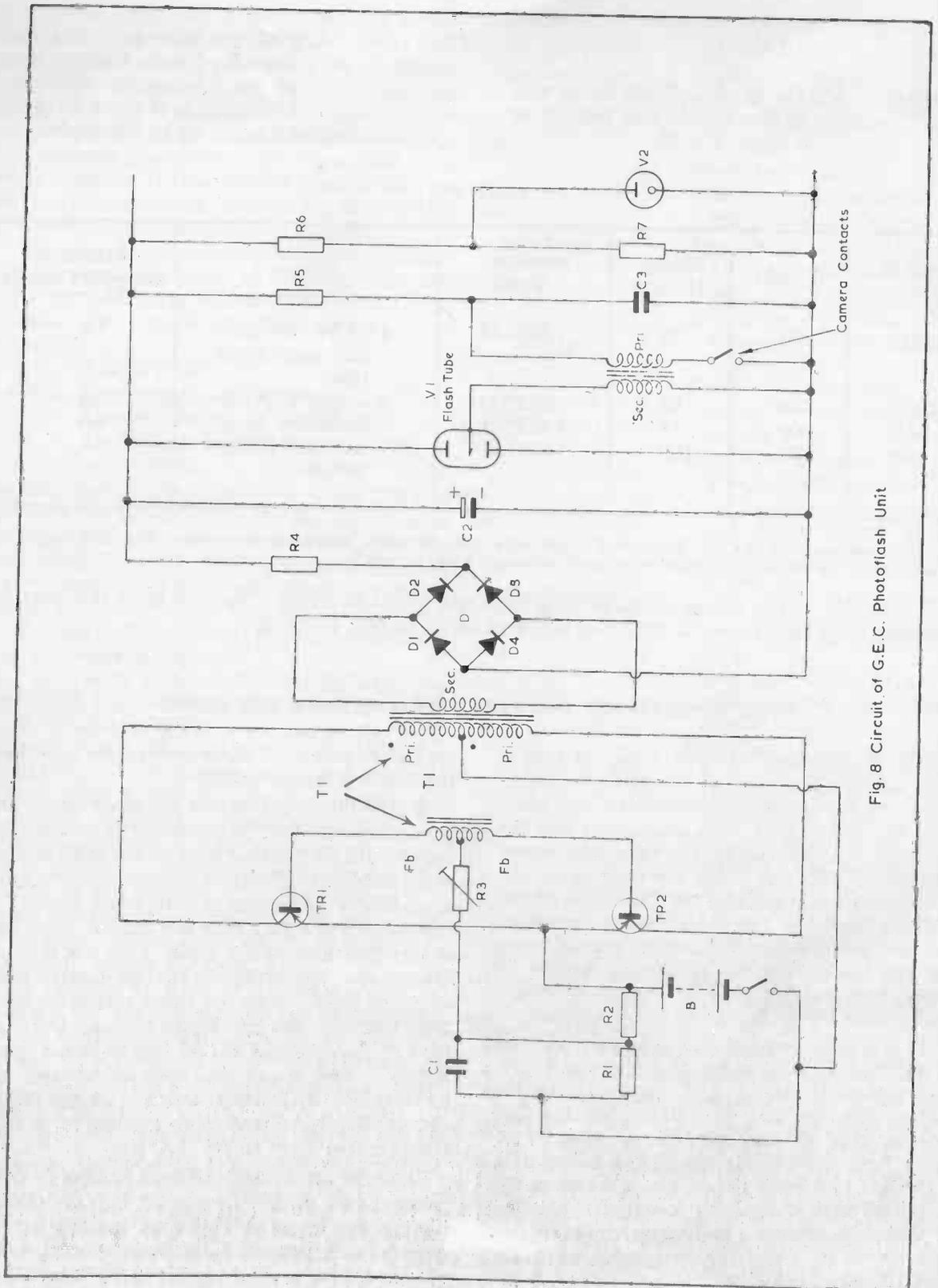


Fig. 8 Circuit of G.E.C. Photoflash Unit

reflex sets still require adequate A.G.C. if they are to function well under all conditions.

The transistor used as Tr1 is the new Mullard AF117. This unit has two considerable advantages over earlier transistors, such as the OC44, in that its cut-off frequency is in the region of 100Mc/s, which makes the R.F. gain much higher than usual, and its common emitter current gain is around 150 which means very high A.F. gain. Should the AF117 not be available an OC169, OC170 or OC171 or even an OC44 may be used but the AF117 is to be preferred.

The R.F. signal is picked up by the new $1\frac{1}{2}$ " TSL subminiature ferrite rod aerial which, although wound on a rod only $\frac{1}{4}$ " in diameter, has the amazingly high 'Q' factor of 230. L_1 is tuned by the first half of the 'Babyvar' tuning capacitor and is coupled to the base-emitter circuit of Tr1. The R.F. output from Tr1 appears in the tuned circuit formed by L_2 and the second half of the 'Babyvar' capacitor. L_2 is a subminiature transistor I.F. transformer with its fixed tuning capacitor removed. This capacitor is normally located in a recess underneath the I.F.T. or in the can itself. The best I.F.T. to use is the one normally designed for coupling the second I.F. transistor to the diode in a conventional superhet but either of the other two may be used. The make of I.F.T. does not matter much so long as the fixed tuning capacitor inside has a value of 200 pf., this being an indication of the inductance of the primary used. The smallest types available, however, are the new TSL set which are only $\frac{1}{4}$ " square.

The secondary of L_2 feeds into the diode detector, D_1 . The A.F. output from the diode is developed across the volume control, R_6 , the residual R.F. component being grounded by the capacitor C_{13} . The output from the diode when the R.F. has been removed, consists of a d.c. level which corresponds to the strength of the R.F. signal received by the set and to an A.F. component which varies in amplitude depending upon the depth of modulation of the original signal. These two components are separated in the receiver. The d.c. component is used to control the bias and hence the gain of Tr1 thus providing A.G.C. The d.c. component is applied to the base via R_3 and R_4 with C_{10} preventing any appreciable A.F. signal from being fed back along this line. C_{10} must be included since, without it there would still be a small A.F. signal applied to the base with the volume control at

minimum setting and the change in volume with v.c. setting would not follow a smooth law. The A.F. signal is fed to the base via C_{11} which, naturally does not pass any d.c.

The A.F. output from Tr1 is not measurably impeded by the primary of L_2 and appears across R_5 , the collector load resistor. From the point of view of collector voltage the value of R_5 could be made considerably larger without any possibility of clipping occurring but this would mean an increased voltage swing on the collector which might well lead to distortion of the R.F. signal. C_{14} prevents any R.F. from being fed to the driver stage. The collector current of Tr1 is just over 1mA with a fresh battery and should not be more than about $1\frac{1}{2}$ mA. This is rather a high level for a stage to which A.G.C. is applied but it is necessary for maximum gain. Furthermore, because the stage uses positive R.F. feedback or regeneration a small reduction in the collector current will produce a comparatively large reduction in the R.F. gain thus providing effective A.G.C. The degree of regeneration is controlled by C_7 which is a miniature solid dielectric trimmer such as may be obtained from TSL. This is set for maximum gain short of regeneration on any part of the band. Since the amount of feedback will vary with the frequency received there will be some alteration in gain over the band but the gain will be sufficiently high at all frequencies. Once set C_7 should not need to be readjusted as long as it is not too close to the point of regeneration. Thus it may be sealed with a blob of wax.

R_7 and C_{12} serve to decouple the first stage from the battery supply at A.F. frequencies and thus help to prevent 'motor boat' oscillations occurring when the battery ages. The driver stage uses an OC71, Tr2 as a common emitter amplifier stabilised by the emitter resistor and potential divider method. The collector current is about 1mA even with a slightly reduced battery voltage. This is more than sufficient to drive the output stage and means that the transistor is operated at a current level which provides maximum gain.

The output stage has a collector current of $1\frac{1}{2}$ mA and provides an output power of 6mW. This is an unusually low level even for a pocket radio and it was chosen for three reasons. Firstly for absolute minimum size a PP5 battery is required and this type will only give a reasonable life if the current consumption is kept to

a minimum. In this set the life of the PP5 will be exceptionally good; probably around 40 hours. Secondly, the loudspeaker specified, an LP45F which has a diameter of $1\frac{3}{4}$ " is an extremely sensitive type which gives a perfectly satisfactory performance with only 6mW input power making it unnecessary to use more. Thirdly, this level of output power makes it possible to use a 4K ohm impedance load in the collector of Tr3 thus obtaining an unusually high gain from the output stage. The total consumption of the set should be about 4mA with a new battery.

Alignment of the set is primarily a matter of adjusting L_1 and L_2 so that their inductances are equal. For best alignment the following steps should be followed:—

1. Set C_1 and C_3 to their minimum values. These are the trimmers on the back of the 'Babyvar' and they are at their minimum setting when their plates are completely visible.

2. Set L_2 for maximum inductance by screwing in the slug in the top of the can as far as it will go.

3. With C_1 at its minimum value or disconnected tune the set back and forth across the band continuously whilst sliding L_1 up and down the ferrite rod to obtain maximum volume. When the best position for L_1 has been found leave it there.

4. Connect C_4 into circuit and increase its value as far as possible without oscillation occurring on any part of the band. In some sets oscillation may occur even at the minimum setting of C_4 in which case it must be replaced by a trimmer of lower maximum value, say 10pf.

5. Adjust C_1 and C_3 for maximum volume in that order.

6. Try readjusting the position of L_1 slightly in case an increase in performance can be obtained and then seal it into position with a blob of wax.

When S_1 , a double pole, two-way switch, is closed C_5 and C_6 are brought into circuit and the set should tune the light programme on the long wave band. If 850pf capacitors are not available this value may be built up from

smaller units in parallel. For example, 500pf and 350pf or 500pf, 250pf, and 100pf may be used. If the light programme on long wave is not required, C_5 , C_6 and S_1 may be omitted from the circuit.

The layout of the receiver is not particularly critical but it is important that L_1 be separated, as far as possible, from any metal components such as the loudspeaker and the transistors. For best results L_1 should be at least $\frac{1}{4}$ " from any other component. To avoid coupling between L_1 and L_2 the can of the latter should be connected to earth. Neither L_1 nor L_2 should be positioned near T_1 or the loudspeaker.

An increase in the A.F. gain of the receiver may be obtained by using an OC75 in place of an OC71 for Tr3. The same step may be taken with Tr2 but quite sufficient gain should be obtained using OC71's.

Small signal A.F. transistors other than those specified may be used for Tr2 and Tr3 as long as their gain is reasonably high. Surplus types are definitely not recommended however. The Newmarket type V10/50A will work very well indeed in these positions.

Ordinary R.F. transistors will work in the position of Tr1 but their performance will be nothing like as good as that of the AF117.

Components.

Resistors: All types $\pm 10\%$ tolerance, smallest size available.

R_1	330K ohms	R_7	1K ohm
R_2	330 ohms	R_8	68K ohms
R_3	10K ohms	R_9	10K ohms
R_4	10K ohms	R_{10}	2.2K ohms
R_5	1K ohm	R_{11}	1K ohm
R_3 & S_2	5K ohm volume control with on/off switch.	R_{12}	47K ohms
		R_{13}	10K ohms
S_1 (a & b)	d.p. 2-way switch.	R_{14}	1K ohm

Semiconductors: Tr1 AF117.

Tr2 and Tr3 O.C.71 or any small medium or high gain A.F. type such as OC75 or V10/50A.

D_1 OA90 or OA91: for larger sets OA70 may be used.

Capacitors.

C _{1, 2, 3, 4}	TSL 'Babyvar' tuning capacitor 120pf + 120pf.
C _{5, 6}	850pf polystyrene or ceramic (see text).
C ₇	TSL subminiature 40pf trimming capacitor.
C ₈	0.01 mfd.
C ₉	15 mfd. 3 v.w.
C ₁₀	15 mfd. 3 v.w.
C ₁₁	6 mfd. 3 v.
C ₁₂	50 mfd. 9 v.
C ₁₃	0.01 mfd. 9 v.
C ₁₄	0.01 mfd.
C ₁₅	2 mfd. 9 v.
C ₁₆	15 mfd. 3 v.
C ₁₇	2 mfd. 9 v.
C ₁₈	15 mfd. 3 v.

Higher values of working voltage or capacitance than those specified may be used for the electrolytic capacitors.

Inductances.

L ₁	TSL 1½" ferrite rod aerial.
L ₂	I.F. transformer with capacitor re- moved (see text).
T ₁	20 : 1 turns ratio output transformer. TSL type LT700.
Loudspeaker:	TSL—Lorenz type LP45F.
Battery:	Everready PP5 or equivalent.

SIMPLIFIED VERSION OF DOUBLE-TUNED REFLEX RECEIVER

The receiver that has just been described, whilst excellent from the point of view of performance and stability, uses rather more components than one would like in a miniature receiver.

They do, however, ensure that the best results are obtained from the set under all conditions without the need for adjustments when a transistor is replaced. Basically the same set could be built, however, using only half the number of capacitors and resistors. Such a receiver is shown in Fig. 10.

This receiver achieves a considerable degree of component economy by the use of unorthodox circuit techniques. The overall performance is still very good but the stability is rather poorer. This last point does not normally matter from a performance point of view but it does mean that a certain amount of adjustment may be needed to one or two of the components for the best results.

The circuit arrangement is the same as that of the last set. Tr1, an AF117, is a reflex R.F./A.F. amplifier and Tr2 and Tr3 form a two stage A.F. amplifier.

The biasing, feedback and volume control arrangements of the first stage achieve the same object as before but in a different way. The output from the diode is d.c. coupled to the base of the transistor so that both the A.G.C. and A.F. signals follow the same path. The volume control varies the R.F. gain instead of the A.F. gain adjusted to the last circuit. This is achieved by putting it across the secondary of the aerial coil so that progressively decreasing the resistance in parallel with this secondary also decreases the volume of the set. The main disadvantage with this technique is that its effec-

tiveness is partially countered by the A.G.C. action. This may not matter very much, however, and the system does have the advantage that at low settings of the volume control the degree of regeneration is reduced thus removing any possibility of oscillation occurring.

The base bias of Tr1 depends upon the values of R₁ and the forward resistance of the diode, D₁. Since R₁ is taken from the bottom end of R₃ rather than from the negative side of the battery, this results in a certain amount of stabilisation of the collector current against changes in temperature and in a small amount of negative feedback at audio frequencies. For a given value of R₁ the collector current will depend upon the current gain of the transistor and the resistance of the diode. For optimum performance, therefore, the value of R₁ should be adjusted to give a collector current of 1.25mA with a fresh battery.

Tr2 and Tr3 form a directly-coupled two stage A.F. amplifier with the stabilisation feedback applied over the two stages. This circuit gives very much the same gain as that provided by Tr2 and Tr3 in Fig. 9 with far fewer components but the stabilisation is not quite so good. Tr1 should have a collector current of ½mA and that of Tr2 should be 1½mA. R₆ should be adjusted for a voltage of 1.5 volts across R₇. The output power from Tr3 is the same as in the last set.

For the sake of simplicity the capacitors and switch used for reception of the light programme on the long wave band have been omitted on the circuit diagram. They may be included if required, however, the values being the same as those in Fig. 9.

The alignment procedure is identical to that of the last set.

Components.

Resistors. All types $\pm 10\%$ smallest types available.

R ₁	68K ohms	R ₄	1K ohm
R ₂	5K ohm volume control	R ₅	12K ohms
S ₁	with on/off switch.	R ₆	220K ohms
R ₃	1K ohm	R ₇	1K ohm

Capacitors.

C_{1, 2, 3, 4} TSL 'Babyvar' tuning capacitor
120pf + 120pf.

C ₅	0.01 mfd.	C ₈	0.01 mfd.
C ₆	40pf trimmer	C ₉	2 mfd. 9 v.
C ₇	50 mfd. 9 v.	C ₁₀	25 mfd. 3 v.

Higher values of voltage or capacitance other than those specified may be used for any electrolytic.

FOUR TRANSISTOR POCKET SUPERHET

For the maximum performance on the medium waveband a superhet circuit must be used and, now that a full range or really miniature superhet components is available, such a set need be no larger, and may in fact be smaller, than the smallest Japanese sets on the market.

This set has been designed with no compromise whatsoever from the point of view of performance. Two I.F. stages are used so that the sensitivity should be sufficient even for the most adverse conditions. The number of transistors used has been kept down to only four, instead of the usual six, by reflexing the 2nd I.F. stage so that it acts as a driver and by using a single transistor class A amplifier instead of the more usual class B push-pull type of circuit. This last change means that the current consumption of the set for a given output power is quite a bit higher than usual but, as the output power is limited to 25mW., is still well within the limitations of the Ever Ready PP3 battery.

The first two stages of the set follow conventional lines, Tr1 being an emitter injected autodyne converter and Tr2 the first I.F. amplifier. A.G.C. is applied to Tr2 from the diode. Tr3 is the reflex I.F./A.F. amplifier and drives the class A output stage.

This set, as a constructional project, is only really suitable for those who have already had experience in building transistor superhet receivers

All other components are the same as with the last receiver.

Either the receiver of Fig. 10 or that of Fig. 9 may be used with any type of earpiece, the form of connection depending upon the type used. Crystal earpieces should be connected in parallel with the primary of T₁, the loudspeaker being disconnected. With crystal earpieces it is usually necessary to connect a small capacitor across the earpiece, 0.001 microfarad to 0.05 microfarad, to offset the non-linear response. A similar sized capacitor may also be used with the loudspeaker to improve the quality. In this case the capacitor should be across the primary of T₁ as with the earpiece.

Low impedance earpieces may be connected directly in place of the loudspeaker without any alterations to the circuitry. High impedance magnetic earpieces may be connected in place of the primary of T₁, no transformer being necessary. The set has sufficient output power for all but the least sensitive types of earpiece.

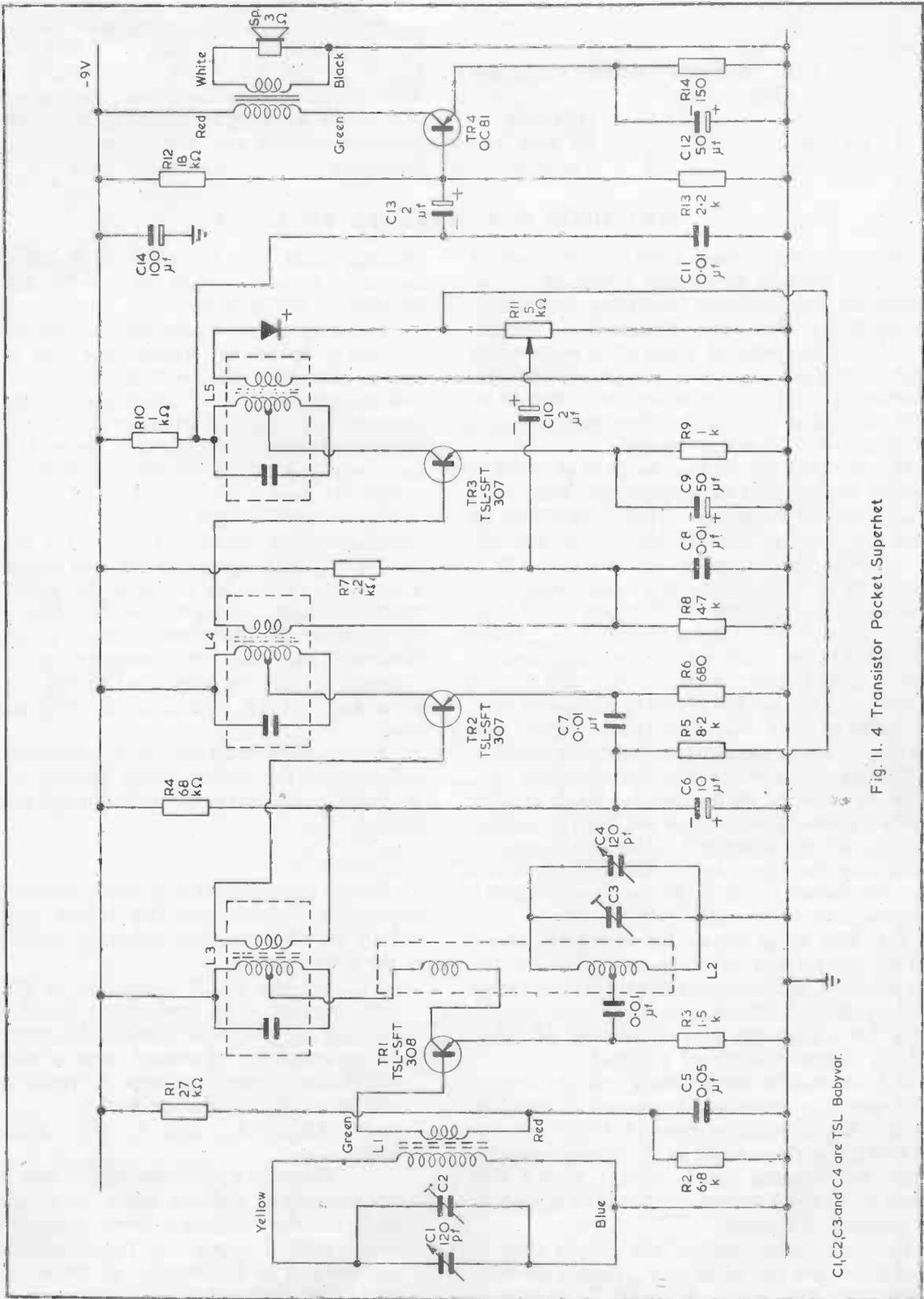
because of the small size of the components. For this reason no particular constructional details will be given here beyond the following pointers. The aerial should be as far as possible from all metal components and the cans of the I.F. transformers should be earthed. The I.F. frequency of 470Kc/s and the design of the components is such that complete coverage of the medium waveband is obtained. If available the new miniature sized OC44, OC45, OC81 range should be used as these fit in very well with the sizes of the other components.

The loudspeaker may be 2" or 2½" in diameter (or more if a larger sized set is required of course), types of these sizes being available with very high levels of sensitivity for their size and of very compact shape.

Components.

Resistors.—All types $\pm 10\%$ smallest sizes available.

R ₁	27K ohms	R ₈	4.7K ohms
R ₂	6.8K ohms	R ₉	1K ohm
R ₃	1.5K ohms	R ₁₀	1K ohm
R ₄	68K ohms	R ₁₁	5K ohms volume control with switch.
R ₅	8.2K ohms		
R ₆	680 ohms	R ₁₂	18K ohms
R ₇	22K ohms	R ₁₃	2.2K ohms
		R ₁₄	150 ohms



C1, C2, C3 and C4 are TSL Babyvar.

Fig. 11. 4 Transistor Pocket Superhet

Capacitors.

$C_{1, 2, 3, 4}$	TSL 'Babyvar' tuning capacitor 120pf + 120pf.	C_8	0.01 mfd.
C_5	0.05 mfd.	C_9	50 mfd. 3 v.
C_6	10 mfd. 6 v.	C_{10}	2 mfd. 3 v.
C_7	0.01 mfd.		

C_{11}	0.01 mfd.	C_{13}	2 mfd. 9 v.
C_{12}	50 mfd. 3 v.	C_{14}	100 mfd. 9 v.

With the electrolytic capacitors the capacitance and/or the working voltage may be larger than specified without any alteration in circuit performance.

MATCHBOX SIZE SUPERHET RECEIVER

Numerous radios have been described which were small enough to fit into a matchbox (see 'Transistor Subminiature Receivers Handbook' published by Bernards (Publishers) Limited, price 5/-) and many of these gave remarkable results for their size. The set described here, however, is unique in that not only may it be built the size of a matchbox but that it uses a highly sensitive superhet circuit.

In order that the set may be built as small as possible the number of components used must be an absolute minimum. This is achieved by using the simplest possible biasing circuits and by reflexing the I.F. stage for A.F. amplification. The combination of these techniques results in a 5 stage superhet receiver which uses only 4 resistors and 4 capacitors ($C_{1, 2, 3, 4}$ count as one being the 'Babyvar' tuning capacitor). A further considerable saving in size is achieved by designing the set for a battery voltage of only 2.6 volts so that only two, shirt button size mercury cells are required to power the receiver.

Biasing of the first stage, the autodyne converter, is achieved by means of a single resistor between the negative side of the battery and the base via the secondary of L_1 . Use of this method means that the transistor is unstabilised, which does not matter much in this case, and that the collector current depends upon the current gain of Tr1. The value shown for R_1 , 220K ohms, will be satisfactory in many cases but for the best results a milliammeter should be connected in the collector circuit and R_1 should be adjusted for a collector current reading of about 0.35mA in the absence of a signal.

Tr2 is biased by the feedback resistor method which provides a reasonable amount of stabilisation but the collector current of Tr2 is still dependent upon the current gain. The value of R_2 should be adjusted for a voltage of 0.5 volt across R_3 or for a collector current of 0.5mA in the absence of a signal.

The collector current of the output stage is not critical and the value of R_4 should be satisfactory with any OC71. If an OC75 is used to

obtain greater gain the value of R_4 should be increased to about 220K ohms. The collector current of Tr3 will be about 1mA.

The total current consumption of the receiver will be no more than about 2mA and may be less so that even the smallest sizes of mercury cell may be used. No battery decoupling components are required because the internal resistance of mercury cells is very low and because only two stages of R—C coupled A.F. amplification are used.

No volume control has been shown on the circuit diagram because it is not felt that one will be required in normal use. The volume can always be altered by rotating the set slightly thereby reducing or increasing the signal picked up by the aerial. If a volume control is required, however, one may be connected across the secondary L_2 in the way used in Fig. 10. Any value between 1K ohm and 5K ohms may be used.

The earpiece must be a high sensitivity magnetic type of the sort used with hearing aids. An ordinary radio earpiece will not be sensitive enough.

Alignment.

Before commencing alignment of this set C_5 should be disconnected. A signal generator should be used and the following steps taken in the order shown:—

1. Set the signal generator to 470Kc/s with internal A.F. modulation switched on. Connect the output of the signal generator to a loop consisting of several turns of wire and put the set inside this loop. A signal should now be audible in the earpiece.

2. Adjust L_2 and L_1 for maximum volume.

3. Connect C_5 into the circuit and adjust for maximum volume short of oscillation. Some sets may require a lower value of C_5 .

4. Repeat step 2 and then readjust C_5 if necessary. The I.F. section of the set should now be in alignment.

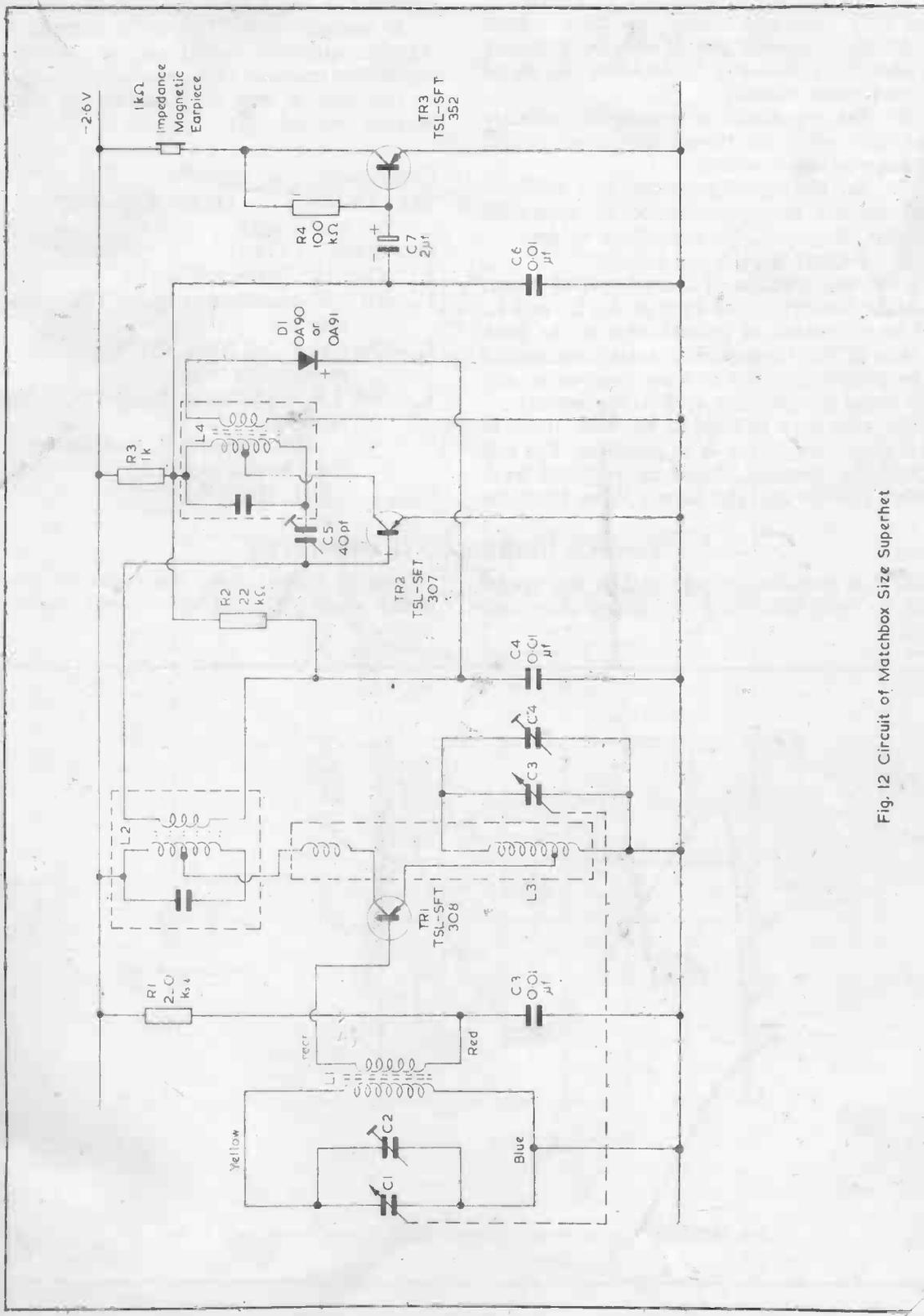


Fig. 12 Circuit of Matchbox Size Superhet

5. Set the signal generator to 1,600Kc/s and fully open the tuning capacitor. Adjust C_4 for maximum volume. It may be necessary to alter the position of L_4 to bring the signal to maximum volume.

6. Set the signal generator to 560Kc/s and fully close the tuning capacitor. Adjust L_3 for maximum volume.

7. Set the signal generator to 1,400Kc/s and set the tuning capacitor to maximum volume. Adjust C_2 for maximum volume.

8. Repeat steps 5 and 6.

In the construction of the set several points should be observed. The cans of L_2 , L_3 and L_4 must be connected to ground; that is, the positive side of the battery. The aerial coil should not be placed too near to these coils or to any other metal components such as the battery.

The radio may be used as an A.M. tuner to feed a tape recorder or A.F. amplifier. For this purpose the earpiece should be replaced by a 1K ohm resistor and the output taken from the

collector of Tr3 via a 1 microfarad capacitor.

If stations beyond the normal range of the set are required an aerial may be connected to the yellow terminal of L_1 via a 10pf. capacitor. In the case of very short aerials the capacitor may be omitted.

Components.

Tr1—OC44; Tr2—OC45; Tr3—OC71 (miniature types).

D_1 —OA90 or OA91.

L_1 —TSL 1½" ferrite rod aerial.

L_2 —1st I.F. transformer from TSL subminiature set.

L_3 —Oscillator coil from TSL subminiature set of superhet coils.

L_4 —3rd I.F. transformer from TSL subminiature set.

(The second I.F. transformer is not need in this circuit.)

$C_{1, 2, 3, 4}$ —TSL 'Babyvar'.

TUNNEL DIODE F.M. TRANSMITTER

There is good reason to consider the tunnel diode the most interesting new amplifying com-

ponent to appear since the transistor made its debut some 11 years ago. It will certainly be

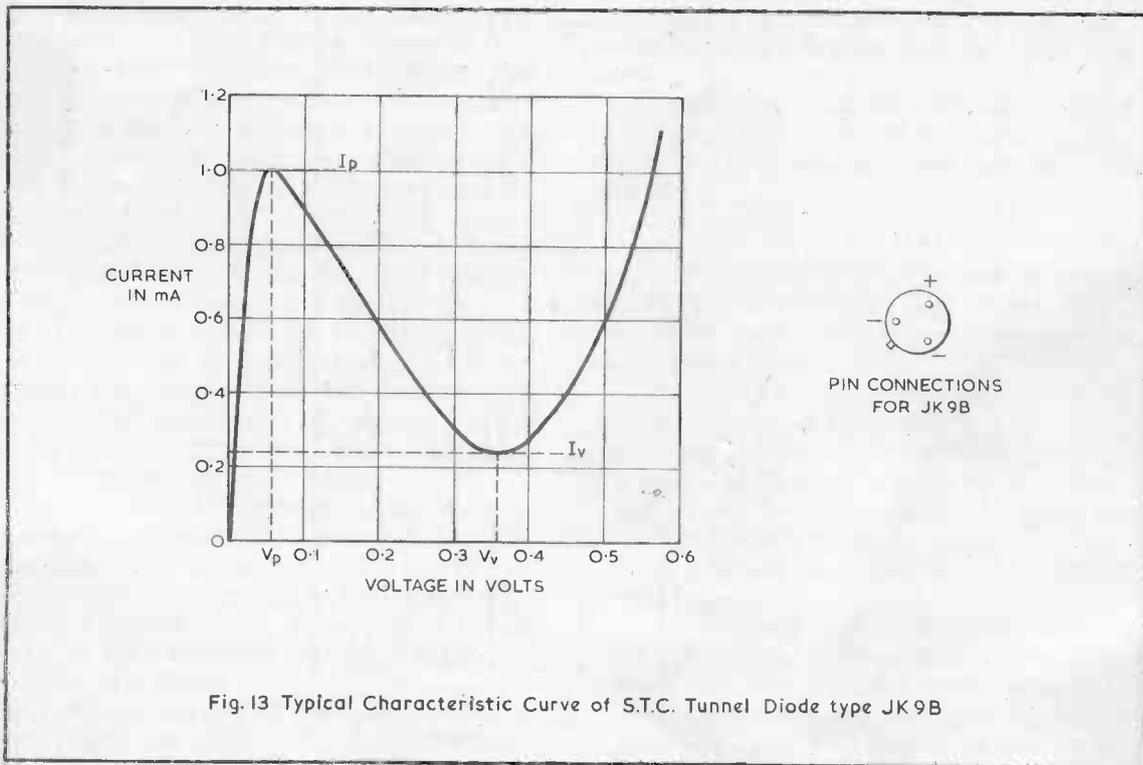


Fig. 13 Typical Characteristic Curve of S.T.C. Tunnel Diode type JK 9B

factor

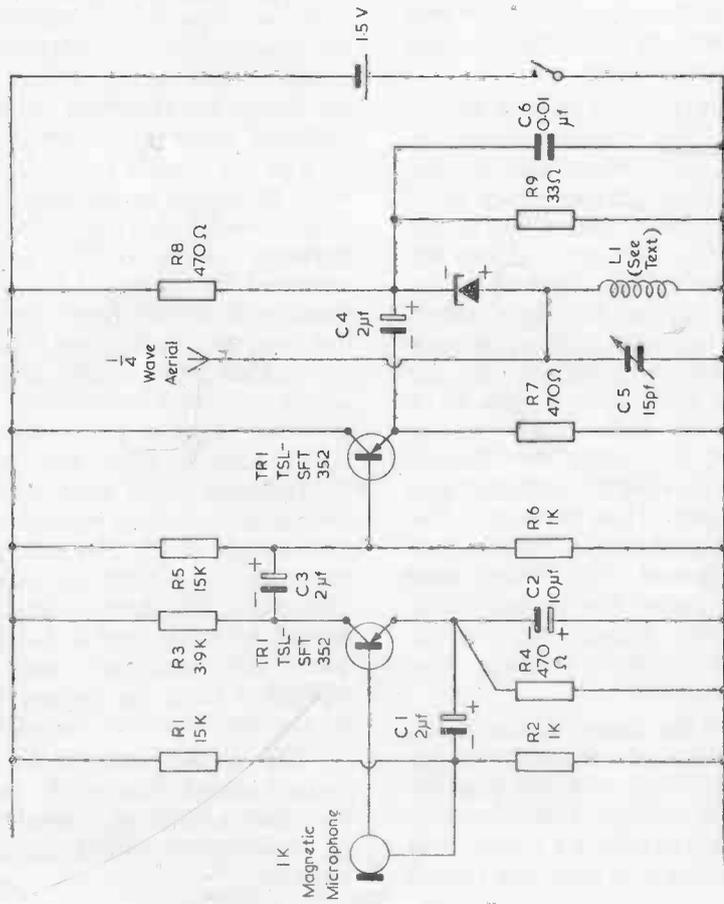


Fig.14. Circuit Diagram of Tunnel Diode F.M. Transmitter.

used extensively in the future in V.H.F. and U.H.F. amplifiers and oscillators. It is not, however, very easy to understand how the tunnel diode works by comparing it to older and more familiar devices because its mode of operation is almost totally new. The means by which it amplifies and oscillates are very different from those used by valves and transistors. Furthermore, conventional circuitry is of little use with tunnel diodes which require completely new designs. Circuits using tunnel diodes need not be more complex than those using transistors, in fact, they may often be much simpler but their unfamiliarity is likely to make them harder to understand for the time being.

The characteristic curve of a typical tunnel diode, the S.T.C. type JK9B, is shown in Fig. 13. The tunnel diode has only electrodes or terminals, although practical devices often have three leads, two of them being connected to the same electrode internally. The curve shows the relationship between the voltage applied to the two terminals and the current flowing through the diode. If the diode were an ordinary resistor the current would increase regularly as the voltage increased and the curve would be a straight line sloping upwards from left to right. Instead of this, however, the voltage starts by rising as the current is increased and then starts dropping again. Thus between 0.05v (Vp) and 0.35v (Vv) an increase in voltage produces a decrease in current. This means that over this part of the curve the tunnel diode behaves like a negative resistor for in an ordinary resistor an increase in voltage produces an increase in current.

It is this property of the tunnel diode that is so important for the negative resistance of the diode can be used to cancel out the positive resistance of a dynamic circuit. Unfortunately lack of space in this book prevents a clearer and more complete explanation and only one circuit

diagram can be given. It is hoped, however, that a future Bernards book will be devoted to the tunnel diode and its uses.

Fig. 14 shows the circuit diagram of a tunnel diode F.M. transmitter working on the ordinary V.H.F. broadcast band. The circuit consists of a two stage modulator using transistors and a tunnel diode, type JK9B, which acts as the oscillator. The condition for oscillation is that the dynamic resistance of the tuned circuit consisting of L_1 and C_5 should be greater than the positive value of the tunnel diode negative resistance. This is not hard to achieve because the negative slope resistance of the JK9B is only about -100 ohms. In a negative resistance oscillator no feedback system of any sort is required hence the simplicity.

For the circuit to oscillate the tunnel diode must be biased in the negative resistance region which means that the voltage across it must be between about 0.05V and 0.35V. This is achieved by means of R_8 and R_9 but it is just possible that with some diodes these values will not produce oscillation in which case R_9 may be replaced by a 100 ohm variable resistor which can then be adjusted to bring the diode into the negative resistance region.

L_1 should have an inductance of about 0.01microH. and may consist of 5 turns of tinned copper wire wound to a diameter of $\frac{1}{4}$ " and length of $\frac{1}{2}$ ". The microphone should be a magnetic type with an impedance of between 250 and 3,000 ohms. A hearing aid microphone would be ideal and a balanced armature ear-piece will work very well. The current consumption from the battery will be about 3mA so the smallest size available may be used.

The output power of the transmitter will not exceed about 50microW. but it will, nevertheless, give a range of several hundred feet if used in conjunction with a sensitive F.M. tuner or receiver.

SFT 352. Transistor
JK9B Tunnel Diode.

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