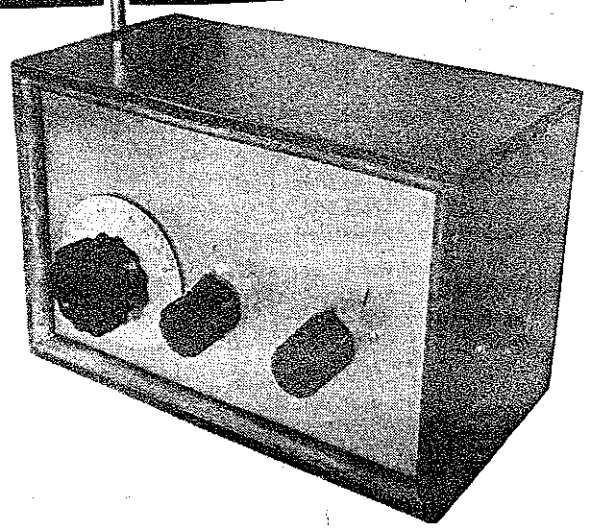
extra bands

fm receiver

F. G. RAYER



THE usual VHF receiver has a single VHF band covering those frequencies used for VHF broadcasting. The actual band varies with different receivers, but is often about 88-108MHz or so. This is usually obtained with fixed coils and a small ganged variable capacitor in conjunction with fixed capacitors and trimmers.

Experiments with a view to increasing coverage beyond that of popular VHF receivers show that the range can be extended in the HF direction by eliminating the parallel fixed capacitors and trimmers in the tuning circuits, as would be expected. For a reasonable inductance to capacitance ratio, tuning values of about 25pF are about the largest useable, but it is found that provided the layout gives the shortest possible leads, miniature plug-in coils are satisfactory, allowing extended coverage.

As trimmers would curtail coverage in the HF direction, and interchangeable coils are envisaged, separate tuning capacitors become almost essential. This eliminates ganging or alignment difficulties in this part of the receiver and works out quite satisfactorily because only the oscillator requires a reduction drive. The second tuning control is merely peaked for best results.

To facilitate alignment only two tuned circuits are used and since a single pair of plug-in coils will cover a band larger than the usual VHF range there is no need to fit other coils if not wanted.

The receiver intermediate frequency is 10.7MHz, so the second channel occurs at 21.4MHz from the wanted tuning frequency. As the tuned circuits have separate controls, some signals can thus be received in two positions of the oscillator tuning, depending on whether the oscillator frequency is 10.7MHz above or below the wanted signal. This is an effect which is unavoidable, if the advantage of separate tuning capacitors is to be retained, but it is not too important provided it is understood that this effect can arise.

In view of this, the bands given below are those of the oscillator coverage:

Band 1 34— 55MHz
Band 2 45— 72MHz
Band 3 82—140MHz
Band 4 110—180MHz

For general VHF use, Band 3 coils will be most suitable, the reception coverage then being approximately 72-130MHz, with the oscillator HF of the signal frequency.

CIRCUIT

Fig. 1 is the circuit of the receiver, the rod aerial or feeder being taken to the primary of L1, which is tuned by VC1. L2 is the oscillator coil, capacitor VC2 having a ball drive and dial for tuning. L1 and L2 are miniature plug-in coils, for changing bands.

Tr1 is the dual-gate FET mixer, output from the drain going to IFT1. Transistors Tr3, Tr4 and Tr5 are the three 10.7MHz IF amplifiers, with double-tuned IF transformers. C8 and C11 are necessary to neutralise these stages. IFT4 is a ratio discriminator transformer with the matched diodes D1 and D2 the audio output being taken via R19 from the tertiary winding.

VR1 is the audio volume control feeding a 3-stage amplifier. A $2\frac{1}{2}$in. speaker is incorporated for portable use, but the output jack allows a larger speaker or headphones to be plugged in.

The mixer and oscillator stages, with associated components, are built on a metal chassis but the IF and AF amplifiers are built as separate units on insulated boards.

CHASSIS AND PANEL

The chassis is 8 x 4in. and is a universal chassis flanged member. For the case described, the panel is flat aluminium, 8 x 5in. Fig. 2 shows the underside of the chassis.

VC1 is mounted centrally and $\frac{1}{4}$in. clear of the chassis. The holder for L1 is placed so that the leads from pins 1 and 6 are as short as possible as shown.

VC2 is mounted on a metal bracket and is set back to accommodate the ball drive. The holder for L2 must also be placed to allow very short leads to VC2. The ball drive requires a $\frac{3}{4}$in. or 1in. hole in the panel and its lug is fixed with a 6BA bolt. VC2 and the drive need to be lined up to give a smooth free movement. The listed drive has a flange and the metal dial can

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★ components

Resistors
R1 100kΩ
R2 2·2kΩ
R3 100kΩ
R4 1kΩ
R5 10kΩ
R6 10kΩ
R7 33kΩ
R8 5·6kΩ
R9 680Ω
R10 1kΩ
R11 33kΩ
R12 5·6kΩ

All 10% ½W exce

Capacitors
C1 22pF
C2 1000pF
C3 5pF
C4 5pF
C5 5000pF
C6 0·01μF
C7 5000pF
C8 5pF
C9 5000pF
C10 5000pF
VC1 and VC2

Semiconductors
Tr1 3N141
Tr2 BF200
Tr3 OC170

Miscellaneous
IFT1/2/3, (Denco
(Home Radio
Chassis, 8 x 4in.
panel 8 x 5in. (H
Ball drive, (Jack
Veroboard 0·15i
socket. Speaker
L1/2, see text.

ALIGN
R1 22kΩ
R2 5·6kΩ

C1 5000pF
C2 1000pF

Miscellaneous
Tr1, OC71. Tr2
L1, (Denco 'Bl
toggle, on/off.
flanged membe

★ components list

Resistors

R1	100kΩ	R13	680Ω	R25	47kΩ
R2	2·2kΩ	R14	1kΩ	R26	3·3kΩ
R3	100kΩ	R15	33kΩ	R27	47kΩ
R4	1kΩ	R16	5·6kΩ	R28	12kΩ
R5	10kΩ	R17	1kΩ	R29	2·7kΩ
R6	10kΩ	R18	680Ω	R30	680Ω
R7	33kΩ	R19	100Ω	R31	2·2kΩ 5%
R8	5·6kΩ	R20	680Ω	R32	39Ω 5%
R9	680Ω	R21	680Ω	R33	5·6kΩ
R10	1kΩ	R22	4·7kΩ	R34	470kΩ
R11	33kΩ	R23	4·7kΩ	VR1	22kΩ log pot. with switch S1
R12	5·6kΩ	R24	5·6kΩ		

All 10% ¼W except R31 and R32, 5%

Capacitors

C1	22pF	C11	5pF	C21	2μF 6V
C2	1000pF	C12	5000pF	C22	0·01μF
C3	5pF	C13	5000pF	C23	2μF 6V
C4	5pF	C14	5000pF	C24	100μF 12V
C5	5000pF	C15	5000pF	C25	2μF 6V
C6	0·01μF	C16	5000pF	C26	60μF 6V
C7	5000pF	C17	5000pF	C27	100μF 12V
C8	5pF	C18	330pF		
C9	5000pF	C19	330pF		
C10	5000pF	C20	0·01μF		
VC1 and VC2		25pF variable (Jackson C804)			

Semiconductors

Tr1	3N141	Tr4	OC170	Tr7	OC81D
Tr2	BF200	Tr5	OC170	Tr8/9	OC81
Tr3	OC170	Tr6	OC71	D1/2	OA79

Miscellaneous

IFT1/2/3, (Denco IFT15). IFT4, (Denco RDT2). T1, (Home Radio TR64). T2, (Home Radio TR65A). Chassis, 8 x 4in. Universal chassis flanged member, panel 8 x 5in. (Home Radio). Valveholders B9A(2) Ball drive, (Jackson 4511/F). Dial 2¾in. dia. (Bulgin). Veroboard 0·15in. matrix, and pins. Knobs. Coaxial socket. Speaker 3Ω, 2½in. dia. Jack socket (switched) L1/2, see text.

ALIGNMENT GENERATOR

R1	22kΩ	R3	1kΩ	R5	5·6kΩ
R2	5·6kΩ	R4	22kΩ		

C1	5000pF	C3	0·01μF	C5	22pF
C2	1000pF	C4	47pF		

Miscellaneous

Tr1, OC71. Tr2, AF117. T1, (Home Radio TR64). L1, (Denco 'Blue' Range 4, Valve type). S1/2 toggle, on/off. Chassis, 5 x 2in. universal chassis flanged member (Home Radio). Veroboard, pins.

the metal dial can be fixed with two very short 8BA bolts run into the tapped holes.

Wiring for Tr2 is shown in Fig. 2. Very short leads are essential to C4 and C5. The shield lead Sh is **not** connected. The oscillator may be tested by connecting a 9V battery to chassis and negative lead (observe the polarity shown). If this stage is oscillating, battery current, as indicated by a meter in one battery lead, will change when VC2 is shorted. If this stage does not oscillate, the receiver cannot work at all. A transistor of doubtful efficiency may oscillate at the lower frequencies but not in the 150-180MHz region. So the test can be made with all coils, and for all positions of VC2

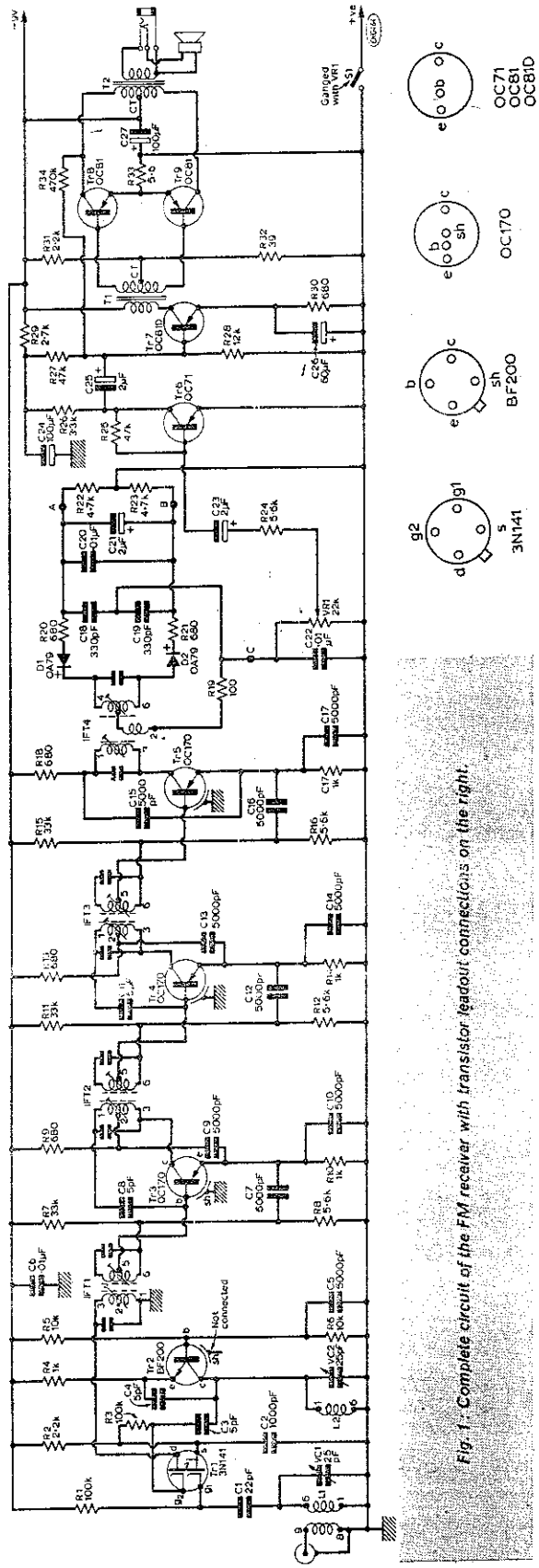


Fig. 1. Complete circuit of the FM receiver with transistor leadout connections on the right.

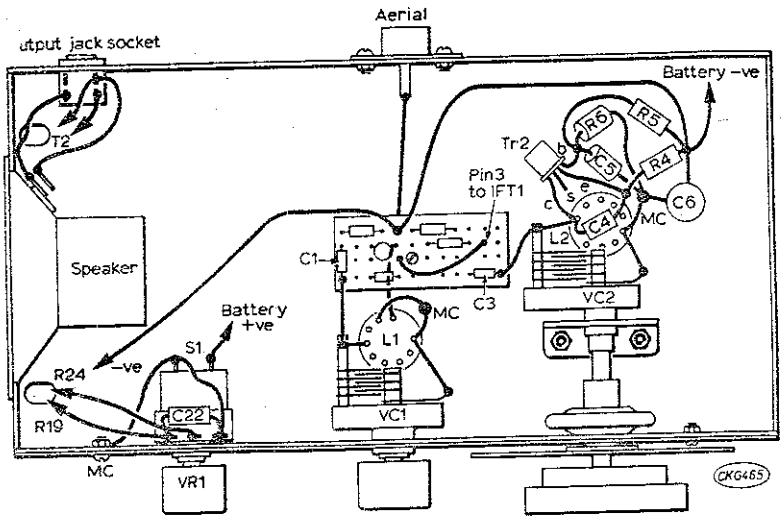


Fig. 2: Layout underneath the chassis with the tuned oscillator stage at the right. The mixer stage board (Fig. 3) is in the centre with its associated tuned circuit. The speaker is interconnected with the headphone jack socket mounted on the rear apron of the chassis

MIXER BOARD

This board is $1\frac{7}{8}$ x $\frac{3}{4}$in. of 0·15in. matrix plain veroboard, wired as in Fig. 3. A 6BA bolt, with extra nuts, allows the board to be locked to the metal chassis, with enough clearance to avoid any short circuits. This bolt forms the earth return.

The leads of C1 and C3 can be left projecting, to solder to VC1 and VC2. Also fit a pin or projecting lead for the negative connection, and a wire which can pass down through the board and chassis, to reach pin 3 of IFT1 on the IF amplifier.

Transistor Tr1 should be supplied with a shorting clip on its leads, and this **must not be removed** until the transistor has been soldered in place. First wire the board as in Fig. 3, omitting Tr1. Solder on the wires which will go to gate 1, gate 2, source and drain, and cut them to length and tin them. Tr1 is then inserted with its wires as shown. The leads can be spread with a sharpened matchstick, but should not be touched with a metal or plastic tool, or the fingers. Solder source and drain leads. Then while holding iron and solder in contact with the lead from C1/R1, solder g1. In the same way, hold the iron and solder against the lead from R3, and solder g2. When the resistors are soldered to provide an external circuit from g1 and g2 to the source, the transistor is protected and the wire clip is removed. If g1 or g2 have to be unsoldered from R1 or R3, or these resistors have to be unsoldered, the transistor leads should first be bound with thin wire.

The board is fixed as in Fig. 2, and external connections are made. The co-axial aerial socket and output socket are fixed to the rear flange of the chassis so that the receiver can be tested out of its case.

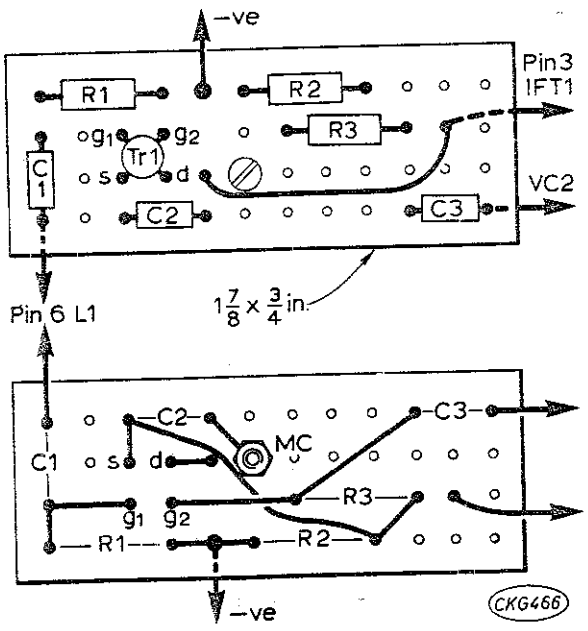


Fig. 3: Both sides of the mixer stage board.

IF AMPLIFIER

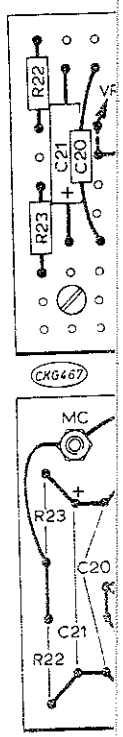
This is assembled on a $5\frac{1}{2}$ x $1\frac{3}{4}$in. board as in Fig. 4. First mark and drill holes for the IFT's and for the two $\frac{1}{2}$in. 6BA bolts. These, with additional nuts, form the chassis return and hold the board the metal chassis.

Leads should be short and direct, and insulated sleeving is put on where necessary. If $\frac{1}{4}$in. lengths of small diameter sleeving are put on the transistor leads this will prevent shorts and hold the transistors at a suitable height, while also identifying the wires.

Note that all the IFT screening cans are earthed. As the IFT's are prealigned, unnecessary disturbance of the cores is better avoided. When wiring D1 and D2, note that these may have a *black* ring to show positive. Polarity must be correct as a DC voltage is produced across C21.

Run a lead from pin 3 of IFT1 to a pin or wire, so that the wire from Tr1 can be soldered on later. A black lead, to go to battery negative, is soldered to R18, Fig. 4. A lead from R19 is provided, and will pass through the chassis to VR1.

If this section is tested with the board separate from the receiver, do not run a signal generator or other lead from pin 3 of IFT1 near the other IFT's or circuits, or instability may be caused which would not be present when the amplifier is fixed to the chassis.



IF ALIGNME

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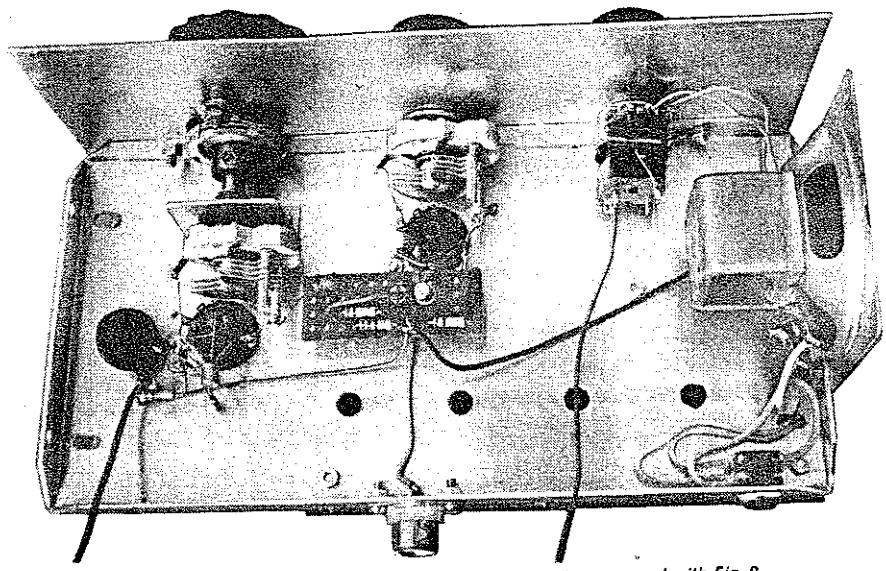

View of the underside of the FM receiver which should be compared with Fig. 2

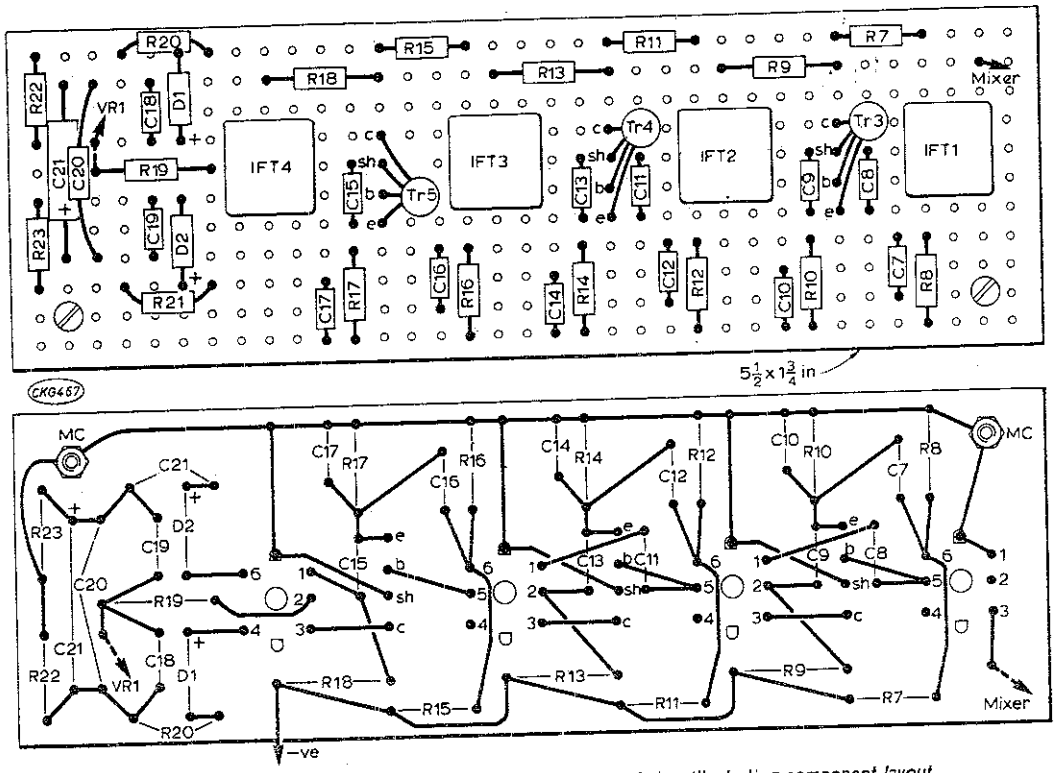

Fig. 4: The two sides of the IF amplifier board, shown actual size, illustrating component layout and wiring

IF ALIGNMENT

This can be carried out with the aid of a high-resistance voltmeter, or the 2·5V range of the usual type of multi-range meter, preferably with a resistance of 10kΩ/volt or better. It is assumed that if alignment equipment for FM receivers is available the means of employing this will be known, so the method of alignment described here is an alternate method.

Three test points are shown on the circuit, Fig. 1, and the multi-range meter is clipped to these for aligning the IF amplifier by this method. Initially, meter negative is clipped to A and meter positive to B. Maximum signal strength at the diodes will then produce maximum voltage from A to B, as shown by the meter. All the IFT cores are adjusted for maximum meter reading and each core should have quite a sharp tuning peak, seen by observing the meter while slowly turning the core.

For the second stage of adjustment, the meter is flipped from point C to chassis, the polarity being unimportant. The bottom core of IFT4 is then adjusted for minimum reading on the meter. In addition to the usual upwards movement of the meter pointer, some backwards movement can normally be seen. By rotating the lower core one way or the other, it should be possible to make the meter pointer move backwards or forwards from its minimum position. Set the core so that the meter shows this "zero". This completes the IF strip adjustment.

When making these adjustments, a properly fitting plastic trimming tool should be used. It is helpful to have a signal generator of the usual type employed with AM receivers and to tune this to 10·7MHz. A lead from the generator is placed near the receiver mixer, to secure sufficient input to allow an indication on the voltmeter as described. When the generator output is amplitude modulated, this will be heard in the speaker, but the adjustments described are made with the generator giving a CW output.

Unnecessary adjustment to the cores before obtaining results is best avoided, as they are approximately adjusted when the IFT's are manufactured. Should IFT's be used which are so far out of adjustment that no signal can pass through the IF strip, couple the signal generator to the base of the last IF amplifier and adjust the last IFT. Then transfer the generator input to the previous amplifier base and adjust the third IFT. After taking the input to the first IF amplifier base and adjusting the second IFT transfer the input to the mixer in the way described, and carefully check all the IFT's.

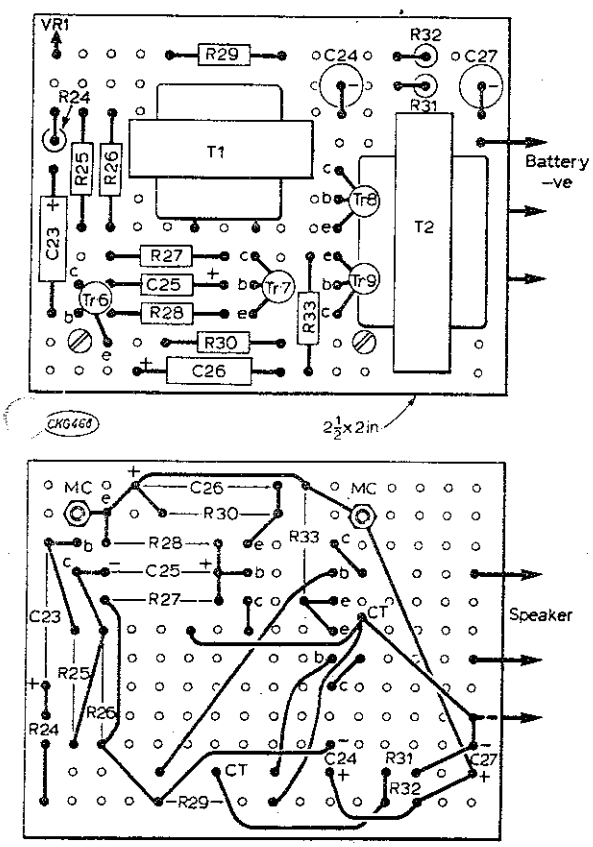

Fig. 5: Details of the audio amplifier board, full size.

Where no signal generator is available, the only method is to tune the receiver until some signal is obtained, and to work on this by ear, adjusting all cores for best volume and the bottom core for best results with an FM transmission. This can prove reasonably satisfactory, unless the IF circuits are so far off tune that the strongest transmission available cannot be heard.

INSTABILITY

With three IF stages and double-tuned transformers it is quite possible for IF instability to arise. This depends on the individual transistors, position and length of leads and similar factors. It is heard as whistling or hissing accompanying signals, or as oscillation liable to start when the IFT's are aligned, but which ceases when some cores are slightly staggered.

Where a small adjustment of some cores prevent this, and results are good, no modification is necessary. Otherwise, the trouble can be cured by placing a resistor between pin 5 of one or more IFT's and the corresponding base lead. This is most easily done by disconnecting the base wire from the pin, so that the resistor can be soldered directly to the pin, under the board. A similar result is achieved by placing a resistor in the lead from collector to pin 3 of the following IFT.

The values of the resistors are not very critical, except that unnecessarily large values will reduce gain. A number of small resistors from about 22Ω to 220Ω or so can readily be tried. In the original IF strip a value of 100Ω was used in the first stage, with 39Ω resistors for each of the following stages.

Though the amplifier can be tested and roughly aligned when clear of the receiver, final adjustments should be made with it fixed in its normal position. Four holes are required in the metal chassis, so that the lower cores can be reached. Final slight readjustment of IFT4 can be made by ear, when a transmission is tuned in. A simple 10·7MHz alignment generator is described later.

COILS

Band 3 was covered with Denco miniature plug-in coils Range 7. A "Yellow" coil is used for L1 and "Red" coil for L2. This is the most generally useful band. Band 2 is covered by using a similar pair of coils, Range 6. The Range 5 coils, which have cores, cover Band 1. All these coils are the valve type. For Band 4, coils were wound using Denco plug-in formers. Place the former in a valve holder before soldering to the pins. L1 is $2\frac{1}{2}$ turns spaced $\frac{1}{8}$in. and tapped at 1 turn from pin 1, for pin 9. L2 is $1\frac{1}{2}$ turns, spaced $\frac{1}{8}$in. Both are 22swg or similar wire.

AF AMPLIFIER

This is assembled on 0·15in. matrix Veroboard, in a similar way to the IF amplifier. The board is $2\frac{1}{2}$in. x 2in. and both sides are shown in Fig. 5.

Transformer T2 has lugs which pass through slots, which can be made by drilling small holes closely together, and the lugs are twisted to hold the transformer to the board. Two $\frac{1}{2}$in. 6BA bolts secure tags which form the chassis (positive) return.

The wiring of this unit should prove to be quite straightforward. Observe the polarity of electrolytic

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CABINET

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capacitors and put sleeving on any leads where this is necessary to avoid short-circuits. Two thin flexible leads are soldered to the secondary tags of T2, for the speaker connections. A Veropin or projecting wire is provided for the connection to VR1 and another for fixing a black flexible lead for battery negative.

A great advantage of this circuit is that it provides quite high gain while the DC operating conditions of each stage are isolated from those of other stages. The specified transistors are readily available, but if similar types are to hand it is quite likely that they could be used. In some cases, the value of one or more resistors might have to be changed to suit the transistors. This is especially so in the output stage, where unsuitable values may cause high battery drain on the one hand, or very low drain with distortion, on the other.

It is quite a good plan to test the AF amplifier by itself, when it is completed. This is done by taking an AF input to the volume control VR1, which may be left in circuit to avoid overloading. The speaker and battery are connected when the amplifier should draw about 10mA, rising to 25-50mA or so with ample volume.

The parts are assembled with glue and panel pins. Four $\frac{1}{4}$in. strips are glued flush with the front edges, inside. The receiver can then be inserted as a complete unit from the back.

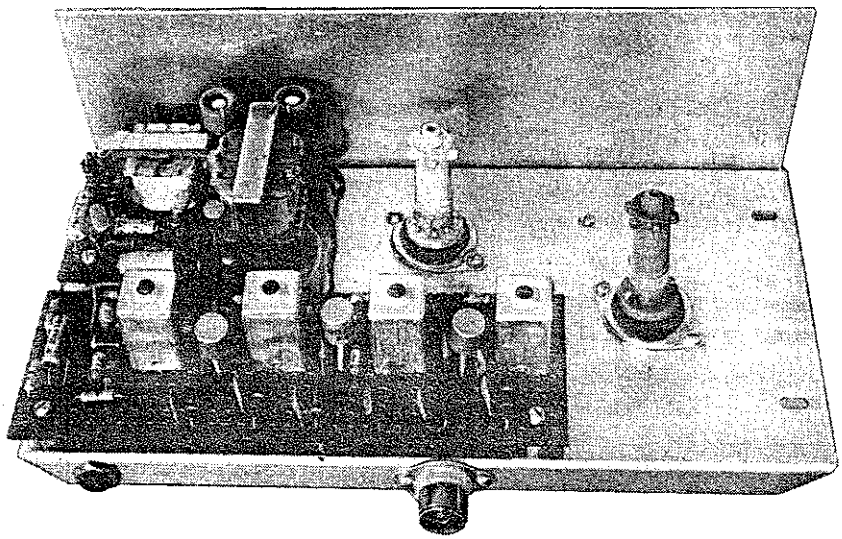
Bolts through the holes which are punched in the chassis flanges hold the receiver in the case. The back is thin plywood or paxolin, held by small woodscrews.

An extending telescopic rod aerial can be fixed to the left-hand side and connected by a short flexible lead to the co-axial socket. The latter can also be used for an external aerial.

AERIALS

In those areas where VHF transmissions are normally well received a telescopic aerial or short wire should be quite adequate. The wire can be 2ft. to 6ft. or so long. The position of the receiver and aerial can influence volume, even with a vertical aerial.

It is also easy to try wires which are very long in terms of wavelength and part of the aerial system can then be out of doors. But with rather long wires the chances of 10·7MHz breakthrough are increased.



This photograph shows the position of the IF and AF boards on top of the chassis

The negative feedback is not essential and R34 may be omitted or changed to between 470 and 680kΩ. If used, connect it from driver base to one output transistor collector at T2 primary. If volume falls slightly, this is correct. Should oscillation begin, transfer the connection to the other collector.

As the first AF stage is followed by two stages of amplification, a noisy transistor here will cause a hiss in the speaker. This was so in the amplifier shown and was traced to the use of a noisy, cheap surplus OC71 in the first stage. When this transistor was replaced, the noisy background ceased.

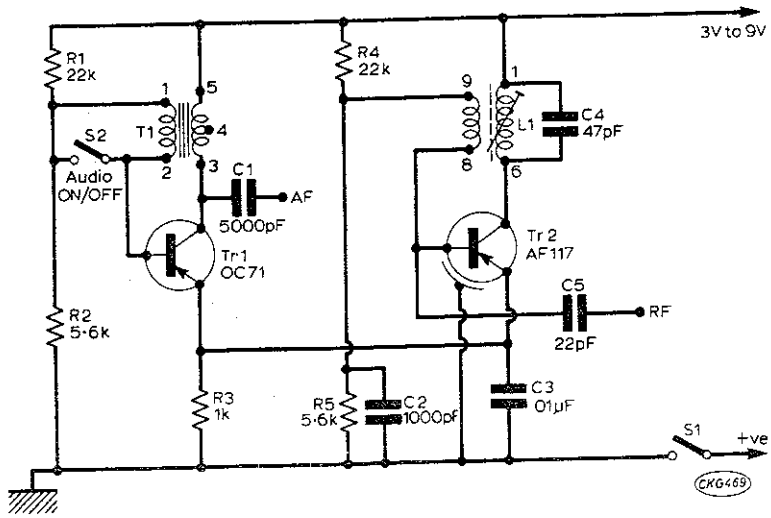
CABINET

The cabinet is made from $\frac{1}{4}$in. plywood. Each side is $5\frac{1}{4}$ x $4\frac{1}{2}$in. and the top and bottom are $8\frac{5}{8}$ x $4\frac{1}{2}$in. An aperture to match the small internal speaker is cut in the right-hand side and covered with speaker gauze or similar material.

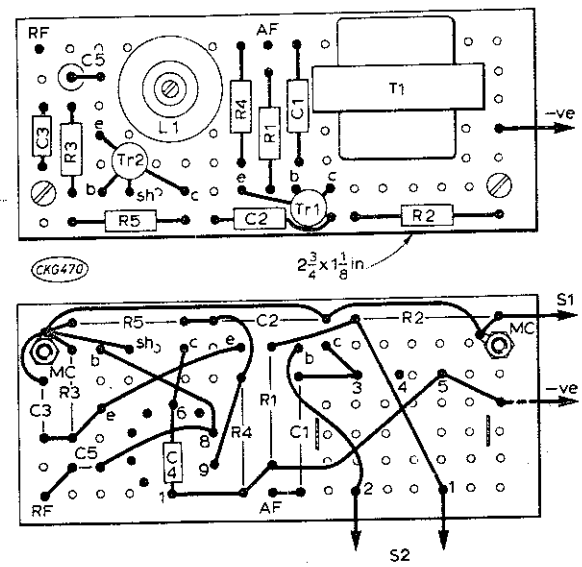
Best possible results are obtained by making a VHF type aerial of suitable dimensions for a chosen band. The aerial can then be high and in the clear outside, a co-axial down-lead going to the receiver. This can give a very great increase in signal strength.

ALIGNMENT GENERATOR

If necessary, a simple 10·7MHz alignment generator can be built using the circuit shown in Fig. 6. Tr1 is an audio oscillator and output from this may be taken, via the isolating capacitor C1, from the "AF" pin. This output may be useful for checking the AF circuits as well as providing amplitude modulation (and a certain amount of FM also) of the RF oscillator Tr2. The RF oscillator is tuned by means of the core of L1 and output can be had via C5 at the "RF" pin. Enough input to the IF strip may be obtained by just placing the generator near the circuits of IFT1.



◀ *Fig. 6. Circuit diagram of the simple alignment oscillator providing RF or modulated RF at 10·7MHz*

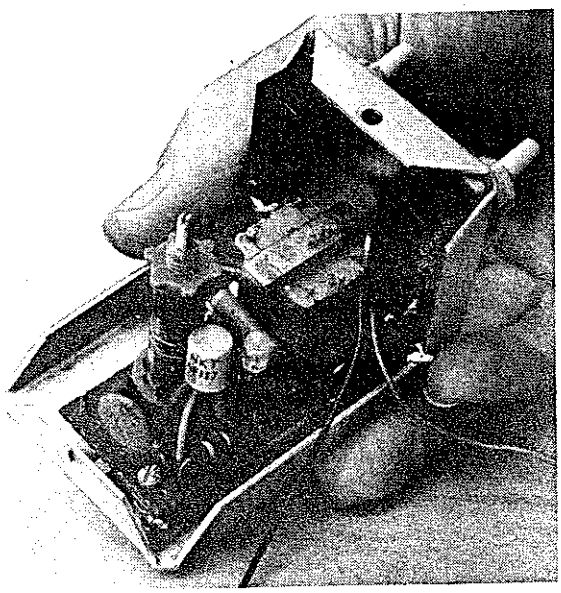


▼ *Fig. 7. Most of the components for the oscillator are mounted on the circuit board shown below*

Constructing this generator is straightforward. A 5in. x 2in. flanged "universal chassis" member has its flanges cut 2in. from one end, so that a 2 x 2in section can be bent at right angles. Two toggle switches (S1 and S2) are mounted on this part, near the top and edges to clear the transformer T1.

The generator is assembled on a small piece of Veroboard, as in Fig. 7. Drill the board for the pins of L1 and T1 and for two ½in. 6BA bolts, which with extra nuts will provide the chassis return and allow the wired board to be mounted in the small chassis described. Two Veropins are inserted, at the points "AF" and "RF" so that leads can be clipped or soldered on, if wanted. If preferred, two small sockets could be mounted between the switches and be wired to these pins.

The circuit was found to operate with any battery from 3V to 9V. When S2 is open, an audio tone accompanies the signal, when this is tuned in. With S2 closed, no modulation is present. The modulated signal is more easily found on a receiver or obtained through the IF amplifier, but the unmodulated signal is used for final alignment, in the way explained.



As can be seen here the oscillator is very small and is easy to construct

If an accurately calibrated receiver is available set this to 10·7MHz and rotate the core of L1 to tune the generator accurately to this, with S2 closed for final adjustment. If an accurately calibrated signal generator can be borrowed (but will not be available later) set the generator to 10·7MHz, tune this in on another receiver, and adjust L1 (with S2 closed) for zero beat.

With an FM receiver with 10·7MHz IF, place the alignment generator near this and adjust L1 to the correct frequency. If no such receiver is available, open S2 and place an insulated lead from the "RF" pin near the 1st IFT of the IF amplifier, which should give a strong enough signal for the core of L1 to be adjusted. Subsequently, reduce the coupling as much as possible, so that the IFT cores can be peaked as described, with S2 closed. There is no need for the IFT's to be exactly on 10·7MHz provided all the cores can be peaked and are still free to be moved either way.