Band II F.M. Tuner Unit

Design Suitable for Use With a Wide Range of A.F. Amplifiers

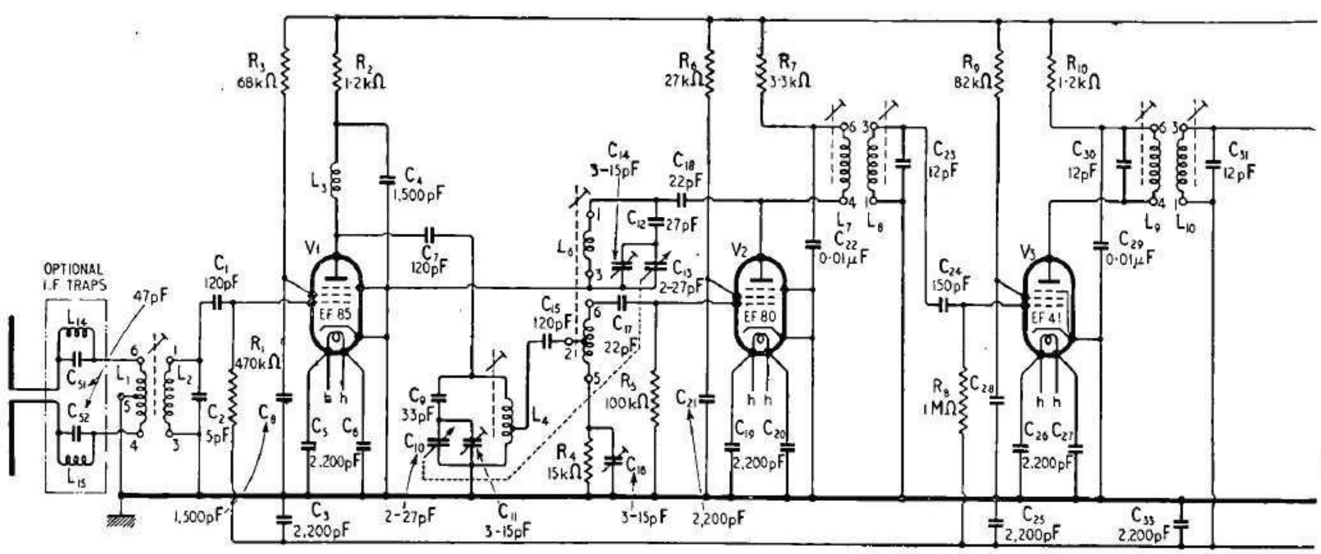
ALTHOUGH the tuner circuit described in the following pages was designed primarily for use with the Mullard 5-valve 10-watt amplifier circuit[1], or with the 20-watt circuit using EL34s[2], it is suitable for use with a wide range of amplifiers. The frequency range covers the whole of Band II (87.5-100 Mc/s), and while the circuit design chosen incorporates some of the more modern developments applicable to this type of reception, the construction is kept free from complication. The power supply would normally be taken from the main audio amplifier.

Circuit Description.—A complete circuit of the tuner unit is given in Fig. 1. The r.f. stage is a conventional pentode amplifier circuit, using a Mullard EF85. The associated aerial circuit is pre-tuned to the centre of the Band II range. In the anode circuit is an r.f. choke (L_3), with the parallel-fed r.f. tuned circuit (L_4, C_9, C_{10}, C_{11}), of which C_{10} forms one section of the two-gang tuning capacitor. The r.f. voltage, taken from a tap on L_4, is fed into the grid circuit of a Mullard EF80 operating as a self-oscillating additive mixer. The oscillator section of the mixer is basically of the tuned-anode type, with a tuned circuit consisting of L_6, C_{12}, C_{13} and C_{14} (C_{13} forming the second section of the tuning gang.) The intermediate frequency developed by the mixer valve is fed to two conventional i.f. stages using Mullard EF41s, at an intermediate frequency of 10.7 Mc/s. In the second i.f. stage the EF41 operates as a partial limiter valve at high signal levels, and the bias developed across its associated grid circuit capacitor C_{32} is fed back to the first i.f. valve and to the r.f. valve. The final i.f. stage drives a ratio detector circuit containing a Mullard double diode, type EB91. Audio-frequency voltages developed in the detector circuit are taken through a 50-microsecond de-emphasis network consisting of R_{16} and C_{45}, and thence to the a.f. output socket for feeding to the audio amplifier.

Aerial Circuit and R.F. Stage.—The aerial circuit has been designed to be matched to a 75-Ω balanced feeder line, thus permitting a simple connection from a conventional type of dipole aerial. In cases where the feeder line of this type is unscreened, L_1 may be centre-tapped to earth so that any noise voltages picked up in the feeder itself are reduced. Dust core tuning is employed, and the resonant frequency of the grid tuned circuit is arranged to be 94 Mc/s. The total tuning capacitance in the grid circuit is of the order of 18pF, of which C_2 forms 5pF and the remainder is formed by the valve input capacitance, plus stray capacitance. The input damping of the valve amounts to 3,800 Ω, giving an effective secondary circuit impedance of the order of 1,600 Ω (without the aerial circuit connected). When attached to an appropriate feeder cable, the aerial circuit bandwidth is 10.8 Mc/s for 3 dB down on 94 Mc/s and the measured aerial gain is 14 dB.

C_{10} which has a maximum capacitance of 27pF tunes the r.f. circuit, and the series capacitor C_9 and trimmer C_{11} are added to track the r.f. circuit correctly to the oscillator circuit. Thus the equivalent capacitance swing is limited to approximately 8pF, and, in addition to the lumped capacitor constants, a further 12pF and 4pF are added to the circuits in the form of the r.f. valve output capacitance plus strays and the equivalent input capacitance of the mixer reflected into the tuned circuit, respectively. To assist further in obtaining correct tracking over

Fig. 1. Complete circuit diagram. Further details of component specification are given at the end of the article.



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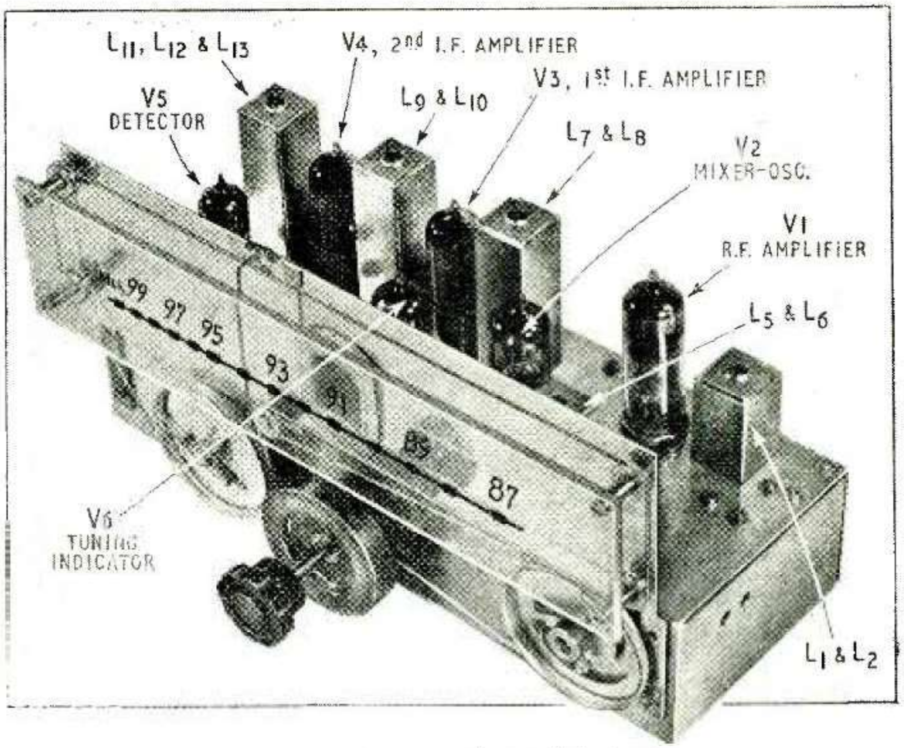

Layout of components on the top of the chassis.

the whole of the band, L_4 is tapped by means of C_{15}, so that the loaded Q factor of the r.f. circuit is comparatively high. The average value is 75, and a mean bandwidth of 1.3 Mc/s for 3 dB attenuation is maintained over the whole tuning coverage, for any point in the band. Therefore, with an equivalent load impedance of the order of 4.5kΩ at 94 Mc/s for the r.f. tuned circuit, a theoretical gain of 43 dB is obtained for the r.f. stage (including the aerial circuit). Under the circuit conditions shown the EF85 operates at a mutual conductance in the region of 9.5mA/V. Measurement of the stage gain showed it to be only slightly less than calculated.

Mixer Circuit.—The self-oscillating type of mixer adopted in this circuit, has proved highly popular in countries where f.m. reception is well established. For successful operation the frequency difference between the developed intermediate frequency and the incoming signal frequency should be large. Fortunately this is generally so in f.m. receiver applications, where the intermediate frequency is usually about 10 Mc/s. As its name implies it is essentially an oscillator with provision for feeding in an r.f. signal, so that additive mixing occurs on a common electrode (in this case the control grid of the EF80). The anode circuit contains an i.f. transformer which is tuned to the intermediate frequency developed.

The voltage gain of this single valve circuit is equivalent to that of a two-valve stage consisting of an oscillator and a separate mixer. At the same time the inherently low equivalent noise resistance obtainable with additive mixing is retained. In addition the use of a single valve makes the circuit economically more attractive.

In a mixer of this type, it is generally essential to have some form of "isolation" between the r.f. tuned circuit and the oscillator circuit of the mixer to prevent interaction and pulling of the oscillator section. This is achieved by operating the oscillator in a bridge circuit, the equivalent circuit of which is shown in Fig. 2. It will be seen then, that for the bridge circuit to be in balance, the relation,

$$C_{16} = \frac{C_{in} \times L_{5A}}{L_{5B}}$$

must hold. When this condition has been achieved there will be minimum interaction between the two relevant circuits. An obvious added advantage of this bridge connection is that when in balance, there will be minimum oscillator voltage at the r.f. input point. This is important in order

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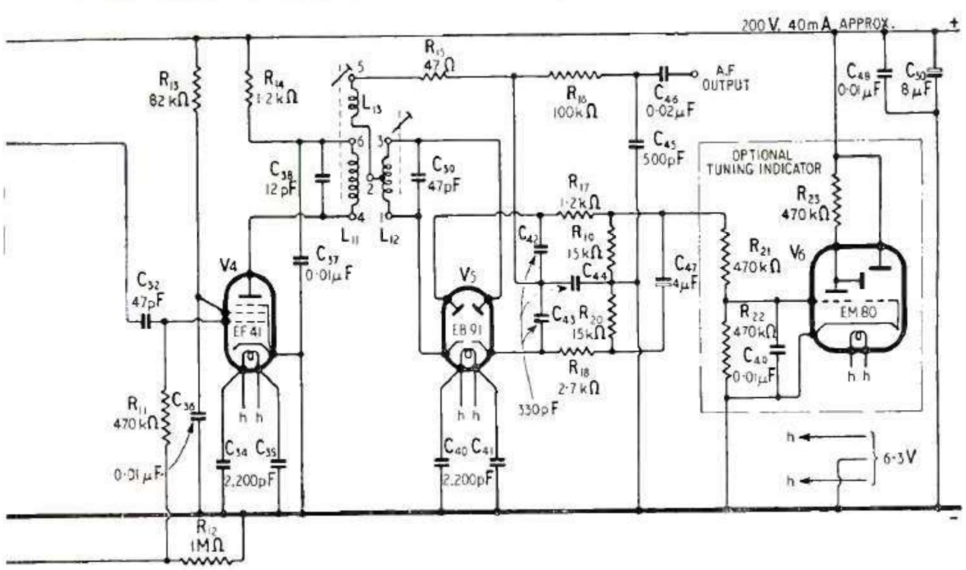

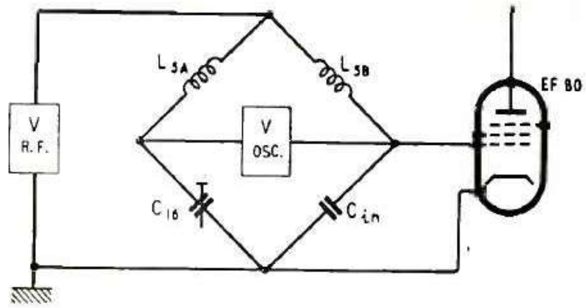

Fig. 2. Equivalent bridge circuit of oscillator section of mixer valve. C_{in} represents the valve input capacitance.

to keep the oscillator voltage at the aerial terminals as low as possible. In this circuit, it is possible to reduce the oscillator voltage to an average value of 100mV at the r.f. input point.

The oscillator circuit is operated at a frequency higher than the signal frequency, i.e. at approximately 97 to 111 Mc/s. As with the r.f. circuit, a series capacitor C_{12} and a parallel trimmer C_{14} are included for tracking purposes, giving an effective swing of the tuning capacitor C_{13} of approximately 7 pF. To keep the oscillator circuit as stable as possible the total capacitance associated with the tuned circuit has been made as large as possible, consistent with obtaining sufficient oscillator drive for the mixer valve. Also the cathode of the mixer valve is directly earthed in order to avoid capacitive hum modulation.

The blocking capacitor C_{18} also forms the tuning capacitance for L_7, since L_6 is effectively a short-circuit at the intermediate frequency. Similarly L_7 forms an r.f. choke at the oscillator frequency. It will be seen then that the effective lumped tuning capacitance across L_7 is equivalent to:

$$\frac{C_{22} \times C_{18}}{C_{22} + C_{18}}$$

and the voltage tap down in the i.f. transformer is equal to

$$\frac{C_{22}}{C_{out} + C_{18} + C_{22}}$$ where C_{out} is the valve output capacitance.

However, as the value of C_{22} is so much higher than C_{18}, the loss in gain of the mixer is negligible.

In order to ensure that the mixer valve operates on the optimum point of the conversion conductance curve, it is recommended that the oscillator grid current should not fall below a level of 35μA in any part of the band. It will be found in operation that the oscillator grid current will not vary by more than approximately $\pm 10\%$ of the mean value over the tuning range.

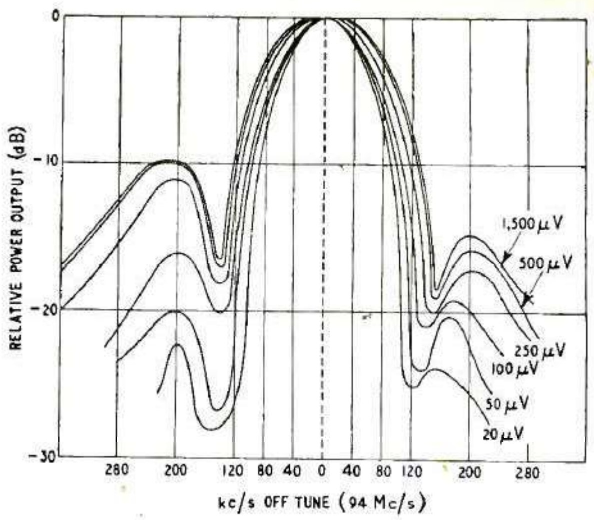

Fig. 3. Tuning characteristics for various input signal levels at the aerial terminals, with a frequency deviation of 22.5 kc/s.

A conversion conductance of 2.5 mA/V is obtainable with the EF80. Therefore, with the i.f. transformer used, the mixer gain from the tap point of L_5 to the signal grid of the first i.f. valve will be 32 dB. Due to the tapping of L_4, the effective gain of the r.f. stage is proportionately reduced to 34 dB. At 94 Mc/s the overall "front end" gain is of the order of 66 dB, measured from the aerial terminal to the control grid of the first i.f. valve.

I.F. Stages.—The design of i.f. stages for f.m. receivers presents a considerable number of conflicting problems. Very briefly summarized they are:—

(i) There should be adequate transmission of the significant side currents.

(ii) A good measure of adjacent channel selectivity is required.

(iii) There should be a reasonably linear phase/frequency characteristic in the transformers.

(iv) A certain allowance in the bandwidth should be made for small random drift in the oscillator.

(v) The uses of comparatively large values of overcoupling to give a wider bandwidth can produce a high degree of amplitude modulation on the carrier wave, and may give rise to ringing with impulsive interference.

It was decided that for the two i.f. transformers used in this tuner, a coupling factor K of design centre 1.2, would be most suitable to meet a compromise for the above requirements, provided the average loaded Q factor of the tuned circuits in the i.f. transformers is in the region of 60 to 70. ($K = k\sqrt{Q_pQ_s}$, where k is the coupling coefficient and Q_p and Q_s refer to primary and secondary windings.)

TABLE I

	1st I.F. Transformer		2nd I.F. Transformer		Ratio Detector	
	Prim. L_7	Sec. L_8	Prim. L_9	Sec. L_{10}	Prim. L_{11}	Sec. L_{12}
Fixed tuning capacitance (pF)	22	12	12	12	12	47
Valve capacitance + strays (pF)	8	10	10	10	10	—
Loaded Q in circuit	55	55	68	60	35	26
Coupling factor	1.25		1.25		0.65	
$K = k\sqrt{Q_pQ_s}$	15.8		21.2		—	
Transfer impedance (kΩ)	—		—		16.8	
Input impedance (kΩ)						