EFM 1 A.F. Amplifier and electronic indicator

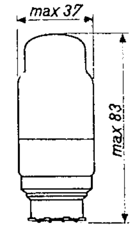

Fig. 1
Dimensions in mm.

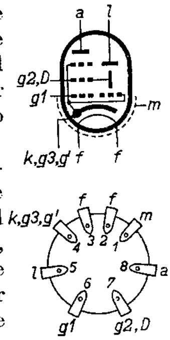

Fig. 2
Arrangement of electrodes and base connections.

The EFM 1 combines a variable-mu A.F. amplifier pentode with an electronic indicator, the former being the lower of the two assemblies in the envelope; a conical fluorescent screen, of the type used in the EM 1, is mounted above the pentode unit, so as to be visible at the top of the envelope. The cathode extends into the space formed by the fluorescent screen and is screened off, so that the light emitted by the cathode will not be visible; this screen is supported on two rods, arranged in such a manner that they are invisible from the outside. Between the cathode and the screen, a grid and two deflectors are mounted; the grid is wound without backbones and is supported only at the ends. A space charge thus occurs in front of the grid and this promotes a more uniform flow of electrons to the fluorescent screen. Further, on very weak signals, when the fluorescing areas are only small, the electron stream is thus confined to a relatively small working area of the screen. The two deflector rods are connected to the screen grid of the pentode unit and two fluorescent spots appear on the screen.

The pentode section is designed on the sliding screen-voltage principle, the screen, therefore, being fed through a resistor. When the A.G.C. voltage is applied to the grid the screen current drops and the voltage on the screen, and therefore also on the deflectors, increases. The fluorescent screen being connected directly to the supply voltage, the difference between the potential of the deflector electrodes and that of the fluorescent screen decreases, as also the deflecting effect of the two electrodes, in consequence of which the fluorescent areas are increased and the dark sections decreased in size. As the screen grid is decoupled by a capacitor, it is possible simultaneously to apply A.F. voltages to the grid, without affecting the size of the luminous sectors. The anode circuit may be resistance-coupled to the next valve for further amplification of the A.F. signal.

To produce the desired indication of the correct receiver tuning, the direct voltage from the detector diode, or the A.G.C. control vol-

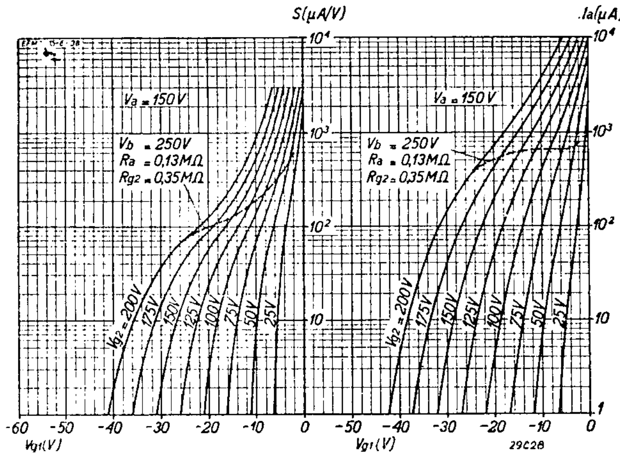

Fig. 3

Right-hand diagram. Anode current as a function of the grid bias, with screen voltage as parameter. These curves relate to an anode voltage of 150 V. The broken line represents the dynamic characteristic at Vb = 250 V, Rg_2 = 0.35 M Ohm and Ra = 0.13 M Ohm.

Left-hand diagram. Mutual conductance as a function of the grid bias, with screen voltage as parameter. These curves are in respect of an anode voltage of 150 V. The broken line refers to the mutual conductance as a function of the grid bias, using a screen-grid resistor of 0.35 M Ohm and an anode resistor of 0.13 M Ohm, both on a 250 V supply.

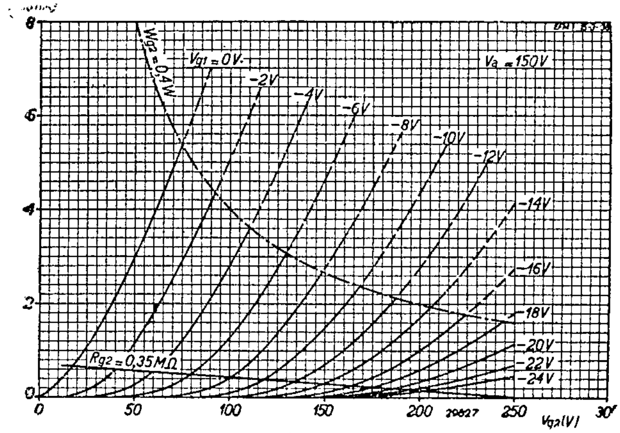

Fig. 4
Screen-grid current as a function of the screen voltage, with grid bias as parameter: resistance-line for Rg_2 = 350,000 ohms.

tage is applied to the grid. When a strong signal arrives at the diode the grid of the EFM 1 is rendered strongly negative and the amplification is reduced, which means, of course, that the A.F. amplification stage is included in the A.G.C.

This combination of electronic indicator and A.F. pentode thus virtually automatically furnishes a variable-mu A.F. amplifier, and a pentode of this type must necessarily meet the requirement that distortion shall remain low throughout the whole range of control. The pentode part of the EFM 1 is designed to give an amplification factor of about 60 with an anode resistor of 130,000 ohms and a screen series resistor of 350,000 ohms, with —2 V grid bias. By increasing the bias from —2 to —20 V the amplification is reduced from 60 to roughly 13, giving a control of 1: 4.5, and this extra amount of control can be put to good use where effective automatic gain control is required.

The above variation in grid bias just corresponds to the full deflection of the fluorescent bands and the construction of the screen grid is such as to ensure a constant anode current over the whole of the range. The amount of distortion is therefore also fairly constant and, at the same time, well within the ordinary practical limits. In order to suppress distortion, a fairly high control voltage is needed for the amplifier section of the valve, so that per degree of deflection in the indicator a greater voltage variation must be established on the grid of the EFM 1 than is the case with, say, the tuning indicator EM 1.

The use of the combined amplifier — indicator makes it possible to reduce the total number of valves required for many different types of radio receiver, without dispensing with electronic indication, or reducing the sensitivity. As this valve is necessarily a compromise, however, it must not be expected that it will give results in every way comparable

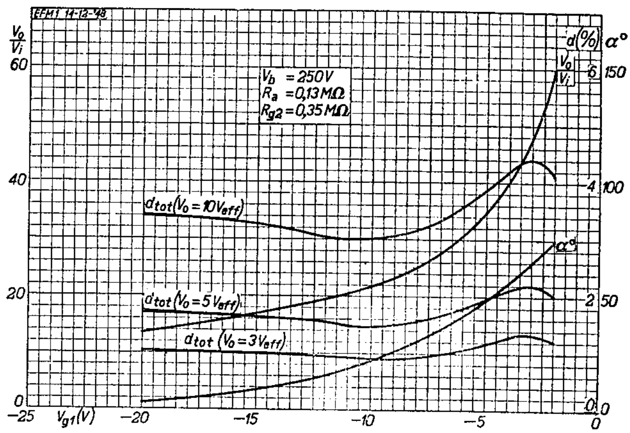

Fig. 5
Distortion as a function of the grid bias, with alternating output voltage as parameter, at Rg_2 = 350,000 ohms, Ra = 130,000 ohms and Vb = 250 V; also shadow angle α as a function of the grid bias.

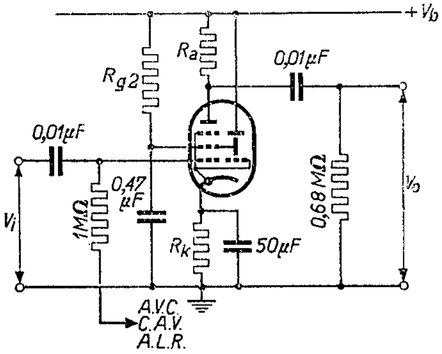

Fig. 6
Circuit diagram illustrating the symbols used in the relevant data.

with those of an A.F. amplifier with separate indicator.

The EFM 1 has no diodes for detection and will therefore be frequently used in conjunction with the double-diode I.F. pentode EBF 2; it can also be employed successfully with a separate diode such as the EAB 1 or EB 4.

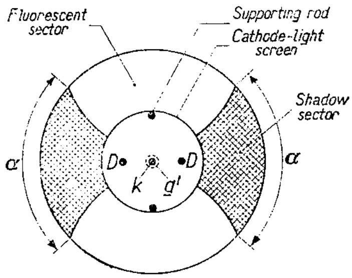

Fig. 7
Sketch of the fluorescent screen, showing the light and dark sectors.

HEATER RATINGS

Heating: indirect, A.C. or D.C., series or parallel supply.

Heater voltage	V_f	= 6.3 V
Heater current	I_f	= 0.200 A

OPERATING DATA

Supply and fluorescent screen voltage	$V_b = V_l$ =	250 V	
Anode resistor	R_a =	130,000 ohms	
Screen-grid series resistor	R_{g2} =	350,000 ohms	
Cathode resistor	R_k =	980 ohms	
Grid bias in uncontrolled condition	V_{g1} =	—2 V	—
Grid bias with full control	V_{g1} =	—	—20 V
Anode current	I_a =	0.8 mA	0.5 mA
Screen-grid current	I_{g2} =	0.6 mA	0.2 mA
Current on fluor. screen	I_l =	0.65 mA	0.8 mA
Screen-grid voltage	V_{g2} =	40 V	180 V
Anode voltage	V_a =	146 V	185 V
Voltage gain	V_o/V_i =	60	13
Distortion at 5V (eff) A.C. anode	d_{tot} =	2 %	1.7 %
Shadow angle of single sector, measured at edge of screen	α	> 70°	< 5°

MAXIMUM RATINGS

Anode voltage in cold condition	V_{ao}	= max. 550 V
Anode voltage	V_a	= max. 300 V

Anode dissipation	W_a	= max. 0.4 W
Screen-grid voltage in cold condition	V_{g2o}	= max. 550 V
Screen-grid voltage	V_{g2}	= max. 300 V
Screen-grid dissipation	W_{g2}	= max. 0.4 W
Voltage on fluorescent screen in cold condition	V_{lo}	= max. 550 V
Voltage on fluorescent screen	V_l	= max. 300 V
Voltage on fluorescent screen	V_l	= min. 200 V
Cathode current	I_k	= max. 5 mA
Grid voltage at grid current start (I_{g1} = + 0.3 μA)	V_{g1}	= max. —1.3 V
Screen-grid current under same conditions	I_{g2}	= min. 0.53 mA
Resistance between grid and cathode	R_{g1k}	= max. 3 M ohms
Resistance between filament and cathode	R_{fk}	= max. 20,000 ohms
Voltage between filament and cathode (direct voltage or effective value of A.C. voltage)	V_{fk}	= max. 100 V

APPLICATIONS

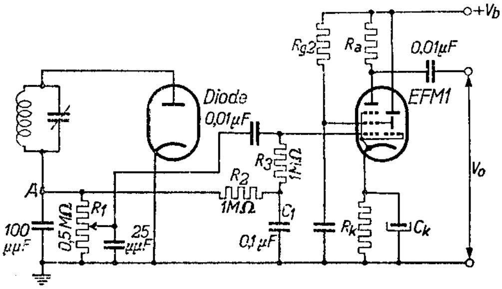

Fig. 8
Circuit diagram showing EFM 1 used as variable A. F. amplifier and electronic indicator, following a diode-detector stage.

The EFM 1 can be used only as an A.F. amplifier combined with an electronic indicator, and Fig. 8 shows the theoretical circuit of the valve in conjunction with a preceding, detector, valve. The R.F. signal from the diode resistor R_1 is fed through a capacitor to the grid of the EFM 1 and the negative D.C. voltage across the grid leak is fed from A, by way of resistors R_2 and R_3, also to this grid. Resistor R_2 and capacitor C_1 make up a smoothing filter for the A.F. voltage occurring across the diode resistor, to ensure that only direct voltage reaches the grid of the EFM 1 along this path. R_3 is the grid leak.

The negative D.C. voltage for the control of the EFM 1 is usually taken from the detector diode; it can be derived also from the A.G.C. diode, but in the case of delayed automatic gain control the cathode-ray indication, on signals of the strength less than that of the delay voltage, will then not function.

In view of possible microphony, the A. F. sensitivity at the grid of the EFM 1 should not be too great and care should be taken when mounting the valve itself that no trouble can occur through acoustic vibration. If a steep-slope output valve such as the EL 3 is used in the next stage, it is advisable to reduce the sensitivity by applying sufficient negative feed-back. To prevent hum, the direct voltage applied to the anode coupling resistor must in every case be smoothed by an R.C. filter, but no allowance has been made for this filter in the data and characteristics, since these will depend on each individual case and will also differ according to the supply voltage employed.

Practical applications of the EFM 1 are confined to two possibilities. One is the improvement of the A.G.C. of a receiver, by virtue of the fact that the control voltage applied to the grid is also operative on the EFM 1. As already stated, the A.F. gain in the case of a high-mutual-conductance output valve may be reduced by means of negative feed-back; if the cathode capacitor of the EL 3 be omitted, the negative feed-back factor will be about $2^1/_2$, but this does not represent a sufficient reduction in the sensitivity and the only alternatives are to use a higher value of cathode resistor

for the output valve, or to reduce the gain of the EFM 1 in the uncontrolled condition. To ensure the proper amount of grid bias the grid of the EL 3 should, in the first instance, be connected to a tapping on the cathode resistor; a value of 500 ohms for the latter gives a feed-back factor of about $4^1/_2$ and will ensure sufficient reduction in the sensitivity. Naturally, however, this amount of feed-back is obtained at the expense of the optimum output power; with a resistor of R_k = 500 ohms, the maximum obtainable output is not more than about 3.3 W and for this reason preference is usually given to a reduction in the amplification of the EFM 1. This can also be achieved by using a higher value for the cathode resistor, but it will result in a smaller variation in the shadow angle of the indicator (see also Fig. 5). A cathode resistor of, say, 2,000 ohms provides a bias of about —4 V; the corresponding amplification factor is then 40 instead of 60 and the range of deflection of the indicator is thereby reduced from 5—75° to 5—65°.
Another method consists in the use of a lower anode coupling resistor than the value of 130,000 ohms suggested; a smoothing resistor is then connected in series with it to bring the value up to 130,000 ohms, or the appropriate higher value in the case of higher supply voltages.
One result of the limited feed-back when using high-mutual-conductance output valves (EL 5 or EL 6) is that the A.F. sensitivity is still quite high. As the reader will be aware, the strength of the I.F. signal to be applied to the detector diode and, therefore, also the delay voltage for the A.G.C. is determined by the amount of A.F. gain. When the A.F. sensitivity is high it is not necessary to have a large signal strength at the detector and this leaves only small voltages available for controlling the EFM 1; this means, in effect, that the dark sectors will be reduced only on very weak signals, or that the electronic indicator will be relatively insensitive.
A still greater reduction in the A.F. sensitivity than by means of simple feed-back in a steep-slope output valve may be obtained by means of a valve having low A.F. sensitivity, such as the triode AD 1, in which case the sensitivity of the indicator will be greatly improved.
Notwithstanding the higher alternating output voltage of the EFM 1 necessary to load fully the AD 1, the distortion is extremely slight; on an average, the distortion from the combination of EFM 1 + AD 1 is less than in the AD 1 alone, this being due to the compensation of the second harmonics.
The second course open in the application of the EFM 1 consists in shifting the point of equilibrium of the sensitivity of the indicator unit in such a way that it will contribute less towards the A.G.C. In this case a higher D.C. voltage is required at the detector and therefore also a stronger I.F. signal, with less A.F. amplification; the latter may be reduced by means of strong negative feed-back. Since negative feed-back produced by the omission of the cathode capacitor from the output valve results in a considerable loss of output power, it is necessary to feed back from the loudspeaker to the grid of the EFM 1. Voltage feed-back to the EFM 1 has the advantage that the A.F. gain can be reduced at will by increasing the amount of coupling, whilst, further, the internal resistance of the output stage is reduced instead of increased, as in the case of current-coupling by omission of the cathode capacitor. In this way it is possible to include in the feed-back circuit components which are dependent on the frequency, so as to improve the frequency characteristic.
The object of this voltage feed-back, then, is to stabilize the amount of gain, but a great part of the A.F. gain control is thereby lost. On a strong carrier wave the EFM 1 can be fully controlled, in which case the amplification is lower and the negative feed-back weaker; there is also less distortion.

COMBINATION OF EFM 1 and EBF 2

When the EFM 1 is used as L.F. amplifier the EBF 2 will often be selected to serve as I.F. amplifier and detector, and this arrangement opens two possibilities:
1) EFM 1 as A.F. amplifier with weak negative feed-back on the output valve; the electronic indicator is then more or less insensitive.
2) EFM 1 as A.F. amplifier with strong feed-back from the loudspeaker to this valve. It has already been mentioned that the A.F. gain must be on the low side if a good tuning indication is to be obtained; in this case the delay voltage should be somewhat higher (5 to 6 V). The most suitable circuit is shown in the diagram of Fig. 9; the cathode voltage of the EBF 2 is 5—6 V and the cathode of the EFM 1 is connected to that of the EBF 2 through a resistor R_3 the voltage drop of which supplies the grid bias for the EFM 1. This resistor is not capacitively decoupled and it serves also as part of the potential divider for the negative feed-back.

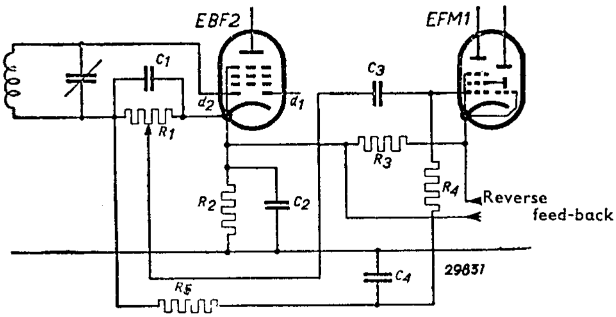

Fig. 9
Circuit diagram showing the EFM 1 used in conjunction with the EBF 2 with negative feed-back to the former.

When the EFM 1 is employed with negative feed-back the delay voltage from the A.G.C. must be higher than the normal cathode voltage of the EBF 2 (2 V), firstly in order to load fully the output valve and secondly so as not to limit the operation of the electronic indicator on weak signals. For, if the A.G.C. comes into operation before the output valve is fully loaded the direct voltage on the detector, for the same signal, is restricted and the sensitivity of the indicator reduced. A delay of 5 to 6 V is in most cases sufficient.
One complication to be taken into account is as follows. If efforts are directed towards less A.F. amplification, not by means of negative feed-back, but by using an output stage of lower sensitivity (e.g., the AD 1), the increased control on the EFM 1 will mean that the total A.F. gain on increasing signal strengths will again be reduced. In consequence, a very much stronger signal is needed at the detector to load fully the output valve on strong incoming signals than would be the case if the A.F. control were compensated by the negative feed-back, i.e., the delay voltage of the A.G.C. should be higher than the value suggested, and this in turn introduces still greater obstacles in the control of the EBF 2. It will therefore be appreciated that the use of negative feed-back is much to be preferred in reducing the A.F. gain subsequent to the detector stage.