EM 4 Dual-sensitivity electronic indicator

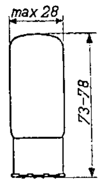

Fig. 1
Dimensions in mm.

The EM 4 is a dual-sensitivity electronic indicator valve which enables weak and strong signals to be tuned in with equal ease and accuracy. It is hardly possible to distinguish this tube from the EM 1 as regards appearance; it works on the same principle and also has the conical fluorescent screen, upon which shadow sectors are produced by deflection of the electron streams, these sectors being variable in width. Here, too, the screen is observed from the top of the valve. Instead of 4 fluorescent sectors, this tube gives only two and, therefore, also two shadow zones; in the case of the EM 4 tuning is effected by means of the shadow sectors rather than by the light. The shadow sectors do not vary in size to an equal extent when the set is being tuned; one sector is very much more sensitive than the other, that is to say, the angular variation takes place more rapidly.

The development of this tube was prompted by the following considerations: in circuits employing the EM 1 it was often found difficult to obtain a satisfactory indication on weak signals as well as on strong ones, so that, if a sensitive indication is essential on weak signals as well, there is no alternative but to feed the grid of the EM 1 directly with the direct voltage from the load resistor of the receiving diode or, at any rate, to reduce this voltage only slightly by means of a potential divider. On strong signals, however, such a high voltage occurs on the grid of the indicator that the fluorescent sectors cover the whole of the screen long before the centre of the resonance curve is reached.

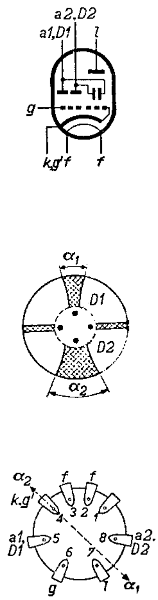

Fig. 2
Arrangement of electrodes and base connections.

On the other hand, if preference is given to a good, clearly visible indication on strong transmitters, a suitable tapping being provided on the potential divider for this purpose, there will be hardly any indication at all on the weaker stations; the direct voltage variations at the grid during tuning are so small that the movement at the edges of the fluorescent zones is barely visible.

In view of the above, a satisfactory indication on both weak and strong signals can virtually be obtained only by using two indicators, one being connected direct and the other across a potential divider, to the load resistor of the receiving diode, but a better solution consists in connecting the two indicators to the load resistor

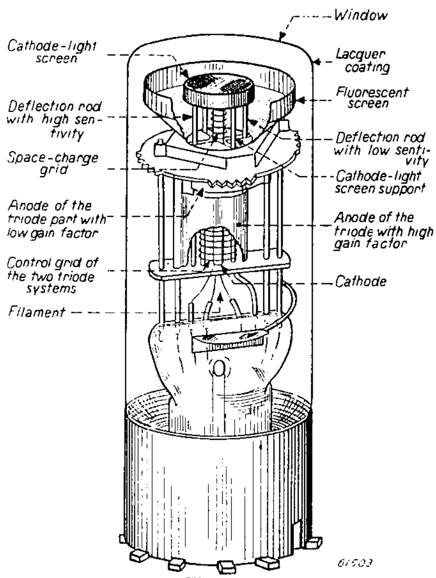

Fig. 3
Construction of Philips Electronic Indicator EM 4.

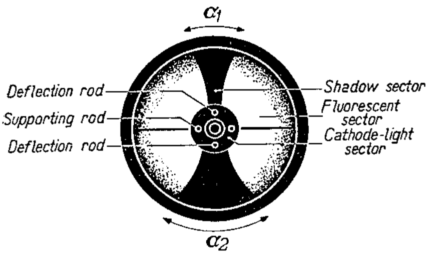

Fig. 4
Arrangement of the components in the indicator section of the EM 4.

in the same manner, e.g. one of the indicators being very sensitive and the other of low sensitivity.

By sensitivity, in the case of an electronic indicator, is meant the angular variation in the fluorescent and shadow sectors for one volt variation in grid voltage. The use of two valves for indicating purposes, due to the high cost and extra space required, would be out of the question, however, even in the highest class types of receiver and the need, therefore, is for a valve that will embrace the qualities of both high and low sensitivity.

Hence the EM 4, which may be regarded as a combination of two electronic indicators of different sensitivity, was developed; the construction, however, is almost as simple as that of the EM 1. The two units have a common fluorescent screen and cathode. one half of the screen serving each of the units.

The construction is as shown in Fig. 3: the conical fluorescent screen is at the top of the tube and the extremity of the cathode projects into it. Between the cathode and the screen, taking the components in order from the centre outwards, there is a space-charge grid, connected to the cathode, and two diametrically opposed deflector rods. The top end of the cathode is screened with a small cap to counteract the unpleasant effect of the light emitted by the cathode. This cap rests on two rods mounted vertically on the fluorescent screen, in contrast with the EM 1, which has an oblique rod. The two rods are fitted on a bar lying at 90° to them (see Fig. 4) and are at the same potential as the screen.

The amplifier section of the tube is at the lower end and consists of two triodes, of different amplification factors, mounted one above the other around the cathode; they are served by a common grid, but the latter is wound at a different pitch for each triode unit. The two anodes are electrically isolated from each other; the upper one, this being the smaller, is that of the high-amplification-factor triode. Each anode is connected to one of the deflector rods of the indicator unit and has its own separate contact on the base of the tube.

In the circuit (see Fig. 9) these anodes are connected across 1 megohm resistors to the positive H.T. line of the receiver; the fluorescent screen is at the same potential.

The two triodes are controlled simultaneously by the bias on the grid (control voltage from the detector diode) and they function as voltage amplifiers; variations in the bias are equivalent to a voltage drop across the anode resistors and therefore produce a variation in the width of the shadow sector behind the deflector rods.

The high-sensitivity triode unit produces a greater variation in the shadow angle behind the relative deflector rod than the other section, for a given grid voltage; in this tube the shadow angle for 0 V

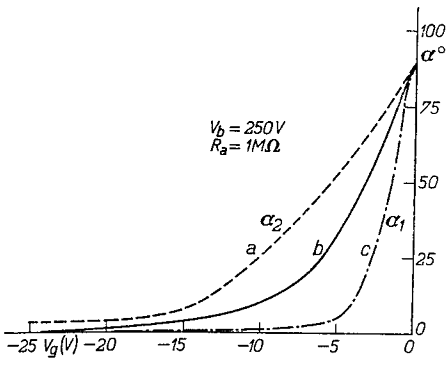

Fig. 5
Various characteristics of the shadow angle plotted against grid voltage:
a. Characteristic of the less sensitive unit of the EM 4.
b. Characteristic of a valve with variable pitch grid.
c. Characteristic of the more sensitive unit of the EM 4.

grid potential (and 250 V supply), is 90°. With —5 V on the grid the shadow angle of the high sensitivity deflector rod is 5° whereas the less sensitive rod does not give this shadow angle until —16 V is reached.

Fig. 6 shows the characteristics of the sections of the valve, which clearly demonstrate the action of the indicator. The two sensitivities of the EM 4 are thus obtained by the use of two amplifier triodes having different amplification factors. Originally, a solution to the problem of obtaining a clear indication for both weak and strong signals was sought in a special form of characteristic in the amplifier part of the triode, for instance by employing a grid of varying pitch, so that the I_a/V_g characteristic would have a long "tail", but characteristics of this type do not give good results, as will be seen from Fig. 5, in which curve (b) represents the shadow angle as a function of the grid voltage of a tube of this kind. At small grid voltages the mutual conductance is relatively high, giving fairly good sensitivity on weak signals, but not nearly so high as in curve (c) in the figure, which refers to the more sensitive section of the EM 4. At high values of grid potential the tube operates on the tail of the curve and the mutual conductance is low, with correspondingly low sensitivity of the indicator. From Fig. 5 it will be noticed, however, that even on strong signals the indicator is anything but satisfactory; assuming a direct voltage of —10 to —15 V during tuning, curve (a) gives an angular variation of 18° and curve (b) only 6°.

The indication obtained on strong signals is thus not sensitive enough when the indication for weak signals is good; valves made with varying pitch do, in actual fact, yield curves as shown in *b*, which means that such tubes are satisfactory only on weak signals. For a really good indication for both weak and strong signals the only solution is a tube of

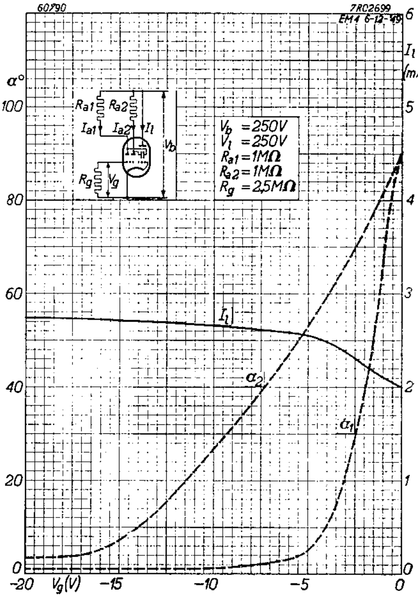

Fig. 6
Shadow angles α_1 and α_2 measured at the edge of the screen, and screen current I_l as functions of the grid voltage on a supply of 250 V.

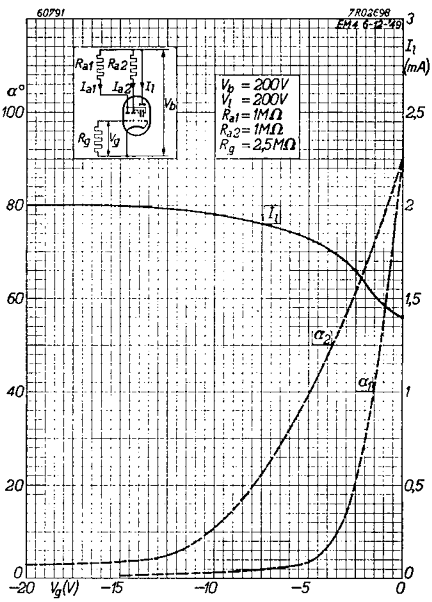

Fig. 7
Shadow angles α_1 and α_2 measured at the edge of the screen, and screen current I_l as functions of the grid potential on a supply of 200 V.

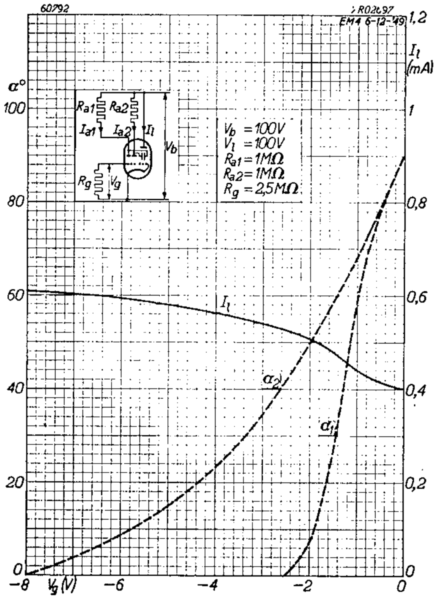

Fig. 8
Shadow angles α_1 and α_2 measured at the edge of the screen, and screen current I_l as functions of the grid potential

the type of the EM 4 with its dual sensitivity ranges.

It should be noted that the EM 4 has only two fluorescent zones instead of the four in the EM 1. In the first place this ensures greater angular variation in each of the individual sectors; secondly, experience has shown that the average listener finds it easier to tune with only two sectors than with four. When there are four fluorescent sectors the layman invariably tries to obtain a symmetrical pattern on the screen, with correspondingly faulty tuning. With only two shadow sectors there is less to occupy the eye and there is not so much tendency towards inaccurate tuning. Due to the presence of the two rods supporting the cathode-light screen, the fluorescent areas are divided by two thin lines of shadow. Fig. 6 shows that at —16 V and —5 V the characteristic commences to flatten out; small lines of shadow remain over, due to the fact that the deflector rods absorb a certain amount of current which in turn produces a voltage drop across the coupling resistor, this preventing the rods from exceeding a certain positive potential. It is on account of this fact that the fluorescent areas cannot overlap each other. Fig. 4 depicts diagrammatically the arrangement of the electrodes and supporting rods in the indicator section of the EM 4.

At the upper end the bulb is moulded to a special shape, being, as it were, depressed to a concave surface, in order that the edge of the glass, which is lacquered, may form a dark background before the actual "window" of the tube. In this way the contrast between the fluorescence and the dark background is accentuated and very slight variations in the light and shadow during tuning are rendered more easily perceptible.

Heater ratings have been chosen for this tube that will render it suitable for parallel feeding on 6.3 V as well as series feeding in 200 mA circuits. Needless to say in A.C./D.C. receivers operating on 110 V the brilliance of the fluorescent sectors is less than when the applied screen voltage is 250 V.

HEATER RATINGS

Heating: indirect by 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: EM 4 used as tuning indicator

Voltage supply to screen and anode circuits	V_b	= 100 V	200 V	250 V
Anode series resistor for the high-sensitivity section	R_{a1}	= 1 M ohm	1 M ohm	1 M ohm
Anode series resistor for the low-sensitivity section	R_{a2}	= 1 M ohm	1 M ohm	1 M ohm
Screen current at $V_g = 0$ V	I_l	= 0.2 mA	0.55 mA	0.75 mA
Grid voltage for a shadow angle of 90° in the high-sensitivity section	V_g (α_1 = 90°)	= 0 V	0 V	0 V
Grid voltage for a shadow angle of 90° in the low-sensitivity section	V_g (α_2 = 90°)	= 0 V	0 V	0 V
Grid voltage for a shadow angle of 0° in the high-sensitivity section	V_g (α_1 = 0°)	= —2.5 V	—	—
Grid voltage for a shadow angle of 0° in the low-sensitivity section	V_g (α_2 = 0°)	= —8 V	—	—
Grid voltage for a shadow angle of 5° in the high-sensitivity section	V_g (α_1 = 5°)	= —	—4.2 V	—5 V
Grid voltage for a shadow angle of 5° in the low-sensitivity section	V_g (α_2 = 5°)	= —	—12.5 V	—16 V

α_1 = shadow angle with respect to deflector rod D_1, measured at the edge of the screen.
α_2 = the same with respect to deflector rod D_2.

MAXIMUM RATINGS

V_{a10}	= max. 550 V	V_l	= max. 275 V
V_{a1}	= max. 275 V	V_g (I_g = + 0.3 μA)	= max. —1.3 V
V_{a20}	= max. 550 V	R_{gk}	= max. 3 M ohms
V_{a2}	= max. 275 V	R_{fk}	= max. 20,000 ohms
V_{lo}	= max. 550 V	V_{fk}	= max. 100 V [1])

[1]) Direct voltage or effective value of alternating voltage

APPLICATIONS

The EM 4 can be used in all A.C. or A.C./D.C. receivers incorporating diode rectification, so long as the signal strength at the diode detector is sufficiently great (superheterodynes). The electronic indicator should for preference be connected to the diode load resistor; connection to the A.G.C. diode in the case of delayed control has the disadvantage that the indicator will not then function on signals which are below the delay level. Since the more sensitive side of the EM 4 is otherwise designed to permit of exact tuning on weak signals and will do so even when the signal is below the delay level, it is advisable to connect the grid of the EM 4 directly to the detector diode. In this way, moreover, the control voltage rises more quickly during tuning, because the signal voltage at the diode is taken from the second tuned circuit in the I.F. band-pass filter, whilst the signal voltage for the A.G.C. diode is usually derived from the first tuned circuit.
The apparent sensitivity is thus greater at the detector diode than at the A.G.C. diode. Fig. 9 is a typical example of a superhet receiver circuit incorporating the EM 4.

Here the grid receives the *full* control voltage across the load resistor of the detector diode. An R.C.-filter circuit is provided to suppress low frequencies existing across the load resistor. Nonetheless, in many cases the signals on the diode will be too strong and it will be found necessary to cut down the direct voltage across the load resistor by means of a potential divider. In this, however, care should be taken to see that the A.C. resistance (R_w) of the diode circuit is not reduced too far, as this will have a bad effect on the ratio of R_g to R_w and the maximum modulation depth for undistorted rectification will be reduced; this can be avoided by using high-ohmic resistors for the potential divider. Actually the same applies to the resistance of the R.C.-filter circuit shown in Fig. 9. In general it will be necessary to ensure that the direct voltage on the grid of the EM 4 corresponding to the strongest anticipated aerial signal is just sufficient to produce the smallest possible shadow sector α_2 of the less sensitive side of the indicator. If this can be done the indications will be excellent. The sensitivity values of the two indicator sections are such that in the majority of cases accurate tuning will be possible on the weakest signals; but, if even greater sensitivity is required on very weak signals, this can be obtained only at the expense of the deflection on the stronger signals. Should the resonance curve of the receiver exhibit two peaks, the indicator may possibly give a maximum deflection on one of the sidebands, and every care must be exercised in ensuring that the band-pass filter produces a single peak only. When the indicator is used in low voltage A.C./D.C. receivers, efforts must be made to see that the screen receives the highest possible potential; otherwise the brightness of the fluorescence will be too low. It may also be found that on a 100 V supply the high-sensitivity section of the indicator gives only a slight indication, and this can be explained in the following manner.

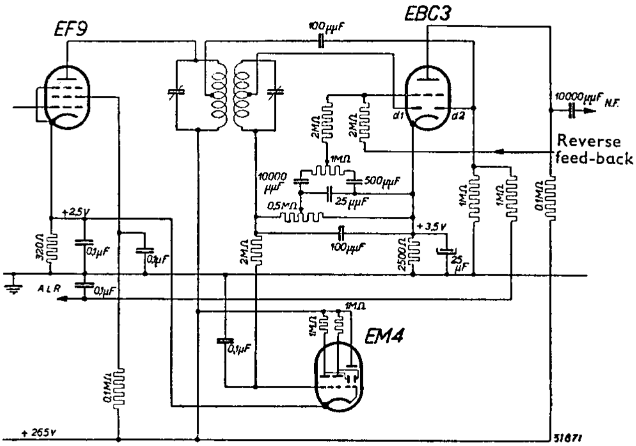

Fig. 9
Theoretical circuit diagram showing the EM 4 in a superheterodyne receiver. The diagram reproduces the I.F. and A.F. sections only.

The grid circuit of the EM 4 must include a resistor of from 1 to 2.5 megohms with a decoupling capacitor to filter out any modulation on the load resistor of the detector diode (see Fig. 9). With no signal, grid current flows, which produces a potential of about 1 V negative, across this resistor. Since the grid swing of the sensitive side of the indicator is only about 2.5 V on a supply of 100 V, this negative potential of 1 V considerably reduces the deflection of the shadow sector; Fig. 10 demonstrates the actual effect of a grid resistor of 1 and 2.5 megohms respectively (chain-dot and dotted lines in fig. 10).

On high supply voltages this effect is not so marked, because the grid swing of the sensitive unit is then much greater, although the effects of grid current are, nevertheless, perceptible.

In view of the above, the sensitive side of the indicator is not generally used in receivers operating on a supply of 100 V and, as the less-sensitive part is then much more sensitive than normally on 250 V, approximating more closely the characteristic of the EM 1 at 250 V, this section of the indicator will give a much more satisfactory range of deflection on average signal strengths.

In A.C./D.C. receivers operating on 100 V it is also possible to short the two anodes of the triode and feed them through a common resistor of 1 megohm, and the

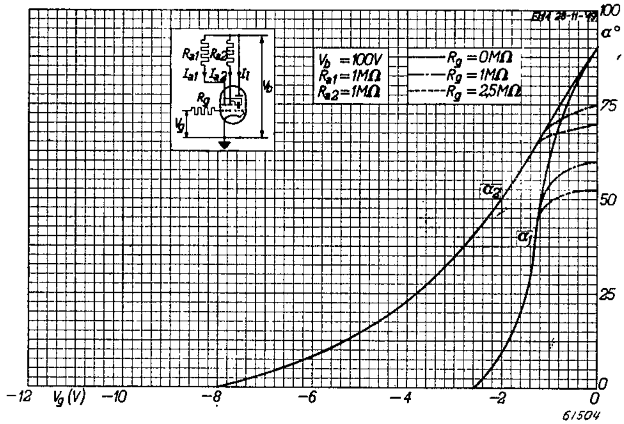

Fig. 10
Full line. Shadow angles α_1 and α_2 measured at the edge of the screen, as a function of the grid potential on 100 V supply, with no resistor connected in series with the grid.
Chain-dot line. The same with a resistor of 1 megohm connected to the grid.
Dotted line. The same with a resistor of 2.5 megohms in series with grid.
As from — 1.2 V, the three curves coincide.

characteristics in Fig. 11 show the working conditions under this arrangement, which ensures a marked variation in the shadow angles following upon voltage variations on the grid, even at potentials below the control level. The curve of the shadow angle plotted against the control voltage now lies roughly between that of the more sensitive section of the EM 4 and that of the low sensitivity side on a supply of 250 V. In Fig. 11 the shadow angle refers to a grid resistor of 2.5 megohms; at lower values of the control voltage it is true that the bend in the curve caused by grid current is plainly to be seen, but this bend is nevertheless not nearly so marked as in the characteristic shown in Fig. 10. At a grid potential of 0 V the mutual conductance is higher, from which it follows that the indicator sensitivity is greater. This arrangement will give a maximum shadow angle of about 70°, which is quite sufficient for all tuning purposes; both the shadow angles of the EM 4 are then the same, as is also the angular variation in the two sectors.

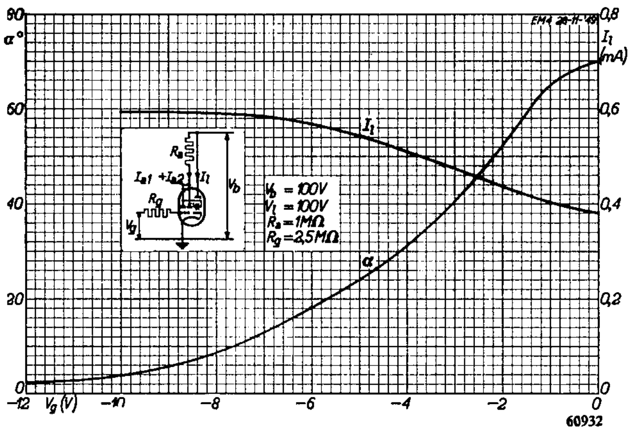

Fig. 11
Shadow angle α of the two sectors, and screen current I_l as functions of the grid voltage on 100 V supply, with the two anodes interconnected and fed through a resistor of 1 megohm. A resistor of 2.5 megohms is connected to the grid.