May 28, 1940. P. F. M. GLOESS 2,202,522

THERMIONIC VALVE CIRCUITS

Filed April 16, 1937

Fig. 1.

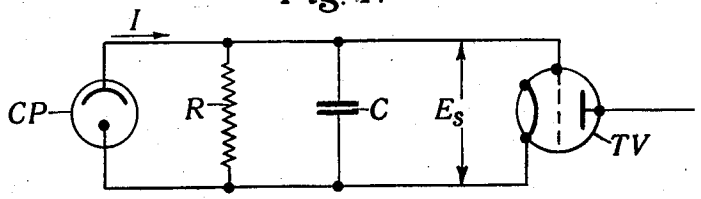


Fig. 2.

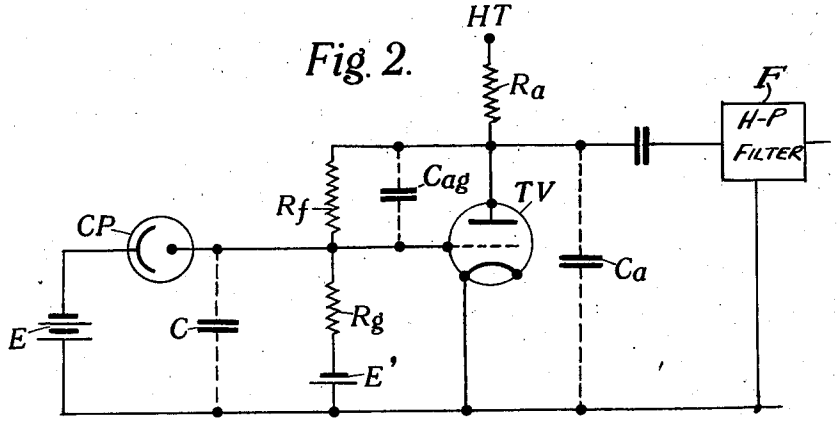
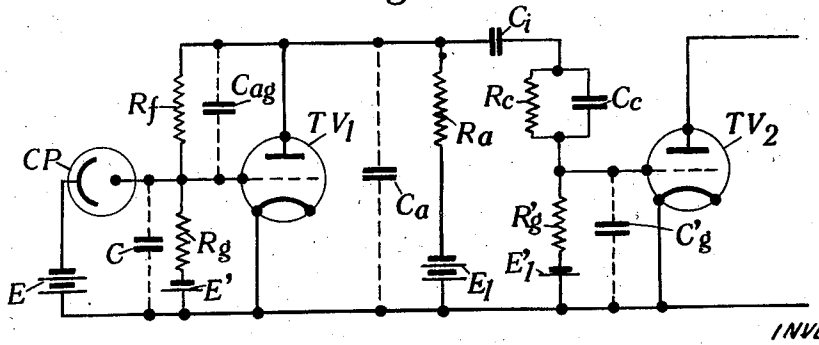


Fig. 3.



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THERMIONIC VALVE CIRCUITS

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6 Claims. (Cl. 179—171)

The present invention relates to improvements in devices such as amplifiers adapted to employ very weak currents, particularly to devices comprising photoelectric cells. The arrangements acording to the invention are particularly advantageous in systems such as television systems where a wide band of frequencies is to be amplified.

One object of the invention is to provide amplifier devices in which the parasitic noises are considerably reduced or partially or totally eliminated.

Another object of the invention is to provide coupling circuits between photoelectric cells and vacuum tubes employed in such amplifiers.

The system considered by way of example in the following description comprises a simple photoelectric cell element connected to a vacuum tube amplifier, and may be considered as representative of other more complicated arrangements such as electron beam devices, for example, the iconoscope associated with amplifiers. In such a system the harmful noises are mainly due (*a*) to variations which are either slow or temporarily accentuated by the intensity of the current in the photoelectric cell under the action of light, these variations resulting from the thermionic agitation in the resistances of the coupling circuits and in the internal and external plate resistances of the tube and (*b*) to the sudden variations of the plate current caused by secondary electron emission or from the degree of ionisation of the tube. The mechanical vibrations and the variations in the feed of the tube also give rise to noises in the amplifier.

In the majority of cases, however, the noise due to thermionic agitation in the coupling resistance between the photoelectric cell and the vacuum tube is the most important and it is a particular object of the invention to reduce this noise.

Another object of the invention is to reduce the noise due to the fluctuation of the grid current which becomes more troublesome when the noise of the thermionic agitation in the coupling circuit has been stifled.

Still another object of the invention is to reduce the noise due to the thermionic agitation in the external resistances of the plate of the tube.

The features of the invention are set out in the appended claims and will be clearly understood by means of the following description read in relation to the attached drawing in which:

Fig. 1 shows an example of coupling between a photoelectric cell and a vacuum tube of an amplifier according to the characteristics of the invention;

Fig. 2 shows an example of coupling between a photoelectric cell and a vacuum tube of an amplifier employing a return feed; and

Fig. 3 shows an example of coupling adapted to reduce distortion in signals due to the grid resistance of the tube.

Fig. 1 shows a photoelectric cell CP and a vacuum tube TV and their coupling circuit. In this coupling circuit, R represents a pure resistance which is the resultant of the insulating resistance of the photoelectric cell, the resistance of the vacuum tube and of an additional resistance. When a circuit is employed for operation on a wide frequency band, the additional resistance normally placed in the circuit is relatively low (for example of the order of 10,000 to 100,000 ohms) in order to reduce the effect of the capacity C which tends to reduce the gain for high frequencies. For such values of the photoelectric cell resistance other components coming in the resistance R may be neglected. The capacity C mentioned and shown in the drawing is a pure capacity and its value is determined by the capacities offered by the photoelectric cell, the additional resistance, the connection line and the vacuum tube.

The intensity of the current produced by the effect of light on the photoelectric cell will be called I and the difference of potential at the input of the vacuum tube will be indicated by E_s. This difference of potential at the terminals of the tube is equal to I. Z, if Z represents the impedance of R and of C in parallel. Consequently:

$$E_s=\frac{IR}{\sqrt{1+\omega^2C^2R^2}}$$

The difference of potential due to the thermionic agitation at the input of the tube for a frequency band equal to 1 is at the input of the tube;

$$E_T=2\sqrt{kTr}$$

in which relation k is the Boltzmann constant, T the absolute temperature and r the resistive component of the combination of R and C in parallel. Replacing r by its value

$$\frac{R}{1+\omega^2C^2R^2}$$

the difference of potential E_T is written:

$$E_T=\frac{2\sqrt{kTR}}{\sqrt{1+\omega^2C^2R^2}}$$

The term

$$\frac{E_S}{E_T}$$

then becomes:

$$\frac{E_s}{E_T}=\frac{IR}{\sqrt{1+\omega^2C^2R^2}}\times\frac{\sqrt{1+\omega^2C^2R^2}}{2\sqrt{kTR}}=\frac{I\sqrt{R}}{2\sqrt{kT}}$$

Consequently this term is in direct proportion to

$$\sqrt{R}$$

In order to improve the signal-to-noise ratio of a photoelectric cell and an amplifier and supposing that the current I generated by light in the cell has been taken as great as possible and the temperature T as small as possible, the resistance R must thus be increased.

However, the high frequencies will then be considerably attenuated. It is, however, always possible to compensate this attenuation by a corrector network suitably provided.

In the example under consideration the combination of R and C has been considered, but it is clear that any other combination of impedances may be considered without abandoning the characteristic of the invention which consists in reducing the resistive component of the combination of impedances considered.

When the resistance R has no upper limit and is given an extremely high value, the resistance of the photoelectric cell and of the vacuum tube and the grid-cathode resistance are no longer negligible with respect to the resistance shunted on the connecting circuit, and as in general these resistances are not constant, the device tends to become unstable. Even for resistances of 10 to 100 megohms it may sometimes be necessary to avoid variations in the insulation resistances by drying the air surrounding the envelopes of the photoelectric cell and the vacuum tube. Alternatively or in addition the tube may be chosen and operated so that the grid current is of low intensity and consequently negligible.

In this case in which the grid current and the insulation resistance no longer give a limit to the value of the resistance, the noise introduced by the resistance of the tube and the output plate circuit must then be considered. There is no reason to increase the input resistance further when the noise due to the thermionic agitation therein to the high frequencies is of the same order of intensity as the other noises. In order to take the greatest advantage of the reduction of this noise due to thermionic agitation it is consequently necessary to choose a tube giving only slight noises due to the effects of rapid or wavy fluctuation of the anode current, and to avoid any secondary ionisation and emission. The total noise produced by the tube should not be greater than the unavoidable noise due to the thermionic agitation in the plate circuit. One method of obtaining this condition is to reduce as far as possible the plate tension, even if the slope of the tube is thereby reduced.

If the noises have been reduced so that the noise due to thermionic agitation in the output plate resistance alone becomes important, this resistance must be increased as much as possible so as to increase the amplification and to reduce the noise due to the thermionic agitation due to this resistance. There is no reason to increase this resistance to a great extent, first because the gain would be little when it became greater than the internal plate resistance, and secondly because the distortion would be increased. As the output resistance is shunted by the parasitic capacities of the tube, of the coupling and of the connection circuit, the gain at the high frequencies would be less than at the low frequencies.

This additional distortion can be reduced or wholly compensated by the use of a return feed circuit of which an embodiment is shown in Fig. 2.

The filament-grid circuit of the tube comprising the photo-electric cell also comprises a source E in series with the cell, and a parasitic capacity C in shunt between the connection wires, and a resistance R_g in series with a battery E' also shunted between the connection wires. The plate of the tube is connected to the high tension source through a resistance R_a and a parasitic capacity C_a appears in shunt on the output circuit of the tube. The return feed circuit between the plate and the grid comprises a resistance R_f and the parasitic capacity C_{ag}. The values of R_g and R_f are taken so as to have for the value of the return feed β a value independent of the frequency:

$$\frac{C}{C_{ag}}=\frac{R_f}{R_g}\text{ and }\beta=\frac{R_g}{R_g+R_f}=\frac{C_{ag}}{C_{ag}+C}$$

The amplification μ of the tube depends on the frequency, but its minimum value is taken such that in the formula of the resultant gain:

$$\mu=\frac{\mu}{1+\mu\beta}$$

$1+\mu\beta$ may be nearly equal to $\mu\beta$ that is to say, $\mu\beta$ is large with respect to 1. Then at all frequencies:

$$\mu=\frac{1}{\beta}=\text{constant}$$

Another effect of the return feed is to reduce at very low frequencies the incoming load which otherwise would be considerable.

The return feed must be such that the remaining gain of the tube is still considerable. It should also be noted that the existence of a return feed slightly reduces in itself the signal; noise ratio.

The distortion due to the presence of the parasitic capacities in parallel with the high resistance of the circuit can also be corrected in another way. When a wide frequency band is to be transmitted it may become possible to ignore the frequencies lower than a certain value (for example, for a television image of 240 lines, the frequencies lower than 5000 p. p. s.). These frequencies may be eliminated by any well known means such as a filter F having a low frequency cut-off. The attenuation for all the frequencies higher than this value can then follow a simple law and may be compensated in a simple manner by a suitable network of resistances and capacities. In the case in which the lower frequencies are partially required they can be reintroduced by separate means.

The suppression of the very low frequencies also has the advantage that the loading of the tube is much smaller because these frequencies would always have a very high amplitude on account of the high value of the grid resistance.

By ignoring the very low frequencies and keeping at a high level the lowest frequencies which must be considered, the following advantages can be obtained:

1. The mechanical noise cannot disturb the

amplifier and it is not necessary to take special precautions from this point of view.

2. The induction due to powerful low frequency fields does not have to be considered, which is advantageous on account of the difficulties met in low frequency systems.

3. The current variations due to the feed networks have no influence on the device. The feed circuits, which before were expensive on account of the difficulty of filtering low frequencies, can thus be simplified.

4. The decoupling between the various parts of the feed system is rendered easier.

Fig. 3 represents a circuit including means for correcting the distortion due to a high grid resistance. The photoelectric cell CP is connected to a vacuum tube TV1 by a circuit comprising the batteries E and E' and by the resistance R_g shunted by the parasitic capacity C. This tube, in the output of which is placed in series with the battery E_1, the anode resistance R_a shunted by the parasitic capacity C_a, is provided with a return feed obtained by a circuit comprising the resistance R_f shunted by the parasitic capacity C_{ag}.

The connection between the tube TV1 and a second tube TV2 is composed of a coupling condenser C_1, a correction circuit comprising in parallel the resistance R_c and the capacity C_c and finally in series with the source E'_1 the grid resistance R'_g shunted by the parasitic capacity C'_g.

The values R_aC_a, $R'_gC'_g$, R_cC_c are low and the correction will be almost complete for the band width concerned provided that the time constant R_cC_c has the same value as the constant R_gC. In the case in which R_g is very high the input impedance is practically equal to

$$\frac{1}{C\omega}$$

and it is then possible to dispense with R_c and C_1.

It is clear that the devices described above have only been so described by way of example and that the invention may be applied to various devices in which the parasitic noises must be reduced.

What is claimed is:

1. An amplifier comprising a thermionic valve having a plate resistance of such great magnitude that noise due to thermionic agitation in said resistance is small and the amplifier gain at high frequencies tends to decrease and means for counteracting the decrease of gain comprising a feed-back circuit including a resistance connected between the anode and grid of said valve for feeding a portion of the amplifier output back to the input in phase opposition to the signal to be amplified.

2. An amplifier according to claim 1 in which the ratio of the feed-back resistance to the grid-leak resistance of the valve approximates to the ratio of the inherent input capacity to the inherent capacity across the feed-back resistance.

3. A negative feed-back amplifier in which the feed-back circuit comprises an impedance connected between the anode and control grid of the valve said feed-back circuit having a time constant approximating to that of the input impedance of the valve whereby the ratio of feed-back with respect to output substantially independent of frequency.

4. An amplifier according to claim 1, further comprising means for suppressing all frequencies below a predetermined frequency range.

5. An amplifier having a large plate resistance to reduce noise due to thermionic agitation, comprising a thermionic valve so constructed that substantially no grid current flows, means for compensating the high frequency gain losses introduced by said large resistance, comprising a feed-back circuit connected between the anode and grid of said valve for feeding back a portion of the amplified output back to the input in phase opposition..

6. An amplifier according to claim 5, in which the ratio of the feed-back resistance to the grid-leak resistance of the valve is substantially equal to the ratio of the inherent input capacity of the valve to the inherent capacity across the feed-back resistance.

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