A Method of Demonstrating the Retroactive Property of a Triode Oscillator

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X. *A Method of Demonstrating the Retroactive Property of a Triode Oscillator.* By E. V. APPLETON, M.A., M.Sc.

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ABSTRACT.

THE author, following Vallauri, gives an approximate treatment of the conditions which gives rise to retroaction between the grid and anode circuits of a triode valve, and describes an arrangement of circuits whereby the property can easily be demonstrated to a large audience.

The method of using triode retroaction for the amplification of wireless signals is now well known. Of the various examples of the use of this method the arrangement described by Armstrong * may be regarded as typical. Here the usual oscillatory circuit L_1C (see Fig. 1) is connected to the grid and filament of a triode, retroaction being obtained by means of the coil L_2 in the anode circuit.

FIG. 1.

If the mutual inductance between L_1 and L_2 is of the correct sense and magnitude it is possible to cause the variations of the anode current, produced by a free or forced oscillation in L_1C , to induce favourably timed electromotive forces in the oscillatory circuit and so partly or wholly compensate for Joulean and other losses. In the case of total compensation, of course, the oscillation is undamped.

The following approximate quantitative treatment, suggested by the work of Vallauri,† seems to make the matter clearer. Consider a free oscillation in the circuit L_1C . Ignoring for the moment the effect of L_2 we have for the

* E. H. Armstrong, "Proc." Inst. Rad. Eng., 3, p. 215, 1915.

† G. Vallauri, "L'Elettrotecnica," 3, p. 43, 1917.

ordinary expression of the electromotive forces in the circuit

$$L_1\ddot{Q} + R\dot{Q} + \frac{Q}{C} = 0, \quad \dots \quad (1)$$

where Q is the charge on the plate (a) of the condenser at any instant.

If we now take into account the mutual inductance M between L_1 and L_2 , and also assume that the resistances of both coils are small compared with their reactances for the particular frequency considered, we have approximately

$$\frac{V}{v} = \frac{M}{L_1},$$

where V and v are the induced anode and grid voltages respectively. Also the value of v at any instant is $\frac{Q}{C}$.

If we now assume that the anode current changes in the tube are proportional to the anode and grid voltage changes involved, we have, if I is the value of the anode current,

$$I = av + bV + c,$$

where a , b and c are constants.

On substituting for V and v this becomes

$$I = a\frac{Q}{C} + \frac{bMQ}{L_1C} + c,$$

that is

$$MI = \frac{aMQ}{C} + \frac{bM^2Q}{L_1C}.$$

Now $-MI$ is the value of the E.M.F. induced in the oscillation circuit by the anode current variations. In the retroactive case we must, therefore, rewrite (1) as follows :

$$L_1\ddot{Q} + \left(R + \frac{Ma}{C} + \frac{bM^2}{L_1C}\right)\dot{Q} + \frac{Q}{C} = 0. \quad \dots \quad (2)$$

For retroaction in the circuit we are considering it is well known that M must be negative and thus the effective resistance of the circuit may be written as

$$R - \frac{Ma}{C} + \frac{M^2b}{L_1C},$$

where M represents the numerical value of the mutual inductance. We may make this effective resistance as small as we please by increasing the numerical value of M ,

as in a practical case $\frac{bM}{L_1}$ is small compared with a . This reduction in the effective resistance of the oscillatory circuit makes, of course, a corresponding reduction in the damping. Now the time required for a free oscillation to decay to one-hundredth of its value in a non-retroactive circuit is

$$\frac{9 \cdot 212 L_1}{R} \text{ seconds}$$

(L and R being in a consistent set of units). In a retro-active circuit we must write this

$$\frac{9 \cdot 212 L_1}{R - \frac{Ma}{C} + \frac{bM^2}{L_1 C}} \text{ seconds.}$$

It is possible to demonstrate the difference between these two times in circuits where L_1 is very large and the

FIG. 2.

signals are of acoustic frequency. A simple circuit for this is shown in Fig. 2. The condenser C is charged by putting the change-over switch in the (A) position and then discharged through the inductance L_1 by changing to the (B) position. The oscillation in the $L_1 C$ circuit is heard in the telephone T . By performing this experiment first with the coils L_1 and L_2 very loosely coupled, and afterwards with the value of M adjusted so that the effective resistance is appreciably diminished, it is possible to show to a large audience that a free oscillation, which, without retroaction, sinks to inaudibility in a fraction of a second, can, by means of retroaction, be prolonged for 4 or 5 seconds.

If a vibration galvanometer is used instead of a telephone a quantitative determination of the effective resistance in any particular case is possible.

[*Note added Jan. 26th.*—A slightly more satisfactory arrangement than that shown in Fig. 2 is obtained when the oscillatory circuit is impulsed electrically by means of a neighbouring aperiodic circuit.]

DISCUSSION.

Prof. W. ECCLES said the method would be very useful as a lecture experiment. Those who were accustomed to high-frequency work were familiar with these phenomena, but students were often mystified by the perfect silence of high-frequency circuits. The author's arrangement for demonstrating the effect at audio frequencies was therefore valuable. It reminded him of one apparatus, which Mr. Jordan and himself had shown, in which a tuning fork took the place of a condenser and inductance, the mass standing for the inductance and the elasticity for the capacity. The arrangement was very portable. The author's treatment of the conditions of the experiment was a very useful amplification of Vallauri's analysis.

Prof. HOWE said he presumed the reason why the time during which the oscillations remained audible could not be extended beyond a few seconds was that harmonics had to be taken into account, whereas the analysis assumed a single sine wave.

Dr. D. OWEN said that it was quite possible to hear the note produced in a shunted telephone included in an oscillatory circuit of audible natural frequency, on charging or discharging the condenser. By use of tuning fork and monochord the frequency could be measured, and thus the oscillatory nature of the discharge, and the laws connecting the frequency with inductance and capacity could be verified by the individual student. He had tried to multiply the effect by the aid of a tuning-fork interruptor, but not with much success. The author's method made the demonstration possible to an audience, though at the sacrifice of simplicity. It was to be noted also that the reaction of the mutual inductance would have the effect of slightly raising the frequency of the original circuit. This rise of frequency appeared to be a general consequence of supplying energy for the production of maintained vibrations in an oscillatory system.