Physics. — *"The audion as an amplifier."* By G. HOLST and E. OOSTERHUIS. (Communicated by Prof. H. A. LORENTZ.)

(Communicated in the meeting of October 26, 1918).

In a recently published article G. VALLAURI[1]) communicated some calculations about the audion as an amplifier. He points out, that under normal conditions, one may approximately represent the anode current of the audion I as a lineair function of the grid potential v and the plate potential V:

$$I = av + bV + c.$$

If in the plate circuit a resistance R is placed, it may be easily calculated that the variations of the current I_υ in the plate circuit depend upon the variations v_υ of the grid potential in the following way:

$$I_\upsilon = \frac{a}{1 + bR} v_\upsilon .$$

Now VALLAURI takes the ratio $\frac{I_\upsilon}{v_\upsilon}$ as a measure for the amplification. It appears to us that more satisfactory results are obtained, if we do not assume $\frac{I_\upsilon}{v_\upsilon}$ as the amplification, but the dimensionless ratio of the potential variations on the resistance R to the variations of the grid potential. The amplification then becomes $G = \frac{aR}{1 + bR}$ and for large values of R: $G_{max} = \frac{a}{b}$.

If instead of a resistance a selfinduction L is placed in the anode circuit, we get, if the frequency of the grid variations is n:

$$G = \frac{\text{variation potential on selfinduction}}{\text{variation grid potential}} = \frac{2\pi\, n\, La}{\sqrt{1 + 4\pi^2 n^2 b^2 L^2}},$$

and for large values of L: $G_{max} = \frac{a}{b}$.

In the case of a capacity C connected in parallel to the selfinduction L we obtain:

[1]) Nuovo Cimento (13) 169, 1917.

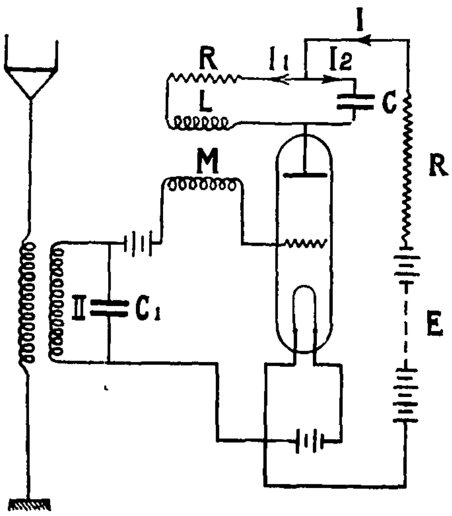
$$G = \frac{2\pi\, n\, La}{\sqrt{(1 - 4\pi^2 n^2 LC)^2 + 4\pi^2 n^2 b^2 L^2}}.$$

G now becomes a maximum for $4\pi^2 n^2 LC = 1$, i e. if the circuit (LC) is tuned to the grid potential frequency [1]).

We again find $G_{max} = \frac{a}{b}$.

The amplification as defined above, has the same maximum value $\frac{a}{b}$ in any case, so that it indicates a property of the audion. That our definition is an obvious one, is readily seen in the case one has to do with several audions connected in series. The tension on the resistance or self-induction in the anode circuit of the first audion is connected to the grid of the second and so on. The ratio of the variations in the grid potentials of the two audions is therefore equal to G, and so will be the ratio of the anode current variations. This latter ratio can easily be measured. Indeed we found the maximum ratio of the anode current variations to be equal to $\frac{a}{b}$.

2. In order to increase the amplifying action of the audion, FRANKLIN among others have advised the use of reaction circuits, in which the plate current reacts on the grid circuit, e.g. by magnetic coupling.



We will discuss now, the characteristic properties of the audion that are of importance in reaction circuits and more specially in the case of figure 1.[2])

We have assumed that in the secondary circuit a damped vibration is set up, and that the potential on the condensor C_1 is of the form

$$v = f(t) = w \sin 2\pi\, nt\, (1 - e^{-\rho t})\, e^{-\sigma t}$$

In this case we get the following system of equations

[1]) While in the two previously treated cases, large values of R and L must be used to obtain maximum amplification, here normal L and C will suffice.

[2]) See VALLAURI loc. cit. fig. 7.

$$I = av + bV + c \qquad I = I_1 + I_2$$

$$W - RI_1 - L\frac{dI_1}{dt} = 0 \qquad v = f(t) - M\frac{dI_1}{dt}$$

$$W - \frac{1}{C}\int I_2\, dt = 0 \qquad V = E - R' I - W.$$

Here W is the potential on the condensor C and M the coefficient of mutual induction of the reaction coil.

From these equations a differential equation for W may be derived

$$\alpha\frac{d^2 W}{dt^2} - \beta\frac{dW}{dt} + \gamma W = \delta + Raf(t) + Laf'(t).$$

where

$$\alpha = CL(1 + bR')$$
$$\beta = CR(1 + bR') + bL + aM.$$
$$\gamma = 1 + b(R + R')$$
$$\delta = R(c + bE).$$

The solution of this equation is of the form

$$W = \frac{\delta}{\gamma} + e^{-\frac{\beta}{2\alpha}t}\, P \sin\left(\frac{\sqrt{4\alpha\gamma - \beta^2}}{2\alpha} t + \varphi\right)$$
$$+ e^{-\sigma t}\, aw\, A \sin(2\pi nt + \chi)$$
$$- e^{-(\rho+\sigma)t}\, aw\, B \sin(2\pi nt + \psi).$$

If the circuit (LRC) is tuned to the incoming oscillations $\sqrt{4\alpha\gamma - \beta^2} = 4\pi n\alpha$. Putting the damping factor $\frac{\beta}{2\alpha} = D$ we find for the variable part of W an expression of the form:

$$W_v = aw\frac{4\pi^2 n^2 + D^2}{1 + b(R + R')}\left\{\begin{array}{ll} e^{-Dt} & F \sin(2\pi nt + \xi) \\ + e^{-\sigma t} & G \sin(2\pi nt + \eta) \\ - e^{-(\rho+\sigma)t} & H \sin(2\pi nt + \zeta) \end{array}\right\}$$

in which F, G and H are functions of σ, ϱ, L, R and D only.

The first four quantities are independent of the audion, the last one D however is a function of a and b, but by varying the coefficient of mutual induction M of the reaction coil any value of D may be obtained, so that independent of a and b the most effective damping can always be obtained.

So we come to the conclusion, that in a reaction circuit, when R and R' are not extraordinarily large, W_v is proportional to a and independent of the value $\frac{a}{b}$, which gave the maximum amplification in the previously treated cases.

Eindhoven. *Physical laboratory* of *Philips' incandescent lamp Works Ltd.*