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MATHEMATICAL SQUARING DEVICE OF THE ELECTRON TUBE TYPE

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Fig. 1.

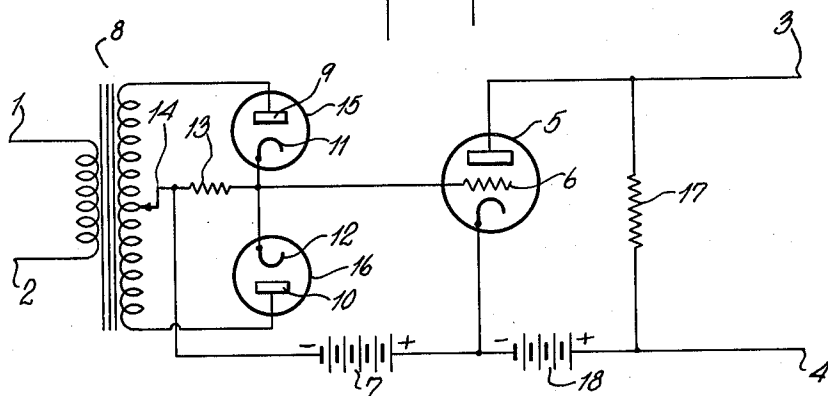
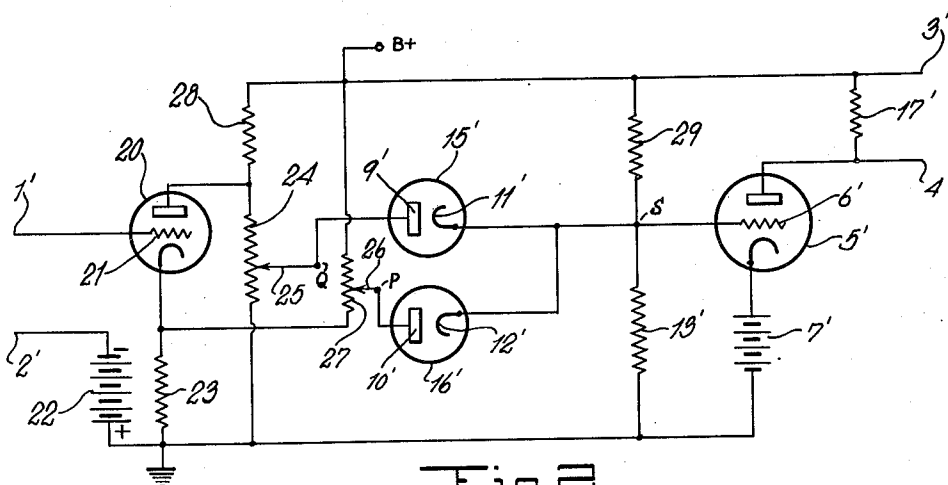


Fig. 2.

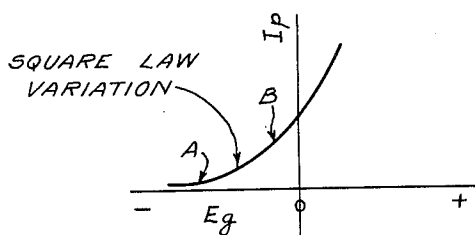


Fig. 3.

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MATHEMATICAL SQUARING DEVICE OF THE
ELECTRON TUBE TYPEMichael T. Bagley, Philadelphia, Pa., assignor to
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4 Claims. (Cl. 250—27)

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This invention relates to systems for deriving an algebraic square function of another function, and in particular to such devices as employ electron tubes for that purpose.

A principal object of the invention is to provide a novel and more stable squaring function device using electron tubes.

Heretofore in electronic devices for producing a squared output function from a given input control function, it has been customary to use a pair of grid-controlled tubes connected in balanced phase opposition to the input circuit, of which the well-known push-pull arrangement is typical. One of the disadvantages of such prior arrangements is that in order to derive the necessary squared output function, it is necessary to select the grid controlled push-pull tubes with substantially identical characteristics. This is particularly bothersome because the tubes must have substantially identical plate current-grid voltage characteristics in the curved portions thereof. Furthermore, even if a pair of perfectly matched tubes is initially selected, after continued use one tube may change slightly with respect to the other. This limitation is therefore peculiar to grid-controlled tubes. I have found that the necessary squared function can be achieved without using matched grid-controlled tubes. Accordingly, another principal object of the invention relates to a squaring system having the desirable advantages of push-pull grid-controlled tubes, but using a pair of diodes so connected to a single grid-controlled tube that substantially only the even harmonics of an input signal appear in the output of the grid-controlled tube.

Another principal object is to provide a novel phase inversion circuit employing a single grid-controlled tube and a pair of diodes.

A feature of the invention relates to a circuit arrangement wherein a single grid-controlled tube is operated on the non-linear portion of its control grid voltage vs. plate current characteristic, and a squaring action is obtained in the output by using a special double diode controlled input to suppress odd harmonics in the output.

Another feature relates to a novel network for producing a squared output function of an input control signal, including not only the A. C. components of the said signal but also D. C. components thereof.

A further feature relates to a novel phase inverter which operates satisfactorily on pure A. C. input signals or on signals having both A. C. and D. C. components.

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A still further feature relates to the novel organization, arrangement and relative interconnection of parts which cooperate to produce an improved algebraic squaring device.

Other features and advantages not specifically enumerated will become apparent after considering the following detailed descriptions and the appended claims.

While the invention finds its immediate utility in so-called automatic calibrators where an algebraic square function is to be derived from an input control function, it will be clear that the invention in its various phases is equally well applicable to other uses, particularly those where even harmonics of input signals are required, and where phase inversion of both A. C. and D. C. components is required. Therefore in the drawing two preferred embodiments are shown for explanatory purposes but not by way of limitation thereto.

Fig. 1 is a schematic wiring diagram of a square function derivative system for A. C. input signals.

Fig. 2 is a schematic wiring diagram of a square function derivative system useful with input signals having both A. C. and D. C. components.

Fig. 3 is a characteristic curve showing the range of operation of the grid-controlled tube used with the invention.

Referring to Fig. 1, the terminals 1, 2 are connectable to any source of control signals the fundamental voltage of which may represent, for example, a mathematical function whose square is to be derived at the output terminals 3, 4. In order to achieve this squaring function, it is requisite that the grid-controlled tube 5 be operated on the curved portion of its E_g-I_p characteristic, which should preferably be such that the relation between control grid voltage and plate current follows a square law as represented for example by the section AB of the characteristic curve of Fig. 3. It is also requisite that only the even harmonics, and predominantly the second harmonic, of the input signal wave appear in the output. In order to accomplish the first of these two requisites, tube 5 has its control grid 6 normally negatively biased, as for example by bias battery 7, to substantially plate current cut-off, e. g. at the point A (Fig. 3). In order to achieve the second of the above requisites, it is necessary to modulate or drive the grid bias 6 by means of a phase inverting circuit. For this purpose the input signal is applied through a phase inverting transformer 8 the secondary of which is connected in opposed balanced relation to the re-

spective anodes 9, 10 of two rectifier diodes 15, 16, the cathodes 11 and 12 of which are connected in common to load resistor 13 and thence to the electric mid-point 14 of the secondary winding of transformer 8. If desired, the connection of resistor 13 to the secondary winding may be adjustable. It will be understood that instead of using two separate diode tubes, the diodes may be in a single envelope constituting any well-known double diode tube. Likewise while the tube 5 is shown as a simple triode, it will be understood that any other equivalent grid-controlled tube having two or more grids such for example as a shield grid tube, a pentode tube, or the like, may be employed so long as the characteristic curve of the tube has the necessary square law function near the plate cut-off region as represented in Fig. 3.

It will be observed that the rectified voltages developed across load resistor 13 are injected into the grid circuit of tube 5 in series with the bias battery grid 7. However the voltage so developed is of opposite polarity to the battery 7, thus causing the grid 6 to be subjected to potential swings towards the positive direction as represented by the range A—B (Fig. 3).

Because of the full wave rectifying action of diodes 15, 16, the voltage developed across resistor 13 is a rectified version of the input control signal at terminals 1, 2, and is applied to control grid 6. The output of tube 5 is taken off by means of a suitable load resistor 17 at terminals 3, 4, it being understood that the positive D. C. operating plate potential for tube 5 is represented schematically by battery 18.

With the arrangement described, since the tube 5 is operating on a non-linear portion of its plate current vs. grid voltage characteristic curve, then the output at terminals 3, 4 will contain only even harmonics of the input at terminals 1, 2, and for positive swings of grid 6 the output will be predominantly proportioned to the algebraic square of the input signals.

Referring to Fig. 2 there is shown a modification which operates on the D. C. components of the input signal as well as on the A. C. components. In this embodiment the parts which correspond functionally to similar parts in Fig. 1 bear the same designation numerals primed. However instead of using a transformer coupled phase inverter, a grid-controlled electron tube 20 is provided, the input terminals 1' and 2' being connected in D. C. conductive relation across the control grid 21 and in series with the negative grid bias battery 22 and the cathode load resistor 23. The series arrangement of the plate-to-cathode space of tube 20 and resistor 23 is shunted by a plate load resistor 24 which is variably tapped by contact 25 to the anode 9' of rectifier diode 15'. The potential of point Q is therefore a function of the phase of the plate current of tube 20. Likewise the anode 10' of rectifier diode 16' is adjustably connected by tap 26 to resistor 27. The positive D. C. operating plate potential for tube 20 is applied through a resistor 28. With this arrangement and with suitable values for resistors 23 and 28 the change in potential of points P and Q can be made proportionate to the signal potential applied at terminals 1', 2'. Furthermore as the grid 21 swings in a positive direction the potential of point P swings positive and the potential of point Q swings negatively. On the other hand for negative swings on grid 21 point P swings negatively and point Q swings positively. Thus

phase inversion at the anode 9' and 10' is the same as that of Fig. 1.

By a suitable adjustment of taps 25 and 26 and with no A. C. signal components at terminals 1', 2', it is possible to make the D. C. components of potential at points P and Q equal. Thus changes in phase of both the A. C. and D. C. components of the input signals results in the proper phase inversion at points P and Q. The rectified output of diodes 15', 16' is taken off across resistor 13' which controls the potential of grid 6' in the same way as above described in connection with Fig. 1. Ordinarily the resistors 13' and 29 are chosen so that with no signal applied to terminals 1', 2', the potential of the common point S is the same as that of points P and Q, thus maintaining both diodes unbiassed. By means of negative bias battery 7' the grid 6' is normally (i. e. in the absence of signals at 1', 2') substantially at plate current cut-off. When signals are applied to 1', 2' the potentials at 3', 4' are substantially only the even harmonics of the input signal and have a squared function with respect to the said input signals.

In both of the foregoing embodiments the diodes 15, 16, and 15', 16', if not identical in electrical characteristics can be easily made sufficiently identical for the desired purpose by making the load resistor 13 or 13' high compared to the plate resistance of the diodes themselves, as it practically always is. It will be understood of course that the signal at the output terminals 3, 4, or 3', 4', consists predominantly of the second harmonic of the input signal. If a simple square function is desired the remaining even harmonics if any are present, can be suppressed by suitable suppression or filter networks. It will be understood of course that the invention is not limited to a simple square function, thus if a fourth power function is desired the terminals 3, 4, or 3', 4', may be connected to suitable filter networks of the band pass type for passing only the fourth harmonic. It will also be understood that this filter network may be adjustable so as to select any even harmonic function in the output signal.

Various changes and modifications may be made in the disclosed embodiments without departing from the spirit and scope of the invention.

What is claimed is:

1. In a device of the character described, input terminals, output terminals, and means to derive at said output terminals a squared function of the signals applied to the input terminals, the last mentioned means comprising a grid-controlled tube having its input electrodes connected to said input terminals, another grid-controlled tube having its output electrodes connected to said output circuit, and means to couple the output electrodes of the first tube to the input electrodes of the second tube for phase inversion and comprising a pair of rectifier diodes connected respectively to a point in the cathode load and plate load circuits of said first tube which points are substantially of opposite phase for a given input signal, said diodes having a common load impedance which is connected in the grid input circuit of said second tube.

2. In a device of the character described, input terminals, output terminals, a first grid-controlled electron tube having its input electrodes connected to said input terminals and including a cathode load resistor, a second grid-controlled

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electron tube having its output electrodes connected to said output terminals, a plate load resistor for said first tube, a pair of rectifier diodes, means for adjustably connecting the anode of one of said diodes to a point in said plate load resistor, means for adjustably connecting the anode of the other diode to a point in the said cathode load resistor, a common load resistor for said diodes connected to the cathodes thereof, and means connecting said common load resistor in the grid input circuit of said second tube.

3. A device according to claim 2 in which said second tube has a negative grid bias source connected in series with said common load resistor in the grid input circuit of said second tube, the voltages developed across said common load resistor being of opposite polarity with respect to said bias source.

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4. A device according to claim 2 in which the cathodes of the said diodes are maintained normally at the same potential as the anodes in the absence of signals applied to said input electrodes.

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