

March 13, 1934.

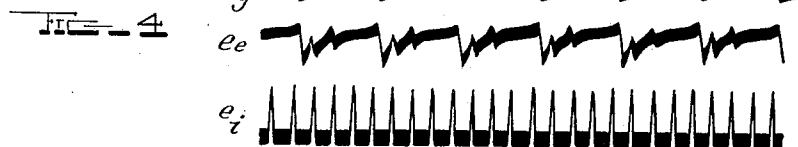
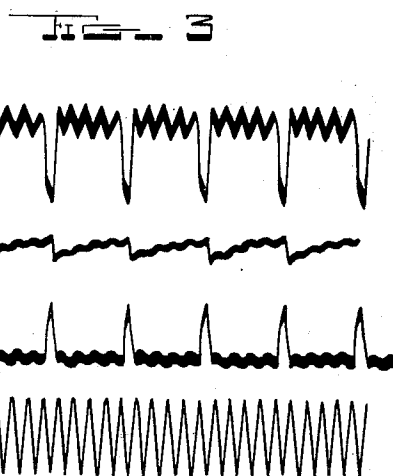
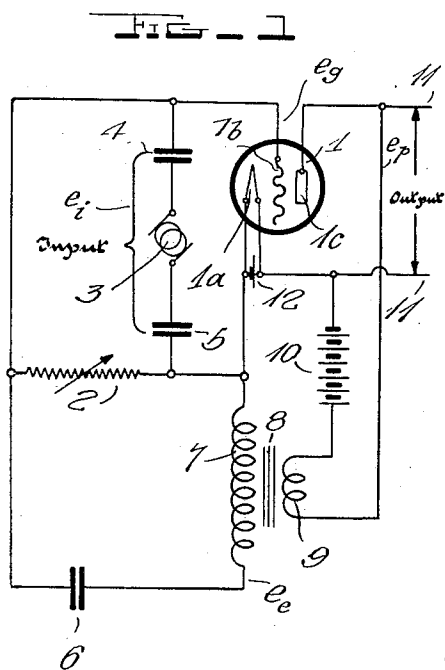
W. F. CURTIS

1,950,400

FREQUENCY DIVIDER

Filed March 13, 1931

3 Sheets-Sheet 1



INVENTOR.
Wesley F. Curtis.
BY Robert A. Lammie
ATTORNEY.

March 13, 1934.

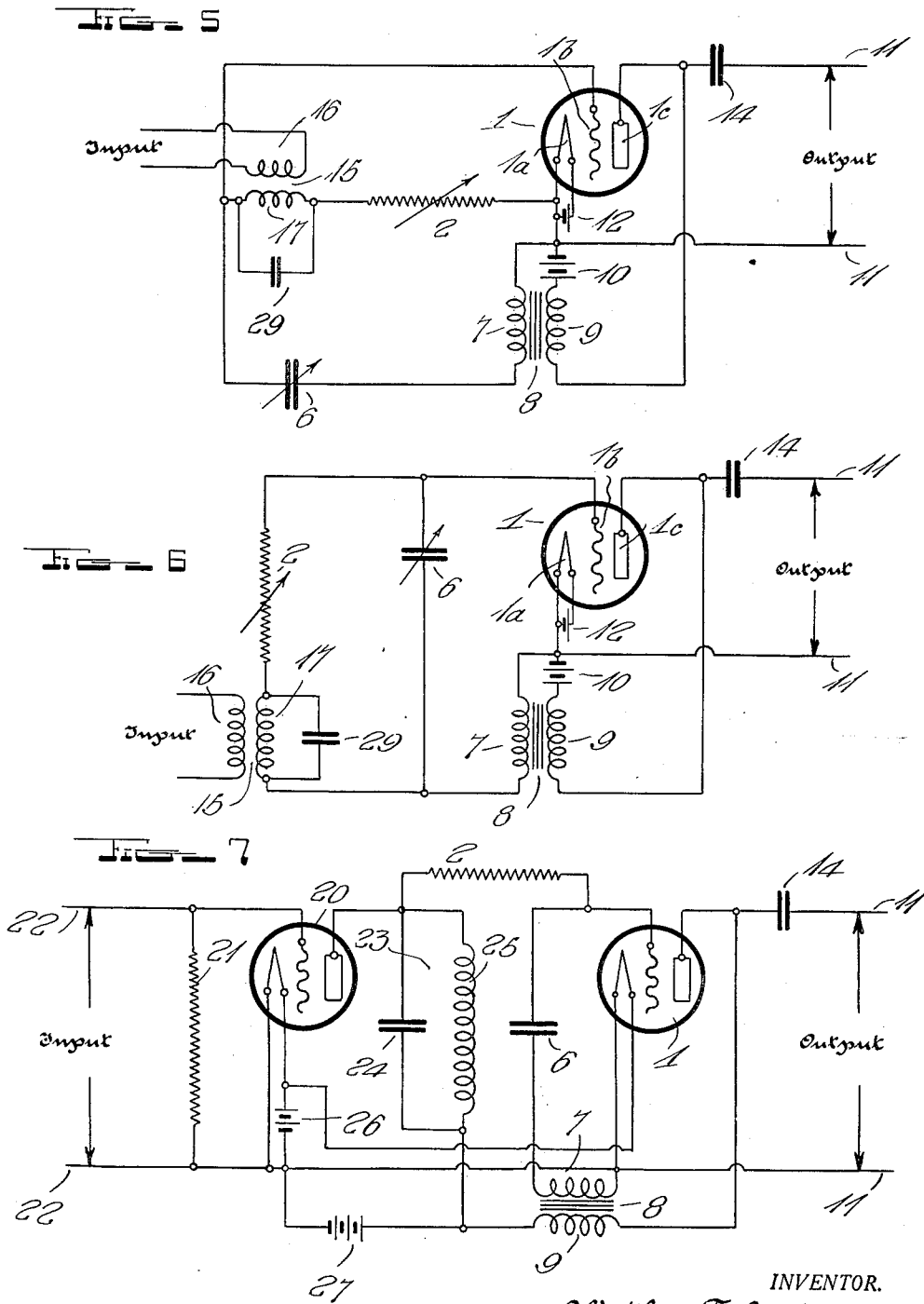
W. F. CURTIS

1,950,400

FREQUENCY DIVIDER

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3 Sheets-Sheet 2



March 13, 1934.

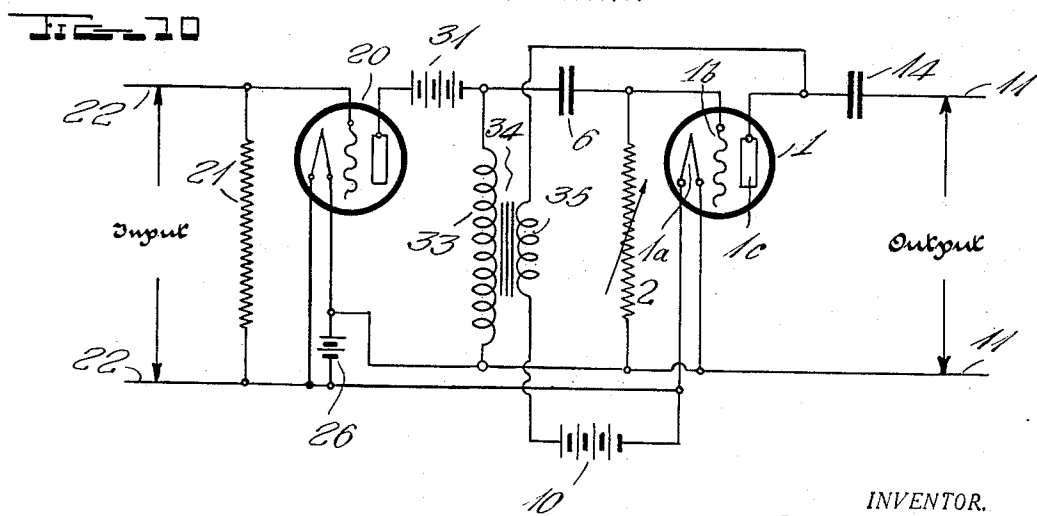
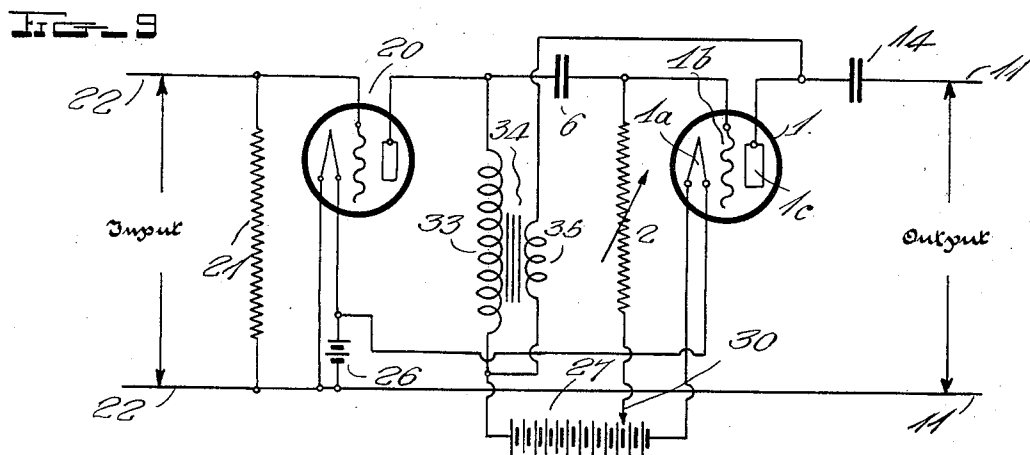
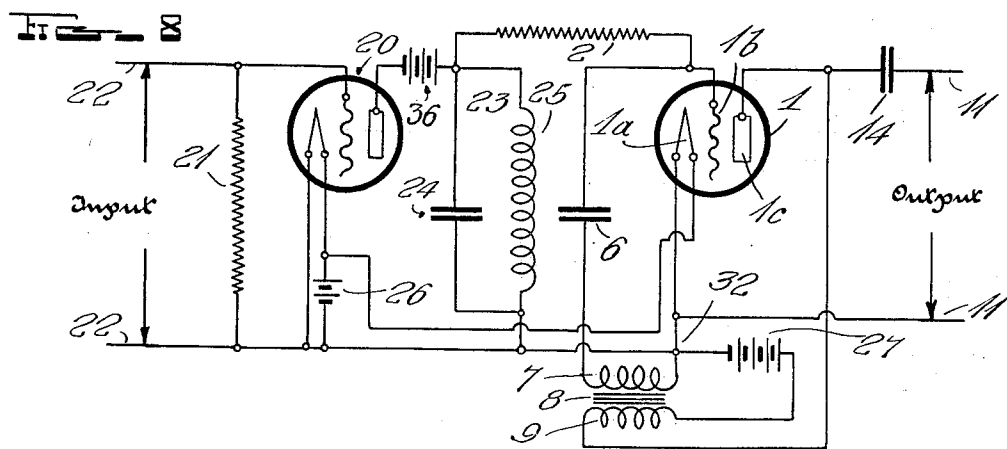
W. F. CURTIS

1,950,400

FREQUENCY DIVIDER

Filed March 13, 1931

3 Sheets-Sheet 3



INVENTOR.
Wesley F. Curtis,
BY Robert A. Lavender
ATTORNEY.

UNITED STATES PATENT OFFICE

1,950,400

FREQUENCY DIVIDER

Westley F. Curtis, Washington, D. C.

Application March 13, 1931, Serial No. 522,421

5 Claims. (Cl. 250—36)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

My invention relates broadly to oscillation systems and more particularly to a frequency division circuit.

One of the objects of my invention is to provide a circuit arrangement for a frequency division system in which applied frequencies may be divided in predetermined ratios for producing selected lower frequencies.

Another object of my invention is to provide a frequency division circuit having means for impressing a high frequency thereon and deriving a low frequency therefrom.

Still another object of my invention is to provide a circuit arrangement for a frequency division circuit in which low frequencies may be divided from impressed high frequencies and amplified to a required amplitude.

Other and further objects of my invention reside in the circuit arrangement for a frequency division system as set forth more fully in the specification hereinafter following by reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic circuit arrangement explaining the principles of operation of the frequency division circuit of my invention; Figs. 2, 3 and 4 are reproductions of oscillograms showing the characteristics of currents in the frequency division circuit of my invention under different conditions; Fig. 5 illustrates a modified circuit arrangement for the frequency divider of my invention; Fig. 6 illustrates a further modified form of frequency division circuit embodying the principles of my invention; Fig. 7 shows a circuit arrangement in which a radio frequency amplifier is associated with the input of a frequency division circuit according to my invention; Fig. 8 illustrates a modified arrangement of amplifier and frequency division circuit embodying the principles of my invention; Fig. 9 illustrates a further modified arrangement of input amplifier and frequency division circuit operating according to the principles of my invention; and Fig. 10 shows a further modified form of amplifier and frequency division circuit constructed according to my invention.

I have found the frequency division system of my invention highly stable in operation and not subject to change in the order of division under conditions of minute changes in potential supplied to the filament or plate circuits. The frequency divider of my invention is particularly useful in obtaining a synchronizing current in television systems which may be depended upon for absolute constancy.

The circuit arrangement of my invention may

be employed for dividing frequencies up to 1,000 kilocycles with a high degree of accuracy. With an input of 100,000 cycles, an output may be obtained equal to any submultiple of 100,000 cycles, such as 1,000 cycles to 50,000 cycles; that is 50,000, 33,333 $\frac{1}{3}$, 25,000, 20,000, 16,666 $\frac{2}{3}$, 14,280, cycles. The frequency division circuit of my invention is useful over a range from 1 cycle to 250,000 cycles and will divide frequencies in any ratio from 2:1 to 100:1 or more. I have obtained 500 to 1000 hours continuous operation with no adjustments at this frequency. The frequency of the oscillations is varied by changing the effective resistance in a portion of the oscillatory path. The oscillator does not function according to the law:

$$\omega^2 = \frac{1}{LC}$$

as would normally be expected, as the frequency depends upon the value of the resistance rendered effective in the circuit.

Referring to the drawings in more detail reference character 1 designates a triode including cathode 1a, a control grid 1b, and a plate electrode 1c. An output circuit connects across the control grid 1b and cathode 1a through the resistance path 2. The high frequency energy which is impressed upon the frequency divider circuit is indicated by the source 3 capacitatively coupled through condensers 4 and 5 to the input circuit of the frequency division system. A shunt path extends around the resistance 2 including the condenser 6 and the secondary winding 7 of the audio frequency transformer 8 whose primary winding 9 is included in series with the high potential source 10 in the output circuit of the frequency divider system. The output terminals for the frequency divider are represented at 11 from which the lower frequency being a submultiple of the higher frequency impressed upon the input circuit of the source 3 is derived from the circuit. The cathode 1a is heated from a suitable source 12. The resistance 2 is variable over a predetermined range according to the division frequency which is to be effected.

In Figs. 2, 3 and 4, I have shown reproductions of oscillograms taken of voltages at the points which I have indicated in the diagram of Fig. 1, e_p representing the plate voltage; e_g representing the grid voltage; e_s being the voltage across the secondary winding 7 of the transformer 8; and e_i being the high frequency input voltage at the source 3. The oscillograms shown in Fig. 3 show the oscillation of the cir-

cuit where the oscillograph records are taken at the points in the circuit at e_p , e_g , e_e , and e_i , the frequency division being effected in the ratio of 5 to 1. That is, with an impressed frequency at the source 3 of 500 cycles, a frequency of 100 cycles is obtained at the terminals 11.

In Fig. 4, I have shown the characteristics of the circuits with a frequency divided in the ratio of 4 to 1. In this instance the applied energy is obtained from another relaxation circuit oscillator where the input circuit is a train of aperiodic pulses indicated at e_i . The change in ratio of division is effected by change in the value of resistance 2. The oscillations in the circuit are established by the successively charging and discharging action of the condenser 6 through the resistance 2. The circuit of my invention permits any desired low frequency to be selected out of a band of higher frequencies.

The operation of the frequency division circuit as a relaxation oscillator is as follows: Consider the circuit when the cathode 1a of the tube 1 is glowing but the plate is not connected to the B battery 10. Then when the plate connection is made, plate current starts to flow, inducing a positive charge on the grid 1b through the action of the transformer 8. This causes progressive increase in plate current, which goes on until saturation is attained. As the plate current can no longer increase, no further charge is received by the grid 1b. The charge already there leaks off through the grid resistance 2, and the plate current decreases. The decrease in plate current induces a negative charge on the grid 1b, charging also the condenser 6 to the appropriate potential of the same polarity. The negative charge on the grid 1b blocks the plate current. The sudden stopping of plate current induces a very large negative charge on grid 1b and condenser 6, so that the tube 1 remains blocked until this charge has had time to leak off through the grid resistor 2, whereupon the cycle repeats itself. The frequency is fixed chiefly by the capacity of the condenser 6, the effective inductance of the grid coil 7, and the value of the grid resistance 2.

The action of the circuit as a frequency divider may now be more readily understood. There are two critical voltages in the operation of the circuit:—V1, the grid voltage at which plate current starts to flow, and V2, the grid voltage at which plate current can no longer increase fast enough to supply sufficient induced charge to balance leakage across the grid resistor 2. When the grid voltage reaches V1, plate current starts to flow and the condenser 6 charges positively. When grid voltage reaches V2, plate current falls and the condenser 6 charges negatively. Consider now the triode oscillating at some frequency f_1 . Impress upon the grid a higher frequency f . Some positive voltage peak of the high frequency wave will bring the grid voltage to V1, and start the charge. A definite number of cycles later, for example m cycles, a positive voltage peak will cause grid voltage to reach V2 and trip off the discharge. p cycles later, a voltage peak of the high frequency will again make grid voltage equal to V1, again starting the charge. p and m will be constant with respect to time if the circuit constants remain within certain limits. Letting p plus m equal n , the period of the relaxator will be n times the period of the high frequency, and the frequency will be f/n . Frequency division will be thus accomplished.

In Fig. 5, I have shown a modified division cir-

cuit wherein the impressed frequency is supplied through transformer 15 having primary winding 16 and secondary winding 17, the secondary winding 17 being connected in series with the adjustable resistor 2 and across the grid electrode 1b and the cathode 1a. The output circuit of the frequency divider is shown coupled through the audio frequency transformer 8 to the input circuit in a manner similar to the arrangement described in Fig. 1, the output for the frequency divider system being taken off at terminals 11 through coupling condenser 14. The condenser 6 is shown variable for controlling the order of frequency division.

In the modified form of circuit illustrated in Fig. 6, the variable resistor 2 is connected in series with the secondary winding 17 of the input transformer 15 and the input energy impressed thereon through the primary winding 16. The secondary winding 17 is shunted by by-pass condenser 29. The combined series circuit including resistance 2 and secondary winding 17 is shunted by the adjustable condenser 6 which determines the frequency at which the frequency divider operates. In this arrangement the adjustable condenser 6 is directly in shunt with the path extending between the grid electrode 1b and the cathode 1a through the secondary winding 7 of the transformer 8.

The manner of selectively applying energy of proper amplitude to the frequency division circuit is shown in Fig. 7 wherein the amplifier 20 has its output circuit arranged to impress oscillator energy of desired frequency upon the frequency divider circuit of tube 1. The input from the oscillator to the amplifier tube 20 is connected at terminals 22. The required bias potential is impressed upon the grid of amplifier tube 20 through biasing resistance 21. The cathode of tube 20 and the cathode of the frequency divider tube 1 are heated from suitable potential source 26. The output circuit of tube 20 includes a resonant circuit 23 tuned to the frequency which is impressed upon the input of the frequency divider tube 1. The resonant circuit 23 includes the inductance 25 shunted by condenser 24. The circuit is disposed in series with the resistance 2 and the primary winding 9 of transformer 8. High potential is supplied to the plate circuit of amplifier tube 20 and the plate circuit of frequency division tube 1 from the high potential source 27. The input circuit of the frequency divider tube 1 includes the secondary winding 7 of the audio frequency transformer 8 and the condenser 6 which is periodically charged and discharged for effecting frequency division of the energy impressed upon the frequency divider circuit 1 through the resistor 2. The terminals 11 connect with the output circuit of the frequency divider in a manner similar to the arrangement described in Figs. 1, 5 and 6.

Fig. 8 shows a modified form of the circuit illustrated in Fig. 7 in which the path through the resistance 2 and the inductance 25 returns to the input circuit of the frequency divider at the point 32 so that the input circuit directly includes the paths through resistance 2 and inductance 25 and through condenser 6 and secondary winding 7, the period of frequency division being controlled by resistance 2 and condenser 6. The plate supply for amplifier tube 20 is obtained from battery 27.

Fig. 9 illustrates a further modified form of frequency division circuit wherein the transformer which couples the input and output circuits of frequency division tube 1 also provides

coupling means between the output of the amplifier 20 and the input of the frequency division circuit. The source of potential for the plate circuits of the tubes 1 and 20 is illustrated at 27. The plate energy for tube 20 is supplied through the winding 33 of transformer 34. The plate energy for the frequency division tube 1 is supplied through winding 35 of transformer 34 as shown. The resistance 2 connects to a point 30 along potential source 27 placing a bias potential upon the grid electrode 1b and providing a path across the input circuit of the frequency divider tube 1 for controlling the effect of the charging and discharging of condenser 6 for effecting the frequency division operation of the circuit.

Fig. 10 shows a further modified form of frequency division circuit and amplifier system for impressing energy at desired frequency and amplitude upon the frequency division system. In this arrangement the transformer 34 is connected between the output circuit of amplifier 20 and the input circuit of the frequency division tube 1. The output circuit of amplifier 20 is completed through the high potential source 31 and the winding 33 of transformer 34. The output circuit of frequency divider tube 1 is completed through high potential source 10 and winding 35 of the transformer 34 as shown. The winding 33 is included in the input circuit of the frequency division tube 1 through condenser 6. The resistance 2 is connected in shunt with the input including condenser 6 and winding 33. The output of the frequency division circuit connects to the terminals 11 in the manner heretofore described.

I have found the triode frequency divider circuit of my invention highly practical and successful in its operation and while I have described my invention in certain preferred embodiments, I desire that it be understood that modifications may be made and that no limitations upon my invention are intended other than are imposed by the scope of the appended claims.

The invention herein described may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. A frequency divider circuit comprising an electron tube having a cathode, grid and plate electrodes, an input circuit including a series connected resistance device variable over a predetermined range, terminals for impressing alternating current upon said input circuit, an audio frequency transformer including a pair of coupled windings, one of said windings being connected in a series path through a condenser, said path being disposed in shunt with said vari-

able resistance device, the other of said windings being disposed in series with a high potential source and connected with the plate and cathode of said tube and connections leading from said plate and cathode for deriving a frequency from said circuit which is a sub-multiple of the frequency applied across said cathode and grid electrodes.

2. A frequency division circuit comprising an electron tube having a cathode and grid and plate electrodes, an input circuit connected across said grid and cathode, an output circuit connected across said plate and cathode, an electromagnetic coupling means constituted by a pair of inductively related windings disposed between said circuits and a pair of separate paths connected with said grid and cathode, one of said paths including a variable resistance device and another of said paths including a capacity and a portion of one of the windings constituting part of said electromagnetic coupling means, and means for applying a predetermined frequency to said input circuit and deriving a submultiple frequency from said output circuit.

3. A frequency division system comprising an electron tube having input and output circuits, means electromagnetically coupling said circuits, a variable resistance disposed in said input circuit, and a branch of said input circuit including a condenser and a portion of said electromagnetic coupling means disposed in shunt with said resistance for controlling the energy supplied to said input circuit for deriving a submultiple frequency from said output frequency.

4. A frequency division system comprising an electron tube having input and output circuits, said input circuit including two independent paths, one of said paths including a variable resistance and another of said paths including an inductance and condenser, parallel connections extending between said paths, a high potential source, an independent inductance, a series circuit extending from said plate and cathode through said high potential source and through said independent inductance in series, said inductances being electromagnetically coupled for establishing oscillations controllable by the adjustment of said resistance in said input circuit for effecting a division in frequency of an applied frequency at said input circuit.

5. In combination, an electron tube having input and output circuits, a grid leak and a condenser connected in said input circuit, means responsive to changes in current flow in said output circuit for charging and discharging said condenser, means for impressing oscillations of a given frequency upon said input circuit and means for rendering the charge and discharge rate of said condenser a sub-harmonic of said given frequency.

WESTLEY F. CURTIS.