Jan. 7, 1947. J. C. COYKENDALL 2,413,956

FREQUENCY DIVIDER

Filed Oct. 9, 1942

Fig. 1.

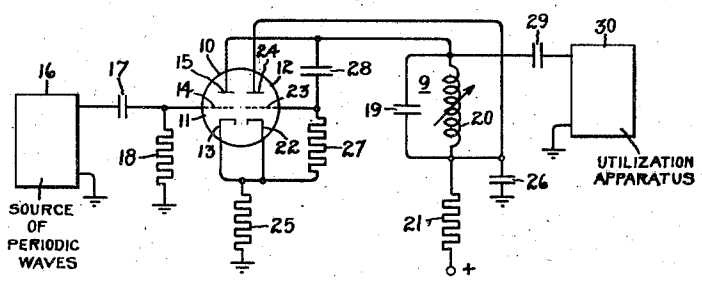


Fig. 2.

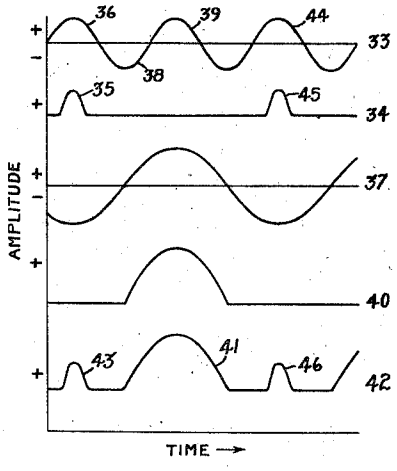
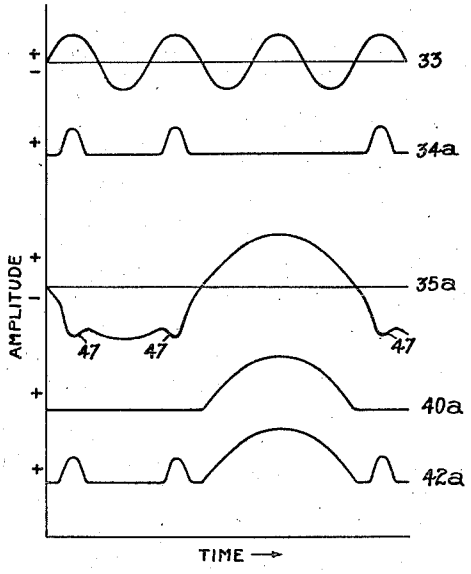


Fig. 3.



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FREQUENCY DIVIDER

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4 Claims. (Cl. 250—36)

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My invention relates to frequency dividing apparatus and particularly to frequency dividing circuits arranged to produce an output wave of sine wave form.

It is an object of my invention to provide a frequency dividing circuit including an improved arrangement for producing a sine wave at the output of the apparatus.

Another object of my invention is to provide an apparatus for producing a sine wave of reduced frequency when either a sine wave or a wave of positive pulses is impressed upon the apparatus.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood with reference to the following description taken in connection with the accompanying drawing in which Fig. 1 diagrammatically represents one form of a frequency dividing circuit embodying my invention, and Figs. 2 and 3 represent curves illustrating the operating characteristics of the circuit of Fig. 1.

Briefly, the illustrated embodiment of my invention comprises a frequency dividing circuit comprising two electron discharge devices each having a cathode and an anode and a control electrode. A common resistor is connected in the cathode circuits of the two devices and the circuit is coupled to apparatus for impressing a signal or voltage wave of predetermined frequency on the control electrode of the first electron discharge device. The other electron discharge device is normally conducting and the resulting drop in the common cathode resistor produces a negative bias for rendering the first device normally nonconducting. An oscillatory circuit tuned to a subharmonic of the impressed frequency is connected in the anode circuit of the first device and is coupled to the control electrode of the second device in such a manner as to prevent or limit excitation or energization of the tuned circuit by operation of the first electron discharge device during alternate half cycles of the alternating current potential across the tuned circuit. The output circuit is coupled to the tuned circuit and the resulting operation of the apparatus is such that an output potential of sine wave form is produced at a frequency approximately determined by the tuned circuit but synchronized with the impressed signal.

Referring now to the drawing, the frequency

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divider shown in Fig. 1 includes a twin triode amplifier tube 10 comprising a first electron discharge device 11 and a second electron discharge device 12 mounted within a common envelope. Obviously, two separate triodes might be employed equally well. The electron discharge device 11 comprises a cathode 13, a grid or control electrode 14 and an anode or plate 15. Waves of a predetermined frequency are supplied from a source 16 which is coupled through a condenser 17 and a resistor 18 to the control grid 14 of the device 11. A parallel tuned circuit, or tank 9 comprising a condenser 19 and a variable inductance element 20 connected in parallel therewith is connected in the anode circuit of the device 11 between the anode 15 and a resistance 21 which in turn is connected to the positive side of a suitable source of positive plate potential. The inductance 20 may be made variable by any suitable arrangement; for example, the coil may be provided with an iron plug or core so mounted that its position within the coil may be changed so as to change the effective permeability of the core and vary the inductance. Obviously, the inductance 20 could be fixed, and the capacitor 19 variable, if it were desired to secure tuning in this manner. The electron discharge device 12 includes a cathode 22, a grid or control electrode 23 and an anode or plate 24. The cathodes 13 and 22 are connected through a common resistance 25 to ground, and the plate 24 is connected through the resistance 21 to the positive side of the plate voltage source, a suitable decoupling condenser 26 being provided between the plate 24 and ground. The grid 23 of tube 12 is connected to the cathode 22 through a resistance 27 and the tube 12 is, therefore, normally conducting so that anode current flows through the resistance 25 and produces sufficient voltage drop in the resistor 25 to bias the tube 11 beyond cutoff and render the divider inoperative when no positive potential is impressed upon the input grid 14. The tuned circuit comprising the condenser 19 and the inductance 20 is coupled to the grid 23 through a suitable condenser 28 for a purpose which will be described below. The output of the divider is taken off the tuned circuit between the circuit and the plate 15 and is coupled through a condenser 29 to a suitable utilization apparatus indicated at 30.

When excitation such as a sine wave of predetermined frequency is supplied to the grid 14 from the source 16, a positive impulse on the grid 14 causes the device 11 to draw plate current and thereby excite the tuned circuit 9 which, as stated

above, is tuned to a subharmonic of the frequency supplied from the source 16; for example, the oscillatory circuit 9 may be tuned to one-half the frequency of the source 16. The voltage produced across the circuit 9 when a positive impulse is impressed on the grid 14 is negative and the grid 23 of the device 12 is thereby driven negative which causes a reduction or even cutoff of the plate current flowing through the device 12. However, the reduction of plate current and the corresponding reduction in drop across the resistor 25 do not affect the operation of the device 11, since the change in bias is in a positive direction and does not interfere with the operation of the device 11 produced by the impressing of a positive impulse thereon. When the impressed voltage swings to negative in the second half of the driving cycle the plate current of the device 11 drops to zero. The voltage across the tuned circuit 9 passes from negative to positive during this negative half of the driving cycle since the frequency of the circuit is only one-half that of the impressed frequency. When the second positive impulse is applied to the grid 14, i. e., when the frequency of the source has changed through 360°, the frequency of the tuned circuit changes through only 180°, and the grid 23 is at a relatively high positive potential; the device 12 then passes a heavy plate current such that the drop across resistance 25 provides sufficient bias to prevent the impressed positive pulse from raising the potential of the grid 14 sufficiently to make the device 11 conducting. As a result, the device 11 remains nonconducting and no bucking energy is transferred to the tuned circuit. When the next positive impulse is impressed on the grid 14 the tuned circuit will have passed through 360° and the potential across the circuit will be negative; the plate current through the device 12 will have been reduced and the bias of the grid 14 correspondingly reduced so that the device 11 will be rendered conducting and the tuned circuit 9 will be energized. The device 12 will thus be seen to operate to suppress alternate positive impulses of the impressed wave. The voltage produced by this operation as seen at the output is a sine wave having a frequency one-half that of the frequency of the source 16.

The manner in which the above described circuit operates is indicated by the characteristic curves shown in Fig. 2 which illustrate the steady state conditions of operation. The top curve in Fig. 2 indicated at 33 is a sine wave indicating the potential impressed upon the grid 14 from the source 16. The curve 34 shows the plate current of the device 11, a pulse 35 of plate current corresponding to the first positive pulse indicated at 36 on the curve 33. When current flows in the device 11 as indicated by the pulse 35, a negative potential appears across the tuned circuit 9 due to the potential drop in the plate circuit. Energy is therefore transferred to the tuned circuit 9 which is tuned to one-half the frequency of the source 16 as indicated by the curve 37. The negative portion 38 of the curve 33 has no effect upon the divider, and when the second positive impulse as indicated at 39 appears on the grid 14 the potential across the tuned circuit 9 is also positive as indicated by the curve 37. The grid 23 has, therefore, been driven positive and a high plate current flows in the tube 12 as indicated by the curve 40. A large voltage drop, therefore, appears across the resistance 25 as indicated by a pulse 41 shown on the curve 42 at the bottom of Fig. 2. The drop across resistor 25 is also increased when additional plate current flows in the device 11 and pulses 43 appear which correspond to the pulses in the plate current curve 34 of the device 11. When a third positive impulse as indicated at 44 on curve 33 is impressed upon the grid 14, plate current again flows in the device 11 as indicated by the pulse 45 which is the same as the pulse 35, and energy is again transferred to the tuned circuit 9 which continues to oscillate to produce the sine wave of curve 37. While plate current is flowing as indicated by the pulse 45 the drop across the resistor 25 also increases as indicated by the pulse 46 which is the same as the pulse 43. The divider thus operates to provide a sine wave of voltage as shown by the curve 37 having one-half the frequency of the voltage supplied by the source 16.

It will be obvious to those skilled in the art that the source 16 need not necessarily supply a sine wave, but that the frequency divider operates equally well if a wave of positive pulses such as a square wave be supplied to the grid 14. The form of the output voltage, however, remains a sine wave.

It has been found that the frequency divider described above operates to provide frequencies as low as $\frac{1}{5}$ that of the driving frequency. However, the stability and wave form of the device are best at one-half the driving frequency. In Fig. 3 are illustrated characteristic curves for the frequency divider when the tuned circuit in tuned to one-third the frequency impressed upon the input of the divider. The curve 33 is repeated in Fig. 3 to show the wave form of the voltage supplied by the source 16. The plate current of the device 11 is shown by a curve 34*a* and the potential across the tuned circuit by a curve 35*a*. Curves 40*a* and 42*a* correspond to the curves 40 and 42 and show the plate current flowing through the tube 12 and the voltage across resistance 25, respectively. When the circuit 9 is tuned to one-third the frequency of the impressed voltage, the device passes two driving impulses out of three and suppresses the third, and small humps 47 appear in the output corresponding to the positive plate current pulses appearing in curve 34*a*.

The tuned circuit 9 is preferably a circuit having a relatively low capacity and high inductance which provides a high circuit impedance.

It will be evident that I have provided a simple and effective frequency dividing circuit which provides a sine wave output. By way of illustration only and not by way of limitation there are listed below values of circuit constants which have been found to be suitable for the circuit of Fig. 1 when employed in a particular apparatus for dividing by two a frequency of 15 kilocycles per second. The tube 10 was a 6SN7-GT twin triode amplifier, the tank circuit 9 was tuned to a frequency of 7.5 kilocycles per second, and the positive plate supply was approximately 150 volts:

Capacitor 17	mmfd	5600
Capacitor 28	mmfd	5600
Capacitor 19	mmfd	3500
Capacitor 26	mfd	0.25
Capacitor 29	mmfd	5600
Inductance 20, plug tuned coil	mh	90–165
Resistance 18	ohms	470000
Resistance 25	do	4700
Resistance 27	megohms	1
Resistance 21	ohms	1000

While I have shown a particular embodiment

of my invention it will, of course, be understood that I do not wish to be limited thereto since various modifications may be made and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

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

1. A frequency divider comprising a first electron discharge device and a second electron discharge device, means connecting said devices for rendering said first device nonconducting while current is flowing through said second device, means rendering said second device normally conducting, means for impressing a periodic voltage wave of a predetermined frequency on said first device to render said first device conducting during positive half cycles of said wave, a circuit tuned to a subharmonic of said frequency and connected to be excited by said first device when said first device is rendered conducting, and means coupling said tuned circuit and said second device for maintaining said second device conducting to maintain said first device nonconducting during positive half cycles of the wave across said tuned circuit and to prevent excitation of said tuned circuit by said first device during alternate half cycles of the alternating voltage wave across said tuned circuit.

2. A frequency divider comprising a source of waves of predetermined frequency, a circuit tuned to a subharmonic of said frequency, means including an electron discharge device having a cathode and an anode and a control electrode for exciting said tuned circuit to cause said circuit to oscillate at said subharmonic frequency, a second electron discharge device having an anode and a cathode and a control electrode, means rendering said second device normally conducting, means connecting said devices for biasing said first device to be non-conducting during the passage of current through said second device, means coupling said tuned circuit to the control electrode of said second device for rendering said second device non-conducting during negative half cycles of the voltage wave across said tuned circuit and for maintaining said second device conducting during positive half cycles of the voltage wave whereby the excitation of said tuned circuit by said exciting means is prevented during alternate half cycles of the alternating voltage wave across said tuned circuit, and an output circuit coupled to said tuned circuit.

3. A frequency divider comprising two electron discharge devices, each of said devices having a cathode and an anode and a control electrode, a common resistor connecting the cathodes of both of said devices to the negative side of a source of voltage, means for connecting the anodes of said devices to the positive side of the source of voltage, means for impressing a wave of predetermined frequency on the control electrode of one of said devices, the other of said devices being connected to be normally conducting and providing a bias potential across said common resistor rendering said one of said devices normally nonconducting, a circuit tuned to a subharmonic of said frequency and connected in said connecting means between the anode of said one of said devices and the source of voltage, means coupling said tuned circuit and the control electrode of said other of said devices for preventing excitation of said tuned circuit by said one of said devices during alternate half cycles of the alternating voltage wave across said tuned circuit, and an output circuit coupled to said tuned circuit.

4. A frequency divider comprising a first electron discharge device having a cathode and an anode and a control electrode, means for connecting said anode to the positive side of a source of voltage, means for impressing a wave of predetermined frequency on said control electrode, a circuit tuned to a subharmonic of said frequency and connected in said connecting means between the anode of said device and the source of voltage, a second electron discharge device having a cathode and an anode and a control electrode, means for connecting the anode of said second device to the positive side of the source of voltage, a common resistor connected between the cathodes of both of said devices and the negative side of the source of voltage, means rendering said second device normally conducting whereby the voltage drop in said resistor produces a bias on the control electrode of said first device to render said first device nonconducting, means coupling said tuned circuit and the control electrode of said second device for providing an increased flow of current through said second device when a positive potential exists across said tuned circuit to bias the control electrode of said first device beyond cut-off and prevent excitation of said tuned circuit by said first device during the positive half cycles of the alternating voltage wave across said tuned circuit, and an output circuit coupled to said tuned circuit.

JOHN C. COYKENDALL.