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FREQUENCY DIVIDER

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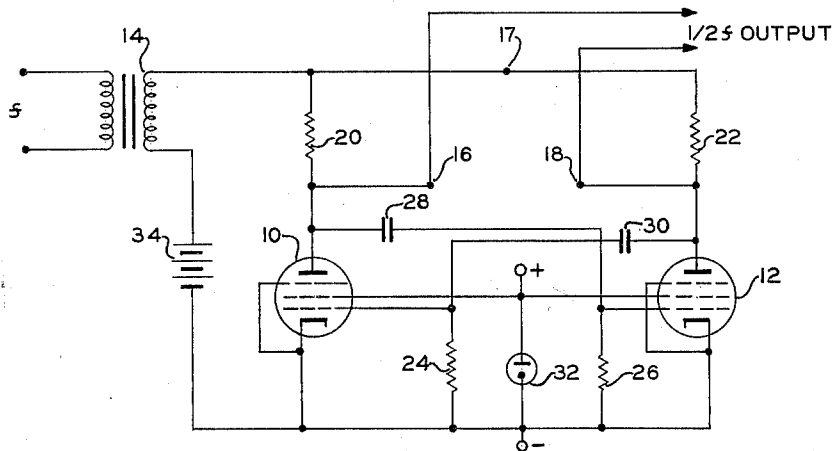


FIG. 1

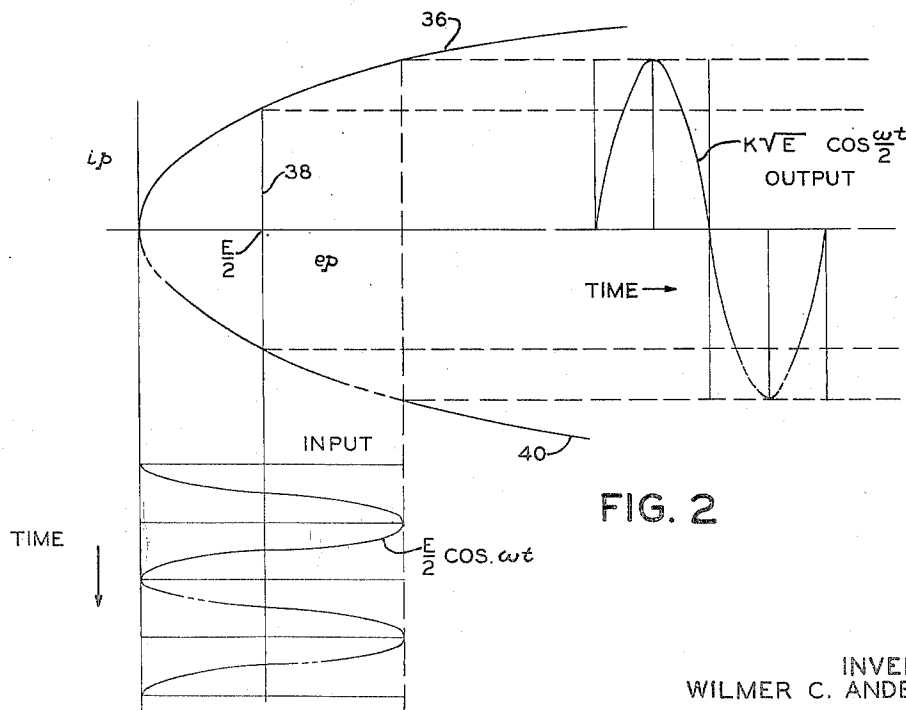


FIG. 2

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FREQUENCY DIVIDER

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This invention relates to frequency dividers. Its object is to produce a frequency divider having a sine-wave output of half the frequency of the input sine wave.

In the past, frequency dividers have been built around multivibrators, which have characteristically yielded undesirable output waves. R-C oscillators used in frequency dividers have limited frequency range. According to this invention, vacuum tubes are selected (notably pentodes) wherein the plate current-plate voltage characteristic has the relation $i^2 = ke$. This characteristic is utilized to convert an incoming sine wave to a wave resembling the rectified signal of the same peak frequency, but the arrangement is such that alternate peaks are in effect reversed so as to yield a sine wave of half its original frequency.

For a better understanding of the invention, reference is made to the following detailed description and to the drawings, wherein:

Fig. 1 is a wiring diagram of a preferred embodiment; and

Fig. 2 is a graphical representation of the operation of the device.

Shown in Fig. 1 are pentodes 10 and 12 which form the basic elements of this improved frequency divider. 14 is an input transformer, and 16 and 18 are the output terminals. The arrangement is such that the frequency which appears at output terminals 16 and 18 is half that of the input. Load resistors 20 and 22 are provided in the plate circuit of the tubes. Resistors 24 and 26 provide grid bias. Capacitors 28 and 30 cross-couple each grid to the plate of the opposite tube. The screens of tubes 10 and 12 are provided with a suitable value of positive potential which is kept constant by means of a voltage regulator 32. A convenient voltage source 34 supplies plate current through the input transformer 14 and the load resistors 20 and 22.

Referring now to Fig. 2, 36 is the plate characteristic of the type of tube desired. Ideally, it obeys the equation $i_p = k\sqrt{e_p}$. A voltage point 38 on the curve is equal to

$$\frac{E}{2}$$

A signal is impressed on a constant voltage source 34 equal to

$$\frac{E}{2} \cos \omega t$$

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Then

$$e_p = \frac{E}{2} + \frac{E}{2} \cos \omega t$$

and

$$i_p = k\sqrt{E} \sqrt{\frac{1 + \cos \omega t}{2}}$$

$$= k\sqrt{E} \cos \frac{\omega t}{2}$$

If the voltage equal to

$$\frac{E}{2} + \frac{E}{2} \cos \omega t$$

were impressed upon a single pentode having a plate load, then the output would be similar to a rectified sine wave, and there would be one peak for each 360° of the sine wave. Were this passed through a filter resonant at the frequency of the peaks, then there would be only a sine wave output equal to the frequency of the input wave. If, however, alternate peaks could be inverted, then the need for a filter would be obviated and a sine wave of half the input frequency would result. This is accomplished by the circuit of Fig. 1, the operation of which will now be described.

It may be assumed that tubes 10 and 12 are somewhat dissimilar. When the input signal and the constant potential are impressed on both plates, the current in one will build up at a rate somewhat greater than the other. The tube having the higher current will have a lower voltage at its plate than the other. This voltage drop, applied through capacitor 28 or 30, causes the grid of the opposite tube to have a negative potential. The negative grid potential causes a decrease in plate current in its tube, causing a rise in the plate voltage of this tube, with a corresponding rise in the grid voltage of the first tube and hence a rise in plate current of the first tube. The net effect of all this build-up of plate current in one tube and decay in the other is to drive one tube to cut-off while the other draws current according to Fig. 2. This results in 180° of an output sine wave, and requires 360° of the input sine wave.

When the plate current of the conducting tube approaches and reaches zero, the conditions are such as to allow the other tube to commence conducting, which in turn cuts off the first operative tube. For the next 360° of input signal, the plate current of the second tube follows the same curve as the first.

Through the use of two tubes, it is possible to reverse alternating-voltage peaks at output terminals 16 and 18. If it be assumed that tube 12 is cut off, then terminal 18 is at the potential of point 17 and terminal 16 varies with respect thereto according to the current variation in resistor 20. Likewise, when tube 10 is cut off, terminal 16 varies with respect to point 17 according to the plate current of tube 12. Since terminals 16 and 18 are at opposite ends of the series-connected resistors 20 and 22, alternating pulses of current through tubes 10 and 12 produce opposite voltage peaks. This is illustrated in Fig. 2, wherein the dot-dash traces, as for example curve 40, pertain to one of the tubes while the full line curves pertain to the other tube. The output is ideally a sine wave. It departs from this to the extent that curves 36 and 40 depart from the equation $i_p = ke_p$ for the tubes selected.

Typical values used in the circuit of Fig. 1 were as follows: resistors 20 and 22 were 50,000 ohms; resistors 24 and 26 were 1.0 megohm; capacitors 23 and 30 were .01 microfarad; tubes 10 and 12 were type 6SK7; and the constant voltage supply was a 45-volt battery.

The circuit described is purely illustrative in so far as the control grids are concerned. Depending on various factors, other circuits for cutting tubes 10 and 12 off alternately may be adopted. Trigger circuits may be added to insure the action described. These are all known variants and are equivalent to the arrangement described.

An important feature of the above circuit is that it depends only on the current and voltage relations of the tubes and not tuned LC or RC circuits. The input frequency, therefore, may be any value within a very wide range. This is in contrast with the known multivibrator and RC-oscillator frequency dividers. It is notable that the circuit will reproduce a distorted sine wave or a modulated carrier at half its frequency, to a rough approximation.

Having thus described my invention, what I claim is:

1. A frequency divider comprising, first and second electron tubes each having at least an anode and a control grid, and each having an anode voltage-anode current characteristic which approximates a square law function, the control grid of each of said first and second tubes being capacitively coupled to the anode of the other tube, first and second equal load resistors being respectively connected to the anodes of said first and second tubes and joined at a common point, an input circuit, a direct voltage source connected in series with said input circuit being connected to said common point, means for applying an input alternating signal having a peak amplitude substantially equal to the magnitude of said direct voltage to said input circuit, and output terminals connected to the anodes of said first and second tubes, the voltage appearing at said output terminals being an alternating signal of half the frequency of said input signal and having an amplitude proportional to the square root of the magnitude of said direct voltage.

2. A frequency divider comprising, first and second electron tubes each having at least an anode and a control grid, and each having an anode voltage-anode current characteristic which approximates a square law function, first and second substantially equal load resistors being respectively connected to the anodes of said first and second tubes and joined at a common point, an input circuit, a direct voltage source connected

in series with said input circuit and connected to said common point, means for applying an alternating voltage having a peak amplitude substantially equal to the magnitude of said direct voltage to said input circuit, cross-coupling means between the anode of each tube and the control grid of the other for rendering said tubes alternately conducting in synchronism with said alternating voltage, whereby an alternating output signal of one-half the frequency of the input signal and of an amplitude proportional to the square root of the magnitude of said direct voltage appears at said anodes.

3. A frequency divider comprising, first and second electron tubes each having an anode, a cathode, and a control grid, and each having an anode voltage-anode current characteristic which approximates a square law function, means providing substantially equal bias voltage to the control grids of said first and second tubes, first and second equal load resistances serially connected between the anodes of said first and second tubes, a direct voltage source having a positive terminal connected to the junction of said first and second resistors, means for applying a sine wave signal having a peak amplitude substantially equal to the magnitude of said direct voltage to the junction of said first and second resistors, cross-coupling means connected between the anode of each tube and the control grid of the other for rendering said tubes alternately conducting in synchronism with said sine wave signal, whereby a sine wave signal of one-half the frequency of said applied sine wave signal and of an amplitude proportional to the square root of the magnitude of said direct voltage appears at said anodes.

4. Apparatus for dividing by two the frequency of an input sine wave signal and producing a sine wave output signal comprising, a pair of pentode electron tubes each having at least an anode, a cathode, a control grid and a screen grid, a first potential source connected to said screen grids for maintaining them at a constant potential, capacitive coupling means cross-connecting the control grid of each of said tubes with the anode of the other tube, a source of direct potential of a magnitude substantially equal to the peak amplitude of said input sine wave signal, means for applying said input sine wave signal to the anodes of said tubes in series with said source of direct potential, and output terminals connected to the anodes of said first and second tubes, the signal appearing across said output terminals being a sine wave signal of half the frequency of said input signal and of an amplitude proportional to the square root of the magnitude of said direct potential.

5. A frequency dividing circuit comprising, a source of sine wave signals to be divided, a source of direct potential of a magnitude substantially equal to the peak amplitude of said sine wave signals, a pair of discharge devices each having at least an anode and a control grid and an anode current-anode voltage characteristic which approximates a square law function, capacitive coupling means connecting the control grid of each of said discharge devices to the anode of the opposite discharge device, means resistively coupling said source of sine wave signals and said source of direct potential to the anodes of said discharge devices, and output terminals connected to the anodes of said discharge devices.

6. A frequency divider comprising a source of symmetrical alternating current waves at a selected frequency, a source of direct potential of

magnitude equal to the peak amplitude of said alternating current waves, a multivibrator including a pair of electron tubes each having a plate voltage-plate current characteristic which approximates a square law function, means serially connecting said source of alternating current waves and said source of direct potential and coupling both said sources to the plates of the electron tubes of said multivibrator, and output terminals connected to the plates of said electron tubes, the signal appearing across said output terminals being a sine wave signal of half the frequency of said first frequency and of an amplitude proportional to the square root of the magnitude of said direct potential.

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