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GATING FREQUENCY DIVIDER

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FIG. 1.

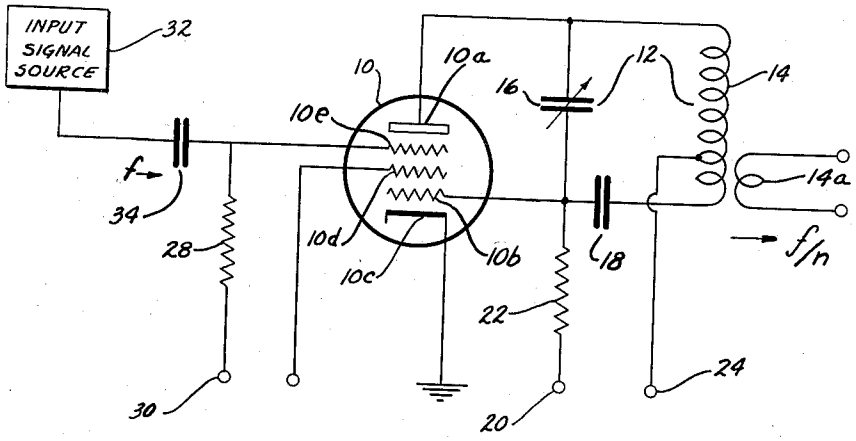
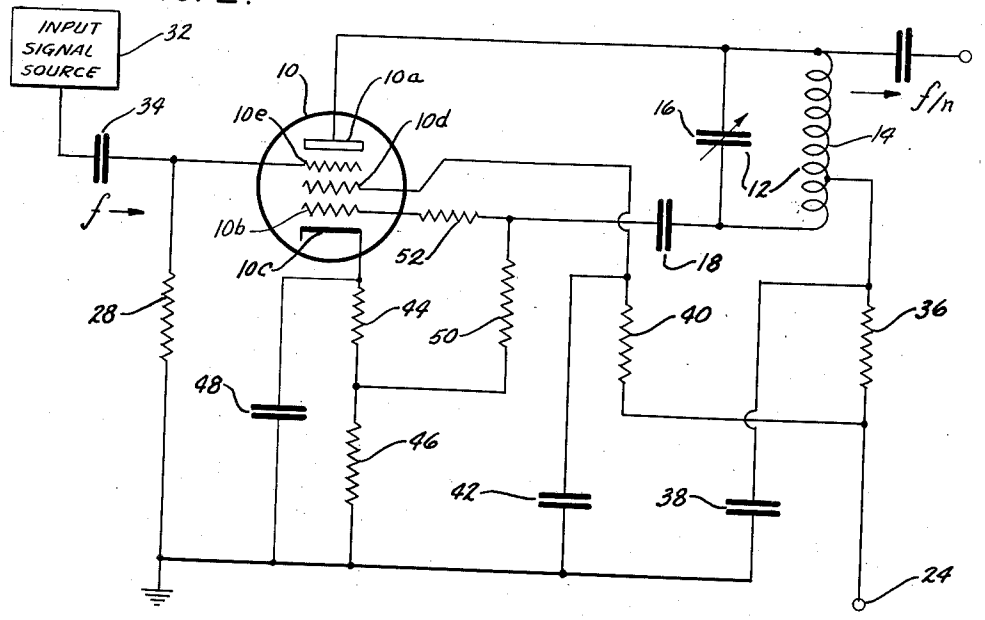


FIG. 2.



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GATING FREQUENCY DIVIDER

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The present invention relates to frequency dividers.

An object of this invention is to provide a novel frequency divider of simplified construction; a novel frequency divider of improved operating characteristics; and more specifically, a novel, non-oscillating feed-back type of frequency divider.

The present invention contrasts with blocking oscillators, multi-vibrators, and locked oscillators, used as frequency dividers, in that the novel frequency divider hereby provided is relatively immune to the effects of supply voltage variation and the regenerative instability that characterizes the other frequency dividers mentioned. The locked-oscillator frequency divider has for long been known, but it has found only limited application because of its numerous shortcomings. In an article entitled "Analysis and Performance of Locked-Oscillator Frequency Dividers Employing Non-Linear Elements" by William L. Hughes in the February 1953 issue of Proceedings of the I. R. E. at page 241, the various ideal properties of frequency dividers are listed. These are as follows: They should require no special wave form, they should be independent of random tube changes, they should rarely if ever require adjustment, they should require no special plate voltage regulation, they should not lose synchronization over a reasonably wide range of input frequency, they should not lose synchronization over wide ranges of input-signal-voltage amplitudes, and the principle of operation should be applicable over wide frequency ranges.

A further object of the present invention is to provide a new frequency divider having the foregoing properties, and in several ways representing an improvement over the type of locked-oscillator described in this article by Hughes. The novel frequency divider provided does not rely on a special form of non-linear circuit element, upon which the Hughes device is dependent. The novel frequency divider furthermore, is substantially simplified in comparison to the Hughes circuit, and in comparison with other known frequency dividers whose operating characteristics approach those of the present frequency divider. In this connection, a specific object of the invention is to provide a frequency divider of the feed back type employing a single-purpose vacuum tube. The term "single-purpose" is here used to distinguish from multiple electrode assemblies in a single envelope where those assemblies operate relatively independently of each other and in reality amount to multiple vacuum tubes.

Two illustrative embodiments of the invention are described in detail below, and these will be seen to include a resonant circuit connected to a vacuum tube in a manner to cause the resonant circuit to ring at its natural frequency. The tube is biased so as to render it normally non-conductive. An input circuit, connected to the signal source whose frequency is to be divided, causes the vacuum tube to conduct momentarily, and thereby to "ring" the resonant circuit.

In the illustrative embodiments the resonant circuit has a positive feed back loop to a separate control electrode

of the tube, so as normally to suggest a free-running oscillator; but the feed-back loop is isolated from the signal input electrode, and this, coupled with the cut-off bias of the tube, prevents any such free oscillation. There is consequently no gain around the whole circuit such as is a characteristic of a free running oscillator.

Various levels of bias may be employed, varying from class B bias to class C bias, depending upon the desired application of the frequency divider. If it is desired to preserve amplitude modulation through the input signal, class B bias should be employed and the band width of the resonant circuit should be appropriate to sustain the modulation side-bands. Class C bias would tend to suppress such side-bands but is more desirable for providing a single output frequency. In either bias condition the frequency divider will pass frequency-modulated signals, with an appropriately broad-band resonant circuit.

The nature of the invention and further details and features of novelty will be better appreciated from the following detailed disclosure of the invention shown in the accompanying drawings, forming part of this disclosure. In the drawings:

Fig. 1 is the wiring diagram of an embodiment of the invention employing fixed potential supplies; and

Fig. 2 is a wiring diagram of a similar circuit adapted to a single source of direct-current supply.

Referring now to Fig. 1 a vacuum tube 10 of typical pentode construction is shown connected to a resonant circuit 12 including coil 14 and tuning condenser 16. Coil 14 has a direct-current connection to the anode 10*a* of pentode 10, and coil 14 is coupled via blocking condenser 18 to the signal or control grid 10*b* of pentode 10. This grid has a source of normal negative bias connected to it at terminal 20, through a resistor 22. The operating potential for the anode is connected at terminal 24, joined to a tap in coil 14 as illustrated, the negative terminal being returned to ground where cathode 10*c* is connected, as shown. The screen grid 10*d* has its appropriate positive potential supply; and negative cut-off bias is applied to the suppressor grid 10*e* via resistor 28, this cut-off bias being applied between terminal 30 and ground. The input signal source 32 is coupled via direct-current blocking or signal coupling condenser 34 to suppressor grid 10*e* which here is used as a control electrode. In the absence of input signal from this source 32, suppressor grid 10*e* blocks conduction of the pentode 10.

The connection of the positive potential from terminal 24 to the tap in coil 14 causes cathode 10*c* and the tap to operate at the same signal potential, there being no signal voltage drop between terminal 24 and ground. Consequently, there is a positive feed-back loop between the tap and grid 10*b*. This positive feed-back loop advantageously is adequate to produce oscillation if pentode 10 were operated at normal potentials. However, since the tube is normally cut off, oscillation is effectively suppressed.

Resonant circuit 12 is tuned to a frequency that is the desired sub-multiple of the signal frequency from source 32. In the event that this input signal has side bands, the band-width of resonant circuit 12 is made appropriately great to sustain side-bands. The bias applied to terminal 30 for the suppressor grid should be approximately class B level, if it is desired to reproduce the side bands in the frequency-divided signal. If a bias greatly in excess of this is applied amplitude modulation will be largely eliminated. Frequency modulation will be sustained whether class B or class C bias is used provided that resonant circuit 12 has an adequate band-width.

A typical example may be helpful. In this example tube 10 is a pentode type 6AS6. A negative bias of 2 volts is applied at terminal 20, a negative bias of 10 volts is applied at terminal 30, and a positive B supply

of 150 volts is connected at terminal 24. If the division of the input frequency is, for example to be by a factor of 2, it is evident that the first positive going signal impulse will render tube 10 conductive (presuming sufficient input signal amplitude) and this conduction will endure for only a small part of the natural period of resonant circuit 12. During the "on" time of pentode 10, current rises in coil 14, and the rate of change of this current is enhanced by the positive feed-back loop to control grid 10*b*. The resulting sudden rise of current in coil 14 causes resonant circuit 12 to "ring" at its natural frequency. The energy in the resonant circuit is sustained even when the input signal of the suppressor grid is negative-going.

The next positive-going impulse from source 32 in the frequency division of 2 being considered occurs when the potential applied by resonant circuit 12 to grid 10*b* is such that tube 10 is not conductive. Thereafter, during the third positive swing of the signal from the source 32, resonant circuit 12 is again in a portion of its cycle such that tube 10 is conductive, and the energy in resonant circuit 12 is again increased. With appropriately adjusted potentials, this level of energization may very nearly approximate the variation in potential applied to suppressor grid 10*e*.

Larger frequency division frequency factors than 2 may be used, both even and odd numbers, up to a practical limit of approximately 10. This limit is set by realizable Q and accuracy of tuning of the resonant circuit.

It is evident that the frequency divider of Fig. 1 is a single-tube circuit employing a single resonant circuit, and even though a positive feed-back loop is included, self-sustained or free running oscillation is effectively prevented by the cut-off bias or suppresser grid 10*e*. The signal that is impressed on the tube is effectively isolated from the feed-back loop. There is no gain around the circuit considered from the input electrode 10*e* to the output electrode 10*a*, and consequently there is no possibility of free running oscillation. This frequency divider may be termed a resonant frequency divider of the feed-back type but it is not a locked oscillator. It may also be termed a "gating divider." The principles of operation are applicable very widely, over frequencies where lumped constants are employed, to higher limits where space resonators are employed with special designs of vacuum tubes; and in fact the circuit components may even be integrated into the vacuum tube itself as is usual at very high frequencies. Since the tube operates between on and off, the operation is relatively independent of tube changes and adjustment of the circuit or of the supply voltage is rarely required. It is of course evident that double resonant circuits and other broad band forms of resonant impedances may be substituted for the simple inductance-capacitance tuned circuit shown in Fig. 1, and where a broad band device is employed, naturally the frequency divider will not lose synchronization over a relatively broad input frequency variation. The device is also insensitive to variations in signal input amplitude variation except where it is adjusted to reproduce the amplitude modulation of the input signal source. It is of special interest that these excellent characteristics are achieved through the use of a circuit of elemental simplicity with a minimum number of components and wherein each of these components is entirely unspecialized and of general application.

It was noted above that the circuit in this Fig. 1 uses separate bias and operating potential supplies for each of the electrodes of the pentode. This is by no means a limitation. The circuit in Fig. 2 has the same excellent operating properties of that in Fig. 1 but the latter circuit requires a single potential supply only, the various required bias and operating potentials being developed in the circuit itself. The same numerals are employed in Fig. 2 as those in Fig. 1. The description of operation of the circuit is not here repeated since it is in all respects the same as that in Fig. 1. The differences relate to the manner in which the various potentials are developed. Positive potential is applied at point 24, as in Fig. 1. An isolating resistor 36 and a by-pass condenser 38 are provided for the anode potential applied via coil 14. The potential at terminal 24 is reduced in a resistor 40 connected to screen 10*d*, and a by-pass condenser 42 is connected between screen 10*d* and ground in conventional fashion. Bias for the two control electrodes 10*b* and 10*c* is developed in the cathode circuit by resistors 44 and 46 connected in series between cathode 10*b* and ground, these resistors being by-passed by condenser 48 from cathode to ground. The entire bias developed in this resistance-capacitance circuit is applied between cathode 10*c* and a screen 10*e*, through screen-grid return resistor 28; and the bias developed in resistor 44 is applied to control grid 10*b* through isolating resistor 50 and through grid-current limiting resistor 52. A tabulation of the resistors in this network may be of interest, and is as follows:

Resistor:		Resistance
36	ohms	1,000
40	do	22,000
44	do	1,000
46	do	20,000
50	megohms	1
52	do	0.1

These values are for a 250 volt potential applied between terminal 24 and ground, with a 6AS6 tube. The values of the condensers used will naturally be determined by the frequency of the signals in the circuit.

The foregoing illustrative embodiments of the invention represent presently preferred forms of application of the novel frequency divider. The principles of this novel frequency divider will naturally find varied application and are susceptible to a wide range of variation, as will be recognized by those skilled in the art. Accordingly, the invention should be broadly construed, consistent with its full spirit and scope.

What I claim is:

1. A frequency divider including a multi-grid vacuum tube, said tube having an anode, a cathode, and multiple control grids between said anode and said cathode, a resonant circuit having connections at opposite terminals thereof to said anode and to one of said control grids respectively, and a signal connection from said cathode to a signal point in the resonant circuit between said terminals, cut-off bias means for the other of said grids, and a signal input source connected to said other grid, the natural frequency of said resonant circuit being a submultiple of said input signal.

2. A frequency divider including a pentode having an anode, a cathode, a control grid, and a suppressor grid, a resonant circuit connected to said pentode with oppositely phased signal connections to said anode and said control grid, a connection from the cathode to an intermediate point of the resonant circuit, cut-off bias means to said suppressor grid, and an input signal source coupled to said suppressor grid and effective to drive said pentode into conduction and thereby to ring the resonant circuit, the natural frequency of said resonant circuit being a submultiple of the input signal frequency.

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