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FREQUENCY DIVIDER CIRCUITS

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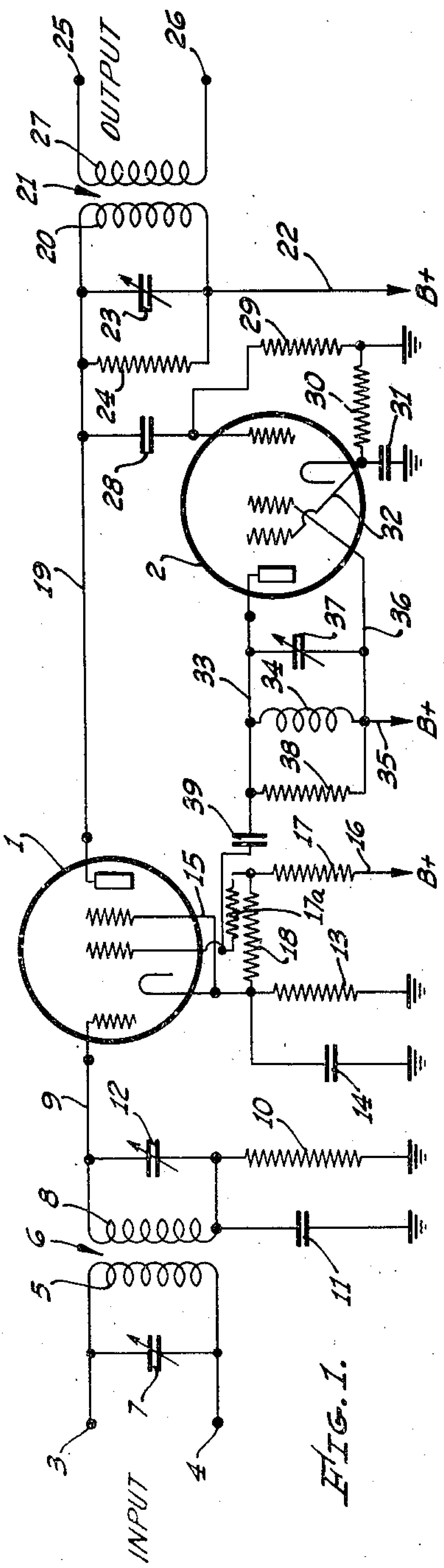

FIG. 1.

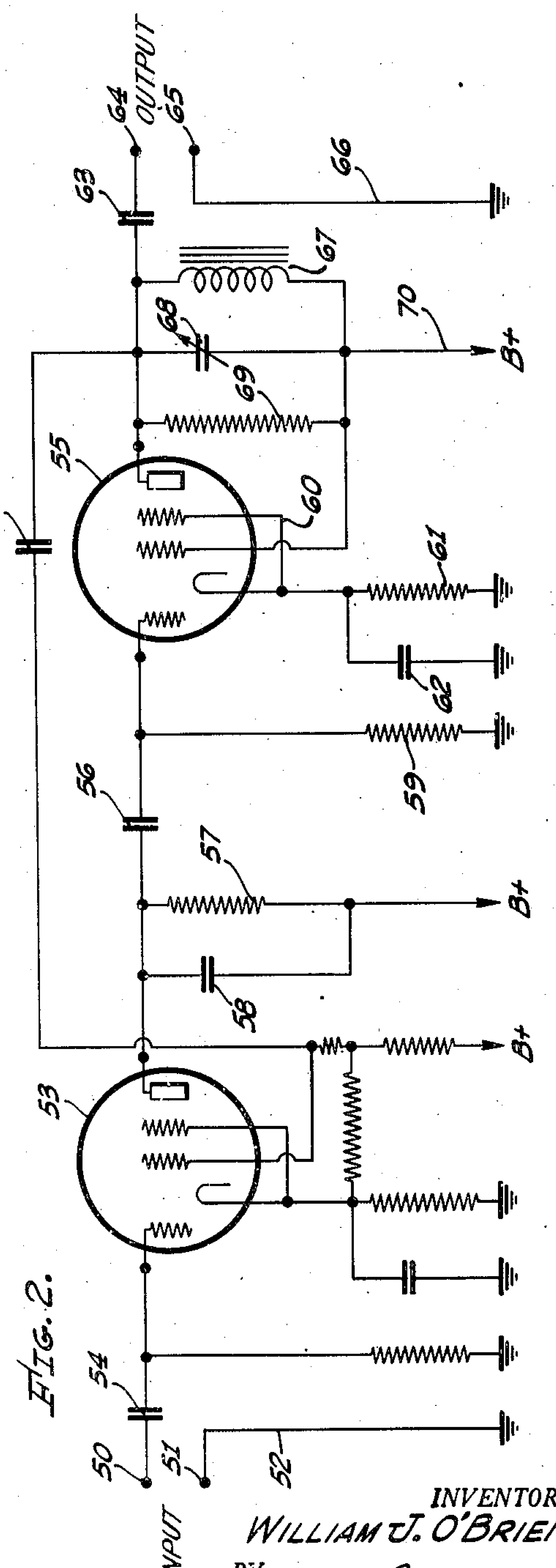

FIG. 2.

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FREQUENCY DIVIDER CIRCUITS

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My invention relates to frequency divider circuits and has particular reference to thermionic vacuum tube circuits for converting an input signal of given frequency to an output signal of lower frequency, and having a frequency dividing range which is much larger than that of previous circuits designed for similar use.

In the radio transmission and control art, it is often necessary to produce a frequency which is less than that of a given source of radio frequency. This is usually accomplished by means of multi-vibrator circuits.

Multi-vibrator circuits have the disadvantage of producing a change in output frequency with changes in input voltage exceeding ten percent. Also the frequency of the output of a multi-vibrator circuit is controlled by the charging and discharging time of a condenser in a resistance capacity circuit. Since this time is a function of the voltage applied to the condenser, the multi-vibrator circuit is sensitive to voltage changes and does not necessarily produce an output frequency which bears the desired relationship to the input frequency.

It is, therefore, an object of my invention to provide frequency dividing circuits in which the output frequency is substantially independent of the input voltage.

It is also an object of my invention to provide a frequency divider circuit of the character set forth in the preceding paragraph which may be used at either audio or radio frequency.

It is an additional object of my invention to provide a frequency dividing circuit in which the output frequency is determined by a tuned circuit to make the output frequency substantially independent of the input voltage.

It is a still further object of my invention to provide in a frequency dividing circuit of the character described a synchronizing circuit for synchronizing the output frequency with the input frequency so that the two frequencies bear a whole number ratio to each other.

It is additionally an object of my invention to provide a frequency divider circuit of the character set forth in which the output signal is characterized by including a number of harmonics to facilitate the use of a plurality of subsequent frequency multiplying circuits.

Other objects and advantages of my invention will be apparent from a study of the following specifications, read in connection with the accompanying drawings, wherein:

Fig. 1 is a schematic wiring diagram illustrating a frequency divider circuit intended particularly for use at radio frequencies; and

Fig. 2 is a schematic wiring diagram illustrating a frequency divider circuit which is intended particularly for use at audio frequency.

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Referring to the drawings, I have illustrated in Fig. 1 a frequency dividing circuit which is intended particularly for use at radio frequencies. In Fig. 1 the cathode heater circuits have been omitted as these circuits are conventional and well understood. Similarly the sources of high voltage direct current used for plate and screen grid supply have been omitted and connections to a suitable source of such voltage are indicated merely by an arrow bearing the legend B+. It is to be understood that any suitable source of plate supply potential may be used.

The circuit which is shown in Fig. 1 includes an input tube **1** and a frequency regulating tube **2**. These vacuum tubes are shown as pentode tubes, although tetrode or screen grid type may be used. The radio frequency input, the frequency of which is to be divided, is connected to input terminals **3** and **4** which are connected to a primary winding **5** is tuned to the input frequency by a condenser **7** connected across the primary **5**. The transformer **6** includes a secondary winding **8**, one end of which is connected as by conductor **9** to the grid of the vacuum tube **1**. The other end of the secondary **8** is connected to ground through a resistance **10** which is shunted by a condenser **11**. The secondary **8** is tuned to the input frequency by a condenser **12** connected across the winding **8**.

The cathode of the tube **1** is connected to ground through a cathode bias resistor **13** which is preferably by-passed by a condenser **14**. The suppressor grid of the tube **1** is connected directly to the cathode as by a conductor **15**. The screen grid voltage for the tube **1** is obtained from a suitable source of high voltage direct current, to the positive terminal of which is connected a conductor **16**. The conductor **16** is connected to the screen grid of the tube **1** through resistances **17** and **17a**. The mid-point between resistors **17** and **17a** is connected to the cathode through a resistance **18**.

The plate of the tube **1** is connected by a conductor **19** to the primary **20** of an output transformer **21**. The other end of the primary winding **20** is connected to the source of plate supply potential by a conductor **22**. The primary winding **20** is shunted by a condenser **23** and a resistance **24**. The condenser **23** is used to tune the winding **20** to the frequency desired for the output, the output signal appearing across the terminals **25** and **26** connected to a secondary winding **27** of the transformer **21**. The resistance **24** is connected across the tuned primary **20** to reduce the "Q" of the circuit to the tube to make the output circuit tune rather broadly. The output frequency is so chosen that the ratio between the input frequency and the output frequency is some whole number such as, for example, three.

The conductor 19 which is connected to the plate of the tube 1 is also coupled to the control grid of the tube 2 through a condenser 28. The grid of the tube 2 is also connected to ground through a resistance 29. The cathode of the tube 2 is also connected to ground through a cathode biasing resistor 30 which is by-passed as by a condenser 31. A conductor 32 serves to connect the suppressor grid directly to the cathode. The plate of the tube 2 is connected by a conductor 33 to a tuning coil or inductance 34. The other terminal is connected as by means of a conductor 35 to the source of plate supply potential. This source is connected also by a conductor 36 to the screen grid of the tube 2. The tuning coil 34 is tuned to the same frequency as the coil 20 by a tuning condenser 37 and the "Q" of the tuned circuit is reduced by a resistance 38 connected in parallel with the coil 34. The plate of the tube 2 and the plate conductor 33 are coupled to the screen grid of the tube 1 through a coupling condenser 39.

In the circuit just described, the resistances 13, 17 and 18 are chosen to bias the tube 1 at or near cut-off. The feed-back connection between the plate of the tube 2 and the screen grid of the tube 1 and between the plate of the tube 1 and the control grid of the tube 2 provides a regenerative circuit which may oscillate in the absence of an input signal. Such oscillation is not, however, a requisite for proper operation.

Assuming, for example, that the input frequency which is applied to the input terminals 3 and 4 is say 60 kc. and it is desired to produce across the output terminals 25 and 26 a frequency of 20 kilocycles, the circuit 34–37 will be tuned to a frequency of 20 kilocycles. The resistances 13, 17 and 18 are also so proportioned as to apply to the screen grid of the tube 1 a positive direct potential which is less than the output voltage developed by the regulating tube 2 so that for each positive half cycle of the output of the tube 2, the potential of the screen grid of the tube 1 will be raised to a substantial value, whereas during the negative half cycles of the output of the tube 2, the screen grid of the tube 1 will be driven negative. The resistance 17*a* has a high ohmic value and operates as a grid leak to hold the screen grid negative during operation except during the positive maxima in the outputs from tube 2. Since the tube 1 is operative only when the screen grid has a positive potential impressed thereon, it is seen that the tube 1 operates as an electronic switch which is closed only once for each cycle of the output of the oscillator 2 or, in the assumed example, at a frequency of 20 kilocycles.

Since the input to the control grid of the tube 1, in the assumed example, is at a frequency of 60 kilocycles, two positive grid swings occur while the tube is blocked and one occurs while the tube is conductive. There is thus applied to the primary winding 20 of the transformer 21 a 20 kilocycle voltage. The current which flows in conductor 22 is not of sine wave form but is rich in harmonics. This is advantageous since it permits exciting frequency multiplying circuits if it is required to produce an end frequency different than the output frequency, as for example 40 kc.

The use of low "Q" tuned circuits for the circuits 20, 23 and 34, 37 makes the tuning very broad. Since the tube 2 is excited at its control grid by the output of the tube 1, the output of tube 2 is in forced sub-multiple synchronism with the input signal which is applied to the grid of the tube 1. This is accomplished even though the optimum tuning of the tuned circuits 20, 23 and 34, 37 is not precisely one-third input frequency.

In Fig. 2 I have illustrated a circuit which is very similar to that shown in Fig. 1 but which is intended particularly for use at audio frequency. The frequency which is to be divided is applied to input terminals 50 and 51, the latter being connected to ground as by a conductor 52. The terminal 50 is connected to the grid of a vacuum tube 53 through a coupling condenser 54. The vacuum tube 53 and a second vacuum tube 55 are shown in Fig. 2 as being pentodes. However, the tetrode or screen grid type of tube may be employed if desired. The cathode, screen grid and suppressor grid circuits for the tube 53 are identical to those shown for the tube 1 in Fig. 1 and the values of the resistances involved are chosen to produce the same type of operation as has been described in connection with Fig. 1.

The plate of the tube 53 is coupled to the grid of the tube 55 through a coupling condenser 56. A plate load resistance 57 by-passed by a bypass condenser 58 serves as a plate load for the tube 53 and is connected between the plate and a suitable source of plate potential. The grid of the tube 55 is connected to ground through a grid resistance 59. The cathode and suppressor grids of the tube 55 are connected to ground through a cathode-biasing resistor 61 which is preferably by-passed by a condenser 62. The plate of the tube 55 is coupled through a coupling condenser 63 to one of a pair of output terminals 64 and 65, the other of which is connected to ground as by a conductor 66. The plate load for the tube 55 comprises a tuned circuit including a tuning coil or inductance 67 shunted by a tuning condenser 68 and loading resistance 69. The screen grid and the plate of the tube 55 derive operating potential through a conductor 70 connected to the source of plate supply potential. The plate of the tube 55 is coupled in a feed-back circuit including a coupling condenser 71 to the screen grid of the tube 53.

The operation of the circuit shown in Fig. 2 is nearly identical with that which has been described in connection with Fig. 1. The tubes 53 and 55 constitute a circuit which may oscillate at the desired output frequency in the absence of an input signal. The operation of the tube 53 is periodically blocked at the output frequency by the application of negative voltages to the screen grid of the tube 53 in the same manner as has been described in Fig. 1. The principal difference between the two circuits is, first, that the circuit shown in Fig. 2 has been arranged for operation at low or audible frequencies, whereas the circuit of Fig. 1 is intended to operate at relatively high or radio frequencies and, second that the resistance capacity network 56—59 operates as a low "Q" bandpass filter which, through the proper selection of resistance and capacity values, may be in effect tuned to the selected sub-multiple of the input frequency.

From the foregoing, it will be observed that I have provided frequency divider circuits which may be used at either radio or audio frequency and that these circuits serve to produce an output frequency to which the input frequency bears a whole number ratio. These circuits include a synchronizing tie which maintains this whole number ratio between the input and output frequencies.

It will also be noted that tuned circuits are employed for determining the output frequency and that for this reason the circuits are not subject to the frequency error which characterizes multi-vibrator circuits, depending for frequency regulation upon the time constant of resistance capacity circuits. With circuits of the character just described, input voltages may be varied from one-half the normal operating voltage to double the operating voltage without affecting the output frequency. This is a particular advantage over the previously employed multi-vibrator circuits in which the output frequency was a function of the input voltage, requiring variations in input voltage to be held below ten percent.

I have found that frequency divider circuits of the character described herein will permit operation at an input frequency to output frequency ratio as high as twelve, although more satisfactory operation is obtained at lower ratios.

While I have shown and described the preferred embodiment of my invention, I do not desire to be limited to any of the details of construction shown or described herein, except as defined in the appended claims.

I claim:

1. In a frequency dividing circuit, the combination of: a vacuum tube amplifier stage including an input circuit tuned to an input frequency to be divided; a vacuum tube regulating stage including an output circuit tuned to a sub-multiple of said input frequency; a coupling circuit also tuned to said sub-multiple of said input frequency and coupling the output of said amplifier stage to the input of said regulating stage; and means coupling said regulating stage to said amplifier stage for rendering said amplifier stage conductive only during coincidence in time of positive maxima of said input frequency and said sub-multiple thereof.

2. In a frequency divider for producing an output frequency to which an input frequency bears a whole number ratio, the combination of: a vacuum tube connected in a regenerative circuit and coupled to band-pass filter circuits all resonant at said output frequency; and a synchronizing circuit energized at said input frequency and connected to force said circuit to oscillate in sub-multiple synchronism with said input frequency.

3. In a frequency divider for producing an output frequency to which an input frequency bears a whole number ratio, the combination of: a vacuum tube amplifier circuit including an input circuit to be supplied with said input frequency and including an output circuit tuned to said output frequency; a vacuum tube regulating stage tuned to said output frequency; means coupling said regulating stage to said output circuit for exciting said regulating stage at the frequency of said output circuit; and a control circuit connecting said regulating stage to said amplifier circuit for alternately blocking and releasing said amplifier circuit at the frequency of said output circuit.

4. In a frequency divider for producing an output frequency to which an input frequency bears a whole number ratio, the combination of: an amplifier circuit comprising a vacuum tube having a pair of control elements and a plate and comprising also input and output circuits including, respectively, one of said control elements and said plate; means for energizing said input circuit at said input frequency; a vacuum tube regulating stage excited from said output circuit and tuned to said output frequency; and a control circuit connecting said regulating stage to the other of said control elements for rendering said amplifier circuit conductive only when the positive half cycle of the regulating stage output coincides in time with the positive half cycle of said input frequency.

5. In a frequency divider for producing an output frequency to which an input frequency bears a whole number ratio, the combination of: an amplifier circuit comprising a vacuum tube having a pair of control elements and a plate and comprising also input and output circuits including, respectively, one of said control elements and said plate; means normally biasing said vacuum tube substantially at cut-off; means for energizing said input circuit at said input frequency; a vacuum tube regulating stage excited from said output circuit and broadly tuned to said output frequency; and a control circuit connecting said regulating stage to said other control element for holding said element at a negative potential except during the peak of the positive half cycle of said regulating stage output.

6. In a frequency divider for producing an output frequency to which an input frequency bears a whole number ratio, the combination of: a vacuum tube amplifier stage including an output circuit and two input circuits; a vacuum tube regulating stage connected in a regenerative circuit between said output circuit and one of said input circuits; means tuning said regenerative circuit to said output frequency; and means for applying said input frequency to the other of said input circuits.

7. In a frequency divider for producing an output frequency to which an input frequency bears a whole number ratio, the combination of: an input circuit to be supplied with current of said input frequency; an output circuit for supplying said output frequency; a vacuum tube connected in an electronic switch circuit between said input and output circuits and including a control element for opening and closing said switch; a vacuum tube regulating stage; a synchronizing circuit connecting said regulating stage between said output circuit and said control element; and means tuning said synchronizing circuit to said output frequency.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,874,845	Albersheim	Aug. 30, 1932
2,124,191	Geiger	July 19, 1938
2,344,678	Crosby	Mar. 21, 1944

FOREIGN PATENTS

Number	Country	Date
479,935	Great Britain	Feb. 14, 1938