



## UNITED STATES PATENT OFFICE

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## FREQUENCY DIVIDER

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This invention relates to an improved frequency divider or electrical pulse counter of the type employing a storage condenser on which incremental charges of voltage are stored or built-up in response to input pulses to be counted.

A difficulty experienced with a known frequency divider of this type is that the range of frequencies over which it will divide by a constant factor varies considerably with changes in voltage of the cathode heater supply. It is believed that this difficulty is due to a variation of the grid-to-cathode impedance of the vacuum tube with a change in the cathode heater voltage supply during the discharge time of the storage condenser.

An object of the present invention is to provide a frequency divider or counter having improved stability despite changes in voltage of the cathode heater supply.

Another object is to provide a frequency divider or counter capable of counting pulses over an extremely wide band of frequencies at a constant fixed integer and with relatively good stability with changes of cathode heater voltage.

A further object is to provide a frequency divider capable of counting pulses over an extremely wide band of frequencies (repetition rates) of the pulses to be divided.

A feature of the invention is the use of an extra vacuum tube for discharging the storage condenser, and a resistor for assuring that the major portion of the discharge passes through this extra vacuum tube.

A detailed description of the invention follows in conjunction with a drawing, wherein:

Figs. 1 and 2 illustrate two different frequency dividers embodying the principles of the invention.

In the drawing, the same or equivalent parts are designated by the same reference characters.

Referring to Fig. 1, the frequency divider includes a pair of diodes D1 and D2 which, if desired, may be in a single envelope, and which are fed by the pulses to be counted or divided from lead 10 and through condenser 11. The cathode of D1 is directly connected to the anode of D2 and both of these electrodes are connected to condenser 11. The anode of diode D1 is grounded, while the cathode of D2 is connected to storage condenser C across which a step wave voltage is developed. Each step or stair of this developed step wave voltage corresponds to an increment of voltage built-up in response to a pulse applied to input lead 10. Condenser 11 is appreciably smaller in size than conden-

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ser C and these condensers may have a relation, for example, of 1:5 depending upon the number of pulses to be counted; or stated otherwise, depending upon the constant fixed integer or factor by which the frequency of the input pulses is to be divided.

The cathode of diode D2 is also connected to one terminal of winding 2 of a three-winding pulse transformer T. The other terminal of winding 2 is connected through a resistor R to the control grid of a vacuum tube V2. The anode of tube V2 is connected through winding 1 of transformer T to the plus or positive terminal of a source of unidirectional potential 12 whose negative terminal is connected to ground. A bleeder network 13 is connected across the source 12, and a tap 14 on this bleeder is connected to the cathode of tube V2 for supplying a positive potential to this cathode of sufficient magnitude to normally bias tube V2 beyond cut-off. The bias for tube V2 can be varied by varying tap 14.

The third winding 3 of transformer T is shunted by a damping resistor 15 and is connected between ground and the control grid of discharge vacuum tube V1. The anode of tube V1 is connected to a point between winding 2 of transformer T and resistor R. The cathode of tube V1 is connected by way of lead 18 to a point on bleeder 13 so as to bias this tube V1 beyond cut-off. The cathodes of tubes V1 and V2 are also connected to ground through bypass condensers 16 and 17, respectively.

In the operation of the frequency divider of Fig. 1, the bias on tube V2 is set by means of tap 14 so that anode current through tube V2 will be cut-off until the voltage supplied to its grid from storage condenser C reaches a predetermined magnitude sufficient to overcome this cut-off bias. The values of condensers 11 and C and the setting of tap 14 are so correlated that the frequency divider counts the desired number of input pulses before tube V2 conducts and causes storage condenser C to discharge.

Let it be assumed that the frequency divider is to divide by 5, and that the input impulses applied to lead 10 are positive in polarity. On the positive rising edge (leading or starting edge) of the input pulse, diode D2 will conduct but diode D1 will not conduct, as a result of which the circuit will look as though the two condensers 11 and C are in series relative to ground. Hence, a portion of the total input voltage appears across condenser C, producing an incremental charge on condenser C. This incremental increase in charge on condenser C is equivalent to

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a step or rise on the step voltage wave. On the negative falling edge (trailing edge) of the pulse supplied to condenser 11, diode D1 will conduct and discharge condenser 11, but diode D2 will not conduct, thus leaving unchanged the voltage on condenser C acquired during the immediately preceding positive rise of the pulse. The voltage on condenser 11 will be completely discharged to ground through diode D1 during this negative drop; or putting it in other words, the negative going edge of the input pulses is shorted to ground through diode D1. During the next positive rise in voltage caused by the succeeding pulse applied to condenser 11, the condenser 11 will be recharged through diode D2. It will thus be seen that each time there is a positive rise in voltage applied to condenser 11, there will be an incremental increase or step-up in voltage on condenser C. Although each charge on condenser C after the first is slightly less than the preceding one; it should be noted that there is no resistance whatever across condenser C, in order to avoid any leakage during the voltage step-up or charge build-up operation.

On the fifth pulse, the resulting incremental rise in voltage on condenser C will overcome the cut-off bias on tube V2 and cause current to conduct therein. The windings 1, 2 and 3 of the pulse transformer T are so poled that the initial flow of current in tube V2 causes the application of an amplified positive pulse to the grids of tubes V2 and V1. This resulting positive pulse expedites the flow of current through tube V2 and is of sufficient magnitude to cause tube V1 to conduct. Tube V2 acts as a single-shot oscillator which amplifies the pulse fed back from its anode to its control grid when it starts to conduct current.

When tube V1 conducts, it serves as a discharge path for the storage condenser C. The presence of resistor R in the grid circuit of tube V2 assures that the major portion of the discharge of condenser C is through tube V1. Since the grid-cathode space path of V2 has considerably less impedance than the anode-cathode space path of tube V1, the discharge of condenser C would in the absence of resistor R otherwise go through tube V2.

Because the impedance of the anode-cathode discharge path (tube V1) varies relatively less than the impedance of the grid-cathode path of tube V2, with change in voltage of the cathode heater supply, the frequency divider is more stable by the provision of the discharge tube V1 and the means (resistor R) for assuring the main discharge of the storage condenser through the space path of this tube V1.

Fig. 2 is a modification of the frequency divider of Fig. 1. In the frequency divider of Fig. 2, the pulse produced by tube V2 when it starts to conduct, is amplified by vacuum tube V3 before being used to cause tube V1 to conduct and hence discharge the storage condenser V1. It should be noted that the grid of tube V3 is connected to one end of winding 3 of pulse transformer T through a connection 19. Tube V3 is normally non-conductive (like tubes V2 and V1) and obtains its cut-off bias from lead 20 which supplies a positive potential to the cathode of tube V3. The positive pulse applied to the grid of tube V3 by winding 3 of transformer T, when tube V2 starts to conduct, is of sufficient magnitude to overcome the cut-off bias on tube V3 and cause this tube to conduct. Tube V3 may act as a class C amplifier. The transformer T1 serves to

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reverse the polarity of the pulse in the output of tube V3 so that it is positive when applied to the grid of tube V1.

It should be understood that the invention is independent of the particular system shown for storing charges on condenser C, and that other circuits may be employed to build up a predetermined charge on condenser C in response to a desired number of input pulses, without the necessity of using diodes D1 and D2.

The following tabulation provides a comparison between the frequency divider systems of Figs. 1 and 2 of the invention and a known system which did not use the extra discharge tube V1 nor the resistor R. The dividing factor was 5:

*Frequency range in kilocycles*

| Heater Volts | Known System  | Fig. 1    | Fig. 2 |
|--------------|---------------|-----------|--------|
| 7.0          | 760-1,200     | 370-1,400 | 50-850 |
| 6.5          | 825-1,220     | -----     | 30-950 |
| 6.0          | 1,120-1,510   | -----     | -----  |
| 5.5          | count changes | 330-1,300 | -----  |

The foregoing tabulation indicates that with heater volts of 7.0 the frequency range of the known system was less than 2 to 1, while with the system of Fig. 1 the range was 3 to 1 and with the system of Fig. 2 the range was 17 to 1. With heater volts of 6.5 the frequency range of the known system was still less than 2 to 1, while the frequency range of the system of Fig. 2 was about 31 to 1. No measurement was taken of the system of Fig. 1 in this particular example using heater volts of 6.5.

In the embodiments of the invention successfully tried out in practice, tubes V1 and V3 of Fig. 2 were part of a double triode 6SNT-GT. The tube V2 of both Figs. 1 and 2 was a 6 AC7 pentode tube connected as a triode. The pulse transformer T was a Ferranti 5029 type. The resistor R had a value of 500 ohms.

It should be understood that the term "ground" used in the specification and appended claims is not limited to an actual earth connection, but is deemed to include any point of reference potential, such as zero radio frequency potential.

What is claimed is:

1. A frequency divider comprising a storage condenser for storing a charge by increments in response to a series of recurring pulses, a pulse transformer having a plurality of windings, an indirectly-heated and normally non-conductive vacuum tube having a grid, a cathode and an anode, a direct current connection from said storage condenser to said grid through the series circuit of one winding of said pulse transformer and a resistor, said resistor being located between said grid and said one winding, a feedback circuit for said tube including a connection from said anode to another winding of said transformer, whereby said tube forms a single-shot oscillator which passes current when the charge on said storage condenser reaches a predetermined value, a second indirectly heated and normally non-conductive vacuum tube having a grid, an anode and a cathode, a direct connection from the anode of said second tube to the junction between said resistor and said one winding of said transformer, alternating current connections from the cathodes of said tubes to a point of reference potential, and means for applying a pulse of positive polarity to the grid of said

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second tube of sufficient magnitude to cause said second tube to conduct when said first tube conducts, whereby said second tube forms a discharge path for said storage condenser.

2. A frequency divider comprising a storage condenser for storing a charge by increments in response to a series of recurring pulses, a pulse transformer having first, second and third windings, a first electric tube normally biased to cut-off and having a grid, an anode and a cathode, a direct current connection from said storage condenser to said grid through the series circuit of said first winding and a resistor, a feedback circuit from said anode to said grid including the second winding of said transformer, a second electric tube normally biased to cut-off and having a grid, a cathode and an anode, a direct current connection from said last anode to the junction between said resistor and said first winding, a connection from the grid of said second tube to said third winding, and capacitors coupling the cathodes of said tubes to a point of reference potential, said windings being so poled that the flow of current through said first tube in response to a predetermined charge on said storage condenser causes the application of a positive pulse to the grid of said second tube of sufficient magnitude to cause said second tube to conduct.

3. A frequency divider comprising a storage condenser, means for building up a predetermined charge on said condenser by increments in response to pulses applied to said divider and whose frequency of occurrence is to be divided, a first electron discharge device having a control grid, an anode and a cathode, a pulse transformer having first, second and third windings, a connection from said storage condenser to one terminal of said first winding, a connection including a series arranged resistor from the other terminal of said first winding to the control grid of said device, a connection from said anode to the positive terminal of a source of polarizing potential through the second winding of said transformer, a second electron discharge device having anode, control grid and cathode elec-

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trodes, a connection from the anode of said last device to the junction between said resistor and the first winding of said transformer, connections capable of passing alternating current from the cathodes of said two electron discharge devices to a point of reference potential, means supplying bias to said devices to cause them to be normally non-conductive, and means including said third winding of said pulse transformer for overcoming the cut-off bias on said second device when said first device passes current, said windings of said pulse transformer being so poled that the flow of current through said first device in response to a predetermined charge on said storage condenser causes the application of a positive pulse to the grid of said second device.

4. A frequency divider in accordance with claim 3, including a damping resistor across said third winding of said pulse transformer, and characterized by the use of a third electron discharge device normally biased to cut-off and arranged as an amplifier, said third device having an input electrode coupled to said third winding and an output electrode coupled to the grid of said second device through a phase reverser.

5. A frequency divider in accordance with claim 3, including a damping resistor across said third winding of said pulse transformer, and a direct connection between the grid of said second device and one terminal of said third winding.

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#### REFERENCES CITED

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

#### UNITED STATES PATENTS

| Number    | Name         | Date          |
|-----------|--------------|---------------|
| 2,113,011 | White        | Apr. 5, 1938  |
| 2,154,492 | Clough       | Apr. 18, 1939 |
| 2,411,573 | Holst et al. | Nov. 26, 1946 |
| 2,413,440 | Farrington   | Dec. 31, 1946 |
| 2,415,918 | Thomas       | Feb. 18, 1947 |
| 2,415,919 | Thomas       | Feb. 18, 1947 |