Nov. 3, 1931. H. NUKIYAMA ET AL 1,830,238

RELAY AND DISCHARGE TUBE CIRCUIT

Filed Aug. 4, 1930

FIG. 1

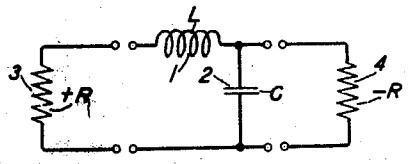


FIG. 2

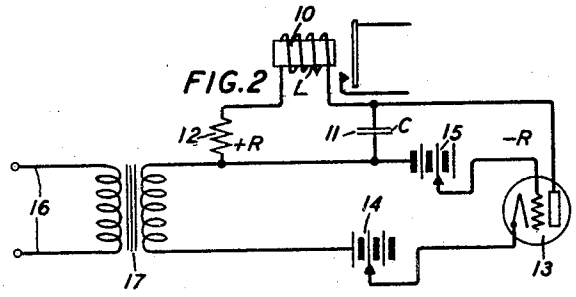


FIG. 3

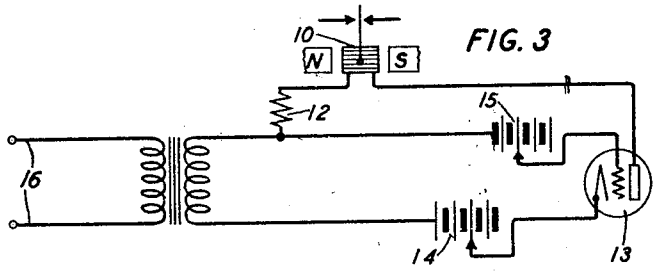


FIG. 4

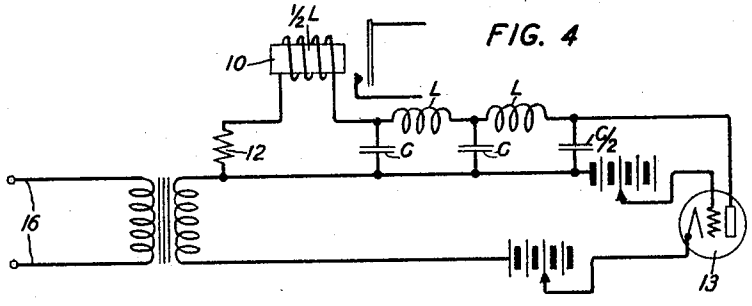
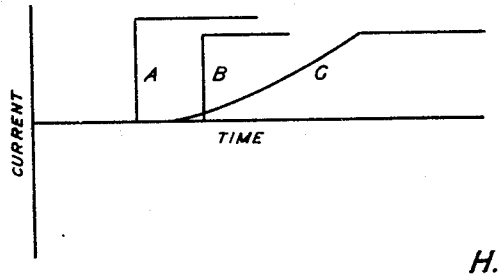


FIG. 5



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1,830,238

UNITED STATES PATENT OFFICE

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RELAY AND DISCHARGE TUBE CIRCUIT

Application filed August 4, 1930, Serial No. 472,994, and in Japan September 5, 1929.

The present invention relates to a circuit employing a space discharge device to operate an electromagnetic relay or other inductive load.

An object of the invention is to secure high speed of operation together with amplification.

In accordance with the specific embodiment of the invention to be described hereinafter, a relay forms part or all of the series inductance of a low-pass filter which is terminated at one end in a positive resistance and at the other end in a negative resistance.

The negative resistance termination is obtained by use of a space discharge device having its electrodes suitably related to the filter elements of which the relay forms a part. The signals or other waves that are controlled by the actuation of the relay are applied to the input terminals of the space discharge device. The best results are obtained when the filter is terminated at each end in its image impedance, in one end in the positive impedance referred to and in the other end in the negative impedance referred to.

The invention will be more fully understood from the following detailed description in connection with the drawings in which Fig. 1 is a circuit diagram illustrating one of the principles of design in accordance with the invention, Figs. 2, 3 and 4 are circuit diagrams of a system according to the invention, and Fig. 5 shows response curves.

The quick action secured by the circuit of the invention results in part from the use of the negative resistance termination referred to above. In the circuits to be described, the negative resistance is obtained by use of secondary electron emission in a vacuum tube, resulting in sudden and rapid rise of plate current in response to applied signal waves. This effect cooperates with the low-pass filter characteristic in securing quick response. The low-pass filter includes series inductance of which the relay winding forms a part and shunt capacity which assists in overcoming the inertia of the relay due to its inductance.

The general form of circuit employed is of the type shown in Fig. 1 comprising a low-pass filter terminated in its image impedance at both ends. The low-pass filter comprises the series inductance 1 and shunt capacity 2 and the terminating resistances are shown at 3 and 4 respectively. The resistance 3 is a positive resistance which may be an ordinary ohmic resistance, while resistance 4 is a negative resistance, the nature of which will be described later. The inductance 1 consists partly or wholly of the relay winding.

Fig. 2 is of the general type of circuit of Fig. 1 but shows the individual circuit elements. The low-pass filter comprises as a whole a winding of relay 10 and a shunt capacity 11. The positive termination is shown at 12 and the negative termination is obtained by the use of the vacuum tube 13 and associated circuits.

This vacuum tube 13 may be of the ordinary 3-electrode type including cathode, anode and grid or control element. It is provided with a plate potential source 14 and an additional grid voltage source 15, both of which are preferably adjustable. The signal voltages or other control voltages for the relay 10 are supplied at terminals 16 which lead to the primary of input transformer 17. With the filament lighted (filament energizing source not shown) and with the other constants of the circuits and applied voltages properly adjusted, secondary electron emission is developed in a manner of itself well known in the art, and a negative resistance effect is produced between the plate and grid of tube 13. The constants of the circuit are adjusted to make this negative resistance equal to the image impedance of the filter comprising elements 10 and 11.

In operation, signal waves applied at 16 control the grid potential and in turn the space current, resulting in a very rapid rise of current in the winding of relay 10, the rapidity of the current rise being assisted by the capacity 11. Preferably the relay winding and the condenser form a resonant circuit which is tuned to the frequency of the applied waves.

In practice, the constants of the circuit should be such that (referring to Fig. 1)

$$|-R| \cdot = . + R = (1 \pm 0.2)\sqrt{\frac{L}{C}}$$

If the inductance of the relay is negligible the coupling condenser may be omitted, in which case the system reduces to the form shown in Fig. 3 which is otherwise similar to Fig. 2 already described.

In some cases it may be desirable to use more than a single section of low-pass filter and Fig. 4 discloses the use of 2½ sections of filter. In this system the series inductance is not so completely neutralized by shunt capacity as is the case in Fig. 2 and therefore a certain amount of delay is inherent in the system.

An idea of the response characteristic of the relay of the invention can be obtained from Fig. 5 in which curve C shows the response characteristic of a known prior art type of high speed relay, curve A shows the relay operate time of the circuit of Fig. 2, and curve B shows the response time of the circuit of Fig. 4.

It has been found in practice that a telegraph transmitting speed up to 290 dots per second may be obtained with the circuit of the invention using a carrier frequency of 1800 cycles per second. This speed was obtained with a relay of several henries inductance.

It will be understood that the invention is not limited to the operation of electromagnetic relays and also that it may be employed either with low frequency or with high frequency control waves or with modulated carrier waves. The invention is also not limited to the particular type of tube disclosed nor to this method of obtaining a negative resistance effect.

What is claimed is:

1. In combination, an electric discharge device having an anode, a cathode and a grid or the equivalent, circuit connections developing a negative resistance across two of the electrodes of said device by the use of secondary electron emission, a low-pass filter comprising an inductive load element as a series filter inductance, a resistance terminating said filter at one end, equal to the image impedance of said filter, said filter being terminated at the opposite end by said negative resistance across said electrodes of said discharge device, which is equal to the image impedance of said filter, and connections for applying a control wave between said grid and cathode for controlling said load element.

2. The combination defined in claim 1 in which the inductive load comprises the winding of an electromagnetic relay having an armature, said combination operating to produce quick action of said relay.

3. The combination defined in claim 1 in which said filter comprises a plurality of filter sections.

4. The combination defined in claim 1 in which the image impedances (−R and +R) are approximately equal to each other and to the quantity

$$(1 \pm 0.2)\sqrt{\frac{L}{C}},$$

where L and C are the series inductance and shunt capacity of said filter, respectively.

In witness whereof, we hereunto subscribe our names this 10th day of July, 1930.

HEIICHI NUKIYAMA.
KENZO NAGAI.