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R. CREVELING ET AL

2,883,535

THYRATRON SWITCH

Filed March 15, 1956

2 Sheets-Sheet 1

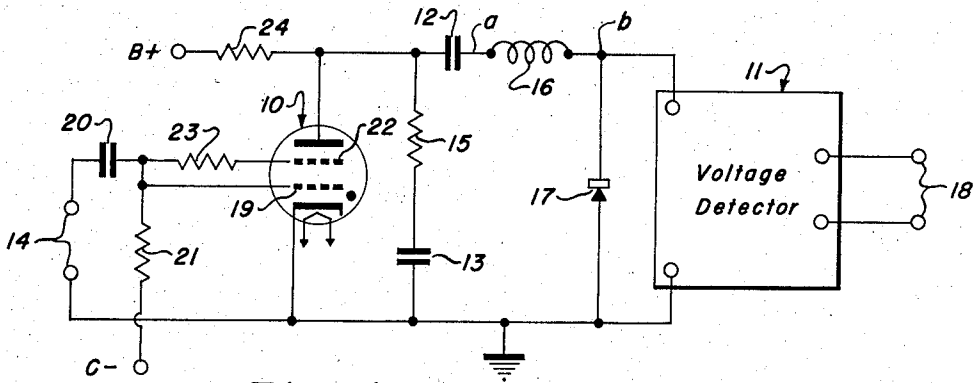


Fig. 1

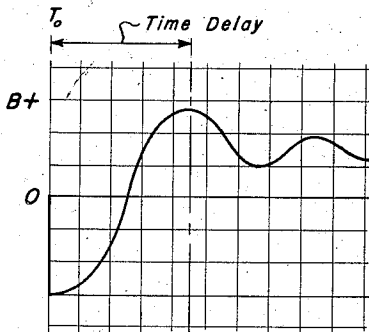


Fig. 2

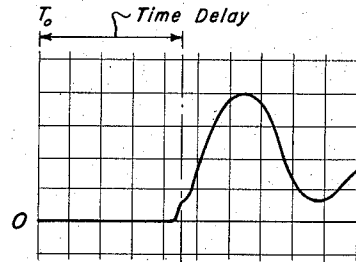


Fig. 3

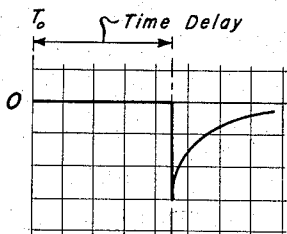


Fig. 4

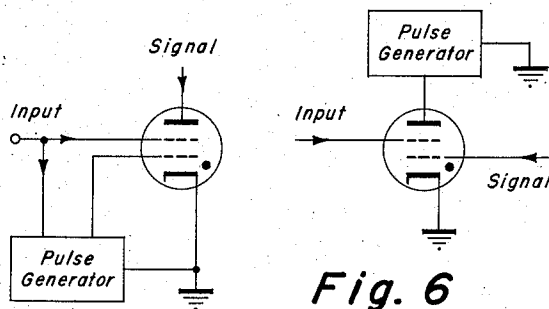


Fig. 5

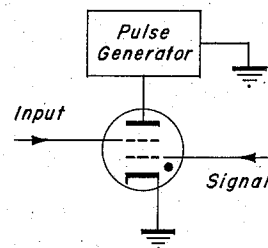


Fig. 6

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2 Sheets-Sheet 2

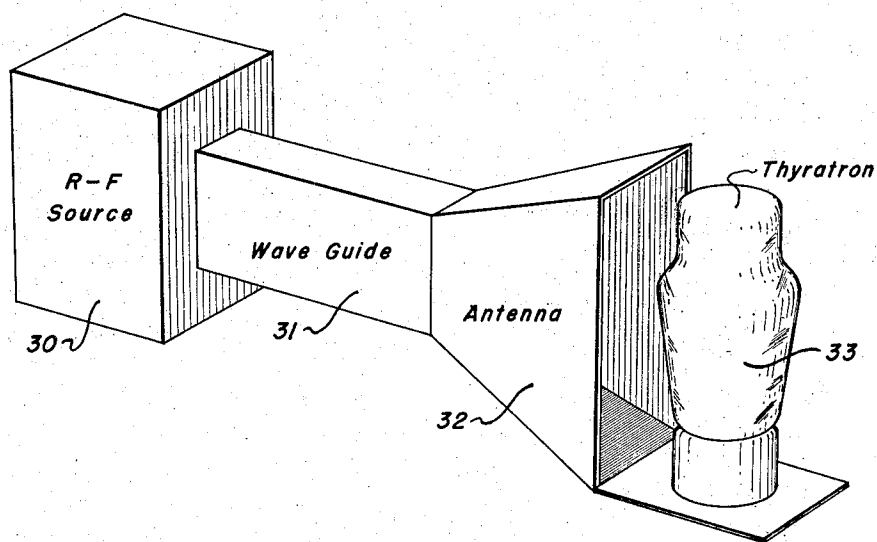


Fig. 7

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THYRATRON SWITCH

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Application March 15, 1956, Serial No. 571,845

2 Claims. (Cl. 250—27)

This invention relates to thyratrons in general, and more particularly to a method and means of utilizing a thyatron as an efficient electrical switch. Thyratrons have been used for years in the control of large amounts of electrical power, as in welding, lighting control, motor control and voltage regulation and control of rectifiers. Recently, coincident with the general growth of electronics, the use of thyratrons in the control of much smaller amounts of power has greatly increased. The thyatron is a fast-acting, compact switch which has no moving parts and is perfectly satisfactory in many electronic applications, particularly those which require the tube to carry a large current.

However, when the thyatron is required to carry only a fraction of its maximum rated current, the very action by which conduction is maintained within the tube acts against the efficiency of the switch. During low-current conduction the voltage drop across the tube oscillates at an irregular rate, spending a certain amount of time at or slightly above the ionizing potential to produce a supply of ions, then falling to a much lower value, near zero volts, until this supply is used up. In general, the time spent producing the ion supply is much less than the time duration of the lower voltage. As a result, irregularly spaced voltage spikes, generally referred to as "noise," are observed between the plate and the cathode of the thyatron.

Since the ionization potential of xenon, a gas commonly used in thyratrons, is 12.08 volts, it is seen that these noise spikes can easily prove annoying in electronic triggering circuits. Voltages of that order of magnitude are commonly used as control voltages both for thyratrons and for other electron tubes. In particular, where thyratrons are used in electronic circuits which perform critical timing operations involving times of the order of microseconds, the noise generated by the thyratrons can well be sufficient to considerably reduce the accuracy and repeatability of the operations.

Therefore it is an object of this invention to provide a method of utilizing a thyatron as an electrical switch which has a low voltage drop and which introduces very little noise into the signal being switched.

Another object of the invention is to provide various means of practicing the above method according to the demands of the associated circuitry.

Briefly, the method practiced in this invention is to create a superabundance of ions within the thyatron sufficient to prolong the time duration of the low tube drop between noise spikes. During this time the signal current is conducted through the tube, depleting the ion supply.

One embodiment of the invention practices the above method by providing a capacitor which is previously charged to a high potential, then discharged through the thyatron to produce a superabundance of ions to be used during the later conduction of a signal current.

Other embodiments utilize a pulse generator whose output terminals are connected between two elements of the

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thyatron so that heavy current pulses are passed between those elements, producing the desired superabundance of ions.

Still another embodiment includes a radio-frequency generator arranged so that an ionizing electromagnetic field is passed through the thyatron, producing sufficient ions to prolong the noise-free conduction of the tube.

If it is necessary to conduct a signal current for a longer period of time than is afforded by the supply of ions produced by any of the described embodiments, those embodiments using the pulse generator and the radio-frequency generator are particularly adaptable to the emission of a series of ionizing pulses so spaced in time as to successively replenish the supply of ions.

A better understanding of the invention may be had, and other objects of the invention will become apparent, by reading the following more detailed description in conjunction with the appended claims and the attached drawings in which:

Fig. 1 is the circuit diagram of a time-delay circuit incorporating the invention as embodied in a capacitor-discharge device for ionizing the gas within a thyatron;

Fig. 2 shows the voltage waveform observable at point *a* of the circuit of Fig. 1 during operation of the circuit;

Fig. 3 shows the voltage waveform observable at point *b* of the circuit of Fig. 1;

Fig. 4 shows the output voltage pulse of the circuit of Fig. 1;

Fig. 5 is the circuit diagram of an embodiment of the invention utilizing a pulse generator to provide ionizing pulses between the grid and the cathode of a thyatron; and

Fig. 6 is the circuit diagram of another embodiment, which includes a pulse generator connected to supply ionizing pulses between the plate and the cathode of a thyatron.

Fig. 7 shows an arrangement of apparatus for the application of an electromagnetic field to a thyatron.

Referring now to Fig. 1, which shows the invention incorporated in a time delay circuit claimed and more completely described in a copending application of Robert Creveling, Serial Number 571,844, filed March 15, 1956, thyatron 10 is in the non-conducting state, maintained that way by the C-bias on control grid 19. Capacitors 12 and 13 are each charged positively at B+, the plate supply voltage. At time T_0 tube 10 is triggered into the conducting state by a positive pulse applied between terminals 14. The plate of tube 10 drops to practically ground potential due to the voltage drop across resistor 24. Capacitor 13 then discharges through current-limiting resistor 15 and tube 10 to ground in less than a microsecond. The surge of current, which is near the maximum tube rating, creates a large number of ions within the tube so that the subsequent voltage drop from plate to cathode due to the lesser signal current is low and free of oscillations. The side of capacitor 12 that was at a high potential is now only a few volts above ground.

Fig. 2 shows the potential of point *a* in Fig. 1 as it varies with time. It is seen to drop quickly from ground potential to a voltage equal in value but having opposite polarity to B+ when tube 10 fires, then to rise to near B+ following a sinusoidal variation to the extent of half a cycle. The duration of this half-cycle of oscillation, which is the desired time delay, is determined by the values of capacitor 12 and coil 16. The circuit involved includes tube 10, the forward resistance of diode 17, coil 16, and capacitor 12. The relatively small current flowing through tube 10 during the time delay uses the supply of ions created in tube 10 by the discharge of capacitor 13. Until this supply is exhausted, the tube

does not attempt to replenish it and no noise is added to the waveform of Fig. 2.

It is particularly important that this waveform be noise free near its most positive point, which corresponds to the end of the time delay, because of the triggering action to follow. When the voltage at point *a* reaches its peak and starts to decrease in a second half-cycle, current in the oscillatory circuit is prevented from reversing by diode 17, since it can conduct efficiently in only one direction. Hence, the energy stored in coil 16 is dissipated by decaying voltage oscillations at a frequency determined by the coil inductance and its stray capacitance.

Fig. 3 shows this voltage as observed at point *b* of the circuit. The sudden rise in voltage at the start of the oscillations triggers voltage detector 11, causing an inflection in the waveform, and the output pulse shown in Fig. 4, observable at terminals 18, is produced at the desired delay time after the signal pulse.

This time delay circuit is designed to produce a delay of the order of tens of microseconds between input and output pulses. It is seen that the occurrence of a noise pulse near the triggering time of voltage detector 11 could easily cause early or late triggering, creating a variation in the time delay. In the prior art such noise-caused variations were commonly between three and 250 milliseconds. The use of this invention as shown in Fig. 1 yields time delays having variations of less than three millimicroseconds.

In Fig. 1, thyatron 10 is shown to be the type having four elements, such as the 2D21, although the invention may instead include a three-element thyatron. Grid 19 is that usually referred to as "grid number one" or "control grid," for which capacitor 20 and resistor 21 form R-C coupling from terminals 14.

Grid 22 is that usually called "grid number two" or "shield grid" and is normally connected to ground or to the cathode. However, in this instance it is used to supplement the triggering of the thyatron. Since the triggering voltage acts directly on grid 19, ionization is started therewith, closely followed by further ionization due to the triggering voltage reaching grid 22 by way of resistor 23, which is of the order of a thousand ohms.

Fig. 5 shows the use of a pulse generator in producing one or more ionizing pulses. Here the input pulse is applied to the shield grid and the pulse generator at the start of the time delay, firing the thyatron and triggering the pulse generator. The generated current pulse, which may be considerably larger than the input pulse, is applied to the control grid and provides an overabundance of ions within the thyatron. The signal current from a source not shown then flows through the thyatron from plate to cathode, using the supply of ions.

If more ions are needed than can be supplied by one pulse from the pulse generator, a self-triggering generator may be used. This type of generator would be turned on by the input pulse and would then continue to generate ionizing pulses at a repetition rate sufficient to prevent the exhaustion of ions while the signal current flows.

As shown in Fig. 6, the pulse generator may be connected between plate and cathode, in which case the generator can be free-running. The generated pulses will have no effect on the ionization of the thyatron until it is fired by a positive pulse on one of the grids. In this case the input pulse is applied to the shield grid, causing the tube to conduct at the desired firing time, and then successive pulses from the pulse generator keep the supply of ions replenished. The signal current can be caused to flow through the thyatron at any time after the tube fires, by any of various known means, not shown.

Since the construction of most thyatrons is such that the grids may conduct substantial currents without damage, other connections between the thyatron and the external circuitry are possible. If necessary, ionizing pulses may be applied between two grids, or between the plate and a grid. The pulses should be several hundred volts

in amplitude to insure ionization, since the ionization in this case depends upon the formation of a "cold cathode" at the tube element used as the negative terminal of the pulsing circuit. Also, the requirements of a particular application may allow connections whereby a grid carries both the input pulse and the ionizing pulse, permitting the use of a triode instead of the tetrode shown in Figs. 5 and 6.

Another embodiment of the invention, shown in Fig. 7, makes use of an electromagnetic field to ionize the gas within the thyatron. In this embodiment a thyatron such as the 3C23, which has no shield around the plate, grid and cathode, is recommended, since ionization of the gas between those elements is more quickly effected in the absence of such a shield. No separate triggering means is needed, since application of the electromagnetic field to the tube will simultaneously fire the tube and provide a superabundance of ions to be used in conduction of a signal current.

Referring to Fig. 7, radio-frequency source 30 radiates an electromagnetic field which is conducted by wave guide 31 to antenna 32. Thyatron 33 is supported before the antenna so that the radiated electromagnetic field passes through the thyatron, ionizing the gas within. The power of source 30 depends upon the degree of ionization required and whether the electromagnetic field is applied in pulses as needed to prevent noise or applied continuously.

A method of increasing the efficiency of a thyatron switch has been described, along with several specific embodiments which may be used in practicing the method. It should be noted that besides being useful in the microsecond timing field, the invention will add considerably to the efficiency of many other electronic circuits in which the presence of thyatron noise is bothersome. Various changes in, and additions to, the method and devices described may be made by one skilled in the art without departing from the sphere and scope of the invention as defined in the claims below.

What is claimed is:

1. A thyatron switch having the operating characteristic of a prolonged noise-free time interval immediately following the start of switch conduction, comprising a thyatron having at least an anode, a cathode and a control grid; a series circuit connected between the cathode and the anode including a capacitor and a resistor (R) of such size relative to a voltage (E) established across the capacitor as to limit a capacitor discharge current (I) at approximately the maximum rated current of the thyatron, the relationship

$$I = \frac{E}{R}$$

applying; means for establishing the voltage (E) across the capacitor; means for firing the thyatron; and means including the anode and the cathode for automatically conducting a relatively small signal current compared to the maximum current rating through the thyatron upon its firing and for limiting the time duration of the signal current to a value short of the time of occurrence of noise pulses in the thyatron, said thyatron having a characteristic rate of occurrence of noise pulses which normally would cause noise pulses to be introduced to the signal current.

2. For use with a unidirectional series resonant time-delay circuit connected between the anode and the cathode of a thyatron and so constructed and arranged as to conduct a small fraction of the maximum rated current of the thyatron during the delay time, means for delaying the occurrence of noise pulses within the thyatron until after conduction of a half cycle of an oscillatory signal generated by said time-delay circuit, comprising a series circuit connected in parallel with said time-delay circuit and including a capacitor and a resistor (R) of such size relative to a voltage (E) established across the

capacitor as to limit a capacitor discharge current (I) at approximately the maximum rated current of the thyatron, the relationship

$$I = \frac{E}{R}$$

applying, means for establishing the voltage (E) across the capacitor, and means for firing the thyatron, said thyatron having a characteristic rate of occurrence of noise pulses which normally would cause noise pulses to be introduced to the signal current.

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