

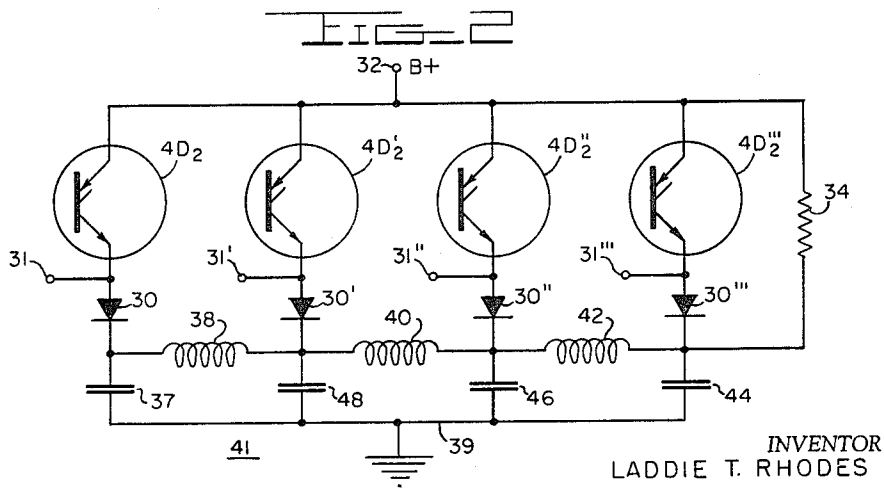
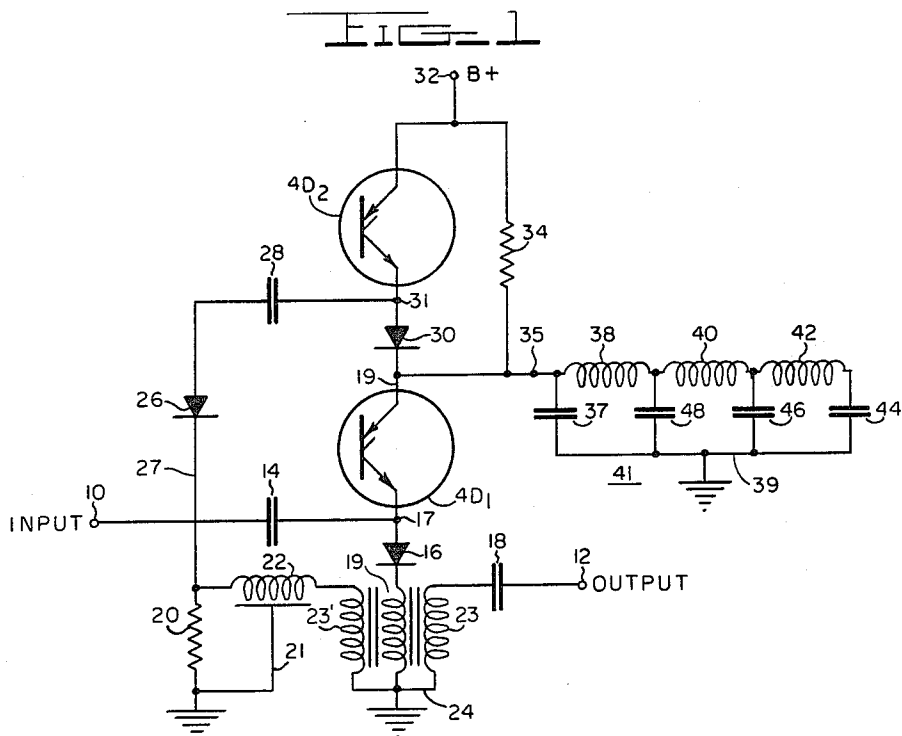
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FAST RECHARGING PULSE GENERATOR

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FAST RECHARGING PULSE GENERATOR

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates generally to a pulse generating circuit and more particularly to a pulse forming network having a very short recovery time.

In many applications, it is desirable to provide a pulse train having a series of very short duration voltage pulses equally or randomly spaced in time sequence. Previous circuits employing blocking oscillators and multivibrators have been used to produce such a series of pulses, but variations in bias voltages and circuit parameters cause significant variation in the repetitive rate of the pulses. Other pulse forming circuits have been devised wherein an energy storage device is charged and then discharged by various forms of switching apparatus. These circuits, while sufficient in some instances, are limited in their application due to the relatively long time period required for the energy storage device to return to its initial state of full energy storage capacity after having been discharged. To compensate for this limited use, multiple delay lines and charging networks have been used to form pulse trains wherein the time sequence between successive pulses is critical; however, the problem of providing identical charging networks and delay lines becomes extremely costly and complex.

The switching apparatus for discharging a pulse forming network has also proved to be, in many applications, inadequate; as, for example, when employing gas discharge tubes for switching, difficulty has been experienced from failure of the tubes to deionize as and when they should, thereby causing unwanted variations in the formation of a pulse train.

The general purpose of this invention is to provide a pulse generating circuit which embraces all the advantages of similarly employed circuits and possesses none of the afordescribed disadvantages. To attain this, the present invention contemplates a unique switching arrangement for charging and discharging a pulse forming network using a feedback circuit and two terminal four-layer switching diodes.

It is accordingly an object of my invention to provide a method for generating pulse trains wherein the time interval between successive pulses can be made extremely short by reducing the minimum recovery time that must be allowed to recharge the pulse forming network.

It is an object of this invention to provide a pulse-shaping energy storage device capable of producing time-spaced pulses by the periodic charge and discharge of the device wherein the spacing between pulses is only limited by the circuit parameters and whose spacing between pulses can be less than the width of the pulses.

It is a further object of this invention to provide a pulse forming network of the charging type in which the triggering time of the discharging means is not critical as compared to previous methods because of a unique method of recharging the network in an extremely short time and wherein a much lower potential is required for the network for providing equal output voltage.

It is yet another object of this invention to provide a pulse forming network having an extremely fast recovery time compared to previous methods and employing bi-

stable semiconductor switching devices having minimum power requirements and high-speed switching characteristics.

It is still another object of this invention to provide a network capable of generating a rectangular pulse of varying train length and optimum shape, decreasing the time required to recharge the network, with only a single pulse forming network which requires only a minimum number of components, occupying a minimum amount of space and still remaining highly efficient and extremely reliable.

Other objects and advantages of this invention will hereinafter become more fully apparent from the following description of the accompanying sheet of drawing, which illustrates a preferred embodiment and wherein:

FIG. 1 shows a schematic diagram of a pulse generating circuit in accordance with the principles of my invention.

FIG. 2 shows a modification of the charging apparatus for the pulse forming network.

Referring now to the drawings, wherein like reference characters designate like or corresponding parts, there is shown in FIG. 1 a pulse generating circuit consisting essentially of three sections: a charging circuit, a pulse forming network and a discharging circuit.

Here, the pulse forming network 41 is initially charged from a source of potential 34 through the high charging resistor 32 and when sufficient time has elapsed the network can be assumed to be at full capacity for storing energy. At the end of the charging period, a four layer switch diode 4D₁ biased by the network just below breakdown potential may be closed, permitting the network to discharge through a load impedance 19, producing a pulse across the load. At the same time, the pulse also appears across delay line 22, being delayed for the time period required to fully discharge network 41 through load 19, and is fed back to the unbiased terminal of the four layer switch diode 4D₂, causing the breakdown voltage and holding current of the diode to be exceeded and the diode changed from an open to closed state. This in turn causes the pulse forming network to be quickly recharged to its full capacity, several orders of magnitude quicker than the initial charging by means of charging resistor 34, so that the network is prepared to again discharge through the load impedance whenever discharge switching diode 4D₁ is again switched to the closed state.

Considering the circuit in more detail, I provide a charging switch, represented by four-layer diode 4D₂ and a discharging switch represented by four-layer diode 4D₁, connected in series by means of diode 30. A source of potential 32 biases the charging switch diode 4D₂ just below the diodes breakdown voltage. An output transformer 19 having an output winding 23 and a feedback winding 23' is coupled on one side to the discharging switch diode 4D₁ by diode 16 and on the other side to ground at point 24. A triggering pulse is supplied at terminal 10 and coupled through capacitor 14 to point 17 the lower potential terminal of a two terminal four layer diode 4D₁. The feedback winding 23' is serially connected to the lower potential terminal of a two terminal four layer diode 4D₂, point 31, by delay line 22, diode 26 and capacitor 28, thereby forming a feedback circuit 27 that provides a delayed trigger pulse for firing diode 4D₂.

There is also provided a pulse forming network, generally indicated at 41, consisting of a plurality of sections of inductances 28, 40, 42 and capacitances 37, 48, 46, 44 connected to form a uniform ladder of the transmission line type. This network is initially charged to the potential of source 32 through charging resistance 34. The network is also connected to point 19 for impressing the

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proper positive potential on the switch diode $4D_1$ so as to maintain the diode at a bias potential just below its breakdown voltage.

The circuit operates in the following manner: Both four-layer diodes $4D_1$ and $4D_2$ are initially in the non-conducting or "open" state, consequently the voltage across the output transformer 19 and at output terminal 12 is zero. The pulse forming network is then initially charged to a voltage determined by the voltage difference between terminal point 32 and ground 39, which in this case is just below the breakdown voltage of switch diode $4D_1$. It is well understood by those skilled in the art that when such a network 41 is arranged to discharge through a predetermined impedance, the network will dissipate substantially all of its stored energy therein in a single current pulse in the form of a rectangular pulse.

The pulse forming network 41 is connected to one side of a four-layer switching diode $4D_1$ such that when the diode $4D_1$ is closed or conducting, it acts as a discharging switch and permits the network 41 to discharge through an impedance matching load transformer 19. Transformer 19 is preferably of the iron core type which is capable of reproducing rectangular or square pulses of very short duration, although other forms of load impedances could be used. The mutual coupling between windings 19, 23 and 23' causes a voltage pulse corresponding to the rectangular pulse from network 41, to be induced in winding 23 and appear at terminal 12 and also to be inducted on winding 23' and returned to point 31 by means of feedback circuit 27.

The pulse forming network 41 need not be of the specific type shown, but may be of any suitable configuration and contain any desired number of sections. An infinite number of sections would give a perfectly flat-topped pulse; however, practical considerations require that only a few sections be used and 3 to 5 have been found to be satisfactory.

Upon being discharged through the load impedance 19, the pulse forming network should be recharged to its initial energy storage state as quickly as possible in order to be capable of discharging another rectangular pulse when the discharging switch is again closed. The shorter the recovery time for network 41, the more rapid the repetitive rate will be for the output pulse train.

To recharge the network, the pulse developed across winding 23' is delayed for a short period, sufficient to allow network 41 to discharge through winding 19. The pulse is then fed to point 31 by means of feedback circuit 27 and used to fire the four-layer diode $4D_2$, which quickly charges the network 41 to the potential of point 32. The network is thereby quickly recharged to its initial energy storage capacity and prepared to discharge another rectangular pulse whenever the discharging switch $4D_1$ is again closed.

A unique feature of this invention resides in the excellent switching characteristics that are obtained by employing four layer diodes. The bistable aspects of the four layer diode, the low impedance when in the conducting state and the high speed with which it may be triggered from one state to the other state, made such a diode highly desirable for use in a circuit wherein fast repetitive pulse rates are generated.

To achieve a very fast repetitive pulse sequence, a bistable four-layer diode $4D_1$ is provided for discharging the network 41. Here diode $4D_1$ is biased just below the breakdown voltage when the network 41 is fully charged. If a triggering pulse of sufficiently negative voltage is applied at terminal 10, the input signal will add to the bias and thereby raise the voltage across the diode $4D_1$ to a value exceeding the breakdown or switching voltage of the diode, switching to the conducting or "closed" state. The required switching voltage and, accordingly, the charging voltage applied at terminal 32 is generally determined by what amplitude is desired of the output pulses at terminal 12, because substantially all of the voltage stored in the

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network 41 is converted into a pulse across winding 19 upon closing of the four-layer diode $4D_1$. The purpose of diode 16 is to present a high impedance to the input signal and to act as a short circuit to ground for any positive signal. It should be noted that the duration and amplitude of the output pulse derived from the pulse forming network 41 is controlled by the constituents thereof and is independent of the amplitude and duration of the triggering pulse at terminal 10.

In prior circuits the pulse forming network 41 would be recharged through resistor 34; however, I have found that if it were possible to recharge the network through a four-layer switch diode which conducts immediately after the network discharges, due to the feedback circuit, the recovery time for the network can be substantially lessened. Observations have shown that the recovery time may be hundreds of thousands of times faster than is possible with the usual choke or resistance charging elements and, in practical applications, a recovery time of less than the time required for the shortest width output pulse is feasible. To do this, a four-layer diode is biased by a potential applied at terminal 32 just below the switching or breakdown voltage of the network. The discharge pulse forming the output pulse at terminal 12 is then fed back to point 31 appearing across diode 39, in proper time sequence, and, as the pulse applied at point 17, the feedback pulse adds to the bias voltage across the diode $4D_2$ to a value exceeding the breakdown voltage causing diode $4D_2$ to enter the conducting or closed state. The low impedance conducting diode allows the potential at point 32 to quickly charge the pulse forming network 41.

It should be appreciated that while the output coupling capacitor 18 is shown connected to output winding 23, it is to be understood that the output pulse could also be developed from the circuit in a different manner than described above, as for example, across the pulse forming network.

When pulse trains of exceptionally fast repetitive rates are required, it may become necessary to use the charging circuit shown in FIG. 2. Here a multiple array of four-layer diodes are used, each diode being triggered into a conduction or closed state by a delayed negative pulse fed back from the output load impedance to point 31, 31^1 , 31^{11} and 31^{111} . By using several four-layer diodes in this manner, the recovery time for the pulse forming network is further reduced. This circuit is initially charged by source 32 through charging resistor 34.

It should be appreciated that the pulse forming network 41 could also be a continuously wound delay line with four-layer diodes connected at each end.

It will be seen from the above explanation and description that I have provided a circuit which will produce a voltage pulse by simply closing a switch and that the pulse is susceptible of varying amplitude and width depending upon the selection of circuit parameters while, at the same time, providing a unique circuit that will produce a pulse train of extremely fast repetitive rate due to the fast recovery time of the pulse forming network.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A fast recovery pulse generator for providing a pulse train of very short duration pulses comprising a pulse forming network, a potential source, a load, charging switch means comprising a first four-layer diode connected between said potential source and said pulse forming network, discharging switch means comprising a second four-layer diode connected between said load and said pulse forming network for permitting said pulse forming network to discharge through said discharging switch means and across said load, means for connect-

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ing said potential source to said pulse forming network through which the pulse forming network is initially charged, and feedback circuit means including delay means connected between said load and said charging switch means for producing a delayed trigger pulse for firing the charging switch means, said pulse being delayed for a time sufficient to allow the pulse forming network to discharge through said load, whereby said pulse forming network is recharged when said charging switch means is fired.

2. A fast recovery pulse generator for providing a pulse train of very short duration pulses comprising a pulse forming network, a potential source, a load comprising a transformer having a feedback winding and an output winding, charging switch means comprising a first four-layer diode connected between said potential source and said pulse forming network, discharging switch means comprising a second four-layer diode connected between said load and said pulse forming network for permitting said pulse forming network to discharge through said discharging switch means and across said load, means for connecting said potential source to said pulse forming network through which the pulse forming network is initially charged, and feedback circuit means including delay means connected between said transformer feedback winding and said charging switch means for producing a delayed trigger pulse for firing the charging

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switch means, said pulse being delayed for a time sufficient to allow the pulse forming network to discharge through said load, whereby said pulse forming network is recharged when said charging switch means is fired.

3. A fast recovery pulse generator as recited in claim 2, wherein said feedback circuit means further includes a diode and capacitor serially connected to said delay means.

4. A fast recovery pulse generator as recited in claim 2, wherein a diode is electrically coupled between said charging switch means and said pulse forming network.

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