

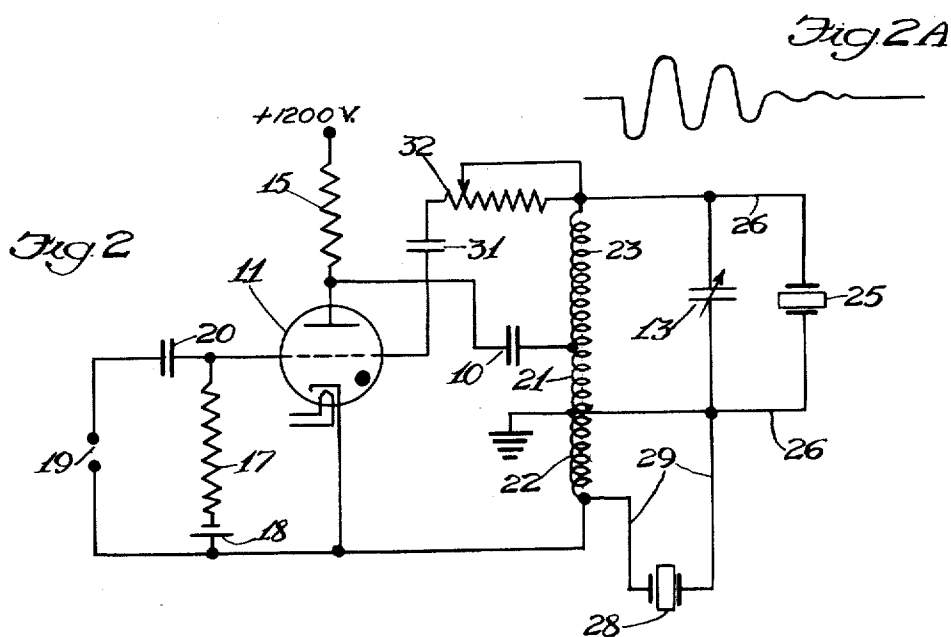
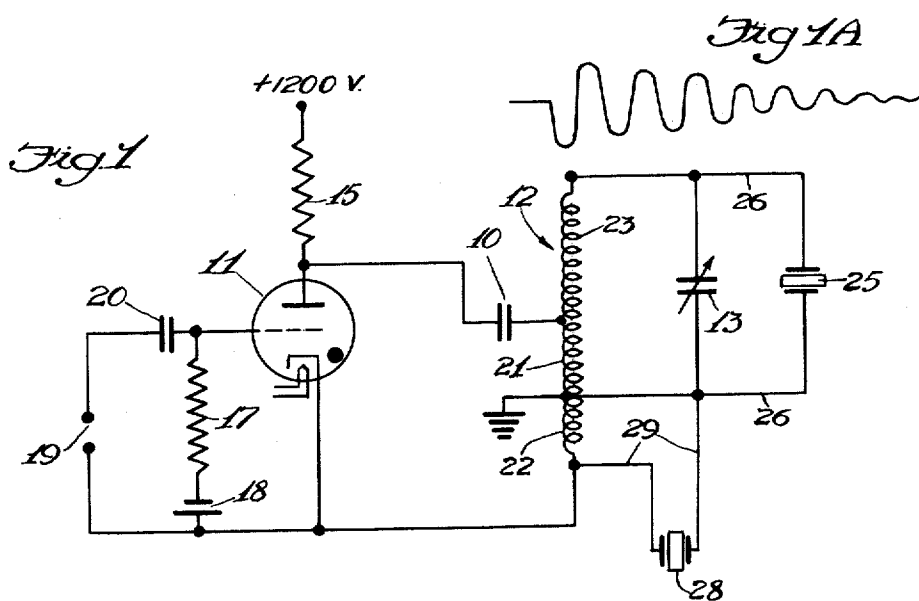
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VOLTAGE TRAIN GENERATING DEVICE

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VOLTAGE TRAIN GENERATING DEVICE

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The present invention relates to an improved device for generating voltage trains and is particularly concerned with producing high frequency voltage trains of maximum amplitude and minimum time duration.

The device finds particular use in connection with pulse-echo type supersonic inspection apparatus wherein a voltage train is applied to a piezoelectric element to cause the element to set up mechanical vibrations of supersonic frequency in a body under test. In such applications it is frequently necessary to inspect regions immediately adjacent the surface of the body and since the elapsed time between transmission of the signal and reception of the echo from a point adjacent the surface is quite small, the transmitted wave train must be of extremely short time duration so that the transmission phase will terminate before the reception phase is initiated. This prevents the reflected signal from being obscured by the more powerful transmitted signal.

In addition, the transmitted signal must terminate within sufficient time to permit the receiving apparatus to recover from the disabling effect of the relatively high energy transmitted signal. This disabling effect is particularly strong in systems in which a single crystal acts as both the sending transducer and the receiving transducer.

Accordingly it is the principal object of the present invention to provide a simplified voltage train generating device that is capable of producing high energy voltage trains of extremely short duration.

Other objects and advantages of the invention will be apparent during the course of the following description.

In the accompanying drawings forming a part of this specification, and in which like numerals are employed to designate like parts throughout the same,

Fig. 1 shows a simplified form of voltage train generator capable of producing voltage trains of large amplitude;

Fig. 1A shows a voltage train produced by the circuit of Fig. 1;

Fig. 2 shows an alternative form of voltage train generator that produces voltage trains of large amplitude and extremely short time duration; and

Fig. 2A shows a voltage train produced by the circuit of Fig. 2.

It should be understood that the description of the preferred form of the invention is for the purpose of complying with section 112, title 35 of the United States Code, and that the appended claims should be construed as broadly as the prior art will permit.

Briefly, the apparatus of the present invention produces a voltage train by ringing a high frequency oscillatory circuit by a sudden discharge of the electrical energy stored in a condenser; however, the discharge circuit supplies energy to the oscillatory circuit through a transformer action and this arrangement produces an output voltage train of unusually large amplitude. Large amplitude voltage trains offer the important advantage of increased sensitivity. The transformer impedance pro-

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vides a favorable impedance match for the high current discharge of the condenser and eliminates the useless dissipation of energy in the non-operative portion of the discharge path.

Preferably the condenser discharge is effected by a grid controlled discharge tube, the condenser being connected in the plate circuit of the tube and provision is made for establishing an electrical connection from the heavily biased grid of the tube to the oscillatory circuit in order to abruptly terminate the oscillations after an extremely short time.

Referring to the drawings and particularly to Fig. 1, the novel voltage train generator comprises an energy storing condenser 10 connected in the plate circuit of a discharge tube 11 and adapted to discharge through a portion of a transformer winding, generally indicated at 12, to set up vibrations in an oscillatory circuit consisting of a condenser 13 and a portion of the winding 12. The condenser 10 is charged through a resistor 15 which is connected to a source of direct current energy that may be of the value of 1,200 volts, as indicated on Fig. 1. Due to the high voltage applied to the plate, the grid must be maintained negative by a large bias voltage and this may be accomplished in the usual manner by a grid leak resistor 17 and grid biasing battery 18 connected in the grid to cathode circuit.

Because of the magnitudes of the discharge currents involved, it is preferred to employ a gas filled discharge tube though it is recognized that in applications involving smaller discharge currents, a vacuum type tube can also be employed. The tube 11, as shown, is of the three element type employing a plate, a cathode and a grid, and it is normally maintained non-conducting by the grid biasing circuit. After the condenser 10 has been charged, it may be discharged by applying a suitable positive triggering pulse to the input terminals 19. This input pulse is coupled to the grid through a condenser 20 and sufficiently overcomes the negative bias on the grid to permit the strongly positive plate voltage to cause the tube to ionize and establish a discharge path for the condenser 10 in the plate to cathode circuit of the tube. Included in the discharge path for the condenser 10 is a winding portion 21 and a winding portion 22. The remaining portion of the transformer winding is designated 23 and it cooperates with the portion 21 and the condenser 13 to form an oscillatory circuit. When the triggering pulse introduced at the input terminals 18 of the grid causes the tube 11 to ionize, the condenser 10 discharges very rapidly through transformer winding portions 21 and 22 and creates a ringing vibration in the oscillatory circuit which consists of the condenser 13 and transformer winding portions 21 and 23.

The winding portions 21 and 22 are arranged to provide a good impedance match for the condenser 10 and they thereby effect a high energy transfer from the plate to cathode circuit to the oscillatory circuit. Due to the transformer action, the amplitude of the voltage train produced by the oscillatory circuit is substantially larger than the voltage across discharge condenser 10 and this is an important advantage in applications requiring increased sensitivity.

The wave form produced by the oscillatory circuit is shown in Fig. 1A and it exhibits the usual exponential decay.

In Fig. 1 the output of the oscillatory circuit is shown applied to a transducer 25 which may be composed of a quartz crystal. The lines 26 which connect the quartz crystal to the terminals of the condenser 13 may represent a shielded cable and it should be noted that the capacities of the lines 26 and of the quartz crystal 25 will affect the make up of the oscillatory circuit. Ac-

cordingly the condenser 13 is made variable in order to tune the circuit to the desired resonant condition.

A second transducer 28 is shown connected across the winding portion 22 by means of the lines 29 which may also represent a shielded cable. This transducer also receives a voltage train of the shape shown in Fig. 1A; however, the amplitude is considerably less than the amplitude of the voltage train applied to the transducer 25. It should be apparent that though winding portion 22 is not itself included in the oscillatory circuit, it nevertheless will produce a voltage train output of similar character to that of the oscillatory circuit. This, of course, is due to the transformer action.

The transducer 28 is composed of a barium titanate crystal and this material requires a voltage train of significantly smaller amplitude than does quartz in order to produce an output vibration of a given amplitude. The transducer 28 is shown merely to point up the fact that the circuit of the present invention can be used for either a quartz crystal or a barium titanate crystal or may operate with both crystals at the same time if desired. It should be apparent that if the barium titanate transducer 28 were omitted, the winding portion 22 could also be eliminated as it has no major effect upon the operation of the voltage train generator.

Returning now to the instant when the condenser 10 is suddenly discharged, it should be understood that after the high initial discharge current of the condenser 10, its voltage will fall rapidly and it will be capable of producing only a minute current. Similarly, resistor 15 is sufficiently large to limit the current flow from the 1,200 volt source of supply to such a low value that ionization can no longer be maintained. Once the tube deionizes, it is again returned to the control of the highly negative grid and the condenser 10 is slowly recharged through resistor 15.

In a test setup of the circuit of Fig. 1, the following parameters were used in the pertinent portions of the circuit:

Resistor 15.....	1 megohm.
Condenser 10.....	1,000 micro-microfarads.
Condenser 13.....	20-150 micro-microfarads.
Winding 21 plus winding 23..	60 turns.
Winding 22.....	10 turns.

In this circuit, with condenser 13 set at approximately its average value, a maximum amplitude voltage train was produced when the ratio of turns in winding 23 to the turns in winding 21 was approximately 3 to 1. The frequency of the voltage train was approximately 10 megacycles. With condenser 10 charged to approximately 1,200 volts and with the above described circuit arrangement, the amplitude of the voltage across windings 21 and 23 was approximately 2,000 volts and across winding 22 was approximately 700 volts. The discharge time of condenser 10 was approximately $\frac{1}{10}$ of a microsecond. As the capacity of condenser 13 is decreased, this turns ratio must be correspondingly increased in order to obtain maximum amplitude.

It should be understood that the transformer action may be connected into the circuit in a number of different ways; for instance, instead of employing an auto transformer, as is shown at 12 in Fig. 1, the primary and secondary windings may be separated from one another with the secondary winding being connected to a condenser to form an oscillatory circuit. In such an arrangement, the discharge condenser 10 may be connected in series with only the primary winding or with the primary winding plus a portion of the secondary winding. All such modified transformer arrangements are considered within the scope of the present invention.

It may be seen by referring to the wave form of Fig. 1A that the circuit of Fig. 1 produces a voltage train of considerable time duration, and though the successive cycles are of continually diminishing amplitude, they are

nevertheless quite large when compared with reflections from echoes. When inspections are being made at extremely short range, it is more than likely that the reflected signals will arrive before the energy of the voltage train is fully spent. Thus the trailing portion of the original voltage train will obscure the reflected signals which it is desired to detect. In order to prevent this obscuring of the reflected signal, it is proposed to prematurely terminate the ringing of the oscillatory circuit.

According to the present invention, a simplified arrangement is provided for this purpose. Fig. 2 discloses a circuit adapted to produce voltage trains of extremely short-time duration, and in large part this circuit is similar to that of Fig. 1. The corresponding circuit portions are numbered identically, and since they function in an identical manner, need not be discussed in detail.

In the circuit of Fig. 2 condenser 10 is charged in a similar manner and discharges suddenly through winding portions 21 and 22 to shock the oscillatory circuit into vibration. The voltage train thus produced is similar in all respects to that shown in Fig. 1A; however, the circuit of Fig. 2 includes a condenser 31 and variable resistor 32 connected in series between the grid of the gas filled tube 11 and the upper end of winding portion 23, and these elements are effective to prematurely terminate the oscillations.

In tests, a condenser having a value of 100 micro-microfarads has been used at 31, and with the variable resistor 32 set at zero, oscillations have been terminated in approximately $2\frac{1}{2}$ cycles. As the resistance of resistor 32 is increased, the time duration of the voltage train also increases. This circuit arrangement permits the high negative potential in the grid circuit to act as a damper on the oscillatory circuit and represents an important simplification over all known prior art arrangements for prematurely terminating a voltage train.

It is important to note that terminating circuitry does not in any way impair the operation of the voltage train generator. The amplitude and frequency of the output voltage trains is substantially the same whether condenser 31 and resistor 32 are in the circuit or not. A typical voltage train wave form produced by the circuit of Fig. 2 is shown in Fig. 2A. The important feature in the terminating circuit arrangement is the concept of utilizing the grid bias to cut off oscillations in the oscillatory circuit and this concept may be applied to other voltage train generators with equally successful results.

Thus it may be seen that the objects of the present invention have been accomplished in that a circuit arrangement of simplified design and high efficiency capable of producing output voltage trains of greatly increased magnitude has been provided. In addition, a novel circuit device for prematurely terminating these output wave forms without in any way impairing their original characteristics has been provided.

I claim:

1. A voltage train generator comprising a condenser, means for charging the condenser, means including a grid controlled discharge tube for suddenly discharging the condenser and setting up vibrations in an oscillatory circuit having a given normal damping time, means connected between said oscillatory circuit and the grid of said tube for coupling energy from the grid to the oscillatory circuit during the time of said vibrations for prematurely terminating said vibrations, and a utilization circuit connected to said oscillatory circuit.

2. A voltage train generator comprising a condenser, means for charging the condenser, means including a grid controlled discharge tube for suddenly discharging the condenser and setting up vibrations in an oscillatory circuit having a given normal damping time, condenser means connected between said oscillatory circuit and the grid of said tube for coupling energy from the grid to the oscillatory circuit during the time of said vibrations for prematurely terminating said vibrations, and a utilization circuit connected to said oscillatory circuit.

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3. A voltage train generator comprising a condenser, means for charging the condenser, means including a grid controlled discharge tube for suddenly discharging the condenser and setting up vibrations in an oscillatory circuit having a given normal damping time, time delay means connected between said oscillatory circuit and the grid of said tube for coupling energy from the grid to the oscillatory circuit during the time of said vibrations for prematurely terminating said vibrations, and a utilization circuit connected to said oscillatory circuit.

4. A voltage train generator comprising a condenser, means for charging said condenser, transformer means in series with said condenser, a grid controlled discharge tube having its plate and cathode connected respectively to said condenser and said transformer means, a second condenser connected to said transformer means to form therewith an oscillatory circuit, means normally rendering said tube non-conducting and means temporarily rendering said tube conductive for suddenly discharging said condenser and setting up vibrations in said oscillatory circuit having a given normal damping time, means connected between said oscillatory circuit and the grid of said tube for coupling energy from the grid to the oscillatory circuit during the time of said vibrations for prematurely terminating said vibrations, and a utilization circuit connected to said oscillatory circuit.

5. A voltage train generator for generating voltage trains of ultrasonic frequency for use in the ultrasonic testing of materials and comprising a condenser, means for charging said condenser, means for suddenly discharging said condenser, an oscillatory circuit including a second condenser and a step-up transformer means, said step-up transformer means being connected in the discharge path of said first mentioned condenser to transfer the energy of the discharge to said oscillatory circuit at a substantially increased voltage level, and a piezoelectric crystal connected across said second condenser.

6. A voltage train generator for generating voltage trains of ultrasonic frequency for use in the ultrasonic testing of materials and comprising a condenser, means for charging said condenser, means including a grid controlled discharge tube for suddenly discharging said condenser, an oscillatory circuit including a second condenser and a step-up transformer means, said step-up transformer means being connected in the discharge path of said first mentioned condenser to transfer the energy of

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the discharge to said oscillatory circuit at a substantially increased voltage level, and a piezoelectric crystal connected across said second condenser.

7. A voltage train generator for generating voltage trains of ultrasonic frequency for use in the ultrasonic testing of materials and comprising a condenser, means for charging said condenser, an oscillatory circuit including a second condenser and a step-up transformer means, said step-up transformer means being connected to said first mentioned condenser, a grid controlled discharge tube having its plate connected to said condenser and its cathode connected to said transformer means, means normally rendering said tube non-conducting and means temporarily rendering said tube conductive for suddenly discharging said first mentioned condenser such that the energy of the discharge is transferred through said step-up transformer means to said oscillatory circuit at a substantially increased voltage level, and a piezoelectric crystal connected across said second condenser.

8. A voltage train generator for generating voltage trains of ultrasonic frequency for use in the ultrasonic testing of materials comprising a condenser, means for charging said condenser, an oscillatory circuit including a second condenser and a step-up transformer, a grid-controlled discharge tube having its plate and cathode connected respectively to said first condenser and said transformer, means normally rendering said tube non-conducting and means temporarily rendering said tube conductive for suddenly discharging said first condenser, said step-up transformer being connected in the discharge path of said first condenser to transfer the energy of the discharge to said oscillatory circuit at substantially increased voltage level, said oscillatory circuit having a given normal damping time, a third condenser connected between said oscillatory circuit and the grid of said tube for coupling energy from the grid to the oscillatory circuit during the time said oscillatory circuit is vibrating for prematurely terminating such vibration and a piezoelectric crystal connected across said second condenser.

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