

April 1, 1947.

E. LABIN ET AL

2,418,128

IMPULSE GENERATOR

Filed Feb. 13, 1943

2 Sheets-Sheet 1

Fig. 1.

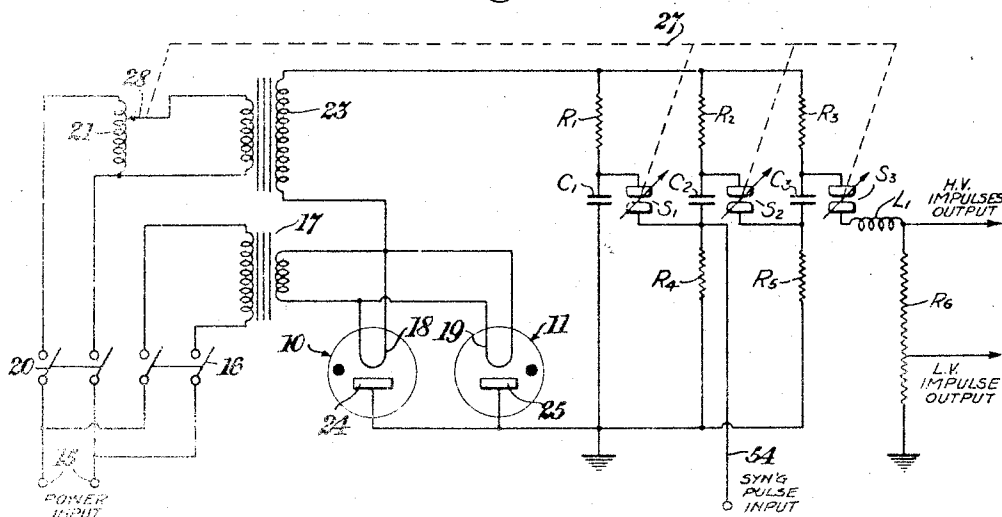


Fig. 4.

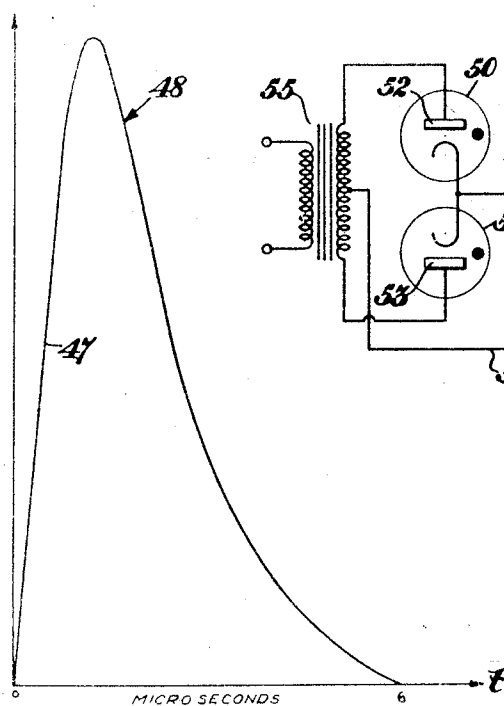
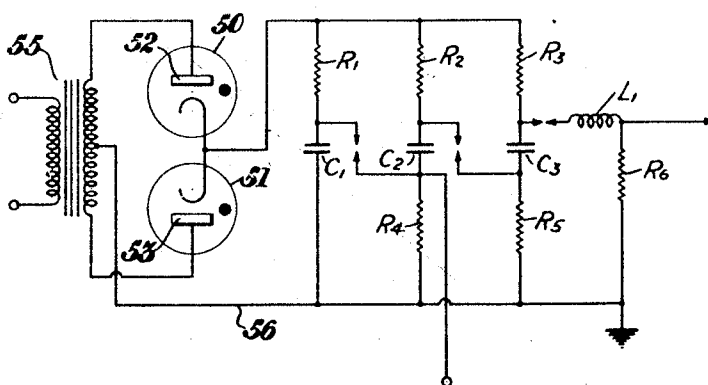


Fig. 2.



INVENTORS
EMILE LABIN
EVERT MANUEL OSTLUND
BY *Perry P. Lantz*
ATTORNEY

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E. LABIN ET AL

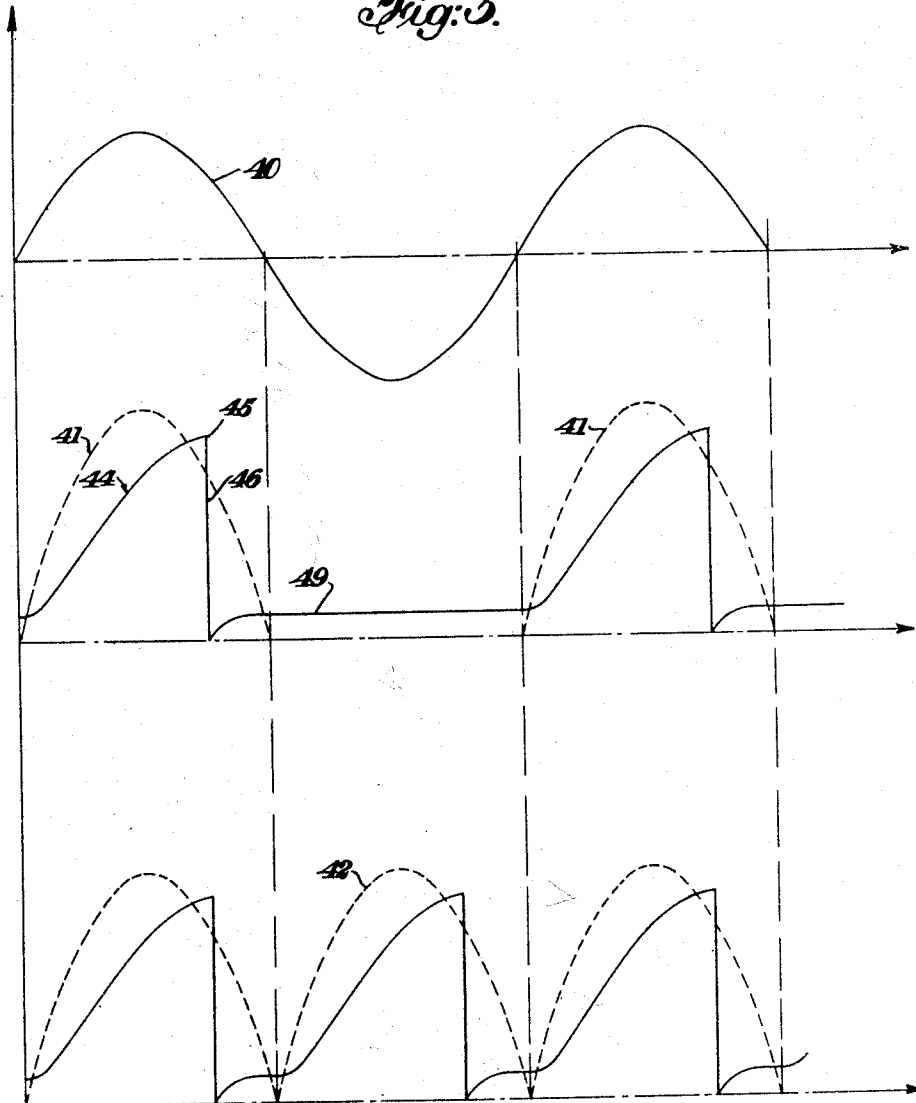
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Fig. 3.



INVENTORS
EMILE LABIN
EVERT MANUEL OSTLUND
BY *Ruby P. Lantry*
ATTORNEY

UNITED STATES PATENT OFFICE

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IMPULSE GENERATOR

Emile Labin, New York, N. Y., and Evert Manuel Ostlund, Montclair, N. J., assignors to Federal Telephone and Radio Corporation, Newark, N. J., a corporation of Delaware

Application February 13, 1943, Serial No. 475,738

3 Claims. (Cl. 171-97)

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This invention relates to radio impulse systems and more particularly to the generation of impulses for use in pulse modulation systems and other electrical systems where high power impulses are desirable.

High voltage surges have been generated heretofore by use of circuits containing spark gaps known generally as "lightning generators." These circuits are used chiefly for high voltage testing of electrical insulators and power equipment. These "lightning generator" circuits, while capable of producing high peak voltage and current with steep wave fronts are not suitable for such uses as pulse modulation. This is largely due to the fact that the impulses generated by such circuits have a duration which is relatively long, the pulse repetition rate is very low and the wave front is usually excessively steep.

It is one of the objects of this invention to provide a system utilizing spark gaps for generating and shaping impulses applicable for pulse modulation of radio frequency transmitters without the aforementioned and other objections of the spark gap circuits heretofore proposed.

Another object of this invention is to provide a simplified impulse generator capable of furnishing short duration, high voltage, high peak power impulses at high repetition rates and of selected shape particularly useful for pulse modulating purposes in radio detection systems such as that disclosed in the copending application of E. Labin Serial No. 473,310, filed January 23, 1943. The Labin system is arranged to operate directly on raw alternating current and therefore avoids the necessity of much of the weighty apparatus required to furnish direct current heretofore believed necessary for radio detection systems. The present system which may derive its power from an alternating current source is particularly useful as a pulse modulator for the aforementioned Labin radio detection system.

The above and other objects of this invention will become more apparent upon consideration of the following detailed description to be read in connection with the accompanying drawings, in which:

Figs. 1 and 2 are schematic wiring diagrams of two forms of impulse generators in accordance with this invention;

Fig. 3 is a graphical illustration of the operation of the two forms shown in Figs. 1 and 2, and;

Fig. 4 is an enlarged view showing the general shape of a high voltage impulse produced in accordance with this invention.

Referring to Fig. 1 of the drawings, the gener-

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ator therein shown comprises three condensers C_1 , C_2 and C_3 adapted to be charged in parallel through isolating resistors R_1 , R_2 , R_3 , R_4 and R_5 from an unfiltered half-wave rectifier comprising rectifier tubes 10 and 11. The condensers C_1 and C_2 are connected in series relation by a spark gap S_1 , the condensers C_2 and C_3 are connected in series relation by a second spark gap S_2 and the output side of the condenser C_3 is connected to a third spark gap S_3 . By this arrangement, the three condensers are charged in parallel arrangement and discharged in series through a load circuit comprising a shaping inductance L_1 and a load resistance R_6 . The voltage peak output is approximately three times the voltage to which the condensers C_1 , C_2 and C_3 are charged. While three condensers and three spark gaps are shown in this circuit, it will be understood that any other number may be used, giving a peak output voltage equal to a corresponding multiple of the condenser charging voltage. It will also be understood that any suitable type of rectifying means may be substituted for the tubes 10 and 11.

The power supply for the generator may comprise any available source of alternating current applied to the input of the circuit at the terminals 15. The power supply is applied through a switch 16 to a filament transformer 17 whereby the filaments 18 and 19 of the tubes 10 and 11 can be preliminarily heated before the generator is used for generation of impulses. A switch 20 is provided to control application of the power to an auto-transformer 21 which is connected to a transformer 23 adapted to provide a potential upon the plates 24 and 25 of the tubes 10 and 11. The auto-transformer provides an adjustment for varying the plate potential. The spark gaps S_1 , S_2 and S_3 are made adjustable and may be interconnected as indicated by the broken lines 27 and associated with the control 28 of the auto-transformer 21.

The spark gap S_1 in the absence of a source of synchronizing pulses for triggering the generator may be adjusted closer than the gaps S_2 and S_3 . This will enable the system to be triggered by the potential of the positive half-cycle of the alternating current applied at the terminals 15. Thus, as the potential of the applied power rises from zero to the positive crest the gap S_1 will be caused to break down at a selected potential and thereby provide a conducting path. With the first gap conducting, current flows in circuit loops $C_2R_1S_1$ and $C_1R_4S_1$ so as to produce breakdown voltage across the second gap S_2 . Due to the extremely high overvoltage impressed across this

gap, it becomes conductive in a very short time, of the order of a small fraction of a microsecond. Breakdown of the two gaps S_1 and S_2 connects C_1 , C_2 and C_3 in series with the output gap S_3 which fires to connect the condensers in series with the load circuit L_1R_s . Complete discharge of the series bank of condensers takes place through the load circuit and the series parallel combination of isolating resistors in parallel. The charging circuit is non-conductive in the reverse direction as well as isolated by series resistance during this portion of the cycle.

The voltage across the gaps drops rapidly to zero in a time determined by the time constant of the load resistance and the series condenser combination. Deionisation of the gaps occurs at this zero voltage point restoring their high voltage breakdown characteristics. Deionisation of the gaps is also effected rapidly at this point because of the flat face shape of the spark gap electrodes. This flat face shape provides maximum surface from which a multiplicity of paths of electrons are capable of building-up rapidly once the gap arcs across, and since the electrode faces are flat, these arc paths may vary in location continuously back and forth thereacross. This prevents the electrodes developing high temperature spots which would tend to prolong the arc by establishment of a concentrated electron flow. In other words, by properly shaping the electrodes as illustrated schematically in Fig. 1 a maximum surface is provided for re-combination of the ions and since points of concentration are avoided blow-out action of the active ions is in effect provided. Consequently, a rapid recovery of the initial high breakdown voltage of the spark gaps is effected by the quick extinction of the arc by this spark gap construction.

The rate of discharge of the series combination of three condensers, is determined by their capacitance, the inductance of shaping coil L_1 and the resistance R_s of the load circuit. The rate of rise of the discharge pulse is determined by the value of inductance L_1 which may be conveniently made of such a value as to give desired output pulse rise-to-decay time ratios. The limitation on L_1 is then that it may not be larger than the critical value of the inductance for the damped discharge circuit. It is evident that with small values of L_1 , the total condenser voltage will be obtained across the output. As L_1 is increased, the output voltage decreases until for the critical damped case, 74% of the condenser voltage is obtained in the output.

The behavior of the circuit on discharge is determined by the following equations. The general expression for the load current for the damped case is:

$$i = \frac{Ee^{-\alpha t}}{L\beta} \sinh \beta t \text{-----amperes (1)}$$

where

$$\alpha = \frac{R}{2L}; \beta = \sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}$$

E =peak series condenser voltage; R =load resistance (R_s); L =inductance (L_1); and

$$C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

The width of wave-front, that is, rate of rise to maximum load current is given by:

$$t_{\max} = \frac{1}{\beta} \tanh^{-1} \left(\frac{\beta}{\alpha} \right) \text{-----seconds (2)}$$

and the maximum current is expressed by:

$$i_{\max} = \frac{E}{\omega_0 L} \left(\frac{\alpha + \beta}{\omega_0} \right) - \frac{\alpha}{\beta} \text{-----amperes (3)}$$

where

$$\omega_0^2 = \frac{1}{LC}$$

For the limiting case of critical damping, the current is:

$$i = \frac{E}{L} t e^{-\alpha t} \text{-----amperes (4)}$$

which gives for the maximum value

$$i_{\max} = 0.74 \frac{E}{R} \text{-----amperes (5)}$$

In Fig. 3, a sinusoidal wave 40 is shown in the form of an alternating current applied as the source of power to the terminals 15. The rectifier tubes 10 and 11 provide, in response to the alternating current, voltage pulsations 41 for successive positive half portions of the alternating current wave. These pulsations are applied to the condenser-resistance circuits R_1C_1 , $R_2C_2R_4$ and $R_3C_3R_5$. The wave 44 illustrates the charging of the condensers in response to the voltage pulsations 41. The condensers charge up to a point 45 at which the spark gap S_1 is adjusted to breakdown thereby causing a sharp voltage drop 46. The discharge of the condensers in series, represented by the voltage drop 46 produces a sharp voltage rise 47 (Fig. 4) across the output circuit the build-up and duration of which is controlled by the inductance L_1 , the resistance R_s and the series capacitance C . By proper choice of the values of these discharge parameters, the voltage impulse 48 is shaped so as to be applicable as a source of high voltage energy for pulse modulating purposes. The rapid deionisation of the spark gaps rendering them non-conductive after the drop 46 (Fig. 3) of the voltage across them below their extinction potential, insures the desired zero current interval between pulses and accordingly a high peak to average output current ratio. A typical output impulse 48 is shown in Fig. 4, having in this case a six microsecond duration. This is, of course, a very small fraction of the total time interval of 16,666 $\frac{2}{3}$ microseconds of a single cycle of 60-cycle alternating current such as commonly used.

Referring back to Fig. 3, it will be noted that the voltage pulsation 41 continues after the voltage drop 46, the amplitude of the pulsation, of course, decreasing thereafter. This portion of the pulsation 41 starts to re-charge the condensers C_1 , C_2 and C_3 and the re-charge is indicated by the level 49. Since the negative portions of the alternating current 40 are not rectified by the tubes 10 and 11, the voltage level 49 continues until the next positive portion of the alternating current wave occurs. The condensers are then charged as before until the spark gaps breakdown. The pulse output, when the gap firing is dependent upon the rising charge upon the condensers as described above, is semi-synchronous, that is, the firing time may vary slightly one way or another from a selected discharge point. Where true synchronized pulse output is desired, the generator is provided with a source of synchronizing pulses arranged to cause breakdown of the spark gaps at a selected point along a cycle of the alternating current wave. For ex-

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ternally synchronized operation, the gaps are so adjusted as to be non-conductive for the peak voltage normally attained by the condensers in response to a cycle of alternating current. At the proper time during the charging, as when the condensers have attained a desired voltage, a synchronizing voltage pulse having a steep wave-front and of short duration is applied over an input connection 54 across the resistor R₄. This pulse has such a polarity, in this case negative, as to increase the voltage across the spark gap S₁ beyond the breakdown value thereof thereby causing it to fire. The series discharge of the condensers which follow is as hereinbefore described. Such synchronizing voltage impulse may be applied, of course, at other points in the circuit so as to produce the required voltage rise across a spark gap.

In Fig. 2 a circuit similar to that of Fig. 1 is shown wherein the rectifier is a full wave rectifier comprising tubes 50 and 51 having the anodes 52 and 53 thereof connected across the secondary of a transformer 55. The cathodes of the tubes 50 and 51 are interconnecting and the output thereof is applied to one side of the resistor-condenser circuits R₁C₁, R₂C₂R₄ and R₃C₃R₅. The other sides of these circuits are connected by a connection 56 to ground and to a mid-tap on the secondary of the transformer 55.

This circuit (Fig. 2) operates in a manner similar to that of Fig. 1 with the exception that voltage pulsations 42 are provided for the negative portions of the alternating current wave 40 (Fig. 3). Thus, by using a full wave rectifier pulses are generated at twice the repetition rate of the generator of Fig. 1.

From the foregoing description, it will be clear that the generators of this invention provide for synchronous or semi-synchronous or random pulse output, as the case may be, and at a high repetition rate. By proper selection of circuit constants, such as the transformer 28 and the spacing of the spark gaps as controlled by the connection 27, a random or limited random pulse output may be obtained. The pulse produced has a duration which is maintained short, and the

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pulse is provided with a wave-front the steepness of which is controlled. In other words, the discharge of the generator is highly damped and gives strictly a single output pulse. The rapid deionisation of the spark gaps insures high damping discharge operation, and by proper selection of the time constants of the circuit the charging time of the condensers is maintained shorter than the repetition period of the pulses.

While we have shown and described two specific forms of apparatus to illustrate the principles of the invention, it will be understood that they are shown by way of illustration only and not as limiting the invention as set forth in the objects thereof and in the appended claims.

What is claimed is:

1. An electrical impulse generator comprising a circuit having a plurality of condensers connected in parallel, means including a plurality of spark gaps each disposed in series connection with respect to said condensers, means to supply energy to said condensers, means to control breakdown of said gaps to effect discharge of the energy stored in said condensers in series additive relation through said gaps to produce a large discharge impulse, an output load resistance, an inductance coil in series between said spark gaps and said output load resistance to control the rise-to-decay time ratio of the produced impulse.

2. The generator defined in claim 1 wherein the gap breakdown control means comprises means to control the spacing of the gaps.

3. The generator defined in claim 1 wherein the gap breakdown control means comprises means to control the spacing of the gaps and means to control the potential of the energy supplied to said condensers.

EMILE LABIN.

EVERT MANUEL OSTLUND.

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

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Number	Name	Date
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