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ELECTRIC TRIGGER CIRCUITS

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FIG. 1.

FIG. 2.

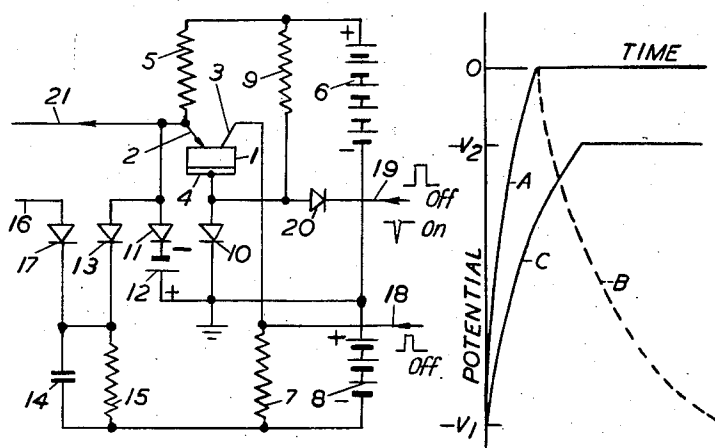
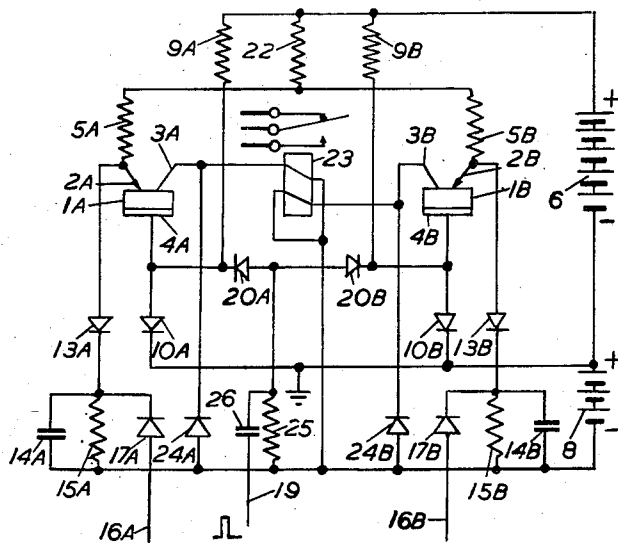


FIG. 3.



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ELECTRIC TRIGGER CIRCUITS

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The present invention relates to electric trigger circuits such as are used, for example, in electric counting arrangements, and for many other analogous purposes.

Such a trigger circuit frequently consists of a device such as a thermionic valve or gas-filled tube arranged to be capable of assuming two different current or voltage conditions, with means for triggering or switching the device from one condition to the other. Some trigger circuits are only stable in one condition, and revert automatically to that condition after having been triggered.

Semi-conductor amplifying devices known as crystal triodes have been developed in recent years, and have proved to be particularly suitable for use in trigger circuits, and it has been the usual practice hitherto to apply triggering pulses to the emitter or base electrode for triggering the device from one condition to the other. However, owing to the very low impedance presented to the triggering pulses by the emitter or base electrode circuits of a crystal triode when in the "on" or high-current condition, difficulties are sometimes experienced when it is desired to select or gate the triggering pulses, so that only certain desired pulses will have any effect.

The principal object of the invention, therefore, is to provide an improved crystal triode trigger circuit which is easily arranged to respond only to certain selected triggering pulses.

According to the present invention there is provided an electric two-condition trigger circuit comprising a crystal triode having emitter, collector and base electrodes, and associated circuit components so disposed that said crystal triode can assume either a high-current or a low-current condition, means for applying a control potential to said trigger circuit to switch said crystal triode from a low-current condition to a high-current condition, means for applying further control potential to said trigger circuit to switch said crystal triode from a high-current condition to a low-current condition, and further means for applying a control potential to said trigger circuit to prevent said crystal triode from being switched from a high-current condition to a low-current condition when said further potential is applied.

According to the present invention there is further provided an electric two-condition trigger circuit comprising two crystal triodes and associated circuit components coupled together in such a manner that each said crystal triode can assume either a high-current or a low-current condition and when either one of said crystal triodes assumes a high-current (or low-current) condition the other assumes a low current (or high-current) condition, means for applying a potential to said circuit to reverse the conditions of said crystal triodes and means for applying a control potential to said circuit to prevent said reversal when said reversing potential is applied.

According to the present invention there is yet further provided an electric two-condition trigger circuit comprising a crystal triode having emitter, collector and base electrodes, a first direct current source for polarising said emitter electrode positively to said base electrode through

a first load resistor, a second direct current source for polarising said collector electrode negatively to said base electrode, the two sources having a common terminal connected to said base electrode through a first rectifier so directed as to present a low resistance to a current flowing from said base electrode to said common terminal, a second load resistor connecting said base electrode to the first source, a second rectifier connected between said emitter electrode and a delay network consisting of a capacitor shunted by a third resistor, the end of said network remote from said second rectifier being connected to said second source and said second rectifier being so directed as to present a low resistance to a current flowing from said emitter electrode to said delay circuit, the arrangement being such that said crystal triode is in the "on" condition with emitter and collector currents flowing, means for applying a trigger pulse to said emitter or base electrode with such sign as to switch the crystal triode to the "off" condition, the time constant of said delay circuit being greater than the time constant corresponding to the change of potential of the leading edge of said pulse, and means for applying a control potential in such manner as to block said second rectifier for the purpose of effectively disconnecting said delay circuit from said emitter electrode, thereby preventing the crystal triode from being switched off by said pulse.

The invention will be described with reference to the accompanying drawing, in which:

Fig. 1 shows a schematic circuit diagram of an embodiment of the invention;

Fig. 2 shows graphs used to explain the operation of Fig. 1; and

Fig. 3 shows a schematic circuit diagram of another embodiment of the invention.

The two-condition trigger circuit shown in Fig. 1 comprises a crystal triode 1 having an emitter electrode 2, a collector electrode 3, and a base electrode 4, and it will be assumed that it employs an N-type semiconductor. The emitter electrode is shown with an arrow-head to distinguish it from the collector electrode. The emitter electrode 2 is connected through a resistor 5 to the positive terminal of a direct current source 6, and the collector electrode 3 is connected through a resistor 7 to the negative terminal of a direct current source 8. The negative terminal of source 6, and the positive terminal of source 8, are connected to ground, and these sources may, for example, provide operating potentials of 150 and 15 volts respectively. The base electrode 4 is connected to the positive terminal of the source 6 through a resistor 9, and to ground through a rectifier 10 directed so as to be blocked when the base electrode is negative to ground.

The emitter electrode 2 is connected through a rectifier 11 to the negative terminal of a grounded direct current source 12 supplying a small potential of the order of 3 volts, for example. The rectifier 11 is directed so that it will be blocked when the emitter electrode has a negative potential greater than that of the source 12. The emitter electrode 2 is further connected to the negative terminal of source 8 through a rectifier 13 and a reactive circuit consisting of a capacitor 14 and resistor 15 in parallel. A conductor 16, to which control potentials may be applied, is connected through a rectifier 17 to the junction point of elements 13, 14 and 15. Rectifiers 13 and 17 are directed in the same way as rectifier 11. An input conductor 18, to which triggering pulses may be applied, is connected to the collector electrode 3. A second input conductor 19 for triggering pulses is connected through a rectifier 20 to the base electrode 4. Rectifier 20 is directed so that it will pass negative pulses to the base electrode. An output conductor 21 is connected to the emitter electrode.

The crystal triode 1 should be of the type having a

current gain greater than 1. Let it be first assumed that the crystal triode is in the "off" or blocked condition. The emitter current is substantially zero, so that the potential of the emitter electrode 2 will be held at the negative potential of the source 12 on account of the unblocking of the rectifier 11 by the current from source 6 through the resistor 5. The collector current will also be substantially zero, and the base electrode 4 will be held at ground potential owing to the unblocking of the rectifier 10 by the current from source 6 through the resistor 9. If now a short negative triggering pulse, of amplitude exceeding the potential of the source 12, be applied to the base electrode 4 over conductor 19 and rectifier 20, the emitter contact is unblocked, and emitter current starts to flow. This turns on some collector current which flows from source 6 through resistor 9 and the base electrode 4 and through the collector contact and resistor 7 to the source 8. The potential drop in the resistor 9 causes the potential of the base electrode 4 to fall, thereby increasing the emitter current which in turn increases the collector current still further, and the potential of the emitter electrode 2 also starts to fall owing to the increased potential drop in the resistor 5.

This effect is cumulative, and the base and emitter potentials continue to fall rapidly owing to the continually increasing potential drops in resistors 5 and 9, until the three electrodes 2, 3 and 4 finally settle down at potentials not differing very much from that of source 8, if the resistor 7 is not very large (say a few hundred ohms). Thus the crystal triode quickly assumes the "on" condition. It will be understood, however, that in this fully "on" condition, the emitter electrode 2 will be slightly positive to the base electrode 4, which will be slightly positive to the collector electrode 3. As soon as the potentials of the emitter and base electrodes 2 and 4 begin to fall immediately after triggering, both the rectifiers 11 and 10 will be blocked and will remain so while the crystal triode is in the "on" condition.

Assuming that no potential is applied to the conductor 16, the rectifier 13 will be just unblocked when the crystal triode is "off," because the emitter potential is more positive than the source 8; and the capacitor 14 will be charged substantially to this potential difference. As soon as the potential of the emitter electrode begins to fall after the triggering pulse is applied to the base electrode 4, the rectifier 13 will block because the capacitor 14 will not have had time to discharge appreciably through the resistor 15, so the elements 14 and 15 can have substantially no effect on the triggering of the crystal triode from "off" to "on." When the crystal triode has finally assumed the "on" condition, the capacitor 14 discharges through the resistor 15, and the rectifier 13 will be unblocked again. The elements 14 and 15 are, however, essential for controlling the triggering in the opposite direction from "on" to "off" as will now be explained.

The crystal triode is triggered "off" by applying a positive pulse to the collector electrode 3 over conductor 18. This pulse should be of sufficient amplitude to raise the potential of the collector electrode a little above ground potential. This will cut off the collector current and, because of the reduction in the potential drop through resistor 9, the potential of the base electrode will be raised quickly to ground potential where it will be held by the rectifier 10. At the same time, because the emitter current is also cut off, the potential of the emitter electrode will be drawn towards ground potential, but the potential rise will be retarded by the charging of the capacitor 14 through the resistor 5 and unblocked rectifier 13, so that this potential rise will lag behind the potential rise of the leading edge of the triggering pulse, assuming that no control potential is applied to conductor 16. This effect will be understood from Fig. 2 in which the abscissae represent times and the ordinates represent voltages.

The triggering pulse is supposed to begin to be applied

at zero time, and curve A represents the resulting change of potential of the base electrode, and also substantially represents the leading edge of the triggering pulse. Curve A will usually be of logarithmic form, with an equivalent time-constant T_1 which will generally be very small.

The dotted curve B represents the trailing edge of the triggering pulse, which will generally have a rather larger equivalent time constant. Curve C shows the logarithmic change of potential of the emitter electrode 2, the time constant of which is T_2 , which is greater than T_1 . Curves A and C start at $-V_1$ at zero time, V_1 being slightly less than the potential of the source 8 (Fig. 1). Curve A rises to zero potential and then follows the time axis, on account of the rectifier 10. Curve B rises to a potential $-V_2$, which is determined by the source 12, and then follows a line parallel to the time axis. It will be seen that so long as curve C is always below curve A, the crystal triode will be in the "off" condition because the emitter electrode will then always be negative to the base electrode. When the triggering pulse has disappeared, the crystal triode is left in the "off" condition with the base electrode held at zero potential and the emitter electrode held at $-V_2$. If the circuit 14, 15 (Fig. 1) were disconnected, the emitter potential would substantially follow the leading edge of the pulse and the crystal triode would not be cut off, and would be left in the "on" condition after the disappearance of the pulse.

Thus if it is desired to prevent the crystal triode from being triggered "off" by one or more of the pulses arriving over conductor 18, a zero or small positive control potential is applied to conductor 16. This causes rectifier 17 to conduct and so blocks the rectifier 13, thus effectively disconnecting the elements 14, 15 from the emitter electrode 2. The potential of the emitter electrode can now rise as quickly as the leading edge of the triggering pulse (curve A, Fig. 2) and the crystal triode is thus prevented from being switched "off" by any triggering pulse which arrives during the period when the control potential is applied to conductor 16.

Evidently one or more additional control conductors (not shown) may be connected through rectifiers (also not shown) corresponding to 17, and a control potential applied to any one of these additional conductors will prevent the triggering of the crystal triode.

When the crystal triode has been triggered "off" it can be switched "on" again by a negative pulse applied over conductor 19. In this case the emitter current will be reestablished as soon as the base potential falls below $-V_2$, and the potential of all the electrodes then falls to $-V_1$. In the absence of a control potential on conductor 16, the capacitor 14 can now discharge through the resistor 15, and when it is fully discharged, the circuit may be triggered "off" again, as before.

It will be noted that when the crystal triode 1 is "off," the base electrode 4 presents a high impedance to negative pulses applied over conductor 19 until the crystal triode is actually switched. It is therefore quite satisfactory to supply the negative pulses to conductor 19 through a conventional simple gating circuit (not shown) employing rectifiers, if it is desired to select certain of them for triggering the crystal triode "on."

It should be pointed out that if the rectifier 20 be reversed, it is possible to apply positive triggering pulses over conductor 19 to switch the crystal triode from "on" to "off." Since in the "on" condition the base electrode presents a low impedance to the positive pulses, it is not very satisfactory to supply them through a gating circuit, but the triggering pulses can be selected by means of a control potential supplied over conductor 16 as already described.

The changes of the emitter potential which occur when the crystal triode is switched from "on" to "off" or from "off" to "on" are applied to the output conductor 21 and can be used for some desired operation. Alternatively,

the output could be taken from the base electrode or from the collector electrode.

Fig. 3 shows a pair of trigger circuits similar to Fig. 1 interconnected to form a double stable multivibrator or flip-flop circuit arranged to be triggered by pulses from one condition to the other, either way. It comprises two crystal triodes 1A and 1B each of which is provided with circuit elements corresponding to those of Fig. 1, such elements being designated by the same numerals as in Fig. 1, but with the letter A or B added. There are no elements corresponding to 7, 11, 12, 18 or 21 of Fig. 1. The rectifiers 20A and 20B correspond to rectifier 20 but are oppositely directed. There are some additional elements which do not correspond to anything in Fig. 1. A single resistor 22 is inserted between the junction point of the resistors 5A and 5B and the positive terminal of the source 6, and a polar relay 23 has its two equal windings connected respectively between the collector electrodes 3A and 3B and the negative terminal of the source 8. These windings are also respectively shunted by two rectifiers 24A and 24B directed so that the collector electrodes cannot acquire a negative potential greater than that of the source 8. The windings of the relay 23 are so connected to the collector electrodes that the moving contact will be operated to the position shown when the crystal triode 1A is "on," and to the opposite position when crystal triode 1B is "on." This relay is provided as a convenient means for utilising the operations of the circuit, and its contacts may be connected to some other circuit or device (not shown) in any desired manner.

The rectifiers 20A and 20B are connected through a resistor 25 to the negative terminal of the source 8, and the triggering conductor 19 (only one is required) is connected to the rectifiers through a blocking capacitor 26.

Let it be assumed that the crystal triode 1A is "on" and that 1B is "off." As already explained with reference to Fig. 1, the electrodes 2A, 3A and 4A will all be at potentials near $-V_1$ (about -15 volts), and there will be a moderate collector current. The value of the resistor 22 is so chosen that in this condition the emitter electrode 2B is at a potential $-V_2$ (about -3 volts). The base electrode 4B will be held at ground potential by the rectifier 10B and there will be practically no current from the collector electrode 3B. The relay 23 will accordingly have a larger current in the winding connected to the collector electrode 3A than in the other winding, and the moving contact will be operated to the position shown. Suppose now a positive triggering pulse arrives over conductor 19. It can have no effect on the crystal triode 1B because the base electrode is held at ground potential by the rectifier 10B thus blocking rectifier 20B, the other terminal of which is polarised at about $-V_1$ through resistor 25. Rectifier 20A will, however, be unblocked and so the pulse will trigger the crystal triode 1A "off" as a result of the action of the elements 14A, 15A for the reasons already explained with reference to Fig. 1. Since the emitter current is cut off, the potential of the junction point of elements 5A, 5B and 22 suddenly becomes positive and causes the potential of the emitter electrode 2B to rise until the crystal triode 1B becomes unblocked and is accordingly switched "on." The rise of the potential of the emitter electrode 2B will, of course, be delayed by the elements 14B and 15B since the rectifier 13B will be unblocked. When the crystal triode 1B is unblocked, the potentials of all its electrodes will fall practically to $-V_1$, as already explained. The emitter electrode 2A of crystal triode 1A (which is "off") will now be at a potential of $-V_2$. Thus the condition of the circuit has been reversed by the triggering pulse, and the relay 23 will be changed over.

If now another positive triggering pulse be applied over conductor 19, the circuit will be triggered back again to the original condition in which crystal triode 1A is "on" and 1B is "off." Every successive triggering

pulse will reverse the condition of the circuit, and the contacts of the relay 23 may be connected, for example, to provide an output when the circuit is switched one way but not when it is switched the other way, so that it acts as a divider circuit dividing by 2. It will be evident from the explanation given with reference to Fig. 1, that any triggering pulse applied over conductor 19 may be prevented from triggering one of the crystal triodes 1A or 1B "off," and thus from reversing the condition of the circuit by applying a positive or zero control potential to conductor 16A or 16B, respectively.

It will be understood that the relay 23 has been shown only to give one example of the means whereby the reversal of the circuit may be caused to carry out some operation; and since changes occur in the potentials of all the electrodes when either crystal triode is switched "on" or "off," output can be taken in some suitable way (not shown) from any of the electrodes.

It has been assumed above that the crystal triodes employed in the embodiments which have been described are of the type requiring the emitter and collector electrodes to be polarised positively, and negatively, respectively, to the base electrode when operating as an amplifier. The opposite kind of crystal triodes could alternatively be used, in which case the current sources and rectifiers should all be reversed, and triggering pulses of the opposite sign to those specified above should be used.

While the principles of the invention have been described above in connection with specific embodiments, and particular modifications thereof, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of the invention.

What I claim is:

1. An electric two condition trigger circuit comprising a crystal triode having emitter, collector and base electrodes, and associated circuit components so disposed that said crystal triode can assume either a high-current or a low-current condition, a first input conductor, means connecting said first input conductor to said base electrode, means including a diode rectifier for applying a control pulse to said first input conductor to switch said crystal triode from a low-current condition to a high-current condition, a second input conductor, means connecting said second input conductor to said collector electrode, means for applying further control potential to said second input conductor to switch said crystal triode from a high-current condition to a low-current condition, a third input conductor, means connecting said third input conductor to said emitter electrode and further means for applying a control potential to said third input conductor to prevent said crystal triode from being switched from a high-current condition to a low-current condition when said further potential is applied.

2. An electric two-condition trigger circuit comprising a crystal triode having emitter, collector and base electrodes, a first direct current source for polarising said emitter electrode positively to said base electrode through a first load resistor, a second direct current source for polarising said collector electrode negatively to said base electrode, the two sources having a common terminal connected to said base electrode through a first rectifier so directed as to present a low resistance to a current flowing from said base electrode to said common terminal, a second load resistor connecting said base electrode to the first source, a second rectifier connected between said emitter electrode and a delay network consisting of a capacitor shunted by a third resistor, the end of said network remote from said second rectifier being connected to said second source and said second rectifier being so directed as to present a low resistance to a current flowing from said emitter electrode to said delay circuit, the arrangement being such that said crystal triode is in the "on" condition with emitter and collector currents flowing, means for applying a trigger pulse to

said emitter with such sign as to switch the crystal triode to the "off" condition, the time constant of said delay circuit being greater than the time constant corresponding to the change of potential of the leading edge of said pulse, and means for applying a control potential in such manner as to block said second rectifier for the purpose of effectively disconnecting said delay circuit from said emitter electrode, thereby preventing the crystal triode from being switched "off" by said pulse.

3. A trigger circuit according to claim 2 comprising means for applying a negative restoring pulse to the base electrode for switching the crystal triode back to the "on" condition.

4. A trigger circuit according to claim 2 comprising a third direct current source of potential less than said second source and having its positive terminal connected to said common terminal and its negative terminal connected to the emitter electrode through a third rectifier so connected as to prevent the potential of the emitter electrode from rising above that of the third source.

5. A trigger circuit according to claim 2, comprising means for deriving an output signal from the emitter electrode in response to the switching of said crystal triode by said trigger or restoring pulse.

6. A trigger circuit as claimed in claim 4 and wherein a fourth resistor is inserted between said collector electrode and said second source and means are provided for

applying a positive triggering pulse to said collector electrode to switch said crystal triode to its "off" condition.

7. An electric two-condition flip-flop circuit comprising two trigger circuits according to claim 2 which share in common the said first and second direct current sources, in which the said first load resistors of the two trigger circuits are connected to the first direct current source through a fifth resistor through which the emitter currents of both crystal triodes flow, whereby the two trigger circuits are coupled in such manner that when one crystal triode is switched "off," the other is switched "on," and in which an input lead is provided for applying positive trigger pulses simultaneously to both base electrodes and in which the collector electrodes of the two crystal triodes are connected to the second direct current source respectively through two equal windings of a polar relay, the connections being such that the relay is changed over when the conditions of the two crystal triodes are interchanged by a trigger pulse.

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