March 30, 1948. L. L. LAKATOS 2,438,638

PULSE TO RECTANGULAR WAVE CONVERTER

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Fig. 1.

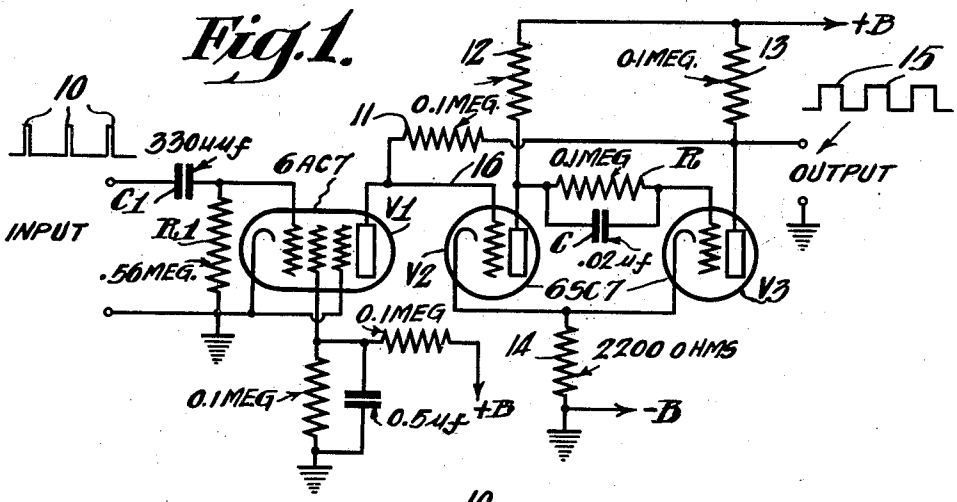


Fig. 2.

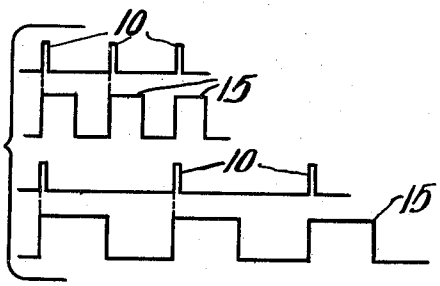


Fig. 3.

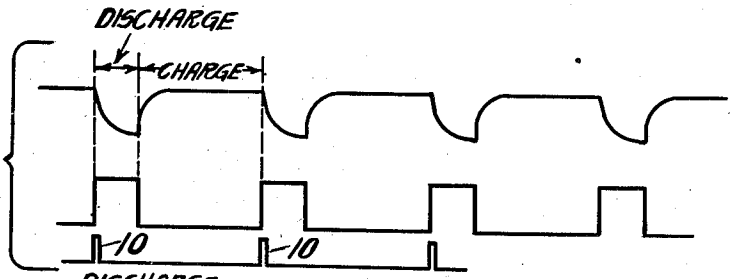
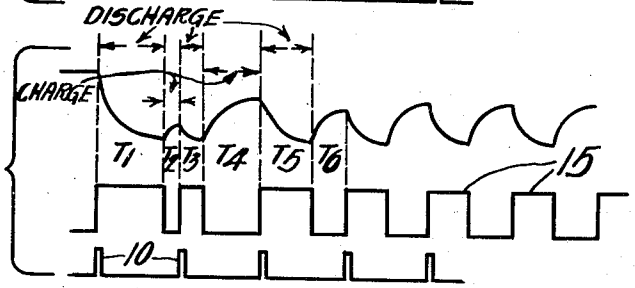


Fig. 4.



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Fig. 5.

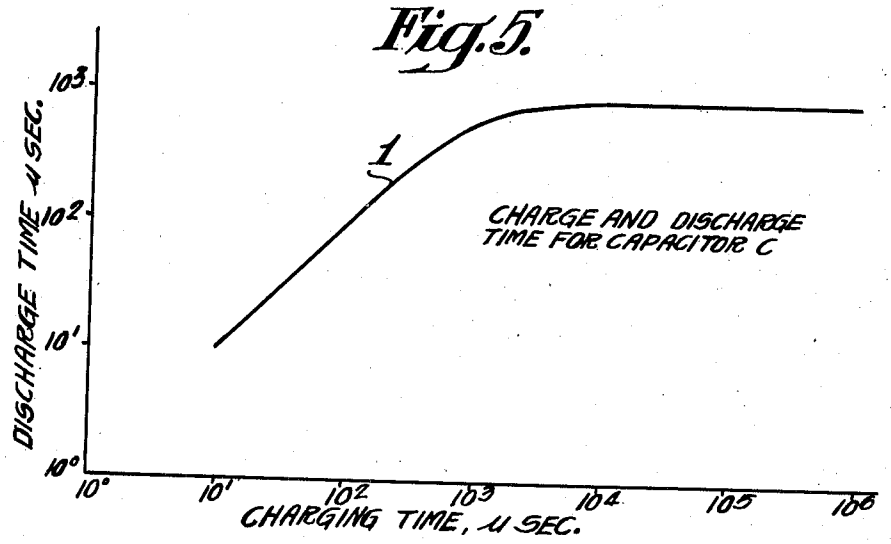
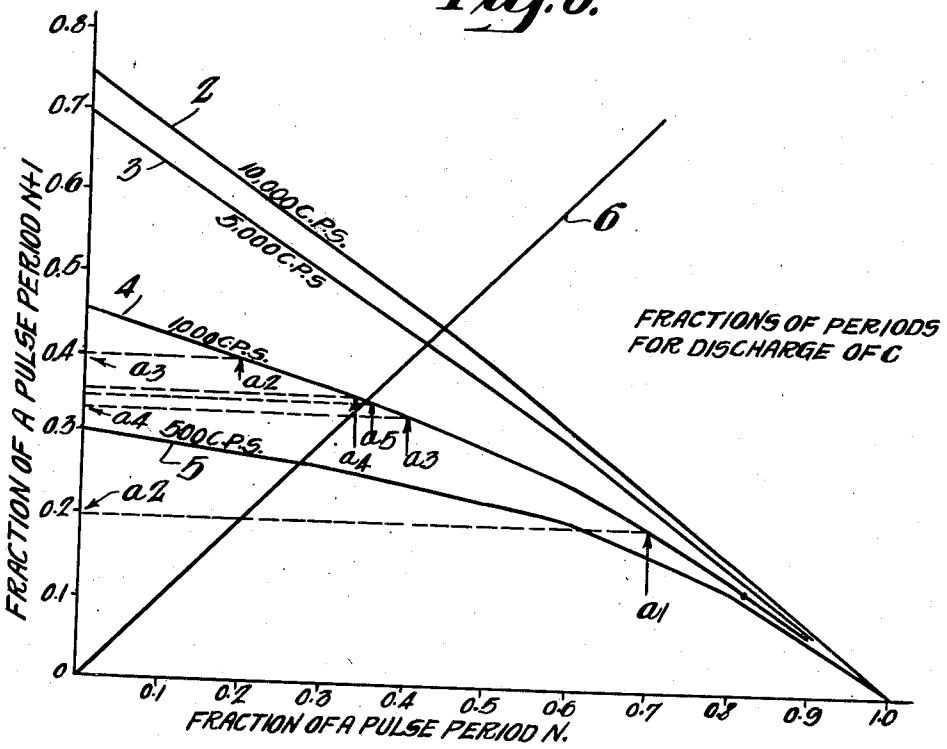


Fig. 6.



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PULSE TO RECTANGULAR WAVE CONVERTER

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9 Claims. (Cl. 250—27)

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My invention relates to apparatus for utilizing or for indicating the reception of electrical pulses of short duration which recur at different repetition rates and particularly to apparatus which is effective to increase the energy content of such pulses.

The invention is useful in pulse-echo recognition systems, for example, where the received pulses are of only a few micro-seconds duration and where their repetition rate may be any one of a large number of preassigned repetition rates. One of the problems in designing such equipment is to obtain an output signal from the receiver which contains sufficient energy at the repetition rate of the received pulses to operate the associated equipment such as a decoder and/or a recorder or to obtain a strong audible signal.

An object of the invention is to provide an improved method of and means for converting periodic short electrical pulses into a corresponding periodic signal of increased energy content.

A further object of the invention is to provide improved apparatus for converting short electrical pulses recurring at a certain frequency into an approximately square wave signal having the same fundamental frequency as said repetition frequency and of increased energy content at this frequency.

In a preferred embodiment of the invention the short electrical pulses are supplied through an amplifier to a relaxation circuit comprising a pair of tubes which are direct-current connected plate-to-grid in multivibrator fashion and which block and unblock alternately. One of the plate-to-grid connections includes a coupling capacitor shunted by a resistor, the capacitor and resistor having a suitable time constant to permit partial charge of the capacitor between successive received pulses. In the absence of received pulses, the coupling capacitor has a direct-current charge thereon, having been charged by a flow of grid current. The other plate-to-grid connection includes a resistor only. Upon reception of the first short pulse, the first tube is unblocked and the second tube is blocked and held blocked by the coupling capacitor for a short time. Meanwhile, the coupling capacitor discharges until the second tube is unblocked at which time the first tube is again blocked. Meanwhile the coupling capacitor receives an additional charge. Upon reception of the next short pulse the cycle of operation is repeated.

The periods available for charge and discharge of the coupling capacitor are interdependent and, as a result, after a few cycles of operation

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the two periods are approximately equal whereby a substantially square wave is produced within the operating range of the apparatus regardless of the repetition rate of the received pulses. The circuit constants are such that the relaxation circuit always goes through one full cycle of operation between successive received pulses.

The invention will be better understood from the following description taken in connection with the accompanying drawing in which

Figure 1 is a circuit diagram of a preferred embodiment of the invention,

Figure 2 is a group of graphs illustrating the results obtained with the apparatus of Fig. 1,

Figure 3 is a group of graphs that are referred to in explaining the operation of the invention,

Figure 4 is a group of graphs illustrating the operation of the circuit of Fig. 1 for the first few cycles when it is functioning according to the invention, and

Figures 5 and 6 are graphs that are referred to in explaining the invention.

Referring to Fig. 1, the short received pulses indicated at 10 are supplied through a vacuum tube V1 to a relaxation circuit comprising a pair of vacuum tubes V2 and V3. In this particular embodiment of the invention the pulses 10 are applied to the tube V1 with positive polarity and each pulse is immediately followed by a short negative pulse due to the grid-leak biasing action of the grid capacitor C1 and the grid-leak resistor R1 in the input circuit of tube V1. This negative pulse, which appears reversed in polarity at the anode of the tube V1, is the pulse that triggers the relaxation circuit V2—V3. This method of applying triggering pulses to the circuit V2—V3 is not an essential feature of the invention but it has certain advantages and will be discussed in detail hereinafter.

Referring more particularly to the circuit comprising the tubes V2 and V3, the anode of tube V2 is connected to the grid of tube V3 through a capacitor C which is shunted by a resistor R. The anode of tube V3 is connected to the grid of tube V2 through a resistor 11. Operating voltage is supplied to the anodes of tubes V2 and V3 through anode resistors 12 and 13, respectively. The cathodes of tubes V2 and V3 are connected to ground through a common cathode biasing resistor 14.

The short triggering pulses appearing on the anode of the tube V1 are impressed upon the grid of the tube V2 through a direct-current connection 16. Operating voltage is applied to the anode

of the tube V1 through the anode resistor 13, and the coupling resistor 11.

In the absence of incoming pulses 10, the relative voltage drops in anode resistor 13 and coupling resistor 11 and in cathode resistor 14 will be such that the grid of tube V2 will be sufficiently negative with respect to its associated cathode to block the tube V2. The anode of tube V2 is now at its maximum positive potential and the tube V3 is conducting since the RC coupling holds its grid positive with respect to its cathode. The capacitor C has a D.-C. charge because of the grid current flow in the tube V3.

Upon the reception of a positive pulse 10, the grid of tube V1 draws current and the small grid capacitor C1 is charged. At the end of pulse 10, capacitor C1 discharges through the grid resistor R1 to put a short negative pulse on the grid of tube V1, thus making the plate of tube V1 go more positive to apply a positive pulse to the grid of tube V2. This makes tube V2 conducting, its anode goes less positive whereby the grid of tube V3 goes less positive and the anode of tube V3 is made more positive. This change in the anode voltage of tube V3 is fed back to the grid of tube V2 through the coupling resistor 11. By this regenerative action the tube V3 is almost instantly driven to anode current cut-off and it is held in this condition by the charge on coupling capacitor C until the charge has leaked off through resistor R sufficiently to permit the tube V3 again to conduct anode current, at which time the reverse action takes place whereby the tube V2 is driven to cut-off and is held at cut-off by the anode current and the grid current of the tube V3 flowing through the cathode resistor 14. Meanwhile the flow of grid current in tube V3 applies an additional charge to capacitor C. When the next pulse 10 occurs, the tube V2 is again unblocked and the cycle of operation repeats.

The discharge and charge periods for successive cycles of operation are unlike and changing in duration for several pulse periods or cycles as illustrated in Fig. 4. During the first cycle the discharge period T_1 is long compared with the charging period T_2, but during the second cycle the discharge period T_3 is short compared with the charging period T_4. During the third cycle the discharge period T_5 again is longer than the charging period T_6 but it will be noted that by this time the two periods are more nearly equal. After about five cycles, for example, the discharge and charge periods are of substantially constant duration and are so nearly equal that the wave form of the output wave 15 is fairly close to the of a symmetrical square wave. Within the operating range of the equipment, this action takes place regardless of the repetition rate of the received pulses 10. This fact is illustrated in Fig. 2 where two groups of pulses 10 are shown as occurring at two different rates. However, the output wave 15 is approximately a symmetrical square wave in each instance, and each square wave has the same repetition rate as that of the pulses 10 being applied to the circuit.

It may be noted that with apparatus having given circuit constants, if the repetition rate of the received pulses 10 is too low, the apparatus will not function as described above and as illustrated in Fig. 4. Instead, it will operate as shown in Fig. 3 because the coupling capacitor C will have time to acquire a full charge before the second received pulse 10 occurs. More specifically, if the pulse period is too long, as is assumed in Fig. 3, the discharge time for capacitor C is substantially constant whereas if the pulse period is shorter, as is assumed in Figs. 2 and 4, the discharge time for capacitor C is a function of the charging time of capacitor C and the apparatus will function as desired.

The reason that my circuit operates as illustrated in Figs. 2 and 4 may be seen more clearly by referring to the graphs of Figs. 5 and 6. The graph 1 in Fig. 5 shows the discharge time of the coupling capacitor C plotted against its charging time. As here used, discharge time means the time following an input pulse which is required to discharge capacitor C to a potential which will permit the two tubes V2 and V3 to switch; while the charging time refers to the time from the switching point to the next impulse, during which capacitor C charges.

Referring to the graph of Fig. 5, it will be noted that if the charging time for capacitor C is greater than 10^4 micro-seconds, the discharge time is substantially constant; but if the charging time is less than 10^3 micro-seconds, the discharge time is almost a linear function of the charging time. It is in or near the latter region of the graph that my invention applies.

Referring now to Fig. 6, the graphs 2, 3, 4 and 5 are for different repetition rates of the received pulses 10 and they are plotted for a circuit having the constants indicated in Fig. 1. In Fig. 1 the capacity and resistance values, given by way of example, are indicated in microfarads, micro-microfarads, ohms and megohms. The abscissas and ordinates are fractions of a pulse period, i. e., fractions of one period of pulses 10. Each of the graphs shows (by its ordinate values) the fraction of a certain pulse period $N+1$ required for the discharge time of capacitor C when in the preceding pulse period N the fraction of the period N required for the discharge time of capacitor C is a certain value (abscissa values). For example, assume any value between 0 and 1 for this fraction of period N, say the value $a1=0.7$, and assume that the repetition rate is 1000 cycles per second. The fraction of the next cycle or period $N+1$ required for discharge of capacitor C is indicated on the graph 4 by the arrow at the right, this ordinate value being $a2=0.19$. Now taking $a2$ as the abscissa value, it will be seen that for the next period, the friction of the period required for discharge of capacitor C is $a3=0.4$. Similarly, for the next period the fraction $a4$ is 0.35. It is apparent that the fractions $a1$, $a2$, etc. for successive pulse periods oscillate about and converge to the intersection of the graph 4 and the 45 degree line 6 representing equal discharge periods for successive pulse periods.

It will be seen that the discharge period is substantially constant for successive pulse periods after about the fifth pulse period and that the convergence to a fixed value holds for graphs 2, 3 and 5 as well as for graph 4. It may be noted that at the higher pulse rates, this fixed value is closer to 0.5 (the fraction for a perfectly symmetrical square wave) than at the lower pulse rates. By a suitable selection of circuit constants, a wide range of frequencies can be covered. For example, over a frequency range of 500 c. p. s. to 15,000 c. p. s., a range of 1 to 30, the positive half cycles of the wave 15 have the following percentages of a full half cycle:—500 c. p. s.—56 percent; 1000 c. p . s.—70 percent; 5000 c. p. s.—80 percent; 10,000 c. p. s.—88 percent; 15,000 c. p. s.—90 percent.

As previously stated, it is not necessary to

utilize the grid-leak biasing action at the input circuit of the tube V1 for triggering the relaxation circuit V2—V3. For example, the tube V1 may be operated as a class A amplifier drawing no grid current, in which case the received pulses 10 are applied thereto with negative polarity. The arrangement illustrated and previously described is preferred, however, as it is a simple way of making certain that the triggering pulse which appears on the grid of the tube V2 is of sufficient duration to give the circuit V2—V3 time to switch to the alternate condition of tube blocking. It will be understood that by selecting properly the values of C1 and R1, the negative pulse immediately following a positive pulse 10 may be given a width or duration greater than that of the pulse 10.

It has been found that for best operation of the specific circuit described the amplitude of the input pulses should be limited to values between 3 volts and 15 volts positive. While specific circuit values have been given by way of example, the values are not critical and may, for instance, be changed individually by plus or minus 50 percent with little change in operation. The +B voltage may be from 150 volts to 250 volts, for example.

Mention may be made of the fact that if the tube V1 is omitted from the circuit, the remaining circuit comprising tubes V2 and V3 will oscillate as a multivibrator with the frequency of oscillation determined largely by the time constant of the circuit RC.

The complete circuit comprising tubes V1, V2, and V3 may be utilized as an electronic frequency meter by measuring the alternating current voltage appearing across the capacitor C. This A.-C. voltage is a function of the repetition of the applied pulses and is substantially independent of the amplitude and of the wave form of the input wave within the limits of circuit operation. The peak value of the said A.-C. voltage decreases as the frequency of the input signal decreases.

I claim as my invention:

1. The method of operating a pair of cross-connected tubes wherein one of the cross-connections consists of a capacitor shunted by a resistor and wherein the time constant for both charge and discharge of said capacitor is long compared with the period between successive applied pulses, said method comprising applying regularly recurring short electrical pulses to said pair of tubes and initiating the discharge of said capacitor in response to the occurrence of a short pulse, causing said capacitor to charge partially in response to said capacitor discharging to a predetermined voltage value, and again initiating the discharge of said capacitor by the next succeeding short pulse while said capacitor is only partially charged whereby said charge and discharge periods tend to become equal after a few cycles of operation.

2. Apparatus for converting periodically recurring short electrical pulses into pulses of longer duration recurring at the same rate as the short pulses, said apparatus comprising a pair of amplifier tubes having cathodes and having anodes and grids which are direct-current cross-connected, one of said connections including a series capacitor shunted by a resistor, the other of said connections being substantially purely resistive, and a cathode resistor common to said tubes, the time constant of said series capacitor and shunting resistor being long compared with the period between successive short pulses.

3. In combination a pair of vacuum tubes each having a cathode, a grid and an anode, a cathode resistor common to said tubes, a coupling capacitor shunted by a resistor connected between the anode of one tube and the grid of the other tube, a coupling resistor only connected between the anode of said other tube and the grid of said one tube, and means for applying short periodically recurring pulses of positive polarity to the grid of said one tube, the time constant of the charging circuit for said coupling capacitor being substantially greater than the period of said recurring pulses.

4. In combination a pair of vacuum tubes each having a cathode, a grid and an anode, an anode resistor for each tube through which a direct-current voltage is applied to its anode, a cathode resistor common to said tubes, a coupling capacitor shunted by a resistor connected between the anode of one tube and the grid of the other tube, and a coupling resistor only connected between the anode of said other tube and the grid of said one tube, and means for applying short periodically recurring pulses of positive polarity to the grid of said one tube, the time constants of the charging circuit and of the discharge circuit for said coupling capacitor being substantially greater than the period of said recurring pulses.

5. In apparatus responsive to periodically recurring electrical signals, a pair of amplifier tubes each having an anode and a grid, said tubes having direct current connections from the anode of one tube to the grid of the other tube, the said connections from the anode of one tube including a series capacitor shunted by a resistor, the said connection from the anode of the other tube being substantially purely resistive and the time constant of said series capacitor and shunting resistor being long compared with the period between said successive electrical signals, means for maintaining said one tube biased substantially to cut-off in the absence of a signal voltage on its grid, and means for applying said electrical signals to the grid of said one tube.

6. Apparatus for converting periodically recurring short electrical pulses into pulses of longer duration recurring at the same rate as the short pulses, said apparatus comprising a pair of amplifier tubes each having an anode and a grid, said tubes having direct-current connections from the anode of one tube to the grid of the other tube, the said connection from the anode of one tube including a series capacitor shunted by a resistor, the said connection from the anode of the other tube being substantially purely resistive and the time constant of said series capacitor and shunting resistor being long compared with the period between said successive short pulses, means for maintaining said one tube biased substantially to cut-off in the absence of a signal voltage on its grid, and means for applying said short electrical pulses with positive polarity to the grid of said one tube.

7. In apparatus responsive to periodically recurring electrical signals, a pair of amplifier tubes each having an anode and a grid, said tubes having direct current connections from the anode of one tube to the grid of the other tube, the said connection from the anode of one tube including a series capacitor shunted by a resistor, the said connection from the anode of the other tube being substantially purely resistive and the time constant of said series capacitor and shunting resistor being long compared with the period between said successive electrical signals, means

for maintaining said one tube biased substantially to cut-off in the absence of a signal voltage on its grid, and means for applying said short electrical pulses to the grid of said one tube whereby there appears across said series capacitor an alternating current voltage having a peak value that decreases as the repetition rate of the electrical signals increases.

8. The invention according to claim 3 wherein said means for applying short pulses includes an amplifier tube having an output electrode that is direct-current connected to the grid of said one tube.

9. The invention according to claim 5 wherein said means for maintaining said one tube biased substantially to cut-off in the absence of a signal voltage on its grid includes an amplifier tube having an anode that is direct-current connected to the grid of said one tube.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,262,838	Deloraine et al.	Nov. 18, 1941

FOREIGN PATENTS

Number	Country	Date
356,111	Great Britain	Aug. 24, 1931
456,840	Great Britain	Nov. 12, 1936