DUAL-TRIODE Trigger Circuits

Non-mathematical step-by-step description of the operation of the Eccles-Jordan trigger circuit, with practical suggestions for making the circuit distinguish between positive and negative pulses, and other helpful design data

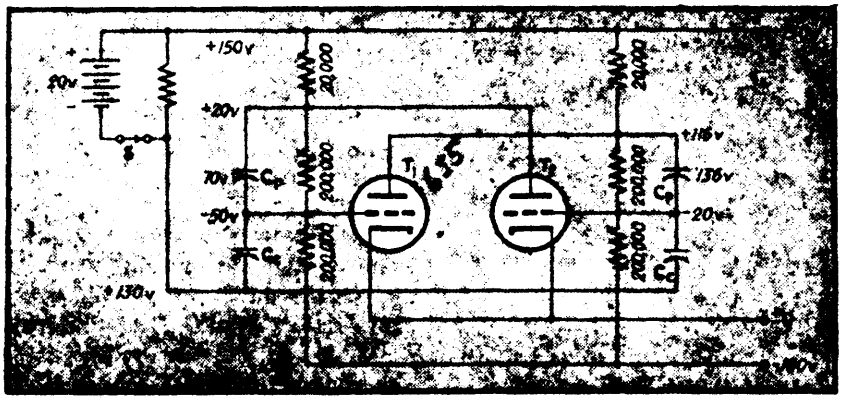

FIG. 1—The basic Eccles-Jordan trigger circuit

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THIS PAPER is an attempt to give a graphical analysis of dual-triode trigger operation. It is hoped that it will clear up several points that apparently have not been too well understood, in particular the very vital function of the grid-to-plate capacitor (C_p in attached sketches) and the ability of the Eccles-Jordan type of triode trigger circuit to distinguish between positive and negative pulses if properly designed.

The dual-triode trigger described here is a device using two triode tubes so interconnected that one tube is normally conducting while the other is non-conducting. A suitable impulse applied at the proper points causes the first tube to become non-conducting and the other to conduct. A second impulse restores the original condition. This cycle may be repeated at will at any speed from zero up to speeds in the low radio-frequency range or even higher, depending on the circuit constants used.

The trigger may be used as a locking circuit, somewhat as a gaseous tube is used. Where it is so used, the circuit may be turned off as fast as it can be turned on, and very little energy is required to make it perform either function. Since two impulses are required to provide a complete trigger cycle, ie., to turn any one tube on and then off, the trigger can also be arranged to give one output impulse for every two input impulses and thus act as a frequency divider.

Basic Principle

Figure 1 shows the basic Eccles-Jordan trigger circuit. The two triodes T_1 and T_2 are so connected that the plate of each controls the grid of the other in such a manner that only one tube can conduct (on)

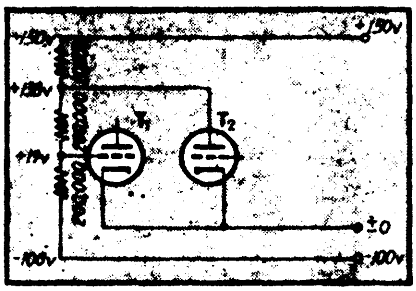

FIG. 2—Assuming that both tubes are initially non-conducting, application of voltage to the resistor network makes the grid of T_1 positive with respect to its cathode and this tube conducts

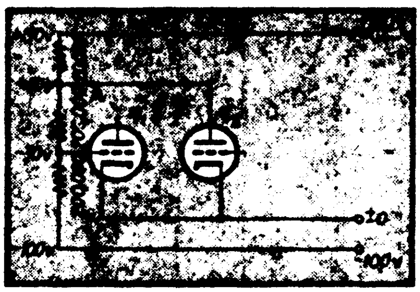

FIG. 3—When tube T_2 is conducting, tube T_1 is negatively biased and does not conduct. The plate of tube T_2 drops to +40 volts and point A is held at that potential during this part of the operating cycle

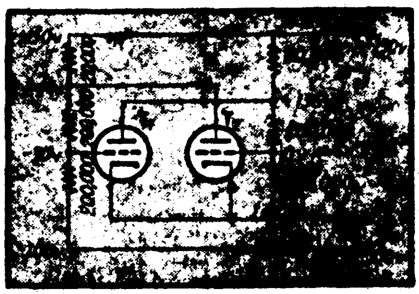

FIG. 4—The use of two resistor networks enables tube T_1 to control tube T_2 in a manner similar the way in which T_2 controls T_1 in Fig. 3. Voltages shown here are those applying when T_1 is conducting

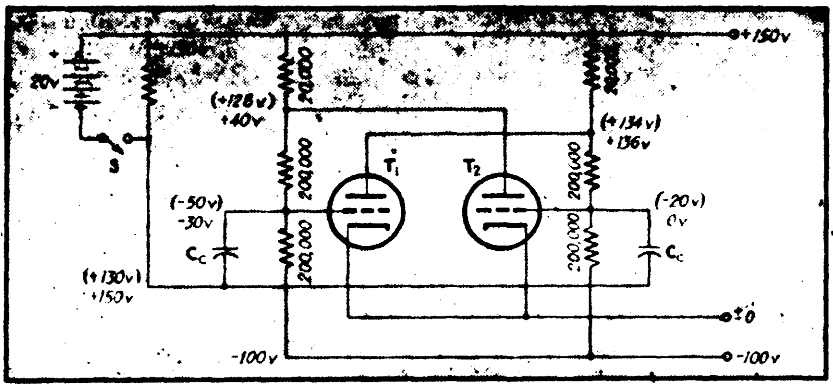

FIG. 5—Coupling capacitors C_c provide a means of temporarily biasing both grids together. This circuit is, however, incapable of reversing on the application of an impulse to both grids. Voltages indicated without parentheses are those applying with T_1 conducting but with switch *S* open. Voltages in parentheses are those applying at the instant switch *S* is closed

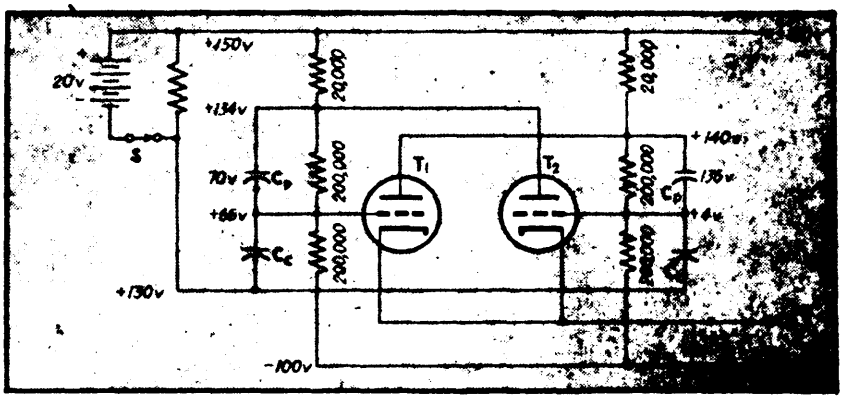

FIG. 7—Addition of capacitors C_p as shown here to the circuit of Fig. 5 makes possible the desired reversing trigger action. Voltages are those applying with T_2 conducting

at a time. The component values shown are merely illustrative and are used to simplify the analysis. However, these values will make a satisfactory trigger for relatively slow-speed operation.

The tubes used are 6J5's or equivalent and may be considered essentially as switches. When the grid of a 6J5 is at the same potential as its cathode the tube is conducting, just like a closed switch except that there is in the circuit illustrated a 40-volt drop between plate and cathode. When the grid is made negative with respect to its cathode by 8 volts or more, the tube is non-conducting and resembles an open switch in that no current can flow between plate and cathode.

Figure 2 shows more clearly how tube T_1 can control tube T_2. With both tubes arbitrarily rendered non-conducting, the voltage at the grid of T_1 is determined by the resistor network shown between the +150-volt line and the −100-volt line. By Kirchhoff's law, the grid of T_1 may be calculated to be 19-

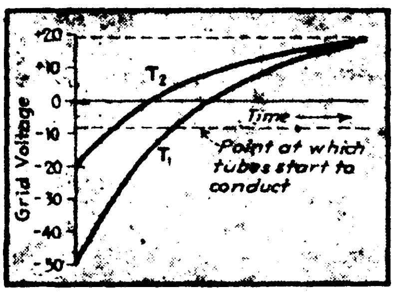

FIG. 6—Calculated grid-voltage rise after switch *S* of Fig. 5 is closed. Obviously, the grid of tube T_2 will be the first to reach the − 8-volt line, so that T_2 turns on first when an initiating pulse arrives

volts positive with respect to its cathode, thus turning T_1 on. (Actually, sufficient grid current will normally flow in T_1 to hold its grid down to approximately cathode potential).

When tube T_1 is made conducting as shown in Fig. 3, its plate will drop to +40 volts and point *A* will be held at that potential. Again applying Kirchhoff's law, we find that the grid of T_2 is now 30-volts negative with respect to its cathode and that T_2 is thus held non-conducting by T_1. Connecting the grid of T_1 to the plate of T_2 with a similar network as shown in Fig. 4, will enable T_2 to control T_1 in the same manner, and we have the desired condition in which only one tube can be on at a time.

Circuit Details

Figure 5 shows a means of temporarily biasing-off both grids together through coupling capacitors C_c. Although this circuit has sometimes been shown as the basic Eccles-Jordan trigger circuit, it is fundamentally incapable of reversing on application of an impulse to both grids. The voltage values shown without parentheses are those existing with T_1 conducting and switch *S* open. Those in parentheses are the instantaneous values obtained when switch *S* is closed, delivering a 20-volt negative impulse to the grids through capacitors C_c. This 20-volt negative impulse will render both tubes non-conducting. Both grids will immediately start to rise to the resistance-network-limited value of +19 volts, the rate of rise being determined by the time constant of the resistor network and the C_c combination. Since these are the same for each tube, the time constant will be the same for both grids.

The rise of voltage on both grids will be as shown in Fig. 6. Obviously the grid of T_2 will be the first to reach the −8-volt line, which means that T_2 will be turned on first and will hold T_1 off as before. In other words, the trigger has not been reversed. Likewise, a positive pulse will not reverse the trigger since any effect it might have on the non-conducting tube will be

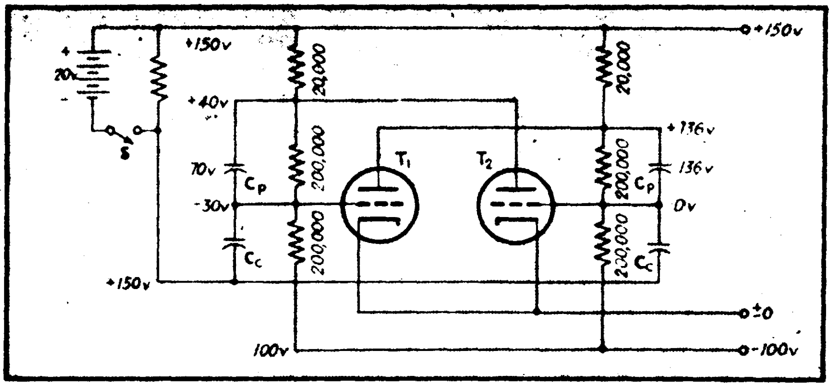

FIG. 8—A 20-volt negative impulse applied to the circuit of Fig. 7 by closing switch S, as shown here, drops instantaneous resistor-network potentials 20 volts

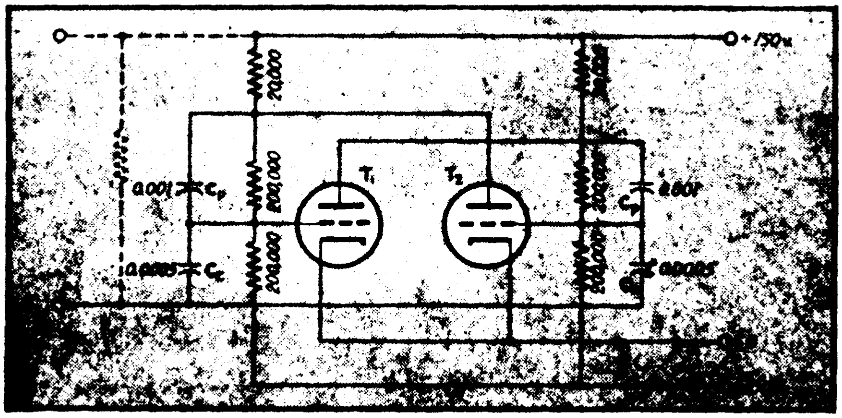

FIG. 9—If both tubes are held non-conducting by some external means, voltages shown in Fig. 8 will rise to these values soon after switch S is closed

offset by a stronger effect on the conducting tube.

It is the addition of the plate-to-grid capacitors C_p that makes possible the desired reversing trigger action. Figure 7 shows the addition of such capacitors to Fig. 5 and the steady-state voltages that exist with T_2 conducting. A 20-volt negative impulse provided by closing switch *S* will instantly drop all network voltages by 20 volts, as shown in Fig. 8. For simplification, assume that plate-to-grid capacitors C_p are so large in comparison to coupling capacitors C_c that there will be no change of voltage across them in the time required for the smaller coupling-capacitors to reach a steady-state condition. Assuming that the tubes are held non-conducting by some external means, the voltages in Fig. 8 will soon change to those in Fig. 9, with the coupling capacitors C_c in equilibrium. The rise of voltage of the grids will be as shown in Fig. 10.

While these curves might be accurately calculated, they were actually obtained by plotting an ϵ^{-x} curve between the known limits of grid voltage. Because of the much greater voltage-swing on T_1, caused by the relatively low voltage existing on the grid-to-plate coupling capacitor C_p between it and the plate of T_2, we see that the grid of T_1 (which has been non-conducting) is the first to reach the conducting point of −8 volts. Thus T_1 becomes conducting and blocks off T_2 and the trigger is reversed. The addition of the plate-to-grid capacitors C_p has produced the desired trigger action and the trigger will now reverse itself every time the grids are given a negative impulse.

In drawing Fig. 10, it was assumed that the grid-to-plate capacitors C_p were much larger than the grid capacitors C_c. That this assumption does not alter the general shape of the curves of grid voltage rise is best shown in Fig. 11, which is a sketch of the grid-voltage rise in an actual trigger circuit (as shown in Fig. 1 with $C_p = 2\ C_c$) as viewed on a large cathode-ray oscilloscope.

Originally tube T_2 is conducting and T_1 is held non-conducting by the −30-volt potential on its grid (voltage as shown in Fig. 7). At time T_0 a 20-volt negative impulse is applied to both grids through the coupling capacitors C_c. Due to internal impedance of the square-wave generator used in this instance, the negative impulse as it appears at the grids is not quite square and at the grids the peak negative dip is −15 volts. As soon as the maximum negative potential is reached, both grids start to rise in potential. As in Fig. 10, the grid of T_1 rises much faster than the grid of T_2 and reaches the conducting point first. When T_1 starts to conduct, its plate goes down, forcing the grid of T_2 way down and holding T_2 non-conducting. After an interval of less than 0.0001 sec., the charges on all capacitors have been equalized and the circuit is as before, except that T_1 is now conducting instead of T_2. The dotted lines indicate what the rise of the grid voltages might look like if the tubes could be held non-conducting by some external means.

Figure 12 shows both grid and plate-voltage changes for tube T_1 when the trigger (circuit as in Fig. 1) is triggered or reversed continually by a 3000-cycle square-wave input. (The grid-voltage curve is the same as those in Fig. 11.)

Positive and Negative Impulses

So far nothing has been said about the ability of this trigger circuit to distinguish between positive and negative impulses.

If a square-wave input is of a low enough frequency, the positive rise of the square wave will appear to the trigger grids as a positive impulse of a magnitude equal to the negative impulse produced by the negative shift of the square-wave signal. To act as a frequency divider, the trigger must respond only to the negative shift. This it will do if the impulse is kept within reasonable limits. For example, a 20-volt negative impulse will cut off the conducting tube, enabling the trigger to transfer; a 20-volt positive impulse will not bring the grid of the non-conducting tube up to the conducting

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point and thus cannot make the tube start to conduct. Its only action on the conducting tube is to drive the grid slightly positive. Therefore, the trigger will transfer only on a negative impulse or voltage shift and the trigger will act as a frequency divider on a 20-volt square-wave input.

The trigger circuit as shown will respond to negative pulses only, as long as they remain between the limits of 10 to 40 volts. Figure 12 shows why the trigger is not reversed on a positive pulse which is theoretically large enough to bring the grid of the non-conducting tube up to the conducting point. Notice that a point *B* the grid of the nonconducting tube actually appears to go negative although the square-wave input is shifting positively. This is because the positive impulse acting on the grid of the conducting tube drives its plate down almost 20 volts (point *C*). Through the plate-to-grid capacitor *C*, this dip of the plate of the conducting tube over-rides the positive impulse on the grid of the non-conducting tube, producing a negative dip as shown at *B*. (Although point *C*, as shown for tube T_1 is 180 deg. out of phase with point *B*, the corresponding point on the plate of T_2, if it were shown on Fig. 12, would be in phase with point *B*.

For a positive impulse to turn on the non-conducting tube, it must be large enough to overcome the initial bias plus the negative swing produced at the non-conducting tube's grid by the voltage dip of the conducting tube's plate. The dip in the conducting tube's plate voltage is in this case caused by the same positive impulse acting on its own grid. The input limits depend on the impedance of the input circuit. The figures of 10-40 volts were obtained with a battery serving as a very low impedance source. With a 20,000-ohm output impedance of the square-wave generator, the input may be varied from 10 to over 70 volts at 3000 cycles.

Coupling Several Triggers

All that is required to use a trigger circuit of the type described as a frequency divider is to hold the input signal to reasonable limits (25 volts ±15 volts for a low-impedance source). No extra tubes or pulse selectors are required.

To couple two triggers together, it is only necessary to tap one plate resistor of the first trigger at one-quarter to one-half its value, coupling to the input capacitors of the second trigger as shown in Fig. 13. Tapping the plate-load resistor at one-quarter to one-half its value serves to furnish a portion of the output of the first trigger within the required limits for operation of the second trigger. Thus we have a simple straightforward trigger circuit which is capable of distinguishing between positive and negative pulses without additional tubes. Such triggers when properly designed are stable, dependable, and independent of any reasonable voltage-supply variation (±20 percent variation in either bias or plate supply, more if both vary together).

As many triggers as desired may be coupled together by the methods outlined above to obtain any desired frequency reduction, the frequency being reduced by a factor of two for each trigger used. Such a frequency divider may be used in many ways, in combination with a mechanical counter for counting high-speed pulses far above the speed of the mechanical counter alone, in high-speed calculating, etc. A combination of a trigger and a power tube, where the trigger controls the power tube, may be used in place of a thyratron with the advantage that it may be turned off as easily as it is turned on. The triggers alone or in combination may also be used as electronic storage devices, since they are perfectly stable in either position.

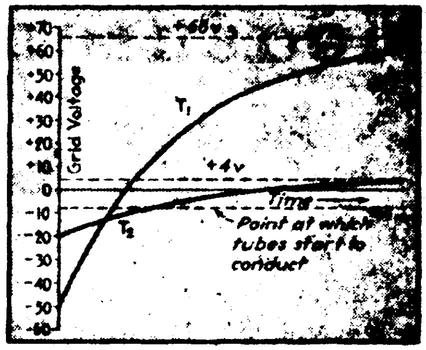

FIG. 10—Calculated grid-voltage rise as circuit voltages change from those shown in Fig. 8 to those shown in Fig. 9

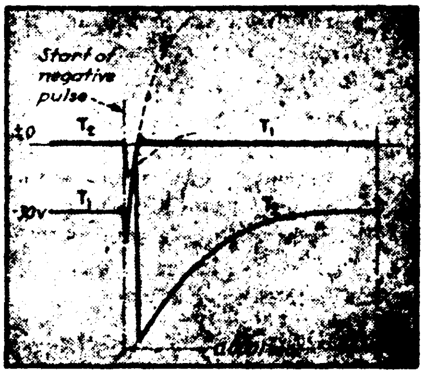

FIG. 11—Actual grid-voltage rise in the circuit of Fig. 1, as viewed on a cathode-ray oscilloscope

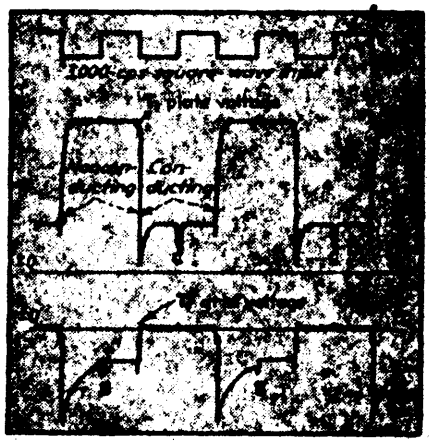
FIG. 12—Overall trigger circuit operation, as sketched from a cathode-ray oscilloscope

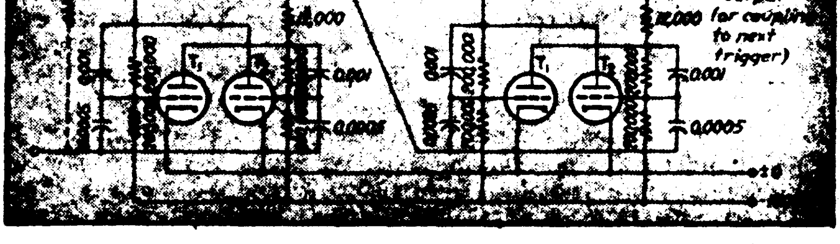

FIG. 13—Method of coupling two or more dual-triode trigger circuits

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