TUNING FORK MULTIVIBRATOR

By CPL. HAYWARD L. TALLEY

Instructor, Signal Corps Schools

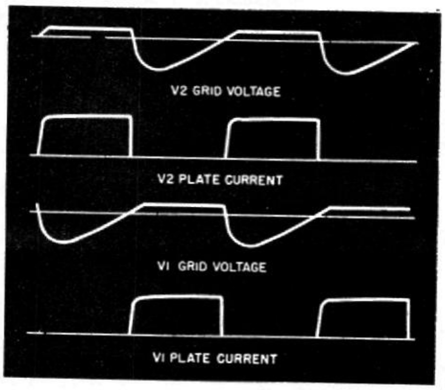


Fig. 2. Oscillograms show wave form at various points of the circuit. The multivibrator, as an independent oscillator, can generate frequencies from one to one hundred thousand cycles-per-sec.

THE control of oscillator frequencies has long been of primary importance in the electronics field. In the case of radio-frequency oscillators the question of frequency control was largely solved with the advent of the quartz crystal oscillator.

The use of quartz crystals is far from practical in the case of audio oscillators however. The thickness of a crystal is inversely proportional to frequency, and the thickness of a crystal for the audio range would therefore exceed all practical limits. The thickness of a 1000 cycle crystal would be between 66 and 112.6 inches depending upon the cut used. Accordingly another system of oscillation control must be used for the audio frequency range.

One such system is the tuning fork multivibrator. The fork long has had a record of faithful service. Today, with its application in oscillator control circuits, its scope of usefulness has been multiplied.

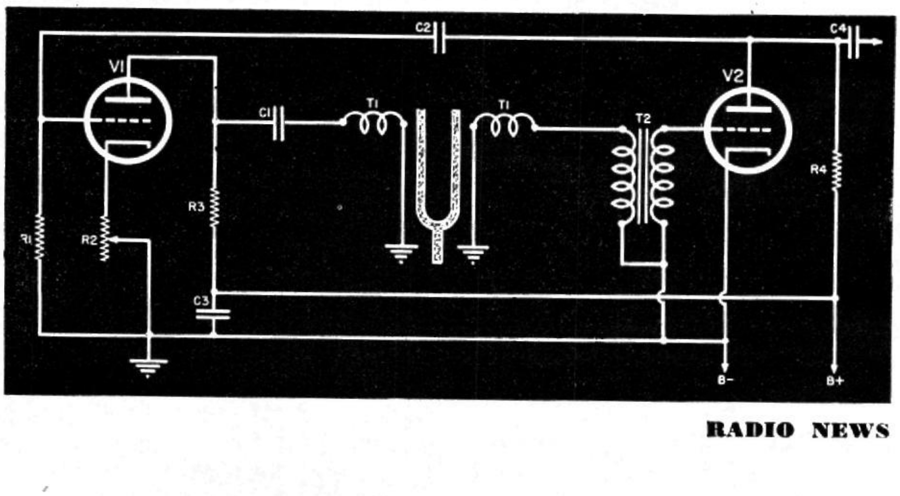
The multivibrator is well known today for its part in radio frequency measurements. When operated as an independent oscillator, the multivibrator may be designed to generate frequencies ranging from as low as one cycle-per-minute to frequencies in excess of 100,000 cycles-per-second.

Uncontrolled, the multivibrator is notoriously unstable. Its frequency is altered abruptly by shifts in operating voltages or circuit values. However, the device has another noteworthy property. It may be stabilized readily, and in the controlled state the stability and frequency accuracy of the multivibrator reach the same order as those properties of the controlling device.

A simple fork-controlled multivibrator is shown in Fig. 1. It is seen to be essentially a two-stage triode resistance-coupled amplifier with the exception that the output is coupled back to the input through the feedback condenser C_2. C_1 is the interstage coupling condenser, C_3 the plate circuit by-pass condenser usually encountered in *RC* amplifier circuits. T_2 compensates for the phase change encountered in the tuning fork transformer T_1, thus maintaining the conditions for positive feedback. The tubes are identical in type, often the two sections of a twin triode such as the 6N7.

The precision tuning fork is of bimetallic construction giving it a low temperature coefficient of frequency and permitting a large mass for a given frequency. In the best laboratory units where the maximum amount of precision is desired, the fork itself is held at constant tem-

Fig. 1. Diagram of tuning fork controlled multivibrator.



perature in an oven similar to those employed in quartz crystal stabilization. Such a control may be satisfactory when incorporated in any oscillator not requiring closer original frequency adjustment than about .005 per-cent or smaller frequency drift than approximately .01 per-cent. Such applications include the synchronization of facsimile scanning drums, timepiece and power alternator rating, and certain a.c. bridge measurements.

The operation of the multivibrator may be understood by reference to the oscillograms of Fig. 2. Oscillation begins as a result of a surge of electrons in one of the tubes (say tube V_2) as plate voltage is applied. This causes the plate voltage of tube V_2 to decrease, and likewise the grid of tube V_1. As plate current in tube V_1 decreases the plate becomes more positive. The positive pulse passes through condenser C_1 (Fig. 1), the tuning fork transformer T_1, and transformer T_2 to the grid of tube V_2. In this way the current in tube V_2 increases and that in tube V_1 decreases until tube V_1 cuts off. Tube V_1 cannot remain cut off however for C_2 will slowly discharge through R_1 allowing the grid of tube V_1 to lose its negative potential. As tube V_1 begins to conduct, the grid of tube V_2 becomes more negative so that the initial action is reversed. This is clearly shown in Fig. 2.

The characteristic frequency of the uncontrolled multivibrator is determined primarily by the grid-leak resistance and the grid condenser capacity. This characteristic frequency is duplicated by the natural frequency of the tuning fork.

The fork is set into vibration by the initial pulse from T_1. As long as the amplitude of the driving pulses remains constant the multivibrator is held rigidly to a fixed frequency, due to the switch-like action of the fork as it varies the coupling between the primary and secondary of T_1. A vernier frequency adjustment is provided by a potentiometer in the cathode circuit of tube V_1 which allows a slight variation in the amplitude of the driving pulses. If the amplitude of vibration is sufficiently high this range of control may be extended to allow the fork to be manually set to frequency through a wide temperature change. A more accurate method, however, is to temperature control the fork in the manner described earlier. In this case the amplitude of vibration of the fork may be reduced greatly and the vernier range of control becomes very small. A low amplitude of vibration makes the fork far more accurate.

Design Data

Usually it is desirable to make C_1 equal to C_2 and R_1 equal to the impedance of the secondary of T_2 at the frequency under consideration. In some cases it may become necessary to add a resistor in series with the secondary of T_2 to ground. An approximation of the necessary values may be obtained by the use of the formula

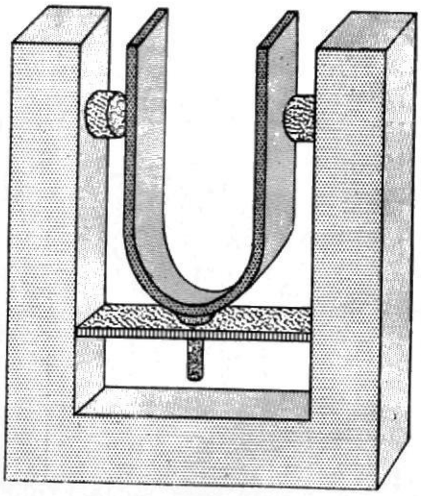


Fig. 3. Tuning fork transformer assembly.

$$F = \frac{1{,}000{,}000}{R_1 C_2 Z C_1}$$

where

F = frequency in cycles
C = capacitance in microfarads
R = resistance in ohms
Z = total impedance of T_2 secondary and any series resistance used.

Typical operating values for a 1000 cycle frequency are as follows:

$C_1 = .01$ microfarads
$C_2 = .01$ microfarads
$R_1 = 50{,}000$ ohms
$Z = 50{,}000$ ohms

For the most reliable operation, C_1 and C_2 should be first grade mica condensers whenever the capacitance permits. They should be mounted below the instrument chassis away from the heat of tubes and close to their points of connection. As far as practicable the triodes should be matched in characteristics, particularly inter-electrode capacitances. The resistors should be of not less than 2 watt ratings for any of the receiving type triodes operated at less than 250 volts on the plate.

The fork and transformer assembly (see Fig. 3) is composed of a tuning fork of an alloy having a suitable temperature coefficient of frequency as previously described, a non-magnetic framework, preferably of cast aluminum, and a clamp of the same material for holding the tuning fork fast within the frame. A coil is fastened to each side of the upper portion of the frame; together these coils compose T_1.

Obviously, care must be taken to assure that sufficient clearance is allowed between the fork and these transformer coils to eliminate any possibility of the coils impeding the movement of the tines of the fork as the fork is driven by an impulse of reasonable amplitude. It is often desirable to mount the entire assembly within a can covered with a blanket of rock wool or other insulating material to reduce the effect of radical changes in temperature.

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