A VACUUM TUBE TUNING FORK DRIVE, USING FORKS OF SEVERAL DIFFERENT FREQUENCIES

HAROLD D. WEBB, Indiana University

The electrically driven tuning fork has been known for some time, but has the disadvantage that the necessary metallic contact with the fork, such as solder or make and break contacts, tends to change the frequency of the fork, and also tends to produce over-tones. A vacuum tube driven tuning fork eliminates this undesirable feature, since no contact with the fork is required, and a pure tone is obtained.

The first vacuum tube tuning fork drive was described by Eccles in 1919[1]. The circuit that he used was very much the same as that shown in fig. 1, if the variable condenser, C, is eliminated. The circuit consisted of two electromagnets, the windings of the one being placed in the grid circuit, and the windings of the other being placed in the plate circuit, which act upon the prongs of the fork. When the fork is in motion the electromotive force in the grid magnet coil controls the current flowing in the plate circuit and its magnet, the vibrations of the fork being sustained. F. E. Smith[1] found that when a condenser was placed in the circuit, as C in fig. 1, the fork responded more readily.

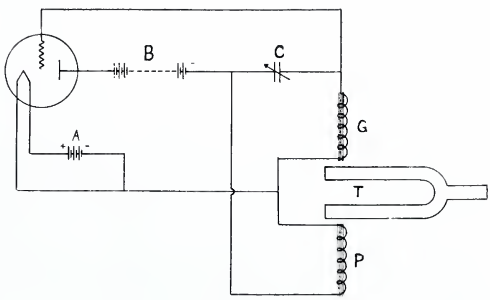

Fig. 1.

Butterworth has described the circuit used by Eccles[2], and has done some more work along the same line.

In 1922 Eckhardt, Karcher and Keiser, devised another vacuum tube tuning fork drive which was an improvement over the one described by Eccles[3], and in 1925 Hodgkinson developed another circuit in which no condensers were used[4].

[1] W. H. Eccles, Proc. Phys. Soc., Vol. 31, 1919, p. 269.
[2] S. Butterworth, Proc. Phys. Soc., Vol. 32, 1920, p. 345.

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

The circuits that have been devised by previous workers rely more or less upon tuning, or are designed to operate a particular tuning fork of a particular frequency. In the devices described by Eccles, Butterworth, and Hodgkinson the tuning fork is permanently magnetized. In the description of the device used by Eckhardt, Karcher, and Keiser, the magnetic circuit is emphasized. These features are objectionable, because it may be desired to maintain the vibrations of forks of several different frequencies, singly, without changing the circuit in any way other than replacing the tuning fork. It is the purpose of this paper to describe a vacuum tube tuning fork drive which may be used for forks of any desired frequency, within a reasonable range. It is also desirable to make the magnet coil core as short as possible. A circuit is to be described which is so designed that a fork of any frequency, within a reasonable range, may be inserted in the circuit and its variations sustained without the necessity of retuning or changing the circuit in any other manner.

The first circuit to be described can be used for forks of different frequencies by tuning the circuit. The circuit, which is essentially a Hartley circuit, is shown in fig. 1. The grid coil, G, having a laminated iron core, was wound with 5000 turns of No. 36 copper wire. The plate coil, P, was wound in a similar manner. The coils were connected, as shown in the diagram, to the grid and plate of the tube, with a common tap between the coils connected to the negative filament. A variable condenser, C, made up of several fixed condensers and a variable condenser connected in parallel, so arranged that the capacity could be made any value between zero and .1 microfarad, was connected between the grid and plate connections. By leaving coil P fixed, by changing the capacity, and by varying the distance of coil G from the fork prong, the oscillations of the circuit may be brought to the same frequency as that of the fork. When the circuit is in resonance with the frequency of the fork, the fork will vibrate freely, the vibrations being sustained.

The value of C using a 201A tube and a tuning fork of 256 cycles was of the order of .047 microfarad. A Western Electric VT2 tube was found to be satisfactory, as well as a 201A tube. A 112 tube, and a 171 tube were tried with no results, and it was concluded that a tube, in order to be used in the above circuit, must be a good oscillator.

The theory of the circuit is as follows. Suppose the circuit to be oscillating at the same frequency as the frequency of the fork. In that condition there will be an alternating current in the plate circuit superimposed upon a direct current in such a manner that the current is in no case negative, but rises to a maximum value and falls to a minimum. When the current rises to a maximum a magnetic flux is set up in the core of the coil P which causes the core to attract the fork prong next to it. When the current falls to a minimum the magnetic flux is diminished, so that the prong is released and moves to the position farthest from the coil P. The current in coil P again rises to a maximum, the fork prong is again attracted, and the vibrations of the fork are sustained.

[3] E. A. Eckhardt, J. C. Karcher, and M. Keiser, Opt. Soc. Am., J., Vol. 6, 1922, pp. 949-957.

[4] T. G. Hodgkinson, Proc. Phys. Soc., Vol. 38, 1925, pp. 24-33.

It is thus seen that the oscillations of the circuit must be in resonance with the frequency of the fork for the vibrations to be sustained.

The circuit is rather simple to construct, but has the disadvantage that the tuning is very sensitive. The tuning fork must be made of a magnetic material.

When one stage of amplification is used in the circuit of fig. 1 the amplitude of vibration of the fork is greater, but the circuit modified in this manner is more sensitive to tuning than that of fig. 1. The value of C is somewhat less with one stage of amplification.

In an attempt to get the circuit desired the primary of a low impedance output transformer was connected in place of coil P of fig. 1, to the secondary of which was connected a small coil having 500 turns of No. 36 copper wire. While the plate current is increasing an electromotive force will be set up in one direction in the coil when the transformer arrangement is used, thus setting up a magnetic flux in the core

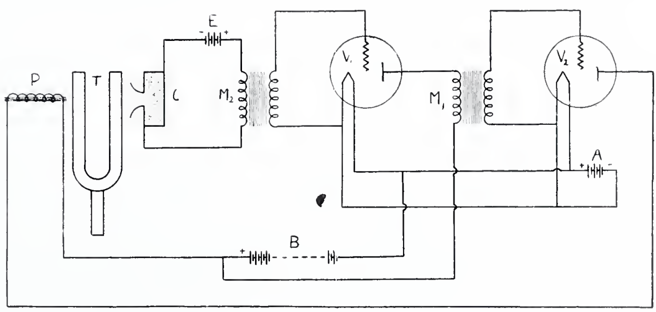

Fig. 2.

of the coil and while the plate current is decreasing an electromotive force is set up in the opposite direction, setting up a magnetic flux in the core. Thus, since the tuning fork is not permanently magnetized, the fork prong will be attracted by the coil core when the plate current is increasing and also when the plate current is decreasing. The circuit must be oscillating at a frequency equal to one-half that of the fork for the vibrations to be sustained. This transformer arrangement was not successful.

The circuit which fulfilled the requirements of the problem is shown in fig. 2. In it no tuning is required. A carbon button microphone is connected in the grid circuit of V_1 through a microphone transformer, M_2, of ratio 30 to 1. The potential E is about 6 volts. V_1 is coupled to V_2 by means of an audio frequency transformer, M_1, of ratio 3½ to 1. The coil P was wound with 5000 turns of No. 36 copper wire. The core was made up of iron wire. Coil P is connected in the plate circuit of the tube V_2. The tuning fork T was placed between the coil P and the microphone C, as shown in fig. 2. The B potential was near the maximum rated value for the tubes used. 201A tubes were first used in the arrangement.

When sound waves are incident upon a carbon button microphone the pressure thus exerted upon the carbon particles changes the resistance of the microphone, and thus the resistance of the circuit. Suppose now that the fork has been set into vibration. The sound waves of the given frequency will change the resistance of the microphone circuit from a maximum to a minimum value for each vibration of the fork. A change of resistance in the grid circuit of the tube V_1 will cause a change in the grid potential. When the potential on the grid is increased the plate current of the tube V_2 will be increased, and when the grid potential is decreased the plate current of V_2 will be decreased, so that the current in coil P will rise to a maximum and fall to a minimum, always remaining positive, for each cycle of the sound wave entering the microphone. There will then be a changing magnetic flux in the core of coil P which will be a maximum when the current in the coil is a maximum, at which time the fork prong will be attracted. When the current in the coil is a minimum, the magnetic flux will be a minimum and the fork prong will not be attracted, but will move to its position farthest removed from the coil. The vibrations of the fork will thus be sustained.

The transformer arrangement already described was tried in place of coil P. It is seen from the theory previously given and from that given above that it is impossible to drive the tuning fork with the transformer arrangement.

If the tuning fork is set into vibration the vibrations will build up until a maximum is reached. By changing the position of the microphone and coil with respect to the face of the fork prongs, a position of maximum amplitude of vibration may be found. Sometimes the fork will begin to vibrate of its own accord. At other times it is necessary to start it.

When two 201A tubes were used forks of frequencies 256 cycles, 287.5 cycles, 320 cycles, 341.3 cycles, 384 cycles, 426.7 cycles, 480 cycles, and 512 cycles were used. All of these tuning forks responded quite well, but not equally well, however.

To give maximum output the coil should have the same impedance as that of the plate of the tube V_2. When the plate potential of a 201A tube is 135 volts, the plate resistance is about 10,000 ohms, so that in order to give maximum output, the impedance of the coil should be equal to about 10,000 ohms. The impedance of the coil was measured at several different frequencies on Mr. Hershman's impedance meter. The results are given in the following table.

Impedance of the coil in ohms	Frequency in cycles per sec.
9300	1000
4800	500
2950	300
1090	60

For the range of frequencies used the A. C. plate resistance of a 112 tube is near the impedance of the coil used. When 112 tubes were used in the circuit, the amplitude of vibration of the fork was greater in all cases, as was expected.

The circuit just described, and diagramed in fig. 2, has the following advantages over the circuits previously described for maintaining the vibrations of a tuning fork: (1) this circuit is untuned, (2) forks of any frequency, within a reasonable range, may be inserted between the microphone and plate coil, the vibrations thereby being sustained without otherwise changing the circuit in any way, (3) the core of the coil is relatively small, and (4) the circuit is easy to construct and operate. It must be remembered, of course, that the fork used in the circuit must be made from a magnetic material.

The author wishes to use this means of expressing his sincere thanks and appreciation to Dr. R. R. Ramsey, who suggested the problem, for his continued interest and help throughout the course of this experiment. I also wish to thank all others who have helped with the work, and who have offered valuable suggestions.