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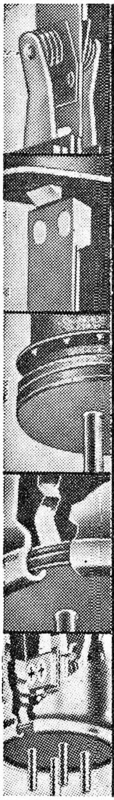

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THE HOW AND WHY OF VIBRATORS

History and Development

PART II

In the preceding issue the basic theory upon which the satisfactory operation of a vibrator depends was developed and illustrated. It was shown that in order to have a satisfactory substitute for a set of "B" batteries, a correctly designed combination of certain components was required. This combination consisted of a low-voltage DC source, such as a storage battery, an inverter, a transformer, a rectifier, and a filter. The inverter was the only unusual component in this group, and was required because the transformer could not function on the DC from the battery. Thus, a device must be inserted between the battery and the transformer to change the character of the DC so that it would appear to the transformer to be AC. The vibrator is to be the inverter in the combination of components listed above.

Our previous discussion also developed the necessary interdependence of the vibrator, transformer, and the "buffer" capacitor, (where the vibrator had progressed as far as the pulsating key in Figure 7), in the correct electrical operation of the power unit. We were at the point where we were ready to convert the manual key into an automatically-actuated vibrating switch, or vibrator, and discuss its performance in the circuit.

Now refer to Figure 8. The circuit shown here is somewhat different from that in Figure 7. The key of Figure 7 has been replaced by a switch controlled by the magnetic coil in series with the battery and transformer primary. When the battery circuit is closed, the magnetizing current for the transformer flows through the switch and magnetic coil, energizing the latter and pulling the switch arm toward it. This opens the transformer circuit and releases the magnetic pull of the switch coil, allowing the switch to close, again starting the cycle of events just described. So long as the battery has energy available the switch will continue to operate at a regular rate, this depending upon the rate of

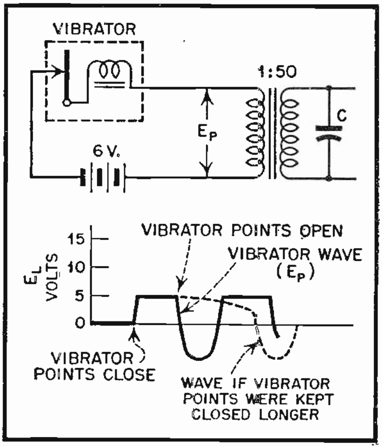

Fig. 8.

build-up of current in the circuit and upon the mechanical characteristics of the switch. Thus the VIBRATOR became a reality, although the similarity to the bell-buzzer of Figure 3 is readily noted.

Another change shown in the circuit of Figure 8 is the moving of the Capacitor "C" from its former location across the primary terminals to a new location across the secondary terminals of the transformer. Because the primary and secondary coils are usually closely coupled, the effect of the capacitance across the secondary will be almost perfectly reflected into the primary. However, since the tuning effect of the secondary coil as compared to the primary coil is dependent upon the square of the number of turns for each coil, (square of the turn ratio), the value of capacitance needed for proper equivalent tuning usually is much smaller for connection in the secondary than for in the primary circuit. For instance, if the turn-ratio is 50, the square of this number is 2500, and the size of capacitor needed for the secondary will be 1/2500 of that needed in the primary.

The waveform resulting from the circuit shown in Figure 8 is illustrated in the accompanying graph. The vibrator characteristics of frequency and time efficiency can be so matched to the transformer characteristics and the capacitance of "C" that the contacts open before the transformer core begins to saturate and close with the tuned-circuit oscillation voltage practically equal to the battery voltage. This circuit characteristic protects the vibrator contacts from excessive sparking and electrical wear. If we connect a rectifier tube and filter to the secondary of the transformer, as shown in the circuit of Figure 9, we can supply direct current to a load connected to the terminals marked "B+" and "B—". If the rectifier tube is properly polarized for the primary battery connections, it will conduct current during the portion of the cycle when the vibrator contacts are closed, (the square-topped pulse), and a fairly good efficiency will be realized. If the battery polarity is reversed, however, the polarity of the secondary voltage will be reversed and the rectifier tube will now conduct only during the portion of the cycle when the vibrator contacts are open, (the rounded pulse), and the only energy available will be that stored in the core of the transformer and in the buffer condenser. This results in low output capabilities and poor efficiencies.

Several manufacturers produced "B" eliminators of this type, which met with rather wide acceptance and gave reasonably good life and performance. One radio manufacturer produced a receiver in which he built in the power unit and thus made the forerunner of the present type of set. There were several inherent drawbacks to such a design of power-unit, however, and it is desirable to outline these in order to see the reasons for future developments. The first, and possibly most obvious, difficulty lay in the method of driving the vibrator. Since the

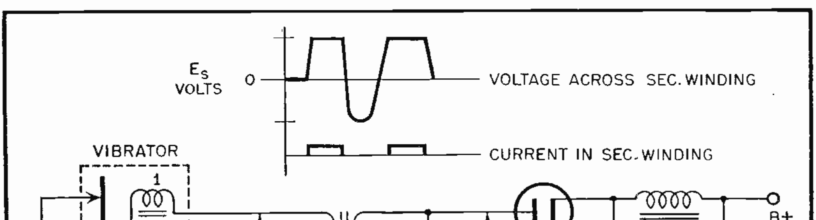

Fig. 9.

driving-coil was in series with the primary circuit, all of the magnetizing and load current passed through the coil and thus produced the magnetic pull affecting the movement of the reed. Therefore, if the load current changed, the magnetic pull changed and directly affected the operating characteristics of the vibrator. Under a no-load condition, the pull would be slight and the reed would merely flutter. Under an overload condition, the pull would be great and the reed amplitude would be excessive. Under both conditions the tuning of the circuit would be bad and severe sparking would result. With excessive amplitude, reed breakage would probably occur. Thus, for a given design of power-unit, only a narrow range of loads could be handled. This was partially met by the introduction of a series of units with different values of output loads, each having a vibrator with a coil designed for that load. These varied from a low of about 135 volts at 15 ma to a high of 180 volts at 40 ma. The no-load condition was sometimes taken care of by the use of a "phantom load", which was a resistor connected across the output until the set load became large enough to operate a relay having a coil in series with the output circuit.

The fact that the system operated "half-wave" was another source of difficulty. The transformer core was subjected to pulses of DC load current, with the result that inefficient transformer action occurred, the core having a large residual magnetization in one direction. This fact limited the amount of energy that could be transferred to the load circuit. In addition, it necessitated the use of an exceptionally large transformer in order to operate at low flux-densities. The other problem has already been discussed in a preceding paragraph, where the relation between the polarity of the battery and that of the rectifier tube affects the unit's efficiency. A method of providing for this difficulty had to be arranged for, such as switching the input leads, switching of transformer terminals, etc.

After considerable thought, a simple change in the design of the vibrator enabled the engineers to correct the difficulty encountered in driving the vibrator. If we did not want the unit to be sensitive to load current, we should make its driving power dependent upon the battery voltage instead, which remains substantially constant. By supplying a high-resistance voltage coil instead of the low-resistance current coil, and connecting this across the vibrator contacts instead of in series with them, we can make the unit drive independently of the load current. In Figure 10 we see this arrangement, where the coil is ener-

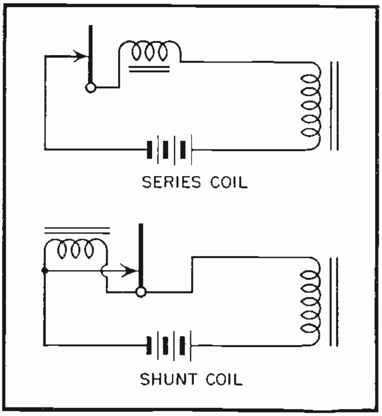

Fig. 10.

gized when the contacts are open, and is shorted out when the contacts close. One other major difference is now involved. At rest, the vibrator contacts must be open in order to start the vibrator with the shunt coil, while they must be closed in order to start the vibrator with the series coil.

To correct the inherent difficulties of operating the circuit half-wave, however, meant that some means would have to be developed to change to full-wave operation if all of the desirable features were to be secured. If we wind the transformer coils in duplicate and place them on the same iron core, we can cancel the residual magnetism caused by the pulsating DC if we pass the current through one set of coils in one direction on one half-cycle and through the other set of coils in the opposite direction on the other half-cycle. Thus the energy that can be transferred is greatly increased, the size of the transformer can be reduced by operating at much higher flux-densities, and a full-wave rectifier can be used which will operate equally well regardless of the battery polarity. To operate such a transformer, however, required two vibrators of the type we have just considered, mechanically synchronized 180 degrees out of phase. One set of contacts had to be closed while the other set was open. Naturally, the next step was to combine the two vibrators into one, having sets of contacts on both sides of the moving reed which engaged on opposite half-cycles of operation. This arrangement is illustrated in Figure 11. As there is an appreciable percentage of the total time of each half-cycle required to switch the contacts from one side to the other in the circuit, the on-contact time for each cycle is always less than 100% of the total time. The actual percentage of contacting time is referred to as the time-efficiency, or in some instances as the time-constant, of the vibrator.

Because the time-efficiency is less than 100%, there will be gaps in the horizontal voltage trace between successive half-cycles. However, we have the timing, or buffer capacitor connected to the transformer, which can be so selected that the rate of oscillation on the break of each half-cycle will permit filling in this gap with a voltage reversal. Thus the trace shown in the graph of Figure 11 has the voltage wave with slanting lines connecting the horizontal portions. When the induced counter-voltage in the transformer primary is as indicated by the voltage graph, the current pulses passed by the rectifier tube will be as shown. Naturally, after going through the tube the pulses will be all of the same polarity. Thus we have arrived at the basic vibrator circuit still used today in the large majority of auto radio receivers, as well as many other applications. Without the rectifier, and with a few refinements, this is the basic arrangement for the power converters made by Cornell-Dubilier for providing AC power from a DC source. The vibrator is commonly called the "INTERRUPTER TYPE", the full-wave feature now being taken for granted. When correctly designed, and when used with properly matched components, this vibrator structure has worked very satisfactorily and provides excellent life characteristics.

Early in the history of vibrator power supplies for auto sets there was a desire to reduce the overall size and weight as well as cost. Because the early rectifier tubes were gas-filled half-wave types, and were large and costly, this appeared to be one logical place to start in achieving the reductions. Additional insulated sets of contacts were added to the

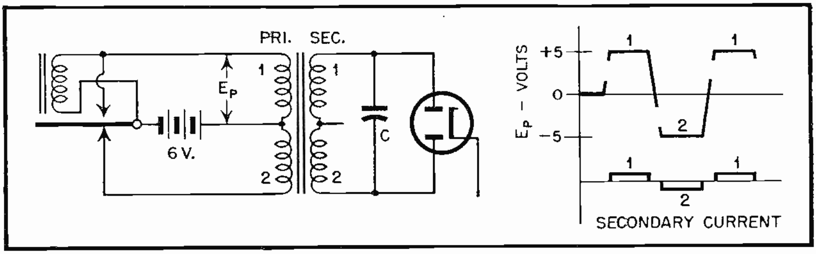

Fig. 11.

vibrator structure which were operated in synchronism with the already present interrupter contacts. This was first done on the half-wave structure, and resulted in a synchronized half-wave rectifier of a mechanical type replacing the tube. Decided disadvantages resulted from this arrangement in addition to those already described for the half-wave interrupter. However, the feasibility of the synchronous rectifier was demonstrated, and the same principle was then applied to the full-wave unit after its introduction. This arrangement is shown in Figure 12, where the Non-Synchronous (or Interrupter) and the Synchronous (Self-Rectifying) types are compared.

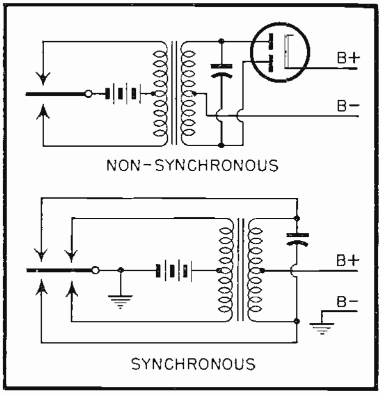

Fig. 12.

This structure permits the elimination of the tube rectifier for a cost and space reduction, gives slightly higher efficiency because of the elimination of tube losses (both plate voltage drop and filament current must be considered), and in general gives a longer vibrator life. The use of this type of self-rectifying unit, however, introduces several disadvantages. First, the output DC circuit must be electrically connected to the input DC circuit, as both use the common vibrating reed as a switch. Usually B— is connected to the grounded terminal of the battery, and this may be positive or negative, depending upon the car manufacturer's choice. This is of little moment at the present, since cathode-bias is common practice in receivers and indirectly-heated cathode-type tubes are used. However, the fact that the rectification is done mechanically results in a reversal of the output polarity when the battery ground is reversed. Since receivers won't operate with the plates negative, and other difficulties such as polarized capacitors arise, it is obvious that this condition must be corrected where receivers are manufactured for use in any make of car. Of course, where custom-built original equipment is considered, this reversed condition need never occur.

Figure 13 illustrates the effect of the reversal of battery polarity on a power unit using the Non-Synchronous type and on another using the Synchronous type of vibrator. On the left of the illustration we see that the rectifier tube acts as an automatic valve, so that, regardless of the battery polarity (and therefore the transformer secondary polarity), the output circuit is always polarized correctly. On the right we have substituted a mechanical selector switch for the tube for the purpose of rectification. In the upper circuit we see that, regardless of the position of the vibrator reed, the output circuit is always positive at the secondary center-tap because when the current through the primary is reversed, the connection to the secondary winding is reversed also. In the lower circuit, the connections to the vibrator and transformer have remained the same, but the battery polarity has been reversed. As a result, the polarity of the output circuit is now the opposite of that formerly prevailing, with the center-tap connection being maintained negative.

(Continued on page 10)

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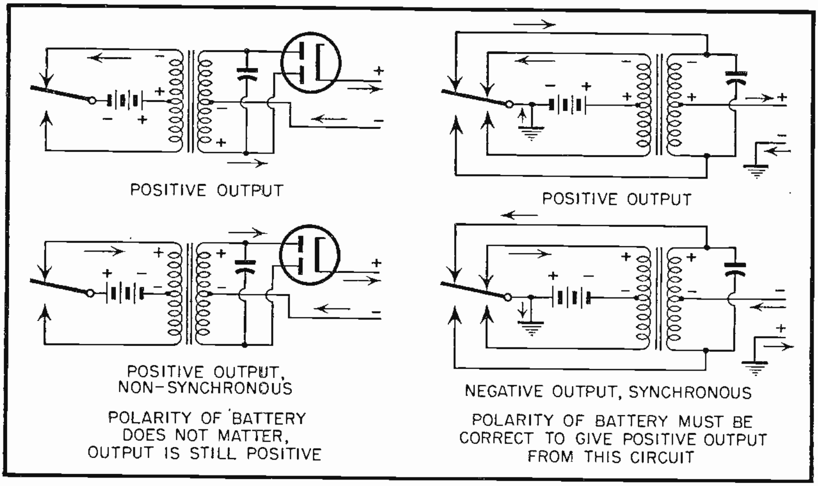

Fig. 13.

Thus it would be desirable to incorporate in the receiver some easy method of interchanging the connections of either the primary or the secondary of the transformer to the vibrator when the receiver is to be installed in cars with opposite battery polarities. Early models incorporated a terminal board to which transformer leads were connected. Later the vibrator basing shown at the left in Figure 14 was developed in order to use the vibrator itself as a reversing switch. This is used with a symetrically arranged socket, as shown at the right, which will receive the vibrator in either of two positions, 180 degrees apart. By connecting the transformer to the socket as shown, provision is made to reverse the secondary or rectifier side-reeds when the vibrator is reversed in its position, but the cross-connection provides no reversal of the primary, (or interrupter), side-reeds; therefore, output reversal can be corrected by vibrator positioning. This type of vibrator has been highly successful, and permits the full realization of the real advantages of the self-rectifying vibrator without its most important disadvantage.

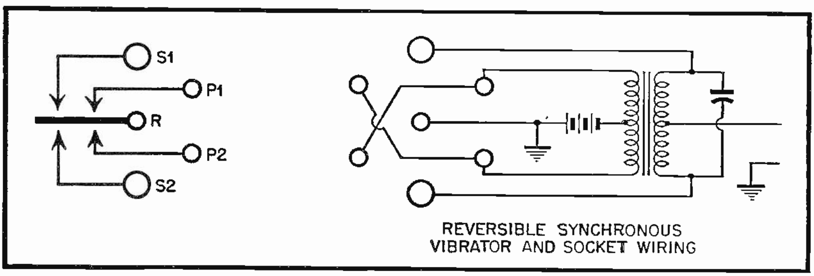

Fig. 14.