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THE HOW AND WHY OF VIBRATORS

History and Development

PART I

The following article gives an outline on the evolution and development of modern vibrators. Owing to limited space, together with the introduction of new C-D products in this issue, the second part of this history and development discourse will be continued in the August issue. — Ed.

Early in the history of Radio Broadcasting, practically all receivers using vacuum tubes operated from batteries. A low-voltage battery was used to heat the tube filaments and lower capacity, but decidedly higher voltage batteries were used to supply the necessary tube plate and grid-bias circuits. If the tube filaments were operated directly from an alternating current source instead of from direct current, the result was an interfering hum having the same frequency as the power line. In any case, the plate voltage had to be DC in order to secure proper tube operation.

The cost and inconvenience of operating home receivers from these bulky and often messy sets of batteries delayed the expansion of the radio industry. One step in improving these conditions was the introduction of the "B Eliminator" which operated directly from the AC power line. It provided a tube rectifier and a suitable smoothing filter, to supply the high-voltage requirements formerly secured from a set of "B" batteries. The usual storage battery still had to be supplied in order to operate the filaments of the tubes.

The step that gave the greatest impetus to the manufacture and sale of home receivers was the perfection of the indirectly-heated-cathode type of vacuum tube. This arrived around 1927 and, together with improvements in built-in "B Eliminators", permitted the manufacture of the self-contained AC-operated receiver. Comparatively sensitive receivers could be designed without appreciable hum interference, and thus satisfactory reception could be secured in weak-signal areas with small antennas.

With the advent of more sensitive receivers, the more experimentally inclined listeners attempted to install receivers in their automobiles. As might be anticipated, many obstacles and difficulties were encountered in working out such installations. What is now an every-day occurrence often took days of experimenting and weeks of effort in the early days. One advantage was present; the storage-battery which was a necessity was provided by the car manufacturer. This could be used to supply the filaments of the tubes. Since no high voltage was available, however, it was necessary to return to "B" batteries for plate power. The new power-output tubes required higher voltage and more current than had been the case in earlier battery receivers, in order to enable the receiver to operate at a power level which would be satisfactory, considering car and wind noise. This factor required the use of more and larger "B" batteries, and presented a problem in finding storage space for such a bulky package. Remember that, in those days, no built-in trunks were provided in cars, and interior space was at a premium. Most of the installations included a sheetmetal battery box "splash-proofed", and suspended beneath the floor boards.

At this stage in the development of auto radio, household receivers had only recently been converted to full AC operation. Investigations on auto radios began with the intent of discovering a suitable substitute for the

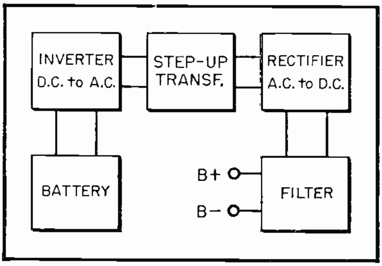

Fig. 1.

bulky, costly, short-lived, and inconvenient "B" batteries. Dynamotors were the first substitute for "B" batteries that were seriously considered. Rotary-type machines were well understood and some development was made along that line. However, their large size, low efficiency, and heavy noise, together with service difficulties, prevented their widespread use. Furthermore, the initial cost was almost prohibitive. As early as 1930, engineers at several companies began investigating other methods of securing the high DC voltage from the low-voltage storage battery using relatively inexpensive and small components. Referring to earlier vibrating types of devices (such as door-bell buzzers, mechanical rectifiers for battery-chargers, and bell-ringers for telephones, to mention a few), they came up with "the little black box" which became the forerunner of all Vibrator Power Supplies.

Referring to Figure 1, we find a block diagram which illustrates the requirements for a simple power unit. The direct current from the BATTERY cannot be changed in voltage value until its character has been altered in such a way that a transformer will handle it as an alternating voltage. The device which accomplishes this function is the INVERTER, shown as the second block in the diagram. The power TRANSFORMER, which has a "step-up" voltage ratio, follows the INVERTER. A RECTIFIER follows the transformer, changing the high-voltage AC to pulsating DC, and is followed in turn by the smoothing FILTER, which provided essentially pure DC to the receiver. As is well known by now, the vibrator with its make and break contacting action provides the INVERTER portion of this diagram.

Early versions of the power unit included those shown in Figures 2 and 3. The former illustrates the adaptation of the then familiar ignition spark-coil, having an integral vibrating contact. The latter shows the adaptation of the door-bell buzzer to

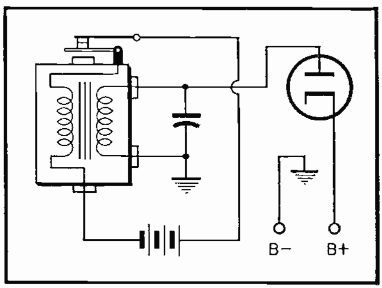

Fig. 2.

the system. The former utilizes the primary of the coil (transformer) as the actuating magnet for the vibrating reed, and the secondary to supply high-voltage to the rectifier tube. The buzzer required the use of the added transformer. Both types of "vibrators" used the driving coil in series with the transformer primary and thus were dependent upon the load current for the magnetizing force used to drive the reed. They are also both of the "one-half wave" type of unit, in which the energy is drawn from the battery one-half of the time, or in pulses

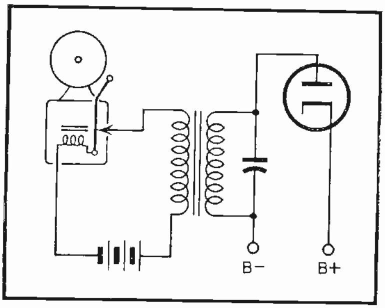

Fig. 3.

through the transformer primary without reversal of the magnetic flux in the core. The circuit shown in Figure 3 is essentially that used in the first auto radio "B" battery eliminator, with the addition of necessary filter circuits. The first rectifier tubes were of the gas-filled, cold-cathode type, as the indirectly-heated cathode rectifiers were not yet available.

It is interesting to develop what happens in this circuit during operation, even though it has been obsolete many years, since the basic theory is the same as for our present systems. Figure 4 illustrates the basic circuit involved, as well as the graph of one cycle of the voltage appearing across the primary coil of the transformer which is here considered as a single-coil iron-core inductor. The series resistor shown is the lumped equivalent resistance of the leads, contacts, driving coil, and inductor. When the key is first closed, current from the battery begins to flow through the series circuit. This current flowing in the coil of the inductor creates a magnetic field in its core which is steadily increasing with the passage of time. The change in the flux of the magnetic field induces a voltage in the coil (known as the counter e. m. f.) which opposes the battery voltage and thus limits the flow of current in the circuit to that necessary to magnetize the core. The counter-voltage must equal the battery voltage minus the IXR voltage drop in the resistance, since all of the voltages in the circuit must add up to zero.

Figure 5 illustrates the typical shape of the B-H, or Magnetization, curve of silicon transformer lamination steel. As can be quickly noted, the effect of applying a steadily increasing magnetizing force (H) on the core does not result in a correspondingly uni-

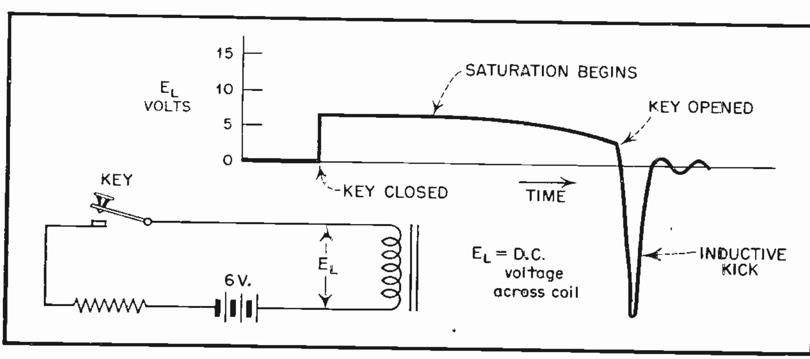

Fig. 4.

formly increasing flux in the core, except over short ranges of operation. Since the voltage applied to the inductor from the battery is constant, the counter-voltage induced must be constant except as the IR voltage drop changes with changes in the magnetizing current. To induce this constant voltage the flux-density must change at a constant rate. Referring to the

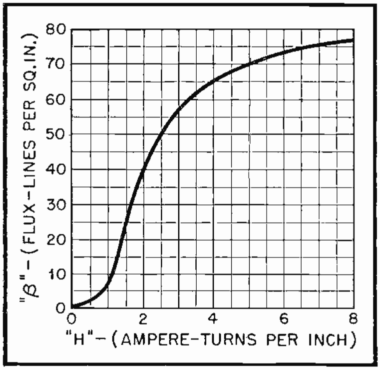

Fig. 5.

curve in Figure 5, however, we see that as the flux-density increases beyond 50,000 lines per square inch, the iron begins to "saturate" and increasingly greater values of current must be furnished in order to maintain the same rate of increase of the flux. As this increase in the value of magnetizing current occurs, a larger portion of the battery voltage appears across the series resistance and less across the inductor. This is shown in the graph as a reduction in the height of the trace, as indicated. If we allowed the key to remain closed, the iron would finally cease to exert any influence and the current flowing would be limited only by the series resistance in the circuit. However, considerable energy is stored in the core in the form of magnetism, which remains there so long as the current in the coil is maintained.

Now if we open the key in the circuit of Figure 4, we interrupt the flow of magnetizing current in the inductor coil. The removal of this magnetizing force allows the magnetic flux in the core to collapse, thus reversing the polarity of the rate of change of flux. This effect induces a voltage in the coil of the inductor which is opposite in polarity to the counter - voltage originally induced when the battery was connected, and which trys to maintain the current flow in the circuit as the key is opened. If the key opens slowly, this collapse voltage maintains an arc across the contact gap until the stored energy has been dissipated. If the key is opened quickly, with the contact gap comparatively wide, the current is interrupted before much of the stored energy has been used up. The induced voltage then rises to a value much greater than the battery voltage, since the rate of collapse is much more rapid under these conditions than was the rate of increase. This is indicated by the sharply peaked reverse voltage shown on the graph of Figure 4. This is the effect causing the "shock" noticed when the field of an electro-dynamic speaker is opened.

The winding of the inductor coil has a certain amount of distributed capacitance which appears across its terminals. Combined with the coil inductance, this capacitance forms a tuned electrical circuit, which will oscillate at a given frequency when shocked into excitation by the collapse of the magnetic field. This is shown in Figure 4 by the continued successive reversals of the voltage wave. Now if we add additional capacitance to the circuit of Figure 4, as shown in Figure 6 by the Capacitor "C", we change the frequency of the oscillation just described to a lower frequency determined by the values of the components. If the value of capacitance

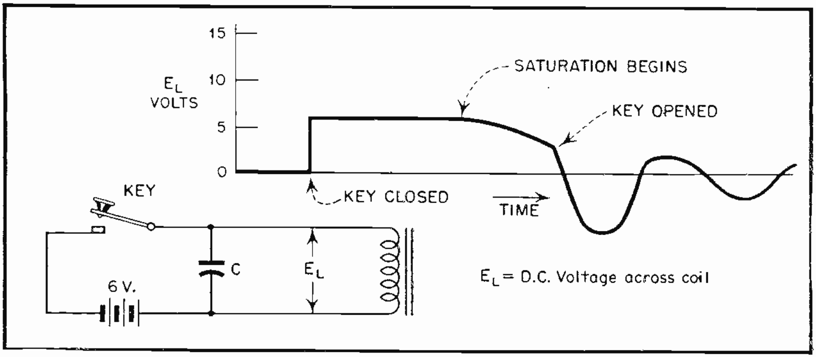

Fig. 6.

is sufficiently high, the energy needed to reverse the charge on the capacitor will equal the stored energy in the inductor, and the "inductive kick", or reverse voltage, induced will be held to a very low value Capacitors used in this manner are usually referred to as "buffer" condensers, although they are essentially tuning, or "timing" capacitors.

With an understanding of these basic principles, the development of the complete power-supply circuit is not difficult to understand. If a second coil is wound on the same core as the inductor of Figure 6, it will be linked by the same magnetic flux that is induced in the core by current in the original coil. This flux will induce a voltage in the second coil which will have a value proportional to the number of turns in the coil. If the second coil (or secondary) has 50 times as many turns as the original coil (or primary), the voltage appearing across the secondary coil on open circuit will be 50 times the voltage across the primary coil, and will have essentially the same wave-form. If the "turn-ratio" is 3, the secondary voltage will be 3 times that of the primary. This is illustrated by the graph shown in Figure 7, where E_p and E_s are the induced voltages in the transformer, which we have pointed out are of the opposite polarity to that of the battery. Our circuit is now approaching the necessary requirements we outlined in the block diagram of Figure

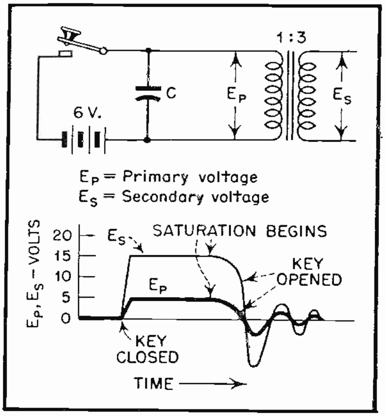

Fig. 7.

1. We have the battery, the switch, and the transformer. If we can make the key of Figure 7 operate rapidly enough, and at a steady rate, we will have the Inverter. By supplying a rectifier and adding a filter, the power unit will be complete.

(*To be continued*)

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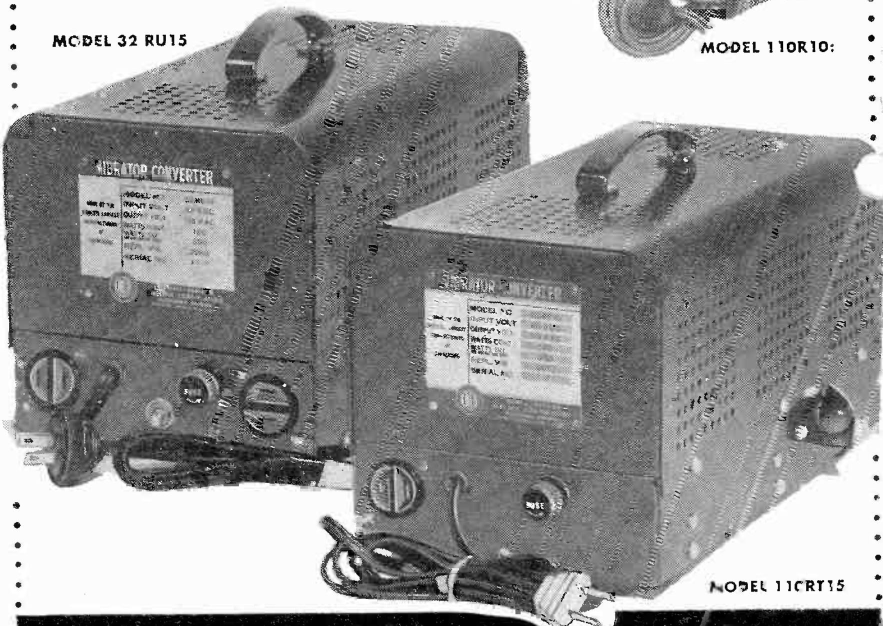

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