A mutual inductance shocker

H. D. KIMMEL, J. KING, J. J. HUDY, and K. A. GARDNER
University of South Florida, Tampa, Florida 33620

A simple dc shock-generating device is described. The principle of operation relies upon the mutual inductance effect between the primary and secondary coils of a transformer.

This shock stimulus device was designed to be safe and simple and to provide an effective means of eliminating artifacts in polygraph recordings. Being battery powered, it has no path to ground or power lines. Compactness allows it to be attached directly to the subject.

The operation of this device is based upon Oersted's discovery that an electric current is accompanied by a magnetic field in conjunction with the complementary flux concept of Faraday, which states that a changing magnetic field can induce an electric current (Haber-Schaim, Cross, Dodge, & Walter, 1971). The application of this reciprocal relationship is illustrated quite simply in Figure 1.

There are two coils arranged on a common axis. A current sent through Coil 1 by the operation of the switch causes a magnetic field to cut through the coil. Since Coil 2 is in close physical proximity to Coil 1, the magnetic field will also be induced to cut through this second coil. When the switch connected to Coil 1 is opened, current ceases to flow and the magnetic field surrounding both coils collapses. It is this change of the magnetic field around Coil 2 that induces a current to flow through the coil to the shock output. The speed of collapse of the magnetic field and the number of turns in the secondary coil determine the voltage that is induced. A familiar application of

Figure 1. Mutual field inductance between coils.

Figure 2. Schematic diagram for complete shocker circuit.

this arrangement occurs in the ignition systems of internal combustion engines.

In order to ensure the optimal flow of magnetic field around both coils, the maximum possible coefficient of coupling may be approached when the two coils are wound one over the other on a closed iron core. A surplus audio-matching transformer (TRIAD HS-52) is used to achieve this arrangement. Figure 2 presents the complete schematic diagram.

The small capacitor placed across the switch serves to eliminate arcing and also allows the primary coil to deenergize rapidly. This in turn causes a rapid collapse of the magnetic field, thereby enhancing the output of the secondary coil. Without the capacitor, the induced current in the primary coil would cause an arc across the contact points of the switch as they opened and the energy stored in the magnetic field surrounding the coil would be lost in that arc. To prevent this, the capacitor stores the current and returns it to the circuit in the opposite direction, causing it to ring or oscillate. Thus the output of the primary stage of the circuit is actually a high-frequency

ac voltage that subsequently produces the rapid flux of the magnetic field in the secondary stage of the circuit.

The relay that interrupts the secondary coil circuit acts as an isolator, preventing any current's flowing to output during the energizing of the shocker unit. When Coil 1 is energized and the magnetic field expands through both coils, current is induced to flow to shock output, inasmuch as any relative movement of a magnetic field through Coil 2 will induce current regardless of its direction of movement in relation to a stationary external reference. The output during energization is relatively small, however, in that the field builds slowly when the switch is closed, producing less than 40 V.

A primary energizing voltage supplied from a 9-V dc radio battery and a 300:1 turn ratio between primary and secondary coils in the transformer will produce an output pulse of approximately 4 mA with a duration of roughly 1 msec. Figure 3 illustrates the output characteristics of the unit during both charge and discharge cycles. The charging phase produces

Figure 3. Output during charge and discharge cycles.

a very low voltage with a relatively long rise time, whereas the discharge phase produces a high voltage within a very short interval of time.

REFERENCE

HABER-SCHAIM, U., CROSS, J. B., DODGE, J. H., & WALTER, J. A. *PSSC physics* (3rd ed.). Lexington, Mass: Heath, 1971.

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