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Simple, Inexpensive Geiger Counters

By the Engineering Department, Aerovox Corporation

LIGHTWEIGHT, portable radioactivity detecting instruments presently are in demand both for prospecting and for civil defense stocks. Although small Geiger counters are available commercially in a variety of types and over a wide price range, many electronic technicians and engineers will elect to build their own.

The technician has a number of circuits from which to choose. The beginner undoubtedly will select the simpler ones. A simpler instrument also will be the logical choice for the person having no interest in uranium prospecting but wanting to keep a Geiger counter handy for probable civilian emergency use. In such an emergency, such as might follow a bombing, the radioactivity level would be expected to be high, and the high sensitivity of more complicated instruments not needed. The more serious uranium prospector would seek the higher sensitivity of the more complex circuits. In any event, the technician who builds his own Geiger counter expects that, in addition to the education and enjoyment secured from the work, his instrument will cost him less than a comparable manufactured one.

In this article, we have gathered together a representative group of simple Geiger counter circuits. These circuits have been tested. All frills have been eliminated in order to obtain foolproof operation and to insure that any reasonably competent technician might duplicate the instruments successfully with ordinary tools and equipment.

The counter tubes used in the circuits shown here are Victoreen Types 1B85 and 1B86. Tubes having equivalent electrical characteristics also may be employed. The 1B85 requires a d-c operating voltage of 900 v. Its threshold voltage is 800 v, and its minimum plateau length 200 volts (plateau slope 3%/100 v). Its life is 10^8 counts. The 1B86 requires a d-c operating voltage of only 300 v. Its threshold voltage is 280 v, and its minimum plateau length 60 volts (plateau slope 30%/50 v). Its life is 5 x 10^7 counts. The counter tube may be operated in a probe on the end of a shielded cable, or it may be installed inside the instrument case, with a suitable opening, holes, or louvers for entry of radiant energy.

Basically, the differences between Geiger counter circuitry result from (1) the method of obtaining the high voltage for the counter tube, (2) whether amplification is employed, and (3) whether indications are aural, visual, or both.

Typical Circuits

Eight representative Geiger counter circuits are shown. These are discussed separately in the following paragraphs.

Circuit 1. This is the simplest possible arrangement. Here, a 1B86 counter tube is connected in series with a miniature 300-volt battery (similar to Burgess U200 or RCA VS093), headphones, and a 1-megohm current-limiting resistor. A spst switch allows the circuit to be disabled when not in use.

Each ionizing particle penetrating the counter tube causes a pulse of current to flow through the circuit, and this produces a click in the headphones. In order to complete the circuit, the headphones must be of the magnetic type and must have high impedance. A stepdown matching transformer would be required for low-impedance headphones. Crystal-type headphones, although possessing remarkably high impedance, are unsatisfactory in this circuit because they provide no continuity for dc.

The 1B86 is a glass-wall gamma ray tube. Its diameter is 0.4 inch and its over-all length, including its 1⅛″ tinned leads, is 4¾ inch. For more compact assembly or smaller-sized probes, Type 1B88 counter tube

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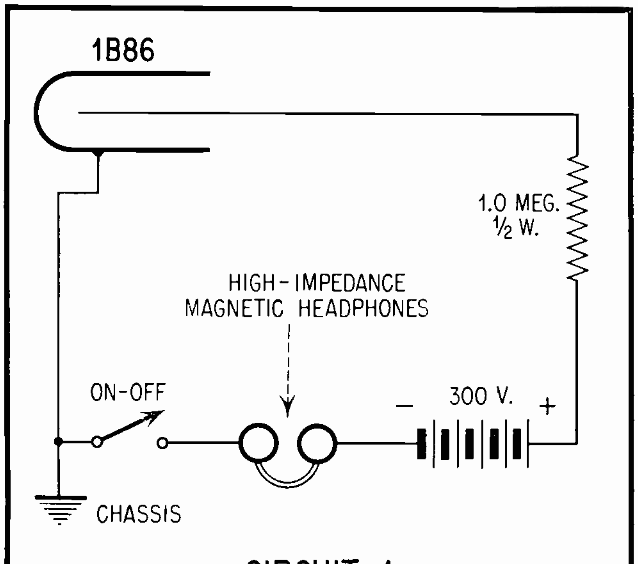
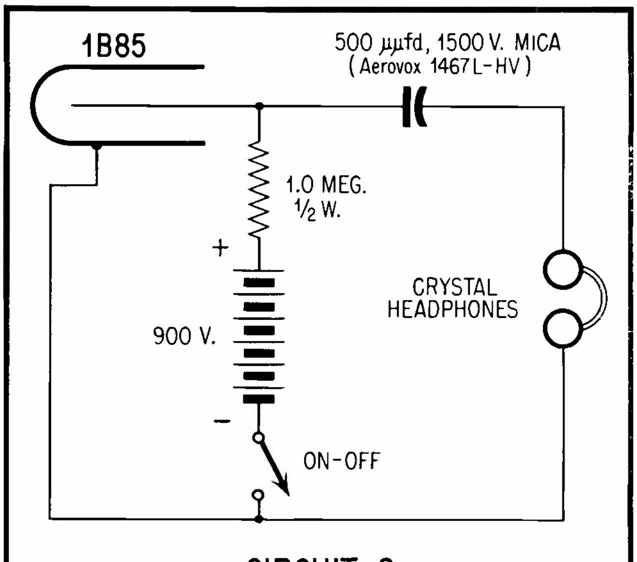


CIRCUIT 1



CIRCUIT 2

may be substituted. The latter also has a diameter of 0.4 inch, but its over-all length (including 1⅛″ tinned leads) is only 2¾ inches.

The 300-volt Type U200 battery measures 2-11/16″ x 2-7/32″ x 3-29/32″.

Circuit 2. The sensitivity of the simple, battery-operated counter may be improved by employing a general-purpose betagamma counter tube, such as Type 1B85, with a 900-volt d-c supply. The high voltage is obtained from three miniature 300-volt batteries(such as specified for single use in Circuit 1) connected in series. Circuit 2 shows this arrangement.

Because the 900-volt potential constitutes a serious shock hazard, we do not recommend connecting the headphones in series with the other elements in the way this was done in Circuit 1. Instead, high-impedance headphones are capacitance-coupled to the circuit through a 500-uufd 1500-volt mica capacitor. Crystal-type headphones can be used to advantage in this circuit.

The 1B85 is an aluminum wall tube having an A1-82 coaxial base. Its diameter is 51/64 inch, and its over-all length, including the coaxial base, is 4¼ inches.

Because of the higher d-c voltage employed in Circuit 2, particular care must be exercised during construction of the instrument to insulate the various parts of the assembly. To prevent leakage, use only high-grade non-hygroscopic insulating materials and keep all circuit points separated as widely as possible.

Circuit 3. In this arrangement, a pentode amplifier has been added to the rudimentary circuit (Circuit 1) to increase sensitivity and to provide louder clicks. Pulses from the 1B85 counter tube are transmitted to the grid of the 1U5 amplifier through coupling capacitor C_1.

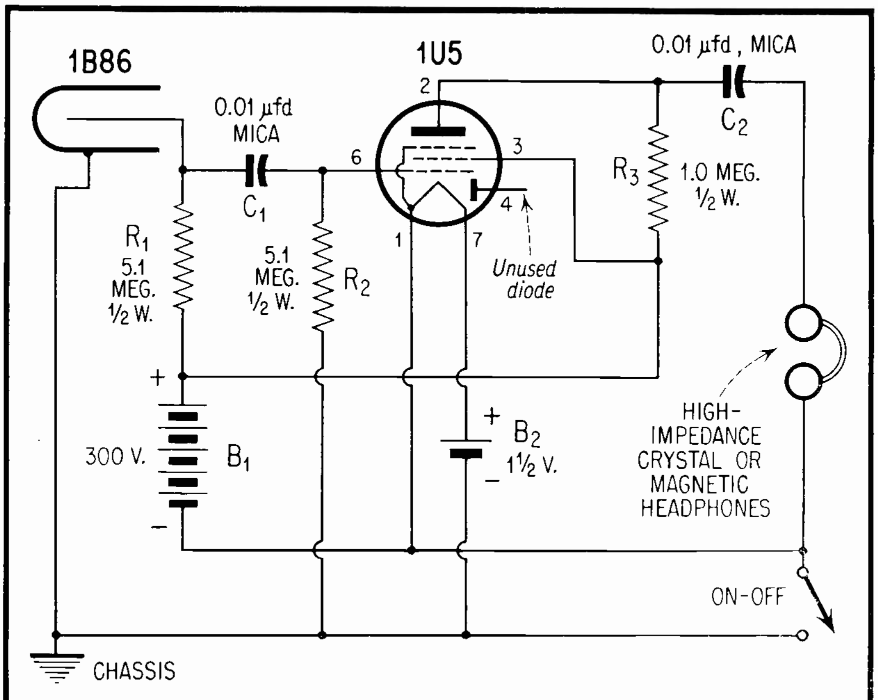
The midget 300-volt battery, B_1, supplies both the counter tube and the plate and screen of the amplifier. The second battery, B_2, is a 1½-volt Size-D flashlight cell. The spst ON-OFF switch is connected to open both battery circuits simultaneously when in its OFF position.

Maximum efficiency will be obtained with high-impedance headphones. Crystal-type phones are recommended.

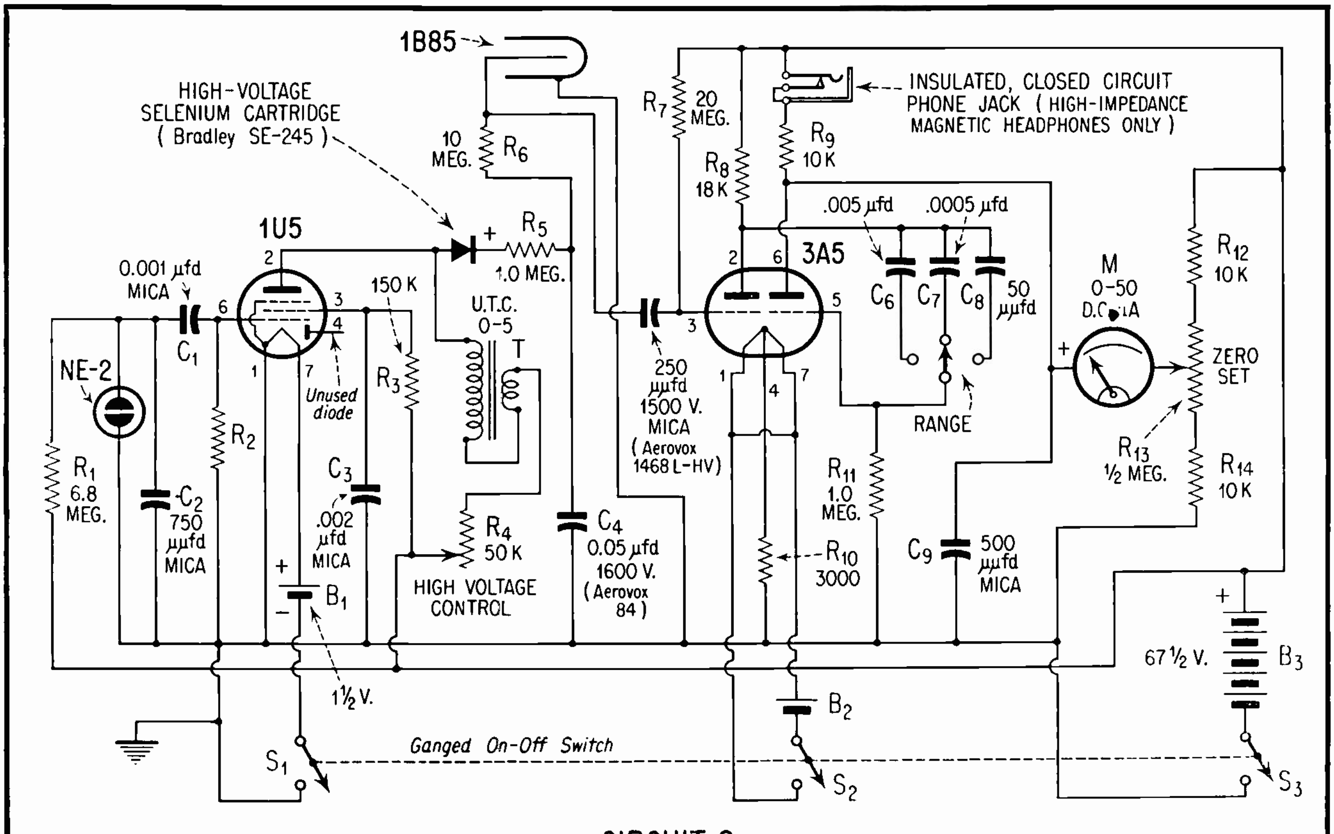
The shorter Type 1B88 counter tube also may be employed in this circuit.

Circuit 4. This is a variation of Circuit 3. Here, the plate and screen of the 1U5 tube have been disconnected from the important 300-volt battery and are supplied by the separate, midget 67½-volt battery, B_3. In all other respects, Circuit 4 is identical to Circuit 3.

This circuit change is important when the instrument is to be used regularly over protracted periods.



CIRCUIT 3



CIRCUIT 8

3A5 tube. The other, SE_2, is poled for negative output for the 1B85. The 50-microfarad, 150-volt electrolytic capacitor, C_4, filters the 3A5 voltage, and its normal leakage holds this voltage approximately to 80 volts at 200 microamperes. The Victoreen Type 5841 regulator tube holds the counter tube voltage to a constant 900-volt level. Capacitors C_2 and C_3 and resistor R_1 form the high-voltage filter.

The 3A5 tube provides a 2-stage RC-coupled amplifier. The output triode is capacitance-coupled, through C_6, to a rectifier-type voltmeter comprised by the 1N34 diode and the 0-50 d-c microammeter, M.

The meter deflection is proportional to the number of pulses per unit time arriving from the counter tube. Its scale may be calibrated at various settings of potentiometer R_5 (which might also be a step-type attenuator) with the aid of a series of calibrated radioactive samples held close to the 1B85 tube. Magnetic-type headphones inserted into the phone jack will provide aural indications. Since this jack is of the closed-circuit type, it will restore the plate circuit of the second triode automatically when the headphone plug is extracted.

Circuit 8. This circuit employs a 3A5 dual triode in a cathode-coupled one-shot multivibrator circuit. The multivibrator is triggered by pulses from the 1B85 counter tube. Each pulse switches the multivibrator on and off, causing a single pulse to be delivered to the metering circuit. Capacitors C_6, C_7, and C_8, switched into the circuit, alter the pulse duration and repetition rate of the multivibrator and thus change the meter range. The microammeter thus is provided with several "total count" ranges. The microammeter scale accordingly may be calibrated in counts per unit time, milliroentgens per hour, or similar units. For this purpose, a series of calibrated radioactive samples may be employed.

Like a v-t voltmeter, the meter is set initially to zero in the absence of any input signal, by adjustment of potentiometer R_{13}. An aural indication is obtainable from magnetic-type headphones plugged into the closed-circuit jack.

This multivibrator-type Geiger counter circuit is adapted from a similar one developed by Friedland. (See *Radiological Monitoring*. Stephen S. Friedland. QST, June 1951, p. 29).

The 900-volt potential for the counter tube is developed by a special power supply based upon a neon-bulb relaxation oscillator. Operated from the same 67½-volt battery, B_3, that furnishes the 3A4 plate voltage, the relaxation oscillator consists of resistor R_1, capacitor C_2, and the NE-2 neon bulb. The sawtooth voltage developed by this oscillator is applied to the grid of the 1U5 tube. A choke coil, consisting of a miniature "Ouncer" transformer, T, with its primary and secondary connected together in series-aiding, is connected in series with the 1U5 plate. The rapid fall of current through this choke, due to the decay ("flyback") of the sawtooth wave, induces a high voltage across the choke. This high voltage then is rectified by the high-voltage selenium cartridge, filtered by R_5 and C_4, and applied to the 1B85 tube. The high-voltage dc may be set exactly to the required level of 900 volts (preferably with the aid of an electrostatic voltmeter) by adjustment of potentiometer R_4.

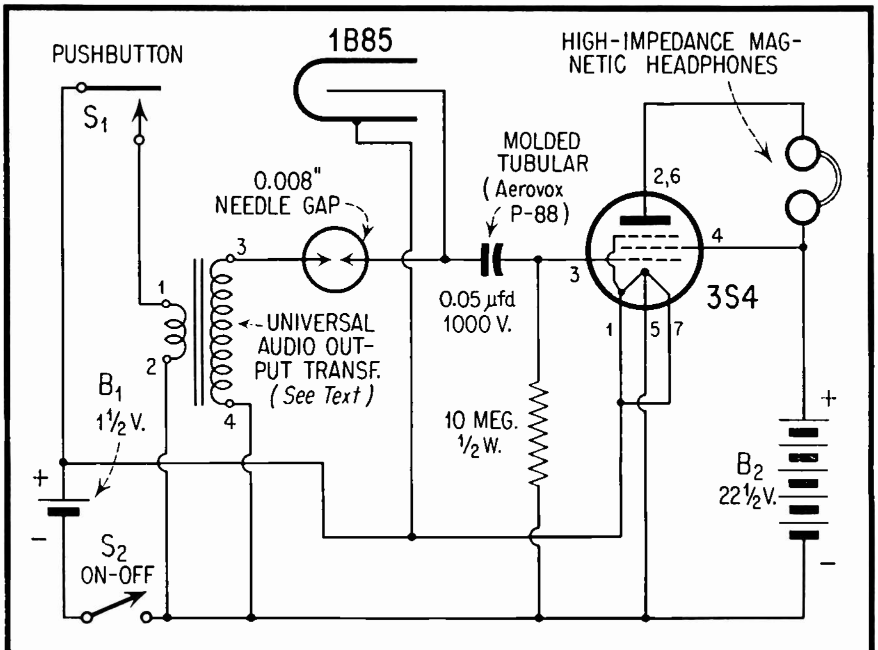
A separate 1½-volt cell, B_2, is required for the 3A5 filament, since the cathode-coupled circuit in which this tube is used requires that the filament "float" 3000 ohms above ground. B_1 and B_2 are Size-D flashlight cells. B_3 is a radio-type 67½-volt B-battery.

and the high-voltage winding of the transformer. A discharge takes place across this gap when the pushbutton (S_1) is depressed and released, and the capacitor is charged. Several, successive, rapid pulsings of the push-button will charge the capacitor fully.

As the 1B85 tube fires under the influence of penetrating radioactive particles, the resulting pulses are presented to the grid of the 3S4 amplifier tube, and the amplified pulses are delivered to the headphones.

The 1½-volt battery, B_1, supplies both the transformer and the 3S4 filament. The 22½-volt battery, B_2, supplies only the plate and screen of the 3S4. For light-duty application, B_1 may be a single Size-D flashlight cell and B_2 a hearing aid battery. For more exacting work, B_1 should be made up of two or more Size-D cells connected in parallel, and B_2 should be a midget 22½-volt radio-type B-battery.

As in Circuit 5, the length of time that the capacitor will remain charged will depend upon ambient humidity and capacitor leakage and usually will be between 5 and 30 minutes. An occasional succession of rapid pulsings of the pushbotton switch, S_1, will restore the charge.

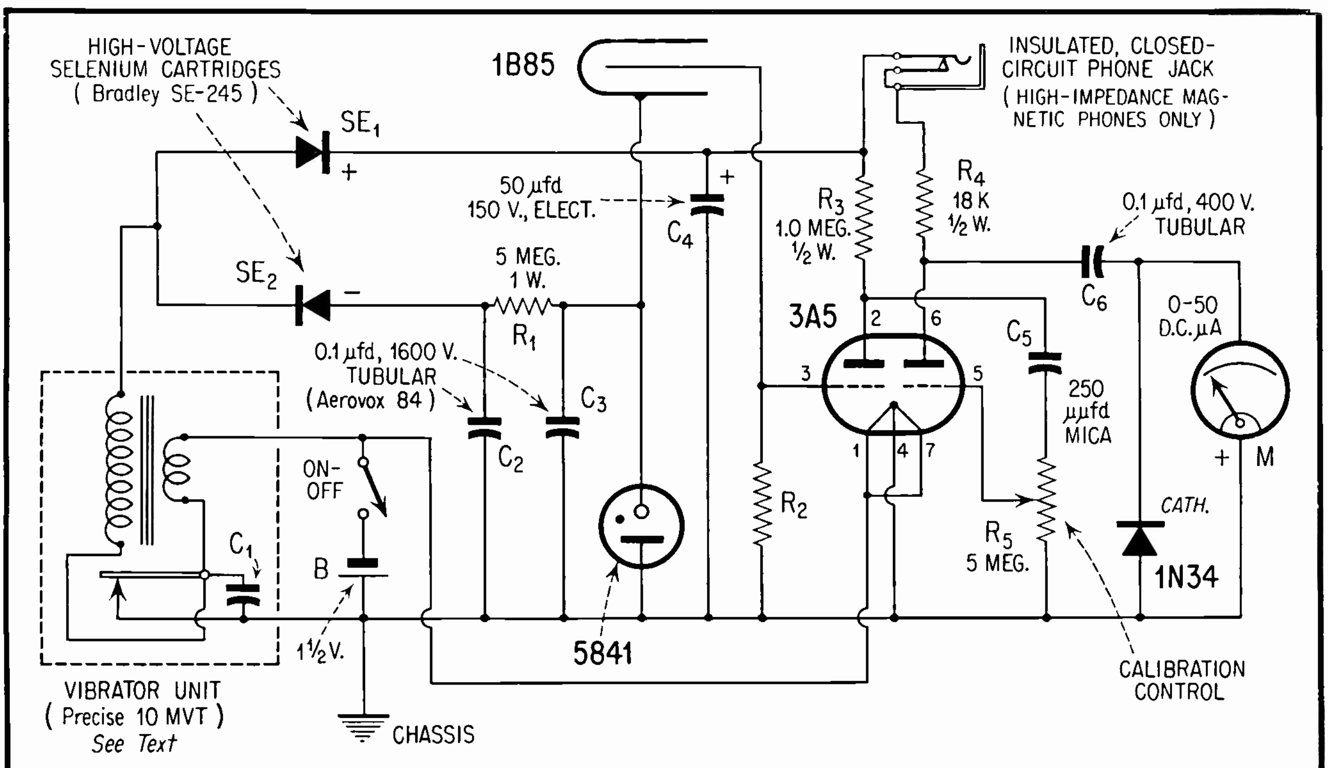


CIRCUIT 6

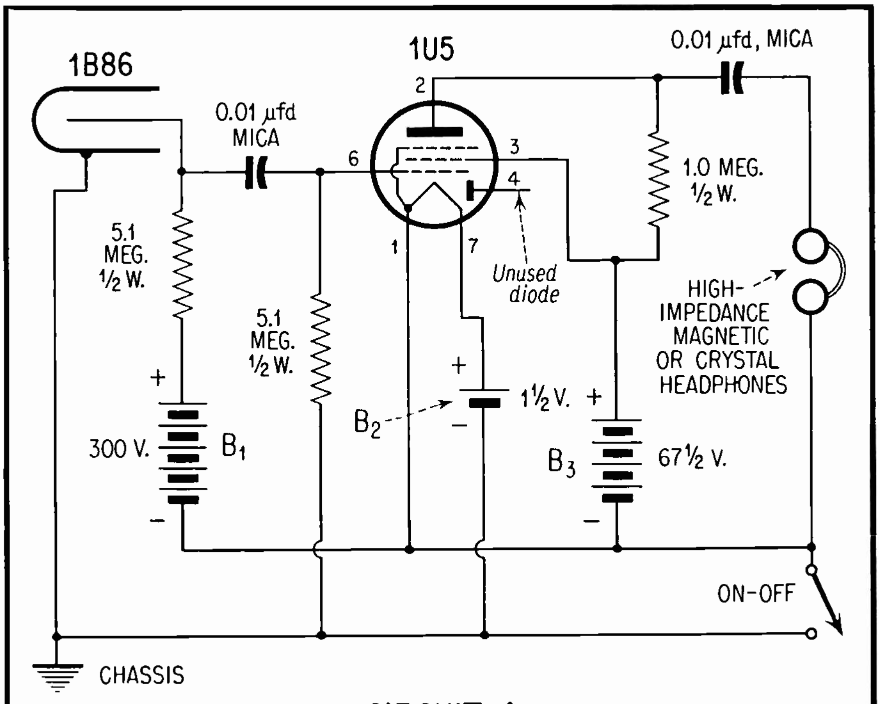
Circuit 7. This Geiger counter has a self-contained, miniature, vibrator-type power supply operated from a single 1½-volt Size-D flashlight cell. The vibrator unit supplies the 1B85 counter tube and the 3A5 dual-triode amplifier tube. Meter readings, as well as headphone signals, are obtained with this circuit.

The miniature vibrator unit is a Model 10MVT, a product of Precise Measurements Co., Brooklyn, N. Y. It consists of a vibrator integral with a high-voltage transformer. The spark-suppressing capacitor, C_1, is self-contained.

The high-voltage a-c output of the transformer is rectified by two subminiature high-voltage selenium cartridges. One of these, SE_1, is poled to supply positive output for the



CIRCUIT 7



CIRCUIT 4

Under such circumstances, removal of the tube drain from the 300-volt battery and the consequent longer life of this battery sufficiently offsets the additional cost, complication, and weight of the additional battery, B_3, to warrant the modification.

The spst switch interrupts all three battery circuits when thrown to its OFF position.

Circuit 5. This is an interesting 300-volt Geiger counter which is powered from a single 1½-volt Size-D flashlight cell. The high d-c voltage required for operation of the 1B86 counter tube is obtained by charging a capacitor through a high-turns-ratio stepup transformer.

The transformer may be any small universal replacement-type output unit, such as Merit A2900. Terminals A and B represent the *entire* primary winding of this transformer. (Do not use the center tap). Terminals C and D are two of the low-impedance connector lugs selected from the transformer connection chart for a turns ratio between CD and AB of 300 to 1, or higher.

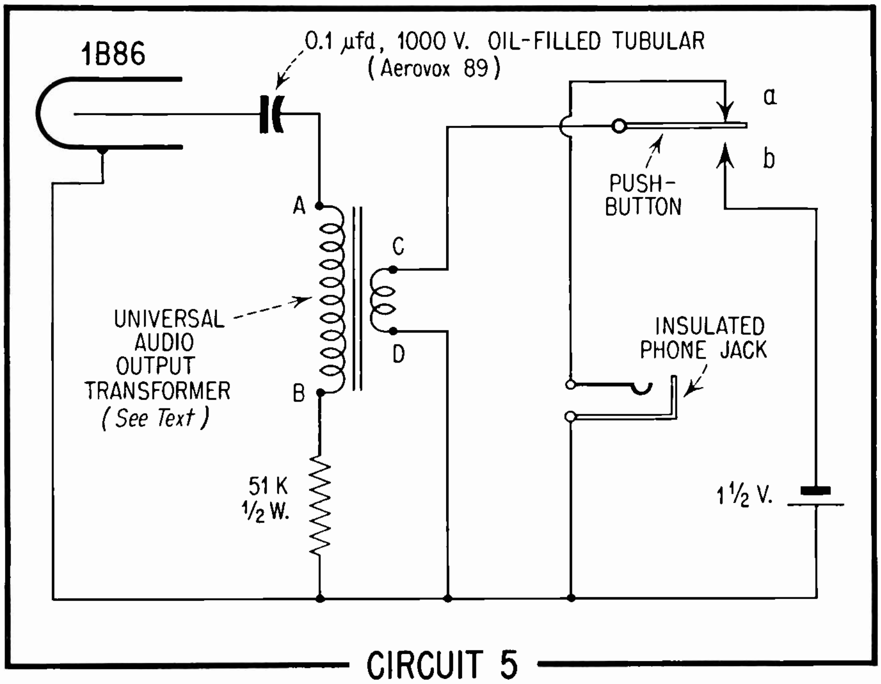
The spdt pushbutton switch normally rests in position a. This connects the headphones (plugged into the insulated phone jack) to the low-impedance winding of the transformer. When the switch is depressed and released momentarily, making a quick make-and-break connection in position b, a high-voltage pulse is induced across the high-turns winding, AB. This pulse fires the 1B86 tube and charges the 0.1-microfarad capacitor. Several repeated operations of the pushbutton switch will charge this capacitor fully. With the switch resting in position a, the capacitor cannot discharge through the circuit because of the insulating property of the 1B86 when it is not fired. The capacitor accordingly retains its charge and serves as a 900-volt source. When the counter tube is penetrated by a radioactive ionizing particle, however, it fires and induces a voltage across winding CD, and this produces a click in the headphones.

The length of time the capacitor will hold its charge depends upon the leakage characteristics of the capacitor and how well the circuit is protected from ambient humidity. This will vary from 5 to 30 minutes in most cases. As the charge leaks away, because of either leakage or rapid counting, the capacitor may be re-charged readily by quickly pulsing the pushbutton switch several times.

Because of the nature of this circuit, very small size may be attained in the completed instrument. An added advantage is the fact that the headphones, being inductively coupled, are not included directly in the high-voltage circuit and any possibility of shock, ground, or short circuit consequently is removed.

Circuit 6. The high potential of 900 volts is obtained in this circuit also by pushbutton-pulsing a 1½-volt cell through a backward-connected universal output transformer to charge a capacitor. Here, however, terminals 1 and 2 of the transformer are the lugs (selected from the transformer connections chart) which supply the *lowest* impedance. This permits the highest stepup ratio. 3 and 4 represent the *entire* primary winding of the transformer. (Do not use the center tap.)

A small needle-type spark gap is connected between the 1B85 tube



CIRCUIT 5

JUST ONE WILL DO...

SO WHY BUY TWO?

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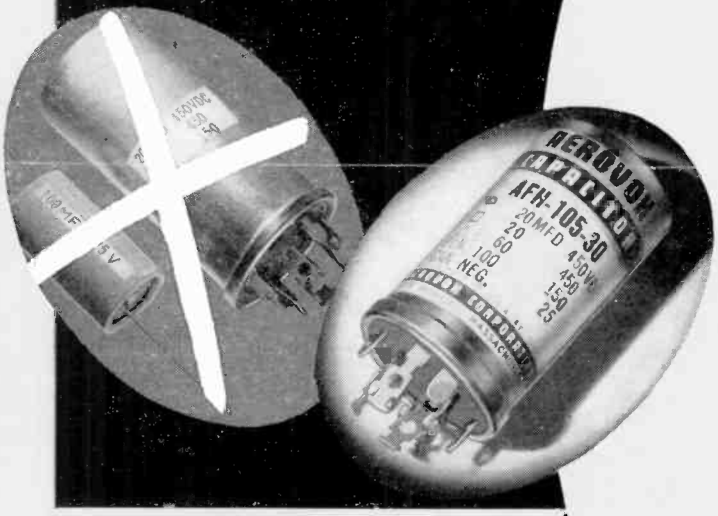
TWIST-PRONG ELECTROLYTICS



Voltages, capacitances, sections—in several hundred different combinations—go to meet today's twist-prong electrolytic capacitor replacement needs.

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