THE Geiger counter described in this article is small enough to be slipped into the pocket and taken out into the country to look for radioactive minerals. Quarries and old mine workings are good hunting grounds, particularly if geologically old rocks are being uncovered. Unfortunately, your search is not likely to be very rewarding in this country.

Nevertheless, the instrument will show that we are being exposed continually to a natural background radiation made up of cosmic rays and the emissions from radioactive materials in the ground and air around us and over which we have very little control. The instrument can also be used to locate sources of radioactivity should these be mislaid in the workshop and laboratory.

The instrument is quite sensitive, it will count by producing a click in an earpiece, a single beta particle (an electron) whose mass is about one million billion billionth of a kilogram (10^{-30}kg) and which could be moving at about 800 million kilometres per hour!

GEIGER COUNTER

By M. PLANT M.Sc.

The accompanying photographs show one form of the completed Geiger counter with the electronics housed in a plastics slide box. In use the box is held close to the ear, the thumb holding the push-button switch down.

THE GEIGER TUBE

The Geiger counter tube is the part which is sensitive to the atomic radiations which are emitted from radioactive sources and which make up cosmic rays. The type of tube shown in the photographs is fairly common and consists of a central anode surrounded by the cathode. Photos show the kind of tube which has an end window to allow it to respond to alpha particles (the nuclei of helium atoms) and to low energy beta particles, both of which are most easily absorbed by the material through which they pass. The less sensitive tube shown in the model responds to the very penetrating radiation of gamma rays and high energy beta particles.

Geiger tubes (strictly called Geiger-Muller or GM tubes) are available on the government surplus market for a few pounds and are often advertised in the pages of this journal or are available from suppliers of Mullard equipment.

The tube selected should have an operating voltage of about 400V. An important feature of the counts per minute versus voltage across the anode-to-cathode of a geiger tube is the so-called plateau of operating voltage which is shown in Fig. 1. The sensitivity of the tube increases gradually over this plateau and it is important to operate the tube within this range of voltage; the midpoint of the plateau is usually chosen and the present instrument can be adjusted to operate the tube at this voltage. Geiger-Muller tubes have commonly a two-pin base requiring a special holder, but some have an octal base although just two of these pins actually make connection to the tube.

THE CIRCUIT

Fig. 2 shows the circuit which consists essentially of three parts, an inverter or d.c.-to-d.c. converter, a voltage doubler, and an amplifier. The inverter and voltage doubler enable a 9V battery to provide up to 500V to operate the GM tube, and the amplifier is required to amplify the voltage pulses obtained across a resistor in series with the tube when the tube responds to the effect of a particle passing through it.

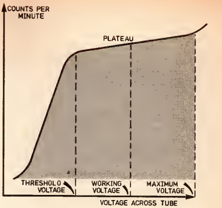


Fig. 1. The characteristic curve of a GM tube

THE INVERTER

The inverter is a simple resistance-coupled oscillator which gives about 250V across the secondary of the 9-0-9V/250V transformer at a frequency of about 40Hz.

Up to 250V a.c. is available across the secondary winding of the transformer and this is doubled and rectified by the diodes D1 and D2 and the capacitors C2 and C3 to provide about 500 V d.c.

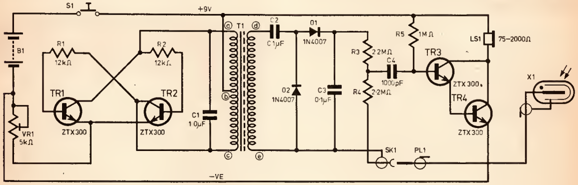


Fig. 2. Circuit diagram of the power supply, GM tube and amplifier

TR1 starts to conduct when the circuit is switched on and current increases in the associated half of the primary winding of the transformer, induces a voltage in the other primary half which rapidly drives TR1 into saturation via the base coupling resistor R1 and thus biases TR2 off.

Flux increases in the core of the transformer until saturation is reached when the positive feedback provided by the induced primary voltage falls to zero. TR1 is returned to the off state and this ends the first half cycle of the period of oscillation. The collapsing flux in the transformer core induces a voltage in the primary winding associated with TR2 to drive it on, so initiating a second similar half-cycle.

Capacitor C1 across the collectors of the transistors eliminates the possibility of high frequency oscillation and makes for reliable starting of the inverter. The actual primary voltage being switched by the two halves of the primary winding of the transformer can be varied by means of the variable resistor VR1 in series with the 9V battery so that the voltage available from the voltage doubler can be varied to suit the characteristics of the tube used.

The output from the supply is applied across the GM tube via R3 and R4. The passage of a radioactive particle through the gas filling the tube causes some of the gas to be ionised. Under the high voltage between the anode and cathode, a rapid avalanche of ionisation occurs and ions are collected by the electrodes resulting in a very small current through the external resistors R3 and R4. This pulse of ionisation is short-lived and the tube is quickly ready to respond to another ionising particle passing through it. The voltage change across the external resistors is coupled to a two-transistor amplifier by the coupling capacitor C4 so that a loud click is heard in the earpiece.

ASSEMBLY

A piece of Veroboard was selected for assembling the circuit, the precise dimensions depending on the physical size of the components to hand and the case used. In the present instance the case used in the prototype was a Kodak slide box measuring 108 × 32 × 52mm and the Veroboard measured 46 × 54mm.

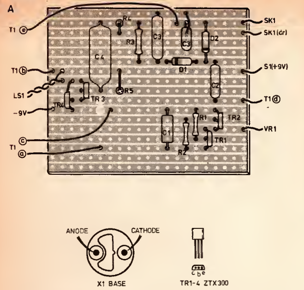
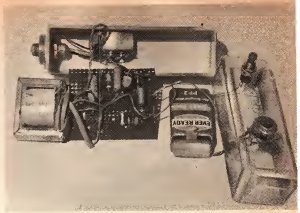


Fig. 3. Component layout and Veroboard cutting details for the counter



Completed Geiger Counter ready for installing in a photographic slide case

COMPONENTS . . .

Resistors
R1, R2 12kΩ, 2 off
R3, R4 2·2MΩ, 2 off
R5 1MΩ
All ¼W, 10%

Potentiometers
VR1 5kΩ skeleton pre-set

Capacitors
C1 1μF, 250V
C2 0·1μF, 250V
C3 2 off 0·22μF, 250V to make up 0·1μF, 500V
C4 1,000pF mica

Semiconductors
TR1, 2, 3 & 4 Silicon *npn* ZTX300 or similar, 4 off
D1, 2 1N4007, 2 off

Switches
S1 Push-to-make button switch or slide switch

Miscellaneous
T1 Transformer, 9–0–9V primary, 240V secondary. Midget mains type such as Osmor MT9
LS1 Small earphone, 75Ω or above (to 200Ω)
X1 Mullard MX168 or similar low voltage type GM tube. Possible sources Henry's Radio, 20th Century Electronics Ltd., New Addington, Croydon, Surrey
B1 9V, PP3 or PP6 suits
Tube holder; co-ax cable; co-ax plug and socket; Veroboard; wire; solder; suitable box.

Fig. 3 shows the component layout of the prototype circuit in which C3 is made up of two 0·22μF, 250V capacitors connected in series to give, effectively, a 0·1μF, 500V capacitor. However, a suitable single capacitor may be obtained for this circuit, although physical size may preclude use. The main precaution to be taken is to ensure that the high voltage cannot be inadvertently connected to the low voltage side of the circuit, otherwise damage to the transistors and C1 may result.

SETTING-UP

After assembly and before connecting the Geiger tube, switch on the circuit and listen for a faint low frequency hum coming from the earpiece which indicates that the inverter is working. Rotate the high-voltage-adjust variable resistor VR1 and the hum should change in intensity and frequency slightly.

Next, use a high impedance voltmeter to measure the voltage available at the socket for the GM tube and adjust this voltage to that required to drive the tube. Sometimes this voltage is marked on the side of the tube.

If the voltage is not marked and you are unsure of the correct operating voltage, connect the tube and increase the voltage slowly by means of VR1 until the tube begins to respond to the background radiation and clicks are heard. Increase the voltage by about 20V and then leave VR1 alone. The counting rate due to the background depends upon your locality, the operating voltage of the tube and the volume of the gas in the tube as well as its construction.

Using a gamma-ray sensitive tube, a background count rate of about 45 clicks per minute should be obtained.

Bring up a luminous watch or clock face to the tube and the count rate will increase. The Geiger counter is now ready for use. From time to time it will be necessary to adjust VR1 to compensate for the fall with use of the terminal voltage of the battery. Never operate the tube at too high a voltage so that it breaks into continuous discharge for this will decrease its useful life markedly. ★