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# RADIOACTIVE?

## Geiger counter to build



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# Simple, sensitive Geiger counter

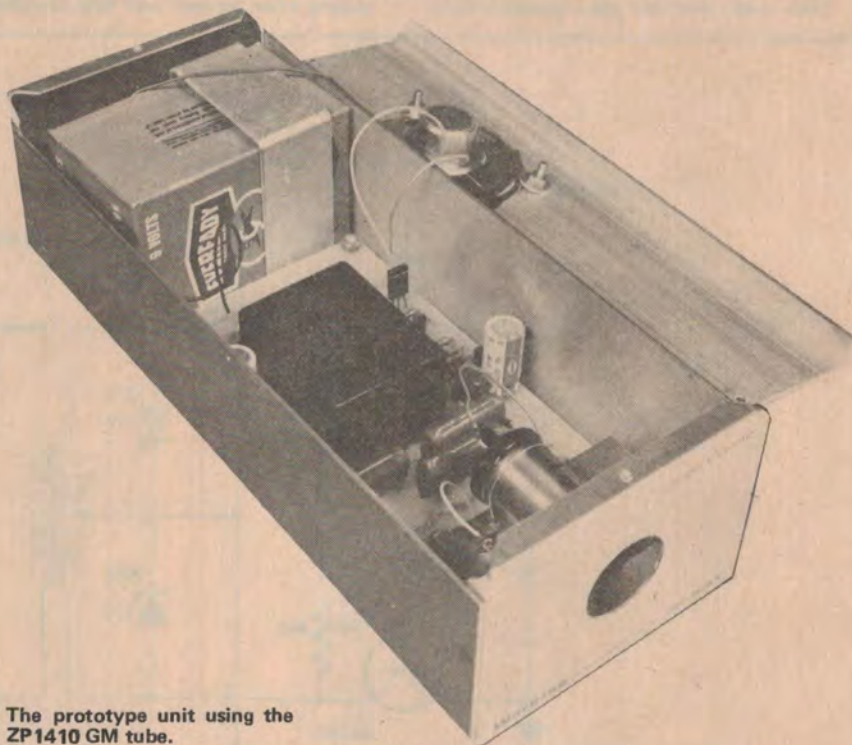
Radioactivity is a fascinating subject. The more you learn about it, the more questions there are to ask! This project is simple to construct and relatively inexpensive. It should prove of great interest to science teachers, students and anyone generally interested in radioactivity.

David Tilbrook

IN 1896, Henri Becquerel announced the discovery of radioactivity. He had been experimenting with the element uranium and found that it spontaneously emitted energy, without activation by another energy source. Immediately, researchers started the quest for other elements that might also exhibit this property of natural radioactivity. Pierre and Marie Curie isolated two new elements from a uranium ore called pitchblende. Naming these elements polonium and radium they discovered their new elements were enormously radioactive. Polonium for example, is approximately 10 billion times more active than an equivalent mass of uranium.

The radiation emitted by radioactive elements was at first likened to X-rays, discovered only four months earlier, but it was Ernest Rutherford who first found that there was more than one kind of radiation. The most obvious difference was the ability of the radiation to penetrate matter and he called the least penetrating radiation  $\alpha$  (alpha) rays, and the other more penetrating radiation  $\beta$  (beta) rays. Magnetic field deflection of the rays showed that  $\beta$  rays were in fact free electrons. Further work carried out by Rutherford on the  $\alpha$  ray showed that it consisted of particles also and had a positive charge equal to the charge of two protons. The particle of the  $\alpha$  ray was later proved to be the nucleus of the element helium, consisting of two protons and two neutrons bonded together. The poor penetrating ability of the particle is thought to be due to its positive charge and the repulsive force it will experience if it approaches the nucleus of an atom.

In 1900 a third kind of radiation was discovered. Called 'gamma' ( $\gamma$ ) radiation, it was found to have tremendous penetrating power because of its neutral charge. Gamma particles turned out to be electromagnetic radiation, the same as light, but with much higher energy.



The prototype unit using the ZP1410 GM tube.

## Measuring radioactivity

With the development of the understanding of radioactivity it was necessary to invent detectors which would enable the radiations to be recognised and measured. The most sophisticated of these is the *bubble chamber*. A development of earlier cloud chambers, these devices enable the tracks of nuclear particles to be studied, the particles themselves being recognised by the characteristic 'tracks' they make in the chambers.

Just as important are the simpler radiation detectors, the *scintillation counter* and the *geiger counter*. These enable the presence of radiation to be recognised and measured quickly and conveniently.

Scintillation counters use a crystal that fluoresces when a particle travels through it. This crystal is mounted on top of a sensitive photomultiplier,

which will detect any generation of a light pulse in the crystal. Scintillation tubes however are expensive and require a complicated power supply and amplifier, making them unsuitable for home construction. The geiger counter, on the other hand, is simple to construct and inexpensive.

## Geiger counter

Since this project is designed as a general purpose geiger counter I have made it compatible with two GM tubes. These are manufactured by Philips and are designated ZP1310 and ZP1410. The ZP1410 is an end window  $\alpha$ ,  $\beta$  and  $\gamma$  sensitive tube and is therefore more expensive than the ZP1310. It is also more fragile and the end window should not be touched. The ZP1310 having no end window will only detect particles with sufficient energy to penetrate the tube, such as higher ▶

## HOW IT WORKS – ETI 562

The geiger tubes specified for this project have plateau regions around 600 V. To obtain this voltage from a six or nine volt battery the circuit uses an astable multivibrator, formed by Q1 and Q2, driving the 12 volt side of a Ferguson pc board mounting power transformer. This is normally the secondary side of the transformer but in this circuit it is used as the primary. Zener diodes ZD1 and ZD2 limit the voltage that can be applied to the primary of the transformer to around 10.5 volts, and this gives approximately

200 volts on the secondary. Diodes D1, D2 and D3, and capacitors C3, C4 and C5 form a voltage tripler that produces 600 V at the point marked X on the circuit diagram.

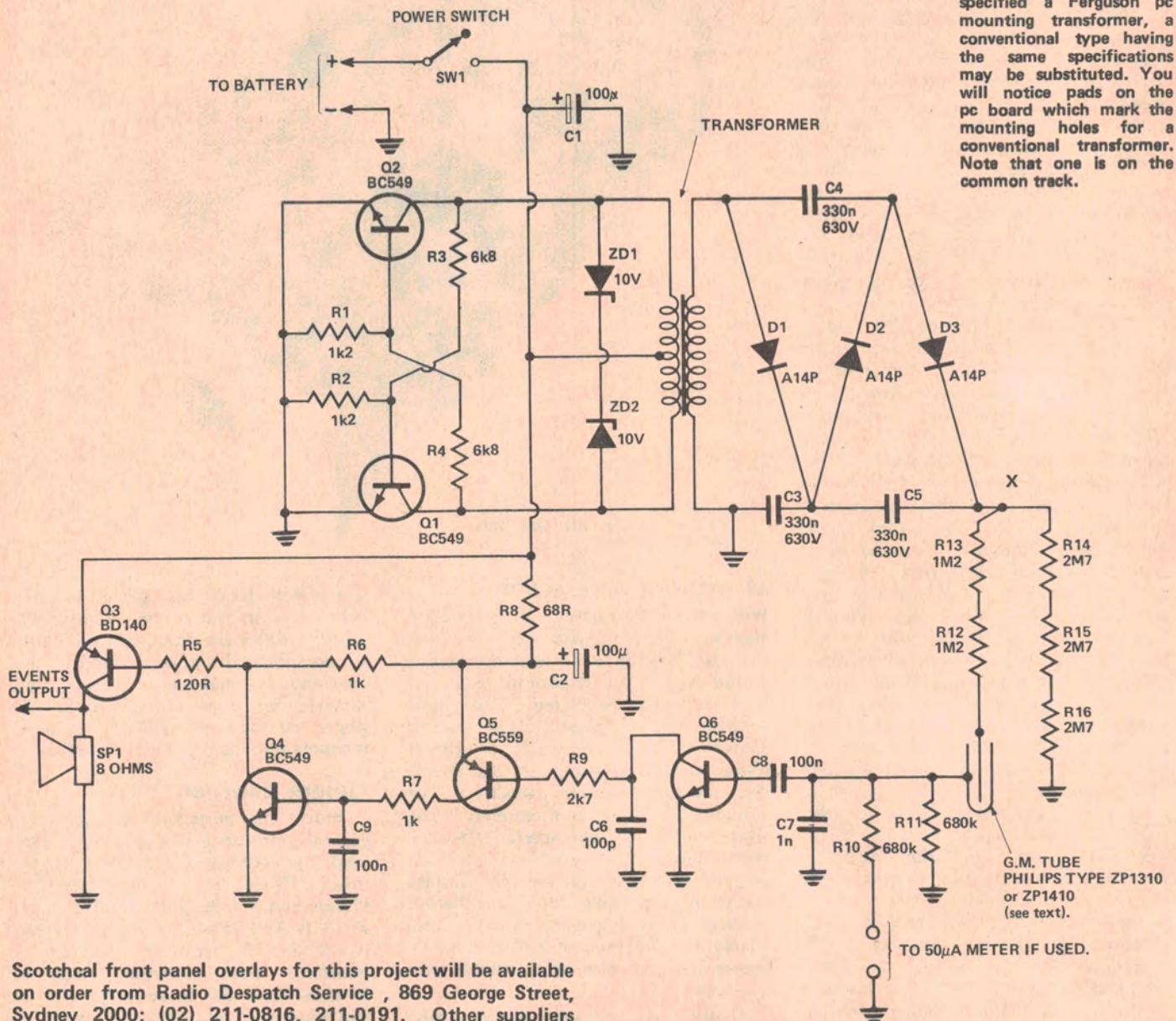
This voltage is applied to the anode of the GM tube via two 1M2 resistors R12 and R13. Most common 1/2W resistors have maximum voltage ratings around 270 volts, so it is necessary to use the series combination of R12 and R13 to provide the series anode resistance for the tube, rather than use a single 2M2 resistor. Resistors R14, R15 and R16 discharge the supply after turn-off and help to stabilise

the anode voltage by providing a slight current drain on the tripler at all times.

When a particle enters the tube, ionisations take place and a current pulse flows through the tube via R11 to ground. This pulse causes a momentary voltage rise across R11. When this voltage gets to 0.6 volts the base emitter of Q6 is turned on, causing Q5 to conduct momentarily. This provides a pulse onto the base of Q4, driving Q3 to produce a pulse in the loudspeaker.

The capacitors C2, C6, C7 and C9 provide filtering, primarily to remove any injection from the multivibrator.

Note: although we have specified a Ferguson pc mounting transformer, a conventional type having the same specifications may be substituted. You will notice pads on the pc board which mark the mounting holes for a conventional transformer. Note that one is on the common track.



Scotchcal front panel overlays for this project will be available on order from Radio Despatch Service, 869 George Street, Sydney 2000; (02) 211-0816, 211-0191. Other suppliers may also make them available.

The pc board patterns are on page 113.

energy  $\beta$  particles and  $\gamma$  particles. Fortunately most radioactive elements emit all three radiations so the ZP1310 is entirely adequate for most purposes.

## Construction

The construction is reasonably simple, since it is mostly confined to the printed circuit board. Start by mounting the resistors and capacitors on the pc board. Then mount the transistors, diodes and power transformer. Be sure the transistors, diodes and electrolytic capacitors are connected the correct way around. The pc board has provision to drive a 50  $\mu$ A meter movement although I did not use this facility when building the prototype. The biggest problem is one of calibration. The meter is useless unless one has access to a calibrated reference instrument. For most purposes it is sufficient to use the click rate as an indication as to how radioactive a sample is.

If the ZP1310 tube is used it is mounted directly onto the pc board. Do not solder directly to the anode of the tube. The tube should be supplied with an anode connector. Solder this onto the pc board first and then plug the tube into it. If the tube is not supplied with an anode connector remove one of the socket pins from a 9-pin valve socket and use this instead. Once the anode is connected the

cathode strap supplied with the tube can be soldered to the pc board. Do not solder directly to the GM tube to make the cathode connection. If you are using the ZP1410 tube, this must be mounted so that it is insulated from the case and connecting wires taken back to the pc board. I used a piece of pc board that is mounted on insulated 25 mm spacers. The tube is fixed to the board using two wire loops,

around the tube and through holes drilled in the board. The cathode connection to the tube is made by soldering the cathode strap onto the small pc board. As with the ZP1310 do not solder directly to the anode of the tube. Use an anode connector if it is supplied or a socket pin from a 9-pin valve socket.

Once the board is completed it can be mounted in a suitable chassis. I used ▶

## PARTS LIST - ETI 562

### Resistors ..... all 1/2W, 5%

|     |       |      |
|-----|-------|------|
| R1  | ..... | 1k2  |
| R2  | ..... | 1k2  |
| R3  | ..... | 6k8  |
| R4  | ..... | 6k8  |
| R5  | ..... | 120R |
| R6  | ..... | 1k   |
| R7  | ..... | 1k   |
| R8  | ..... | 68R  |
| R9  | ..... | 2k7  |
| R10 | ..... | 680k |
| R11 | ..... | 680k |
| R12 | ..... | 1M2  |
| R13 | ..... | 1M2  |
| R14 | ..... | 2M7  |
| R15 | ..... | 2M7  |
| R16 | ..... | 2M7  |

### Capacitors

|    |       |                       |
|----|-------|-----------------------|
| C1 | ..... | 100u 25V electrolytic |
| C2 | ..... | 100u 25V electrolytic |
| C3 | ..... | 330n 630V greencap    |
| C4 | ..... | 330n 630V greencap    |

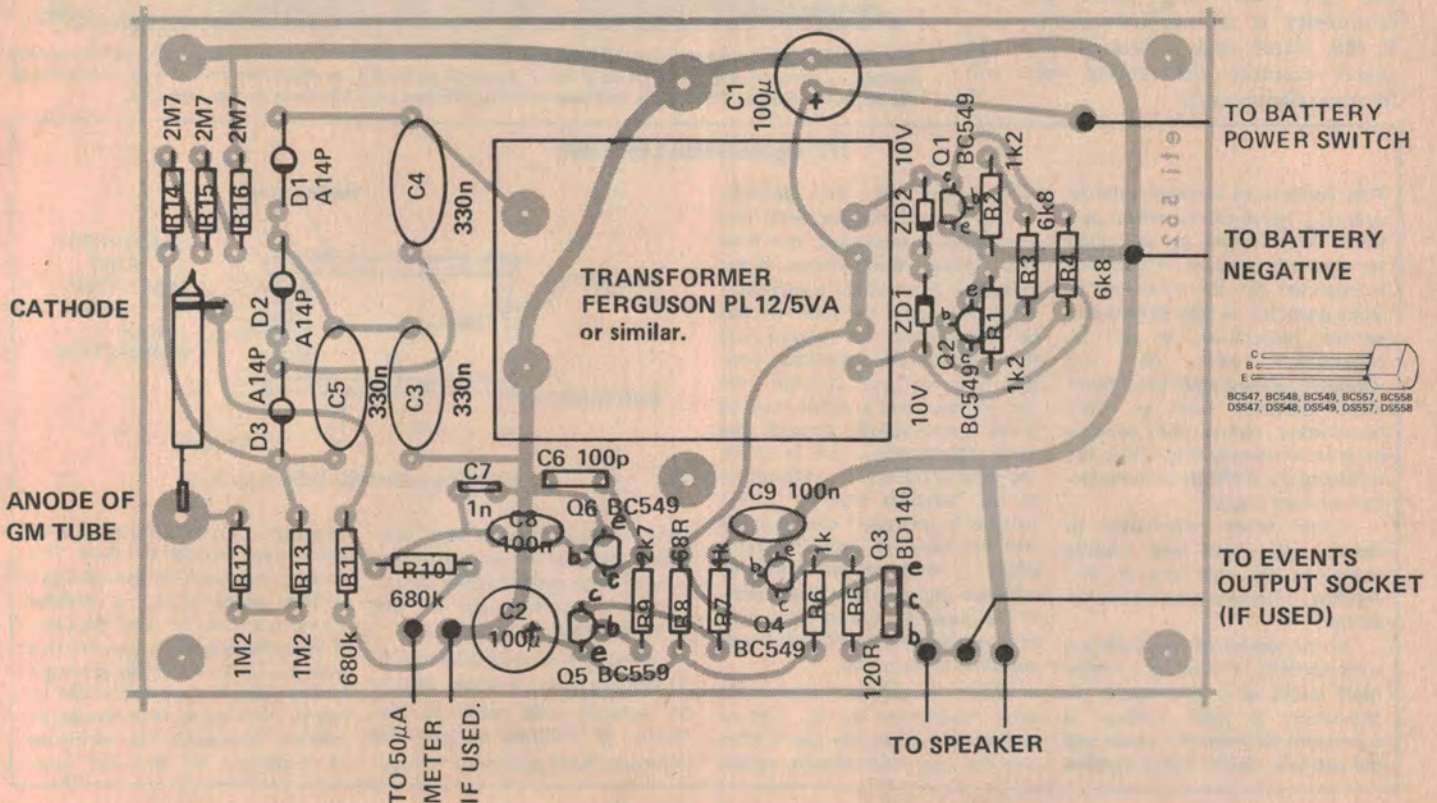
|    |       |                    |
|----|-------|--------------------|
| C5 | ..... | 330n 630V greencap |
| C6 | ..... | 100p disc ceramic  |
| C7 | ..... | 1n greencap        |
| C8 | ..... | 100n greencap      |
| C9 | ..... | 100n greencap      |

### Semiconductors

|            |       |                                 |
|------------|-------|---------------------------------|
| Q1         | ..... | BC549                           |
| Q2         | ..... | BC549                           |
| Q3         | ..... | BD140                           |
| Q4         | ..... | BC549                           |
| Q5         | ..... | BC559                           |
| Q6         | ..... | BC549                           |
| D1, D2, D3 | ..... | A14P or similar 1000V piv diode |
| ZD1, ZD2   | ..... | 10V 400mW Zenner diode          |

### Miscellaneous

1 x pc board ETI562; 1 x Ferguson pc mounting power transformer; 1 x ZP1310 or ZP1410 geiger tube (see text); 1 x Horwood aluminium chassis, type 34/10/DS; 1 x battery - Eveready 276-P or equiv.; 1 x on/off switch, spst; 1 x chassis mounting RCA socket; assorted nuts, bolts, washers etc.



# Project 562

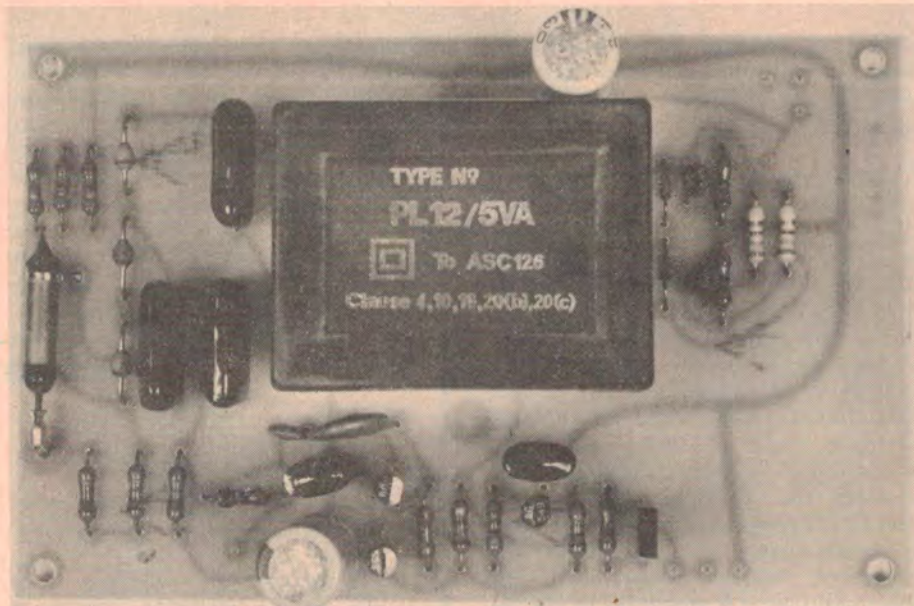
a Horwood type 34/10/DS, in which everything fits quite nicely. The circuit operates from six to nine volts and the battery used in the prototype was an Eveready type 276-P. This is a nine volt battery and is best mounted using a bracket of bent-up aluminium. The circuit pulls around 50 mA, so whatever battery you choose make sure it is capable of delivering this amount of current.

## Powering up

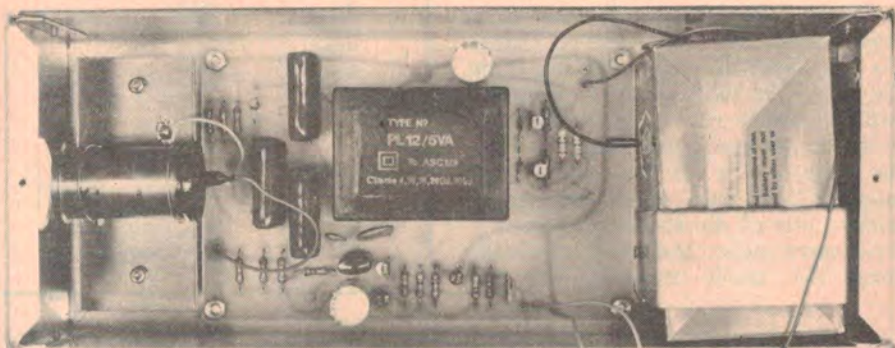
Before applying power to the circuit check the pc board layout. Make sure that all polarised components have been mounted on the pc board correctly. Make a special check of the two 10 V zener diodes. These regulate the voltage that is applied to the tube so it is important that they are inserted correctly. If all is well connect the battery and measure the voltage at point X on the pc board. This is the output of the voltage multiplier and the voltage at this point should be between 550 V and 650 V.

The moment the unit is turned on it will start to detect background radiation. The unit will 'click' once every couple of seconds. This background radiation is caused mainly by cosmic radiation.

Some older watches used small amounts of radioactive isotopes to activate the luminous dial. Even if the dial has long since lost its luminosity it will still be radioactive. If this watch dial is brought near the geiger counter the count rate will increase significantly. ●



Overall view of the pc board of one unit constructed using the lower cost beta/gamma GM tube, ZP1310. Be careful with the anode and cathode connections, as explained in the text.



The alpha/beta/gamma-sensitive GM tube is an end-window type and requires a different mounting method. I secured the ZP1410 to a small piece of pc board, as described in the text, mounted in the end of the case. The tube's window must be aligned with the hole in the case end.

## THE GEIGER MULLER TUBE

This consists of a metal tube or cylinder, hermetically sealed and filled with a gas at less than atmospheric pressure. If the tube is intended for the detection of alpha particles (as well as beta and gamma radiations), it will be constructed with an 'end window', as illustrated here. Since alpha particles have so little penetrating ability the window must be extremely thin. Thus, the windows are difficult to manufacture and are *fragile*.

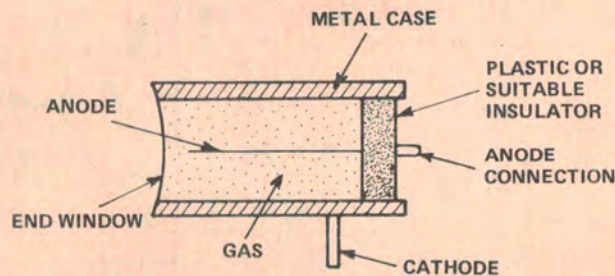
Geiger tubes constructed to detect only beta and gamma radiations do not have an end window, otherwise construction is similar.

In the centre of the tube is a wire ANODE. The metal cylinder itself serves as a CATHODE. In operation, a high voltage is connected between the anode and the cathode, anode being positive

with respect to the cathode.

As the voltage between the electrodes is increased, the tube goes through three phases: if the voltage is lower than a particular value, the gas in the tube will not be ionised and no current will flow. Above this particular voltage (the 'striking' voltage), the gas ionises and a small current flows continuously through the tube. This is the phase in which the tube is operated — referred to as the "plateau region". If the voltage is increased even further still the tube will enter the third phase — that of arc discharge between the anode and cathode. If the tube is allowed to operate in these conditions it will almost certainly be damaged.

When a particle enters the tube operating in its plateau region, it ionises the gas further and the ions produced are accele-



A TYPICAL END WINDOW G.M. TUBE

rated towards the cathode, electrons towards the anode. These moving ions cause further ionisations and an avalanche of ions (and electrons) occurs.

When the tube is operated in its plateau region a single particle of radiation will cause an avalanche of millions of ions and electrons. Each avalanche is regis-

tered as a momentary increase in the current through the tube. This current pulse can be detected as a voltage pulse across a resistor connected in series with the tube. If the voltage pulse is coupled to a sensitive audio amplifier driving a loudspeaker, a sharp 'click' will be heard. Each 'click' from the geiger counter represents the incidence of a particle on the GM tube.