A NEW SERIES FOR THE BEGINNER

THIS

If the input or output device connected to an electronic circuit converts one form of energy into another it is called a "transducer".

The block diagram in Fig. 5.1 shows a typical transducer application, the Geiger counter. A Geiger Müller tube converts energy resulting from radioactive decay processes into pulses of electrical energy, which are then amplified for conversion into "clicks" of sound energy by a loudspeaker.

In the following descriptions transducers are grouped under six main headings; light, heat, sound, magnetism, motion, and atomic radiation, denoting the type of energy conversion involved.

LIGHT SENSORS

Photoemissive Cell

The photoemissive cell in Fig. 5.2a consists of two electrodes in a vacuum or gas. The cathode is coated with a material (such as caesium-antimony alloy) which emits electrons when exposed to light. The anode is positively charged by the battery.

When light falls on the cathode, electrons are liberated and flow to the anode; a voltage appears across resistor R. The output voltage is nearly proportional to light intensity.

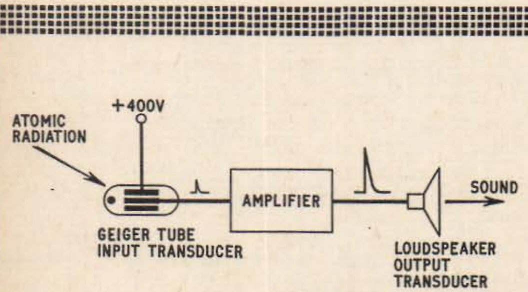

Fig. 5.1. Block diagram of a simple Geiger counter with the circuit symbol for a Geiger-Müller tube

Photodiode

A reverse biased semiconductor diode conducts a negligible leakage current, but if light is allowed to reach the *pn* junction it will cause a reverse current to flow. This phenomenon is called *photoconductivity*.

In the circuit in Fig. 5.2b, the diode is reverse biased by the battery, the output voltage being roughly proportional to light intensity.

Photovoltaic Diode

The solar cell used in space satellites is an example of a photovoltaic diode, which acts like a battery when exposed to light (Fig. 5.2c). A small silicon photovoltaic diode will generate a current of several milliamps at a potential of about 0·5V in direct sunlight.

Photovoltaic cells used in photographic light meters employ selenium as the photosensitive material.

Light Dependent Resistor

A photoresistor or light dependent resistor (Fig. 5.2d) has a resistive element, usually made of cadmium sulphide, contained in a transparent case. When light shines on the element its resistance decreases. In the circuit in Fig. 5.2d, the output voltage increases with illumination.

The photoresistor is not polarised like a diode, and behaves like an ordinary resistor under conditions of constant illumination, so can be fed from an a.c. as well as d.c. source.

Phototransistor

The phototransistor has a built-in amplification characteristic. Light on the base-emitter junction causes an internal base current to flow, even when the base lead is left disconnected, and this gives rise to a much larger collector current. In the circuit in Fig. 5.2e, the output varies inversely with light intensity.

Response

There is a limit to the speed with which a photosensor will respond to rapid changes of light intensity. For example, the output signal from cadmium sulphide photoresistors and selenium cells tends to fall off if the light input is made to pulsate rapidly at frequencies in excess of a few hundred hertz.

Ordinary silicon phototransistors and photodiodes can respond quite well to light pulsating at 20kHz, while special photoconductive diodes will reach 300MHz. The upper frequency limit of photoemissive cells is theoretically high, but is usually limited in practice, by the high impedance of the device, to around 25kHz.

LIGHT SENSORS

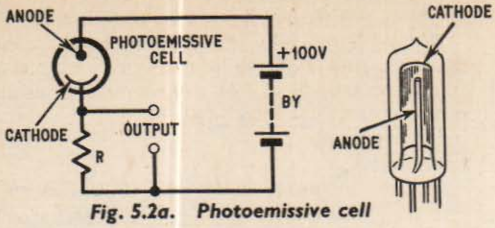

Fig. 5.2a. Photoemissive cell

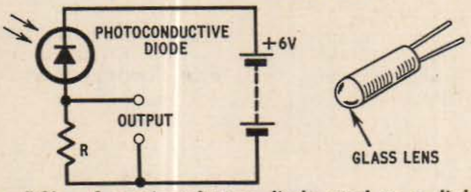

Fig. 5.2b. A semiconductor diode used as a light-sensor

LIGHT EMITTERS

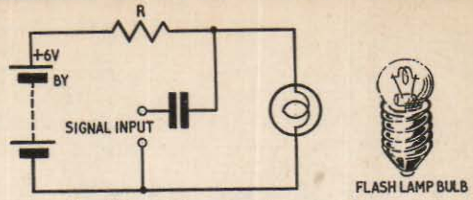

Fig. 5.3a. Tungsten filament lamp

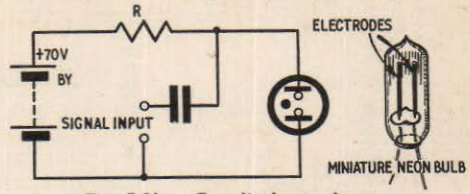

Fig. 5.3b. Gas discharge lamp

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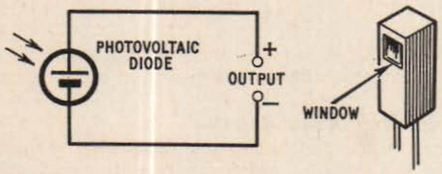

Fig. 5.2c. Photovoltaic diode or solar cell

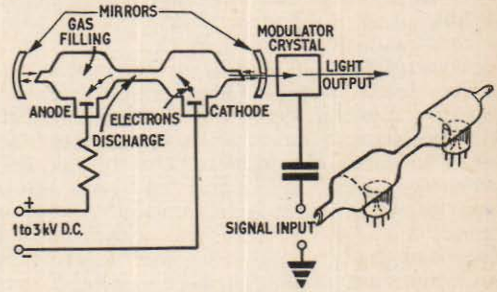

Fig. 5.3c. Laser tube

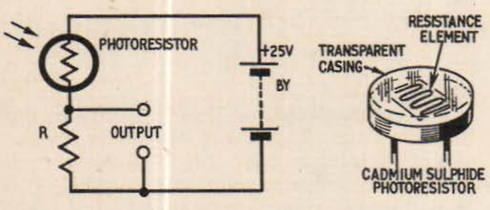

Fig. 5.2d. Light dependent resistor

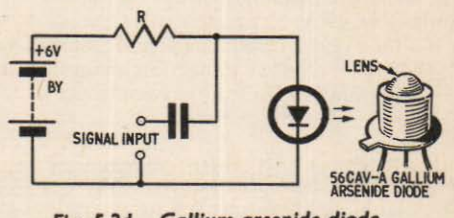

Fig. 5.3d. Gallium arsenide diode

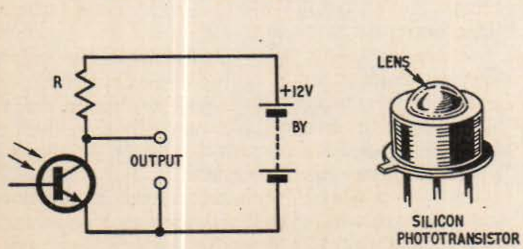

Fig. 5.2e. Phototransistor has light sensitive base emitter junction

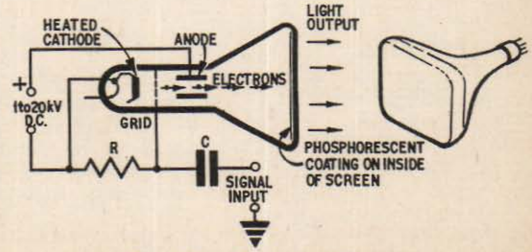

Fig. 5.3e. Cathode ray tube

LIGHT EMITTERS

Filament Lamp

Tungsten filament lamps can be used as output transducers to convert an electrical signal into a modulated light signal, (Fig. 5.3a) examples being colour organs, psychedelic displays, and systems for transmitting information by modulating light instead of radio waves to one of the photosensors mentioned above.

Unfortunately, the tungsten filament transducer is hampered by thermal inertia and cannot respond efficiently to a.c. input signals of more than a few hundred hertz.

Gas Discharge Tube

Gas discharge tubes (Fig. 5.3b) can give pulsating light outputs up to several kilohertz when fed from a high voltage input signal. Applications are similar to those of the tungsten lamp, but also include the stroboscope and photographer's electronic flash gun.

The light amplifier or laser shown in Fig. 5.3c is basically a gas discharge tube, arranged so that most of its light output is reflected back into the tube by mirrors, thus causing a build-up of energy. The output taken from a small orifice in one of the mirrors can be a narrow, high intensity parallel beam of coherent light or infra-red.

One method of modulating the light output is to pass the beam through a crystal which exhibits variable light transmission with applied voltage. Lasers also make effective heat emitters due to the high energy content of the beam.

Semiconductor Diode

Semiconductor diodes made of gallium arsenide will emit infra-red energy (just beyond the red end of the visible spectrum) when forward biased (see electroluminescent diode Fig. 5.3d). Light output is proportional to forward current and can be modulated up to 100MHz.

Cathode Ray Tube

In a television cathode ray tube, a narrow, controlled beam of electrons bombards a phosphorus coating and causes it to emit visible light, Fig. 5.3e.

Although the cathode ray tube is electrically capable of responding to high frequency signals, and can give a fine definition picture of slow moving images, the rate at which the phosphorescent output can change state from white to black is restricted by the afterglow properties of the coating.

Special phosphors used with film scanners can have an afterglow persistence of less than 0·2μs, equivalent to a modulated light output of 5MHz, but ordinary television tubes are much slower than this, say 50μs or more.

HEAT SENSORS

A heat sensor can either work by conduction, in direct physical contact with a heat emitting substance or device, or by radiation when infra-red energy is absorbed. The energy and wavelength of infra-red radiation is dependent on temperature. Several types of light sensor will also respond to infra-red emissions from substances which are not quite red hot, say at 300 degrees C, but are unsuitable for lower temperatures.

There are certain semiconductor devices—mainly confined to the laboratory—that will detect the heat of the human body, but they usually have to be refrigerated in a cryostat at near absolute zero temperature. For temperatures below 300°C there remain the devices which operate by conduction.

HEAT SENSORS

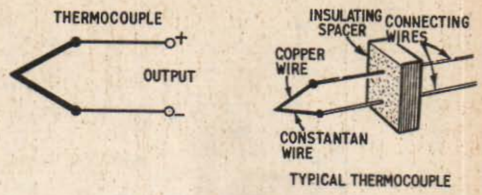

Fig. 5.4a. Thermocouple

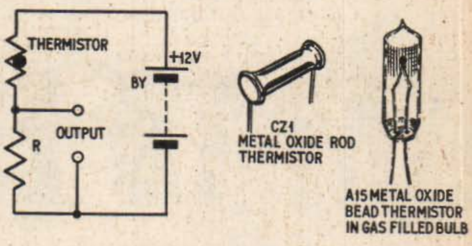

Fig. 5.4b. Thermistor

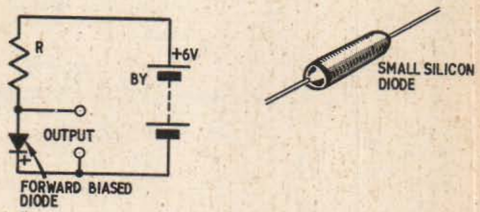

Fig. 5.4c. Heat sensitive diode

Thermocouple

The first example of a heat sensor is the thermocouple in Fig. 5.4a. Two wires of dissimilar metals, say copper and constantan, are joined together to form a bimetal junction. A voltage will be produced across this junction when it is heated or cooled relative to the connecting wires. Output is zero at ambient temperature and of opposite polarities for hot and cold.

Thermistor

A thermistor (Fig. 5.4b) has an exaggerated negative temperature coefficient, that is to say its resistance

HEAT EMITTERS

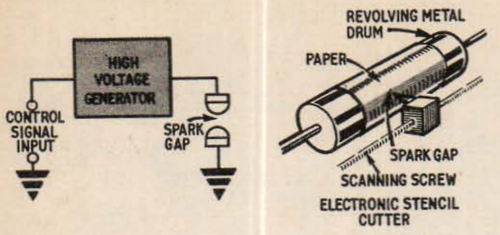

Fig. 5.5a. Electronic stencil cutter

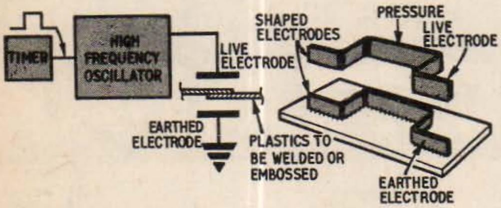

Fig. 5.5b. Dielectric heater

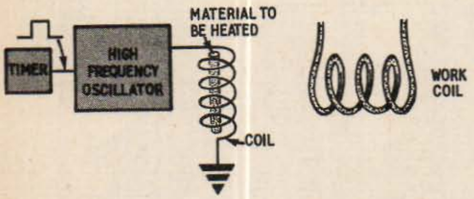

Fig. 5.5c. Inductive heater

decreases markedly with a rise in temperature. In the circuit in Fig. 5.4b, a thermistor is arranged in series with a resistor, so that output voltage will increase with temperature.

The response of a thermistor to temperature is not linear, but varies exponentially with inverse absolute temperature (°K). Positive temperature coefficient thermistors are shown in circuit diagrams with a small circle in place of the black dot.

Heat Sensitive Diode

An ordinary silicon signal diode of the type commonly encountered in electronic circuits will act as a heat sensor when forward biased. The output voltage taken from across the diode in the circuit of Fig. 5.4c is inversely proportional to temperature.

HEAT EMITTERS

Heat emission occurs in electronic circuits as a by-product when resistive components are conducting a current, but this is not the deliberate use of heat as output energy from a transducer.

Spark Maker

The humble electric spark is a heat emitter which is often taken for granted. For instance, the output from an electronic car ignition system is applied at precise intervals by means of a spark.

Then there is the electronic stencil cutter which employs a spark to burn holes of variable diameter in ink duplicator stencils, see Fig. 5.5a. A similar idea is sometimes used to reproduce weather maps from satellite transmissions, on heat sensitive paper.

Dielectric Heater

A dielectric heater—resembling a capacitor—can weld or emboss sheets of thermoplastic material, in the manufacture of motor car seats, purses, wallets, and so on (see Fig. 5.5b).

The plastics to be heated are inserted between two cold electrodes of almost any desired shape and surface finish, which are then pressed together by a spring. One electrode is earthed and the other is fed from the output of a powerful high frequency oscillator (30–50MHz at 1–10kW).

Molecular disturbance within the plastics generates internal heat without appreciable heating of the electrodes, thus softening the plastics. A microwave household oven works on a very similar principle to cook food right through in a short time.

Inductive Heater

Inductive heaters (Fig. 5.5c) are suitable for heat treatment of conductive materials, or materials enclosed in a conductive container. Processes such as melting, hardening, tempering, annealing, soldering, brazing, and sintering can be performed with great precision in this manner.

In Fig. 5.5c an oscillator supplies a.c. to a coil of copper tubing, into which the work to be heated is placed. At low frequencies the work will be heated uniformly, but if the oscillator is tuned to several megahertz, heating will take place only at the surface of the workpiece.

Gas Discharge

Lasers have been successfully employed as heat emitters for micro-spot welding of metals and for fixing detached retinas in eye operations, refer back to Fig. 5.3c.

Part six next month will continue the section on transducers and the series will be concluded with descriptions of miscellaneous electronic devices.

POINTS ARISING

MUSICAL STAVE *(May 1970)*

In the paragraph relating to power output the r.m.s. output voltage should have been given as $\frac{9}{2\sqrt{2}}$ since a sinusoidal swing would be between ± 4½ volts. As the actual output from the circuit is rectangular, the power available will vary with the signal mark-space ratio reaching a peak of 580 milliwatts when the ratio is unity.