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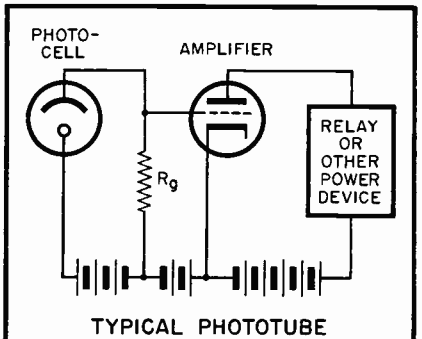
Photoelectric Cell Applications

By the Engineering Department, Aerovox Corporation

THE photoelectric cell, or "electric eye" as it is often referred to, has many applications—from use in burglar alarms and smoke detectors to facsimile, television, and even the measurement of microscopic tissue cells. It is based on a discovery by Hertz in 1887 that emission of electrons can be caused by light striking the surface of certain materials such as sodium and potassium.

Photosensitive devices fall into three general classes: (1) *photoelectric* or "phototubes", (2) *photoconductive* cells, and (3) *photovoltaic* cells. Phototubes are those in which impinging light causes emission of electrons from the photosensitive surface. Most practical photosensitive devices, such as the burglar alarm, automatic counter, door opener, and smoke detector, fall in this category. Photoconductive cells are those in which the internal resistance varies with the amount of light striking the sensitive surface. These cells are used to operate very sensitive relays and in the measurement of infrared radiation. Photovoltaic cells are those which generate an internal emf upon exposure to light. The ordinary light-intensity meter used in photography employs a photovoltaic cell connected directly across a low resistance meter.

This issue of the AEROVOX RESEARCH WORKER is devoted to some typical applications of the various types of photosensitive devices mentioned above.



TYPICAL PHOTOTUBE AMPLIFIER CIRCUIT

FIG. 1

Phototubes

Commercial phototubes are essentially diodes contained in glass envelopes very similar to those used for thermionic vacuum tubes. The cathode is usually a large semi-cylinderical surface coated with a photoemissive material. The anode is a wire lying parallel to the cathode axis. These elements may be inclosed in an evacuated bulb, or one which is gas-filled. The gas tubes ionize when the plate voltage exceeds a certain value and thus pass a larger current than do the high vacuum types. Gas-filled tubes are employed largely in motion picture work where their higher sensitivity reduces the amplification needed. High vacuum phototubes are used in light measurement work and in certain relay operating applications. They are less subject to damage due to application of excessive voltage or current, and their sensitivity remains more constant over a period of time.

The most common applications of phototubes involve the use of associated vacuum tube amplifiers, as in Fig. 1. The tube is coupled to the input of an amplifier by means of a large resistance, Rg. Since the current flow through the cell is of the order of a few microamperes, this resistance should be very high. By proper amplifying circuits, the current in the final output stage of the amplifier may be sufficient to operate a relay or a loudspeaker as in the sound picture industry. See Fig. 2.

Another valuable application of the photoelecrtic cell is the control of lighting. The tube is used with an amplifier and relay to turn the lighting system on when daylight decreases and off when natural light is again adequate. Fig. 3 illustrates a circuit in which the relay is energized

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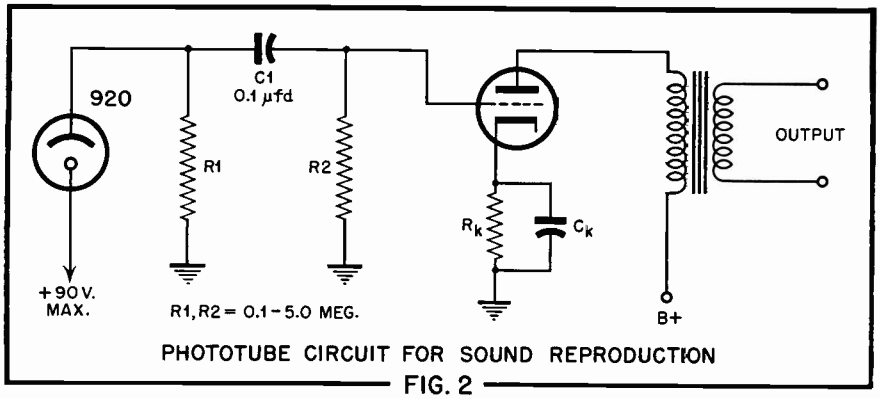


PHOTOTUBE CIRCUIT FOR SOUND REPRODUCTION

FIG. 2

by an increase in light. As long as the illuminaton on the phototube is below a certain value, the 2051 grid potential is below cutoff, and prevents conduction. When illumination rises, grid voltage is made less negative and the tube conducts, closing the relay. The function of R4 is to keep the current through the 2051 within the tubes maximum rating. Note that this circuit works directly on a.c. line voltage, requiring no d.c. supply.

Photoelectric Counting System

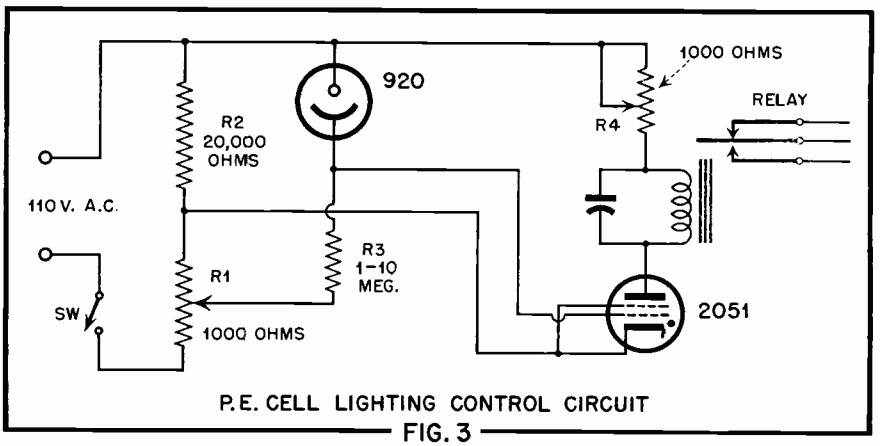
The simplest use of the phototube and relay is that of counting. A beam of light is directed across a conveyor belt into a photoelectric tube which operates a counter. When the beam of light is interrupted by one of the objects to be counted, the change in tube current operates the counter. An interesting circuit of this type is the one-way counter illustrated in Fig. 4. This arrangement records objects passing in one direction, but not in the other.

Suppose an object is passing downward in Fig. 4 so that it obscures phototube A and then B. When the light to tube A is interrupted, plate current flows in tube X, opening the contacts of relay X. As the object continues downward, both tubes are obscured and relay Y closes. But since the contacts of X relay are open, no current flows through the Z relay and the counter is inoperable. Now suppose that the object passes from B to A. Relay Y is operated when amplifier tube B starts to conduct. Then, when the object obscures both phototubes, the current through the amplifier tube associated with phototube A passes mainly through the contacts of relays X and Y to operate the Z relay and the counter. Relay X does not operate and its contacts remain closed. Thus, the counter is actuated only by objects passing in the direction from B to A.

Industrial Safety Controls

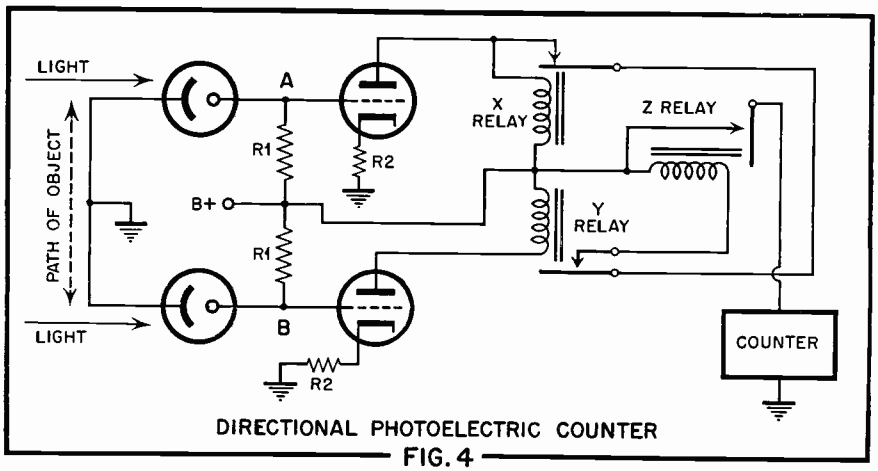
The applications of photoelectric cells to safety devices are very numerous. Some of the more familiar safety controls are the smoke detectors, traffic control, and protective door openers which prevent automatic doors from closing until personnel are clear. Another important protective circuit of this type is the flame-failure detector shown in Fig. 5. This device, intended to safeguard oil furnaces, uses a dual triode as its principal element. When light from the flame is present, photocurrent flows and the first triode section is blocked. The second section normally conducts current enough to close the relay which opens the soleniod oil valve and allows the flame to burn. Should a flame failure occur, the photocell no longer provides blocking voltage to the first section, which then conducts and applies a blocking voltage to the grid of the second triode section. The blocking of current in the second triode opens the relay and closes the oil valve with the simultaneous ringing of an alarm bell.

An even more common kind of industrial safety control is the "light curtain" type of protective device used to safeguard the operators of heavy machines. In this application of photoelectric devices, a light curtain is formed about the area of danger by a series of beam projectors and mirrors, the beam falling ultimately on a set of phototubes. If the operator inadvertantly reaches into the protected area, one of the beams of light is interrupted and the machinery is stopped by an interlock operated by the photocell relay. Fig. 6 is a typical circuit of this kind. Here the bias potentiometer (R1) is adjusted to cutoff so that the 6J5 does not conduct in the absence of light on the photocell cathode. With incident light the photocurrent through this bias resistor causes the tube to conduct and



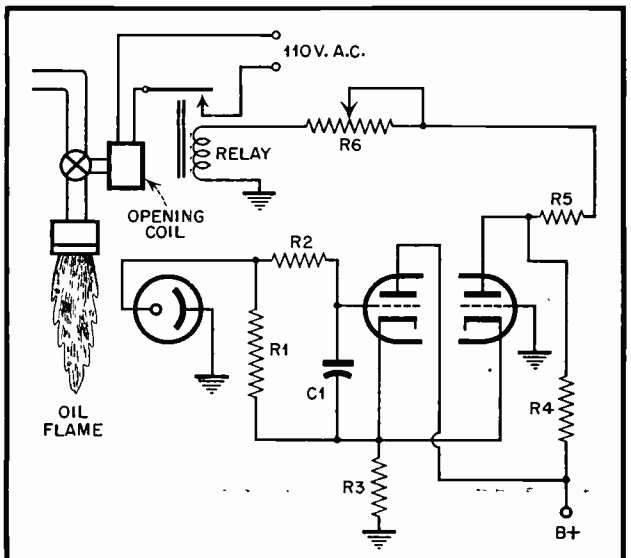
P.E. CELL LIGHTING CONTROL CIRCUIT

FIG. 3



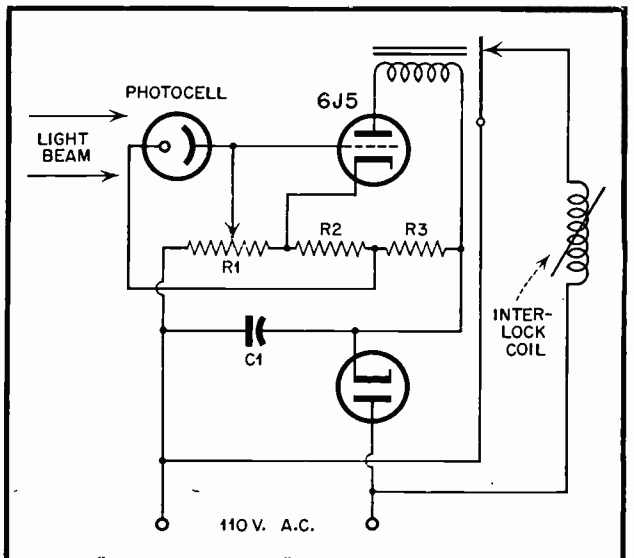
DIRECTIONAL PHOTOELECTRIC COUNTER

FIG. 4



FLAME FAILURE PROTECTIVE CIRCUIT

FIG. 5



"LIGHT CURTAIN" PROTECTIVE CIRCUIT

FIG. 6

operate its load relay which, in turn, operates an interlock which permits the machine to operate. Interruption of the incident light beam causes the 6J5 to cut off and stops or delays the operation of the machine. A safety control of this type is most frequently used with punch presses.

Photoelectric Gages

Phototubes also find many applications in the measurement of time, distance, thickness of materials, etc. A photoelectric device can be made to operate as a micrometer for razor blades, wire, tube stock, and many other materials. A good example is its use in making precision measurements on piston rings. One light beam, directed at a phototube, scans the separation of the sample ring and a master. If the sample exceeds the permitted tolorance, a rejection signal is operated. A mechanical shutter cuts off this beam as the piston ring gap is scanned. A second beam, scanning the gap, causes other rejection signals if the gap dimension is under or over tolorances The entire inspection cycle requires less than 5 seconds.

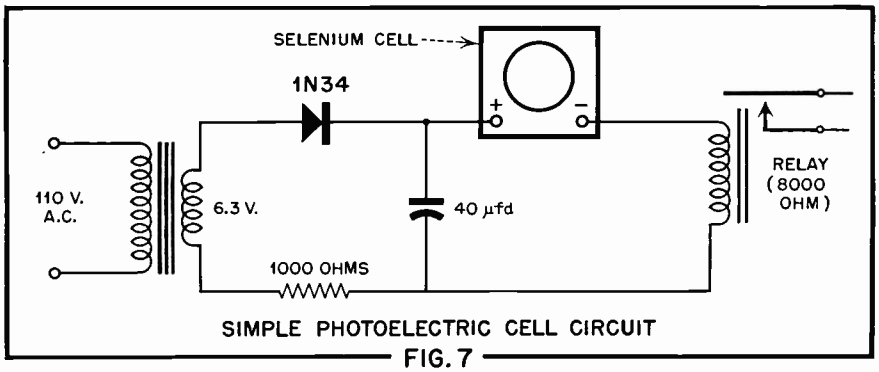
Photoconductive Cells

The selenium cell is the most common photoconductive cell in modern usage. It is usually mounted in a glass container filled with an inert gas. Although used in conjunction with an amplifier in some cases, the photoconductive cell will pass sufficient current to operate a very sensitive relay directly. A relay having a winding resistance of 5000 to 10,000 ohms is frequently used in connection with these cells. When an amplifier is used with photoconductive cells, the choice of the grid resistance should depend upon the light resistance of the particular cell used, rather than being as high as possible, as with phototubes.

Fig. 7 illustrates the novel use of a self-generating selenium cell with a 1N34 germanium crystal rectifiier to operate a rugged, less expensive relay. A small d.c. operating bias is provided by the crystal rectifier operated from the 6.3 volt winding of the filament transformer. This circuit is applicable to a wide variety of devices such as intrusion alarms, light-operated switches, garage door openers, etc. It is also used frequently in crowd-attracting window displays because of its simplicity and the fact that the absence of a high gain amplifier makes it immune to false operation by extraneous signals.

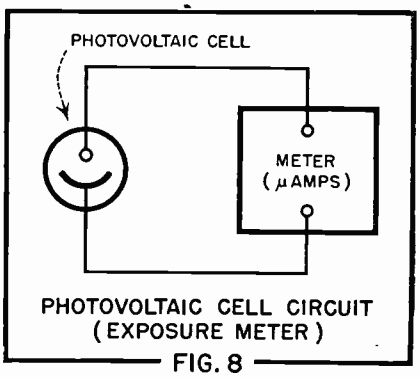
Photovoltaic Cells

Photovoltaic cells are most frequently used directly in series with a relay, meter, or other load. See Fig. 8. A simple photovoltaic cell consists of a lead electrode and an oxidized copper electrode immersed in an electrolyte. Exposure to light causes the cell to become a generator. Other "dry" photovoltaic cells consist of a sandwitch of iron and selenium fitted with copper electrodes. Since such cells generate an emf., they require no external source of power. The copper oxide type of cell (Photox) has a color response almost identical with that of the human eye and hence is used in illumination control and in regulating industrial processes in which color or change of color of the product are important.



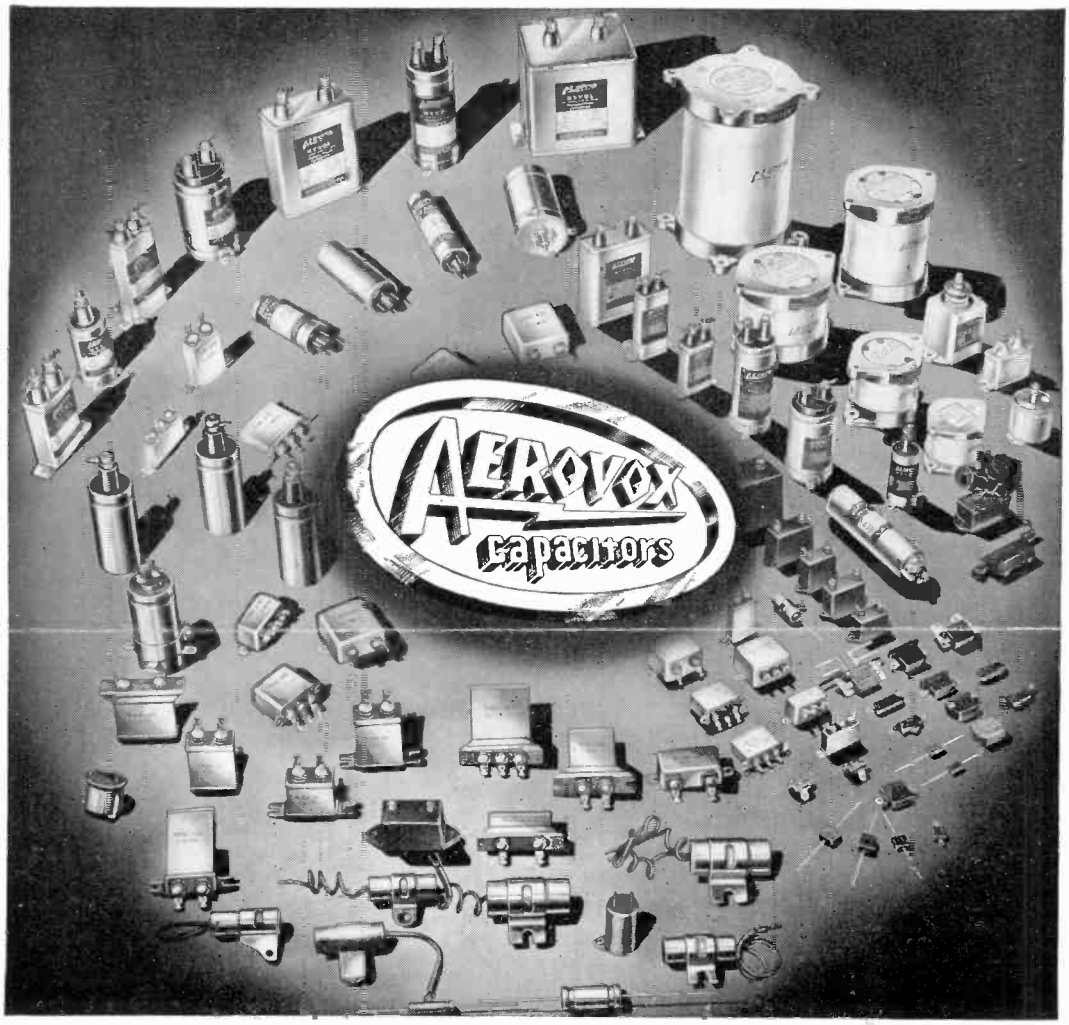
SIMPLE PHOTOELECTRIC CELL CIRCUIT

FIG. 7



PHOTOVOLTAIC CELL CIRCUIT (EXPOSURE METER)

FIG. 8



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