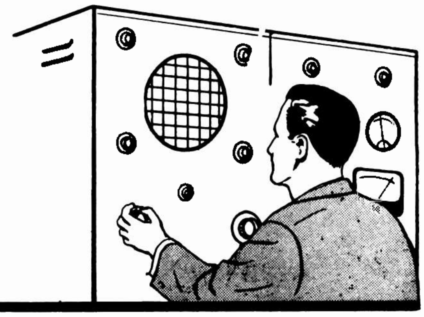
AEROVOX RESEARCH WORKER



The Aerovox Research Worker is edited and published by the Aerovox Corporation to bring to the Radio Experimenter and Engineer, authoritative, first hand information on capacitors and resistors for electrical and electronic application.

VOL. 34 NOS. 4-5-6 APRIL-MAY-JUNE, 1964 Subscription By Application Only

Modern Photodevices and Applications

It was as a light sensor in simple alarms and object counters that the early phototube and photocell found their original application. Later applications included light, transparency, color, density, and temperature measurement; sound-on-film reproduction technique; television pickup; facsimile pickup; industrial control; door opening; and light-beam communications. From time to time, we have reported on photodevice applications[1] and have been referenced in other publications.

New applications and improvements of old ones have followed rapidly the development of new or improved photodevices. In these uses, solid-state light-sensitive devices have almost completely supplanted the phototube, thereby eliminating a larger, fragile component and, in many instances, removing the need for a power supply. Aside from their use in various industrial and household control systems, modern photodevices (photocells, photodiodes, phototransistors, light-activated switches, etc.) act as sensors in punched-tape and punched-card readers, light-beam coupling in high-speed computers, power meters, automatic camera adjustment, electro-optical switching, infra-red measurements, scanning, cataloging, computor memory, anoxemia detection, voltage regulation, and electronic motor control. Additionally, the modern high-output silicon photovoltaic cell is the heart of the solar battery in terrestrial and space systems. New tasks are performed and old ones are done better by improved photodevices developed in the last five years.

This article describes some of the commercial devices which were introduced or greatly improved since our last survey of the art.

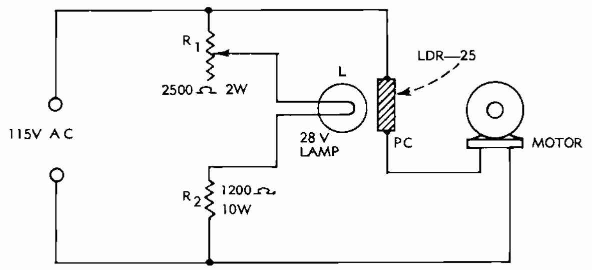


FIGURE 1. PHOTOELECTRIC MOTOR CONTROL

[1] See the following issues of the *Aerovox Research Worker*: August 1939, December 1941-January 1942, February-March 1944, May 1951, September 1951, October-November 1952, and May-June 1959.

Printed by Aerovox Corporation, New Bedford, Mass., U.S.A.

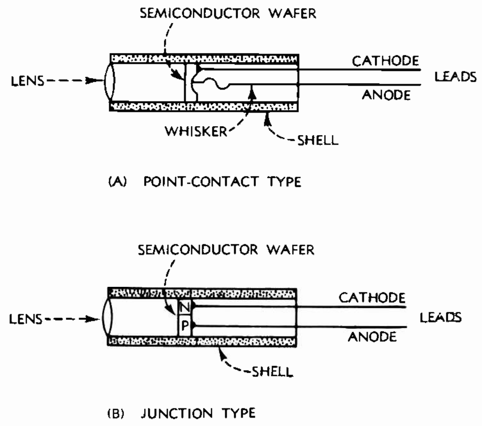


FIGURE 2. PHOTODIODE DETAILS

IMPROVED PHOTOCONDUCTIVE CELLS

A few years ago, the cadmium sulfide, cadmium selenide, and lead sulfide photoconductive cells opened new areas of application unattainable with the older selenium photoconductive cells which were limited to low voltages. Line-voltage operation of various light-operated devices thus provided higher output current and voltage and in many instances obviated amplification.

Modern small-sized inexpensive cadmium sulfide cells are obtainable in ratings up to 500 volts dc at ½ watt power dissipation and with increased dark-light resistance ratio. Lately, improved production techniques have given a commercial, small-sized cadmium sulfide cell which operates directly from 110 volts ac (200 vdc) at 15 watts maximum power dissipation.[2] With illumination from a tiny neon lamp, this photocell will switch 40 watts - action representing a power gain of 80.

This cell lends itself readily to direct control of devices which would require considerable power amplification if a lower-powered cell were used. Figure 1 shows the Delco circuit for smooth control of a 115-volt a-c motor (or other appliance rated at up to 100 watts). The control is the small 2-watt radio-type rheostat (R1) which adjusts the brilliance of 28-volt lamp L. The photocell, PC, acts as a light-controlled variable resistor in series with the motor or other load. Smooth control may be obtained also by operating the lamp at full brilliance and rotating a variable-opacity vane between the lamp and cell to adjust the illumination of the latter.

NEW PHOTOVOLTAIC CELLS

In addition to improved silicon photovoltaic cells, self-generating cells are available now in gallium arsenide, indium antimonide, and indium arsenide types. The indium antimonide type provides operation up to 77°K. All are obtainable in very small sizes (e.g., down to 0.01" square) and with d-c output, depending upon light intensity, of the order of 50 to 125 millivolts. Cells of such small size offer many possibilities for inclusion in mosaics for instantaneous reproduction of images and for parallel handling of data.

PHOTODIODE

The photodiode essentially is a miniature photocell. This component is available both in photoconductive and photovoltaic types, and some photodiodes may be used either way.

Figure 2 shows basic structural details of the photodiode. In this unit, a semiconductor wafer (geranium or silicon) is illuminated through a tiny lens in the nose of the enclosing shell. In the point-contact type (Figure 2A), a well is etched to provide a very thin wall at the center of the wafer, and a catswhisker makes contact with the wafer at the bottom of this well. The wafer is mounted so that the whisker-semiconductor junction can be illuminated. In the junction type (Figure 2B), the wafer contains a single PN junction and is mounted so that this junction can be illuminated. In both types, the wafer is very small.

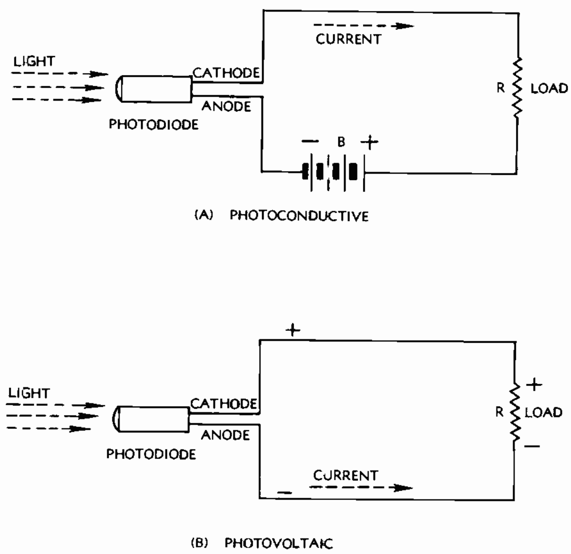


FIGURE 3. PHOTODIODE ACTION

[2] Delco Type LDR-25

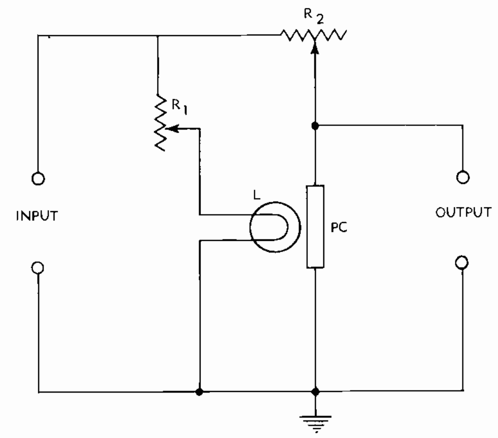


FIGURE 9. VOLTAGE REGULATOR

The repetitive illumination of the cells make them alternately conducting and blocking, and this action results in a switching of the d-c input-signal current alternately through the low-turns primary of transformer T. The stepped-up a-c voltage which appears across the secondary then is amplified, and the increased signal rectified.

Voltage Regulator. Figure 9 shows the essential circuit of a voltage regulator which may be used principally to stabilize the output voltage against input-voltage variations.

In this arrangement, rheostat R2 and photoconductive cell PC form a voltage divider across the INPUT terminals. Output voltage is taken across PC. In operation, R1 and R2 are adjusted so that the output voltage has the desired value. If subsequently the input voltage rises, lamp L will glow brighter, lowering the resistance of the photocell and thereby reducing the output voltage. When the input voltage falls, the lamp dims, increasing the photocell resistance and the output voltage. Thus, the output voltage may be regulated to a predetermined level.

Contactless Potentiometer. In Figure 10, a rotatable vane or disc is mounted between a dc-operated constant-light lamp and photoconductive cell, PC. A potentiometer is formed with fixed resistor R as the upper leg and the internal resistance of the photocell as the lower. If the vane is processed to have variable opacity, it will admit a different amount of light at each of its settings. This, in turn, will determine the photocell resistance and the output voltage.

Any desired variation of output voltage against angular rotation (such as linear, square law, logarithmic, sine, cosine, etc.) may be obtained by suitably grading the opacity of the vane. Contact wear and backlash, experienced with some conventional potentiometers, thus are eliminated. Infinite resolution is possible.

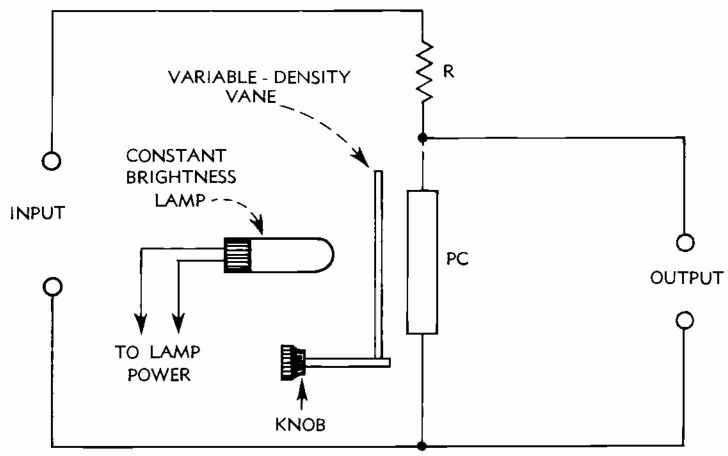


FIGURE 10. CONTACTLESS POTENTIOMETER

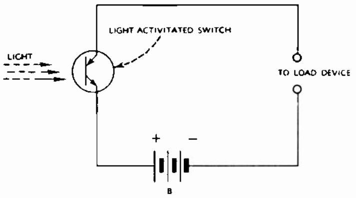


FIGURE 6 LIGHT ACTIVATED SWITCH

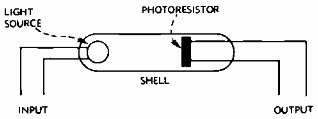


FIGURE 7. BASIC ELEMENTS OF RAYSISTOR

LIGHT-ACTIVATED SWITCH

This is a new, transistor-like bistable component of the PNPN type. Like a 4-layer diode, once this unit is triggered to its ON state, it will continue to conduct current from an external power source in series with a load device until the power is interrupted. Its difference is its use of illumination, instead of a trigger signalvoltage, to switch conduction ON. Circuitry (see Figure 6) is similar to that of the phototransistor. In addition to the thyratron-like latching action provided by this photodevice, straight ON-OFF switching may be obtained by means of suitable circuitry which will render the device self-extinguishing.

Depending upon model, the light-activated switch is rated at peak reverse voltage of 12 to 400 v, and triggering light levels as low as 50 foot-candles.

In addition to obvious use in relays, latching, and sorting, the light-activated switch is adaptable to appliance control and solenoid operation. It has been tested in computor and "intelligent circuitry" for logic functions, character recognition, and punched-card and punched-tape reading.

RAYSISTOR

In the Raysistor[3], a light source and photoresistor (photoconductive cell) are combined. The light source is an incandescent lamp in some models, a glow lamp in others. Basic structural details are shown in Figure 7.

Operation is somewhat similar to that of a conventional lamp-photocell combination, except that the small lamp and cell are enclosed in a light-tight housing in the Raysistor. The dark (OFF) resistance of the cell is as high as 1800 meghoms at 10 v (depending upon Raysistor type); the light (ON) resistance drops to as low as 300 ohms.

When this unit is used as a switch, application of the signal consists simply of turning the lamp on. Switch-on time is 1.2 - 35 milliseconds, switch-off time 22 - 105 msec, depending upon Raysistor type and external circuit constants. When the unit is used as a signal-transfer device, the input signal is applied in series with the light-source voltage, and the output signal is taken from a load resistor, inductor, or transformer in series with the photocell and its bias voltage.

Various types of Raysistor are available for operation between 1 and 120 volts, depending upon whether the illuminator is incandescent or gas-discharge.

A particular feature of the Raysistor as a switching device or signal transfer component is the high degree of isolation it provides between input and output circuits.

MISCELLANEOUS APPLICATIONS

Photoelectric Chopper. Figure 8 shows the circuit of a photoresistor-type chopper for converting a low-level d-c signal to ac for amplification by a-c amplifier and subsequent rectification back to dc at a higher level.

Here, the d-c signal (such as the voltage delivered by a thermocouple or strain gauge) is applied to two photoconductive cells (photoresistors), PC1 and PC2, in series. These cells have such high resistance that they may be considered practically to be nonconducting when dark. A neon lamp (L1, L2) is rigidly mounted close to each cell, and these lamps are the active elements in a relaxation oscillator ("flasher") circuit — B-C-L1-L2-R1-R2. The lamps flash on and off at a frequency governed by the values of C, R1, R2, and the d-c voltage of the battery, B.

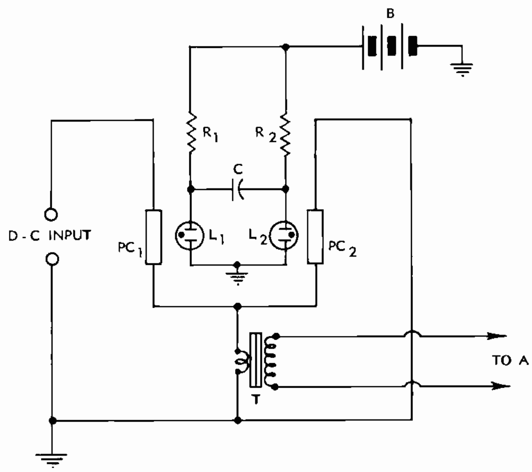


FIGURE 8. PHOTOELECTRIC CHOPPER

[3] Trademark, Raytheon Company

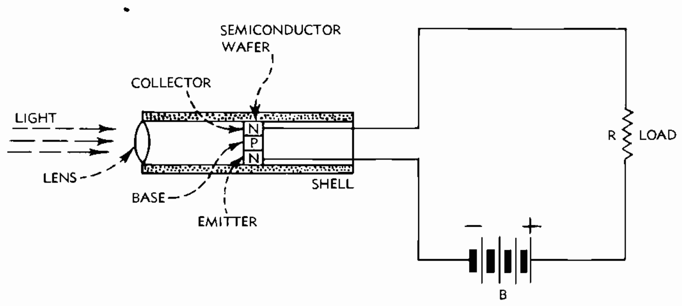


FIGURE 4. PHOTOTRANSISTOR DETAILS

Illumination of the diode wafer has two effects: First, the diode reverse resistance is changed from a very high value (e.g., 100 megohms at -50 v) to a low value (e.g., 100K). These typical values correspond to 3000 foot-candles illumination. This gives the device its photoconductive properties. Second, with no applied voltage, illumination sets up a d-c voltage across the output terminals. This voltage is typically 150 mv across a 10,000-ohm load at approximately 300 foot-candles for the point-contact diode, and 250 mv for the junction type, but output voltage and current vary with diode model.

The photodiode finds use in relay, counting, and alarm circuits where its small size and fast operation are desirable. It is used also in sound-on-film reproduction and in punched-tape and punched-card reading.

Figure 3 (A) shows the basic diode photoconductive circuit, and Figure 3 (B) the photovoltaic circuit.

PHOTOTRANSISTOR

The phototransistor is a junction transistor structure with leads attached to the collector and emitter regions of the semiconductor wafer but none to the base region. In the package, the wafer is mounted so that the base region may be illuminated through a tiny lens in the nose of the enclosing shell (see Figure 4).

A d-c voltage is applied between emitter and collector in the conventional manner. The circuit thus is that of a common-emitter amplifier. When the wafer is darkened, collector (cutoff) current flow is extremely low, being the i_{CO} value normal for the applied voltage. But illumination of the wafer causes current carriers to be injected into the base region. The resulting base current is amplified beta times by the transistor structure, and a large collector current proportional to the light intensity then flows.

A modern silicon planar NPN phototransistor may be operated at 40 volts dc, provides 9 ma collector current at 1000 foot-candles illumination. Maximum dark current at 30 vdc collector voltage is 0.025 micro-ampere, and maximum power dissipation is 50 williwatts. Upper frequency limit is of the order of 26 kc.

The phototransistor has the advantage that it provides amplification; a relatively low light intensity produces a comparatively large output current. Additional amplification usually is not needed. This device may be operated with either steady or modulated light.

Typical applications include d-c relay operation, sound-on-film reproduction, optical coupling, light-beam reception, alarm service, electro-optical control service, counting applications, and punched-card and punched-tape reading. Figure 5 shows an emitter-coupled transistor switching circuit which is actuated by a phototransistor, Q1. Here, zener diode D3 is the common coupling element for switching transistors Q2 andQ3, and silicon diodes D1 and D2 are isolating-coupling elements for the dc-coupled circuit.

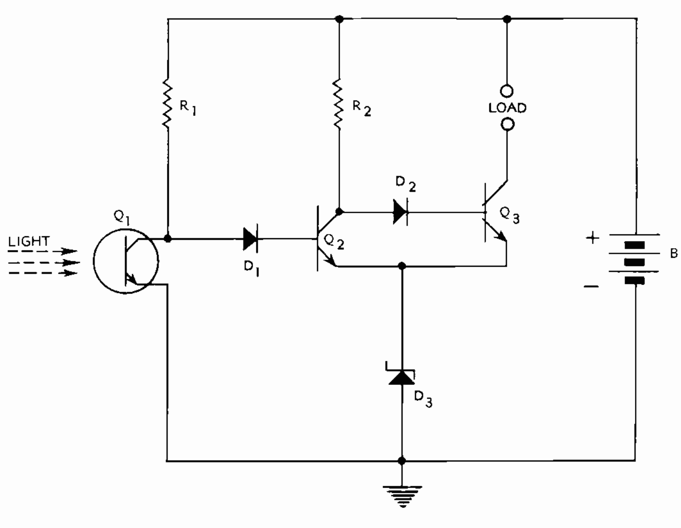
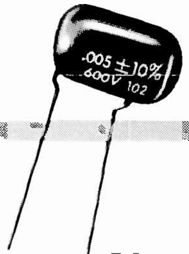


FIGURE 5. LIGHT-OPERATED SWITCHING CIRCUIT
FOR CARD OR TAPE READER

Now the Best Choice is Yours...



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