Photoelectric Sensors and Controls

SELECTION AND APPLICATION

Scott M. Juds

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Preface

Light sensing as a means of industrial control has been available for many decades. The technology incorporated into photoelectric controls and sensors since the early 1970s has revolutionized the market with significant advances in the state of the art in electronics, optics, and packaging. These advances have enabled photoelectric controls and sensors to overcome most of the barriers to their practical application.

The scope of technologies encompassed by these products generally extends into one or more areas in which the user has little background or training. This book is designed to provide the background and reference information necessary for making informed selection decisions. It is designed to improve the success in application of these devices by maintenance personnel, electricians, designers, and engineers. Material in this text is targeted at system designers, who must make the initial selection, and at maintenance personnel, who make sure installed systems keep working.

The book covers the basic fundamentals of optics and also gives an in-depth practical analysis of the major sensor configurations. Electrical control interfaces, control logic functions and specifications are described. Environmental issues, often a "gotcha" and important for system reliability, are discussed.

Finally, application issues and specific examples are discussed to help the reader understand the possibilities, practical limitations, and pitfalls. I thoroughly recommend experimentation as you read to help solidify concepts. Confucius put it this way: "I hear and I forget, I see and I remember, I do and I understand."

The text was specifically designed to be useful to readers with minimal experience in enclosures, optics, electronics, or industrial controls. Many drawings and graphs are used to simplify explanations and impart a solid practical understanding.

After ding *Photoelectric Sensors and Controls* you will be prepar l with the insight and knowledge to tackle even the toughe optical sensing and control problems.

I ild like to extend special thanks and appreciation to physic Rocky Kyle for his technical review and for the photoelectri optics expertise he was willing to share over the years; to elec ical engineer and photoelectric expert Paul Mathews, who re ewed the manuscript while sailing his boat to exotic places the South Pacific; to artist John Jolley for his accuracy nd aesthetic interpretation of my stick figures; and to secret: y Jeri Barnhart for her assistance with the intricacies of our vritten language, compilations, and correspondence.

Scott M. Juds

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Photoelectric Sensors and Controls: Introduction

History, a distillation of rumour.

Thomas Carlyle
The French Revolution

In this chapter we provide a description of photoelectric controls and sensors, what they are, principles of operation, basic terminology, a look backward, and a look forward. Much of the information here will already be familiar to many readers. However, the foundation for material in other chapters will be laid here and may be useful to a complete understanding of later chapters.

1.1 INTRODUCTION

The number and variety of light-operated or light-controlled devices and equipment produced is tremendous. Photoelectric controls and sensors are only a small part of this vast product spectrum. Dusk lamp controls, television brightness compensation for ambient light, photo interrupters for paper and ribbon cartridge empty signals on printers, cassette auto-reverse sensors, automobile ignition electronic cams, television and stereo remote controls, door annunciators in small shops, smoke detectors, CRT light pens, the optical mouse for personal computers, shaft encoders, elevator door safety guards, invisible perimeter security sensors, and garage and toll gate automobile detection are a few of the many light-sensitive controls and sensors with which we interact in everyday life. Many of these are very specific in form to a particular market or need. As such, they will not be discussed here directly, although the principles of operation are likely to apply. Hidden within industry are countless other varieties of optically based sensors, controls, array scanners, bar code scanners, measurement scanners, range finders, and machine vision systems. In the larger sense, all of the aforementioned devices could be considered photoelectric controls and sensors. However, in this book, a more categorical definition will be used with particular attention to industrial sensors and controls.

The term "sensor" will be used to refer to a device that provides a simple signal-level output that is determined by the light level it receives. The term "control" will be used to refer to a device that, in addition to sensing, provides a control output capable of switching power to actuators that alter the flow of materials or other process events. Both sensors and controls are concerned with only a single sense point. The term "scanner" will be reserved for devices that have built-in physical or electronically synthesized scanning motion in order to gather information from more than a single sense point. A scanner may be a self-contained unit or an ensemble of sensors connected to a scan controller. Single-point sensors and controls are often erroneously referred to as scanners despite their inability, physically or electronically, to move the sense point in space. Although fixed-beam sensors and controls are not scanners, they can provide that function when the scanning motion is provided external to the sensor by the object's motion through the sensor's beam. In this book, these definitions are used consistently to avoid confusion.

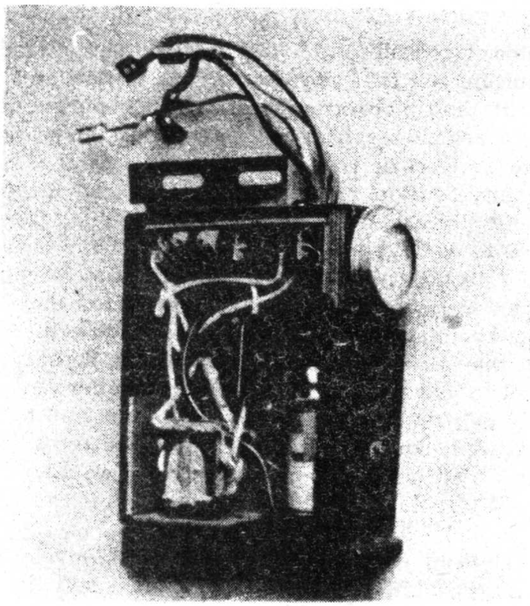
1.2 PRINCIPLES OF OPERATION

An industrial photoelectric sensor is a device composed of a light transmitter and light receiver. Light is directed toward the object by the transmitter. The receiver is pointed toward the same object and detects the presence or absence of reflected light originating from the transmitter. Detection of the light generates an output signal for use by an actuator, controller, or computer. The output signal can be analog or digital and is often internally modified with timing logic, scaling, or offset adjustments prior to output.

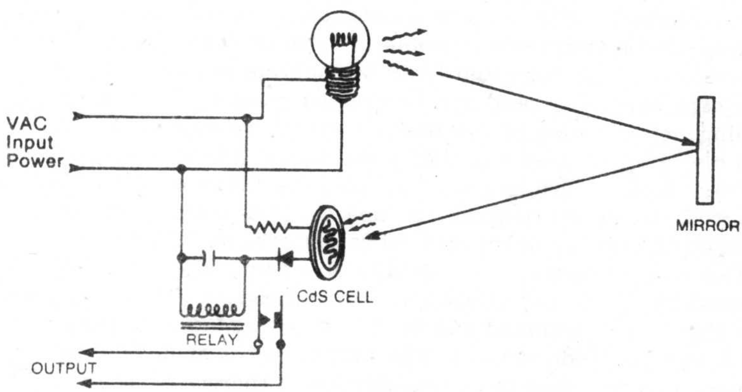
1.2.1 Conventional Unmodulated Photoelectrics

The light beam in early photoelectrics was generated by a constant-intensity (unmodulated) incandescent filament bulb much like those used for automotive taillights. The light detector was generally a cadmium sulfide cell that allowed current to flow and energize a relay when lit, and blocked current flow, deenergizing the relay when dark. A cadmium sulfide cell is a photoresistive detector. Its ability to conduct or resist the flow of current is controlled by the intensity of light incident on its surface. Early photoelectrics were generally called "electric eyes" and even today are frequently referred to as "eyes." Figure 1.1a shows an early electric eye, and Fig. 1.1b shows schematically how it functioned. In operation, this device projected light toward a reflector that would return it back to the electric eye's cadmium sulfide cell. If enough light fell on the cell, sufficient current would be conducted through the cell to activate the relay. It was generally necessary to shield the detector from other light sources and to use a powerful filament light source to achieve any sensitivity without false triggering. An object breaking the beam would then cause the darkened cadmium sulfide cell to switch off the relay.

In the late 1960s, the light-emitting diode (LED) was developed and provided an alternative light source to the incandescent light bulb. LEDs are a common sight today as numerical displays in clocks and stereos, illuminators in toy games, and indicator lamps on security system controls and floppy disk drives. A solid-state LED, sketched in Fig. 1.2, is constructed without the two most serious life-limiting design problems found in incandescent bulbs. Incandescent bulb tungsten filaments operate at about 4000°F. This high operating temperature creates great thermal stress, causing deterioration of the filament structure over time. The high operating temperature limits the useful life of these bulbs to about 2000 to 5000 hours. Further, the filament is a coil spring structure stretched between two posts. This delicate structure is stressed heavily by shock and vibration common to industrial production environments. The already short bulb life is significantly reduced by shock and vibration. In contrast, the LED has a bond wire that is encapsulated and is able to withstand extremely high shock and vibration stress. The LED operates at nearly ambient temperature and does not encounter great thermal stress. The typical rated life of an LED is in excess of 100,000 hours, which is more than 10 years of 24-hour days. This does not guarantee that all LEDs will last 10 years and then die. It means that the field failure rate will be on the order of 2 to 5% of that experienced with incandescent bulbs. This is a feature of significant value when the cost of maintenance and production downtime are considered.



(a)



(b)

Figure 1.1 (a) Early electric eye with its cover removed; (b) schematic diagram of its function.