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The use of optocouplers to improve passenger elevator safety

Aliev Ulugbek *

Department of mobile communication technologies, Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Tashkent, Uzbekistan.

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Abstract

The article discusses the use of wireless technologies for monitoring the condition of elevators in high-rise buildings and the use of optocouplers for generating and transmitting alarm signals in the event of a power failure. It describes the distinctive features, promising areas of development and application of optocoupler technology, the classification of optocoupler product parameters, and the features of designing wireless networks for such systems, taking into account the characteristics of buildings. The analysis shows that the proposed autonomous system for alerting about elevator stoppages due to sudden power outages allows for the rapid rescue of people trapped in elevators, monitoring the technical condition of elevators, and preventing accidents, which is especially relevant for outdated elevators in Uzbekistan.

Keywords: Optocoupler; Optocoupler; Emitter; Receiver; Led; Phototransistor; Feedback; Elevator; Safety; Wireless Network; LTE; Wi-Fi; Router

1. Introduction

The idea of creating and using optocouplers dates back to 1955, when Loebner E. E. "Optoelectronic devices network," a whole series of devices with optical and electrical connections between elements was proposed, which made it possible to amplify and spectrally convert light signals, create devices with two stable states - bistable optocouplers, optoelectronic devices for accumulating and storing information, logic circuits, and shift registers. The term "optocoupler" formed as an abbreviation of the English "optical-electronic device," was also proposed there.

The optocouplers described in this work, while perfectly illustrating the principles, proved unsuitable for industrial implementation, as they were based on an imperfect elementary base - inefficient and inertial powder electroluminescent capacitors (emitter) and photoresistors (receiver). The most important operational characteristics of the devices were also imperfect: low-temperature and temporal stability of parameters, insufficient resistance to mechanical stress. Therefore, at first, the optocoupler remained only an interesting scientific achievement with no application in technology [1].

It was only in the mid-1960s, with the development of semiconductor light-emitting diodes and technologically advanced, highly efficient, fast-acting silicon photodetectors with p-n junctions (photodiodes and phototransistors), that the basic foundation of modern optocoupler technology began to be laid. By the early 1970s, the production of optocouplers in the world's leading countries had become an important and rapidly developing branch of electronic technology, successfully complementing traditional microelectronics.

* Corresponding author: Aliev Ulugbek

An optocoupler, or optocoupler, as it has recently come to be called, consists of two elements: an emitter and a photodetector, usually combined in a common sealed housing (Figure 1). In the emitter, the energy of the electrical signal is converted into light, and in the photodetector, vice versa.

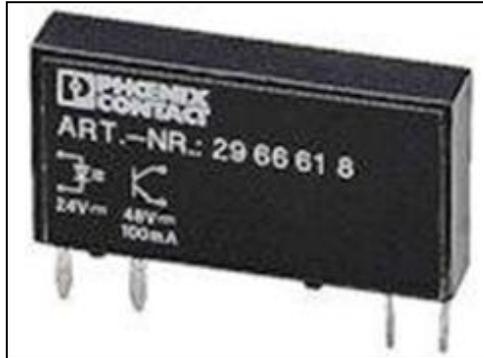


Figure 1 Optocoupler: LED-phototransistor

2. Energy Functions

In energy mode, optocouplers are used in conjunction with secondary EMF or current sources. The efficiency of optocoupler energy converters is low. However, the ability to introduce an additional voltage or current source into any circuit of the device without galvanic connection to the primary power source gives the developer a new degree of freedom, which is especially useful when solving non-standard technical problems. A generalized diagram of optocouplers is shown in Figure 2

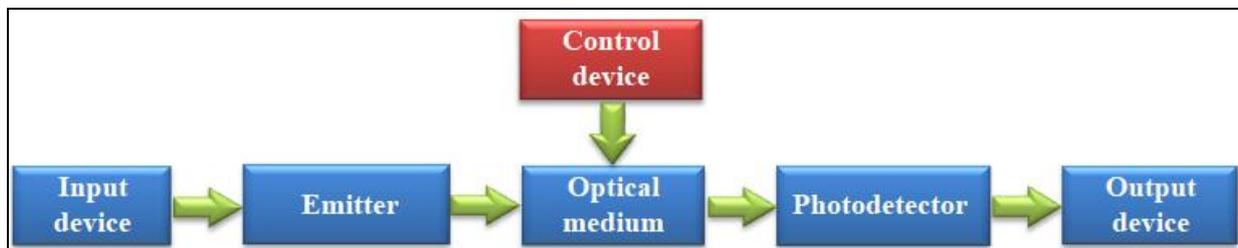


Figure 2 Generalized optoelectronic converter circuit

The advantages of these devices are based on the general optoelectronic principle of using electrically neutral photons to transfer information. The main ones are as follows [1,2]:

- the ability to provide perfect electrical (galvanic) isolation between the input and output; there are no fundamental physical or design limitations for optocouplers in terms of achieving arbitrarily high voltages and isolation resistances and arbitrarily low leakage capacitance;
- the ability to implement contactless optical control of electronic objects and the resulting diversity and flexibility of control circuit design solutions;
- unidirectional propagation of information through the optical channel, no feedback from the receiver to the emitter;
- wide frequency bandwidth of the optocoupler, no low-frequency limitation (which is characteristic of pulse transformers);
- the ability to transmit both pulse signals and DC components through the optocoupler circuit;
- the ability to control the output signal of an optocoupler by acting (including non-electrically) on the material of the optical channel and the resulting possibility of creating various sensors, as well as various devices for transmitting information;
- the ability to create functional microelectronic devices with photodetectors whose characteristics change according to a complex predetermined law when illuminated;
- the immunity of optical communication channels to the effects of electromagnetic fields, which in the case of "long" optocouplers (with an extended fiber-optic light guide between the emitter and receiver) ensures their protection from interference and information leakage, and also eliminates mutual interference;

- physical and design-technological compatibility with other semiconductor and microelectronic devices.

2.1.1. *Optocouplers also have certain disadvantages*

- significant power consumption due to the need for double energy conversion (electricity - light - electricity) and low efficiency of these transitions;
- increased sensitivity of parameters and characteristics to the effects of elevated temperatures and penetrating nuclear radiation;
- more or less noticeable temporary degradation (deterioration) of parameters;
- relatively high level of inherent noise, caused, like the two previous disadvantages, by the peculiarities of LED physics;
- complexity of implementing feedback, caused by the electrical disconnection of the input and output circuits;
- design and technological imperfections associated with the use of hybrid non-planar technology (with the need to combine several separate crystals from different semiconductors located in different planes in a single device).

The listed disadvantages of optocouplers are being partially eliminated as materials, technology, and circuitry improve, but nevertheless, they will remain quite fundamental for a long time to come. However, their advantages are so great that they ensure the unrivaled competitiveness of optocouplers among other microelectronic devices.

3. Promising Areas for the Development and Application of Optronic Technology

Promising areas for the development and application of optronic technology have been largely determined. Optocouplers and optronic microcircuits are effectively used to transmit information between devices. Optoelectronic devices remain traditionally strong in the field of information acquisition and display technology. Optocoupler sensors designed to control processes and objects that are very different in nature and purpose are of independent importance in this area. Functional optocoupler microcircuit technology, focused on performing a variety of operations related to the conversion, accumulation, and storage of information, is making noticeable progress. The replacement of large, temporary, and non-technological electromechanical products with optoelectronic devices and equipment has proven to be effective and useful. The use of optoelectronic elements for energy purposes is quite specific, but in many cases justified and useful [3-4].

Optocouplers with internal optical connection are widely used in various fields of radio engineering and electronics, electrical engineering, computer technology, and automation. In digital devices, they are used to connect devices manufactured on different bases. They are used to control the power circuits of motors controlled by low-voltage logic circuits; to connect logic circuits to peripheral computer equipment; as ground isolation elements in power supplies; as low-power relays in electroluminescent information display systems; and in control and measuring devices.

Two factors are taken into account when classifying optoelectronic devices: the type of photodetector and the design features of the device as a whole.

The choice of the first classification feature is due to the fact that virtually all optocouplers have an LED at the input, and the functional capabilities of the device are determined by the output characteristics of the photo receiver.

The second feature is the design, which determines the specific application of the optocoupler.

Diode optocouplers (Figure 3) characterize the level of optocoupler technology to a greater extent than any other devices. Connecting various amplifying elements to a diode optocoupler provides the developer with many conveniences in terms of interfacing different devices, but this is not very efficient in terms of energy consumption.

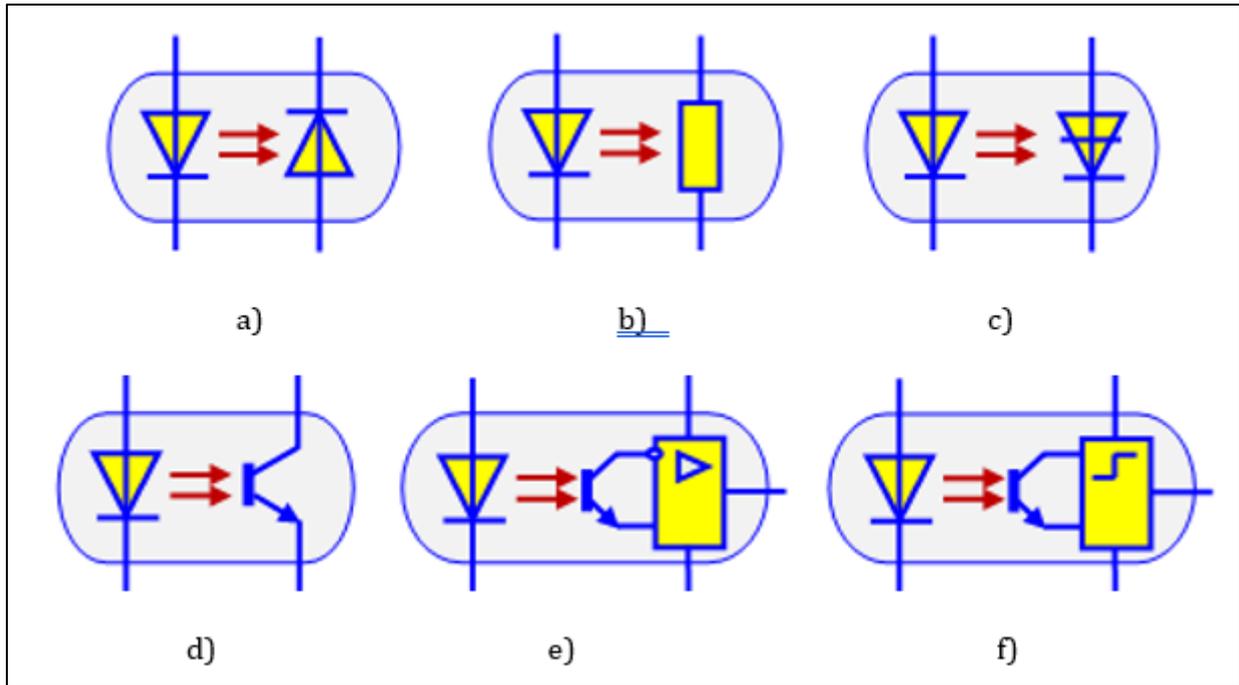


Figure 3 Symbols for optoelectronic devices: a) LED-photodiode; b) LED-photoresistor; c) LED-photo thyristor; d) LED-phototransistor; e) LED-phototransistor with analog amplifier; f) LED-phototransistor with Schmitt trigger

4. Information Transmission

When transmitting information, optocouplers are used as communication elements and, as a rule, do not carry an independent functional load. Their use allows for the galvanic isolation of control and load devices (Figure 4) operating in different electrical conditions and modes. The introduction of optocouplers significantly increases the noise immunity of communication channels; “parasitic” interactions on ground and power supply circuits are virtually eliminated. Also of interest is the rational and reliable coordination of digital integrated devices with a heterogeneous element base (TTL, ESL, I2L, CMOS, etc.).

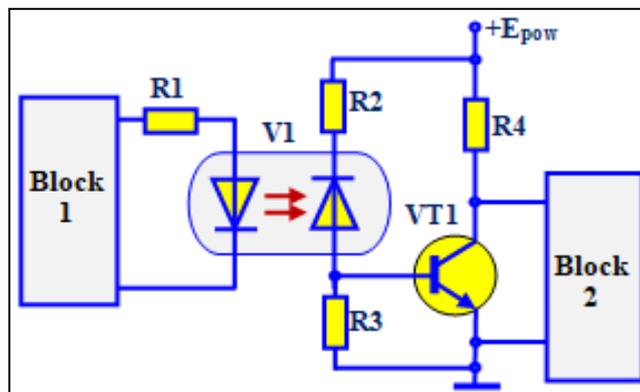


Figure 4 Diagram of interlock galvanic isolation

The circuit for matching a transistor-transistor logic (TTL) element with an integrated device based on MOS transistors is built on a transistor optocoupler (Figure 5). In this particular case: $E_1 = E_2 = 5\text{ V}$, $E_3 = -15\text{ V}$, R_1 and $R_2 = 820\ \Omega$, $R_3 = 24\text{ k}\Omega$ - the optocoupler LED is excited by a current (5 mA) sufficient to saturate the transistor and reliably control the device based on MOS transistors.

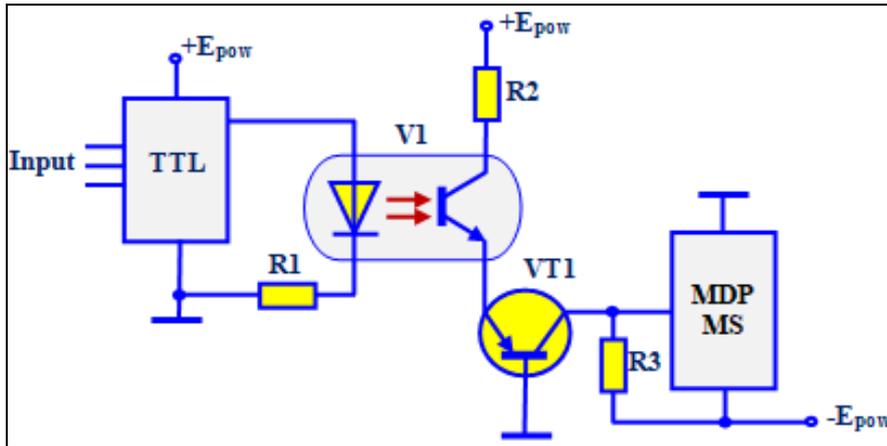


Figure 5 Schematic diagram of TTL and MDP element interfacing via an optical channel

Optical connections are actively used in telephone devices and systems. With the help of optocouplers, it is possible to connect microelectronic devices designed for calling, indication, control, and other purposes to telephone lines using technically simple means. The introduction of optical connections into electronic measuring equipment, in addition to the galvanic isolation of the object under study and the measuring device, which is useful in many respects, also allows for a significant reduction in the influence of interference acting on grounding and power supply circuits. The possibilities and experience of using optoelectronic devices and equipment in biomedical equipment are of considerable interest. Optocouplers can be used to isolate patients from high voltages, such as those found in electrocardiographic devices. Contactless control of powerful, high-voltage circuits via optical channels is very convenient and safe in complex technical modes characteristic of many industrial electronic devices and systems. Thyristor optocouplers are particularly strong in this area (Figure 6).

5. Information Acquisition and Display

Optocouplers and optocoupler microcircuits occupy a leading position in contactless remote technology for the rapid acquisition and accurate display of information about the characteristics and properties of processes and objects that are very different in nature and purpose. Optocouplers with open optical channels have unique capabilities in this regard. These include optoelectronic interrupters that respond to opaque objects crossing the optical channel (Figure 7) and reflective optocouplers, in which the effect of light emitters on photodetectors is entirely due to the reflection of the emitted flux from external objects [1-4].

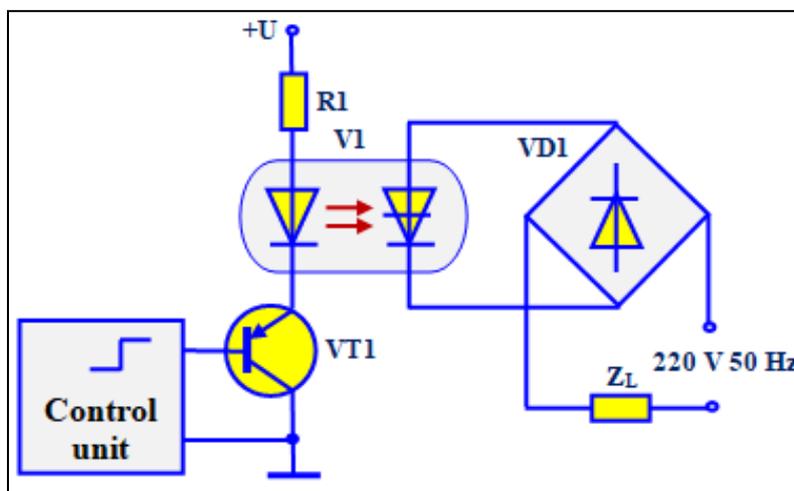


Figure 6 AC load switching circuit

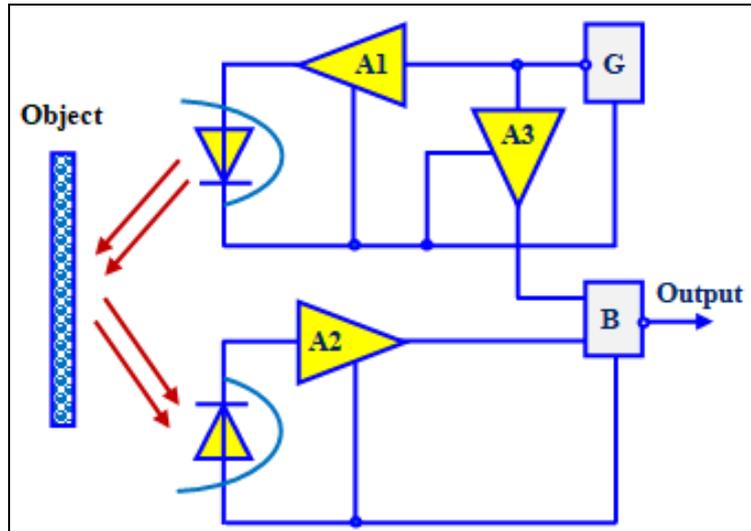


Figure 7 Optoelectronic sensor

The range of applications for optocouplers with open optical channels is extensive and varied. As early as the 1960s, optocouplers of this type were effectively used to detect objects and items. In such detection, which is primarily characteristic of automatic control and object counting devices, as well as for the detection and indication of various types of defects and failures, it is important to clearly determine the location of the object or reflect the fact of its existence. Optocouplers perform detection functions reliably and quickly.

6. The Use of Optocouplers in Elevator Safety Systems

With the gradual development of urbanization, the number of high-rise buildings in cities continues to grow. Elevators play an indispensable role in the urban vertical transportation system [5-8]. Accidents in elevators have occurred frequently, causing increasing concern in recent years. Recently, news feeds in the capital have been filled with alarming reports from the Ministry of Emergency Situations about the rescue of people trapped in elevators. It seems that elevators in Tashkent are increasingly becoming not a means of transportation between floors, but a trap from which it is not so easy to escape without the intervention of rescuers. Not only adults, but also children and the elderly find themselves trapped in elevators. And in the conditions of approaching heat, poor ventilation, and stress, being in a metal cage becomes a real ordeal. In some cases, people have to wait 30-40 minutes for help. This is not just an inconvenience - it is a threat to life and health. Therefore, it is extremely important to implement an advanced and effective method to ensure the safe operation of elevators.

The introduction of wireless technologies for connecting elevator systems to the network and the use of optocouplers for transmitting alarm signals opens up new opportunities for creating flexible and effective solutions for monitoring and managing safety, as well as reducing capital and operating costs.

Let's consider options for organizing an elevator safety monitoring system using modern LTE and Wi-Fi technologies for data transmission, which provide a stable and high-speed connection.

Figure 8 shows a stand-alone diagram of the elevator safety monitoring and alarm signal transmission system in the event of a sudden power failure. For local conditions in Uzbekistan, it is proposed to install a stand-alone system for notifying passengers of elevator stoppages due to power failures inside the elevator cabin on older elevators [5], [9], [10].

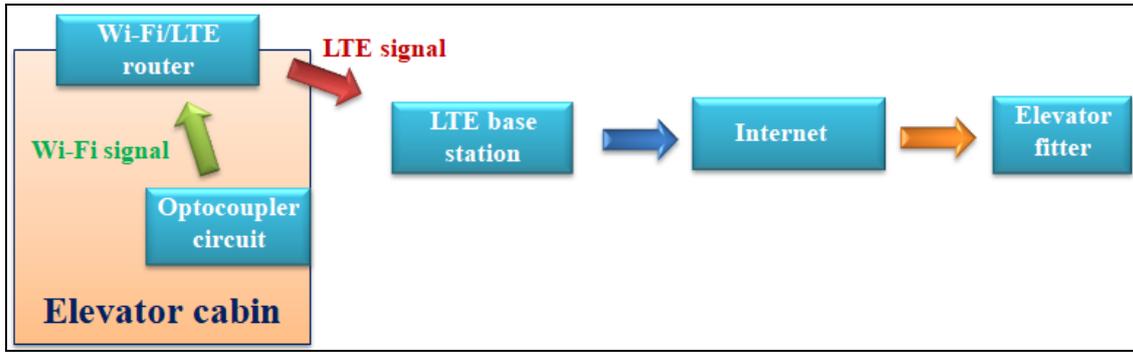


Figure 8 Diagram of the elevator safety monitoring system and alarm transmission in the event of a sudden power failure

The autonomous system for alerting about elevator stoppages due to sudden power outages consists of two parts: an optocoupler activation circuit (battery-powered) and a Wi-Fi module (Wi-Fi transmitter) (battery-powered) (Figure 9) [9], [11].

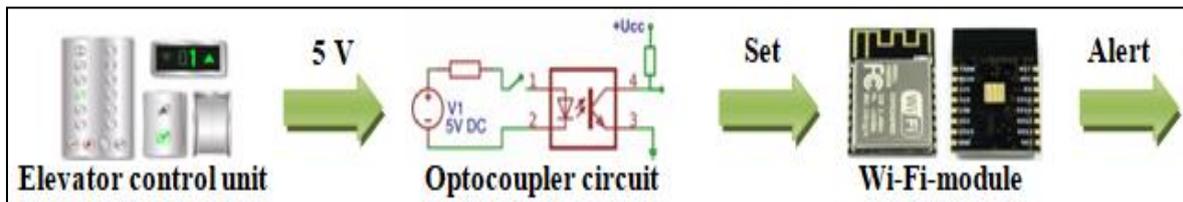


Figure 9 Autonomous elevator stop notification system in case of sudden power failure

The system operates as follows. In normal mode, the elevator control unit is powered and the elevator stop notification system is disabled. In emergency mode, i.e., in the event of a sudden power failure, when the “Alarm” button inside the cabin is pressed, the optocoupler circuit is activated in the absence of voltage in the elevator control unit and starts the Wi-Fi module, which in turn transmits an alarm signal to the LTE network and then to the elevator repairman's smartphone app. This way, the elevator repairman will be able to receive the message in time and arrive at the scene, thus preventing an unpleasant incident [12-14].

7. Conclusion

Optocouplers are widely used in various electronic devices. Due to the rapid development of digital communication technologies and the continuous expansion of the application of automatic control components, such as optical isolators and solid-state relays, in security systems, as well as the application and promotion of microprocessors in various fields (sometimes the number of microcomputers used can reach tens or even hundreds), and the gradual improvement of product characteristics, the market for optocouplers will continue to expand, and their socio-economic significance will be quite significant. In the future, optocouplers will evolve in the direction of increased speed, performance, compactness, and weight.

The introduction of wireless technologies and the use of optocouplers allows real-time monitoring of elevator status and prediction of potential breakdowns and accidents. It is important to consider the architectural features of buildings, the type of elevators, and the strategic location of access points when designing wireless networks for such systems. This is especially relevant for Uzbekistan, where most elevators are outdated and require modernization. The system also provides the ability to monitor emergency situations, such as power outages, which is critical for ensuring the safe operation of elevators, and to promptly notify maintenance personnel or the organization.

Compliance with ethical standarts

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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