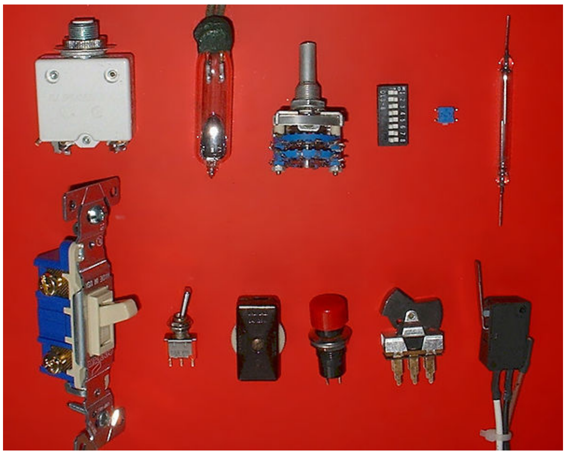
Switch

Contents

Chapter 1

Switch

For other uses, see Switch (disambiguation).
"Toggle button" redirects here. For the GUI widget, see Cycle button.
In electrical engineering, a **switch** is an electrical component that can break an electrical circuit, interrupting the current or diverting it from one conductor to another.[1][2] The mechanism of a switch may be operated directly by a human operator to control a circuit (for example, a light switch or a keyboard button), may be operated by a moving object such as a door-operated switch, or may be operated by some sensing element for pressure, temperature or flow. A relay is a switch that is operated by electricity. Switches are made to handle a wide range of voltages and currents; very large switches may be used to isolate high-voltage circuits in electrical substations.



Electrical switches. Top, left to right: circuit breaker, mercury switch, wafer switch, DIP switch, surface mount switch, reed switch. Bottom, left to right: wall switch (U.S. style), miniature toggle switch, in-line switch, push-button switch, rocker switch, microswitch.

1.1 Description

The most familiar form of switch is a manually operated electromechanical device with one or more sets of electrical contacts, which are connected to external circuits. Each set of contacts can be in one of two states: either "closed" meaning the contacts are touching and electricity can flow between them, or "open", meaning the contacts are separated and the switch is nonconducting. The mechanism actuating the transition between these two states (open or closed) can be either a "*toggle*" (flip switch for continuous "on" or "off") or "*momentary*" (push-for "on" or push-for "off") type.

A switch may be directly manipulated by a human as a control signal to a system, such as a computer keyboard button, or to control power flow in a circuit, such as a light switch. Automatically operated switches can be used to control the motions of machines, for example, to indicate that a garage door has reached its full open position or that a machine tool is in a position to accept another workpiece. Switches may be operated by process variables such as pressure, temperature, flow, current, voltage, and force, acting as sensors in a process and used to automatically control a system. For example, a thermostat is a temperature-operated switch used to control a heating process. A switch that is operated by another electrical circuit is called a relay. Large switches may be remotely operated by a motor drive mechanism. Some switches are used to isolate electric power from a system, providing a visible point of isolation that can be padlocked if necessary to prevent accidental operation of a machine during maintenance, or to prevent electric shock.

An ideal switch would have no voltage drop when closed, and would have no limits on voltage or current rating. It would have zero rise time and fall time during state changes, and would change state without "bouncing" between on and off positions.

Practical switches fall short of this ideal; they have resistance, limits on the current and voltage they can handle, finite switching time, etc. The ideal switch is often used in circuit analysis as it greatly simplifies the system of equations to be solved, but this can lead to a less accurate solution. Theoretical treatment of the effects of non-ideal properties is required in the design of large networks of switches, as for example used in telephone exchanges.

A toggle switch in the "on" position.

Triple-pole single-throw (TPST or 3PST) knife switch used to short the windings of a 3-phase wind turbine for braking purposes. Here the switch is shown in the open position.

1.2 Contacts

In the simplest case, a switch has two conductive pieces, often metal, called *contacts*, connected to an external circuit, that touch to complete (make) the circuit, and separate to open (break) the circuit. The contact material is chosen for its resistance to corrosion, because most metals form insulating oxides that would prevent the switch from working. Contact materials are also chosen on the basis of electrical conductivity, hardness (resistance to abrasive wear), mechanical strength, low cost and low toxicity.[3]

Sometimes the contacts are plated with noble metals. They may be designed to wipe against each other to clean off any contamination. Nonmetallic conductors, such as conductive plastic, are sometimes used. To prevent the formation of insulating oxides, a minimum wetting current may be specified for a given switch design.

1.2.1 Contact terminology

In electronics, switches are classified according to the arrangement of their contacts. A pair of contacts is said to be "*closed*" when current can flow from one to the other. When the contacts are separated by an insulating air gap, they are said to be "*open*", and no current can flow between them at normal voltages. The terms "*make*" for closure of contacts and "*break*" for opening of contacts are also widely used.

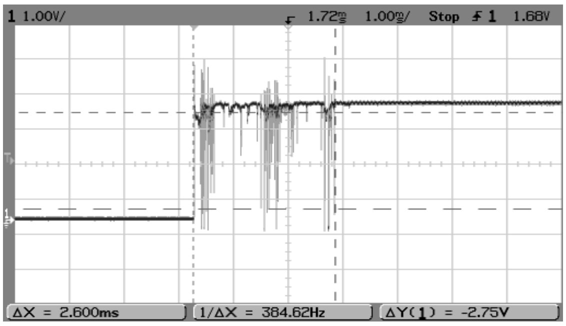
The terms **pole** and **throw** are also used to describe switch contact variations. The number of "*poles*" is the number of separate circuits which are controlled by a single switch. For example, a "*2-pole*" switch has two separate identical sets of contacts controlled by the same switch. The number of "*throws*" is the number of separate wiring path choices other than "open" that the switch can adopt for each pole. A single-throw switch has one pair of contacts that can either be closed or open. A double-throw switch has a contact that can be connected to either of two other contacts, a triple-throw has a contact which can be connected to one of three other contacts, etc.[4]

In a switch where the contacts remain in one state unless actuated, such as a push-button switch, the contacts can either be **normally open** (abbreviated "**n.o.**" or "**no**") until closed by operation of the switch, or **normally closed** ("**n.c.**" or "**nc**") and opened by the switch action. A switch with both types of contact is called a *changeover switch*. These may be "**make-before-break**" ("**MBB**" or shorting) which momentarily connects both circuits, or may be "**break-before-make**" ("**BBM**" or non-shorting) which interrupts one circuit before closing the other.

These terms have given rise to abbreviations for the types of switch which are used in the electronics industry such as "*single-pole, single-throw*" (SPST) (the simplest type, "on or off") or "*single-pole, double-throw*" (SPDT), connecting either of two terminals to the common terminal. In electrical power wiring (i.e., house and building wiring by electricians), names generally involve the suffix *"-way"*; however, these terms differ between British English and American English (i.e., the terms *two way* and *three way* are used with different meanings).[5]

Switches with larger numbers of poles or throws can be described by replacing the "S" or "D" with a number (e.g. 3PST, 4PST, etc.) or in some cases the letter "T" (for "triple") or "Q" (for "quadruple"). In the rest of this article the terms *SPST*, *SPDT* and *intermediate* will be used to avoid the ambiguity.

1.2.2 Contact bounce



Snapshot of switch bounce on an oscilloscope. The switch bounces between on and off several times before settling.

Contact bounce (also called *chatter*) is a common problem with mechanical switches and relays. Switch and relay contacts are usually made of springy metals. When the contacts strike together, their momentum and elasticity act together to cause them to bounce apart one or more times before making steady contact. The result is a rapidly pulsed electric current instead of a clean transition from zero to full current. The effect is usually unimportant in power circuits, but causes problems in some analogue and logic circuits that respond fast enough to misinterpret the on-off pulses as a data stream.[6]

The effects of contact bounce can be eliminated by use of mercury-wetted contacts, but these are now infrequently used because of the hazard of mercury release. Alternatively, contact circuits can be low-pass filtered to reduce or eliminate multiple pulses. In digital systems, multiple samples of the contact state can be taken or a time delay can be implemented in order for the contact bounce to settle before the contact input is used to control anything. Bounce in an SPDT switch can be eliminated by an SR latch.[7] All of these methods are referred to as "debouncing" circuits.

By analogy, the term "debounce" has arisen in the software development industry to describe rate-limiting or throttling the frequency of a method's execution.[8]

1.2.3 Arcs and quenching

When the power being switched is sufficiently large, the electron flow across opening switch contacts is sufficient to ionize the air molecules across the tiny gap between the contacts as the switch is opened, forming a gas plasma, also known as an electric arc. The plasma is of low resistance and is able to sustain power flow, even with the separation distance between the switch contacts steadily increasing. The plasma is also very hot and is capable of eroding the metal surfaces of the switch contacts. Electric current arcing causes significant degradation of the contacts and also significant electromagnetic interference (EMI), requiring the use of arc suppression methods.[9]

Where the voltage is sufficiently high, an arc can also form as the switch is closed and the contacts approach. If the voltage potential is sufficient to exceed the breakdown voltage of the air separating the contacts, an arc forms which is sustained until the switch closes completely and the switch surfaces make contact.

In either case, the standard method for minimizing arc formation and preventing contact damage is to use a fast-moving switch mechanism, typically using a spring-operated tipping-point mechanism to assure quick motion of switch contacts, regardless of the speed at which the switch control is operated by the user. Movement of the switch control lever applies tension to a spring until a tipping point is reached, and the contacts suddenly snap open or closed as the spring tension is released.

As the power being switched increases, other methods are used to minimize or prevent arc formation. A plasma is hot and will rise due to convection air currents. The arc can be quenched with a series of nonconductive blades spanning the distance between switch contacts, and as the arc rises its length increases as it forms ridges rising into the spaces between the blades, until the arc is too long to stay sustained and is extinguished. A *puffer* may be used to blow a sudden high velocity burst of gas across the switch contacts, which rapidly extends the length of the arc to extinguish it quickly.

Extremely large switches in excess of 100,000-watt capacity often have switch contacts surrounded by something other than air to more rapidly extinguish the arc. For example, the switch contacts may operate in a vacuum, immersed in mineral oil, or in sulfur hexafluoride.

In AC power service, the current periodically passes through zero; this effect makes it harder to sustain an arc on opening. Manufacturers may rate switches with lower voltage or current rating when used in DC circuits.[10][11]

1.2.4 Power switching

When a switch is designed to switch significant power, the transitional state of the switch as well as the ability to withstand continuous operating currents must be considered. When a switch is in the on state, its resistance is near zero and very little power is dropped in the contacts; when a switch is in the off state, its resistance is extremely high and even less power is dropped in the contacts. However, when the switch is flicked, the resistance must pass through a state where a quarter of the load's rated power (or worse if the load is not purely resistive) is briefly dropped in the switch.

For this reason, power switches intended to interrupt a load current have spring mechanisms to make sure the transition between on and off is as short as possible regardless of the speed at which the user moves the rocker.

Power switches usually come in two types. A momentary on-off switch (such as on a laser pointer) usually takes the form of a button and only closes the circuit when the button is depressed. A regular on-off switch (such as on a flashlight) has a constant on-off feature. Dual-action switches incorporate both of these features.

1.2.5 Inductive loads

When a strongly inductive load such as an electric motor is switched off, the current cannot drop instantaneously to zero; a spark will jump across the opening contacts. Switches for inductive loads must be rated to handle these cases. The spark will cause electromagnetic interference if not suppressed; a snubber network of a resistor and capacitor in series will quell the spark.

1.2.6 Incandescent loads

When turned on, an incandescent lamp draws a large inrush current of about ten times the steady-state current; as the filament heats up, its resistance rises and the current decreases to a steady-state value. A switch designed for an incandescent lamp load can withstand this inrush current.[12]

1.2.7 Wetting current

Wetting current is the minimum current needing to flow through a mechanical switch while it is operated to break through any film of oxidation that may have been deposited on the switch contacts.[13] The film of oxidation occurs often in areas with high humidity. Providing a sufficient amount of wetting current is a crucial step in designing systems that use delicate switches with small contact pressure as sensor inputs. Failing to do this might result in switches remaining electrically "open" due to contact oxidation.

A "T-rated" wall switch (the T is for Tungsten *filament)[12] that is suited for incandescent loads.*

1.3 Actuator

The moving part that applies the operating force to the contacts is called the *actuator*, and may be a **toggle** or *dolly*, a **rocker**, a **push-button** or any type of mechanical linkage *(see photo).*

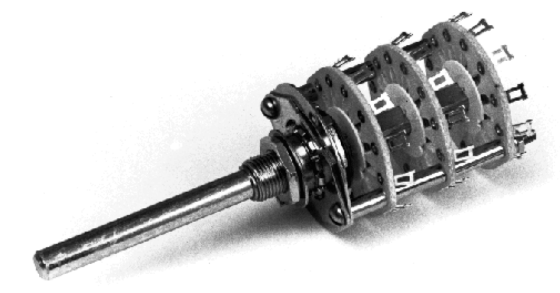
1.3.1 Biased switches

The momentary push-button switch is a type of biased switch. The most common type is a "push-to-make" (or normally-open or NO) switch, which makes contact when the button is pressed and breaks when the button is released. Each key of a computer keyboard, for example, is a normally-open "push-to-make" switch. A "push-to-break" (or normally-closed or NC) switch, on the other hand, breaks contact when the button is pressed and makes contact when it is released. An example of a push-to-break switch is a button used to release a door held closed by an electromagnet. The interior lamp of a household refrigerator is controlled by a switch that is held open when the door is closed.

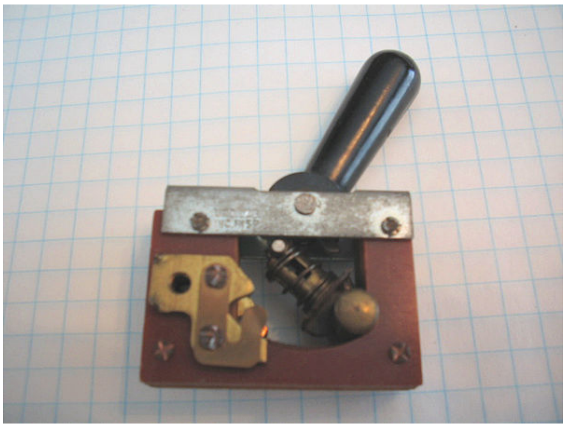
1.3.2 Rotary switch

Main article: Rotary switch

A rotary switch operates with a twisting motion of the operating handle with at least two positions. One or more positions of the switch may be momentary (biased with a spring), requiring the operator to hold the switch in the position. Other positions may have a detent to hold the position when released. A rotary switch may have multiple levels or "decks" in order to allow it to control multiple



A three-deck stacked rotary switch. Any number of switching elements may be stacked in this manner, by using a longer shaft and additional spacing standoffs between each switching element.



Large toggle switch, depicted in circuit "open" position, electrical contacts to left; background is 1/4" square graph paper

Bank of toggle switches on a Data General Nova minicomputer front panel.

Toggle switches with the shared cover preventing certain forbidden combinations

circuits.

One form of rotary switch consists of a spindle or "rotor" that has a contact arm or "spoke" which projects from its surface like a cam. It has an array of terminals, arranged in a circle around the rotor, each of which serves as a contact for the "spoke" through which any one of a number of different electrical circuits can be connected to the rotor. The switch is layered to allow the use of multiple poles, each layer is equivalent to one pole. Usually such a switch has a detent mechanism so it "clicks" from one active position to another rather than stalls in an intermediate position. Thus a rotary switch provides greater pole and throw capabilities than simpler switches do.

Other types use a cam mechanism to operate multiple independent sets of contacts.

Rotary switches were used as channel selectors on television receivers until the early 1970s, as range selectors on electrical metering equipment, as band selectors on multi-band radios and other similar purposes. In industry, rotary switches are used for control of measuring instruments, switchgear, or in control circuits. For example, a radio controlled overhead crane may have a large multi-circuit rotary switch to transfer hard-wired control signals from the local manual controls in the cab to the outputs of the remote control receiver.

1.3.3 Toggle switch

A toggle switch is a class of electrical switches that are manually actuated by a mechanical lever, handle, or rocking mechanism.

Toggle switches are available in many different styles and sizes, and are used in numerous applications. Many are designed to provide the simultaneous actuation of multiple sets of electrical contacts, or the control of large amounts of electric current or mains voltages.

The word "toggle" is a reference to a kind of mechanism or joint consisting of two arms, which are almost in line with each other, connected with an elbow-like pivot. However, the phrase "toggle switch" is applied to a switch with a short handle and a positive snap-action, whether it actually contains a toggle mechanism or not. Similarly, a switch where a definitive click is heard, is called a "positive on-off switch"[14] - - the most common use of this type of switch is a typical light switch or electrical outlet switch.

Multiple toggle switches may be mechanically interlocked to prevent forbidden combinations.

Opened float switch of a dirty water pump

A high-voltage disconnect switch used in an electrical substation. Such switches are used mostly to isolate circuits, and usually cannot break load current. High-voltage switches are available for the highest transmission voltages, up to 1 million volts. This switch is gang-operated so that all three phases are interrupted at the same time.

1.4 Special types

Switches can be designed to respond to any type of mechanical stimulus: for example, vibration (the trembler switch), tilt, air pressure, fluid level (a float switch), the turning of a key (key switch), linear or rotary movement (a limit switch or microswitch), or presence of a magnetic field (the reed switch). Many switches are operated automatically by changes in some environmental condition or by motion of machinery. A limit switch is used, for example, in machine tools to interlock operation with the proper position of tools. In heating or cooling systems a sail switch ensures that air flow is adequate in a duct. Pressure switches respond to fluid pressure.

1.4.1 Mercury tilt switch

Main article: Mercury switch

The mercury switch consists of a drop of mercury inside a glass bulb with two or more contacts. The two contacts pass through the glass, and are connected by the mercury when the bulb is tilted to make the mercury roll on to them.

This type of switch performs much better than the ball tilt switch, as the liquid metal connection is unaffected by dirt, debris and oxidation, it wets the contacts ensuring a very low resistance bounce-free connection, and movement and vibration do not produce a poor contact. These types can be used for precision works.

It can also be used where arcing is dangerous (such as in the presence of explosive vapour) as the entire unit is sealed.

1.4.2 Knife switch

Main article: Knife switch

Knife switches consist of a flat metal blade, hinged at one end, with an insulating handle for operation, and a fixed contact. When the switch is closed, current flows through the hinged pivot and blade and through the fixed contact. Such switches are usually not enclosed. The knife and contacts are typically formed of copper, steel, or brass, depending on the application. Fixed contacts may be backed up with a spring. Several parallel blades can be operated at the same time by one handle. The parts may be mounted on an insulating base with terminals for wiring, or may be directly bolted to an insulated switch board in a large assembly. Since the electrical contacts are exposed, the switch is used only where people cannot accidentally come in contact with the switch or where the voltage is so low as to not present a hazard.

Knife switches are made in many sizes from miniature switches to large devices used to carry thousands of amperes. In electrical transmission and distribution, gang-operated switches are used in circuits up to the highest voltages.

The disadvantages of the knife switch are the slow opening speed and the proximity of the operator to exposed live parts. Metal-enclosed safety disconnect switches are used for isolation of circuits in industrial power distribution. Sometimes spring-loaded auxiliary blades are fitted which momentarily carry the full current during opening, then quickly part to rapidly extinguish the arc.

1.4.3 Footswitch

A footswitch is a rugged switch which is operated by foot pressure. An example of use is in the control of a machine tool, allowing the operator to have both hands free to manipulate the workpiece. The foot control of an electric guitar is also a footswitch.

1.4.4 Reversing switch

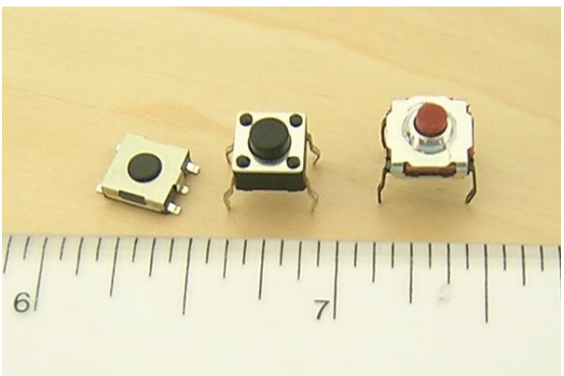
A DPDT switch has six connections, but since polarity reversal is a very common usage of DPDT switches, some variations of the DPDT switch are internally wired specifically for polarity reversal. These crossover switches only have four terminals rather than six. Two of the terminals are inputs and two are outputs. When connected to a battery or other DC source, the 4-way switch selects from either normal or reversed polarity. Such switches can also be used as intermediate switches in a multiway switching system for control of lamps by more than two switches.

1.5 Light switches

Main article: Light switch

In building wiring, light switches are installed at convenient locations to control lighting and occasionally other circuits. By use of multiple-pole switches, multiway switching control of a lamp can be obtained from two or more places, such as the ends of a corridor or stairwell. A wireless light switch allows remote control of lamps for convenience; some lamps include a touch switch which electronically controls the lamp if touched anywhere. In public buildings several types of vandal resistant switches are used to prevent unauthorized use.

1.6 Electronic switches



Three push button switches (Tactile Switches). Major scale is inches.

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching—often a silicon-controlled rectifier or triac.

The analogue switch uses two MOSFET transistors in a transmission gate arrangement as a switch that works much like a relay, with some advantages and several limitations compared to an electromechanical relay.

The power transistor(s) in a switching voltage regulator, such as a power supply unit, are used like a switch to alternately let power flow and block power from flowing.

Many people use metonymy to call a variety of devices “switches” that conceptually connect or disconnect signals and communication paths between electrical devices, analogous to the way mechanical switches connect and disconnect paths for electrons to flow between two conductors. Early telephone systems used an automatically operated Strowger switch to connect telephone callers; telephone exchanges contain one or more crossbar switches today.

Since the advent of digital logic in the 1950s, the term *switch* has spread to a variety of digital active devices such as transistors and logic gates whose function is to change their output state between two logic levels or connect different signal lines, and even computers, network switches, whose function is to provide connections between different ports in a computer network.[15] The term 'switched' is also applied to telecommunications networks, and signifies a network that is circuit switched, providing dedicated circuits for communication between end nodes, such as the public switched telephone network. The common feature of all these usages is they refer to devices that control a binary state: they are either *on* or *off*, *closed* or *open*, *connected* or *not connected*.

1.7 Other switches

- Centrifugal switch
- Dead man’s switch
- Fireman’s switch
- Hall-effect switch
- Inertial switch
- Isolator switch
- Kill switch
- Light switch
- Latching switch
- Load control switch
- Membrane switch
- Piezo switch

- Pull switch
- Push switch
- RF Switch Matrix
- Sense switch
- Staircase time switch
- Slotted optical switch
- Stepping switch
- Switch access
- Electric switchboard
- Switchgear
- Thermal switch
- Time switch
- Touch switch
- Transfer switch

1.8 See also

- Commutator (electric)
- Cutout
- DIN rail

1.9 References

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[10] http://uk.farnell.com/panasonic-ew/abj151261j/microswitch-hinge-lever/dp/2095696?in_merch=New%20Products&in_merch=Featured%20New%20Products&MER=i-9b10-00002068

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[14] Gladstone, Bernard (1978). *The New York times complete manual of home repair*. Times Books. p. 399.

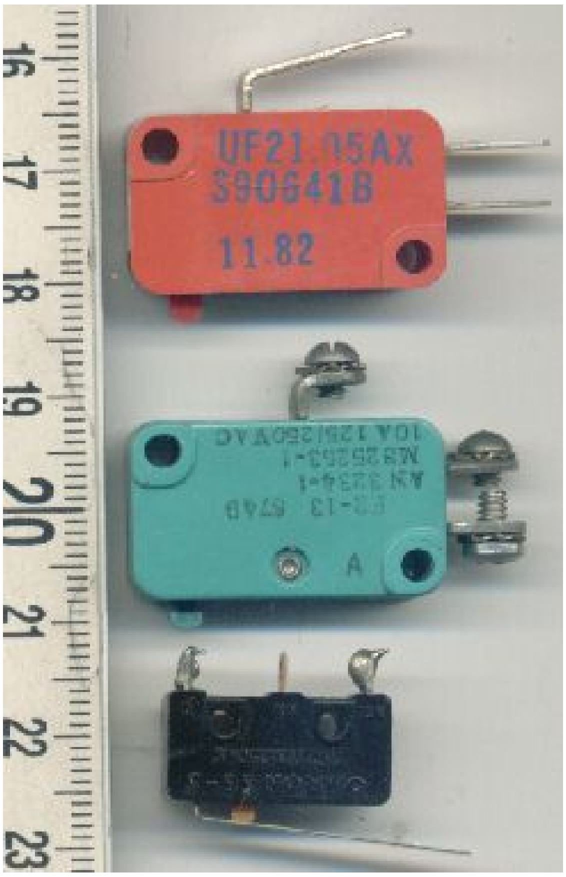
[15] "'Switch'". *Telecom definitions*. SearchTelecom.com. 2007. Retrieved 2008-12-27.

1.10 External links

- Glossary of Electric Switches
- Types of switches ON-ON, ON-(ON), etc.

Chapter 2

Miniature snap-action switch

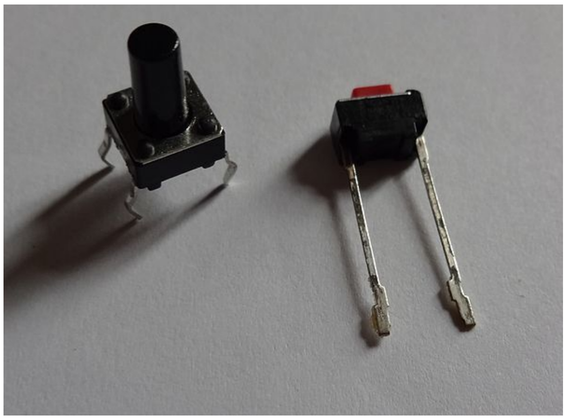


Comparison of some different switches.

A **miniature snap-action switch**, also trademarked and frequently known as a **micro switch**, is an electric switch that is actuated by very little physical force, through the use of a tipping-point mechanism, sometimes called an "over-center" mechanism.

Switching happens reliably at specific and repeatable positions of the actuator, which is not necessarily true of other mechanisms. They are very common due to their low cost and durability, greater than 1 million cycles and up to 10 million cycles for heavy duty models. This durability is a natural consequence of the design.

The defining feature of micro switches is that a relatively small movement at the actuator button produces a relatively large movement at the electrical contacts, which occurs at high speed (regardless of the speed of actuation). Most successful designs also exhibit hysteresis, meaning that a small reversal of the actuator is insufficient to reverse the contacts; there must be a significant movement in the opposite direction. Both of these characteristics help to achieve a clean and reliable interruption to the switched circuit.



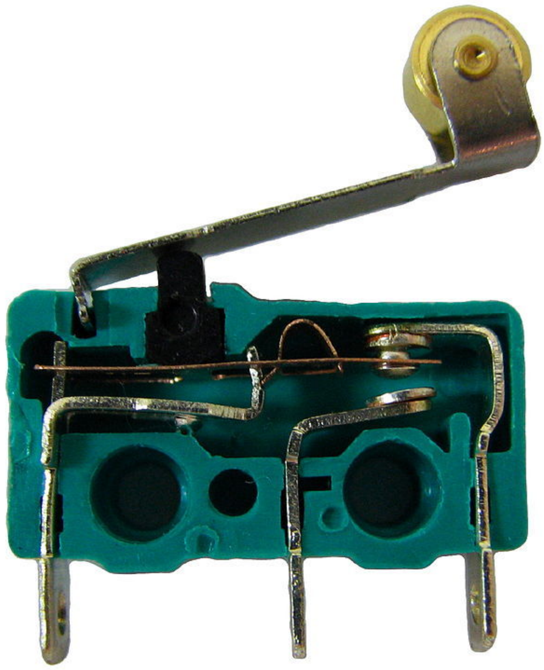
2 different microswitches

2.1 History

The first micro switch was invented by Peter McGall in 1932 in Freeport, Illinois. McGall was an employee of the Burgess Battery Company at the time. In 1937 W.B. Schulte, [1]McGall's employer, started the company MICRO SWITCH. The company and the *Micro Switch* trademark has been owned by Honeywell Sensing and Control since 1950.[2] The trademark has become genericized for any snap-action switch. Companies other than Honeywell now manufacture miniature snap-action switches.

2.2 Construction and operation

In one type of microswitch, internally there are two conductive springs. A long flat spring is hinged at one end of



The internals of a micro switch. Contacts, from left to right, are common, normally open, and normally closed.

the switch (the left, in the photograph) and has electrical contacts on the other. A small curved spring, preloaded (i.e., compressed during assembly) so it attempts to extend itself (at the top, just right of center in the photo), is connected between the flat spring near the contacts. A fulcrum is near the midpoint of the flat spring. An actuator nub presses on the flat spring near its hinge point.

Because the flat spring is anchored and strong in tension the curved spring cannot move it to the right. The curved spring presses, or pulls, the flat spring upward, that is away, from the anchor point. Owing to the geometry, the upward force is proportional to the displacement which decreases as the flat spring moves downward. (Actually, the force is proportional to the sine of the angle, which is approximately proportional to the angle for small angles.)

As the actuator depresses it flexes the flat spring while the curved spring keeps the electrical contacts touching. When the flat spring is flexed enough it will provide sufficient force to compress the curved spring and the contacts will begin to move.

As the flat spring moves downward the upward force of the curved spring reduces causing the motion to accelerate even in the absence of further motion of the actuator until the flat spring impacts the normally-open contact. Even though the flat spring unflexes as it moves downward, the switch is designed so the net effect is acceleration. This "over-center" action produces a very distinctive clicking sound and a very crisp feel.

In the actuated position the curved spring provides some upward force. If the actuator is released this will move the flat spring upward. As the flat spring moves, the force from the curved spring increases. This results in acceleration until the normally-closed contacts are hit. Just as in the downward direction, the switch is designed so that the curved spring is strong enough to move the contacts, even if the flat spring must flex, because the actuator does not move during the changeover.

2.3 Applications

Common applications of micro switches include the door interlock on a microwave oven, levelling and safety switches in elevators, vending machines, and to detect paper jams or other faults in photocopiers. Micro switches are commonly used in tamper switches on gate valves on fire sprinkler systems and other water pipe systems, where it is necessary to know if a valve has been opened or shut.

Micro switches are very widely used; among their applications are appliances, machinery, industrial controls, vehicles, convertible tops and many other places for control of electrical circuits. They are usually rated to carry current in control circuits only, although some switches can be directly used to control small motors, solenoids, lamps, or other devices. Special low-force versions can sense coins in vending machines, or with a vane attached, air flow. Micro switches may be directly operated by a mechanism, or may be packaged as part of a pressure, flow, or temperature switch, operated by a sensing mechanism such as a Bourdon tube. In these latter applications, the repeatability of the actuator position when switching happens is essential for long-term accuracy. A motor driven cam (usually relatively slow-speed) and one or more micro switches form a timer mechanism. The snap-switch mechanism can be enclosed in a metal housing including actuating levers, plungers or rollers, forming a limit switch useful for control of machine tools or electrically-driven machinery.

2.4 See also

- Mercury switch
- Reed switch

2.5 References

[1] Shouer, Dick (1 March 2015). *Honeywell History*. Honeywell.

[2] MICRO SWITCH Timeline - 1950s

2.6 External links

- Honeywell celebrates the 75th anniversary of the

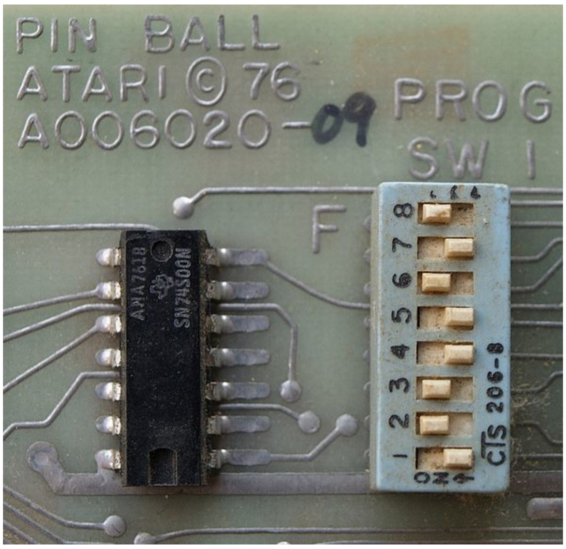
Micro Switch

Chapter 3

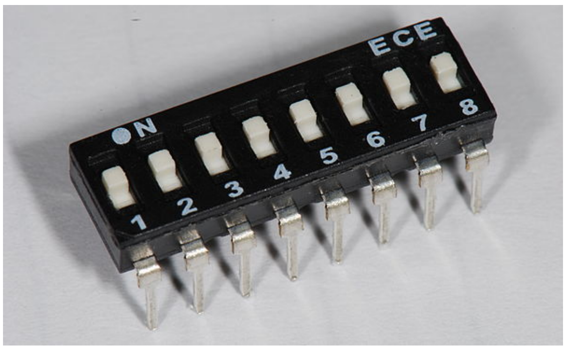
DIP switch

For the headlamp component, see headlamp.

A **DIP switch** is a manual electric switch that is pack-



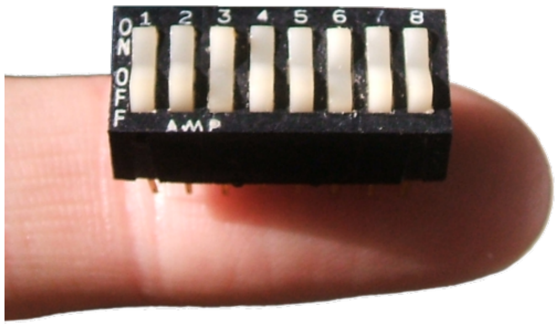
An early DIP switch (1976)



A slide-style DIP switch

aged with others in a group in a standard dual in-line package (DIP). The term may refer to each individual switch, or to the unit as a whole. This type of switch is designed to be used on a printed circuit board along with other electronic components and is commonly used to customize the behavior of an electronic device for specific situations.

DIP switches are an alternative to jumper blocks. Their



A rocker-style DIP switch

main advantages are that they are quicker to change and there are no parts to lose.

The DIP switch with sliding levers was granted US Patent 4012608 in 1976.[1] It was applied for 1974 and was used in 1977 in an ATARI Flipper game.[2]

3.1 Types

There are many different kinds of DIP switches. Some of the most common are the rotary, slide, and rocker types.

Rotary DIP switches contain multiple electrical contacts, one of which is selected by rotating the switch to align it with a number printed on the package. These may be large like thumbwheels, or so small that a screwdriver must be used to change them (although there are also small potentiometers of this type).

The slide and rocker types, which are very common, are arrays of simple single pole, single throw (SPST) contacts, which can be either on or off. This allows each switch to select a one-bit binary value. The values of all switches in the package can also be interpreted as one number. For example, seven switches offer 128 combinations, allowing them to select a standard ASCII character. Eight switches offer 256 combinations, which is equivalent to one byte.

The DIP switch package also has socket pins or mounting leads to provide an electrical path from the switch contacts to the circuit board. Although circuits can use the electrical contacts directly, it is more common to convert them into high and low signals. In this case, the circuit board also needs interface circuitry for the DIP switch, consisting of a series of pull-up or pull-down resistors, a buffer, decode logic, and other components.[3] Typically, the device's firmware reads the DIP switches when the device is powered on.

3.2 Applications

DIP switches were used extensively in ISA architecture of PC expansion cards to select IRQs and memory addresses. They were also often used on arcade games in the 1980s and early 1990s to store settings before the advent of cheaper, battery-backed RAM, and were very commonly used to set security codes on garage door openers as well as on some early cordless phones. This design, which used up to 12 switches in a group, was used to avoid RF interference from other nearby door opener remotes or other devices. Current garage door openers use rolling code systems for better security.

These type of switches were used on early video cards for early computers to facilitate compatibility with other video standards. For example, CGA cards allowed for MDA compatibility.

Recently (since the late 1990s), DIP switches have become less common in consumer electronics. Reasons include the trend toward smaller products, the demand for easier configuration through software menus, and the falling price of non-volatile memory. However, DIP switches are still widely used in industrial equipment because they are inexpensive and easy to incorporate into circuit designs, and because they allow settings to be checked at a glance without powering the system on.

DIP switches are still used in some remote controls to prevent interference; for example, to control a ceiling fan (and its light fixture) that was retrofitted to a single-circuit junction box. The DIP switches set a different radio frequency for each transmitter/receiver pair, so that multiple units can be installed in different rooms of the same house, or different units of the same apartment building, without unintentionally controlling each other.

Rotary switches are also used in X10 home automation to select house and unit numbers. Rotary switches are also used in some radio transmitters (particularly VHF and FM broadcast) to select the DC bias used to set the voltage-controlled oscillator, which determines the center frequency of the carrier wave output.

3.3 Notes

[1] US Patent 4012608 Miniature switch with substantial wiping action

[2] ATARI Airborne Avenger Service Manual, TM-102, 1st printing 1977

[3] US Patent 5010445 Patent for a DIP switch with built-in active interfacing circuitry

3.4 External links

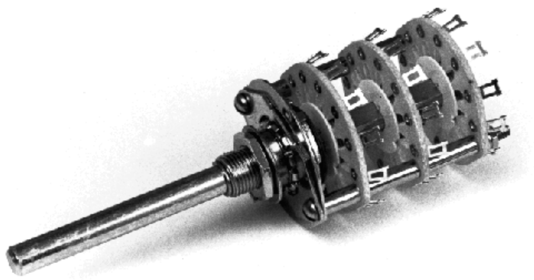
- Media related to DIP switches at Wikimedia Commons

Chapter 4

Rotary switch

For the Rotary Machine Switching System telephone exchange, see rotary system.

A **rotary switch** is a switch operated by rotation. These are often chosen when more than 2 positions are needed, such as a three-speed fan or a CB radio with multiple frequencies of reception or "channels".



Three-deck rotary switch allows controlling three different circuit functions

Bottom view of a 12-position rotary switch showing wiper and contacts.

A rotary switch consists of a spindle or "rotor" that has a contact arm or "spoke" which projects from its surface like a cam. It has an array of terminals, arranged in a circle around the rotor, each of which serves as a contact for the "spoke" through which any one of a number of different electrical circuits can be connected to the rotor. The switch is layered to allow the use of multiple poles, each layer is equivalent to one pole. Usually such a switch has a detent mechanism so it "clicks" from one active position to another rather than stalls in an intermediate position. Thus a rotary switch provides greater pole and throw capabilities than simpler switches do.

Rotary switches were used as channel selectors on television receivers until the early 1970s, as range selectors on electrical metering equipment, as band selectors on multi-band radios, etc.

Modern rotary switches utilise a "star wheel" mechanism to provide the switching positions, such as at every 30, 45, 60, or 90 degrees. Nylon cams are then mounted behind this mechanism and spring-loaded electrical contacts slide around these cams. The cams are notched or cut where the contact should close to complete an electrical circuit.

Some rotary switches are user configurable in relation to the number of positions. A special toothed washer that sits below the holding nut can be positioned so that the tooth is inserted into one of a number of slots in a way that limits the number of positions available for selection. For example, if only four positions are required on a twelve position switch, the washer can be positioned so that only four switching positions can be selected when in use.

4.1 See also

- Stepping switch
- Rotary system

Chapter 5

Limit switch

In electrical engineering a **limit switch** is a switch operated by the motion of a machine part or presence of an object.

They are used for controlling machinery as part of a control system, as a safety interlocks, or to count objects passing a point.[1] A limit switch is an electromechanical device that consists of an actuator mechanically linked to a set of contacts. When an object comes into contact with the actuator, the device operates the contacts to make or break an electrical connection.

Limit switches are used in a variety of applications and environments because of their ruggedness, ease of installation, and reliability of operation. They can determine the presence or absence, passing, positioning, and end of travel of an object. They were first used to define the limit of travel of an object; hence the name “Limit Switch”.

A limit switch with a roller-lever operator; this is installed on a gate on a canal lock, and indicates the position of a gate to a control system.

Standardized limit switches are industrial control components manufactured with a variety of operator types, including lever, roller plunger, and whisker type. Limit switches may be directly mechanically operated by the motion of the operating lever. A reed switch may be used to indicate proximity of a magnet mounted on some moving part. Proximity switches operate by the disturbance of an electromagnetic field, by capacitance, or by sensing a magnetic field.

Rarely, a final operating device such as a lamp or solenoid valve will be directly controlled by the contacts of an industrial limit switch, but more typically the limit switch will be wired through a control relay, a motor contactor control circuit, or as an input to a programmable logic controller.

Miniature snap-action switch may be used for example as components of such devices as photocopiers, computer printers, convertible tops or microwave ovens to ensure internal components are in the correct position for operation and to prevent operation when access doors are opened. A set of adjustable limit switches are installed on a garage door opener to shut off the motor when the door has reached the fully raised or fully lowered position. A numerical control machine such as a lathe will have limit switches to identify maximum limits for machine parts or to provide a known reference point for incremental motions.

A limit switch mounted on a moving part of a bridge.

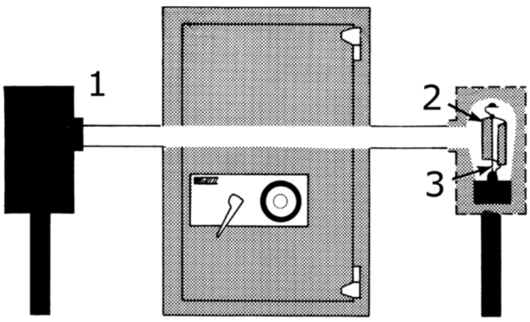
5.1 References

[1] Stephen Herman, *Industrial Motor Control* Cengage Learning, 2009 chapter 11 “Limit Switches” ISBN 1435442393,

Chapter 6

Photoelectric sensor

A **photoelectric sensor**, or photo eye, is a device used to detect the distance, absence, or presence of an object by using a light transmitter, often infrared, and a photoelectric receiver. They are used extensively in industrial manufacturing. There are three different functional types: opposed (through beam), retro-reflective, and proximity-sensing (diffused).



Conceptual through-beam system to detect unauthorized access to a secure door. If the beam is broken, the detector triggers some remote alerting device.

6.1 Types

A self-contained photoelectric sensor contains the optics, along with the electronics. It requires only a power source. The sensor performs its own modulation, demodulation, amplification, and output switching. Some self-contained sensors provide such options as built-in control timers or counters. Because of technological progress, self-contained photoelectric sensors have become increasingly smaller.

Remote photoelectric sensors used for remote sensing contain only the optical components of a sensor. The circuitry for power input, amplification, and output switching are located elsewhere, typically in a control panel. This allows the sensor, itself, to be very small. Also, the controls for the sensor are more accessible, since they may be bigger.

When space is restricted or the environment too hostile even for remote sensors, fiber optics may be used. Fiber optics are passive mechanical sensing components. They may be used with either remote or self-contained sensors. They have no electrical circuitry and no moving parts, and can safely pipe light into and out of hostile environments.[1]

6.2 Sensing modes

A through beam arrangement consists of a receiver located within the line-of-sight of the transmitter. In this mode, an object is detected when the light beam is blocked from getting to the receiver from the transmitter.

A retroreflective arrangement places the transmitter and receiver at the same location and uses a reflector to bounce the light beam back from the transmitter to the receiver. An object is sensed when the beam is interrupted and fails to reach the receiver.

A proximity-sensing (diffused) arrangement is one in which the transmitted radiation must reflect off the object in order to reach the receiver. In this mode, an object is detected when the receiver sees the transmitted source rather than when it fails to see it.

Some photo eyes have two different operational types, light operate and dark operate. Light operate photo eyes become operational when the receiver “receives” the transmitter signal. Dark operate photo eyes become operational when the receiver “does not receive” the transmitter signal.

The detecting range of a photoelectric sensor is its “field of view”, or the maximum distance from which the sensor can retrieve information, minus the minimum distance. A minimum detectable object is the smallest object the sensor can detect. More accurate sensors can often have minimum detectable objects of minuscule size.

6.2.1 Difference Between Modes

[2]

Certain types of smoke detector use a photoelectric sensor to warn of smoldering fires.

6.3 See also

- List of sensors
- Photodetector
- Sensor

6.4 References

[1] http://info.bannersalesforce.com/xpedio/groups/public/documents/literature/pr_p1_t1_e.pdf.pdf *Types of Optical Sensors*, Banner Engineering Corporation

[2] http://www.automationdirect.com/static/specs/peselection.pdf

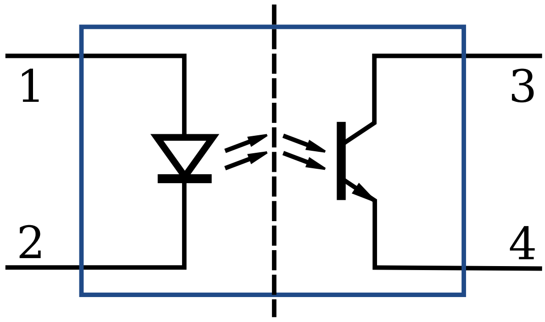
- *Mounting Brackets & Components for Photoelectric/Automation Sensors*, 2010, SoftNoze USA Inc, Frankfort, NY USA
- *Guide to Sensing*, 2002, Banner Engineering Corporation, P/N 120236
- http://sensors-transducers.globalspec.com/LearnMore/Sensors_Transducers_Detectors/Proximity_Presence_Sensing/Photoelectric_Sensors

Chapter 7

Opto-isolator

This article is about the electronic component. For the optical component, see optical isolator.

In electronics, an **opto-isolator**, also called an **opto-coupler**, **photocoupler**, or **optical isolator**, is a component that transfers electrical signals between two isolated circuits by using light.[1] Opto-isolators prevent high voltages from affecting the system receiving the signal.[2] Commercially available opto-isolators withstand input-to-output voltages up to 10 kV[3] and voltage transients with speeds up to 10 kV/μs.[4]



Schematic diagram of an opto-isolator showing source of light (LED) on the left, dielectric barrier in the center, and sensor (phototransistor) on the right.[note 1]

A common type of opto-isolator consists of an LED and a phototransistor in the same opaque package. Other types of source-sensor combinations include LED-photodiode, LED-LASCR, and lamp-photoresistor pairs. Usually opto-isolators transfer digital (on-off) signals, but some techniques allow them to be used with analog signals.

7.1 History

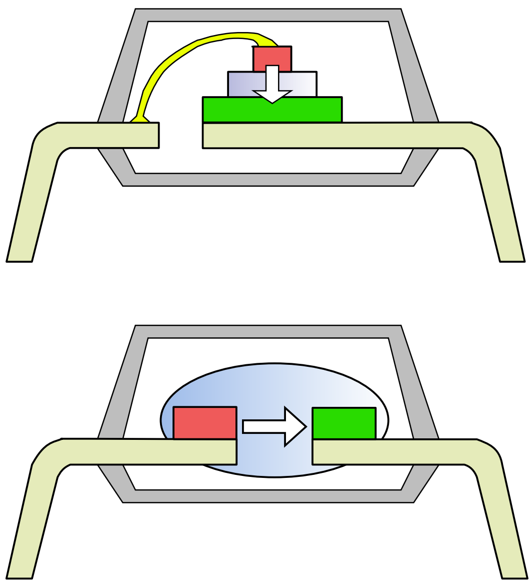
The value of optically coupling a solid state light emitter to a semiconductor detector for the purpose of electrical isolation was recognized in 1963 by Akmenkalns,et al. (US patent 3,417,249). Photoresistor-based opto-isolators were introduced in 1968. They are the slowest, but also the most linear isolators and still retain a niche market in audio and music industry. Commercialization of LED technology in 1968–1970 caused a boom in optoelectronics, and by the end of the 1970s the industry developed all principal types of opto-isolators. The majority of opto-isolators on the market use bipolar silicon phototransistor sensors.[5] They attain medium data transfer speed, sufficient for applications like electroencephalography.[6] The fastest opto-isolators use PIN diodes in photoconductive mode.

7.2 Operation

An opto-isolator contains a source (emitter) of light, almost always a near infrared light-emitting diode (LED), that converts electrical input signal into light, a closed optical channel (also called dielectrical channel[7]), and a photosensor, which detects incoming light and either generates electric energy directly, or modulates electric current flowing from an external power supply. The sensor can be a photoresistor, a photodiode, a phototransistor, a silicon-controlled rectifier (SCR) or a triac. Because LEDs can sense light in addition to emitting it, construction of symmetrical, bidirectional opto-isolators is possible. An optocoupled solid state relay contains a photodiode opto-isolator which drives a power switch, usually a complementary pair of MOSFETs. A slotted optical switch contains a source of light and a sensor, but its optical channel is open, allowing modulation of light by external objects obstructing the path of light or reflecting light into the sensor.

7.3 Electric isolation

Electronic equipment and signal and power transmission lines can be subjected to voltage surges induced by lightning, electrostatic discharge, radio frequency transmissions, switching pulses (spikes) and perturbations in power supply.[8] Remote lightning strikes can induce surges up to 10 kV, one thousand times more than the voltage limits of many electronic components.[9] A circuit can also incorporate high voltages by design, in which case it needs safe, reliable means of interfacing its high-voltage components with low-voltage ones.[10]



Planar (top) and silicone dome (bottom) layouts - cross-section through a standard dual in-line package. Relative sizes of LED (red) and sensor (green) are exaggerated.[note 2]

The main function of an opto-isolator is to block such high voltages and voltage transients, so that a surge in one part of the system will not disrupt or destroy the other parts.[2][11] Historically, this function was delegated to isolation transformers, which use inductive coupling between galvanically isolated input and output sides. Transformers and opto-isolators are the only two classes of electronic devices that offer *reinforced protection* — they protect both the equipment *and* the human user operating this equipment.[12] They contain a single physical isolation barrier, but provide protection equivalent to double isolation.[12] Safety, testing and approval of opto-couplers are regulated by national and international standards: IEC 60747-5-2, EN (CENELEC) 60747-5-2, UL 1577, CSA Component Acceptance Notice #5, etc.[13] Opto-isolator specifications published by manufacturers always follow at least one of these regulatory frameworks.

An opto-isolator connects input and output sides with a beam of light modulated by input current. It transforms useful input signal into light, sends it across the dielectric channel, captures light on the output side and transforms it back into electric signal. Unlike transformers, which pass energy in both directions[note 3] with very low losses, opto-isolators are unidirectional (see exceptions) and they cannot transmit *power*.[14] Typical opto-isolators can only modulate the flow of energy already present on the output side.[14] Unlike transformers, opto-isolators can pass DC or slow-moving signals and do not require matching impedances between input and output sides.[note 4] Both transformers and opto-isolators are effective in breaking ground loops, common in industrial and stage equipment, caused by high or noisy return currents in ground wires.[15]

The physical layout of an opto-isolator depends primarily on the desired isolation voltage. Devices rated for less than a few kV have planar (or sandwich) construction.[16] The sensor die is mounted directly on the lead frame of its package (usually, a six-pin or a four-pin dual in-line package).[7] The sensor is covered with a sheet of glass or clear plastic, which is topped with the LED die.[7] The LED beam fires downward. To minimize losses of light, the useful absorption spectrum of the sensor must match the output spectrum of the LED, which almost invariably lies in the near infrared.[17] The optical channel is made as thin as possible for a desired breakdown voltage.[16] For example, to be rated for short-term voltages of 3.75 kV and transients of 1 kV/μs, the clear polyimide sheet in the Avago ASSR-300 series is only 0.08 mm thick.[18] Breakdown voltages of planar assemblies depend on the thickness of the transparent sheet[16] and the configuration of bonding wires that connect the dies with external pins.[7] Real in-circuit isolation voltage is further reduced by creepage over the PCB and the surface of the package. Safe design rules require a minimal clearance of 25 mm/kV for bare metal conductors or 8.3 mm/kV for coated conductors.[19]

Opto-isolators rated for 2.5 to 6 kV employ a different layout called *silicone dome*.[20] Here, the LED and sensor dies are placed on the opposite sides of the package; the LED fires into the sensor horizontally.[20] The LED, the sensor and the gap between them are encapsulated in a blob, or dome, of transparent silicone. The dome acts as a reflector, retaining all stray light and reflecting it onto the surface of the sensor, minimizing losses in a relatively long optical channel.[20] In *double mold* designs the space between the silicone blob (“inner mold”) and the outer shell (“outer mold”) is filled with dark dielectric compound with a matched coefficient of thermal expansion.[21]

7.4 Types of opto-isolators

7.4.1 Resistive opto-isolators

Main article: Resistive opto-isolator

The earliest opto-isolators, originally marketed as *light cells*, emerged in the 1960s. They employed miniature incandescent light bulbs as sources of light, and cadmium sulfide (CdS) or cadmium selenide (CdSe) photoresistors (also called light-dependent resistors, LDRs) as receivers. In applications where control linearity was not important, or where available current was too low for driving an incandescent bulb (as was the case in vacuum tube amplifiers), it was replaced with a neon lamp. These devices (or just their LDR component) were commonly named *Vactrols*, after a trademark of Vactec, Inc. The trademark has since been genericized,[note 8] but the original Vactrols are still being manufactured by PerkinElmer.[24][note 9]

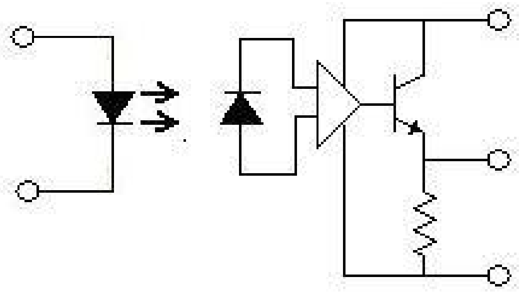
The turn-on and turn-off lag of an incandescent bulb lies in hundreds of milliseconds range, which makes the bulb an effective low-pass filter and rectifier but limits the practical modulation frequency range to a few Hertz. With the introduction of light-emitting diodes (LEDs) in 1968–1970,[25] the manufacturers replaced incandescent and neon lamps with LEDs and achieved response times of 5 milliseconds and modulation frequencies up to 250 Hz.[26] The name *Vactrol* was carried over on LED-based devices which are, as of 2010, still produced in small quantities.[27]

Photoresistors used in opto-isolators rely on bulk effects in a uniform film of semiconductor; there are no p-n junctions.[28] Uniquely among photosensors, photoresistors are non-polar devices suited for either AC or DC circuits.[28] Their resistance drops in reverse proportion to the intensity of incoming light, from virtually infinity to a residual floor that may be as low as less than a hundred Ohms.[28] These properties made the original Vactrol a convenient and cheap automatic gain control and compressor for telephone networks. The photoresistors easily withstood voltages up to 400 volts,[28] which made them ideal for driving vacuum fluorescent displays. Other industrial applications included photocopiers, industrial automation, professional light measurement instruments and auto-exposure meters.[28] Most of these applications are now obsolete, but resistive opto-isolators retained a niche in audio, in particular guitar amplifier, markets.

American guitar and organ manufacturers of the 1960s embraced the resistive opto-isolator as a convenient and cheap tremolo modulator. Fender's early tremolo effects used two vacuum tubes; after 1964 one of these tubes was replaced by an optocoupler made of a LDR and a neon lamp.[29] To date, Vactrols activated by pressing the stompbox pedal are ubiquitous in the music industry.[30] Shortages of genuine PerkinElmer Vactrols forced the DIY guitar community to "roll their own" resistive opto-isolators.[31] Guitarists to date prefer opto-isolated effects because their superior separation of audio and control grounds results in "inherently high quality of the sound".[31] However, the distortion introduced by a photoresistor at line level signal is higher than that of a professional electrically-coupled voltage-controlled amplifier.[32] Performance is further compromised by slow fluctuations of resistance owing to light history, a memory effect inherent in cadmium compounds. Such fluctuations take hours to settle and can be only partially offset with feedback in the control circuit.[33]

7.4.2 Photodiode opto-isolators

Diode opto-isolators employ LEDs as sources of light and silicon photodiodes as sensors. When the photodiode is reverse-biased with an external voltage source, incoming light increases the reverse current flowing through the diode. The diode itself does not generate energy; it modulates the flow of energy from an external source. This mode of operation is called photoconductive mode. Alternatively, in the absence of external bias the diode converts the energy of light into electric energy by charging its terminals to a voltage of up to 0.7 V. The rate of charge is proportional to the intensity of incoming light. The energy is harvested by draining the charge through an external high-impedance path; the ratio of current transfer can reach 0.2%.[22] This mode of operation is called photovoltaic mode.



A fast photodiode opto-isolator with an output-side amplifier circuit.

The fastest opto-isolators employ PIN diodes in photoconductive mode. The response times of PIN diodes lie in the subnanosecond range; overall system speed is limited by delays in LED output and in biasing circuitry. To minimize these delays, fast digital opto-isolators contain their own LED drivers and output amplifiers optimized for speed. These devices are called *full logic opto-isolators*: their LEDs and sensors are fully encapsulated within a digital logic circuit.[34] The Hewlett-Packard 6N137/HPCL2601 family of devices equipped with internal output amplifiers was introduced in the late 1970s and attained 10 MBd data transfer speeds.[35] It remained an industry standard until the introduction of the 50 MBd Agilent Technologies[note 10] 7723/0723 family in 2002.[36] The 7723/0723 series opto-isolators contain CMOS LED drivers and a CMOS buffered amplifiers, which require two independent external power supplies of 5 V each.[37]

Photodiode opto-isolators can be used for interfacing analog signals, although their non-linearity invariably distorts the signal. A special class of analog opto-isolators introduced by Burr-Brown uses *two* photodiodes and an input-side operational amplifier to compensate for diode non-linearity. One of two identical diodes is wired into the feedback loop of the amplifier, which maintains overall current transfer ratio at a constant level regardless of the non-linearity in the second (output) diode.[38]

A novel idea of a particular optical analog signal isolator was submitted on 3, June 2011. The proposed configuration consist of two different parts. One of them transfers the signal, and the other establishes a negative feedback to ensure that the output signal has the same features as the input signal. This proposed analog isolator is linear over a wide range of input voltage and frequency.[39]

Solid-state relays built around MOSFET switches usually employ a photodiode opto-isolator to drive the switch. The gate of a MOSFET requires relatively small total charge to turn on and its leakage current in steady state is very low. A photodiode in photovoltaic mode can generate turn-on *charge* in a reasonably short time but its output *voltage* is many times less than the MOSFET's threshold voltage. To reach the required threshold, solid-state relays contain stacks of up to thirty photodiodes wired in series.[21]

7.4.3 Phototransistor opto-isolators

Phototransistors are inherently slower than photodiodes.[40] The earliest and the slowest but still common 4N35 opto-isolator, for example, has rise and fall times of 5 µs into a 100 Ohm load[41] and its bandwidth is limited at around 10 kilohertz - sufficient for applications like electroencephalography[6] or pulse-width motor control.[42] Devices like PC-900 or 6N138 recommended in the original 1983 Musical Instrument Digital Interface specification[43] allow digital data transfer speeds of tens of kiloBauds.[44] Phototransistors must be properly biased and loaded to achieve their maximum speeds, for example, the 4N28 operates at up to 50 kHz with optimum bias and less than 4 kHz without it.[45]

Design with transistor opto-isolators requires generous allowances for wide fluctuations of parameters found in commercially available devices.[45] Such fluctuations may be destructive, for example, when an opto-isolator in the feedback loop of a DC-to-DC converter changes its transfer function and causes spurious oscillations,[20] or when unexpected delays in opto-isolators cause a short circuit through one side of an H-bridge.[46] Manufacturers' datasheets typically list only worst-case values for critical parameters; actual devices surpass these worst-case estimates in an unpredictable fashion.[45] Bob Pease observed that current transfer ratio in a batch of 4N28's can vary from 15% to more than 100%; the datasheet specified only a minimum of 10%. Transistor beta in the same batch can vary from 300 to 3000, resulting in 10:1 variance in bandwidth.[45]

Opto-isolators using field-effect transistors (FETs) as sensors are rare and, like vactrols, can be used as remote-controlled analog potentiometers provided that the voltage across the FET's output terminal does not exceed a few hundred mV.[38] Opto-FETs turn on without injecting switching charge in the output circuit, which is particularly useful in sample and hold circuits.[11]

7.4.4 Bidirectional opto-isolators

All opto-isolators described so far are uni-directional. Optical channel always works one way, from the source (LED) to the sensor. The sensors, be it photoresistors, photodiodes or phototransistors, cannot emit light.[note 11] But LEDs, like all semiconductor diodes,[note 12] are capable of detecting incoming light, which makes possible construction of a two-way opto-isolator from a pair of LEDs. The simplest bidirectional opto-isolator is merely a pair of LEDs placed face to face and held together with heat-shrink tubing. If necessary, the gap between two LEDs can be extended with a glass fiber insert.[47]

Visible spectrum LEDs have relatively poor transfer efficiency, thus near infrared spectrum GaAs, GaAs:Si and AlGaAs:Si LEDs are the preferred choice for bidirectional devices. Bidirectional opto-isolators built around pairs of GaAs:Si LEDs have current transfer ratio of around 0.06% in either photovoltaic or photoconductive mode — less than photodiode-based isolators,[48] but sufficiently practical for real-world applications.[47]

7.5 Types of configurations

Usually, optocouplers have a *closed pair* configuration. This configuration refers to optocouplers enclosed in a dark container wherein the source and sensor are facing each other.

Some optocouplers have a *slotted coupler/interrupter* configuration. This configuration refers to optocouplers with an open slot between the source and sensor that has the ability to influence incoming signals. The *slotted coupler/interrupter* configuration is suitable for object detection, vibration detection, and bounce-free switching.

Some optocouplers have a *reflective pair* configuration. This configuration refers to optocouplers that contain a source that emits light and a sensor that only detects light when it has reflected off an object. The *reflective pair* configuration is suitable for the development of tachometers, movement detectors and reflectance monitors.

The later two configurations are frequently referred to as 'optosensors'.

7.6 Alternatives

Further information: Microelectromechanical systems

Alternative isolators are typically built using ultra thin (0.01 mm – 0.02 mm) insulation layers, whereas optocouplers have insulation thicknesses up to 2 mm. The thinner insulation barrier means that alternative isolators experience much higher electric-field stress than optocouplers, and could be less robust under high voltages.

Currently, there are no IEC component level safety standard available for such isolators. As a result, some manufacturers might seek IEC 60747-5-2 (older revision) or IEC 60747-5-5 (current revision) certification (a standard originally intended for optocouplers). Alternative isolators are structurally different from optocouplers and thus do not qualified for full IEC60747-5-2/5 certification, but only for BASIC insulation.[49]

The following are claims from manufacturers of alternative isolators:

- Developers have long recognized that Optocouplers are based on outdated technology, and only recently have cost effective and easy to use alternatives become available. These advanced package and pin compatible drop-in optocoupler replacements provide sustainability higher performance and reliability with none of the technical liabilities of optocouplers. Digital isolators can directly replace 6-pin and 8-pin optocouplers and are suitable for both optocoupler retrofit and new system designs. These devices use CMOS-based isolation architecture that are ten times more reliable than optocouplers, enabling manufacturers to support longer end product warranties and reduce costs associated with repairs or replacement.

- Opto-isolators can be too slow and bulky for modern digital applications. Since the 1990s, researchers have examined and perfected alternative, faster and more compact isolation technologies. Two of these technologies, transformer based isolators and capacitor-coupled isolators, reached the mass market in the 2000s. The third alternative, based on giant magnetoresistance, has been present on the market since 2002 in limited quantities. As of 2010, production models of all three types allow data transfer speeds of 150 Mbit/s and resist voltage transients of up to 25 kV/μs, compared to 10 kV/μs for opto-isolators.[4] Unlike opto-isolators, which are stacks of discrete LEDs and sensors, the new devices are monolithic integrated circuits, and are easily scalable into multi-bit data bus isolators.[50]

Notable events concerning alternative isolators:

- In 2000 Analog Devices introduced integrated magnetic isolators — electrically-decoupled 100 Mbit/s, 2.5 kV isolation circuits employing air core transformers micromachined on the surface of silicon integrated circuits. They featured lesser power consumption, lesser cost[note 13] and were four times faster than the fastest contemporary opto-isolators.[51] In 2010, Analog increased the speed of their magnetic isolators to 150 Mbit/s and offered isolation up to 5 kV.[52] Microtransformer-based isolators can work as dc-dc converters, passing both signal *and* power. Commercially available ICs can carry up to four isolated digital channels and a 2 W isolated power channel in miniature 20-pin packages.[53] According to Analog Devices, by December 2011 the company has more "than 750 million [magnetic isolator] channels deployed".[53] In the same year NEC and Renesas announced transformer-based CMOS devices with transfer rates of 250 Mbit/s.[54][55]

- High-speed capacitive-coupled isolators[note 14] were introduced in 2000 by Silicon Laboratories and commercialized by Texas Instruments. These devices convert an incoming data stream into an amplitude-modulated UHF signal, pass it through a silicon dioxide isolation layer, and demodulate the received signal. The spectra of spurious voltage transients, which can pass through the capacitive barrier and disrupt operation, lie far below the modulation frequency and can be effectively blocked. As of 2010, capacitive-coupled isolators offer data transfer speeds of 150 Mbit/s and voltage isolation of 560 V continuous and 4 kV peak across the barrier.[56]

- NVE Corporation, the pioneer of magnetoresistive random-access memory, markets an alternative type of isolator based on giant magnetoresistance (GMR) effect (*Spintronic* and *IsoLoop* trademarks). Each isolation cell of these devices is formed by a flat square coil which is micromachined above four spin valve sensors buried in the silicon wafer.[57] These sensors, wired into a Wheatstone bridge circuit, generate binary on/off output signals.[58] At the time of their introduction in 2002, NVE advertised speeds 5 to 10 times higher than the fastest opto-isolators;[57] and in March 2008 commercial devices marketed by NVE were rated for speeds up to 150 Mbit/s.[58]

7.7 Notes

[1] Real-world schematic diagrams omit the barrier symbol, and use a single set of directional arrows.

[2] Based on conceptual drawings published by Basso and by Mims, p. 100. Real-world LEDs and sensors are much smaller; see the photograph in Avago, p. 3 for an example.

[3] A transformer can have as many coils as necessary. Each coil can act as a *primary*, pumping energy into a common magnetic core, or as a *secondary* – picking up energy stored in the core.

[4] The input side circuitry and the LED must be matched, the output side and the sensor must be matched, but there is, usually, no need to match input *and* output sides.

[5] See Horowitz and Hill, p. 597, for an expanded list of opto-isolator types with their schematic symbols and typical specifications.

[6] Current through the photoresistor (output current) is proportional to the voltage applied across it. In theory it can exceed 100% of input current, but in practice dissipation of heat according to Joule's law limits current transfer ratio at below 100%.

[7] Low-cost solid-state relays have switching times of tens of milliseconds. Modern high-speed solid-state relays like Avago ASSR-300 series (see datasheet) attain switching times of less than 70 nanoseconds.

[8] According to the United States Patent and Trademark Office, trademark registered in 1969 for "photocell combined with a light source" is now dead (USPTO database record serial number 72318344. Retrieved November 5, 2010). The same trademark, registered in 1993 for "medico-surgical tubing connector sold as a component of suction catheters" is now live and owned by Mallinckrodt Inc. (USPTO database record serial number 74381130. Retrieved November 5, 2010).

[9] Vactec was purchased by EG&G (Edgerton, Germeshausen, and Grier, Inc.), a defense contractor, in 1983. In 1999 EG&G purchased formerly independent PerkinElmer, and changed own name PerkinElmer (see reverse takeover). An unrelated company, Silonex (a division of Carlyle Group) brands its photoresistive opto-isolators *Audiohm Optocouplers*.

[10] The former semiconductor division of Agilent Technologies operates as an independent company, Avago Technologies, since 2005.

[11] Exception: Ternary and quaternary GaAsP photodiodes can generate light. - Mims, p. 102.

[12] "Even the garden variety signal diodes you use in circuits have a small photovoltaic effect. There are amusing stories of bizarre circuit behavior finally traced to this." - Horowitz and Hill, p. 184.

[13] "Low cost" of components, in industry language, means "low price for the [bulk volume] buyer". It does not necessarily indicate low costs to produce these components, particularly when the manufacturer introduces a new type of device.

[14] Burr-Brown introduced a distinct class of capacitive-coupled analog *isolation amplifiers* in the 1980s. These hybrid circuits attain analog bandwidth of 70 kHz and isolation of 3.5 kV. - Horowitz and Hill, p. 464.

7.8 References

[1] Graf, p. 522.

[2] Lee et al., p. 2.

[3] Hasse, p. 145.

[4] Joffe and Kai-Sang Lock, p. 279.

[5] Graf, p. 522; PerkinElmer, p. 28.

[6] See Ananthi, pp. 56, 62 for a practical example of an opto-coupled EEG application.

[7] Mims, p. 100.

[8] Hasse, p. 43.

[9] Hasse, p. 60.

[10] See Basso for a discussion of such interfacing in switched-mode power supplies.

[11] Horowitz and Hill, p. 595.

[12] Jaus, p. 48.

[13] Jaus, pp. 50–51.

[14] Joffe and Kai-Sang Lock, p. 277.

[15] Joffe and Kai-Sang Lock, pp. 268, 276.

[16] Mataré, p. 174

[17] Ball, p. 69.

[18] Avago Technologies (2007). *ASSR-301C and ASSR-302C (datasheet)*. Retrieved November 3, 2010.

[19] Bottrill et al., p. 175.

[20] Basso.

[21] Vishay Semiconductor.

[22] Mataré, p. 177, table 5.1.

[23] Mataré, p. 177

[24] Weber, p. 190; PerkinElmer, p. 28; Collins, p. 181.

[25] Schubert, pp. 8–9.

[26] PerkinElmer, pp. 6–7: "at 1 fc of illumination the response times are typically in the range of 5 ms to 100 ms."

[27] Weber, p. 190; PerkinElmer, pp. 2,7,28; Collins, p. 181.

[28] PerkinElmer, p. 3

[29] Fliegler and Eiche, p. 28; Teagle and Sprung, p. 225.

[30] Weber, p. 190.

[31] Collins, p. 181.

[32] PerkinElmer, pp. 35–36; Silonex, p. 1 (see also distortion charts on subsequent pages).

[33] PerkinElmer, pp. 7, 29, 38; Silonex, p. 8.

[34] Horowitz and Hill, pp. 596–597.

[35] Porat and Barna, p. 464. See also full specifications of currently produced devices: *6N137 / HCPL-2601 datasheet*. Avago Technologies. March 2010. Retrieved November 2, 2010.

[36] *Agilent Technologies Introduces Industry's Fastest Opto-couplers*. Business Wire. December 2, 2002.

[37] Agilent Technologies (2005). *Agilent HCPL-7723 & HCPL-0723 50 MBd 2 ns PWD High Speed CMOS Optocoupler (Datasheet)*. Retrieved November 2, 2010.

[38] Horowitz and Hill, p. 598.

[39] Modern Applied Science Vol 5, No 3 (2011). *A Novel Approach to Analog Signal Isolation through Digital Opto-coupler (YOUTAB)*.

[40] Ball, p. 61.

[41] Horowitz and Hill, p. 596. Ball p. 68, provides rise and fall time of 10 μs but does not specify load impedance.

[42] Ball, p. 68.

[43] *MIDI Electrical Specification Diagram & Proper Design of Joystick/MIDI Adapter*. MIDI Manufacturers Association. 1985. Retrieved November 2, 2010.

[44] Ball, p. 67.

[45] Pease, p. 73.

[46] Ball, pp. 181–182. Shorting one side of an H-bridge is called *shoot-through*.

[47] Mims vol. 2, p. 102.

[48] Photodiode opto-isolators have current transfer ratios of up to 0.2% - Mataré, p. 177, table 5.1.

[49] http://www.avagotech.com/docs/AV02-3446EN

[50] Joffe and Kai-Sang Lock, p. 280.

[51] Bindra 2000.

[52] Selection Data Table: Standard Isolators. Analog Devices. Retrieved November 4, 2010.

[53] Kincaid.

[54] Kaeriyama et al.

[55] Renesas (2010). *Renesas Electronics Introduces New CMOS Isolator Technology that Realizes Highly-Integrated Inverter Circuits for Energy-Efficient Home Appliances and Electric Vehicles*. July 20, 2010. Retrieved November 4, 2010.

[56] Texas Instruments (2010). *ISO721, ISO721M (Datasheet)*. January 2006, revised July 2010. Retrieved November 4, 2010.

[57] Myers; NVE Corporation 2007, p. 1.

[58] NVE Corporation 2007, p. 2.

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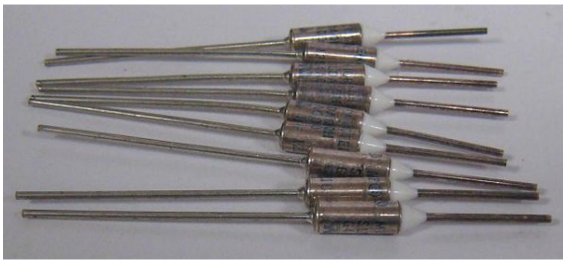
7.10 External links

- Optocouplers: When and how to use them PDF (157 KB)
- Trends in Optocoupler Radiation Degradation PDF (89.1 KB)
- How Optical Isolation Works - Illustration

Chapter 8

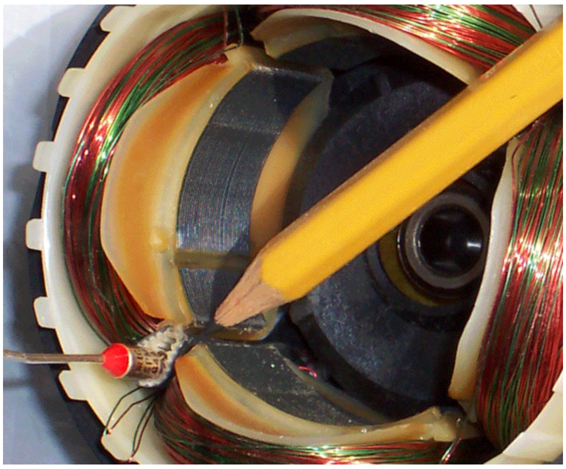
Thermal cutoff



An assortment of thermal fuses

A **thermal cutoff** is an electrical safety device that interrupts electric current when heated to a specific temperature. These devices may be for one-time use or may be reset manually or automatically.

8.1 Thermal fuse



A thermal fuse protecting the windings of a small motor

A **thermal fuse** is a cutoff which uses a one-time fusible link. Unlike the thermal switch which automatically resets itself when the temperature drops, the thermal fuse is more like an electrical fuse: a single-use device that cannot be reset and must be replaced when it fails or is triggered. A thermal fuse is used when the overheating is a result of a rare occurrence, such as failure requiring repair (which would also replace the fuse) or replacement at the end of service life.

One mechanism is a small meltable pellet that holds down a spring. When the pellet melts, the spring is released, separating the contacts and breaking the circuit. The Tamura LE series, NEC Sefuse SF series, Microtemp G4A series, and Hosho Elmwood D series, for example, may use alloy pellets that contain copper, beryllium, and silver to melt at a precise temperature.

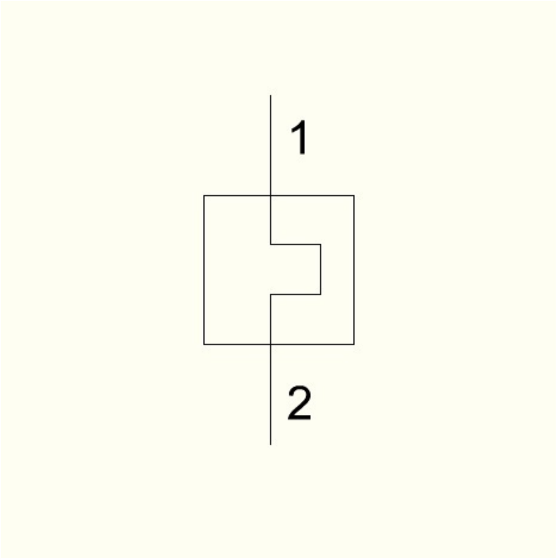
Thermal fuses are usually found in heat-producing electrical appliances such as coffeemakers and hair dryers. They function as safety devices to disconnect the current to the heating element in case of a malfunction (such as a defective thermostat) that would otherwise allow the temperature to rise to dangerous levels, possibly starting a fire.

Unlike electrical fuses or circuit breakers, thermal fuses only react to excessive temperature, not excessive current, unless the excessive current is sufficient to cause the thermal fuse itself to heat up to the trigger temperature. Such an arrangement may be found in a surge protector. The thermal fuses are wired in series with the varistors; when the varistors conduct, the fuse heats up and fails, which eliminates the risk of fire which can occur when the varistors are overloaded.

8.2 Thermal switch

Two thermal switches

A **thermal switch** (sometimes **thermal reset** or **thermal cutout** (TCO)) is a device which normally opens at a high temperature (often with a faint “plink” sound) and recloses when the temperature drops. The thermal switch may be a bimetallic strip, often encased in a tubular glass



Schematic symbol for a thermal overload switch

bulb to protect it from dust or short circuit. Another common design uses a bimetallic shallow dome-shaped cap which "clicks" to an inside-out inverted cap shape when heated, such as the "Klixon" brand of thermal cutouts.

Unlike a thermal fuse, a thermal switch is usually reusable, and is therefore suited to protecting against temporary situations which are common and user-correctable. Thermal switches are used in power supplies in case of overload, and also as thermostats in some heating and cooling systems.

Another type of thermal switch is a PTC thermistor; these thermistors have a "switch" temperature at which the resistance suddenly rises rapidly, limiting the current through the circuit.

Thermal switches are included in some light fixtures, particularly with recessed lights, where excessive heat is most likely to occur. This may lead to "cycling", where a light turns off and back on every few minutes. Flashing incandescent Christmas lights take advantage of this effect. Some flasher bulbs interrupt power when heated, while other twinkle/sparkle mini-bulbs momentarily shunt current around the filament.

Thermal switches are part of the normal operation of older fluorescent light fixtures, where they are the major part of the starter module.

GE trademarked the name "Guardette" for the thermal protection switches used on their refrigeration compressors.

8.2.1 Manual reset

Some thermal switches must be reset manually after they have been tripped. This design is used when an automatic and unattended restart would create a hazardous condition, such as sudden startup of a powerful motor without warning. These types of thermal cutouts are usually reset by pressing a pushbutton by hand or with a special tool.

8.3 See also

- Thermistor

8.4 References

Chapter 9

Pressure switch

Murphy oil pressure gauges with switches that activate on low pressure

A **pressure switch** is a form of switch that closes an electrical contact when a certain set pressure has been reached on its input. The switch may be designed to make contact either on pressure rise or on pressure fall.

Another type of pressure switch detects mechanical force; for example, a pressure-sensitive mat is used to automatically open doors on commercial buildings.

9.1 Pressure switches

A pressure switch for sensing fluid pressure contains a capsule, bellows, Bourdon tube, diaphragm or piston element that deforms or displaces proportionally to the applied pressure. The resulting motion is applied, either directly or through amplifying levers, to a set of switch contacts. Since pressure may be changing slowly and contacts should operate quickly, some kind of over-center mechanism such as a miniature snap-action switch is used to ensure quick operation of the contacts. One sensitive type of pressure switch uses mercury switches mounted on a Bourdon tube; the shifting weight of the mercury provides a useful over-center characteristic.

The pressure switch may be adjustable, by moving the contacts or adjusting tension in a counterbalance spring. Industrial pressure switches may have a calibrated scale and pointer to show the set point of the switch. A pressure switch will have a differential range around its set-point in which small changes of pressure do not change the state of the contacts. Some types allow adjustment of the differential.[1]

The pressure-sensing element of a pressure switch may be arranged to respond to the difference of two pressures. Such switches are useful when the difference is significant, for example, to detect a clogged filter in a water supply system. The switches must be designed to respond only to the difference and not to false-operate for changes in the common mode pressure.

The contacts of the pressure switch may be rated a few tenths of an ampere to around 15 amperes, with smaller ratings found on more sensitive switches. Often a pressure switch will operate a relay or other control device, but some types can directly control small electric motors or other loads.

Since the internal parts of the switch are exposed to the process fluid, they must be chosen to balance strength and life expectancy against compatibility with process fluids. For example, rubber diaphragms are commonly used in contact with water, but would quickly degrade if used in a system containing mineral oil.

Switches designed for use in hazardous areas with flammable gas have enclosure to prevent an arc at the contacts from igniting the surrounding gas. Switch enclosures may also be required to be weatherproof, corrosion resistant, or submersible.

An electronic pressure switch incorporates some variety of pressure transducer (strain gauge, capacitive element, or other) and an internal circuit to compare the measured pressure to a set point. Such devices may provide improved repeatability, accuracy and precision over a mechanical switch.

9.2 Examples

9.2.1 Pneumatic

Uses of pneumatic pressure switches include:

- Switch a household well water pump automatically

Electronic pressure switch with LED display

when water is drawn from the pressure tank.

- Switching off an electrically driven gas compressor when a set pressure is achieved in the reservoir
- Switching off a gas compressor, whenever there is no feed in the suction stage.
- in-cell charge control in a battery
- Switching on/off an alarm light in the cockpit of an aircraft if cabin pressure (based on altitude) is critically low.
- Air filled hoses that activate switches when vehicles drive over them. Common for counting traffic and at gas stations.

9.2.2 Hydraulic

Hydraulic pressure switches have various uses in automobiles, for example:

- To switch on a warning light if the engine´s oil pressure falls below a safe level
- In dust control systems (bag filter), a pressure switch is mounted on the header which will raise an alarm when air pressure in the header is less than necessary to gain or decline energy beyond the set value
- To control automatic transmission torque converter lock-up.

9.3 See also

- Dynamic pressure
- List of sensors
- MAP sensor
- Oxsensis
- Pressure sensor

9.4 References

[1] Bela G. Liptak (ed), *Instrument Engineers' Handbook, Fourth Edition* CRC Press, 2003 ISBN 1420064029 pages 790-793

9.5 External links

Chapter 10

Proximity sensor

Infrared proximity sensor.

A **proximity sensor** is a sensor able to detect the presence of nearby objects without any physical contact.

A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal. The object being sensed is often referred to as the proximity sensor's target. Different proximity sensor targets demand different sensors. For example, a capacitive or photoelectric sensor might be suitable for a plastic target; an inductive proximity sensor always requires a metal target.

The maximum distance that this sensor can detect is defined "nominal range". Some sensors have adjustments of the nominal range or means to report a graduated detection distance.

Proximity sensors can have a high reliability and long functional life because of the absence of mechanical parts and lack of physical contact between sensor and the sensed object.

Proximity sensors are commonly used on smartphones to detect (and skip) accidental touchscreen taps when held to the ear during a call.[1] They are also used in machine vibration monitoring to measure the variation in distance between a shaft and its support bearing. This is common in large steam turbines, compressors, and motors that use sleeve-type bearings.

International Electrotechnical Commission (IEC) 60947-5-2 defines the technical details of proximity sensors.

A proximity sensor adjusted to a very short range is often used as a touch switch.

10.1 Types of sensors

- Capacitive
- Capacitive displacement sensor
- Doppler effect (sensor based on effect)
- Eddy-current
- Inductive
- Laser rangefinder
- Magnetic, including Magnetic proximity fuse
- Passive optical (such as charge-coupled devices)
- Passive thermal infrared
- Photocell (reflective)
- Radar
- Reflection of ionising radiation
- Sonar (typically active or passive)
- Ultrasonic sensor (sonar which runs in air)
- Fiber optics sensor
- Hall effect sensor

10.2 Applications

- Parking sensors, systems mounted on car bumpers that sense distance to nearby cars for parking
- Ground proximity warning system for aviation safety
- Vibration measurements of rotating shafts in machinery [2]
- Top dead centre (TDC)/camshaft sensor in reciprocating engines.
- Sheet break sensing in paper machine.

- Anti-aircraft warfare
- Roller coasters
- Conveyor systems
- Beverage and food can making lines[3]\
- Improvised Explosive Devices or IEDs
- Mobile devices
    - Touch screens that come in close proximity to the face[1]
    - Attenuating radio power in close proximity to the body, in order to reduce radiation exposure[4]

10.3 Manufacturers

- Autonics
- Aeco http://www.aecosensors.com/
- Omron
- Contrinex
- di-soric
- M.D. Micro Detectors
- c3controls
- Pepperl+Fuchs
- Turck
- Rockwell Automation
- Eaton
- Sick AG
- schneider Electric
- Protocontrol instruments
- Banner
- Bently Nevada
- Senstronic
- S K INTERNATIONAL - Proximity housing Tube
- Proxel
- Osna Electronics Pvt. Ltd.
- IFM Efector

10.4 References

http://www.sensors-transducers.machinedesign.com/guiEdits/Content/bdeee4/bdeee4_7.aspx

[1] "Proximity sensor on Android smartphones". TheCodeArtist.

[2] Proximity Probes for industrial machinery vibration monitoring

[3]

[4] Can a $100 iPad Case Improve 3G Data Power? Lab Test!

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10.5.1 Text

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