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Towne et al.

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[45] **Jan. 1, 1974**

[54] SOLID-STATE SWITCH

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[52] **U.S. Cl.** .... **250/221 R,** 250/229, 250/239
[51] **Int. Cl.** **H01j 39/12**
[58] **Field of Search**..................... 307/311; 250/214, 250/217 S, 221, 222, 229, 237, 231, 239, 211; 200/67, 76

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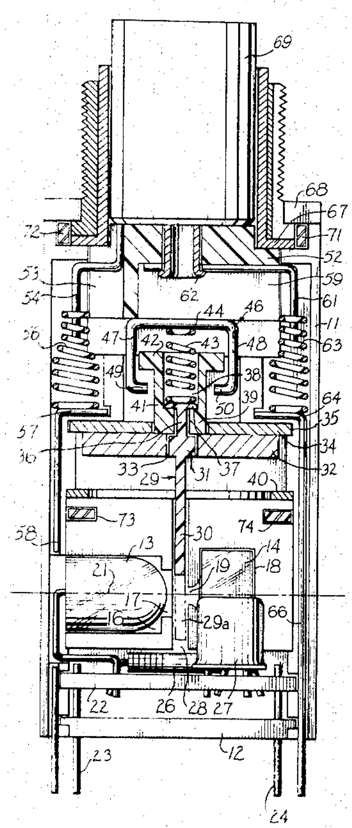
Primary Examiner—James W. Lawrence
Assistant Examiner—D. C. Nelms
Attorney—Frank R. Trifari

[57] **ABSTRACT**

A switch utilizing a solid-state circuit in place of ohmic contacts. A light-emitting diode illuminates a photosensitive solid-state device to make the circuit conductive or non-conductive, depending upon whether the light path from the diode to the photosensitive device is interrupted by a shutter or not. The shutter is controlled by an actuator to move between "on" and "off" positions. Motion of the shutter may be made more sudden and tease-proof by attaching the shutter to a magnetic device attracted to a fixed member to prevent the shutter from moving until enough force is applied via the actuator to overcome the magnetic attraction. Movement may be further speeded by connecting the shutter and actuator by a lost motion device and placing a compression spring between the shutter and actuator to store energy to overcome the magnetic field and then release the stored energy sharply. Another fixed magnetic member at the other end of travel of the shutter provides audible detection of operation and some energy storage and release for return motion.

14 Claims, 5 Drawing Figures



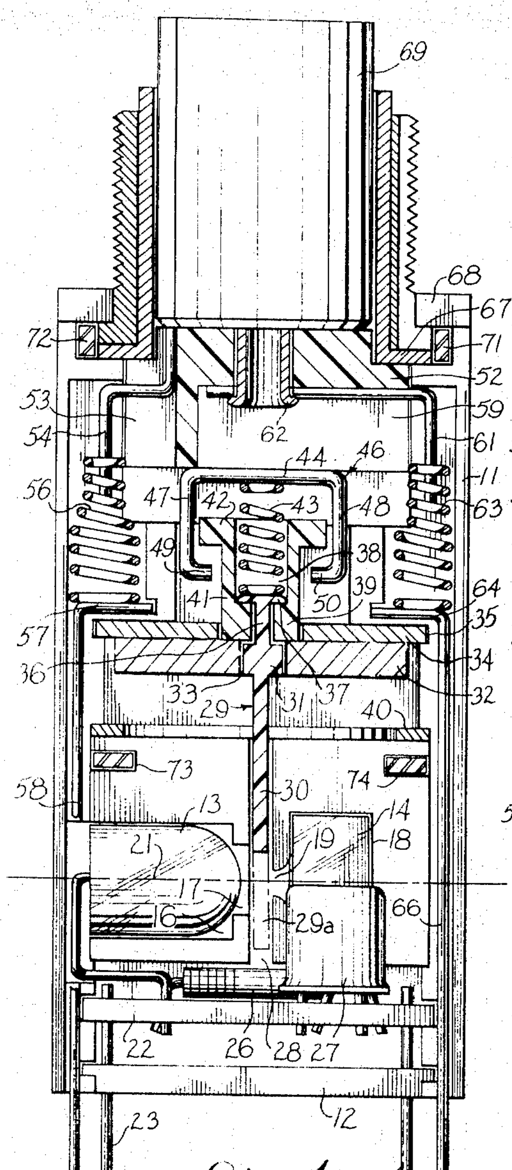

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fig 1

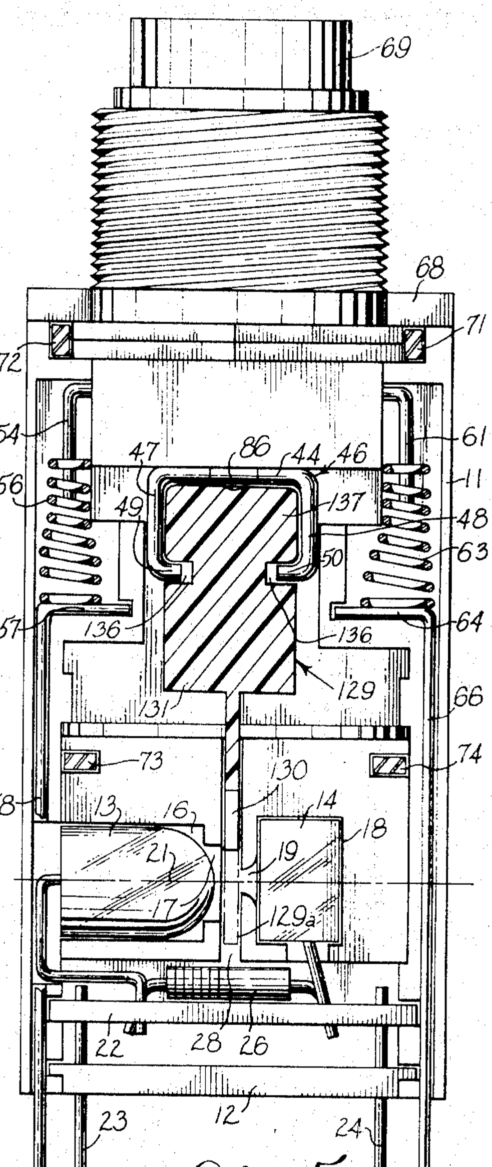
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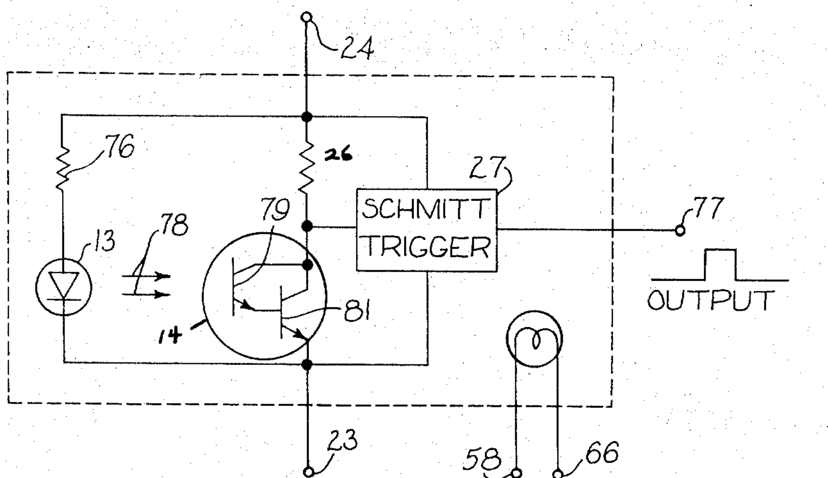
fig 5

fig 2



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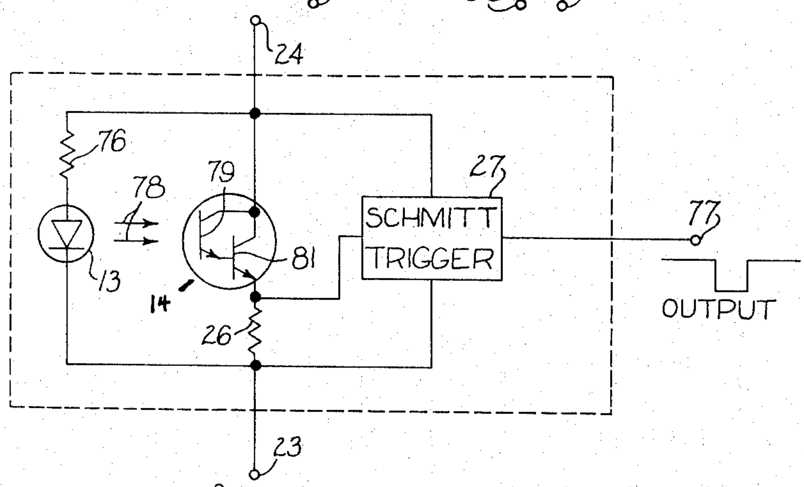
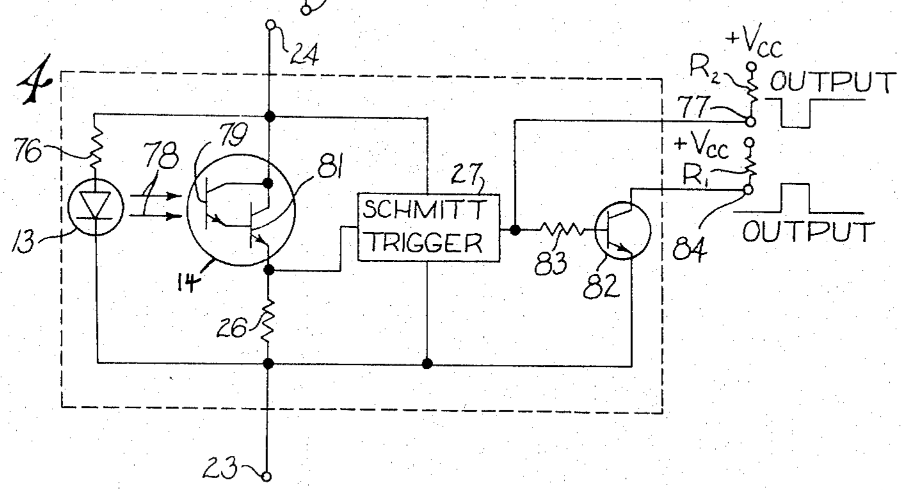


fig 4



SOLID-STATE SWITCH

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of momentary action switches and particularly to a momentary action switch using a photo-controlled solid-state circuit to form the conductive path and mechanically actuated shutter means, preferably spring-and magnetically-controlled, to interrupt the light path.

2. The Prior Art

Momentary action switches actuated by pushbuttons and incorporating metallic, or ohmic, fixed and movable contacts have been in wide use for a long time. One of the disadvantages of such switches is that the ohmic contacts are subject to electrical erosion, due largely to arcing. Another disadvantage in many such switches is the necessity to provide resilient means capable of carrying the current to be switched or to provide a double set of contacts connected in series. In any case, contact bounce is a problem.

Solid-state relays have also been proposed, including relays in which the conductive path that corresponds to the path through the ohmic contacts of mechanical relays is controlled by a photosensitive solid-state device actuated by light from a light-emitting diode.

One of the objects of the present invention is to provide a momentary action switch that has the longevity of a solid-state circuit, is free from contact bounce, requires only simple mechanical actuation, is capable of extremely fast rise and fall times, and is not affected by environmental conditions. It is also an object of this invention to provide a tease-proof momentary action switch. A still further object is to provide a mechanically actuated switch that interfaces directly with solid-state circuits, including both discrete and integrated circuits and further including all types of logic circuits, such as RTL, DTL, TTL, and HTL.

BRIEF DESCRIPTION OF THE INVENTION

The switch of the present invention includes a solid-state diode capable of emitting electromagnetic radiation, usually in the form of visible light. A photosensitive device that responds to this radiation is located with the emitter in a housing opaque to such radiation so that the photosensitive device will be irradiated only by the diode. Between the diode and the photosensitive device is space for a shutter that can be moved between one position, in which it does not interfere with the passage of the radiation from the diode to the photosensitive device, to an alternate position, in which it completely intercepts such radiation. The shutter is connected to an actuator and is resiliently biased toward one of its positions.

In one embodiment, the shutter has a magnetic device connected to move with it. A fixed magnetic device attracts the movable one and assists in holding the shutter in one position. As a result, the shutter tends to snap to the alternate position when enough pressure is applied via the actuator to overcome the magnetic field. To increase the speed of movement of the shutter, a spring may be placed between the shutter and the actuator to be compressed when the actuator is depressed, thus storing energy as pressure builds up against the magnetic field. When the magnetic force that holds the two magnetic members (one of which may be permanently magnetized though the other is not) together is finally overcome, the energy stored in the spring is suddenly free to be released, and this gives an added impetus to movement of the shutter toward its opposite position. Another magnetic member, for example, a piece of unmagnetized steel, may be located so as to attract the movable magnetic member when the latter moves with the shutter to the opposite position. This can be used to provide an audible click to indicate that the switch has suddenly shifted from one condition to the other, and it may also help to make the return movement of the shutter occur with suddenness, more or less like the initial movement.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional side view of a solid-state switch constructed according to the invention.

FIGS. **2–4** are circuit diagrams of the solid-state circuit used in the switch in FIG. **1.**

FIG. **5** is a cross-sectional side view of a modified form of solid-state switch incorporating some of the features of the switch in FIG. **1.**

DETAILED DESCRIPTION OF THE INVENTION

The switch in FIG. **1** is constructed in an opaque housing **11** which may be similar in size and shape to mechanical momentary action switches. For convenience of manufacture, the housing is divided into two parts, and FIG. **1** shows only one of these parts. Inside the housing, and near the rear wall **12,** is a light-emitting diode, or radiator, **13** that provides the electromagnetic wave radiation required for operation. Facing the diode is a photosensitive solid-state device, or detector, **14,** such as a photo-Darlington device, which will be described in connection with FIG. **2.** The radiator **13** is placed within a recess **16** molded into the housing **11** and shaped to hold the diode relatively snugly to make sure that light from the radiator is always directed through an opening **17** toward the photosensitive detector **14.** The latter is also mounted in a restricted space **18** that has an opening **19** facing the radiator **13.** An optical axis **21** may be considered to exist between the photoemissive surface in the radiator **13** and the photosensitive surface in the detector **14,** although the alignment of these components on the optical axis need not be as exact as is required in most optical instruments.

It is worth noting that the radiation given off by the radiator **13** need not be in the visible range of wavelengths, although the radiator is referred to as a light-emitting diode. Many such radiators do emit visible radiation, but others emit invisible radiation, such as infrared radiation. In any case, the detector **14** must be sensitive to the wavelength of the radiation emitted by the radiator **13.** If the detector **14** is also sensitive to radiation of other wavelengths, the housing **11** must be opaque to such other wavelengths, as well as to the radiation emitted by the radiator **13,** so that the detector **14** can be energized only by radiation from the radiator.

In addition, the interior walls of the housing **11** must be sufficiently non-reflecting so that only the radiation traveling along the optical axis **21** will energize the detector **14.**

The detector **14** and the radiator **13** are electrically connected to a printed circuit board **22** which is attached to terminal pins **23** and **24** imbedded in the rear wall **12** of the housing **11.** Other electronic components

26 and 27, which will be described in connection with FIG. 2, are also connected to the printed circuit board 22.

Between the spaces 16 and 18 that enclose the emitter 13 and the detector 14 is a slot 28 in which a shutter 29 is free to slide. This shutter is shown at the upper one of its two end positions. In the lower end portion 29*a* shown in broken lines, the shutter prevents radiation emitted from the radiator 13 from reaching the detector 14.

The shutter 29 comprises a blade-shaped lower portion 30 which is relatively wide. Above that portion is a central portion 31 that is thicker than the blade 30 but not as wide, and an annular disc 32 of permanently magnetized material, such as Alnico, encircles this central portion. The disc 32 may be magnetized so as to have limited north and south pole areas around it, and it is prevented from dropping below the central portion 31 by the fact that the shutter blade 30 forms shoulders in line with the bottom level of the central portion. These shoulders are much wider than the central opening 33 in the magnet.

An annular steel plate 34 held in a slot 35 in the housing 11 also encircles the shutter above the central portion 31. The plate 33 acts as a keeper for the magnet 32, and the magnet force of attraction between the movable magnet 32 and the stationary plate 34 helps to hold the magnet in its upper position, as shown, and helps to draw it back to this position when the magnet 32 and the shutter 29 are moved to their alternate positions.

At the upper end of the central portion 31 is a neck 36 with a head 37 formed thereon. The neck extends through a reduced-diameter channel 38 formed by an inwardly directed shoulder, or flange, 39 at the lower end of a hollow connecting member 41. The outer dimensions of the lower end of the connecting member 41 are larger than the diameter of the hole 33 in the magnet 32, and so the magnet 32 is captured between the connecting member 41 and the upper edge of the shutter blade 30. The shutter 29 is preferably molded of thermoplastic material, and the head 37 is hot-formed after the magnet 32 and the disc 34 have been threaded on the neck 36 and the neck has been inserted into the channel 38 in the connecting member 41. The blade 30 extends through a thin, steel annular ring 40, the upper surface of which is struck by the magnet 32 when the shutter descends to its alternate position 29*a*.

Above the flange 39 the channel 38 is somewhat wider and at the uppermost end of the connecting member 41 there is an outwardly directed flange 42. A compression spring 43 is confined within the channel 38 above the head 37. The uncompressed length of this spring is greater than the length of that part of the channel 38 above the head 37 so that the upper end of the spring 43 extends above the connecting member and preferably presses against the juxtaposed central part 44 of a generally C-shaped member 46. The C-shaped member has two arms 47 and 48 that extend alongside the upper end of the connecting member 41 but do not frictionally engage it. At their free ends, the arms 47 and 48 bend inwardly to form hooks 49 and 50, respectively. The spacing between the ends of these hooks is greater than the width of the connecting member 41 below the flange 42 but is less than the width of the flange. Moreover, the length of the arms 47 and 48 is such that, when the shutter 29 and the connecting member 41 are in the end position shown, there is a substantial distance between the lower surface of the flange 42 and the upper surfaces of the hooks 49 and 50. It is also preferable that the distance between the uppermost surface of the connecting member and the juxtaposed surface of the central part 44 be less than the distance between the lowermost ends of the arms 47 and 48 and the juxtaposed surface of the plate 35 so as to permit the maximum amount of energy to be stored in the spring 43, as will be described hereinafter.

The C-shaped member 46 is part of the actuator of the switch and is attached to a block 52 of insulating material. This block has a channel 53 in one side and a connecting bar 54 is attached to the block 52 and extends along this channel. One end of the bar 54 extends below the block 52 and into a compression spring 56. The other end of this spring presses against the bent-over end 57 of a terminal rod 58. The block 52 has another channel 59, and a second connecting bar 61 is seated therein and held in place by a hollow rivet 62. The free end of the bar 61 extends parallel to the free end of the bar 54 and fits into a compression spring 63 similar to the spring 56. The spring 63 presses against the bent-over end 64 of another terminal rod 66. The upper surface of the block 52 has a raised center that fits into an externally threaded bushing 67, which is attached to the front wall 68 of the housing 11. Within the bushing is a pushbutton 69 that may be illuminated by connecting the bar 54 and the rivet 62 to a lamp socket within the pushbutton 69. Such an arrangement for lighting a pushbutton has been known heretofore and does not constitute part of this invention. The two sections that make up the housing 11 are held together by four pins 71–74 of rectangular cross-section.

The springs 56 and 63 furnish the resilient force that keeps the actuator in the end position shown. When the switch is to be actuated, pressure is applied to the pushbutton 69 to move it toward the rear wall 12. Due to the magnetic force of attraction between the magnet 32 and the plate 34, the magnet and, hence, the shutter 29 do not move at first. Instead, the spring 43 compresses, or compresses more, between the central part 44 of the C-shaped member 46 and the head 37 of the shutter 29, thus storing energy in the spring. Pressure on the pushbutton 69 also compresses the springs 56 and 63.

As more pressure is applied to the pushbutton 69, the point is eventually reached at which the force of the spring 43 overcomes the magnetic force of attraction between the magnet 32 and the plate 34, or the surface of the central part 44 comes into contact with the juxtaposed surface of the connecting member 41. In either case, the magnet 32 will start to move away from the plate 34, and the magnetic force of attraction between them will drop suddenly due to this separation. In that case the energy stored in the spring 43 will suddenly be released and will push the shutter 29 to its alternative end position 29*a* in which illumination of the detector 14 by the radiator 13 is suddenly cut off. It should be noted that it is not necessary to cut off this illumination completely, provided it is reduced to a level definitely lower than the level required to actuate the detector 14. When the shutter moves to the alternate position 29*a*, the magnet 32 strikes the ring 40 with an audible snap, thus indicating that the switch has been actuated.

One of the difficulties with mechanical momentary action switches is that they can frequently be teased into improper action. Teasing means to apply just enough pressure to the pushbutton **69** to move the contact controller, which in this case would be the shutter **29**, to a central position between its two end positions and in which the state of the switch, i.e. whether it was "on" or "off," could easily be changed by an exceedingly small movement of the pushbutton. In the present switch, the force of the spring **43** is suddenly brought into action, and it has been found to be impossible to tease the shutter **29** into remaining in a central position.

Similarly, after the pushbutton **69** has been completely depressed and is being released, the magnet **32** is held to the ring **40** by magnetic attraction until the block **52** has moved far enough to cause the hooks **49** and **50** to engage the flange **42** and lift it to cause the magnet **32** to become disengaged from the ring **40.** Because of the lost motion between the C-shaped member **46** and the flange **42,** the central part **44** will be so near its original position by the time the magnet **32** starts to move that the magnet will be able to move sharply under the force of magnetic attraction to impact the plate **34.**

FIG. **2** shows the electronic circuit for the switch in FIG. **1.** The light-emitting diode **13** is connected in series with a resistor **76** between the terminals **23** and **24.** Typically, the terminal **23** is grounded and the terminal **24** is connected to a positive source of voltage of the order of **5** volts. The resistor **26** and the detector **14,** which in this instance is a photo-Darlington, are also connected in series between the terminals **23** and **24** and, therefore, in parallel with the radiator **13** and the resistor **76.** A Schmitt trigger circuit **27** has its input connected across the resistor **26.** The Schmitt trigger circuit is also connected to the terminals **23** and **24** to derive operating power therefrom. The output terminal for the switch and for the Schmitt trigger circuit **27** is terminal **77.** FIG. **2** also shows a lamp for illuminating the pushbutton. This lamp, which may be an incandescent bulb operating on a voltage of about 5 volts to 28 volts, is connected to the terminals **58** and **66.**

When the radiator **13** is not separated from the photosensitive detector **14,** radiation indicated by the arrows **78** from the emitter reaches the detector **14.** The latter incorporates a phototransistor **79** and an amplifying transistor **81** in one housing. The phototransistor **79** has a photosensitive base electrode. Its emitter and collector are connected, respectively, to the base and collector of the transistor **81** in a Darlington arrangement. The reception of photons by the base of the phototransistor **79** causes a current to flow therein and this current, flowing into the base of the transistor **81,** is greatly amplified and causes a voltage drop across the resistor **26.** This voltage drop actuates the Schmitt trigger to produce an output pulse that goes positive and remains there as long as the pushbutton **69** is depressed. As soon as the button is released, the voltage at the output terminal **77** drops sharply to its original value. This switch is electrically equivalent to a normally closed switch.

The circuit in FIG. **3** is identical to that in FIG. **2** except that the resistor **26** is connected between the emitter of the transistor **81** and the terminal **23.** The operation is, therefore, the inverse of the operation of the switch in FIG. **2** and is the equivalent of a normally open switch.

FIG. **4** shows the equivalent of a single-pole-double-throw switch and is identical to the circuit in FIG. **3** with the addition of an inverter transistor **82,** a base isolation resistor **83,** and a second output terminal **84.**

In use the terminals **77** and **84** would normally be connected by resistors R_1 and R_2 to a power supply having a positive voltage V_{CC}. The following table shows typical values of R_1 and R_2 when the switches of FIGS. **2–4** are used in resistor-transistor logic (RTL), diode-transistor logic (DTL), transistor-transistor logic (TTL), and high threshold logic (HTL) circuits.

Logic type	R_1	R_2	Max. fan out.	V_{cc}	Min. out. high state, volts	Max. out. low state, volts
RTL (low power)	1.2K	1.2K	8	3±.5	1.4	0.3
RTL	1.2K	1.2K	2	3±.5	1.4	0.3
DTL	1.8K	2.7K	10	5±.5	2.5	0.3
TTL	1.8K	2.7K	10	5±.5	2.5	0.3
HTL	2.2K	10K	10	15±1	10	0.3

FIG. **5** shows a switch similar to that in FIG. **1** but without the magnetic means for providing snap action and without audible indication that the switch has been operated. Parts that are identical with those in FIG. **1** have the same reference numerals.

The difference between the switches in FIG. **1** and FIG. **5** is in the shutter, which, in FIG. **5,** is identified by reference numeral **129.** The housings **11** for both switches are identical, and therefore the major dimensions of the shutter **129** can be no larger than those of the shutter **29** in FIG. **1.** The shutter **129** in FIG. **5** has a blade **130** that slides in the groove **28** to block radiation from the radiator **13** from reaching the detector **14** when the shutter is in its alternate position **129*a*.** Since there is no need to make the central portion **131** of the shutter **129** fit into the hole in an annular magnet, it has a relatively large size, as shown. The neck **136** is only a pair of notches for the hooks **49** and **50** to fit into, and the head **137** substantially fills the C-shaped member **46** because, in this switch, no lost motion is desired. Instead, it is preferable for the shutter **129** to move up and down precisely with the pushbutton **69.** The C-shaped member **46** is attached to the block **52** by hot-forming heads on a pair of projections that extend downwardly from the block. One such head **86** is shown.

We claim:

1. A solid-state switch comprising: a solid-state radiator of electromagnetic waves; a solid-state detector having one condition of conductivity when irradiated by said waves and a different condition of conductivity in the absence of radiation from said radiator; a housing opaque to said radiation, said emitter and said detector being located in said housing, whereby said waves from said radiator can reach said detector; a shutter movable between a first position, in which said shutter allows said radiation to pass from said radiator to said detector, and a second position, in which said shutter prevents said waves from said radiator from reaching said detector; means connected to said shutter for urging said shutter from one of said positions toward the other, and spring means resiliently biasing said shutter toward said first position.

2. The switch of claim **1** in which said radiator is a light-emitting diode.

3. The switch of claim **1** in which said detector comprises a photo-Darlington amplifier.

4. The switch of claim **1** in which said detector comprises; a radiation-responsive solid-state device comprising:

1. a radiation-responsive input electrode, and
2. emitter and collector output electrodes; and a load impedance connected in series with said output electrodes.

5. The switch of claim **4** comprising, in addition, a Schmitt trigger comprising an input circuit connected across said load impedance.

6. The switch of claim **4** in which said load impedance is directly connected to said emitter.

7. The switch of claim **4** in which said load impedance is directly connected to said collector.

8. The switch of claim **1** comprising, in addition, an actuator slidably mounted in said housing and extending therefrom and movable between first and second positions corresponding to said first and second positions, respectively, of said shutter, said actuator comprising means engaging said shutter to move said shutter in at least one direction.

9. The switch of claim **8** in which said shutter comprises a head portion, and said means engaging said shutter comprises a generally C-shaped member, engaging recess means below said head portion.

10. The switch of claim **1** wherein said means urging said shutter from one of said positions toward the other comprises permanently magnetized means attached to said shutter to move therewith, and means stationarily mounted within housing magnetically cooperating with said permanently magnetized means.

11. The switch of claim **10** comprising, in addition, compression spring means between said shutter and said actuator to store energy when said actuator is depressed and to release said energy suddenly when the magnetic attraction between said permanently magnetized means and said fixed magnetic means is overcome, whereby said shutter moves suddenly from said one of said positions to the other.

12. The switch of claim **10** in which said shutter comprises; a first portion that moves into and out of the path of said radiation from said radiator to said detector, and a head at one end; and in which said switch comprises, in addition, a connecting member comprising; means engaging said head, and lost motion means connecting said connecting member to said actuator to impart motion from said actuator to said connecting member only after said actuator has moved part of the way from one of its end positions to the other.

13. The switch of claim **12** in which said permanently magnetized means comprises an annular magnet encircling said shutter between said first portion and said head.

14. The switch of claim **13** in which said connecting member has a channel extending therethrough with an inwardly directed shelf to engage said head, said switch comprising, in addition, a compression spring confined within said channel and engaging said actuator when the latter is depressed.

* * * * *

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,783,274 Dated January 1, 1974

Inventor(s) HERBERT TOWNE and HAROLD RAPP

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading:

After "[76] Inventors: " insert

--[73] Assignee: Dialight Corporation, Brooklyn, N.Y., a corporation of Delaware --

Signed and sealed this 20th day of August 1974.

(SEAL)
Attest:

McCOY M. GIBSON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents