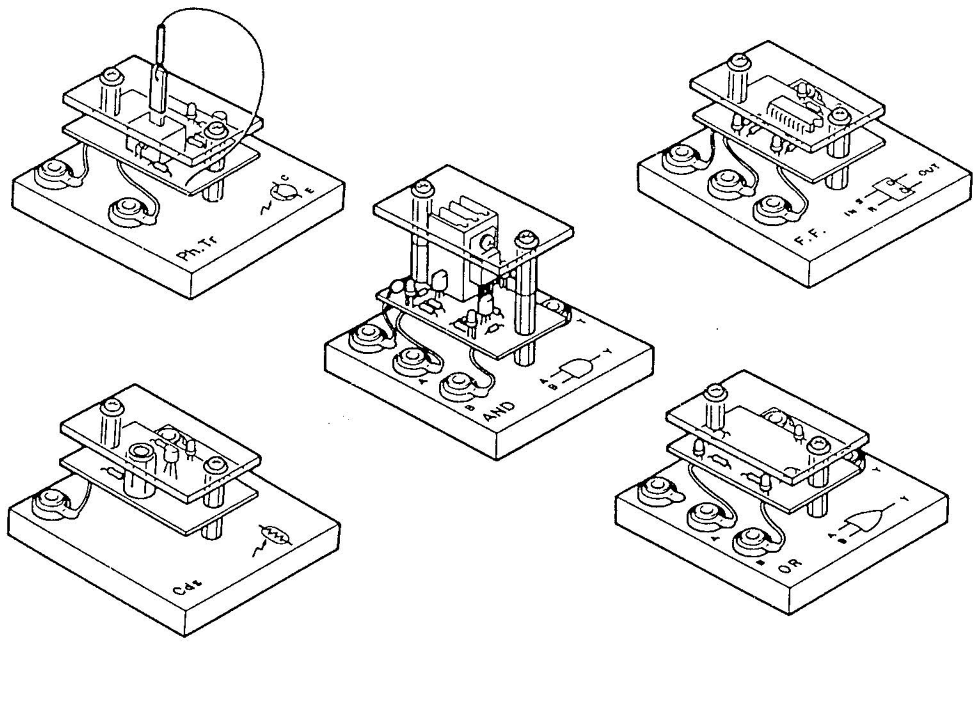
TOYOTA
SERVICE TRAINING

ELECTRONICS MASTER

Hi-Tech Training Instructions



TOYOTA MOTOR CORPORATION

OVERSEAS SERVICE DIVISION

STM024ZY

FOREWORD

Electrical and electronic systems used in vehicles are becoming more and more complicated every year, and are coming to play an increasingly major role in a vehicle's operation. Such new systems require that all personnel engaged in automotive afterservice have a basic knowledge of electricity and electronics, and that they are thoroughly competent in conducting electrical inspections of these systems.

The Electronics Master and this textbook have been prepared as training material in order to help meet this demand. Through the simple and easy to understand exercises contained herein, service personnel can gain the basic knowledge of electricity and electronics required for the servicing of automobiles.

Those persons who receive training using these materials can be expected to gain a deeper understanding of electrical and electronic systems based on the knowledge and know-how obtained in this training, thus enabling them to offer top-quality service to the users of Toyota vehicles.

TOYOTA MOTOR CORPORATION

CONTENTS

TRAINING OBJECTIVES

The object of training using the Electronics Master is to acquire a fundamental knowledge of electricity and electronics:

1. An understanding of special electrical terms.
2. An understanding of the basic configuration of electrical circuits and their characteristics.
3. An understanding of the basic operation of logic circuits.
4. An understanding of the characteristics of basic photoelectric parts such as phototransistors and photodiodes and of the simple electronic circuits which use them.

HOW TO USE THE ELECTRONICS MASTER

1. **The following items should be provided when using the Electronics Master:**

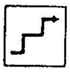
   (1) DC 12-V, 10-A power supply (battery, etc.)

   (2) Circuit tester or multi-meter
   As far as possible, circuit testers with the following measuring capacities should be used.
   - As a voltmeter .... 0 to 25 V (DC)

2. **Carry out all experiments according to the instructions printed in this textbook.**

3. **Turn the main switch off and disconnect the battery ground wire from the battery when making connections between electrical parts.**
   (After making connections between each electrical parts, connect the battery ground wire to the negative terminal of the battery first, then turn on the main switch.)

4. **The following symbols and marks are used in this textbook:**

    : Practice

    : Result

    : Comment

Related Materials

The following related materials are also available for use with the Electronics Master:

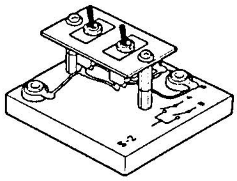
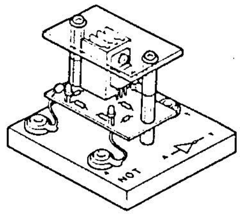
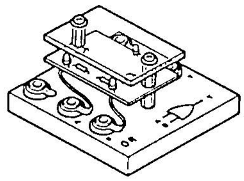
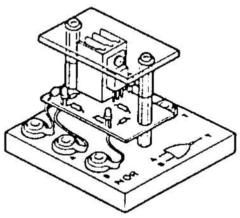
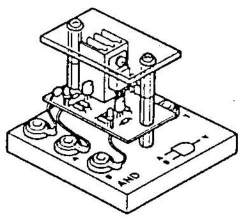
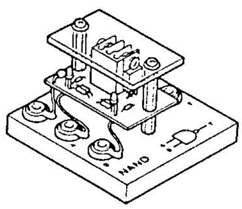
- Hi-Tech Training Instructions, "Electricity Master" (Pub. No. STM001ZY)
- New TEAM training manual, "Fundamentals of Electricity" (TTM214E)
- New TEAM training manual, "Fundamentals of Electronics" (TTM309E)

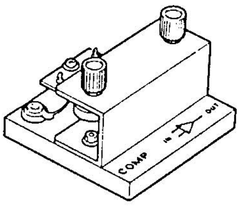
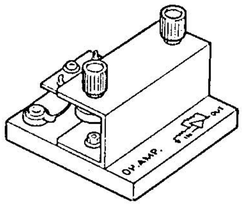
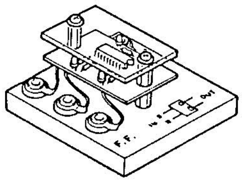
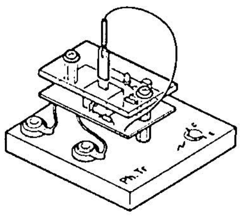
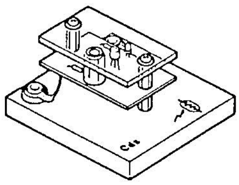
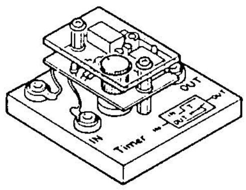
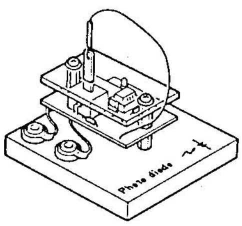
ORDERING INFORMATION

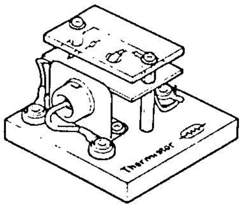
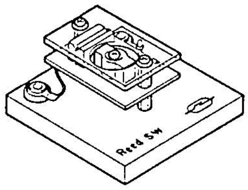
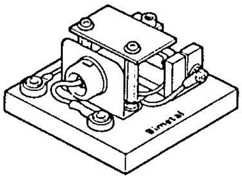
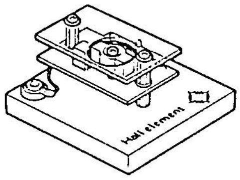
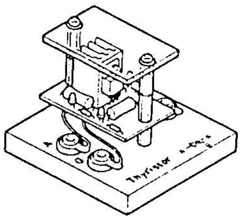
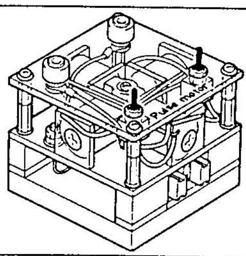
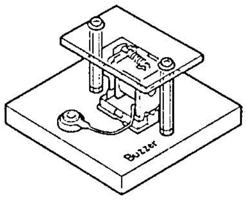
When ordering, please note that there are *two* Electronics Master kits, A and B. See page 6 for details.

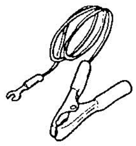
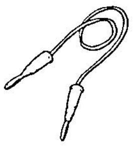
COMPOSITION OF THE ELECTRONICS MASTER

The Electronics Master is composed of the following component electronic parts.

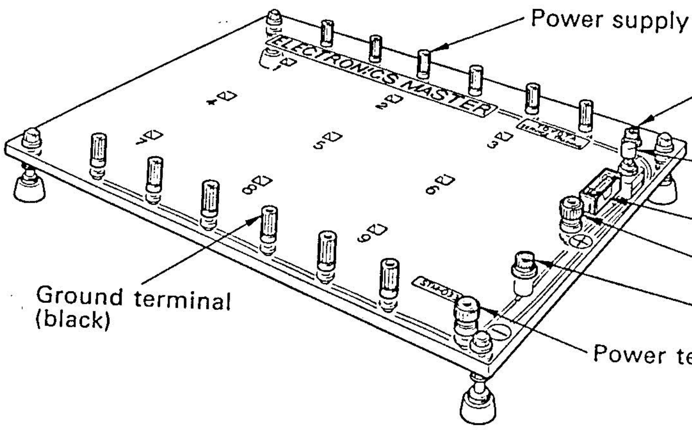
NAME	ILLUSTRATION	SPECIFICATIONS	Q'TY
Switch (S-2)		Toggle switches	1
NOT gate (NOT)		Output 12 V, 10 W	1
OR gate (OR)		Output 12 V, 10 W	1
NOR gate (NOR)		Output 12 V, 10 W	1
AND gate (AND)		Output 12 V, 10 W	1
NAND gate (NAND)		Output 12 V, 10 W	1

NAME	ILLUSTRATION	SPECIFICATIONS	Q'TY
Comparator (Comp.)			1
Operational amplifier (opamp)			1
Flip-Flop			1
Phototransistor (Ph. Tr.)			1
Cadmium sulfide photoconductive cell (CdS)			1
Timer		Output 12 V, 10 W	1
Photodiode			1

NAME	ILLUSTRATION	SPECIFICATIONS	Q'TY
Thermistor		NTC Type	1
Reed switch			1
Bimetal switch			1
Hall element			1
Thyristor		Output 12 V, 10 W	1
Pulse motor			1
Buzzer			1

NAME	ILLUSTRATION	SPECIFICATIONS	Q'TY
Power wires (Kit B only)			Red .... 1 Black 1
Lead wires (Kit B only)			Red .... 8 Yellow .... 6 Black 6

Base Panel (Kit B only)



Notes:

1) This base panel is supplied with Kit B only. (Those who already have the previously supplied Electricity Master may employ its base panel and therefore need order only Kit A. The only difference between the base panel supplied with Kit B and the previous base panel is the absence of the variable resistor.)

2) The base panels shown in the illustrations in the practice section of this manual are from the previous Electricity Master. However, the Kit B panel may also be used without any problem.

3) The pilot lamp (indicating the status of the power supply) goes on when a battery or other power source is hooked up to the power terminal.

4) The pilot lamp for the main switch goes on only when the pilot lamp is lit up (i.e., power is supplied) and the main switch is turned on.

5) The main switch should only be turned on after all wiring is installed.

PRACTICE

Page

1 FUNCTION OF NOT GATE

A NOT gate inverts input:

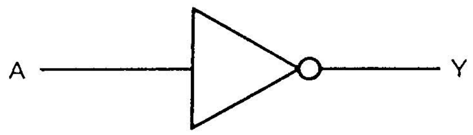
If the input is "0", the output will be "1".

If the input is "1", the output will be "0".

The truth table for a NOT gate is shown below.

TRUTH TABLE

INPUT	OUTPUT
A	Y
0	1
1	0



LOGIC SYMBOL FOR NOT GATE

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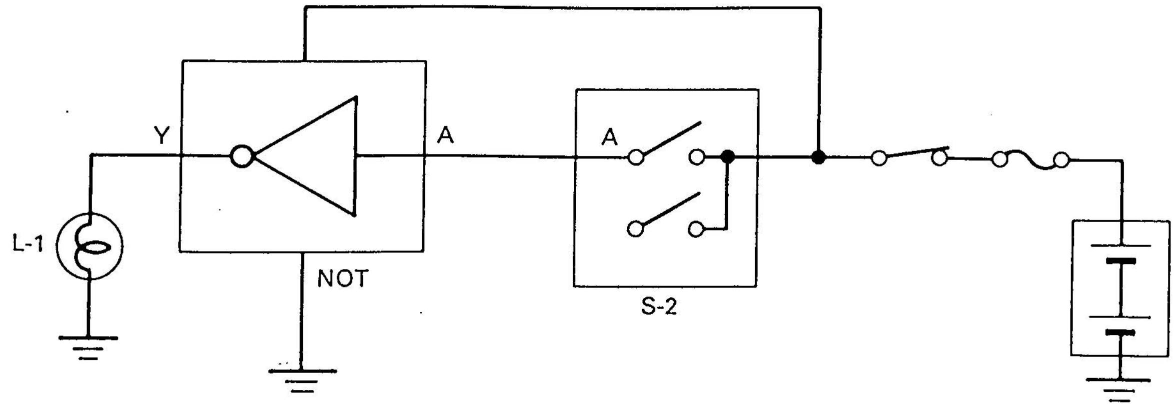
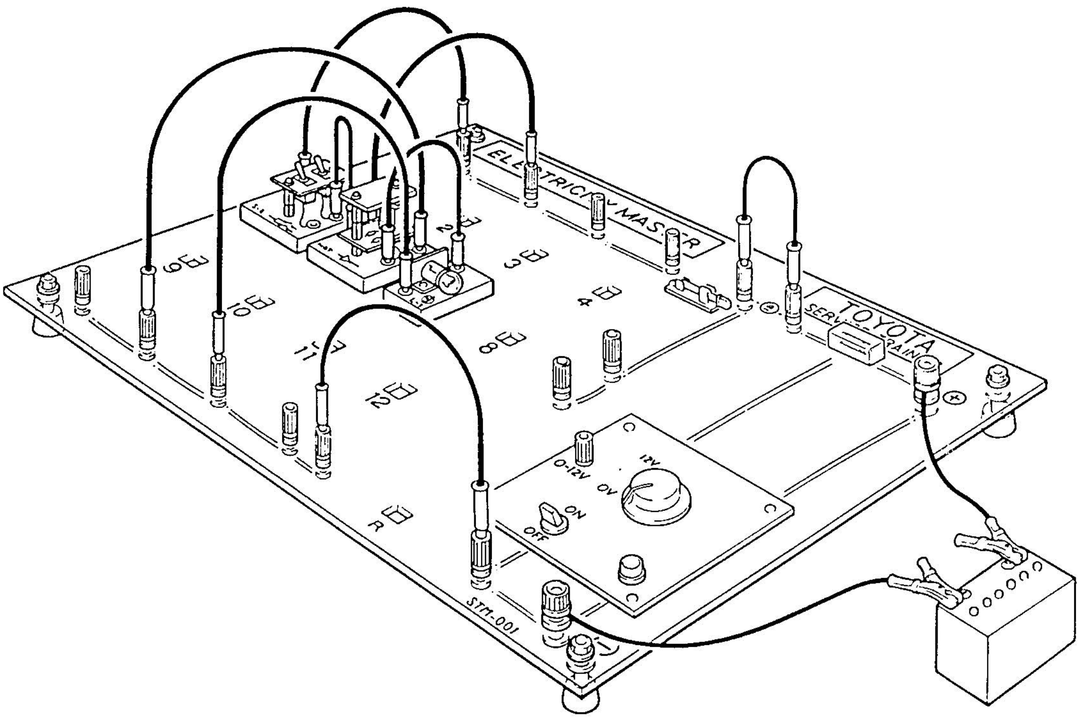
CIRCUIT USING NOT GATE

1. Make the circuit shown below using a NOT gate, L-1, and S-2.

2. Check the whether L-1 lights when contact A of S-2 is turned on (or off).





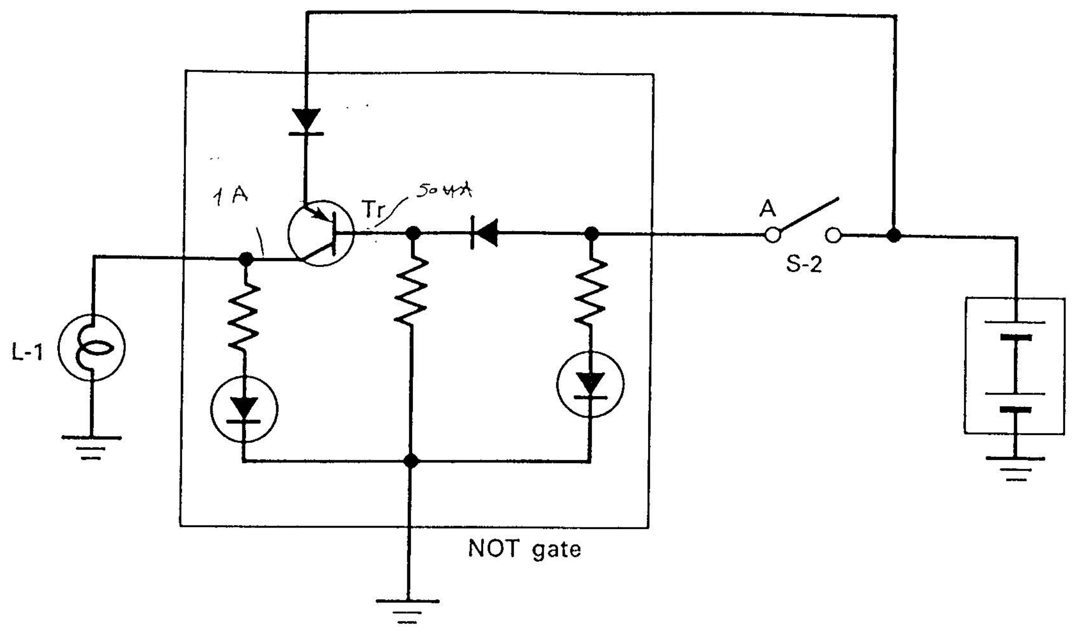
3. Results

S-2 (A)	L-1
OFF	
ON	

INTERNAL CONSTRUCTION OF NOT GATE

1. In the figure below, when contact A of S-2 is turned off, voltage is no longer applied to the base of transistor Tr. Therefore, transistor Tr is goes on and L-1 lights up. In other words, if the input to the NOT gate is "0", its output is "1".

2. When contact A of S-2 is turned on, voltage is applied to the base of the transistor Tr. Therefore both transistor Tr and lamp L-1 go off. In other words, if the input is "1", the output is "0".



EXAMPLE OF APPLICATION

This circuit is used for the seat belt warning relay. For details, see page 20.

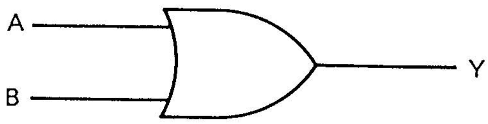
2	FUNCTION OF OR GATE

In an OR gate, the output is "1" if either one of the input values is "1".

A truth table for a two-input OR gate is shown below.

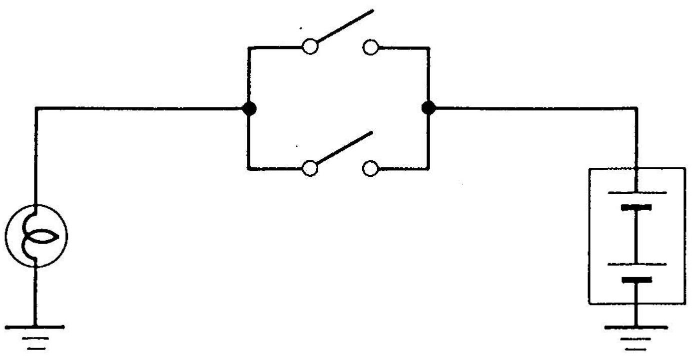
TRUTH TABLE

INPUT		OUTPUT
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1



LOGIC SYMBOL FOR OR GATE

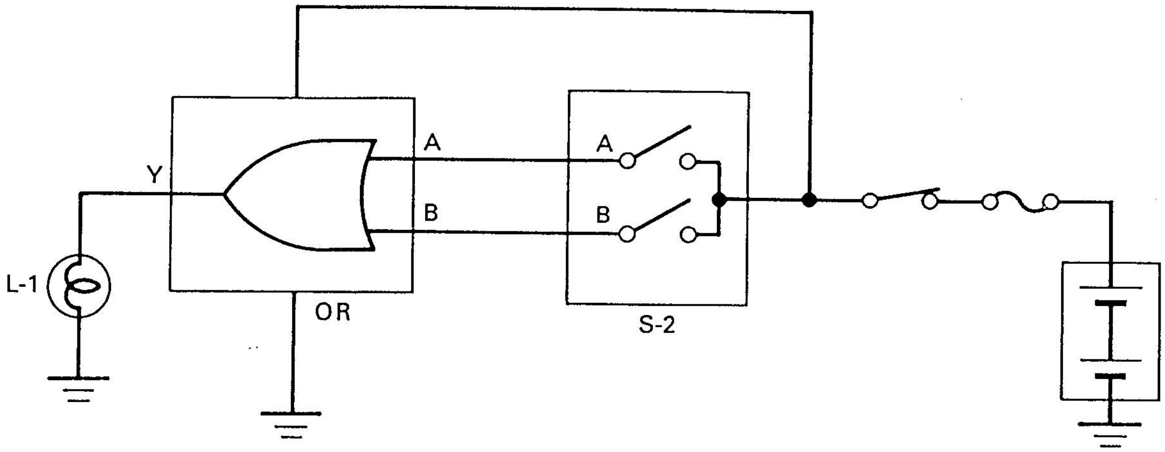
An OR gate functions just like two switches installed in parallel. If *either one* (or both) of the switches is turned on, the lamp lights up.

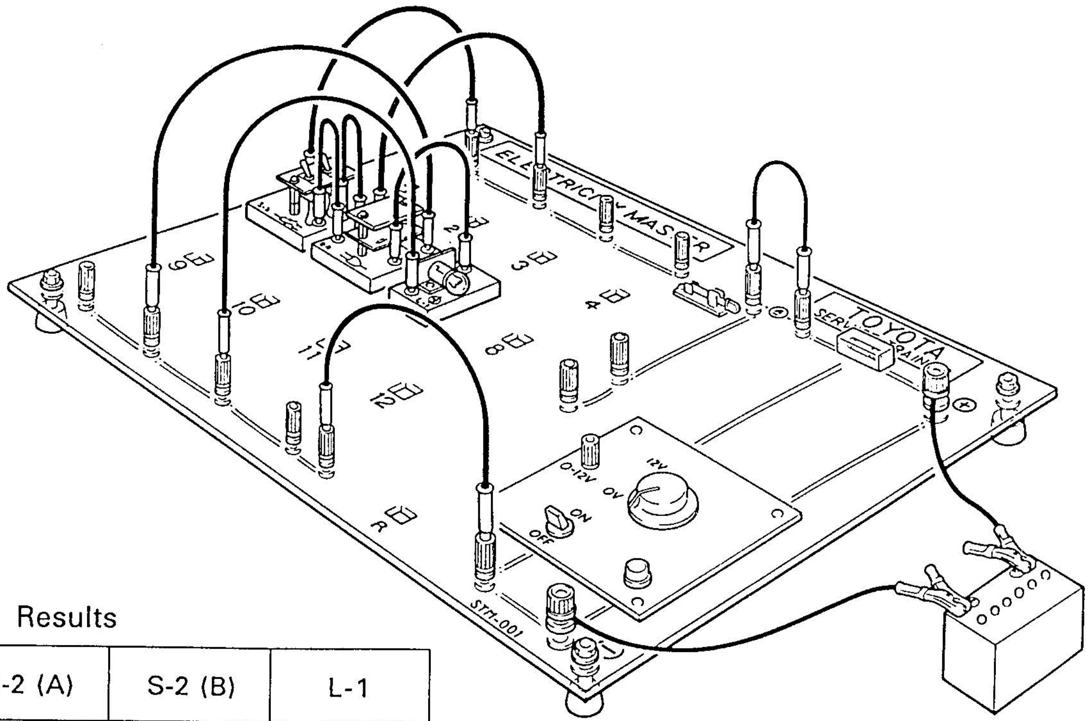


CIRCUIT USING OR GATE

1. Make the circuit shown in the figure below using an OR gate, L-1, and S-2.

2. Check whether L-1 lights up when contact A and contact B of S-2 are turned on (or off).





3. Results

S-2 (A)	S-2 (B)	L-1
OFF	OFF	
OFF	ON	
ON	OFF	
ON	ON	

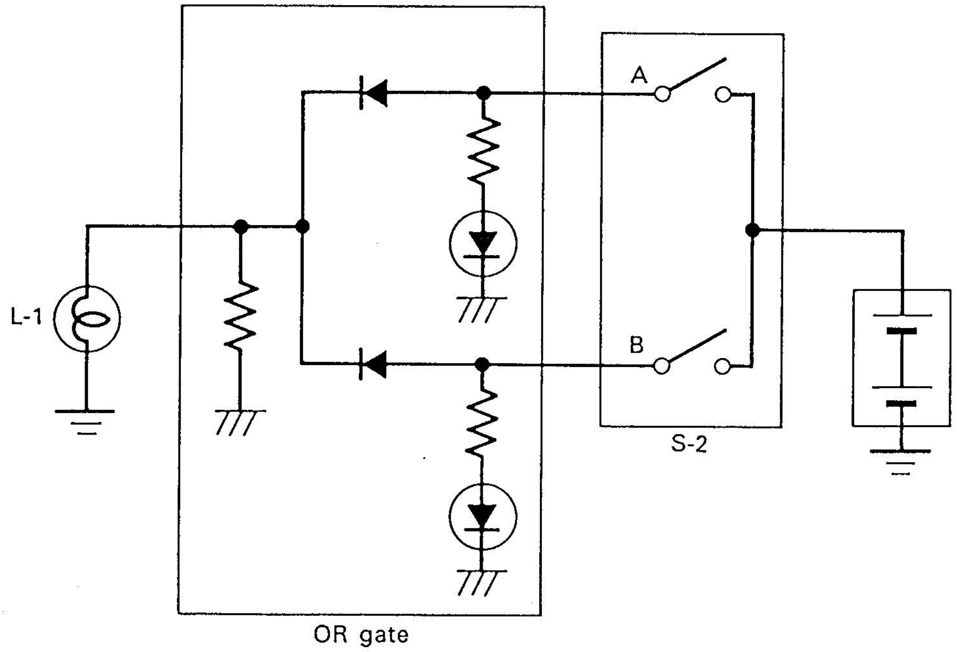
INTERNAL CONSTRUCTION OF OR GATE

1. Both contact A and contact B of S-2 off
   In the figure below, since both contact A and contact B of S-2 are off, no current flows to L-1, so it stays off.

2. Contact A of S-2 off, contact B on
   Since contact A of S-2 is off, no current flows from contact A of S-2. However, since contact B of S-2 is on, current flows through it and L-1 lights up.

3. Contact A of S-2 on, contact B off
   This is the opposite of 2. above: current flows from contact A of S-2 and L-1 lights up.

4. Both contact A and contact B of S-2 on
   Since both contact A and contact B of S-2 are on, current flows through them and L-1 lights up.



EXAMPLE OF APPLICATION

This circuit is used in the seat belt warning relay. For details, see page 20.

3	FUNCTION OF NOR GATE

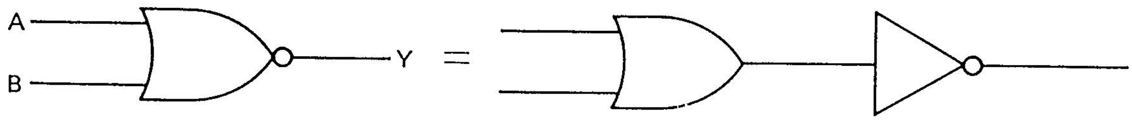
A NOR gate is equivalent to an OR gate with a NOT gate placed after it.

In other words, its output is the exact reverse of the output of an OR gate, so it only outputs a "1" if *both* inputs are "0".

The figure below shows a truth table for a two-input NOR gate.

TRUTH TABLE

INPUT		OUTPUT
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

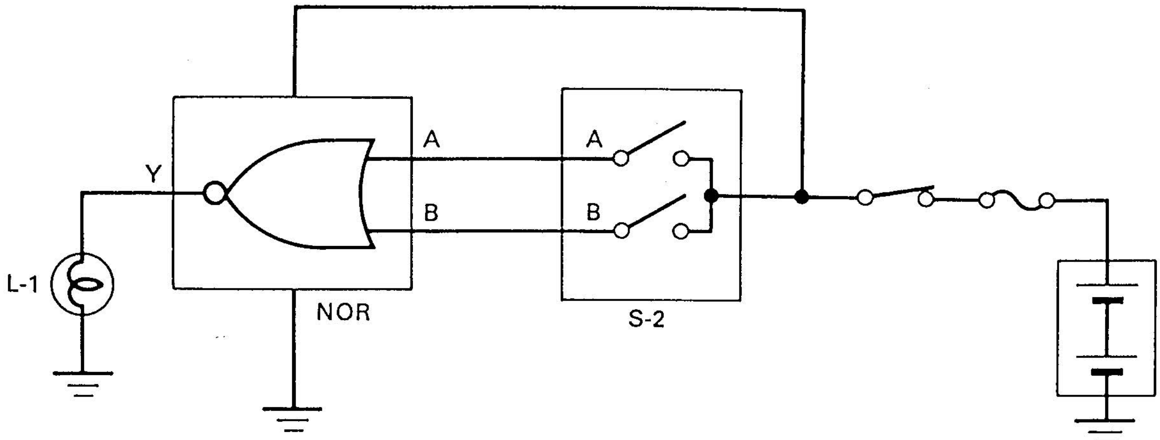


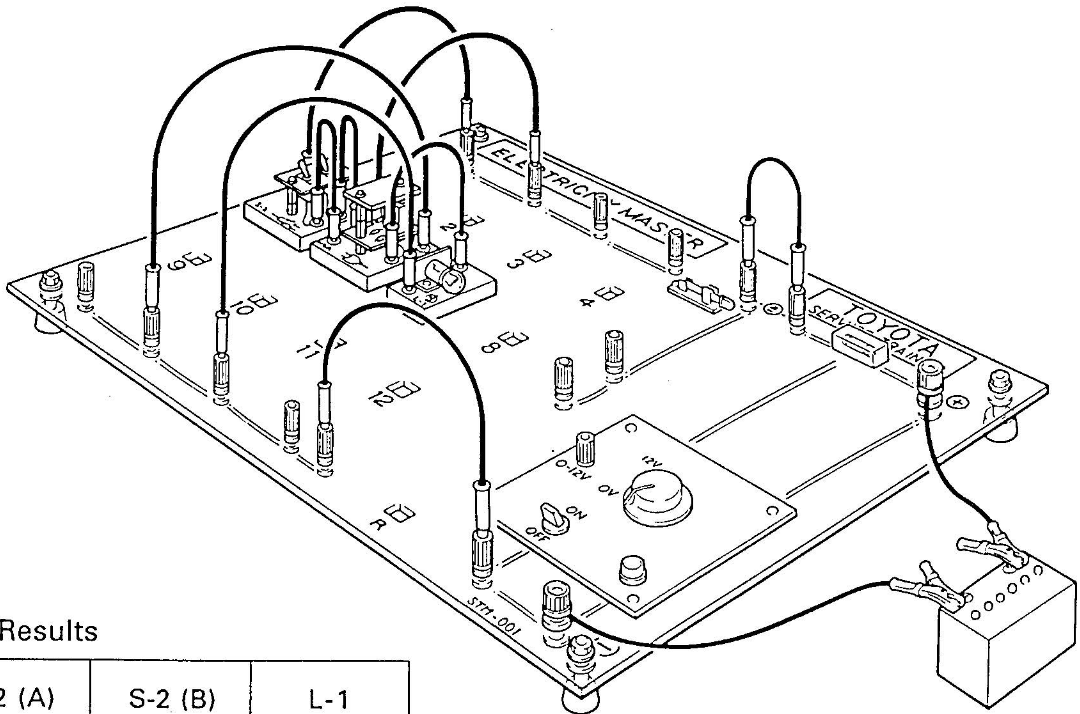
LOGIC SYMBOL FOR NOR GATE

CIRCUIT USING NOR GATE

1. Make a circuit shown in the figure below using a NOR gate, L-1 and S-2.

2. Check whether L-1 lights up when contact A and contact B of S-2 are turned on (or off).





3. Results

S-2 (A)	S-2 (B)	L-1
OFF	OFF	
OFF	ON	
ON	OFF	
ON	ON	

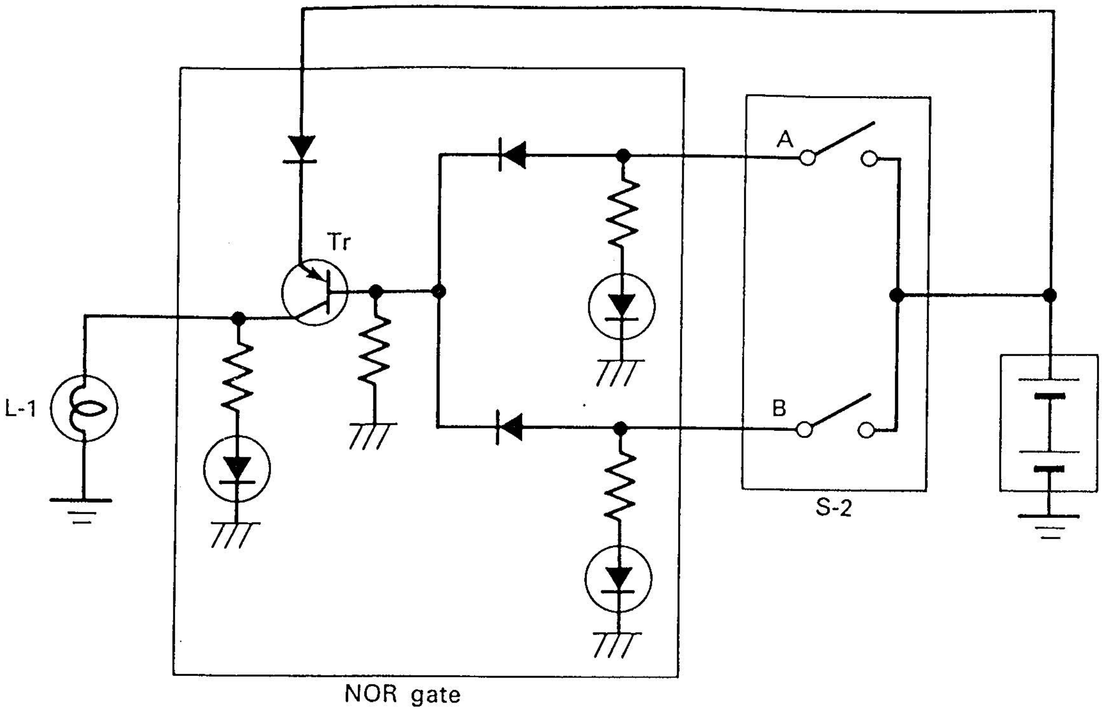
INTERNAL CONSTRUCTION OF NOR GATE

1. Both contact A and contact B of S-2 off
   When contact A and contact B of S-2 are both off, voltage is not applied to the base of transistor Tr. Therefore, transistor Tr goes on and L-1 lights up.

2. Contact A of S-2 off, contact B on
   Since contact B of S-2 is on, voltage is applied to the base of transistor Tr. Therefore transistor Tr goes off and L-1 is turned off.

3. Contact A of S-2 on, contact B off
   Since contact A of S-2 is on, voltage is applied to the base of transistor Tr. Therefore transistor Tr goes off and L-1 is turned off.

4. Both contact A and contact B of S-2 on
   Since contact A and contact B of S-2 are both on, voltage is applied to the base of transistor Tr. Therefore transistor Tr goes off and L-1 is turned off.



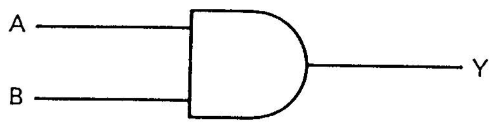
4 FUNCTION OF AND GATE

An AND gate outputs "1" only when *all* input values are "1".

The truth table of a two-input AND gate is shown below:

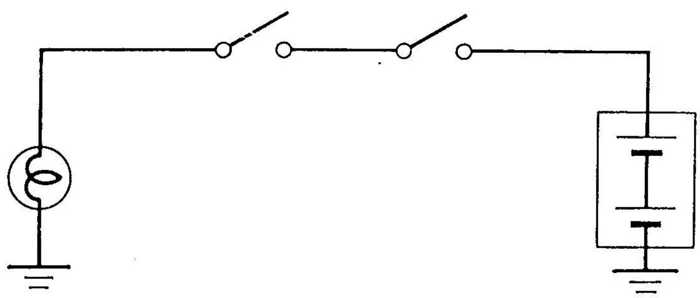
TRUTH TABLE

INPUT		OUTPUT
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1



LOGIC SYMBOL FOR AND GATE

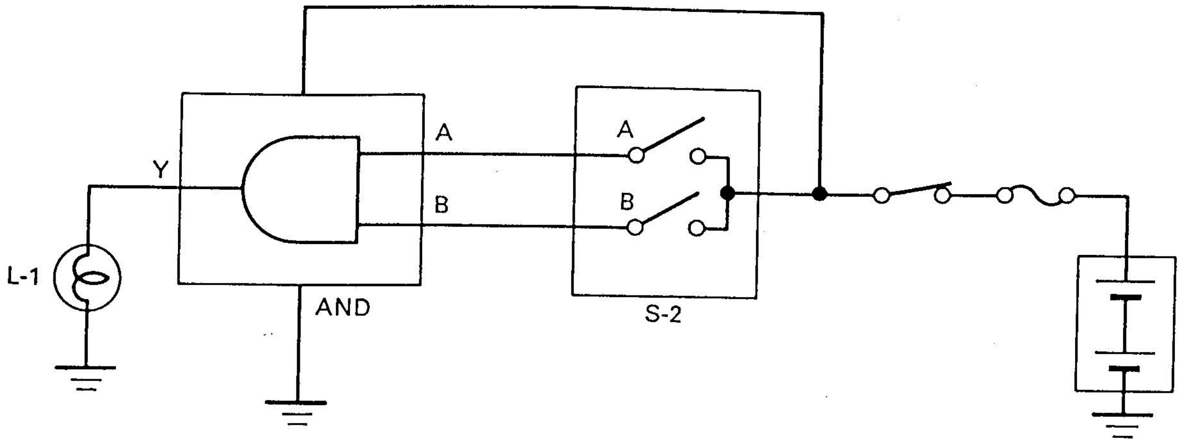
An AND gate is equivalent to switches arranged in a series. Only when all switches are on does the current flow in the circuit and the lamp light up.

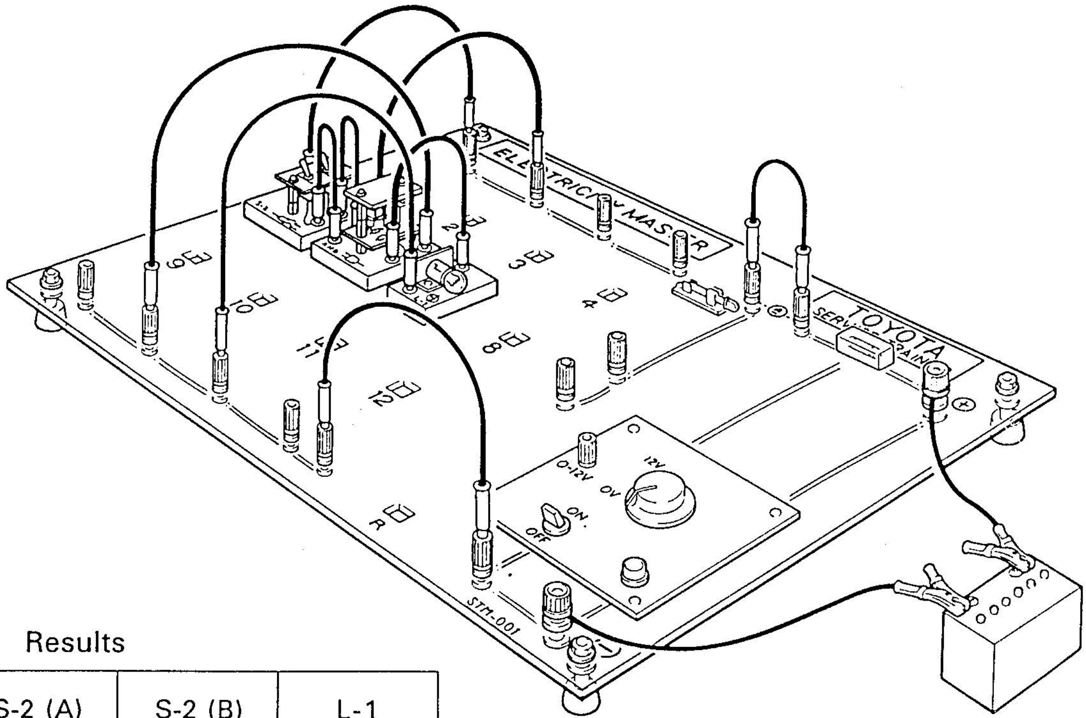


CIRCUIT USING AND GATE

1. Make the circuit shown in the figure below using an AND gate, L-1, and S-2.

2. Check whether L-1 lights up when contact A and contact B of S-2 are turned on (or off).





3. Results

S-2 (A)	S-2 (B)	L-1
OFF	OFF	
OFF	ON	
ON	OFF	
ON	ON	

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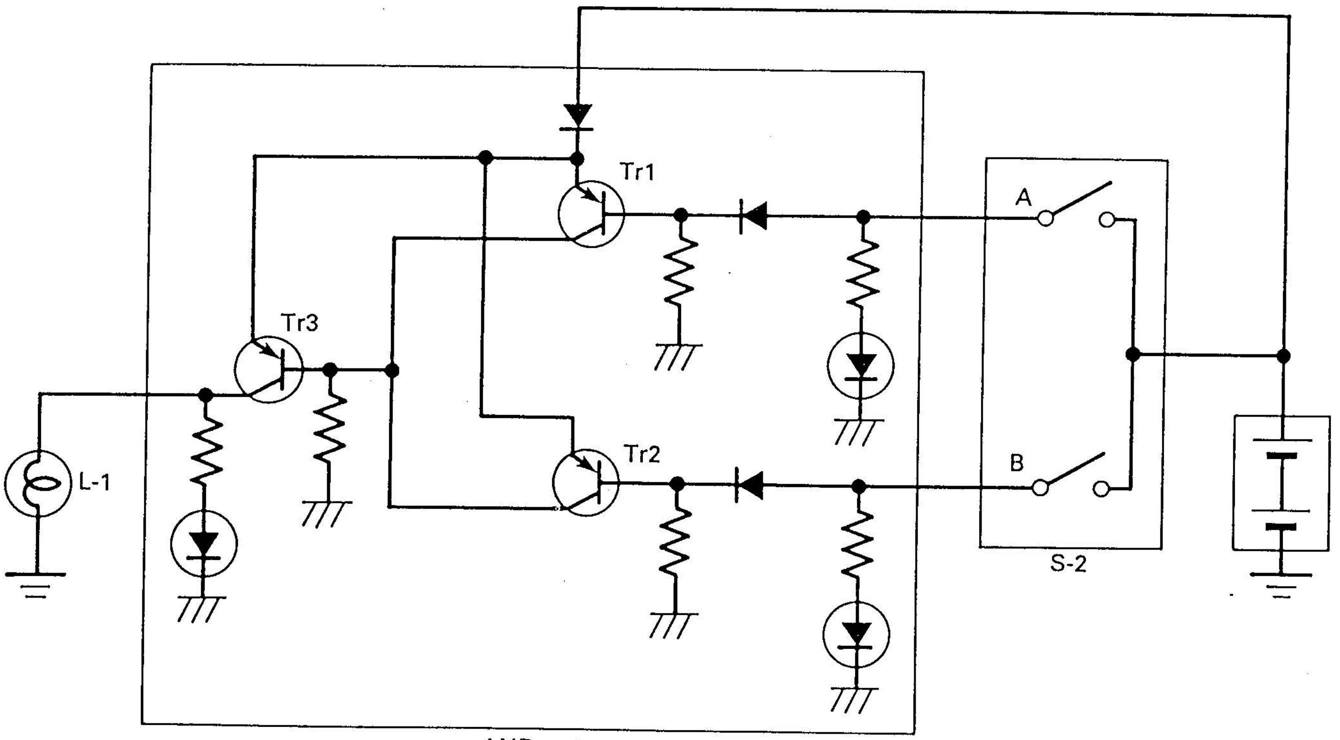
INTERNAL CONSTRUCTION OF AND GATE

1. Both contact A and contact B of S-2 off
   Since no voltage is applied to the bases of transistors Tr1 and Tr2 when contact A and contact B of S-2 are off, both Tr1 and Tr2 are on. When Tr1 and Tr2 are on, voltage is applied to the base of Tr3. Tr3 therefore goes off and L-1 is turned off.

2. Contact A of S-2 off, contact B on
   Since no voltage is applied to the base of Tr1 when contact A of S-2 is off, Tr1 is on. Since contact B of S-2 is on, however, voltage is applied to the base of Tr2 and Tr2 goes off. Since Tr1 is on, voltage is applied to the base of Tr3 and Tr3 is turned off. L-1 is therefore turned off.

3. Contact A of S-2 on, contact B off
   This is the inversion of 2. above. Tr1 is turned off and Tr2 is turned on. Voltage is therefore applied from Tr2 to the base of Tr3, so Tr3 goes off and L-1 is turned off.

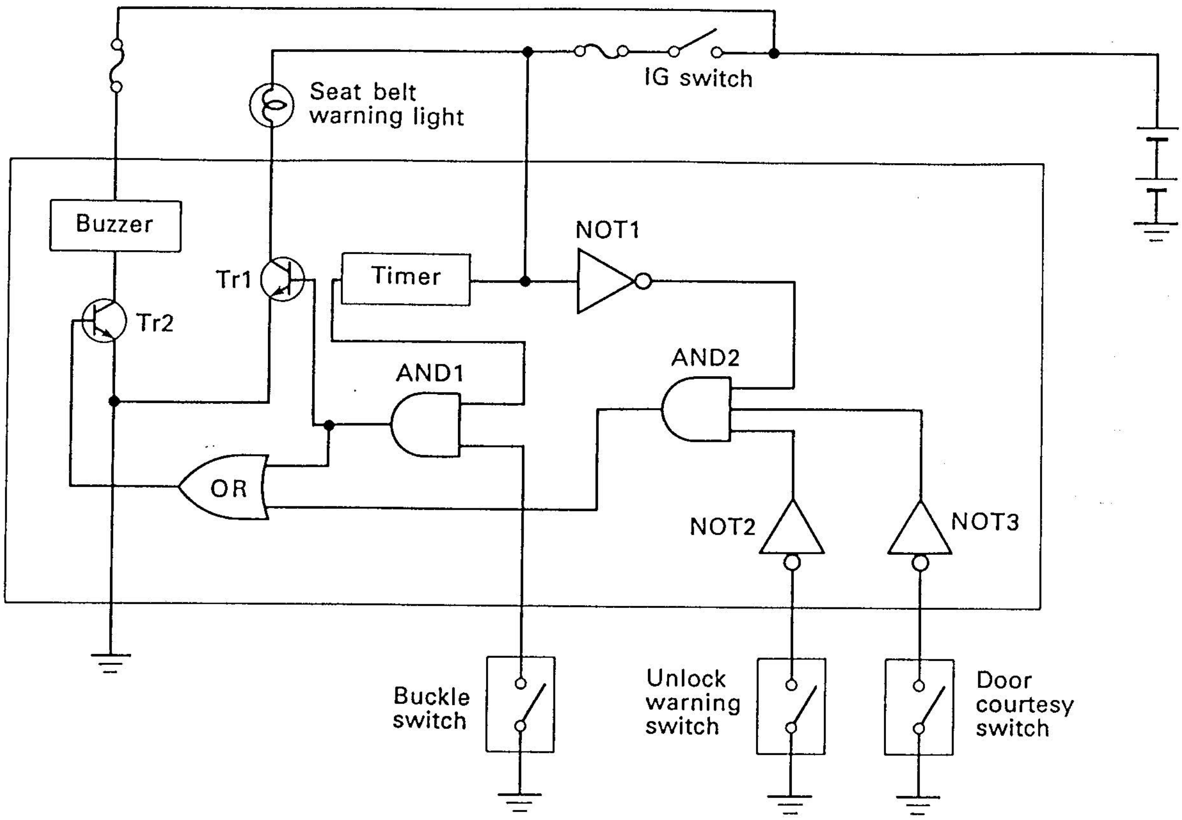
4. Both contact A and contact B of S-2 on
   When contact A and contact B of S-2 are both on, voltage is applied to the bases of Tr1 and Tr2. Therefore both Tr1 and Tr2 go off. Since Tr1 and Tr2 are off, and no voltage is applied to the base of Tr3, Tr3 is turned on and L-1 lights up.



AND gate

EXAMPLES OF APPLICATION

This circuit is used in the seat belt warning relay.



(1) SEAT BELT WARNING FUNCTION

When the ignition switch is on and the buckle switch is off, the timer is actuated. The timer inputs a "1" to AND1 for a fixed length of time. Because the buckle switch is off, "1" is input to AND1. Therefore, since all the input values to AND1 are "1", an output of "1" is input to the OR gate. The output of OR is "1", so Tr1 and Tr2 are turned on. The seat belt warning lamp therefore lights up and the buzzer sounds for a certain length of time (until the timer output becomes "0").

(2) UNLOCK WARNING BUZZER

When the door is opened with the ignition switch off but the key inserted in the ignition, the three input values to AND2 all become "1". This occurs for the following reasons: (1) because the ignition switch is off, NOT1 output is "1"; (2) because the key is inserted and the unlock warning switch is on, NOT2 output is "1"; and (3) because the door is open and the door courtesy switch is on, NOT3 output is "1".

Because all inputs are "1", AND2 outputs a "1". Because the OR output is also "1", Tr2 goes on, causing the buzzer to sound.

5 FUNCTION OF NAND GATE

In a NAND gate, the output is "0" only when all input values are "1".

This is equivalent to a combination of an AND gate and a NOT gate hooked up in series. A truth table of a two-input NAND gate is shown below.

TRUTH TABLE

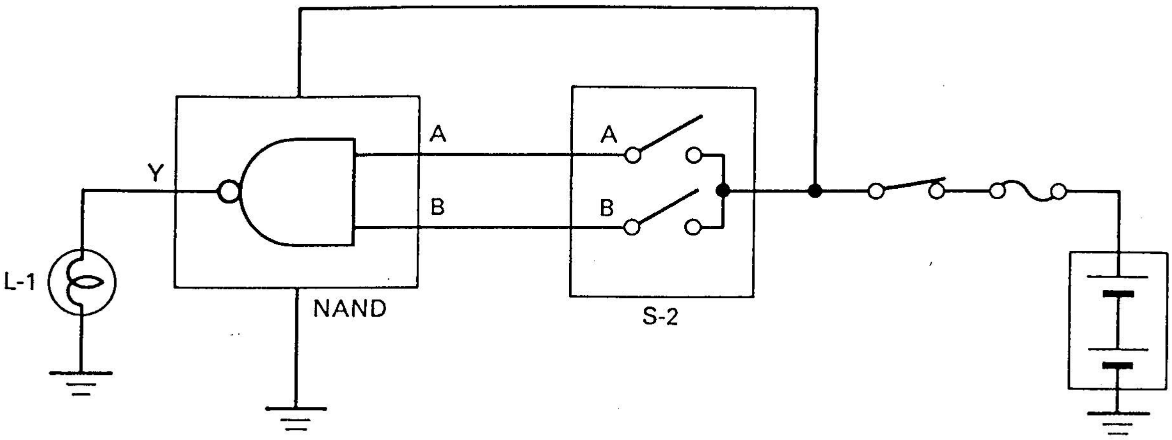
INPUT		OUTPUT
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

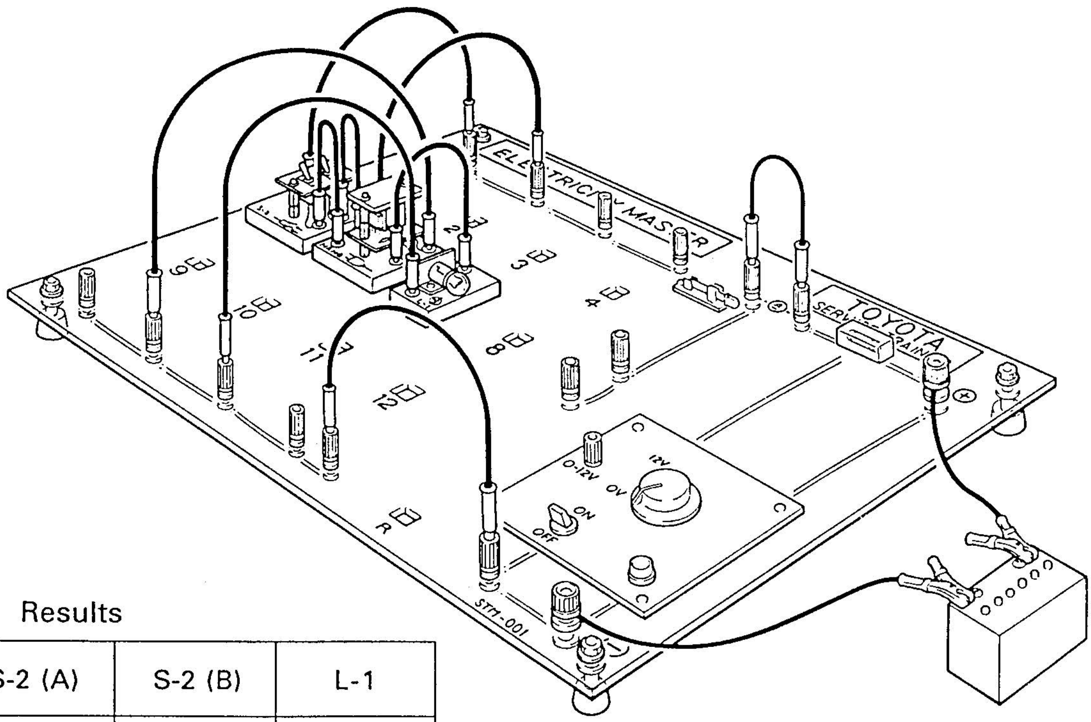
LOGIC SYMBOL FOR NAND GATE

CIRCUIT USING NAND GATE

1. Make the circuit shown below using a NAND gate, L-1, and S-2.

2. Check whether L-1 lights up when contact A and contact B of S-2 are turned on (or off).





3. Results

S-2 (A)	S-2 (B)	L-1
OFF	OFF	
OFF	ON	
ON	OFF	
ON	ON	

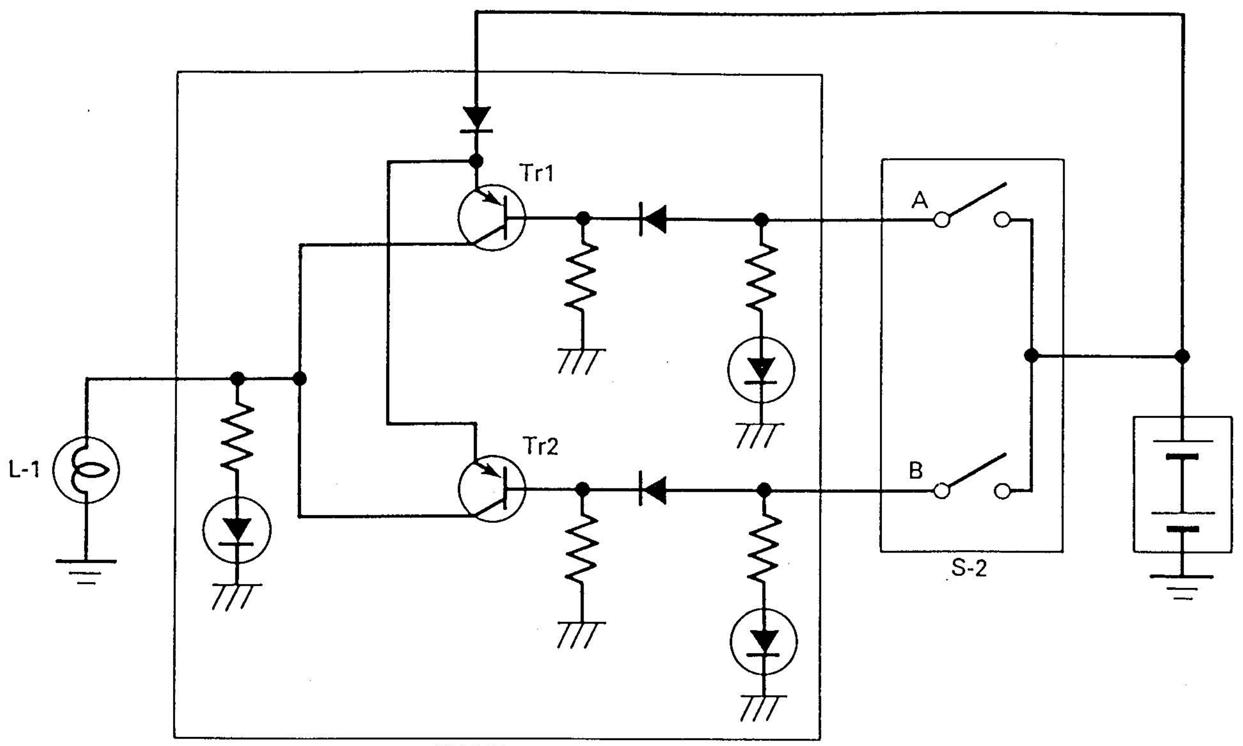
INTERNAL CONSTRNCTION OF NAND GATE

1. Both contact A and contact B of S-2 off
   When both contact A and contact B of S-2 are off, no voltage is applied to the bases of Tr1 and Tr2. Therefore, both Tr1 and Tr2 are on and L-1 lights up.

2. Contact A of S-2 off, contact B on
   When contact A of S-2 is off, no voltage is applied to the base of Tr1. Therefore, Tr1 is on and L-1 lights up. When contact B of S-2 is on, voltage is applied to the base of Tr2, which therefore goes off.

3. Contact A of S-2 on, contact B off
   When contact A of S-2 is on, voltage is applied to the base of Tr1, which goes off. When contact B of S-2 is off, no voltage is applied to the base of Tr2, so goes on and L-1 lights up.

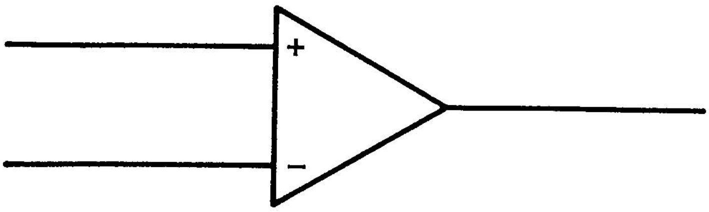
4. Both contact A and contact B of S-2 on
   When contact A and contact B of S-2 are both on, voltage is applied to the bases of Tr1 and Tr2. They both go off and L-1 is turned off.



NAND gate

6	FUNCTION OF COMPARATOR

A comparator compares a positive input with a negative input. If the positive input is greater than the negative input, the output goes high ("1"). In the opposite case, the output goes low ("0").

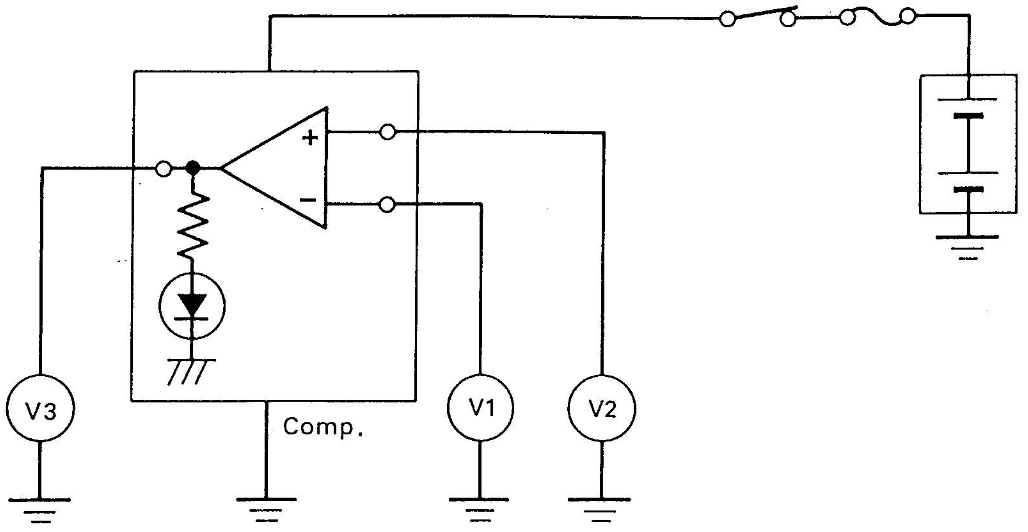


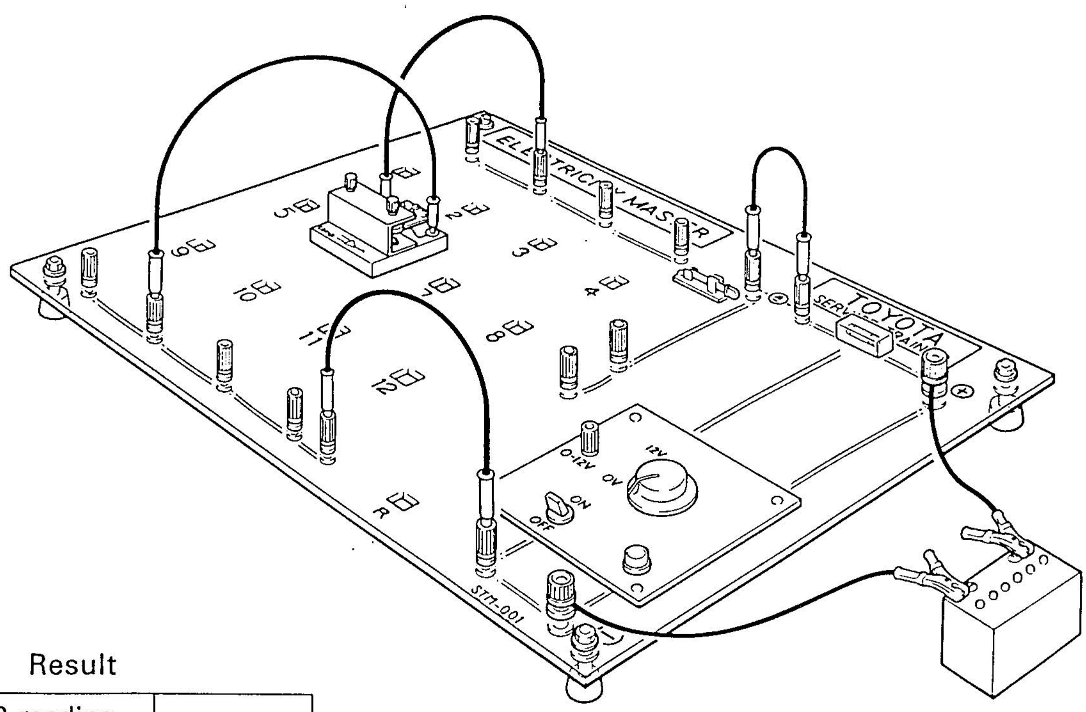
SYMBOL FOR COMPARATOR

CIRCUIT USING COMPARATOR

1. Make the circuit shown below using a comparator.

2. Adjust the voltage of IN(–) by setting V1 to 5 V. Check how the LED lights up as the voltage of IN(+) is gradually increased from the minimum level. Also read the voltage of V2 when the LED lights up.





3. Result

V2 reading when LED lights up:	(V)

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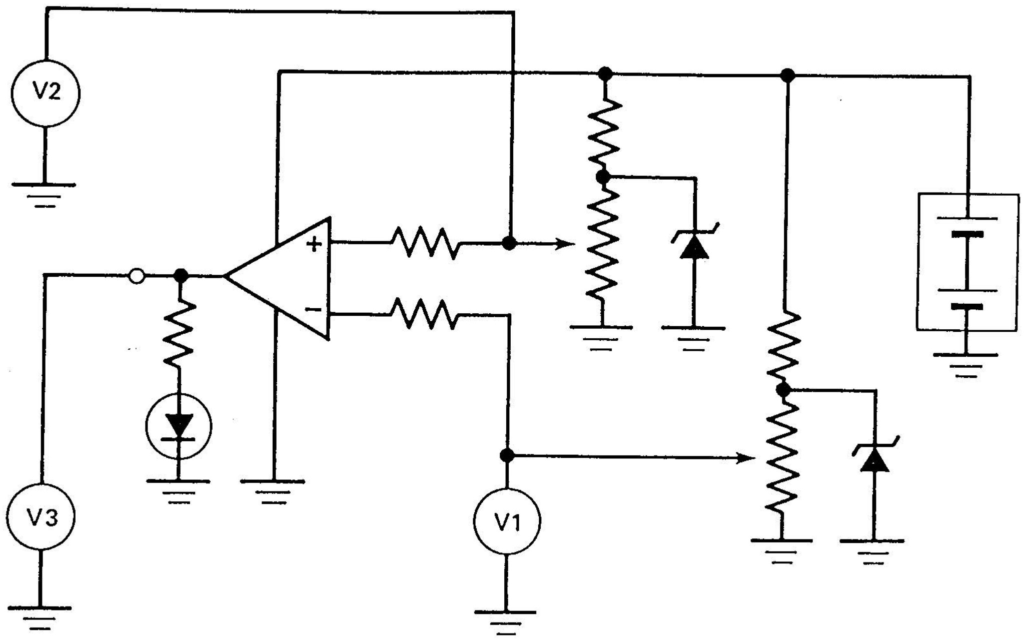
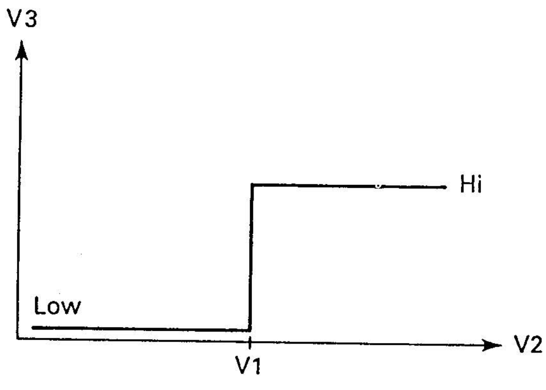
INTERNAL CONSTRUCTION OF COMPARATOR

When IN(–) voltage V1 is set to 5 V, the comparator output V3 goes low and the LED is turned off if the IN(+) voltage V2 is under 5 V. If V2 is over 5 V, comparator output V3 goes high and the LED lights up.



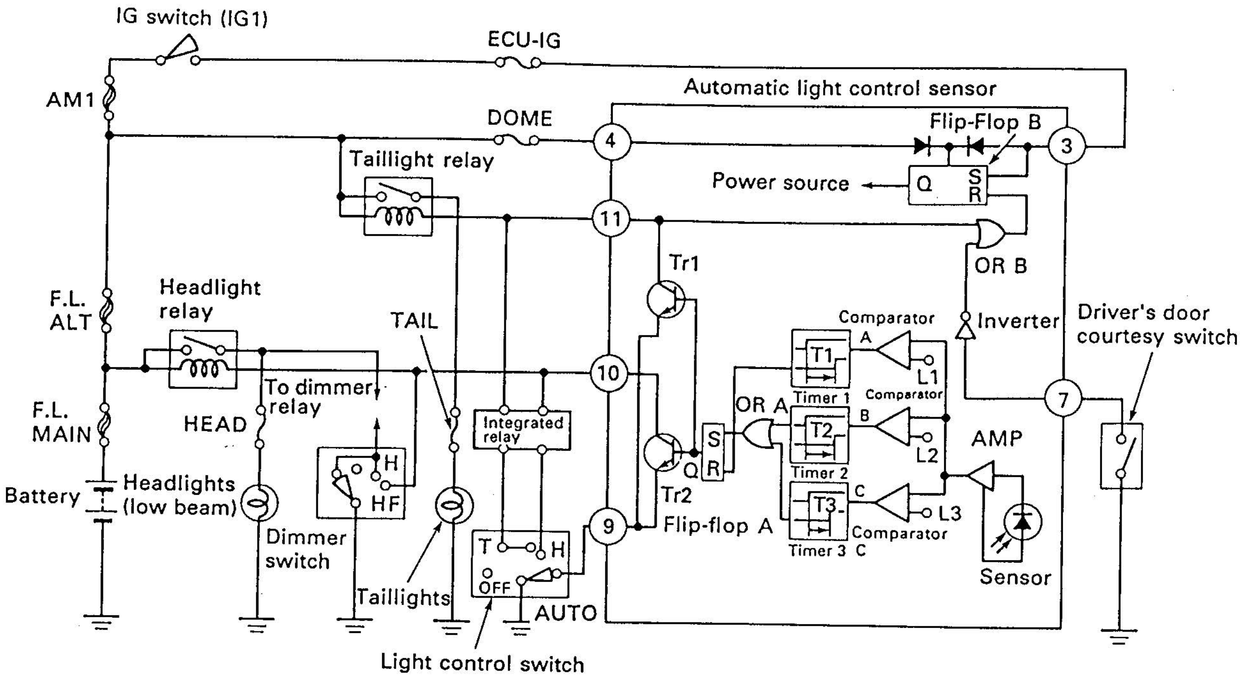
Comparator



Comparator output

EXAMPLE OF APPLICATION

The figure below shows an example of an application of a comparator combined with flip-flops (see pages 29 and 35).



OPERATION

(Light Control Switch in AUTO Position)

Ambient condition — bright (pattern 1)

When the ambient brightness is brighter than the thresholds (L2, L3) of comparators B and C, the comparator's output will remain at "0". Tr1 and Tr2 will therefore remain off, so the lights also remain unlit.

Ambient condition — momentary darkness (pattern 2)

During the daytime, if the vehicle is driven under a bridge, and the momentary darkness drops below threshold L2 of Comparator B, the comparator's output will change from "0" to "1". However, Timer 2 will output "0" while its delay T2 is active, so the lights will not turn on. If the ambient brightness remains under threshold L2 even after delay T2 has elapsed, the lights automatically turn on. But if it is brighter than threshold L1, the lights will not go on. However, if it becomes suddenly dark to the level below threshold L3 of Comparator C, the comparator's output will change from "0" to "1", and Timer 3 will also output "1" after delay T3. This will cause OR A and Flip-flop A to operate, turning on Tr1 and Tr2 and causing the lights to turn on.

Ambient condition — dark (pattern 3)
When the ambient condition is darker than threshold L2 of Comparator B, the comparator's output will change from "0" to "1". Timer 2 will also output "1" after delay T2. This will cause OR A and Flip-flop A to operate, turning on Tr1 and Tr2, and causing the lights to come on.

Ambient condition — bright momentarily (pattern 4)
While the lights are on, a sudden brightness above threshold L1 will cause Comparator A's output to change from "0" to "1". However, during delay T1, Timer 1 output will remain at "0", so the lights will remain lit.

Ignition switch turned off (pattern 5)
When the lights are lit, turning the ignition switch off will change the terminal ③ output from 12 V to 0 V. However, Flip-flop B's output will remain at "1", supplying current to the circuit, which causes the lights to remain lit.

Ignition switch turned off and driver's door open (pattern 6) ... Automatic Light Turn-off Function
While the circuitry is in the prevous state (pattern 5), opening the driver's door will turn on the door courtesy light switch, and the voltage at terminal ⑦ will drop from 12 V to 0 V. The inverter and OR B will therefore operate, changing the Flip-flop B output from "1" to "0", which cuts off the current in the circuit and turns off the lights.

Ignition switch turned off and driver's door opened and then closed (pattern 7)
While the circuitry is in the previous state (pattern 6), closing the driver's door will turn off the door courtesy light switch and the voltage at terminal ⑦ will rise from 0 V to 12 V. However, since Flip-flop B output will remain at "0", there will be no current flowing in the circuit. The lights will therefore remain off.

Ignition switch turned on with driver's door closed (pattern 8)
While the circuity is in the previous state (pattern 7), turning the ignition switch on will cause the terminal ③ voltage to rise from 0 V to 12 V. The Flip-flop B output will also change from "0" to "1". This will cause current to flow in the circuit, so if it is dark outside, the lights will turn on.

Driver's door opened again (pattern 9)
While the circuitry is in the previous state (pattern 8), opening the driver's door will turn on the door courtesy light switch. This will change the voltage at terminal ⑦ from 12 V to 0 V, activating the inverter and OR B. However, since the "Set" (S) input takes precedence in Flip-flop B, Flip-flop B will maintain the "1" output. Therefore, current will continue flowing in the circuit, and the lights will remain on as long as it is dark outside.

▶ **Specifications** ◀

On/off threshold for the lights	Off	(L1)	Approx. 1000 lux
	On	(L2)	Approx. 475 lux
		(L3)	Approx. 90 lux
On/off delay for the lights	Off	(T1)	Approx. 5 sec.
	On	(T2)	Approx. 5 sec.
		(T3)	Approx. 3 sec.

▶ **Operation pattern** ◀

●: Turned off ○: Turned on

No.	Light control switch	Ignition switch	Driver's door courtesy switch	Ambient light condition	Taillights, parking lights, etc.	Headlights (low-beam)
1	AUTO	ON	OFF	Bright	●	●
2	↑	↑	↑	Sudden darkness	●	●
3	↑	↑	↑	Dark	○	○
4	↑	↑	↑	Momentary brightness	○	○
5	↑	OFF	↑	Dark	○	○
6	↑	↑	ON	↑	●	●
7	↑	↑	OFF	↑	●	●
8	↑	ON	↑	↑	○	○
9	↑	↑	ON	↑	○	○

REFERENCE

Flip-flop

A flip-flop changes the output of terminal Q in accordance with the signals input to terminals R and S. The logic of this circuit is shown in the table at the right.
In Flip-flop B, "Set" is dominant. For this reason, when both inputs S and R are "1", it will output "1", having determined that it is in the "Set" condition.

▶ **Logic Table** ◀

Input signals		Output signal
S	R	Q
0	1	0
1	0	1
0	0	Hold
1	1	0 (Flip-flop A)
		1 (Flip-flop B)

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7 FUNCTION OF OPERATIONAL AMPLIFIER

An operational amplifier (opamp) amplifies input signals before they are output.

The opamp is basically used for providing the following three functions:

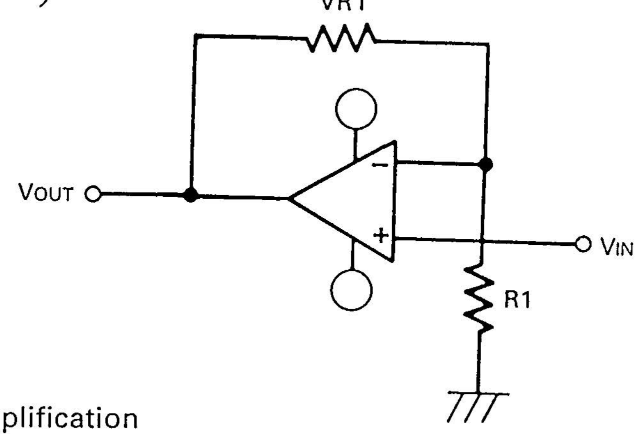
(1) In-phase amplification
(2) Antiphase amplification
(3) Differential amplification

1. In-phase amplification

When a signal is delivered to the positive input, the input and output will be in phase. This amplification is referred to as in-phase amplification.

In the figure shown below, the output voltage $V_{OUT} = \left(1 + \frac{VR1}{R1}\right) V_{IN}$

Where: $\left(1 + \frac{VR1}{R1}\right)$ is the amplification ratio or gain.

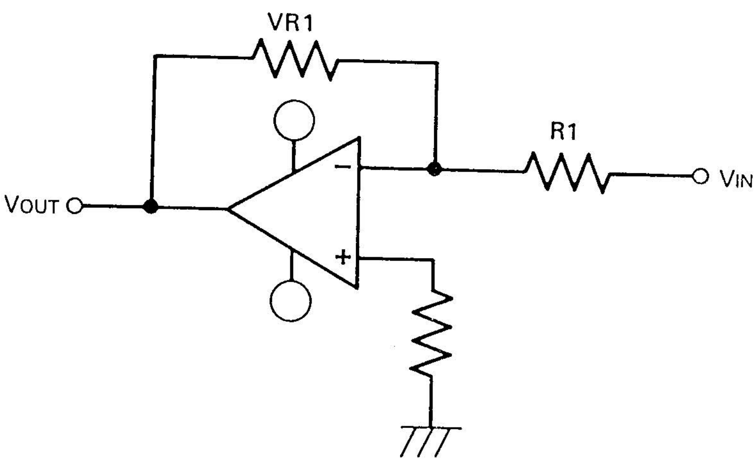


2. Antiphase amplification

When signal is delivered to the negative input, the input and output will be in antiphase. This amplification is referred to as antiphase amplification.

In the figure shown below, the output voltage $V_{OUT} = -\left(\frac{VR1}{R1}\right) V_{IN}$

Where: $-\left(\frac{VR1}{R1}\right)$ is the gain.

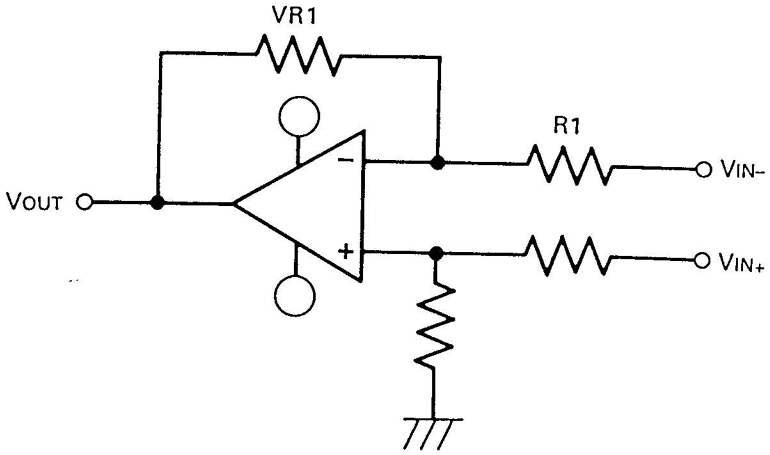


3. Differential amplification

This refers to the amplification of the difference between the positive input and the negative input.

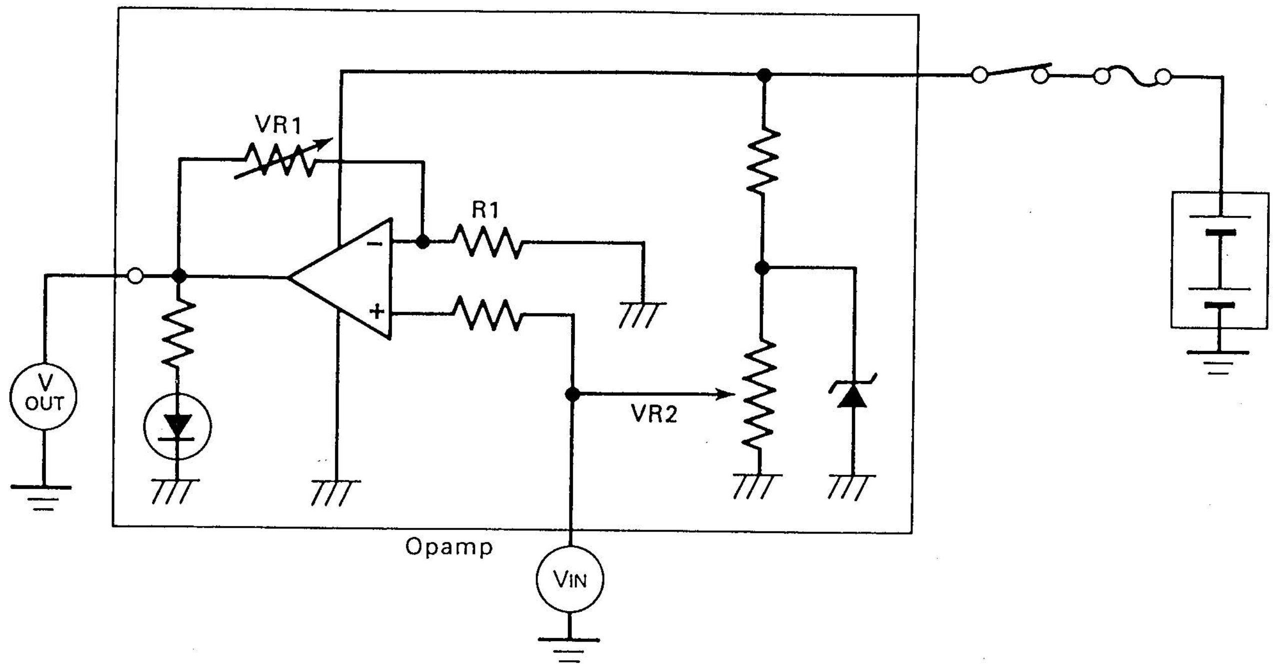
In the figure shown below, the output voltage $V_{OUT} = \frac{VR1}{R1}(V_{IN+} - V_{IN-})$

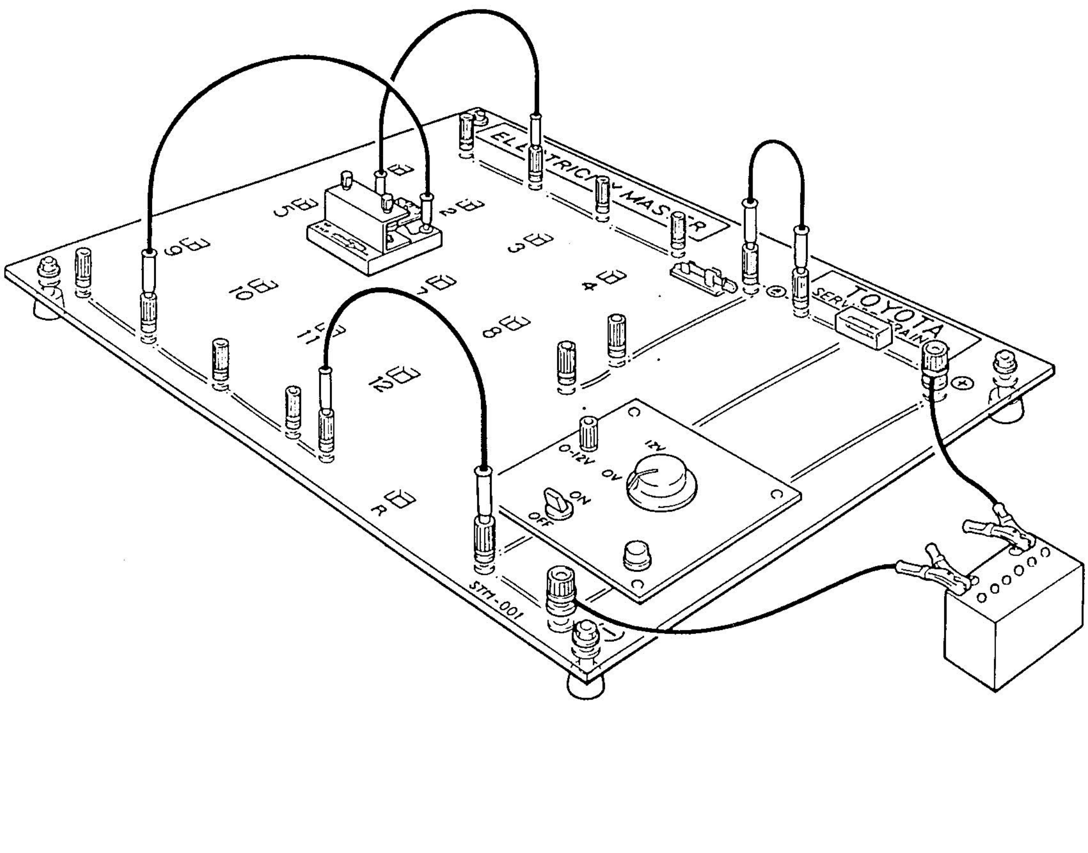
Where: $\frac{VR1}{R1}$ is the gain.



CIRCUIT USING OPERATIONAL AMPLIFIER

1. Make the circuit shown in the figure below using an opamp.





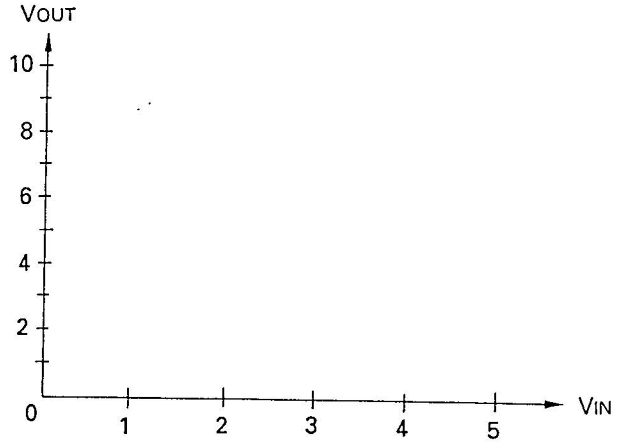
2. Increase the gain to 1/3 from the minimum. Increase the input voltage gradually from minimum. Measure the voltage of V_{OUT} when the V_{IN} voltage reaches the following values:

VIN	VOUT
1.0 V	V
2.0 V	V
3.0 V	V
4.0 V	V
5.0 V	V

3. Turn the gain control to medium. Turn the IN control gradually to maximum from minimum. Measure the voltage of V_{OUT} when the V_{IN} voltage reaches the following values:

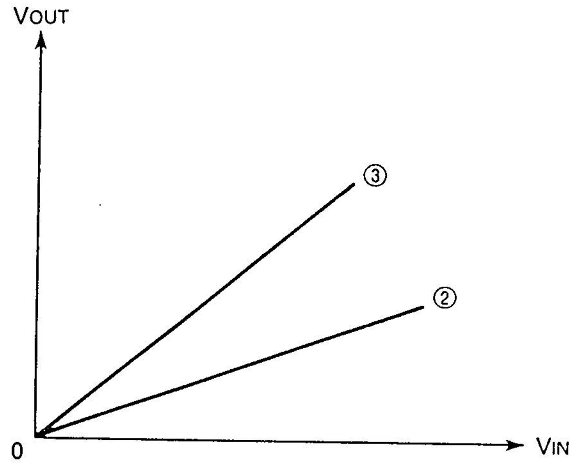
VIN	VOUT
0.5 V	V
1.0 V	V
1.5 V	V
2.0 V	V
2.5 V	V

4. Draw the result of measurements 2. and 3. on the graph.



When the gain control is turned 1/3 of the way from MIN, the gain $\left(1+\frac{VR1}{R1}\right)$ becomes smaller because the resistance of VR1 is small.

When the gain control is turned to medium, the gain increases because the VR1 resistance becomes larger than in the preceding situation. The input voltage V_{IN} and the output may be graphed as shown below:



The slope of each line ② and ③ represents the amplification ratio obtained in 2. and 3. on the previous page.

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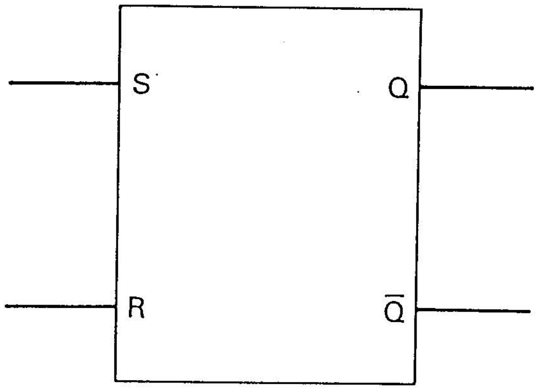
8	FUNCTION OF FLIP-FLOP

A flip-flop is a circuit that changes its state depending on the input sent to it. Most flip-flops have two outputs (called Q and $\overline{Q}$ — see reference) and two inputs (R and S, or J and K), though some have one or three inputs.

Flip-flops consist of networks of logic gates. For this reason, they are more complex than gates, and can be designed to deliver many different types of output. (Gates, on the other hand, can deliver only specified, stereotypical outputs: an AND gate, for example, can deliver a "1" only if both inputs are "1", but not in any other situation; flip-flops do not have such limitations.)



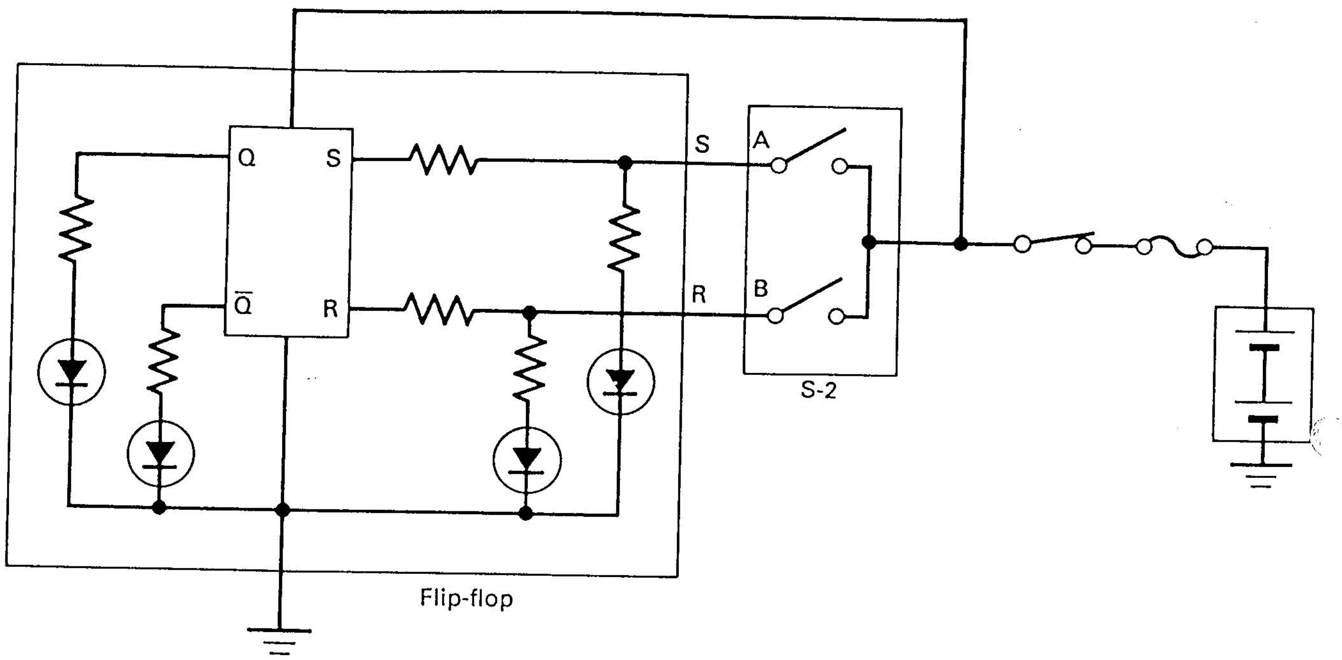
SYMBOL FOR FLIP-FLOP

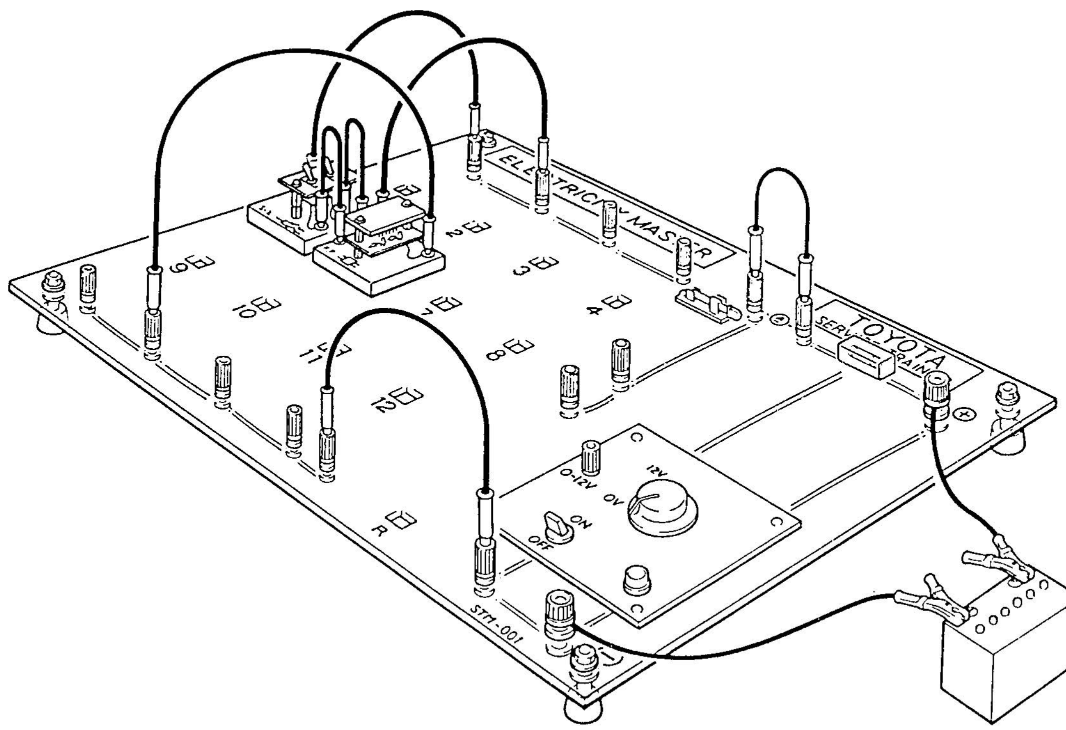
REFERENCE

"$\overline{Q}$" is read "Q bar" and means that it is the opposite of Q. For example, if Q is "1", then $\overline{Q}$ is "0". (In fact, a bar over the name of any input or output symbol means that it has the opposite value of its non-barred counterpart.)

1. Make a circuit as shown below using a flip-flop and S-2.

2. Check whether the LEDs associated with outputs Q and $\bar{Q}$ of the flip-flop light when contact A and contact B of S-2 are turned on (or off).





3. Results

S-2 (A)	S-2 (B)	Q	$\overline{Q}$
OFF	OFF		
OFF	ON		
OFF	OFF		
ON	OFF		
ON	ON		
ON	OFF		
OFF	OFF		

The flip-flop used in this circuit has inputs S and R and outputs Q and $\overline{Q}$. The relationship between the inputs and outputs is shown below.

(1) If input S is "0":

- Outputs Q and $\overline{Q}$ retain their previous value when input R is "0". (If they were "1" previously, their output is "1". If they were "0" previously, their output remains "0".)
- Output Q is "0" and $\overline{Q}$ is "1" when input R is "1".

(2) If input S is "1":

- Output Q is "1" and output $\overline{Q}$ is "0" when input R is "0".
- Output Q and $\overline{Q}$ are both "1" when input R is "1".

S	R	Q	$\overline{Q}$
0	0	Hold	Hold
0	1	0	1
1	0	1	0
1	1	1	1

EXAMPLE OF APPLICATION

This type of circuit is used for the Automatic Light Control. For details, see page 27.

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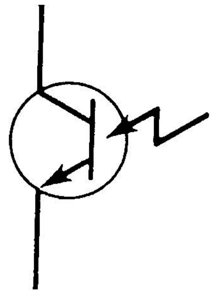
9	FUNCTION OF PHOTOTRANSISTOR

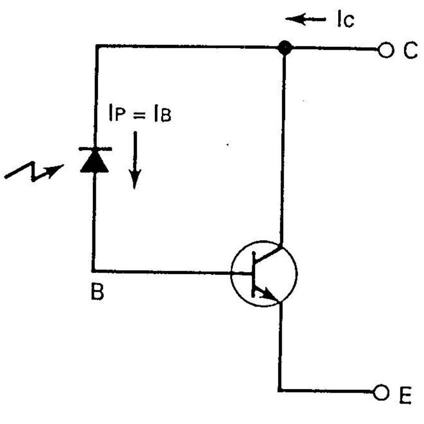
A phototransistor is a photoelectric element that converts optical signals into electrical signals.

As shown in the figure below, it is configured from a photodiode and an NPN transistor used for amplification.

When the photodiode is irradiated with the light, photoelectric current I_P flows to become the base current I_B of the transistor. The collector current I_C is $I_C = H_{FE} \cdot I_B$. Compared with the photoelectric current in a photodiode (see page 49), a greater output current can be obtained.



SYMBOL FOR PHOTOTRANSISTOR

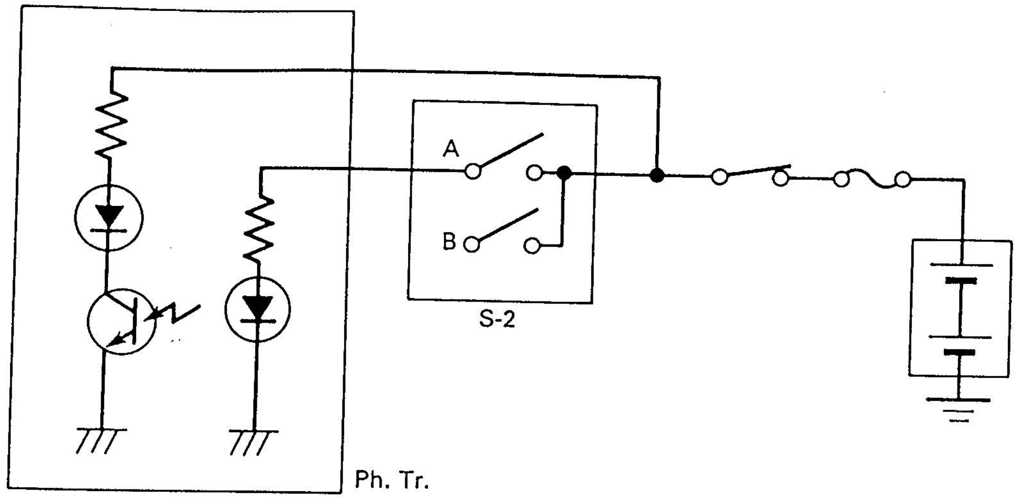


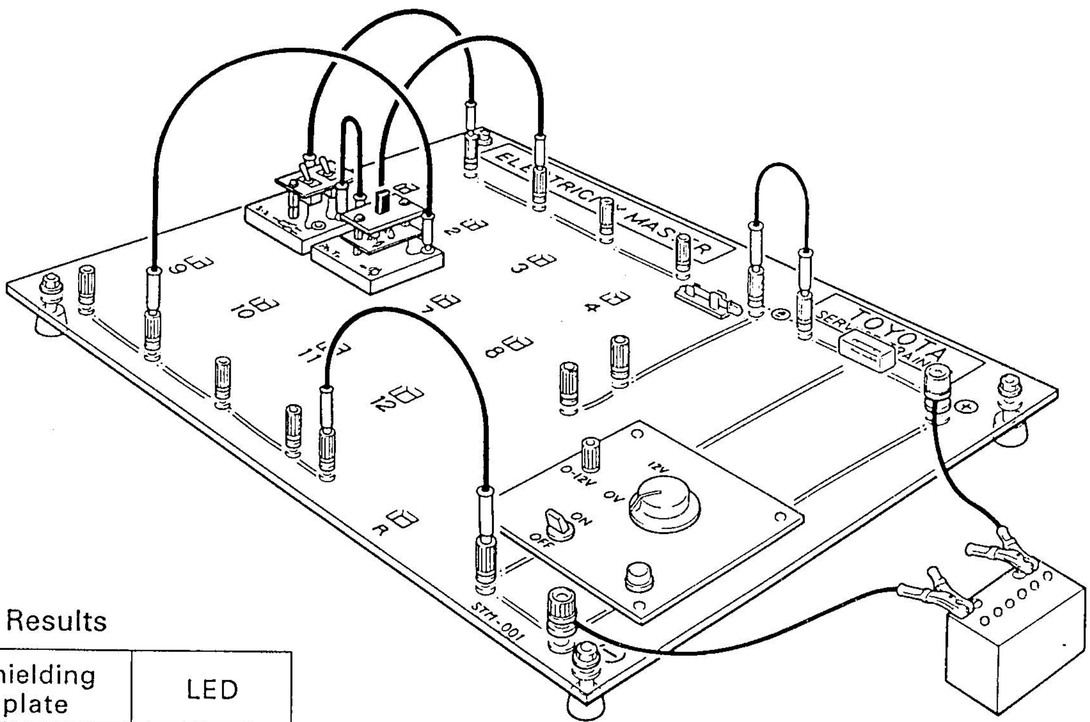
ACTUAL CONSTRUCTION
OF PHTOTRANSISTOR

CIRCUIT USING A PHOTOTRANSISTOR

1. Make the circuit shown below using a phototransistor and S-2.

2. Check the operation of the LED when contact A of S-2 is turned on and a shielding plate is inserted and removed.





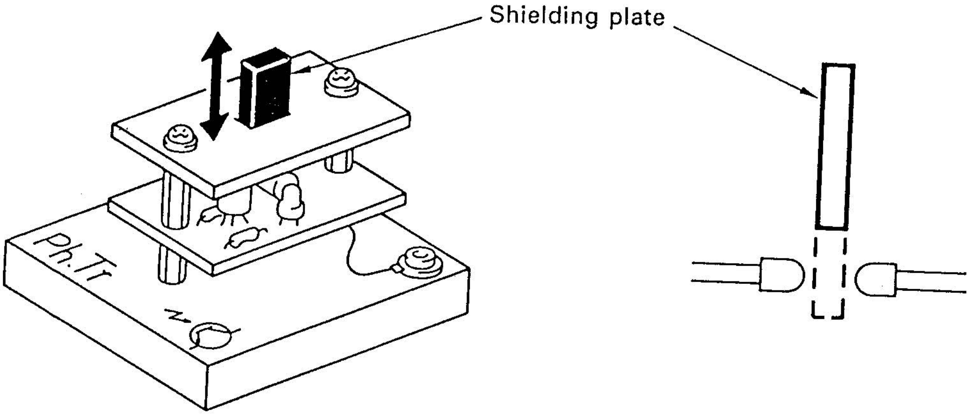
3. Results

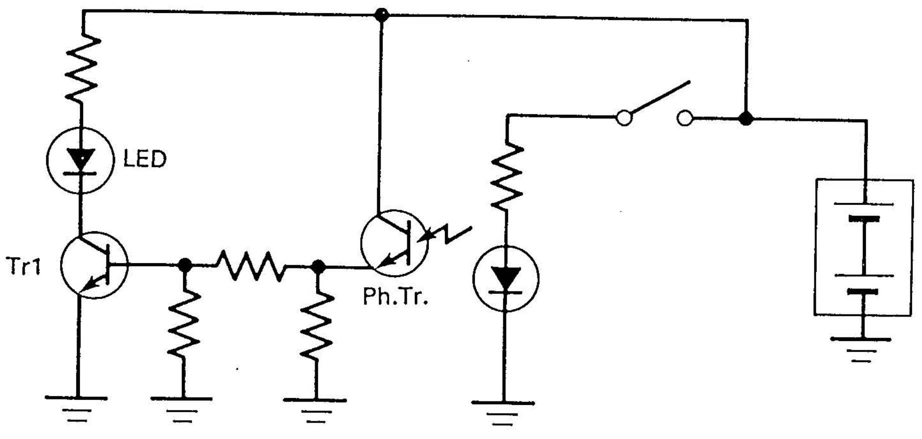
Shielding plate	LED
Inserted	
Removed	

In the circuit diagram shown below:

1. When the shielding plate is inserted, it prevents the phototransistor from being irradiated with light, causing it to go off. Current stops flowing to the base of the transistor Tr1, so Tr1 goes off, turning off the LED.

2. When the shielding plate is removed, the phototransistor is exposed to the light, so it goes on. Current therefore flows to the base of Tr1, turning it on and causing the LED to light up.





EXAMPLE OF APPLICATION

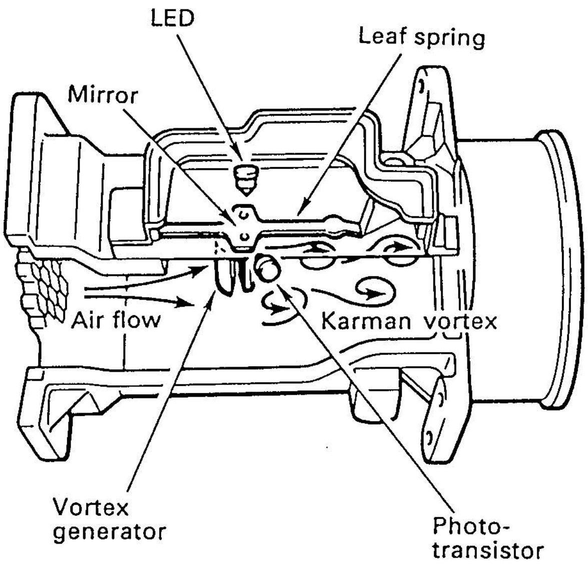
An air flow meter is shown below as an example of an application of a phototransistor.

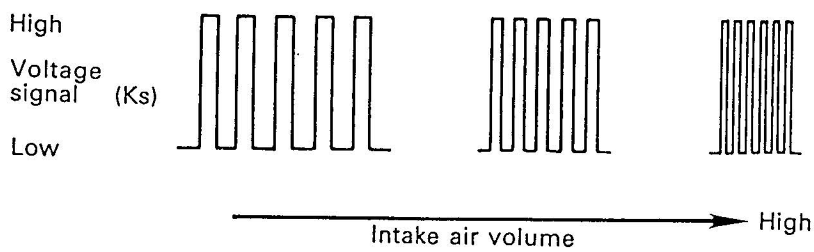
CONSTRUCTION AND OPERATION

The air flow meter is fitted with a vortex generator. As air flows past the vortex generator, vortices are generated at a frequency proportional to the velocity of the air flow. A calculation of the frequency can then determine the amount of air flow.

The vortices are detected by subjecting the surface of a piece of thin metal foil (the mirror) to the pressure of the vortices and optically detecting the oscillations in the mirror by means of an LED and a phototransistor.

The intake air volume signal (Ks) is the pulse signal. When the intake air volume is low, this signal has a low frequency. When the intake air volume is high, it has a high frequency.

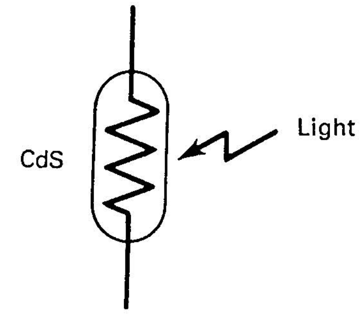




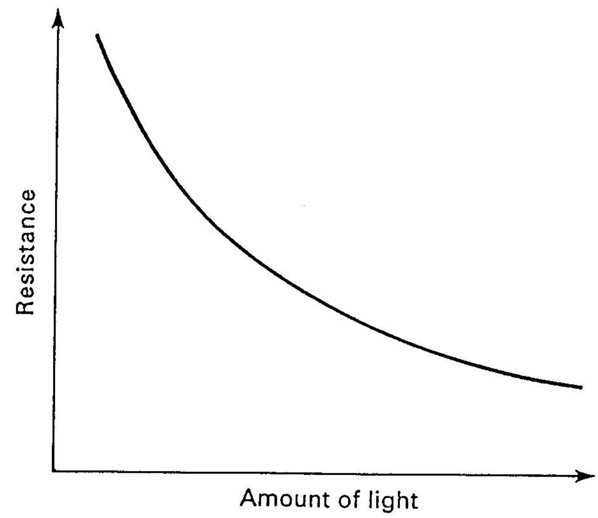
10 FUNCTION OF PHOTOCONDUCTIVE CELL

A photoconductive cell is a photoelectric element whose resistance varies according to the amount of light falling on it. It is also called a cadmium cell (abbreviated CdS, for "cadmium sulfide", one of the substances used in manufacturing such cells.)

As shown in the figure below, the greater the amount of light, the smaller the resistance.



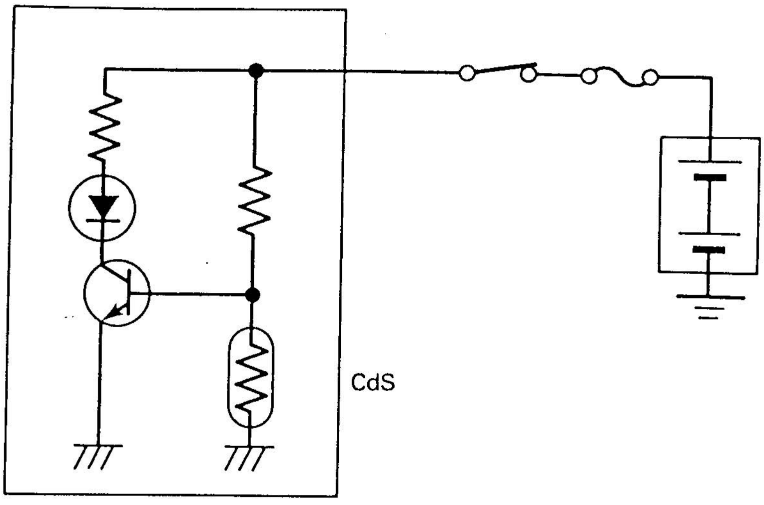
SYMBOL FOR CdS

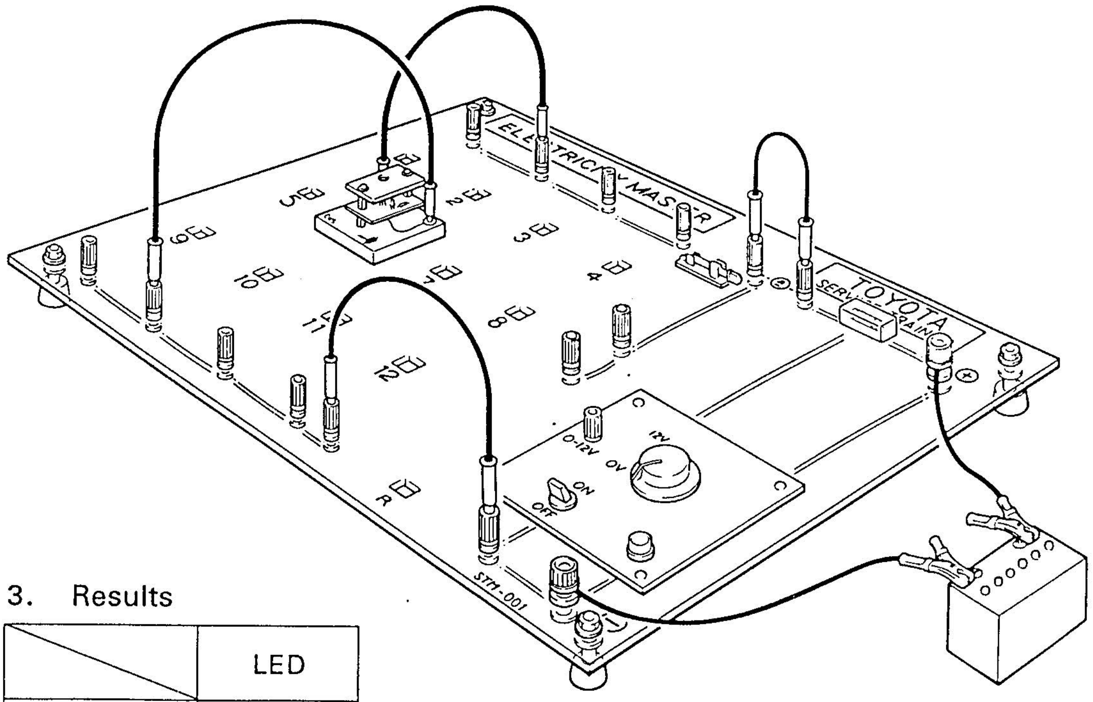


CIRCUIT USING PHOTOCONDUCTIVE CELL

1. Make the circuit shown below using a photoconductive cell.

2. Check whether the LED lights up when the hole in the cover of the CdS is covered (or uncovered) with your hand.

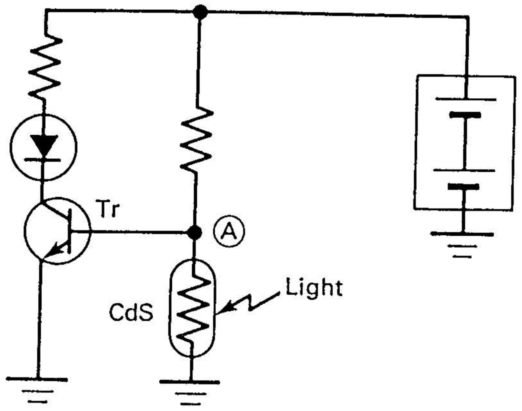




3. Results

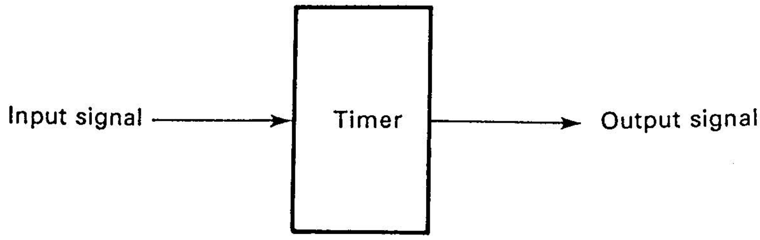
	LED
Hole covered	
Hole uncovered	

When the hole in the cover is covered, the light to the CdS is shut off, increasing the resistance of the CdS. This causes the voltage at point Ⓐ to rise and base current to flow to the transistor Tr. Tr goes on as a result, and the LED lights up.
When the CdS is not shielded from the light, the resistance of the CdS falls, lowering the voltage at point Ⓐ and turning the transistor and the LED off.



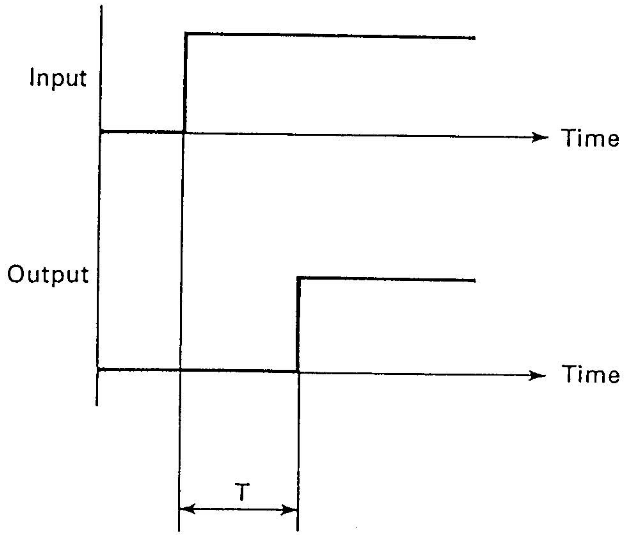
11 FUNCTION OF TIMER

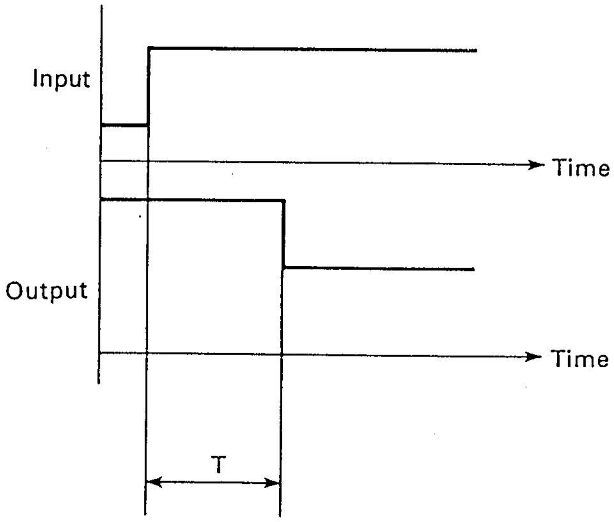
A timer delays the output of input signals for a prescribed length of time.



SYMBOL FOR TIMER

As shown in the graphs below, when a signal is input, it is output after a delay of time T.

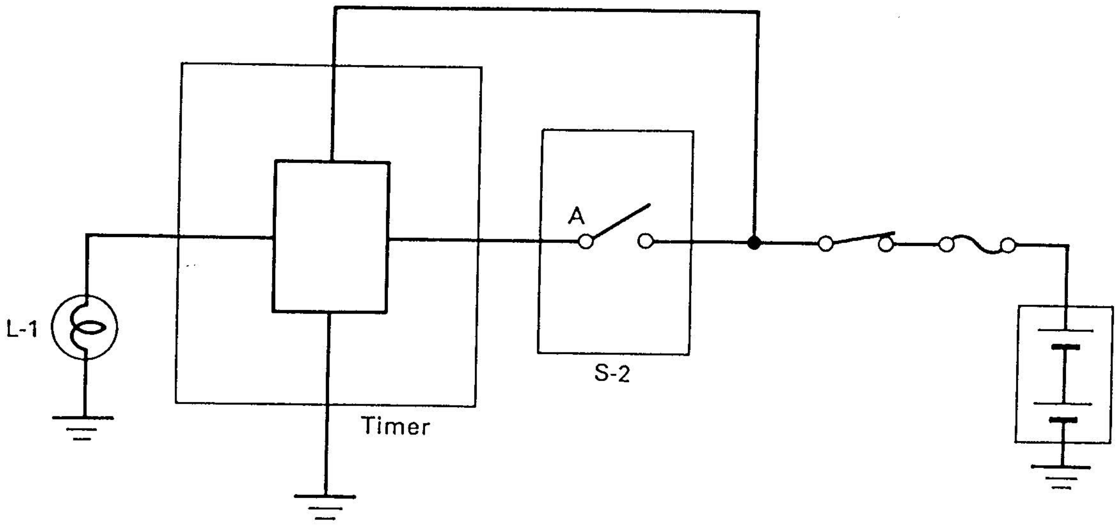


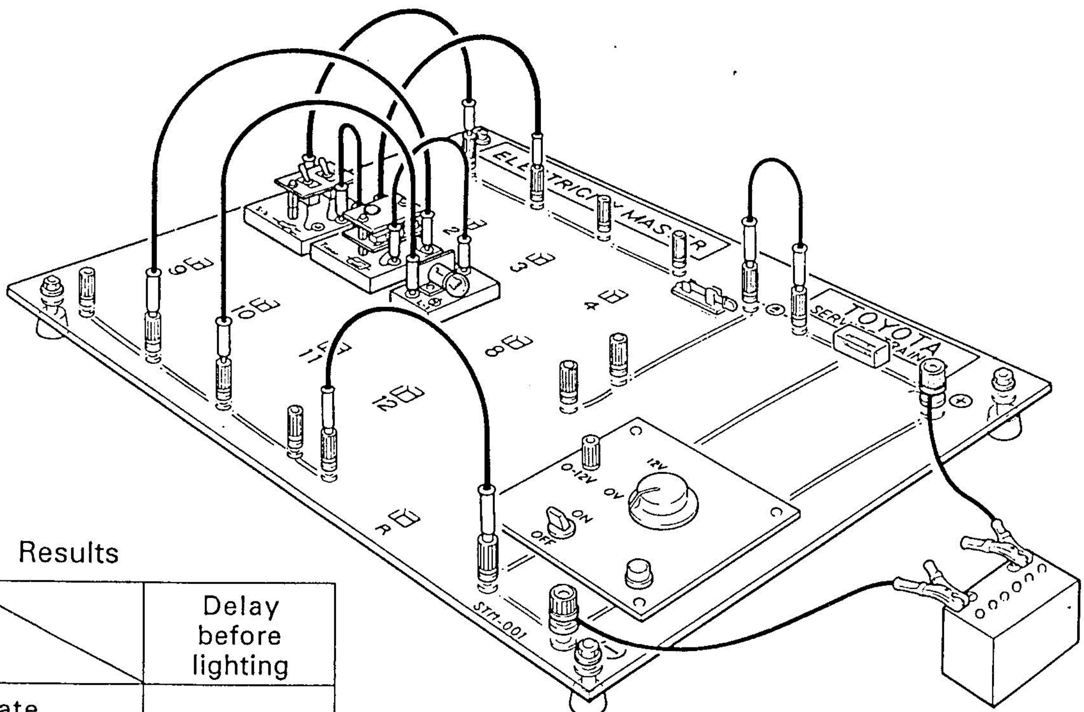


CIRCUIT USING TIMER

1. Make the circuit shown below using a timer, S-2, and L-1.

2. Measure the time required for L-1 to light up when contact A of S-2 is turned on in the two states shown below:
   ① Timer control turned fully counterclockwise.
   ② Timer control set to medium.





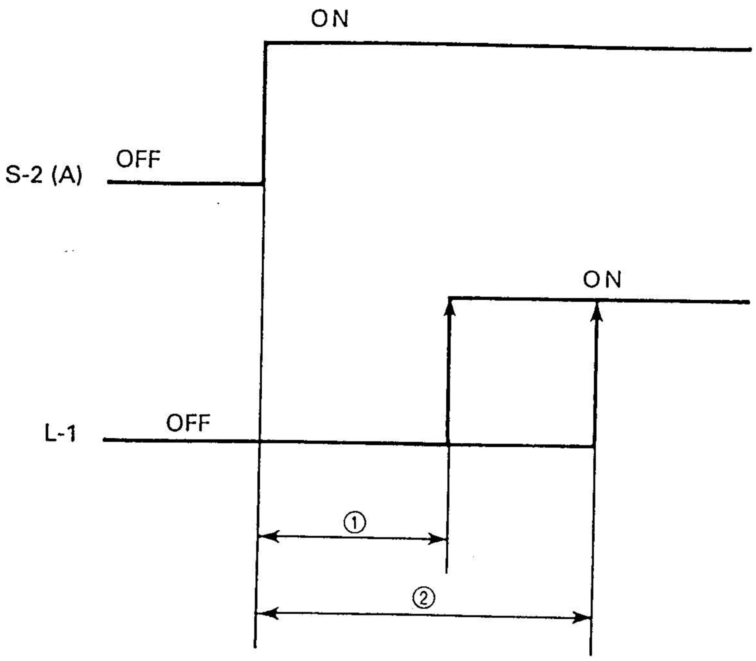
3. Results

	Delay before lighting
State shown in ①	
State shown in ②	

1. In state ①, since the timer is set for only a short delay, L-1 lights up shortly after contact A of S-2 is turned on.

2. In state ②, since the timer is set for a long delay, it takes a longer time for L-1 to light up than in state ①.

   Note: If contact A of S-2 is turned on, but is turned off again before L-1 lights up, the timer will be reset.



EXAMPLE OF APPLICATION

As an example of the use of a timer, an automatic light control can be mentioned. (For details, see page 27.)

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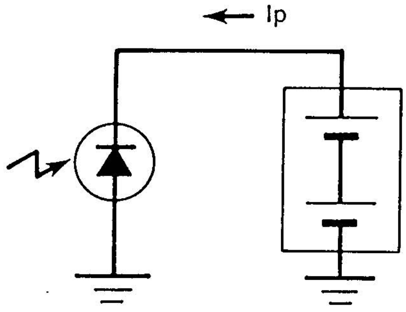
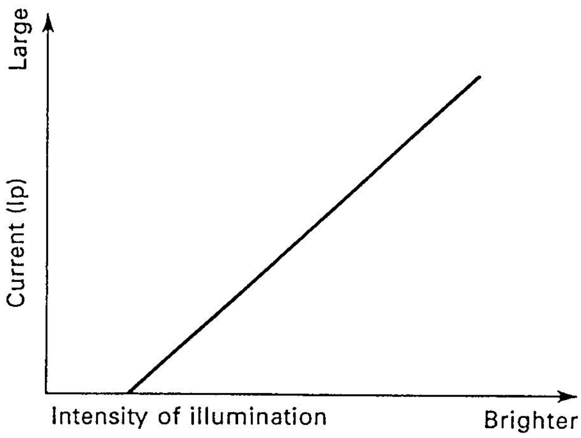
12 FUNCTION OF PHOTODIODE

A photodiode is a type of photoelectric conversion element in which electrical current flows in proportion to the amount of light falling on it.



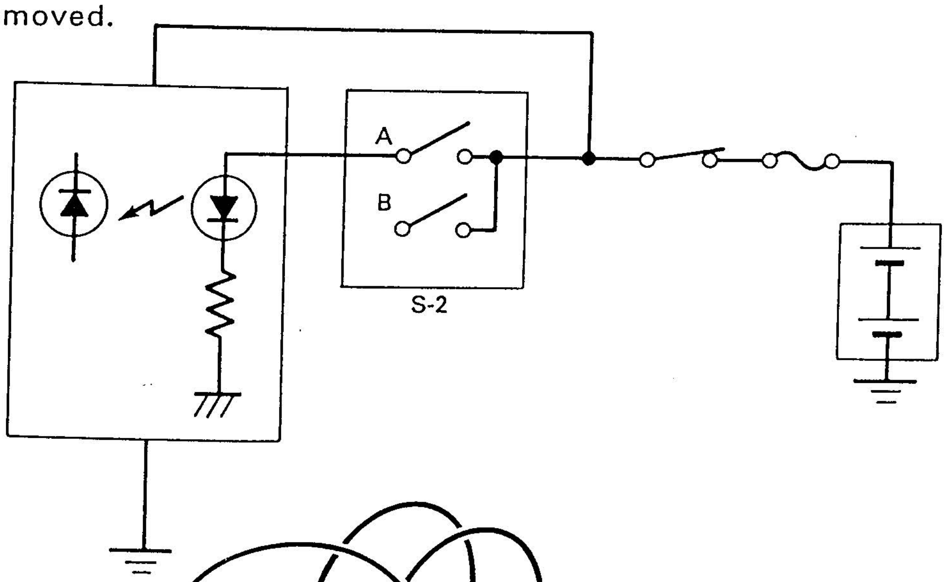
SYMBOL FOR PHOTODIODE

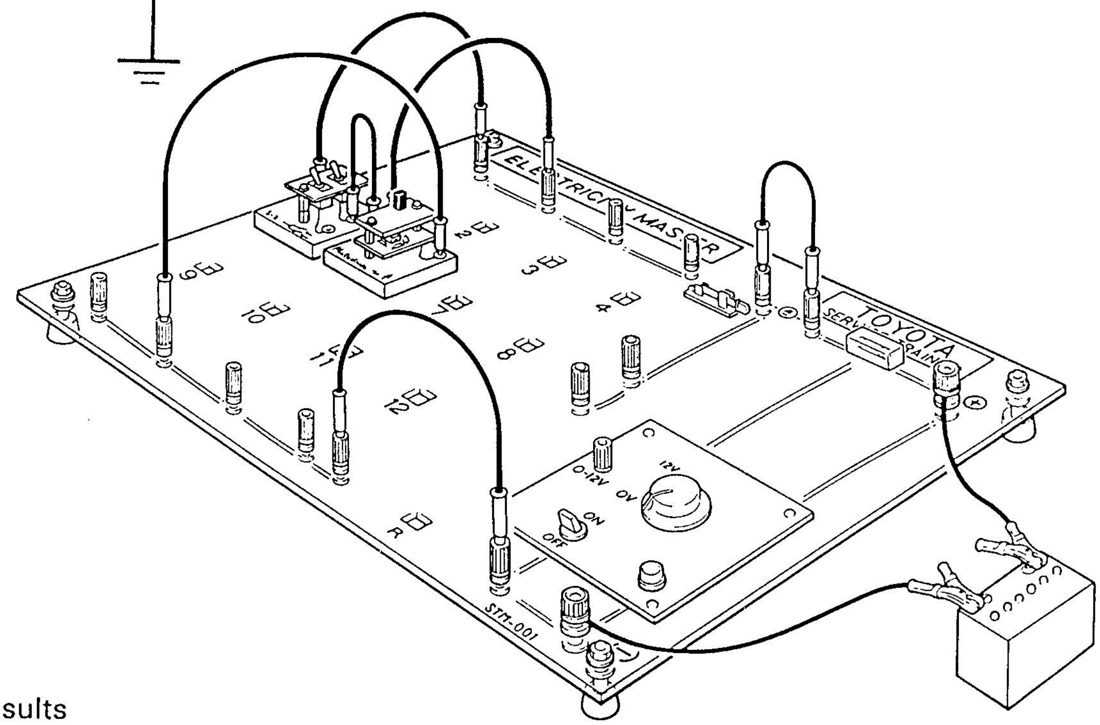


CIRCUIT USING PHOTODIODE

1. Make the circuit shown below using a photodiode and S-2.

2. Turn contact A of S-2 on with the shielding plate inserted.
   Check whether the LED lights up. Then check it when the shielding plate is slowly removed.



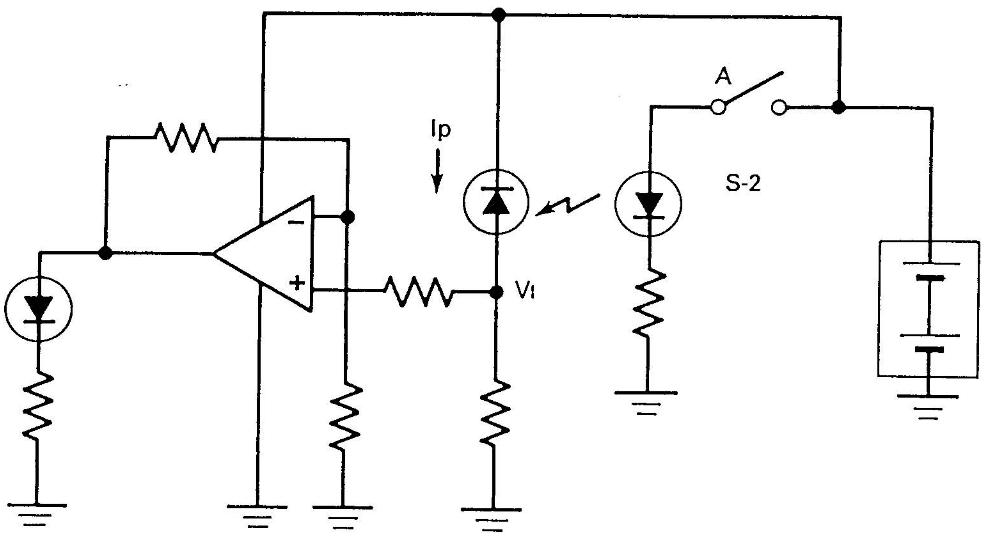


3. Results

State of LED with shielding plate inserted	State of LED while shielding plate is slowly removed

1. In the circuit diagram shown below, when "A" of S-2 is turned on, the LED lights up. A photodiode is installed opposite the LED. When the shielding plate is inserted, light from the LED is prevented from irradiating the photodiode, so current Ip does not flow. Therefore, input to the opamp is "0" and the LED does not light up.

2. As the shielding plate is slowly removed, the amount of light striking the photodiode gradually increases. Current Ip therefore gradually increases, increasing the voltage at point VI. Input to the opamp therefore increases also. This in turn increases the output from the opamp, and the LED gradually becomes brighter.



EXAMPLE OF APPLICATION

As an example of an application of a photodiode, an automatic light control may be mentioned. (See page 27.)

13	FUNCTION OF THERMISTOR

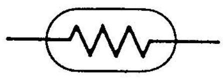
A thermistor is a device made from a material whose electrical resistance sharply fluctuates in accordance with temperature.

There are the following three types of thermistor:

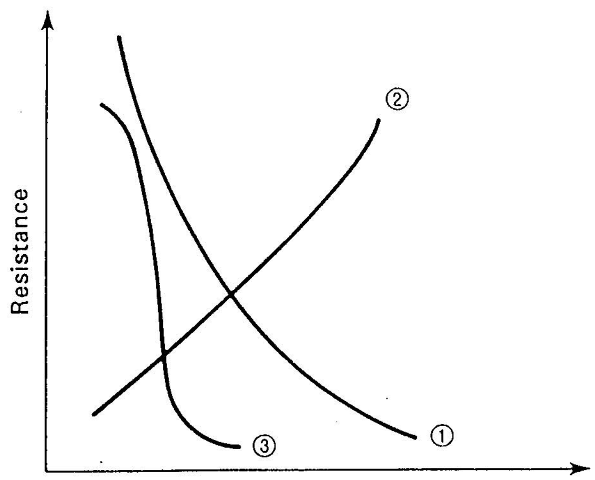
① Negative Temperature Coefficient (NTC) thermistor, whose resistance sharply *decreases* with the rise in temperature.

② Positive Temperature Coefficient (PTC) thermistor, whose resistance sharply *increases* with the rise in temperature.

③ Critical Temperature Resistor (CTR) thermistor, whose resistance decreases at a specific temperature.



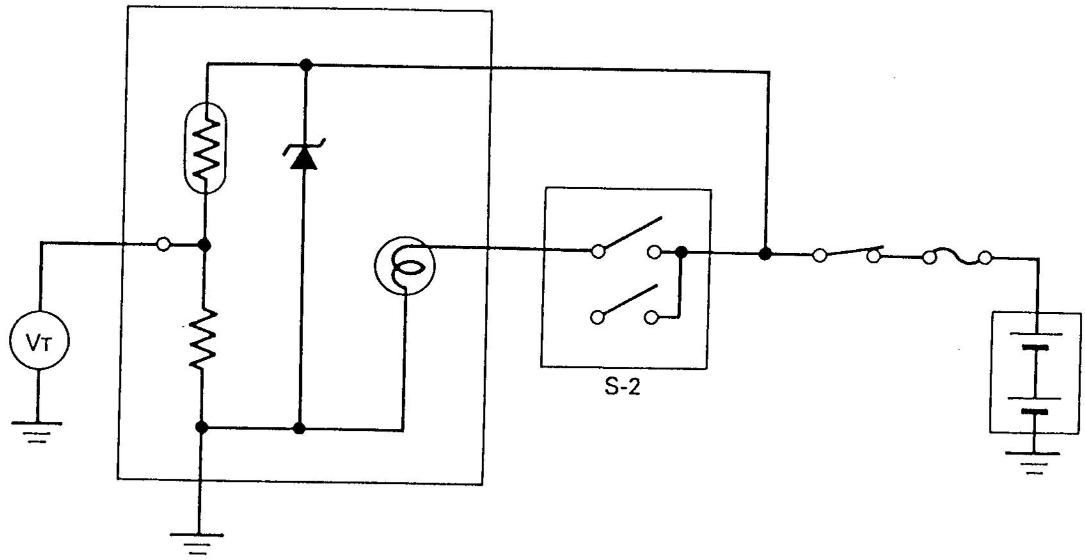
SYMBOL FOR THERMISTOR

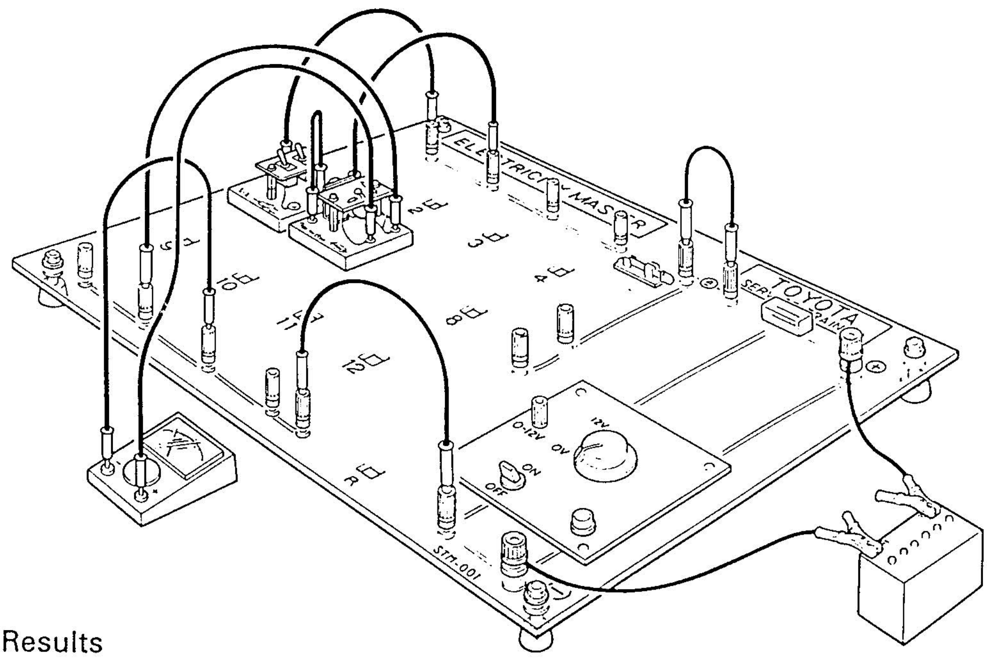


CIRCUIT USING THERMISTOR

1. Make the circuit shown below using a thermistor and S-2.

2. Measure the voltage V_T from the time the lamp lights up by turning on contact A of S-2; check the voltage fluctuation.

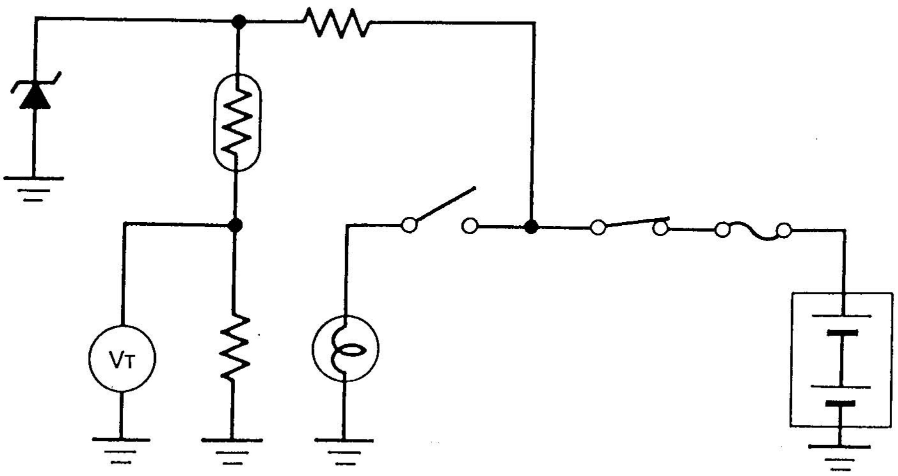




3. Results

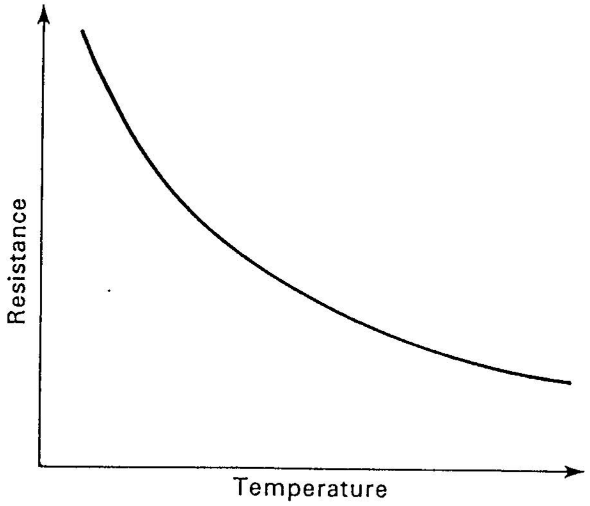
Time (sec)	Before turning on contact A of S-2	10	20	40	60	90	120
V_T (V)							

The heat from the lamp causes the temperature of the thermistor to rise. This results in a drop in the resistance of the thermistor, which causes the voltage V_T to rise.



EXAMPLE OF APPLICATION

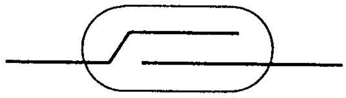
A thermistor is used as the water temperature sensor in the radiator. An NTC type is used for this sensor as shown in the graph.



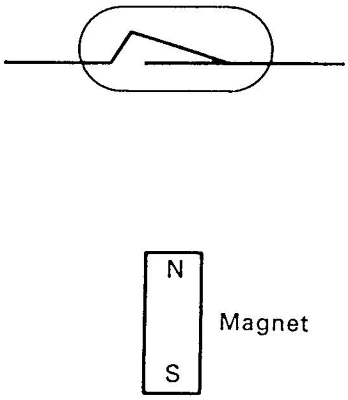
14 FUNCTION OF REED SWITCH

A reed switch is turned on and off by magnetic force.

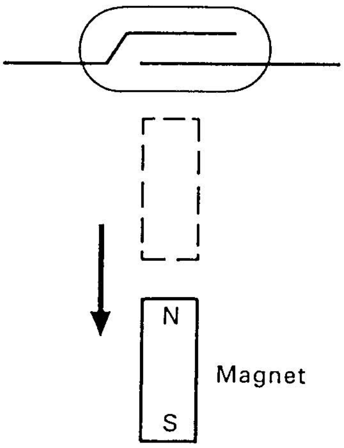
As shown in the figure below, when a magnet is placed near the reed switch, the contact of the switch is attracted, turning it on. When the magnet is moved away the contact opens.



SYMBOL FOR REED SWITCH



Reed switch on

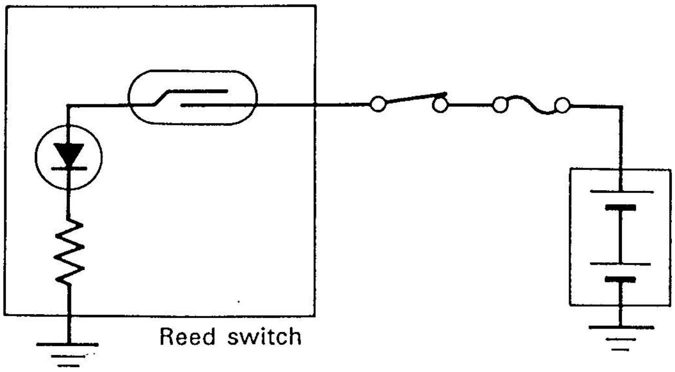


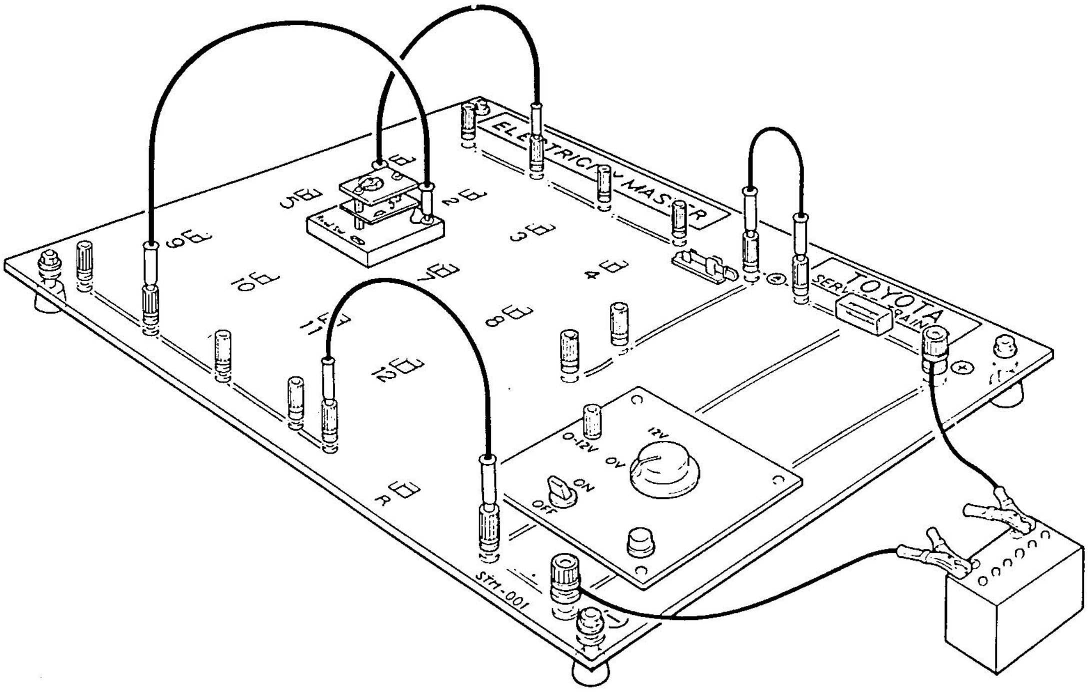
Reed switch off

CIRCUIT USING REED SWITCH

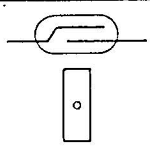
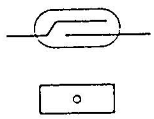
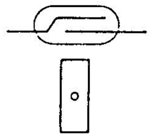
1. Make the circuit shown below using a reed switch.

2. Check whether the LED lights up when the magnet is turned by hand.





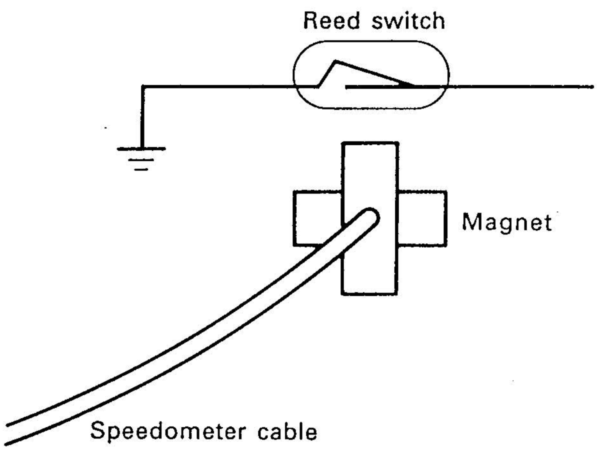
3. Results

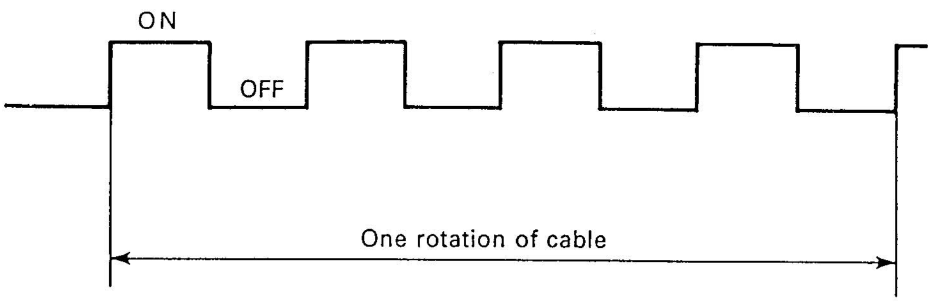
Position of reed switch and magnet			
LED			

As the magnet is rotated, the reed switch goes on when the switch and magnet are at right angles to each other. The reed switch goes off when it is parallel to the magnet.

EXAMPLE OF APPLICATION

A reed switch is used in the vehicle speed sensor.
The speedometer cable rotates the magnet and causes it to open and close the reed switch, generating pulse signals in accordance with the vehicle speed.





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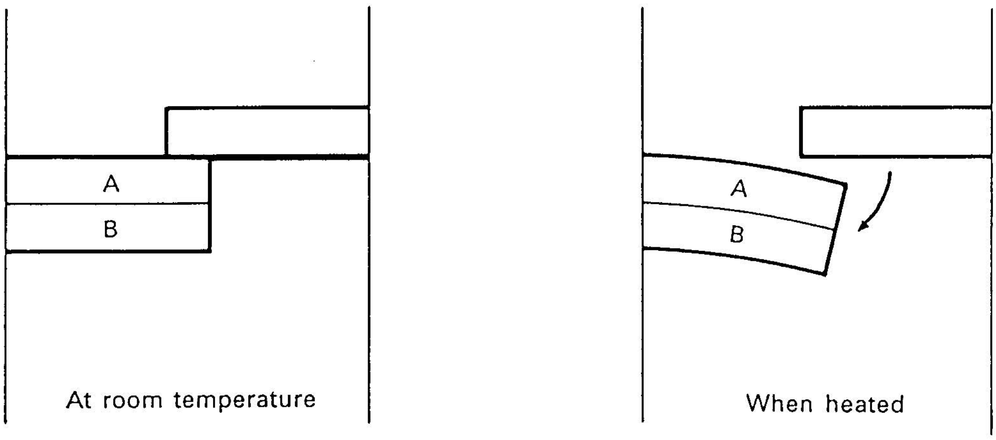
15 FUNCTION OF BIMETAL SWITCH

A bimetal switch is a metal strip manufactured by welding together two strips of metal having different coefficients of thermal expansion. As shown in the figures below, when a bimetal switch is heated above room temperature, a difference is created in the thermal expansion of each metal strip, causing it to bend in the direction of strip B, which has a smaller thermal expansion coefficient. This turns the contact off.

SYMBOL FOR BIMETAL SWITCH



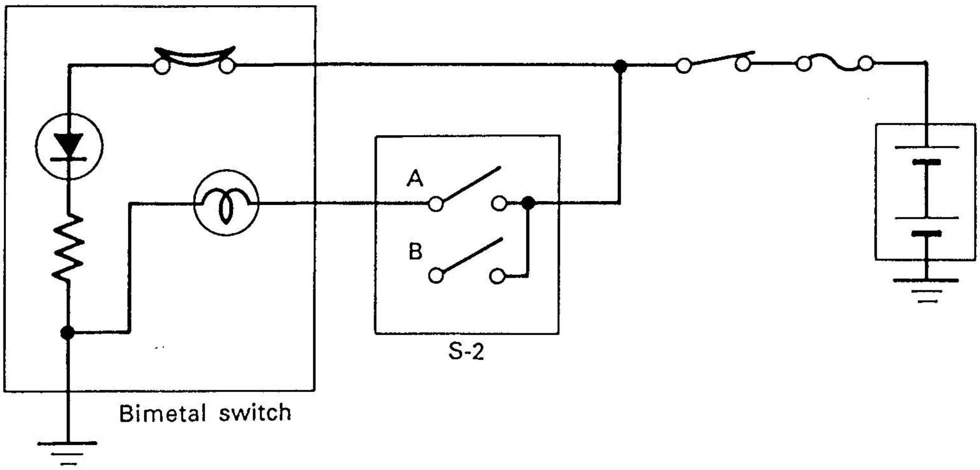
At room temperature

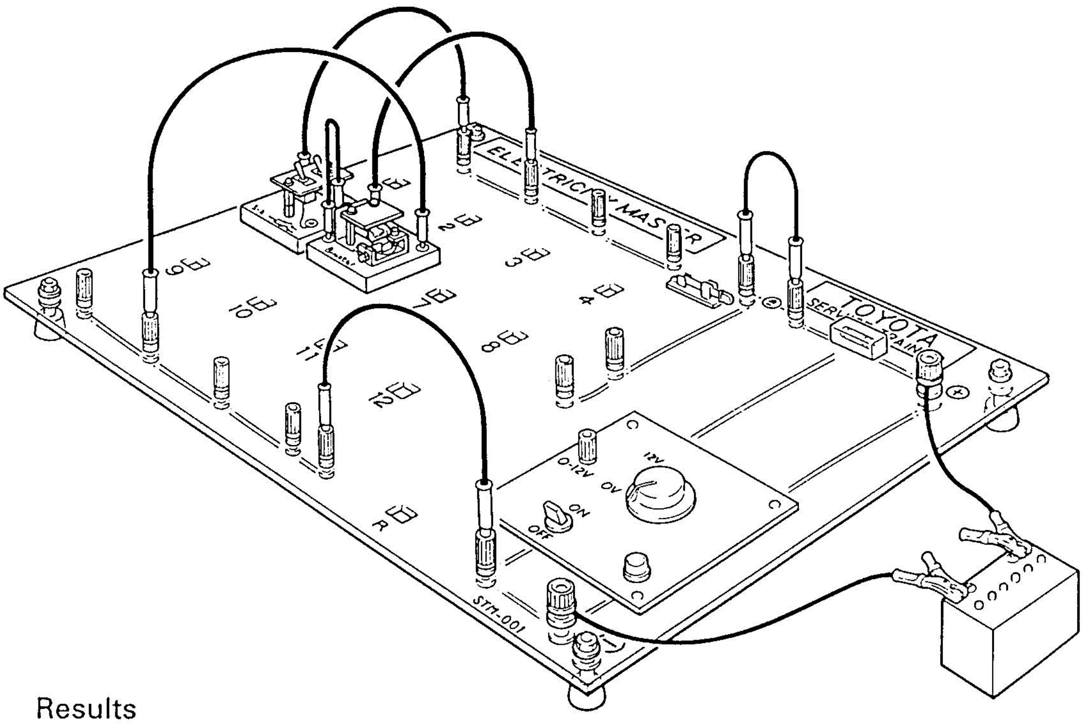
When heated

CIRCUIT USING BIMETAL SWITCH

1. Make the circuit shown below using a bimetal switch and S-2.

2. Check whether the LED lights up after turning on contact A of S-2.





3. Results

LED before contact A is turned on	LED after contact A is turned on

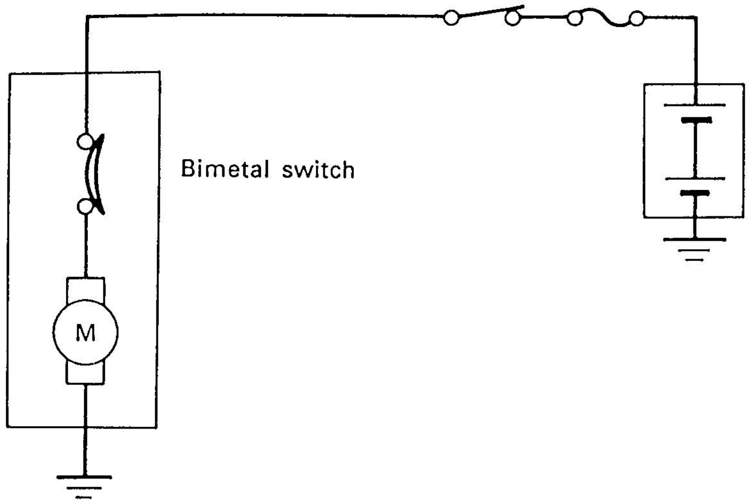
When contact A of S-2 is turned on, the lamp lights up, heating the bimetal switch. When the element reaches a predetermined temperature, the contact opens and the LED goes off.

When contact A of S-2 is turned off, the lamp goes off. The bimetal switch cools off, causing the contact to close and the LED to light up.

EXAMPLE OF APPLICATION

Some bimetal switches are incorporated into electric motors as protection against overheating.

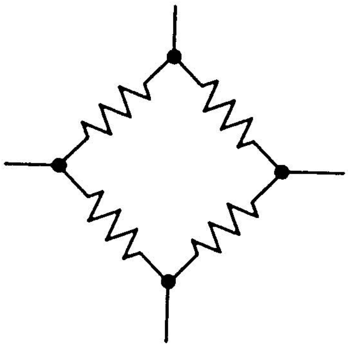
When an overcurrent flows to the motor, the temperature of the switch itself, as well as the heat from the motor, cause the contact to open, shutting the current off. The motor therefore stops. When the temperature drops, the contact closes again, and the motor starts operating once more.



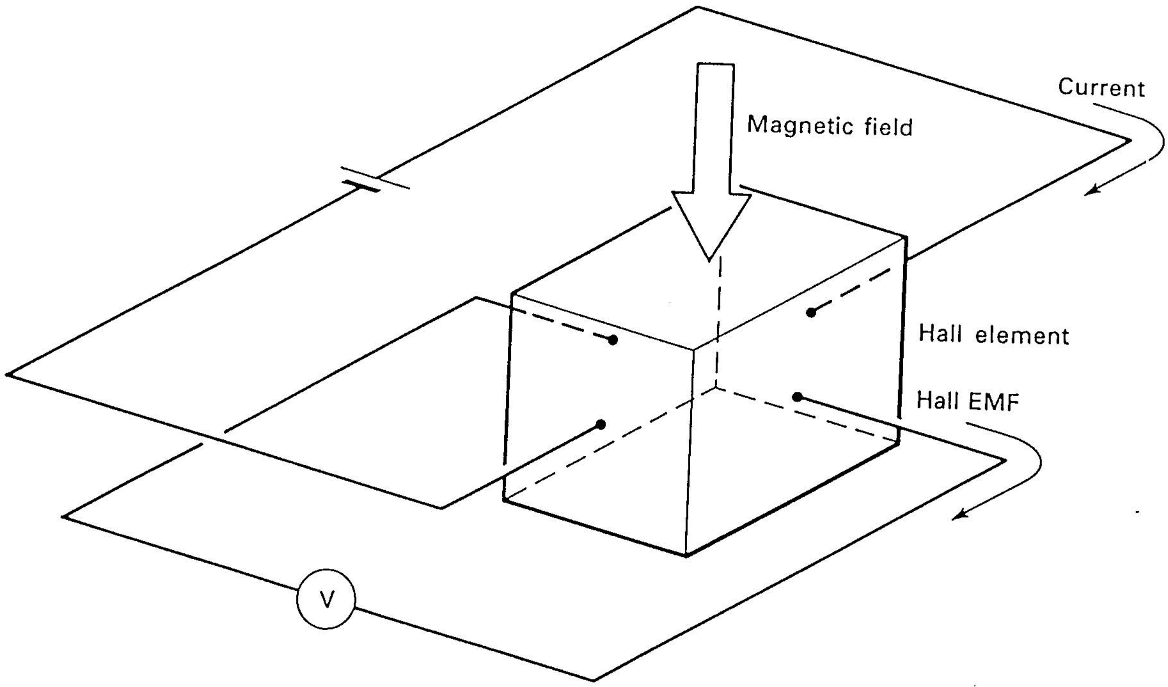
16	FUNCTION OF HALL ELEMENT

If a current-carrying semiconductor is placed in a magnetic field and oriented so that the field is at right angles to the direction of the current, an electric field, and therefore an electromotive force, will be produced in the conductor. This field (and the EMF) will be oriented at right angles to both the current and the magnetic field. This phenomenon is called the Hall effect.

A Hall-effect device, or Hall element, refers to an element that uses the Hall effect for detecting the intensity of a magnetic field as an electric signal. The size of the electromotive force is proportional to the intensity of the magnetic field and the strength the current.



SYMBOL FOR HALL ELEMENT



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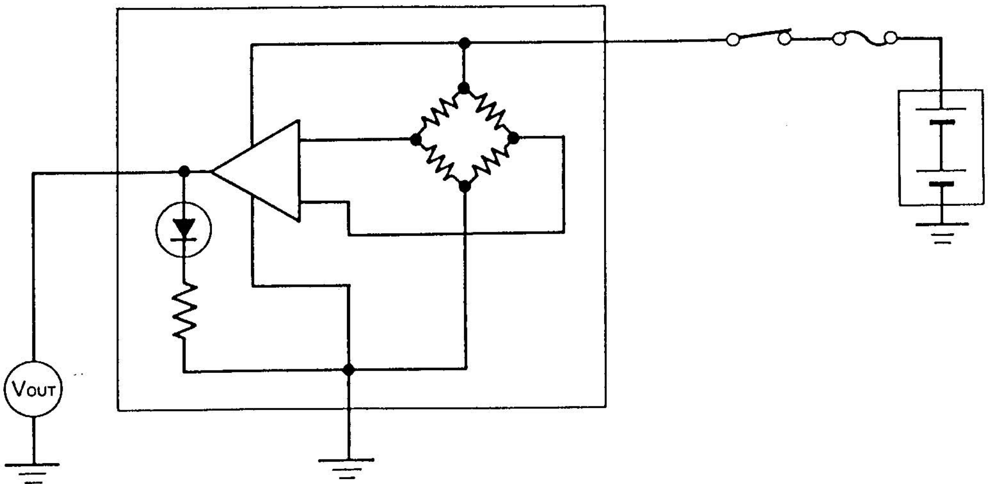
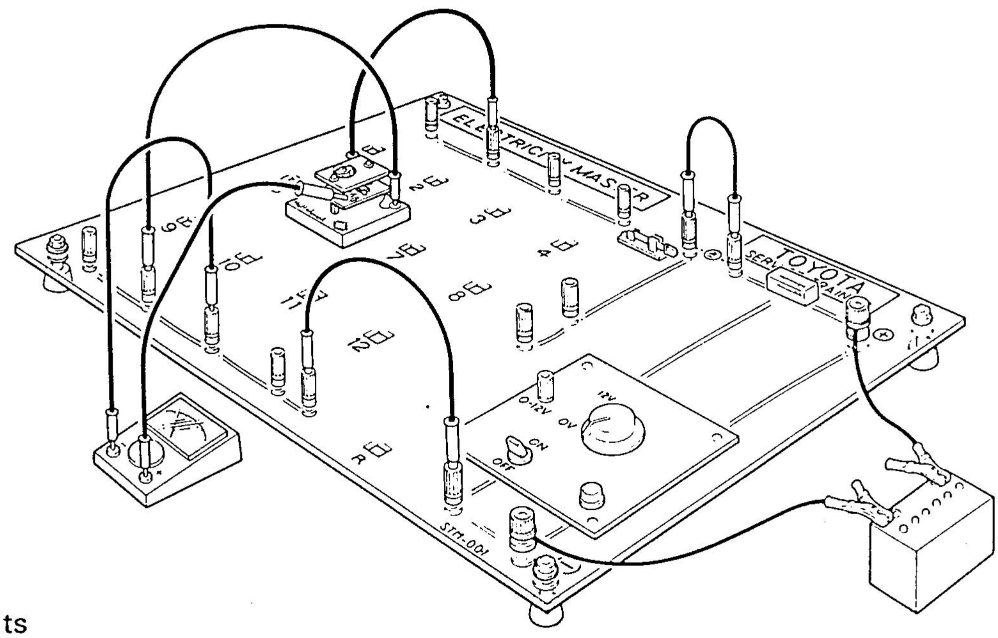
CIRCUIT USING HALL ELEMENT

1. Make the circuit shown below using a Hall element.

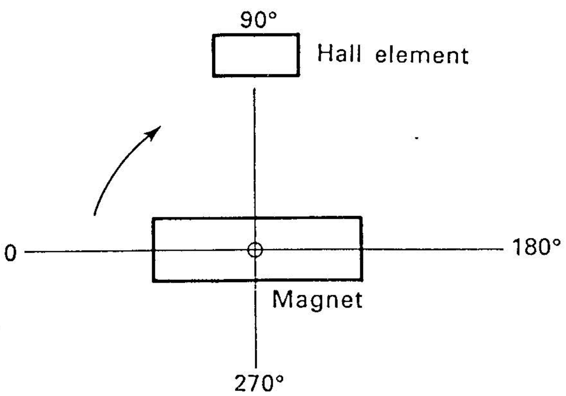
2. Check the relationship between the angle of the magnet and the output voltage when the magnet is slowly rotated.



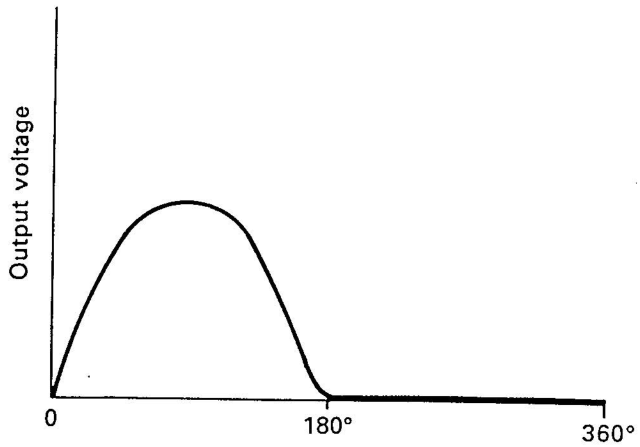


3. Results

Angle	Output voltage	Angle	Output voltage
0°		225°	
45°		270°	
90°		315°	
135°		360°	
180°			



The relationship between the angle of magnet and the output voltage should be as follows:



REFERENCE

Output voltage

If we symbolize the intensity of the magnetic field as ϕ, the intensity of this field as the magnet rotates between 0 and 180 degrees will be $\phi\theta = \phi \cdot \sin\theta$ and the output voltage will trace a sine curve.

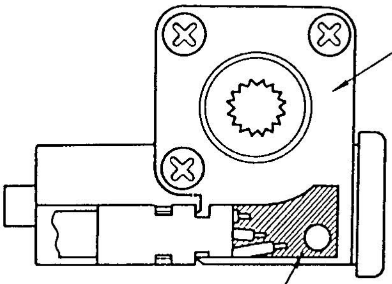
Between 180 and 360 degrees, the output voltage becomes zero because the orientation of the magnetic field is reversed.

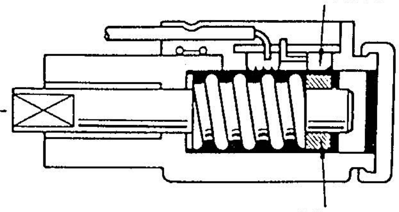
EXAMPLE OF APPLICATION

A Hall IC (an integrated circuit using a Hall element) is used for the position sensor of the power seat. In this case, the output is in a pulse waveform. The power seat computer counts the number of pulses and to detect the seat position.

Slide, vertical, and headrest position sensors

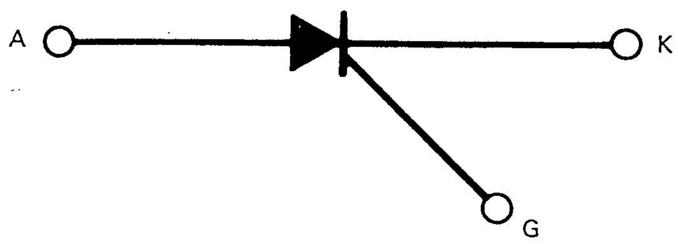
These position sensors are installed in the housing of each adjuster. The magnet is connected directly to a motor. Only one pulse is generated per rotation of the magnet.





17 FUNCTION OF THYRISTOR

A thyristor is a type of switching element which consists of an anode (A), a cathode (K), and a gate (G). A thyristor is also called a silicon-controlled rectifier, or SCR. When a voltage is applied to the gate of the thyristor, current begins to flow between the anode and the cathode. Once this occurs, the conductance between them is maintained even after the gate voltage is turned off. Current can only be cut off by reducing the anode voltage to near zero.



SYMBOL FOR THYRISTOR

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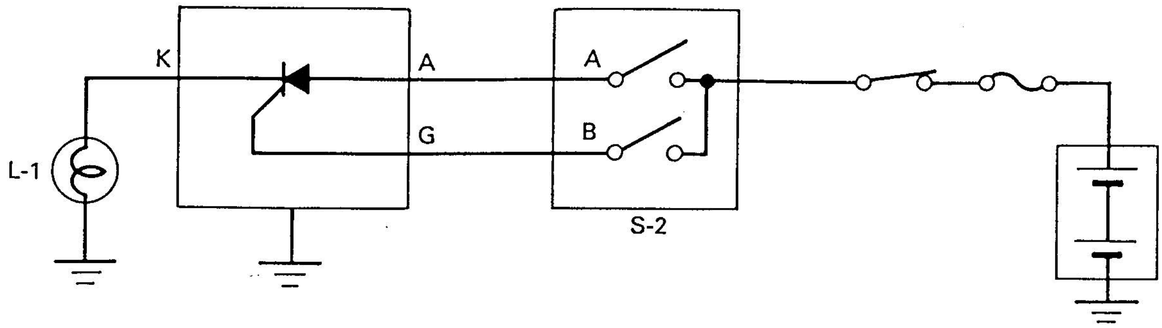
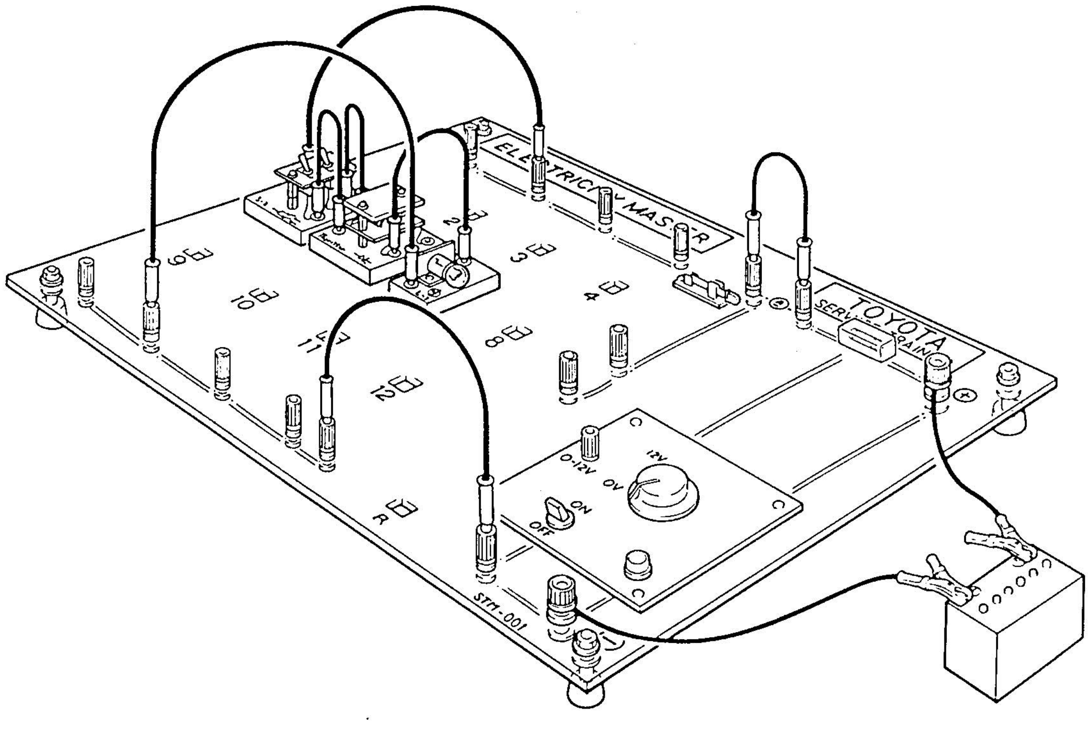
CIRCUIT USING THYRISTOR

1. Make the circuit shown below using a thyristor, L-1, and S-2.

2. After turning on contact A of S-2, check that L-1 goes on when contact B of S-2 is turned on, then off again.



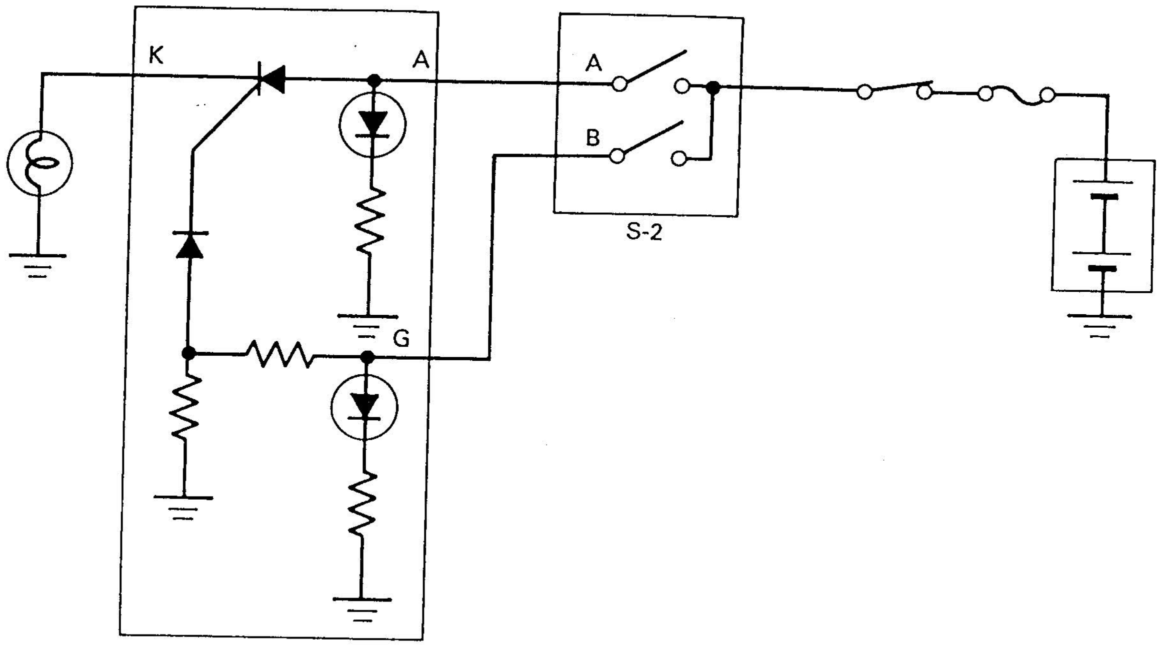


3. Results

	S-2 (B) OFF	ON	OFF
L-1			

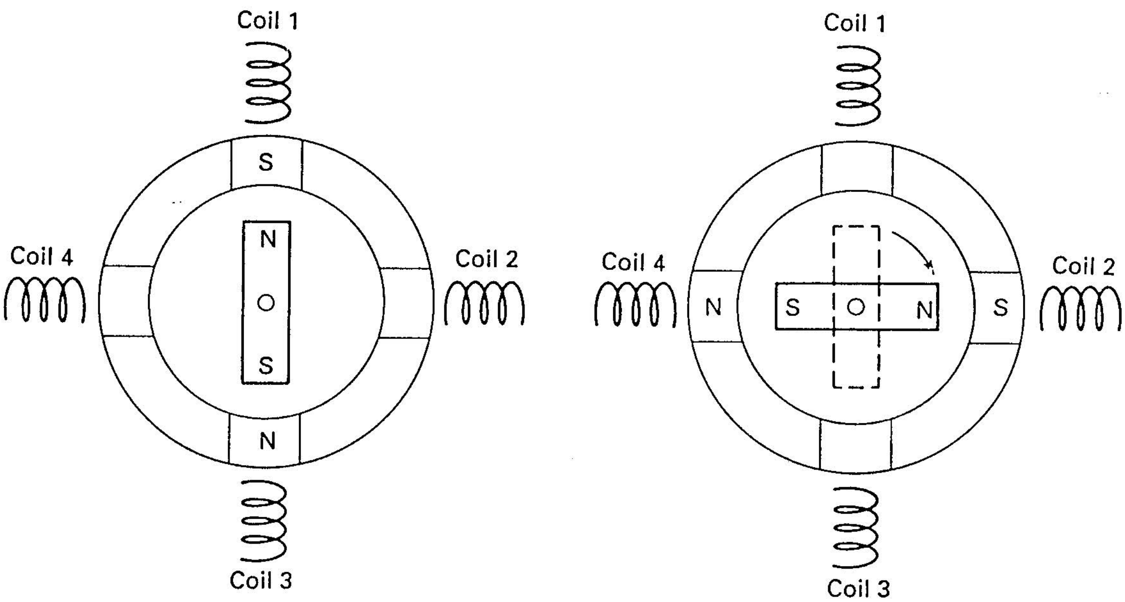
In the circuit diagram shown below, both contact A and contact B of S-2 are off. When contact A of S-2 is turned on, the anode A of the thyrister is energized.

Next, when contact B of S-2 is turned on, voltage is applied to the gate G. The anode and the cathode K become conductive (i.e., current flows between them) and L-1 lights up. Even if contact B of S-2 is subsequently turned off, conductance is maintained between the anode and cathode and L-2 remains lit. To turn L-1 off, turn off contact A of S-2.



18 FUNCTION OF PULSE MOTOR

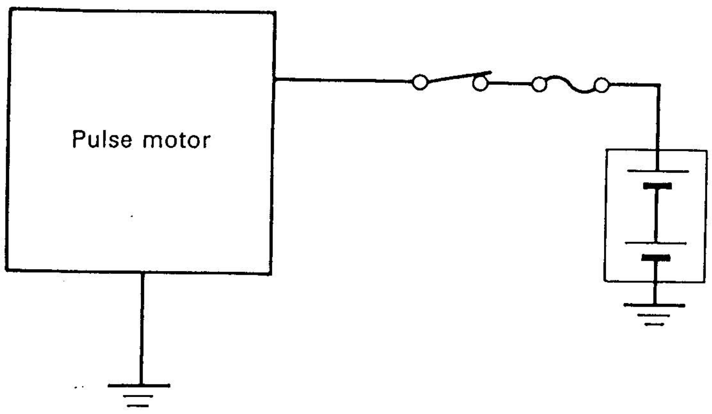
A pulse motor rotates a rotor (which is a permanent magnet) by causing the external magnetic field to rotate.
Since the external magnetic field is generated by sending electrical current through coils, the magnetic field can be rotated simply by changing the timing of the energization of each coil and the direction of the flow of the current.

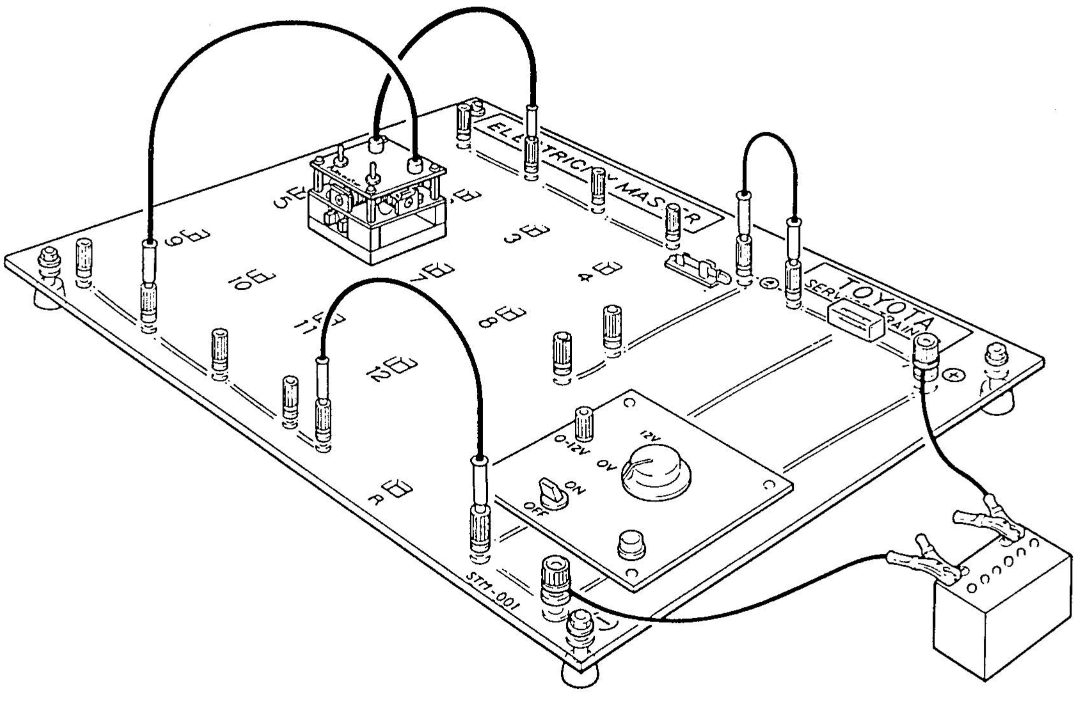


As shown above, when coils 1 and 3 are energized and the magnetic polarity of the external field becomes as indicated in the first figure, the north pole (N) of the rotor is attracted by the south pole (S) of the external magnetic field (and its south pole by the north pole). Next, when coils 1 and 3 are turned off and coils 2 and 4 are energized, the north pole of the rotor rotates to follow the south pole of the external magnetic field. The continual repetition of this causes the rotor to continuously rotate.

CIRCUIT USING PULSE MOTOR

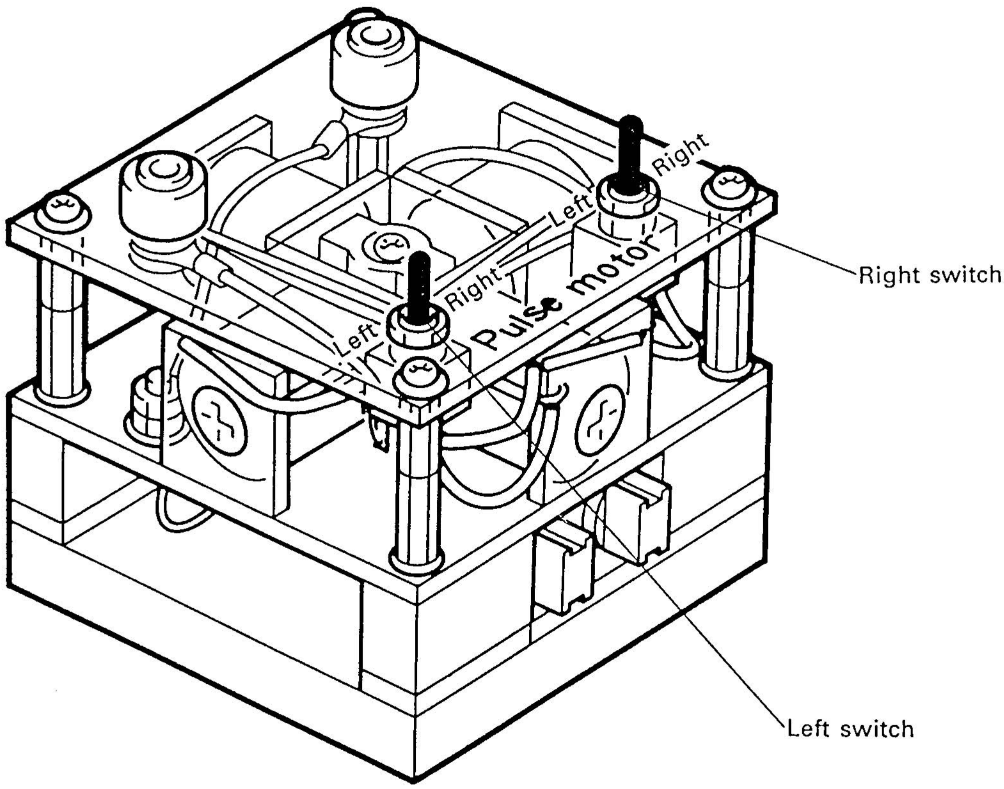
1. Make the circuit shown below using a pulse motor.





2. Check the rotation of the rotor when the switches are set to the following states:

Left switch	Left	Neutral	Right	Neutral	Left	Neutral	Right	Neutral	Left
Right switch	Neutral	Left	Neutral	Right	Neutral	Right	Neutral	Left	Neutral
Rotational direction of rotor									



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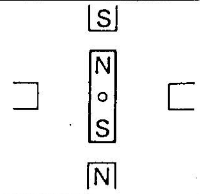
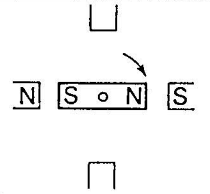
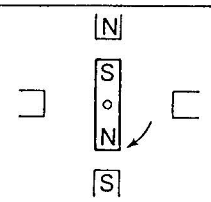
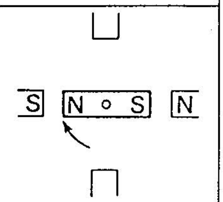
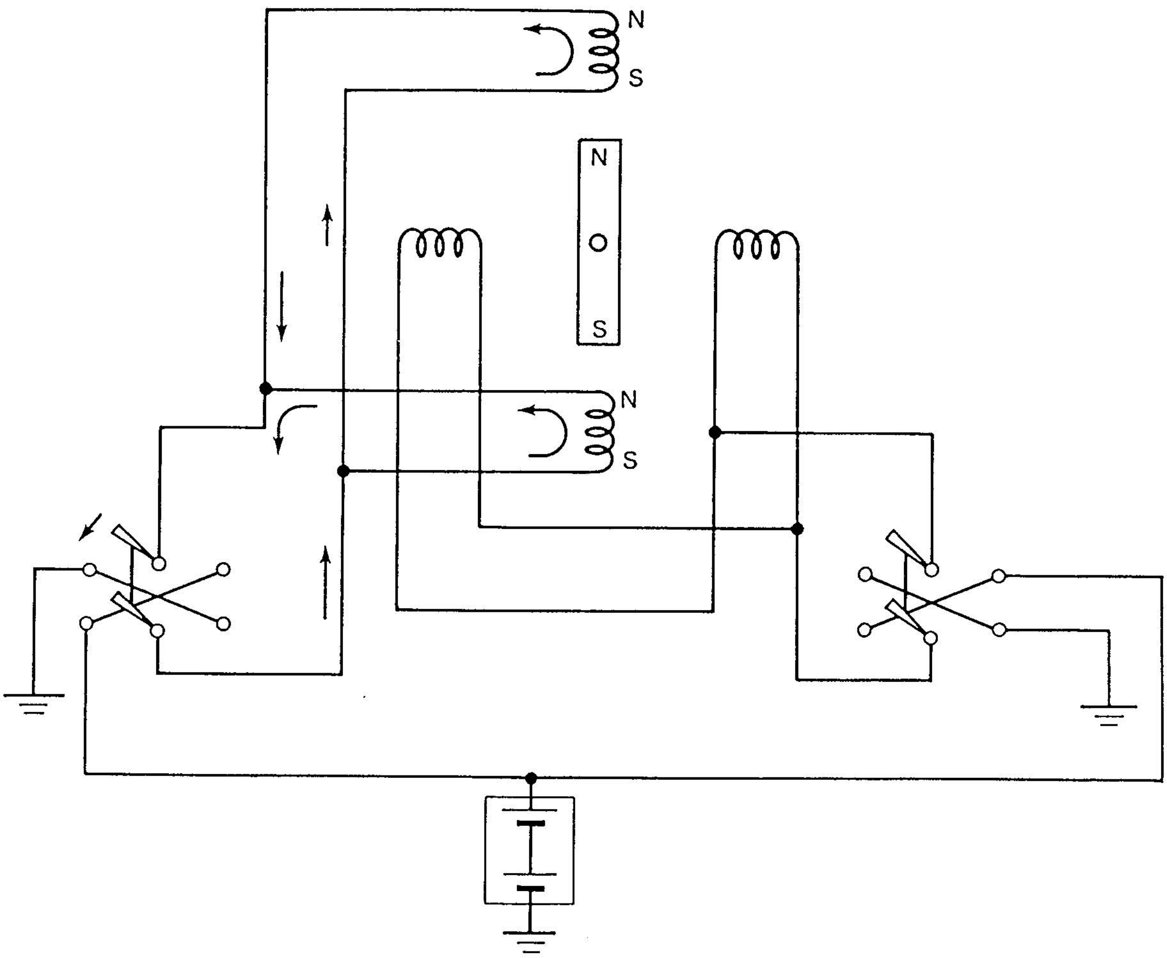
The rotor rotates when the magnetic field is rotated by the switching of the direction of the current flowing in the coils. The state of the switches and the magnetic field are shown below:

Left switch	Left	Neutral	Right	Neutral
Right switch	Neutral	Left	Neutral	Right
Magnetic polarity and rotational direction of rotor				

The figure below shows the flow of current and the state of the magnetic field when the left switch is turned to the left.

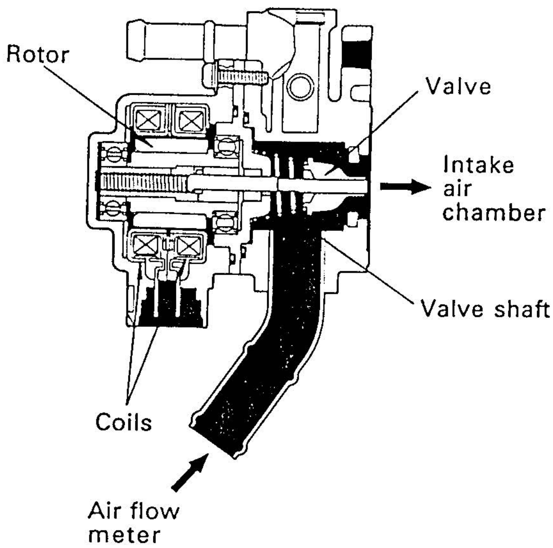


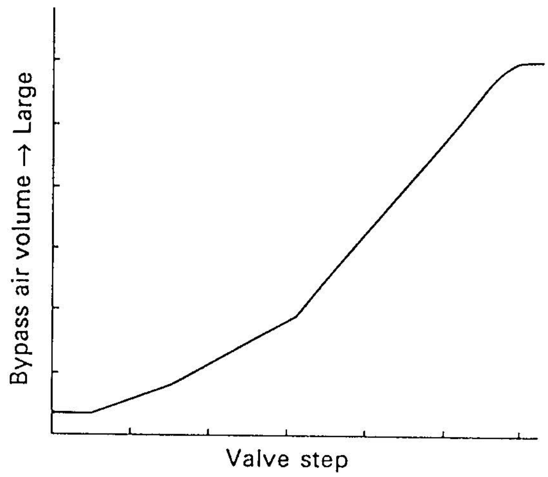
EXAMPLE OF APPLICATION

A pulse motor is used in the idle speed control (ISC) valve.

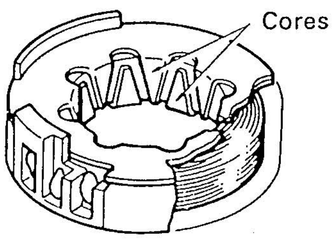
ISC Valve

The ISC valve is provided on the intake air chamber. Intake air bypassing the throttle valve is directed to the ISC valve through a hose.
A step motor is built into the ISC valve. It consists of four coils, the magnetic rotor, valve shaft and valve.
When current flows to the coils due to signals from the ECU, the rotor turns and moves the valve shaft forward or backward, changing the clearance between the valve and the valve seat. The intake air volume bypassing the throttle valve is regulated in this way, controlling the engine speed.
There are 125 possible positions to which the valve can be opened.





- Rotor .... constructed of a 16-pole permanent magnet.
- Stator .... two sets of 16-pole cores, each of which is staggered by half a pitch in relation to the other; two coils are wound around each core, each coil being wound in opposing directions.



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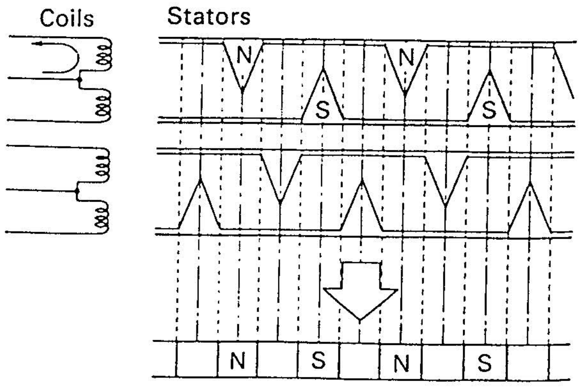
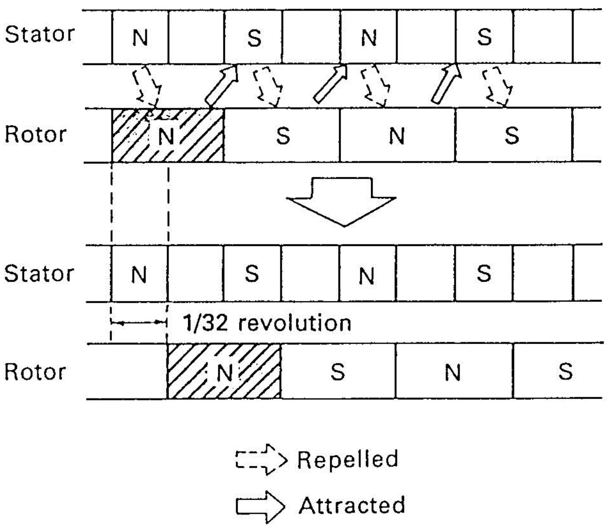
Movement of Valve

The valve shaft is screwed into the rotor. It is prevented from turning by means of a stopper plate so it moves in and out as the rotor rotates. This causes the distance between the valve and valve seat to decrease or increase, thus regulating the amount of air allowed through the bypass.



Rotation of Rotor

The direction of rotation of the rotor is reversed by changing the order in which current is allowed to pass through the four coils. The rotor rotates about 11° (1/32 of a revolution) each time electrical current flows through the coils.
When the rotor rotates one step, the positional relationship shown in the figure develops and the stator coil is excited. Since the north poles tend to be attracted to the south poles, and since like poles tend to repel each other, the rotor turns one step.



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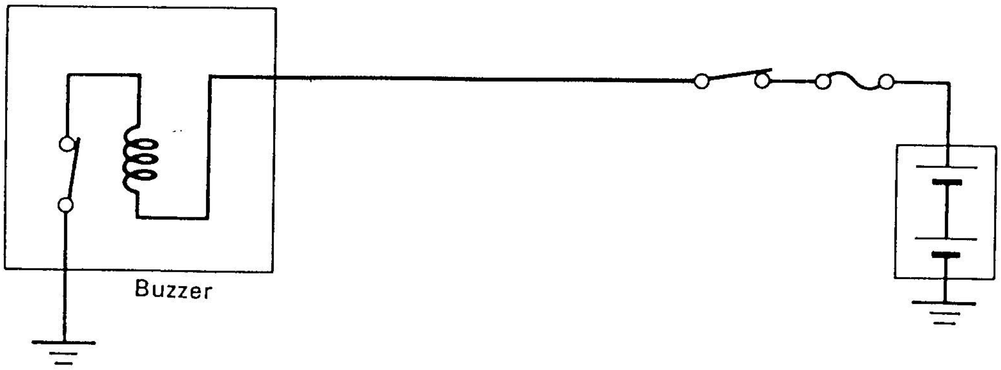
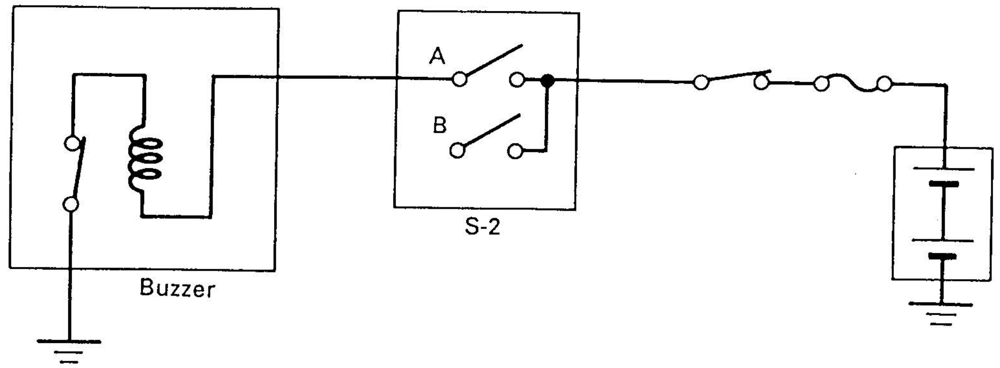
19	FUNCTION OF BUZZER

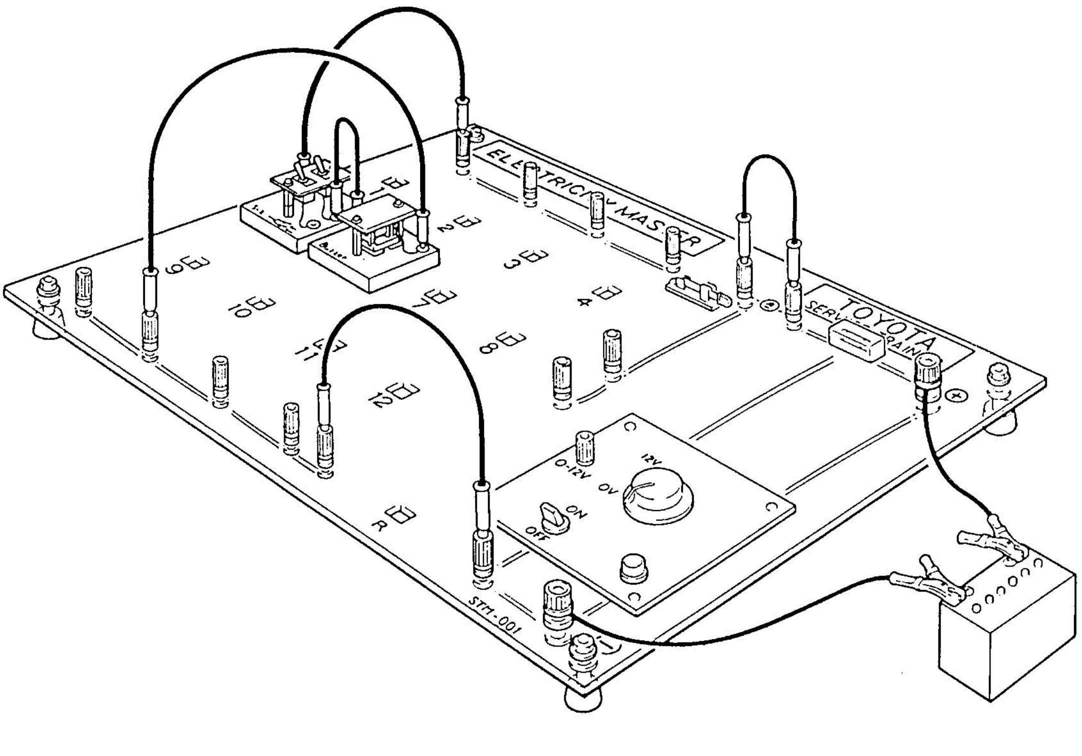
The buzzer has a similar construction to the relay. As shown in the diagram below, when current flows in the coil, the contacts open and current stops flowing. When the current stops flowing, the contacts close. When the contacts close, current again flows in the coil, causing the contacts to open again. This is repeated continuously, and the clicking sound of the contacts opening and closing makes a continuous noise like that of a buzzer.



1. Make the circuit shown below using a buzzer and S-2.

2. Check the operation of the buzzer when contact A of S-2 is turned on.





EXAMPLE OF APPLICATION

This circuit is used for the seat belt warning relay. For details, see page 20.

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Microcomputer-Controlled
Automatic Air Conditioner

AIRBAG

Theft Deterrent
System

TEMS

Diagnostic Systems

TCCS

Computer-Controlled
Combination Meter

CCS

A.B.S.

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