Si-57

Service Manual of Electronic Circuit in DAIKIN Air Conditioners

DAIKIN INDUSTRIES, LTD.

After sales service Div.

-- Introduction--

Today, it is said that the technical ability of service engineers in electronics does not overtake the rapid progress of electronic control system of air conditioners.
Printed circuit boards are often replaced without any careful inspections.
Moreover, insufficient understanding and awareness of electronics result in necessity of frequent servicing for air conditioners, and "enforcement of technical ability of service engineers in electronics" has become critical.
Therefore, this manual is issued with a hope to improve the electronic technology level of service engineers, covering the items below:

(1) Understanding of basic knowledge of electronics
(2) Ability for correct diagnosis of defects

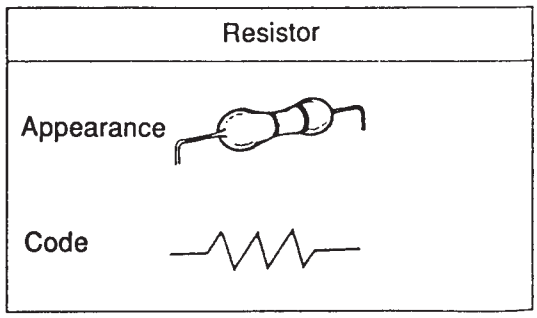
Caution
Repair inside printed circuit boards by anyone orher than qualified Daikin engineers is not allowed. An wrong repair of a PCB may result in failure of the relating parts. Chapter 4 "Repair of printed circuit board" should be referred to only for repair for emergency cases before the new printed circuit board is supplied or for repair of simple defects such as solder defects.

--Contents--

1 Basic knowledge of electrical parts

1) Resistor

1-1 Use of resistor

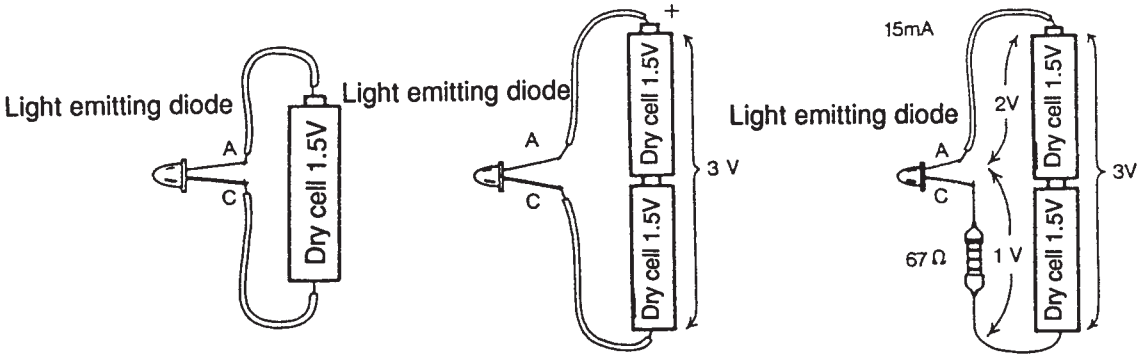


For what are the resistors used? We will explain the role of a resistor using light emitting diode as an example.

Light emitting diode is a semiconductive element, and is highly efficient in energy-saving because its operating voltage and current are as low as approx. 2V and 15mA, respectively.

Since the operating voltage of light emitting diode is approx. 2V, it cannot emit light with one dry cell (1.5V) as shown in Fig. (a) below. On the other hand, if two dry cells are connected in series (3V) as shown in Fig. (b), the voltage becomes too high and excessive current may flow into the diode, resulting in damage to the diode.

However, when a resistor of approx. 67Ω is connected in the circuit above, the voltage and current applied to the light emitting diode become approx. 2V and 15mA, respectively, which are appropriate for the diode to emit light.



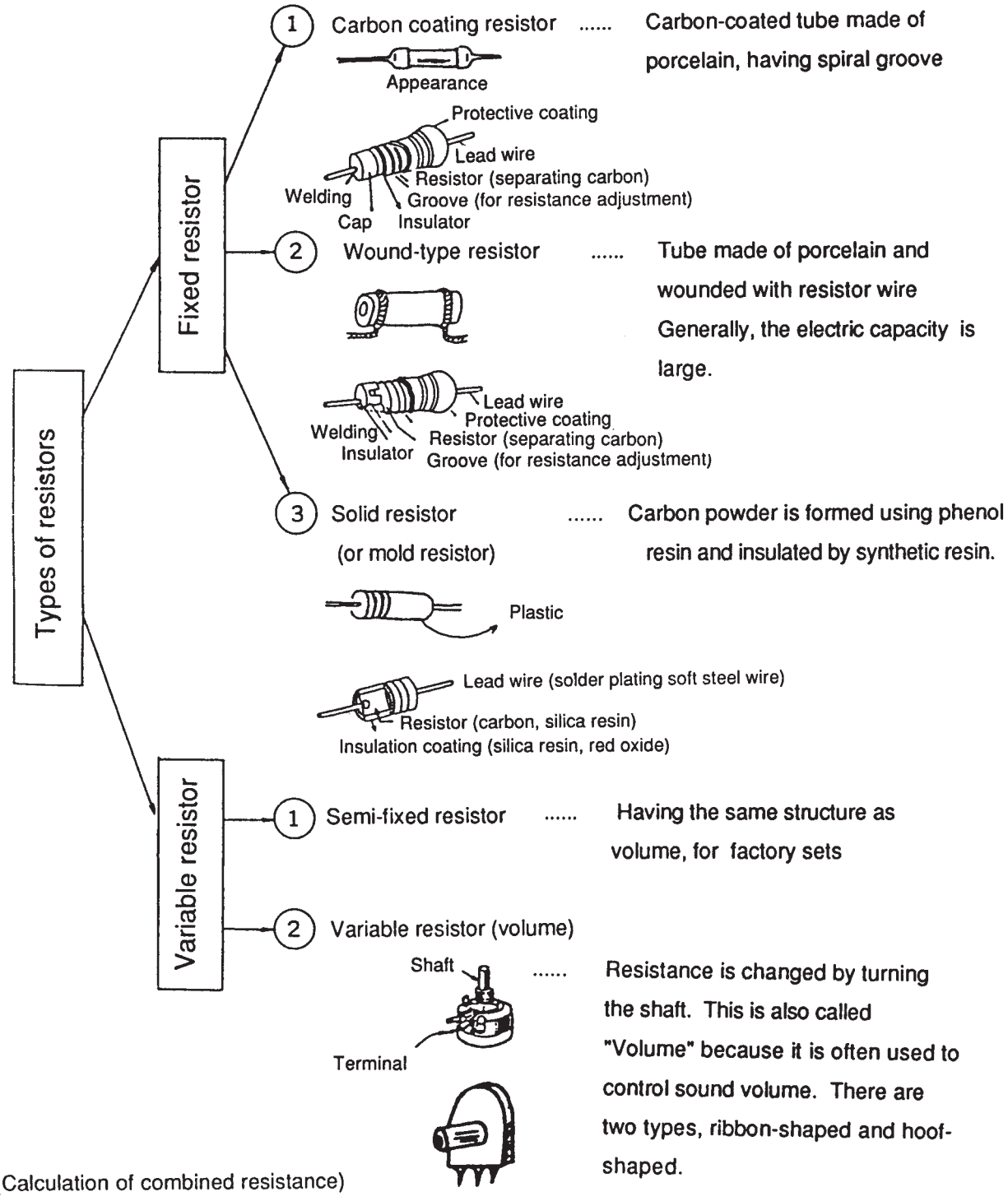
(a) Diode does not emit light. (b) Excessive current flows. (Loss of current.) (c) Desirable condition

Circuit of Light emitting diode

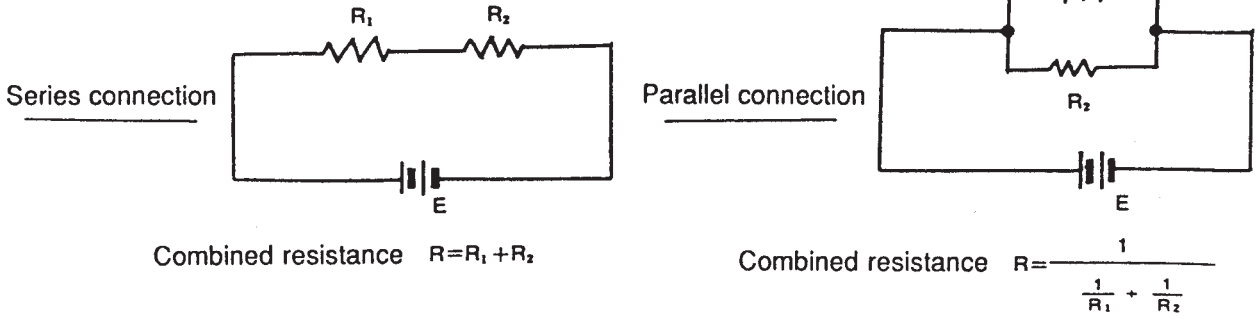
As shown in the example of light emitting diode, a resistor can control the voltage and current supplied from the power source to the levels required by the transistor and IC.

The resistor can also control the signal level generated by the signal source to an appropriate level for the next circuit to receive.

1-2 Types of resistors



(Calculation of combined resistance)



1-3 Color code

Color codes are used to indicate the rated value of small type mold fixed resistor, ceramic or Mica capacitor. Colors regulated by the standards below are normally used:

1 JIS

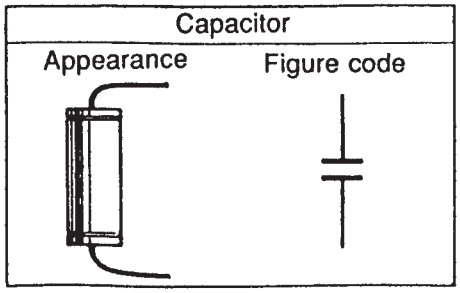
2 RMA

The JIS color codes are also used for circuit wiring, IFT and terminals. The table below shows the color codes when significant figure of resistance is 2 digits. It is same even when the significant figure is 3 digits.

Color	1st color band	2nd color band	3rd color band	4th color band
	1st figure	2nd figure	Multiplier	Allowable resistance difference
Black	0	0	$10^0=1$	-
Brown	1	1	10^1	±0.1%
Red	2	2	10^2	±0.2%
Orange	3	3	10^3	-
Yellow	4	4	10^4	-
Green	5	5	10^5	±0.5%
Blue	6	6	10^6	±0.25%
Purple	7	7	10^7	±0.1%
Grey	8	8	10^8	-
White	9	9	10^9	-
Gold	-	-	$10^{-1}=0.1$	±5%
Silver	-	-	$10^{-2}=0.01$	±10%
None	-	-	-	±20%

2) Capacitor

2-1 Capacitor characteristics



A capacitor is an element shaped as shown in the figure on the right. Many capacitors are utilized in circuits of electrical appliances.

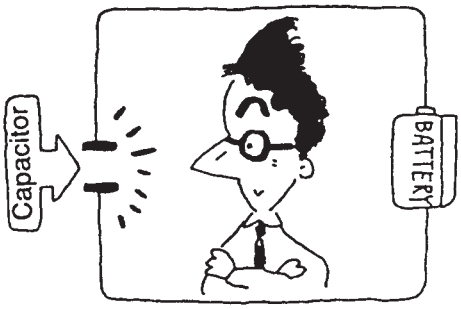
The main function of a capacitor is to store electricity. The volume of a capacitor as the container of electricity is referred to as "electrostatic capacity" and expressed in the unit of F (Farad).

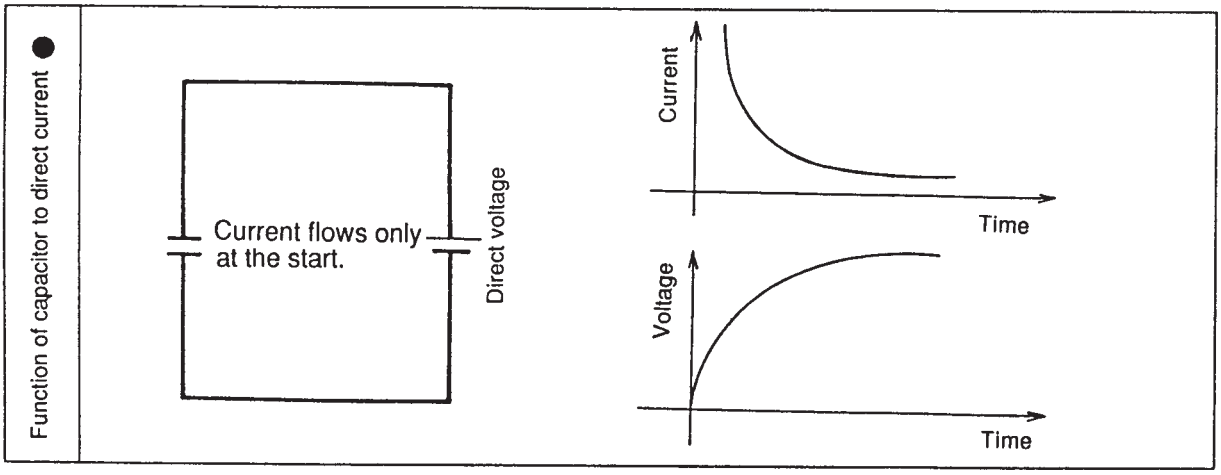
(1(F): Volume of electricity when electrical current of 1(A) flows for 1 second when a voltage of 1(V).is applied)

For direct current

The main function of a capacitor is to store electricity. When direct current is flown between the both terminals of a capacitor, the current freely flows at the start, but it stops when the capacitor is filled with electricity.

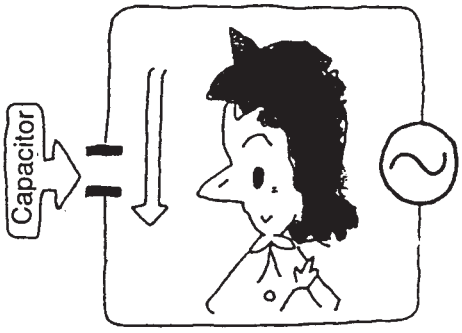
Therefore, the functions of a capacitor are to store the electricity and to stop the current flow as well.

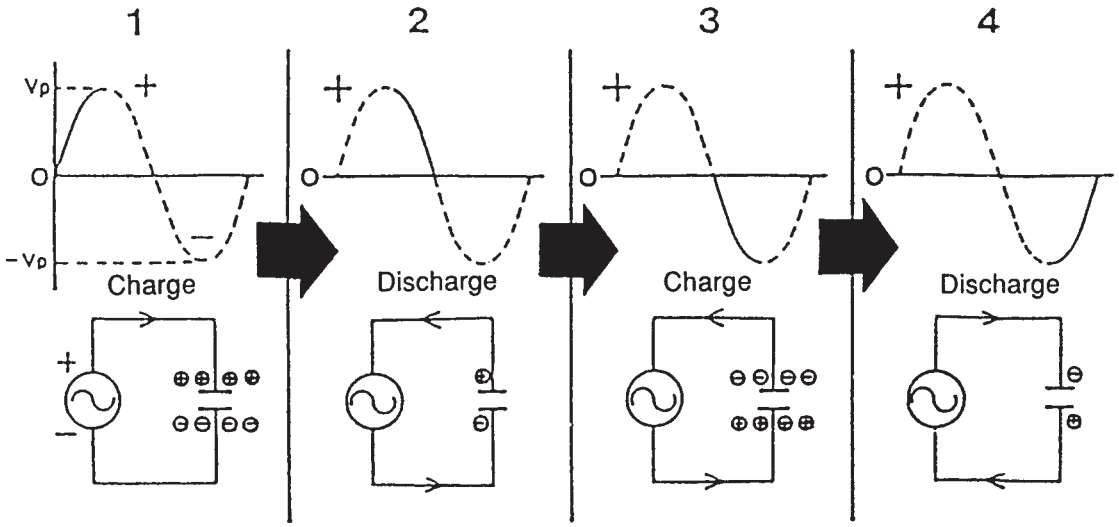




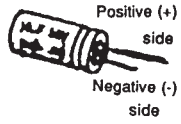
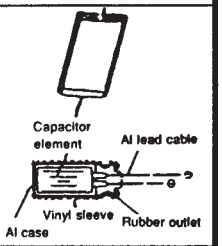
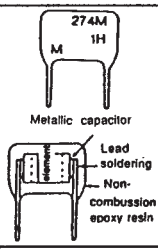
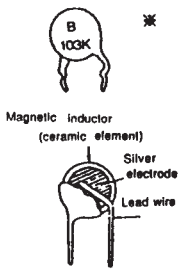
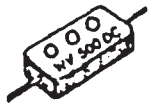
For alternative current

What is the function of a capacitor for alternative current? In AC, the level and the direction of electricity change as the time elapses. When alternative current is flown to a capacitor, charge (store electricity) and discharge (flow current) are conducted alternatively. As the result, the alternative current can flow, and the flow rate changes in proportional with the electrostatic volume of the capacitor.





2-2 Types of capacitors

	Type	Features	Application	Appearance
Capacitor	Electrolytic capacitor	Small in size but has large electrostatic capacity Polarity (positive and negative) High frequency characteristics is worst.	Rectifier circuit Timer circuit	
	Metallic film capacitor	Even when an insulation damage occurred, the metal of the damaged area evaporates due to the heat. Therefore, it can be used even after the insulation damage.	Operation and start-up of single phase motor	
	Plastic film capacitor	Good temperature and insulation characteristics	Various electronic circuits	
	Magnetic capacitor ceramic	Compact and cheap. Temperature characteristics are bad. Good high frequency characteristics 1pF~0.5μF Frequently used for **noise absorption**	Various electronic circuits	
	Paper capacitor	It was generally used. Heat resistance is low and the size is large.		
	Mica capacitor	It is not used often due to the large size despite the good characteristics.		
	Variable capacitor (Vari-con)	It is used to select broadcasting station of radio.	Station selector of radio	

※ How to read capacitor volume

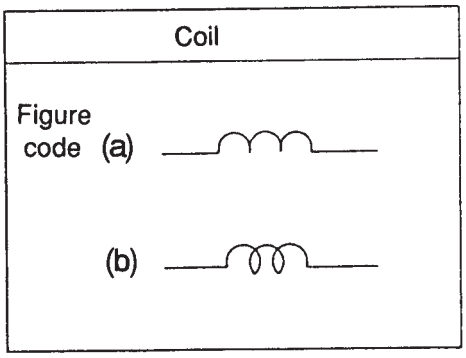
1 0 3 ·····10×10^{3}pF=10,000pF=0.01 μF

5 0 1 ·····50×10^{1}pF=500pF

1 0 4 ·····10×10^{4}pF=100,000pF=0.1 μF

3) Coil

As shown by the figure code, a coil is made of conductive wire wounded in spiral. The function varies according to the magnetic force generated when electricity flows.



Many coils are used in our daily life such as motors in washing machine, etc., stabilizer in fluororescent lamp, electromagnetic switch of a buzzer, transformer on electric pole, transformer in an AC adaptor, bar antenna coil, medium frequency transformer, oscillation coil, I/O transformer, filter, power source transformer, pulse transformer, relay coil and speaker.

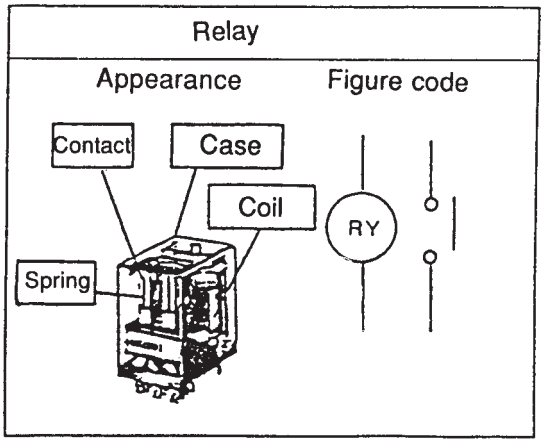
Functions of coil	Applications
To generate magnetic field by electric current	Electromagnetic motor in relay and buzzer
To generate power in accordance with the changes of magnetic flux	Transformer, inductive motor. microphone, pick-up
To surpress AC current flow of high frequency	Filter, choke coil
To delay signal communication	Delay circuit
Resonance when used with a capacitor	Harmonizing circuit, oscillation circuit
To generate magnetic field in proportion with the electric current	Speaker, meter Deflection coil, hall generator

4) Relay

4-1 Principle and features of relay

Relays have long been used for transmission of electrical signals and ON/OFF of power circuit. There are various types of relays for DC and AC usages.

As shown in the figure on the right, a DC relay consists of a coil, a contact and a spring. Normally, a relay is placed in a transparent case in order to prevent malfunction due to dust accumulation.



4-2 Ratings of relay

The voltage of a DC relay coil is generally rated to 5V, 6V, 12V and 24V, and in most cases the contact functions to open and close a load of AC 100V and 200V. Therefore, the features are as outline below:

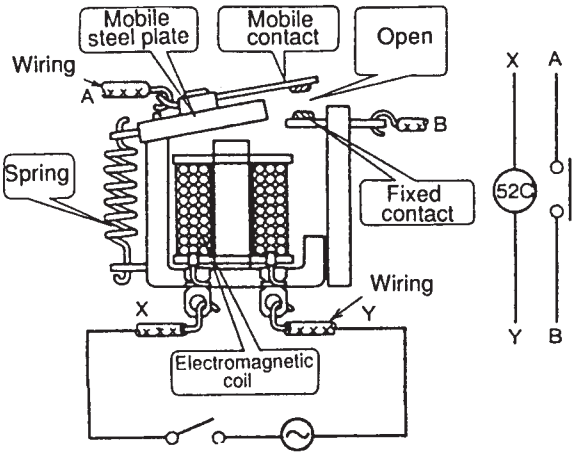
1. Optimal for on/off of power circuit
2. Suitable for circuit insulation
3. Highly durable against noise and highly reliable

The cautions when a relay is utilized for on/off of power circuit are as below:

1. The ratings of voltage and current should be observed.
2. Care should be taken in the rated on/off voltage and current at the contact.
3. Whether the load is inductive or non-inductive should be confirmed.

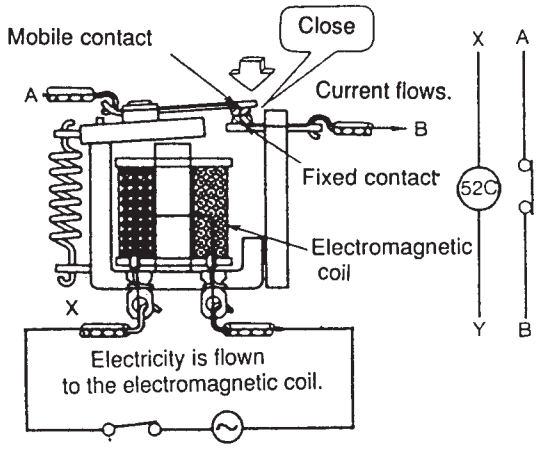
4-3 Movement of electromagnetic relay contact (a)

- Reset ..... Power is not supplied to the electromagnetic coil.



The mobile and fixed contacts are separated with the force of the spring and the electric flow route opens.

- Operating ..... Power is supplied to the electromagnetic coil.

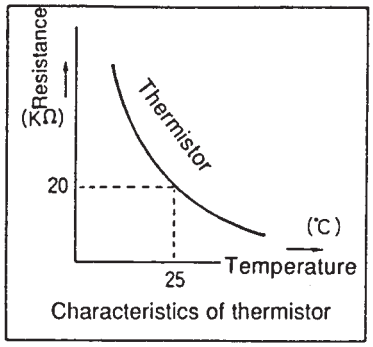


An electromagnet is formed when electricity is flown to the electromagnetic coil, and the mobile steel plate is moved with magnetic force. The mechanism interlocked with the mobile steel plate functions to join the mobile and fixed contacts, closing the electric flow route.

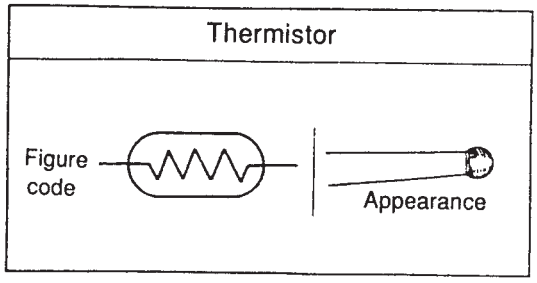
5) Thermistor

Thermistor has a characteristics that the resistance lowers as the temperature rises, which is opposite to that of normal resistor. (NTC thermistor)
By utilizing this characteristics (resistance change), thermistors are incorporated into the sensors of electronic thermostats in room air conditioners, Sky-Air system and boilers.

Code and characteristics of thermistor



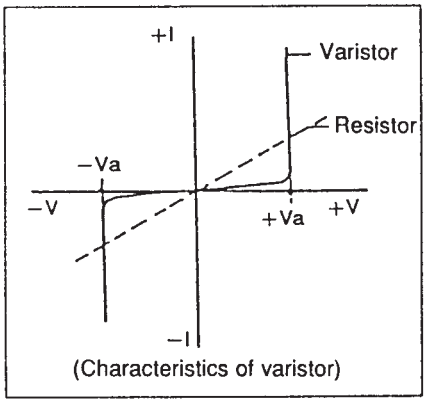
Characteristics of thermistor



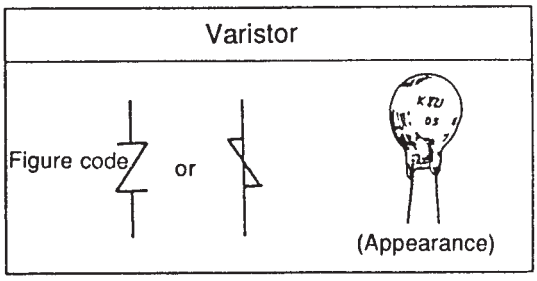
6) Varistor

When an abnormally high voltage (AC200V is applied to AC100V circuit, or lightning serge) is applied to an printed circuit board (electronic circuit), the varistor absorbs the abnormal voltage (serge voltage) and is broken (short-circuit) to protect the printed circuit board.

Characteristics of varistor



(Characteristics of varistor)

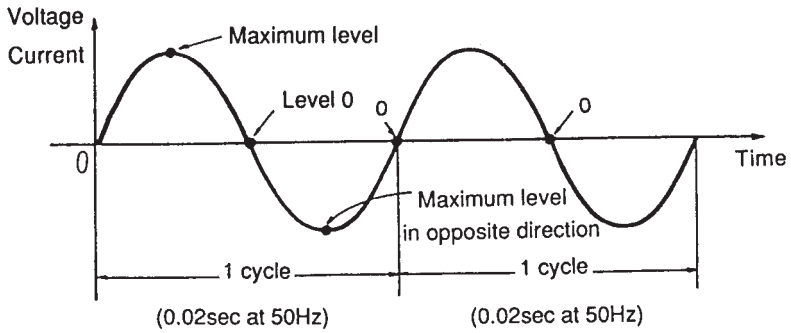


When the voltage (V) increases as shown in the figure, current (I) flows abruptly. In other words, an abrupt change of resistance results from the voltage change.

7) Unit of electricity

7-1 Frequency and cycle of AC current

The frequency refers to the number of repetition of changes of voltage and direction (+ and -) per second.



Cycle and frequency

The AC current keeps changing from 0 - max. level in positive direction -0 to the max. level in negative direction as shown in the figure on the previous page. The time required for 1 complete change is referred to as cycle. At 50Hz, this change is repeated 50 times in 1 second. Therefore, the time required for 1 change is calculated as below:

T(sec) =1/f(Hz) T: cycle (sec)

1 (cycle)=1 (sec) /50 (times) =0.02sec f:frequency (Hz)

As obtained above, the time required for 1 cycle is 0.02 second.

Although "cycle" was once used as the unit of frequency, it is "cycle/sec" in the correct form. Today, "Hz" is the unit used world-wide. "Helz" is named after a German scholar (born in 1857) who discovered electric wave.

As an example, the electric wave used for broadcasting station #1 of NHK radio is 594 (kHz). This is so high as it repeats the cycle 590,000 times a second. Moreover, the electric waves used for TV and micro-wave communication are higher than that for radio broadcasting by 1,000 times and millions of times. When compared with these high frequencies, 50Hz and 60Hz, which are used in power system, can be easily understood.

7-2 Wavelength

The distance of wave transmitted in 1 cycle is referred to as λ and obtained by the equation below:

(wavelength) λ=(light speed) C/(frequency)f (m) Light speed : $3x10^8$ (m/sec)

Electrical unit and prefix

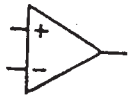
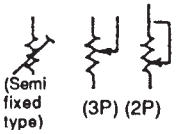
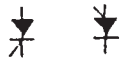
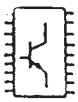
Electrical units

Name	Code	Description
Ampere	A	Electric current
Volt	V	Electric voltage
Watt	W	Electric power
Watt.hour	Wh	Electric energy
Helz	Hz	Frequency
Joule	J	Energy
Ohm	Ω	Electric resistance, reactance, impedance
Farad	F	Electrostatic capacity
Coulomb	C	Electric capacity
Weber	Wb	Magnetic flux
Lux	Lx	Brightness

Prefix of unit

Name	Code	Volume	Name	Code	Volume
exa	E	10^{18}	deci	d	10^{-1}
peta	P	10^{15}	centi	c	10^{-2}
tera	T	10^{12}	mili	m	10^{-3}
giga	G	10^{9}	micro	μ	10^{-6}
mega	M	10^{6}	nano	n	10^{-9}
kilo	k	10^{3}	pico	p	10^{-12}
hecto	h	10^{2}	femt	f	10^{-15}
deka	da	10	atto	a	10^{-18}

3) Major parts and circuit codes

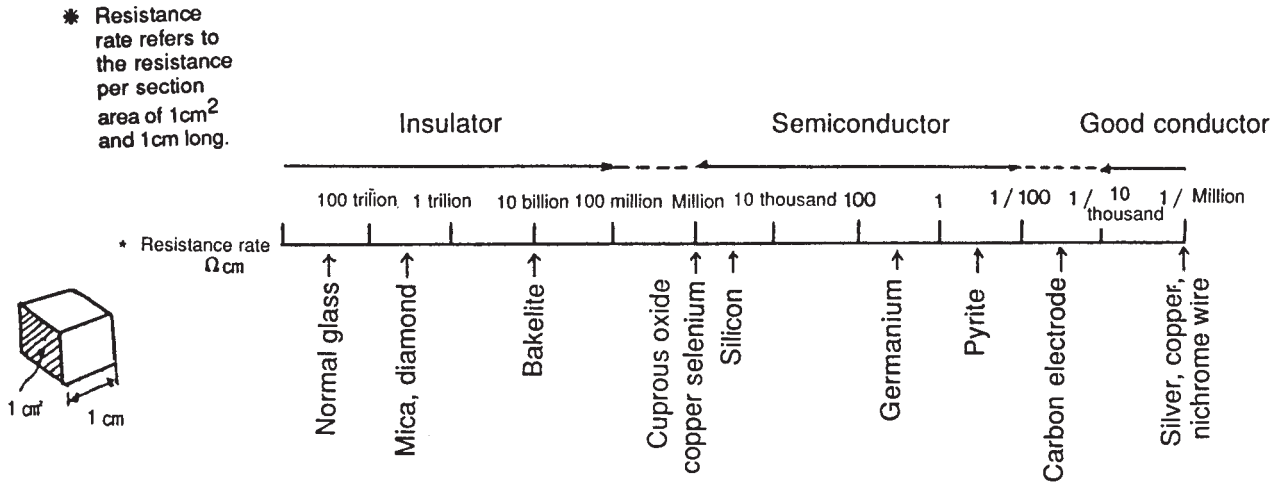
Name	Code	Remarks	Name	Code	Remarks
Diode			Ope. amp.		
Constant-voltage diode (Zener diode)			Photo coupler		 is accepted.
Luminous diode			Varistor	 or	
Photo diode		Codes can be put in a circle as shown above. Diode, etc. can be expressed as	Thermistor		
Transistor	 (NPN) (PNP)		Fixed resistor (carbon coating type, metallic film coating, solid type)		
Photo transistor	 (P channel)		Variable resistor (carbon coating, metallic coating, wound type)	 (Semi fixed type) (3P) (2P)	
Field effect transistor (FET)	 (N channel) (P channel)		Fixed capacitor (film, ceramic, Mica)		
Darlington transistor			Electrolytic capacitor (aluminum, tantalum)		
Thyristor	 (P gate) (n gate)		Coil	 or (with steel core)	
Transistor array			Transformer		 is accepted.
Triac			Rectifier (bridge connection type)		

2 Basic knowledge of electronic components

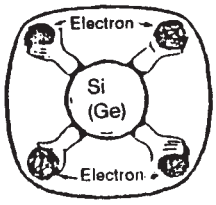
1) What is semiconductor?

Electric resistance of various substances are roughly classified into three groups. One is good conductor (copper, silver, carbon, etc.) which conducts electricity very well. Another group is insulator (insulator and synthetic resin) which does not conduct electricity at all.

Other than these two groups, there are many substances with conductivities not as high as good conductor but substantially higher than insulator. These substances are called **semiconductors.**



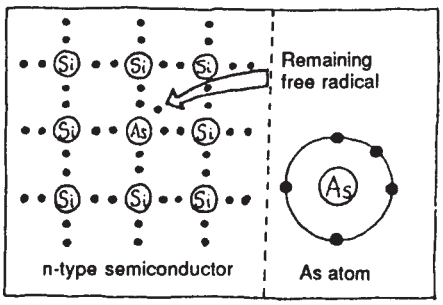
The materials used for semiconductors are silicon (Si), germanium (Ge) and selenium (Se). Chemically, these materials are the elements belonging group #4 (the number of electrons at the outer layer is 4). When impurities are added to an element in group #4, various semiconductors are formed.

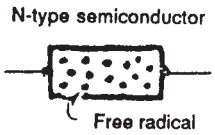


N-type semiconductor (N: negative)

When a small amount of elements in group #5 such as arsenieals (AS), stibium antimony (Sb) or phosphorus (P) is mixed with elements in group #4 such as silicon (or germanium), antimony is formed in the crystal of silicon. At the same time, antimony lose one valency electron and this valency electron becomes a free radical inside the silicon crystal.

The semiconductor thus formed is referred to as N-type semiconductor.





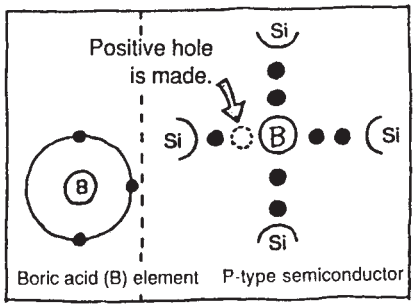
P-type semiconductor (P:positive)

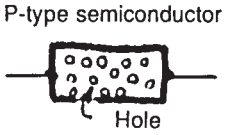
P-type semiconductors are formed by mixing elements in group #3. Elements included in group #3 are aluminum (Al), insium (In) and boric acid (B), etc..

Since the group #3 elements have only 3 valency electrons, electron is short by one in the silicon crystal. Therefore, a positive hole is made when an element is combined with silicon.

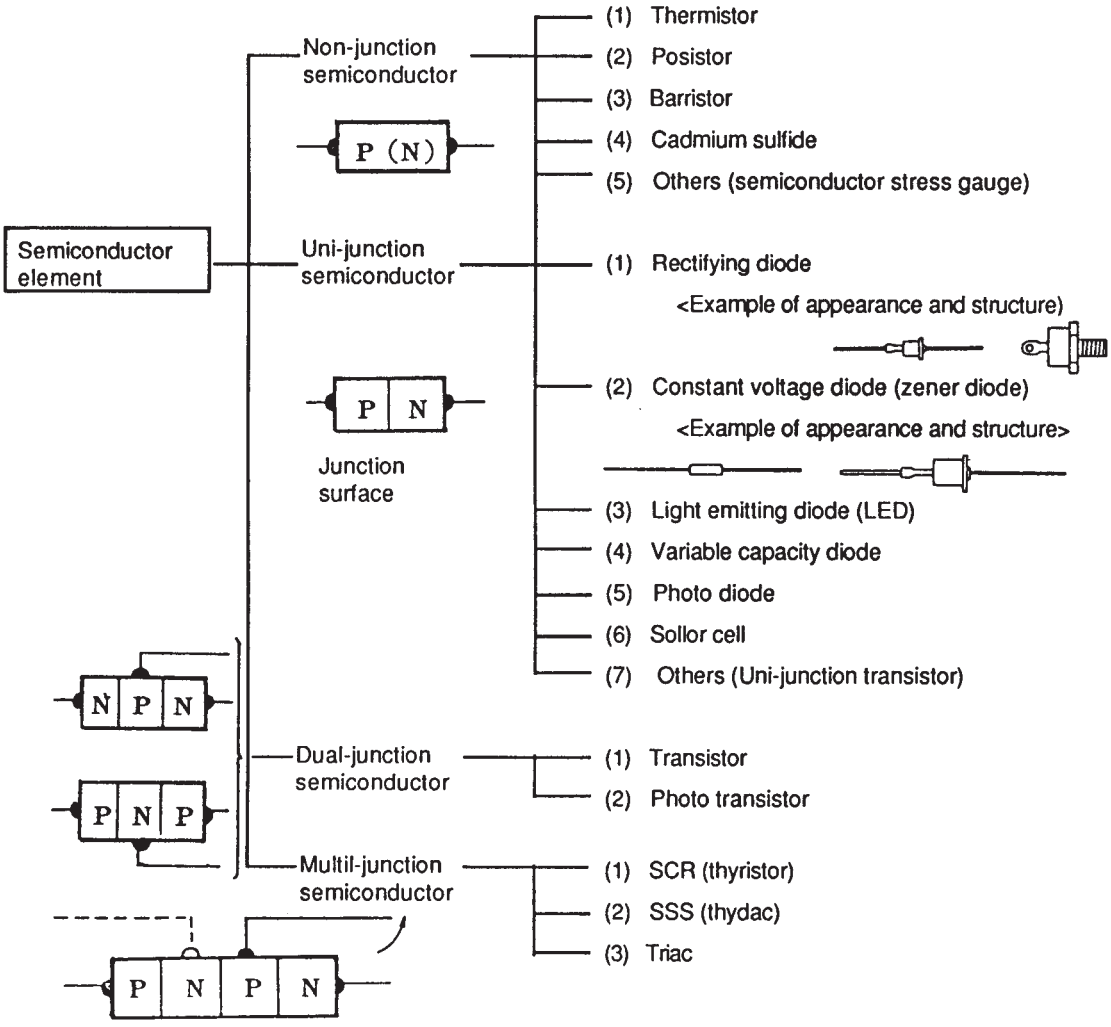
Group #5 elements in N-type semiconductor are referred to as "Donor", while the elements in group #3 in P-type semiconductor is referred to as "Acceptor".

In addition, the free radical and the positive hole are referred to as "Carrier" because they conduct electricity in semiconductor.





1-1 Types of semiconducting element



1-2 Naming of semi-conductive element (JIS C7012)

	1st column	2nd column	3rd column	4th column	5th column
	Numeric figure	Character	Character	Numeric figure	Character
(Example)	2	S	C	828	A

(1) The numeric figure at the 1st column indicates the type of the semiconductive element as regulated below:

The numeric figure equals the number obtained by subtracting 1 from the number of effective electrical connections of the element.

(Example) Generally, the numeric figure given to the 1st column of a transistor with 3 lead wires is 2 because 3-1=2.

The table below shows the numeric values at the 1st column and the types of semiconductor elements.

Numeric figure	Type
0	Photo transistor Photo diode
1	Various diodes, rectifier
2	Transistor, FET (single gate), SCR, UJT
3	FET (dual gate)

(Note) The number of effective electrical connection refers to the number of electrical connections required for the semiconductor to function.

(2) "S", which is the initial letter of semiconductor, is given to the 2nd column, indicating that it is the semiconductor registered by Electronic Machinery Industrial Association.

(3) The character given to the 3rd column indicates the polarity (structure) and the application of the semiconductor, and the classification is as below:

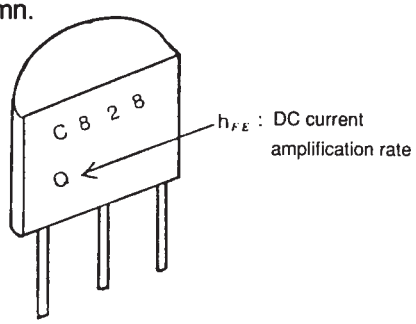
Character	Polarity (structure) and application
A	PNP transistor for high frequency
B	PNP transistor for low frequency
C	NPN transistor for high frequency
D	NPN transistor for low frequency

Character		Polarity	Application
A-D	Transistor		
F	SCR	PNP gate	PNPN switch
G		NPN gate	NPNP switch
H	UJT		
J	FET	P channel	
K		N channel	
M	SSS		

(4) The numeric figure given to the 4th column is determined according to the order of registration to the Electronic Machinery Industrial Association for each group classified by the 1st, 2nd and 3rd column. The number starts from 11.

(5) The character at the 5th column shows modification. Characters A,B,C,D,E,F, G, H, J and K are used in order of modification made. ("I" is not used because it may be mistaken as 1.)

(6) Even when transistors have the same name, performance of individual transistor varies significantly (especially in H_{FE}). For instance, the H_{FE} of 2SC828 fluctuates from 65 to 700. Therefore, the transistors may be classified into several groups according to the H_{FE} size, and indicated on each product using alphabets.



H_{FE}	65~130	90~180	130~260	180~360	260~520	360~700
Classification	O	P	Q	R	S	T

2) Electric current flow in semiconductor

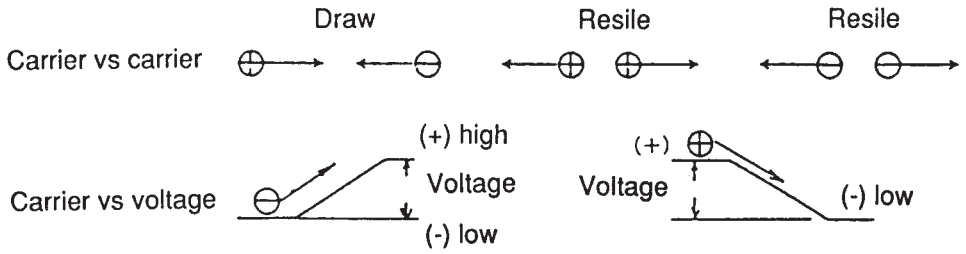
1 The substance which conducts electricity is called "Carrier", and semiconductors have two types of carriers (positive and negative).

Negative carrier ----- Electrons which carry negative electricity (free radical)

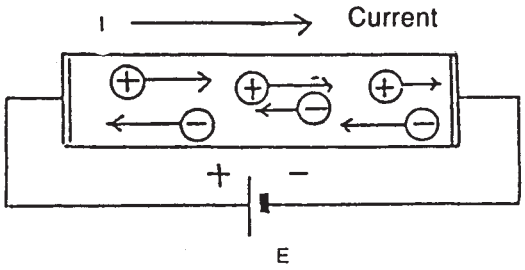
Positive carrier ------ Holes which carry positive electricity

(Hole with positive electricity generated by loss of electron.)

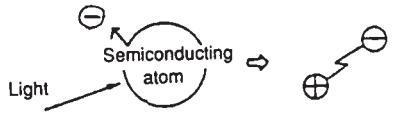
2 Polarity refers to the electricity with positive or negative charges. Electrodes with the same polarity resile with each other, while those with opposite polarity draw with each other. (magnet)



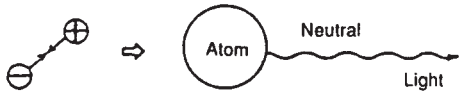
3 Positive carriers move in the direction of current as shown in the figure, while negative carriers move in the opposite direction of the current.



4 When light is applied to a semi-conductive crystal (light is energy), electron leaves the crystal, and a hole with positive electricity is made due to the absence of electron, thus the carriers are separated into negative and positive ones.
On the other hand, when the electron and the hole collide, they re-combine with each other (electrically neutral) and emit light.



A pair of positive and negative of carriers is made by the energy of light.

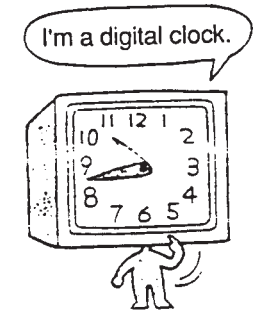


Light is generated by the energy of collision.

3) Analogue and digital

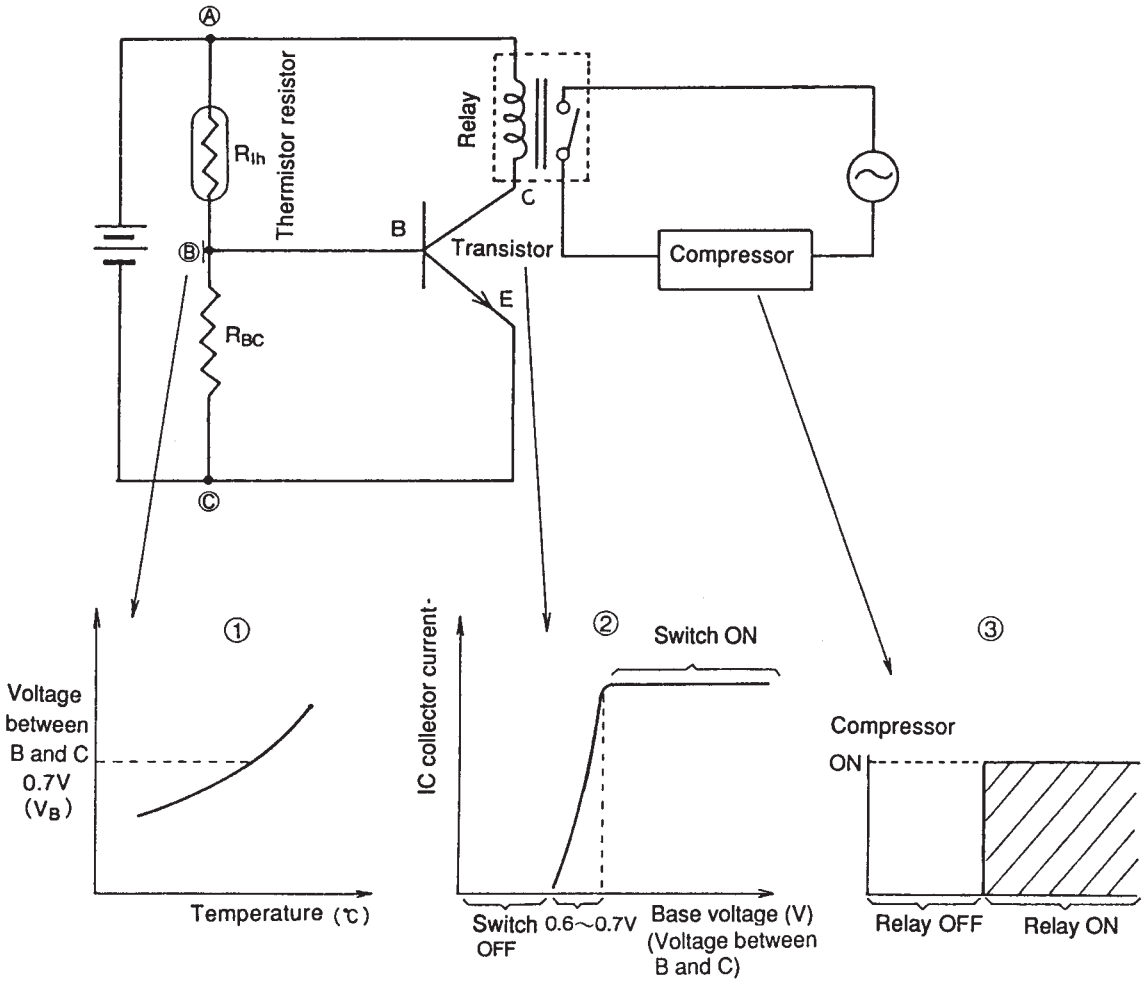
3-1 Difference between analogue and digital

The words, analogue and digital, reminds us of a clock or watch. With a analogue watch, time is indicated continuously with the needle moving. "Continuously" means that we can know time in the unit of second or more minute unit if we have ultra-human eyesights even the clock has no needle to indicate second.
With the digital clock, on the other hand, 3 o'clock 1 minute is read after 3 o'clock. In other words, the indication is not continuous.
When we check the word "analogue" in a dictionary, it has a meaning "similar". However, it should be understood as "continuous" when it is used in technical field.
"Digital" is translated as "fingers of hand and foot" or "numeric figure" in dictionaries. With the digital clock, time is indicated not by needles but by numeric values, which coincides the meaning given in dictionaries.



3-2 Analogue and digital used in air conditioner (example of thermo-control)

Example of compressor ON/OFF by temperature change



① Temperature rises. → Resistance of thermistor decreases.

→ Voltage between B and C increases.

② Voltage between B and C increases. → Collector current flows in transistor.

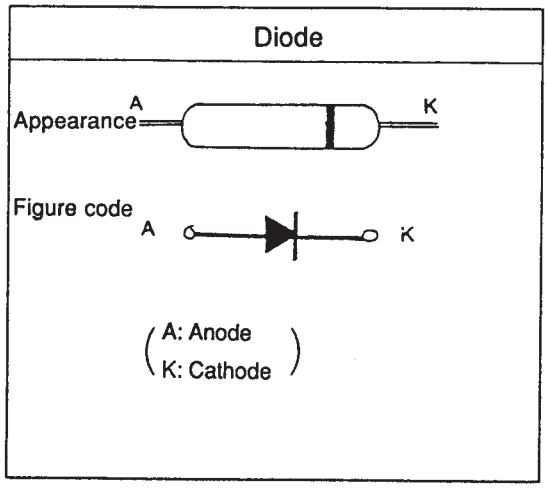
→ Current flows through the relay coil.

③ Current flows through the relay coil. → Relay contact closes. (ON) → Compressor turns on.

① Input		③ Output
Temperature change	⇨	Compressor ON/OFF
(Voltage between B and C)		(Relay ON/OFF)
Analogue		Digital

4) Diode

A diode is made by combining P and N type semiconductors, and utilized for rectification, switching and in constant-voltage devices.



4-1 Rectifying diode

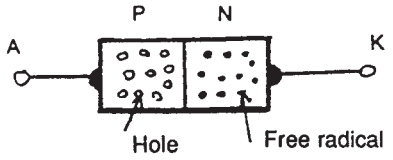
→|— is used as the code for rectifying diode.

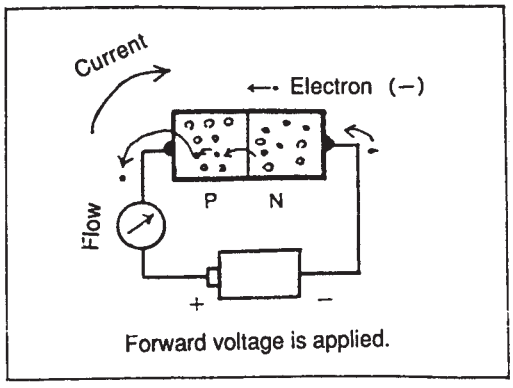
The arrow mark (→) shows the flow direction of current. The rectifying diode is used as the base for generating DC current from AC current.

This diode is utilized to convert the power sources of household electric appliances (single phase 100V) to DC current, and incorporated also into printed circuit boards (electronic circuit) to flow current in one direction.

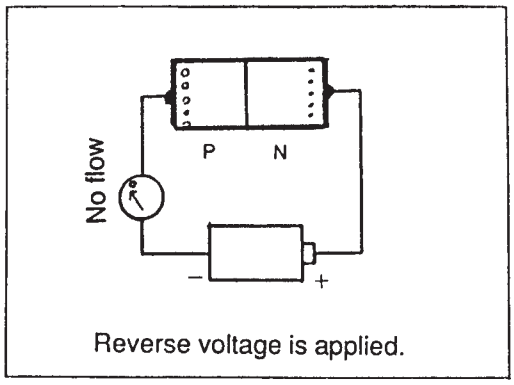
① Rectification by diode

When the positive and negative poles of a battery are connected to P-type and N-type, respectively, the electrons (free radicals) are pushed out from the N-type and moves toward the holes in the P-type. Then, the electrons moved to the holes in the P-type are drawn toward the positive pole of the battery. Thus the electricity flows, and this connection is referred to as forward connection.

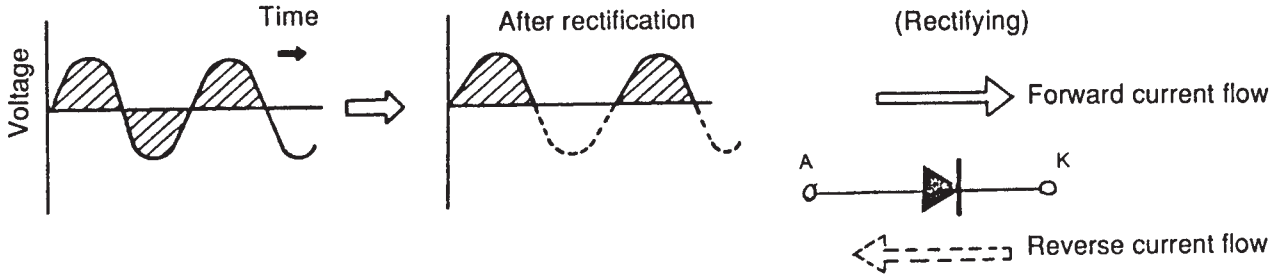




* The "reverse connection" refers to the connection opposite to the one above.
  The electrons of N-type are drawn toward the positive pole of the battery, while the holes of P-type move toward the negative pole of the battery. Thus no electrons move from N to P or vice versa, and electricity does not flow.
* As explained above, a diode allows current to flow in the forward direction but inhibits the flow in the reverse direction. This is called **rectification by diode**.

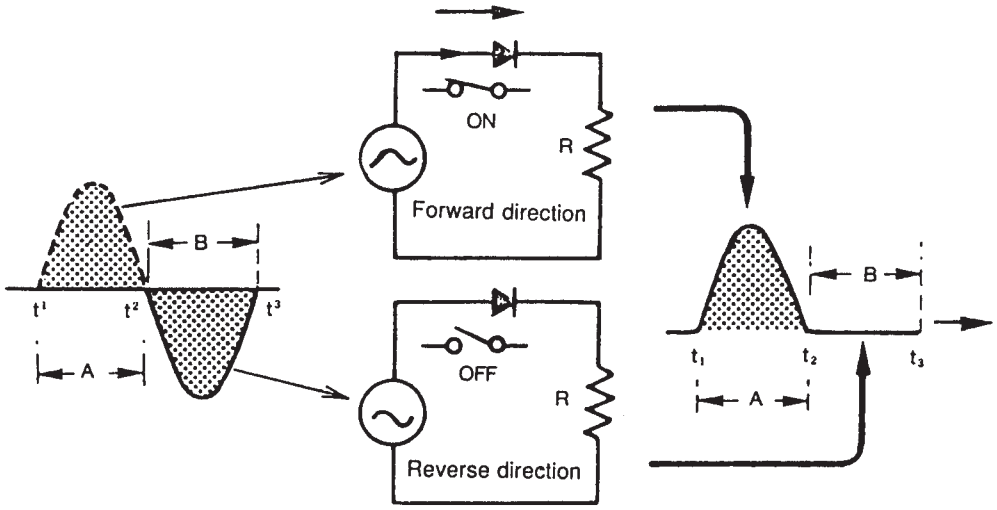


Reverse voltage is applied.



② Switching by diode

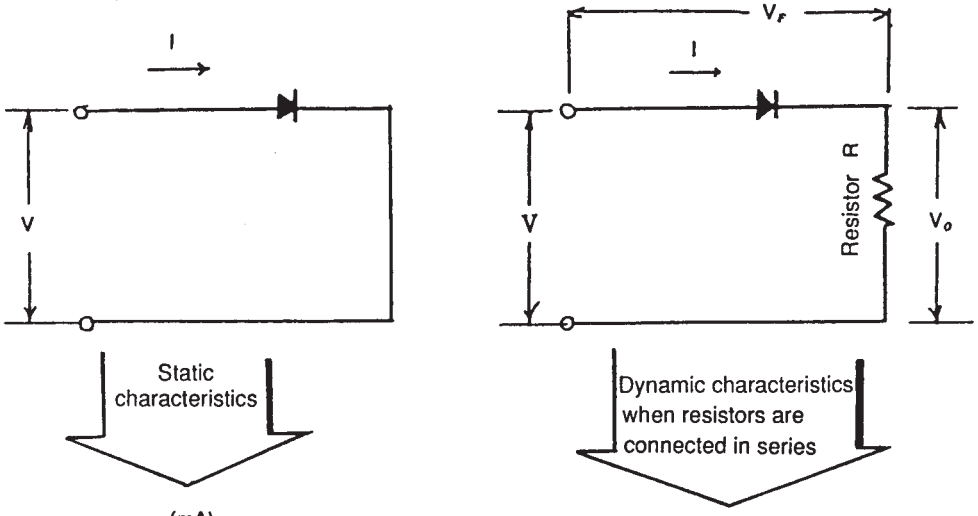
The forward resistance of a diode is extremely small, while the reverse resistance is extremely large. (when an power of several volts is input)
Therefore, diode can function as a switch due to this characteristics.

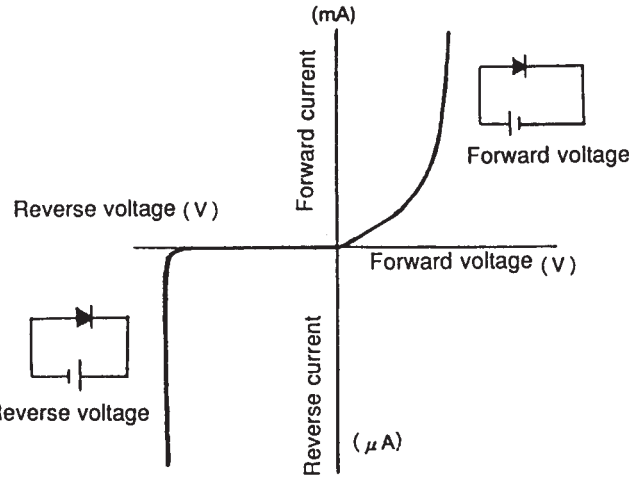


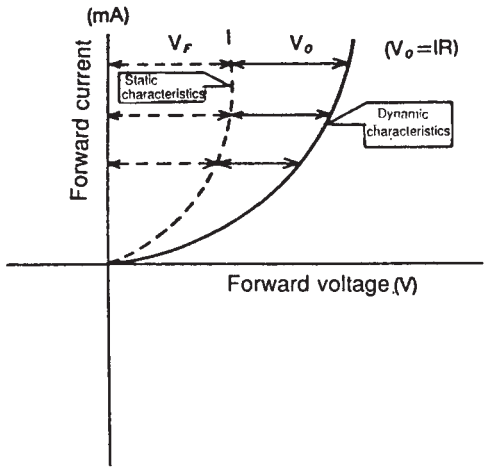
Switching

③ Characteristics of diode

The (voltage-current) characteristics of a diode is referred to as static characteristics. On the other hand, the (voltage-current) characteristics which a diode exhibits when resistors are connected in series is referred to as dynamic characteristics.



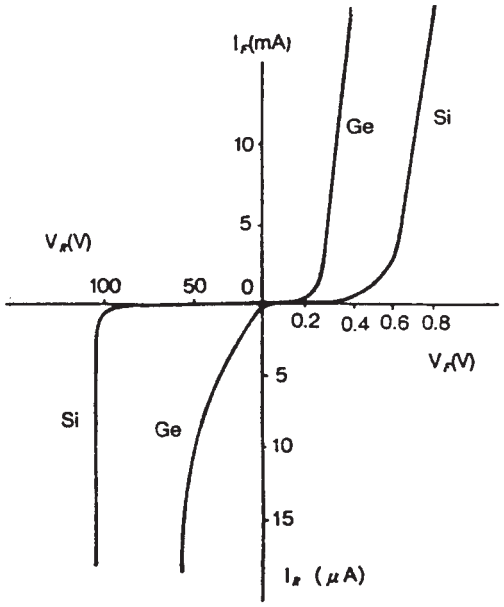




Static characteristics

When forward voltage is gradually applied, an abrupt change of the current occurs at around 0.6V. In other words, the resistance of diode changes in accordance with the voltage changes. When reverse voltage is applied, the current hardly flows but it start flowing suddenly when the voltage reaches a certain level.

Normally, the reverse current is approximately several μA ~ several 10's μA , which is much lower than the level of forward current.

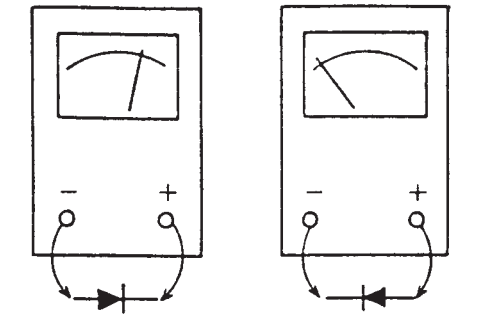


④ Evaluation of diode

Check the resistance of a diode using a tester. Since the negative terminal of the tester is the positive terminal of the internal battery, care should be exercised in forward and reverse direction.

Zener diode and light emitting diode are handled in the same manner.

If conductivity is detected in both directions or when electricity is not conducted in both directions, the diode should be rejected.

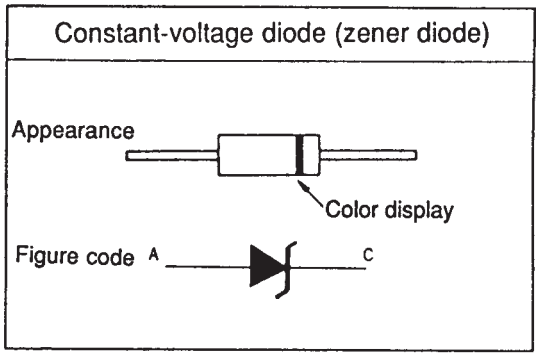


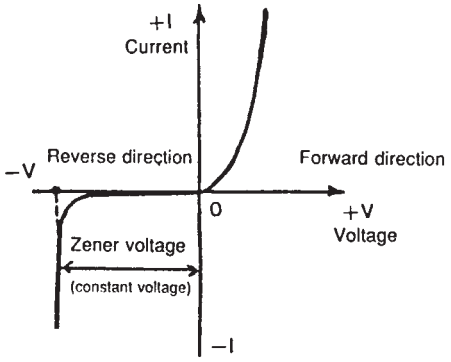
Forward direction Reverse direction

4-2 Constant-voltage diode (Zener diode, ZD)

When reverse voltage applied to a diode is gradually increased, electric current flow starts suddenly when the voltage exceeds a certain level.

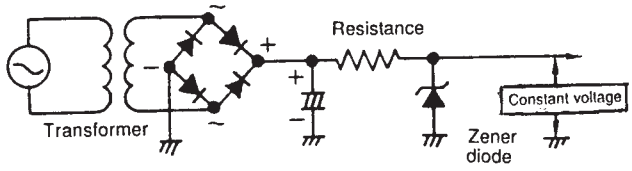
Due to this characteristics, the constant-voltage diodes are used in constant-voltage circuits in Sky-Air systems and room air conditioners in order to supply constant voltage to the electronic circuits (IC, microcomputer).





It was already explained that electric current hardly flow in the diode when voltage is applied in reverse direction. However, when the reverse voltage is increased and exceeds a certain level (referred to as Zener voltage), current flow occurs suddenly. In addition, when a voltage higher than the zener voltage is applied, the voltage between the terminals of the diode does not increase and remains to be constant despite the increase of the current. (a constant-voltage diode is used by connecting voltage in reverse direction.) By using the characteristics above, the circuit shown in the figure below is utilized in electronic circuits whose precision deteriorates due to fluctuation in power source voltage.

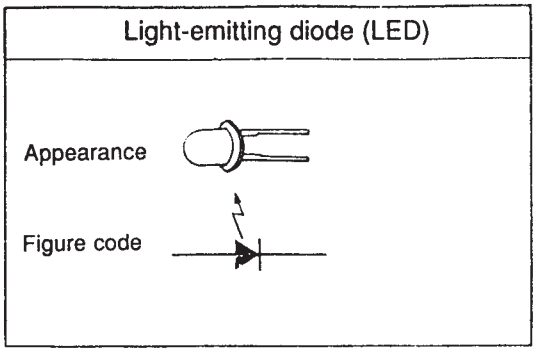
Zener diode includes a special diode Vz≒3V~40V use made of silicon semiconductor. With this diode, a constant voltage can be obtained by connecting a power source whose voltage is slightly higher than Vz (zener voltage).



Constant-voltage circuit with Zener diode

4-3 Light-emitting diode (LED)

The light-emitting diode is the semiconducting element which converts electric signals to optical signals, and used in indicator lamps to indicate operation and error.



When forward current is flown to a diode consisting of P and N types of semiconductors, it emits light from the connection surface of the semiconductors. This diode is called light-emitting diode (LED).

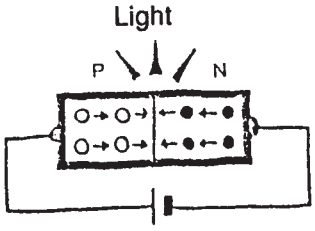
The advantages of light-emitting diode are as below:

Long operational life (semi-permanent)

Emits light at low voltage (2~3V)

Small power consumption (approx. 0.05W)

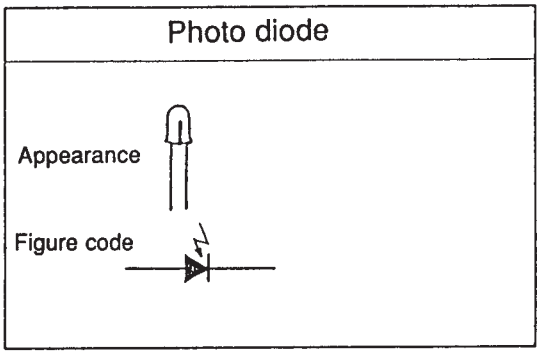
Quick flickering response (1/1000000 sec)



4-4 Photo diode (SPD: Silicon Photo Diode)

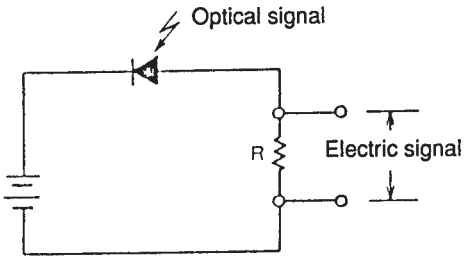
This is an element to convert optical signals to electric signals , and used by applying voltage in reverse direction. (A substantial changes in reverse current occurs according to the light amount as shown in the figure on the right.)

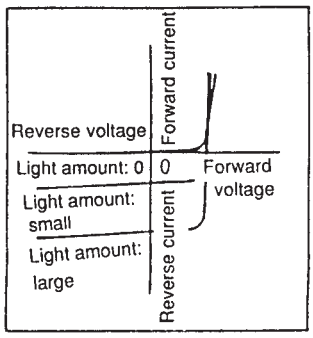
The advantages of photo diode is the quick response, which is much quicker than that of Cds.



Electric signals once played major roles in information communications (broadcasting, radio, etc.). However, today when information communications are conducted with optical signals, this element is indispensable in opto-electronics.

In air conditioners, this element is utilized in the photo receive unit which receives signals (infrared ray) sent from a wireless remote controller.

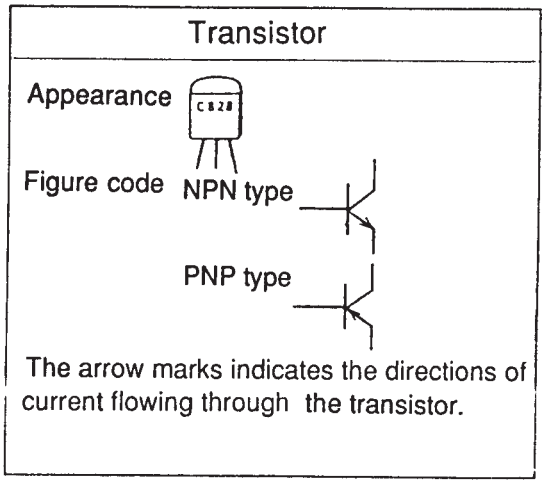




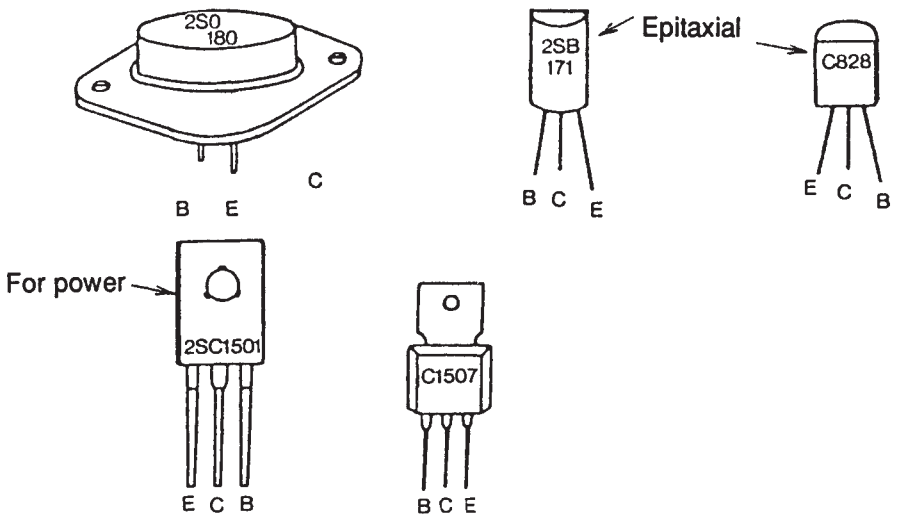
5) Transistor

A combination of P and N type semiconductors are called transistor. There are two types of transistors, PNP and NPN types, according to the combination of semiconductors.

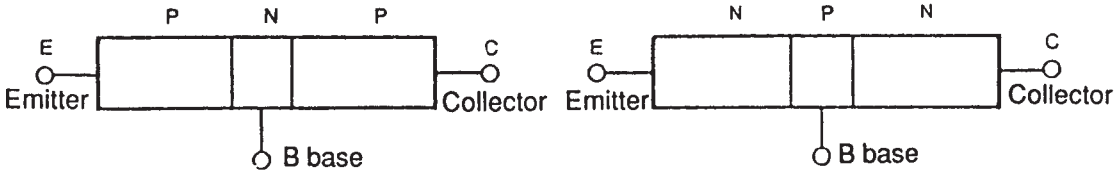
The function of a transistor is roughly classified into two groups, which are "switching" and "amplification". In air conditioners, the switching and amplification functions are utilized in control circuits and electronic thermostat, respectively.



Relationship between the outer shape and electrodes of transistor



Structure of a transistor



(a) PNP type

(b) NPN type

As shown in the figure above, there are two types of transistors. Transistors having N type in the intermediate layer is called PNP type, while the ones with P type in the intermediate layer is called NPN type.

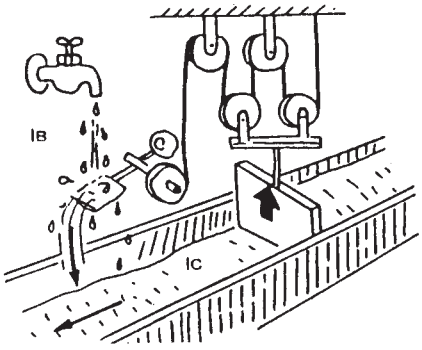
Therefore, a transistor has three electrodes and the electrode in the intermediate layer is called base (B). Other electrodes are called collector (C) and emitter (E), and these three electrodes are expressed by the symbols shown in the figure on the previous page.

The arrow marks for emitters in NPN type and PNP type are opposite with each other. Beware that the voltage is applied in the opposite direction.

5-1 Applying voltage and flow of current

To make a transistor function, it is necessary to externally apply a voltage in the direction so that the current flows as shown by the arrow mark of the emitter.

When a voltage is applied, the current flowing to individual electrodes of the transistor are referred to as emitter current (Ie), collector current (Ic) and base current (Ib). The sum of Ic and Ib equals Ie (Ie=Ic+Ib).



(A) Amplification

When a voltage is applied to the base (B), electricity is conducted from E to C. Although the current (I_B) flowing the base is only slight, the current (Ic: current flowing to the collector) level becomes as large as 30~1000 times of the base current and it looks like that the I_B is amplified.

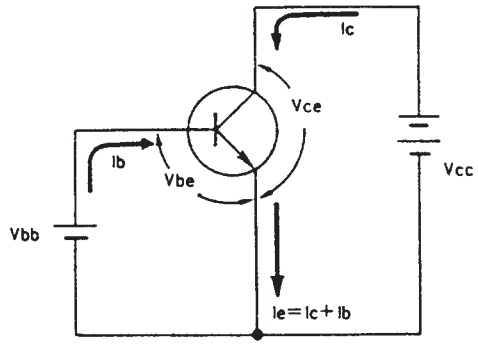
Figure (A) is an example of the characteristics of a transistor.

When I_B (base current) changes, Ic (collector current) changes proportionally. This proportional constant is referred to as (DC current) amplification rate.

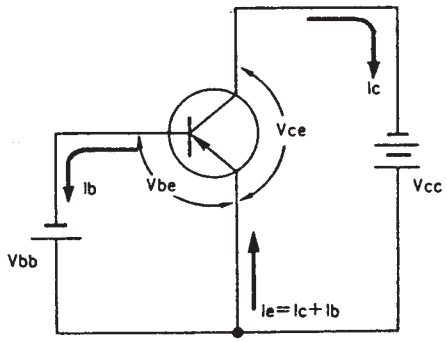
$I_C/I_B = h_{FE}$ (DC current amplification rate)

Therefore, it can be said that the transistor in the figure on the right has an amplification rate of approx. 100 times. --- **Amplification**

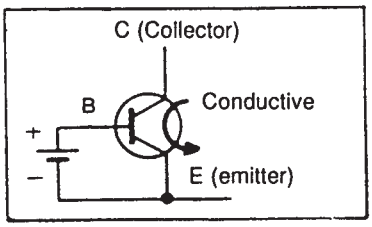
When a base current flow of 0.5mA occurs abruptly, approx. 50mA current flows between E and C, and a switch using a transistor can be made by connecting an electromagnetic relay in series . --- **Switching**

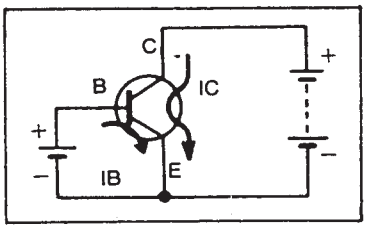


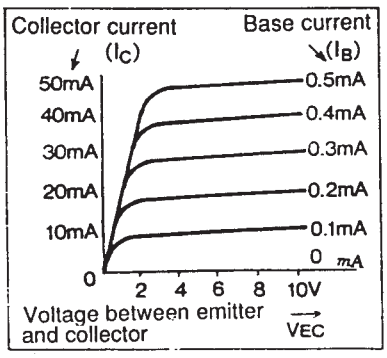
(a) NPN type



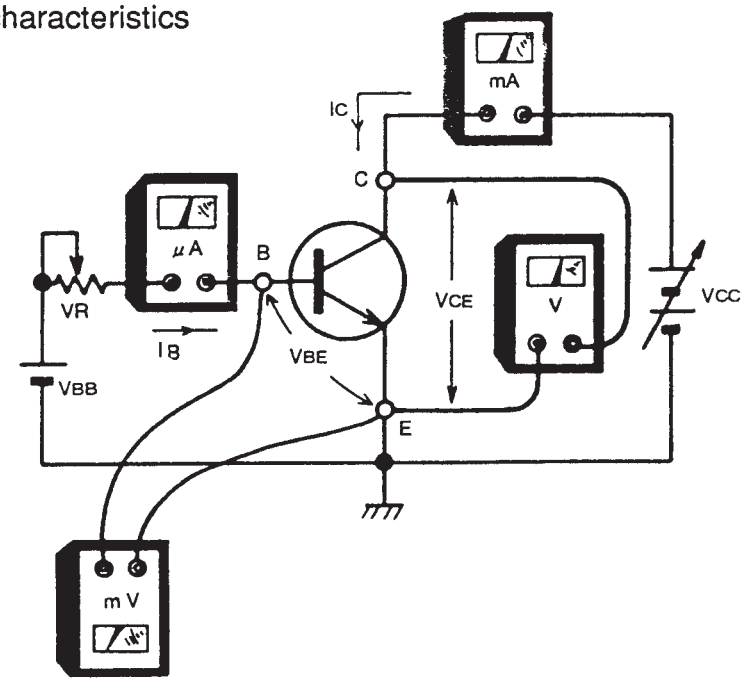
(b) PNP type





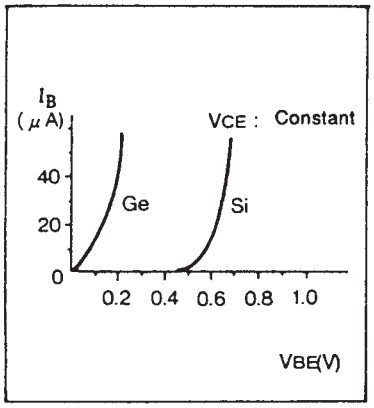


5-2 Static characteristics

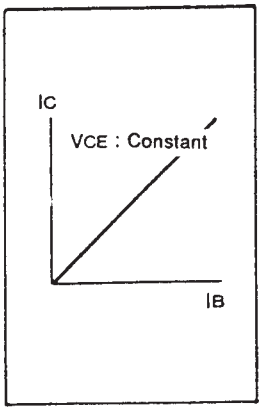


■ Static characteristics of a transistor

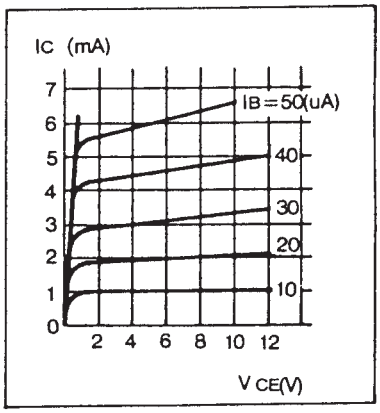
I_B-V_{BE} characteristics



I_C-I_B characteristics



I_C-V_{CE} characteristics



The electric characteristics of a transistor is referred to as static characteristics.

In the calculation of an actual circuit, the values are obtained by drawing a graph based on the static characteristics because the static characteristics of a transistor is non-linear type.

Although the static characteristics vary according to the grounding methods, it is indicated by the emitter grounding in normal case, including the three types below:

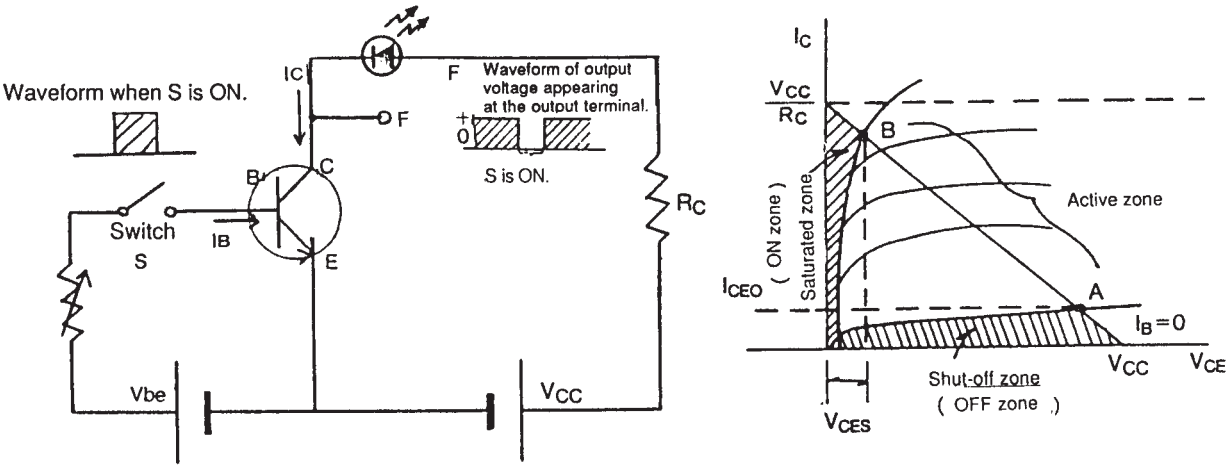
I_B-V_{BE} characteristics (input characteristics)

I_C-I_B characteristics (current transmission characteristics)

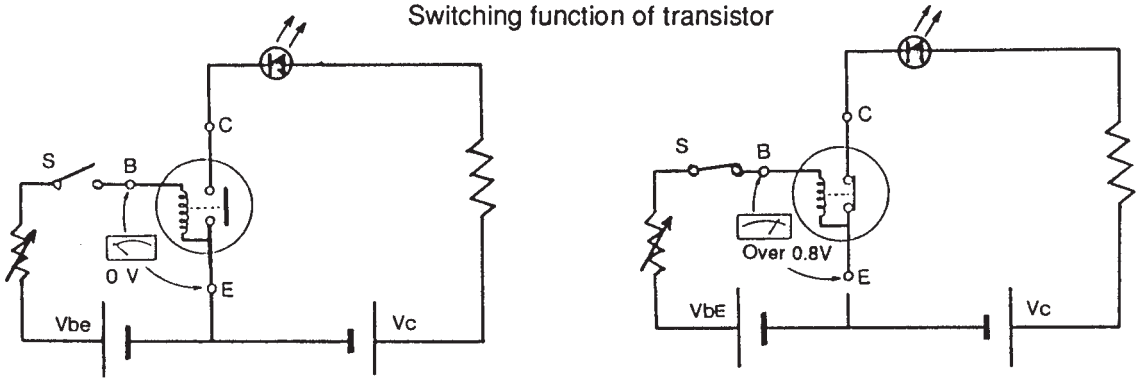
I_C-V_{CE} characteristics (output characteristics)

5-3 Switching

In control system of an air conditioner, etc., the transistor is used to turn the circuit between the collector and the emitter on and off by controlling the base voltage to the minimum (0V) and the maximum (0.8V or higher) levels. The figure below shows this function using a relay.



Switching function of transistor

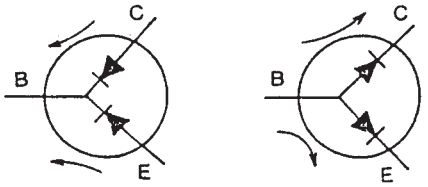


Switch S:OFF　　Switch S:ON

Evaluation of transistor

(1) Evaluation in switching circuit

The transistor is accepted if the voltage (V_{CE}) between the collector and emitter is 0V when the voltage (V_{BE}) between the base and the emitter is 0.8V or higher. That is, the voltage of collector is 0V if the emitter voltage is 0V, and if the emitter voltage is 12V the collector voltage is also 12V.



PNP type　　NPN type

(2) Evaluation of transistor itself

As shown in the figure on the right, a diode is formed between the terminals of a transistor. Check the conductivity between these terminals. At this time, the resistance between the collector and the emitter shows a high value because a diode is connected in series in opposite direction regardless of the direction of the silicon transistor. However, the resistance is comparatively low when a germanium transistor is used.

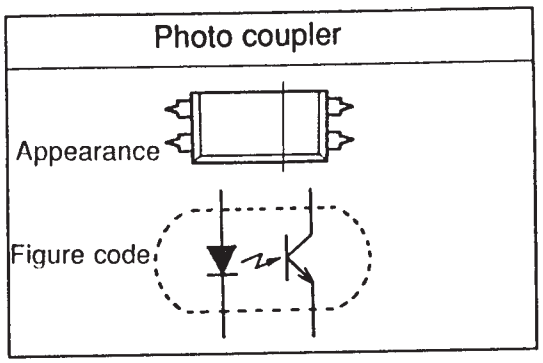
6) Photo coupler

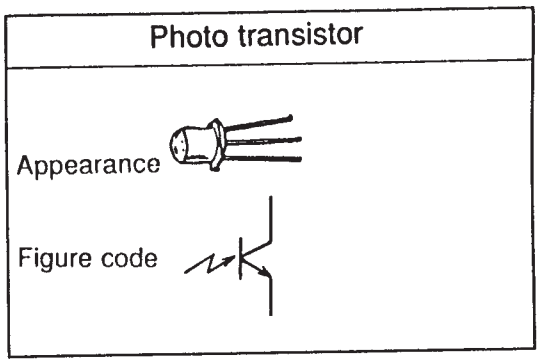
A photo coupler consists of a light emitting diode (LED) and a photo transistor* placed in a case. The photo coupler converts electric signal to optical signal with the light emitting diode and then re-converts the optical signal to electric signal.

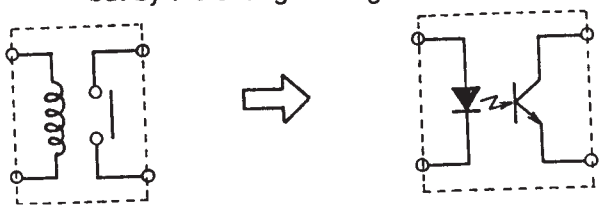
The photo couplers are used mainly for signal communications (protective device signal input, defrost signal input and transmission signal input, etc.) between the different voltages (200V and 120V, etc.)

Photo couplers are electrically insulated for optical signal communications and used for prevention of troubles resulting from noise and interferences of voltage and current.

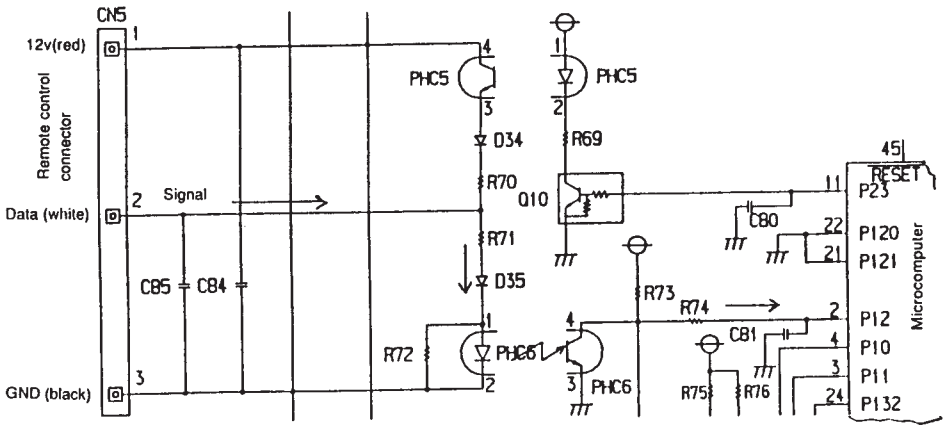
❋ Photo transistor: Photo transistor controls the current flowing from the collector to the emitter not by the changes of base current but by the changes of light.







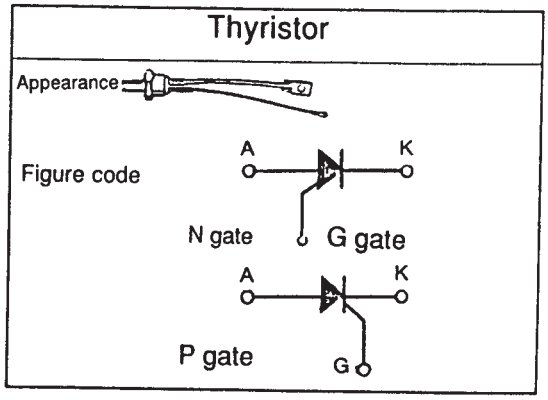
Example of application of photo coupler (signal communication between remote controller and indoor printed circuit board)



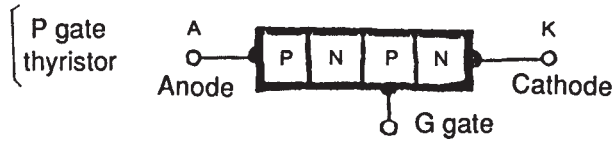
The photo coupler converts the electric signal sent from the remote controller to optical signal, and also converts the optical signal to electric signal (low voltage DC current) to input to the microcomputer.

7) Thyristor

Thyristor is a power control element consisting of P and N type semiconductors connected in 4 layers. This is used in speed control of DC motor, light control device of electric lamp and non-contact switch utilizing its rectifying and switching functions. Moreover, the thyristor can turn on and off the extremely high voltage/current of several thousand volts and several thousand ampere with one element which is so small that it is placed on our palm.

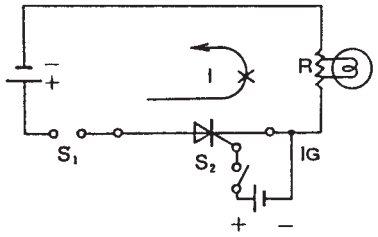


Thyristor (SCR: Silicon Controlled Rectifier)

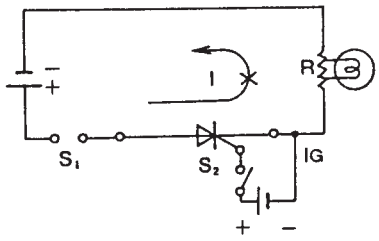


Operational principle of thyristor

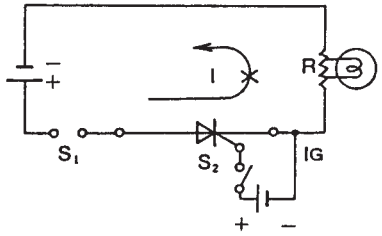
(a) I does not flow even when S_1 is turned on.



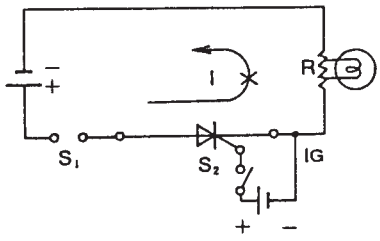
(b) I flows when I_G is flown by turning S_2 on.



(c) I keeps flowing even when S_2 is opened.



(d) I stops flowing when S_1 is opened, but it does not start flowing even when S_1 is turned on unless S_2 is turned on.



The voltage applied between G (gate) and K (cathode) to turn the thyristor on is referred to as trigger voltage.

To change the ON status to OFF status, the value of I is decreased below a certain level or a reverse voltage is applied between A (anode) and K (cathode).

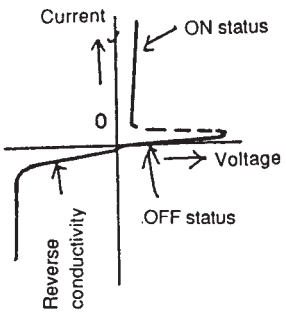
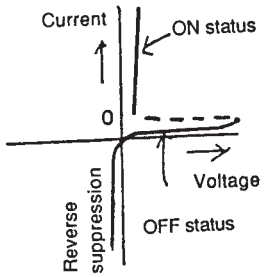
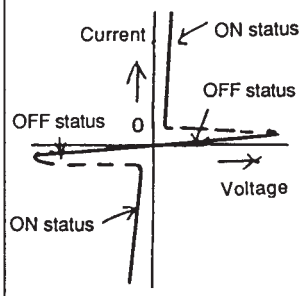
7-1 Application of thyristor

(1) Rectifying circuit ----- SCR can convert AC current to DC current as was done with the rectifying diode. Moreover, it is possible to control the DC voltage by controlling the gate (G).

(2) Electronic control by phase control ----- Power applied to a load can be controlled by regulating the gate (G) at a proper timing.

(3) Inverter ----- DC current can be converted to AC current.

7-2 Classification according to the functions of thyristor

Characteristics of quadrant #3		Suppression	Conductive	Switching
Number of terminals	2	Reverse suppression 2-terminal thyristor	Reverse conductive 2-terminal thyristor	Dual direction 2-terminal thyristor
	3	Reverse suppression 3-terminal thyristor	Reverse conductive 3-terminal thyristor	Dual direction 3-terminal thyristor
Main electrode Voltage-current characteristics (Positive electrode characteristics)				
Reference		The reverse suppression 3-terminal thyristor is generally called as SCR, which is the commercial name given by GE, developer of this element.		The dual direction 3-terminal thyristor is generally called as triac. This name was originally a commercial name given by GE, and has become the standard term used world-wide.

8) Triac

Triac is a 3-polar dual direction thyristor which can flow electric current in both directions (AC) and functions with both positive and negative gate voltages. The functions are the same as those obtained by combining thyristors in parallel and in reverse direction.

Triac	
Figure code	

Triac has a 5-layer structure of NPNPN, which is the same as SSS, and is used for AC non-contact switch, electric heater control, light adjusting device, three-phase motor control and temperature control of copy machines (Xerox, PPC). In Daikin products, it is used for phase control of indoor unit fan of room air conditioners and sky air systems.

❋ Photo triac

Photo triac functions when light is emitted instead of applying gate voltage, and is often used as light receiving element of photo coupler. It is also often incorporated into phase control circuit of fans by combining with light emitting diode (LED).

Photo triac	
Figure code	

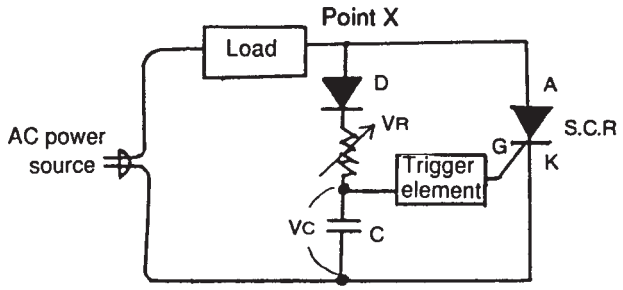
9) Dyac

Dyac is often used as the trigger element in AC phase control circuit such as muffling access ignition device of water boilers, etc..

Another name of dyac --- Dual direction diode thyristor

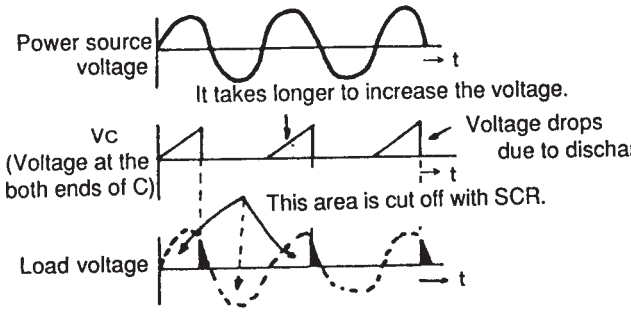
Dyac	
Figure code	

Half-wave phase control using thyristor

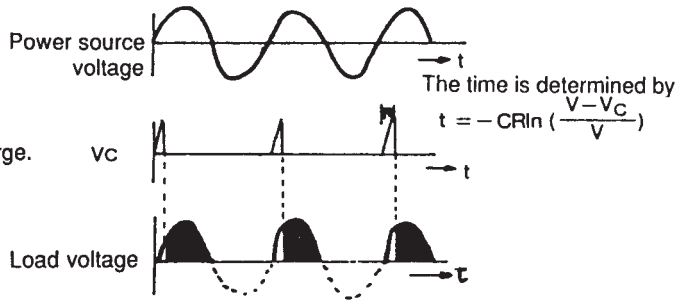


The figure on the left shows the principle. Noise prevention circuit and serge absorption circuit are incorporated into an actual circuits.

- When the value of R of VR is large:



- When the value of R of VR is small:



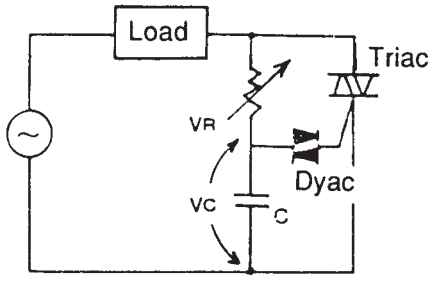
Time is expressed by ms order in this document.

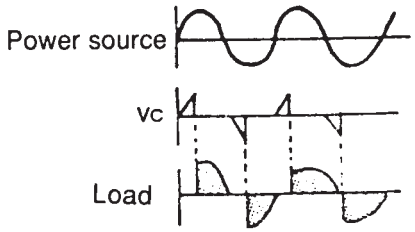
Stepless phase control (load current control) is possible by controlling the variable resistor VR. When the value of R is decreased, the time constant (CxR) becomes smaller, thus the Vc voltage increases quickly and turns the SCR on.

On the other hand, when the value R is increased, it takes more time for the Vc voltage to increase, resulting in delay in turning SCR on.

All wave phase control is also necessary for controlling motors, and it is easily conducted using a dual direction thyristor instead of a reverse suppression thyristor.

All wave phase control using triac



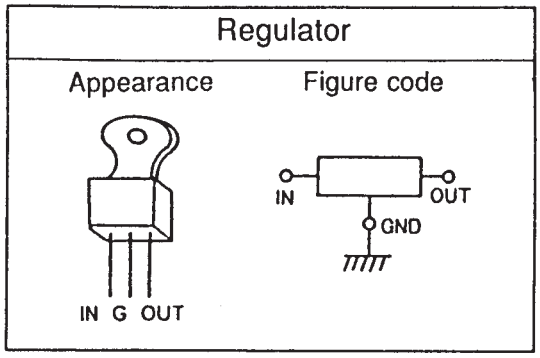


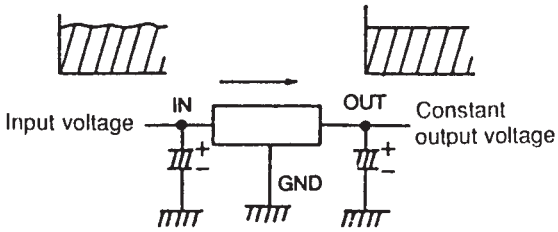
The waveform shown above is the one when a pure resistance is connected as the load. The phase will slightly differ if an inductive load is connected.

10) Regulator

Regulator is an IC for power stabilization. The regulator can control the output voltage to a constant level regardless of the input voltage.

The accuracy of regulator is higher than that of zener diode, and can take a heavy power source out.

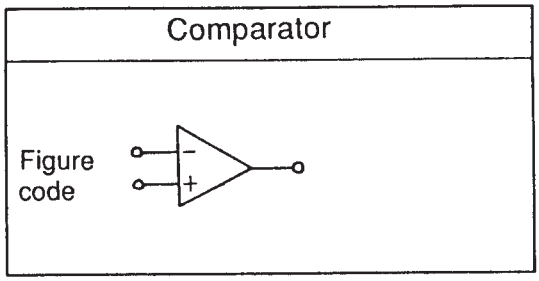


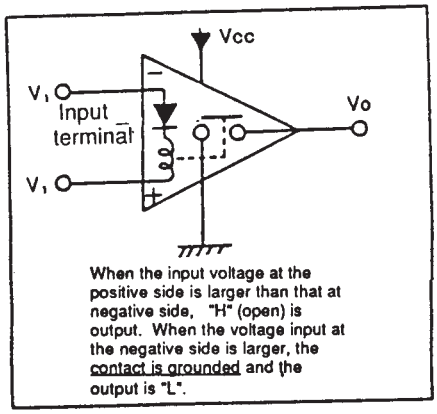


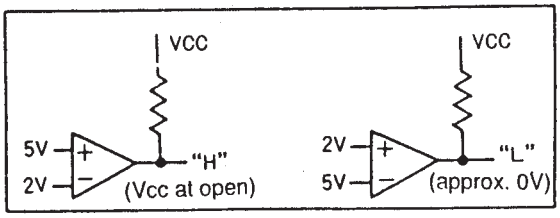
11) Comparator

Comparator compares two input voltages and outputs the result as "H" or "L". The input terminal has positive side and negative side, and if the voltage input to positive side is higher than that input to negative side, the results is output as "H", while "L" is output in the opposite case.

The figure below shows this function using a relay as an example.



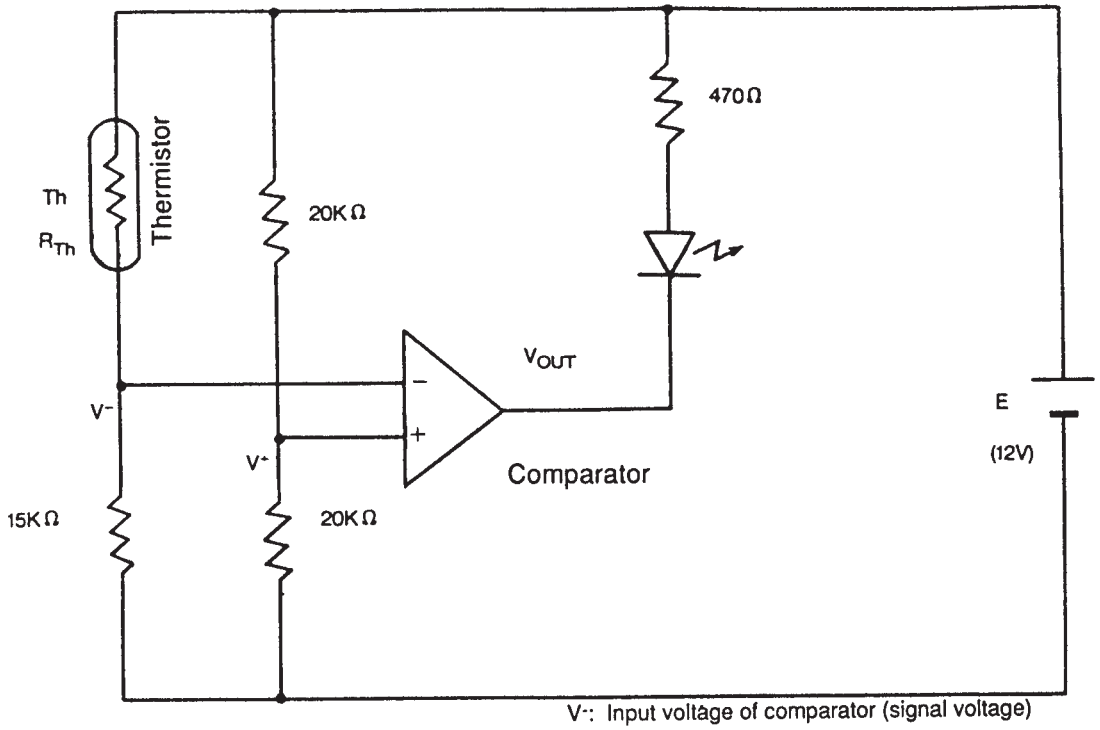




Applications of comparator

The comparator IC is often used as an A-D converter to convert the control codes (analogue) of thermistors to operating codes (digital).

Example of LED circuit by thermistor control signal (analogue)



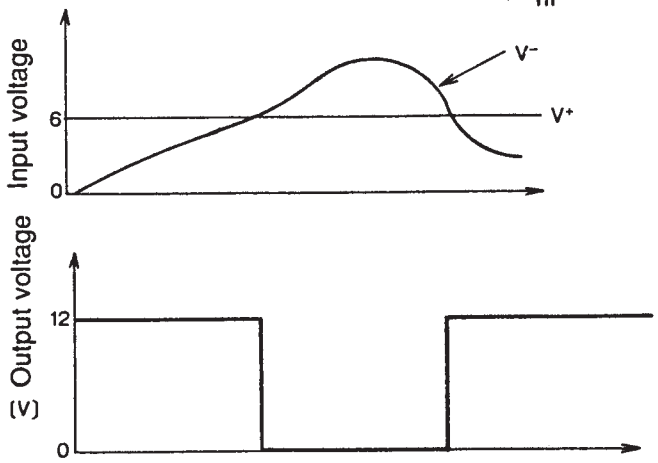
V⁻: Input voltage of comparator (signal voltage)

V⁺: Input voltage of comparator (reference voltage)

V_{OUT}: Output voltage of comparator

R_{Th}: Resistance (kΩ) of thermistor

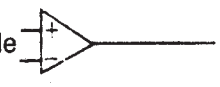
$$V^- = 12 \times \frac{15}{15+R_{Th}},\ V^+ = 12 \times \frac{20}{20+20} = 6\ (V)$$



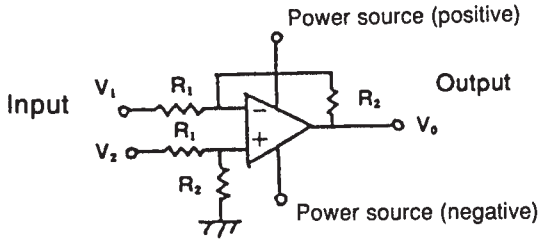
Waveforms of input voltage V^- and output voltage V_{OUT}

12) Ope. amp

Ope. amp is an integrated circuit called as calculation amplifier. It is used for 1) calculation, 2) Impedance change, 3) measurement control and 4) oscillator, etc. by connecting to an appropriate external circuit.

Ope. amp
Figure code 

○ Differential amplification



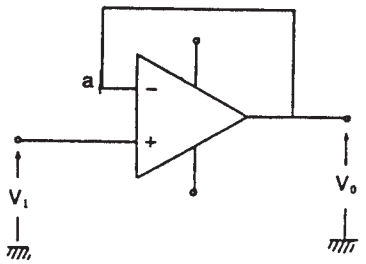
$$V_0 = A\ (V_2 - V_1)$$

A is determined by R.

$$A = \frac{R_2}{R_1}$$

(A is voltage amplification.)

○ Voltage follow (impedance change)

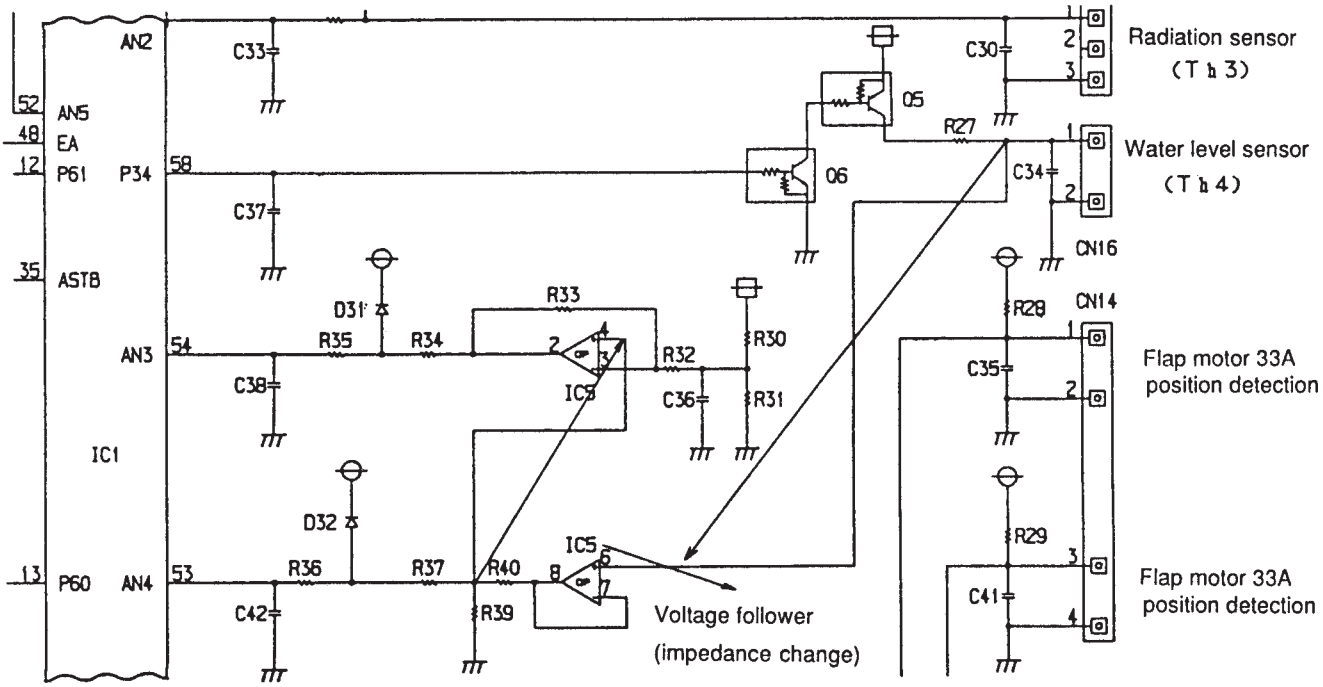


Circuit with amplification of 1, in which current hardly flows between positive and negative input terminals and a large current can be taken out from the output terminal.

* Electric potential at point a = V_1

*$V_0 = V_1$

Example of application of ope. amp. in electronic circuit of an air conditioner



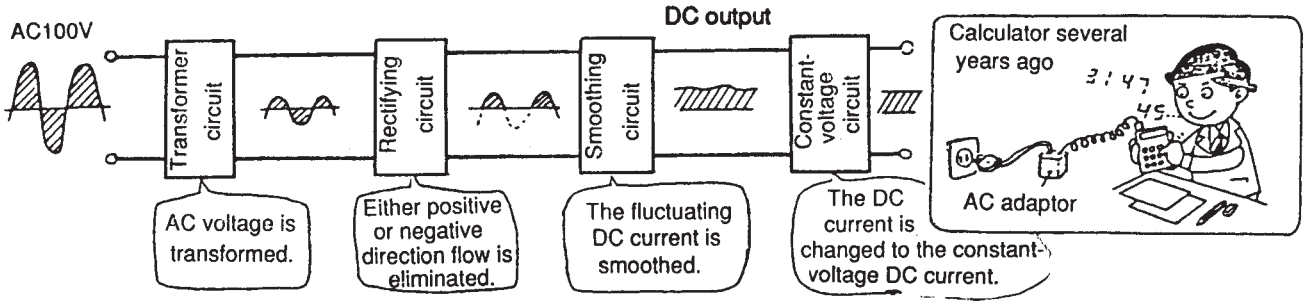
The voltage of terminal #1 of the water level sensor is entered to terminal #6 of IC5 (ope. amp), converted to impedance, output to terminal #8 (a large current is taken out) and finally input to terminal #53 of the microcomputer. --- **Voltage follower**

On the other hand, the output of terminal #8 is entered to terminal #4 of IC5, the difference from the voltage entered to terminal #3 is amplified and finally entered to terminal #54 of the microcomputer. --- **Differential amplification**

3 Electronic circuits in air conditioners

1) Power source circuit

Electronic circuits operates with DC voltages of 5~24V although it differs according to the machines and applications. Since household or commercial use power sources are AC100V or AC200V, it is necessary to convert the power source to low voltage DC current. The procedure to change the AC power source to a low voltage DC power source is as illustrated below:

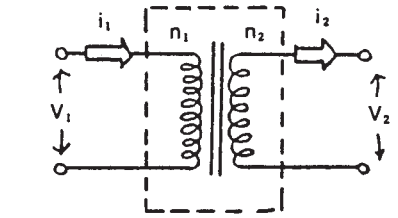


① Transforming circuit

Normally , voltages are changed to the necessary level with a transformer. When the number of turns, voltage and current are expressed as n_1, n_2, V_1, V_2 and i_1 and i_2, respectively, the equation below is obtained.

$$\frac{V_1}{V_2} = \frac{i_2}{i_1} = \frac{n_1}{n_2}$$

$\frac{n_1}{n_2}$ is referred to as turn ratio.

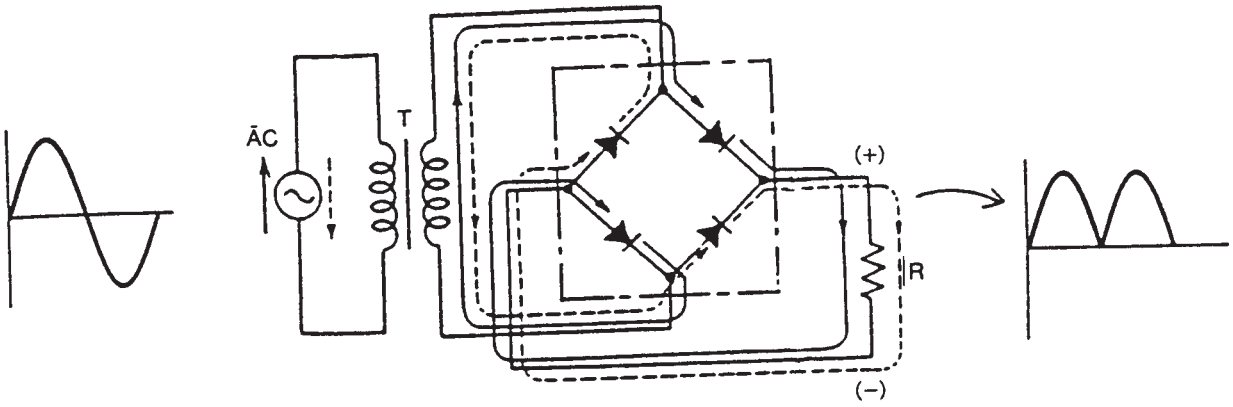


② Rectifying circuit

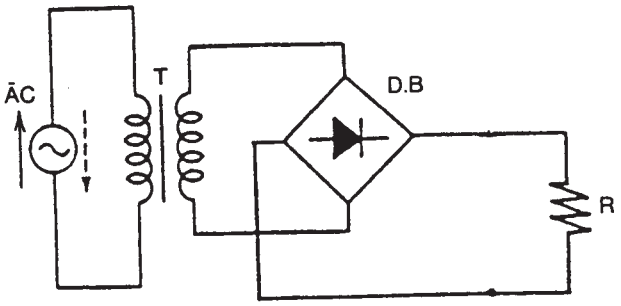
Rectifying circuit includes half-wave, all-wave and double-voltage rectifying circuits. The all-wave rectifying circuits with diode bridges are normally used in air conditioners .

Bridge-type all-wave rectifying circuit

This rectifying circuit is normally used in air conditioners. In addition, diode bridge consisting of 4 diodes is used in actual circuits.

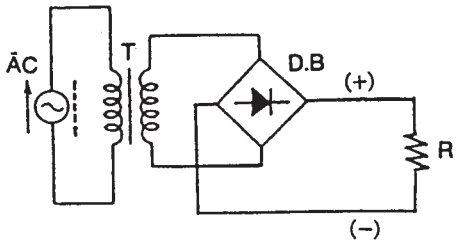


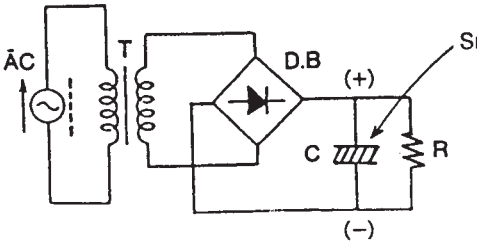
The diode bridge (D.B) is shown by the code in the figure on the right.



③ Smoothing circuit

When a capacitor C is connected to a rectifying circuit, the voltage becomes a fairy smooth DC voltage due to the discharge function of the capacitor. The capacitors with this function is called as smoothing capacitors.





Smoothing by a capacitor

④ Constant-voltage circuit

It is necessary for the reference voltage of main circuit in an electronic control circuit to maintain a certain level despite fluctuations in loads.

The elements below are utilized in order to further stabilize the smoothed power source:

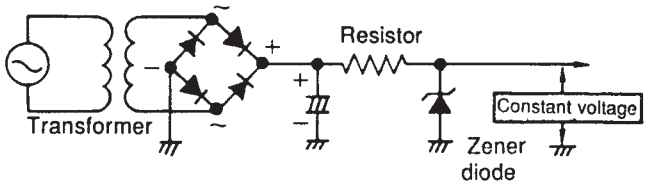
(1) Zener diode (ZD)

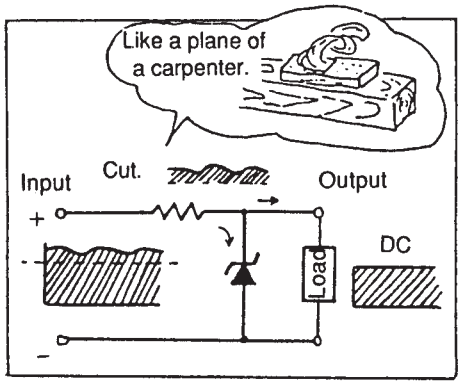
(2) 3-terminal regulator

(1) Zener diode (ZD)

Zener diode is used with reverse voltage (zener voltage). When voltage in reverse direction applied to the zener diode is increased, a sudden increase of current occurs at a certain voltage level despite the voltage remains to be constant.

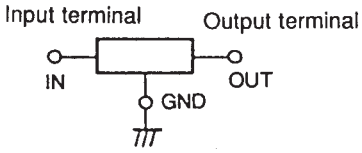
Zener diodes of 3V~40V are available.



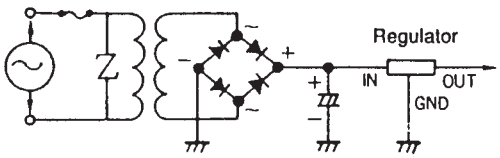


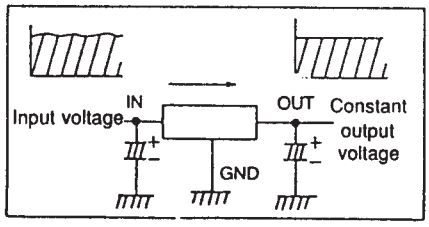
(2) 3-terminal regulator

Regulator (IC for power source stabilization) is utilized to stabilize the voltage of a circuit whose reference voltage is comparatively high or to take out a large output current.

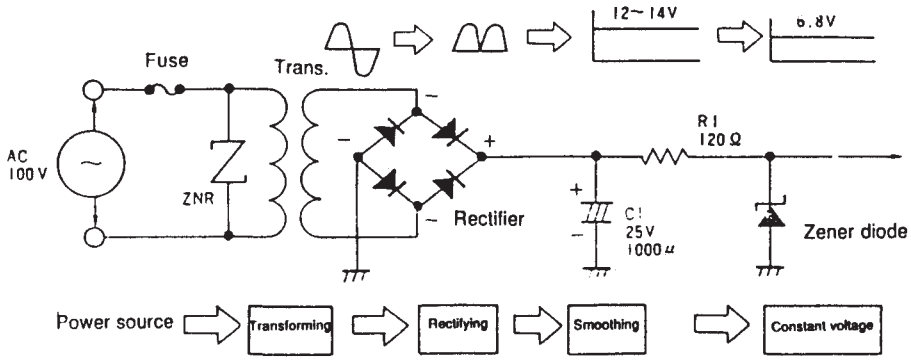


Symbol of regulator





Example of integrated circuit



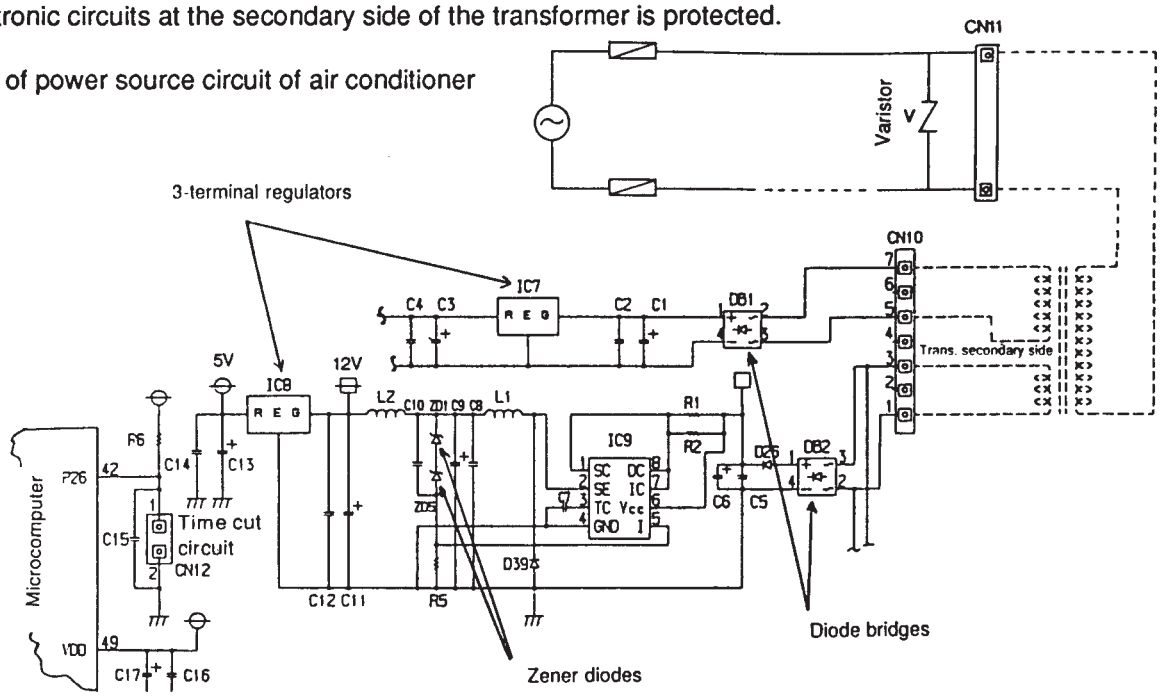
○ Varistor and fuse

Varistor is used to protect electronic circuit against lightning serge or abnormally high voltage (200V in the example above).

When an excessive voltage is applied to power source, the varistor short-circuits and is broken.

At this time, the fuse blows off due to the overcurrent, the electricity route is shut-off, and thus the electronic circuits at the secondary side of the transformer is protected.

Example of power source circuit of air conditioner



2) Room temperature thermostat circuit

● **Example of room temperature input**

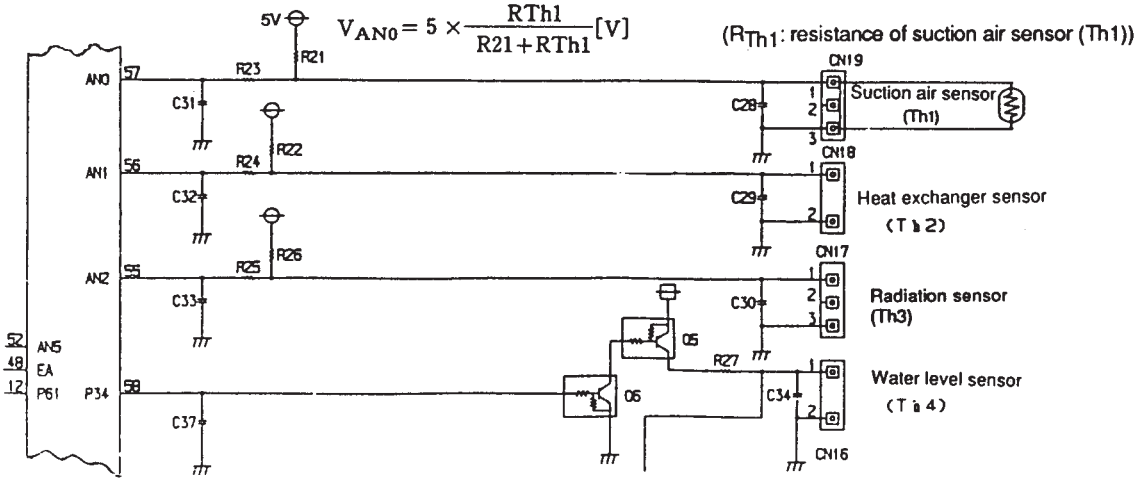
* The voltage divided by the suction air sensor (Th1) and the resistor (R21) is input to port 57 (AN0) of the microcomputer port (IC1).

* When the temperature of the room increases, the resistance of the sensor (Th1) decreases, decreasing the voltage input to the microcomputer port. When the voltage becomes lower than the preset value, a signal to turn the compressor on is output when cooler is in operation.

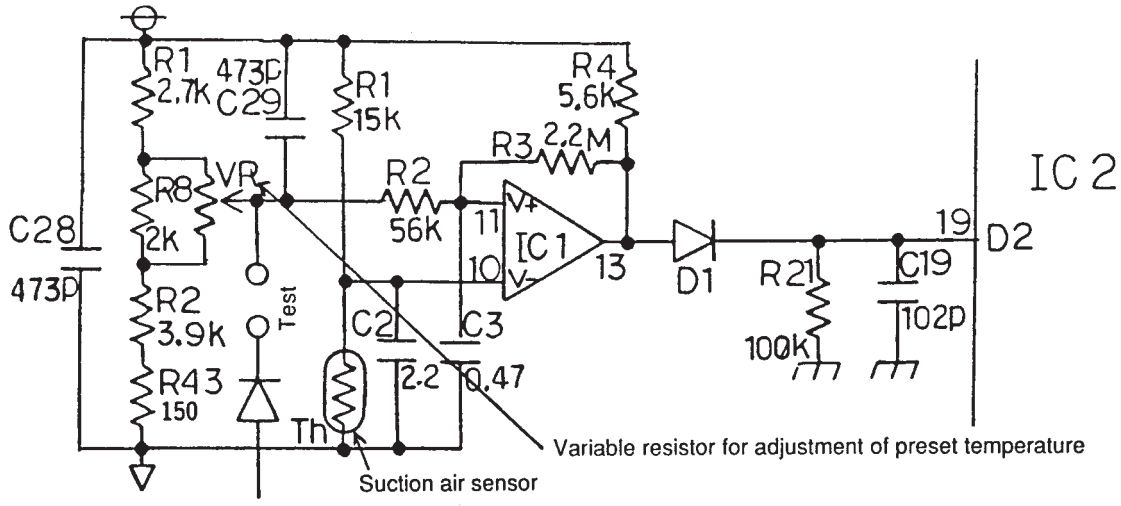
※ The voltage V_{AN0} input to the analogue port (AN0) of the microcomputer is obtained with the equation below:

$$V_{AN0} = 5 \times \frac{RTh1}{R21 + RTh1} [V]$$

(R_{Th1}: resistance of suction air sensor (Th1))



● Example of inputs of room temperature and preset temperature



The reference voltage which has already been divided is entered to the positive terminal V^+ (pin 11) of the comparator.

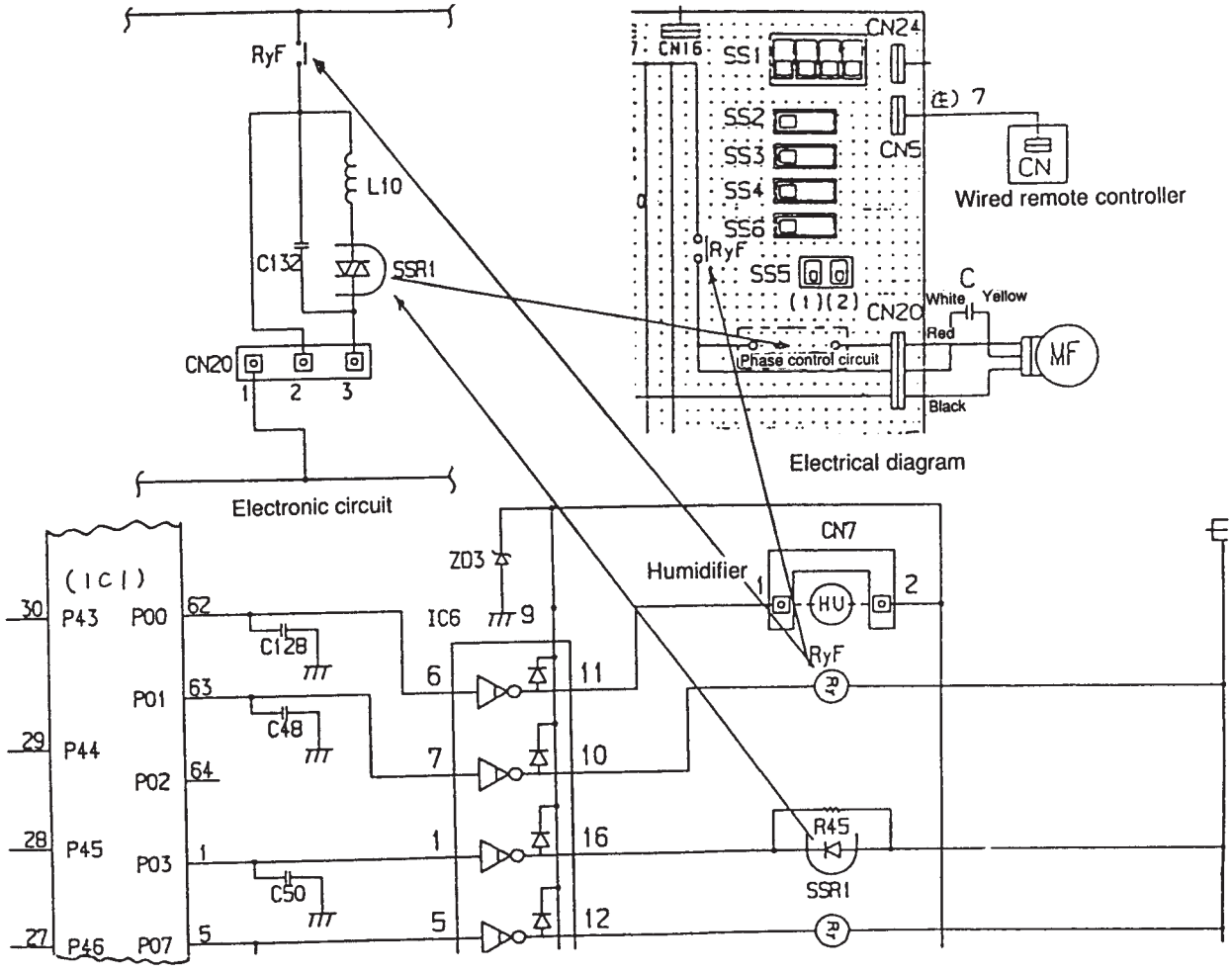
The temperature converted to voltage with the thermistor and R1 is entered to V^- (pin 10).

As the temperature increases, the potential at V^- side (pin 10) decreases below the potential at V^+ side. Therefore, the comparator outputs "H" signal and this "H" signal is input to microcomputer D2 (pin19).

On the other hand, when the temperature falls, the potential at V^- side (pin 10) increases above the potential at V^+ side. Therefore, the comparator outputs "L" signal and this "L" signal is input to microcomputer D2 (pin19).

3) Fan control circuit

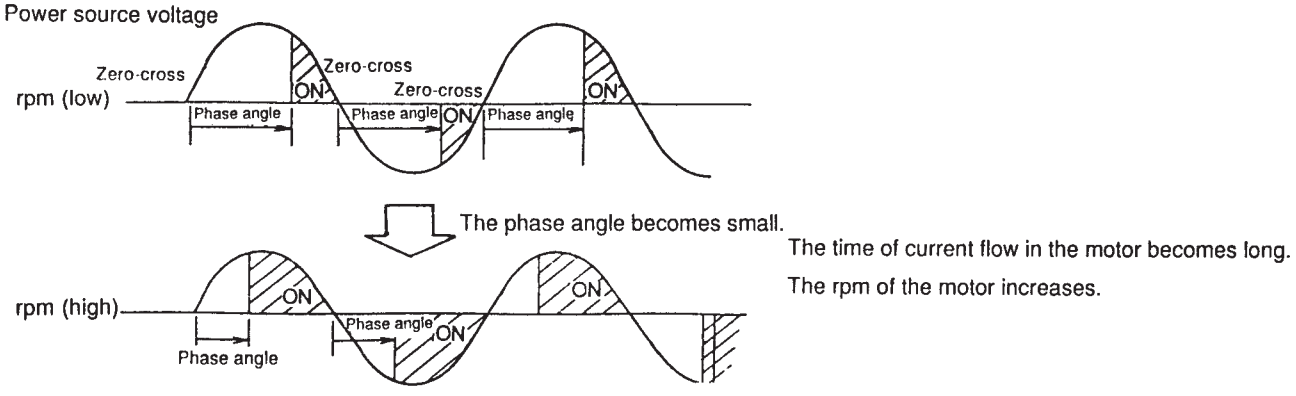
When "H" signal is entered to port PO1 (pin 63) of the microcomputer (IC1), port #10 of IC6 outputs "L" signal. The coil of RyF (indoor fan) is excited and contact a closes, thus the indoor fan starts when the photo triac (SSR1) turns on.



Electronic circuit

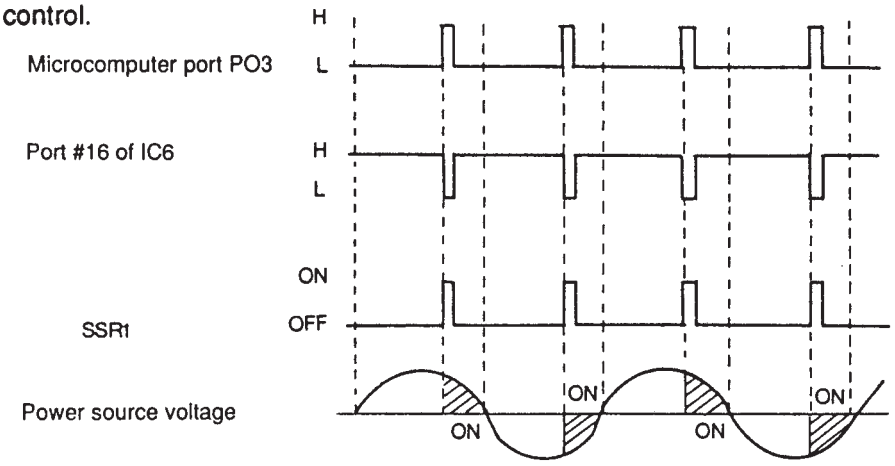
3-1 Fan motor phase control (constant phase angle control)

The voltage of fan motor is controlled with the phase angle from the zero-cross of the power source voltage waveform. With this voltage control, he rpm of the fan motor can be changed linearly.

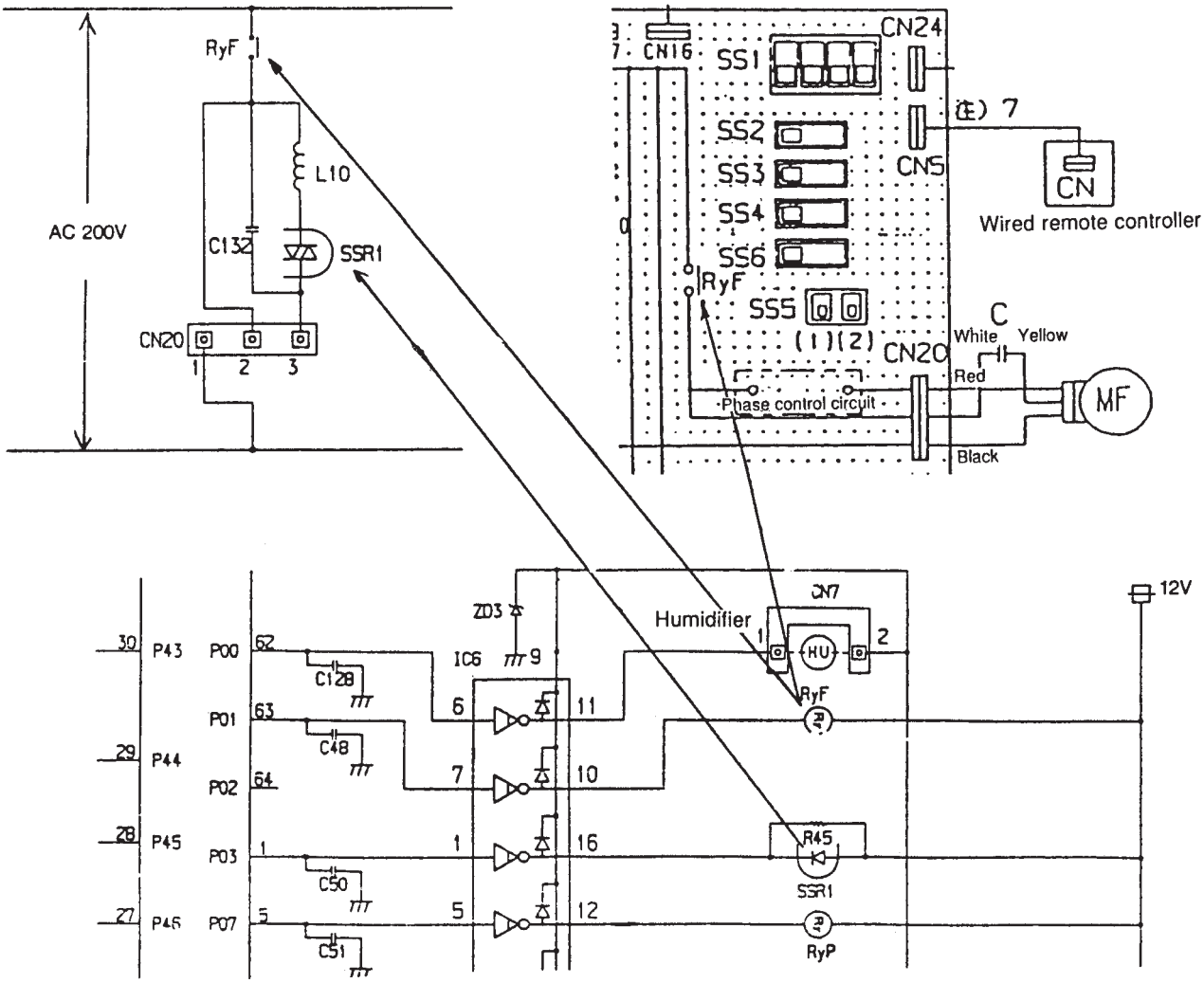


The time of current flow in the motor becomes long.
The rpm of the motor increases.

In the figure below, "H" (5V) and "L" (0V) signals are entered alternatively to port PO3 (1) of microcomputer (IC1), and also the signals below are entered to port #16 of IC6. The photo triac (SSR1) is turned on and off with these signals, and regulates the fan speed with the all-wave phase control.



When the fan speed is set to a higher level via the remote controller, "H" signal is output from P03 of the microcomputer more frequently (the phase angle becomes small.), increasing the time length when the power source voltage is turned on. Thus the speed of the fan increases.

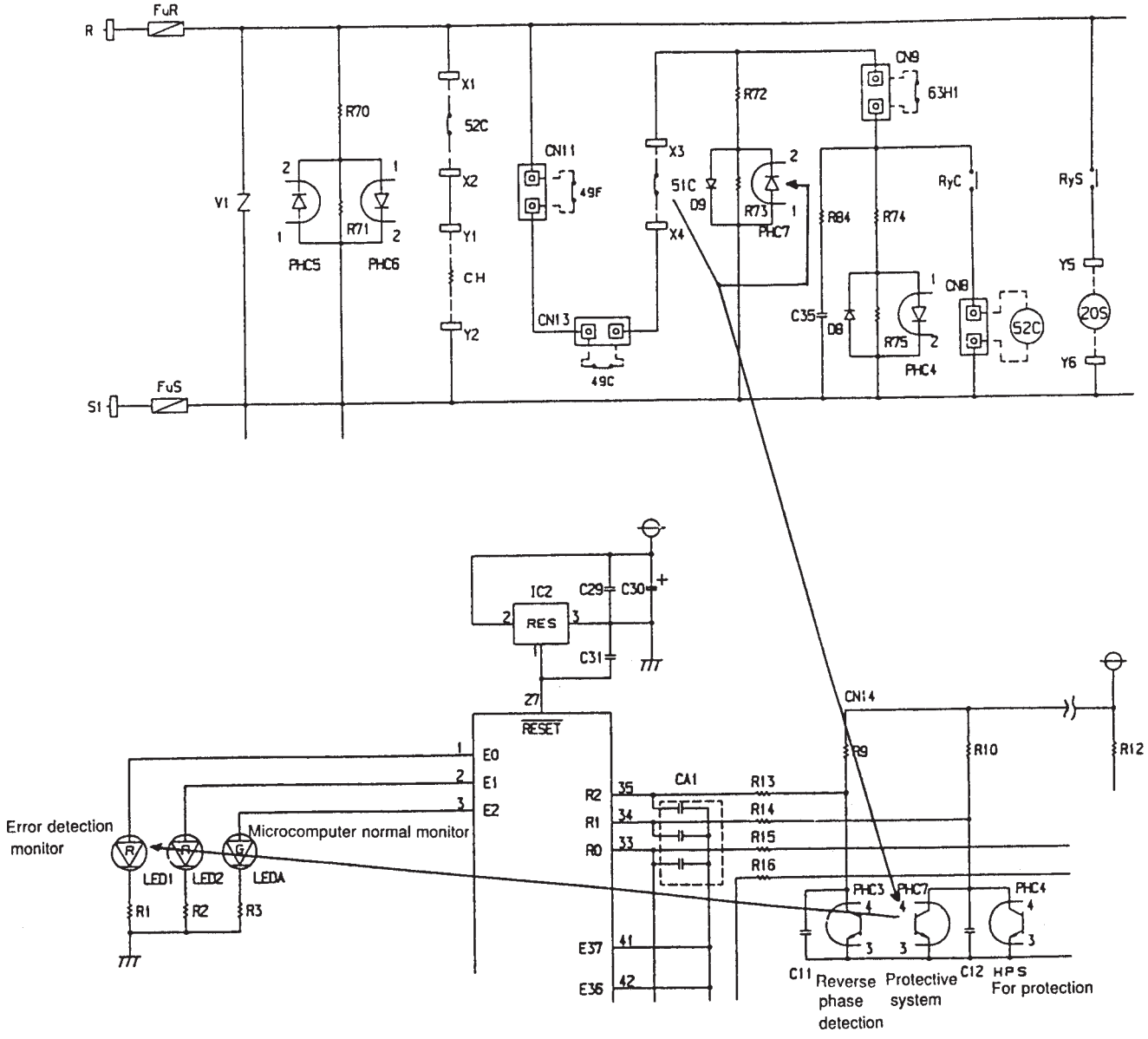


4) Error detection monitor display circuit

In this section, the process from when the protective system is activated to when the error detection monitor lights is explained.

For example, when 51C (compressor overcurrent relay) is activated, PHC7 (photo coupler) cannot function because voltage is not applied. Therefore, H (5V) is applied to terminal R1 (pin 34) of the microcomputer.

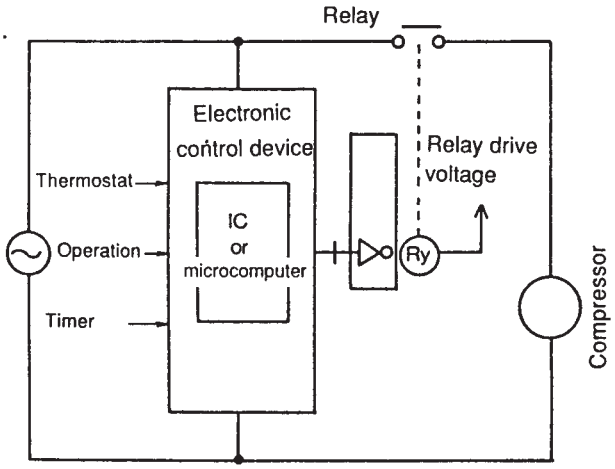
When H (5V) is applied to microcomputer terminal R1, terminal E0 (pin 1) detects the H (5V) and LED1 (error detection monitor) lights up, indicating that the protective system is activated.



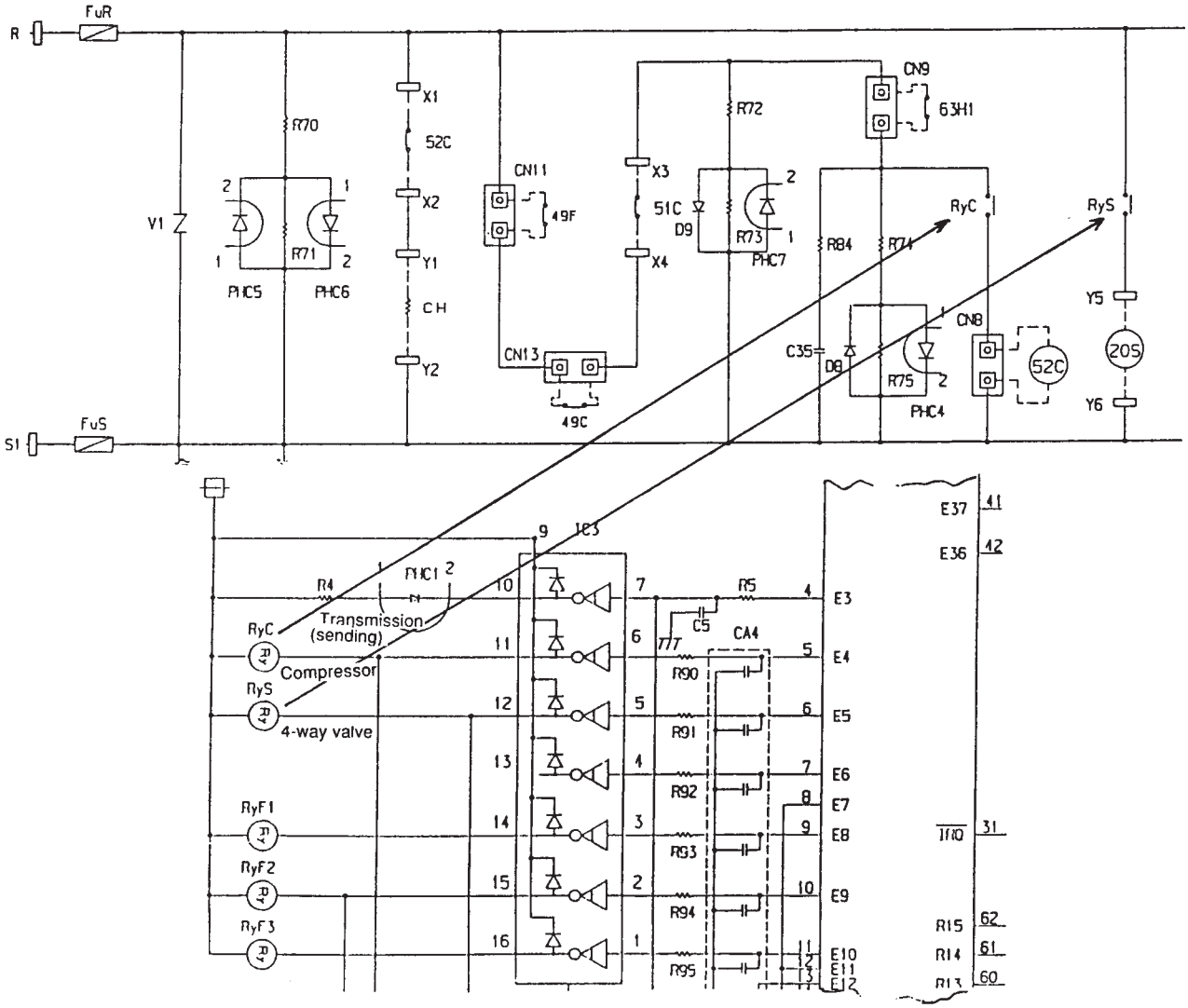
5) Compressor drive circuit

- **Relay drive circuit**

  Although the relay is driven by the signal output by the microcomputer, the current output by the microcomputer is insufficient. Therefore, the current is amplified with a transistor or a driver (NOT IC) before it flows to the relay coil. In the figure below, the relay turns on when the output port of the microcomputer is H (50).



Relay drive circuit



Compressor drive circuit of Sky-Air System outdoor unit

6) Microcomputer control of air conditioner

The circuits shown in Fig.1 and 2 are the simple examples of microcomputer control circuits. The microcomputer determines the content to control based on the control signal sent from the remote controller and the data entered from the temperature sensor, and then outputs signals to the relay. Thus the microcomputer controls the indoor fan, compressor and solenoid valve coil, etc.. In addition, the microcomputer sends signals to LEDs (light emitting diode) in order to display the operational conditions.

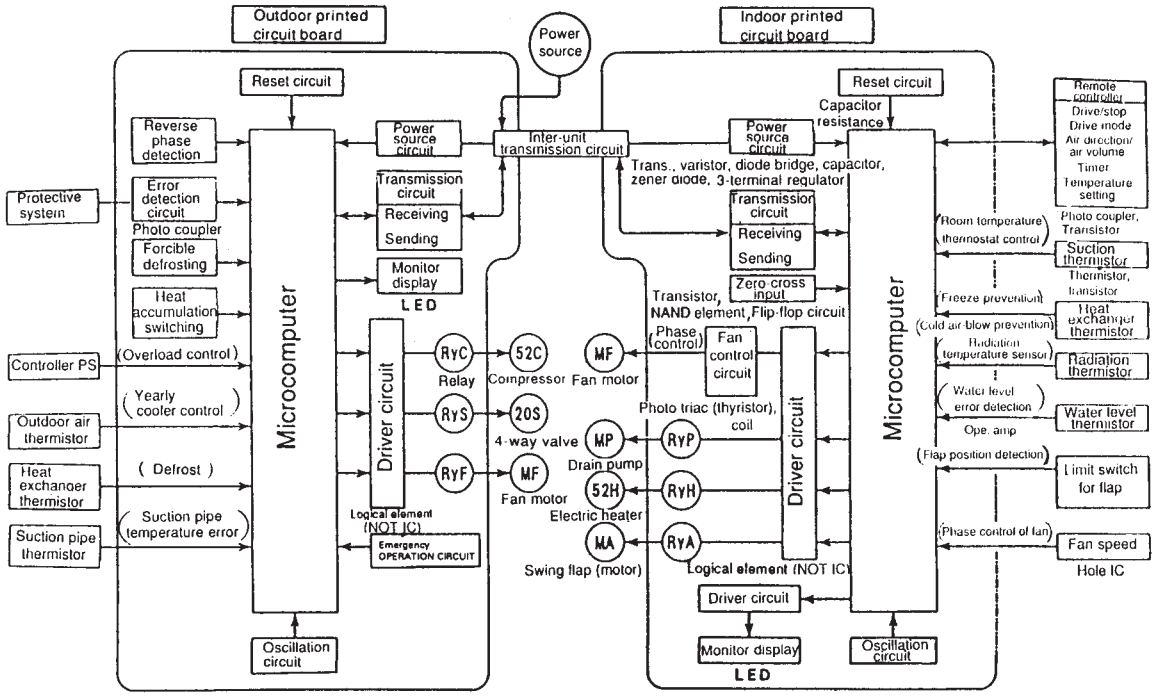


Fig.1 Example of microcomputer control (Sky-Air System)

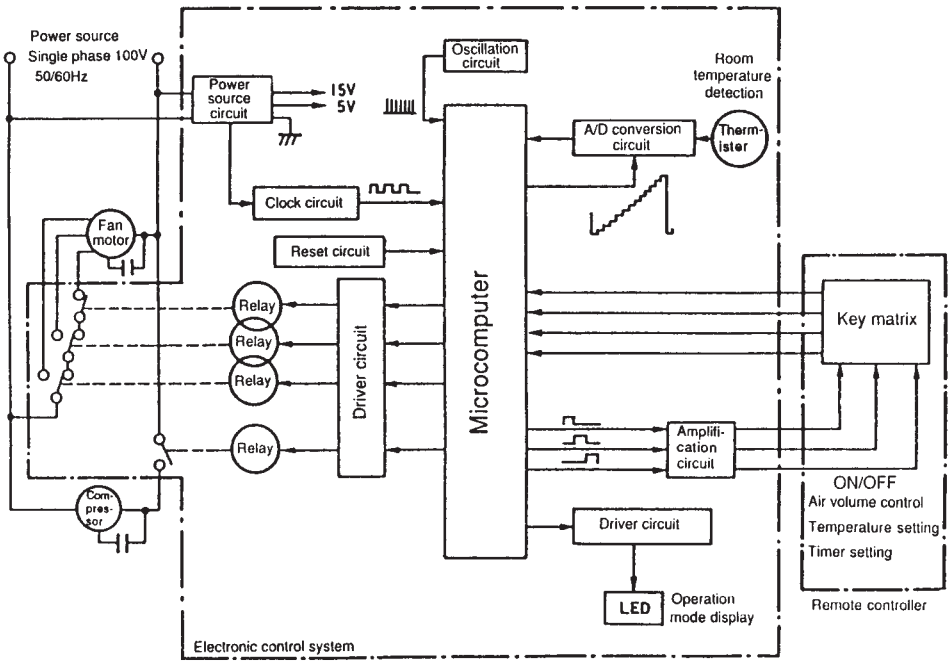
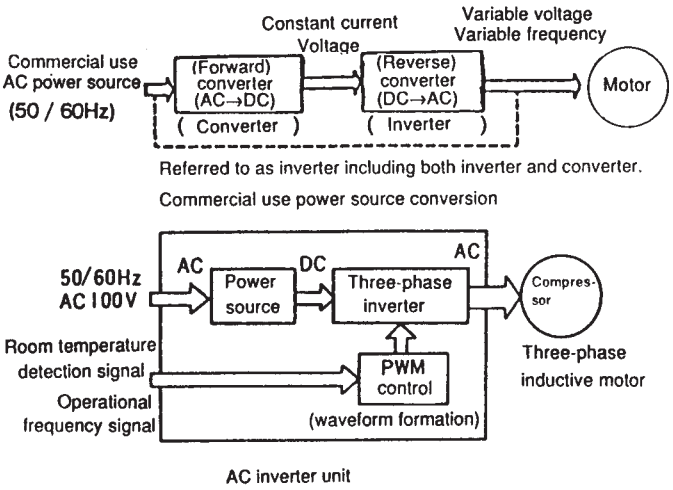


Fig.2 Example of microcomputer control (room air conditioner)

7) Inverter control

"Inverter" means DC-AC conversion device. When used for air conditioners, "Inverter" refers to frequency conversion system which can generate AC current with freely set frequency and voltage from the commercial use AC power source, including the converter's "AC-DC conversion" function. With the inverter, the motor speed of a compressor can be freely changed.



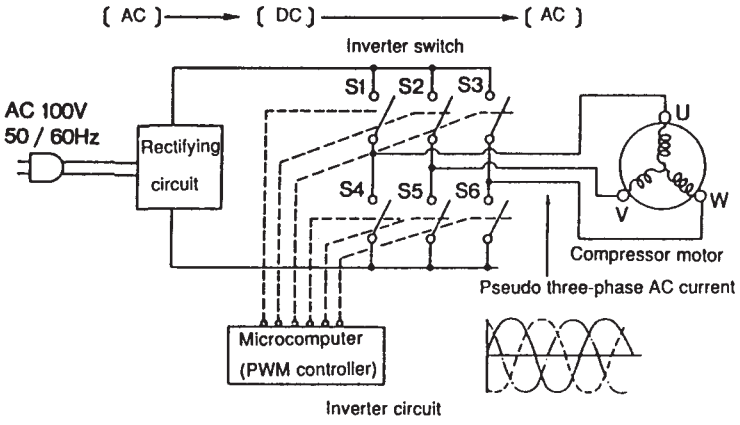
AC inverter unit

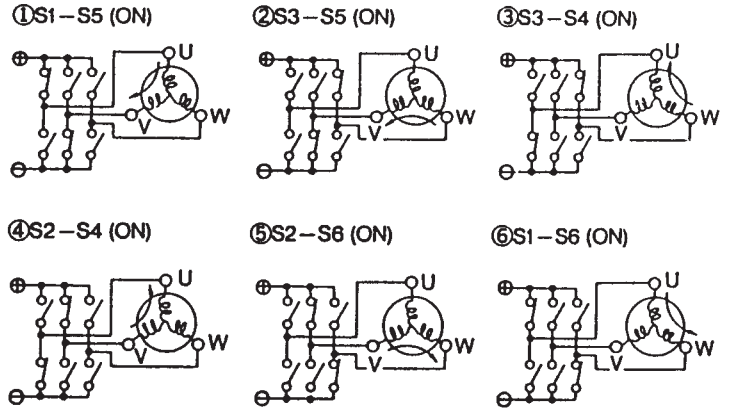
Operational principle of inverter

(1) AC 100V power is converted to DC280V power with the power source unit (rectifying circuit).
(Double-voltage rectifying circuit consisting of capacitor and diode)

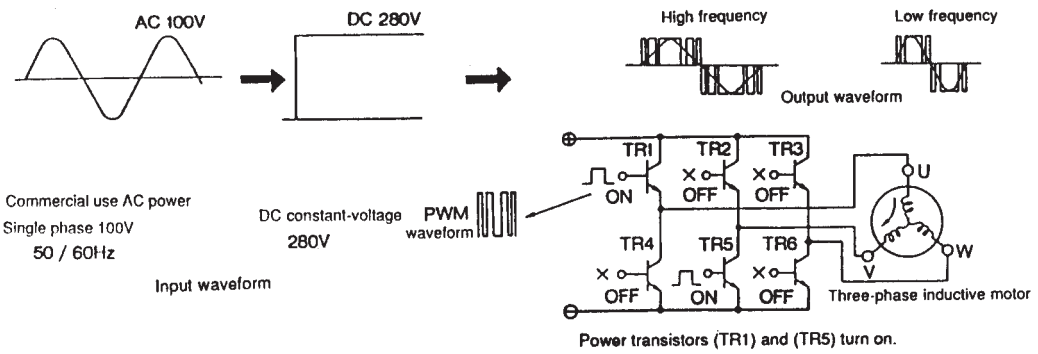
(2) As shown by the inverter circuit in the figure on the right, the microcomputer outputs the ON/OFF signals (PWM waveform, PWM: Pulse Width Modulation) of inverter switch (power transistor) according to the operational sequence (1)~(6) of the inverter switch. When operations (1)~(6) are switched 90 times per second (90Hz), the motor speed is 90 rotation /sec, which is 5400 rpm. The switch waveform per rotation is pulse voltage (PWM waveform) finely divided.

The inverter structure can be summarized as described on the next page.

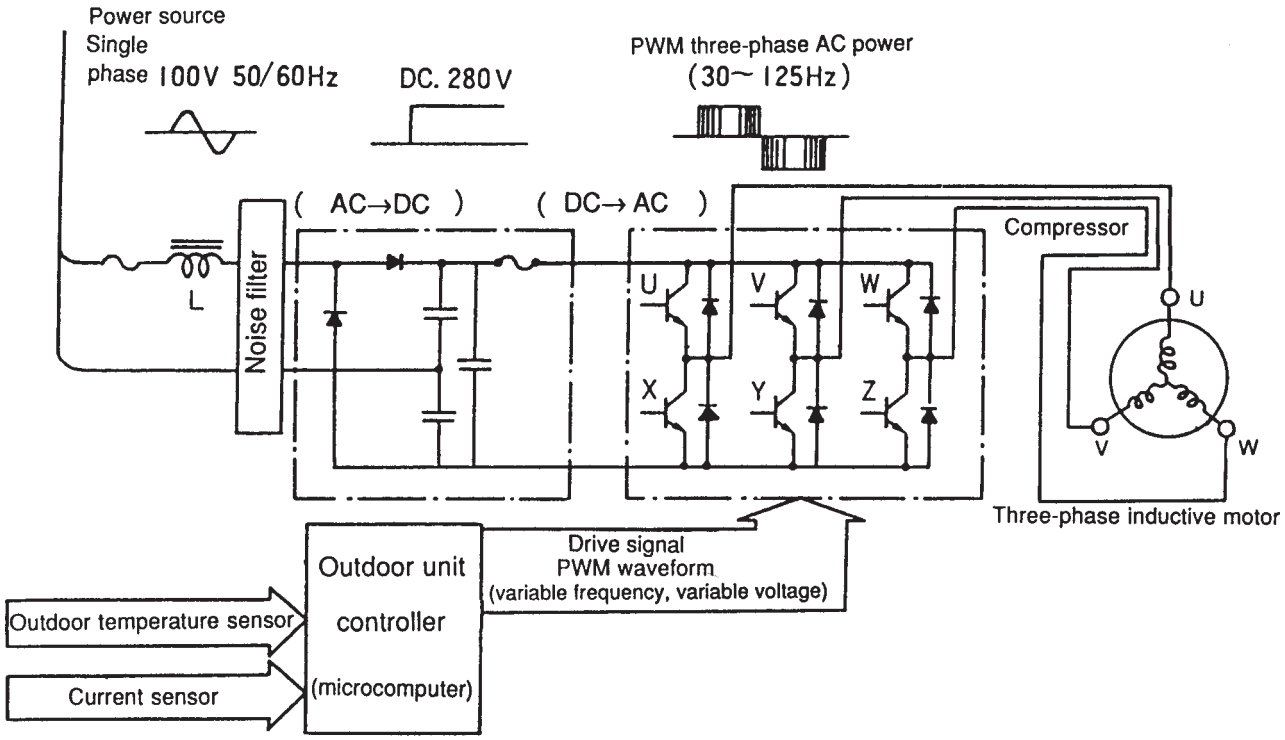




Operational sequence of inverter switch



Structure of inverter



● Features of inverter air conditioners

Stepless control of compressor's rotation speed realizes the capacity control of air conditioner in accordance with the load applied.

As the results, the features outlined below are achieved:

(1) The operational efficiency is improved, thus the power consumption is saved.

(2) The start-up loss due to the compressor ON/OFF is reduced. (The ON-OFF of the compressor becomes less frequent.)

(3) Fluctuation in the room temperature is reduced and higher comfort is realized.

(4) The start-up current is reduced. (The air conditioner can start with a low frequency and low voltage.)

(5) Improvement in low temperature characteristics during heater operation

(6) Increase of defrosting speed, improvement of defrosting capacity in positive cycle

4 Repair of printed circuit boards

1) Cautions in handling components

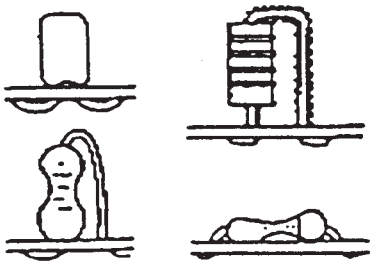
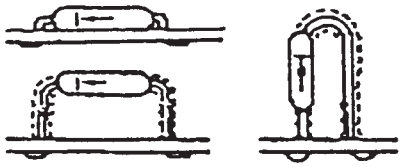
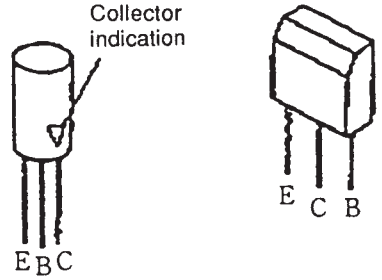
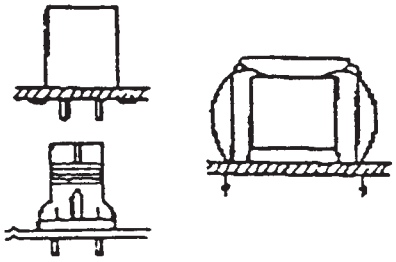
① Mounting components

The kinds of electrical components are many. Given in Table 1-8 are the cautions to be observed when mounting components which are normally used.

② Bending lead wire

After the components are inserted into printed circuit boards, the leads are bent because it is impossible to wind them.

[Table 1-8] Cautions for mounting components

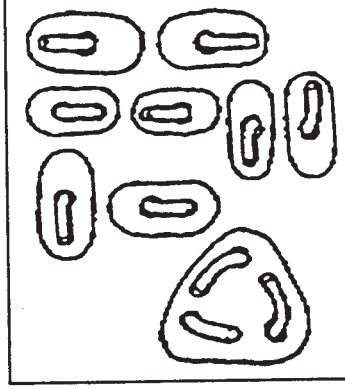
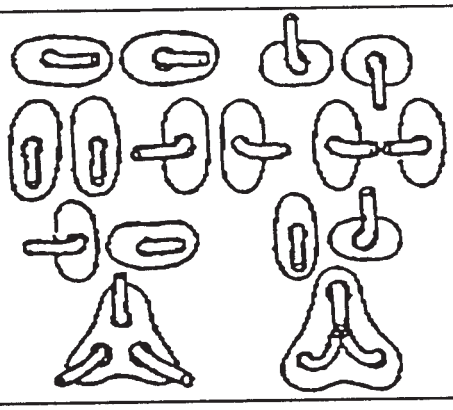
Component	Illustration	Cautions
Resistor Capacitor		* When resistors and capacitors are mounted on printed circuit boards, the leads should be completely inserted and then bent. * The components with tubes should be mounted in the same manner as above. * Electrolytic capacitor has polarity. Be careful.
Diode		* When mounting a diode, care should be exercised to the polarity. * The lead may be damaged if it is bent from the root. Be careful.
Transistor		* Care should be exercised to the polarity of individual transistors (E,B,C) and varistors (+, -). * The components should not slant after they are mounted by completely bending the leads.
Transformer Coil		* Care should be exercised to the polarities of start and end of turning wire. * The terminal should be completely bent and contacted with the copper foil surface. * There should be no slanting. Especially, the terminal should completely protrude to the surface on which the pattern is printed.

The bending direction of lead wire is very important. If leads are bent in improper direction, the components may come off or solder troubles such as solder loose may occur.
The lead should be bent with the cautions as below:

(1) The leads should be bent outside. If it is impossible due to the shape of the printed circuit board, bend them inside.
(2) When two or more leads are bent in the same pattern, the leads should not overlap or exceed the pattern area.
(3) The bending direction of lead should be determined so that it does not exceed the pattern area by taking the stability and fixation of components into consideration.

Shown in Table 1-9 are the examples of good and bad bending conditions of leads.

[Table 1-9] Bending direction of lead

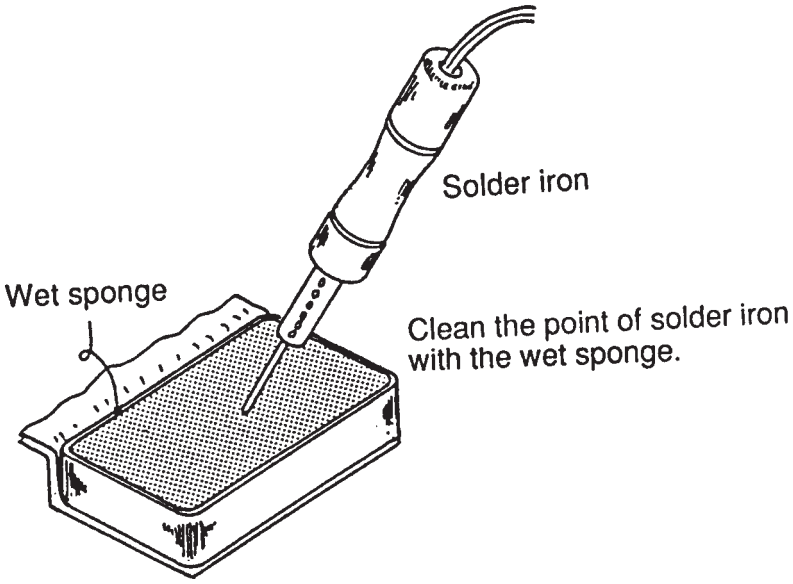
Good direction	Bad direction
	

2) Fundamental knowledge of soldering

Use a solder iron of 15W ~20W (power consumption) for ICs.
If a solder iron larger than this is used, electronic components such as ICs may be damaged with its heat. A solder iron with a sharp point is recommended because the soldered area of a component is very small.

Preparation of solder iron

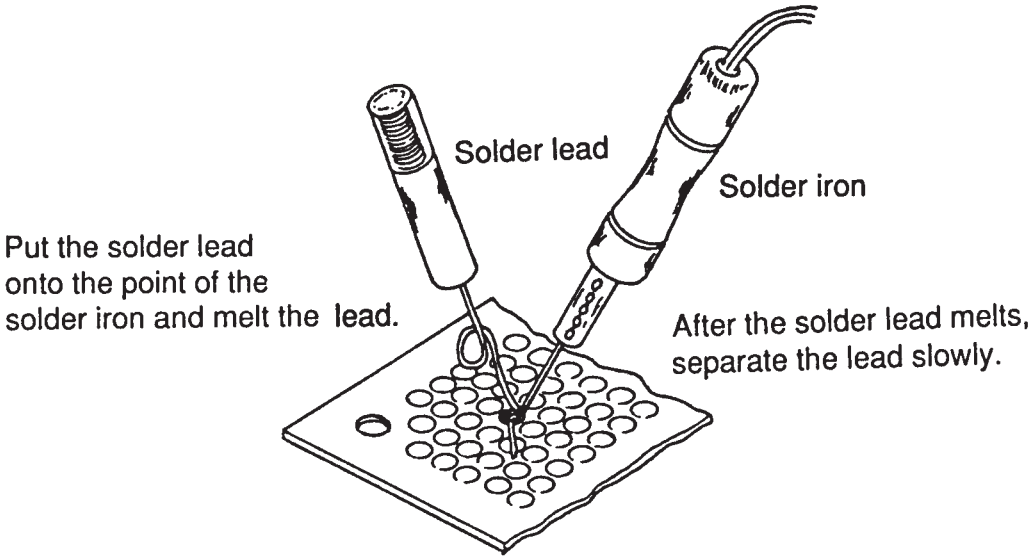
Before starting soldering, let's check the solder iron. The solder iron made of silver is shiny when it is brand new. Once it is used, however, the surface is covered with membrane produced by oxidation, and becomes blackish. For good soldering, it is necessary to put a good shine on the iron point. Remove the oxidation membrane using a file or sand paper.



However, the surface of solder irons today are specially processed or coated with ceramics. Therefore, the iron point is always shiny and it is not necessary to polish or shave any more. Moreover, point of recent solder iron must not be polished or shaved. It should be gently cleaned with an wet sponge. It is recommended to make it a rule to clean the solder iron with an wet sponge before starting soldering.

Soldering technique

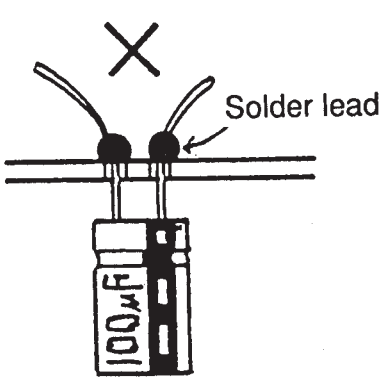
As shown in the figure below, press the point (shiny part) of the solder iron against the area to be soldered for 2~3 seconds. After the heat of the solder iron is well conducted to the soldered area, put solder lead with resin onto the point of the solder iron and melt it. After the solder lead melts and sticks, remove the solder lead with resin first. Then, slowly separate the solder iron. If the sequence of these steps is wrong, good soldering cannot be done. Observe the sequence strictly.



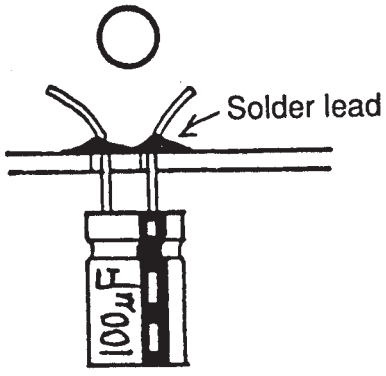
Now, check whether or not the soldering is good using the figures below.

In the figure on the right, the soldering is good because the solder lead forms a smooth shape like Mt. Fuji. On the other hand, solder lead in the figure on the left is round like water drops on leaves after rain, and this is not good soldering at all.

When handling ICs, soldering at an extremely narrow area is required. Therefore, it is recommended to practice soldering before starting actual jobs.



The solder should not be like a ball.

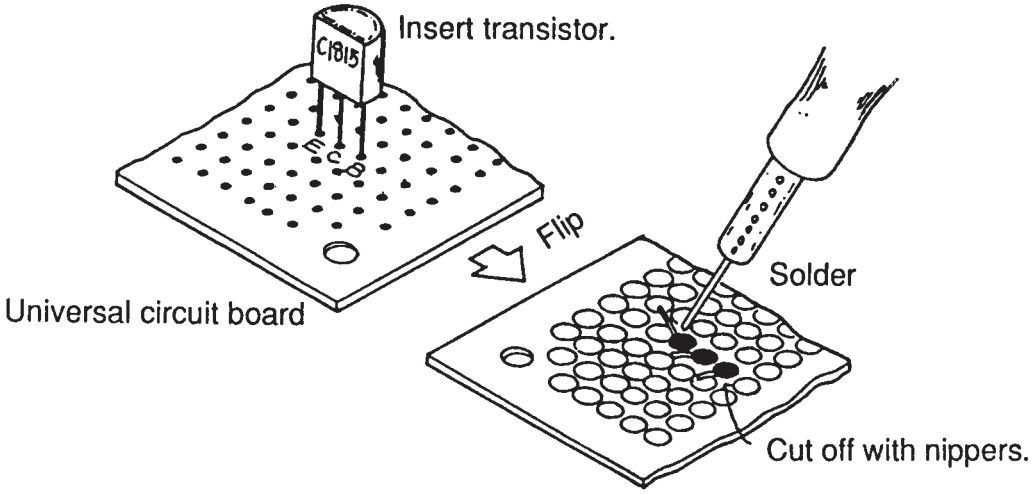


The solder should have a smooth shape like Mt. Fuji.

Mounting transistor

Transistors used for IC making include 2SC1815 and 2SC2001, etc..

A transistor has 3 lead wires, and each of them is named emitter (E), collector (C) and base (B).

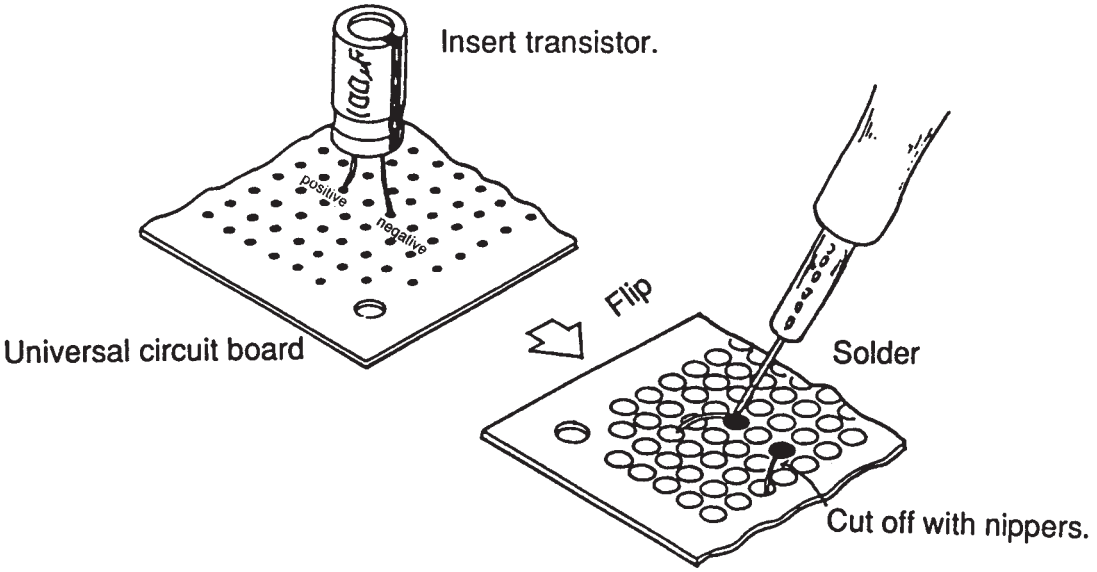


As shown in the figure above, insert the IC to the universal circuit board and solder it on the rear surface of the circuit board. If the leads are too long, shorten them by cutting with nippers.

Mounting electrolytic capacitor

An electrolytic capacitor has 2 leads, one is long and the other is short. The longer lead is the positive electrode and the shorter one is the negative electrode.

As shown in the figure above, insert the capacitor to the universal circuit board and solder it on the rear surface of the circuit board. If lead is too long, cut it short with a nipper.

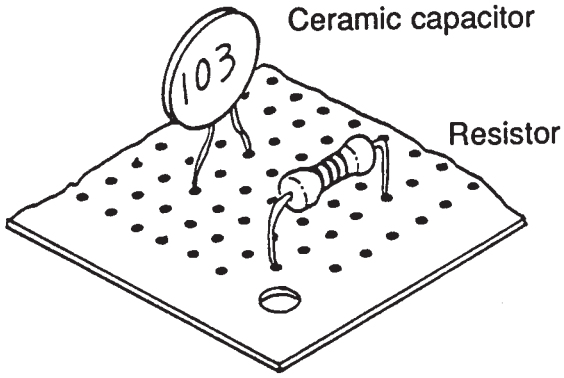


Mounting capacitor

The capacitor used for IC making is ceramic capacitor. It also has 2 leads, but has no polarity. Insert the lead into the universal circuit board.

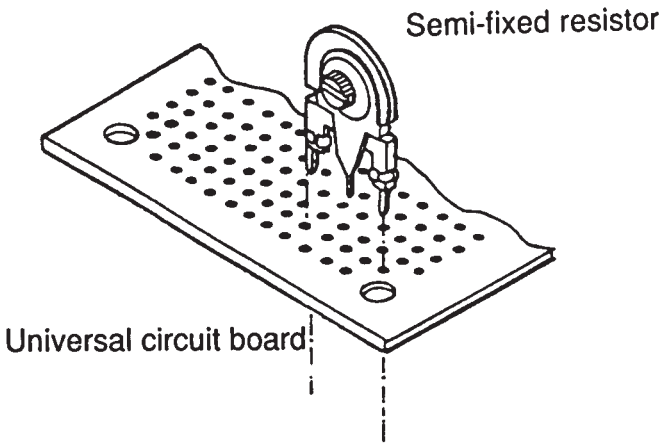
Mounting resistor

Resistors have no polarity. As illustrated below, bend the 2 leads by 90° and insert them into the universal circuit board.



Mounting semi-fixed resistor

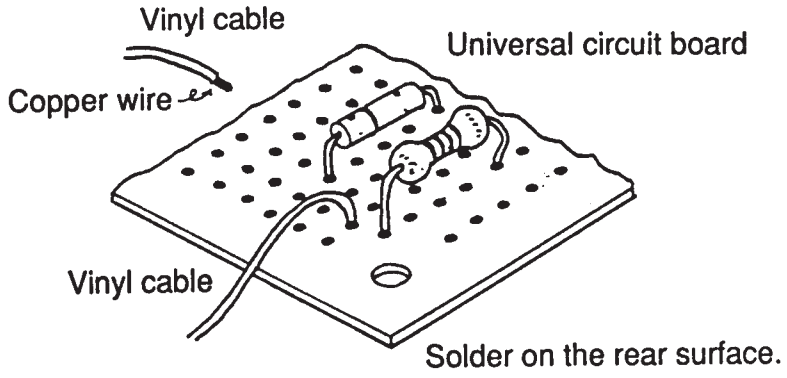
The semi-fixed type resistors should be mounted or adjusted so that the knob can be easily turned. The holes of the universal circuit board may be too small for some semi-fixed resistors. If so, slightly enlarge the hole.



Connecting vinyl cables

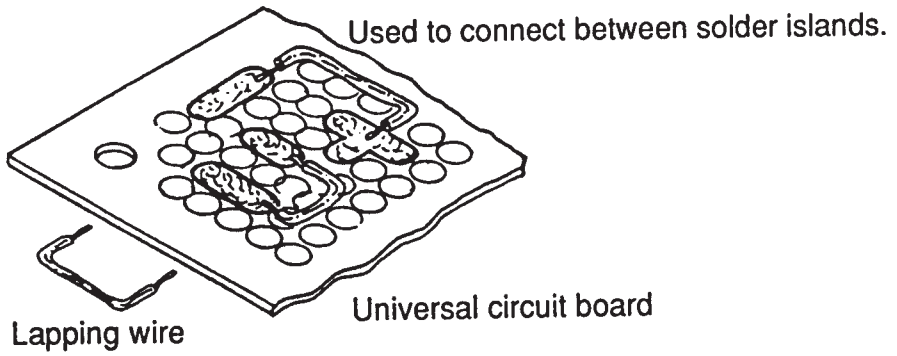
In IC making, use thin vinyl cable with diameter of approx. 3mm.

Remove the vinyl cover at the end of the cable to expose the copper wire. Insert the copper wire from the top surface of the universal circuit board and solder it on the rear surface. The copper wire exposed should not be too long.



How to use lapping wire

Lapping wire of 0.5mmø is recommended for IC making. On the rear surface of the universal circuit board, ICs and many other electronic components are soldered.



The lapping wire is used to connect between these solder islands. As illustrated on the previous page, cut the lapping wire off to an appropriate length (distance between islands), remove the vinyl cover at the both ends and solder.

3) Tools

Various tools are necessary for digital IC making.

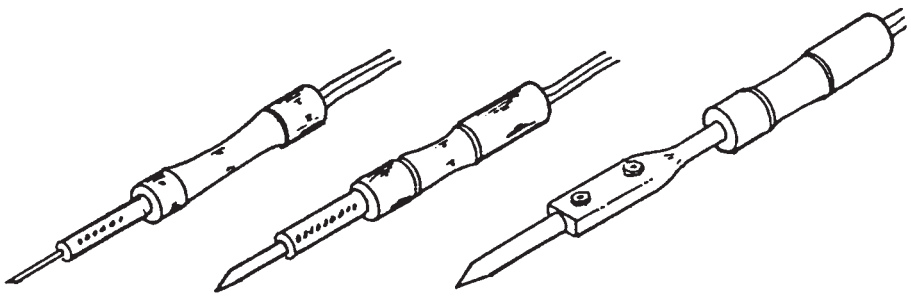
However, it is not necessary for you to buy them all. If you buy, buy only indispensable tools. Borrow tools from your friends if possible and do not waste your money. It is not too late if you buy tools after you start real electronic making.

Tools for wiring

Solder iron

Solder iron is used to melt and apply solder lead in order to secure the electrical connection of electronic components mounted on the circuit boards. This is one of the most important tools in IC making.

Various types of solder irons are available according to the usage, electrical capacity, shape of the points and the metals used. First, select an solder iron with suitable electric capacity. A small solder iron of 15~30W is used for electronic making.



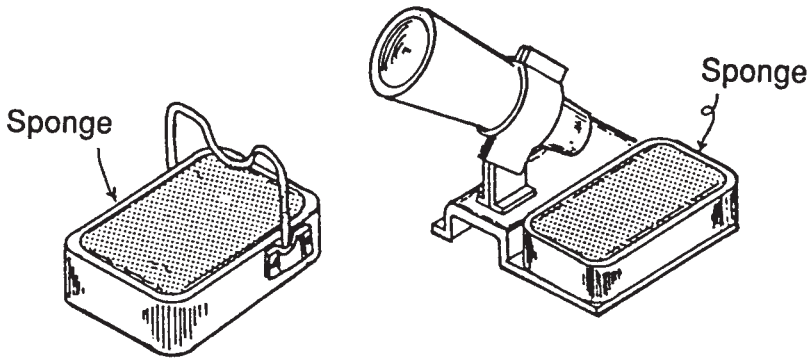
15W 30W 60W

Solder iron

Especially for soldering small components in IC making, a solder iron with a ceramic heater of 15~20 W and a long stick (thin part) should be selected. Success in IC making is dependent upon the solder iron. Select the solder iron with a great care.

Solder iron stand

Although solder iron stands are sold, it is not necessary to buy them. You can make it by yourself, but the easiest way is to use an ashtray made of glass or of earthenware. The solder iron stand sold on the market has a iron holder, sponge and its container. Use the sponge by soaking water to clean the point of the solder iron or to cool it when the temperature becomes too high.

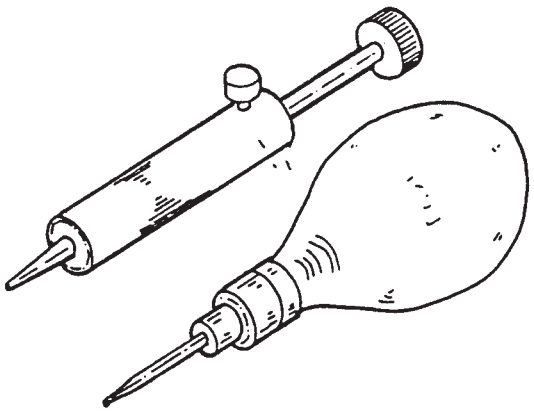


Solder iron stand

In IC making, the area to be soldered is fairy small. Therefore, it is necessary to keep the point of the solder iron clean. If you do not use the solder iron stand sold on the market, find a sponge used as packing material and use it.

Solder absorber

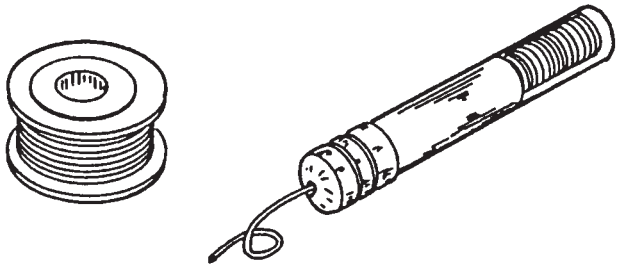
This is used to remove extra solder or the solder applied by mistake. The melted solder lead is absorbed into the vacuum container.



Solder absorber

Solder

This is not a tool, but is used for soldering. Since solder is the alloy of stannum and lead, the temperature to melt is determined by the mixture rate. A high quality solder contains a larger

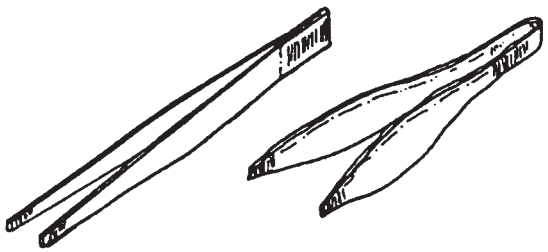


Solder wire

amount of stannum. Solder wires of various thicknesses are also available. Choose resin-containing solder lead with diameter of about 1mm.

Tweezers

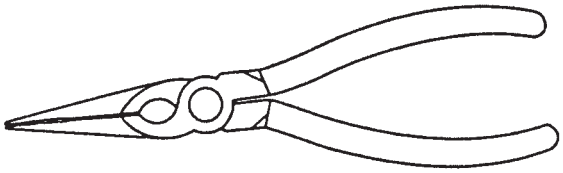
In IC making, it is necessary to solder very narrow areas. Tweezers are useful to hold or pick up the components to be soldered.



Tweezers

Pliers

This is also used to pick up the components to be soldered.

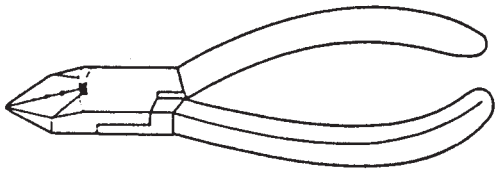


Pliers

Tools to cut or to screw

Nipper

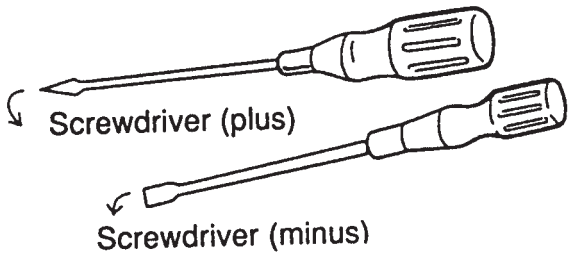
This is used to cut wires (i.e. Sn-coated wire) and to remove the vinyl cover of cables.



Nipper

Screwdriver

Everyone knows this tool. This is used to tighten the screws. There are various types of screwdrivers including plus and minus types.

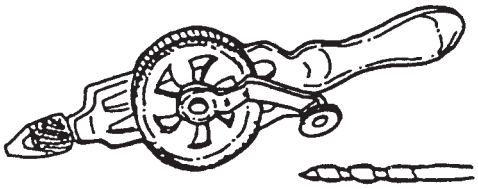


Tools to drill holes

Hand drill

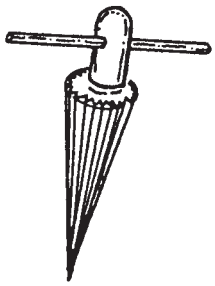
Drill blade with diameter of 1~8mm is connected to the end of the hand drill and it is turned by hand to open a hole. Drill blades used in digital IC making are those between 3.5mmø and 5mmø.

Tool to drill holes



Hand drill

Tool to widen the hole



Reamer

Taper reamer

The size of a hole drilled by a hand drill is not larger than 8mmø. Taper reamer is used when a larger hole is required. Various sizes are available.

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Imprimé en Belgique / Si - 57 / 11 - 99