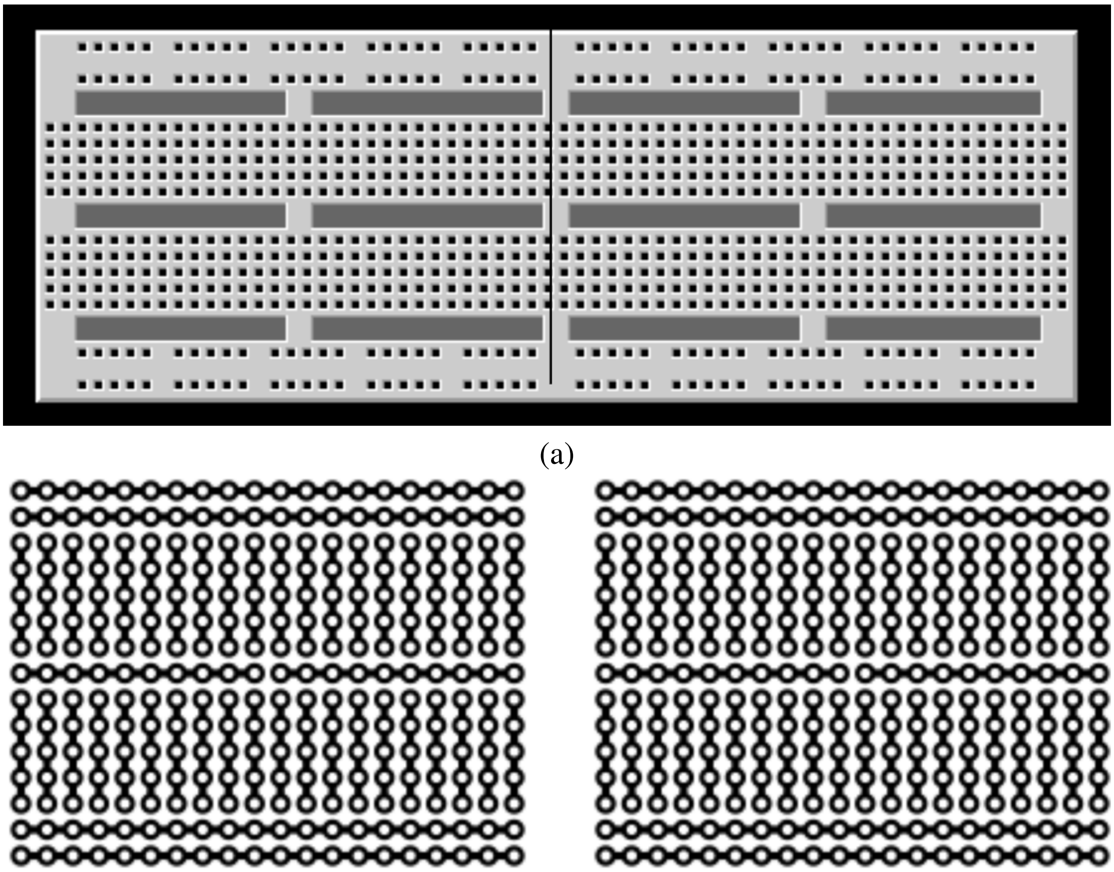
Experiment

Identification of circuit components

1 Breadboards

In order to temporarily construct a circuit without damaging the components used to build it, we must have some sort of a platform that will both hold the components in place and provide the needed electrical connections. In the early days of electronics, most experimenters were amateur radio operators. They constructed their radio circuits on wooden breadboards. Although more sophisticated techniques and devices have been developed to make the assembly and testing of electronic circuits easier, the concept of the breadboard still remains in assembling components on a temporary platform.



(a)

(b)

Figure 1: (a) A typical breadboard. (b) Its connection details.

A real breadboard is shown in figure 1(a) and the connection details on its rear side are shown in 1(b). The five holes in each individual column on either side of the central groove are electrically connected to each other, but remain insulated from all other sets of holes. In addition to the main columns of holes, however, you'll note four sets or groups of holes along the top and bottom. Each of these consists of five separate sets of five holes each, for a total of 25 holes. These groups of 25 holes are all connected together on either side of the dotted line indicated on figure 1(a) and need an external connection if one wishes the entire row to be connected. This makes them ideal for distributing power to multiple ICs or other circuits. These breadboard sockets are sturdy and rugged, and can take quite a bit of handling. However, there are a few rules you need to observe, in order to extend the useful life of the electrical contacts and to avoid damage to components. These rules are:

- Always make sure power is disconnected when constructing or modifying your experimental circuit. It is possible to damage components or incur an electrical shock if you leave power connected when making changes.
- Never use larger wire as jumpers. #24 wire (used for normal telephone wiring) is an excellent choice for this application. Observe the same limitation with respect to the size of component leads.
- Whenever possible, use 1/4 watt resistors in your circuits. 1/2 watt resistors may be used when necessary; resistors of higher power ratings should never be inserted directly into a breadboard socket.
- Never force component leads into contact holes on the breadboard socket. Doing so can damage the contact and make it useless.
- Do not insert stranded wire or soldered wire into the breadboard socket. If you must have stranded wire (as with an inductor or transformer lead), solder (or use a wire nut to connect) the stranded wire to a short length of solid hookup wire, and insert only the solid wire into the breadboard. If you follow these basic rules, your breadboard will last indefinitely, and your experimental components will last a long time.

2 Resistors

Most axial resistors use a pattern of colored stripes to indicate resistance. A 4 band identification is the most commonly used color coding scheme on all resistors. It consists of four colored bands that are painted around the body of the resistor. Resistor values are always coded in ohms (Ω). The color codes are given in the following table in table 1.

- Band **A** is first significant figure of component value
- Band **B** is the second significant figure
- Band **C** is the decimal multiplier
- Band **D** if present, indicates tolerance of value in percent (no color means 20%)

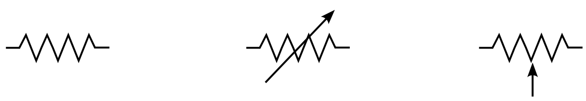
Table 1: Color codes of resistors.

Color	Value	Multiplier	Tolerance
Black	0	$\times 10^0$	± 20 %
Brown	1	$\times 10^1$	± 1 %
Red	2	$\times 10^2$	± 2 %
Orange	3	$\times 10^3$	± 3 %
Yellow	4	$\times 10^4$	$-0, +100$ %
Green	5	$\times 10^5$	± 0.5 %
Blue	6	$\times 10^6$	± 0.25 %
Violet	7	$\times 10^7$	± 0.10 %
Gray	8	$\times 10^8$	± 0.05 %
White	9	$\times 10^9$	± 10 %
Gold	–	$\times 10^{-1}$	± 5 %
Silver	–	$\times 10^{-2}$	± 10 %

For example, a resistor with bands of yellow, violet, red, and gold will have first digit 4 (yellow in table below), second digit 7 (violet), followed by 2 (red) zeros: 4,700 Ω. Gold signifies that the tolerance is ±5%, so the real resistance could lie anywhere between 4,465 and 4,935 Ω. Tight tolerance resistors may have three bands for significant figures rather than two, and/or an additional band indicating temperature coefficient, in units of ppm/K. For large power resistors and potentiometers, the value is usually written out implicitly as "10 kΩ", for instance.

Variable Resistor (Potentiometer): A variable resistor is a resistor of which the electric resistance value can be adjusted. A variable resistor is in essence an electro-mechanical transducer and normally works by sliding a contact (wiper) over a resistive element. When a variable resistor is used as a potential divider by using 3 terminals it is called a potentiometer. When only two terminals are used, it functions as a variable resistance and is called a rheostat.

Potentiometer: The potentiometer is the most common variable resistor. It functions as a resistive divider and is typically used to generate a voltage signal depending on the position of the potentiometer. This signal can be used for a very wide variety of applications including: amplifier gain control (audio volume), measurement of distance or angles, tuning of circuits, and much more. When variable resistors are used to tune or calibrate a circuit or application, trimmer potentiometers or trim pots are used. These are most often small potentiometers mounted on the circuit board and can be adjusted using a screwdriver.



Resistor | Variable resistor | Potentiometer

Figure 2: Symbols for resistors and potentiometer.

3 Capacitors

A capacitor is a device that stores electrical energy in an electric field by virtue of accumulating electric charges on two close surfaces insulated from each other. It is a passive electronic component with two terminals.

There are many types of capacitors depending upon their function, the dielectric material used, their shape etc. The main classification is done according to fixed and variable capacitors. You will mostly use electrolytic and ceramic capacitors for your experiments.

3.1 Electrolytic capacitors

An electrolytic capacitor is a type of capacitor that uses an electrolyte, an ionic conducting liquid, as one of its plates, to achieve a larger capacitance per unit volume than other types. They are used in relatively high-current and low-frequency electrical circuits. However, the voltage applied to these capacitors must be polarized; one specified terminal must always have positive potential with respect to the other. These are of two types, axial and radial capacitors as shown in figure 3. The arrowed stripe indicates the polarity, with the arrows pointing towards the negative pin.

Figure 3: Axial and Radial Electrolytic capacitors.

Warning: connecting electrolytic capacitors in reverse polarity can easily damage or destroy the capacitor. Most large electrolytic capacitors have the voltage, capacitance, temperature ratings, and company name written on them without having any special color coding schemes.

Axial electrolytic capacitors have connections on both ends. These are most frequently used in devices where there is no space for vertically mounted capacitors.

Radial electrolytic capacitors are like axial electrolytic ones, except both pins come out the same end. Usually that end (the "bottom end") is mounted flat against the PCB and the capacitor rises perpendicular to the PCB it is mounted on. This type of capacitor probably accounts for at least 70% of capacitors in consumer electronics.

3.2 Ceramic capacitors

Ceramic capacitors are generally non-polarized and almost as common as radial electrolytic capacitors. Generally, they use an alphanumeric marking system. The number part is the same as for SMT resistors, except that the value represented is in pF. They may also be written out directly, for instance, 2n2 = 2.2 nF.

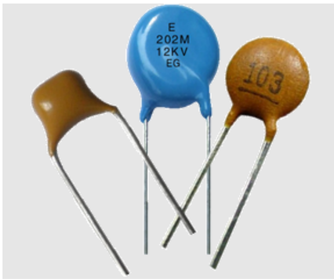


Figure 4: A picture of ceramic capacitors.

3.3 Variable capacitors

A variable capacitor is a capacitor whose capacitance may be intentionally and repeatedly changed mechanically or electronically. Variable capacitors are often used in L/C circuits to set the resonance frequency.

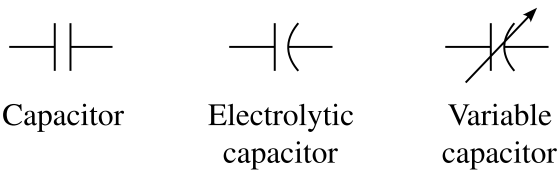


Figure 5: Symbols of different types of capacitors.

4 Inductor

An inductor, also called a coil, choke, or reactor, is a passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it. An inductor typically consists of an insulated wire wound into a coil.

When the current flowing through the coil changes, the time-varying magnetic field induces an electromotive force (emf) (voltage) in the conductor, described by Faraday's law of induction. According to Lenz's law, the induced voltage has a polarity (direction) which opposes the change in current that created it. As a result, inductors oppose any changes in current through them.

Figure 6: Symbols of different types of inductors.

4.1 Variable Inductor

A variable inductor definition is an inductor or coil whose effective inductance is adjustable continuously. The frequency range of this inductor typically ranges from 10 μH to 100 μH & currently available inductors range from 10 nH to 100 mH. The variable inductor symbol is shown in figure 6.

5 Diodes

Diode is an electrical component that allows the flow of current in only one direction. In circuit diagrams, a diode is represented by a triangle with a line across one vertex. The most common type of diode uses a p-n junction. In this type of diode, one material (n) in which electrons are charge carriers abuts a second material (p) in which holes (places depleted of electrons that act as positively charged particles) act as charge carriers. At their interface, a depletion region is formed across which electrons diffuse to fill holes in the p-side. This stops the further flow of electrons. When this junction is forward biased (that is, a positive voltage is applied to the p-side), electrons can easily move across the junction to fill the holes, and a current flows through the diode. When the junction is reverse biased (that is, a negative voltage is applied to the p-side), the depletion region widens and electrons cannot easily move across. The current remains very small until a certain voltage (the breakdown voltage) is reached and the current suddenly increases.

As illustrated in this figure 7(a) and figure 7(b), the system uses numbers and letters to identify different types of semiconductor devices. The first number in the system indicates the number of junctions in the semiconductor device and is a number, one less than the number of active elements. Thus 1 designates a diode; 2 designates a transistor (which may be considered as made up of two diodes); and 3 designates a tetrode (a four-element transistor). The letter "N" following the first number indicates a semiconductor. The 2- or 3-digit number following the letter "N" is a serialized identification number. If needed, this number may contain a suffix letter after the last digit. For example, the suffix letter "M" may be used to describe matching pairs of separate semiconductor devices or the letter "R" may be used to indicate reverse polarity. Other letters are used to indicate modified versions of the device which can be substituted for the basic numbered unit. For example, a semiconductor diode designated as type 1N345A signifies a two-element diode (1) of semiconductor material (N) that is an improved version (A) of type 345.

When working with different types of diodes, it is also necessary to distinguish one end of the diode from the other (anode from cathode). For this reason, manufacturers

XNYYY

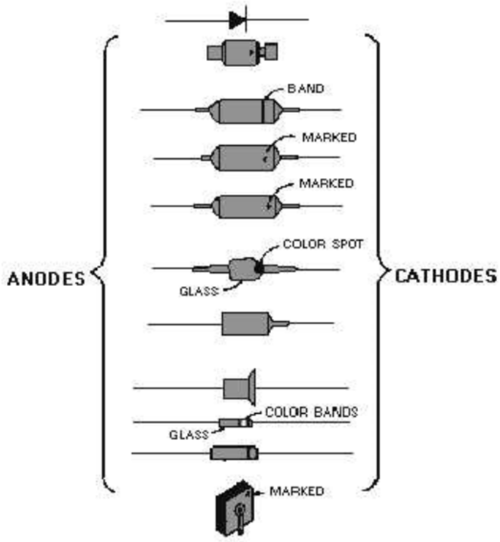
XN **YYY**

COMPONENT **IDENTIFICATION**

- **X** - Number of semiconductor junctions
- **N** - A semiconductor
- **YYY** - Identification number (Order or registration number). Also includes suffix letter (if applicable) to indicate
  1. Matching devices
  2. Reverse polarity
  3. Modification

Example - 1N345A (An improved version of the semiconductor diode of type 345)

(a)



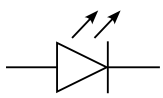
(b)

Figure 7: (a) Identification of diodes. (b) Identification of cathode.

generally code the cathode end of the diode with a “k”, “+”, “cath”, a color dot or band, or by an unusual shape (raised edge or taper) as shown in figure 7(b). In some cases, standard color code bands are placed on the cathode end of the diode. This serves two purposes: (1) it identifies the cathode end of the diode, and (2) it also serves to identify the diode by number.

6 Light Emitting diode (LED)

A light emitting diode is a semiconductor device that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons. The color of the light (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the band gap of the semiconductor. White light is obtained by using multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device.



Light emitting diode

Figure 8: Symbol of a light emitting diode (LED).

7 Transistors

Transistors are identified by a Joint Army-Navy (JAN) designation printed directly on the case of the transistor. If in doubt about a transistor's markings, always replace a transistor with one having identical markings, or consult an equipment or transistor manual to ensure that an identical replacement or substitute is used.

Example:

2	N	130	A
NUMBER OF JUNCTIONS (TRANSISTOR)	SEMICONDUCTOR	IDENTIFICATION NUMBER	FIRST MODIFICATION

TESTING A TRANSISTOR to determine if it is good or bad can be done with an ohmmeter or transistor tester. PRECAUTIONS should be taken when working with transistors since they are susceptible to damage by electrical overloads, heat, humidity, and radiation. TRANSISTOR LEAD IDENTIFICATION plays an important part in transistor maintenance because before a transistor can be tested or replaced, its leads must be identified. Since there is NO standard method of identifying transistor leads, check some typical lead identification schemes or a transistor manual before attempting to replace a transistor. Identification of leads for some common case styles is shown in figure 9.

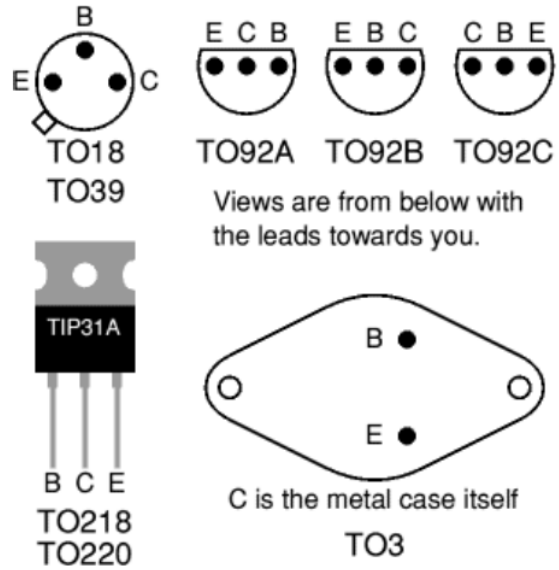


Figure 9: Identification of a transistor.

7.1 Testing a transistor

Transistors are basically made up of two diodes connected together back-to-back (Figure 10). We can use this analogy to determine whether a transistor is of the type PNP or NPN by testing its Resistance between the three different leads, Emitter, Base and Collector.

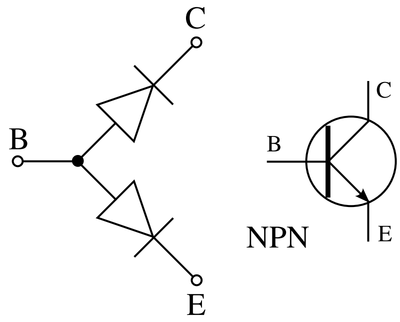


Figure 10: Identification of a transistor.

7.1.1 Testing with a multimeter

Use a multimeter or a simple tester (battery, resistor and LED) to check each pair of leads for conduction. Set a digital multimeter to diode test and an analogue multimeter to a low resistance range.

Test each pair of leads both ways (six tests in total):

- The **base-emitter (BE)** junction should behave like a diode and conduct one way only.
- The **base-collector (BC)** junction should behave like a diode and conduct one way only.
- The **collector-emitter (CE)** should not conduct either way.

The table 2 shows how the junctions behave in an NPN transistor. The diodes are reversed in a PNP transistor but the same test procedure can be used.

Table 2: Transistor Resistance Values for the PNP and NPN transistor types

Between Transistor Terminals		PNP	NPN
Collector	Emitter	R_{HIGH}	R_{HIGH}
Collector	Base	R_{LOW}	R_{HIGH}
Emitter	Collector	R_{HIGH}	R_{HIGH}
Emitter	Base	R_{LOW}	R_{HIGH}
Base	Collector	R_{HIGH}	R_{LOW}
Base	Emitter	R_{HIGH}	R_{LOW}