Module 18
Everyday Electronics

What this module is about

What are the technologies have made our life easier and more comfortable? Cellular phones, computers, television sets, sensors and cameras, robots and full-featured automobiles are among them. Looking back four or five decades ago, when these gadgets did not exist yet or when these gadgets were not as good as they are now, we can't help but wonder what brilliant ideas have ushered us from a primitive, obsolete ways of living to a world of sophistication. It is even more surprising to know that behind the wonders of these emerging technologies is just a simple "thing" we've learned previously. Do you know that these huge advancements are caused by the very small particle called the electron? It is through the world of electronics, meaning control of flow of electrons, that these devices are made possible. This module gives us a slice of the huge, complicated world of electronics in the following lessons:

- **Lesson 1 - History and Development of Electronics**
- **Lesson 2 - Active and Passive Electronic Components**
- **Lesson 3 - Integrated Circuits**
- **Lesson 4 - Electronic Systems**
- **Lesson 5 - Applications of Electronics**

What you are expected to learn

At the end of this module, you should be able to:

1. trace the history and development of electronics;
2. classify electronic components as active or passive;
3. interpret the color codes of common electronic elements;
4. identify the components of electronic systems; and
5. cite applications of electronics in different fields.

How to learn from this module

Going through this module can be both a fun and a meaningful learning experience. All you need to do is make use of your time and resources efficiently. To do this, here are some tips for you:

1. Take time in reading and understanding each lesson. It is better to be slow but sure than to hurry finishing the module only to find out that you missed the concepts you are supposed to learn.
2. Do not jump from one chapter to another. Usually, the lessons are arranged such that one is built upon another, hence an understanding of the first is essential in comprehending the succeeding lessons.
3. Be honest. When answering the test items, do not turn to the key to correction page unless you are done. Likewise, when performing experiments, record only what you have really observed.
4. Safety first. Perform the experiments with extra precaution. Wear safety gears whenever necessary.
5. Don't hesitate to ask. If you need to clarify something, approach your teacher or any knowledgeable person.

What to do before (Pretest)

Direction: Write the letter of the option that answers the question or completes the statement.

1. All of the following are passive elements EXCEPT
   a. resistors.
   b. capacitors.
   c. inductors.
   d. transistors.

2. The resistance of a resistor is 32 kΩ. What are the first two colors in the color bands of the resistor?
   a. Orange, Red
   b. Red, Orange
   c. Red, Brown
   d. Yellow, Green

3. If you are to allow current to flow in one direction, which of the following should you use?
    a. inductors
    b. transistors
    c. diodes
    d. IC’s

4. Which of the following statements is/are true?
    I. Passive components operate even without power source
    II. A diode is a passive component
    a. I only
    b. II only
    c. Both I and II
    d. Neither I and II

5. Which of the following gives the correct flow for electronic systems?
    a. sensors – processors – actuators
    b. actuators – sensors – processors
    c. sensors – actuators – processors
    d. processors – sensors –actuators

6. If you want to store electrical charges for future use, which of the following should you use?
    a. Resistor
    b. Inductor
    c. Capacitor
    d. Diode

7. What electronic component allows current to flow in only one direction?
    a. Transistor
    b. Capacitor
    c. Diode
    d. Integrated circuit

8. In 1950’s, Joyce Kilby and Robert Noyce invented a device that puts together many components in a single, tiny package. What do you call this device?
    a. Resistor
    b. Sensor
    c. Integrated Circuit
    d. Transistor

9. Current flows in a diode when it is ________.
    a. unbiased.
    b. reverse biased.
    c. forward biased.
    d. reverse or forward biased.

10. When doped with pentavalent impurity, a semiconductor becomes what type of material?
    a. N-type
    b. P-type
    c. S-type
    d. C-type

11. Which of the following is NOT an actuator in the electronic systems of a personal computer?
    a. Printers
    b. Monitors
    c. Keyboards
    d. Speakers

12. Which of the following elements CANNOT be used in the construction or manufacture of electronic components?
    a. Carbon
    b. Germanium
    c. Argon
    d. Silicon

13. Transistors have three pins, namely emitter, collector and ______________.
    a. back-up
    b. base
    c. board
    d. filter

14. What does the fourth, separately marked color code in a resistor represent?
    a. Minimal value
    b. Tolerance
    c. Power rating
    d. Current rating

15. Which of the following electronic devices is used in the field of medicine?
    a. Ultrasound
    b. Magnetic resonance imaging
    c. Electrocardiograph
    d. All of the above

Key to Correction on page 24

Lesson 1 Development of Electronics

We will begin our discussion by tracing the roots of electronics. After J.J. Thompson discovered the electron, the carrier of negative electric charge, many scientists were fascinated and became curious about the behavior of this fundamental particle. Scientists worked in laboratories until their ideas were perfected and made to proper use. The electron was subjected to different conditions and was controlled in different media like vacuum, gas and semiconductor materials.

Below is a concise time line of electronic discoveries. Study the timeline very carefully.

1904	Sir John Ambrose Fleming invents the vacuum tube and diode.
1906	Lee De Forest develops the triode.
1934	Electronic hearing aid invented
1947	John Bardeen, Walter H. Brattain, and William B. Shockley of Bell Telephone Laboratories invent the transistor.
1950s	Germanium is used to make semiconductors in transistors. Late in the 1950s, silicon begins to replace germanium as a semiconductor material.
1954	The transistor radio is introduced and becomes the largest selling item of the time
1958	Jack Kilby of Texas Instruments invents the integrated circuit (IC).
1958	Robert Noyce develops an integrated circuit that can be miniaturized and reliably manufactured
1958	Seymour Cray at Control Data Corp. develops a transistorized computer
1961	Silicon chips first appear
1967	First handheld calculator using an integrated circuit is made by Texas Instruments.
1968	Robert Noyce cofounds Intel.
1970	The bar code system is created.
1971	Intel introduces its popular 4004 4-bit microprocessor, starting the evolution of Intel's famous line of 386, 486, and Pentium processors
1971	First video game and video disc introduced.
1979	Mattel Toy Company receives 1 millionth chip for electronic games
1980s	Integrated circuits applied to computers
1981	32-bit silicon chips developed.

1984 Compact disc (CD) player introduced.

1984 CD-ROM (compact-disc read-only memory) is available

Looking at the timeline, electronics appear to have developed to address the need for a means of communication, that is, the process of sending signals from place to another. It is no wonder that today, what makes use of electronics the most are the fields of communication and transportation. However, other fields now equally recognize the vital role of electronics, just like the field of medicine, which we shall include in our discussion for lesson 5.

What you will do

Self-Test 1.1

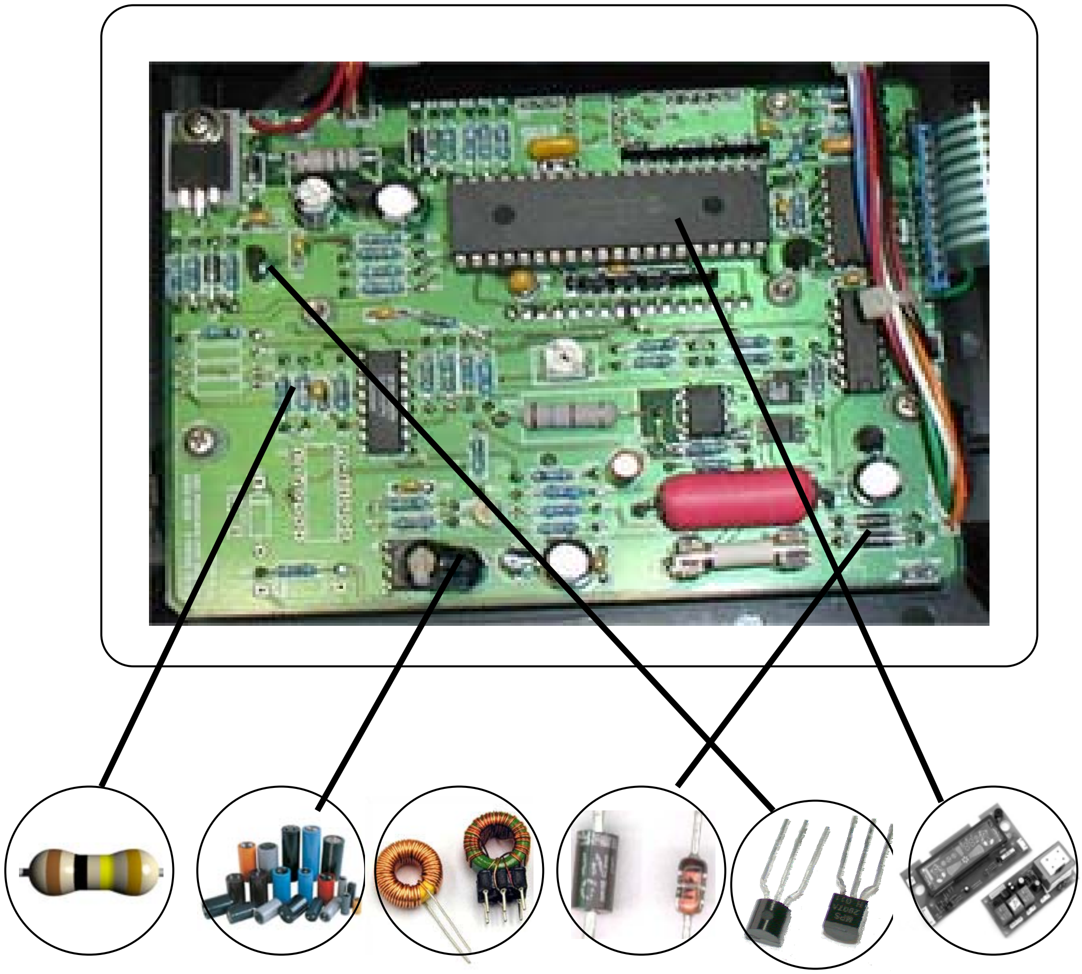
Direction: Identify the scientist in column B who is associated with the discovery/invention listed in colum A . Write the letter only

A	B
1. Vacuum tubes in televisions	a. William Shockley
2. Integrated circuits	b. John Fleming
3. Telegraph	c. Seymon Cray
4. Transistorized computer	d. Jack Kilby
5. Triodes	e. Lee de Forest

Key to answers on page 24

Lesson 2 Passive and Active Electronic Components

If you open some of your appliances at home, let's say your radio or television unit, you are likely to see components similar to the components on the picture.



Let us see how many of these can you correctly identify.

Resistors

Those small, tube-like elements with strips of different colors are called **resistors**. In a circuit, a resistor's function is to limit the amount of current passing through different points in the circuit. Do you still remember Ohm's Law? If a small amount of current is desired, we should increase the resistance by connecting a resistor in series with an element.

Capacitors

Do you also see components larger than resistors that resemble the shape of a tin can? We call these capacitors. **Capacitors** store electrical energy in a circuit. They can be thought of as tiny rechargeable batteries – capacitors can be charged and discharged! Capacitors that look like small tin cans are electrolytic capacitors, which are widely used now. Other capacitors may have different shapes, depending on the value of their capacitance. The unit of capacitance is farad (F), but a farad is too big that capacitors are commonly rated in micro-farads.

Inductors

Inductors are most commonly in the form of coils, but even a straight piece of wire can have inductance. Winding it into a coil simply concentrates the magnetic filed and increases the inductance considerably for a given length of wire. Inductors, like transformers, are used in the output of power amplifiers to prevent instability with capacitance loads.

Diodes

Diodes let electrons flow through them in one direction. In diodes, electron flows from cathode to anode. The cathode side is marked with a band around it. In one of the activities, we shall study how a diode works by properly biasing it.

There are three different types of diodes: the ordinary rectifier diodes, Zener diodes and Light-emitting diodes (LED). Zener diodes operate in the reverse bias mode and are used in voltage regulators. LEDS are the diodes that give off light when electrons pass through them.

Transistors

Transistors are two diodes combined and are used as switch and amplifiers. We will discuss two types of transistors: PNP and NPN transistors. Both of these transistors have 3 pins: emitter, base and collector.

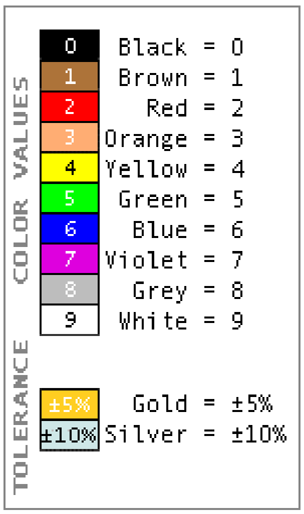
There are other more specialized components like thyristors, Junction field effect transistors (JFETS), and Integrated Circuits. They are specialized because they are made for special purposes only.

There may be bewildering electronic components, but we can classify them into two: **passive** and **active** components. The main difference between active and passive components is that active ones require to be powered in some way to make them work. Unlike passive components, the active ones modify or amplify electric signals. Resistors, capacitors, inductors are passive components, while diodes and transistors are active components.

Electronic elements are provided with markings that tell us their electrical properties like the values of resistance, capacitance and inductance, power ratings and voltage ratings. These markings may directly provide us these information but some may also require us to interpret some systems of codes, like color, letter assignment and symbols. Electrolytic capacitors and diodes contain markings that directly tell us their characteristics. Transistors' markings always start with 2N, while integrated circuits come with an IC manual. However, resistors make use of color bands.

Read this:

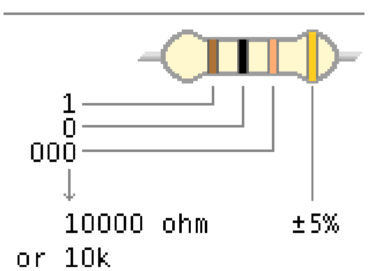
How do we read resistor codes?



The color bands around the resistors are color codes that tell you its resistance value. Recall that resistance is measured in Ohms.

The tolerance bands indicate the accuracy of the values. A gold tolerance band indicates that the resistor will be within 5% of its value and a silver band indicates a range of 10%.

To get the value of the resistor, hold the resistor so that the tolerance band is on the right. The first two color bands are the significant figures – simply write down the numbers represented by the colors. The third band is the multiplier – it tells you how many zeros to add after the significant figures. Put them all together and you have the value.

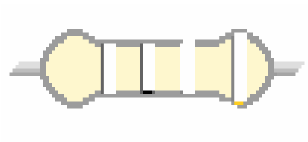


The resistor at the left has color codes brown, black, orange and gold. Brown has a value of 1 and black has a value of zero, therefore the first two significant digits are 10. Since orange is the third band, our multiplier is 3, meaning we have to add three zeroes to the first two significant digits. The tolerance code is gold, corresponding to 5% tolerance. This means that the resistor can function 5% below or above the specified value.

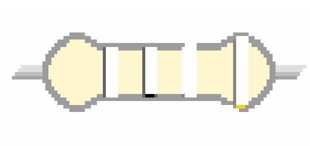
What you will do

Activity 2.1

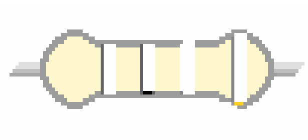
With the values of resistance for each item, identify what must be the bands of the resistors. You may use different colored pens or pencils in indicating your answer.

1. 

12 kΩ , 5% tolerance
Hint: Kilo means thousand

2. 

5600 Ω , 10% tolerance

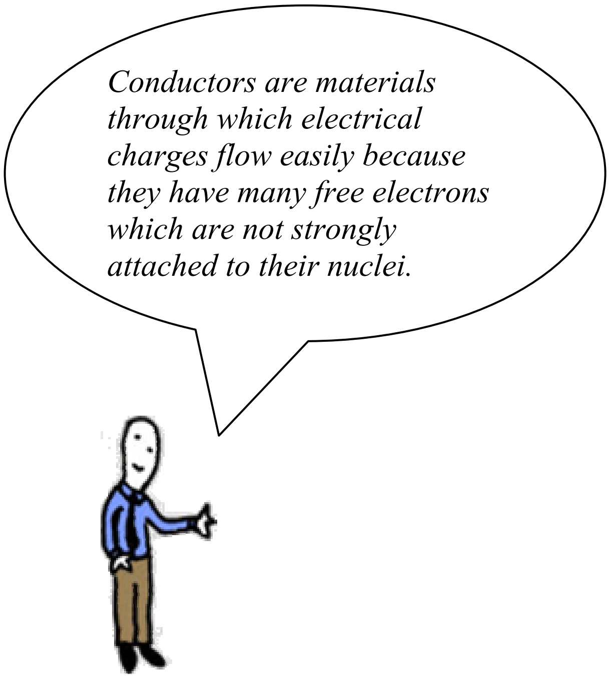
3. 

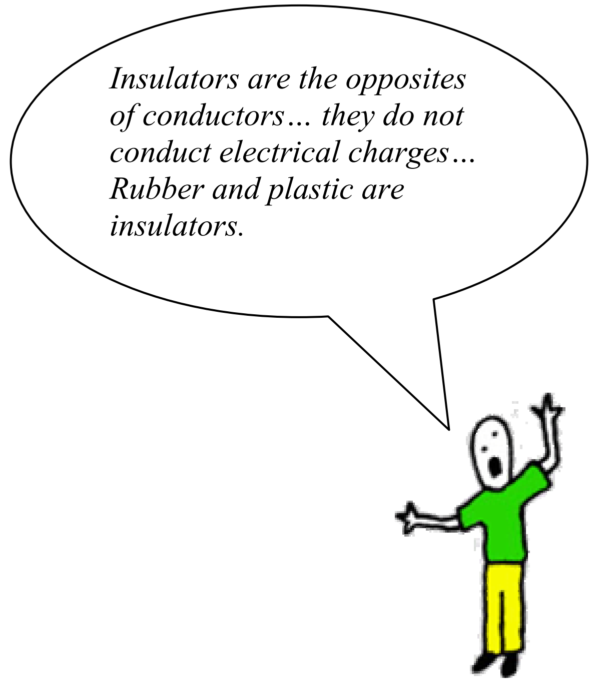
12 MΩ , 5% tolerance
Hint: Mega means million

Key to answers on page 25

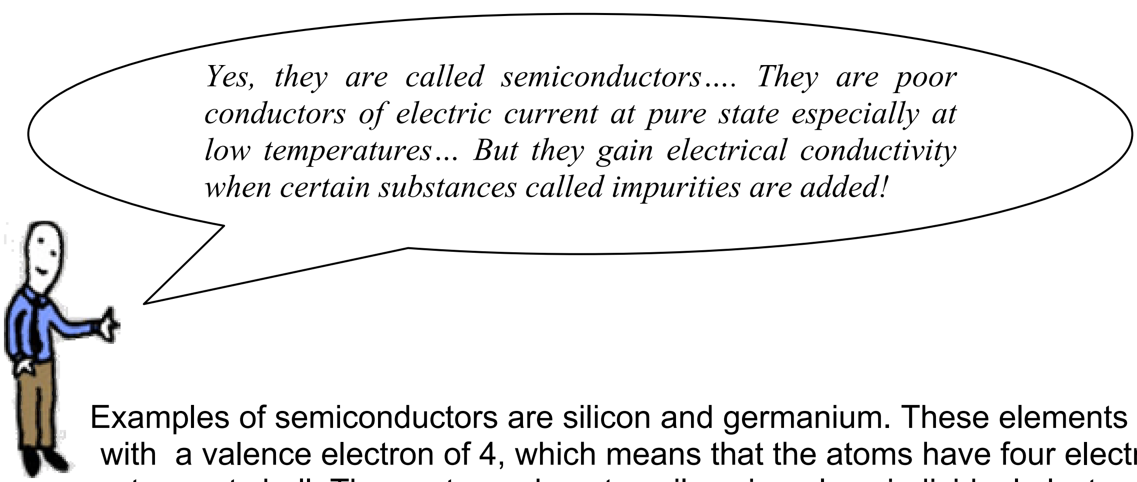
Read this:

In earlier modules we have learned about conductors and insulators. Can you still recall what conductors are? How about insulators?





How about those materials that are neither conductors or insulators? Is it really possible to have materials whose ability to conduct electricity lies between conductors and insulators?



Examples of semiconductors are silicon and germanium. These elements have atoms with a valence electron of 4, which means that the atoms have four electrons in their outermost shell. These atoms do not easily gain or lose individual electrons. Instead, the semiconductor atoms share the four valence electrons with other atoms, thus forming a covalent bond.

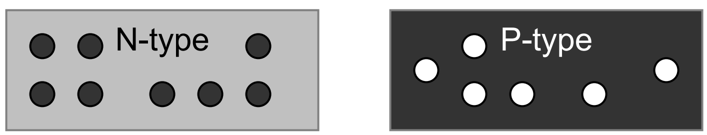
When electrical charges are added to a semiconductor, we can control the flow of electrons in them. This process of adding charges is called **doping**. Doping can be accomplished in many ways that can be put into a single idea like putting an impurity to make it deficient or excessive of electrical charges.

When electrons are added, the result is negative or N-type material. N-type materials are produced by adding pentavalent element to the semiconductor. Pentavalent elements have five valence electrons.

Semiconductor **Pentavalent impurity** = N-type

Semiconductor **Trivalent Impurity** = P-type

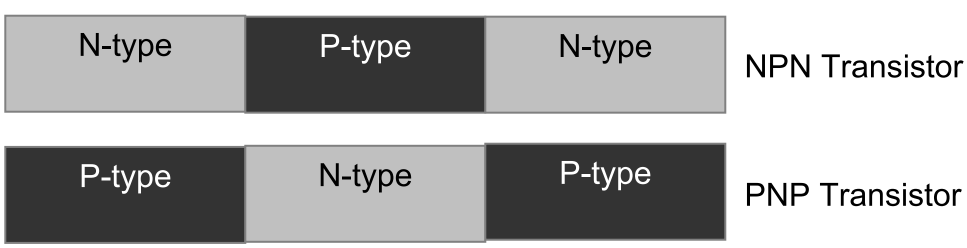
N-materials have excess electrons and P-type have deficiency of electrons, called holes. When N-types and P-type materials are joined, a diode is formed.



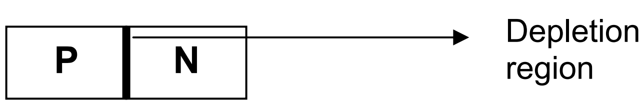
The majority charge carriers in an N-type material are electrons, represented by the dots.

The majority charge carriers in an N-type material are protons, represented by the holes.

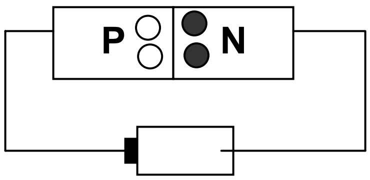
What if we add a third layer? Then, a **transisto**r is formed



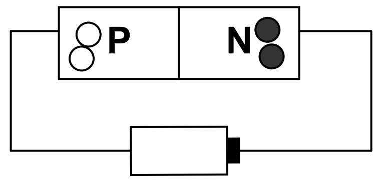
We create a PN Junction diode by joining together two pieces of semiconductor-doped n-type and p-type. This causes the depletion zone to form around the junction between the materials. The depletion zone controls the flow of electron and behavior of diode.



When we apply potential difference between the two wires we tend to pull the electrons and holes away from the junction, this makes it even harder to cross the depletion zone. The polarity of the voltage applied makes the diode reverse biased.



Forward bias: there is current



Reverse bias: there is no current

When the voltage is applied the other way around, we push the electrons and holes toward the junction. The recombined charges then pass through the junction. With this polarity, the diode is forward biased.

What you will do

Self-Test 2.1

Direction: Select the letter of the option that correctly answers the questions or completes the statements.

1. What electronic component is formed when a layer of N-type material is joined with a p-type material?
   a. resistor c. diode
   b. transistor d. capacitor

2. Which of the following is NOT a passive electronic element?
   a. capacitor c. inductor
   b. resistor d. transistor

3. An N-type material can be formed by adding impurity to a semiconductor element in a process called _________.
   a. recombination
   b. biasing
   c. doping
   d. impurifying

4. Which of the following is a semiconductor?
   a. copper
   b. silicon
   c. helium
   d. gold

5. Which of the following pairs work by biasing?
    a. diode and resistor
    b. diode and capacitor
    c. diode and transistor
    d. capacitor and inductor

Key to Correction on page 25

Lesson 3 Integrated Circuits

The functioning of electronic devices depends on complex circuits containing the elements we have discussed in lesson 2. Can you imagine how bulky a device must be if it were to contain more than a hundred or even more circuits and elements? Well, if that's the case, more sophisticated devices should look bigger because of more elements to support their functions. But now, notice that the more advanced an electronic device is, the smaller it becomes? Cellular phones, cameras and other gadgets now come in very small sizes, television sets have become flat and medical gadgets become handy. How did this paradox come about?

The answer to this is the **integrated circuit.** As its name implies, it is a device that contains hundreds to even millions of circuits already put into a single, tiny package called **chip**. Integrated circuits save space in electronic devices, making them small and light.

An integrated circuit (IC) is a thin chip consisting of at least two interconnected semiconductor devices, mainly transistors, as well as passive components like resistors. As of 2004, typical chips are of size 1 cm^2 or smaller, and contain millions of interconnected devices, but larger ones exist as well. Among the most advanced integrated circuits are the microprocessors, which drive everything from computers and cellular phones to digital microwave ovens. Digital memory chips are another family of integrated circuits that are crucially important in modern society.

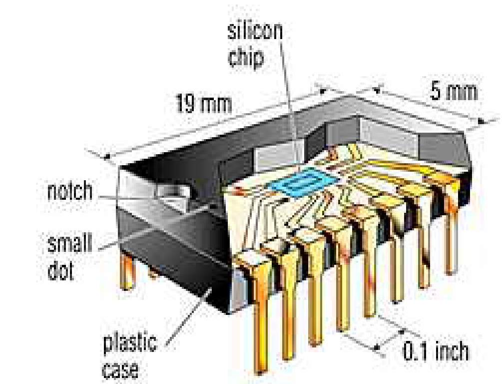
The integrated circuit was made possible by mid-20th-century technology advancements in semiconductor device fabrication and experimental discoveries which showed that semiconductor devices could perform the functions performed by vacuum tubes at the time. The integration of large numbers of tiny transistors onto a small chip was an enormous improvement to the manual assembly of finger-sized vacuum tubes. The integrated circuit's small size, reliability, fast switching speeds, low power consumption, mass production capability, and ease of adding complexity quickly pushed vacuum tubes into obsolescence.

The size of an integrated circuit is determined by the number of transistors it contains. This system of classification is called the scale integration:

Small Scale Integration (SSI)	- up to10 transistors per chip
Medium Scale Integration	- up to 100 transistors per chip
Large Scale Integration	- up to10, 000 transistors per chip
Very Large Scale Integration	- up to100, 000 transistors per chip
Ultra Large Scale Integration	- up to1 million transistors per chip

Almost, if not all, electronic devices have ICs in them. ICs simplify the manufacturing of these devices because a single IC replaces several electronic components. However, once an IC is damaged, it could not be repaired. It has to be replaced because its small size, packaging and complex circuitry makes it impossible to troubleshoot. ICs may cost for as low as a few pesos to as much as a billion of pesos. Ordinary electronic devices make use of cheaper ICs, while those used in advanced scientific and medical fields use rather expensive ones.

What's inside an IC chip?



The figure on the left shows a miniaturized electronic circuit produced on a single crystal, or chip, of a semiconducting material – usually silicon. It may contain many millions of components and yet measures only 5 mm^2 or 0.2 in^2 in surface area and 1 mm or 0.04 inches in thickness. The IC is encapsulated within a plastic or ceramic case, and linked via gold wires to metal pins with which it is connected to a printed circuit board and the other components that make up such electronic devices as computers and calculators.

How are IC's produced? Let us take at the following block diagram:

Semiconductors (usually silicon) are sliced to make wafers.

↓

The wafer is polished and a layer of SiO_2 is formed on the wafer. Some parts of the wafer are doped. The wafer is divided into several chips

↓

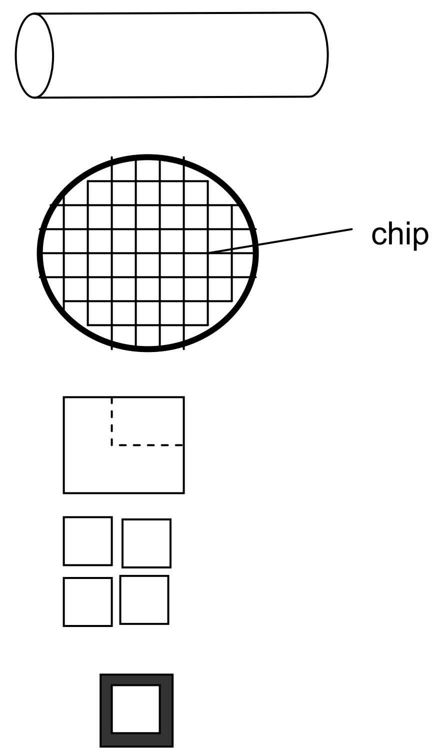
Each chip is provided with desired wirings by automatic equipment

↓

The wafer is cut into several chips by laser or diamond point.

↓

Each chip is mounted on a plastic case.



What you will do

Self-Test 3.1

1. An integrated circuit's size is determined by counting the number of _ r _ _ _ _ _ _ _ _ r it contains.

2. Production of ICs begin with cutting a semiconductor ingot into _ a _ _ _ s.

3. The semiconductor usually used in the production of IC is s _ _ _ _ _ o _.

4. A single piece of integrated circuit is called _ _ i _.

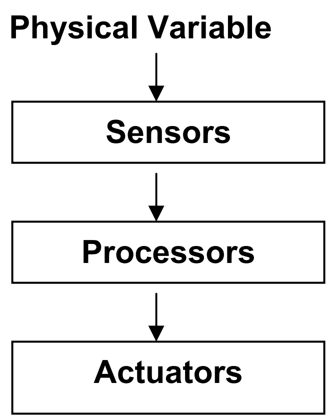
5. Precise cutting of silicon wafers into chips is done by _ _ s _ _ s.

Key to Correction on page 25

Lesson 4   Electronic Systems

Like the different parts of our body, electronic elements are nothing when they stand alone. To perform certain tasks, they have to be used together because each element provides a different but complementing task to the other. When we put electronic elements together, we form **electronic systems**.

Let us visualize an electronic system using the block diagram

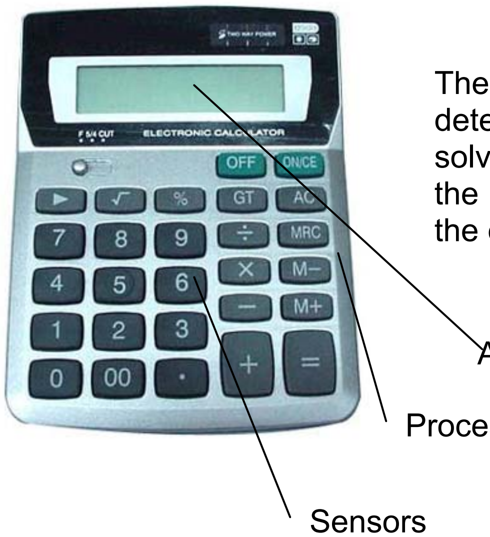


Sensors detect the signals or parameters to be used by the processor. A special type of sensor, called transducer, converts the sensed signal into electronic signal before processing takes place. Sensors are made up of diodes, resistors, capacitors, and inductors.

The **processor** is the “thinking” mechanism of the system. Processors are usually integrated circuits and transistors that make use of logic to evaluate a sensed signal. Processors work depending on the program that we input on them. The processor in e-systems is analogous to our brain. It determines what we are supposed to do with what we see and feel using our senses.

The **actuators** perform activities as a result of processing in the processors. Actuators maybe electric motors that can do work or loudspeakers and lamps that give off sound and light as signals.

A **very good example of electronic system is a simple calculator.**



The keypads of the calculator serve as sensor. They determine what number you pressed. The processor solves the number operation you input. The actuator is in the LCD display of the calculator. It displays the answer to the operation.

What you will do

Self-test 4.1

Can you identify the sensor, processor and activator in each appliance?

1. Computer

2. Radio Receiver

Key to Correction on page 25

Lesson 5 Everyday Electronics (Application of Electronics)

In today's modern world, the applications of electronics in different fields is almost limitless. In our homes alone, all the appliances we use are products of electronics- television sets, radio, cellular phones, computers, microwave oven and other kitchen appliances, telephones down to the simple calculators. Needless to say, they have simplified our daily chores and have provided us convenience and entertainment. Let us step out of our homes and explore the other fields where electronics is of great use… surely, you will appreciate electronics more.

In industries and factories…

With the use of sensors and industrial robots, the manufacture of goods becomes fast, error-free and hygienic.

In communication companies

With advanced communication facilities (cellular phones, internet, fax machines), it became very easy to get connected to the world

In medicine

Precise diagnosis can now be done with patients without the need for surgery. This includes imaging systems, laser technology and computerized monitoring system.

In transportation

Computerized navigation is now done by transportation companies like buses,g airplanes and ships. Even their ticketing process makes use of electronic devices.

In scientific laboratories

Research activities are now done by sensors and computerized equipment. This has saved scientists from exposing themselves to unnecessary dangers.

In space exploration and research

Space shuttles make use of integrated circuits because IC's are compact and have minimal weight.

Much more indeed can be expected of electronics. What may seem futuristic and figments of our imagination today may one day become possible because of advances in electronics.

What you will do

Activity 4.1

.

Browse the newspaper and cut advertisements that illustrate the recent applications of electronics in the Philippines. In your own words, describe how the device operates, what its electronic components are and in what fields can such device be of great use.

Let's summarize

In this module, we have learned that:

1. Electronics is the study of control of electrons in different media such as vacuum, tubes, gasses and semiconductor materials.

2. Electronic components are passive when they do not need power to operate. Otherwise, the components are active. Resistors, capacitors and inductors are passive components while diodes and transistors are active components

3. Integrated circuits are electronic devices that incorporate up to millions of electronic components into a single package called chip.

4. Doping is the process of adding impurities to semiconductor elements. Diodes and transistors are doped components.

5. Biasing is the proper application of voltage to active elements to control the flow of electrons in them. Forward bias allows the flow of electricity in one direction.

6. Electronic systems are composed of sensors, processors and actuators. Sensors detect the stimuli, processors evaluates the information, and actuators perform the task defined by the processors.

7. Electronics is being widely used in many fields including research, communication and transportation, medicine, education and industries.

Posttest

Directions: Select the letter of the option that correctly answers the given questions. Write your answer on a separate sheet of paper.

1. Which of the following does NOT belong to the group?
    a. transistors
    b. capacitors
    c. inductors
    d. resistors

2. A 42 kΩ resistor has its third color erased. What do you think is the color of that band?
    a. Red
    b. Yellow
    c. Blue
    d. Orange

3. Which of the following elements can be charged or discharged?
    a. IC
    b. Diode
    c. Capacitors
    d. Resistors

4. Which of the following statements is/ are true?
    i. Active components operate only when they are connected to a source.
    ii. An integrated circuit is an active electronic component.

    a. I only
    b. II only
    c. Both I and II
    d. Neither I or II

5. In electronic systems, what part performs the tasks provided by the programs?
    a. sensors
    b. actuators
    c. processors
    d. regulators

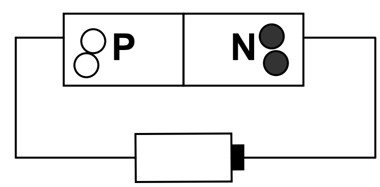
6. The capability of transistors to switch and amplify signals is useful in electronic systems as
    a. sensors
    b. processors
    c. actuators

d. regulators

7. Which of the following statements is TRUE about transistor?
    a. Transistors are made up of diodes.
    b. Transistors conduct current in only one direction.
    c. Transistors store charges.
    d. Both a and b

8. The classification of Integrated Circuits into scale integration is based on the number of _______________ an IC contains.
    a. resistors
    b. transistors
    c. diodes
    d. capacitors

9. In the diagram shown, the diode is
    a. unbiased
    b. reverse biased
    c. forward biased
    d. None of the above



10. An n-type material has deficiency of
    a. electrons
    b. protons
    c. neutrons
    d. positron

11. The display that we see in the counters of department stores and shops is what part of an electronic system?
    a. Processor
    b. Actuator
    c. Sensor
    d. Regulator

12. Which of the following electronic components is made up of coils that concentrates magnetic and electric fields in it?
    a. Resistor
    b. Capacitor
    c. Inductor
    d. Integrated Circuit

13. What do you call the region formed when a P-type material and N-type material are joined together and then biased?
    a. PN region
    b. Depletion region
    c. Formation region
    d. Junction region

14. When current passes through a PN material, then such material is said to be
    a. unbiased
    b. forward biased
    c. reversed biased
    d. either b or c

15. Which of the following is an example of the applications of electronic systems?
    a. On-line ticketing services of airline companies
    b. Sending text messages through cellular phones and e-mail
    c. Using robots to perform dangerous experiments
    d. All of the above

Key to Correction on page 25

Key to Answers

Pretest

1. d
2. b
3. c
4. a
5. a
6. c
7. c
8. c
9. c
10. a
11. c
12. c
13. b
14. b
15. d

Lesson 1

Self-Test 1.1

1. b
2. d
3. a
4. c
5. e

Lesson 2

Self-Test 2.1

1. c
2. d
3. c
4. b
5. c

Activity 2.1

1. Brown, Red, Orange, Gold
2. Green, Blue, Red, Silver
3. Red, Blue, Blue, Gold

Lesson 3

Self-Test 3.1

5. Transistors
6. Wafers
7. Silicon
8. Chip
9. Lasers

Lesson 4

Self-Test 4.1

	Radio System	**Computer**
Sensors	Volume control Tuner	Keyboard, mouse
Processor	Radio circuit	CPU
Actuator	Loudspeaker	Monitor, printer

Posttest

1. a
2. d
3. c
4. c
5. b
6. b
7. a
8. b
9. b
10. b
11. b
12. c
13. b
14. b
15. d

-End of Module-

References

Hewitt, P.G. (1997). *Conceptual physics.* USA: Addison-Wesley Publishing Co., Inc.

Navasa, D. & Valdez, B.J. (2001). *Physics.* Quezon City: Sibs Publishing House, Inc.

Salmorin, L.M. & Florido, A. (2004). *Physics IV.* Quezon City: Abiva Publishing House, Inc.

See Tho Weng Fong (1995). *Science for secondary schools.* Singapore: Longman Singapore Publishers.

Taffel, A. (1992). *Physics: Its methods and meanings.* USA: Prentice Hall Publishers.

Tan, M. (2001). *TIMSS-LIKE test items in science and mathematics.* DOST-SEI, UPNISMED, Pundasyon Para sa mga Guro ng Agham at Matematika, Ink.

Tillery, B.W. (1999). *Physical science.* Singapore: WCB McGraw-Hill.

Urone, P. (2004). *Physics with health science applications.* Manila.

Yong Loo Wan, Wai Kwok & Fong See Tho Weng. (2004). *Physics insights.* Phil. Edition. Pearson Educ. South Asia PTE LTD.

Tillery, B. W. (1999). *Physical science*. Singapore: WCB McGraw Hill

Young, H. D. (2004). *University physics*. USA: Pearson Education Inc.

Van Heuvelen, A. (1986). *Physics: A general introduction..* Canada: Little Brown and Company (Canada) Limited