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«Комсомольский-на-Амуре государственный технический университет»

Н. С. Кутузова

ENGLISH FOR ELECTRICAL AND ELECTRONICS ENGINEERS

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Цель пособия – развитие у обучаемых умений и навыков читать литературу по специальности и извлекать из нее необходимую информацию, делать сообщения с использованием специальной терминологии. Текстовой материал подобран из оригинальных английских источников. Материалы пособия развивают и закрепляют у студентов знания по грамматике изучаемого языка, формируют и развивают умения и навыки применения разных видов чтения с извлечением информации из научной, научно-популярной, а также профессионально-ориентированной литературы.

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INTRODUCTION

What Electrical and Electronics Engineers do

Electrical engineers design, develop, test, and supervise the manufacturing of electrical equipment such as electric motors, radar and navigation systems, communications systems, and power generation equipment. Electronics engineers design and develop electronic equipment, such as broadcast and communications systems – from portable music players to global positioning systems (GPS).

Work Environment

Electrical and electronics engineers work primarily in industries that conduct research and development, for engineering services firms, in manufacturing, and in the federal government. They generally work indoors in offices. However, they may have to visit sites to observe a problem or a piece of complex equipment.

How to become an Electrical or Electronics Engineer

Electrical and electronics engineers must have a bachelor’s degree. Employers also value practical experience, so graduates of cooperative engineering programs, in which students earn academic credit for structured work experience, are valuable as well.

MODULE 1. ELECTRICAL CURRENT

The Ancient Greeks noted that the amber buttons could attract light objects such as hair, and that if they rubbed the amber for long enough, they could even get a spark to jump. This is the origin of the word “electricity”, from the Greek ēlektron = “amber”, which came from an old root ēlek- = “shine”.

Ex. 1. Work with a dictionary, translate the following terms and match the words from the table with their translation below the table. Check up your answers. At home memorize the terms.

magnitude	flow	skin effect	rectifier	current	the same	vary (*v*)
conventional	charge carrier	supply (*v*)	unit	direction	prior to	density
alternating	output	measure (*v*)	power	cross-sectional area	direct	instantaneous
propagation	cell	pulsating	occur (*v*)	circular	conductor	wireless

1) амплитуда; 2) носитель заряда; 3) до/раньше/перед; 4) направление; 5) переменный; 6) единица; 7) ток; 8) мощность/выходная мощность; 9) элемент; 10) выпрямитель, диод; 11) энергия, электроэнергия; 12) постоянный; 13) одинаковый; 14) снабжать; 15) меняться; 16) измерять; 17) происходить; 18) площадь поперечного сечения; 19) поток; 20) плотность; 21) циркулярный/кольцевой/круговой; 22) проводник; 23) распространение; 24) мгновенный; 25) пульсирующий; 26) условный; 27) эффект вытеснения тока (поверхностный эффект); 28) беспроводной.

Ex. 2. Translate the words below without a dictionary.

Electrical, cycle, magnetic, electron, standard, atom, ampere, symbol, coulomb, second, physicist, positive, magnetic field, negative, situation, frequency, hertz, electrochemical, electronic, component, active, characteristically, electromagnetic, conductor, signal.

Ex. 3. Choose two terms from Ex. 1 and explain them to your group mates so that they could guess them.

Ex. 4. Word formation.

Electric…, electro…, electrical…, electro…, electro…, electric…., electrici…
-al/ -ly/ -acupunture/ - ty/ -ian/ -cardiogram/ -car

Ex. 5. Read and translate the following words:

Convention – conventional – conventionalize;
to measure – measurement – measurer – measured – measureless;
to produce – producer – production – product – productive – productivity;
to occur – occurring – occurrence;
vary – various – variety;
to pay – payable – paying – payment – paid;
wire – wireless.

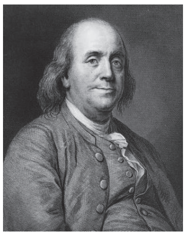
Ex. 6. Match a word from the box with its definition:

flow / direct / supply (*v*) / alternating / density / measure (*v*) / current / wireless / frequency

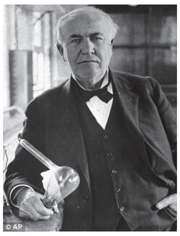
	the rate per second of a vibration constituting a wave, either in a material (as in sound waves), or in an electromagnetic field (as in radio waves and light)
	move steadily and continuously in a current or stream
	make (something needed or wanted) available to someone; provide
	a flow of electricity which results from the ordered directional movement of electrically charged particles; a quantity representing the rate of flow of electric charge, usually measured in amperes
	ascertain the size, amount, or degree of (something) by using an instrument or device marked in standard units
	an electric current that reverses its direction many times a second at regular intervals, typically used in power supplies

	using radio, microwaves, etc. (as opposed to wires or cables) to transmit signals
	extending or moving from one place to another without changing direction or stopping
	the degree of compactness of a substance

A little about electrical history…



Electricity was not invented. It occurs naturally in our world. People, however, have invented ways to measure it and to control it for our use. Ben Franklin started working with electricity in 1740's. He believed that lightning was a flow of electricity taking place in nature. He performed his famous kite experiment in 1752 which proved that electricity and lightning were the same thing.



Thomas Alva Edison is another name important in the history of electricity. In the late 1800's he developed 1,093 inventions, but his most famous is the incandescent light bulb. He wanted to bring light into homes and factories. Up until then people used candles or whale oil lamps for light.

Ex. 7. Answer the following questions:

1) What does symbol A stand for?
2) What does symbol I stand for?
3) What do symbols AC/DC stand for?
4) What does abbreviation FET mean?
5) What is a coulomb?
6) How many coulombs are there in one ampere?
7) What do you know about a) Franklin current; b) skin effect?
8) What is frequency measured in?

Ex. 8. Look for the right answers to the above questions in the text.

Ex. 9. Translate the following sentence:

The greater the current in a conductor, the higher the current density.

Ex. 10. Read and translate the text.

Current is a flow of electrical charge carriers, usually electrons or electron-deficient atoms. The common symbol for current is the uppercase letter I. The standard unit is the ampere, symbolized by A. One ampere of current represents one coulomb of electrical charge (6.24×10^{18} charge carriers) moving past a specific point in one second. Physicists consider current to flow from relatively positive points to relatively negative points; this is called conventional current or Franklin current. Electrons, the most common charge carriers, are negatively charged. They flow from relatively negative points to relatively positive points.

Electric current can be either direct or alternating. Direct current (DC) flows in the same direction at all points in time, although the instantaneous magnitude of the current might vary. In an alternating current (AC), the flow of charge carriers reverses direction periodically. The number of complete AC cycles per second is the frequency, which is measured in hertz. An example of pure DC is the current produced by an electrochemical cell. The output of a power-supply rectifier, prior to filtering, is an example of pulsating DC. The output of common utility outlets is AC.

Current per unit cross-sectional area is known as *current density*. It is expressed in amperes per square meter, amperes per square centimeter, or amperes per square millimeter. Current density can also be expressed in amperes per circular mil. In general, the greater the current in a conductor, the higher the current density. However, in some situations, current density varies in different parts of an electrical conductor. A classic example is the so-called *skin effect*, in which current density is high near the outer surface of a conductor, and low near the center. This effect occurs with alternating currents at high frequencies. Another example is the current inside an active electronic component such as a field-effect transistor (FET).

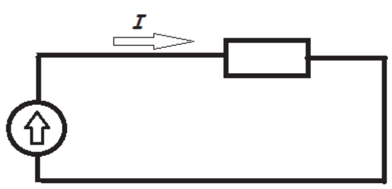
An electric current always produces a magnetic field. The stronger the current, the more intense the magnetic field. A pulsating DC, or an AC, characteristically produces an electromagnetic field. This is the principle by which wireless signal propagation occurs.

Ex. 11. Answer the questions:

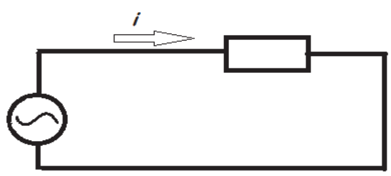
1) What is called conventional or Franklin current?
2) What types of current do you know?
3) In what can current density be expressed?
4) What is the frequency?
5) What does an electric current always produce?
6) Explain what skin effect is.

Ex. 12. Define the type of current:

Scheme A



Scheme B



Ex. 13. Make a plan of the text and be ready to speak on the topic.

Ex. 14. Translate from Russian into English.

Текст А.

Вся материя состоит из очень маленьких частиц, называемых атомами. Эти атомы состоят из еще более маленьких частиц, называемых электронами. Электроны вращаются вокруг центрального ядра, состоящего из одного или более протонов и нейтронов. Электроны являются отрицательно заряженными частицами, протоны – положительно заряженными, а нейтроны – нейтрально заряженными.

Текст Б.

Электрический ток – это упорядоченное движение свободных электрически заряженных частиц, например, под воздействием электрического поля. Такими частицами могут являться: в проводниках – электроны, в электролитах – ионы (катионы и анионы), в газах – ионы и электроны, в вакууме при определенных условиях – электроны, в полупроводниках – электроны и дырки. Электрический ток широко используется в энергетике для передачи энергии на расстоянии, а в телекоммуникациях – для передачи информации на расстоянии. В медицине электрический ток используют в реанимации.

Ex. 15. At home prepare the topic on "Current".

Ex. 16. Fill in the blanks with a word from the box below.

frequency / direct current / three-phrase / positive polarity / alternating current / Current distribution / negative polarity

Current Distribution Symbols

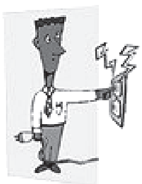
_____________ uses the "~" symbol to signify the relationship between ___________ m-phases and frequency. The term "1~50 Hz", for example, signifies a single-phase alternating current with a ____________ of 50 hertz. The term "3~50 Hz" states a ____________ alternating current with a frequency of 50 hertz.

A long, straight line signifies _______________ . For example, the term "110 V ---- 110 V" states a direct current relationship between two 110-volt sources. A "+" symbol shows ______________ while "-" shows _______________ .

MODULE 2. ELECTRIC CIRCUIT

Unit 2.1. Fundamentals

Be Safe!



Are you ready for this? Your brain and muscles need electricity in a very tiny amount to work. Because of this, large amounts of electricity are very dangerous to you. The electricity flowing through a light bulb is enough to stop your breathing.

Ex. 1. Find the proper Russian equivalents for the following English terms:

convert (*v*)	bulb	load	device	wire
in order to	in parallel	in series	fuse	terminal
source	consume (*v*)	mend (*v*)	circuit	switch

1) клемма; 2) нагрузка; 3) последовательно; 4) источник; 5) лампочка; 6) переключатель; 7) ремонтировать; 8) потреблять; 9) цепь, контур, схема (syn. loop); 10) параллельно; 11) чтобы; 12) устройство; 13) преобразовывать; 14) пробка/предохранитель; 15) провод/проволока.

Ex. 2. Read the following words and define their part of speech where it is possible:

Switch	Switch + ed	Switch + ing		
Drive	Driv + en	Driv + ing	Driv + er	
Convert	Convert + er	Convert + ibili + ty	Convert + ible	
Consume	Consum + ed	Consum + er	Consum + ing	Consum + able

Ex. 3. Choose two terms from Ex. 1 and explain them to your group mates so that they could guess them.

Ex. 4. Read and guess the meaning of the following words and word combinations:

A closed loop, power source, negative terminal, a light bulb, a complete circuit, a safety device, the amount of electricity, the same distance, flexible thread, a strip of wire.

Some Facts about Electricity:

1) Electricity travels at the speed of light – more than 186,000 miles per second!

2) A spark of static electricity can measure up to three thousand (3,000) volts.

3) A bolt of lightning can measure up to three million (3,000,000) volts, and it lasts less than one second!

4) Electricity always tries to find the easiest path to the ground.

5) Electricity can be made from wind, water, the sun and even animal poop.

6) A 600 megawatt natural gas plant can power 220,000 homes.

7) The first power plant – owned by Thomas Edison – opened in New York City in 1882.

8) Thomas Edison invented more than 2,000 new products, including almost everything needed for us to use electricity in our homes: switches, fuses, sockets and meters.

9) Benjamin Franklin didn't discover electricity, but he did prove that lightning is a form of electrical energy.

Ex. 5. Speaking:

1) What is an electrical circuit?
2) What is a load?
3) Provide the examples of a load.
4) What symbols used in electrical circuits do you know?
5) How many types of electrical connections do you know?
6) Draw some examples of electrical circuits.

Ex. 6. Match a word with its definition:

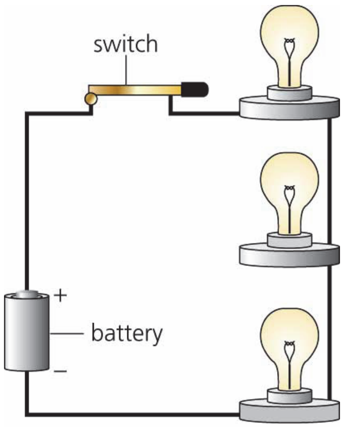
Word	Definition
1) Circuit	A) A point of connection for closing an electric circuit
2) Loop	B) A safety device consisting of a strip of wire that melts and breaks an electric circuit if the current exceeds a safe level
3) Series	C) An impedance or circuit that receives or develops the output of a transistor or other device
4) Mend	D) Electrical circuits or components arranged so that the current passes through each successively
5) Fuse	E) A complete circuit for an electric current
6) Switch	F) To change or adapt the form, character, or function of; transform
7) Load	G) A device for making and breaking the connection in an electric circuit
8) Source	H) A complete route which an electric current can flow around.
9) Parallel	I) A place, person, or thing from which something originates or can be obtained
10) Convert	J) A thing made or adapted for a particular purpose, especially a piece of mechanical or electronic equipment
11) Device	K) Repair (something that is broken or damaged)
12) Wire	L) Side by side and having the same distance continuously between them
13) Terminal	M) Metal drawn out into the form of a thin flexible thread or rod

Ex. 7. Look for the right answers to the above questions in the text.

Ex. 8. Translate the following sentence:

Electric circuits can be drawn in diagrams using symbols. Any device that consumes the energy flowing through a circuit and converts that energy into work is called a load.

Ex. 9. Read and translate the text.

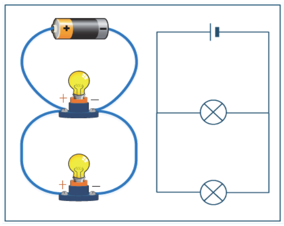


An electrical circuit is a closed loop formed by a power source, wires, a fuse, a load, and a switch. When the switch is turned on, the electrical circuit is complete and current flows from the negative terminal of the power source, through the wire to the load, to the positive terminal. Any device that consumes the energy flowing through a circuit and converts that energy into work is called a load. A light bulb is one example of a load; it consumes the electricity from a circuit and converts it into work – heat and light.

Electric circuits can be drawn in diagrams using symbols. There are agreed ways of drawing these symbols so that circuit diagrams can be read by lots of different people in order to make electrical devices or to mend them.

There are three types of circuits: series circuits, parallel circuits, and series-parallel circuits. A series circuit is the simplest because it has only one possible path that the electrical current may flow. If the electrical circuit is broken, none of the load devices will work. A parallel circuit has more than one path, so if one of the paths is broken, the other paths will continue to work.

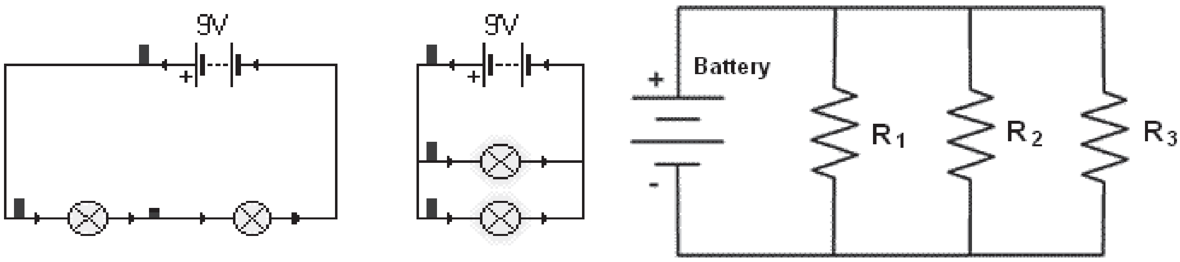
A series-parallel circuit attaches some of the loads to a series circuit and others to parallel circuits. If the series circuit breaks, none of the loads will function. If one of the parallel circuits breaks, however, that parallel circuit and the series circuit will stop working, but the other parallel circuits will continue to work.



Ex. 10. Answer the questions:

1) What does an electrical circuit consist of?
2) What is a load?
3) Provide the examples of a load.
4) What are the symbols of electrical circuit used for?
5) How many types of electrical circuits are there?
6) How do they differ? What will a trouble result in?

Ex. 11. Read the schemes (see Appendix 1).



Mini-quiz to check your understanding

1) Why do they call it a DC circuit?
a) The electricity flows from the source around and back to the source in a circuit.
b) Because most have a circuit breaker installed.
c) To warn people of possible shocks.

2) What happens when a light burns out in a series circuit?
a) The other lights remain lit.
b) The voltage increases dramatically.
c) The circuit is broken and all lights go out.

3) How could you turn off a parallel circuit?
a) You can't turn off a parallel circuit.
b) Put a switch before the parallel configuration, like near the battery.
c) Unscrew one light bulb.

Unit 2.2. Ohm's Law

1826 George Simon Ohm (1787–1854) wanted to measure the motive force of electrical currents. He found that some conductors worked better than others and quantified the differences. He waited quite some time to announce "Ohm's Law" because his theory was not accepted by his peers. The unit for resistance is named after him.

Ex. 1. Consult a dictionary and find out if there is any difference between a battery and a cell.

Ex. 2. What can you tell about Ohm's Law?

Ex. 3. Translate the following sentence and word combinations:

Resistance is the opposition of an object to having current pass through it; directly proportional, inversely proportional.

Ex. 4. Fill in the blanks with a word from the box below and translate the text.

inversely proportional / resistance / current / directly proportional / Ohm's Law / voltage / Source voltage

Many "laws" apply to electrical circuits, but _____________ is probably the most well-known. To understand Ohm's Law, it's important to understand the concepts of current, voltage, and resistance. ____________ is the flow of an electric charge. _____________, or electrical potential difference, is the force that drives the current in one direction. ____________ is the opposition of an object to having current pass through it.

Ohm's Law states that an electrical circuit's current is _____________ to its voltage and _____________ to its resistance. So, if voltage increases, for example, the current will also increase, and if resistance increases, current decreases. The formula for Ohm's Law is $E = I \times R$, where E = voltage in volts, I = current in amperes, and R = resistance in ohms.

____________ is another important concept in electrical circuits. It refers to the amount of voltage that is applied to the circuit and is produced by the power source. Source voltage is affected by the amount of resistance within the electrical circuit and affects the amount of current. The current is affected by both voltage and resistance. Resistance is not affected by voltage or current, but it affects both voltage and current.

Ex. 5. Translate from Russian into English.

1) Электрическая схема – это чертеж, на котором показано упрощенное и наглядное изображение связи между отдельными элементами электрической цепи, выполненное с применением условных графических обозначений, позволяющий понять принцип действия устройства.

2) Любая электрическая цепь состоит из источников энергии и ее потребителей.

3) Кроме того, в электрическую цепь входят аппараты для включения и отключения всей цепи или отдельных ее участков и потребителей, измерительные приборы, устройства защиты и другие аппараты.

4) Графические обозначения элементов устройства и соединяющие их линии располагают на схеме таким образом, чтобы обеспечить наилучшее представление о структуре изделия и взаимодействии его составных частей.

5) Общие требования устанавливают виды и типы схем изделий всех отраслей промышленности и подразделяют схемы на электрические, пневматические и кинематические.

6) В зависимости от назначения электрические схемы разделяют на следующие: структурные, функциональные, принципиальные (полные), соединений (монтажные), расположения и некоторые другие.

MODULE 3. RESISTORS

Unit 3.1. Fundamentals

Ex. 1. Translate the words below without a dictionary.

Primary, constant, harmonic, critical, project, agency, agent, style, logic, analysis, diagram, element, processor, argument, formula, method.

Ex. 2. Read the following words and define their part of speech where it is possible:

Resist	resist + or	resistive + ty	resist + ance	
Value	value + tion	valu + able	valu + ed	
Indicate	indicat + ed	indica + tion	indicat + ive	indicat + ing
Oppose	oppose + tion	oppos + ing	oppos + ed	
Generate				

Ex. 3. Work with a dictionary, translate the following terms and match. Check up your answers. At home memorize the terms.

property	inversely proportional	indicate (*v*)	voltage drop	opposition	controlling gain
subject to	directly proportional	in terms of	value (*v*, *n*)	inherent	flow (*v*)

1) указывать; 2) противопоставление; 3) при условии; 4) исходя из, на основе; 5) программируемое усиление; 6) свойство; 7) обратно пропорционально; 8) прямо пропорционально; 9) врожденный; 10) падение напряжения; 11) течь; 12) значение, величина, оценивать, ценить.

Ex. 4. Find 7 words:

PROPERTYSUBJECTINDICATECONTROLLINGINHERENTGAINOPPOSITION

Ex. 5. Choose two terms from ex. 3 and explain them to your group mates so that they could guess them.

Ex. 6. Circle 22 terms from modules 1, 2, 3.

C	N	M	A	G	N	I	T	U	D	E	V	I	C	E
O	L	F	L	O	W	Q	S	N	V	H	J	J	U	O
N	G	I	T	T	Z	A	D	I	R	E	C	T	T	P
V	O	M	E	N	D	A	E	T	A	W	I	R	E	P
E	U	P	R	O	P	A	G	A	T	I	O	N	R	O
N	N	U	N	A	U	A	M	E	O	R	R	A	M	S
T	L	O	A	D	E	C	U	R	R	E	N	T	I	I
I	E	A	T	E	A	M	M	O	E	L	O	R	N	T
O	S	W	I	T	C	H	H	M	C	E	L	L	A	I
N	O	A	N	A	I	Q	O	F	U	S	E	A	L	O
A	U	O	G	U	R	O	P	A	H	S	R	A	U	N
L	R	U	A	I	C	I	N	D	I	C	A	T	E	R
O	C	E	I	O	U	Q	M	Q	H	E	A	U	R	A
U	E	O	M	I	I	P	R	O	P	E	R	T	Y	E
A	E	V	O	L	T	A	G	E	D	R	O	P	A	U

Ex. 7. Study the resistor colour code.

colour	code	colour	code
black	0	green	5
brown	1	blue	6
red	2	violet	7
orange	3	grey	8
yellow	4	white	9

Ex. 8. Work with a dictionary and find out if there is any difference between resistivity and resistance.

Ex. 9. Look through the text and answer:

1) What is a resistor?
2) What is its primary function?

Ex. 10. Read and translate the text.

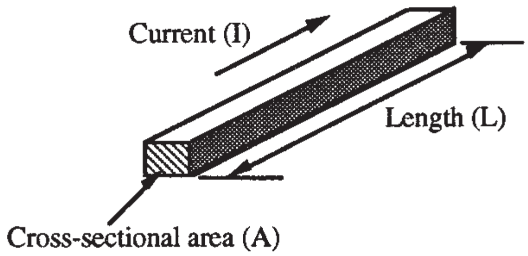
Text A.

Voltage and Current Characteristics of Resistors

The resistor is an electrical device whose primary function is to introduce resistance to the flow of electric current. The magnitude of opposition to the flow of current is called the resistance of the resistor. A larger resistance value indicates a greater opposition to current flow. The resistance is measured in ohms. An ohm is the resistance that arises when a current of one ampere is passed through a resistor subjected to one volt across its terminals. The various uses of resistors include setting biases in p-n junction, controlling gain, fixing time constants, matching and loading circuits, voltage division, and heat generation.

The resistance of a resistor is directly proportional to the resistivity of the material and the length of the resistor and inversely proportional to the cross-sectional area perpendicular to the direction of current flow. Resistivity is an inherent property of materials. Good resistor materials typically have resistivities between 2×10^{-6} and 200×10^{-6} Ω·cm.

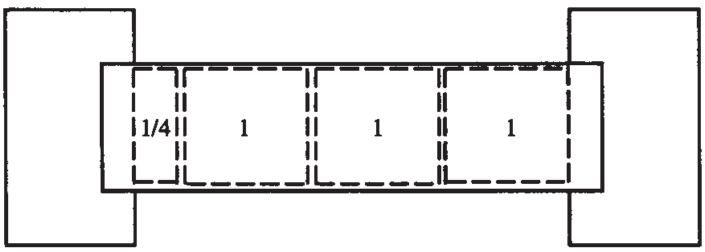
The resistance can also be defined in terms of sheet resistivity. If the sheet resistivity is used, a standard sheet thickness is assumed and factored into resistivity. Typically, resistors are rectangular in shape; therefore the length *l* divided by the width *w* gives the number of squares within the resistor. The number of squares multiplied by the resistivity is the resistance.



The resistance of a resistor can be defined in terms of the *voltage drop* across the resistor and current through the resistor related by Ohm's law. Whenever current is passed through a resistor, a voltage is dropped across the ends of the resistor.

Ex. 11. Answer the questions to the text A:

1) What's the primary function of a resistor?
2) How is the magnitude of opposition to the flow of current called?
3) What is an Ohm?
4) What are the characteristics of resistors?
5) What is shown in the scheme below?



THE ABOVE RESISTOR IS 3.25 SQUARES
IF ρ = 100 Ω/□, THEN R = 3.25□ X 100 Ω/□ = 325 Ω

A resistor with resistance R having a current I flowing through it will have a voltage drop of IR across it

Resistors connected in series

Ex. 12. Solve the following problems.

1) You have an electrical device. You notice that when 5 volts is applied across the device, that 10 milliamps flows through the device. What is the resistance of the device?

2) Next, you apply 10 volts across the device and 50 milliamps flows through the device. What do you conclude?

3) The data below are all taken from measurements of the same resistor. What is the value of the resistance?

Voltage (v)	0.95	2.03	2.99	5.11
Current (ma)	12.0	24.8	37.1	60.0

4) Which is the correct expression for Ohm's law when polarities are defined as shown below?

Questions

Actually, there are many questions about resistors. Note the following characteristics of resistors.

1) Resistors have voltage directly proportional to the current. That's true at every instant of time and for every frequency. Is it possible to have a situation in which voltage and current are not proportional?

2) The voltage across a resistor and the current through the resistor depend upon the values at the same time. Is it possible to have other kinds of relationships?

And, ***if Ohm hadn't discovered his famous law – and lost his job and been blackballed for ten years – you wouldn't be reading this now (see Appendix 2).***

1) In diodes – and many other devices, current and voltage are nonlinearly related. There are many devices in which the relationship is not proportional or linear.

2) In a capacitor, we have i(t) = Cdv(t)/dt.

In an inductor, we have v(t) = Ldi(t)/dt.

Capacitors and inductors have voltage and current related to derivatives! That's really a different situation because it means you have to learn how to solve differential equations to predict behavior of circuits with these components. That's a whole new kettle of fish.

Ex. 13. Translate into English.

Слово «резистор» произошло от латинского «resisto», что значит «сопротивляюсь». Резисторы относятся к наиболее распространенным деталям радиоэлектронной аппаратуры. Основным параметром резисторов является их номинальное сопротивление, измеряемое в омах (Ом), килоомах (кОм) или мегаомах (МОм). Номинальные значения сопротивлений указываются на корпусе резисторов, однако действительная величина сопротивления может отличаться от номинального значения. Эти отклонения устанавливаются стандартом в соответствии с классом точности, определяющим величину погрешности.

Unit 3.2. Fixed Resistors

Ex. 1. Work with a dictionary, translate the following terms. Check up your answers. At home memorize the terms.

fixed resistor	composition resistor	semiprecision resistor	wire-wound resistor
power resistor	precision resistor	general-purpose resistor	metal-film resistor

1) прецизионный резистор (тип резистора с очень малым отклонением сопротивления от указанного на нём номинала); 2) полупрецизионный резистор; 3) постоянный резистор; 4) силовой резистор; 5) композиционный резистор; 6) проволочный резистор; 7) универсальный/общего назначения резистор; 8) металлопленочный резистор.

Ex. 2. Translate some information from Resistor datasheet specification.

THE TEMPERATURE COEFFICIENT

The temperature coefficient of resistance is a ratio which indicates the rate of increase (decrease) of resistance per degree (°C) increase (decrease) of temperature within a specified range, and is expressed in parts per million per °C (ppm/°C).

DEFINITION OF SYMBOLS (SEE FIGS 11, 12, 13 AND 14)

Symbol	Description
$\hat{P}$	applied peak pulse power
$\hat{P}_{max}$	maximum permissible peak pulse power (Fig.11)
$\hat{V}_i$	applied peak pulse voltage (Figs 13 and 14)
$\hat{V}_{max}$	maximum permissible peak pulse voltage (Fig.12)
R_{nom}	nominal resistance value
t_i	pulse duration (rectangular pulses)
t_P	pulse repetition time
τ	time constant (exponential pulses)
T_{amb}	ambient temperature
$T_{m(max.)}$	maximum hot-spot temperature of the resistor

Ex. 3. Work with a dictionary, translate the following terms. Check up your answers. At home memorize the terms.

winding	neighborhood	reactance	vitreous coating
alloy	mixture	tolerance	shunted capacitance
binder	molded	encapsulate	capacitive characteristics
attach	hardened by baking	resistor leads	assembly

1) закалённый обжигом; 2) процесс намотки/обмотка; 3) горячее эмалевое покрытие/стекловидное покрытие; 4) формованный/отлитый в форме; 5) присоединять/монтировать; 6) связующее вещество; 7) шунтируемая ёмкость; 8) выводы резистора; 9) реактивное сопротивление; 10) предел/погрешность; 11) близлежащая область/условие; 12) смесь/смешивание; 13) примесь/сплав; 14) емкостные характеристики; 15) сборка/монтаж, 16) герметизировать.

Ex. 4. Choose two terms from Ex. 2 and explain them to your group mates so that they could guess them.

Ex. 5. Match a word with its definition:

Word	Definition
1) Winding	A) a unit consisting of components that have been fitted together
2) Capacitance	B) metal made by combining two or more metallic elements, especially to give greater strength or resistance to corrosion
3) Attach	C) the ability of a system to store an electric charge
4) Alloy	D) having a range of potential uses or functions; not specialized in design
5) Assembly	E) to join, fasten, or connect
6) General-purpose	F) an electrical conductor that is wound round a magnetic material, especially one encircling part of the stator or rotor of an electric motor or generator or forming part of a transformer

Ex. 6. Find some misspelled words:

Capacitanse	____________________	Dencity	____________________
Culomb	____________________	Simbol	____________________
Circit	____________________	Devise	____________________

Ex. 7. Underline the synonyms, found in Ex. 2.

Ex. 8. From Unit 3.1 recollect the following information about resistors:

- What is a resistor?
- What is a resistance of a resistor?
- What is an Ohm?
- What are the interconnections between: a) the resistance of a resistor and the resistivity of a material; b) the resistance of a resistor and the length of the resistor; c) the resistance of a resistor and the cross-sectional area?
- Say the types of resistors you know.

Ex. 9. Translate the following phrases and sentences, mind the proper translation of "either……or" expression.

- *Either* come in *or* go out.
- He can *either* be a friend *or* a foe.
- A door must be *either* shut *or* open.
- Data is supplied in *either* a file, a stream, *or* as an array.

Ex. 10. Study specification for general-purpose fixed resistors.

Examples of general purpose fixed resistors

Type	 *Carbon film*	 *Metal film*	 *Wirewound*
Tolerance	2-10% (5%)	0.1-5% (1%)	0.1-5% (1%)
Power rating	0.125-2W (¼W)	0.1-5W (¼W)	1-200W (10W)
Temp. coefficient	250-450 ppm/K (450)	10-250 ppm/K (50)	20-400 ppm/K (50)

Ex. 11. Look through text B quickly and give the title to the text.

Ex. 12. Read the descriptions below and fill in the blanks with a proper term from the box.

Ex. 13. Read the text once more, while reading it, make some notes, so that you have a scheme of resistor types.

The fixed resistors / Power resistors / Metal-film resistors / Precision resistors / Composition resistors / Semiprecision resistors / Wire-Wound Resistors / General-purpose resistors

Text B

Resistors can be broadly categorized as fixed, variable, and special-purpose.

1) __________________ are those whose value cannot be varied after manufacture. …………………… are classified into composition resistors, wire-wound resistors, and metal-film resistors.

2) __________________ are made by winding wire of nickel-chromium alloy on a ceramic tube covering with a vitreous coating. The spiral winding has inductive and capacitive characteristics that make it unsuitable for operation above 50 kHz. The frequency limit can be raised by noninductive winding so that the magnetic fields produced by the two parts of the winding cancel.

3) __________________ are composed of carbon particles mixed with a binder. This mixture is molded into a cylindrical shape and hardened by baking. Leads are attached axially to each end, and the assembly is encapsulated in a protective encapsulation coating. Color bands on the outer surface indicate the resistance value and tolerance. __________________ are economical and exhibit low noise levels for resistances above 1 MOhm. __________________ are usually rated for temperatures in the neighborhood of 70 °C for power ranging from 1/8 to 2 W. __________________ have end-to-end shunted capacitance that may be noticed at frequencies in the neighborhood of 100 kHz, especially for resistance values above 0.3 MOhm.

4) __________________ are commonly made of nichrome, tin-oxide, or tantalum nitride, either hermetically sealed or using molded-phenolic cases. __________________ resistors are not as stable as the wire-wound resistors.

Depending on the application, fixed resistors are manufactured as precision resistors, semiprecision resistors, standard general-purpose resistors, or power resistors.

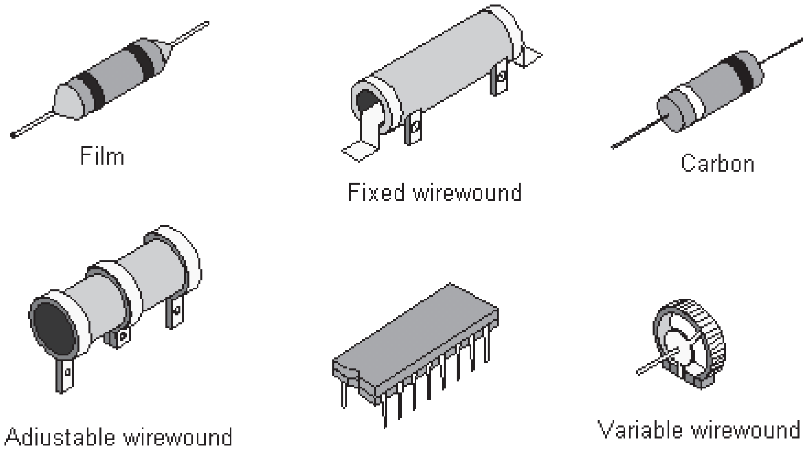
5) __________________ have low voltage and power coefficients, excellent temperature and time stabilities, low noise, and very low reactance. These resistors are available in metal-film or wire constructions and are typically designed for circuits having very close resistance tolerances on values.

6) __________________ are smaller than precision resistors and are primarily used for current-limiting or voltage-dropping functions in circuit applications. ________________ have long-term temperature stability.

7) __________________ are used in circuits that do not require tight resistance tolerances or long-term stability. For __________________, initial resistance variation may be in the neighborhood of 5 % and the variation in resistance under full-rated power may approach 20 %. Typically, __________________ have a high coefficient of resistance and high noise levels.

8) __________________ are used for power supplies, control circuits, and voltage dividers where operational stability of 5 % is acceptable. __________________ are available in wire-wound and film constructions. Film-type power resistors have the advantage of stability at high frequencies and have higher resistance values than wire-wound resistors for a given size.

Ex. 14. What types of resistors are there below?



Ex. 15. Find 21 words.

E	N	C	A	P	S	U	L	A	T	E	M	E	B	V
T	F	T	O	L	E	R	A	N	C	E	A	Y	R	O
N	G	J	F	C	A	D	G	F	B	R	S	T	E	L
O	E	M	P	O	W	E	R	Y	R	E	S	I	S	T
Q	N	O	H	M	E	V	N	G	C	S	D	E	I	A
S	E	M	I	P	R	E	C	I	S	I	O	N	S	G
C	R	E	Y	O	E	O	R	E	F	S	F	U	T	E
I	A	T	U	S	Z	I	T	W	G	T	I	Y	I	D
R	L	A	W	I	N	D	I	N	G	O	X	A	V	R
C	P	L	H	T	J	K	O	I	H	R	E	V	I	O
U	U	F	W	I	R	E	W	O	U	N	D	A	T	P
I	R	I	A	O	K	A	S	S	E	M	B	L	Y	N
T	P	L	G	N	C	U	R	R	E	N	T	L	H	O
Q	O	M	I	X	T	U	R	E	R	U	E	O	M	L
C	S	V	R	E	A	C	T	A	N	C	E	Y	H	C
R	E	S	I	S	T	A	N	C	E	Z	B	H	O	T

Unit 3.3. Variable Resistors

Ex. 1. Translate the words below without a dictionary.

Relay contacts, the potentiometer, rheostat, section, resistive element, control, motor, classified, categories, semiconductor resistor, silicon, varistor.

Ex. 2. Fill in the missing derivatives of the words below. Read the following words. Define their part of speech where it is possible:

diffuse	diffused		diffuser	diffusion
	used	using		usage
reduce	reduced		reducer	reduction
compose	composed	composing	composer	
provide		providing		provision
	bombarded	bombarding		bombardment

Ex. 3. Find synonyms. Match them with their translation.

1) шпиндель/стержень/штифт/вал; 2) виток; 3) скользящий/плавающий контакт; 4) налаживать/регулировать; 5) основа; нижний слой; 6) решётка; 7) гравировать; травить; 8) монтировать, присоединять; 9) распространять, распылять

adjust / turn (*n*) / shaft / axle, spindle / layer, base / array, grating / regulate / sliding contact / substrate / movable contact / engrave / attach / etch / twist / diffused / lattice / spread / mount

№	Synonym 1	Synonym 2	Translation
1			
2			
3			
4			
5			
6			
7			
8			
9			

Ex. 4. Find antonyms and write down their translation.

Word A	Translation	Word B	Translation
1) conductor		A) stand still	
2) thick-film		B) unique	
3) rotate		C) general-purpose	
4) patterned		D) unlike	
5) shallow layer		E) thin-film resistors	
6) special-purpose		F) fixed resistors	
7) variable resistors		G) deep layer	
8) the same		H) insulator	

Ex. 5. Work with a dictionary, translate the following terms. Check up your answers. At home memorize the terms.

Integrated circuit	bulk resistor	doped semiconductor	pinched resistor	deposited film resistor	variable resistor/varistor
bleeder circuit	bulk resistivity	ion-implanted resistor	diffused resistor	yield	

1) легированный полупроводник; 2) пленочный резистор; 3) пинч-резистор; 4) переменные резисторы / варистор; 5) цепь делителя напряжения; 6) объёмный резистор; 7) интегральная схема; 8) удельное объёмное сопротивление; 9) выход / отдача; 10) диффузионный резистор; 11) ионно-легированный резистор.

Ex. 6. Fill in the blanks with the words below.

resistive element / the rheostat terminals / the potentiometer / variable potentiometers / rheostats

Variable Resistors

_____________ is a special form of _____________ resistor with three terminals. Two _____________ are connected to the opposite sides of the resistive element, and the third connects to a sliding contact that can be adjusted as a voltage divider. Potentiometers are usually circular in form with the movable contact attached to a shaft that rotates.

_____________ are manufactured as carbon composition, metallic film, and wire-wound resistors available in single-turn or multiturn units. The movable contact does not go all the way toward the end of the _____________, and a small resistance is present to prevent accidental burning of the resistive element.

_____________ is a current-setting device in which one terminal is connected to the resistive element and the second terminal is connected to a movable contact to place a selected section of the resistive element into the circuit. Typically, _____________ are wire-wound resistors used as speed controls for motors, ovens, and heater controls and in applications where adjustments on the voltage and current levels are required, such as voltage dividers and bleeder circuits.

Ex. 7. Fill in the blanks with the words below.

pinched resistors / integrated circuit resistors / semiconductor resistors thickness / varistors / ion-implanted resistors / deposited film resistors / diffused semiconductor resistors / Special-Purpose Resistors

_____________ are classified into two general categories: _____________ and _____________ Semiconductor resistors use the bulk resistivity of doped semiconductor regions to obtain the desired resistance value. Deposited film resistors are formed by depositing resistance films on an insulating substrate which are etched and patterned to form the desired resistive network.

Depending on the _____________ and dimensions of the deposited films, the resistors are classified into thick-film and thin-film resistors.

Semiconductor resistors can be divided into four types: *diffused, bulk, pinched, and ion-implanted.*

_____________ use resistivity of the diffused region in the semiconductor substrate to introduce a resistance in the circuit. Both n-type and p-type diffusions are used to form the diffused resistor.

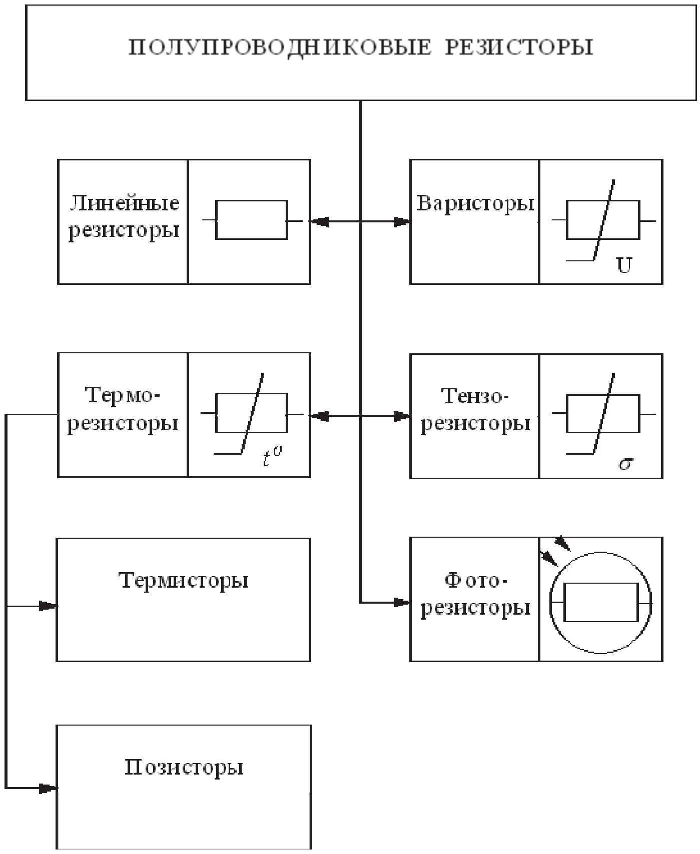
A bulk resistor uses the bulk resistivity of the semiconductor to introduce a resistance into the circuit.

_____________ are formed by reducing the effective cross-sectional area of diffused resistors. The reduced cross section of the diffused length results in extremely high sheet resistivities from ordinary diffused resistors.

_____________ are formed by implanting ions on the semiconductor surface by bombarding the silicon lattice with high-energy ions. The implanted ions lie in a very shallow layer along the surface (0.1 to 0.8 mm). For similar thicknesses ion-implanted resistors yield sheet resistivities 20 times greater than diffused resistors.

_____________ are voltage-dependent resistors that show a high degree of nonlinearity between their resistance value and applied voltage. They are composed of a nonhomogeneous material that provides a rectifying action. _____________ are used for protection of electronic circuits, semiconductor components, collectors of motors, and relay contacts against over voltage.

Ex. 8. Consult a dictionary, find all the terms you need and try to describe the schemes below. You can use the following words: to divide, to subdivide, to connect, to interconnect, to form, to include, to consist and others.



Chip Varistors

Countermeasure for surge voltage and static electricity

AVR series

Type: **AVR-M**
AVRL

Issue date: September 2011

FEATURES

- No polarity, due to symmetrical current-voltage characteristics. Equivalent to anode common type Zener diode.
- Excellent electrostatic absorption capability.
  Response is as good or better than Zener diode.
  Keeps symmetrical current-voltage characteristics even after electrostatic absorption.
- Adopted the inner electrodes lamination structure.
  Wide range of varistor voltages are available in series (6.8 to 39V).
  Low capacitance items are available in series (1.1pF to).
  World's smallest 0603-, 1005-, 1608-, 2012-chip types and 1410-array type are available in series.
- Excellent mount reliability. Good for Pb-free soldering.
  Adopted (Ni/Sn) electroplating.
  Achieved good solderability and solder heat resistance.
- Can replace a Zener diode + capacitor combination.
  Reduced footprint and total mounting cost.

APPLICATIONS

- Electrostatic absorption
- Pulse noise absorption

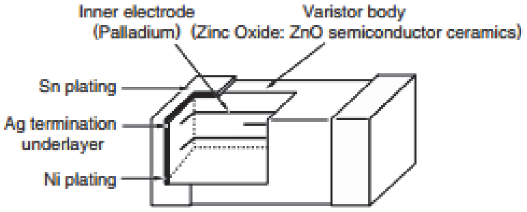
TEMPERATURE RANGES

Type	AVR-M1005/1608/2012	AVR-M14A2/0603/AVRL
Operating	–40 to +125°C	–40 to +85°C
Storage	–40 to +125°C	–40 to +85°C

APPLICATION EXAMPLES

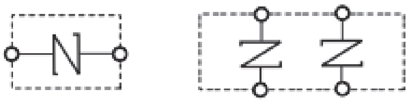
Consumer product	Application
Mobile phone	Data terminal
Digital video camera	LCD panel
Digital camera	Touch panel
PDA	Button and switch unit
Note PC	Battery terminal
DVD-ROM, CD-ROM	Audio-Video input-output terminal
CD/MD/MP3 player	Microphone/receiver unit
Game machine	Controller unit
	CAN-BUS ECU

INTERNAL STRUCTURE

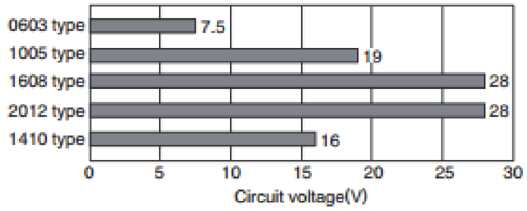


CIRCUITS

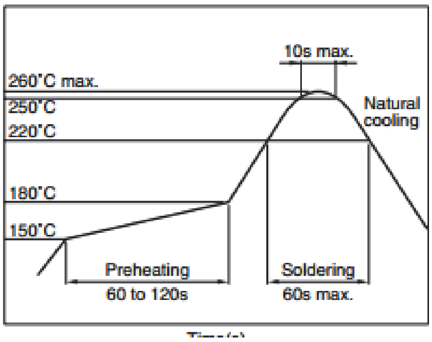
SINGLE TYPE **ARRAY TYPE**



OPERATIONAL VOLTAGE RANGES



RECOMMENDED REFLOW SOLDERING CONDITIONS



DEFINITION OF SYMBOLS (SEE FIGS 11, 12, 13 AND 14)

Symbol	Description
$\hat{P}$	applied peak pulse power
$\hat{P}_{max}$	maximum permissible peak pulse power (Fig.11)
$\hat{V}_i$	applied peak pulse voltage (Figs 13 and 14)
$\hat{V}_{max}$	maximum permissible peak pulse voltage (Fig.12)
R_{nom}	nominal resistance value
t_i	pulse duration (rectangular pulses)
t_P	pulse repetition time
τ	time constant (exponential pulses)
T_{amb}	ambient temperature
$T_{m(max.)}$	maximum hot-spot temperature of the resistor

Переменные резисторы Bourns®

3310

Износоустойчивость	50 тыс. циклов
Резистивный элемент	Проводящий пластик
Выключатель	Стандартный поворотный
Число секций	2
Фиксация	Нет
Рабочая температура	–40…+125°С
Мощность	0.25 Вт
Линейность	±5 %

Особенности

- Проводящий пластик
- Печатный и навесной монтаж
- Пластиковые вал и резьбовая втулка на корпусе
- Выдерживает типовые промышленные процессы мойки
- Компактный корпус
- Наличие моделей с логарифмической характеристикой
- Имеются варианты исполнения, соответствующие директиве RoHS

3851

Износоустойчивость	100 тыс. циклов
Резистивный элемент	Проводящий пластик
Выключатель	Нет
Число секций	1
Фиксация	Нет
Рабочая температура	–10…+125°С
Мощность	0.5…1.0 Вт
Линейность	±10 %

Особенности

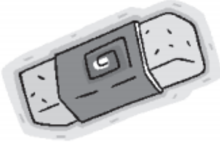
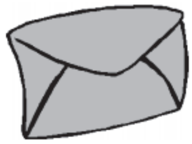
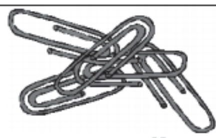
- Линейная и логарифмическая характеристики
- Широкий диапазон сопротивлений
- Минимальная глубина корпуса
- Хорошее разрешение
- Имеются варианты исполнения, соответствующие директиве RoHS

MODULE 4. CONDUCTORS AND INSULATORS

Every material in the world can be defined in terms of how well it conducts electricity. Certain things, such as cold glass, never conduct electricity. They're known as insulators. Materials which do conduct electricity are called conductors. Semiconductors don't conduct as well as conductors, but can carry current. Superconductors are materials which when brought down to very low temperatures turn into superhighways of current and conduct electricity without any resistance.

This power adapter uses metal wires and connectors to conduct electricity from the wall socket to a laptop computer. The conducting wires allow electrons to move freely through the cables, which are shielded by rubber and plastic. These materials act as insulators that don't allow electric charge to escape outward.

Ex. 1. Challenge. Do you think the following items are more likely conductors or insulators?

 **Eraser** □ Conductor □ Insulator	 **Metal Pen** □ Conductor □ Insulator	 **Paper Envelope** □ Conductor □ Insulator
 **Pencil** □ Conductor □ Insulator	 **Paper Clip** □ Conductor □ Insulator	 **Chalk** □ Conductor □ Insulator
 **Coin** □ Conductor □ Insulator	 **Spoon** □ Conductor □ Insulator	 **Nail** □ Conductor □ Insulator

Ex. 2. Look through the text C below and find international words.

Ex. 3. Work with a dictionary and translate the following words:

substance	______________________	relative	____________________
bound (*v*)	______________________	collide	____________________

Ex. 4. Find the words in a bold type in the text C and explain them in English. You are going to read a text, suggest the content of the text.

Ex. 5. Read the text and compare your suggestions with the information from the text C.

Text C

Some substances, such as metals and salty water, allow charges to move through them with relative ease. Some of the electrons in metals and similar conductors are not bound to individual atoms or sites in the material. These ***free electrons*** can move through the material much as air moves through loose sand. *Any substance that has free electrons and allows charge to move relatively freely through it is called a* ***conductor****.* The moving electrons may collide with fixed atoms and molecules, losing some energy, but they can move in a conductor. Superconductors allow the movement of charge without any loss of energy. Salty water and other similar conducting materials contain free ions that can move through them.

Other substances, such as glass, do not allow charges to move through them. These are called ***insulators***. Electrons and ions in insulators are bound in the structure and cannot move easily. Pure water and dry table salt are insulators, for example, but molten salt and salty water are conductors.

Ex. 6. How many parts can the text be divided?

Ex. 7. Suggest the titles to them.

Ex. 8. Close your books and try to sum up the content.

Ex. 9. Put all possible questions to the sentence in Italics.

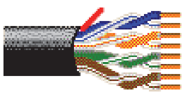
Ex. 10. Study the following specifications and translate them into Russian.

Detailed Specifications & Technical Data

ENGLISH MEASUREMENT VERSION

BELDEN
SENDING ALL THE RIGHT SIGNALS

1583A Multi-Conductor - Category 5e Nonbonded-Pair Cable



For more Information
please call

1-800-Belden1

RoHS COMPLIANT ENVIRONMENTALLY FRIENDLY

Mechanical Characteristics (Overall)

Storage Temperature Range:	-20°C To +75°C
Installation Temperature Range:	0°C To +60°C
Operating Temperature Range:	-20°C To +60°C

TECHNICAL DATA SHEET

FERRET ACSR CONDUCTOR

Date of issue: 19/03/03

Specification: IEC 61089

Stranding and wire diameter	mm	6/1/3.00
Diameter over steel	mm	3.00
Overall diameter	mm	9.00
Aluminium area	mm²	42.41
Steel area	mm²	7.07
Total Area	mm²	49.48
Aluminium mass	kg/km	117.0
Steel mass	kg/km	55.60
Total mass	kg/km	173.0
D.C. Resistance at 20°C	ohms/km	0.6766
Ultimate tensile strength	newtons	15200
Breaking load	kg	1530
Coefficient of expansion	per °C x 10^{-6}	19.31
Initial modulus of elasticity	N/mm²	50200
Final modulus of elasticity	N/mm²	80400
Current rating	A	210

Conditions, under which the above Current Rating applies are:	
Max. operating temperature	75°C
Ambient Temperature	30°C
Wind speed	0.44m/s
Solar radiation	0.089 W.cm^{-2}
Conductor – Black and exposed to Sun	

Ex. 11. Translate into English.

1) Изолятор (или диэлектрик) – тело, не содержащее внутри свободные электрические заряды. 2) В изоляторах электрический ток невозможен. 3) К диэлектрикам можно отнести: стекло, пластик, резину, картон, воздух. Тела, изготовленные из диэлектриков, называют изоляторами. 4) Абсолютно непроводящая жидкость – дистиллированная, т.е. очищенная вода, любая другая вода (водопроводная или морская) содержит какое-то количество примесей и является проводником.

Ex. 12. At home surf the internet, find some insulator specifications written in English and then translate the following insulator specification into English.

Технические параметры

Тип	Рис.	Номинальное напряжение, кВ	Расчетная механическая нагрузка, кН	Высота Н, мм	Разрядное расстояние, мм	Минимальное расстояние тока утечки, мм	Выдерживаемое напряжение грозового импульса, ≥кВ (пиковое)	Выдерживаемое напряжение при промышленной частоте, влажное состояние, ≥кВ (среднеквадратичное)
FPW-12/5	1	12	5	290	195	315	100	45
	2	12	5	270	195	315	100	45
FPW-15/5	3	15	5	310	215	450	120	50
	4	15	5	290	215	450	120	50

MODULE 5. CAPACITORS

Half Full or Half Empty? Thoughts on Capacity.

If you put a pint of liquid into a quart pot, the optimist will declare it half full, but on the other hand the pessimist will complain that it's half empty. Engineers, on the gripping hand, know that the glass is too large.

Ex. 1. Translate the words below without a dictionary.

Electrolytic, dielectric, equivalent, concentrate, material, Farad, coulomb, term, region, combination, object, physical, pulsating, vector, sum, inductive, magnetized, identical, identification, process, context, linguistic, morphological, syntactic and lexical processes.

Ex. 2. Find the proper Russian equivalents for the following English sentences and phrases.

1) Revolutionary changes in tube design.
2) Practical minor-aperture size.
3) We have found it practical.
4) Integrated circuits and memory <u>*chips*</u> are burned onto crystalline <u>*silicon*</u>.
5) To open new horizons for exploration.

Ex. 3. Find the proper Russian equivalents for the following English terms:

unlike	restricted	the same	capacitor
dielectric	discharge	insulation	potential difference
regain	capacitance	plate	

1) конденсатор; 2) разный, отличный, непохожий; 3) анод, пластина; 4) разряд, разряжать; 5) диэлектрик, непроводник; 6) изоляция; 7) разность потенциалов; 8) восстанавливать; 9) одинаковый; 10) емкость; 11) узкий, ограниченный.

Ex. 4. Choose two terms from Ex. 3 and explain them to your group mates so that they could guess them.

Ex. 5. Work with a dictionary and find out if there is any difference between capacitance and capacity.

Ex. 6. Read and guess the meaning of the following words and word combinations:

capacitance balance, Capacitance Bridge, capacitance coefficient, capacitance coupling, capacitance current, capacitance element.

Ex. 7. Search for the words of Ex. 2

CAPACITORESTRICTEDIELECTRICAPACITOREGAINEGATIVE

Ex. 8. Complete the sentences with a word from the box below.

insulation / discharge / capacitance / potential difference / discharge dielectric charge / plates / restricted

1) Access is severely ________ (mid july to mid aug).
2) ___________ also depends on the ___________ constant of the substance separating the plates.
3) Electric ___________ in gases occurs when electric current flows through a gaseous medium. Depending on several factors, the ___________ may radiate visible light.
4) An easy way to accelerate a ___________ is to allow it to move through a ___________.
5) The distance between the capacitor ___________ can be changed.
6) Electrical ___________ is the absence of electrical conduction.

Ex. 9. What knowledge have you got about capacitor?

In October 1745, Ewald Georg von Kleist of Pomerania in Germany found that charge could be stored by connecting a high-voltage electrostatic generator by a wire to a volume of water in a hand-held glass jar. Von Kleist's hand and the water acted as conductors, and the jar as a dielectric. Von Kleist found, after removing the generator that touching the wire resulted in a painful spark. The following year, the Dutch physicist Pieter van Musschenbroek invented a similar capacitor, which was named the Leyden jar, after the University of Leiden where he worked.

Ex. 10. Look through the text D quickly and say: What is capacitance?

Ex. 11. What do the following uppercase letters W, F, V, C, and J stand for?

Ex. 12. Read the text.

Text D

If a potential difference is found between two points, an electric field exists that is the result of the separation of unlike charges. The strength of the field will depend on the amount the charges have been separated. *Capacitance* is the concept of energy storage in an electric field and is restricted to the area, shape, and spacing of the capacitor plates and the property of the material separating them. *When electrical current flows into a capacitor, a force is established between two parallel plates separated by a dielectric.* This energy is stored and remains even after the input is removed. By connecting a conductor (a resistor, hard wire, or even air) across the capacitor, the charged capacitor can regain electron balance, that is, discharge its stored energy. The work necessary to transport a unit charge from one plate to the other is $e = kg$, where e = volts expressing energy per unit charge, g = coulombs of charge already transported, and k = proportionality factor between work necessary to carry a unit charge between the two plates and charge already transported. It is equal to $1/C$, where C is the capacitance, F. The energy stored in a capacitor is: W = energy, J; C = capacitance, F; and V = applied voltage, V.

Ex. 13. Complete the following sentences:

1) The strength of the field will depend on …
2) Capacitance is the concept of energy storage in an electric field and is restricted to…
3) An electric field exists if…
4) When electrical current flows into a capacitor…
5) By connecting a conductor (a resistor, hard wire, or even air) across the capacitor…

Ex. 14. Put all possible Wh-questions to the sentence in italics. Be ready to answer the questions.

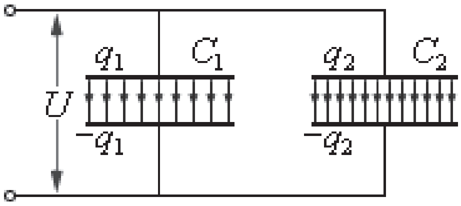
1) What does the separation of unlike charges result in?
2) What is capacitance?
3) What is established between two parallel plates separated by a dielectric when electrical current flows into a capacitor?
4) In what way can the charged capacitor regain its electron balance?

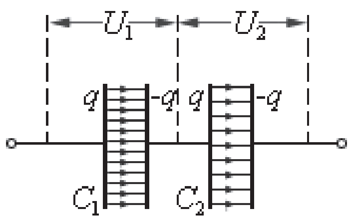
Ex. 15. Translate into English.

Если двум изолированным друг от друга проводникам сообщить заряды q_1 и q_2, то между ними возникает некоторая разность потенциалов Δφ, зависящая от величин зарядов и геометрии проводников. Разность потенциалов Δφ между двумя точками в электрическом поле часто называют напряжением и обозначают буквой U. Наибольший практический интерес представляет случай, когда заряды проводников одинаковы по модулю и противоположны по знаку: $q_1 = -q_2 = q$. В этом случае можно ввести понятие электрической емкости.

Электроемкостью системы из двух проводников называется физическая величина, определяемая как отношение заряда q одного из проводников к разности потенциалов Δφ между ними. Единица электроемкости – фарад.

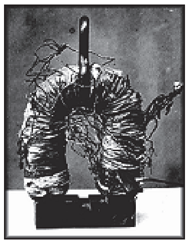
Ex. 16. Explain the types of capacitors connection.





MODULE 6. INDUCTORS

Unit 6.1. Fundamentals



US scientist Joseph Henry (1797–1878) invented his "electro-magnet" consisting of many turns of wire coiled around various iron shapes. His familiar "horse shoe" magnet could be connected to a battery and used to pick up small magnetic objects and release them when the current flow was interrupted by an open switch. Joseph Henry used this principle to also operate a second switch that could interrupt an even larger current flow demonstrating the principle of a "relay". Samuel Morse, it is said, later swiped this invention to patent it as one of his own in the invention of the telegraph, also using electro-magnets. It appears that Joseph Henry did not contest this patent but went on make further discoveries in electro-magnetism based on concepts of self-induction, mutual induction (e.g. as used in transformers) and the first electric motor.

Ex. 1. Translate the words below without a dictionary.

Карьера, муниципальный, химический, биология, экология, канал, динамика, сталь, система, статистика, дисциплина, код, природный ресурс, компьютер, механический, математик, демонстрировать, сигнал, радиус.

Ex. 2. Read the following words and define their part of speech where it is possible:

Induct	Induct + ance	Induct + or	Induct + ive	Induc + tion
Store	Stor + ed	Stor + age	Stor + ing	Stor + able
Insert	Inser + tion	Insert + ing	Insert + ed	

Ex. 3. Translate the following words and word combinations:

induction – mutual inductance – total inductance – inductance measurement – inductance meter – inductible – self-inductance.

Ex. 4. Work with a dictionary, translate the following terms and match A with B, *pay attention that each word should have only one Russian equivalent*. Check up your answers. At home memorize the terms.

storage	lag	coil	impedance	inductor	wave
turn (*n*)	winding	choke	therefore	sine (*adj*)	coupled
core	insertion loss	inductive reactance	equation		

1) виток; 2) сердечник; 3) обмотка; 4) таким образом; 5) катушка индуктивности; 6) полное сопротивление; 7) заслонка/заглушка/дроссель; 8) хранение, сохранение; 9) волна; 10) отставать; запаздывать; 11) индуктивное сопротивление; 12) уравнение;

13) катушка; 14) синусоидный; 15) связанные (напр. о колебаниях), связанный, соединённый, сцепленный; 16) вносимое затухание, вносимые потери.

Ex. 5. Study the following information from a capacitor specification datasheet.

Capacitor Parameters

Capacitors have five parameters. Capacitance (Farads), Tolerance (%), Maximum Working Voltage (Volts), Surge Voltage (Volts) and leakage. Because a Farad is a very large unit, most capacitors are normally measured in the ranges of pico, nano and micro farads.

Surge Voltages

The maximum **instantaneous** voltage a capacitor can withstand. If the surge voltage is exceeded over too long a period there is a very good chance that the capacitor will be destroyed by the voltage 'punching' through the insulating material inside the casing of the capacitor. If a circuit has a surging characteristic, choose a capacitor with a high rated surge voltage.

Leakage

Refers to the amount of charge that is lost when the capacitor has a voltage across its terminals. If a capacitor has a low leakage it means that very little power is lost. Generally leakage is very small and is not normally a consideration for general purpose circuits.

Tolerance

As with resistors, tolerance indicates how close the capacitor is to its noted value. These are normally written on the larger capacitors and encoded on the small ones

Code	Tolerance	Code	Tolerance
C	±0.25pF	D	±0.5pF
E	±1pF	G	±2%
J	± 5%	K	±10%
L	±15%	M	±20%
N	±30%		

Capacitor Markings

There are a two methods for marking capacitor values. One is to write the information numerically directly onto the capacitor itself. The second is to use the EIA coding system.

Ex. 6. Circle the words.

Q	U	O	C	O	U	P	L	E	D	A	F	E	A	O
A	F	B	H	K	T	Q	E	J	A	K	O	W	T	D
E	R	C	O	I	L	O	W	I	R	E	I	A	I	E
V	S	D	K	L	B	I	V	N	S	L	E	V	B	Q
I	N	S	E	R	I	E	S	O	S	I	N	E	A	U
N	A	B	W	V	N	E	T	C	L	M	Q	E	U	A
D	J	I	P	U	S	V	O	B	N	P	Z	C	N	T
U	L	O	S	S	E	B	R	S	G	E	J	O	Q	I
C	A	U	Z	O	R	Q	A	E	I	D	N	I	E	O
T	G	I	A	A	T	O	G	V	O	A	W	N	B	N
I	A	G	D	I	I	E	E	A	L	N	U	Q	R	O
V	O	C	F	H	O	J	L	P	W	C	X	I	S	N
E	H	B	W	I	N	D	I	N	G	E	Z	P	K	E
F	D	Y	R	A	K	B	M	O	Y	K	O	G	L	I
R	E	A	C	T	A	N	C	E	C	A	T	U	R	N

Ex. 7. Find antonyms:

Word A	Translation	Word B	Translation
passive		in series	
increase		unlike	
charge		multiply	
the same		reduce	
in parallel		active	
divide		discharge	

Ex. 8. Choose 2 terms from Ex. 4 and try to explain them.

Ex. 9. Look through the text quickly and say: What is inductance used for? How can one get inductance increase? How can one reduce inductance? What is an inductor? Are there any perfect inductors? What are they?

Ex. 10. Read the text carefully.

An inductor (also choke, coil or reactor) is a passive electronic component that stores energy in the form of a magnetic field. In its simplest form, an inductor consists of a wire loop or coil. The inductance is directly proportional to the number of turns in the coil. Inductance also depends on the radius of the coil and on the type of material around which the coil is wound. For a given coil radius and number of turns, air cores result in the least inductance.

Inductance is used for the storage of magnetic energy. Magnetic energy is stored as long as current keeps flowing through the inductor. In a perfect inductor, the current of a sine wave lags the voltage by 90°.

The type of wire used for its construction does not affect the inductance of a coil. *Q* of the coil will be governed by the resistance of the wire. Therefore coils wound with silver or gold wire have the highest *Q* for a given design.

To increase inductance, inductors are connected in series. The total inductance will always be greater than the largest inductor. $L\,T = L1 + L2 + \cdots + Ln.$

To reduce inductance, inductors are connected in parallel. The total inductance will always be less than the value of the lowest inductor.

Mutual inductance is the property that exists between two conductors carrying current when their magnetic lines of force link together.

The *coupled inductance* can be also determined by the following equations.

In series with fields aiding, $L\,T = L1 + L2 + 2M.$

In series with fields opposing, $L\,T = L1 + L\,2 - 2M.$

Where $L\,T$ = total inductance, H; $L1$ and $L2$ = inductances of the individual coils, H; and M = mutual inductance, H.

Ex. 11. Complete the sentences with a word from the box below.

storage (2) / coil / wire / winding/ inductive reactance / equation / insertion loss / coil

1) Computer data __________, often called __________ or memory, is a technology consisting of computer components and recording media used to retain digital data. (1)

2) __________-wound resistors are made by __________ __________ of nickel-chromium alloy on a ceramic tube covering with a vitreous coating. (2)

3) You attach an inductance meter to the __________ and see what the inductance of the __________ is.

4) Mathematical statement that asserts the equality of two expressions is _________.

5) __________ is an opposition to the change of current on an inductive element.

6) In telecommunications, __________ is the loss of signal power resulting from the insertion of a device in a transmission line or optical fiber and is usually expressed in decibels.

Unit 6.2. Coil Inductance

Let's say you take a coil of wire perhaps 6 feet (2 meters) in diameter, containing five or six loops of wire. You cut some grooves in a road and place the coil in the grooves. You attach an inductance meter to the coil and see what the inductance of the coil is. Now you park a car over the coil and check the inductance again. The inductance will be much larger because of the large steel object positioned in the loop's magnetic field. The car parked over the coil is acting like the core of the inductor, and its presence changes the inductance of the coil. Most traffic light sensors use the loop in this way. The sensor constantly tests the inductance of the loop in the road, and when the inductance rises it knows there is a car waiting!

Ex. 1. Work with a dictionary, translate the following terms and match A with B. Check up your answers. At home memorize the terms.

velocity	angle	multiply	flux
permeability	screw	per	inch

1) проницаемость, проходимость; 2) скорость; 3) умножать; 4) поток; 5) винт, шуруп, скручивать; 6) дюйм; 7) из расчёта на, за, в; 8) угол.

Ex. 2. Match a word with its definition:

Word	Definition
1) Flux	A) the speed of something in a given direction
2) Permeability	B) for each (used with units to express a rate)
3) Core	C) increase or cause to increase greatly in number or quantity
4) Velocity	D) a corner, especially an external projection or an internal recess of a part of a building or other structure
5) Per	E) a quantity measuring the influence of a substance on the magnetic flux in the region it occupies
6) Screw	F) a unit of linear measure equal to one twelfth of a foot (2.54 cm)
7) Multiply	G) a piece of soft iron forming the centre of an electromagnet or an induction coil
8) Angle	H) the rate of flow of a fluid, radiant energy, or particles across a given area/the action or process of flowing or flowing out
9) Inch	I) a short, slender, sharp-pointed metal pin with a raised helical thread running around it and a slotted head, used to join things together by being rotated so that it pierces wood or other material and is held tightly in place

Ex. 3. Translate the following phrases:

per second, per head, per hour, per day, per mil, per mile, per month, per unit, per year, per inch.

Ex. 4. What do the abbreviations mmf and emf stand for? If you don’t know the right answer look it for in the text below.

Ex. 5. Read the text below and answer the questions:

1) How does an air gap influence upon the inductance?
2) What connection is there between:
- the permeability of the core material and the inductance;
- a shorted turn and the inductance;
- the length of the winding and the inductance?

Coil Inductance

Inductance is related to the turns in a coil as follows:

1) The inductance is proportional to the square of the turns.

2) The inductance increases as the length of the winding is increased.

3) A shorted turn decreases the inductance, affects the frequency response, and increases the insertion loss.

4) The inductance increases as the permeability of the core material increases.

5) The inductance increases with an increase in the cross-sectional area of the core material.

6) Inductance is increased by inserting an iron core into the coil.

7) Introducing an air gap into a choke reduces the inductance.

The maximum voltage induced in a conductor moving in a magnetic field is proportional to the number of magnetic lines of force cut by that conductor. *When a conductor moves parallel to the lines of force, it cuts no lines of force; therefore, no current is generated in the conductor.* A conductor that moves at right angles to the lines of force cuts the maximum number of lines per inch per second, therefore, creating a maximum voltage.

The right-hand rule determines direction of the induced electromotive force (emf). The emf is in the direction in which the axis of a right-hand screw, when turned with the velocity vector, moves through the smallest angle toward the flux density vector.

The magnetomotive force (mmf) in ampere-turns produced by a coil is found by multiplying the number of turns of wire in the coil by the current flowing through it.

Ex. 6. Put all possible questions to the underlined sentence.

Ex. 7. Translate from Russian into English.

Катушка индуктивности – это элемент, вносящий в цепь определенную постоянную или регулируемую индуктивность. Катушку индуктивности часто выполняют навивкой проволоки на корпус, сделанный из изолятора. Навивка может быть одно- или многослойной. Катушки бывают воздушными (безсердечниковыми) либо с магнитным сердечником. Катушки индуктивности в основном характеризуются следующими параметрами: индуктивностью и добротностью.

Основной единицей индуктивности является генри (Гн). Чаще используют в тысячу раз меньшую единицу, называемую миллигенри (мГн), и в миллион раз меньшую – микрогенри (мкГн).

Индуктивность катушки возрастает с увеличением ее размеров и числа витков. Воздушные катушки имеют индуктивность от 1 Гн до нескольких десятков миллигенри. Большие значения индуктивности (даже несколько тысяч генри) получают, когда катушки индуктивности выполняют на ферромагнитных стержнях. Регулировка индуктивности чаще всего выполняется перемещением сердечника относительно навивки (например, путем вворачивания или выворачивания сердечника отверткой).

MODULE 7. P-N JUNCTION

In 1956, in a Stockholm concert hall, three American scientists, John Bardeen, William Shockley, and Walter Brattain, received the Nobel prize "for research in semiconductors and the discovery of transistor effect". This represented a major breakthrough in physics, and ensured their names would be forever etched in the history of science. However, they were not the only ones to carry out such research. Fifteen years earlier, at the beginning of 1941, a young scientist called Vadim Lashkaryov published an article describing how two sides of a "barrier layer", located parallel to the interface between copper and cuprous oxide, would exhibit opposite signs of charge carriers. Afterwards, this discovery would be named "p-n junction" (p for "positive", n for "negative"), and be the phenomenon underpinning the scientific breakthrough for which the Americans were awarded the Nobel prize. In addition, Lashkaryov's article revealed the injection mechanism, a crucial phenomenon providing the operational basis of semiconductor diodes and transistors. Unfortunately, Lashkaryov's research did not reach the West and so he did not receive the credit that his work deserved.

Ex. 1. Translate the following words without a dictionary. Check up your translation.

Формировать, тип, кристалл, ион, материал, транзистор, биполярный, блок, элементарный, диод, роль, управлять (манипулировать), эпитаксия, электронное устройство, специальный, проводимый, поток электричества.

Ex. 2. Match a word with its translation, check it up, and memorize them at home.

junction	fusion	p-n junction	diffusion	utility	epitaxy
diffusion diode	solar cell	dopant	to dope	hence	boundary
to deplete	to scatter	p-doped semiconductor	n-doped semiconductor	forward bias	reverse bias

1) рассеивать; 2) электронно-дырочный переход; 3) диффузионный диод; 4) эпитаксия; 5) граница; 6) примесь (легирующий элемент); 7) легировать; 8) прямое смещение; 9) диффузия; 10) полупроводник с дырочной проводимостью; 11) полупроводник с электронной проводимостью; 12) эффективность; 13) следовательно; 14) фотогальванический элемент; 15) истощать, исчерпывать; 16) сплавление; 17) обратное смещение, 18) соединение-переход.

Ex. 3. Using the following prefixes and affixes, form the derivatives of the verbs.

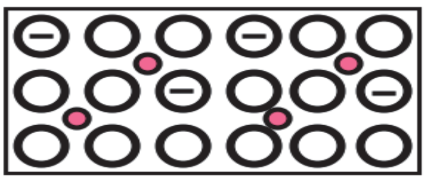
-er/or -ive -tion -ant/ent -ing -sion -able -ible -ed semi-

Consume					
Conduct					
Scatter					
Implant					
Dope					
Diffuse					

Ex. 4. Translate the following words, word combinations and phrases.

to inhibit utility, solar cell, p-n junction, in a single crystal, by scattering the electrons and holes, bipolar junction transistors, to have useful applications, diffusion of dopants, ion implantation.

Ex. 5. Study some information.

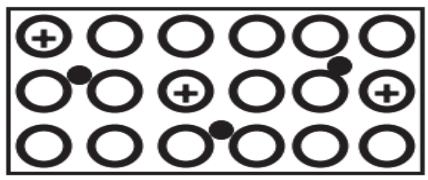


p-type material

Semiconductor material doped with **acceptors**.

Material has high hole concentration

Concentration of free electrons in p-type material is very low.



n-type material

Semiconductor material doped with **donors**.

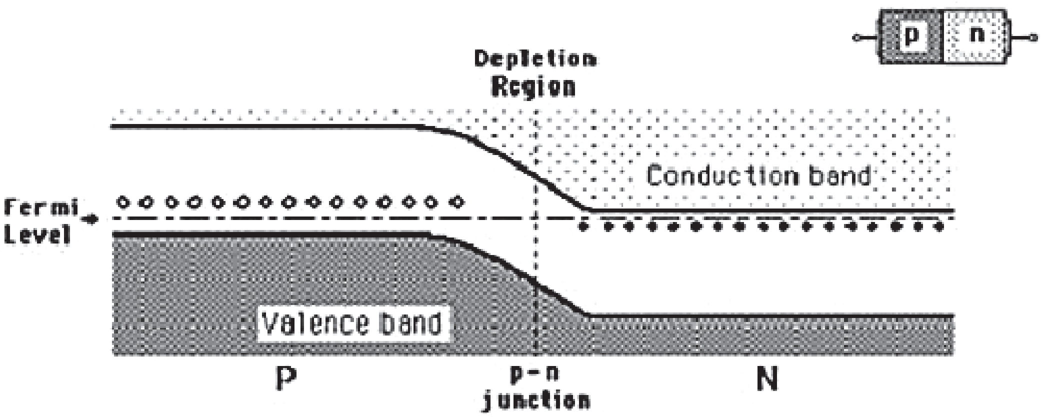
Material has high concentration of free electrons.

Concentration of holes in n-type material is very low.

Ex. 6. Circle 25 words.

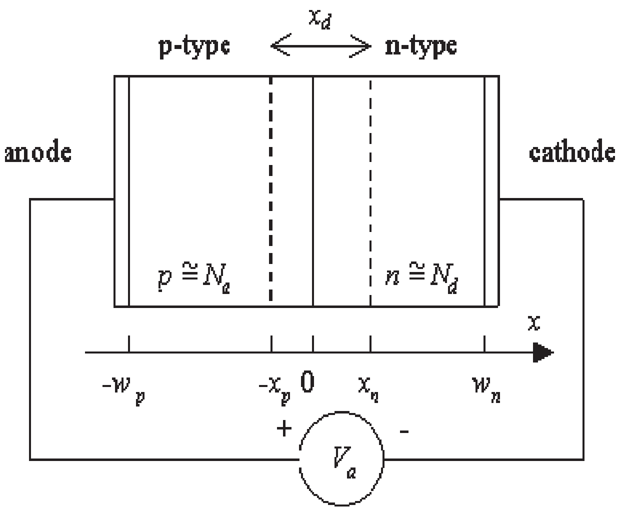
D	I	F	F	U	S	I	O	N	D	I	O	D	E	H
I	P	D	O	P	E	D	C	E	L	C	C	L	L	E
F	L	O	W	K	S	I	O	N	D	I	O	D	E	S
F	C	H	I	N	H	I	B	I	T	L	I	K	C	C
U	B	O	A	R	H	E	D	L	C	E	L	J	T	A
S	O	L	A	R	C	E	L	L	X	P	M	U	R	T
I	U	E	B	H	E	L	W	H	R	N	H	N	O	T
O	N	W	I	K	W	E	M	E	W	J	A	C	N	E
N	D	O	P	E	D	C	O	N	D	U	C	T	O	R
H	A	E	O	P	O	K	X	C	C	N	O	I	K	E
A	R	A	L	I	P	C	V	E	L	C	R	O	C	S
L	Y	X	A	T	A	H	T	V	F	T	E	N	X	I
I	O	N	R	A	N	U	T	I	L	I	T	Y	O	S
E	X	E	V	X	T	M	K	A	U	O	G	O	K	T
H	M	C	R	Y	S	T	A	L	X	N	V	A	H	E

Ex. 7. Describe the picture below.



Ex. 8. Fill in the blankets with a word from the box.

hole / p-type / semiconductor regions / The dopants / A p-n junction / n-type / acceptor



____________ consists of two ____________ with opposite doping type. The region on the left is ____________ with an acceptor density Na, while the region on the right is ____________ with a donor density Nd. ____________ are assumed to be shallow, so that the electron (____________) density in the n-type (p-type) region is approximately equal to the donor (____________) density.

Ex. 9. Guess: what does the abbreviation LED stand for?

Ex. 10. Look through the text below, find the words in bold and explain their meaning in English.

Ex. 11. Read the text quickly and say if the statements below are true, false or the text doesn't say this information:

- A p-n junction is a boundary between p-type and n-type material in a semiconductor device.
- Various types of semiconductor devices are based on p-n junctions.

Ex. 12. Read the text and answer the questions: "What is a p-n junction and why is it important in electronics?"

A **p-n junction** is formed at the boundary between a p-type and n-type semiconductor created in a single crystal of semiconductor by **doping**, for example by ion implantation, diffusion of dopants, or by epitaxy (**growing** a layer of crystal doped with one type of dopant on top of a layer of crystal doped with another type of dopant). If two separate pieces of material were used, this would introduce a grain boundary between the semiconductors that severely inhibits its utility by scattering the electrons and holes.

P-n junctions are **elementary** "building **blocks**" of most semiconductor electronic devices such as diodes, transistors, solar cells, LEDs, and integrated circuits; they are the active sites where the electronic action of the device **takes place**. For example, a common type of transistor, the bipolar junction transistor, consists of two p-n junctions in series, in the form n-p-n or p-n-p.

The discovery of the p-n junction is usually attributed to American physicist Russell Ohl of Bell Laboratories. A Schottky junction is a special case of a p-n junction, where metal serves the role of the n-type semiconductor.

The p-n junction possesses some interesting properties that have useful applications in modern electronics. **A p-doped semiconductor** is relatively conductive. The same is true of an n-doped semiconductor, but the junction between them can become depleted of charge carriers, and hence **non-conductive**, depending on the relative voltages of the two semiconductor regions. By manipulating this non-conductive layer, p-n junctions are commonly used as diodes: **circuit** elements that allow a flow of electricity in one direction but not in the other (opposite) direction. This property is explained in terms of *forward bias* and *reverse bias*, where the term *bias* refers to an application of electric voltage to the p-n junction.

Ex. 13. Suggest a suitable title for each paragraph so that you have a detailed plan of the text.

Ex. 14. Read the text once again and say what paragraph (1, 2, 3, 4) contains the following information:

P-n junctions are basic units or elementary "building blocks" of most semiconductor electronic devices.

Ex. 15.Give the English equivalents for:

Полупроводник, п-н переход, биполярный транзистор, носители заряда, применение, обладать интересными свойствами, на одном кристалле, исчерпанный, непроводящий слой, прямое напряжение, обратное напряжение, ионное внедрение, диффузия, эпитаксия, легирующая (донорная) примесь, полупроводник п-типа с примесью.

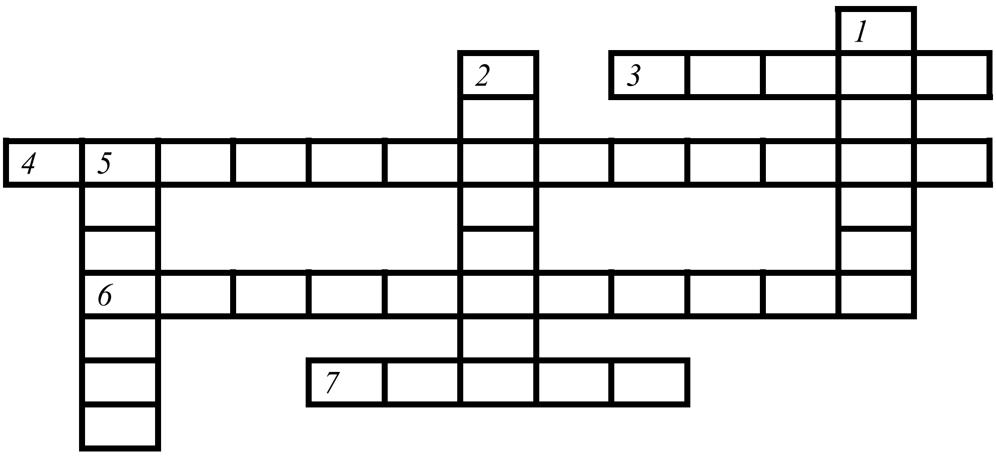
Ex. 16. Put all possible questions to the underlined sentences.

Ex. 17. Explain the meaning of the words in bold.

Ex. 18. Translate the following sentences into English using the active vocabulary of the unit.

1) В основе большинства полупроводниковых диодов и транзисторов лежит контакт двух полупроводников с различным типом электропроводности.
2) Такой контакт называют электронно-дырочным переходом или p-n-переходом.
3) Он может быть получен, например, путем диффузии донорной примеси в полупроводник p-типа.
4) Таким образом, через p-n-переход протекают диффузионные потоки основных носителей заряда.
5) В области контакта появляется встроенное электрическое поле, локализованное вблизи границы.

Ex. 19. Crossword.



CROSS
3. A discrete particle or crystal in a metal, igneous rock, etc., typically visible only when a surface is magnified.
4. A solid substance that has conductivity between that of an insulator and that of most metals, either due to the addition of an impurity or because of temperature effects.
6. A semiconductor device with three connections, capable of amplification in addition to rectification.
7. As a consequence; for this reason.

DOWN
1. Using both positive and negative charge carriers.
2. A point where two or more things are joined.
5. The growth of a thin layer on the surface of a crystal so that the layer has the same structure as the underlying crystal.

Ex. 20. Translate the text below from Russian into English.

Электронно-дырочный переход и его свойства

Электронно-дырочным переходом называют тонкий слой между двумя частями полупроводникового кристалла, в котором одна часть имеет электронную, а другая – дырочную электропроводность. Технологический процесс создания электронно-дырочного перехода может быть различным: сплавление (сплавные диоды), диффузия одного вещества в другое (диффузионные диоды), эпитаксия – ориентированный рост одного кристалла на поверхности другого (эпитаксиальные диоды) и др.

По конструкции электронно-дырочные переходы могут быть симметричными и несимметричными, резкими и плавными, плоскостными и точечными и др. Однако для всех типов переходов основным свойством является несимметричная электропроводность, при которой в одном направлении кристалл пропускает ток, а в другом – не пропускает.

MODULE 8. DIODES

Unit 8.1. Fundamentals

Early researchers of semiconductor materials in the 1800s described effects which can be explained by the rectifying properties of a diode. They might, without knowing it, have had the first diodes. For example Ferdinand Braun (Germany) investigated metal-lead sulphide junctions in 1874, which were used in early radio receivers. Even earlier, in 1839, Bequerel found that an illuminated junction of an insulator (which happened to be a semiconductor) and an electrolyte creates a voltage – the first solar cell was born! In 1904, J.A. Fleming (UK) invented the vacuum tube diode and brought rectifying devices into commercial use. In 1926, L.O. Grondahl and P.H. Geiger (USA) found rectifying properties in a (semiconducting) copper oxide-copper junction and by 1938 W. Schottky (Germany) developed a theoretical explanation for it. The p-n-diode (all the above were Schottky diodes) finally was described by W. Schockley (USA) in 1949, even after J. Bardeen, W.H. Brattain and W. Schockley had invented the transistor.

Ex. 1. Translate from Russian into English.

Диод, ток, полупроводник, отрицательно заряженные носители, процесс производства, увеличение напряжения, варистор, варактор.

Ex. 2. Use a dictionary and translate the following word combinations.

твердотельный / полное сопротивление / арсенид галлия / карбид кремния / трансформировать / примесь, загрязняющее вещество / подходящий, соответствующий / материал-основа

solid-state	impedance	to modify	silicon-carbide
host	impurity	gallium-arsenide	appropriate

Ex. 3. Find in the text below the words in bold and explain their meaning.

Ex. 4. Look through the text and: 1) find different types of diodes and try to translate them; 2) try to explain what a diode is; 3) recollect the types of a diode you know; 4) look through text and say: what phenomenon is the base for diode operation; 5) say if the following sentence is true: “Diodes are made in order to meet the purpose for which they will be used”; 6) read the text and be ready to translate it.

A diode is a p-n junction semiconductor that allows current to flow in only one direction. *A diode generally refers to a two-terminal* ***solid-state*** *semiconductor device that presents low* ***impedance*** *to current flow in one direction and high impedance to current flow in the opposite direction.* Most diodes are made from a host crystal of silicon (Si) with appropriate impurity elements introduced to modify, in a controlled manner, the electrical characteristics of the device. These diodes are the typical p-n junction (or **bipolar**) devices used in electronic circuits. Another type is the Schottky diode (unipolar), produced by placing a metal layer directly onto the semiconductor. The metal semiconductor interface serves the same function as the p-n junction in the common diode structure. Other semiconductor materials such as gallium-arsenide (GaAs) and silicon-carbide (SiC) are also in use for new and specialized **applications** of diodes. Diodes are made, based on the purpose for which they are going to be used. For example, a varactor diode is used as a variable **capacitor** and a zener diode is operated in the reverse biased mode, hence their manufacturing process is also different. An LED is constructed, in such a way that the holes and electrons on recombination, **release** energy in the form of light. Hence, they are manufactured from materials like gallium arsenide, gallium phosphide, etc. instead of silicon, so as to have a higher potential barrier.

Ex. 5. Put all possible questions to the sentence in Italics.

Ex. 6. Divide the text into several parts, give the titles to them.

Ex. 7. Sum up the information of the text.

Ex. 8. Translate into English.

1) Полупроводниковый диод – прибор, обладающий способностью хорошо пропускать через себя электрический ток одного направления и плохо – ток противоположного направления.

2) Это свойство диода используют, например, в выпрямителях для преобразования переменного тока в постоянный.

3) Слово «диод» образовалось от греческой приставки «ди» – «дважды» и сокращения слова «электрод».

4) Полупроводниковый диод представляет собой полупроводниковую пластинку с двумя областями разной проводимости: электронной (n-типа) и дырочной (p-типа). Между ними – разделяющая граница, называемая p-n переходом.

Unit 8.2. V-I characteristic

Ex. 1. Match a word with its definition.

режим обратного смещения / пороговое напряжение / напряжение пробоя / отталкивать / режим прямого смещения / заставлять / график / вольт-амперные характеристики / причина / размещенный, помещенный

graph	V-I characteristics	breakdown voltage	repel	reverse biased mode
cause	forward biased mode	threshold voltage	plotted	voltage controlled device

Ex. 2. Look through the text quickly and suggest a possible title for it.

Ex. 3. Answer the following questions:

1) What is important to understand a diode operation?
2) When is a diode in in the forward biased mode?
3) What happens to the charge in the forward biased mode?

To know how a diode works, we will need to understand its V-I characteristics. V-I characteristic is the graph plotted between the voltage and the current, at which the diode is working. A diode is a voltage controlled device. In a diode, current flows in the forward biased mode, while there is no flow of charge, when the diode is reverse biased. A diode is said to be in the forward biased mode when the positive terminal of the battery is connected to the p-terminal and negative side of the diode is connected to the n-terminal. Once the voltage is applied to the diode in the forward biased mode, the diode immediately does not allow the charge to flow. On increasing the voltage, in such a way that it reaches the breakdown voltage, the current flow starts increasing and reaches its maximum. This breakdown voltage is different for different semiconductor materials. For silicon, the breakdown voltage is 0.7 volt. On applying the voltage, the positively charged holes are repelled by the positive terminal of the battery and the negatively charged electrons are repelled by the negative terminal of the battery and start flowing in the opposite directions. This causes flow of charge in the positive to negative direction.

Ex. 4. Fill in the blankets with a word from the box below.

reverse direction / depletion region / diode / a wide range of applications / junction / holes / electrons

Recombination of the _____________ and _____________ takes place at the junction and a small region is developed at the _____________. It consists of minority carriers, electrons in the p-layer and majority carriers, holes in the n-layer. This limited region on both sides of the junctions is known as the _____________. Once the depletion region is formed, the current flow becomes practically constant. Further increase in voltage can destroy the depletion region and hence the diode. Most diodes when operated in the reverse biased mode get destroyed on increasing the voltage to a large extent. When a _____________ is operated in the reverse biased mode, there is practically no flow of charge initially. When the voltage is increased and reaches the reverse threshold voltage, current increases indefinitely and flows in the _____________, destroying the diode. However, zener diode is operated in the reverse biased mode and finds _______________.

Ex. 5. Write down the scientists names below the pictures and match them with a description of a discovery.




____________ ___________ ____________ ____________

Joseph Henry (USA) / W. Schockley (USA) / W. Schottky (Germany) / Ewald Georg von Kleist

1) ______________ German administrator and cleric who the Leyden jar, a fundamental electric circuit element for storing electricity, now usually referred to as a capacitor.

2) ______________ His research has been centred on energy bands in solids; order and disorder in alloys; theory of vacuum tubes; self-diffusion of copper; theories of dislocations and grain boundaries; experiment and theory on ferromagnetic domains; experiments on photoelectrons in silver chloride; various topics in transistor physics and operations research on the statistics of salary and individual productivity in research laboratories.

3) ______________ In 1938 he created a theory that explained the rectifying behavior of a metal-semiconductor contact as dependent on a barrier layer at the surface of contact between the two materials. The metal semiconductor diodes later built on the basis of this theory are called ……………… barrier diodes. He also discovered that the current emitted from the metal cathode into the vacuum in a valve depends on the metals' work function, and that this function was lowered from its normal value by the presence of image forces and by the electric field at the cathode. This effect later became known as the ______________ effect.

4) ______________ invented his "electro-magnet".

Ex. 6. Sum up all information you have learnt from module 8, make a plan of your report and be ready to speak on the topic (see Appendix 3).

Ex. 7. Study Schottky diodes specification datasheet.

Transys Electronics LIMITED

1N5826(R) THRU 1N5828(R)

SCHOTTKY DIODES STUD TYPE 15 A

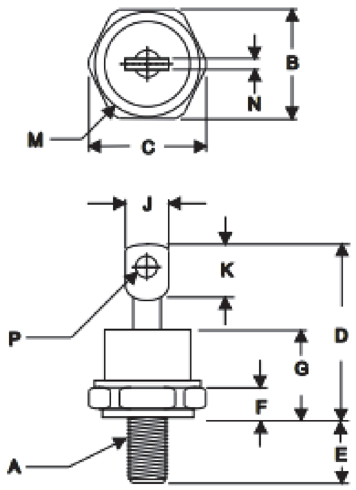
Features

High Surge Capability

Types up to 40V V_{RRM}

15Amp Rectifier
20-40 Volts

DO-5



Notes:
1.Standard Polarity:Stud is Cathode
2.Reverse Polarity:Stud is Anode

Maximum Ratings

Operating Temperature: -65 ℃ to +150 ℃

Storage Temperature: -65 ℃ to +175 ℃

Part Number	Maximum Recurrent Peak Reverse Voltage	Maximum RMS Voltage	Maximum DC Blocking Voltage
1N5826(R)	20V	14V	20V
1N5827(R)	30V	21V	30V
1N5828(R)	40V	28V	40V

Electrical Characteristics @ 25 ℃ Unless Otherwise Specified

Average Forward Current	$I_{F(AV)}$	15A	T_C = 100 ℃
Peak Forward Surge Current	I_{FSM}	500A	8.3ms, half sine
Maximum Instantaneous Forward Voltage NOTE (1)	V_F	0.44V 0.47V 0.50V	(1N5826) (1N5827) (1N5828) I_{FM} = 15 A ; T_J = 25 ℃
Maximum Instantaneous Reverse Current At Rated DC Blocking Voltage NOTE (1)	I_R	10 mA 250 mA	T_J = 25 ℃ T_J = 125 ℃
Maximum Thermal Resistance, Junction To Case	$R_{\theta JC}$	1.8℃/W	

DIMENSIONS					
	INCHES		MM		
DIM	MIN	MAX	MIN	MAX	NOTE
A	1/4 -28 Threads		Standard	Polarity	
B	.669	.687	17.19	17.44	
C	-----	.794	-----	20.16	
D	-----	1.020	-----	25.91	
E	.422	.453	10.72	11.50	
F	.115	.200	2.93	5.08	
G	-----	.460	-----	11.68	
H	-----	-----	-----	-----	
J	-----	.375	-----	9.52	
K	.156	-----	3.96	-----	
M	-----	.667	-----	16.94	
N	-----	.080	-----	2.03	
P	.140	.175	3.56	4.45	

NOTE :
(1) Pulse Test: Pulse Width 300 usec, Duty Cycle < 2%

MODULE 9. FROM THE HISTORY OF TRANSISTORS

Before you start reading:

- *Ask yourself "What must I find out from the research text?"*
- *Look for a series of dates; words in **bold** or italic script, names and surnames. Think: "What information do they give me?"*

While you are reading:

- *Highlight the topic sentences;*
- *Think: "which paragraph(s) will probably give me the answer to my research questions?"*
- *Read these paragraphs first;*
- *Make notes.*

After reading:

Think: *Did the text answer all my research questions?*

Using the topic sentences to summarize:

The topic sentences of a text normally make a good basis for a summary.

Follow this procedure:

- *Locate the topic sentences;*
- *Paraphrase them – rewrite them in your own words so that the meaning is the same. Do not simply copy them. (This is a form of plagiarism.)*
- *Add supporting information.*

If cells are the building blocks of life, transistors are the building blocks of the digital revolution. Without transistors, the technological wonders you use every day – *cell phones, computers*, cars – would be vastly different, if they existed at all.

Before transistors, product engineers used vacuum tubes and electromechanical switches to complete electrical *circuits*. Tubes were far from ideal. They had to warm up before they worked (and sometimes overheated when they did), they were unreliable and bulky and they used too much energy. Everything from televisions, to telephone systems, to early computers used these components, but in the years after World War II, scientists were looking for alternatives to vacuum tubes. They'd soon find their answer from work done decades earlier.

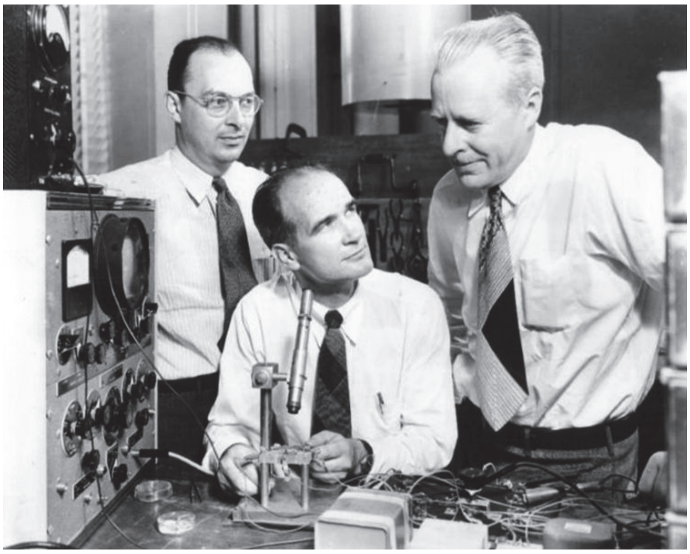
In the late 1920's, Polish American physicist Julius Lilienfeld filed patents for a three-electrode device made from copper sulfide. There's no evidence that he actually created the component, but his research helped develop what today is a field effect transistor, the building block of silicon chips.

Twenty years after Lilienfeld filed his patents, scientists were trying to put his ideas to practical use. The Bell Telephone System, in particular, needed something **better** than vacuum tubes to keep its communications systems working. The company assembled what amounted to an all-star team of scientific minds, including John Bardeen, Walter Brattain and William Shockley, and put them to work researching vacuum tube substitutes.

In 1947, Shockley was director of transistor research at Bell Telephone Labs. Brattain was an authority on solid-state physics as well as expert on nature of atomic structure of solids and Bardeen was an electrical engineer and physicist. Within a year, Bardeen and Brittain used the element germanium to create an amplifying circuit, also called **a point-contact transistor**. Soon afterward, Shockley improved on their idea by developing **a junction transistor**.

The next year, Bell Labs announced to the world that it had invented working transistors. The original patent name for the first transistor went by this description: Semiconductor amplifier; three-electrode circuit element utilizing semi conductive materials. It was an innocuous-sounding phrase. But this invention netted the Bell team the 1956 Nobel Prize for Physics, and allowed scientists and product engineers far greater control over the flow of electricity.

It's no exaggeration that transistors have enabled some of humankind's biggest leaps in technology. Keep reading to see exactly how transistors work, how they altered the course of technology, and in the process, human history, too.



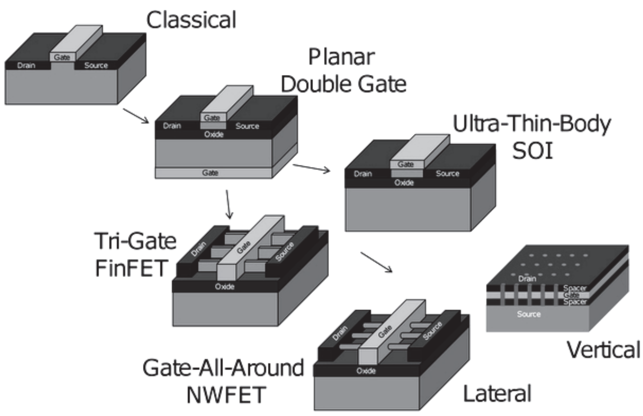
MODULE 10. JUNCTION FIELD-EFFECT TRANSISTORS

1) The word transistor is a combination of "transconductance" (transfer of a charge) and "variable resistor" or "varistor."

2) Early transistors were used to amplify audio signals.

3) A computer can't operate without an integrated circuit (chip), and a chip can't operate without a transistor.

4) The first Intel computer chip had 2,300 transistors, while the latest one has 820 million.



Ex. 1. Translate the words below without a dictionary.

Control (*v*), model, normally, mobile, algebraic, sinusoid, sinusoidal vibrations, reflex, distribution, chaos, pulse, synchronous, orbit, pyramid, type.

Ex. 2. Work with a dictionary, translate the following terms and match the words from the table with their translation below the table; check up your answers; at home memorize the terms.

gate / gate electrode	drain / drain electrode	pinch-off	available	reverse bias
reverse bias voltage	pinch-off voltage	entirety	source	*n*-type channel
to contribute	depletion region	to constrict	gate-to-source voltage	

1) сток/электрод, подключенный к каналу; 2) затвор/управляющий электрод; 3) обратное напряжение; 4) напряжение отсечки/пороговое напряжение; 5) цельность; 6) способствовать; 7) сжимать/ограничивать; 8) напряжение между затвором и истоком; 9) канал n-типа; 10) доступный; 11) регион обеднения; 12) обратное смещение; 13) исток, 14) отсечка.

Ex. 3. Using the following affixes form the derivatives:

-er/or -ive -tion -ant/ent -ing -sion -able -ible -ed semi-

deplete				
constrict				
apply				
contribute				
reverse				
reduce				

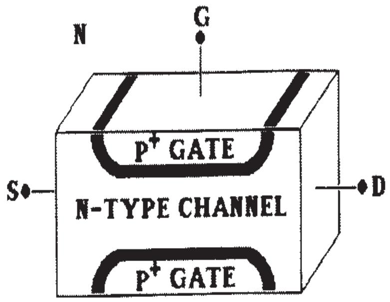
Ex. 4. Read the first paragraph and answer: What does abbreviation JFET stand for?

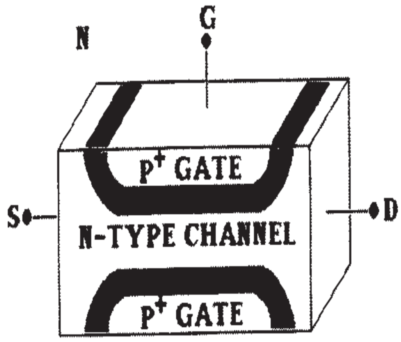
Ex. 5. Match a sentence with its translation.

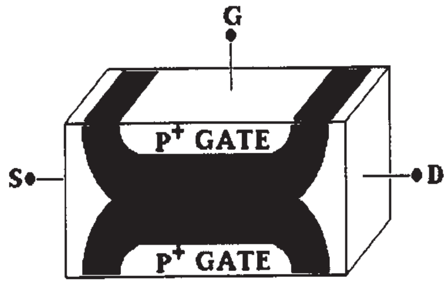
Thus as the gate voltage increases, the cross-sectional areas of the *n*-type channel available for current flow decreases	*С увеличением напряжения затвора, канал дальше становится узким и поток тока уменьшается*
The gate-to-channel pn junction is normally kept reverse-biased	*В этом месте поток тока между стоком и истоком сокращается до нуля*
As the gate voltage increases, the channel gets further constricted, and the current flow gets smaller	*Область, обеднённая носителями зарядов, образуется в канале n-типа из-за сильного легирования p-области*
At this point the current flow between drain and source is reduced to essentially zero	*Таким образом, вместе с увеличением напряжения затвора, уменьшается площадь поперечного сечения канала n-типа, доступного для потока тока*
The depletion region extends mostly into the *n*-type channel because of the heavy doping on the *p*+side	*Затвор выполнен в виде обратно смещенного p-n перехода*

Ex. 6. Look through the text quickly and translate the sentences and phrases in italic into Russian.

A junction field-effect transistor, or the junction gate field-effect transistor (JFET/FET or JUGFET), is a type of transistor in which the current flow through the device between the drain and source electrodes is controlled by the voltage applied to the gate electrode.

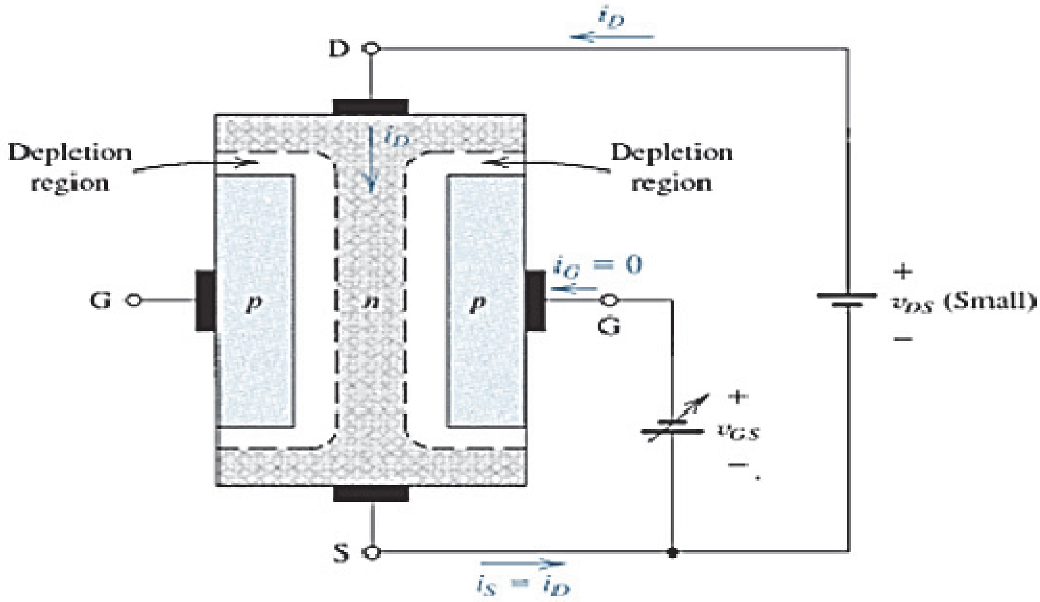




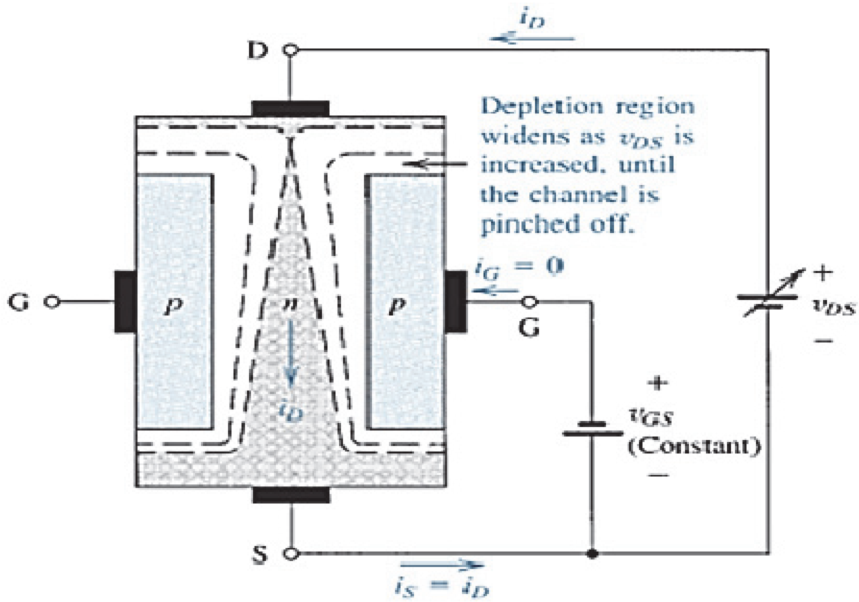


A simple physical model of the JFET is shown in Fig. 1. In this JFET an *n*-type conducting channel exists between drain and source. The gate is a *p*+region that surrounds the *n*-type channel. *The gate-to-channel pn junction is normally kept reverse-biased.* As the reverse bias voltage between gate and channel increases, the depletion region width increases, as shown in Fig. 2. The depletion region extends mostly into the *n*-type channel because of the heavy **doping** on the *p*+side. *The depletion region is depleted of mobile* ***charge carriers*** *and thus cannot contribute to the conduction of current between drain and source.* Thus as the gate voltage increases, the cross-sectional areas of the *n*-type channel available for current flow decreases. This reduces the current flow between **drain** and source. As the gate voltage increases, the channel gets further constricted, and the current flow gets smaller. Finally when the **depletion** regions meet in the middle of the channel, as shown in Fig. 3, the channel is pinched off in its entirety between source and drain. At this point the current flow between drain and source *is reduced to essentially zero*. This voltage is called the **pinch-off voltage,** *V P*. The pinch-off voltage *is also represented by VGS (off) as being the gate-to-source voltage* that turns the drain-to source current *I DS* off. We have been considering here an *n*-channel JFET. The complementary device is the *p*-channel JFET that has an *n*+gate region surrounding a *p*-type channel. The operation of a *p*-channel JFET is the same as for an *n*-channel device, except the algebraic signs of all dc voltages and currents are reversed. We have been considering the case for *VDS* small compared to the pinch-off voltage such that the channel *is essentially uniform* from drain to source.

Ex. 7. Describe the pictures below, using active vocabulary.



(a)



Ex. 8. Divide the text into several parts and give the titles to them so that you could have a plan of the text.

Ex. 9. How can you describe the figures above?

Ex. 10. Find in the text the answers for the following questions:

- What is JFET? What peculiarities does it have?
- What does the gate voltage increase result in?
- What are the relations between the reverse bias voltage and depletion region width?
- What is pinch-off voltage?

• What happens when the depletion regions meet in the middle of the channel? What does it result in?

Ex. 11. Give antonyms to the underlined words in the text above.

Ex. 12. Explain the meaning of the words in bold.

Ex. 13. Put all possible questions to the underlined sentences.

Ex. 14. Translate into English.

Транзистор – полупроводниковый элемент электронной техники, который позволяет управлять током, протекающим через него, с помощью прилагаемого к дополнительному электроду напряжения.

Транзисторы являются основными элементами современной электроники. Обычно они применяются в усилителях и логических электронных схемах. В микросхемах в единый функциональный блок объединены тысячи и миллионы отдельных транзисторов.

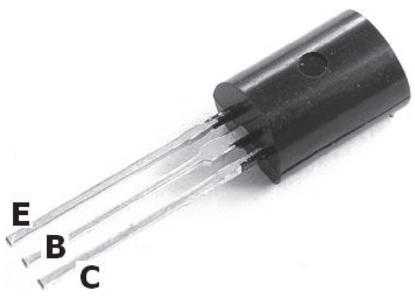
По строению и принципу действия транзисторы делятся на два больших класса: биполярные транзисторы и полевые транзисторы. В каждый из этих классов входят многочисленные типы транзисторов, отличающихся по строению и характеристикам.

Ex. 15.Circle 16 words.

G	A	T	E	E	L	E	C	T	R	O	D	E	C	D
P	V	O	V	I	Q	M	O	Q	E	J	R	L	I	E
I	A	P	G	V	Z	U	N	O	N	U	A	E	R	P
N	I	R	E	V	E	R	S	E	T	N	I	C	C	L
C	L	Q	B	V	Z	M	T	Q	I	C	N	T	U	E
H	A	F	I	E	L	D	R	O	R	T	I	R	I	T
O	B	P	A	I	D	Z	I	M	E	I	D	O	T	I
F	L	Q	S	O	U	R	C	E	T	O	O	D	H	O
F	E	E	F	F	E	C	T	P	Y	N	I	E	N	N
V	O	L	T	A	G	E	I	Q	R	E	G	I	O	N

MODULE 11. JUNCTION BIPOLAR TRANSISTORS (BJT)

The invention of the bipolar transistor in 1948 ushered in a revolution in electronics. Technical feats previously requiring relatively large, mechanically fragile, power-hungry vacuum tubes were suddenly achievable with tiny, mechanically rugged, power-thrifty specks of crystalline silicon. This revolution made possible the design and manufacture of light-weight, inexpensive electronic devices that we now take for granted.



Ex. 1. Translate the words below without a dictionary.

Биполярный, транзистор, сэндвич, коллектор, база, эффект, концентрировать, разнообразие, проводимость, зоны, полярность, величина, формировать, пара.

Ex. 2. Work with a dictionary, translate the following terms and match the words from the table with their translation below the table; check up your answers; at home memorize the terms.

therefore	collector	filling	base	exhibit	emitter
provided that	back-to-back	moderate	valence band	conduction band	

1) область проводимости; 2) показывать; 3) наполнение; 4) коллектор; 5) при условии, что; 6) эмиттер; 7) умеренный; 8) валентная область; 9) поэтому; 10) последовательно; 11) база.

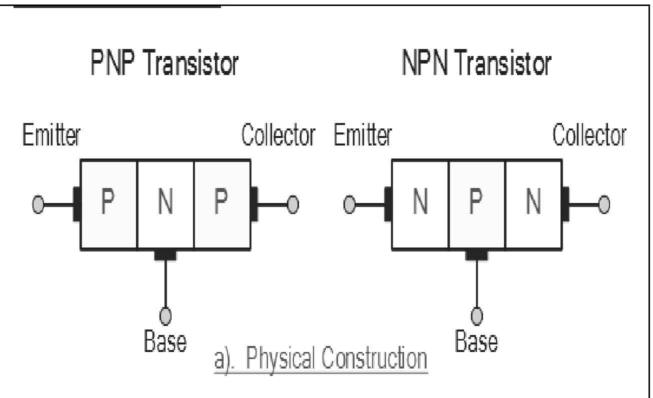
Ex. 3. Choose two terms from Ex. 2 and explain them to your group mates so that they could guess them.

Ex. 4. Jumbled words.

abes______________ hrrteoefe_______________ xieithb_______________
nlceave____________ ticnodncou_____________ tremtei_______________

Ex. 5. Circle 10 words from modules 10, 11.

F	*M*	*O*	*D*	*E*	*R*	*A*	*T*	*E*
I	*S*	*E*	*X*	*H*	*I*	*B*	*I*	*T*
L	*O*	*D*	*M*	*B*	*G*	*A*	*T*	*E*
L	*U*	*R*	*U*	*I*	*E*	*N*	*A*	*U*
I	*R*	*A*	*A*	*B*	*T*	*D*	*U*	*B*
N	*C*	*I*	*E*	*A*	*U*	*T*	*O*	*E*
G	*E*	*N*	*B*	*S*	*A*	*O*	*E*	*U*
C	*O*	*L*	*L*	*E*	*C*	*T*	*O*	*R*



Ex.6. Before reading Text E recollect some information on text research from module 9 (see Appendix 4).

Ex. 7. Read text E according to the scheme of module 9.

Text E

A Bipolar Transistor essentially consists of a pair of PN Junction Diodes that are joined back-to-back. This forms a sort of a sandwich where one kind of semiconductor is placed in between two others. There are therefore two kinds of Bipolar sandwich, the NPN and PNP varieties. The three layers of the sandwich are conventionally called the Collector, Base, and Emitter.

Some of the basic properties exhibited by a Bipolar Transistor are immediately recognizable as being diode-like. However, when the 'filling' of the sandwich is fairly thin some interesting effects become possible that allow using the Transistor as an amplifier or a switch. To see how the Bipolar Transistor works we can concentrate on the NPN variety.

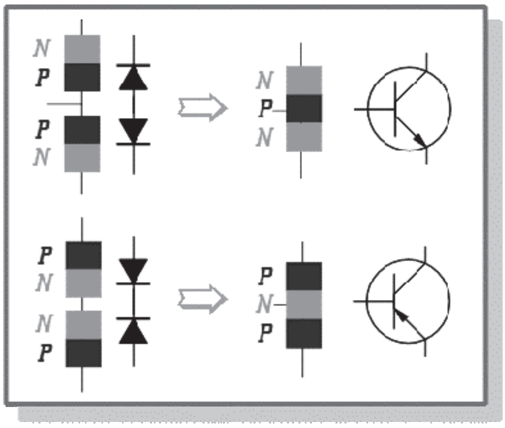


Figure 1 shows the energy levels in an NPN transistor when we aren't externally applying any voltages. The arrangement looks like a back-to-back pair of PN Diode junctions with a thin P-type filling between two N-type slices of 'bread'. In each of the N-type layers conduction can take place by the free movement of electrons in the conduction band. In the P-type (filling) layer conduction can take place by the movement of the free holes in the valence band. However, in the absence of any externally applied electric field, depletion zones form at both PN-Junctions, so no charge wants to move from one layer to another.

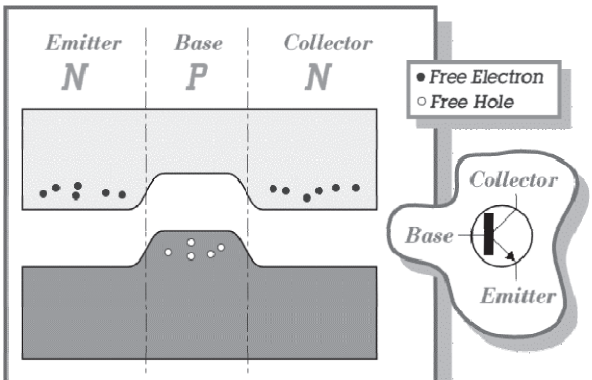


Fig 1 NPN Bipolar Transistor

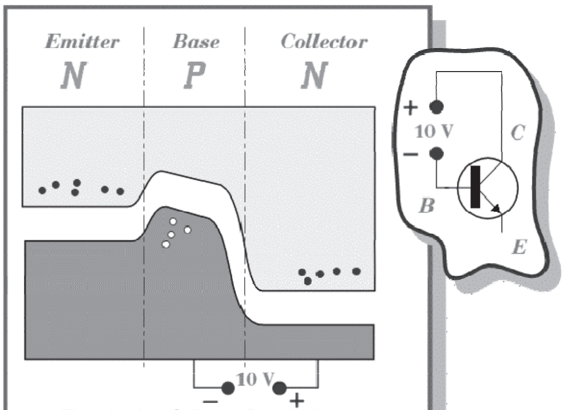


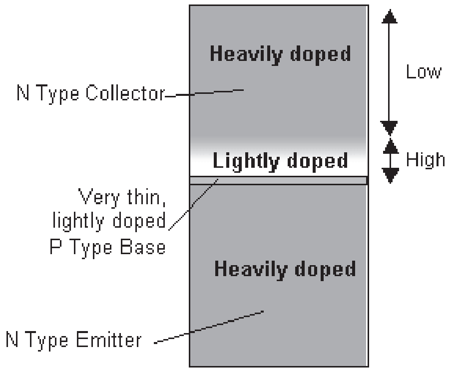
Fig 2 Apply a Collector-Base Voltage

What happens when we apply a moderate voltage between the Collector and Base parts of the transistor? The polarity of the applied voltage is chosen to increase the force pulling the N-type electrons and P-type holes apart. (i.e. we make the Collector positive with respect to the Base.) This widens the depletion zone between the Collector and base and so no current will flow. In effect we have reverse-biased the Base-Collector diode junction. The precise value of the Base-Collector voltage doesn't really matter to what happens provided we don't make it too big and blow up the transistor!

Ex. 8. Divide text A into paragraphs and prepare 2 questions on the text to your group mates.

Ex. 9. Fill in the blanks with a word from the box.

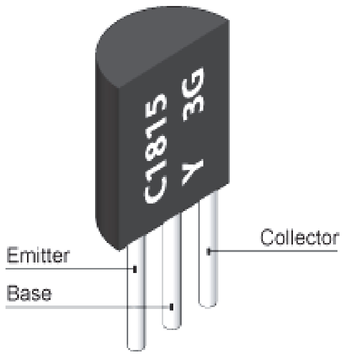
N type emitter / thin / resistivity / ensures / doping / lightly / operation



How a transistor is doped.

The _____________ of the transistor is very dependent on the degree of _____________ of the various parts of the semiconductor crystal. The _____________ is very heavily doped to provide many free electrons as majority charge carriers. The _____________ doped P type base region is extremely _____________, and the N type collector is very heavily doped to give it a low _____________ apart from a layer of less heavily doped material near to the base region. This change in the resistivity of the collector close to the base _____________ that a large potential is present within the collector material close to the base.

Ex. 10. Translate into English.



Биполярным транзистором называется полупроводниковый прибор, имеющий два взаимодействующих между собой p-n перехода. Технология изготовления биполярных транзисторов может быть различной (сплавление, диффузия, эпитаксия), что в значительной мере определяет характеристики прибора. В зависимости от последовательности чередования областей с различным типом проводимости различают n-p-n транзисторы и p-n-p транзисторы. Средняя часть структуры называется базой, одна крайняя область – коллектором, а другая – эмиттером. Работа транзисторов основана на управлении токами электродов в зависимости от приложенных к его переходам напряжений.

Ex. 11. Study the following information about transistor specifications.

The manufacturer's data sheets contains information in the following general categories:

1. Maximum (Breakdown) Ratings
2. "On" Characteristics
3. Small Signal Characteristics
4. Switching Characteristics

V_{CEO} is the maximum **collector-emitter voltage** and **V_{CBO}** is the maximum **collector-base voltage**. Fortunately, these breakdown voltages are well above the typical 12v used in most QRP applications.

MAXIMUM (BREAKDOWN) RATINGS						
		2N 2222	2N 2222A	2N 3904	2N 4401	MMBT 3904
Collector–Emitter	V_{CEO}	30v	40v	40v	40v	40v
Collector–Base	V_{CBO}	60v	75v	60v	60v	60v
Emitter–Base	V_{EBO}	5v	6v	6v	6v	6v
Max. Coll. Current	Ic	600mA	600mA	200mA	600mA	200mA
Power dissipation	Pd	625mW	625mW	625mW	625mW	225mW

Rule of thumb for V_{EBO}: V_{EBO}(max) or Vbe(max) for most general purpose BJTs is 5–6v – the *maximum* emitter-base voltage. Don't forget to include the peak voltage of the AC signal!

Rule of thumb for Ic(max): There isn't one! The only safe way to know the maximum Ic for a transistor is to consult the data sheets.

Rule of thumb for HFE:
Conventions used in electronic literature:

HFE or **hFE** (upper case letters) is the ***DC Current Gain***

Hfe or **hfe** (lower case) is the ***AC current gain***

Collector Current, Ic(max), is the other maximum rating to be closely followed. Collector current exceeding Ic(max) can damage the transistor, due to excessive current through the device, initiating thermal runaway – destroying the collector-emitter junction. The destruction of a transistor

DC "ON" CHARACTERISTICS						
		2N 2222	2N 2222A	2N 3904	2N 4401	MMBT 3904
DC Current Gain, HFE						
Ic= 0.1mA, V_{CE}=10v	HFE Min.	35	35	40	20	40
Ic=1.0 mA, V_{CE}=10v	HFE Min.	50	50	70	40	70
	HFE Max.	150	150	200	—	200
Ic= 10 mA, V_{CE}=10v	HFE Min.	75	75	100	80	100
	HFE Max.	225	250	300	—	300
Collector-Emitter Saturation Voltage, V_{CE}(sat)						
Ic= 150mA, I_B= 15mA	V_{CE}(sat)	0.4vdc	0.3vdc	0.3vdc†	0.4vdc	0.2vdc†
Base-Emitter Saturation Voltage, V_{BE}(sat)						
Ic= 150mA, I_B= 15mA	V_{BE}(sat)	1.3vdc	1.2vdc	0.85vdc	0.95vdc	.85vdc†

† Ic=50mA, I_B=5mA on 2N3904

Rule of thumb for <u>HFE</u>:
Conventions used in electronic literature:

HFE or **hFE** (upper case letters) is the ***DC Current Gain***
Hfe or **hfe** (lower case) is the ***AC current gain***

1) gain bandwidth product (**Ft**)
2) the AC current gain (**hfe**)
3) input and output impedances (**hie** and **hoe**)
4) input and output capacitances (**Cibo** and **Cobo**)
5) the noise figure (**NF**).

SMALL SIGNAL CHARACTERISTICS – Part 1						
		2N 2222	**2N 2222A**	**2N 3904**	**2N 4401**	**MMBT 3904**
Gain Bandwidth Prod.	Ft (MHz).	250	300	300	250	300
Small Signal Current Gain, hfe						
Ic=1.0 mA, Vce=10v†	hfe Min.	50	50	100	40	100
	hfe Max.	300	300	400	500	400
Estimated	hfe Typ.	150	150	200	225	200
Ic= 10 mA, Vce=10v†	HFE Min.	75	75	—	—	—
	HFE Max.	375	375	—	—	—

† Measured at 1 KHz

SMALL SIGNAL CHARACTERISTICS – Part 2						
		2N 2222	**2N 2222A**	**2N 3904**	**2N 4401**	**MMBT 3904**
Input capacitance ‡	Cibo (max)	30pF	25pF	8pF	30pF	8pF
Output capacitance‡	Cobo (max)	8pF	8pF	4pF	7pF	4pF
Input Impedance, typ.†	hie (min)	2KΩ	2KΩ	1KΩ	1KΩ	1KΩ
	hie (max)	8KΩ	8KΩ	10KΩ	15KΩ	10KΩ
Output Admittance †	hoe (min)	5*	5*	1*	1*	1*
	hoe (max)	35*	35*	40*	30*	40*
Noise Figure †	NF (max)	4dB	4dB	5dB	4.5dB	4dB

† Measured at 1 KHz ‡ Measured at 1 MHz * µmhos

SWITCHING CHARACTERISTICS						
		2N 2222	**2N 2222A**	**2N 3904**	**2N 4401**	**MMBT 3904**
Delay time	td	10ns	10ns	35ns	15ns	35ns
Rise time	tr	25ns	25ns	35ns	20ns	35ns
Storage time	ts	225ns	225ns	200ns	225ns	200ns
Fall time	tf	60ns	60ns	50ns	30ns	50ns

AmQRP.ORG **HOMEBREWER** No. 5

Paul Harden, NA5N

The Handyman's Guide to – UNDERSTANDING TRANSISTOR DATA SHEETS & SPECIFICATIONS

Introduction

*The most common bipolar junction transistors (BJT) used by hobbyists and QRPers are the **2N2222**, **2N3904** and **2N4401**. These NPN transistors have similar characteristics, and perform well at HF frequencies.*

This tutorial explains how to "read" the data sheets on these devices and understand the specifications – which will enable you to interpret data sheets for other devices as well.

The manufacturer's data sheets contains information in the following general categories:

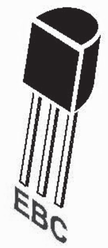
1. Maximum (Breakdown) Ratings
2. "On" Characteristics
3. Small Signal Characteristics
4. Switching Characteristics

The QRPer's Favorite

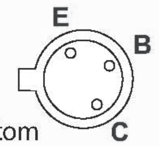
GENERAL PURPOSE NPN TRANSISTORS

2N2222
2N3904
2N4401
MPS2222
MPS3904

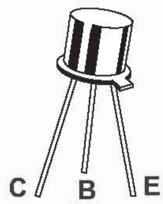
TO–92
Plastic Encapsulated Transistor



TO–18
Metal Can Transistor

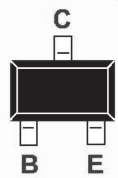


Bottom View



SOT-23
Surface Mount Transistor

MMBT2222LT1
MMBT3904LT1
MMBT4401LT1



1. Maximum (Breakdown) Ratings

The maximum ratings are provided to ensure that the voltages and currents applied do not damage or cause excessive heating to the device. The maximum ratings for the 2N2222, 2N3904 and 2N4401are shown in **Table 1**. The voltages, currents and power dissipation listed should *not be exceeded* to prevent damage to the device.

VCEO is the maximum **collector-emitter voltage** and **VCBO** is the maximum **collector-base voltage**. Fortunately, these breakdown voltages are well above the typical 12v used in most QRP applications.

This is not the case with **VEBO,** the **maximum emitter-base voltage**, typically 5–6v. If exceeded, this can cause a physical breakdown of the base junction, destroying the

Table 1 – MAXIMUM (BREAKDOWN) RATINGS

		2N 2222	2N 2222A	2N 3904	2N 4401	MMBT 3904
Collector–Emitter	VCEO	30v	40v	40v	40v	40v
Collector–Base	VCBO	60v	75v	60v	60v	60v
Emitter–Base	VEBO	5v	6v	6v	6v	6v
Max. Coll. Current	Ic	600mA	600mA	200mA	600mA	200mA
Power dissipation	Pd	625mW	625mW	625mW	625mW	225mW

transistor. In a circuit, the biasing scheme sets the base-emitter voltage, V_{BE}, to be safely below V_{EBO}. However, in large-signal applications, V_{BE} must include the DC base bias *and the peak voltage of the signal* to ensure V_{EBO} will not be exceeded.

Collector Current, Ic(max), is the other maximum rating to be closely followed. Collector current exceeding Ic(max) can damage the transistor, due to excessive current through the device, initiating thermal runaway – destroying the collector-emitter junction. The destruction of a transistor in this manner is technically called *catastrophic substrate failure* for good reason!

Most QRP circuits are usually biased for well below Ic(max). Vbe(max) and Ic(max) are generally a concern only in large-signal applications, such as RF drivers, PA stages, and some oscillator circuits.

2. ON CHARACTERISTICS

These specifications define the DC performance of the device while it is forward biased (Vbe ≥0.7v), causing collector current to flow, or "on." The DC Characteristics in **Table 2** are not absolute design values, but rather *test values* as measured by the manufacturer. This is why the data is listed with the test conditions, such as "Ic=1mA, V_{CE}=10v."

HFE is the *measured* **DC current gain** of the transistor (see *Rule of thumb for HFE*). It is used for biasing the device in the linear region – primarily class A. Most data sheets provide HFE at two different collector currents, usually 1 and 10mA. Since most QRP circuits are biased for Ic ≤5mA (to conserve battery drain), HFE at Ic=1mA is typically used.

HFE also varies from transistor–to–transistor. This is why the data sheets list both HFE (min) and HFE (max). The manufacturer tested a large batch of 2N2222s and determined that hfe ranged from 50 (HFE **min**) to 150 (HFE **max**) at Ic=1mA, as shown on the data sheets (**Table 2**). Statistically, most transistors will fall between 50 and 150, or about HFE=100. This is why most design guides will recommend using a value of HFE=100 for bias calculations. Since the 2N3904 has a higher DC current gain, often HFE=150 is recommended for that device.

HFE min. and max, at Ic=1 and 10mA, can be plotted on a logarithmic graph (lines 1 and 2 on **Fig. 1**). The average

Rule of thumb for <u>VEBO</u>: V_{EBO}(max) or Vbe(max) for most general purpose BJTs is 5–6v – the *maximum* emitter-base voltage. Don't forget to include the peak voltage of the AC signal!

Rule of thumb for <u>Ic(max)</u>: There isn't one! The only safe way to know the maximum Ic for a transistor is to consult the data sheets.

Table 2 – DC "ON" CHARACTERISTICS

		2N 2222	2N 2222A	2N 3904	2N 4401	MMBT 3904
DC Current Gain, HFE						
Ic= 0.1mA, V_{CE}=10v	HFE Min.	35	35	40	20	40
Ic=1.0 mA, V_{CE}=10v	HFE Min.	50	50	70	40	70
	HFE Max.	150	150	200	—	200
Ic= 10 mA, V_{CE}=10v	HFE Min.	75	75	100	80	100
	HFE Max.	225	250	300	—	300
Collector-Emitter Saturation Voltage, V_{CE}(sat)						
Ic= 150mA, I_B= 15mA	V_{CE}(sat)	0.4vdc	0.3vdc	0.3vdc†	0.4vdc	0.2vdc†
Base-Emitter Saturation Voltage, V_{BE}(sat)						
Ic= 150mA, I_B= 15mA	V_{BE}(sat)	1.3vdc	1.2vdc	0.85vdc	0.95vdc	.85vdc†

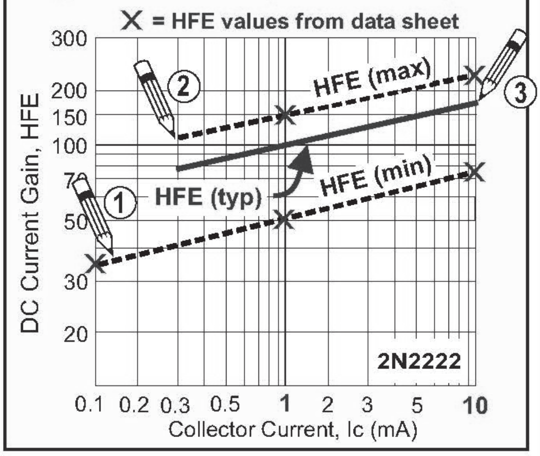
† Ic=50mA, I_B=5mA on 2N3904

Rule of thumb for <u>HFE</u>:
Conventions used in electronic literature:

HFE or **hFE** (upper case letters) is the ***DC Current Gain***

Hfe or **hfe** (lower case) is the ***AC current gain***

Fig. 1 – Constructing an HFE vs. Ic plot



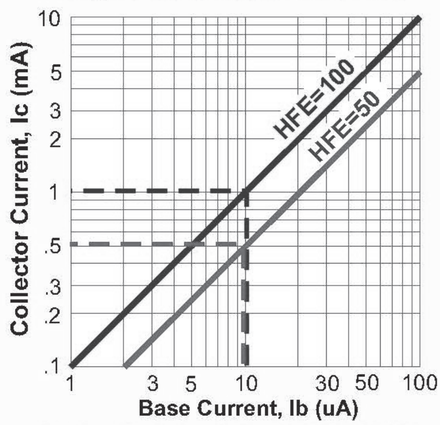
value, HFE typ., can then be drawn (line 3, **Fig. 1**). This gives you HFE (typ) for various collector currents.

The value used for HFE is not critical. Using HFE=100, or even the conservative value of 50, will work 99% of the time. Therefore, one scarcely needs the data sheets for the DC characteristics, as the typical HFE = 100 at Ic=1mA is valid for most general purpose NPN transistors. **Fig. 2** shows **Ib vs. Ic** for HFE at 50 and 100.

Saturation voltages, VCE(sat) and **VBE(sat)**, defines the transistor behavior *outside* the linear operating region, that is, in the saturated region. This is of interest when operating the transistor as a saturated switch. The keying transistor in a transmitter, forming the +12v transmit voltage on key–down, is an example of a saturated switch.

Rule of thumb for HFE: Most general purpose NPN transistors have a DC HFE = 100 (typ) and thus used in most biasing equations for DC and low frequencies.

Fig. 2 – Ic vs. Ib defines HFE



At Ib=10uA, Ic=0.5mA @ HFE=50
At Ib=10uA, Ic=1.0mA @ HFE=100

3. SMALL SIGNAL CHARACTERISTICS

The small-signal characteristics describe the AC performance of the device. There is no standardized industry definition of small-signal (vs. large-signal), but is generally defined where the *AC signal* is small compared to the DC bias voltage. That is, the signal levels are well within the linear operating region of the transistor.

The small signal characteristics include:

1) gain bandwidth product (**Ft**)
2) the AC current gain (**hfe**)
3) input and output impedances (**hie** and **hoe**)
4) input and output capacitances (**Cibo** and **Cobo**)
5) the noise figure (**NF**).

The small signal parameters are the most important to understand, as they describe the transistor's behavior at audio and RF frequencies, and used in the circuit design equations. These parameters vary greatly from one transistor type to another, such that making assumptions (as we did with DC HFE =~100) can be risky. The data sheets must be used. The small-signal characteristics for **Ft** and **hfe**, from the data sheets, are shown in **Table 3**

Table 3 – SMALL SIGNAL CHARACTERISTICS – Part 1

		2N 2222	2N 2222A	2N 3904	2N 4401	MMBT 3904
Gain Bandwidth Prod.	Ft (MHz).	250	300	300	250	300
Small Signal Current Gain, hfe						
Ic=1.0 mA, Vce=10v†	hfe Min.	50	50	100	40	100
	hfe Max.	300	300	400	500	400
Estimated	hfe Typ.	150	150	200	225	200
Ic= 10 mA, Vce=10v†	HFE Min.	75	75	—	—	—
	HFE Max.	375	375	—	—	—

† Measured at 1 KHz

Gain Bandwidth Product, or **Ft**, is defined as the frequency at which the AC current gain, hfe, equals 1 (0dB). See **Fig. 3** (next page). This is the maximum frequency the device produces gain as an amplifier or oscillator.

On RF transistor data sheets, Ft is not always given. Instead, the **power gain, Gp** (or **Gpe** for common emitter power gain) is tested at a specific frequency. Ft can be derived from this information as shown in **Table 4**. Equations *x* and *Gp(mag)* convert the power gain, in dB, to unitless magnitude, as is hfe.

Table 4 – Calculating Ft from Gpe

$$x = \frac{Gp(dB)}{10} \qquad Gp(mag) = 10^{x}$$

$$Ft = f\sqrt{Gp(mag)}$$

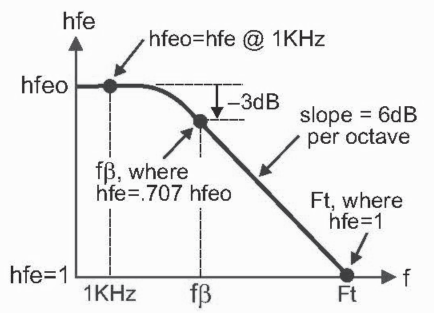
Example:
The data sheet for the 2N5179 lists Gpe=15dB at 200MHz. Determine Ft.

$$x = \frac{15dB}{10} = \mathbf{1.5} \qquad Gp(mag) = 10^{1.5} = \mathbf{32}$$

$$Ft = 200MHz\sqrt{32} = \mathbf{1130\ MHz}$$

hfe is the **ac small-signal current gain**, and dependent on both frequency and the collector current. Hfe is also known as the *ac beta*. Ft and hfe work together to define the overall AC gain of the transistor at a specific frequency, as illustrated in **Fig. 3**.

Fig. 3 – Common Emitter AC current gain vs. Frequency



<u>**hfeo**</u> is the low-frequency hfe, often very close to the DC HFE. The values for hfe shown in the data sheets are normally measured at 1KHz and Ic=1mA (sometimes @10mA). Hfeo is fairly constant from the audio frequencies to about 300 KHz.

<u>**Beta cut-off frequency, fβ**</u>, is the "3db point" of hfe, where hfe= 0.707hfeo, or fβ=Ft/hfeo. Fβ is seldom listed on the data sheets.

hfe drops fairly linearly from fβ to Ft at 6dB/octave.

Fβ, and the hfe vs. frequency plots, are seldom shown in the data books. ***This is why learning to interpret the data sheets is important to determine the actual gain (hfe) a transistor will provide at a specific frequency.***

Design Example: Constructing an Hfe vs. Frequency Plot
Let's figure out what hfe will be for a 2N2222 on the 40M band, using both graphical and equational methods. It's really easy.

From **Table 3**, hfe=50 (min) to 300 (max). Let's pick hfe=150 as the average. Since hfe is measured at 1KHz, this is also **hfeo**. Draw a line on a chart to represent hfeo=150 (line #1, **Fig. 4**).

Calculate fβ and hfe @fβ as follows: (Ft=250MHz, 2N2222)

fβ = Ft/hfeo = 250MHz ÷ 150 = 1.7 MHz

hfe@fβ = .707hfeo = 0.707 x 150 = 106

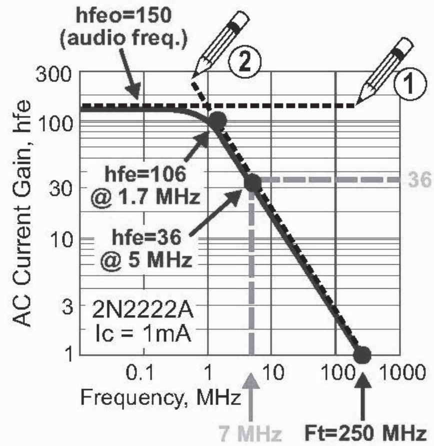
Draw a dot at hfe@fβ on the chart (hfe=106 @ 1.7 MHz)

Or ... calculate hfe at the desired frequency, fo, such as 7MHz

hfe@fo = Ft/fo = 250MHz ÷ 7MHz = 36

Draw a line between fβ (or fo) and Ft (line #2, **Fig. 4**) to complete the hfe vs. frequency plot of the 2N2222 at Ic=1mA.

Fig. 4 – Constructing an hfe gain plot for the 2N2222 (Common Emitter)



For gain at any frequency, fβ < fo < Ft

$$\text{hfe} = \frac{\text{Ft}}{\text{fo}} \qquad \text{Gain(dB)} = 10\log(\text{hfe})$$

Therefore, at <u>7 MHz</u>

ac gain is hfe = 36

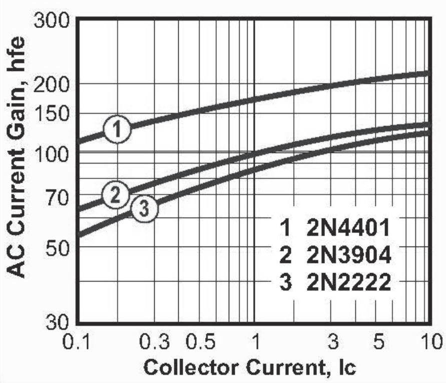
How much signal gain will the 2N2222 provide at <u>144 MHz</u>?

hfe = Ft/fo = 250MHz ÷ 144MHz = 1.7, or almost unity!

This is why general purpose transistors (Ft <400MHz) are not used at VHF for lack of useful gain above ~50 MHz.

Hfe vs. Ic. Hfe is also a function of Ic as shown in **Fig. 5**. This data sheet chart is used to adjust hfe at Ic other than 1mA, where hfe is measured. For designing battery powered circuits, Ic=1mA is recommended. Firstly, data sheet values can be used directly, saving additional calculations, since most parameters are listed for Ic=1mA. Secondly, these transistors have ample gains at Ic=1mA or less. The additional gain at a higher Ic may not justify

Fig. 5 – Hfe vs. Collector Current



the increase in battery drain. I.e., two amplifiers at Ic=1mA will yield far more gain than one amplifier at Ic=2mA.

Table 6 shows hfe at different frequencies for the 2N2222.

Table 5 lists the remaining small-signal characteristics.

Table 5 – SMALL SIGNAL CHARACTERISTICS – Part 2

		2N 2222	2N 2222A	2N 3904	2N 4401	MMBT 3904
Input capacitance ‡	Cibo (max)	30pF	25pF	8pF	30pF	8pF
Output capacitance‡	Cobo (max)	8pF	8pF	4pF	7pF	4pF
Input Impedance, typ.†	hie (min)	2KΩ	2KΩ	1KΩ	1KΩ	1KΩ
	hie (max)	8KΩ	8KΩ	10KΩ	15KΩ	10KΩ
Output Admittance †	hoe (min)	5*	5*	1*	1*	1*
	hoe (max)	35*	35*	40*	30*	40*
Noise Figure †	NF (max)	4dB	4dB	5dB	4.5dB	4dB

† Measured at 1 KHz ‡ Measured at 1 MHz * μmhos

Input impedance, hie, is the resistive element of the base-emitter junction, and varies with Ic. It is used for input impedance calculations, and not particularly useful in itself without considering Cibo.

Input capacitance, Cibo, is the capacitance across the base-emitter junction. For the 2N2222, Cibo(max)=30pF. The reactance (Xc) of Cibo is in parallel with hie (Xc||hie) – causing the equivalent input impedance, Zin, to be frequency dependent as shown in **Table 6**. As can be seen, Xc(Cibo) dictates the input impedance of the transistor, *not hie*. Cibo is thus important in estimating Zin at any given frequency. In selecting a transistor for RF, the smaller the value of Cibo, the better. In this case, the input *impedance* is called Zin, since it includes the frequency dependent *reactance* components.

Input resistance, Rin, for the common-emitter transistor, can also be estimated using hfe and emitter current, Ie, as follows:

$$Rin = re(hfe+1) \quad \text{where, } re = 26 \div Ie(mA) \ (Ie \approx Ic)$$

The results of Rin from the above are also shown in **Table 6** for comparison. This method is generally preferred since hfe and Ie are known with greater accuracy than is hie and Cibo. In this case, the input *impedance* is called Rin, since it only includes resistive components (no *reactance* components).

The differences between the two methods, while close, demonstrates the difficulty in determining with certainty the input impedance of a transistor.

Table 6 – 2N2222 Input Impedances

hfe: based on hfeo=150; Rin: based on hfe and re; Zin: based on Xc(Cibo) || hie

Freq	hfe	Rin	Xc(Cibo)	Zin
3.5	71	1872Ω	1516Ω	1150Ω
7.0	36	962Ω	758Ω	658Ω
10.1	25	676Ω	525Ω	475Ω
14.0	18	494Ω	379Ω	352Ω
21.0	12	312Ω	253Ω	241Ω
28.0	9	234Ω	190Ω	183Ω
50.0	5	130Ω	106Ω	104Ω
144	2	52Ω	37Ω	36Ω

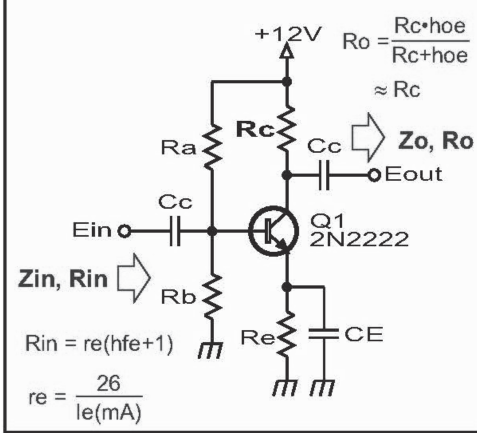
Rin=re(hfe+1) where, re=26/Ie(mA) =26Ω@1mA

Zin(eq) = Xc||hie where, Cibo = 30pF hie = 5KΩ

Output Admittance, hoe, represents the output resistance of the transistor by taking the reciprocal of the admittance. For example, at hoe(typ)=10umhos, Rout = 1/hoe = 1/10umhos = 100KΩ. Like hie, hoe is not particularly useful by itself.

Output Resistance, Ro, is approximately the parallel equivalent of hoe and the collector load resistance, Rc, or Ro = Rc||hoe. See **Fig. 6**. Since Rc tends to be in the 1–5KΩ range, and hoe 20–100KΩ, Rc will dominate the output resistance of the transistor. As a result, output impedance is usually estimated by: Zo ≈ Rc. Note that the output impedance is set primarily by circuit values (Rc), and not by the transistor's small-signal parameters.

Fig. 6 – Input/Output Impedances
basic amplifier configuration



Cobo is the **output capacitance**, and is in parallel with the output resistance. However, Cobo is <10pF in most general purpose NPN transistors and has little effect at HF. This parameter is important in RF transistors operating in the VHF/UHF spectrum, where the shunting effect becomes a significant component of the output impedance. Obviously, the lower the value of Cobo, the better.

Noise Figure, NF, is defined as the ratio of the input to the output noise, neither of which is easily measurable by the amateur. The transistor will add noise, then be amplified by the hfe of the device just as the signal is, forming signal plus noise output, or S+N. The excess in the S+N to signal power is due to the noise figure (NF) of the device.

For the QRPer, the NF of the transistor is not highly important on HF. See **Table 7**. Select a transistor with a low NF for the audio stage(s), however, as this is where it will be the most evident.

Transconductance, gm, is another parameter provided on some data sheets. If not provided, gm can be estimated by: gm = .038 x Ie(mA).

Table 7 – HF vs VHF Noise Figures

At HF – antenna and atmospheric noise is in the 20–30dB range, far exceeding the 10-12dB NF of a typical HF receiver. In other words, more noise is introduced to the receiver by the antenna and band conditions than the NF of the stages can introduce. For HF receiver applications, a NF of 4-6dB per transistor is sufficient. This is not the case at VHF.

At VHF/UHF – antenna and atmospheric noise is very low, often less than 10dB of noise power, making the overall system noise a function of the receiver, and the NF of the individual stages. At VHF/UHF, the NF of the transistors becomes very important, with transistors being selected with NF's in the 1.5dB to 2dB range not uncommon.

4. SWITCHING CHARACTERISTICS

The Switching Characteristics define the operating limits of the transistor when used in pulsed, digital logic, or switching applications. QRP switching circuits include T-R switching, CW keying and band switching circuits using transistors. These are really large-signal characteristics, since the transistor is being driven from cut-off to saturation in most switching applications.

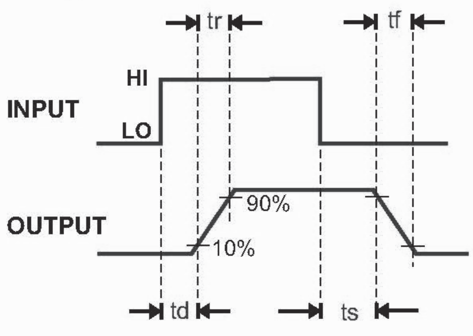
Table 8 – SWITCHING CHARACTERISTICS

		2N 2222	2N 2222A	2N 3904	2N 4401	MMBT 3904
Delay time	td	10ns	10ns	35ns	15ns	35ns
Rise time	tr	25ns	25ns	35ns	20ns	35ns
Storage time	ts	225ns	225ns	200ns	225ns	200ns
Fall time	tf	60ns	60ns	50ns	30ns	50ns

Fig. 7 illustrates the switching characteristics terms:
td, delay time is the time from the input L–H transition until the output begins to respond.
tr, rise time is the time it takes the output to go from 10% to 90% output voltage.
ts, storage time is the time from the input H–L transition until the output responds. This is usually the longest delay.
tf, fall time is the time it takes the output to go from 90% to 10% output voltage.

These switching times, in the tens of nanoseconds, are thousands of times faster than the requirements for QRP applications, and seldom a design criteria when selecting a transistor. It is presented here for completeness only.

Fig. 7 – Switching Characteristics



This tutorial should allow one to interpret the transistor data sheets, whether the complete data sheets from the manufacturer, or the abbreviated listings, such as found in the NTE Cross-Reference or in the ARRL Handbook. Many manufacturer's provide complete data sheets online. Understanding transistor specifications is essential in designing your own circuits, or identifying those "ham fest special" transistors and their suitability for your next project. Biasing transistors using these specs will be presented in a future *Handyman's* tutorial.

CONCLUSION

Top Salary

The top 10 percent of electrical engineers earn a monthly salary of $10,972 or more, according to the U.S. Bureau of Labor Statistics. This is equivalent to an annual full-time salary of $131,660, or an hourly wage of $63.30. Salaries in the range of $11,000 per month or more usually go to engineers with at least 10 years experience, according to ElectricalEngineerSalary.com. By way of comparison, the average monthly income for 154,250 electrical engineers nationwide was $7,433 in 2011, according to the bureau survey.

Electronics engineer: salary and conditions

- Starting salaries for newly graduated electrical/electronics engineers are in the range of £18,000-£29,000. Salaries for PhD holders may be higher.
- Qualified electronics engineers can earn between £35,000 and £45,000, with more senior engineers earning between £40,000 and £55,000. Highly experienced engineers can earn in excess of £65,000.
- Salaries vary from company to company, with some sectors attracting higher salaries due to demand. Hours of work can vary and this may affect the final salary. A 40-hour week is typical. However, the commercial pressures associated with electronic design mean that extra hours during evenings and weekends may be required at busy times in order to meet deadlines. Contract staff are often recruited to meet peaks in workloads.
- Work usually takes place in a laboratory or office environment, although some projects may require you to work in workshops, factories, or even outdoors.
- Self-employment and freelance work are sometimes possible for qualified engineers with a good track record and experience. Short-term contract work is possible, and is often arranged through agencies.

Job Outlook

Employment of electrical and electronics engineers is expected to grow 6 percent from 2010 to 2020, slower than the average for all occupations.

You can also get the qualification of electrical or electronics engineer here:

UNIVERSITY OF LIVERPOOL | ELECTRICAL ENGINEERING & ELECTRONICS

Imperial College London

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

TRINITY COLLEGE DUBLIN | THE UNIVERSITY OF DUBLIN
COLÁISTE NA TRÍONÓIDE, BAILE ÁTHA CLIATH

UNIVERSITY OF BIRMINGHAM

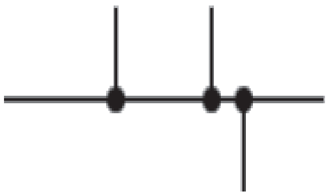
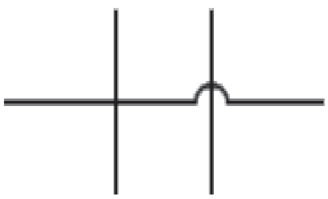
MANCHESTER 1824
The University of Manchester

APPENDIX 1

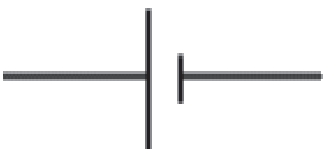
CIRCUIT SYMBOLS

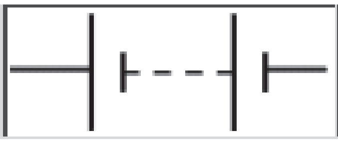
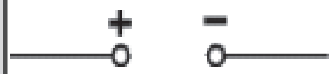
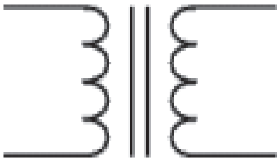
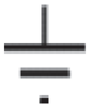
Circuit symbols are used in <u>circuit diagrams</u> which show how a circuit is connected together. The actual layout of the components is usually quite different from the circuit diagram. To build a circuit you need a different diagram showing the layout of the parts on <u>stripboard</u> or <u>printed circuit board</u>.

Wires and connections

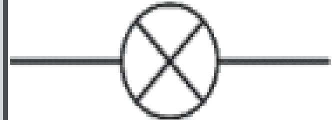
Component	Circuit Symbol	Function of Component
Wire		To pass current very easily from one part of a circuit to another.
Wires joined		A 'blob' should be drawn where wires are connected (joined), but it is sometimes omitted. Wires connected at 'crossroads' should be staggered slightly to form two T-junctions, as shown on the right.
Wires not joined		In complex diagrams it is often necessary to draw wires crossing even though they are not connected. I prefer the 'bridge' symbol shown on the right because the simple crossing on the left may be misread as a join where you have forgotten to add a 'blob'!

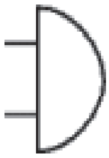
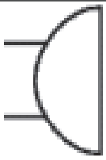
Power Supplies

Component	Circuit Symbol	Function of Component
Cell		Supplies electrical energy. The larger terminal (on the left) is positive (+). A single cell is often called a battery, but strictly a battery is two or more cells joined together.

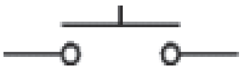
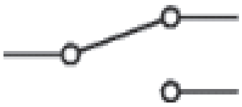
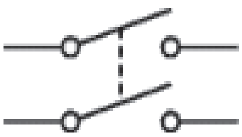
Battery		Supplies electrical energy. A battery is more than one cell. The larger terminal (on the left) is positive (+).
DC supply		Supplies electrical energy. DC = Direct Current, always flowing in one direction.
AC supply		Supplies electrical energy. AC = Alternating Current, continually changing direction.
Fuse		A safety device which will 'blow' (melt) if the current flowing through it exceeds a specified value.
Transformer		Two coils of wire linked by an iron core. Transformers are used to step up (increase) and step down (decrease) AC voltages. Energy is transferred between the coils by the magnetic field in the core. There is no electrical connection between the coils.
Earth (Ground)		A connection to earth. For many electronic circuits this is the 0V (zero volts) of the power supply, but for mains electricity and some radio circuits it really means the earth. It is also known as ground.

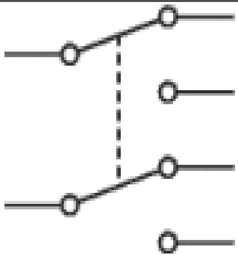
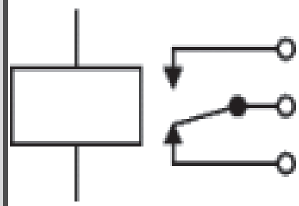
Output Devices: Lamps, Heater, Motor, etc.

Component	Circuit Symbol	Function of Component
Lamp (lighting)		A transducer which converts electrical energy to light. This symbol is used for a lamp providing illumination, for example a car headlamp or torch bulb.
Lamp (indicator)		A transducer which converts electrical energy to light. This symbol is used for a lamp which is an indicator, for example a warning light on a car dashboard.
Heater		A transducer which converts electrical energy to heat.

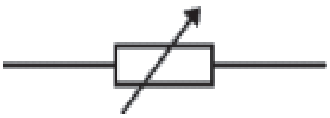
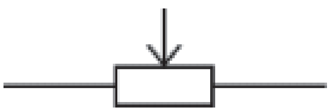
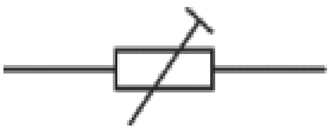
Motor		A transducer which converts electrical energy to kinetic energy (motion).
Bell		A transducer which converts electrical energy to sound.
Buzzer		A transducer which converts electrical energy to sound.
Inductor (Coil, Solenoid)		A coil of wire which creates a magnetic field when current passes through it. It may have an iron core inside the coil. It can be used as a transducer converting electrical energy to mechanical energy by pulling on something.

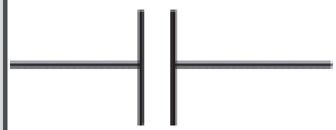
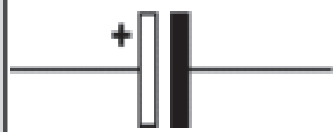
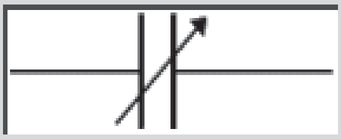
Switches

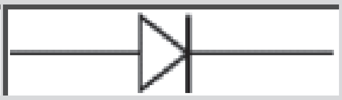
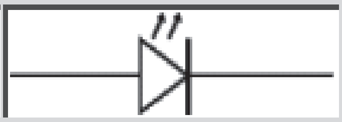
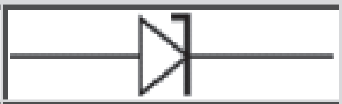
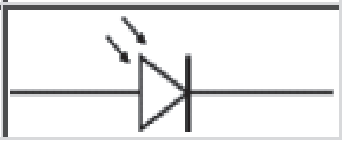
Component	Circuit Symbol	Function of Component
Push Switch (push-to-make)		A push switch allows current to flow only when the button is pressed. This is the switch used to operate a doorbell.
Push-to-Break Switch		This type of push switch is normally closed (on), it is open (off) only when the button is pressed.
On-Off Switch (SPST)		SPST = Single Pole, Single Throw. An on-off switch allows current to flow only when it is in the closed (on) position.
2-way Switch (SPDT)		SPDT = Single Pole, Double Throw. A 2-way changeover switch directs the flow of current to one of two routes according to its position. Some SPDT switches have a central off position and are described as 'on-off-on'.
Dual On-Off Switch (DPST)		DPST = Double Pole, Single Throw. A dual on-off switch which is often used to switch mains electricity because it can isolate both the live and neutral connections.

Reversing Switch (DPDT)		DPDT = Double Pole, Double Throw. This switch can be wired up as a reversing switch for a motor. Some DPDT switches have a central off position.
Relay		An electrically operated switch, for example a 9V battery circuit connected to the coil can switch a 230V AC mains circuit. NO = Normally Open, COM = Common, NC = Normally Closed.

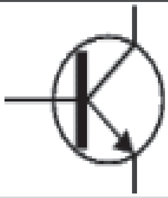
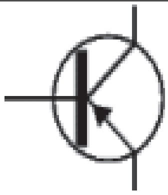
Resistors

Component	Circuit Symbol	Function of Component
Resistor		A resistor restricts the flow of current, for example to limit the current passing through an LED. A resistor is used with a capacitor in a timing circuit. Some publications still use the old resistor symbol: 
Variable Resistor (Rheostat)		This type of variable resistor with 2 contacts (a rheostat) is usually used to control current. Examples include: adjusting lamp brightness, adjusting motor speed, and adjusting the rate of flow of charge into a capacitor in a timing circuit.
Variable Resistor (Potentiometer)		This type of variable resistor with 3 contacts (a potentiometer) is usually used to control voltage. It can be used like this as a transducer converting position (angle of the control spindle) to an electrical signal.
Variable Resistor (Preset)		This type of variable resistor (a preset) is operated with a small screwdriver or similar tool. It is designed to be set when the circuit is made and then left without further adjustment. Presets are cheaper than normal variable resistors so they are often used in projects to reduce the cost.

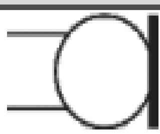
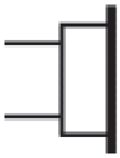
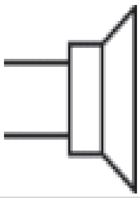
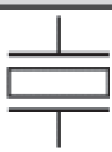
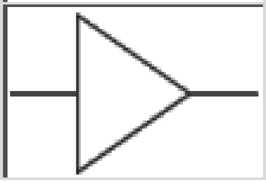
Capacitors		
Component	**Circuit Symbol**	**Function of Component**
Capacitor		A capacitor stores electric charge. A capacitor is used with a resistor in a timing circuit. It can also be used as a filter, to block DC signals but pass AC signals.
Capacitor, polarised		A capacitor stores electric charge. This type must be connected the correct way round. A capacitor is used with a resistor in a timing circuit. It can also be used as a filter, to block DC signals but pass AC signals.
Variable Capacitor		A variable capacitor is used in a radio tuner.
Trimmer Capacitor		This type of variable capacitor (a trimmer) is operated with a small screwdriver or similar tool. It is designed to be set when the circuit is made and then left without further adjustment.

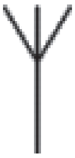
Diodes		
Component	**Circuit Symbol**	**Function of Component**
Diode		A device which only allows current to flow in one direction.
LED Light Emitting Diode		A transducer which converts electrical energy to light.
Zener Diode		A special diode which is used to maintain a fixed voltage across its terminals.
Photodiode		A light-sensitive diode.

Transistors

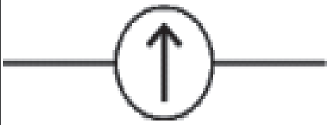
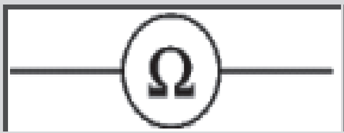
Component	Circuit Symbol	Function of Component
Transistor NPN		A transistor amplifies current. It can be used with other components to make an amplifier or switching circuit.
Transistor PNP		A transistor amplifies current. It can be used with other components to make an amplifier or switching circuit.
Phototransistor		A light-sensitive transistor.

Audio and Radio Devices

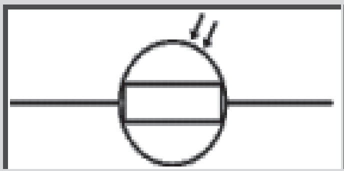
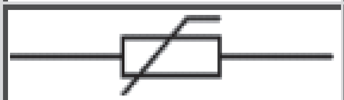
Component	Circuit Symbol	Function of Component
Microphone		A transducer which converts sound to electrical energy.
Earphone		A transducer which converts electrical energy to sound.
Loudspeaker		A transducer which converts electrical energy to sound.
Piezo Transducer		A transducer which converts electrical energy to sound.
Amplifier (general symbol)		An amplifier circuit with one input. Really it is a block diagram symbol because it represents a circuit rather than just one component.

Aerial (Antenna)		A device which is designed to receive or transmit radio signals. It is also known as an antenna.

Meters and Oscilloscope

Component	Circuit Symbol	Function of Component
Voltmeter		A voltmeter is used to measure voltage. The proper name for voltage is 'potential difference', but most people prefer to say voltage!
Ammeter		An ammeter is used to measure current.
Galvanometer		A galvanometer is a very sensitive meter which is used to measure tiny currents, usually 1mA or less.
Ohmmeter		An ohmmeter is used to measure resistance. Most multimeters have an ohmmeter setting.
Oscilloscope		An oscilloscope is used to display the shape of electrical signals and it can be used to measure their voltage and time period.

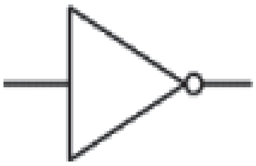
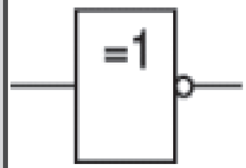
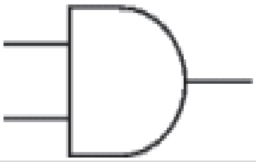
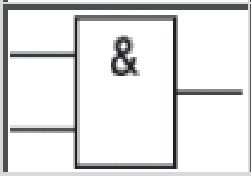
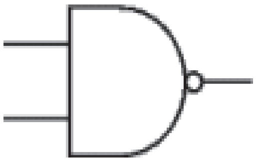
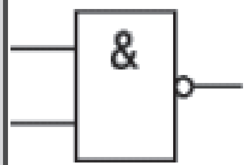
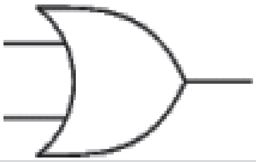
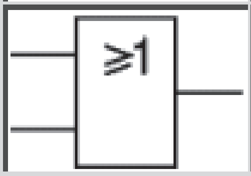
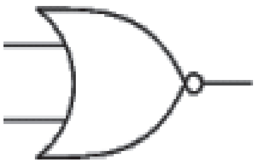
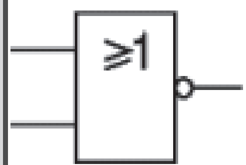
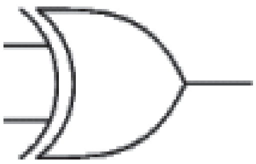
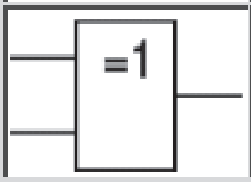
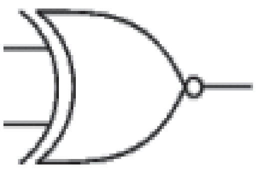
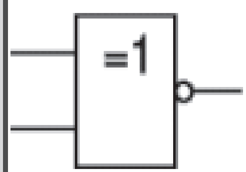
Sensors (input devices)

Component	Circuit Symbol	Function of Component
LDR		A transducer which converts brightness (light) to resistance (an electrical property). LDR = Light Dependent Resistor
Thermistor		A transducer which converts temperature (heat) to resistance (an electrical property).

Logic Gates

Logic gates process signals which represent **true** (1, high, +Vs, on) or **false** (0, low, 0V, off).

There are two sets of symbols: traditional and IEC (International Electrotechnical Commission).

Gate Type	Traditional Symbol	IEC Symbol	Function of Gate
NOT			A NOT gate can only have one input. The 'o' on the output means 'not'. The output of a NOT gate is the inverse (opposite) of its input, so the output is true when the input is false. A NOT gate is also called an inverter.
AND			An AND gate can have two or more inputs. The output of an AND gate is true when all its inputs are true.
NAND			A NAND gate can have two or more inputs. The 'o' on the output means 'not' showing that it is a Not AND gate. The output of a NAND gate is true unless all its inputs are true.
OR			An OR gate can have two or more inputs. The output of an OR gate is true when at least one of its inputs is true.
NOR			A NOR gate can have two or more inputs. The 'o' on the output means 'not' showing that it is a Not OR gate. The output of a NOR gate is true when none of its inputs are true.
EX-OR			An EX-OR gate can only have two inputs. The output of an EX-OR gate is true when its inputs are different (one true, one false).
EX-NOR			An EX-NOR gate can only have two inputs. The 'o' on the output means 'not' showing that it is a Not EX-OR gate. The output of an EX-NOR gate is true when its inputs are the same (both true or both false).

Sets of circuit symbols to download

APPENDIX 2

ARITHMETIC SYMBOLS

+	plus	/'plʌs/
-	minus	/'maɪnəs/
±	plus or minus	/'plʌs ɔ: 'maɪnəs/
×	multiplied by	/'mʌltɪplaɪd baɪ/
/	over; divided by	/'əuvə/ /dɪ'vaɪdəd/
÷	divided	/dɪ'vaɪdəd/
=	equals	/'ɪ:kwəlz/
≈	approximately, similar	/ə'prɒksəmətlɪ / /'sɪmɪlə/
≡	equivalent to; identical	/ɪ'kwɪvələnt tu/ /aɪ'dentɪkl/
≠	not equal to	/'nɒt 'i:kwəl tu/
>	greater than	/'greɪtə ðən/
<	less than	/'les ðən/
>>	much greater than	/'mʌtʃ 'greɪtə ðən/
<<	much less than	/'mʌtʃ 'les ðən/
⊥	perpendicular to	/pɜ:pən'dɪkjulə tu/
∥	parallel to	/'pærəlel tu/
^{2}	squared	/'skweəd/
^{3}	cubed	/'kju:bd/
^{4}	to the fourth; to the power four	/tə ðə 'fɔ:θ/ /tə ðə 'pauə fɔ:/
^{n}	to the n; to the nth; to the power n	/tə ðɪ en/ /tə ðɪ enθ/ /tə ðɪ 'pauə en/
√	root; square root	/ru:t/ /skweə ru:t/
$\sqrt[3]{}$	cube root	/kju:b ru:t/
$\sqrt[4]{}$	fourth root	/fɔ:θ ru:t/
%	percent	/pər'sent/
∞	infinity	/ɪn'fɪnətɪ/
˙	dot	/dɒt/
¨	double dot	/dʌbl dɒt/
:	is to, ratio of	/reɪʃɪəu/
f(x) fx	f; function	/ef/ /'fʌŋkʃən/
f'(x)	f dash; derivative	/dæʃ/ /dɪ'rɪvətɪv/
f''(x)	f double-dash; second derivative	/'dʌbl dæʃ/ /'sekənd dɪ'rɪvətɪv/
f'''(x)	f triple-dash; f treble-dash; third derivative	/trɪpl dæʃ/ /trebl dæʃ/ /θɜ:d dɪ'rɪvətɪv /
$f^{(4)}$	f four; fourth derivative	/fɔ:θ dɪ'rɪvətɪv/
∂	partial derivative, delta	/'pɑ:ʃəl dɪ'rɪvətɪv/ /deltə/
∫	integral	/'ɪntɪgrəl/
∑	sum	/sʌm/
log	log	/lɒg/
∴	therefore	/'ðɛəfɔ:/
∵	because	/bɪ'kɒz/
→	gives, leads to, approaches	/gɪvz/ /li:dz tu/ /əprəutʃəz/
/	per	/pɜ:/
∈	belongs to; a member of; an element of	/bɪ'lɒŋz/ /'membə/ /'elɪmənt/

∉	does not belongs to; is not a member of; is not an element of	/nɒt bɪ'lɒŋ/ /nɒt ə 'membə/ /nɒt ən 'elɪmənt/
⊂	contained in; a proper subset of	/kən'teɪnd ɪn/ /'prɒpə 'sʌbset/
⊆	contained in; subset	/'sʌbset/
⋂	intersection	/'ɪntərsekʃən/
⋃	union	/'ju:nɪən /
cos x	cos x; cosine x	/kɒz/
sin x	sine x	/saɪn/
tan x	tangent x	/tan/
$\|x\|$	mod x; modulus x	/mɒd/ /'mɒdjuləs/
°C	degrees Centigrade	/dɪ'gri:z sentɪgreɪd/
°F	degrees Fahrenheit	/dɪ'gri:z 'færənhaɪt/
°K	degrees Kelvin	/dɪ'gri:z 'kelvɪn/
mm	millimetre	/'mɪlɪmi:tə/
cm	centimetre	/'sentɪmi:tə/
cc, cm^3	cubic centimeter; centimeter cubed	/kju:bɪk 'sentɪmi:tə/ /'sentɪmi:tə 'kju:bd/
m	metre	/'mi:tə/
km	kilometre	/kɪ'lɒmɪtə/
mg	milligram	/'mɪlɪgræm/
g	gram	/græm/
kg	kilogram	/'kɪləgræm/
AC	A.C.	/eɪ si:/
DC	D.C.	/di: si:/

Examples

$x + 1$	x plus one
$x - 1$	x minus one
$x \pm 1$	x plus or minus one
xy	x y; x times y; x multiplied by y
$(x - y)(x + y)$	x minus y, x plus y
x/y	x over y; x divided by y
$x \div y$	x divided by y
$x = 5$	x equals 5; x is equal to 5
$x \approx y$	x is approximately equal to y
$x \equiv y$	x is equivalent to y; x is identical with y
$x \neq y$	x is not equal to y
$x > y$	x is greater than y
$x < y$	x is less than y
$x \geq y$	x is greater than or equal to y
$x \leq y$	x is less than or equal to y
$0 < x < 1$	zero is less than x is less than 1; x is greater than zero and less than 1
$0 \leq x \leq 1$	zero is less than or equal to x is less than or equal to 1; x is greater than or equal to zero and less than or equal to 1
x^2	x squared
x^3	x cubed
x^4	x to the fourth; x to the power four

x^n	x to the n; x to the nth; x to the power n
x^{-n}	x to the minus n; x to the power of minus n
$\sqrt{x}$	root x; square root x; the square root of x
$\sqrt[3]{x}$	the cube root of x
$\sqrt[4]{x}$	the fourth root of x
$\sqrt[n]{x}$	the nth root of x
$(x + y)^2$	x plus y all squared
$(x/y)^2$	x over y all squared
$n!$	n factorial; factorial n
$x\%$	x percent
∞	infinity
$x \propto y$	x varies as y; x is (directly) proportional to y
$x \propto 1/y$	x varies as one over y; x is indirectly proportional to y
$\dot{x}$	x dot
$\ddot{x}$	x double dot
$f(x)$ fx	f of x; the function of x
$f'(x)$	f dash x; the (first) derivative of f with respect to x
$f''(x)$	f double-dash x; the second derivative of f with respect to x
$f'''(x)$	f triple-dash x; f treble-dash x; the third derivative of f with respect to x
$f^{(4)}$	f four x; the fourth derivative of f with respect to x
∂v	the partial derivative of v
$\frac{\partial v}{\partial \theta}$	delta v by delta theta, the partial derivative of v with respect to θ
$\frac{\partial^2}{\partial}\frac{v}{\theta^2}$	delta two v delta theta squared; the second partial derivative of v with respect to θ
dv	the derivative of v
$\frac{dv}{d\theta}$	d v by d theta, the derivative of v with respect to theta
$\frac{d^2}{d}\frac{v}{\theta^2}$	d 2 v by d theta squared, the second derivative of v with respect to theta
$\int$	integral
$\int_0^\infty$	integral from zero to infinity
$\sum$	sum
$\sum_{i=1}^{n}$	the sum from i equals 1 to n
w.r.t.	with respect to
$\log_e y$	log to the base e of y; log y to the base e; natural log (of) y
$\therefore$	therefore
$\because$	because
$\rightarrow$	gives, approaches
m/sec	meters per second
$x \in A$	x belong to F; x is a member of A; x is an element of A
18 °C	eighteen degrees Centigrade
70 °F	seventy degrees Fahrenheit

APPENDIX 3

DIODES AND ISOLATORS APPLICATION

NXP Semiconductors | **Product data sheet**

High-speed diodes — 1N4148; 1N4448

FEATURES

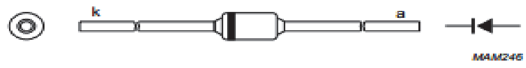
- Hermetically sealed leaded glass SOD27 (DO-35) package
- High switching speed: max. 4 ns
- General application
- Continuous reverse voltage: max. 100 V
- Repetitive peak reverse voltage: max. 100 V
- Repetitive peak forward current: max. 450 mA.

APPLICATIONS

- High-speed switching.

DESCRIPTION

The 1N4148 and 1N4448 are high-speed switching diodes fabricated in planar technology, and encapsulated in hermetically sealed leaded glass SOD27 (DO-35) packages.



The diodes are type branded.

Fig.1 Simplified outline (SOD27; DO-35) and symbol.

MARKING

TYPE NUMBER	MARKING CODE
1N4148	1N4148PH or 4148PH
1N4448	1N4448

ORDERING INFORMATION

TYPE NUMBER	PACKAGE		
	NAME	DESCRIPTION	VERSION
1N4148	–	hermetically sealed glass package; axial leaded; 2 leads	SOD27
1N4448			

NXP Semiconductors | Product data sheet

High-speed diodes — 1N4148; 1N4448

LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 60134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{RRM}	repetitive peak reverse voltage		–	100	V
V_R	continuous reverse voltage		–	100	V
I_F	continuous forward current	see Fig.2; note 1	–	200	mA
I_{FRM}	repetitive peak forward current		–	450	mA
I_{FSM}	non-repetitive peak forward current	square wave; T_j = 25 °C prior to surge; see Fig.4			
		t = 1 µs	–	4	A
		t = 1 ms	–	1	A
		t = 1 s	–	0.5	A
P_{tot}	total power dissipation	T_{amb} = 25 °C; note 1	–	500	mW
T_{stg}	storage temperature		–65	+200	°C
T_j	junction temperature		–	200	°C

Note

1. Device mounted on an FR4 printed-circuit board; lead length 10 mm.

DIGITAL ISOLATORS

Features

- High-speed operation
  - DC to 150 Mbps
- No start-up initialization required
- Wide Operating Supply Voltage: 2.6–5.5 V
- Up to 5000 V_{RMS} isolation
- High electromagnetic immunity
- Ultra low power (typical)
  5 V Operation:
  - < 2.6 mA/channel at 1 Mbps
  - < 6.8 mA/channel at 100 Mbps

  2.70 V Operation:
  - < 2.3 mA/channel at 1 Mbps
  - < 4.6 mA/channel at 100 Mbps
- Schmitt trigger inputs
- Selectable fail-safe mode
  - Default high or low output
- Precise timing (typical)
  - 11 ns propagation delay max
  - 1.5 ns pulse width distortion
  - 0.5 ns channel-channel skew
  - 2 ns propagation delay skew
  - 5 ns minimum pulse width
- Transient immunity 45 kV/µs
- Wide temperature range
  - –40 to 125 °C at 150 Mbps
- RoHS compliant packages
  - SOIC-16 wide body
  - SOIC-8 narrow body

Applications

- Industrial automation systems
- Medical electronics
- Hybrid electric vehicles
- Isolated switch mode supplies
- Isolated ADC, DAC
- Motor control
- Power inverters
- Communication systems

Low Profile, High Current IHLP® Inductors

FEATURES

- Lowest height (3.0 mm) in this package footprint
- Shielded construction
- Frequency range up to 5.0 MHz
- Lowest DCR/µH, in this package size
- Handles high transient current spikes without saturation
- Ultra low buzz noise, due to composite construction
- Compliant to RoHS Directive 2002/95/EC

RoHS
COMPLIANT
GREEN (5-2008)**

APPLICATIONS

- PDA/notebook/desktop/server applications
- High current POL converters
- Low profile, high current power supplies
- Battery powered devices
- DC/DC converters in distributed power systems
- DC/DC converter for Field Programmable Gate Array (FPGA)

APPENDIX 4

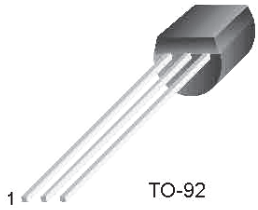
ELECTRICAL CHARACTERISTICS

FAIRCHILD
SEMICONDUCTOR®

BC546/547/548/549/550

Switching and Applications

- High Voltage: BC546, V_{CEO}=65V
- Low Noise: BC549, BC550
- Complement to BC556 ... BC560



TO-92

1. Collector 2. Base 3. Emitter

NPN Epitaxial Silicon Transistor

Absolute Maximum Ratings T_a=25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{CBO}	Collector-Base Voltage : BC546	80	V
	: BC547/550	50	V
	: BC548/549	30	V
V_{CEO}	Collector-Emitter Voltage : BC546	65	V
	: BC547/550	45	V
	: BC548/549	30	V
V_{EBO}	Emitter-Base Voltage : BC546/547	6	V
	: BC548/549/550	5	V
I_C	Collector Current (DC)	100	mA
P_C	Collector Power Dissipation	500	mW
T_J	Junction Temperature	150	°C
T_{STG}	Storage Temperature	-65 ~ 150	°C

Electrical Characteristics T_a=25°C unless otherwise noted

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Units
I_{CBO}	Collector Cut-off Current	V_{CB}=30V, I_E=0			15	nA
h_{FE}	DC Current Gain	V_{CE}=5V, I_C=2mA	110		800	
V_{CE} (sat)	Collector-Emitter Saturation Voltage	I_C=10mA, I_B=0.5mA		90	250	mV
		I_C=100mA, I_B=5mA		200	600	mV
V_{BE} (sat)	Base-Emitter Saturation Voltage	I_C=10mA, I_B=0.5mA		700		mV
		I_C=100mA, I_B=5mA		900		mV
V_{BE} (on)	Base-Emitter On Voltage	V_{CE}=5V, I_C=2mA	580	660	700	mV
		V_{CE}=5V, I_C=10mA			720	mV
f_T	Current Gain Bandwidth Product	V_{CE}=5V, I_C=10mA, f=100MHz		300		MHz
C_{ob}	Output Capacitance	V_{CB}=10V, I_E=0, f=1MHz		3.5	6	pF
C_{ib}	Input Capacitance	V_{EB}=0.5V, I_C=0, f=1MHz		9		pF
NF	Noise Figure : BC546/547/548	V_{CE}=5V, I_C=200µA		2	10	dB
	: BC549/550	f=1KHz, R_G=2KΩ		1.2	4	dB
	: BC549	V_{CE}=5V, I_C=200µA		1.4	4	dB
	: BC550	R_G=2KΩ, f=30~15000MHz		1.4	3	dB

h_{FE} Classification

Classification	A	B	C
h_{FE}	110 ~ 220	200 ~ 450	420 ~ 800

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