

Introduction

Rather than try to give you the material so that you can answer the questions from “first principles,” I will provide enough information that you can recognize the correct answer to each question.

In several case, the correct answer among the available answer choices is also a reasonable explanation of the correct answer. In that case, I just quote the correct answer.

Chapter 5 Notes

In no particular order, the necessary “nuggets:”

1. On logic circuit symbols a curved output means “and” and a pointed output means “or.” I know: ‘O’ is rounded and ‘A’ is pointed; go figure. A little circle on the output means “not.”
2. The input-output relationships of different type of two input logic gate:

input 1	0	0	1	1
input 2	0	1	0	1
ZERO	0	0	0	0
AND	0	0	0	1
Not I1 implies I2	0	0	1	0
I1	0	0	1	1
Not I2 implies I1	0	1	0	0
I2	0	1	0	1
XOR or not equals	0	1	1	0
OR	0	1	1	1
NOR	1	0	0	0
NXOR or equals	1	0	0	1
Not I2	1	0	1	0
I2 implies I1	1	0	1	1
Not I1	1	1	0	0
I1 implies I2	1	1	0	1
NAND	1	1	1	0
ONE	1	1	1	1

3. The common semiconductor elements are carbon, silicon and germanium, which have four electrons in their outer most shell of electrons. Aluminium phosphide, gallium arsenide, indium antimonide are used for special purpose semiconductors, particularly at extremely high frequencies. These compounds are a pairing of an element with three electrons and of five electrons in their outer shell. Diamond semiconductors can operate at several hundred degrees Celisius.

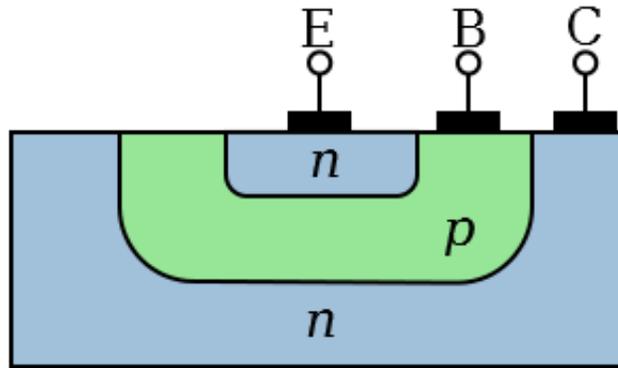
The elemental semiconductors are “doped” (extremely minor amounts of impurities) with elements adjacent horizontally in the periodic table to cause highly mobile electrons or absences of electrons (“holes”) in the crystalline structure. For example, doping silicon with aluminum (3 electrons) causes “holes” and P-type material and doping with phosphorus (5 electrons) causes free electrons and N-type material.

<http://periodic.lanl.gov/index.shtml>

4. Junction transistors are current controlled and therefore have relatively low input impedance. Field effect devices, including vacuum tubes, are voltage controlled and therefore have relatively high input impedance. Vacuum tubes are implicitly diodes as well. Transistor emitter and collector or source and drain elements can be reversed and the device would operate somewhat.

5. In semiconductor schematic symbols, the arrow indicates what type of material the control element is. In a bipolar junction transistor the control element is the base. In a field effect transistor (FET) the control element is the gate. An inward arrow indicates that the control element is N-material. An outward arrow indicates that the control element is P-material.
6. In junction FET devices, there is junction between the channel and the gate: the gate is connected to the bar in the symbol. In MOSFET devices, there is insulation between the channel and the gates: gates may be multiple and they look like capacitors in the symbol for the device.

Schematic diagram of a NPN bipolar transistor:



The current from the emitter is the sum of the base and collector currents.

Question by question explanations:

- E6A01 In what application is gallium arsenide used as a semiconductor material in preference to germanium or silicon?
At microwave frequencies.
At microwave frequencies. GaAs has some electronic properties which are superior to those of silicon. It has a higher saturated electron velocity and higher electron mobility, allowing transistors made from it to function at frequencies in excess of 250 GHz.
- E6A02 Which of the following semiconductor materials contains excess free electrons?
N-type.
Excess electrons indicates N-type material.
- E6A03 What are the majority charge carriers in P-type semiconductor material?
Holes.
Deficiency of electrons is P-type material. Places where electrons are missing are sometimes called "holes."
- E6A04 What is the name given to an impurity atom that adds holes to a semiconductor crystal structure?
Acceptor impurity.
An impurity that accepts electrons and makes "holes" is an acceptor.
- E6A05 What is the alpha of a bipolar junction transistor
The change of collector current with respect to emitter current.
This is a poorly worded question.

$$\alpha_F = \frac{I_C}{I_E} = \frac{\beta_F}{1 + \beta_F + 1}$$

$$\beta_F = \frac{I_C}{I_B} = \frac{\alpha_F}{1 - \alpha_F}$$

In a bipolar junction transistor, the ratio of collector current to emitter current is called alpha (α). It is always less than one and usually ≥ 0.99 .

E6A06 What is the beta of a bipolar junction transistor?

The change in collector current with respect to base current.

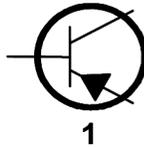
$$\alpha_F = \frac{I_C}{I_E} = \frac{\beta_F}{1 + \beta_F + 1}$$

$$\beta_F = \frac{I_C}{I_B} = \frac{\alpha_F}{1 - \alpha_F}$$

In a bipolar junction transistor, the ratio of controlled (collector) current to controlling current (base) is called beta (β).

E6A07 In Figure E6-1, what is the schematic symbol for a PNP transistor?

1.



E6A08 What term indicates the frequency at which the grounded-base current gain of a transistor has decreased to 0.7 of the gain obtainable at 1 kHz?

Alpha cutoff frequency.

A 3db power reduction requires a $\sqrt{(\frac{1}{2})}$ current reduction from the $P = I^2R$ rule.

Just memorize the answer.

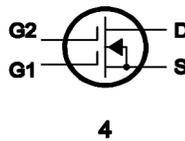
E6A09 What is a depletion-mode FET?

An FET that exhibits a current flow between source and drain when no gate voltage is applied.

Depletion-mode mode means that the device turns off when a control voltage is applied to the gate.

E6A10 In Figure E6-2, what is the schematic symbol for an N-channel dual-gate MOSFET?

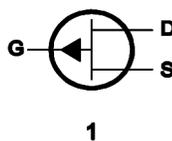
4.



See the “nuggets.” You are looking for two insulated gates and an inward pointing arrow.

E6A11 In Figure E6-2, what is the schematic symbol for a P-channel junction FET?

1.



See the “nuggets.” You are looking for one gate connected to the channel and an outward pointing arrow.

E6A12 Why do many MOSFET devices have internally connected Zener diodes on the gates?

To reduce the chance of the gate insulation being punctured by static discharges or excessive voltages.

The built-in Zener diode has a lower reverse breakdown voltage than the insulator isolating the gate from the channel. Its purpose is to protect the gate insulation.

E6A13 What do the initials CMOS stand for?

Complementary **M**etal-**O**xide **S**emiconductor.

E6A14 How does DC input impedance at the gate of a field-effect transistor compare with the DC input impedance of a bipolar transistor?

An FET has high input impedance; a bipolar transistor has low input impedance

See the “nuggets.”

E6A15 Which of the following semiconductor materials contains an excess of holes in the outer shell of electrons?

P-type.

See the “nuggets.”

E6A16 What are the majority charge carriers in N-type semiconductor material?

Free electrons.

See the “nuggets.”

E6A17 What are the names of the three terminals of a field-effect transistor?

Gate, drain, source.

E6B01 What is the most useful characteristic of a Zener diode?

A constant voltage drop under conditions of varying current.

E6B02 What is an important characteristic of a Schottky diode as compared to an ordinary silicon diode when used as a power supply rectifier?

Less forward voltage drop.

This has two useful effects: less power loss in the rectifier diodes and less switching noise.

E6B03 What special type of diode is capable of both amplification and oscillation?

Tunnel.

Tunnel and Gunn diodes are capable of amplification and therefore also oscillation. Gunn diodes are not among the listed selections.

E6B04 What type of semiconductor device is designed for use as a voltage-controlled capacitor?

Varactor diode.

E6B05 What characteristic of a PIN diode makes it useful as an RF switch or attenuator?

A large region of intrinsic material.

The selected answer is the best of the answers. “Extremely high reverse breakdown voltage” and “ability to dissipate large amounts of power” are simply wrong. “Reverse bias controls its forward voltage drop” is wrong because it is forward bias that controls the resistance of the PIN diode. It is “a large region of intrinsic material” that creates the effect that results in the variable resistance of the PIN diode.

<http://www.microsemi.com/en/sites/default/files/micnotes/701.pdf>

E6B06 Which of the following is a common use of a hot-carrier diode?

As a VHF / UHF mixer or detector.

A Schottky or hot carrier diode has a low forward drop and a very fast switching time. This makes the diode a very effective mixer or detector.

E6B07 What is the failure mechanism when a junction diode fails due to excessive current?

Excessive junction temperature.

$P = I \times E$. The forward drop voltage times the current becomes heat in the device. Get the device too hot and it fails.

E6B08 Which of the following describes a type of semiconductor diode?

Metal-semiconductor junction.

The others are either not diodes or not semiconductors.

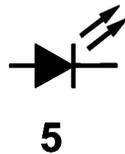
E6B09 What is a common use for point contact diodes?

As an RF detector.

Metal-semiconductor a.k.a. Schottky a.k.a. hot carrier a.k.a. point contact.

E6B10 In Figure E6-3, what is the schematic symbol for a light-emitting diode?

5.



A diode symbol with two outward point arrows for the light that is emitted.

E6B11 What is used to control the attenuation of RF signals by a PIN diode?

Forward DC bias current.

<http://www.microsemi.com/en/sites/default/files/micnotes/701.pdf>

E6B12 What is one common use for PIN diodes?

As an RF switch.

PIN diodes are suitable for attenuators, fast switches, photodetectors, and high voltage power electronics applications. Of the answer selections available, RF switch is the best choice.

E6B13 What type of bias is required for an LED to emit light?

Forward bias.

E6C01 What is the recommended power supply voltage for TTL series integrated circuits?

5 volts.

E6C02 What logic state do the inputs of a TTL device assume if they are left open?

A logic-high state.

Open inputs on a TTL integrated circuit assume a logic high condition because of leakage within the circuit.

E6C03 Which of the following describes tri-state logic?

Logic devices with 0, 1, and high impedance output states.

Do not confuse "tri-state" and "ternary" logic.

E6C04 Which of the following is the primary advantage of tri-state logic?

Ability to connect many device outputs to a common bus.

This ability permits “wired or”.

E6C05 Which of the following is an advantage of CMOS logic devices over TTL devices?

Lower power consumption.

E6C06 Why do CMOS digital integrated circuits have high immunity to noise on the input signal or power supply?

The input switching threshold is about one-half the power supply voltage.

E6C07 In Figure E6-5, what is the schematic symbol for an AND gate?

1.



1

See the “nuggets.” Output is curved and no little circle.

E6C08 In Figure E6-5, what is the schematic symbol for a NAND gate?

2.



2

See the “nuggets.” Output is curved and a little circle.

E6C09 In Figure E6-5, what is the schematic symbol for an OR gate?

3.



3

See the “nuggets.” Output is pointed and no little circle.

E6C10 In Figure E6-5, what is the schematic symbol for a NOR gate?

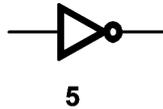
4.



4

See the “nuggets.” Output is pointed and a little circle.

E6C11 In Figure E6-5, what is the schematic symbol for the NOT operation (inverter)?
5.



See the “nuggets.” Single input and a little circle.

E6C12 What is BiCMOS logic?

An integrated circuit logic family using both bipolar and CMOS transistors.

E6C13 Which of the following is an advantage of BiCMOS logic?

It has the high input impedance of CMOS and the low output impedance of bipolar transistors.

<http://en.wikipedia.org/wiki/BiCMOS>

E6D01 What is cathode ray tube (CRT) persistence?

The length of time the image remains on the screen after the beam is turned off.

E6D02 Exceeding what design rating can cause a cathode ray tube (CRT) to generate X-rays?

The anode voltage.

All CRTs generate X-rays. As a matter of safety, the face is typically made of thick lead glass so as to be highly shatter-resistant and to block most X-ray emissions, particularly if the CRT is used in a consumer product.[from Wikipedia Cathode Ray Tube article] With an increased anode voltage, the electrons will be more resistant to deflection. The image will be smaller.

E6D03 Which of the following is true of a charge-coupled device (CCD)?

It samples an analog signal and passes it in stages from the input to the output. A camera sensor is a CCD.

E6D04 What function does a charge-coupled device (CCD) serve in a modern video camera?

It stores photogenerated charges as signals corresponding to pixels.

These analog photogenerated charges are sampled and passed in stages sequentially to the output. See E6D03.

E6D05 What is a liquid-crystal display (LCD)?

A display using a crystalline liquid which, in conjunction with polarizing filters, becomes opaque when voltage is applied.

The default state can be either transparent or opaque. When voltage is applied, the device switches to the other state.

E6D13 What type of CRT deflection is better when high-frequency waveforms are to be displayed on the screen?

Electrostatic.

Electrostatic deflection works better at high or variable frequencies. Electromagnetic works best at low, fixed frequencies such as occur in TV CRTs. The other answers are nonsense.

E6D14 Which is NOT true of a charge-coupled device (CCD)?

It is commonly used as an analog-to-digital converter.

Note well the NOT in the question! A CCD is not commonly used as an analog to digital converter.

E6D15 What is the principle advantage of liquid-crystal display (LCD) devices over other types of display devices?

They consume less power.

LCD displays are commonly used in micropower applications, such as digital watches which may run continuously for five years on a button cell.

- E6E04 What is the most common input and output impedance of circuits that use MMICs?
50 ohms.
Monolithic Microwave Integrated Circuit.
- E6E05 Which of the following noise figure values is typical of a low-noise UHF preamplifier?
2 dB.
http://en.wikipedia.org/wiki/Low-noise_amplifier
Modern LNAs have noise figures of about 1db. The closest answer is 2db.
- E6E06 What characteristics of the MMIC make it a popular choice for VHF through microwave circuits?
Controlled gain, low noise figure, and constant input and output impedance over the specified frequency range.
- E6E07 Which of the following techniques is typically used to construct a MMIC-based microwave amplifier?
Microstrip construction.
Microstrip construction is parallel conductor strips which behave similar to a wave guide.
- E6E08 How is power-supply voltage normally furnished to the most common type of monolithic microwave integrated circuit (MMIC)?
Through a resistor and/or RF choke connected to the amplifier output lead.
- E6E11 Which of the following materials is likely to provide the highest frequency of operation when used in MMICs?
Gallium nitride.
- E6F01 What is photoconductivity?
The increased conductivity of an illuminated semiconductor.
- E6F02 What happens to the conductivity of a photoconductive material when light shines on it?
It increases.
- E6F03 What is the most common configuration of an optoisolator or optocoupler?
An LED and a phototransistor.
A light source, often a **Light Emitting Diode**, and a photoconductor or phototransistor.
- E6F04 What is the photovoltaic effect?
The conversion of light to electrical energy.
The light photons create charge pairs (free electrons and holes) near the PN junction in the semiconductors. The electrostatic field near the PN junction sweep the charge pairs to outside of the solar cell. The electron then travel around the circuit, as a current, to combine with the holes.
- E6F05 Which of the following describes an optical shaft encoder?
A device which detects rotation of a control by interrupting a light source with a patterned wheel.
- E6F06 Which of these materials is affected the most by photoconductivity?
A crystalline semiconductor.
- E6F07 What is a solid state relay?
A device that uses semiconductor devices to implement the functions of an electromechanical relay.
- E6F08 Why are optoisolators often used in conjunction with solid state circuits when switching 120 VAC?
Optoisolators provide a very high degree of electrical isolation between a control circuit and the circuit being switched.

E6F09 What is the efficiency of a photovoltaic cell?

The relative fraction of light that is converted to current.

The ratio of the electrical energy available at the photovoltaic cell output to the energy of the light arriving at the surface of the cell.

E6F10 What is the most common type of photovoltaic cell used for electrical power generation?

Silicon.

E6F11 Which of the following is the approximate open-circuit voltage produced by a fully-illuminated silicon photovoltaic cell?

0.5 V.

E6F12 What absorbs the energy from light falling on a photovoltaic cell?

Electrons.

The correct answer is: electrons and holes.

E7A01 Which of the following is a bistable circuit?

A flip-flop.

E7A02 How many output level changes are obtained for every two trigger pulses applied to the input of a T flip-flop circuit?

Two.

Once up, once down. A single flop-flip circuit generates a single output for each two changes of state. A T flip-flop acts as a divide-by-2 circuit.

E7A03 Which of the following can divide the frequency of a pulse train by 2?

A flip-flop.

E7A04 How many flip-flops are required to divide a signal frequency by 4?

2.

$2 \times 2 = 4$. Two flip-flop stages in series.

E7A05 Which of the following is a circuit that continuously alternates between two states without an external clock?

Astable multivibrator.

E7A06 What is a characteristic of a monostable multivibrator?

It switches momentarily to the opposite binary state and then returns, after a set time, to its original state.

E7A07 What logical operation does a NAND gate perform?

It produces a logic "0" at its output only when all inputs are logic "1".

E7A08 What logical operation does an OR gate perform?

It produces a logic "1" at its output if any or all inputs are logic "1".

E7A09 What logical operation is performed by a two-input exclusive NOR gate?

It produces a logic "0" at its output if any single input is a logic "1"?

A XOR 2-input gate produces a 1 if its inputs are different. A NXOR 2-input gate produces a 1 if its inputs are the same.

E7A10 What is a truth table?

A list of inputs and corresponding outputs for a digital device?

See "nuggets."

- E7A11 What is the name for logic which represents a logic "1" as a high voltage?
Positive logic.
- E7A12 What is the name for logic which represents a logic "0" as a high voltage?
Negative logic.
- E7A13 What is an SR or RS flip-flop?
A set/reset flip-flop whose output is low when R is high and S is low, high when S is high and R is low, and unchanged when both inputs are low.
N.B., the output is undefined if both R and S are high.
- E7A14 What is a JK flip-flop?
A flip-flop similar to an RS except that it toggles when both J and K are high.
See E7A13.
- E7A15 What is a D flip-flop?
A flip-flop whose output takes on the state of the D input when the clock signal transitions from low to high.
- E7F01 What is the purpose of a prescaler circuit?
It divides a higher frequency signal so a low-frequency counter can display the input frequency.
- E7F02 Which of the following would be used to reduce a signal's frequency by a factor of ten?
A prescaler.
- E7F03 What is the function of a decade counter digital IC?
It produces one output pulse for every ten input pulses.
- E7F04 What additional circuitry must be added to a 100-kHz crystal-controlled marker generator so as to provide markers at 50 and 25 kHz?
Two flip-flops
In series to get 25kHz.
- E7F05 Which of the following is a technique for providing high stability oscillators needed for microwave transmission and reception?
All of these choices are correct.
- E7F06 What is one purpose of a marker generator?
To provide a means of calibrating a receiver's frequency settings.
This is commonly done by using a crystal oscillator at the desired frequency, amplifying the signal and then clipping it to a square wave, which has many high order harmonics. A flip-flop divider chain can be used if a higher frequency crystal is desired.
- E7F07 What determines the accuracy of a frequency counter?
The accuracy of the time base.
- E7F08 Which of the following is performed by a frequency counter?
Counting the number of input pulses occurring within a specific period of time.
- E7F09 What is the purpose of a frequency counter?
To provide a digital representation of the frequency of a signal.
- E7F10 What alternate method of determining frequency, other than by directly counting input pulses, is used by some counters?
Period measurement plus mathematical computation.
- E7F11 What is an advantage of a period-measuring frequency counter over a direct-count type?
It provides improved resolution of low-frequency signals within a comparable time period.

Legalese

NCVEC Extra Class Question Pool 2012 declared public domain by NCVEC.

<http://www.ncvec.org/downloads/REVISED%202012-2016%20Extra%20Class%20Pool.txt>

Some schematic symbols extracted from the Extra Graphics PDF.

NPN Bipolar Transistor diagram is Public Domain per author. Found in the Wikipedia Bipolar Transistor article.

© 2011, 2012, Randolph J. Herber, W9HE.

This work is licensed under a Creative Commons Attribution 3.0 United States License (see <http://creativecommons.org/licenses/by/3.0/us/>).

Include this notice in any derivative works, preferably with your own copyright notices.