

**THE UNITED REPUBLIC OF TANZANIA
NATIONAL EXAMINATION COUNCIL
DIPLOMA IN TECHNICAL EDUCATION EXAMINATION**

793

ELECTRONICS

Time: 3 Hours.

SOLUTIONS

Year: 2019

Instructions

1. This paper consists of sections A and B with a total of **fifteen (15)** questions.
2. Answer **all** questions in section A and **three (3)** questions from section B
4. Mathematical tables and non-programmable calculators may be used
4. Cellular phones are **not** allowed inside the examination room.
5. Write your **Examination Number** on every page of your answer booklet

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SECTION A (40 Marks)

Answer all questions in this section.

1.(a) Define the term intrinsic semiconductor and give two examples.

An intrinsic semiconductor is a pure semiconductor material that has not been intentionally doped with impurities, so the number of free electrons is equal to the number of holes, and its electrical conductivity depends only on temperature.

Examples of intrinsic semiconductors include pure silicon and pure germanium, both of which conduct electricity due to thermally generated charge carriers.

(b)(i) Give the meaning of term potential barrier of a semiconductor diode.

The potential barrier of a semiconductor diode is the internal voltage developed across the depletion region of a PN junction that opposes the movement of majority charge carriers from one side of the junction to the other.

(b)(ii) State the threshold voltages for germanium and silicon diodes.

The threshold voltage for a germanium diode is approximately 0.3 V, which is the minimum forward voltage required to allow significant conduction.

The threshold voltage for a silicon diode is approximately 0.7 V, which must be exceeded before the diode conducts appreciable current.

2.(a) If the emitter current of a transistor is changed by 1 mA, its collector current is found to change by 0.995 mA. Calculate its a.c alpha (α).

Change in collector current $\Delta I_c = 0.995 \text{ mA}$

Change in emitter current $\Delta I_e = 1 \text{ mA}$

$$\alpha = \Delta I_c \div \Delta I_e$$

$$\alpha = 0.995 \div 1$$

$$\alpha = 0.995$$

2.(b) Calculate its a.c beta (β).

$$\beta = \alpha \div (1 - \alpha)$$

$$\beta = 0.995 \div (1 - 0.995)$$

$$\beta = 0.995 \div 0.005$$

$$\beta = 199$$

3.(a) How many PN junctions does a BJT have?

A bipolar junction transistor has two PN junctions, namely the emitter-base junction and the collector-base junction.

(b) Why is an ordinary junction transistor called a bipolar transistor?

An ordinary junction transistor is called bipolar because its operation involves both types of charge carriers, electrons and holes, which participate in current conduction.

(c) What are the two characteristics of a good amplifier?

A good amplifier should have high gain so that it can significantly increase the amplitude of the input signal without distortion.

A good amplifier should have good fidelity, meaning it reproduces the input signal accurately without altering its waveform or frequency content.

4.(a) What is meant by integrated circuit as used in electronic systems?

An integrated circuit is a miniaturized electronic circuit in which active and passive components such as transistors, resistors, and capacitors are fabricated on a single semiconductor chip and interconnected internally.

(b) List three drawbacks of ICs.

Integrated circuits cannot handle high power or high voltage applications because of heat dissipation limitations.

They are difficult to repair since individual components inside the IC cannot be replaced separately.

Integrated circuits offer limited flexibility because their internal design cannot be easily modified after manufacture.

5. (a) Name two broad categories of electronic oscillators.

The two broad categories of electronic oscillators are sinusoidal oscillators and non-sinusoidal oscillators.

(b) The resonant circuit of a tuned-collector transistor oscillator has a resonant frequency of 5 MHz. If the value of capacitance is increased by 50 percent, calculate the new resonant frequency.

Original frequency $f_1 = 5 \text{ MHz}$

Resonant frequency is inversely proportional to the square root of capacitance.

New capacitance $C_2 = 1.5 C_1$

$$f_2 = f_1 \div \sqrt{1.5}$$

$$f_2 = 5 \div 1.225$$

$$f_2 \approx 4.08 \text{ MHz}$$

6.(a)(i) Define the term feedback as used in amplifiers.

Feedback in amplifiers is the process of returning a portion of the output signal back to the input of the amplifier to control gain, stability, and performance.

(ii) Which type of feedback is frequently used in amplifier circuits?

Negative feedback is frequently used in amplifier circuits because it improves stability, reduces distortion, and widens bandwidth.

(b) The gain of an amplifier without feedback is 90. If a negative feedback is used with feedback ratio of 0.1, calculate the amplifier gain.

$$A = 90$$

$$\beta = 0.1$$

Gain with feedback A_f

$$A_f = A \div (1 + A\beta)$$

$$A_f = 90 \div (1 + 90 \times 0.1)$$

$$A_f = 90 \div (1 + 9)$$

$$A_f = 90 \div 10$$

$$A_f = 9$$

7.(a) A choke coil takes a current of 2 A lagging 60° behind the applied voltage of 200 V at 50 Hz. Calculate the impedance of the coil.

$$\text{Impedance } Z = V \div I$$

$$Z = 200 \div 2$$

$$Z = 100 \text{ ohms}$$

(b) Calculate the resistance of the coil.

$$\text{Power factor } \cos\phi = \cos 60^\circ = 0.5$$

$$\text{Resistance } R = Z \times \cos\phi$$

$$R = 100 \times 0.5$$

$$R = 50 \text{ ohms}$$

8.(a) Define a light emitting diode with respect to its biasing condition.

A light emitting diode is a PN junction diode that emits light when it is forward biased, allowing current to flow and causing electron-hole recombination that produces visible or infrared radiation.

(b)(i) Draw a circuit symbol for a photoconductive cell.

The circuit symbol of a photoconductive cell consists of a resistor symbol with arrows pointing towards it, indicating incident light affecting its resistance.

(ii) State one application of a photoconductive cell.

A photoconductive cell is used in automatic street lighting systems where it detects changes in ambient light and controls switching of lamps.

SECTION B (60 Marks)

Answer three (3) questions from this section.

11.(a) Draw the equivalent circuit of Figure 1 and locate all the given components with their values.

The equivalent circuit consists of a variable DC input voltage source V_{in} connected in series with a resistor R of 600 ohms. From the junction after the resistor, a Zener diode D_z is connected in reverse bias to ground. The Zener diode has a Zener voltage V_z of 5.1 V, a Zener dynamic resistance r_z of 10 ohms, a minimum Zener current $I_z(\min)$ of 1 mA, and a maximum Zener current $I_z(\max)$ of 15 mA. The output voltage is taken across the Zener diode.

(b) Determine the minimum and maximum input voltages that can be regulated by the Zener diode.

For regulation to occur, the Zener current must remain between $I_z(\min)$ and $I_z(\max)$.

At minimum input voltage, Zener current is $I_z(\min)$.

Voltage drop across resistor

$$V_r(\min) = I_z(\min) \times R$$

$$V_r(\min) = 0.001 \times 600$$

$$V_r(\min) = 0.6 \text{ V}$$

Minimum input voltage

$$V_{in}(\min) = V_z + V_r(\min)$$

$$V_{in(min)} = 5.1 + 0.6$$

$$V_{in(min)} = 5.7 \text{ V}$$

At maximum input voltage, Zener current is $I_z(max)$.

Voltage drop across resistor

$$V_r(max) = I_z(max) \times R$$

$$V_r(max) = 0.015 \times 600$$

$$V_r(max) = 9.0 \text{ V}$$

Maximum input voltage

$$V_{in(max)} = V_z + V_r(max)$$

$$V_{in(max)} = 5.1 + 9.0$$

$$V_{in(max)} = 14.1 \text{ V}$$

Therefore, the regulated input voltage range is from 5.7 V to 14.1 V.

(c)(i) What is ripple factor in electronic power supply?

Ripple factor is a measure of the amount of AC ripple present in the output of a DC power supply. It is defined as the ratio of the rms value of the AC component to the DC component of the output voltage and indicates the quality of DC smoothing.

(ii) Mention three types of RLC filters.

A low-pass RLC filter allows low-frequency signals to pass while attenuating high-frequency components.

A high-pass RLC filter allows high-frequency signals to pass while blocking low-frequency components.

A band-pass RLC filter allows signals within a specific frequency range to pass while attenuating frequencies outside that range.

12.(a) Determine the overall common-mode gain.

CMRR is defined as the ratio of differential gain to common-mode gain.

$$\text{CMRR} = A_d \div A_c$$

Given

$$A_d = 2500$$

$$\text{CMRR} = 30000$$

Common-mode gain

$$A_c = A_d \div \text{CMRR}$$

$$A_c = 2500 \div 30000$$

$$A_c = 0.0833$$

(b) Express the overall CMRR in dB.

$$\text{CMRR(dB)} = 20 \log_{10}(\text{CMRR})$$

$$\text{CMRR(dB)} = 20 \log_{10}(30000)$$

$$\text{CMRR(dB)} = 20 \times 4.477$$

$$\text{CMRR(dB)} \approx 89.5 \text{ dB}$$

(c) Determine the r.m.s output signal for Figure 2(a) and Figure 2(b).

For Figure 2(a), single-ended input signal is 500 microvolts r.m.s and common-mode interference is 1 V r.m.s.

Differential output due to signal

$$V_{\text{out}}(\text{signal}) = A_d \times V_{\text{in}}$$

$$V_{\text{out}}(\text{signal}) = 2500 \times 500 \times 10^{-6}$$

$$V_{\text{out}}(\text{signal}) = 1.25 \text{ V r.m.s}$$

Common-mode output due to interference

$$V_{\text{out}}(\text{cm}) = A_c \times V_{\text{cm}}$$

$$V_{\text{out}}(\text{cm}) = 0.0833 \times 1$$

$$V_{out(cm)} = 0.0833 \text{ V r.m.s}$$

For Figure 2(b), the differential inputs are 500 microvolts r.m.s each and 180° out of phase, giving a differential input of 1 mV.

Differential output

$$V_{out(signal)} = 2500 \times 0.001$$

$$V_{out(signal)} = 2.5 \text{ V r.m.s}$$

Common-mode output remains

$$V_{out(cm)} = 0.0833 \text{ V r.m.s}$$

(d) For the results obtained in 13(c), state the relationship between the output voltage of Figure 2(a) and that of Figure 2(b).

The output voltage in Figure 2(b) is twice that of Figure 2(a) for the signal component because Figure 2(b) uses a true differential input while Figure 2(a) uses a single-ended input. The common-mode output remains the same in both cases.

(e) Determine the value of r.m.s interference voltage on the output.

The r.m.s interference voltage on the output is given by the common-mode output.

$$V_{interference} = A_c \times V_{cm}$$

$$V_{interference} = 0.0833 \times 1$$

$$V_{interference} = 0.0833 \text{ V r.m.s}$$

13.(a) With reference to feedback amplifiers, briefly explain the following terms:

(i) Negative feedback.

(ii) Positive feedback.

Negative feedback is a process in which a fraction of the output signal of an amplifier is fed back to the input in such a way that it opposes the original input signal. This opposition reduces the overall gain but improves important performance

characteristics such as stability, linearity, bandwidth, and reduction of noise and distortion.

Positive feedback is a process in which a fraction of the output signal is fed back to the input in phase with the original input signal. This reinforcement increases the overall gain and can lead to instability and oscillations if not carefully controlled, which is why it is mainly used in oscillator circuits rather than linear amplifiers.

13.(b) Draw a well labeled block diagram to represent the general principle of amplifier feedback.

The general feedback amplifier consists of an input signal applied to a summing junction, where it is combined with a feedback signal. The combined signal is fed into the amplifier block with gain A . The output of the amplifier is then taken as the output signal, and a portion of this output is passed through a feedback network with feedback factor β and returned to the summing junction.

13.(c)(i) State four advantages and one disadvantage of applying negative feedback on an amplifier.

One advantage of negative feedback is improved gain stability, because variations in transistor parameters or temperature have much less effect on the overall gain of the amplifier.

Another advantage is reduction of distortion, since negative feedback linearizes the amplifier operation and minimizes nonlinear effects in the active device.

A third advantage is increased bandwidth, as negative feedback extends the frequency range over which the amplifier operates effectively.

A fourth advantage is reduction of noise, because internally generated noise is also fed back and reduced at the output.

One disadvantage of negative feedback is reduction in overall gain, since part of the output is subtracted from the input.

13.(c)(ii) Mention four types of negative feedback configuration.

Voltage series feedback is a configuration where the output voltage is sampled and fed back in series with the input signal.

Voltage shunt feedback is a configuration where the output voltage is sampled and fed back in parallel with the input signal.

Current series feedback is a configuration where the output current is sampled and fed back in series with the input.

Current shunt feedback is a configuration where the output current is sampled and fed back in parallel with the input.

13.(c)(iii) The open loop voltage gain of an amplifier is 1000. When a negative feedback is applied the voltage gain becomes 40 dB. If the open loop gain increases by 10 percent, what will be the percentage change in the overall gain with negative feedback?

Open loop gain

$$A = 1000$$

Gain with feedback in dB

$$A_f(\text{dB}) = 40$$

Convert 40 dB to linear gain

$$A_f = \text{antilog}(40 \div 20)$$

$$A_f = \text{antilog}(2)$$

$$A_f = 100$$

Feedback factor

$$A_f = A \div (1 + A\beta)$$

$$100 = 1000 \div (1 + 1000\beta)$$

$$1 + 1000\beta = 10$$

$$1000\beta = 9$$

$$\beta = 0.009$$

New open loop gain after increase

$$A' = 1.1 \times 1000$$

$$A' = 1100$$

New gain with feedback

$$A_f' = 1100 \div (1 + 1100 \times 0.009)$$

$$1100 \times 0.009 = 9.9$$

$$A_f = 1100 \div 10.9$$

$$A_f \approx 100.9$$

Percentage change in gain

$$\text{Change} = (100.9 - 100) \div 100 \times 100$$

Percentage change \approx 0.9 percent

14.(a) The amplifier circuit shown in Figure 3 is designed to operate with maximum possible output signal. If the amplifier is properly biased and its emitter voltage (V_E) is 3.3 V, calculate the maximum transistor power rating.

Emitter resistance

$$R_E = 100 \text{ ohms}$$

Emitter current

$$I_E = V_E \div R_E$$

$$I_E = 3.3 \div 100$$

$$I_E = 0.033 \text{ A}$$

Collector voltage swing is approximately half of supply voltage for maximum symmetrical output

$$V_{CE} \approx 24 \div 2$$

$$V_{CE} \approx 12 \text{ V}$$

Maximum transistor power

$$P_{\max} = V_{CE} \times I_C$$

Assuming $I_C \approx I_E$

$$P_{\max} = 12 \times 0.033$$

$$P_{\max} \approx 0.396 \text{ W}$$

14.(b) Calculate the A.C output power.

Load resistance

$$R_L = 300 \text{ ohms}$$

Maximum output voltage swing

$$V_{\text{out(max)}} \approx 12 \text{ V}$$

RMS output voltage

$$V_{\text{rms}} = 12 \div \sqrt{2}$$

$$V_{\text{rms}} \approx 8.49 \text{ V}$$

A.C output power

$$P_{\text{out}} = V_{\text{rms}}^2 \div R_L$$

$$P_{\text{out}} = 8.49^2 \div 300$$

$$P_{\text{out}} \approx 0.24 \text{ W}$$

14.(c) Calculate the efficiency.

Efficiency

$$\eta = P_{out} \div P_{dc}$$

DC input power

$$P_{dc} = V_{CC} \times I_C$$

$$P_{dc} = 24 \times 0.033$$

$$P_{dc} \approx 0.792 \text{ W}$$

Efficiency

$$\eta = 0.24 \div 0.792$$

$$\eta \approx 0.303$$

Efficiency \approx 30.3 percent

15.(a)(i) Point out two necessary regions in which a transistor is normally used as an electronic switch.

One necessary region is the cut-off region, where the transistor is completely off and no collector current flows, representing an open switch.

The other necessary region is the saturation region, where the transistor is fully on and conducts maximum current, representing a closed switch.

15.(a)(ii) Study Figure 4(a) and 4(b) then state the condition of each transistor when used as a switch.

In Figure 4(a), the base is at 0 V, so the transistor is in the cut-off region and behaves as an open switch.

In Figure 4(b), the base is supplied with a positive bias voltage, so the transistor is driven into saturation and behaves as a closed switch.

15.(a)(iii) Give a reason for each of the condition you stated in (a)(ii).

In Figure 4(a), the base-emitter junction is not forward biased, so no base current flows and the transistor remains off.

In Figure 4(b), the base-emitter junction is forward biased sufficiently, allowing a large base current that drives the transistor into saturation.

15.(b)(i) State three applications of Op-Amps.

Operational amplifiers are used as voltage amplifiers in signal conditioning circuits.

They are used as comparators to compare two input voltages and produce a logic-level output.

They are used in active filters to selectively amplify or attenuate certain frequency ranges.

15.(b)(ii) What are the three chief properties of Op-Amps?

One chief property is very high open-loop gain, which allows precise control of closed-loop gain using feedback.

Another chief property is very high input impedance, which minimizes loading of the input signal source.

A third chief property is very low output impedance, which allows the op-amp to drive loads effectively.

15.(c) With reference to PNP structure, construct a two-transistor arrangement to represent the SCR operation.

An SCR can be represented by two transistors connected in regenerative feedback, one PNP transistor and one NPN transistor. The collector of the PNP transistor is connected to the base of the NPN transistor, and the collector of the NPN transistor is connected to the base of the PNP transistor. This interconnection explains the latching behavior of the SCR, where conduction continues even after the gate signal is removed due to mutual reinforcement of base currents.