NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2021

# ELECTRICAL TECHNOLOGY: ELECTRONICS

## MARKING GUIDELINES

Time: 3 hours 200 marks

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**These marking guidelines are prepared for use by examiners and sub-examiners, all of whom are required to attend a standardisation meeting to ensure that the guidelines are consistently interpreted and applied in the marking of candidates' scripts.**

**The IEB will not enter into any discussions or correspondence about any marking guidelines. It is acknowledged that there may be different views about some matters of emphasis or detail in the guidelines. It is also recognised that, without the benefit of attendance at a standardisation meeting, there may be different interpretations of the application of the marking guidelines.**

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## GENERAL

- All marking is done by the marker in red.
- The marker may not make any corrections on the candidate's answer book.
- The memorandum serves as a guideline only.
- Alternative answers must be considered.
- A tick " " must be placed at each correct answer for which a candidate receives a mark.
- A cross "x" must be placed at each answer that is wrong.
- Calculations are marked as follows, unless stated otherwise:
  - 1 mark is awarded for the formula.
  - 1 mark is awarded for the substitution.
  - 1 mark is awarded for the answer with the correct applicable unit shown.
  - If the unit is indicated incorrectly, the answer is marked as wrong.
  - If an incorrect answer has to be used in the subsequent calculation, it is taken as correct in that calculation and the answer of the relevant calculation must be recalculated by the marker and marked accordingly. An arrow must be inserted from the incorrect answer to the subsequent calculation where substitution has been done with the incorrect answer to show that the incorrect answer has been taken into consideration.
- Sketches are marked by awarding 1 mark for the drawing if it was drawn correctly and all the other marks are awarded for the correct labels.
- See also the marking notes at some answers.
- A line must be drawn through all work that is not applicable to the answer, for example rough work.
- A diagonal line must be drawn through the space for questions that the candidate left open.
- A diagonal line must be drawn through all pages of the answer book that were not used by the candidate.
- A horizontal line must be drawn by the marker at the end of each question to indicate the end of the question.
- The marks for each question are written in a circle on the left-hand side at the beginning of the relevant question.
- The mark allocations for answers are written on the right-hand side of the page below one another. No circles are made around these marks.
- **This memorandum consists of 12 pages.**

## QUESTION 1 GENERAL MULTIPLE-CHOICE QUESTIONS

1.1 C

1.2 D

1.3 A

1.4 A

1.5 B

1.6 A

1.7 A

1.8 B

1.9 D

1.10 D

1.11 D

1.12 C

1.13 C

1.14 D

1.15 D

## QUESTION 2 OCCUPATIONAL HEALTH AND SAFETY

2.1 Qualitative risk analysis defines the danger levels and develops measures to remove possible risks.

2.2
- The person must lie down.
- Cover the person warmly to preserve body heat.
- Do not move the person in case there are neck or spine injuries.
- If unconscious, turn the person onto his side (the recovery position).

(Any THREE relevant answers)

2.3 To prevent electric shock, precautionary measures must be taken to insulate yourself when you assist a person to prevent injuries.

2.4 A person who deliberately fiddles with the first-aid equipment may damage it and this may leave the equipment unsafe and endanger the safety of the user.

2.5 Insufficient ventilation may cause dangerous gasses that people would inhale to accumulate in the workshop and this makes it an unsafe condition.

## QUESTION 3 RLC CIRCUITS

3.1 Impedance is the total resistance to the flow of alternating current in a circuit consisting of resistive and reactive components.

3.2 3.2.1

$$X_L = 2\pi fL$$
$$X_L = 2\times\pi\times 60\times 30\times 10^{-3}$$
$$X_L = 11.31$$

3.2.2

$$X_C = \frac{1}{2\pi fC}$$
$$X_C = \frac{1}{2\times\pi\times 60\times 150\times 10^{-6}}$$
$$X_C = 17.68$$

3.2.3

$$Z = \sqrt{R^2 + (X_C - X_L)^2}$$
$$Z = \sqrt{12^2 + (17.68 - 11.31)^2}$$
$$Z = 13.59$$

3.2.4

$$I_T = \frac{V_T}{Z}$$
$$I_T = \frac{120}{13.59}$$
$$I_T = 8.83\,A$$

3.2.5 Power factor

$$\cos\theta = \frac{R}{Z}$$
$$\cos\theta = \frac{12}{13.59}$$
$$\cos\theta = 0.88$$

3.2.6 The phase angle is leading.

3.3 The value of the inductive reactance will double/increase because the inductive reactance is directly proportional to input frequency.
**Note: If only the formula is given = 0**
**If the formula is given as a reason = 1 mark**

3.4 3.4.1

$$I_C = \frac{V_T}{X_C}$$
$$I_C = \frac{220}{60}$$
$$I_C = 3.67\,A$$

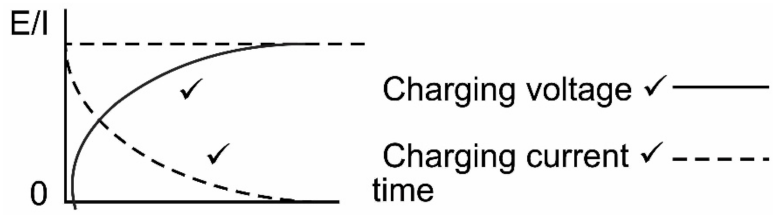
3.4.2 $I_X = I_L - I_C$

$I_X = 6 - 3.67$

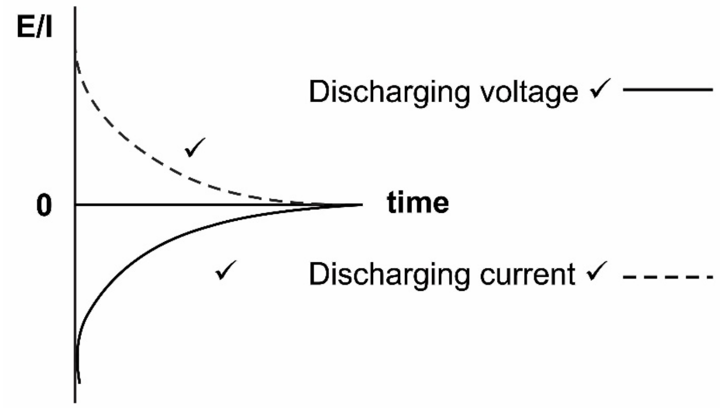
$I_X = 2.33A$

3.4.3 The phase angle is lagging because $I_L$ is greater than $I_C$.

3.5 3.5.1 Capacitor – charging circuit




3.5.2 Capacitor – discharging circuit

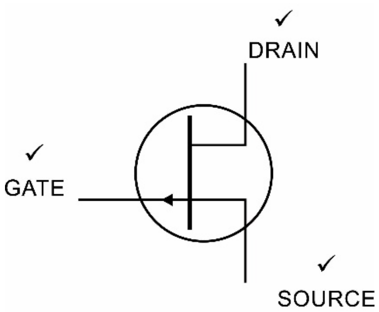



3.6 During resonance an RLC series circuit has the following characteristics:

- Both the reactances are equal $\mathbf{X_C = X_L}$
- The impedance of the circuit is equal to the real resistance **Z = R**
- The **current I** in the circuit is at a **maximum**

## QUESTION 4 SEMICONDUCTOR DEVICES

4.1




4.2 The FET can be used as the following:

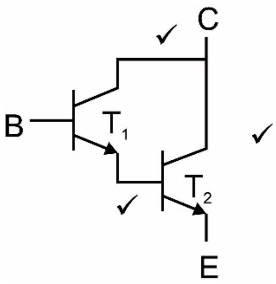
- Switch
- Saw-tooth wave generator

4.3 4.3.1 The intrinsic stand-off ratio (η) is determined by the ratio between $R_{B1}$ and $R_{BB}$ ($R_{BB} = R_{B1} + R_{B2}$).

$$\eta = \frac{r_{b1}}{(r_{b1} + r_{b2})}$$

4.3.2 The moment the emitter voltage $(V_E)$ rises to above $V_X$, the UJT enters its trigger state and it will then fire.

4.4 4.4.1 Darlington-pair transistor



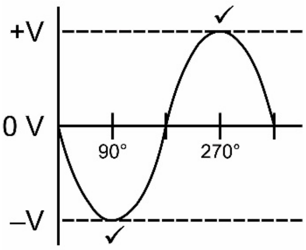

4.4.2 Gain of a Darlington pair is

$$A = ß_1 \times ß_2$$
$$= 50 \times 50$$
$$= 2\,500$$

4.5 4.5.1 Non-inverting input.

4.5.2 Dual-in-line package alignment (DIL)
Surface-mount package (SMD)

4.6




Note: The output may also be driven into saturation. If a square wave or truncated sine wave is drawn with inversion = 2 marks

4.7 4.7.1 Two comparators/amplifiers
One R/S flip-flop
Three 5 kΩ resistors
Transistor

4.7.2 The three 5 kΩ resistors divide the input voltage in two scaled-down voltages of $^1/_3$ and $^2/_3$ of the input voltage.

4.7.3 When the trigger voltage rises above the threshold voltage, then the output of a 555 timer will change from high to low.
**NB: If the answer is given as "Switch off" = 1 mark**

## QUESTION 5 SWITCHING CIRCUITS

5.1 5.1.1 At the one end the potentiometer is connected to 0 Ω. $R_1$ will then prevent the full input from flowing to pin 6 and pin 7 when the potentiometer is in the 0 Ω state.

5.1.2 By changing the value of $C_1$
By changing the value of $R_3$

5.1.3 The time period will increase

5.2 The bistable multivibrator is a circuit that is able to maintain two stable output values, either high or low, when a trigger pulse is received.

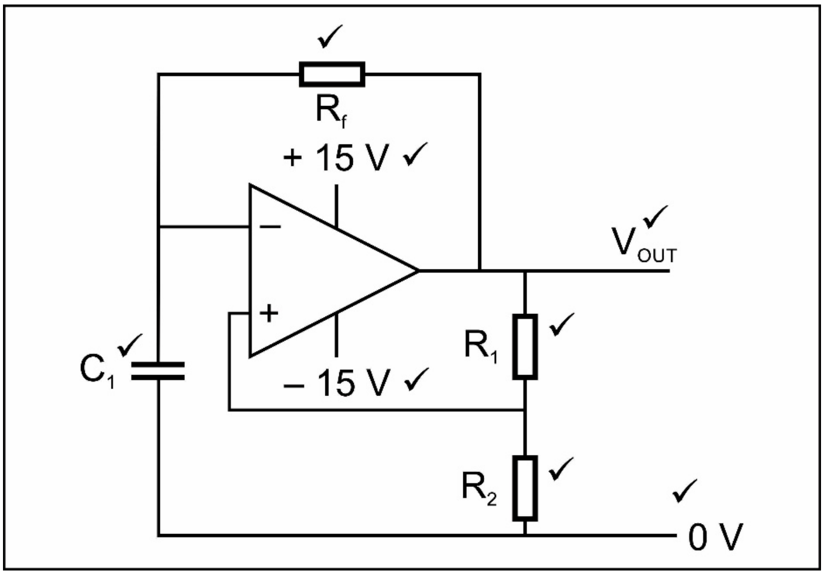
5.3 5.3.1
- When a trigger pulse is received, the output will change from positive saturation to negative saturation.
- It will remain in this state for a predetermined time ($t_1$).
- And it will then return to its original state.

**If the candidate mentions a square wave = 1 mark**

5.3.2 The voltage swing can be changed by changing either the value of the resistance or the capacitor in the RC charging circuit.

5.3.3
- When the circuit is "at rest", its output rises to positive saturation (+15 V).
- When a trigger pulse is received, the state changes and swings the output to negative saturation (–15 V).
- A total change in output voltage of 30 V is obtained.

5.4



5.5 5.5.1 $V_{\text{OUT}} = -\left(V_1 \dfrac{R_f}{R_1} + V_2 \dfrac{R_f}{R_2} + V_3 \dfrac{R_f}{R_3}\right)$

$$V_{\text{OUT}} = -\left(100 \times 10^{-3} \frac{100 \times 10^3}{10 \times 10^3} + 150 \times 10^{-3} \frac{100 \times 10^3}{30 \times 10^3} + 50 \times 10^{-3} \frac{100 \times 10^3}{5 \times 10^3}\right)$$

$$V_{\text{OUT}} = -2.5V$$

Alternatively

$$V_{\text{OUT}} = V_1 \times \left(\frac{R_f}{R_1}\right) + V_2 \times \left(\frac{R_f}{R_2}\right) + V_3 \times \left(\frac{R_f}{R_3}\right)$$

$$V_{\text{OUT}} = 100 \times 10^{-3} \left(\frac{100 \times 10^3}{10 \times 10^3}\right) + 150 \times 10^{-3} \left(\frac{100 \times 10^3}{30 \times 10^3}\right)$$

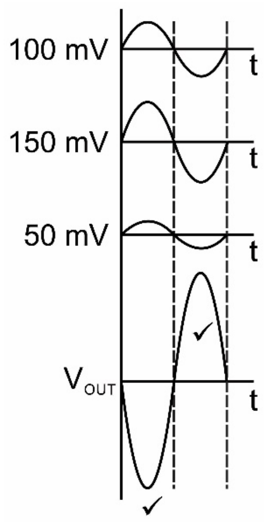
$$+50 \times 10^{-3} \left(\frac{100 \times 10^3}{5 \times 10^3}\right)$$

$$V_{\text{OUT}} = -2.5V$$

5.5.2 The voltage of each signal can be controlled independently by replacing each input resistor with an adjustable resistor.

5.5.3 DC blocking capacitors must be connected at the inputs to prevent the DC from being fed back to the input-voltage sources.

5.5.4




**NOTE:**
**ONE mark for correct polarity**
**ONE mark for AMPLIFICATION**
**If the waveform does not show the correct size, but indicates the correct value of the waveform or any reference to AMPLIFICATION, one mark**

5.6 5.6.1 Inverting summing amplifier

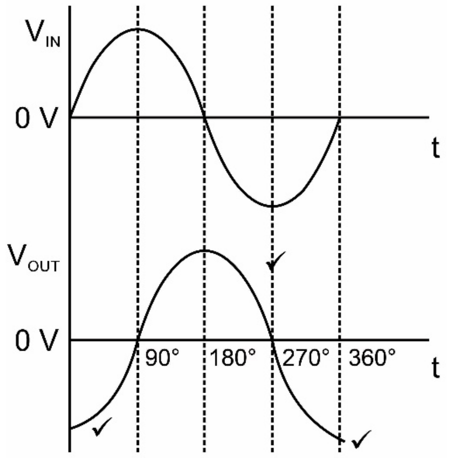
5.6.2 Negative feedback

5.6.3 $V_{\text{OUT}} = -\left(V_1 + V_2 + V_3\right)$

$$V_{\text{OUT}} = -\left(850 \times 10^{-3} + 200 \times 10^{-3} + 950 \times 10^{-3}\right)$$

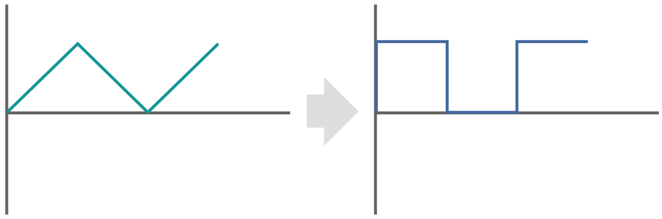
$$V_{\text{OUT}} = -2V$$

5.7 5.7.1




**1 mark for 90° phase shift. Correct orientation will be:**
**1 mark for positive half cycle**
**1 mark for negative half cycle**

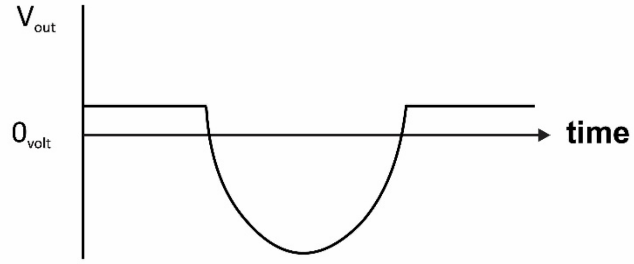
5.7.2



**1 mark for phase shift**
**2 marks for correct orientation**

5.8 5.8.1 **Parallel clipping circuit.** The clipping circuit **"cuts off"** a part of the input wave's **amplitude** (positive or negative).

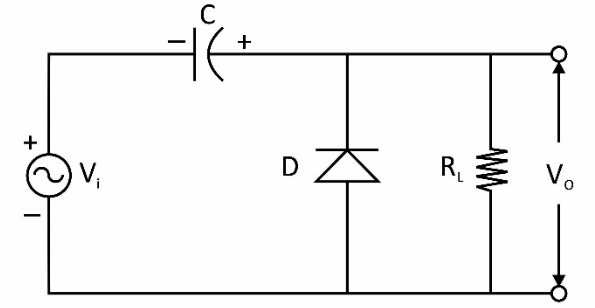
5.8.2




1 mark = clipped positive wave
1 mark = negative half wave
1 mark = axes correct

If the diode is reversed in the circuit, only the positive half of the wave will appear.
**NB: If the candidate draws the waveform and label it correctly, mark on merit.**

5.9




**NB: Award marks as follows**
Positive clamping circuit = 1
Capacitor = 1
Diode = 1
Resistor = 1

## QUESTION 6 AMPLIFIERS

6.1 6.1.1 $V_{CC} = V_{CE} + I_C R_C$

$V_{CC} = V_{CE}$ when the transistor is OFF and the collector current does not flow ($I_C$ = 0 A).

$V_{CE} = 9\ V$

6.1.2 $I_C = \dfrac{V_{CC}}{R_C}$

$I_C = \dfrac{9}{750}$

$I_C = 12\ mA$

6.2 6.2.1 $A_V = 20\log_{10}\dfrac{E_{\text{out}}}{E_{\text{in}}}$

$A_V = 20\log_{10}\dfrac{6.2}{4}$

$A_V = 20 \times 0.19$

$A_V = 3{,}80 dB$

6.2.2 $A_p = 10\log_{10}\dfrac{p_{\text{out}}}{p_{\text{in}}}$

$A_p = 10\log_{10}\dfrac{29}{850\times10^{-3}}$

$A_p = 15.17 dB$

6.3 6.3.1 Positive feedback

6.3.2 The RC phase-shift oscillator is mostly used in the lower audio frequencies (AF) to 10 kHz.

6.4 6.4.1 A radio-frequency amplifier is designed to amplify signals from a single high frequency (usually above 100 kHz) and suppress all other frequencies.

6.4.2 Capacitor $C_1$ and the primary windings of the second transformer ($T_2$) form the tuned circuit resonating at the required frequency. This frequency goes to the second LC tuned circuit that is formed by the winding of transformer $T_2$ and $C_2$, making it more selective.

6.4.3 By making capacitors $C_1$ and $C_2$ adjustable, the tuned circuits will resonate at different frequencies and will, therefore, let through a range of frequencies.

6.5 6.5.1 An oscillator is a device that generates an AC output signal without any external input signals.

6.5.2 The voltage developing across $C_2$ is the feedback voltage and the voltage developing across $C_1$ is the oscillator's output voltage that is fed to the FET's gate terminal.

6.5.3 (i) Resistor $R_2$ is used to reverse bias the FET transistor when the circuit is switched ON.

(ii) $C_4$ is used to stabilise the emitter voltage when the transistor is switched on. It is a shunt capacitor.

6.6 6.6.1 The RC network provides a 180° phase shift. It also determines the oscillation frequency of the circuit using the RC time constant.

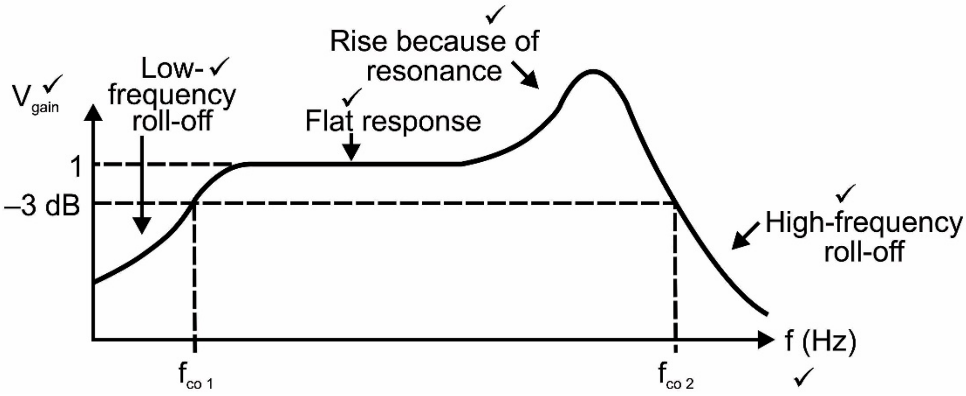
6.6.2 To adjust the frequency of the phase-shift oscillator, the three feedback capacitors must be operated as one collective unit so that the values of all three capacitors are adjusted to the same value. When the values of the capacitors and the resistors are adjusted, the frequency can be adjusted because the RC time constant is changed.

6.7 6.7.1 Impedance adjustment can be done by selecting a transformer with the correct number of primary and secondary windings that corresponds to the impedance of the various stages (steps).

6.7.2 A transformer is used to connect the relative high output impedance of the second stage to the relative low impedance of the speaker, thus matching the output impedance of the amplifier with the load.

6.7.3




6.8 6.8.1 $A_p = 10\log_{10}\frac{p_{\text{out}}}{p_{\text{in}}}$

$A_p = 10\log_{10}\frac{1\,200}{3\,015}$

$A_p = -4\ dB$

6.8.2 $A_V = 20\log_{10}\frac{E_{\text{out}}}{E_{\text{in}}}$

$A_V = 20\log_{10}\frac{219}{230}$

$A_V = -0.43\ dB$

6.9 Excellent impedance adjustment can be obtained. Total DC insulation between stages.

6.10 RF amplifiers are used to mix information with required radio signals for broadcasting.
RF amplifiers are used to increase the levels of poor RF signals, for example in satellite receivers where very small signals must be amplified by the antenna before they can be sent to the decoder.
RF amplifiers are used as buffer stages in transmitters.

**Total: 200 marks**