Singapore Examinations and Assessment Board

CAMBRIDGE International Education

Singapore–Cambridge General Certificate of Education Ordinary Level (2025)

Electronics (Syllabus 6063)

CONTENTS

INTRODUCTION

The O-Level electronics syllabus provides students with an understanding of the fundamental working of electronic components and systems, as well as ideas of engineering design. The syllabus focuses on the application of the knowledge of electronics components and circuit theories to design and build electronics systems that can solve daily problems. The students will also develop testing and troubleshooting skills in the realisation of an electronic system. Through these learning experiences, the subject should provide a broad-base foundation for further studies in electronics engineering and related field.

It is envisaged that teaching and learning programmes based on this syllabus would feature a range of learning experiences designed to promote understanding of electronics and to develop values and attitudes related to engineering. Teachers are encouraged to use a combination of appropriate strategies to effectively engage students in hands-on and applied learning. It is expected that students will apply problem-solving and engineering design skills, effectively communicate the intent of their design and appreciate the contribution electronics makes to our modern living.

AIMS

These are not listed in order of priority.

The aims are to:

1 acquire knowledge of the fundamentals of electronics

2 develop abilities and skills related to the engineering design process such as

- 2.1 systems thinking
- 2.2 design, build and test electronic systems
- 2.3 troubleshooting

3 develop an attitude relevant to engineering such as

- 3.1 perseverance
- 3.2 curiosity
- 3.3 striving for accuracy
- 3.4 open-mindedness
- 3.5 inventiveness
- 3.6 problem-solving (“can do” attitude)
- 3.7 intellectual thoroughness

4 develop an appreciation about the usefulness of electronics and its impact on modern society

5 foster an interest and passion in the engineering field

6 inculcate a strong sense of safety and develop safe working habits

ASSESSMENT OBJECTIVES

A Knowledge with understanding

Candidates should be able to demonstrate knowledge and understanding of scientific facts, concepts, theories and terminology in relation to:

1. electronic systems
2. electricity and circuit theories
3. electrical and electronic components
4. digital electronics.

B Handling Information and solving problems

Candidates should be able to:

1. locate, select, interpret and evaluate information
2. manipulate numerical and other data
3. present reasoned explanations for application and relationships between components
4. solve problems.

C Practical Skills and Project Realisation

Candidates should be able to design, build and test electronic systems involving the following processes:

1. observe, measure and record data accurately
2. analyse problems by considering relevant functional and practical factors
3. conduct research, plan, design and develop solutions
4. use computer simulation software to verify design
5. build a prototype circuit using a prototype board
6. use appropriate test and measurement equipment to test and troubleshoot a prototype circuit
7. present evaluative report on design and solutions to problems.

Weighting of Assessment Objectives

Paper 1 – Written Paper

A Knowledge with Understanding, approximately 40% of the marks.

B Handling Information and Solving Problems, approximately 60% of the marks.

Paper 2 – Coursework

C Practical Skills and Project Realisation 100% of the marks.

SCHEME OF ASSESSMENT

Candidates are required to enter for Papers 1 and 2.

Paper	Type of Paper	Duration	Marks	Weighting
1	Section A (40 marks) Short answer questions	2 h	100	70%
	Section B (60 marks) Long questions			
2	An application-specific **coursework**	32 h	100	30%

Paper 1 (2 h, 100 marks)
This paper consists of two sections.
Section A carries 40 marks and consists of 6–10 compulsory short answer questions.
Section B carries 60 marks and consists of 4 compulsory questions, each of 15 marks.

Paper 2 (32 h, 100 marks)
This is an application-specific electronic project which involves the design, building and testing of an electronic circuit to solve a specific problem. The project is carried out over a period of 32 hours, requiring candidates to build a prototype (project hardware) and document the process (project report), carrying a total of 100 marks.

CONTENT STRUCTURE

Section	Topics
I. Systems	1. Electronic Systems
II. Fundamentals of Electricity	2. Current Electricity 3. Resistors 4. Circuit Theories 5. Alternating Currents 6. Capacitors
III. Analogue Electronics	7. Semiconductor Diodes 8. Input and Output Transducers 9. Bipolar Junction Transistors and Operational Amplifiers
IV. Digital Electronics	10. Introduction to Digital Electronics 11. Basic Logic Gates 12. Combinational Logic Circuits 13. Set-Reset (S–R) Latches 14. Voltage Comparator, Timers and Counters
V. Engineering Design Process	15. Engineering Design Process

SUBJECT CONTENT

SECTION I: SYSTEMS

1 Electronic Systems

Electronic systems are designed to solve specific problems in many areas of our daily lives. A simple system can consist of just an input, a process and an output[1]. However, complex systems can have multiple inputs, processes and outputs. In addition, complex systems are usually made of subsystems with the output of a subsystem becoming the input of another subsystem. Only when all subsystems are functioning properly will the overall system be able to solve the intended problem. This understanding allows electronic engineers to design, build, test and troubleshoot electronic systems in a logical and systematic manner.

Content

- Simple systems
- Electronic systems
- Electrical signals

Learning Outcomes

Candidates should be able to:

(a) recognise and understand that, in general, electronic systems consist of input subsystems, process subsystems and output subsystems

(b) use the symbols of common electrical and electronic components to represent an electrical/electronic system

(c) give examples of electronic systems encountered in daily life

(d) identify the input, process and output subsystems of an electronic system

(e) describe a subsystem as a system that obtains input from, or provides input to, another subsystem

(f) represent complex systems in terms of subsystems using block diagrams

(g) state that an electronic signal is an electrical voltage or current that carries information

(h) recognise that electronic signals may be analogue or digital in nature, and differentiate between them.

[1] A component that has input, process and output can be considered to be a simple system, e.g. an IC chip. By this definition, components such as wires and resistors are not considered a system.

SECTION II: FUNDAMENTALS OF ELECTRICITY

2 Current Electricity

Electronics builds on principles of electricity. It is necessary for learners of electronics to have a firm understanding of the principles related to electric charges, current, voltage, resistance and power.

Content

- SI units
- Standard scientific notation and prefix form
- Conventional current and electron flow
- Charge, e.m.f. and potential difference
- Resistance and Ohm's law
- Measurement of voltage, current and resistance
- Electrical energy and power

Learning Outcomes

Candidates should be able to:

(a) recall common quantities related to electricity (e.g. current, potential difference, power, electric charge, resistivity and frequency) and their SI units

(b) express the magnitude of quantities in scientific (exponential) notation

(c) use the following prefixes and their symbols to indicate decimal submultiples and multiples of the SI units: pico (p), nano (n), micro (μ), milli (m), centi (c), kilo (k), mega (M), giga (G), tera (T)

(d) distinguish between conventional current and electron flow

(e) state that current is the rate of flow of charge and is measured in amperes (A)

(f) recall and apply the relationship *charge* = *current* × *time*

(g) distinguish between electromotive force (e.m.f.) and potential difference (p.d.)

(h) state that both e.m.f. and p.d. are measured in volts (V).

(i) calculate the effective e.m.f. when several sources are connected in series and in parallel

(j) state that $resistance = \dfrac{p.d.}{current}$

(k) state and apply Ohm's law to determine current, voltage, and resistance

(l) sketch and interpret the graphical linear relationship between current and voltage in a purely resistive circuit

(m) state that heat is produced when an electric current flows through a conductor and relate this to the effects of heating of components in an electrical circuit

(n) define power as the rate of energy conversion

(o) recall the power equations $P = VI$, $P = I^2R$ and $P = \frac{V^2}{R}$ and apply the relationships $P = VI$ and $E = VIt$ to solve problems involving resistive circuits

(p) determine the efficiency of an electrical device.

3 Resistors

Resistors are basic electrical components that are used to control the size of current flowing in different parts of electrical circuits. They can be made from different materials and are usually available in standard values.

Content

- Resistivity
- Types of resistors
- Colour code
- Effective resistance

Learning Outcomes

Candidates should be able to:

(a) describe resistivity as the characteristic of a material that affects its electrical conductivity of a material and apply the formula $R = \frac{\rho l}{A}$ to explain how resistivity, length and cross-sectional area of a conductor affects its electrical resistance

(b) describe the structures of various types of resistor (carbon and wire-wound) and select the appropriate resistor for a particular circuit design

(c) use the resistor colour code to determine the ohmic value and tolerance of a resistor, and verify the value by measurement

(d) select a suitable resistor from the E24 resistor series for a particular application

(e) determine the power rating of a resistor and explain the factors affecting it

(f) explain how changing the resistance in a circuit changes the current in the circuit

(g) recall and apply the formulae to calculate the effective resistance of resistors connected in series and in parallel

(h) explain the use of variable resistors in electrical circuits.

4 Circuit Theories

A circuit consists of electrical paths that allow currents to flow. Components in an electronic system are connected as circuits. Circuit theories can be used to determine the voltage and current at different parts of a given circuit. Knowledge of circuit theories is also necessary to design, build and troubleshoot electronic systems.

Content

- Basic terms in circuits
- Series and parallel circuits
- Voltage and current dividers
- Kirchhoff's voltage and current laws

Learning Outcomes

Candidates should be able to:

(a) define the terms – circuit, load, source, open-circuit, short-circuit and overload

(b) show understanding that current flows only in a closed circuit

(c) show understanding of the effect of a short circuit

(d) identify and use common types of switches (PTM, PTB, SPST and SPDT)

(e) apply the following principles to a series-parallel resistive circuit:

  (i) the current at every point in a series circuit is the same

  (ii) the sum of the p.d. in a series circuit is equal to the p.d. across the whole circuit

  (iii) the current from the source is equal to the sum of the currents in the branches of a parallel circuit

  (iv) the p.d. across each branch of a parallel circuit is the same

(f) identify a resistive voltage divider and apply the voltage-divider formula to solve related problems

(g) identify a resistive current divider and apply the current-divider formula to solve related problems

(h) state and apply Kirchhoff's voltage and current laws.

5 Alternating Currents

As opposed to direct currents (DC), which do not change direction, alternating currents (AC) change direction in a regular manner. Many voltages and currents encountered in our daily lives are AC, e.g. the mains supply and music signals. To describe these AC voltages and current, terms such as frequency, period and peak voltage are commonly used.

Content

- Characteristics of alternating current/voltage
- Types of AC waveforms

Learning Outcomes

Candidates should be able to:

(a) distinguish between direct and alternating currents/voltages (in terms of whether there is a change of direction)

(b) give examples of direct current and alternating current

(c) show understanding that alternating currents or voltages can be represented by waveforms

(d) recognise and sketch the common types of AC waveforms (sinusoidal, rectangular, square and triangular)

(e) determine the DC level, frequency, period, peak and peak-to-peak values of an alternating current/voltage from its waveform

(f) determine the duty cycle of a rectangular waveform

(g) apply the relationship $T = \frac{1}{f}$ to solve related problems.

6 Capacitors

Capacitors are components that store electrical charges. A capacitor is made of 2 conductors (usually plates) separated by a dielectric material. It charges up when power is supplied to a circuit and discharges when the power is turned off. Capacitors have many important uses in electronic systems such as smoothing voltages and timing.

Content

- Structure and working principle
- Capacitance
- Charging and discharging a capacitor

Learning Outcomes

Candidates should be able to:

(a) describe the structure and working principles of a basic capacitor

(b) recognise and give examples of polarised and non-polarised capacitors

(c) define capacitance and state its SI unit

(d) recall and apply the equation $C = \frac{Q}{V}$ to solve problems

(e) explain why capacitors have a maximum working voltage

(f) calculate the time constant in a simple resistor-capacitor (RC) circuit using $\tau = RC$

(g) estimate the time for a capacitor to be charged to and discharged by $\frac{2}{3}$ and 100% of the maximum voltage.

SECTION III: ANALOGUE ELECTRONICS

7 Semiconductor Diodes

A semiconductor is a material which has electrical conductivity between that of a conductor and an insulator. There are two types of semiconductors: n-type and p-type. The simplest semiconductor component is the pn junction diode and one of its important uses is the conversion of AC to DC in a process called rectification. Light emitting diodes and Zener diodes are special types of diodes. Unlike normal diodes, Zener diodes allow current to flow in the opposite direction but only when the reverse voltage is large enough. Zener diodes can be used to maintain a steady voltage when it is in reverse-biased thus making them useful to be used in voltage regulators. Due to their low power consumption, LEDs are commonly used for lighting and visual displays.

Content

- Structure and working principles
- Half-wave and full-wave rectification
- Light-emitting diode (LED)
- 7-segment display
- Zener diode and its applications
- Infrared diodes and photodiodes

Learning Outcomes

Candidates should be able to:

(a) state that there are two types of semiconductor: n-type and p-type

(b) describe the basic structure of the PN junction diode and explain how it is biased in the forward and reverse directions

(c) describe the I-V characteristics of a diode

(d) explain the difference between ideal and practical diodes

(e) apply the simplified diode model to solve problems

(f) describe and explain the use of diodes in half-wave and full-wave rectifiers using the simplified diode model

(g) interpret typical diode specifications (forward voltage, max current, max reverse voltage) using datasheets

(h) state that LED is a special type of diode that emits light and infra-red

(i) describe the benefits of using LEDs for lighting as compared to incandescent bulbs

(j) explain why a resistor should be connected in series with an LED in a circuit and calculate its resistance value

(k) describe the use of infrared diodes and photodiodes as transmitting and receiving devices respectively

(l) state that a 7-segment display is made up of 7 LEDs which can be individually controlled

(m) describe the difference between the structure and operation of a common anode and common cathode 7-segment display

(n) describe the I-V characteristics of a Zener diode

(o) explain the use of Zener diodes to regulate voltage (without load).

8 Input and Output Transducers

A transducer is a device that converts a signal from one form of energy to another. As electronic systems can only process electrical signals, input transducers play the important role of converting non-electrical quantities (e.g. temperature) to electrical signals. Output transducers then convert the outcomes of the process to non-electrical quantities. There are many different types of input and output transducers which are differentiated by the type of conversion they perform.

Content

- Basics of input and output transducers
- Thermistor, light-dependent resistor (LDR) and microphone
- Loudspeaker, buzzer, motor and electromechanical relay

Learning Outcomes

Candidates should be able to:

(a) explain what is meant by an input and an output transducer

(b) give examples of input and output transducers

(c) recall and apply the effect of changes in temperature on the resistance of a thermistor to practical situations

(d) recall and apply the effect of changes in light intensity on the resistance of an LDR to practical situations

(e) interpret the characteristic graphs of thermistors and LDRs

(f) describe the function of the following transducers: microphone, loudspeaker, buzzer, low voltage DC motor and electromechanical relay.

9 Bipolar Junction Transistors and Operational Amplifiers

A transistor is a 3-terminal semiconductor device. By applying a small current at one terminal, the current flowing between the other two terminals can be controlled. This property allows the transistor to be used as an amplifier or an electronic switch. Transistors are the basic building blocks of complex integrated circuits and the modern day computer processors consist of hundreds of millions of transistors packed into a small integrated circuit. A basic type of transistor is the bipolar junction transistor. Before it can be used, a BJT needs to be biased using an external circuit so that it will work in the correct operating region. Other than BJT, operational amplifiers are also commonly used as an amplifier due to its higher gain, higher input impedance and better noise immunity. Depending on the configuration, an op-amp can be set up as an inverting or non-inverting amplifier. It also can be configured as a voltage follower to resolve loading effects in complex circuits.

Content

- Structure and working principle
- Operating regions
- BJT applications
- Operational amplifiers

Learning Outcomes

Candidates should be able to:

(a) describe the structures of the two types of bipolar junction transistor (BJT)

(b) describe the working principle of a BJT (a base current controls current between emitter and collector)

(c) describe the different operating regions of BJTs

(d) interpret typical BJT specification (β, I_{Cmax}, V_{BE}, $V_{\mathrm{CE(sat)}}$) using its datasheet

(e) explain how a NPN and PNP BJT can be used as a switch

(f) solve problems in circuits that use transistors as switches by applying the relationships between currents and voltages.

(g) explain the advantage of a Darlington pair over a single transistor in driving an output transducer

(h) describe the working principle and key characteristics of ideal and practical operational amplifiers (op-amps) (e.g. input impedance, output impedance and open loop gain)

(i) explain how an op-amp can be configured to operate as inverting and non-inverting amplifiers

(j) calculate the gain of both inverting and non-inverting op-amps

(k) explain how an op-amp can be configured to operate as a voltage follower.

SECTION IV: DIGITAL ELECTRONICS

10 Introduction to Digital Electronics

Digital electronics is based on analogue electronics. Most modern electronic devices such as the personal computer and mobile phone, use digital electronics to tap on its advantages in terms of cost, size, speed and reliability. A key difference between analogue and digital electronics is the signals. While analogue signals take on continuous values, digital signals take on two discrete levels. For this reason, almost every digital system uses the binary number system. However, humans are more familiar with the decimal number system. To help us deal with binary numbers, a third number system, hexadecimal, can be used.

Content

- Analogue and digital signals
- Pull up/down resistors
- 7-segment display module

Learning Outcomes

Candidates should be able to:

(a) identify analogue and digital signals from oscilloscope traces

(b) state that digital signals can be represented by two logic states: logic 1 (high voltage, usually 5 V); logic 0 (low voltage, usually 0 V)

(c) explain the use of ‘pull up’ and ‘pull-down’ resistors to provide the correct logic levels

(d) list the advantages and disadvantages of digital systems over analogue systems

(e) describe the need to convert between analogue and digital signals

(f) convert between binary, decimal and binary-coded decimal (BCD) systems

(g) describe the function of a BCD to 7-segment display module using a truth table.

(h) identify the pins of a 74LS247 BCD to 7-segment display decoder IC from its specification sheet

(i) describe the operation of a 74LS247 IC

11 Basic Logic Gates

The basic building blocks of digital electronics are logic gates. Each logic gate is a system on its own with 2 or more inputs and one output. Logic gates are used to represent logical decisions which can be presented in the form of truth tables, logic symbols and Boolean notation. Two of the logic gates, NAND and NOR, are special gates called universal gates as they can be used to build all other types of logic gates.

Content

- Basic logic gates
- Universal gates
- Integrated Circuits (ICs)

Learning Outcomes

Candidates should be able to:

(a) describe the truth table as a way to show the output of a digital circuit for different combinations of inputs

(b) state that a logic gate is a device with one output and at least one input; the output is either logic 1 or 0 depending on the inputs

(c) draw symbols and construct truth tables for NOT, AND, OR, NAND, NOR, XOR and XNOR gates

(d) use Boolean notation (‘$\overline{}$’, ‘$\cdot$’, ‘+’ and $\oplus$) to write the Boolean expression for NOT, AND, OR, NAND, NOR, XOR and XNOR gates

(e) state that NAND and NOR gates are universal gates

(f) show how NOT, AND and OR gates can be made using NAND or NOR gates

(g) describe basic characteristics (e.g. general structure, pin configuration, common notation) of a dual in-line IC

(h) use datasheets to identify pin connections of common logic gate ICs.

(i) list the advantages and disadvantages of CMOS over TTL ICs

(j) explain the interfacing between CMOS and TTL ICs.

12 Combinational Logic Circuits

Combinational logic circuits are built using basic logic gates to achieve more complex functions. There are usually more inputs and outputs compared to a basic logic gate. Here, the combinational logic circuit can be viewed as a larger system with the basic logic gates functioning as sub-systems where the outputs are dependent on the inputs and how the logic gates are connected. A combinational logic circuit can also be simplified to achieve the same function with fewer logic gates, helping to save cost and make the circuit less prone to faults. Mathematical tools such as Boolean algebra and Karnaugh maps can help to perform such simplifications in a systematic manner.

Content

- Sum-of-Products Boolean expression
- Boolean algebra and Karnaugh Map
- Applications of combinational logic

Learning Outcomes

Candidates should be able to:

(a) use a truth table to describe the output of a digital system (up to three inputs)

(b) convert a truth table (up to three inputs) into a sum-of-product (SOP) Boolean expression

(c) simplify an SOP Boolean expression (up to three variables) using either Boolean algebra or a Karnaugh map

(d) implement logic circuits using NOT, AND and OR gates given an SOP Boolean expression

(e) describe and explain the function of a given combinational logic circuit

(f) solve system problems using combinations of logic gates (up to three inputs).

13 Set-Reset (S–R) Latches

A key advantage of digital electronics is the ability to remember data. This ability enables digital circuits to perform more complex operations such as counting. The most basic circuit with memory is the S-R latch which can be used to store a single bit of data as either logic ‘1’ or ‘0’ allowing the latch to convert a momentary occurrence into a constant output. Timing diagrams are frequently used to describe and analyse circuits with memory. These diagrams show the logic state (‘1’ or ‘0’) of the system at any point in time and also the time when a change in state occurs.

Content

- NOR gate S-R Latch
- Debounced Switch

Learning Outcomes

Candidates should be able to:

(a) describe the S-R latch as a digital circuit with memory

(b) draw the symbolic representation of an S-R latch using NOR gates

(c) construct the truth table of an S-R latch and use the table to determine the output of the latch

(d) draw the output timing diagram of an S-R latch

(e) explain how an S-R latch is used to convert a momentary occurrence into a constant output

(f) explain how an S-R latch can be used to build a debounced switch.

14 Voltage Comparator, Timer and Counter

Comparing voltages, timing and counting are important applications of electronics which can be carried out by specific IC chips. Voltage comparator ICs, such as the LM311, are commonly used to compare the voltage produced by an input transducer against a reference voltage. Depending on the result of the comparison, the output will either be a high voltage (e.g. 5 V) or a low voltage (e.g. 0 V). This is an example of analogue-to-digital conversion. The most widely used IC chip for timing applications is the 555 timer IC that can be set up to operate as a monostable or astable multivibrator. The time needed to charge or discharge the capacitor in the external circuit determines the duration and frequency of the multivibrator. The 74390 dual decade counter IC contains two 4-bit decade counters that can be used together to count up to 99, lending it to many useful applications that require counting.

Content

- LM311 voltage comparator IC and its applications
- 555 timer IC and its applications
- 74390 4-bit decade counter IC and its applications

Learning Outcomes

Candidates should be able to:

(a) identify the pins of an LM311 voltage comparator IC from its specification sheet

(b) describe the operation and use of an LM311 voltage comparator IC (with single rail supply only)

(c) distinguish between a monostable and astable multivibrator

(d) identify the pins of a 555 timer IC from its specification sheet

(e) recognise whether a 555 timer IC is set up as a monostable or astable multivibrator from a given circuit (students are not required to draw the set-up)

(f) use the formula $T = 1.1RC$ to determine the time period of a 555 IC in monostable mode (formula will be provided)

(g) use the formula $T = \frac{(R_1 + 2R_2)C}{1.44}$ to determine the time period of a 555 IC in astable mode (formula will be provided)

(h) draw output timing diagram of a 555 IC

(i) identify the pins of a 74390 4-bit decade counter IC from its specification sheet

(j) describe the operation and use of a 74390 IC

(k) show understanding of how the output of a 74390 IC can be shown on a 7-segment display

(l) show understanding of how two 4-bit decade counters in a 74390 IC can be connected to count to 99.

SECTION V: ENGINEERING DESIGN PROCESS

15 Engineering Design Process

The engineering design process covers the development of a product from problem definition to the design, build and test of a prototype to the reporting of the development process. To ensure the successful completion of a project, it is important to manage time and resources effectively. In electronics, this often means the completion of an electronic product that can perform a specific function. In the design phase of the project, computer simulation offers a cost- and time-effective means of checking the workability of a design before building a prototype. Electronic engineers use test equipment to check if a prototype is working as planned; if not, they will use the equipment to pinpoint the sources of problem in a process called troubleshooting. The engineers also need to be able to document and communicate the processes, usually in the form of a report.

Content

- Project management
- Project realisation
- Circuit design and computer simulation
- Test and measurement
- Documentation of project

Learning Outcomes

Candidates should be able to:

(a) recognise the characteristics of a successful project plan

(b) draw a Gantt chart for a project with known tasks, precedence, and durations

(c) create new processes, products or projects through the synthesis of ideas from a wide range of sources by:
- (i) using research methods including web search, textbooks, library resources, literature review, etc.
- (ii) specifying the requirements of an electronic product based on the problem definition
- (iii) building a prototype circuit using a prototype board

(d) appreciate the role of computer simulation in circuit design (advantages and limitations)

(e) use circuit simulation software to verify a circuit design

(f) use relevant test and measuring equipment (digital multimeter, function generator and oscilloscope) to test and troubleshoot prototype circuits

(g) maintain and organise records of project work development

(h) write a project report using information collated from the project work.

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

The following list illustrates the common symbols and units that will be used in the question papers and is not meant to be exhaustive.

Quantity	*Symbol*	*Unit*
length	*l, d* ……	m, cm, nm
mass	*m, M*	kg, g
time	*t*	h, min, s, ms, μs, ns
electric charge	*Q*	C
electric current	*I*	A, mA
voltage/potential difference/e.m.f.	*V*	V, mV
resistance	*R*	Ω, kΩ, MΩ
energy	*E*	J
power	*P*	W
resistivity	ρ	Ωm
capacitance	*C*	F, μF, nF
period	*T*	h, min, s, ms, μs, ns
frequency	f	Hz, kHz, MHz, GHz
Celsius temperature	θ	ºC

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PRACTICAL GUIDELINES

Applied subjects are, by their nature, application-based. It is therefore important that the candidates carry out appropriate practical work to support and facilitate the learning of the electronics components, test equipment and theories. A list of suggested practical work is provided below.

- measure voltage, current and resistance using a multimeter
- build electronics circuits on breadboard
- obtain V-I graph of a component
- use test equipment (DC power supply, function generator and oscilloscope)
- use computer simulation software to verify circuit designs
- verify the colour code of resistors
- investigate current and voltage of series/parallel circuits
- verify Kirchhoff's laws
- observe the charging and discharging waveforms of a capacitor in a RC circuit
- build a half-wave and a full-wave rectifier to perform AC to DC conversion
- build a simple voltage regulator using a Zener diode
- use thermistors and LDRs as input transducers
- connect a transistor as a switch
- build an automatic lighting system using LDR and BJT transistor
- build a Darlington Pair
- display decimal digits using 7-segment display module
- verify operation of common logic gate ICs
- build combinational logic circuits
- build a simple S-R latch using NOR gates
- build a debounced switch using S-R latch
- verify operation of a voltage comparator
- set up a 555 timer IC as a monostable and astable multivibrator
- use 74390 4-bit decade counter IC to count to 99
- build a simple stopwatch using 555 timer and 74390 counter

GLOSSARY OF TERMS

It is hoped that the glossary will prove helpful to candidates as a guide, although it is not exhaustive. The glossary has been deliberately kept brief not only with respect to the number of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend in part on its context. They should also note that the number of marks allocated for any part of a question is a guide to the depth of treatment required for the answer.

1. *Define* (the term(s) ...) is intended literally. Only a formal statement or equivalent paraphrase, such as the defining equation with symbols identified, being required.

2. *Explain*/*What is meant by* ... normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in the light of the indicated mark value.

3. *State* implies a concise answer with little or no supporting argument, e.g. a numerical answer that can be obtained ‘by inspection’.

4. *List* requires a number of points with no elaboration. Where a given number of points is specified, this should not be exceeded.

5. *Describe* requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena. The amount of description intended should be interpreted in the light of the indicated mark value.

6. *Discuss* requires candidates to give a critical account of the points involved in the topic.

7. *Predict or deduce* implies that candidates are not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an earlier part of the question.

8. *Suggest* is used in two main contexts. It may either imply that there is no unique answer or that candidates are expected to apply their general knowledge to a 'novel' situation, one that formally may not be ‘in the syllabus’.

9. *Calculate* is used when a numerical answer is required. In general, working should be shown.

10. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or angle, using a protractor.

11. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula.

12. *Show* is used when an algebraic deduction has to be made to prove a given equation. It is important that the terms being used by candidates are stated explicitly.

13. *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned. Candidates should make such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included in the question.

14. *Sketch*, when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct. However, candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having an intercept, asymptote or discontinuity at a particular value. On a sketch graph it is essential that candidates clearly indicate what is being plotted on each axis.

    Sketch, when applied to diagrams, implies that a simple, freehand drawing is acceptable: nevertheless, care should be taken over proportions and the clear exposition of important details.

SPECIAL NOTES

Calculators

An approved calculator may be used in all papers.

ASSESSMENT RUBRIC FOR PROJECT

(1) *Project Plan (5 marks)*
Successful project begins with a detailed project plan. Project planning includes identification of the key activities, time management and resource allocation. The plan should take into consideration time needed for testing, ongoing evaluation and modification during the realisation of the design. A good project plan helps to keep track of the progress of the project.

(2) *Analysis of Project Specifications (5 marks)*
An analysis of the project specifications can be performed by generating a system block diagram, together with its various subsystems (input, process and output), to describe the approach to how the specifications can be realised.

(3) *Research (10 marks)*
Research will allow candidates to obtain information needed to make informed decisions at various stages of the design work. A thorough research involves seeking out information from a range of sources such as textbooks, datasheets, internet and the library. A good research work should answer all aspects of questions posed earlier, allowing relevant findings to be evaluated. Before embarking on research, it is also essential for candidates to pose questions to guide their research on how the specifications can be realised.

(4) *Investigation and Generation of Technical Solutions (10 marks)*
Candidates should generate a range of possible technical solutions and express them through system block diagrams and circuit diagrams. It is also essential for candidates to perform relevant computer simulations to investigate these solutions. A comparison of these simulations should also be provided.

(5) *Detailed Development and Description of the Final Technical Solution (10 marks)*
From the investigation, candidates are to select the best technical solution for prototyping and justify with reasons the selection of this solution. Full details of this solution (e.g. list of components used) should also be included. During prototyping, candidates are to record any modifications/refinements made, including the development of enhancement(s), if any. candidates should include photographs of the prototype, a complete set of circuit diagrams (with test points corresponding to those used during testing), any enhancement(s) made, a list of components and other useful details.

(6) *Enhancement (15 marks)*
Candidates should demonstrate creativity in its design of the project using good engineering design practice that leads to some enhancements in areas such as improving user experience and prototype performing better than the stated specifications.

(7) *Testing Activities and Measurement Results (10 marks)*
Candidates should document all the tests conducted (including enhancement(s), if any) and make comparisons between the results obtained and results from the computer simulation, with plausible explanations for the outcome of the comparison provided. Candidates should also record measurements obtained from tests conducted such as waveforms (e.g. voltage-time graph) and readings (e.g. voltage, current, resistance, frequency and period). To help present the results clearly, candidates should use tables with clear headings.

(8) *Project Reflection (10 marks)*
Engineers can improve their work processes and capture the learning points by performing a reflection of their project, which includes the design process and building of the prototype. The following questions could be used as a guide:
- Do you consider your project a success? Explain.
- If you were to do this project again, would you use the same design choice? Explain.
- How can your project be improved?
- How did you overcome the challenges you faced?
- How could the problems be avoided?

(9) *Functionality of Project (15 marks)*
The prototype should be fully functional and reliable and satisfy all design specifications.

(10) *Quality of Project (5 marks)*
Candidates should reflect the attention to design and construction details and demonstrate a very high degree of workmanship and high quality of finish in the prototype.

(11) *Organisation and Presentation (5 marks)*
The report should be organised and well-structured, with contents presented in a clear, logical and coherent manner. Due recognition and acknowledgement should be accorded to the information sources and person(s) who have rendered help to the project.

Project Plan (5 marks)			
No marks	**Level 1**	**Level 2**	**Level 3**
	1	**2–3**	**4–5**
No project plan	Plan lacked details and clarity.	Fairly detailed work plan that provided a general overview of the project.	Detailed and well thought out plan that provided a good overview of the project. # Completed with minimal or no guidance and assistance

Analysis of Project Specifications (5 marks)			
No marks	**Level 1**	**Level 2**	**Level 3**
	1	**2–3**	**4–5**
No system block diagram for general solution.	System block diagram for general solution was only partially relevant to design brief. No explanation provided for this system block diagram.	System block diagram for general solution was mostly relevant to design brief. An explanation provided for this system block diagram.	System block diagram for general solution was completely relevant to design brief. Detailed and accurate explanation provided for this system block diagram. # Completed with minimal or no guidance and assistance.

Research (10 marks)			
No marks	**Level 1**	**Level 2**	**Level 3**
	1–4	**5–7**	**8–10**
No questions posed, or No research work performed.	Questions posed lack relevance in facilitating research. Information obtained from research was useful for developing a few technical solutions. Some explanation provided to support relevance of information.	Relevant questions posed that would facilitate research into some areas of the coursework. Information obtained from research was useful for developing a fair range of technical solutions. Clear, logical explanation provided to support relevance of information.	Relevant questions posed that would facilitate comprehensive research. Information obtained from research was useful for developing a wide range of technical solutions. Very clear, logical explanation provided to support relevance of information. # Completed with minimal or no guidance and assistance.

Investigation and Generation of Technical Solutions (10 marks)			
No marks	**Level 1**	**Level 2**	**Level 3**
	1–4	**5–7**	**8–10**
No investigation carried out	Technical solution for some subsystems was investigated through computer simulations or other appropriate methods.	A range of technical solutions for some subsystems were investigated through computer simulations or other appropriate methods where computer simulations is not possible. Investigation generated some relevant and useful results. Some comparison made between technical solutions using results of investigation.	A range of technical solutions for all subsystems were investigated through computer simulations or other appropriate methods, where simulations is not possible. Investigation generated relevant and useful results. Comparison made between technical solutions using results of investigation. # Completed with minimal or no guidance and assistance.

Detailed Development and Description of the Final Technical Solution (10 marks)			
No marks	**Level 1**	**Level 2**	**Level 3**
	1–4	**5–7**	**8–10**
No evaluation was carried out, and	An incomplete evaluation was carried out on the comparisons of technical solutions for subsystems to generate a proposed technical solution for the overall system.	A complete but weak evaluation was carried out on the comparisons of technical solutions for subsystems to generate a proposed technical solution for the overall system.	A complete and in-depth evaluation was carried out on the comparisons of technical solutions for subsystems to generate a proposed technical solution for the overall system.
No description of how the complete technical solution was developed.	Unclear description of how the proposed technical solution was developed into the final technical solution.	Some description of how the proposed technical solution was developed into the final technical solution.	A clear and thorough description of how the proposed technical solution was developed into the final technical solution.
No description of the final technical solution and,	An incomplete description of the functionality of the final technical solution, supported by system block diagram, photographs of the prototype, and circuit diagrams with some of the key components and test points clearly labelled.	A description of the functionality of the final technical solution, supported by system block diagram, photographs of the prototype, and circuit diagrams with most of the key components and test points clearly labelled.	A detailed description of the functionality of the final technical solution, supported by system block diagram, photographs of the prototype, and circuit diagrams with all key components and test points clearly labelled.
No list of components used.	Provided a partial list of the components used.	Provided a complete list of the components used.	Provided a complete list of the components used with technical specifications. # Completed with minimal or no guidance and assistance.

Enhancement (15 marks)			
No marks	**Level 1**	**Level 2**	**Level 3**
	1–7	**8–12**	**13–15**
No evidence of improved performance or any enhancement made.	Some attempts to make prototype perform better than the stated specifications. A basic enhancement (above those stated requirements) that may improve the user experience.	Prototype performs better than the stated specifications with underpinning design principles explained. An enhancement (above those stated requirements) that improves the user experience, with rationale described.	Prototype performs significantly better than the stated specifications with underpinning design principles clearly explained. An enhancement (above those stated requirements) that significantly improves the user experience, with rationale clearly described. # Completed with minimal or no guidance and assistance.

Testing Activities and Measurement Results (10 marks)			
No marks	**Level 1**	**Level 2**	**Level 3**
	1–4	**5–7**	**8–10**
No testing activities conducted, and No measurement results presented.	Some tests were conducted. Some plausible measurement results were included. Comparison made between measurement results and some of the results from computer simulations, with no explanation on the comparison provided.	Testing done was adequate and mostly correct – able to show if project's performance met most specifications. Most relevant measurement results were included and presented in appropriate formats. Comparison made between measurement results and most of the results from computer simulations, with an explanation on the comparison provided.	Testing done was thorough, correct and logically sequenced – able to show if project's performance met all specifications. All relevant measurement results were included and presented in appropriate formats (readings, tables, graphs, waveforms, etc.). Comparison made between measurement results and all of the results from computer simulations, with a plausible explanation on the comparison provided. # Completed with minimal or no guidance and assistance.

Project Reflection (10 marks)			
No marks	**Level 1**	**Level 2**	**Level 3**
	1–4	**5–7**	**8–10**
No reflections done.	Reflections on some of the following were provided: • review of project planning. • challenges faced and the learning points derived from these challenges. • possible technical improvements that are realistic and specific to prototype.	Reflections on all the following were provided: • review of project planning. • challenges faced and the learning points derived from these challenges. • possible technical improvements that are realistic and specific to prototype.	Meaningful reflections on all the following were provided: • review of project planning. • challenges faced and the learning points derived from these challenges. • possible technical improvements that are realistic and specific to prototype. # Completed with minimal or no guidance and assistance.

Functionality of Project (15 marks)			
No marks	**Level 1**	**Level 2**	**Level 3**
	1–7	**8–12**	**13–15**
Not functional.	Partially functional – satisfies some of the design specifications.	Mostly functional – Satisfies most of the design specifications. Shows erratic behaviour.	Fully functional – satisfies all the design specifications. Reliable – works consistently after repeated checks. # Completed with minimal or no guidance and assistance.

Quality of Project (5 marks)			
No marks	**Level 1**	**Level 2**	**Level 3**
	1	**2–3**	**4–5**
Unacceptable quality.	Disorganised circuit board layout with few test points labelled. Some components were not firmly connected to circuit board.	Circuit board layout was neat and logically organised with most test points labelled. Most components were firmly connected to circuit board.	Circuit board layout was neat and logically organised: test points were accessible and clearly labelled, appropriate use of wires with different colour. Components were firmly connected to circuit board. # Completed with minimal or no guidance and assistance.

Organisation and Presentation (5 marks)			
No marks	**Level 1**	**Level 2**	**Level 3**
	1	**2–3**	**4–5**
Project was poorly organised, and Sources of information were not credited.	Report was poorly organised with no clear structure. Some sources of information were credited.	Report was mostly organised and well-structured (with proper sub-headings). Some sources of information were appropriately credited.	Report was organised and well-structured (with proper sub-headings). Most sources of information were appropriately credited. # Completed with minimal or no guidance and assistance.

DATA AND FORMULAE

RESISTOR COLOUR CODES

1st Colour Band 1st Digit		2nd Colour Band 2nd Digit		3rd Colour Band Multiplier		4th Colour Band Tolerance	
Black	0	Black	0	Black	0	Gold	± 5 %
Brown	1	Brown	1	Brown	1	Red	± 2 %
Red	2	Red	2	Red	2		
Orange	3	Orange	3	Orange	3		
Yellow	4	Yellow	4	Yellow	4		
Green	5	Green	5	Green	5		
Blue	6	Blue	6	Blue	6		
Violet	7	Violet	7	Violet	7		
Grey	8	Grey	8	Silver	0.01		
White	9	White	9	Gold	0.1		

PREFERRED VALUES FOR RESISTORS (E24 SERIES)

1.0 1.1 1.2 1.3 1.5 1.6 1.8 2.0 2.2 2.4 2.7 3.0 3.3
3.6 3.9 4.3 4.7 5.1 5.6 6.2 6.8 7.5 8.2 9.1 and multiples of ten.

FORMULAE

Astable and monostable generators using 555 timers

Monostable mode: Period T = $1.1RC$

Astable mode: Period T = $\dfrac{(R_1 + 2R_2)C}{1.44}$

Bipolar junction transistor (BJT)

Current gain: $\beta = \dfrac{\text{Collector current}}{\text{Base current}}$

Op-amp closed-loop gain

Non-inverting gain: Gain, $A_{CL} = 1 + \dfrac{R_f}{R_{in}}$

Inverting gain: Gain, $A_{CL} = -\dfrac{R_f}{R_{in}}$

TABLE ON BOOLEAN ALGEBRA

Single-variable theorems	Laws of Complementation	• $\overline{0} = 1$ • $\overline{1} = 0$ • $\overline{\overline{A}} = A$
	AND Laws	• $A \cdot 0 = 0$ • $A \cdot 1 = A$ • $A \cdot A = A$ • $A \cdot \overline{A} = 0$
	OR Laws	• $A + 0 = A$ • $A + 1 = 1$ • $A + A = A$ • $A + \overline{A} = 1$
Multivariable theorems	Commutative Laws	• $A + B = B + A$ • $A \cdot B = B \cdot A$
	Associative Laws	• $A + (B + C) = (A + B) + C = A + B + C$ • $A(B \cdot C) = (A \cdot B)C = A \cdot B \cdot C$
	Distributive Laws	• $A(B + C) = A \cdot B + A \cdot C$ • $(A + B)(C + D) = A \cdot C + B \cdot C + A \cdot D + B \cdot D$
	Absorptive Laws	• $A + A \cdot B = A$ • $A \cdot (A + B) = A$ • $A + \overline{A} \cdot B = A + B$ • $A \cdot (\overline{A} + B) = A \cdot B$
	DeMorgan’s Theorems	• $\left(\overline{A + B}\right) = \overline{A} \cdot \overline{B}$ • $\left(\overline{A \cdot B}\right) = \overline{A} + \overline{B}$