Electronics

Singapore-Cambridge General Certificate of Education Ordinary Level (2018)

(Syllabus 6063)

CONTENTS

Singapore Examinations and Assessment Board

CAMBRIDGE International Examinations

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. develop attitudes relevant to engineering such as perseverance; curiosity; integrity; striving for accuracy; open-mindedness; inventiveness; problem-solving (“can do” attitude); intellectual thoroughness

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. acquire knowledge of the fundamentals of electronics

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

Theory Papers (Paper 1)

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

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

Project (Paper 2)

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	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 electronic project	32 h	100	30%

Paper 1 (2 h, 100 marks) consisting 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 project is carried out over a period of 32 hours in Year 2. It comprises two interrelated components.

(a) Project Report (45 marks)

The project report document shows evidence of the candidate's activities and project implementation. The report reflects the candidate's understanding of the project specification, planning, design brief, analysis, investigation, ideas generation, design proposal, development, building, testing and evaluation.

The report should articulate how information is obtained and used, and the basis on which decisions are made in the development of design proposal. The candidate is advised to use flow diagrams to exemplify the complex project stages and is encouraged to use pictures and graphical illustrations in the report. Due recognition and acknowledgement should be accorded to information sources and person/s rendering help to the project.

The report should include a description of the strengths and weaknesses of the design and how problems, and issues surrounding the project were resolved.

(b) The Project Hardware (55 marks)

The candidate is expected to demonstrate good quality work, appropriate use of electronic components and constructional methods.

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
IV. Digital Electronics	10. Introduction to Digital Electronics 11. Basic Logic Gates 12. Combinational Logic Circuits 13. Memory – Set-Reset Latches 14. Voltage Comparator, Timing and Counting Circuits
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 a simple system consists of an input, a process and an output

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

[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.

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

(d) identify the inputs, processes (amplification, logic, memory, decoding, timing and counting) and outputs of an electronic system (e.g., an audio amplifier)

(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

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 (fundamental and derived)
- 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 the following base quantities and their SI units: mass (kg), length (m), time (s), electric current (A), temperature (K)

(b) recall derived quantities related to electricity (e.g., electric charge, resistivity and frequency) and their SI units

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

(d) 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)

(e) distinguish between conventional current and electron flow

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

(g) recall and apply the relationship $\text{charge} = \text{current} \times \text{time}$

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

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

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

(k) state that $\text{resistance} = \text{p.d.} / \text{current}$

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

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

(n) describe the use of the heating effect of an electric current flowing through a conductor

(o) define power as the rate of energy conversion

(p) recall the power equations $P = VI$, $P = I^2R$ and $P = V^2/R$ and apply the relationships $P = VI$ and $E = VIt$ to solve problems involving resistive circuits

(q) 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 and apply the formula $R = \rho l/A$ to perform calculations

(b) describe the structures of various types of resistors (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) 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

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

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

(g) state and apply Kirchhoff's voltage and current laws

5. Alternating Currents

As opposed to direct currents (DC) that 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 currents and alternating currents

(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 $T=1/f$ 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
- Capacitors in series and parallel
- 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 $C = Q/V$ to solve problems

(e) explain why capacitors have a maximum working voltage

(f) apply the relevant equations for capacitors connected in series and in parallel to solve related problems

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

(h) estimate the time for a capacitor to be charged to and discharged by 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

Learning Outcomes

Candidates should be able to:

(a) state that there are two types of semiconductors: 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

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

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

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

(n) explain the use of Zener diodes to regulate voltage

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), infra-red diode 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 use of infrared diodes as transmitting and receiving devices

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

9. Bipolar Junction Transistors

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.

Content

- Structure and working principle
- Operating regions
- BJT applications

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) relate the operating regions to the different segments of an I_C–V_{CE} characteristic graph

(e) relate the operating regions to the use of a BJT as a switch and an amplifier

(f) explain how a BJT can be biased to operate as a switch and an amplifier

(g) identify common base (CB), common collector (CC) and common emitter (CE) transistor circuits

(h) apply the relationship between the current, voltage and power of a transistor to solve related problems in common emitter circuits

(i) explain the function of coupling and bypass capacitors in transistor amplifier circuits

(j) calculate the approximate AC gain of a voltage-divider biased CE amplifier

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

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

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

11. Basic Logic Gates

The basic building blocks of digital electronics are logic gates. Each logic gate is a system on its own with 1 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 and NOR gates

(d) use Boolean notation ('¯', '•' and '+') to write the Boolean expression for NOT, AND, OR, NAND and NOR 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

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 & 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. Memory – 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

- LM 311 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 a stable 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 duration

(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; and

  (iii) building a prototype circuit using a prototype board

(d) appraise 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	^{o}C

.

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 an audio amplifier using a 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

Project Report (45 marks)

Project plan (5 marks)
Candidate should be able to outline a plan that takes into consideration time needed for testing, ongoing evaluation and modification for the realisation of the design.

Analysis of project specifications (5 marks)
Candidates should be able to communicate technical specifications for the overall system and subsystem(s) and pose questions to guide their research on how these specifications can be realised.

Research (5 marks)
Candidates should be able to conduct research for information needed to make informed decisions at various stages of the design work. Information should be obtained from a range of sources that answer all aspects of questions posed and allowing relevant findings to be evaluated.

Investigation and generation of ideas (5 marks)
Candidates should perform relevant computer simulations, mathematical analyses or other appropriate methods to investigate the designs obtained from their research.

Detailed development of the proposed solution (5 marks)
Candidates should be able to select the best solution for prototyping, detail how initial ideas were developed into the proposed solution and justify the selection of the design over alternative designs.

Description of proposed solution (5 marks)
Candidates should include a complete set of circuit diagrams, any enhancements(s) made, a list of components and other useful details.

Project evaluation (10 marks)
Candidates should be able to perform an evaluation of their project including the design process and the building of the prototype.

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 Hardware (55 marks)

Functionality of project (15 marks)
The prototype should be fully functional and reliable, and satisfy all the design specifications.

Testing activities (10 marks)
Candidates should document all the tests conducted including enhancement(s), if any

Measurements results (10 marks)
Candidates should record measurements obtained from tests conducted and make comparisons between the results obtained, the project requirements and results from the computer simulation.

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

Creativity and enhancement (15 marks)
Candidates should demonstrate creativity in the design of the project; e.g. the circuit design provides enhancements in the area of user experience. It should also include designs that allow the projects to deliver performances beyond the basic design specifications.

Project Report

Project plan			
No marks	**1**	**2–3**	**4–5**
• No project plan	• Plan lacks details and clarity • Plan is not an effective guide to implement the project	• Fairly detailed work plan that provides a general overview of the project • Plan can be used as a guide to implement the project	• Detailed and well thought out plan that provides a good overview of the project. • Plan can be used as an effective guide to implement the project # Completed with minimal or no guidance and assistance

Analysis of project specifications			
No marks	**1**	**2–3**	**4–5**
• No analysis of the project, or • No questions posed	• Weak analysis of the project lacking details of the subsystems • Questions posed lack relevance in facilitating research	• Systematic analysis of the project with details of some of the subsystems presented • Relevant questions posed that would facilitate research into some areas of the project	• Systematic analysis of the project with details of all subsystems clearly presented • Relevant questions posed that would facilitate a comprehensive research # Completed with minimal or no guidance and assistance

Research			
No marks	**1**	**2–3**	**4–5**
• No research work performed	• Minimal research was conducted • No evaluation of the findings	• Adequate research was conducted – some useful information was obtained for further investigation and generation of ideas. • Evaluation of some of the findings	• Extensive research was conducted – a range of useful information was obtained for further investigation and generation of ideas. • Evaluation of most of the findings # Completed with minimal or no guidance and assistance

Investigation and generation of ideas			
No marks	**1**	**2–3**	**4–5**
• No investigation carried out	• A few ideas were investigated • Investigation generate some results	• A fair range of ideas were investigated through computer simulations and other appropriate methods • Investigation generate some reliable results	• A wide range of ideas were investigated through computer simulations and other appropriate methods • Investigation generates reliable results # Completed with minimal or no guidance and assistance

Detailed development of the proposed solution			
No marks	**1**	**2–3**	**4–5**
• No description of the development process, or • No justification on choice of design	• Unclear how initial ideas were developed into the proposed solution • Weak justification on the selection of the proposed solution	• Some description of how initial ideas were developed into the proposed solution using results of the investigation • Some justification on the selection of the proposed solution using the results of investigation	• Clear and thorough description of how initial ideas were developed into the proposed solution through logical interpretation of the results of investigation • Justification on the selection of the proposed solution using results of investigation # Completed with minimal or no guidance and assistance

Description of proposed solution			
No marks	**1**	**2–3**	**4–5**
• No circuit diagram drawn, or • No list of components	• Provide a partial list of the components used • Provide most of the circuit diagrams with only some test points and component values labelled • Describe some parts of the overall system	• Provide a complete list of the components used with some technical specifications missing • Provide a complete set of circuit diagrams with most test points and component values labelled • Describe most parts of the overall system	• Provide a complete list of the components used with full technical specifications • Provide a complete set of organised, well-structured circuit diagrams with all test points and component values labelled • Describe clearly details of the overall system # Completed with minimal or no guidance and assistance

Project evaluation			
No marks	**1–4**	**5–7**	**8–10**
• No evaluation done	• State a learning point <u>or</u> a challenge faced • State a strength <u>or</u> a weakness of the project • State a possible improvement	• Describe learning points and challenges faced • Describe the strengths and weaknesses of the project • Describe further improvements that are relevant to the prototype	• Review project planning and implementation based on the learning points and challenges faced • Detailed assessment of the strengths and weaknesses of the project • Describe further improvements that are realistic and specific to prototype # Completed with minimal or no guidance and assistance

Organisation and presentation			
No marks	**1**	**2–3**	**4–5**
• Project is poorly organised, and • Key ideas and work done missing, or • Sources of information not credited	• Report is poorly organised with no clear structure • Some ideas and work done are described • Some sources of information are credited but with inadequate details	• Report is mostly organised and well-structured (with proper sub-headings) • Most ideas and work done are presented clearly and in a coherent manner • Some sources of information are properly credited with full details	• Report is organised and well-structured (with proper sub-headings) • All ideas and work done are clearly articulated and presented in a coherent manner • Most sources of information are properly credited with full details (in correct order and form) # Completed with minimal or no guidance and assistance

Project Hardware

Functionality of project			
No marks	**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

Testing activities			
No marks	**1–4**	**5–7**	**8–10**
• No testing activities conducted	• Some tests were conducted	• Testing done was adequate and mostly correct – able to show if project's performance met most specifications	• Testing done was thorough, correct and logically sequenced – able to show if project's performance met all specifications. Field test was conducted and documented # Completed with minimal or no guidance and assistance

Measurement results			
No marks	**1–4**	**5–7**	**8–10**
• No measurement results presented	• Some plausible measurement results are included • Comparison made between measurement results and some of the results from computer simulations	• Most relevant measurement results are included and presented in appropriate formats • Comparison made between measurement results and most of the results from computer simulations	• All relevant measurement results are included and presented in appropriate formats (readings, tables, graphs, waveforms, etc.) • Comparison made between measurement results and all of the results from computer simulations # Completed with minimal or no guidance and assistance

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

Creativity and enhancement			
No marks	**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

GUIDELINES TO REPORT WRITING

1. **Project Plan**
   This section should document the details of your project plan, including key activities and timeline.

2. **Analysis of Project Specification**
   This section should document your analysis of the project and the questions you posed to guide your research.

3. **Research**
   This section should document the research work you have conducted and the evaluated findings.

4. **Investigation and Generation of Ideas**
   This section should document the investigations you have performed on the ideas obtained from your research. The investigations should be carried out using computer simulation and other appropriate methods.

5. **Detailed Development of Proposed Solution**
   This section should document how initial ideas were developed into the proposed solution. This section should also explain why the proposed solution is the best among other solutions, and describe the enhancement(s) made.

6. **Description of Proposed Solution**
   This section should contain full details of the finalized design including description of the overall system, a complete set of circuit diagrams and a complete list of components used (with technical specifications).

7. **Testing Activities & Measurement Results**
   This section should document all the tests conducted and the results obtained. You are expected to include waveforms and tables of values. You should also include your comments on the comparisons made between the measured results, the project specifications and results from computer simulations.

8. **Project Evaluation**
   This section should document your review the project planning and implementation based on the learning points and challenges faced. The section should also include your assessment of the strengths and weakness of the project, and possible improvements that can be made.

9. **Bibliography and Acknowledgments**
   This section should acknowledge the information sources and person(s) who have rendered help to the project.

DATA AND FORMULA

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 frequency (t_1 +t_2) — Period $T = \frac{(R_1 + 2R_2)C}{1.44}$

Bipolar Junction Transistor (BJT)

Current gain — $\beta = \frac{\text{Collector current}}{\text{Base current}}$

Voltage gain (for voltage-divider biased CE amplifier, emitter resistor unbypassed)

$$\cong -\frac{R_C}{R_E}$$

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	• $A + (B + C) = (A + B) + C = A + B + C$ • $A(B \cdot C) = (A \cdot B) \cdot C = A \cdot B \cdot C$
	Distributive Laws	• $A \cdot (B + C) = A \cdot B + A \cdot C$ • $(A + B) \cdot (C + D) = A \cdot C + B \cdot C + A \cdot D + B \cdot D$
	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	• $(\overline{A + B}) = \overline{A} \cdot \overline{B}$ • $(\overline{A \cdot B}) = \overline{A} + \overline{B}$