RESTRICTED

ELECTRONICS

TEACHING AND LEARNING SYLLABUS

Upper Secondary

Express Course

Implementation starting with
2024 Secondary 3 Cohort

Ministry of Education
SINGAPORE

© 2024 Curriculum Planning and Development Division.
This publication is not for sale. All rights reserved. No part of this publication may be reproduced without the prior permission of the Ministry of Education, Singapore.

CONTENTS

SECTION 1: INTRODUCTION

1.1 Desired Outcomes of Education and Learning of Electronics
1.2 Value of Electronics in the O-Level Curriculum
1.3 Engineering Design Process in Electronic Engineering
1.4 Design Intent of Syllabus – The Systems Approach
1.5 Electronics Curriculum Framework
1.6 Aims of Syllabus
1.7 21st Century Competencies (21CC) in Electronics Curriculum

1. INTRODUCTION

1.1 Desired Outcomes of Education and Learning of Electronics

The Desired Outcomes of Education (DOE) are attributes that educators aspire for every student to have by the completion of his/her formal education. These outcomes establish a common purpose for educators, drive our policies and programmes, and allow us to determine how well our education system is doing.

The person who is schooled in the Singapore Education system embodies the DOE. He has a good sense of self-awareness, a sound moral compass, and the necessary skills and knowledge to take on challenges of the future. He is responsible to his family, community and nation. He appreciates the beauty of the world around him, possesses a healthy mind and body, and has a zest for life. In sum, he is

- a **confident person** who has a strong sense of right and wrong, is adaptable and resilient, knows himself, is discerning in judgment, thinks independently and critically, and communicates effectively;
- a **self-directed learner** who takes responsibility for his own learning, who questions, reflects and perseveres in the pursuit of learning;
- an **active contributor** who is able to work effectively in teams, exercises initiative, takes calculated risks, is innovative and strives for excellence; and
- a **concerned citizen** who is rooted to Singapore, has a strong civic consciousness, is informed, and takes an active role in bettering the lives of others around him.

The learning of electronics is aligned with the DOE. Through the application of scientific knowledge on electricity and electronics, students solve authentic engineering problems using the *engineering design process*. In the *design* phase of the process, students need to carefully consider the requirements and weigh the pros and cons of different possible designs, before deciding on the optimal one. In the *build* and *test* phases, students realise the design by building a prototype of an electronic system and testing it to verify if it works as designed. In many instances, troubleshooting needs to be performed to identify and remedy faults before the prototype becomes fully functional.

These authentic engineering experiences encourage students to be innovative, take calculated risks and persevere to reach a workable solution. Besides developing this 'can-do' attitude, there are also opportunities for students to think critically, evaluate information and communicate effectively. Students will also see how designing solutions to solve practical problems can improve the lives of people around them. The Electronics syllabus thus realises important aspects of the DOE by developing students useful and transferrable attributes, knowledge and skills related to engineering.

1.2 Value of Electronics in the O-Level Curriculum

Learning electronics allows students to gain insights into the working of electronic devices encountered in daily lives, enabling them to better appreciate technological advancements and benefits that the field of electronics has brought about. As a prominent field of engineering, electronics also has the potential to provide a wide range of authentic contexts to develop engineering skills and dispositions. An Electronics student will experience *the engineering design process* (elaborated in Section 1.3 & 1.5) during the course of study and develop engineering skills such as *troubleshooting, systems thinking and problem-solving skills* in the learning process.

Troubleshooting and Problem-Solving Skills

In engineering, troubleshooting is a logical and systematic search for the source of a problem and usually involves the process of elimination for a workable solution to be generated. Troubleshooting demands students to think critically and apply relevant knowledge to identify and correct the problem. It is a form of problem solving that requires skills such as predicting, making hypothesis, eliminating, generating possibilities, observing, using test equipment, comparing, analysing, evaluating, inferring and verifying.

Systems Thinking and Problem-Solving Skills

Systems thinking is the process of understanding how systems[1] behave, interact with their environment and influence each other. However, it is also a term that has different meanings for different fields and disciplines[2]. In electronics, systems thinking is defined as the ability to (i) understand the parts of a system, their interactions and resulting outputs[3]; and (ii) explain the role of a system in a larger system of which it is a part[4]. Problem solving is an application of systems thinking where problems are viewed as having effects on different parts of a system. This problem-solving process is particularly useful to solve open-ended and complex engineering problems that have multiple possible solutions. By adopting the systems approach as a way of thinking, students learn to recognise essential interconnections in the technological world and appreciate that systems depend on both the behaviour of individual subsystems and interactions between the subsystems.

These skills also support the development of 21st Century Competencies (21CC) in the domain of Critical and Inventive Thinking (CIT); and Communication, Collaboration and Information Skills (CCI), which are elaborated in Section 1.7 **Table 1.7.1**.

---

[1] Systems are defined by placing boundaries around inter-related parts to make them easier to study. There are systems in nature as well as man-made systems.

[2] http://scholar.lib.vt.edu/ejournals/JTE/v24n2/lammi.html

[3] Katehi, L., Pearson, G., & Feder, M. (Eds). (2009). *Engineering in K-12 education: Understanding the status and improving the prospects.* Washington, DC: The National Academies Press.

[4] Pourdehnad, John., et.al. (2011). *Systems & Design Thinking: A Conceptual Framework for their Integration*. Presented at the International Society for the Systems Sciences (ISSS) 55th Annual Conference, "All Together Now: Working Across Disciplines" at University of Hull, Hull, UK, July 17-22.

1.3 Engineering Design Process in Electronic Engineering

As engineering is commonly described as the application of scientific knowledge, engineering and science are often compared with each other, e.g., The Next Generation Science Standard[5] differentiates the goal of science and engineering respectively as:

> *"The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories."* (NRC Framework, 2012, p. 52)[6]

> *"In engineering, the goal is a design rather than an explanation. The process of developing a design is iterative and systematic, as is the process of developing an explanation or a theory in science. Engineers' activities, however, have elements that are distinct from those of scientists. These elements include specifying constraints and criteria for desired qualities of the solution, developing a design plan, producing and testing models or prototypes, selecting among alternative design features to optimise the achievement of design criteria, and refining design ideas based on the performance of a prototype or simulation."* (NRC Framework, 2012, p. 68-69)

Despite the difference in the goals of science and engineering, both are closely related and share many similarities such as *"the use of mathematics, the interplay of creativity and logic, the eagerness to be original and public responsibilities". "Many scientists are doing work that could be described as engineering as well as science. Similarly, many engineers are engaged in science."*

The series of steps that scientists take to develop an explanation is often called the *scientific method* which includes asking questions, constructing a hypothesis, testing the hypothesis by performing experiments, analysis of evidence, drawing of conclusion and communication of results. The series of steps that engineers take to develop a solution to a problem is commonly called the *engineering design process* which includes specifying requirements, performing research, generating and evaluating different designs, building and testing prototypes and communicating results.

Thus, electronic engineering involves the application of the science of electronics to solve problems through the engineering design process. It is an endeavour that drives the rapid development of information and communication technology which has revolutionised the way we live, work and play.

---

[5] NGSS lead States. (2013). Next Generation Science Standards. Washington, DC: National Academies Press. Available at http://www.nextgenscience.org/next-generation-science-standards.

[6] National Research Council. (2012). *A framework for K–12 science education: Practices, cross-cutting concepts and core ideas*. Washington, DC: National Academies Press.

1.4 Design Intent of Syllabus – The Systems Approach

The design of the Electronics curriculum took into consideration the key findings from the environment scans of local and international Electronics syllabuses, and the value proposition of Electronics for our upper secondary school curriculum. The core Electronics content is organised as part of systems; and actively involves students in application of knowledge, and the design and testing of electronic systems.

The following big ideas are presented in the Electronics curriculum to tie the concepts, skills and processes as a coherent whole:

- An electronic system is made up of different components connected as a circuit to achieve intended outcome(s).
- An electronic system receives input, processes the input and sends output into the wider environment or another system.
- Electronic systems are commonly represented by block diagrams and circuit diagrams, while circuit theories are used to understand and analyse electronic circuits.
- The engineering design process is used to design, build and test an electronic system. Different possible designs need to be investigated and evaluated to select the optimal solution to a problem.
- Electronic systems seldom work perfectly when they are first built. Troubleshooting is needed to identify and correct sources of problems.

These big ideas help students integrate and link what they have learnt across different topics. For example, after learning both capacitors and resistors, students should see a resistor-capacitor (RC) circuit as a system made up of components with very different characteristics, yet working together to produce a time delay.

1.5 Electronics Curriculum Framework

The Electronics curriculum aims to give a balanced coverage between theoretical content knowledge and development of engineering skills. The framework (**Fig. 1.5.1**) consists of two domains: (a) the content domain on science of electricity & components, and (b) the process domain on engineering design. These two domains are underpinned by big ideas in systems which are presented as key questions in the framework. An essential feature of the framework is the interplay between these two domains: content knowledge will be applied to design and build electronic systems through the engineering design process, which in turn deepens understanding of the content and big ideas of the subject.

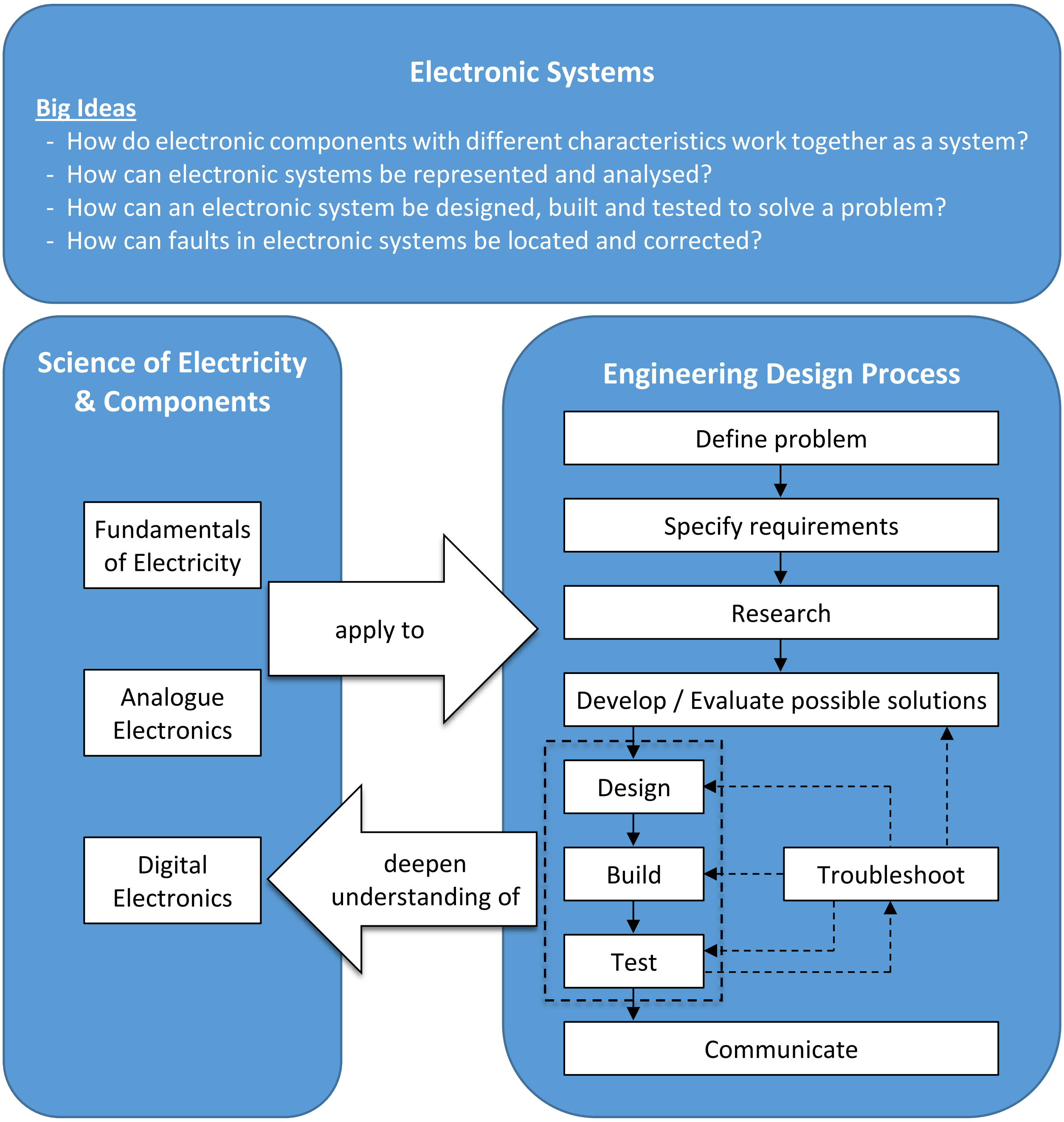

Fig. 1.5.1: Electronics Curriculum Framework

Content Knowledge – Science of Electricity & Components

The content is broadly classified into (i) *Fundamentals of Electricity*, (ii) *Analogue Electronics*, and (iii) *Digital Electronics*. The concepts under *Fundamentals of Electricity* include principles of electricity (e.g., Ohm's law), circuit theories (e.g., voltage divider), and basic electrical components (e.g., capacitor). These concepts are needed to analyse, understand and design electrical circuits. Under *Analogue Electronics*, the operation and use of diodes, transistors and operational amplifiers, are covered. The coverage of *Digital Electronics* includes basic understanding of digital signals, basic logic gates, digital latch and the use of integrated circuits.

Skills Development – Engineering Design Process

The engineering design process is a series of systematic steps that engineers use to develop solutions to engineering problems (see **Table 1.5.1** for explanation of the steps).

Table 1.5.1: Explanation of the Engineering Design Process

Step	Explanation
Define Problem	A problem can be defined using the following question: "[who] need(s) [what] because [why]".
Specify Requirements	State the important characteristics that your design must meet to be successful. When there are conflicts between the requirements, trade-off(s) would be needed.
Research	Using a set of questions derived from the specifications, research is conducted to obtain information on how the requirements of the solution could be met. The research should cover different sources of information such as websites and books. The information should be evaluated for their credibility.
Develop / Evaluate Possible Solutions	Brainstorm and develop solutions or adapt those identified through research. Determine whether each possible solution meets the design requirements. For those that meet the requirements, consider their pros and cons in terms of availability of components, cost, complexity of design, safety, power requirement, etc. Ideas obtained from research should be investigated through circuit simulation or other appropriate methods to test if they could meet the requirements of the system. New ideas might be generated in the process. The pros and cons of different ideas should be considered.
Design	Develop a circuit according to the chosen solution. Simulate the circuit on computer simulation software to check if it works in theory. From the results of the investigations, a complete design is developed based on the ideas that are found to be most suitable for the project. After integration, the design should be simulated to check that it can work. If not, the design would need to be modified.

Step	Explanation
Build	Once the circuit is proven to work through circuit simulation, the next step would be to build a prototype (an operating version of a solution) on breadboards. The prototype should be built using proper techniques to ensure firm electrical connections. The test points should be clearly labelled to facilitate testing. During building, the design might need to be modified if certain components were not available or found to be unsuitable.
Test	Using test equipment, measure and compare the output(s) of the prototype circuit against the requirements. All measurements should be recorded for future reference. If the test shows that the prototype circuit could not meet the requirements, the design might need to be modified.
Troubleshoot	Troubleshooting is a logical and systematic search for the source of a problem and usually involves the process of elimination for a workable solution to be generated. Troubleshooting usually involves two key stages: (i) hypothesis generation to identify one or more potential faults; and (ii) hypothesis evaluation where potential faults are tested and corrected.
Communicate	Communicate the processes and the final solution in the form of a report.

Students will understand what each step entails and be equipped with the necessary skills needed to carry out the process correctly and effectively. Examples of these skills include:

- project planning;
- problem analysis;
- specifying requirements;
- using block diagrams to represent electronic systems;
- conducting research;
- evaluating research findings;
- reading datasheets;
- drawing circuit diagrams;
- performing circuit simulations;
- evaluating circuit designs;
- circuit building;
- troubleshooting;
- developing tests for circuits;
- using test equipment; and
- report writing.

Both content knowledge and skills development are intricately linked, where content knowledge is applied to solve practical problems using the engineering design process. In the process of implementing the solution in the form of electronic circuits, students will in turn develop a deeper understanding of the content knowledge.

1.6 Aims of Syllabus

As elaborated in Section 1.5, the Electronics curriculum provides students with an understanding of the fundamental working of electronic components and systems, as well as the engineering design process. The syllabus focuses on the application of the knowledge of science of electricity and electronic components to design and build electronic systems that can solve daily problems. The students will also develop testing and troubleshooting skills. Through these learning experiences, the subject should provide a broad-based foundation for further studies in electronic engineering and related fields. Specifically, the aims of the syllabus are to:

(i) acquire knowledge of the fundamentals of electronics.

(ii) develop abilities and skills related to the engineering design process such as
- systems thinking;
- design, build and test electronic systems; and
- troubleshooting.

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

(iv) develop an appreciation about the usefulness of electronics and its impact on modern society.

(v) foster an interest and passion in the engineering field.

(vi) inculcate a strong sense of safety and develop safe working habits.

1.7 21st Century Competencies (21CC) in Electronics Curriculum

The Electronics curriculum supports students' development of important competencies necessary for them to thrive in the 21st century that are anchored in enduring values. The framework for the 21CC and student outcomes is presented in **Fig. 1.7.1**.

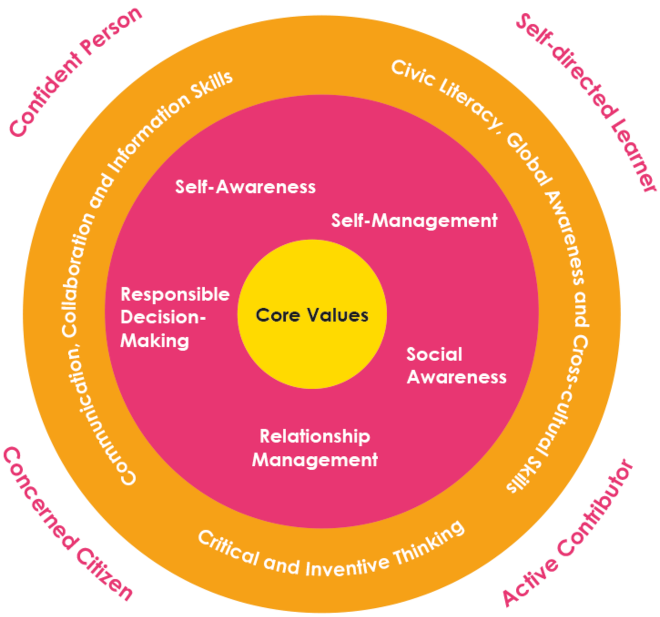

Fig. 1.7.1: Framework for 21CC and Student Outcomes

At the heart of the framework are **Core Values** that underpin the learning. These values (*respect, responsibility, resilience, integrity, care and harmony*) define a person's character and shape beliefs, attitudes and actions of a person.

The middle ring signifies the **Social and Emotional Competencies** – skills necessary for children to recognise (*Self-Awareness*) and manage (*Self-Management*) their emotions, develop care and concern for others (*Social Awareness*), make responsible decisions (*Responsible Decision-Making*), establish positive relationships (*Relationship Management*), as well as to handle challenging situations effectively.

The outer ring of the framework represents the **21st Century Competencies** necessary for the globalised world we live in. These are: *Civic Literacy, Global Awareness and Cross-Cultural Skills; Critical and Inventive Thinking; and Communication, Collaboration and Information Skills*.

Electronics is well-positioned to develop 21CC, especially when solving an engineering problem using the engineering design process. For example, as students analyse and break down a complex engineering problem into manageable tasks, they develop critical and inventive thinking. They will also have opportunities to work collaboratively to discuss and evaluate ideas and research findings, and to present and defend their choice of design. Tapping on the opportunities afforded by the process, the development of 21CC in the areas of "*Communication, Collaboration and Information Skills*" and "*Critical and Inventive Thinking*", is a natural fit. In addition, the 'design, build and test' process fosters character-building traits such as creativity, curiosity, open-mindedness and perseverance. These are illustrated in **Table 1.7.1**.

Table 1.7.1: Development of 21CC in Electronics

Engineering Design Process Step	Values and Social Emotional Learning	Communicating, Collaboration and Information Skills	Critical and Inventive Thinking
• **Define Problem** • **Specify Requirements** • **Research**	Students learn to build positive relationships with other students of different backgrounds as they work collaboratively on a task.	In these steps, students are required to define a problem, specify the requirements that will solve the problem, and perform research to understand similar or related problems. Students develop the ability to identify the information needed, tap into different sources of information, organise the information systematically and evaluate the credibility of the information. Very often, it would involve students interacting with others to construct knowledge and new understanding.	Critical thinking is required to define and scope problems to identify the primary requirements from the non-essential ones. In engineering projects where requirements have been specified by the requesting party, critical thinking is required to understand the basis and rationale of the requirements. During the research process, students need to critically evaluate the information and data for accuracy and relevance to the problem.

Engineering Design Process Step	Values and Social Emotional Learning	Communicating, Collaboration and Information Skills	Critical and Inventive Thinking
• **Develop / Evaluate Possible Solutions**	Engineers need to consider the ethical implications of their designs and solutions, e.g., a design can result in cost saving but endanger the users. When evaluating solutions to select the optimal one, students will be guided by their teachers to consider these implications.	As students develop and refine their solutions, they would need to work collaboratively in teams to discuss and evaluate ideas and findings.	In this step, students need to evaluate the solutions identified through research to determine if they can be adapted or modified to meet the specified requirements of the problem at hand. Students also need to generate ideas and develop possible solutions if there are no existing ones or if the existing ones are not feasible due to cost, safety or other issues. Students then need to evaluate the pros and cons of each solution in order to defend their choice of optimal solution with reasons and evidence.

Engineering Design Process Step	Values and Social Emotional Learning	Communicating, Collaboration and Information Skills	Critical and Inventive Thinking
• **Design** • **Build** • **Test**	Depending on the task, this step can span over several weeks, thus requiring students to exercise self-management skills to handle the stress and demand effectively. Students also need to be disciplined and responsible to stick to the schedule of the task.	As students build their circuit and perform the necessary testing, they would need to communicate their solution and ideas clearly.	After a solution is chosen, students need to design a circuit and simulate the circuit using circuit simulation software to check that it works in theory. Once the simulated circuit is proven to work, the next step is to build a physical prototype. The prototype is then tested to see if the design meets all requirements and performs acceptably. As this step involves a substantial number of electronic components and multiple electrical paths, students need to stay focused and adapt to the demands and challenges of connecting components into a workable system.

Engineering Design Process Step	Values and Social Emotional Learning	Communicating, Collaboration and Information Skills	Critical and Inventive Thinking
• **Troubleshoot**	Troubleshooting can be mentally demanding. Students need to be resilient to continue till the cause of problem has been identified.	In some cases, students would need guidance on troubleshooting faults they are not familiar with. This would involve researching the fault or communicating with peers or the teacher to identify possible causes and resolutions.	Electronic systems seldom work the moment they are first completed. Students frequently need to perform troubleshooting, a logical and systematic search for the source of a problem. This is a dynamic process involving hypothesising possible causes, testing and eliminating causes until the actual cause is pinpointed. For difficult cases, the system needs to be broken down into subsystems to troubleshoot one by one. After identifying the cause, students then need to make the necessary changes to the design and connection of the system. During troubleshooting, students are constantly assessing their own strategies, considering alternative tests, and suspending judgment until a hypothesis is confirmed. It is a process that requires them to manage uncertainty, stay focused and persevere until the cause is pinpointed and solved. Students also need to use systems thinking to analyse and understand a complex task by breaking it down to its essential elements.

SECTION 2: CONTENT

2. CONTENT

2.1 Overview of the 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 Comparators, Timers and Counters
V. Engineering Design Process	15. Engineering Design Process

2.2 Learning Outcomes

SECTION I – SYSTEMS	
Chapter 1 Electronic Systems	• recognise and understand that, in general, electronic systems consist of input subsystems, process subsystems and output subsystems • use the symbols of common electrical and electronic components to represent an electrical/electronic system • give examples of electronic systems encountered in daily life • identify the input, process and output subsystems of an electronic system • describe a subsystem as a system that obtains input from, or provides input to another subsystem • represent complex systems in terms of subsystems using block diagrams • state that an electrical signal is an electrical voltage or current that carries information • recognise that electrical signals may be analogue or digital in nature, and differentiate between them

SECTION II – FUNDAMENTALS OF ELECTRICITY	
Chapter 2 **Current Electricity**	• recall common quantities related to electricity (e.g., current, potential difference, power, electric charge, resistivity and frequency) and their SI units • express the magnitude of quantities in scientific (exponential) notation • 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) • distinguish between conventional current and electron flow • state that current is the rate of flow of charge and is measured in amperes (A) • recall and apply the relationship *charge = current x time* • distinguish between electromotive force (e.m.f.) and potential difference (p.d.) • state that both e.m.f. and p.d. are measured in volts (V) • calculate the effective e.m.f. when several sources are connected in series and in parallel • state that *resistance = p.d. / current* • state and apply Ohm's law to determine current, voltage, and resistance • sketch and interpret the graphical linear relationship between current and voltage in a purely resistive circuit • 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 • define power as the rate of energy conversion • 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 • determine the efficiency of an electrical device

SECTION II – FUNDAMENTALS OF ELECTRICITY	
Chapter 3 **Resistors**	• describe resistivity as the characteristic of a material that affects its electrical conductivity and apply the formula $R = \rho l/A$ to explain how resistivity, length and cross-sectional area of a conductor affects its electrical resistance • describe the structures of various types of resistors (carbon and wire-wound) and select the appropriate resistor for a particular circuit design • use the resistor colour code to determine the ohmic value and tolerance of a resistor, and verify the value by measurement • select a suitable resistor from the E24 resistor series for a particular application • determine the power rating of a resistor and explain the factors affecting it • explain how changing the resistance in a circuit changes the current in the circuit • recall and apply the formulae to calculate the effective resistance of resistors connected in series and in parallel • explain the use of variable resistors in electrical circuits

Chapter 4
Circuit Theories
	• define the terms - circuit, load, source, open-circuit, short-circuit and overload
	• show understanding that current flows only in a closed circuit
	• show understanding of the effect of a short circuit
	• identify and use common types of switches (PTM, PTB, SPST and SPDT)
	• apply the following principles to a series-parallel resistive circuit:
	  ○ the current at every point in a series circuit is the same
	  ○ the sum of the p.d.s in a series circuit is equal to the p.d. across the whole circuit
	  ○ the current from the source is equal to the sum of the currents in the branches of a parallel circuit
	  ○ the p.d. across each branch of a parallel circuit is the same
	• identify a resistive voltage divider and apply the voltage-divider formula to solve related problems
	• identify a resistive current divider and apply the current-divider formula to solve related problems
	• state and apply Kirchhoff's voltage and current laws

SECTION II – FUNDAMENTALS OF ELECTRICITY	
Chapter 5 Alternating Currents	• distinguish between direct and alternating currents/voltages (in terms of whether this is a change of direction) • give examples of direct current and alternating current • show understanding that alternating currents or voltages can be represented by waveforms • recognise and sketch the common types of AC waveforms (sinusoidal, rectangular, square and triangular) • determine the DC level, frequency, period, peak and peak-to-peak values of an alternating current/voltage from its waveform • determine the duty cycle of a rectangular waveform • apply the relationship $T = 1/f$ to solve related problems
Chapter 6 Capacitors	• describe the structure and working principle of a basic capacitor • recognise and give examples of polarised and non-polarised capacitors • define capacitance and state its SI unit • recall and apply the equation $C = Q/V$ to solve problems • explain why capacitors have a maximum working voltage • calculate the time constant of a simple resistor-capacitor (RC) circuit using $\tau = RC$ • 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	
Chapter 7 Semiconductor Diodes	• state that there are two types of semiconductors: n-type and p-type • describe the basic structure of the PN junction diode and explain how it is biased in the forward and reverse directions • describe the I-V characteristics of a diode • explain the difference between ideal and practical diodes • apply the simplified diode model to solve problems • describe and explain the use of diodes in half-wave and full-wave rectifiers using the simplified diode model • interpret typical diode specification (forward voltage, maximum current, maximum reverse voltage) using datasheets • state that LED is a special type of diode that emits light and infra-red • describe the benefits of using LEDs for lighting as compared to incandescent bulbs • explain why a resistor should be connected in series with an LED in a circuit and calculate its resistance value • describe the use of infrared diodes and photodiodes as transmitting and receiving devices respectively • state that a 7-segment display is made up of 7 LEDs which can be individually controlled • describe the difference between the structure and operation of a common anode and a common cathode 7-segment display • describe the I-V characteristics of a Zener diode • explain the use of Zener diodes to regulate voltage (without load)
Chapter 8 Input and Output Transducers	• explain what is meant by an input and an output transducer • give examples of input and output transducers • recall and apply the effect of changes in temperature on the resistance of a thermistor to practical situations • recall and apply the effect of changes in light intensity on the resistance of an LDR to practical situations • interpret the characteristic graphs of thermistors and LDRs • describe the function of the following transducers: microphone, loudspeaker, buzzer, low voltage DC motor and electromechanical relay

SECTION III – ANALOGUE ELECTRONICS	
Chapter 9 Bipolar Junction Transistors and Operational Amplifiers	• describe the structure of the two types of bipolar junction transistor (BJT) • describe the working principle of a BJT (a base current controls current between emitter and collector) • describe the different operating regions of BJTs • interpret typical BJT specifications (β, I_{Cmax}, V_{BE}, $V_{CE(sat)}$) using its datasheet • explain how a NPN and PNP BJT can be used as a switch • solve problems in circuits that use transistors as switches by applying the relationships between currents and voltages • explain the advantage of a Darlington pair over a single transistor in driving an output transducer • 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) • explain how an op-amp can be configured to operate as inverting and non-inverting amplifiers • calculate the gain of both inverting and non-inverting op-amps • explain how an op-amp can be configured to operate as a voltage follower

SECTION IV – DIGITAL ELECTRONICS	
Chapter 10 Introduction to Digital Electronics	• identify analogue and digital signals from oscilloscope traces • 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) • explain the use of pull-up and pull-down resistors to provide the correct logic levels • list the advantages and disadvantages of digital systems over analogue systems • describe the need to convert between analogue and digital signals • convert between binary, decimal and binary-coded decimal (BCD) systems • describe the function of a BCD to 7-segment display module using a truth table • identify the pins of a 74LS247 BCD to 7-segment display decoder IC from its specification sheet • describe the operation of a 74LS247 IC
Chapter 11 Basic Logic Gates	• describe the truth table as a way to show the output of a digital circuit for different combinations of input(s) • 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 input(s) • draw symbols and construct truth tables for NOT, AND, OR, NAND, NOR, XOR and XNOR gates • use Boolean notation (‘—’, ‘·’, ‘+’ and ‘⊕’) to write Boolean expressions for NOT, AND, OR, NAND, NOR, XOR and XNOR gates • state that NAND and NOR gates are universal gates • show how NOT, AND and OR gates can be made using NAND or NOR gates • describe basic characteristics (e.g., general structure, pin configuration, common notation) of a dual in-line IC • use datasheets to identify pin connections of common logic gate ICs • list the advantages and disadvantages of CMOS over TTL ICs • explain the interfacing between CMOS and TTL ICs

SECTION IV – DIGITAL ELECTRONICS	
Chapter 12 Combinational Logic Circuits	• use a truth table to describe the output of a digital system (up to three inputs) • convert a truth table (up to three inputs) into a sum-of-product (SOP) Boolean expression • simplify an SOP Boolean expression (up to three variables) using either Boolean algebra or a Karnaugh map • implement logic circuits using NOT, AND and OR gates given an SOP Boolean expression • describe and explain the function of a given combinational logic circuit • solve system problems using combinations of logic gates (up to three inputs)
Chapter 13 Set-Reset (S-R) Latches	• describe the S-R latch as a digital circuit with memory • draw the symbolic representation of an S-R latch using NOR gates • construct the truth table for a NOR gate S-R latch and use the table to determine the output of the latch • draw the output timing diagram of a NOR gate S-R latch • explain how an S-R latch is used to convert a momentary occurrence into a constant output • explain how an S-R latch can be used to build a debounced switch

SECTION IV – DIGITAL ELECTRONICS	
Chapter 14 Voltage Comparators, Timers and Counters	• identify the pins of an LM311 voltage comparator IC from its specification sheet • describe the operation and use of an LM311 voltage comparator IC (with single rail supply only) • distinguish between a monostable and astable multivibrator • identify the pins of a 555 timer IC from its specification sheet • 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) • use the formula $T = 1.1RC$ to determine the time period of a 555 timer IC in monostable mode (formula will be provided) • use the formula $T = \frac{(R_1+2R_2)C}{1.44}$ to determine the time period of a 555 timer IC in astable mode (formula will be provided) • draw the output timing diagram of a 555 timer IC • identify the pins of a 74LS390 4-bit decade counter IC from its specification sheet • describe the operation and use of a 74LS390 IC • show understanding of how the output of a 74LS390 IC can be shown on a 7-segment display • show understanding of how two 4-bit decade counters in a 74LS390 IC can be connected to count to 99

SECTION V – ENGINEERING DESIGN PROCESS	
Chapter 15 Engineering Design Process	• recognise the characteristics of a successful project plan • draw a Gantt chart for a project with known tasks, precedence and durations • create new processes, products or projects through the synthesis of ideas from a wide range of sources by: ○ using research methods including web search, textbooks, library resources, literature review, etc.; ○ specifying the requirements of an electronic product based on the problem definition; and ○ building a prototype circuit using a prototype board • appreciate the role of computer simulation in circuit design (advantages and limitations) • use circuit simulation software to verify a circuit design • use relevant test and measuring equipment (digital multimeter, function generator and oscilloscope) to test and troubleshoot prototype circuits • maintain and organise records of project work development • write a project report using information collated from the project work

SECTION 3: PEDAGOGY

3. PEDAGOGY

3.1 Pedagogical Considerations

This section elaborates on the three considerations used to identify the key pedagogical approach and the supporting teaching strategies for Electronics.

(i) Alignment with Principles of Applied Learning

Applied learning is a notion that is gathering momentum in many educational contexts around the world, and is often equated to ‘hands-on’ or practical learning experiences. Despite the many definitions of what constitutes applied learning, a number of recurring themes can be found across these definitions. These themes can be viewed as the pedagogical principles that support applied learning (see **Fig. 3.1.1**):

- Emphasises the relevance of what is being learnt to the ‘real world’ outside the classroom, and makes that connection in an immediate and explicit manner.
- Requires students to use hands-on or experiential learning to enact authentic scenarios, where students focus on learning and applying the skills and knowledge they need to solve a problem and implement a project.
- Involves students and teachers in partnerships with the institutions of higher learning, industries, communities, professional training bodies, and individuals outside school.

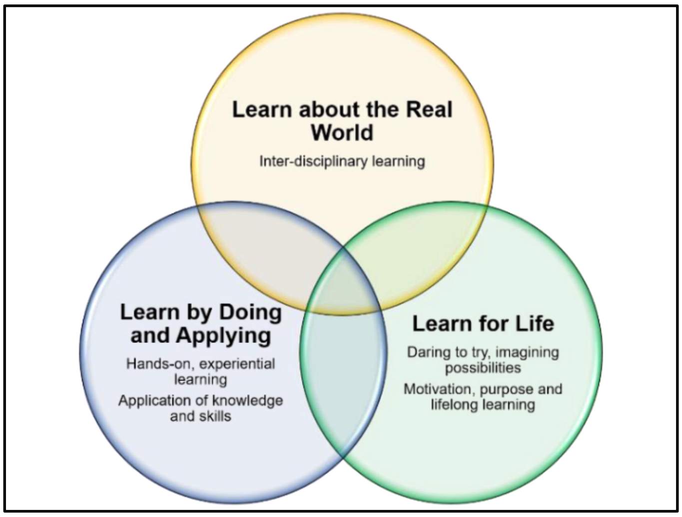

Fig. 3.1.1: Principles of Applied Learning

Electronics aims to bring out the principles of applied learning through an approach that contextualises learning in a way that empowers and motivates students, while assisting them to develop key skills and knowledge required for further education and active participation in their communities. Hence, teachers should plan their teaching to offer plenty of hands-on exploration for their students to construct meaning for themselves, to learn in ways that allow them to directly apply knowledge so as to see the usefulness of electronic engineering in the creation of innovations to solve real-world problems.

(ii) Attaining Goals of Syllabus

The syllabus aims to develop attitudes, skills and knowledge in electronics; and foster the interest in the engineering field. The knowledge includes concepts related to electricity and circuit theories; and how electronic components work so as to use them correctly to attain the desired intent. To design, build and test electronic circuits, students need to be proficient with using test equipment, building circuits and performing circuit simulation. The willingness, mental strength and confidence to take on challenges and setbacks are key traits of a successful engineer. The teaching strategies adopted should effectively be delivering these goals.

(iii) Authenticity of Learning Experiences

In David Perkins' book, "Making Learning Whole", he illustrated how teaching any subject at any grade level can be made more effective if students are introduced to the 'whole game' rather than isolated pieces of a discipline. In electronic engineering, engineers work in teams and apply their knowledge and skills to design, build and test products that can solve real-life problems. Problem solving is what engineers do. It is what they are, or should be good at. Getting students to solve real-world problems provides opportunities for authentic experience in engineering design process.

3.2 Teaching and Learning Strategies

In line with the principles of applied learning, the central pedagogical approach adopted is "learning through doing". This hands-on approach directly involves the learner, by actively encouraging them to do something in order to learn about it. Hands-on learning not only allows students to directly observe and understand what they have learnt, but also helps them to develop a range of engineering skills. In addition, it encourages students to do things for themselves, which will help them to learn independently later in life. Some strategies that support learning through doing are:

(i) Concept and skills building through guided practicals
(ii) Problem solving through mini projects
(iii) Use of ICT

(i) Concept and Skills Building through Guided Practicals

Through these hands-on guided practical tasks, students

- deepen understanding of concepts on electricity and components (e.g., students verifying the operation of a PN junction diode to deepen understanding of the component);
- become competent in the use of test equipment needed for testing and troubleshooting electronic systems (e.g., students develop the skills on how to set up the digital oscilloscope to take relevant measurements); and
- become proficient in the use of circuit simulation software to model circuits.

In addition, a digital logic trainer will be used to help students acquire knowledge of the functions and operations of basic logic gates before moving on to build more complex circuits on breadboards. Collectively, these guided tasks help students to develop their practical skills and build their foundation to embark on the design, build and test phase in the engineering design process.

(ii) Problem Solving through Mini Projects

Students demonstrate their understanding and skills in mini projects that involve the application of concepts from one or more topics. These mini projects are small-scale open-ended tasks where students could work in groups to solve a real-world problem. For example, students can be tasked to build a simple automatic light for a corridor. In this task, students will build on their understanding of a system to identify the input, process and output subsystems and see how different components work together as a system. Students will also apply their knowledge of a transducer (e.g., light-dependent resistor (LDR)) to convert the brightness of the surroundings to an electrical signal, which will then be processed to automatically trigger a light to be switched on.

(iii) Use of ICT

ICT plays an important role to support the teaching and learning of the subject. Circuit simulation software serves as an invaluable teaching and learning tool, allowing students to bring 'alive' circuits found in textbooks or online and observe their performance. Teachers can design assignments by drawing circuits with the software and get their students to make modifications to study how the overall system will respond. In addition, computer-based test equipment will give students access to function generator and digital oscilloscope capabilities outside the electronic lab. Together, these ICT tools extend students' learning beyond the classroom and allow a greater variety of tasks for home-based learning.

In conclusion, it is envisaged that teaching and learning of this syllabus would feature a range of learning experiences designed to promote understanding of electronics and to develop 21CC competencies such as Critical and Inventive Thinking, and Communication, Collaboration and Information Skills. 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 other engineering skills, effectively communicate the intent of their designs and appreciate the contribution electronics makes to our modern living.

3.3 Blended Learning

Blended Learning (BL) is typically characterised by a mix of online and offline learning (**Fig. 3.3.1**).

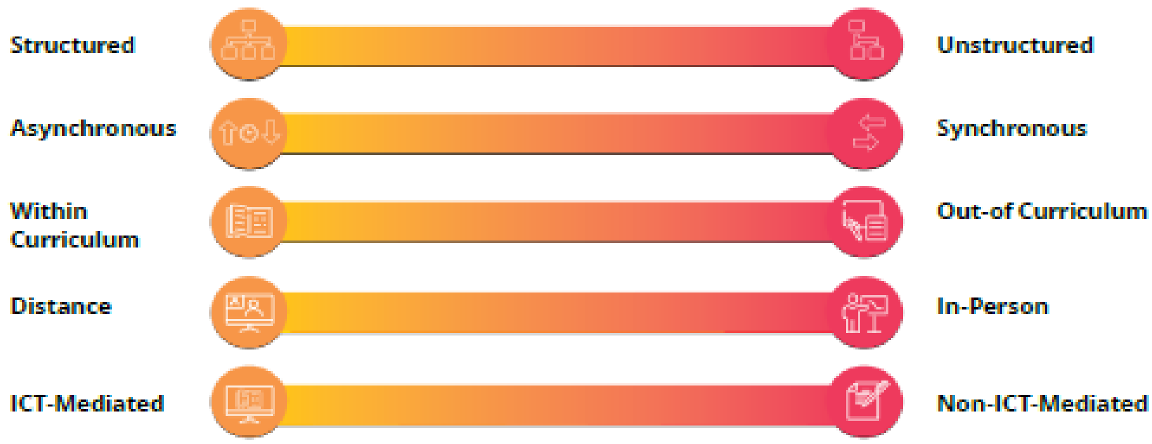

Fig. 3.3.1: Key features of Blended Learning

Structured / Unstructured learning: A combination of structured time for students to learn within a given timeframe and unstructured time for students to learn at their own pace and exercise self-management in learning

Synchronous / Asynchronous learning: A combination of live online lessons and online/offline learning where students learn remotely and at their own pace

Within-Curriculum / Out-of-curriculum learning: Opportunities for students to learn from and beyond the formal curriculum

Distance / In-person learning: Opportunities to learn during face-to-face lessons with teachers and peers in school, complemented by out-of-school learning activities without the physical presence of their teachers and peers

ICT- / non-ICT-mediated learning: Opportunities to learn through a combination of ICT-mediated and non-ICT-mediated learning experiences

<u>MOE's BL</u>

MOE's BL is broader than the conventional understanding of BL. BL in MOE's context refers to the re-imagination of our students' educational experience by providing them with a more seamless blending of different modes of learning. It allows our educators to re-think curriculum and assessment design, and innovate pedagogies to enable students to benefit from a wider spectrum of learning experiences.

Curriculum Delivery through BL

With BL, teaching and learning activities should provide students with a seamless learning experience through a range of learning opportunities in school and beyond school. Traditional in-class learning should be thoughtfully integrated with other learning approaches such as technology-based approaches to bring about an even more effective and student-centric educational experience.

BL thus offers scope for teachers to tap the advantages of both in-person learning and distance learning to plan lessons best suited to each mode of learning opportunity. It also allows teachers to design learning activities which may otherwise be difficult to carry out in school due to factors such as time constraints and large-group teaching.

Through BL, students should become:

- self-directed and independent learners who are able to –
  - take ownership over learning
  - plan, monitor and regulate learning
  - search, access, acquire information
  - extract and evaluate information, and continually refine understanding
- passionate and intrinsically motivated learners – learners who possess the desire and passion to learn for life
  - Curious and eager to new knowledge
  - Open and willing to embrace challenges
  - Pursue and sustain areas of passion

SECTION 4: ASSESSMENT

4. ASSESSMENT

4.1 Assessment for Learning in Electronics

Assessment is an important part of classroom teaching and learning and is an ongoing process by which teachers gather information about students' learning to inform and support teaching. Assessment generally serves two purposes:

- **Summative assessment** is used at the end of a series of learning activities to determine the level of students' attainment of the desired learning outcome. It is commonly used for placement and grading.
- **Formative assessment** is used to determine students' learning of specific skills and/or concepts learnt. Such assessment should be carried out during the instructional process and can be used to identify learning gaps to provide timely feedback to students on their learning and inform teachers on future instruction.

A balanced assessment system should have both summative and formative assessment.

In Electronics, students are expected to demonstrate their ability to apply their theoretical knowledge using the engineering design process to solve real-world problems. To develop the necessary skills, there should be plenty of opportunities for teachers to gather feedback on their students' level of competency so as to provide targeted feedback that can help students improve. The adopted pedagogies and resources (including digital resources) offer ample opportunities for assessment for learning by getting students to perform tasks that demonstrate their understanding of the concepts. Examples of such pedagogies and resources are listed below:

- Mini projects are small-scale, hands-on tasks that require students to demonstrate a range of abilities. Teachers will observe and provide close guidance to their students during these sessions to help students develop deeper conceptual understanding and competency to take on the coursework task at Secondary 4.
- During guided practicals, students demonstrate their abilities in circuit building, basic troubleshooting and use of test equipment. The practicals also require students to make explicit connections between the observations and theoretical knowledge.
- Students are engaged in circuit simulation using computer software during their course of study. The software provides a safe and low-cost way for students to learn how electronic components work individually and together by building virtual circuits. The simulation results provide instantaneous feedback to students. Teachers can also study the circuits drawn by their students to check their understanding.
- Online tasks (e.g., quizzes) will be used to encourage independent learning. In addition to providing feedback to teachers, students can self-check their level of understanding through automated feedback.

4.2 The O-Level Examination for Electronics

Students sit for the GCE O-Level Electronics examination at Secondary 4. The assessment objectives, weighting and scheme of assessment are as follows:

Assessment Objectives

A *Knowledge with Understanding*

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

- electronic systems
- electricity and circuit theories
- electrical and electronic components
- digital electronics

B *Handling Information and Solving Problems*

Candidates should be able to:

- locate, select, interpret and evaluate information
- manipulate numerical and other data
- present reasoned explanations for application and relationships between components
- solve problems

C *Practical Skills and Project Realisation*

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

- observe, measure and record data accurately
- analyse problems by considering relevant functional and practical factors
- conduct research, plan, design and develop solutions
- use computer simulation software to verify design
- build a prototype circuit using a breadboard
- use appropriate test and measurement equipment to test and troubleshoot a prototype circuit
- present evaluative report on design and solutions to problems

Weighting of Assessment Objectives

Theory Paper

A Knowledge with Understanding (approximately 40% of the marks)

B Handling Information and Solving Problems (approximately 60% of the marks)

Coursework

C Practical Skills and Project Realisation (100% of the marks)

Scheme of Assessment

Paper	Type	Duration	Marks	Weighting
1	Written Paper	2 hrs	100	70%
2	Coursework	32 hrs	100	30%

Paper 1

This written paper consists of two sections. All questions are compulsory.

Section A: carries 40 marks and consists of 6-10 short answer questions

Section B: carries 60 marks and consists of 4 questions, each of 15 marks

Paper 2

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 students to build a prototype (project hardware) and document the process (project report), carrying a total of 100 marks.

4.3 Guidelines for Coursework

The project requires students to build a prototype (project hardware) and document the process (project report).

<u>Project Requirements</u>

Component	Requirement	Marks
Project Hardware and Report (100 marks)	(1) Project Plan	5
	(2) Analysis of Project Specifications	5
	(3) Research	10
	(4) Investigation and Generation of Technical Solutions	10
	(5) Detailed Development and Description of the Final Technical Solution	10
	(6) Enhancement	15
	(7) Testing Activities and Measurement Results	10
	(8) Project Reflection	10
	(9) Functionality of Project	15
	(10) Quality of Project	5
	(11) Organisation and Presentation	5
Total		**100**

Explanation for Each Requirement

(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 students 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 students to pose questions to guide their research on how the specifications can be realised.

(4) Investigation and Generation of Technical Solutions (10 marks)

Students should generate a range of possible technical solutions and express them through system block diagrams and circuit diagrams. It is also essential for students 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, students 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, students are to record any modifications/refinements made, including the development of enhancement(s), if any. Students 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)

Students 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)

Students 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 on the outcome of the comparison provided. Students 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, students 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, reliable and satisfy all design specifications.

(10) Quality of Project (5 marks)

Students should reflect 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.