TEACHING DIGITAL ELECTRONICS WITH DEWBOARD©

FOR ACTIVE LEARNING CLASSROOM

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PREFACE

Dear Educator,

We know how challenging it can be to teach Digital Electronics, abstract concepts, complex theories, and to deal with students who feel lost between formulas and real applications. That is why we created DEWBoard®, a compact and modular training kit designed to make your classroom come alive. Instead of only listening, students can now touch, connect, and actually see the circuits in action.

With DEWBoard®, learners can experiment, observe, and validate theories in real time. Combined with ClassPoint for interactive quizzes and submissions, and DEBuddy, an AI learning assistant that explains and guides step by step, you'll have a complete ecosystem for active learning. All of these are framed within the Book-End Division Approach, a structure that naturally keeps students engaged from the first minute of class until the very last.

This guide is written to walk beside you, not just instruct you. Inside, you'll find clear explanations, ready-to-use activities, worksheets, and reflection prompts that make it easier to guide your students from basic understanding to confident application. Every chapter also connects lessons to real-world applications, so learners can see why digital electronics matters far beyond the lab.

Our invitation is simple: use this book not only as a manual, but as your teaching partner. Try out the activities, let your students explore, and give them space to reflect. Slowly but surely, you'll see their confidence grow—because learning is not just about passing exams, it's about building future engineers and technologists who can innovate with purpose.

So, open the first chapter, set up your DEWBoard®, and begin. Together, let's transform the way Digital Electronics is taught and learned.

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To my fellow research team members, lecturers and Subject Matter Experts in Digital Electronics, you have been such an important part of this effort. A special thanks goes to Nur Haziqah Rosli, my student in Senior Design Project, for her contributions and commitment.

I am deeply grateful to the leadership at FTKEE, our Dean, Professor Ts. Dr. Hamzah Ahmad, and our former Dean, Professor Ts. Dr. Hamdan Daniyal, for their continuous trust and encouragement. My heartfelt thanks also to the current Head of Program Dual Degree German, Bachelor of Electrical Engineering (Electronics) with Honours, Dr. Nur Aqilah Othman, and the former Head, Associate Professor Ts. Dr. Mohd Ashraf Bin Ahmad, for their guidance and support. This work has also been officially registered under Copyright Registration No. LY2026E03086.

Finally, I want to take a moment to appreciate my family, friends, and faculty members. Your trust, encouragement, and constant support gave me strength during challenging moments and reminded me why this work matters.

If there's one thing I've learned through this project, it's that innovation in teaching is never a solo journey, it's built on collaboration, trust, and the willingness to support one another. To everyone who stood with me, thank you for walking this path together.



ACTIVE LEARNING STRATEGIES

1.1: ACTIVE LEARNING CLASS DESIGN USING BOOK-END DIVISION APPROACH (BDA)

The Book-End Division Approach (BDA) structures a class into smaller segments to promote engagement, active learning, and better retention. **Figure 1** shows an example of BDA for a 1-hour class session.



Figure 1: The book-end division approach.

A typical session begins with an Advanced Organiser, followed by cycles of Lecture and Intermittent Discussion, and ends with a Closure activity.

- **Advanced Organiser (AO)** – The lecturer triggers students' prior knowledge using ClassPoint and sparks curiosity with a short explanation from DEBuddy.
- **Lecture (L)** – The lecturer explains theory or concepts, which sometimes supported with DEWBoard demonstrations.
- **Intermittent Discussion (ID)** – Students actively engage with the material through ClassPoint activities, guided prompts to DEBuddy, or hands-on practice with DEWBoard.
- **Closure (C)** – Students consolidate their learning and reflect on key takeaways using ClassPoint.

Table 1 shows an example of how a 2-hour lecture session can be structured using BDA with integrated tools: DEWBoard, ClassPoint, and DEBuddy. Furthermore, the detailed use of ClassPoint, DEBuddy, and DEWBoard will be explained in the following section.



DEWBoard Operation

2.1: GETTING STARTED WITH DEWBOARD®

Welcome to DEWBoard®, a compact and modular Digital Electronics training kit designed for hands-on learning. This guide will help you set up and begin using your system.

1. What's Inside the System

- Main Board (Board 1) – Includes digital inputs and outputs for connection with the experiment boards.
- Combinational Logic Board (Board 2) – Experiment board.
- Sequential Logic Board (Board 3) – Experiment board.
- Signal-Scope Adapter Board (Board 4) – Connects circuit inputs/outputs to smartphone for signal visualisation.
- Cables:
  - Micro USB power cable (for powering the Main Board via a power bank).
  - Micro USB data cable (for connecting Raspberry Pi Pico).
  - USB 3.0 OTG Adapter Micro USB Type C Cable (for linking Pico to an Android device).

2. Powering the System

- Only the Main Board requires a direct power supply.
- Connect the Micro USB power cable from the Main Board to a USB power bank.
- The other three boards (Combinational, Sequential, and Signal-Scope Adapter) do not require separate power; simply connect them to the Main Board to operate.

3. Modular Design

- DEWBoard® is modular, you do not need to use all four boards at once.
- Select and connect the board(s) according to the topic you want to teach or learn.
- For detailed experiments, refer to the experiments listed in this book.

4. Using the Signal-Scope Adapter

- The Signal-Scope Adapter acts as a bridge between hardware and oscilloscope tools.
- To use with a smartphone, ensure that:
  a. Phone requirement is an Android device that's running on Android version 6.0 (Marshmallow) or higher.
  b. Install the Scoppy app from Google Play.
  c. Connect the Raspberry Pi Pico to your Android device using the Micro USB data cable + OTG cable.
  d. Open Scoppy apps to visualise waveforms in real time.



Chapter 1: Introduction to DEWBoard

Learning Objectives

By the end of this chapter, students will be able to:

- Identify how 4-bit binary inputs (0000–1111) are mapped to visible outputs.
- Observe digital HIGH/LOW and edges on a mobile oscilloscope.
- Explain why discrete states are reliable.

Brief Concept Explanation

Digital electronics deal with systems that process discrete signals, typically binary 0 and 1, making them more noise-tolerant, easier to store/manipulate, and practical to implement with logic gates on ICs. Some key advantages are reliability, design simplicity, and flexibility, with limits such as clock dependence in sequential systems and quantisation when interfacing to analog. A digital logic signal is just a voltage that must sit in one of two valid regions, LOW or HIGH, bounded by device thresholds (V_IL and V_IH); the separation between these thresholds provides noise margins that protect correctness. Beyond static levels, signals have timing, edges, with finite rise/fall, period, frequency and duty cycle. Using the DEWBoard, students can both generate binary values and see how they behave.



Chapter 2:
Number Systems and Codes

Learning Objectives

By the end of this chapter, students will be able to:

- Convert between decimal, binary, and octal number systems.
- Understand BCD inputs (number codes) and its decimal display.
- Understand positional notation and bit significance.
- Demonstrate the relationship between binary, octal and BCD patterns, and LED displays.

Prerequisites

- Basic arithmetic operations.
- Completion of Chapter 1 activities.

Brief Concept Explanation

Number systems are foundational to digital electronics as they define how data is represented and manipulated. The binary system (base-2) uses only 0 and 1, making it ideal for hardware implementation using logic gates. Decimal (base-10), octal (base-8), and hexadecimal (base-16) systems are used for simplification and human readability. Binary Coded Decimal (BCD) is especially important for digital displays and calculators as it represents decimal digits directly in binary form. Conversions between these systems are a key skill for understanding circuit operation and programming.



Chapter 3: Logic Gates and Boolean Algebra

Learning Objectives

By the end of this chapter, students will be able to:

- Compare truth tables with real-time waveforms for logic gates.
- Prove Boolean algebraic theorems using hardware implementations.
- Design and verify AOI (AND-OR-INVERT) logic expressions.

Prerequisites

- Completion of Chapters 1-2.
- Ability to construct simple truth tables.
- Familiarity with Boolean algebra notation.

Brief Concept Explanation

Logic gates are the building blocks of digital circuits, performing basic logical functions such as AND, OR, and NOT. These gates are represented mathematically using Boolean algebra, which simplifies circuit analysis and design. Understanding the relationship between truth tables, logic symbols, and Boolean expressions is essential. By using DEWBoard, students can connect gates and verify their operations, comparing theoretical outputs with real measurements.



Chapter 4: Combinational Logic Circuits

Learning Objectives

By the end of this chapter, students will be able to:

- Apply Karnaugh maps (K-map) simplification techniques to design efficient combinational circuits.
- Implement logic function with minimal gate count.

Prerequisites

- Completion of Chapters 1-3.
- Proficiency with Boolean algebra and simplification.
- Experience with K-map construction and reading.
- Understanding of Sum of Products (SOP) expressions.

Brief Concept Explanation

Combinational logic circuits are those whose outputs depend only on the present inputs instead of past states. They are widely used in devices such as calculators, data routers, and control systems. Standard forms of logic representation include Sum of Products (SOP) and Product of Sums (POS), which provide structured approaches to designing circuits. Karnaugh maps (K-maps) are a visual tool to simplify Boolean expressions, reducing the number of gates needed. Through DEWBoard, students can implement these designs and confirm their functionality in real time.



Chapter 5: Medium-Scale Integration (MSI) Logic

Learning Objectives

By the end of this chapter, students will be able to:

- Understand the basic principles of decoder and encoder.
- Implement 2-to-4 decoder, 4-to-2 encoder, and 2-to-1 multiplexer using basic logic gates combinations.
- Implement 7-segment display coding for digits 0–9.
- Explain the relationship between binary patterns and LED displays.

Prerequisites

- Completion of Chapters 1-4.
- Familiarity with combinational logic design.

Brief Concept Explanation

Medium Scale Integration (MSI) devices combine several basic gates into a single integrated circuit to perform specific, often more complex, functions. Examples include encoders, decoders, multiplexers, demultiplexers, and adders. These devices reduce circuit size, cost, and complexity while improving reliability. Understanding MSI logic is crucial for building scalable digital systems. DEWBoard allows students to implement MSI devices in practical scenarios, observing how multiple inputs are processed and routed to desired outputs.



Chapter 6:
Flip-Flops (Sequential Logic Fundamentals)

Learning Objectives

By the end of this chapter, students will be able to:

- Demonstrate sample-and-hold operation of D flip-flops.
- Implement and verify JK flip-flop toggle functionality.

Prerequisites

- Completion of Chapters 1–5.
- Understanding of clock signals and timing concepts.

Brief Concept Explanation

Flip-flops are sequential logic devices that store one bit of data, with outputs depending on both current inputs and previous states under the control of clock pulses. The D flip-flop captures the input value on the clock edge and holds it until the next clock, while the JK flip-flop extends the SR flip-flop by eliminating invalid states and allowing toggle operation when both inputs are high. These devices are widely used in registers, counters, and memory circuits. Through DEWBoard, students can observe the behaviours of JK and D flip-flops in response to different inputs and clock signals.



Chapter 7: Counters (Sequential Circuit Applications)

Learning Objectives

By the end of this chapter, students will be able to:

- Implement ripple (asynchronous) counters using JK flip-flops.
- Build synchronous counters using JK flip-flops.

Prerequisites

- Completion of Chapters 1–6.
- Mastery of flip-flop operations and timing.
- Understanding of binary counting sequences.

Brief Concept Explanation

Counters are sequential circuits, widely used in digital systems to count clock pulses, track events, and generate timing sequences. They are implemented using flip-flops. Counters can be broadly categorised into two types:

- **Asynchronous** counters operate by allowing the output of one flip-flop to trigger the next, causing a ripple effect. While simple in design, they introduce propagation delays as flip-flops do not change state simultaneously.
- **Synchronous** counters, on the other hand, have all flip-flops driven by the same clock signal. This ensures simultaneous state changes, resulting in faster and more reliable operation compared to asynchronous counters.



Chapter 8:
Registers (Data Storage and Transfer)

Learning Objectives

By the end of this chapter, students will be able to:

- Understand parallel register operation for simultaneous multi-bit data storage.
- Implement shift register circuits for serial data transfer and processing.

Prerequisites

- Mastery of flip-flop operations and timing requirements.
- Understanding of parallel vs. serial data concepts.
- Knowledge of synchronous circuit design principles.
- Completion of Chapters 1–7.

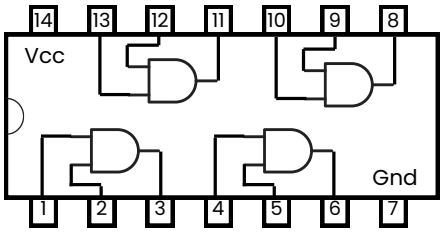
Brief Concept Explanation

Registers are collections of flip-flops used to store multiple bits of data. They are fundamental in microprocessors and other digital systems for temporary data storage and transfer. Types of registers include Serial-In Serial-Out (SISO), Serial-In Parallel-Out (SIPO), Parallel-In Serial-Out (PISO), and Parallel-In Parallel-Out (PIPO). Each type serves specific purposes, such as shifting data for communication or loading multiple bits simultaneously for processing. Using DEWBoard, students can implement these registers and see data movement visually using LEDs.

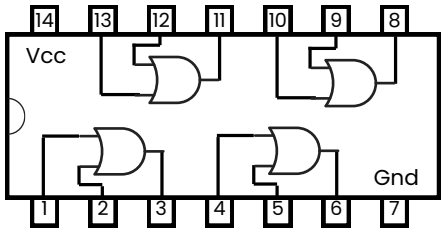


APPENDIX

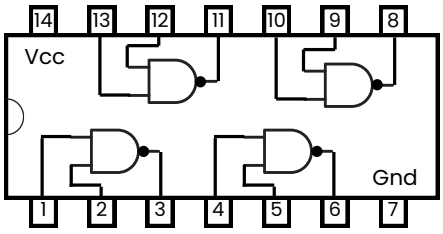
APPENDIX A - Integrated Circuit (IC) DIAGRAMS



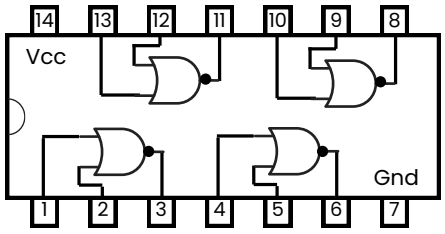
7408 Quad 2 input AND Gates



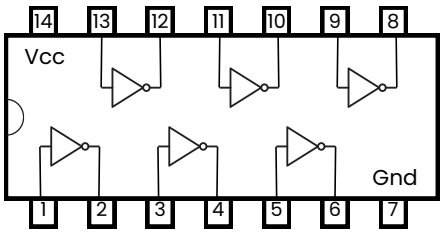
7432 Quad 2 input OR Gates



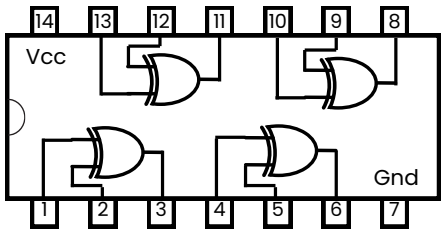
7400 Quad 2 input NAND Gates



7402 Quad 2 input NOR Gates



7404 Hex NOT Gates (Inverters)



7486 Quad 2 input XOR Gates

AUTHOR BIOGRAPHY

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A lecturer at the Faculty of Electrical & Electronics Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA), she holds a Diploma in Electrical Engineering with Education and a B.Eng. (Hons) in Electrical Engineering (Electronics) from Universiti Teknologi Tun Hussein Onn (UTHM), as well as an M.Sc. in Communications & Signal Processing from Newcastle University, United Kingdom. With 19 years of teaching experience in her field, she is currently active in research within the area of engineering education, alongside her specialiSations in computer vision and speech processing. She has also authored several teaching books, including Transforming Education: The Book-End Division Approach and Computer Vision System. She was honored with the Anugerah Khas YB Menteri Pendidikan Tinggi: Rekabentuk Kurikulum dan Penyampaian Inovatif (AKRI) 2024 by the Ministry of Higher Education (KPT) and the University Academic Award (AAU) 2022 by UMPSA, in recognition of her unwavering dedication to academic excellence and contributions to the advancement of education. Within UMPSA, she also serves as a Micro-credential Developer for Digital Electronics courses.

Dr. Nurulfadzilah Hasan



Nurulfadzilah Hasan received her PhD in composite material for antennas at Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA) in 2025. She obtained her bachelor's degree in Computer Engineering from Universiti Teknologi Malaysia in 2003. She then received her master's degree in Electrical Engineering from the same university in 2005. Since 2006, she has been working as a lecturer at Universiti Malaysia Pahang Al-Sultan Abdullah, where she teaches electronics and computer engineering subjects. She often incorporates active learning in her classes and is a ClassPoint Certified Trainer (CCT). Besides teaching, she is also active in research activities. Her fields of research include engineering education, material science for electronics, and wireless communication.

Nor Farizan Zakaria



A lecturer at the Faculty of Electrical & Electronics Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA), with a B.Eng. (Hons) in Electrical Engineering (Electronics), as well as a M.Eng. in Electric - Electronic & Telecommunication from Universiti Teknologi Malaysia (UTM). Currently, she is pursuing her PhD at UMPSA with a research on optimisation algorithms and intelligent systems. With 19 years of teaching experience, she has taught a wide range of courses across diploma, engineering technology, and engineering programs, specialising in digital electronics. Her commitment to education extends beyond the classroom, where she actively supervises student innovation projects, contributes to academic publications, and engages in community-based digital literacy programs. Her passion lies in bridging theory and practice, ensuring students not only master fundamental digital logic concepts but also gain hands-on skills for solving real-world engineering challenges.

Faradila Naim



Faradila Naim is a lecturer at the Faculty of Electrical and Electronics Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA), where she has been teaching since 2010. Prior to her academic career, she worked as an Assistant Researcher at MIMOS Bhd. She holds a B.Sc. in Control and Systems Engineering from Case Western Reserve University (CWRU), USA, and an M.Sc. in Medical Imaging from the University of Surrey, UK. Currently, she is pursuing her Ph.D. at UMPSA with a research on signal processing and feature engineering. She has nearly two decades of work experience, including more than a decade of teaching engineering courses. Her academic and research interests span machine learning, artificial intelligence, signal and image processing, and engineering education. Inspired by nurturing young engineers, she has supervised student projects that have won multiple innovation awards, reflecting her belief in the value of hands-on learning and creativity.