LEARNING

GUIDE

Digital Electronics

2020

School of Electrical and Data Engineering

Faculty of Engineering and Information Technology

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Contents

SUBJECT GUIDE ... 1

Welcome ... 1

Your Subject Coordinator ... 1

Where this subject fits into the course ... 2

The need for this subject ... 2

Subject aims and objectives ... 2

Content ... 2

Other subject information ... 3

Assessment ... 6

STUDY GUIDE ... 7

The *Activity Schedule* ... 7

The *Study Schedule* ... 7

Study Approach ... 7

The Topic Notes ... 8

Exercises ... 8

Textbooks ... 9

The Assessment Tasks ... 9

FEIT Learning Precinct ... 9

Learning in partnership ... 10

Your learning plan ... 10

Activity Schedule ... 11

Study Schedule ... 14

SUBJECT GUIDE

Welcome

Digital Electronics is a subject in the Engineering Degree course for students who major in Electrical or Electronic Engineering.

This subject focuses on developing a set of field-of-practice skills and knowledge:

- It develops an applied base for your field-of-practice knowledge.
- It develops competence in the use of laboratory equipment through laboratory-based project work and problem-based learning.
- It lets you apply core skills and knowledge to a field-of-practice.

Digital Electronics is a subject in the last year of the course – it assumes that you have developed a proficiency in academic and information literacy skills, and provides specialised knowledge for a part of your field-of-practice. It also helps you to apply that specialist knowledge to practical, real-world problems in a laboratory setting and prepares you for the graduate workplace.

You will be expected to take on a significant responsibility for your own learning. While self-managed learning offers you choices about how and when you study, we also understand that you will learn best if there are convenient opportunities for you to interact with fellow students and course staff.

Therefore, the subject provides a balance between the convenience of independent learning and the stimulation of academic life. We hope you enjoy the content, learning experiences and assessment tasks that make up this subject as well as the benefits of managing your own learning.

Your Subject Coordinator

Dr Peter McLean is a Senior Lecturer in the *School of Electrical and Data Engineering* within the *Faculty of Engineering and Information Technology*. He has designed and delivered many subjects throughout the Electrical and Electronics Majors: Introduction to Electrical and Electronic Engineering; Electronics and Circuits; Introductory Digital Systems; Fundamentals of Electrical Engineering; Signals and Systems; Digital Electronics; Analog Electronics and Embedded Software.

He has undertaken numerous research projects in collaboration with industry that normally involve the development of embedded systems hardware and software. These include microcontroller-based power system protection devices, DSP-based power-line carrier systems and a broadband Internet distribution system for the home.

Where this subject fits into the course

This subject is a Stage 7 or 8 field-of-practice subject which is an optional component of the Electrical, Electronic, Mechatronic and Biomedical Majors within various Bachelor of Engineering Degrees.

The need for this subject

It is assumed that you have already been introduced to and attained competence with basic electronics and circuits, digital logic design fundamentals, and learnt to design simple sequential programs in the C language. In this subject you will gain experience in the design of hardware of a digital system. It will be seen that the design of a digital system draws on many fields of engineering expertise, and that techniques of synthesis are highly dependent on system specifications.

The subject lays the foundation for many areas of further interest to the engineer – electronics design and fabrication, embedded software, real-time systems, signal processing and numerical methods.

Subject aims and objectives

The objective of this subject is for students to design, build and test hardware for an embedded application that utilises a modern digital integrated circuit, such as a field programmable gate array (FPGA), a microcontroller or a digital signal processor (DSP). It draws together many elements of engineering – system specification, design, implementation, testing, documentation and management – all in the context of a modern digital electronic system.

The technical content of the subject aims to develop the basic structure, operation and design of digital systems with an in-depth treatment of modern hardware components and design methodologies. The integrated circuits introduced will be field programmable gate arrays, microcontrollers, digital signal processors; memory subsystems; I/O subsystems; serial I/O subsystems; and power subsystems. Modern computer-aided hardware design software will be used extensively. Topics such as PCB manufacturing, surface-mount technology and EMC compliance will also be treated in depth.

"The artist is nothing without the gift, but the gift is nothing without work. "
- Emile Zola (1840-1902)

The technical content is contextualised in a project in which individual students analyse the requirements of an embedded system and design the hardware to meet those requirements. A PCB will be designed, built and tested. Skills in debugging hardware will also be developed through the practice-based nature of the subject.

Three engineering themes permeate the subject. The first theme is the need for a systems perspective in engineering – students will need to analyse and dissect (through a requirements specification) and eventually synthesise in a hierarchical manner (through hardware and software design). The second theme is that students will be expected to draw knowledge from a wide variety of sources – previous subjects, industrial experience, industry publications and the Internet. The third theme is that of the need for engineers to take responsibility for their own professional development. You will produce professional documentation in the form of a project logbook that details requirements specifications, mathematical modelling, electronic and software design and testing as well as project management. A practical demonstration and oral presentation at the end of the project also gives students experience in communicating technical ideas.

Finally, the subject will prepare you for more advanced topics on hardware and software systems which you may encounter in professional practice and in further subjects.

Content

The content covered is divided into the following sections:

1. Passive Components
2. Switched-Mode Power Supplies
3. Digital Logic Families and IC Packaging
4. Crystal Oscillators
5. Electromagnetic Compatibility (EMC)
6. Printed Circuit Boards
7. Thermal Design
8. Digital Measurement Techniques
9. Design Project

"In theory, there is no difference between theory and practice. But, in practice, there is. "
- Jan L.A. van de Snepscheut

Below is a brief summary of the content that is later covered in detail in the lecture notes.

Prerequisite knowledge

You are expected to have successfully completed subjects related to introductory electronics, circuit analysis and data acquisition and distribution systems.

Section 1 – Passive Components

The characteristics of passive components are given in detail, together with selection guides and application areas.

Section 2 – Switched-Mode Power Supplies

Types of switched-mode power supplies are examined for digital logic circuits, as well as some of their design considerations.

Section 3 – Digital Logic Families and IC Packaging

On overview of logic families and their history is given. Logic levels are discussed. Modern CMOS families are reviewed. SMT IC packaging is reviewed.

Section 4 – Crystal Oscillators

Feedback oscillator topologies are examined and the electrical characteristics of crystals are modelled. A brief overview of oscillator design considerations is given.

Section 5 – Electromagnetic Compatibility (EMC)

Principles of EMC are given, including types of sources, coupling and combating EMI. Regulatory standards are also introduced.

Section 6 – Printed Circuit Boards

An overview is given on PCB manufacture.

Section 7 – Thermal Design

The principles of thermal design, such as heat transfer theory, conduction, convection, heat sinks, radiation and modelling, are introduced.

Section 8 – Digital Measurement Techniques

An overview is given on using a DSO to measure digital signals, as well as some of the pitfalls of designing and probing PCBs.

Section 9 – Design Project

The project allows you to gain experience in putting a variety of ideas into practice, and requires the design of an embedded system. You will be required to interpret specifications and come up with sound engineering designs using a variety of methods. A PCB will be produced, populated and tested. Programming of software into the digital chips will be performed. The designs will be implemented and experimentally verified.

Other subject information

The following information takes precedence over the default policies outlined in section 3.3.1 of the Faculty's Student Guide.

Internet

The subject has a web site which contains the subject documentation and links to important learning aids. The URL is:

https://pmcl.net.au/de/


web

You should regularly visit and explore the web site to keep informed of any important announcements such as timetable or assessment changes.

Timetabled Activities


face to face session

Class time is used for lectures and self-directed study sessions. Lectures will introduce new material in a modular fashion that can then be applied to the design of a real embedded system. Towards the end of semester, students will undertake an individual project in which the class time will serve as valuable resource / design / discussion sessions. During the lectures you will have the opportunity to meet with fellow students and with your subject coordinator who will answer questions and highlight selected topics.

Laboratories

The laboratories are unstructured sessions that give you access to specialised equipment. The laboratory work will be project-based and will be complemented with computer simulations and design exercises.

Twenty-four hour access to the Embedded Projects Laboratory will be given to students during the session.

As part of the Faculty's commitment to safety, all students are now required to complete a safety induction. Access to laboratories is dependent upon your successful completion of the safety induction. The induction must be renewed each year.

Laboratory access is contingent upon successful completion of the UTSOnline FEIT – Safety and Wellbeing Essentials Module.

Assessment

Assessment for this subject is criterion-referenced. This means that your performance is measured against a set of criteria, not against the performance of other students.

The assessment criteria for this subject

"Not everything that can be counted counts, and not everything that counts can be counted." - Albert Einstein (1879-1955)

In assessing your performance we will be looking for evidence that:

- You are able to efficiently carry out an accurate analysis of the requirements of a digital system, and are able to implement it with suitable modern electronic components.
- You have understood the concepts used in Electronics Design Automation and are able to apply them to the design of a practical digital system.
- You have understood the methods of project management and are able to apply them to a practical project by keeping a project logbook and communicating your design in both written and verbal form.

Assessment tasks

assessment task

The assessment tasks and their weighting are given in the Project Marking Scheme.

Assessment dates

All assessment dates are shown in the *Activity Schedule*.

STUDY GUIDE

There are two components to completing your study of *Digital Electronics*. They are:

- reading the *Topic Notes* and associated “readings”
- completing the project satisfactorily

To guide you through these tasks there is an *Activity Schedule* and a *Study Schedule*.

The *Activity Schedule*

The *Activity Schedule* lets you know what activities will be occurring during the face-to-face timetabled activities. Each row of the *Activity Schedule* refers to:

– A timetabled activity, color-coded to match myTimetable. A brief description of the activity is given, and any preparation that may be required.

– Assessment tasks that should be started, or are due.

The *Study Schedule*

The *Study Schedule* will help you manage your self-learning. The schedule is organised in logical, linked and digestible steps. Each row of the *Study Schedule* refers to:

– A topic in the *Topic Notes*. Each topic may have associated exercises.

– Textbook sections that are required reading and associated problems.

Study Approach

The *Schedules* encourage you to be an active learner; not a passive learner. You should keep in mind that to achieve the necessary competence to pass this subject it is not sufficient to just read the pages of the *Topic Notes* and textbook readings a few weeks before assessment tasks are due. Apart from understanding the concepts given in the *Study Schedule*, you also need to practice solving problems, undertake laboratories and allow yourself sufficient time to reflect on what you have learnt.

"Whether you think that you can, or that you can't, you are usually right."
- Henry Ford (1863-1947)

You can see what the learning tasks will be for each week of the session before you begin. This enables you to mentally prepare for the learning tasks while you work through the topics. In this way your learning stays focused on the main areas of the program activity; you don't lose your way in the details.

The Topic Notes

The *Topic Notes* should be read before each activity so that class time can concentrate on particular topics of interest rather than trying to cover all the material.

Structure of the *Topic Notes*

The *Topic Notes* summarize important topics and complement the readings. They are updated regularly based on feedback from students attempting to learn the topics. Difficult or hard-to-grasp topics are expanded; or are presented in a different manner to the textbook; or highlight the real-world application of the topic. Prerequisite material is often recapped. The focus of the *Topic Notes* is towards the practical application of theory, so those topics that are important to this goal are treated fairly thoroughly.

Skim through first

Margin notes help you navigate the material

If you are already familiar with the material in any section or if you want to get an overall feel for what it contains, you may like to skim through it first, looking at the headings and margin notes.

Exercises

Topic Notes

The *Topic Notes* have a self-contained set of exercises. These should be attempted before attending class – it is best to obtain help with problems you are working on so that the class time remains relevant. Research has shown that students who regularly test themselves by doing problems have a greater grasp of a topic than those who simply read notes. Doing the exercises will therefore be a significant component of your time and learning.

Textbooks

Textbooks are where you find the detail of the topics covered in this subject.

Prescribed textbook

There is no prescribed textbook for this subject.

Reference textbooks

The following is a list of reference textbooks that delve deeper into the topics of this subject. They may be used for alternative explanations or you may consider purchasing them if they relate to your chosen field:

Barrett, S. F. & Pack, D. J., *Embedded Systems - Design and Applications with the 68HC12 and HCS12*, Prentice Hall, 2005.

Peatman, J. B., *Embedded Design with the PIC18F452 Microcontroller*, Prentice Hall, 2003.

Predko, M., *Programming and Customizing the PIC Microcontroller*, 3rd Ed. McGraw-Hill, 2007. ISBN 978-0-07-147287-6

Shabany, Y., *Heat Transfer – Thermal Management of Electronics*, CRC Press, 2010.

Vahid, F. & Givargis, T., *Embedded System Design*, Wiley & Sons, 2002.

The Assessment Tasks

The Project is published in documents separate to the *Topic Notes*. It is up to you to submit each assessment item on time. The due dates for assessment items are given in the *Activity Schedule*.

FEIT Learning Precinct

The FEIT Learning Precinct (FLP) in room CB11.5.300 is a collaborative, learner-centred space providing students with resources and study areas to support active learning. In between classes, you can study or conduct group work, or you can use the space to access teachers for individual and small group support. The FLP also has reference material, and software and hardware resources.

Learning in partnership

Using a fellow student as a learning partner has been found repeatedly to be an important learning support. The idea is that you contact a fellow student, by whatever means is most convenient, to discuss your interpretation of a learning task, to check if your approaches are the same and to generally clear up any confusions which may have arisen. It has been found that well over half of the concerns students experience about their learning are to do with simply checking that they are 'on the right track' and can be solved using this method. If, however, the concern or uncertainty remains, it is then recommended that you contact your Subject Coordinator.

Your learning plan

Your time

Organising your time is a major challenge in learning. Leaving recommended readings and assessment items to the last minute is a common problem. To assist you with this challenge you may find it useful to plan your study time before you start work on this subject. First decide on the best place and time each week to study without distractions and then make sure to adhere to your own plan.

It is estimated that you should set aside a total of approximately 9 hours of study time each week. It is recommended that you break up those hours into at least two study periods, each on a different day of the week. This is a rough guide only, as people learn at different rates and from different levels of experience.

Activity Schedule

WEEK	ACTIVITY	TOPIC	ASSESSMENT
1	Lec	***1 Passive Components*** Resistor characteristics. Resistor types. Choosing resistors. Capacitor characteristics. Types of dielectrics. Capacitor models. Film capacitors. Ceramic capacitors. Electrolytic capacitors. Mica capacitors. Glass capacitors. Choosing capacitors. Decoupling capacitors.	
2	Lec	***2 Switched-Mode Power Supplies*** Pulse-width modulation. Buck regulator. Boost regulator. Inverting regulator. Single-Ended Primary-Inductor Converter (SEPIC). Selection of components. Output filters.	
3	Lec	***3 Digital Logic Families and IC Packaging*** Levels of integration. Voltage and current parameters. TTL logic and evolution. ECL. CMOS logic and evolution. Logic families. CMOS voltages. IC packaging.	
	Lab	***Lab – Surface Mount Soldering Exercise*** Voltage measurement. Series circuits. The voltage divider. Parallel circuits.	
4	Lec	***4 Crystal Oscillators*** Classification of oscillators. Crystals. Ceramic resonators. Oscillation conditions. Oscillator configurations. The Pierce oscillator using digital IC inverters. Analysis of oscillators. Analysis of the Pierce oscillator.	
5	Lec	***Schematic Review*** Schematics are reviewed before PCB design.	

WEEK	ACTIVITY	TOPIC	ASSESSMENT
S1	-	***Mid-Session StuVac***	
6	Lec	***5 Electromagnetic Compatibility (EMC)*** Principles. Sources. Coupling. Layout and grounding. Digital and analog circuit design. Interfaces, filtering and shielding. EMC management.	**Log Book Section 1**
7	Lec	***6 Printed Circuit Boards*** PCB manufacturing.	
8	Lec	***7 Thermal Design*** Specification. Heat transfer theory. Conduction. Convection. Heat sinks. Radiation. Design tips.	
9	Lec	***PCB Review*** PCBs are reviewed before manufacture.	
10	Lec	***8 Digital Measurement Techniques*** DSOs and bandwidth. Probes and loop inductances. Wires as transmission lines.	

WEEK	ACTIVITY	TOPIC	ASSESSMENT
11	Lab	***Project*** Project work.	
12	Lab	***Project*** Project work.	**Lab Test**
S2	-	***Final StuVac***	
A1		***Project Assessment*** Log book.	**Log Book Section 2**
A2		***Project Assessment*** Oral presentation.	**Oral Presentation**

Study Schedule

WEEK	NOTES	READINGS
1	***1 Passive Components*** Resistor characteristics. Resistor types. Choosing resistors. Capacitor characteristics. Types of dielectrics. Capacitor models. Film capacitors. Ceramic capacitors. Electrolytic capacitors. Mica capacitors. Glass capacitors. Choosing capacitors. Decoupling capacitors.	http://techdocs.altium.com/display/ADOH/Getting+Started+with+Altium+Designer
2	***2 Switched-Mode Power Supplies*** Pulse-width modulation. Buck regulator. Boost regulator. Inverting regulator. Single-Ended Primary-Inductor Converter (SEPIC). Selection of components. Output filters.	http://techdocs.altium.com/display/ADOH/The+Altium+Designer+Environment
3	***3 Digital Logic Families and IC Packaging*** Levels of integration. Voltage and current parameters. TTL logic and evolution. ECL. CMOS logic and evolution. Logic families. CMOS voltages. IC packaging.	http://techdocs.altium.com/display/ADOH/Library+and+Component+Management
4	***4 Crystal Oscillators*** Classification of oscillators. Crystals. Ceramic resonators. Oscillation conditions. Oscillator configurations. The Pierce oscillator using digital IC inverters. Analysis of oscillators. Analysis of the Pierce oscillator.	http://techdocs.altium.com/display/ADOH/Project+Management

WEEK	NOTES	READINGS
5	***Schematic Review*** Schematics are reviewed before PCB design.	http://techdocs.altium.com/display/ADOH/Front-End+Design
S1	***Mid-Session StuVac***	
6	***5 Electromagnetic Compatibility (EMC)*** Principles. Sources. Coupling. Layout and grounding. Digital and analog circuit design. Interfaces, filtering and shielding. EMC management.	http://techdocs.altium.com/display/ADOH/Design+Verification+and+Synchronization
7	***6 Printed Circuit Boards*** PCB manufacturing.	www.ti.com/lit/an/szza009/szza009.pdf http://techdocs.altium.com/display/ADOH/Board+Implementation http://www.murata.com/en-global/products/emc/emifil/knowhow/basic
8	***7 Thermal Design*** Specification. Heat transfer theory. Conduction. Convection. Heat sinks. Radiation. Design tips.	http://techdocs.altium.com/display/ADOH/Design+to+Manufacturing https://www.base2.us/index.php?page=ac http://www.youtube.com/watch?feature=player_detailpage&v=2qk5vxWY46A http://www.youtube.com/watch?feature=player_detailpage&v=nah4BQ9y8IY

WEEK	NOTES	READINGS
9	***PCB Review*** PCBs are reviewed before manufacture.	
10	***8 Digital Measurement Techniques*** DSOs and bandwidth. Probes and loop inductances. Wires as transmission lines.	
11	***Project*** Project work.	
12	***Project*** Project work.	
S1	***Final StuVac***	
A1	***Project Assessment*** Log book.	
A2	***Project Assessment*** Oral presentation.	