T202

ANALOGUE AND DIGITAL ELECTRONICS

OCTOBER 2003

COURSE GUIDE
1 INTRODUCTION

Welcome to T202, Analogue and Digital Electronics.

This course was written by the Open University in U.K., and most of the written materials have been adopted unchanged. Some aspects of the course presentation, however, are very different here in Hong Kong from the way they are in Britain. The main differences relate to the practical work associated with the course. In Britain, students are sent a “Home Kit” consisting of electronic components, circuit modules and a “Generatorscope” (a combined oscilloscope, signal generator and power supplies). With this kit, they are expected to carry out a large number of experiments in their own homes. Here at OUHK we do not issue a home kit, but instead, you are expected to attend a number of “short laboratory” sessions here where you will carry out the same experiments. Don’t be confused by references in the course texts to “home kits”, “home experiments” or “the Generatorscope”, they are not relevant to you. You may also find references to “Summer School”. This is a whole week of practical work, tutorials and lectures which O.U. students must attend. Here in Hong Kong, the same experiments are carried out at “long laboratory” sessions held on Sundays later in the course.

This Course Guide has been designed to provide you with some essential information about the course, and to assist you in planning the best use of your available study time. Sections 2 to 5 present an overview of the course, and therefore help you see the course as a whole. You should therefore read these sections before you start work on Block 1.

You will also have received the Presentation Schedule in this mailing, which shows how long you should spend studying each block of the course. This schedule assists with the overall planning of your 42 weeks of study. To assist your detailed planning, Section 6 of this Guide contains detailed study guides to each of the blocks in the course, showing how you are expected to allocate your time to each of the individual components of a block. You will need to read the relevant Block Guide each time you start your study of a new block. These block guides will assist you in planning the detailed allocation of your study time week by week as you progress through the course. Section 6 also contains some “study notes” which explain ideas or terms used in the texts which U.K. students are assumed to find familiar, but which you may find confusing. Section 7 consists of Errata of the printing of the course blocks. Section 8 gives list of approved calculator.

If, during your study of the course, you have difficulty understanding the course materials, you should contact your Tutor, whose name address and telephone number will be supplied to you by the OUHK Registry.

If you have not received course materials which you believe have been dispatched to you, or if the materials you receive are incomplete, you should contact the Educational Technology and Publishing (ETP) at 2768 6431-3.

If you have any problems other than subject matters in the course materials, or have any suggestions for improvements, please write to:

The T202 Course Co-ordinator,
School of Science & Technology,
The Open University of Hong Kong
30 Good Shepherd Street
Homantin, Kowloon
2 THE AIMS AND OBJECTIVES OF THE COURSE

It is important in electronics to be able to do more than “get the right answer” to a specific set of questions. As in all fields of study in which design is a major activity, the main task is to be able to solve new problems as well as to know the answers to previously solved problems. The kinds of tasks that arise in electronics include:

(i) designing a circuit to meet a new performance specification,
(ii) explaining to someone else the reason why you have designed a circuit the way you have,
(iii) diagnosing the cause of an unfamiliar fault or of a new sort of circuit behaviour so that you can correct it,
(iv) being able to argue the good and bad points of different circuits and ask important questions about them, and so on.

The common feature of all these activities is having the ability to cope sensibly with new and unexpected problems. So it is this ‘capability’, as it is called, that this course tries to help you acquire.

There are subsidiary aims which are much easier to teach and to learn which undoubtedly form part of the capability which the course is trying to help you develop. There are a number of tried and tested circuits that you ought to know about and whose performance you should be able to describe precisely. They often form the starting point for any one of the problem solving tasks listed above. Equally, there are a number of techniques available, like using mathematics or drawing circuit diagrams, that help you analyse a problem in preparation for devising a solution to it. Knowing about these circuits and being able to use these techniques are the beginnings of electronic capability, and they are usually referred to as knowledge and skills. But understanding the circuits and how they are used, and grasping the concepts on which they depend are the key parts of capability. Capability is being able to use such knowledge and skills to solve new problems. It is the ability to go beyond the information given.

The course sets SAQs and assignments to test your knowledge and skills, but to gain the understanding that you need requires you to tackle new problems, or at least problems that are new to you; to try to design things, to try to explain things in your own words, to try to diagnose faults, to ask sensible questions and so on. There may be no “right” answers to these questions, they are set in order to reveal to yourself, as well as to your tutor, your degree of understanding. Giving you model answers merely tempts you to learn the answers by heart instead of thinking about the problem. So the ‘answers’ which are provided may refer only to the sort of things you should have thought about. In trying to answer such assignments, the important thing is not whether you can solve the problem quickly, but whether you can show that you have understood the problem and can see how to tackle it successfully. Unfortunately, T202 does not have time to set really testing projects which fully test your problem-solving skills (TE401, the Electronics Project Course does that), but it may pose a number of open-ended problems which you would be expected to analyse, so that it can be seen if you are taking a sensible approach.

In order to make it clear that you are being asked to learn both knowledge and skills, as well as to acquire understanding, the course includes two kinds of objectives. The specific objectives are those you are used to. They lead to questions about what you know and about the calculations that you should be able to do. The general objectives lead to questions whose aim is to bring out what you understand, and to reveal whether you have grasped the important concepts on which understanding depends.
3 THE COURSE COMPONENTS

The course contains a number of different components, closely integrated to produce a coherent teaching package. These components are as follows.

3.1 The main texts. These form the main teaching medium of the course, and you will spend most of your time reading these texts and answering the self-assessment questions (SAQs) which they contain. It is important that you tackle the SAQs as you read through a block text, as they are the main means you have of testing whether you have understood the contents. These texts are arranged in blocks, most blocks having several parts. The blocks vary in length, and the individual parts within a block are also usually of different lengths.

3.2 The glossary. The course glossary lists each of the new terms and concepts introduced in the course, with a very brief description of each and an indication of where, in the main texts, the term is introduced and described. Whenever a term is used, and you can’t remember the meaning of it, you should first look in the glossary. The short description there may serve to refresh your memory. If that description doesn’t help, you should refer back to the main text where the term has been described in detail.

3.3 The home computing. Throughout the course there are a number of home computing exercises which require you to use Computer Aided Design (CAD) software known as OrCAD to analyse circuit behaviour. These computing exercises are an essential component of the course, and the CAD software is provided as part of the course materials. This package run on an IBM PC or compatible running Windows 95/98/Me/XP and English Window is preferred. In some rare cases, some students have reported problems using OrCAD in Chinese Windows. You will find the software NODALOU, LOGANOU and Phasor used in the main text. You can simply ignored them because these old software have been replaced by OrCAD.

3.4 The short laboratories. Spread throughout the course, and indicated on the Presentation Schedule, are a number of “short laboratory” sessions to be held in OUHK’s own laboratory in Homantin campus. At these sessions, you will carry out experiments designed to reinforce the teaching of skills and knowledge, and to assist in developing understanding. While attendance at these sessions is optional, much of the teaching in the texts assumes you have performed the experiments, so that if you do not attend, the texts will be harder to understand and learn from. Also, some of the assignments may contain questions which you might not be able to answer fully unless you have attended the short laboratory sessions.

3.5 The long laboratories. Near the end of the course, approximately as indicated on the Presentation Schedule, are four “long laboratory” sessions to be held on Sundays in OUHK laboratory. Each of these long labs lasts for a whole day, and provides an opportunity for you to engage in realistic design exercises, as well as to perform extended experiments to reinforce the teaching of essential concepts. Attendance at these sessions is compulsory. If you do not attend, you cannot pass the course.

3.6 The T202 File. As part of the printed course materials, you will be provided with a ring binder to hold (a) the home computing booklets, (b) long-lab experiment notes and (c) the assignment booklets for the course. You are also expected to keep in this file your own notes on experiments and home computing exercises, and your marked TMAs after return from your tutor. The use of the file should reduce the number of loose papers which you have to store, and should therefore reduce the risk of losing important components of the course materials.
3.7 Tutorials. There will be regular face-to-face tutorial sessions with your Tutor, supporting the teaching in the main texts. The Presentation Schedule shows the approximate timing of these tutorial sessions. Exact information about the date, time and place of each tutorial will be sent to you in a separate mailing. Attendance at tutorials is optional.

3.8 Surgeries. Regular surgery sessions are scheduled throughout the course, a tutor will be available to answer specific problems which you may have with the course work. These “surgery” sessions are intended to provide you with specific assistance with specific problems; the tutor will not run a tutorial, and will not have facilities for talking to more than a few students at a time. Since the surgeries are held more frequently, they provide the opportunity for you to resolve difficulties without having to wait for your next scheduled tutorial. Details of these surgery sessions will be sent to you in a separate mailing.

3.9 Web CT and Course Home Page. This course will use the On-line Learning Environment (OLE) known as WebCT. Furthermore, there is a web page for T202 that contains information relating to the course. You are recommended to visit this homepage regularly. The web page address is: http://learn.ouhk.edu.hk/~t202

4 THE COURSE CONTENT

BLOCK 1: INTRODUCTION TO SIGNALS AND CIRCUITS

Part 1: Basic Electrical Principles

This text, as its name suggests, introduces some of the basic concepts with which all students need to be familiar before starting on the course subject matter proper in Part 2 of the block. Topics covered are: current, e.m.f., potential difference, electrical energy, electrical power, resistance and conductance, resistors in series and in parallel, and the measurement of current, voltage and resistance. A short lab introduces the use of a multimeter for the measurement of current, voltage and resistance, and contains some simple experiments to reinforce the concepts introduced in the text. One of the experiments provides data for the introduction of new concepts in Part 2 of the block.

Part 2: Methods of Circuit Analysis

This develops some of the fundamental tools of circuit analysis in the context of d.c. resistive circuits. These concepts include: Kirchhoff’s current and voltage laws, nodal analysis, ideal voltage and current sources, Thévenin and Norton equivalent circuits, and the Superposition principle. There is no short lab associated with this part of the block, but there is a substantial home computing component.

Part 3: Signals and Waveforms

This describes the nature and properties of the current and voltage waveforms which are handled by electronic circuits, with particular reference to sinusoidal waveforms, analogue signals and digital signals. It introduces ideas of: frequency spectra and bandwidth; signals, messages and carriers;
noise and distortion; and the ways in which signals and waveforms are quantified. A short lab introduces the use of an oscilloscope and reinforces some of the concepts introduced in the text.

**Part 4: Basic Circuit Components**

This describes the nature and properties of some basic a.c. circuit components, namely, inductors, capacitors, transformers and rectifiers, and their response to both sinusoidal waveforms and sudden step changes of voltage or current. The role of the transistor as a power amplifier is also described. The concepts of linearity and of the small signal equivalent circuit are introduced.

**Part 5: Amplifiers and Amplification**

This part of the block explains what is meant by amplification, and shows how feedback can be used with operational amplifiers to obtain different kinds of amplifier performance.

**Part 6: Preview of the course**

This is an introductory account of the remainder of the course. Its purposes are (a) to provide an overview of the course so that you can see where the course is leading, (b) to introduce a number of concepts and terms and (c) to put each of the blocks into the context of the subject of electronics as a whole.

**BLOCK 2: ANALOGUE PRINCIPLES**

**Part 1: Phasor Analysis**

This first part of Block 2 develops the basic ideas necessary for the analysis of a.c. circuits, namely, phasors, phasor diagrams, phasor notation, the operator j, complex numbers, phasor manipulations using complex numbers, and phasor operators. It then uses these tools to analyse a number of simple a.c. circuits and to obtain the a.c. voltage transfer function of these circuits. It contains short lab experiments and a number of home computing exercises.

**Part 2: Frequency Response of Linear Circuits**

This text is concerned with the way in which the voltage transfer function of a circuit changes with frequency, and in particular with the Bode plot as a graphical means of representing and interpreting those changes. It develops the Bode plots for a number of simple a.c. circuits, and examines the frequency response of both the series and parallel resonant RLC circuits. Again, there are both short labs and home computing exercises associated with this part of the block.

**Part 3: Amplifiers and Feedback**

This text applies the ideas of a.c. circuit analysis developed in earlier parts of the block to the analysis of the performance of the operational amplifier circuits which were introduced in Part 5 of
Block 1. It deals with the frequency response of an operational amplifier, then examines the frequency response of a range of feedback amplifier configurations. The idea of instability is introduced, and the conditions affecting the stability of a feedback amplifier are discussed. It ends with a discussion of active filters, and of the Wien bridge oscillator as an example of the use of positive feedback. Both short labs and home computing are included.

**BLOCK 3: DIGITAL PRINCIPLES**

**Part 1: Combinational Circuits**

This is concerned with the basic principles of combinational logic circuits, introducing the binary number system, binary signals, gates, de Morgan’s theorem, half- and full-adder, codes and code conversion.

**Part 2: Logic Design and Implementation**

This deals with the design of logic circuits. It describes the process of conversion from a truth table, via a Karnaugh map, to the circuit (consisting of a combination of logic gates) which implements the required logic function. Devices introduced to implement logic circuits include SSI (small-scale integration) devices such as AND, OR, NAND and NOR gates, MSI (medium-scale integration) devices such as decoders and AND-OR-INVERT gates, and programmable devices such as PALs (programmable array logic devices) and PROMs (programmable, read-only memories). The text ends with a description of the TTL (transistor-transistor logic) family of gate devices.

**Part 3: Introduction to Sequential Circuits**

This part of the block is concerned with the design of sequential logic circuits. It describes a design method using the concepts of a general sequential machine, state-transition diagram, state table and state assignment table. Specific sequential logic circuits are implemented using gates and memory elements such as D-type flip-flops. Counters are treated as a special set of examples of sequential logic circuits, and the design of synchronous counters using JK flip-flops is described. The text ends with descriptions of the 555 timer, integrated circuit counters and PLSs (programmable logic sequencers).

**Part 4: Analogue-Digital Conversion**

This final part of the block considers the conversion of analogue signals to digital form. It first describes the digital-to-analogue (D-A) converter, then describes three different methods of analogue-to-digital (A-D) conversion – the flash converter, the counter-ramp converter and the successive approximation converter. It ends with descriptions of sample-and-hold devices and multiplexers. There is a short lab associated with this part of the block which requires you to investigate the characteristics of D-A and A-D converters.

The block ends with a substantial home computing component using OrCAD, the circuit analysis software.
BLOCK 4: TRANSISTORS AND BASIC CIRCUITS

Part 1: p-n Junctions and Transistors

This first part of the block looks at some of the physics underlying semiconductor devices, and explains the properties of diodes and transistors in terms of the properties of silicon and the structure of the devices. It also explains one application of the d.c. characteristics of the devices, the design of d.c. current sources using transistors.

Part 2: Analogue Transistor Circuits

This part of the block is concerned with constructing useful analogue transistor circuits using the knowledge of devices gained in Part 1. The text first looks at the way a transistor can be represented by an equivalent circuit, and how numerical values for the equivalent circuit parameters are obtained from data sheets and from graphs of transistor characteristics. It then describes the common-emitter amplifier, the use of a dynamic load, the long-tailed pair and the emitter follower. These four circuit configurations are finally combined into the design of a simple operational amplifier. The home computing exercises associated with this part of the block allow you investigate the d.c. and small-signal behaviour of the circuits described in the text.

Part 3: Digital Transistor Circuits

This final part of the block deals with digital transistor circuits. It starts by describing the switching properties of transistors, and proceeds to describe the design of various widely-used families of transistor switching circuits, namely, TTL (transistor-transistor logic), ECL (emitter-coupled logic), NMOS (n-channel metal-oxide silicon) and CMOS (complementary metal-oxide silicon). The properties of a selection of these circuits are explained in terms of the properties of the transistors of which they are made.

BLOCK 5: AUDIO AMPLIFIER DESIGN

Although this block is specified as being split into 5 separate parts, each part is smaller than for previous blocks and the divisions between parts are not as clear.

The first part of the block describes some characteristics of signals and of noise, in particular: average value, mean-square value, the Gaussian distribution, line spectrum and power density spectrum. The second part discusses some of the components of a hi-fi audio system and their characteristics, including the magnetic pick-up for a record turntable, the loudspeaker and the amplifier. Amplifier characteristics considered are: output offset voltage, noise sources, frequency response, transient response and distortion. The last three parts of the block are all concerned with the design of an audio amplifier to satisfy a given specification. The required specification is first developed, a pre-amplifier designed using a 741 operational amplifier, and finally the power output stage is designed using both an op-amp and discrete components. The block contains both short labs and home computing exercises. The experiments involve building and testing the audio
amplifier, while the home computing exercises are used to simulate the performance of the designed amplifier and hence predict its performance.

**BLOCK 6: DIGITAL SYSTEMS**

**Part 1: Memory systems**

This describes some of the circuit components used to store digital data, and the way in which these components can be interconnected to form large memories. It deals with registers, RAM (random access memory), DRAM (dynamic RAM), SRAM (static RAM), and a range of different ROM (read-only memory) types.

**Part 2: Microprocessors and Microcontrollers**

This describes the basic characteristics of a microprocessor and of a microcontroller, and shows how such devices can be used as versatile components in digital and analogue circuit design. It introduces concepts such as: sequential operation, stored program, processor architecture, RISC (reduced instruction set computers) and CISC (complex instruction set computers). It goes on to describe in detail a commercially available device, the Motorola MC68HC05B6 microcontroller, and an application of the device in the control of a domestic washing machine. The block ends with a look at an example of digital processing of analogue signals.

**BLOCK 7: POWER SUPPLIES**

This block describes how to obtain a stable, d.c., low voltage source from an a.c. mains supply. It deals with: half- and full-wave rectification, the bridge rectifier, voltage references, regulation, overload protection and switched-mode power supplies. Home computing exercises require you to simulate various sub-systems of the overall regulated power supply to examine their performance characteristics.

**BLOCK 8: HIGHER-FREQUENCY CIRCUITS**

**Part 1: The Hybrid-π Model of a Bipolar Transistor**

This first part of the block explains the performance of transistors and transistor circuits at higher frequencies, that is, frequencies at which the effects of small capacitances within the transistor and/or within the circuit become significant. The transistor is represented by the hybrid-π equivalent circuit which effectively represents the transistor performance at all practical frequencies. Using that equivalent circuit, the behaviour of a common-emitter amplifier is analysed. You are required to check the calculated amplifier behaviour by simulating it on your home computer.

**Part 2: Interconnections**
This part of the block is about the various methods of connecting signals from one place to another. It considers the following interconnection methods, and some of the do’s and don’ts associated with each:

- open wires
- twisted pairs
- twin feeders
- coaxial cables
- multi-way cables
- strip-lines
- optical fibres
- transmission lines.

The text also discusses the connection of test gear to high-frequency circuits, digital circuit characteristics at high frequencies and the characteristics of printed circuit board connections.

**BLOCK 9: RADIO FREQUENCY TECHNIQUES**

**Part 1: Modulation, Demodulation, Propagation and Aerial Systems**

This part describes the basic principles of transmitting and receiving information by radio waves. It deals with the modulation, propagation and demodulation of signals, and describes the types of aerial system used to receive the transmitted signals.

**Part 2: Radio Receivers**

The second part of this block is devoted entirely to radio receivers. It explains basic principles and shows how these principles are applied to the radio receivers in your home. Another short lab provides the opportunity to build and test a small radio receiver.

**5 COURSE ASSESSMENT**

The assessment of this course consists of a continuous assessment component and a final examination. Your progress throughout the course will be assessed by 8 Computer-marked Assignments (CMAs) and 9 Tutor-marked Assignments (TMAs). Three of the TMAs (TMA03, TMA06 and TMA09) are classified as necessary for assessment purposes, which means that the marks you obtain for those assignments will be used in calculating your overall course mark. Of the other TMAs, only the best 4 will be used in the calculation of your overall course mark, while only the best 6 out of 8 CMA scores will be used in the calculation. At the end of the course you will be required to sit a three-hour examination.

Your overall course mark will be calculated from the results of your CMAs and TMAs and from your examination result as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Weightage</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 of 8 CMAs (all equally weighted)</td>
<td>20%</td>
</tr>
<tr>
<td>7 of 9 TMAs (all equally weighted)</td>
<td>30%</td>
</tr>
<tr>
<td>Final Examination</td>
<td>50%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
The first 8 TMAs and all the CMAs are used to assess your progress with the main texts, the home computing and the short labs. TMA09 will assess your performance in the long laboratories.

The final examination is a written paper of 3 hours, and you will be attempting the questions without the help of any notes or printed materials relating to the course. A simple scientific calculator is allowed. A list of approved calculators is shown in section 9 of this course guide. You will be sent a Specimen Examination Paper, which resembles the actual paper in both style and format, so that you can get some idea of what to expect.

6  DETAILED COURSE GUIDE

6.1 The course as a whole

Table 1 shows the amount of study time allocated to each of the blocks of the course. As you can see, the blocks vary considerably in length, from 7 weeks for Blocks 2 and 3 to only 2 weeks for Blocks 7.

Table 1

<table>
<thead>
<tr>
<th>Block</th>
<th>Title</th>
<th>Nominal study weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to Signals and Circuits</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Analogue Principles</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>Digital Principles</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>Transistors and Basic Circuits</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>Audio Amplifier Design</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Digital Systems</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Power Supplies</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Higher Frequency Circuits</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Radio Frequency Techniques</td>
<td>3</td>
</tr>
</tbody>
</table>

The way in which these overall times break down into study times for the individual parts of each block is described in each of the detailed block study guides which follow. Before starting to study each block, you should read the detailed study guide for that block in order to plan the use of your time effectively. The Presentation Schedule shows how the tutorials, short labs and assignments relate to your study of the texts.

Study note - a domestic central heating system.

Twice in Block 1 (in Parts 1 and 5) and again in Block 6, the text authors have used a central heating system, either as an analogy to an electrical circuit, or as an example of the application of electronics. Because the course was written in U.K., where central heating systems are fitted into most homes, the author assumes a familiarity with such systems which Hong Kong residents may not possess. Consequently, included below is a general description of a typical domestic central heating system.
heating system. If you are already familiar with such systems, you will not need to read it. If you do need to read it, remember that it is not materials which will ever be assessed in the continuous assessment or the examination. It is provided solely for clarification when reading the block texts.

In Britain, winters can be very cold, and energy must be used to provide heat to maintain a comfortable living environment inside the home. The most common way of providing this heat in Britain is the domestic central heating system, and the most common form of central heating (in 1991) uses natural gas as the source of energy.

The gas is burned in a boiler, where it raises the temperature of water to about 60°C. A local controller monitors the water temperature and switches on and off the gas supply to the boiler to maintain this water temperature. A pump circulates the water through the boiler and through a number of radiators distributed around the house. Each radiator is a thin hollow rectangle, perhaps 600 mm high by 2 m long, mounted on a wall, and about 50 mm away from it. When the hot water is pumped through it, the surface of the radiator becomes hot and heat is radiated from it (hence the name ‘radiator’) and also removed from it by converted air currents, so warming the room in which the radiator is placed. Each of the radiators is normally connected in parallel between a ‘supply’ hot water pipe from the boiler and the pipe returning the water to the boiler, so that any one radiator can be manually turned off by closing a tap in its supply pipe, without stopping the flow of water to the other radiators in the system.

As well as the local control of the gas consumption in the boiler, a temperature sensor (usually called a thermostat) detects the air temperature at some central point of the house and automatically switches on and off the pump circulating the hot water. When the temperature is lower than the required value, the pump is switched on. When the temperature reaches the required value, the pump is switched off. By this means, a comfortable temperature can automatically be maintained throughout the home.

As well as these two control mechanisms, a central controller usually provides facilities for fixing the times at which the whole system switches itself on and off, for example so that the heating switches on an hour before the occupants of the house wake up in the morning, so that it switches itself off 30 minutes before they go out to work, so that it switches on one hour before they return from work, and so that it automatically switches itself off 30 minutes before they go to bed at night. (Because the house “stores” heat in the furniture, in the walls and in the air contained within the house, the temperature falls quite slowly after the system is switched off, and a considerable amount of costly energy can be saved by switching the system off early.) Such a central controller can also provide facilities for using different switching times at weekends, or for independently controlling the supply of heat to different areas of the house (for example, bedrooms might only be heated for one hour before bed time).

The simple system shown in Figure 9 of Block 1, Part 5 (page 45) is an oversimplified system which is not representative of central heating systems in general, but is adequate for the discussion of feedback systems presented there.

6.2 Block 1 Study Guide

This block is scheduled to occupy about 6 weeks of your study time.

There are six parts in this block, and you are advised to study them in the order in which they are presented. You may find that some of the earlier parts, particularly Part 1, cover topics that you
have studied before, in which case you may need to do no more than read them to refresh your memory.

Parts 1 and 2 are concerned with d.c. currents and voltages, so you will only be considering components such as batteries, resistors and lamps etc. The practical work associated with Part 1 is fairly elementary, and will take place during the first part of Short Lab 1. Please remember that there is more practical work to come in the course, and gaining familiarity with real circuits and components may be more important than you think. The use of a CAD package to calculate circuit performance is almost certain to be new to you, and is something you will return to frequently throughout the course, so it is important for you to become familiar with the package as early as possible, and to gain as much experience of using it as you can.

Parts 3, 4 and 5 introduce some basic ideas concerning a.c. or varying currents and voltages. Their function is to prepare you for the extensive theoretical and practical work associated with Block 2. Part 3 describes a.c. waveforms and the way they can be specified, and the practical work associated with this part, which occupies the remaining part of Short Lab 1, includes an introduction to the use of an oscilloscope and a signal generator. In Part 4, a number of additional components that are used with a.c. waveforms are described and explained, including capacitors, inductors, diodes and transformers. Transistors are also introduced, though they are not dealt with in any detail until Block 4. Part 5 explains some of the things you can do with them. The use of amplification for various purposes is a recurring theme throughout the course.

There are two TMAs (01 and 02) and one CMA (41) associated with Block 1. The first TMA concerns the use of the computer for d.c. circuit analysis. The second is concerned with the topics covered in Parts 1 to 5 of the block. The CMA contains many short questions concerning any of the topics covered in Parts 1 to 5.

Part 6 is something completely different; it has no SAQs and is not intended to teach you any basic principles. It is a ‘preview’ of the course. With the introduction to the basic ideas of electronics which Parts 1 to 5 have presented, Part 6 should enable you to see, more clearly than when you started, what the course is about. It introduces some of the important applications of electronics to be studied later in the course, and so enables you to see why the detailed analytical work of Blocks 2, 3 and 4 is needed. Experience has shown that such a preview is helpful to many students when they are in the process of studying a long course.

Study notes

1  In Part 6 of Block 1 (Section 2.2, page 61) a two-way switching circuit is described. Such a switching system is almost invariably used in houses in U.K. where the house occupies two floors, with a staircase connecting them. The light on the landing at the top of the stairs must be capable of being switched on from the lower floor and off from the upper floor when the occupants wish to go upstairs after dark, and equally must be capable of being switched on from the upper floor and off from the lower floor when the occupants wish to go downstairs after dark. Hence the need for two-way switching, which is usually not needed in the single-level housing which is so common in Hong Kong.

2  Figure 22 on page 83 of Block 1, Part 6 is incomplete. It omits the topic of “Power Supplies” which occurs in the course between “Transistors and Transistor Circuits” and “Higher Frequency Circuits”.
The order of study and the approximate study time for each part of Block 1 is shown below. This assumes that the time which you spend studying the course is about 14 hours per week (on average) for the 41 weeks of the course, plus the time spent at week-end schools. It also assumes, for Part 1, that you have needed to study every section.

<table>
<thead>
<tr>
<th>Component</th>
<th>Approximate study time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 1</td>
<td>13 hours</td>
</tr>
<tr>
<td>Part 2, Sections 1 to 7</td>
<td>13 hours (incl. Short Lab 1)</td>
</tr>
<tr>
<td>Home Computing</td>
<td>7 hours</td>
</tr>
<tr>
<td>Part 2, Section 8</td>
<td>4 hours</td>
</tr>
<tr>
<td>Part 3</td>
<td>13 hours (incl. Short Lab 1)</td>
</tr>
<tr>
<td>Part 4</td>
<td>12 hours</td>
</tr>
<tr>
<td>Part 5</td>
<td>12 hours</td>
</tr>
<tr>
<td>Part 6</td>
<td>6 hours</td>
</tr>
</tbody>
</table>

6.3 Block 2 Study Guide

This block is scheduled to occupy about 7 weeks, making up of 6 weeks of study time plus a one week break at Christmas.

In this block, the main text, the home computing and the short laboratories are closely interrelated. Since the short labs will be held at fixed times, you are strongly advised to keep to the suggested schedule as closely as you can.

The first part of the block develops the basic ideas necessary for the analysis of a.c. circuits and then uses these tools to analyse a number of simple circuits. Part 2 deals with frequency response and Bode plots while Part 3 examines the a.c. behaviour of feedback amplifiers.

There are two TMAs (03 and 04) and a CMA (42) associated with Block 2.

The order of study and the approximate study time for each part of Block 2 is shown below.

<table>
<thead>
<tr>
<th>Component</th>
<th>Approximate study time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 1, Sections 1 to 7</td>
<td>17 hours (incl. Short Lab 2)</td>
</tr>
</tbody>
</table>
Home computing exercises 1 to 2  4 hours
Part 1, Sections 8 to 13  28 hours (incl. Short Labs 3)
Home computing exercises 6 to 8  4 hours
Part 2, Sections 1 to 3  6 hours
Home computing exercise 9  1 hour
Part 2, Sections 4 and 5  8 hours (incl. Short Lab 4)
Home computing exercises 10 to 13  4 hours
Part 3, Sections 1 to 4  14 hours (incl. Short Lab 5)
Home computing exercises 14 to 16  4 hours
Part 3, Section 5  6 hours (incl. Short Lab 6)

(Short labs 5 and 6 will be held during the study period for Block 3.)

6.4  Block 3 Study Guide

This block is scheduled to occupy about 8 weeks, making up of 7 weeks of study time plus one week break at Chinese New Year.

Part 1 introduces you to the concept of binary logic and shows you how a problem can be specified so that it can be finally implemented using electronic devices. Part 2 continues with this theme and develops the necessary skills for you to be able to carry out a complete combinational logic design. Part 3 introduces the topic of synchronous sequential logic circuits. It shows you how these circuits can be designed, using the knowledge that you already have about designing combinational logic circuits, because of the existence of specific types of memory devices. Part 4 deals with the interface between analogue and digital electronics. Finally, there are home computing exercises and short labs. The home computing exercises allow you to simulate and test the logic circuits which you have designed as part of your study of the block. The short lab experiments are based on Part 4 of the block, and are therefore concerned with analogue-to-digital and digital-to-analogue conversion.

There are two TMAs (05 and 06) and one CMA (43) associated with Block 3.

The order of study and the approximate study time for each part of the block is shown below.

<table>
<thead>
<tr>
<th>Component</th>
<th>Approximate study time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 1</td>
<td>17 hours</td>
</tr>
<tr>
<td>Part 2</td>
<td>17 hours</td>
</tr>
</tbody>
</table>
6.5 Block 4 Study Guide

This block is scheduled to occupy about 6 weeks of your study time. Most of the students find this block is a difficult one and need longer time to study.

This block is about diodes and transistors: how they work and how they can be used in basic transistor circuits. Part 1 is about how the devices work; it goes more deeply into the operation of devices than simply describing their properties, but it only provides enough explanation to enable you to cope sensibly with simple circuits. It does not, for example, give sufficient explanation to enable you to construct transistors or even fully understand how they are made. The explanations given are intended, for example, to enable you to calculate what changes in device characteristics to expect when you change the operating current or supply voltage of a device, or to enable you to look for causes of unsatisfactory performance in circuits that you have built.

Part 2 is about the small-signal performance of a number of basic transistor circuits, and you will be required to make circuit calculations yourself, and to use ORCAD to perform the calculations for you. You are not required to use ORCAD until after you have read up to and including Section 2 of Part 2 of the block. You will probably find it more rewarding to read the whole of Block 4 before tackling the home computing exercises.

Part 3 is about the response times of different designs of switching circuits. It explains the causes of speed limitations in transistor switching circuits, as well as the meaning and cause of a number of other important performance parameters. These explanations should, for example, help you choose the kind of circuit to suit a particular application, and to see why there are constraints on the way in which circuits can be put together.

CMA 44 is associated with Block 4 as is part of TMA 07 which is shared with Block 5.

The order of study and the approximate study time for each part of the block is shown below.

<table>
<thead>
<tr>
<th>Component</th>
<th>Approximate study time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 1</td>
<td>23 hours</td>
</tr>
<tr>
<td>Part 2</td>
<td>24 hours</td>
</tr>
<tr>
<td>Part 3</td>
<td>23 hours</td>
</tr>
<tr>
<td>Home computing exercises</td>
<td>11 hours</td>
</tr>
</tbody>
</table>
6.6 Block 5 Study Guide

This block is scheduled to occupy about 3.5 weeks of your study time.

The overall aim of this block is to take you through the design of a ‘hi-fi’ amplifier. In this process, you will have to recall much of what you have learned of circuit analysis, feedback, and transistor circuits. However, even this is not quite enough, and the block takes some topics a little further for you to understand fully all aspects of the design. In order not to interrupt the design procedure, the extra background materials have been put in Parts 1 and 2 of the block, and the amplifier design in Parts 3, 4 and 5. Another reason for doing this is to avoid ‘burying’ important topics within the design study. In separate sections they are easier to refer to later.

One way to study this block is to work straight through from Part 1 to Part 5, studying the more theoretical background materials first. Alternatively, you may find that reading the design in Parts 3, 4 and 5 first helps the study of the background materials. If you wish to study the block in this way, you should first skim quickly through Parts 1 and 2, then study Parts 3, 4 and 5 in detail. At various stages in the design process, you may have to go back to Part 1 or Part 2 for essential detail, but, for some people, this is an effective way to learn.

The block contains both short labs and home computing exercises. The text refers to these activities as alternatives, however you are required to perform both of these components of the course. The assignments set on this block will assume that you have done the home computing exercises and attended the relevant short labs.

In the short labs you will be expected to build and test the circuits of pick-up pre-amplifier of Part 4 and of the main amplifier of Part 5. The home computing exercises require you to use ORCAD to check the frequency response of the pre-amplifier design at a few spot frequencies and to use transient response and frequency spectrum methods to investigate the distortion in the main amplifier.

CMA 45 is associated with this block, as well as TMA 07 which is shared with Block 4.

The approximate study time for each part of the block, assuming that the parts are studied in numerical order, is shown below.

<table>
<thead>
<tr>
<th>Component</th>
<th>Approximate study time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 1</td>
<td>10 hours</td>
</tr>
<tr>
<td>Part 2</td>
<td>12 hours</td>
</tr>
<tr>
<td>Part 3</td>
<td>4 hours</td>
</tr>
<tr>
<td>Part 4</td>
<td>6 hours</td>
</tr>
</tbody>
</table>
6.7 Block 6 Study Guide

This block is scheduled to occupy about 3 weeks of your study time.

Block 6 builds upon the ideas introduced in Block 3, Part 3.

Part 1 of the block is concerned with memory devices, used for the storage and retrieval of data in digital systems. The starting point is the bistable circuit which can be used to store a single bit (binary digit) of data. The text then shows how much larger data storage systems can be built up from these fundamental building blocks, enabling the storage of many millions of bits of data. You will also learn about the implications of memory size on the associated circuitry needed to control the input and retrieval of data from memories.

In Part 2 you will see how the storage retrieval and manipulation of data in a large memory system can be managed by microprocessors and microcontrollers. Since this course is not primarily about computers and computing, the main aim is to introduce and illustrate the range of activities that a microprocessor or microcontroller can carry out. This will enable you to describe what is happening inside the controller when it is programmed to carry out a program of instructions in order to fulfill a well-defined task or function.

There are no home computing exercises or short labs associated with this block.

One half of CMA 46 and one question in TMA 08 are associated with this block.

The approximate study time for each part of the block is as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Approximate study time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 1</td>
<td>19 hours</td>
</tr>
<tr>
<td>Part 2</td>
<td>19 hours</td>
</tr>
</tbody>
</table>

6.8 Block 7 Study Guide

This block is scheduled to occupy about 1.3 weeks of your study time. The Study Schedule allows 2 weeks for this block, so if you are behind in your studies you should have some time to help you to catch up.
Block 7 is about how to derive a stable d.c. voltage source of a few volts from the 200 V to 220 V a.c. mains supply. The text concentrates on the basic elements of most types of regulated d.c. supplies by means of which (a) the a.c. mains can be reduced in voltage to the required level, (b) can be rectified so that the voltage no longer alternates, (c) can be smoothed so that the constant d.c. voltage produced has little mains-frequency fluctuation superimposed on it, (d) the d.c. output voltage can nevertheless be adjusted, (e) the output can be given a low internal resistance so that the d.c. voltage does not change much when the current drawn from it varies, but (f) the circuit is protected against excessive current demands, from short circuits for example, which might otherwise damage the circuit. Such regulated d.c. supplies form a part of all electronic equipment (except those that are designed to be powered only by batteries) and are therefore of considerable practical importance.

There are no short labs associated with this block, although you will be using ORCAD again to simulate some of the circuit functions explained in the home computing book. The purpose of these simulations is mainly to help you understand the way some of the circuit components operate, rather than to calculate the circuit performance of the complete regulated d.c. supply. There is however no computer handbook for this block; the computer activities are now incorporated in the main text since it is expected you no longer need detailed instructions on the use of ORCAD.

The assessment of Block 7 is covered by half of CMA 46 and one third of TMA 08.

You are expected to spend about 18 hours studying this block, including about 4 hours home computing.

**Study note**

This block has been written assuming a mains supply of 240 V, 50 Hz. which is the U.K. supply. Here in Hong Kong, the supply is nominally 220 V (but can be as low as 200 V in places) at 50 Hz. The only difference this makes to the discussion is that, for Hong Kong, the calculated transformer turns ratio would be slightly different. When you read Section 2.1, you should calculate the transformer turns ratio required for a supply voltage of (a) 200 V and (b) 220 V.

### 6.9 Block 8 Study Guide

*This block is scheduled to occupy about 3 weeks of your study time.*

Block 8 introduces some of the problems that occur when higher frequency signals are handled by electronic circuits. Such circuits include those in radio and TV sets as well as those in high-speed computers and other digital circuits.

Part 1 of the block explains how to represent the high-frequency small-signal performance of a bipolar transistor by means of a high-frequency equivalent circuit, called the ‘hybrid-$\pi$ equivalent circuit’. This circuit is no more than an extension of the low-frequency small-signal equivalent circuit introduced in Block 4; the main additional elements in the equivalent circuit being representations of the capacitive behaviour of the two p-n junctions of the transistor.
Part 2 is concerned with the problems of making interconnections between electronic circuits, or between circuit components within electronic circuits, which are designed to handle high-frequency signals or high-speed voltage transients. As you will see, the phase changes or time delays introduced by capacitances and/or inductances, associated even with straight pieces of wire, can create problems which need special attention.

There are no short labs associated with this block, although you will be using ORCAD again to simulate some of the circuit functions explained in the Home Computing Book. Here the purpose of the simulations is two-fold; they aim not only to help you understand the way transistors and other components operate at high frequencies, but also to enable you to use the computer to calculate high-frequency circuit performance more accurately than can be done using approximate calculations. Again there is no computer handbook for this block; the computer activities are incorporated in the main text.

Assessment of this block is covered by CMA 47 and one third of TMA 08.

The approximate study time for each part of the block is as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Approximate study time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 1</td>
<td>21 hours (incl. 4 hours home computing)</td>
</tr>
<tr>
<td>Part 2</td>
<td>17 hours</td>
</tr>
</tbody>
</table>

6.10 Block 9 Study Guide

This block is scheduled to occupy about 3 weeks of your study time.

Block 9 introduces you to some basic radio principles and applications. Part 1 of the block begins with the basic principles of transmitting and receiving information by radio waves using amplitude modulation and detection. It continues with a description of receiving aerials, and domestic aerial distribution systems. After studying Part 1, you will be required to build and test a miniature radio transmitter in a short laboratory session.

Part 2 is devoted to radio receivers. The first half of the text explains basic principles and the design of individual amplifiers. The latter half is devoted to showing how these basic principles are applied to the radio receivers in your home. Finally, in the last short lab session of the course, you will be required to build and test a small radio receiver.

The assessment of this block is covered by CMA 48 and may be covered by part of TMA08.

The approximate study time for each part of the block is as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Approximate study time</th>
</tr>
</thead>
</table>

20
Part 1
21 hours

Part 2
24 hours
plus short lab 10

7 ERRATA OF COURSE BLOCKS

Please refer to the Errata for printing errors and amend the relevant texts immediately.

8 LIST OF APPROVED CALCULATORS

The list of the approved calculators in the examination is shown in Appendix A. Please check that whether your calculator is included within the list. If not please contact the course co-ordinator immediately.

END OF COURSE GUIDE