Electronics Module

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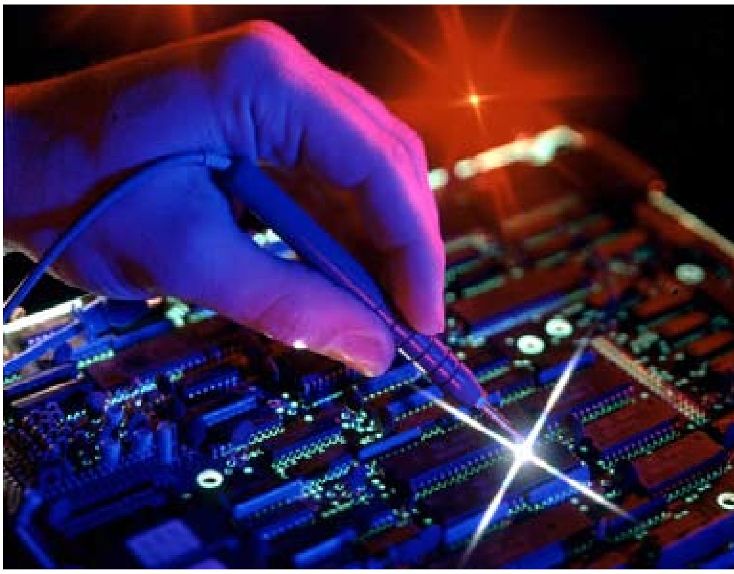
Prepared by Sam Kinyera OBWOYA



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NOTICE

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I. Electronics Module

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II. Prerequisite Courses or Knowledge

The basic prerequisites for this module are the school physics that one has learnt. In particular, knowledge of the following courses are essential for one to follow and understand the module effectively. Some of the prerequisite courses are solids state physics, electricity and magnetism. As a general requirement, you need the knowledge of calculus and algebra in mathematics.

III. Time

A total of 120 hours is required for you to complete this module.

IV. Material

The materials required for the module include access to a computer, but more importantly one needs a steady access to internet. The internet will provide many of the essential references and multimedia resources. These multimedia are important as in some cases they serve as virtual lecturers and sources of equipment that can be used to perform virtual experiments. However, some CD-ROMS will also be available to supplement the use of internet. Other materials include compulsory readings and compulsory resources that may be available at nearby bookshops or schools.

V. Module Rationale

This module is intended to provide a basic foundation of physics to students. This will enable the students to learn the subject matter in order to explain and account for the principles involved in electronics. The module is structured such that the learner has to go through the activities as prescribed for maximum attainment. The overall module will provide the student with basic ideas of what electronics is in terms of the key components' behaviours or characteristics and therefore will be enable to teach most of the school physics effectively.

VI. Content

6.1 Overview

Electronics is the study of the flow of charge through various materials and devices such as, semiconductors, resistors, inductors, capacitors, nano-structures, and vacuum tubes. All applications of electronics involve the transmission of power and possibly information. Although considered to be a theoretical branch of physics, the design and construction of electronic circuits to solve practical problems is an essential technique in the fields of electronic engineering and computer engineering.

The study of new semiconductor devices and surrounding technology is sometimes considered a branch of physics. This module focuses on engineering aspects of electronics. Other important topics include electronic waste and occupational health impacts of semiconductor manufacturing.

This course of electronics is intended for students enrolling for pre-service and in-service students registering for BSc with Education and BEd degrees. As you may be aware, Electronics forms one the back bone of modern physics. The module has six units: Diode Circuits; Transistor Circuits**;** Operational Amplifiers; Digital Circuits; Data acquisition and Process Control; and Computers and Device Interconnection.

In the first unit/activity i.e. diodes circuits, students are expected to explain charge carrier generation, intrinsic and extrinsic semi-conductors, formation and application of P-N junction, and to design and analyse diode circuits (e.g, power supply circuits).

In the second unit/activity i.e. Transistor circuits, the student is expected to explain how a Bipolar Junction Transistor (BJT) works; Design and analyse basic BJT circuits in various configurations (CE, EB, CB); Explain how a junction Field Effect Transistor (JFET) works ; Design and analyse JFET circuits in both configurations (CD, CS); Explain how MOSFET works and also be able to Design and analyse MOSFET circuits.

In unit three the learning outcomes include one being able to explain the construction of operational amplifier; and to Design, analyse and synthesize operational amplifier circuits. In unit four, i.e. Digital Circuits, the student is expected to Manipulate numbers in various bases (2,8,10,16); Apply Boollean algebra in design of logic circuits; Design, analyse and synthesize logic circuits (multiplexer, decoders, Schmitt triggers, flip-flops, registers). In unit five the learner will explain the operation of a transducer in various modes (strain, light, piezo, temp); Explain and apply transducer signal conditioning processes; and to Apply conditioned signal in digital form. Finally, in activity six, i.e. Elements of the Microcomputer 8-, 16- or 32Bit buses, the expected learning will include explaining the systems level components of a microprocessor.

6.2 Outline

Activity 1 (20 hours)

Diode Circuits Review Energy band theory, The PN Junction and the Diode Effect, Circuit, Applications of Ordinary Diodes

Activity 2 (30 hours)

Transistor Circuits Bipolar Junction Transistor (BJT) Common Emitter Amplifier**,** Common Collector Amplifier, Common Base Amplifier. The Junction Field Effect Transistor (JFET), JFET Common Source Amplifier, JFET Common Drain Amplifier. The Insulated-Gate Field Effect Transistor. Power MOSFET Circuits. Multiple Transistor Circuits

Activity 3 (10 hours)

Operational Amplifiers Open-Loop Amplifiers, Ideal Amplifier, Approximation Analysis, Open-Loop Gain

Activity 4 (30 hours)

Digital Circuits Number Systems, Boolean Algebra, Logic Gates, Combinational Logic. Multiplexers and Decoders. Schmitt Trigger, Two-State Storage Elements, Latches and Un-Clocked Flip-Flops. Clocked Flip-Flops, Dynamically clocked Flip-Flops, One-Shot Registers

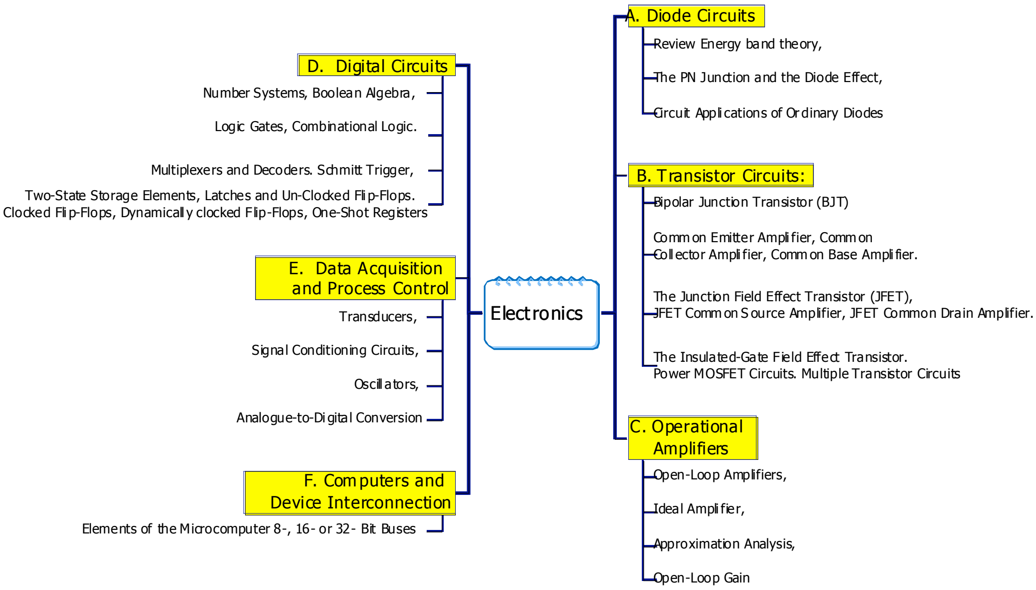
Activity 5 (20 hours)

Data Acquisition and Process Control Transducers, Signal Conditioning Circuits, Oscillators**,** Analogue-to-Digital Conversion

Activity 6 (10 hours)

Computers and Device Interconnection Elements of the Microcomputer 8-, 16- or 32- Bit Buses

6.3 Graphic Organizer



VII. General Objective(S)

After completing the module you should be able to

- appreciate and apply basic electronic concepts and circuits

VIII. Specific Learning Objectives

Unit	Learning objective(s)
1. Diode Circuits (20 hours) • Review Energy band theory, • The PN Junction and the Diode Effect, • Circuit, Applications of Ordinary Diodes.	**Students should be able to** • Explain charge carrier generation intrinsic and extrinsic semi-conductors • Explain formation and application of P-N junction • Design and analyse diode circuits (e.g, power supply circuits)
2. Transistor Circuits: (25 hours) • Bipolar junction Transistor • (BJT);Common Emitter Amplifier; Common Collector Amplifier, Common Base Amplifier. • The Junction Field Effect Transistor (JFET), JFET Common Source Amplifier, JFET Common Drain amplifier. • The Insulated-Gate Field Effect Transistor. Power • MOSFET Circuits, Multiple Transistor Circuit	**Students should be able to** • Explain how a Bipolar Junction Transistor (BJT) works • Design and analyse basic BJT circuits in various configurations (CE, EB, CB) • Explain how a junction Field Effect Transistor (JFET) works (some theory) • Design and analyse JFET circuits in both configurations (CD, CS) • Explain how MOSFET works (theory) • Design and analyse MOSFET circuits
3. Operational Amplifiers (10 hours) • Open loop Amplifiers, • Ideal Amplifiers, Apporoximation Analysis, Ope-loop Gain.	**Students should be able to** • Explain the construction of operational amplifier • Design, analyse and synthesize operational amplifier circuits

4. Digital Circuits (30 hours) • Number systems, Boolean Algebra, Logic Gates, • Combinational Logic, • Multiplexes and decoders, Schmitt Trigger, Two-State storage elements, • Latches and un-clocked flip-flops; • Dynamically clocked flipiflops, • One-shot registers	**Students should be able to** • Manipulate numbers in various bases (2,8,10,16) • Apply Boollean algebra in design of logic circuits • Design, analyse and synthesize logic circuits (multiplexer, decoders, Smchmitt triggers, flip-flops, registers)
5. Data acquisition and Process Control (20 hours) • Transducers, Signal Conditioning • circuits, Oscillators, Analogue-to-Digital Conversion	**Students should be able to** • Explain the operation of a transducer in various modes (strain, light, piezo, temp) • Explain and apply transducer signal conditioning processes • Apply conditioned signal in digital form
6. Computers and Device Interconnection (15 hours) • Elements of the Microcomputer 8-, 16- or 32- Bit Buses	• Explain the systems level components of a microprocessor

IX. Pre-assessment

Are you ready to Learn Electronics?

Title of Pre-assessment : ELECTRONICS

Rationale : The pre-assessment is intended to determine how much one remembers and what one knows about electronics which was done at school and therefore to orient the mind of the learner of the amount of work expected to be covered during the course. The pre-assessment is not intended in anyway to discourage the learner, but rather to motivate one to start the course with a lot of readiness for the challenges ahead.

9.1 Self Evaluation Associated With Electronics

1 The resistance of the semiconductor materials in a photoconductive cell varies with the intensity of incident light.

a. directly
b. inversely
c. exponentially
d. log arithmetically

2 A solar cell operates on the principle of

a. diffusion
b. recombination
c. carrier flow
d. photovoltaic action

3 Which of the following devices has the highest sensitivity?

a. photoconductive cell
b. photovoltaic cell
c. photodiode
d. phototransistor

4 In LED, light is emitted because

a. recombination of charge carriers takes place
b. light falling on the diode gets amplified
c. light gets reflected due to lens action
d. diode gets heated up

5 A transistor series voltage regulator is called emitter-follower regulator because the emitter of the pass transistor follows the voltage.

a. base
b. input
c. output
d. collector

6 A switching voltage regulator can be of the following type:

a. inverting
b. step-up
c. step-down
d. all of the above

7 An ideal voltage regulator has a voltage regulation of

a 0
b. 1
c. 50
d. 100

8 Electronic devices that convert dc power to ac power are called

a inverters
b. rectifiers
c. converters
d. transformers

9 The output of a half-wave rectifier is suitable only for

a. running car radios
b. running ac motors
c. running tape-recorders
d. charging batteries

10 When used in a circuit, a Zener diode is always

a. forward biased
b. reverse-biased
c. connected in series
d. troubled by overheating

11 Zener diodes are used primarily as

a. rectifiers
b. amplifiers
c. oscillators
d. voltage regulators

12 An op-amp shunt regulator differs from the series regulator in the sense that its control element is connected

a. series with line resistor
b. parallel with line resistor
c. parallel with load resistor
d. parallel with input voltage

13 The digital systems usually operates on……system.

a. octal
c. binary
d. decimal
e. hexadecimal

14 The cumulative addition of four binary bits (1 + 1 + 1 + 1) gives

a. 1111
b. 111
c. 110
d. 11

15 The result of binary multiplication 111_2 x 10_2 is

a. 1101
b. 0110
c. 1001
d. 1110

16 A FETs have similar properties to

a. PNP transistor
b. NPN transistor
c. thermionic valves
d. Unijunction transistor

17 The voltage gain of a given common-source JFET amplifier depends on its

a. input impedance
b. amplification factor
c. dynamic drain resistance
d. drain load resistance

18 The extremely high input impedance of a MOSFET is primarily due to the

a. absence of its channel
b. negative gate-source voltage
c. depletion of current carriers
d. extremely small leakage current of its gate capacitor

19 The main use of an emitter follower is as:

a. power amplifier
b. impedance matching
c. low-input impedance
d. follower of base signal

20 The smallest of the four *h*-parameters of a transistor is:

a. hi
b. hr
c. h0
d. hf

Answer Key

1. B	11. D
2. D	12. A
3. D	13. B
4. A	14. B
5. A	15. D
6. D	16. B
7. A	17. D
8. A	18. C
9. B	19. B
10. B	20. C

Pedagogical Comment For Learners

The pre-assessment is intended to determine how much you know of electronic and to prepare you for the module. The outcome of the pre-assessment will tell you of what you need to work on and concentrate on more while studying and learning the module. As you notice, most of the questions contain topics which are normally not done at school.

At the beginning of the module, the module takes you through the review energy band theory, which you could have done in solid state physics. Eventually you will learn about the PN-junction and diode effect, circuit, and applications of ordinary diodes. The expectation here is that you should be able to explain charge carrier generation intrinsic and extrinsic semi-conductors, formation and application of P-N junction; and finally be able to design and analyze diode circuits (e.g. power supply circuits). For every other activity you go through them with the expectation of achieving the stated objectives. Accordingly, you are advised to go through each section of the activity in a chronological order. Where prior knowledge is required, you need to go first through such topics before proceeding further.

A number of references are referred to throughout the activity. What you need to do always is to have access to these references. Most of them are on line. Where you do not have permanent access to internet, the you are advised to download such references and keep hard copies. A number of multimedia resources are also included. These are very useful as they may act as virtual lecturers or sources of virtual laboratory. You are encouraged to use these multimedia resources all the time.

X. Teaching and Learning Activities

Activity 1: Diode Circuits

You will require 20 hours to complete this activity. Only basic guidelines are provided to help you go through the activity. Personal reading and work is strongly advised.

Specific Teaching and Learning Objectives

In this activity you will

(i) Explain charge carrier generation in intrinsic and extrinsic semi-conductors.
(ii) Explain formation and application of P-N junction.
(iii) Design and analyse diode circuits (e.g, power supply circuits.

Summary of the learning activity

This activity includes among others explanation of charge carrier generation, intrinsic and extrinsic semi-conductors; formation and application of P-N junction and finally how to design and analyse diode circuits (e.g, power supply circuits)

List of REQUIRED readings

Reading 1
Complete reference: http://en.wikibooks.org/wiki/Electronics. 3rd October 2007.
Abstract: This is a complete textbook on electronics that deals with among others: analogue circuits: vacuum tubes; diodes, transistors; amplifiers; operational amplifiers, and analogue multipliers.
Rationale: Each of the topic is presented in very simple form that makes it easier for one to read through. However, these simply serve to supplement the learning process.

Reading 2
Reference: http://en.wikipedia.org/wiki/electronics. 5th October 2007.
Abstract: This reading is formed from references obtained from many sites. Their URLs can be obtained from a soft copy of this reading. Basically all the essential topics of the course are covered in this reading 2.
Rationale. The reference provide easy reading sources on electronics that a reader should have no problem using them.

List of relevant MULTIMEDIA resources.

Reference: http://www.educypedia.be/electronics/javacollectors.htm.
Summary: This resource enables one to study Characteristics of NPN transistor.
Rationale: The site gives an elegant simple virtual experiment that one can carry to study the characteristics of NPN transistor.

Reference: http://server.oersted.dtu.dk/personal/ldn/javalab/Circuit04.html
Summary: The resource is for circuit of a primitive common-emitter (CE) amplifier- comprising an npn-transistor and external basis-, collector- and load resistors. The learner will find for a fixed set of component parameters the ranges ofinput voltage that make the transistor cut off, active or saturated, respectively. In the case of a*na-logue applications the learner will d*etermine the differential voltage amplification of the circuit when the transistor is in the active range. While for d*igital applications* one is expected to find the smallest possible current gain (beta) and a corresponding collector resistance that makes the circuit a functional logical inverter.
Rationale: This resource serves to aid one in learning about npn transistor biasing.

Reference: http://server.oersted.dtu.dk/personal/ldn/javalab/Circuit01.html
Summary: This resource gives a circuit of a Thevenin equivalent with a load in which power P is delivered to the load.
Rationale: This site provides a useful resource for learning about voltage divider.

List of Relevant Useful Links

Title: Basic circuit analysis
http://ocw.mit.edu/OcwWeb/Electrical-Engineering-and-Computer-Science/6-002Circuits-and-ElectronicsFall2000/VideoLectures/index.htm.
Abstract: These contain the course lecture slides accompanying video lectures, and description of live demonstration shown by the instructor.

Title: Diodes
URL: http://jersey.uoregon.edu/~rayfrey/431/lab2_431.pdfhttp://jersey.uoregon.edu/
Abstract: This site provides practical work V-I characteristics. In addition, the site provides reading on transistor junctions, transistor switch and saturation etc.

Title: Diode applications
URL: http://morley.eng.ua.edu/G332BW.pdf.
Abstract: Various applications of diodes including power supply, half-wave rectifier, bridge rectifier, full-wave rectifier with filter etc. are presented.

Detailed Description of the Activity (Main Theoretical Elements)

Activity 1.1 Review of energy band theory

Key Concepts about energy band theory

The key concepts one learns about energy band theory under solid state physics are:

(i) That the available energy states form what we call bands.
(ii) That in insulators the electrons in the valence band are separated by a large gap called *forbidden energy gap* from the conduction band.
(iii) That insulators have empty conduction band, but a full valence band.
(iv) That in conductors like metals the valence band overlaps the conduction band, and therefore, there is no structure to establish holes. *The total current in such conductors is simply a flow of electrons.*
(v) That a semiconductor material is one whose electrical properties lie in between those of insulators and good conductors. In terms of energy band, semiconductors can be defined as those materials which have almost an empty conduction band and almost filled valence band. There is a small enough gap between the valence and conduction bands that thermal or other excitations can bridge the gap. With such a small gap, the presence of a small percentage of a doping material can increase conductivity dramatically.
(vi) That the outermost electrons of an atom *i.e.* those in the shell furthermost from the nucleus are called *valence electrons* and have the highest energy or least *binding energy*.
(vii) The band of energy occupied by the valence electrons is called the *valence band* and is *the highest occupied band.* It may be completely filled or partially filled with electrons but never empty.

Task 1.1

Important instruction

1. For each task that you undertake you must make short notes using some of the references that are given to you and including those that you can have access to.

2. Use available electronic text books and other references e.g. http://hyperphysics.phy-astr.gsu.edu; to

   (a) Revise your solid state physics and refresh your memory about the meanings of: *energy band,valence band, conduction band, energy gap, and Fermi level.*

   (b) Make short notes about each one.