COURSE NUMBER: AE3130

COURSE TITLE: Active Circuit Applications

COURSE DESCRIPTION:

The purpose of this course is to provide the learner with an understanding of the operation of integrated circuit amplifier circuits, active filters, and switching power supplies. The theory covered in class will be applied and validated during the laboratory periods.

PREREQUISITES: AE2330 – Analog Electronics I

CO-REQUISITES: None

CREDIT VALUE: Four (4)

COURSE HOURS PER WEEK: Three (3)

LAB HOURS PER WEEK: Two (2)

SUGGESTED TEXT:

Gayakwad, R. A. (1999). *Op-amps and linear integrated circuits* (4th ed.). Englewood Cliffs, NJ: Prentice-Hall. ISBN 10: 0132808682; ISBN 13: 978-0132808682

LEARNING RESOURCES: To be determined by instructor

MAJOR TOPICS:

1.0 Open Loop Operational Amplifier Circuits
2.0 Linear Operational Amplifier Circuits
3.0 Non-Linear Operational Amplifier Circuits
4.0 Analog – Digital Interface Circuits
5.0 Switching Power Supplies

LEARNING OBJECTIVES:

The expected learning outcomes are that the learner will be able to:

1.0 Open Loop Operational Amplifier Circuits

1.1 Describe the characteristics of an *Op-Amp*
  1.1.1 Describe the characteristics of an ideal Op-Amp

- 1.1.2 Explain the frequency response, including phase relationship, of an internally compensated Op-Amp
- 1.1.3 Define the terms open-loop gain, gain bandwidth product, and slew rate
- 1.1.4 Examine the data sheets of practical op-amps to find their open-loop gain, gain bandwidth product, and slew rate
- 1.1.5 Differentiate between practical Op-Amps and the ideal Op-Amp
- 1.1.6 Measure the open-loop gain, bandwidth product, and slew rate of practical op-amps using an oscilloscope

1.2 Describe the operation of comparator and zero-crossing circuits

- 1.2.1 Explain the operation of a Comparator
- 1.2.2 Draw the schematic diagram of a Comparator circuit with inverting and non-inverting inputs
- 1.2.3 Explain how a comparator can be used as a zero-crossing circuit
- 1.2.4 Draw the schematic diagram of a zero crossing circuit with an adjustable reference
- 1.2.5 Select the appropriate op-amp for a zero crossing circuit given the required bandwidth and slew rate
- 1.2.6 Draw the output waveform of a zero crossing circuit with sinusoidal input
- 1.2.7 Analyze the output waveform of a zero crossing circuit with an oscilloscope
- 1.2.8 Draw the schematic of a window detector circuit
- 1.2.9 Design a window detector circuit given the upper and lower detection limits and supply voltage

2.0 Linear Operational Amplifier Circuits

2.1 Assess the operation of a Voltage Follower

- 2.1.1 Describe how negative feedback sets the gain of an op-amp to unity
- 2.1.2 Differentiate between the input characteristics of BJT and FET Op-Amps
- 2.1.3 Determine the gain, input and output impedances, bandwidth, and maximum total output offset voltage of a Voltage Follower circuit
- 2.1.4 Draw the schematic diagram of a Voltage Follower circuit
- 2.1.5 Determine the output waveform of a Voltage Follower for a given input using circuit simulation software
- 2.1.6 Analyze the output waveform of a Voltage Follower for a given input using an oscilloscope

2.2 Asses the operation of an *Inverting Amplifier*

- 2.2.1 Describe how negative feedback using feedback resistors sets the gain of an Op-Amp circuit
- 2.2.2 Explain the use of an Offset Minimizing Resistor on the Non-Inverting input in Op-Amp circuits
- 2.2.3 Differentiate between the output characteristics of *Push-Pull* and *Rail-To-Rail Op-Amps*

2.2.4 Determine the gain, input and output impedances, bandwidth, and maximum total output offset voltage of an *Inverting Amplifier* circuit
2.2.5 Draw the schematic diagram of an Inverting Amplifier circuit
2.2.6 Determine the output waveform of an Inverting Amplifier for a given input using circuit simulation software
2.2.7 Analyze the output waveform of an Inverting Amplifier for a given input using an oscilloscope

2.3 Assess the operation of a *Non-Inverting Amplifier*
2.3.1 Explain the use of Null-Offset Pins in an Op-Amp circuit
2.3.2 Determine the gain, input and output impedances, bandwidth, and maximum total output offset voltage of a Non Inverting Amplifier circuit
2.3.3 Draw the schematic diagram of a Non Inverting Amplifier circuit
2.3.4 Draw the schematic diagram of a Non Inverting Amplifier circuit using a single supply
2.3.5 Determine the output waveform of a Non Inverting Amplifier for a given input using circuit simulation software
2.3.6 Analyze the output waveform of a Non Inverting Amplifier for a given input using an oscilloscope

2.4 Assess the operation of an *Instrumentation Amplifier*
2.4.1 Explain the use of *Common Mode Rejection*
2.4.2 Draw the schematic diagram of a *Differential Amplifier*
2.4.3 Determine the gain, input and output impedances, and bandwidth of a Differential Amplifier
2.4.4 Calculate the voltage of output signals given the differential and common mode input signals and the *Common Mode Rejection Ratio* (CMRR)
2.4.5 Explain how a Differential Amplifier is improved as an instrumentation amplifier
2.4.6 Draw the schematic diagram of an Instrumentation Amplifier
2.4.7 Design an instrumentation amplifier given gain and bandwidth
2.4.8 Determine the output waveform of an Instrumentation Amplifier given the CMRR, common mode input signal and differential input signal using simulation software

2.5 Describe the operation of Summing, Subtracting, Scaling and Averaging amplifiers
2.5.1 Calculate the output of a given *Summing Amplifier* circuit
2.5.2 Calculate the output of a given *Subtracting Amplifier* circuit
2.5.3 Calculate the output of a given *Scaling Amplifier* circuit
2.5.4 Calculate the output of a given *Averaging Amplifier* circuit
2.5.5 Evaluate the use of a Scaling Amplifier as a signal mixer using simulation software

3.0 Non-Linear Operational Amplifier Circuits

3.1 Explain the operation of Differentiator Circuits
- 3.1.1 Draw the schematic diagram of an *Op-Amp Differentiator*
- 3.1.2 Calculate the frequency response of a given differentiator
- 3.1.3 Observe the output of a differentiator with various input waveforms using an oscilloscope

3.2 Explain the operation of Integrator Circuits
- 3.2.1 Draw the schematic diagram of an *Op-Amp Integrator*
- 3.2.2 Calculate the frequency response of a given integrator
- 3.2.3 Observe the output of an integrator with various input waveforms using an oscilloscope

3.3 Assess the operation of Op-Amp Filters
- 3.3.1 Draw the schematic diagram for the following *High Pass Filters* (HPF)
  - 3.3.1.1 Single pole
  - 3.3.1.2 Double pole

- 3.3.2 Draw the schematic diagram for the following *Low Pass Filters* (LPF)
  - 3.3.2.1 Single pole
  - 3.3.2.2 Double pole

- 3.3.3 Calculate the cut-off frequencies for a given HPF or LPF
- 3.3.4 Measure the cut-off frequencies of an HPF and LPF using a signal generator and oscilloscope

3.4 Assess the operation of Band-Pass and Band-Reject Op-Amp Filters
- 3.4.1 Explain how LPF and HPF are combined to make *Band Pass Filters* (BPF)
- 3.4.2 Draw the schematic diagram for a BPF
- 3.4.3 Draw the schematic diagram for a *Notch Filter*
- 3.4.4 Calculate the cut-off frequencies for a given BPF
- 3.4.5 Measure the cut-off frequencies of a BPF using a signal generator and oscilloscope
- 3.4.6 Determine the cut-off frequencies for a BPF using simulation software

3.5 Describe the operation of a *Schmitt Trigger*
- 3.5.1 Describe how positive feedback and hysteresis can be applied to a zero-crossing detector to improve operating characteristics
- 3.5.2 Draw the schematic diagram of a Schmitt Trigger
- 3.5.3 Compare the characteristics of a Schmitt Trigger to a Zero-Crossing detector using an oscilloscope

3.6 Evaluate the operation of *Multivibrators*
- 3.6.1 Describe the operation of a 555 Timer IC as a combination of window detector circuit and a digital flip flop

3.6.2 Design an *Astable Multivibrator* circuit using a 555 Timer IC for a given frequency and duty cycle
3.6.3 Design an *Monostable Multivibrator* circuit using a 555 Timer IC for a given pulse width
3.6.4 Construct an *Astable* 555 Timer circuit
3.6.5 Construct a *Monostable* 555 Timer circuit
3.6.6 Explain how the "control" pin can be used to adjust the pulse width
3.6.7 Measure the output of *Astable* and *Monostable* 555 circuits using an oscilloscope

4.0 Analog – Digital Interface Circuits

4.1 Interface an analog transducer to a microcontroller *Analog to Digital Converter* (ADC) using Op-Amp circuits
4.1.1 Explain the need for impedance matching in ADC interfacing
4.1.2 Explain the need for amplification or attenuation in ADC interfacing (scaling)
4.1.3 Explain the need for filtering in ADC interfacing
4.1.4 Design an ADC interface using Op-Amps
4.1.5 Construct an ADC interface for a given input transducer

4.2 Interface an analog transducer to a microcontroller *Digital to Analog Converter* (DAC) using Op-Amp circuits
4.2.1 Explain the need for amplification DAC interfacing
4.2.2 Explain the need for filtering in DAC interfacing
4.2.3 Design a DAC interface using Op-Amps
4.2.4 Construct a DAC interface for a given output transducer

4.3 Interface a load to a *Pulse Width Modulation* (PWM) output
4.3.1 Explain how variation in duty cycle is used to control power transferred between a power supply and a load
4.3.2 Design a Pulse Width Modulator by combining an Astable 555 circuit with a Monostable 555 circuit, using the control pin to adjust the % DC
4.3.3 Design a power control circuit using a Power MOSFET
4.3.4 Interface a MOSFET power control circuit to a microcontroller PWM output or a 555 IC PWM output

5.0 Switching Power Supplies

5.1 Describe the basic principle of switching power supplies
5.1.1 Describe how Pulse Width Modulation is used to control voltage applied to a load
5.1.2 Differentiate between *Switched Mode* and *Resonant Mode* power supplies

5.2 Explain the operation of Buck (step-down) DC-DC Converters
5.2.1 Draw the basic topology diagram for a Buck Converter

5.2.2 Determine the efficiency and output ripple of a Buck Converter
5.2.3 Simulate the operation of a Buck Converter using simulation software
5.2.4 Measure the efficiency and output ripple of a simple Buck Converter using an oscilloscope

5.3 Explain the operation of Boost (step-up) DC-DC Converters
5.3.1 Draw the basic topology diagram for a Boost Converter
5.3.2 Determine the efficiency and output ripple of a Boost Converter
5.3.3 Simulate the operation of a Boost Converter using simulation software
5.3.4 Measure the efficiency and output ripple of a simple Boost Converter using an oscilloscope

5.4 Describe the operation of an Inverting DC-DC Converter
5.4.1 Draw the basic topology diagram for an Inverting DC-DC Converter
5.4.2 Simulate the operation of an inverting converter using simulation software

EVALUATION:

Labs:	15%
Assignments:	10%
Quizzes:	35%
Final Exam:	40%

DATE DEVELOPED: March 2012 **DATE REVIEWED:**

REVISION NUMBER: **DATE REVISED:**

Note to instructor: Check PIRS to ensure this outline is the most current version.