EET-2220: ELECTRONICS II

Cuyahoga Community College

Viewing: EET-2220 : Electronics II

Board of Trustees:
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Academic Term:
Fall 2023

Subject Code
EET - Electrical/Electronic Engineer

Course Number:
2220

Title:
Electronics II

Catalog Description:
Continuation of electronic circuits. Includes study of operational amplifiers, instrumentation amplifiers, voltage comparators, active and passive filter circuits that includes the complex plane, switched capacitor filters and Analog-to-Digital and Digital-to-Analog converters.

Credit Hour(s):
3

Lecture Hour(s):
2
Lab Hour(s):
2

Other Hour(s):
0

Requisites

Prerequisite and Corequisite
EET-2120 Electronics I.

Outcomes

Course Outcome(s):
Determine the key parameters of an operational amplifier (op-amp).

Essential Learning Outcome Mapping:
Not Applicable: No Essential Learning Outcomes mapped. This course does not require application-level assignments that demonstrate mastery in any of the Essential Learning Outcomes.

Objective(s):
a. Measure input offset voltage.
b. Measure bias current.
c. Measure the fall time.
d. Measure the slew rate of the fall time.
e. Measure the rise time.
f. Measure the slew rate and the rise time.
g. Measure the Common Mode Rejection Ratio (CMRR).
h. Construct a non-inverting op amp circuit and measure the frequency response.
i. Using a data sheet - determine the Unity Gain Bandwidth (UGB).

j. Measure the UGB of a unity gain inverting amplifier.
k. Measure the UGB of a unity gain non-inverting amplifier.

Course Outcome(s):

Determine and measure various components of op-amp specifications.

Objective(s):

a. Design an op-amp that has a given negative (inverting) gain.
b. Build a circuit and measure the inverting gain.
c. Design a circuit that has a given non-inverting gain.
d. Build and measure a circuit that has a non-inverting gain.
e. Design an inverting summing amplifier.
f. Build and test an inverting summing amplifier.
g. Design an instrumentation amplifier with a given gain.
h. Build and test an instrumentation amplifier with a given gain.

Course Outcome(s):

Calculate and measure voltage summing and difference op-amp circuits.

Objective(s):

a. Calculate the total output voltage for an inverting summing op amp circuit.
b. Build the circuit and compare the measured versus theoretical results.
c. Calculate the total voltage for a summing op-amp circuit that uses both the non-inverting and inverting inputs.
d. Build the circuit and compare the measured versus theoretical results and explain why some of the input voltages are subtracted.

Course Outcome(s):

Design a voltage comparator circuit.

Objective(s):

a. Design a comparator using an op amp without hysteresis.
b. Build and test a comparator using an op amp without hysteresis.
c. Design comparator using an op amp with a given hysteresis.
d. Build and test comparator using an op amp with a given hysteresis.
e. Design a window detector using comparators.

Course Outcome(s):

Design amplifier bases upon a rail-to-rail Complementary Metal Oxide Semiconductor (CMOS) integrated circuits.

Objective(s):

a. Design a pseudo-ground to bias a low-voltage CMOS (Complementary Oxide Semiconductor) op-amp.
b. Measure the output of a CMOS op-amp and determine how closely the output approached the power supply rails just before clipping.
c. Show by design proper power supply bypassing at the power supply pins of an op-amp.
d. Explain why the bias current for a CMOS op-amp is significantly less than that of a bipolar op-amp.
e. Determine using instrumentation the output impedance of a CMOS op amp operating at unity gain.
f. Explain the CMOS processes susceptibility to electrostatic discharge.

Course Outcome(s):

Determine the advantage of a push-pull circuit topology and measure the effect of negative feedback.

Objective(s):

a. Construct a push-pull amplifier around an integrated circuit and two discrete output transistors.
b. Close the feedback loop that does not include the output transistors and measure the harmonic distortion.
c. Close the feedback loop that does include the output transistors and measure the harmonic distortion.
d. Sketch the waveforms from the two configurations and identify crossover distortion.
e. Compare the harmonic distortion from the two configurations.

Course Outcome(s):

Characterize an Analog-to-Digital Converter (ADC) and Digital-to-Analog Converter (DAC).

Objective(s):

a. Using the Analog-to-Digital Converter (ADC) and Digital-to-Analog Converter (DAC) trainer, determine the sample rate by inserting a known frequency and viewing the un-smoothed output.
b. Measure the harmonic distortion and listen to a full-scale input signal with smoothing.
c. Measure the harmonic distortion and listen to a full-scale input signal without smoothing.
d. Measure the SINAD (Signal to Noise And Distortion) of a full-scale input signal.
e. Calculate the ENOB (Effective Number Of Bits).
f. Explain the Nyquist - Shannon sampling theorem (sampling frequency limit).
g. Measure, display and listen to the aliased frequency when the sampling frequency limit is violated.
h. Listen to music when the sampling frequency limit is violated and note the distortion.
i. Measure the SFDR (Spurious Free Dynamic Range).
j. Using circuit simulation software, plot the output of a R2R (resistor plus 2 times the value of the resistor) network that is fed from a binary up-counter.

Course Outcome(s):

Determine the properties of a low pass inductor, capacitor and resistor (LRC) filter circuit and plot the zeroes and poles in the complex plane (S plane, introductory material for Sallen - Key filters).

Objective(s):

a. Calculate the critical frequency of an LRC circuit.
b. Calculate the Q (Quality Factor).
c. Write the equation for the filter, using given Laplace transform equivalents of the inductor and capacitor.
d. Arrange the equation so the denominator is solvable using the quadratic formula.
e. Find and plot the poles and zeroes.
f. Use the provided calculator to determine the frequency response.
g. Build the circuit and measure the frequency response using the nearest standard value components.
h. Compare the theoretical results with the measured results value components.
i. Display the poles and zeroes in table form using circuit simulation software.

Course Outcome(s):

Determine the properities of a second-order Sallen-Key low pass filter and plot the poles and zeroes in the S-plane.

Objective(s):

a. Use the design and measurement criteria as stated in the second-order LRC low-pass filter to design and test a second-order low-pass Sallen - Key circuit.
b. Determine and plot the pole locations for a critically damped Sallen - Key circuit.
c. Plot the frequency response of a critically damped circuit Sallen - Key circuit.
d. Determine and plot the pole and zero locations for an overdamped (Butterworth) Sallen - Key circuit.
e. Plot the frequency response of an over damped (Butterworth) Sallen - Key circuit.
f. Build the critically damped circuit and compare the results to the theoretical circuit.
g. Build the over damped circuit (Butterworth) and compare the results to the theoretical circuit.

Course Outcome(s):
Design and measure the frequency response of a 5th order switched capacitor elliptical low pass filter.

Objective(s):
a. Determine the clock frequency given the filter's critical frequency.
b. Design a clocking circuit using inverter integrated circuits.
c. Construct the circuit.
d. Measure and plot the frequency response of the circuit.
e. Using a Digital Multimeter (DMM) locate the zero outside of the pass band.

Course Outcome(s):
Construct and measure the characteristics of an instrumentation-based op-amp.

Objective(s):
a. Determine the value of a gain setting resistor for different given gains.
b. Construct the circuit and verify that the gain is in accord with the theoretical calculations.
c. Determine the gain-bandwidth product and large signal voltage gain from the datasheet.
d. Sweep the circuit until the critical frequency is found or the circuit begins to slow rate limit.
e. Measure the CMRR (Common Mode Rejection Ratio).

Course Outcome(s):
Write a formal laboratory report on the class project.

Objective(s):
a. Use the EET reference manual to write a formal report.
b. Follow the course project instructions upon which the formal report is based.

Course Outcome(s):
Determine and measure the properties of a differentiator and/or integrator circuit.

Essential Learning Outcome Mapping:
Not Applicable: No Essential Learning Outcomes mapped. This course does not require application-level assignments that demonstrate mastery in any of the Essential Learning Outcomes.

Objective(s):
a. Mathematically determine the slope of a triangle or sawtooth waveform (where it is defined) and determine the differentiated output waveform for a non-inverting differentiator: explain the rate-of-change.
b. Build a non-inverting differentiator and, using triangle or sawtooth waveforms, compare the measured results versus theoretical results.
c. Mathematically determine the slope of a sinusoidal waveform and determine the output waveform for a non-inverting differentiator: explain the rate-of-change.
d. Build a non-inverting differentiator and, using a sinusoidal waveform, compare the measured results versus theoretical results.
e. Mathematically determine the area under a rectangular pulse that can be unipolar or bipolar.
f. Design a non-inverting integrator and compare measured results with theoretical results.

Methods of Evaluation:
a. Homework
b. Laboratory reports
c. Circuit simulation software
d. Midterm examination

e. Final examination
f. Functional project

Course Content Outline:

a. Operational amplifiers
    i. Open loop
    ii. Offset voltage and current
    iii. Gain bandwidth product
    iv. Inverting amplifier
    v. Non-inverting amplifier
    vi. Voltage follower
    vii. Voltage summer
    viii. Difference amplifier
    ix. Integrator
    x. Differentiation
    xi. Common mode rejection ratio
    xii. Slew rate limiting
    xiii. Clipping
b. Voltage comparators
    i. Zero-crossing
    ii. Non-zero crossing
    iii. Schmitt trigger
    iv. Hysteresis
c. Analog-to-digital and digital-to-analog conversion
    i. Binary weighted resistor ladder
    ii. R-2R resistor ladder network
    iii. DAC/ADC accuracy and resolution
    iv. Nyquist - Shannon sampling theorem
    v. Aliasing distortion
    vi. Signal-to-harmonic distortion plus noise ratio (SINAD)
    vii. Spurious free dynamic range (SFDR)
    viii. Effective number of bits (ENOB)
d. LRC and Sallen-Key second order low pass filter
    a. Critical frequency
    b. Quality factor
    c. Frequency response
    d. Laplace representation of L and C
    e. Pole and zero plot in the S-plane
    f. Frequency response using circuit simulation software
5. CMOS op-amps
    a. Rail-to-rail output
    b. Pseudo ground
    c. Single power supply
    d. Susceptibility to ESD
    e. Gain bandwidth product
6. Push-pull circuits
    a. Adding output transistors
    b. Cross over distortion
    c. Negative feedback
    d. Harmonic distortion
7. Switched capacitor low pass filters
    a. Clock frequency
    b. Critical frequency
    c. 5th order elliptical
    d. Locate the zero

    - f. Plot the frequency response
- 8. Instrumentation Amplifiers
    - a. Advantages
    - b. Gain setting
    - c. Common mode rejection ratio
    - d. Slew rate limiting

Resources

Robert Boylestad, and Louis Nashelsky. *Electronic Devices and Circuit Theory*. 11th ed. Upper Saddle River: Prentice-Hall, 2015. 12/15/15.

James Kang. *Electric Circuits*. 1st ed. Cengage, 2016. 12/5/2016.

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David A. Johns, Kenneth W. Martin, and Tony Chan Carusone. *Analog Integrated Circuit Design*. 2nd ed. Wiley, 2011. 11/2011.

David Sax. *The Revenge of Analog*. 1st ed. Public Affairs: Persius Book Group, 2016. 11/8/2016.

Frank Ohnhauser. *Analog to Digital Converters for Industrial Applications*. 1st ed . Springer, 2015. 7/15/2015.

Robert W. Erickson, and Dragan Maksimovic. (2020) (8/16/2020) *Fundamentals of Power Electronics*, Springer.

Thomas Floyd, David Buchta, and Gary Snyder. (2019) (5/18/2019) *Electronics Fundamentals: Circuits, Devices, & Applications*, Pearson.

Marcel Pelgram. (2022) (3/16/2022) *Analog to Digital Conversion*, Springer.

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