Facilitator's Guide to Module 10: Introduction to The Operational Amplifier

Introduction

In many first courses on linear circuits there is a short component on the operational amplifier, more commonly called the op amp. While the op amp is not a fundamental circuit element, practical op amps display nearly ideal behaviour, thereby allowing one to construct many useful circuits with relative ease. Consequently, there are two motivations for including a short study of the ideal op amp and common op amp circuits in a first course on linear circuits; Firstly, op amp circuits provide practical examples to practice the many circuit analysis techniques learned in the course. Secondly, op amps provide an easy way to implement many useful circuits providing motivation for many students. This module aims to cover the op amp at a level compatible with these two goals.

Prerequisites

Before starting this module, it will be helpful to be familiar with;

- common circuit elements such as resistors, voltage sources and current sources,
- circuit laws such as Ohm's Law and Kirchhoff's Voltage and Current Laws,
- circuit analysis techniques such as Nodal Analysis and perhaps Mesh Analysis[1],
- finally Superposition, is particularly useful for analyzing op amp circuits.

Outcomes

With careful study, by the end of this module, one should be able to;

- identify the characteristics of an ideal op amp and model the ideal op amp for circuit analysis.
- analyze commonly used single-op amp circuits that perform useful functions such as precisely amplifying signals, combining signals and separating signals.
- analyze circuits containing multiple op amps.

Module overview

This module consists of a sequence of 12 short videos interspersed with self-assessment questions. The videos provide an alternative to in-class lectures and reading the textbook. The videos can be assigned in place of regularly scheduled lectures or as additional material. It is expected that the course instructor, will supplement the module with additional questions and perhaps one or two laboratory exercises.

1. Only KCL, KVL, Nodal Analysis and superposition are used in this module.

Module Contents

Introductory Material

1. OpAmp1a Introduction: Introduction to the ideal op amp's characteristics and modeling of the op amp for circuit analysis.
    - Followed by basic concept questions.
2. OpAmp1b Inverting Config.: Introduction to the inverting configuration and its analysis with a simple model of the op amp. The analysis leads to the concept of the virtual short.
    - Followed by a question that explores the effect of finite gain
3. OpAmp1c Example Inverting Config.: A worked example of analyzing the inverting configuration, including calculation of the op amp's output current.
    - Followed by two numerical problems on the inverting configuration.

Common single-op amp circuit configurations

4. OpAmp2a1 Weighted Summer: Introduction to, and analysis of the weighted summer using basic circuit analysis.
5. OpAmp2a2 Weighted Summer -Superposition: Analysis of the weighted summer using superposition and knowledge of the inverting configuration.
    - Followed by one analysis question an done concept question.
6. OpAmp2b Non-Inverting Config.: Introduction to, and analysis of the non-inverting configuration using basic circuit analysis.
    - Followed by two numerical problems
7. OpAmp2c Differential Config.: Introduction to, and analysis of the differential configuration using superposition and knowledge of the inverting and non-inverting configurations.
8. OpAmp2d Differential Application Example: A worked example of using the differential configuration to separate differential and common-mode signals.
    - Followed by a numerical problem

Circuits with multiple op amps

9. OpAmp3a Multi-Op Amp Circuits: Introduction to analysis of multi-op amp circuits using nodal analysis and using knowledge of the basic op amp configurations.
10. OpAmp3b Example Multi-Op Amp Cascade: An analysis a multi-op amp cascade using knowledge of the basic op amp configurations and the op amp's zero output resistance.
    - Followed by a numerical problem
11. OpAmp3c1 Multi-Op Amp Example: Analysis of a multi-op amp circuit with inter-op amp feedback using knowledge of the basic op amp configurations.
12. OpAmp3c2 Multi-Op Amp Example-Nodal Analysis: Analysis of a multi-op amp circuit with inter-op amp feedback using knowledge of the basic op amp configurations.
    - Followed by a numerical example of a practical application.