

# Lecture 39: Intro to Differential Amplifiers

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## Reading

- All of the reading assignments are done
- Time to start reviewing for the final!

## Context

Next week is the last week of lecture, and we will spend those three lectures reviewing the material of the course, and looking at applications of the material.

Today we are going to look at the basics of differential amplifiers.

## Lecture Outline

- Why differential signaling important, and becoming more important
- Introduction to differential amplifiers

## Device Matching

- One of the things that we depend on in the design of analog integrated circuits is device matching. For example, if we make a current mirror, we are depending on the reference and the mirror device behaving in a very similar fashion. When a gate-source voltage is developed on the reference device, passing a given current, the same voltage appearing across the gate to source on the mirror device will allow the same drain current.

## Differential vs single ended signals

- A voltage is only defined between two points
- Charge times voltage difference gives the energy needed to move a charge between two points.
- A single ended signal is actually a misnomer, because all voltages are measured between two points, its just that single ended signals use "ground" as a reference.

## Variations

- The transistors will generally vary due to several causes:
- Temperature→very similar for devices on the same substrate
- Implant variations→important for small devices
- Variations in width→important for narrow devices
- Variations in length→important for short channel devices
- Layout variations

Often, analog devices will not be minimum sized devices, so that output resistances will be lower, short channel effects will be smaller, and the effect of variations is reduced.

## What is "ground"

- In a low frequency circuit, with a big ground plane available, it is possible to approximate that ground is a stable reference which all voltages can be measured with respect to.
- At high frequencies, and at low voltage swings which are needed for reasonable power consumption, the variation of the "ground" can vary by more than the signal level.
- This is even a problem at low frequencies, if devices are separated by any distance. "ground" at one device can easily be several volts different than "ground" at another device. (DC and AC)

## Differential signaling

- One solution to this problem is to use differential signaling, that is two wires, close to each other, and in a symmetric configuration, carry the signal as a voltage difference.
- They needed to be routed together and twisted to avoid coupling magnetic fields from other wires or sources
- They should also be driven with the same impedance, so they pick up the same noise voltages
- If all of these things are done, then noise picked up by the wires is picked up by both in the same amount and with the same sign—“Common mode”

## Differential Amplifiers

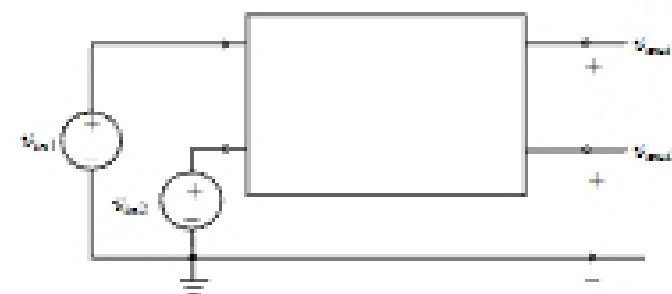
Differential amplifiers also solve some of the other problems that we have brushed aside so far- like how to bias the input to the right quiescent voltage.

## Differential input

- In order to use a differential signaling scheme, we need to produce an amplified version of the difference between the input voltages
- This is called a differential amplifier.
- The output of a differential amplifier can either itself be differential, or it could convert the signal into a single ended version with respect to ground.
- If the inputs change in voltage together, swinging in the same direction, this is called common mode
- A good differential amplifier is designed to cancel the common mode: called common mode rejection.

## The Differential Amplifier Concept

The basic idea: amplify the *difference* between two inputs and reject the common component



$$v_{out,diff} = A_{v,diff}(v_{in,diff}) = A_{v,diff}(v_{in1} - v_{in2}) \dots \text{large}$$

$$v_{out,comm} = A_{v,comm}(v_{in,comm}) = A_{v,comm}[(v_{in1} + v_{in2})/2] \dots \text{small}$$