The University of Texas at Arlington

Talking Points - 4
Analog Signals

CSE@UTA

CSE 3323 – Electronics for Computer Engineers

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With images taken from from wikipedia

The dB Scale

- Relative scale to measure anything against anything
- Logarithmic
  - Meaning of zero, 1, 10, 20, infinity
  - Why? (for large dynamic ranges)
- Usually used to measure power amplification or attenuation
  - Amplification and attenuation is relative
  - $P\ [dB] = 10*\log_{10}(P_{out}/P_{in})$
- As we are usually dealing with signals represented by voltage (not power):
  - $V\ [dB] = 20*\log_{10}(V_{out}/V_{in})$

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Signals Represented by Voltages

- Mostly what we are interested in
- Analog vs. digital
- “virtual” signal source: has an output impedance

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Time vs. Frequency Domain

- We think of signals as a changing value in time.
- At any small time window, the signal in the window can be represented as the superposition of many different sine waves with various frequencies and phases.
- For that time window we could show at what amplitude each of the frequencies is represented at (and at what phase on an other).
- This show the momentary (in the window) frequency components present in the signal.
- If the signal is periodic, we can take a window that represents it’s base period and thus describe the entire signal (momentarity does not matter) in the same frequency domain graph.

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Fourier

- A periodic(!) signal can be "easily" converted into all of its component frequencies (sine waves with phases) mathematically.
- The transformation is called: Fourier transformation. (inverse also exist)
- In general, the steeper of a change there is in the signal, the higher frequencies we are going to need to represent them.

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Fourier of Sine, Square, Triangle

- Most periodic functions can be looked up in reference materials.

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Non-periodic signals

- In many cases, periodic signals are uninteresting.
- In a small time window we can still ask the question: what frequency components (and with what phase) are present.
- This is the temporal spectrum of the signal
- Most signals have an upper limit (of interest), sometimes a lower limit of interest.

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Filters

- In many cases we do want to make sure that signals do not contain frequencies above, below, or both some threshold frequencies.
  - E.g., Shannon-Nyquist sampling theorem
- Optimal filters
- low-pass or high-cut filter
- High-pass or low-cut filter
- Band-pass filter
- Band-cut filter

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Low-pass Filter

- Only want to let low frequencies through
- Can be realized with a simple RC circuit
  - (Xc is falling with a raised frequency)
- τ=R*C ; ω_0=1/(R*C) ; f_0=1/(2*π*R*C)
- Complex representation
  - Magnitude and phase
  - 20dB/decade fall ; -3dB point
- How about RL ?

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High-pass Filter

- We want to cut low frequencies from the signal
- Swapping components of an RC low pass filter
- Similar characteristics (but swapped)

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Band-pass and Band-Cut Filters

- Can be built by combining low and high pass filters
- Can be problematic as impedances do not easily add up
- RLC filters

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Multistage Filters

- As RC filters are far from optimal, we may cascade several RC, (and L) filters after each other
  - Problem is that they interact with each other
  - Complex transfer function can be a pain to obtain and analyze
  - Even that helps little as we want to do synthesis not analysis
  - Doable, but leave it to EE-s.
  - There are programs that can be used

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AMPLIFICATION AND "IMPEDANCE LIBERATION"

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Amplification

- Amplifying analog signals requires negative resistance
  - Cannot be done with passive components
- In order to amplify a signal we need active circuits, i.e., we need external power.
- Signal's D.C. level and domain is important
  - We can always get rid of "all" D.C. with coupling capacitors
- Transistors (including FETs) exhibit linear regions where amplification is possible (LitEE)

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Opamps to the Rescue

- Opamps are multi-transistor concoctions, their design is litEE.
- Opamp symbol
- http://en.wikipedia.org/wiki/Operational_amplifier_applications
- Differential input, single output, works like a comparator due to infinite amplification
- Needs to be powered (not always seen on schematics)
- With no feedback output rests at one of the supply levels
- Theoretical vs. real
  - Power, rail-to-rail, amplification, impedance, etc.

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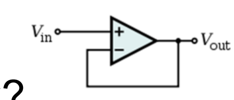
Voltage Follower

- Simplest Opamp circuit (except comparator)
- Schematic



- Why use and how does it work?
- $V_{out}=V_{in}$; $Z_{out} = 0$; $Z_{in} = \infty$
- Perfect for cutting "impedance domains"
- Use a lot of them in prototyping, in production the analog state redesign is LiTEE
- Pay attention to operational voltages!

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Fixed Voltage (Voltage Source)

- Use a resistive divider (Or diode based voltage source) followed by a "follower"
- Creates a fixed voltage source (current drawn will not influence voltage)
- Great to create half voltages if powering opamp from a single power source

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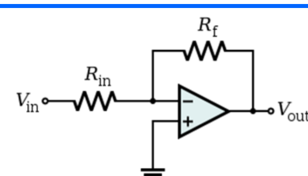
Inverting Amplifier

- Schematic
- $V_{out}=-V_{in}*R_f/R_{in}$
- IT INVERTS! (180deg)
- Amplification can be anything from 0 to infinity (theoretically)
- However:
  - $Z_{in} = R_{in}$



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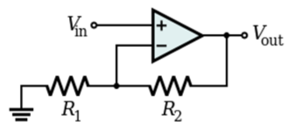
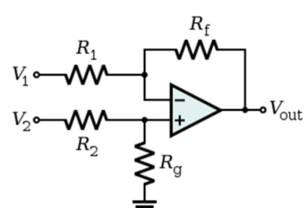
Non-inverting Amplifier

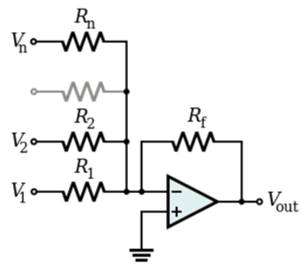
- Schematic
- $V_{out}=V_{in}*(1+R_2/R_1)$
  - (non linear in R_2)
- However:
  - $Z_{in} = \infty$



Difference Amplifier



Summing Amplifier



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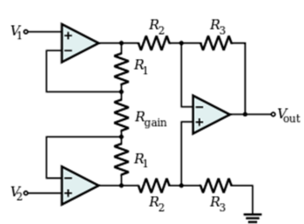
Instrumentation Amplifier



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And Many More…

- Integrator
- Differentiator
- Precision rectifier (for instruments)
- Oscillators
- Inductance gyrator (for creating synthetic inductors)
- Logarithmic output
- Exponential output
- A/D, D/A converters
- etc.