PHY 335, Unit 5 OpAmps and negative feedback

Mini Lecture topics:

- **OpAmps, a basic building block**
- **The concept of negative feedback**
- **OpAmp's open loop gain and transfer function**
- **The "Golden Rules"**
- **Basic Op Amp circuits: follower, amplifiers (inverting and non-inverting), differential amplifier, current source, integrator, differentiator.**
- **Slew Rate**

For this unit, we will use a TL082 or similar OpAmp. Note that different versions of the Texas Instruments (TI) TL082 (M, A, B) are dual packages containing two independent OpAmps with a common power supply. Make sure to refer to the pin assignments in the data sheet, available here: `http://www.ti.com/lit/ds/symlink/tl081.pdf`

1. Look up the datasheet and find the pin out and critical values. What is the maximum supply voltage? What is the open loop amplification? What minimum load resistance seems adequate?

2. OpAmp voltage follower. Build an Opamp-based voltage follower. Build a voltage divider with a potentiometer and two resistors to reduce ±15 V to a voltage in the range of ± 5 V and measure V_{out} for several values of V_{in}. Now, connect a low resistance load to the output of your follower. Choose a load which is considerably lower than the Thevenin equivalent resistance of your divider (but remember what you found for the minimum load resistance). Without a follower this voltage would be reduced by the small load. Check this by removing the Op Amp follower and measuring the voltage delivered to the load directly from the voltage divider. Now, with the follower, convince yourself that you can apply the full desired voltage to the load.

3. Using the Opamp voltage follower, feed in a signal from the signal generator and measure the output amplitude vs. the input amplitude as a function of frequency for an input amplitude around 1V and 12V. Is the output identical to the input?

4. Non-inverting and inverting Op Amp amplifiers. Explain the operation of an opamp non-inverting amplifier using the Golden Rules. Derive an expression for the gain. Build a non-inverting variable gain amplifier with set-able gain between 0 dB and 26 dB. Use a 10 $k\Omega$ potentiometer to set the gain. Make AC gain measurements at various frequencies and describe what you observe.

5. Repeat the above with an inverting amplifier. Do you see the inversion on the scope?

6. Op Amp Current Integrator. Build an integrator using a 100 $k\Omega$ resistor in the input circuit and a $0.1\mu F$ capacitor in the feedback loop. Explain the operation of this circuit, starting with the recollection of how the simple RC integrator works. Connect the input of the integrator to the common ground, and the output to the DVM voltmeter. Turn the power supply on and observer what happens. What is the time scale on which this circuit can be used as an integrator? What determines this time scale?

7. In order to reduce the drift, connect a resistor "T" network. Use two 1 $M\Omega$ and one 10 $k\Omega$ resistors for the "T". Explain how this works. Observe the circuit behavior again as previously. What is the time scale on which this circuit can used as an integrator now that you've added the "T"?

8. Apply a ±1 V square wave to the input. Measure both input and output on the scope. Use several frequencies on the 0.1 Hz – 10 kHz range. Repeat with ±5 V. Comment on the results. Are you indeed integrating correctly?

9. Op Amp differentiator. Build a differentiator. Use the same resistor and capacitor values from the integrator. Observe the input/output relationship for signals of several waveforms and frequencies from the signal generator. Explain the waveforms observed at the output. In particular, drive the circuit with a ±5 V square wave and observe the results. [Note that at some fairly high frequency the differentiator may become unstable. Read about this problem in AoE.]

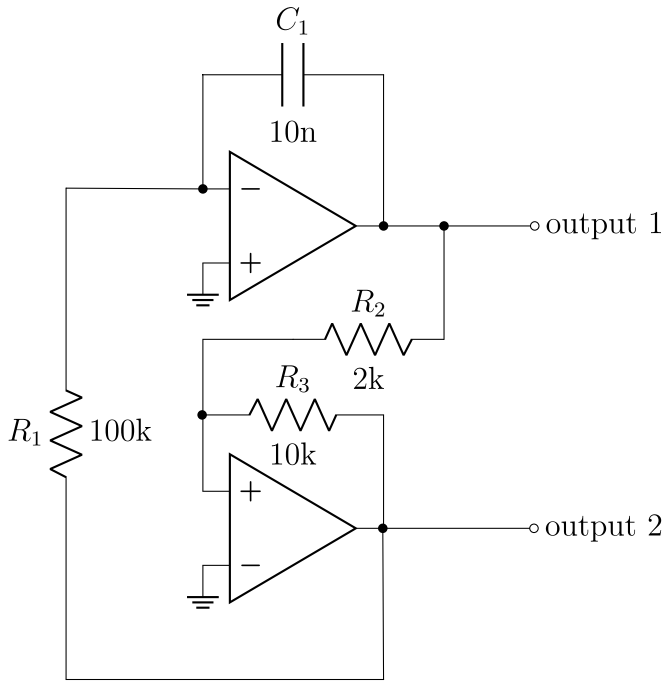
10. Measuring the slew rate: The slew rate is the maximum response rate of the opamp output voltage when the input is driven with high frequency. If we drive the input with increasing frequency signals, at some point the output will not be able to follow. There are two ways of measuring the slew rate:

    (a) Drive the opamp follower with the sinusoidal signal from the SG. Keep increasing the frequency and measure the output voltage. Note the frequency at which the output signal amplitude starts to decrease as compared to the input. This frequency corresponds to the slew rate. Use the formula given in the text to calculate S from that frequency. Make sure you understand its derivation.

    (b) Drive the same follower with a square wave. The finite slew rate will manifest itself as a slope of the output edge of the square wave. This measures the slew rate directly, as $\Delta V/\Delta T$.

    Give the result in units of V/μs.

11. (Bonus) Study the following circuit. What output waveforms to you expect for output 1 and output 2? Explain how the circuit works.



Using the two opamps in a single TL082, build the circuit. Do you observe the expected behavior?