# Phy 355, Unit 5
# Negative Feedback and Operational Amplifiers

**Mini-lecture topics planned:**

- **The concept of negative feedback**
- **Op Amp's open loop gain and transfer function**
- **The two "Golden Rules"**
- **Basic Op Amp circuits: follower, amplifiers (inverting and non-inverting), differential amplifier, current source, integrator, differentiator.**
- **Op Amp slew rate**

*For this unit, use TL082 or similar Op Amp. Note that different versions of the Texas Instruments (TI) TL082 (M, A, B) are dual packages containing two independent Op Amps with a common power supply. Make sure to refer to the pin assignments in the technical specs.*

**1. Op Amp voltage follower.** Build an Op Amp-based voltage follower. Build a voltage divider with potentiometer to reduce ±15 V power to $V_{in}$ in the range of ±5 V and measure $V_{out}$ for several values of Vin. Also use the signal generator(SG) to provide AC input and measure output to see that it is identical to the input.[1] 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. For example, you can divide +15 V in half, delivering 7.5 V. 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.

What are the advantages, if any, of this voltage follower over the transistor follower you have built in the previous unit. First, think of the impedance of the BJT follower and the Op Amp follower. Second, is there a 0.6V shift here?

**2. Non-inverting and inverting Op Amp amplifiers.** Explain the operation of an Op Amp non-inverting amplifier using the Golden Rules. Derive an expression for the gain. Build a non-inverting variable gain amplifier with settable gain between 0 dB and 26 dB[2]. Use a 10 kΩ potentiometer to set the gain. Make AC gain measurements at various frequencies and describe what you observe. *Repeat the above* with an inverting amplifier. Do you see the inversion on the scope?

**3. Op Amp Current Integrator.** Build an integrator using a 100 kΩ (precision) resistor in the input circuit and a 0.1 μF mylar film capacitor[3] in the feedback loop. Explain the operation of this circuit, starting with the recollection of how the simple RC integrator

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[1] Use either the DVM or a scope to measure $V_{in}$ and $V_{out}$. As usual, we're interested in frequency dependence, too.
[2] You'll have to calculate the equivalent gains to determine the component values.
[3] A mylar film capacitor is used because of its low leakage current.

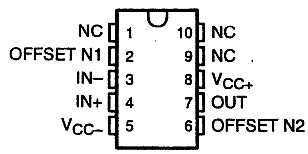
works. Connect the input of the integrator to the common ground, and the output to the DVM voltmeter. Turn the power supply on and observer what happens. What is the time scale on which this circuit can be used as an integrator? What determines this time scale? In order to reduce the drift, connect a resistor "T" network (p. 223 in H&H and pp. 186-187 in the lab manual). Use two 1 MΩ and one 10 kΩ 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"? 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 ± 5V. Comment on the results. Are you indeed integrating correctly?

**4. Op Amp differentiator.** Build a differentiator as shown in Fig. 4.51 in H&H. 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(SG). 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 H&H.]

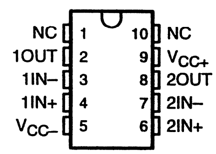
**5. Measuring the slew rate.** The slew rate is the maximum response rate of the Op Amp output voltage when the input is driven with high frequency. If we drive the input with increasing frequency signals, at some point the output will not be able to follow. The slew rate S is measure in Volts/μs. For example, S = 10 V/μs means that the maximum rate of output voltage change is 100,000,000 V/s. Read about this in the textbook. There are two ways of measuring the slew rate:

a. Drive the Op Amp 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 ini 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 front of the square wave. This measures the slew rate directly, as $\Delta V/\Delta T$. Give the result in units of V/μs.

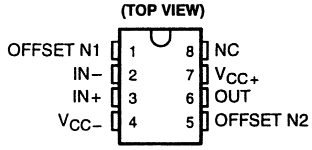
**TL081M**
**U PACKAGE**
**(TOP VIEW)**




**TL082M**
**U PACKAGE**
**(TOP VIEW)**




**TL081, TL081A, TL081B**
**D, JG, P, OR PW PACKAGE**
**(TOP VIEW)**




**TL082, TL082A, TL082B**
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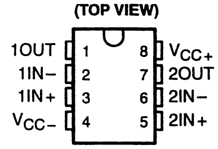
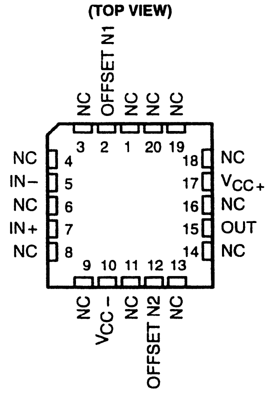
**(TOP VIEW)**

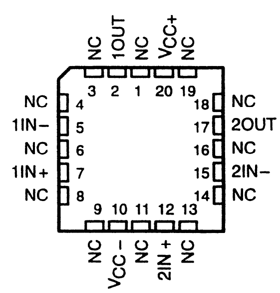



TL082

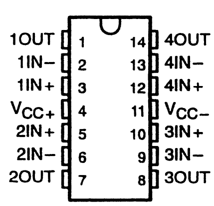
**TL081M . . . FK PACKAGE**
**(TOP VIEW)**



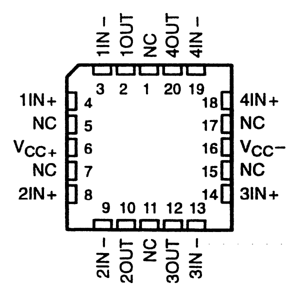

**TL082M . . . FK PACKAGE**
**(TOP VIEW)**




**TL084, TL084A, TL084B**
**D, J, N, PW, OR W PACKAGE**
**(TOP VIEW)**




**TL084M . . . FK PACKAGE**
**(TOP VIEW)**




NC – No internal connection