Name: Roll Number:

Laboratory 5

A: /4	B: /6	Tot: /10

Part A: Measurement of opamp imperfections: V_{os}

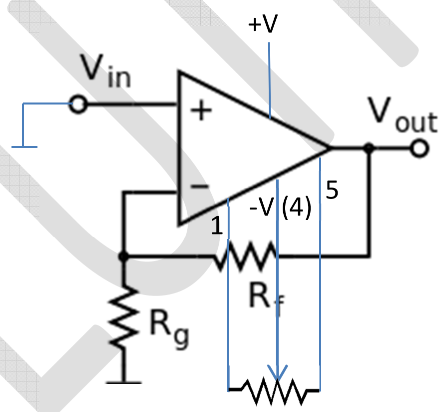
As discussed in the lecture, any opamp suffers from two sources of error *without an external input*. The first is an offset voltage caused by mismatched currents in the emitter legs of the two input transistors that make up the differential input pair. This is relatively easy to measure and compensate. Setup a simple feedback amplifier with a large gain of +1000. Connect *both* V_{in} and the unused opamp input to 0V using short *equal* lengths of wire. Use the measured output value to calculate V_{os}

Note: V_{os} is the offset voltage created at the *input* which is amplified by the gain of your amplifier

Compare the measured value with the specifications of typical V_{os} for LM741 in the datasheet.

Circuit Diagram to measure V_{os} (with component values):

Standard non-inverting feedback with gain of 1000: $R_f = 100k\Omega$, $R_g = 100\Omega$



Measurement of V_{os} ________________ V_{os} = 1 to 6 mV so output V_o should be ~ 1 to 6V

Comparison with expected typical values from the LM741 datasheet:________________

Use a potentiometer connected to the offset null pins 1 and 5 and pin 4 to balance the emitter leg currents of the two halves of the input differential pair (look at the datasheet for the connection details) Demonstrate that you can get rid of V_{os} in your opamp by fine-tuning the value of the potentiometer.

Hint: $\mathcal{O}$(10 kΩ) potentiometer values are usually needed. Multi-turn potentiometers are notoriously sensitive to slight movements of the knob. Make sure that you measure the potentiometer setting after you have fine-tuned the value to null V_{os}. Set it aside so that you don't bump it accidentally and change the settings for Part B of today's experiment.

Name: Roll Number:

Part B: Measurement of opamp imperfections: I_{bias}

The second source of error in an opamp at DC is the mismatch between the bias currents into the bases of the two input transistors. This is called I_{bias}. It is typically:

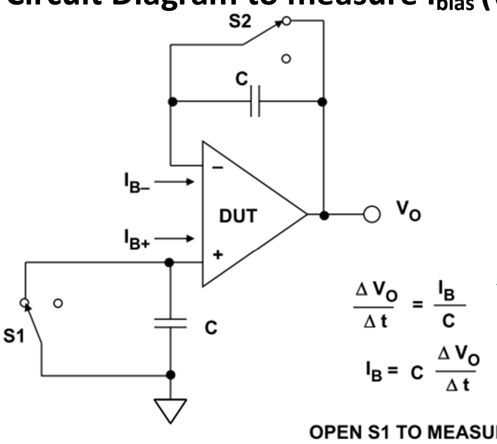
- Of very small value (µA or less)
- Can be different for the two inputs of the opamp, in general $I_{bias+} \neq I_{bias-}$
- Hence, somewhat harder to measure.

Setup a feedback circuit to measure I_{bias} for the LM741 with the assumption that V_{os} has been compensated accurately using the offset null as in Part A

Hints:

1. *Putting a capacitor in the feedback loop* *__integrates__* *any current present at the input with* $V_{in} = 0$
2. *A capacitor's I-V relation gives you* $V = 1/C{*}\int I\,dt$, or more usefully: $I = C{*}dV/dt$
3. After integrating I_{bias}, V_{out} is limited to the saturation values $\pm V_{sat}$ The important point is to determine the *slope* dV/dt
4. *You must measure* I_{bias+} *and* I_{bias-} *separately:* the circuit connections to measure each are similar. When measuring one, the other terminal must be grounded to 0V.

Circuit Diagram to measure I_{bias} (with component values):



OPEN S1 TO MEASURE I_{B+}

OPEN S2 TO MEASURE I_{B-}

Converting to time domain: $1/\omega \to \int$ and $\omega \to d/dt$

For I_{b-} : + terminal is grounded.
$v_o = A(0 - v_-)$ $v_- = I_{b-} * 1/j\omega C$
so v_o will saturate to +/- V_{sat} depending on sign of I_{b-}
$I_{b-} = C{*}dv_o/dt$ i.e. measure the slope of v_o as it (linearly rises towards saturation.

For I_{b+} :
S2 closed and opamp functions as unity gain follower.
$v_o = v_+ = I_{b+} * 1/j\omega C$ and $I_{b+} = C{*}dv_o/dt$

Note: Must measure v_o not v_+ or v_- ! I_{b+} I_{b-} are nA level currents. So putting the DSO probe at v_+ or v_- loads the 'source' of $I_{b+/-}$ with the DSO scope impedance in parallel with C. Above equations will need to be adjusted to account for ($Z_{DSO} \parallel C$)
Some students decided to measure I_{b+} by simply interchanging connections to – and + terminals of the opamp. This is not correct. By doing so you are making a *__positive__* *feedback circuit and driving v_o quickly to saturation which forces the opamp output stage to drive a much larger output current I_o. So current in the $1/j\omega C$ impedance is not just I_{b+} $I_{b+} + I_o$ of which the latter is unknown.*

Measurement of I_{bias} ______________________________ *~1nA typical for LM741*

Comparison with expected typical values from the LM741 datasheet:________________