# Lab 6 Prelab Grading Sheet

**NAME:** _____

Read through the Background section of this lab and print the prelab and in-lab grading sheets. Then complete the steps below and fill in the Prelab 6 Grading Sheet. You will need the information on the Prelab 6 Grading Sheet to complete your in-lab assignment so please **be sure to do the prelab before coming to lab**. Please also bring the printed in-lab grading sheet to lab with you.

1.  Study the instrumentation amplifier schematic in the Background section and do hand calculations to determine an initial set of resistor values that will provide a differential gain of $A_d$ = 30V/V.  It is recommended that you choose resistor values in the range of 200$\Omega$ to 10k$\Omega$. Use series and parallel connections to get the value you need. Record these values on your Grading Sheet and show your calculations.

2.  Using your calculated resistor values, construct the instrumentation amplifier circuit above within a SPICE simulation program.  Use the op467 subcircuit to model the opamp (in .txt file on class website).  Use a power supply voltage of 20V, setting the positive supply to 20V and the negative supply to ground. Do not perform any simulations yet.

3.  We want to design this circuit using a single 20V supply only but we want to be able to amplify both positive and negative signals.  To accomplish this, we must construct an analog reference, typically called analog ground (agnd) that is half way between the positive and negative supply.  In this design, we need to create an agnd = 10V.  Construct a circuit using an opamp in a voltage follower configuration and two 10k$\Omega$ resistors that will produce a 10V output from a 20V to ground supply voltage.  This output will be your analog ground and serve as the ground node for the instrumentation amplifier in the schematic above.  Sketch this circuit in your Grading Sheet.

4.  Add the analog ground amplifier circuit in your SPICE file and define its output as **_agnd_**.  Once your circuit definition is complete in your SPICE file, run an operating point analysis (.op) and observe the *agnd* node.  Confirm it is 10V (or very very close) and enter the exact measured value on your Grading Sheet.  If it is not 10V, check your circuit and simulation file because it should be.

5.  Set node $v_1$ to a 10V dc supply and then setup your simulation file so that the output voltage can be observed as input $v_2$ sweeps from 0 to 20V (relative to ground, not agnd).  This can be done using either a DC analysis or a TRANsient analysis depending on how you setup your simulation and source, but DC analysis is preferred and will make recording the required values easier.

    ```
    Example:   vs1  v1 0 10V      *DC is implied by default
               vs2  v2 0 10V      *value does not matter; will be DC sweep
               .DC vs2 0 20 0.1   *defines source, start, stop, step
    ```
    Before running the simulation, consider what you would expect to see at the output. Answer the questions on the Grading Sheet before continuing.  Also, print a copy of your SPICE file at this point and attach it to your Grading Sheet when you turn it in.

6.  Perform the simulation you setup in step 5 and record the information requested on the Grading Sheet.  The calculated differential gain should be determined from your measured max/min values for $v_o$ and $v_2$.  If it is not close to 30V/V, adjust resistor values until you have a gain of 30V/V +/-1. Record your final resistor values.  Note, in practice using discrete resistors, you have a limited selection of resistor values, so don't try to fine tune your values too much to achieve the correct gain.  Within +/- 1V/V is acceptable.

7.  Adjust your simulation so that $v_2$ varies only +/-0.5V from $v_1$, that is, from 9.5 to 10.5 and run the simulation again.  Measure the slope ($\Delta v_o/\Delta v_2$) of the linear gain region and record this value for differential gain.

8.  Set $v_1$ = *agnd.* Precisely measure the ***agnd*** node voltage.  Find the precise value of $v_2$ at which $v_o$ = *agnd*.  The value of $v_2 - v_1$ at this point is the offset voltage of the amplifier.  Record this value.

9.  Change your simulation file so that $v_1$ and $v_2$ are connected to the same dc source. Vary this source from 8V to 12V and observe the output voltage.  This should show you if your circuit has common mode gain.  Measure the common mode gain, $A_{cm}$.  Using your differential gain value from step 7, calculate the common mode rejection ratio, CMRR = $A_d/A_{cm}$.  Record these values on the Grading Sheet.

10. In preparation for the in-lab assignment, consider that discrete resistor components only come in a handful of discrete values. These are shown in the Background section.  As you may have observed already, a 30V/V gain is achievable using only 2 different resistor values.  Use the resistor color code figure below to determine what two values of actual discrete resistors you could choose to produce a gain of 30V/V, and then specify the selected value for all resistors, recording this in your Grading Sheet.  You may want to use your SPICE simulation to verify your resistor choices, but you are not required to do this.

This ends the prelab.  In Lab 6 you will be constructing the circuit you have simulated and measuring the same performance parameters that you simulated in this prelab.

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## ANSWERS

**A.1**
R1 = _____,
R2 = _____,
R3 = _____,
R4 = _____
Calculations:




**A.3.**
Sketch of analog ground generator circuit.












**A.4.**
Simulated value of ***agnd*** = _____V

**A.5.**

Will the output change for all values of $v_2$?  If now, why?

_____

_____

Will the output be constant for some values of v2?  If so, in what voltage range do you expect a constant output?

_____

_____

What do you expect the minimum and maximum output voltage to be?

_____

Reminder: You should attach a copy of your SPICE file at this point to this Grading Sheet.

**A.6.**

| max output voltage | _____ V | min output voltage | _____ V |
|---|---|---|---|
| max $v_2$ for linear response | _____ V | min $v_2$ for linear response | _____ V |
| $v_2$ voltage for which $v_o$ = 10V (agnd) | _____ V | calculated differential gain, $A_d$ (with initial resistor values) | _____ |

With $v_1$ as the reference input node, is the amplifier inverting or non-inverting? _____

Final resistor values for differential gain of 30V/V:

          R1 = _____, R2 = _____, R3 = _____, R4 = _____

**A.7.**

Differential gain, $A_d$ = _____

**A.8.**

Offset voltage = _____V

**A.9.**

Common mode gain, $A_{cm.}$ = _____, CMRR = _____

**A.10.**

Selected discrete resistor values:

R1 = _____, R2 = _____, R3 = _____, R4 = _____
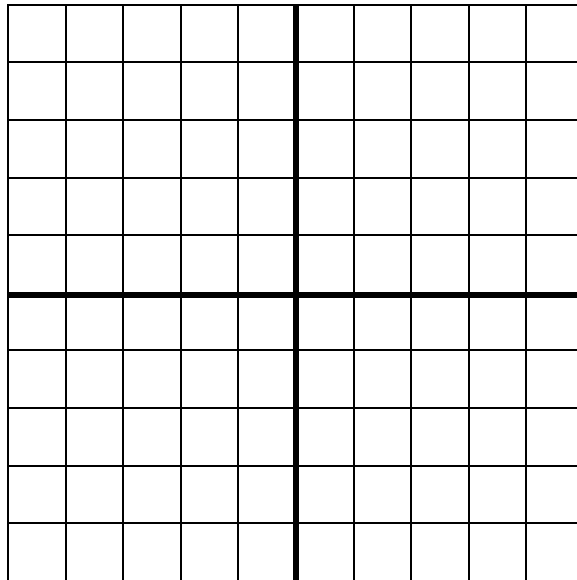
# Lab 6 Grading Sheet

**PARTNER NAMES:** _____

**C.3**    $v_o =$ _____V

**C.4**    $v_o =$ _____V

**C.5**    $v_o =$ _____V
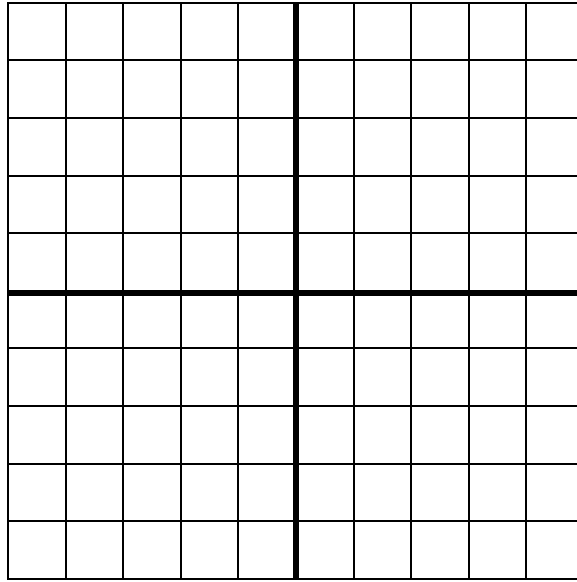
**C.6**    _____

_____

**D.1**



horizontal grid scale = _____, vertical grid scale = _____

**D.3**



horizontal grid scale = _____, vertical grid scale = _____

**D.4**

$v_o$(max) = _____,      $v_o$(min) = _____,      differential gain = _____

_____

_____

_____

**D.5**

Vpp (output) = _____

improved differential gain estimate, $A_d$ = _____

**D.6**

high level voltage=_____V          low level voltage=_____V

agnd=_____V                    offset=_____V

**D.7**

Common mode gain=_____

**D.9.**

input Vpp =_____V                    output Vpp =_____V

_____

_____

**D.10**

| Frequency | 1KHz | 10KHz | 100KHz | 1MHz | 10MHz |
|-----------|------|-------|--------|------|-------|
| Amplitude |      |       |        |      |       |

_____

_____

**D.11**

3dB bandwidth=_____

**D.12**

**TA check off of final demonstration** (TA signature) _____