

Name:

Bench:

Read over entire laboratory #9 and the Prelab 8 notes.

Questions:

1. Use the data sheet to predict the typical maximum output voltage swing, slew rate, small signal unity gain bandwidth, and short circuit current for the circuit in figure 9-3. (5 points)

Max Voltage swing = _____ minimum, _____ typical. I_{SC} = _____ typical

Small signal unity gain BW = _____ typical. Slew Rate = _____ typical

Enter the voltage swing specification in Part I-4 on the Data Sheet.

Enter the Short circuit current spec in Part I-2 on on the Data Sheet.

Enter the bandwidth spec in Part II-2 on the Data Sheet.

Enter the slew rate spec in Part III-2 on the Data Sheet.

2. Calculate the smallest load resistor that will allow a 12V output when limited by the maximum current the op-amp can produce. (10 points)

3. Determine the equation for the gain of the amplifier (in terms of R_1 , R_2 , R_3 , R_L as appropriate) in Fig 8-3. (5 points)

4. Using the circuit in Fig 9-3, calculate the amplifier passband voltage gain = V_o / V_g , passband dB gain, passband output RMS voltage, and small signal bandwidth f_{high} for each value of R_2 in the table below. $V_g = 0.1V_{PP}$ sin wave, $R_1 = R_3 = 10\text{ k}\Omega$, $R_L = 2.2\text{ k}\Omega$. Use the typical Small Signal unity gain specification (see the Gain Bandwidth Product in Part II) to predict the small signal bandwidth of this amplifier. For credit, attach sheet or show work on back of page. (30 points)

R_2	Passband Gain		V_o (rms)	f_{high}	Enter the 47k Ω gain in Part I-2 of the Data Sheet. Enter values for gains, V_o , and cutoff frequencies in table 9-2 and table 9-3 of the Data Sheet.
	Voltage	dB			
10k Ω					
47k Ω					
100k Ω					
470k Ω					

5. Build the circuit for Figure 9-3 in Pspice with $R_1 = 10\text{ k}\Omega$, $R_2 = 47\text{ k}\Omega$, $R_3 = 10\text{ k}\Omega$, and $R_L = 1\Omega$ (1Ω is close enough to a short circuit for the current limit measurement)(Note: you can easily modify the circuit from Lab 8 for this). Apply 5VDC for V_g (use a VDC source) and turn on the current bias display. The current through R_L is the short circuit current I_{sc} .

Simulated $I_{sc} =$ _____ Enter this value on Part I-2 of the Data Sheet. (3 points)

How does this I_{sc} compare to the spec sheet? (2 points)

Edit the information box on the schematic to include at least your name, the date, and PreLab 9 I_{sc} . Print the schematic with the bias currents enabled. (10 points)

6. Modify the circuit from question #5 to change $R_L = 2.2\text{ k}\Omega$ and $V_g = \sin$ source amplitude to 4 (8Vpp) with no DC offset, and a frequency of 1 kHz. Place voltage probes to measure V_g and V_o . Set the Run a transient simulation from 0 to 3 ms with 0.02ms steps. Use the cursors to measure and mark V_{Omax} and V_{Omin} . Add a Label the includes at least your name and PreLab 9 Output Voltage. Print the simulation. (10 points)

$V_{Omax} =$ _____, $V_{Omin} =$ _____ (3 points)

Enter these results on Part I-4 of the Data Sheet.

How do V_{Omax} and V_{Omin} compare to the voltage swing spec on OpAmp data sheet? (2 points)

Edit the information box on the schematic to include at least your name, the date, and PreLab 9 Output Voltage Limit. Print the schematic (with bias currents turned off) and the transient simulation result. (5 points)

7. Modify the Pspice circuit in question #6. Change V_g to a 10Vpp **square wave signal** with no DC offset and $f = 1000\text{Hz}$. Run a transient simulation from 0 to 1.2ms, with a step size of 5us and begin the display at 0.9ms. Use the cursors to measure and mark the slew rate $= \Delta V / \Delta t$ at $V_o \pm 10\text{V}$. Add a label that includes at least your name and PreLab 9 Slew Rate. Print the simulation. (10 points)

$\Delta V =$ _____, $\Delta t =$ _____, Slew Rate $=$ _____ (3 points)

Enter the Slew Rate on Part III-2 of the Data Sheet.

How does the Pspice simulated Slew Rate compare to the spec? (2 points)

OBJECTIVES:

The purpose of this experiment is to study some of the practical limitations of operational amplifiers.

EXERCISES:

This laboratory is broken into three parts:

Part I: Output Circuit Limitations

Part II: Gain Bandwidth Product

Part III: Slew Rate

A pin out diagram of the LM741 is shown in Figure 9-2. Pin 1 is adjacent to the dot.

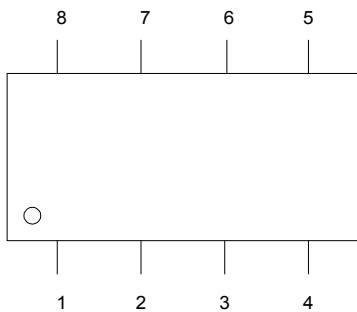


Figure 9-2 LM 741 Pins (Top view)

- Pin 2 is the inverting input
- Pin 3 is the non-inverting input
- Pin 4 is V- power supply
- Pin 7 is V+ power supply
- Pin 6 is the output voltage V_o

- Pins 1 & 5 are offset null connections (not used)
- Pin 8 has no connection

Part I: OUTPUT CIRCUIT LIMITATIONS

1. Construct the circuit in Figure 9-3.

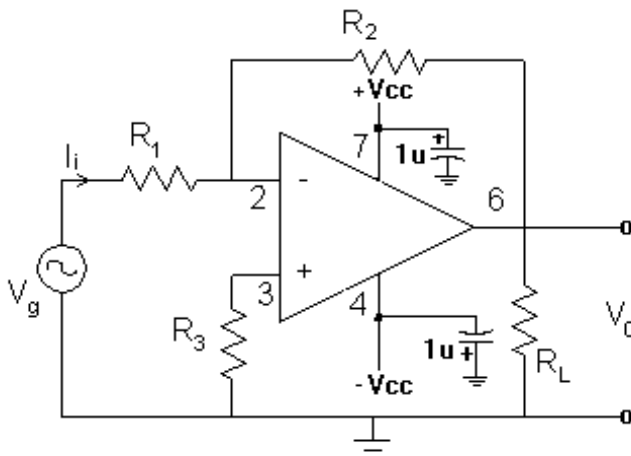


Figure 9-3

- $R_1 = 10 \text{ k}\Omega$,
- $R_2 = 47 \text{ k}\Omega$,
- $R_3 = 10 \text{ k}\Omega$,
- $R_L = \text{Decade resistor}$.
- NOTE: Use +/-15V for the power supply.

2. Adjust a DC power supply to 2V and use this DC voltage for V_g . Remove the load resistor and measure the DC open circuit output voltage. Record your measurements on the Data Sheet. If V_{oc} is

not close to -9.4V, troubleshoot your circuit.

- Use the decade resistance box for R_L and complete Table 9-1 on the Data Sheet for each value of R_L .

For your measured I_{SC} , calculate the smallest load resistance your op-amp can have and still produce a -9.4V output, then set the load resistor to the value you calculated and measure the output voltage. Record this information on the Data Sheet.

- Remove the decade resistor and connect a 2.2k Ω resistor (from the parts bin) as R_L . Use the signal generator to create a V_g with a sine wave at a frequency of 1 kHz at 1V_{pp}. Measure V_g and V_O with the scope, and calculate the actual gain of the amplifier. If the actual gain is not close to the theoretical gain of -4.7, troubleshoot your circuit to find the problem.

While monitoring the output of your amplifier, adjust the input voltage until output signal is solidly clipping. Record the output voltages where the negative output swing and the positive output swing clip (use the scope quickmeasure Vmax and Vmin, the scope Y cursors, or the buffer cursors to measure these voltages). The positive clipping voltage may not be the same as the negative clipping voltage.

PART II: GAIN BANDWIDTH PRODUCT

- Using the same circuit as Part I with $R_2 =$ the values in the table below and $R_L = 2.2k$, use the computer to capture a small signal frequency sweep of the amplifier response. Set $V_i = 0.1V_{pp}$ and sweep from 1 kHz to 1 MHz in 60 steps. Complete the information in Table 9-2 for each value of R_2 .

Tip: Watch the voltmeter as the sweep begins, and if your V_O is not close to the passband V_O values provided by your TA, troubleshoot the circuit until you are reasonable close. V_g is set to V_{pp} on the signal generator and V_O is measured as V_{RMS} by the meter. $V_{RMS} = V_{pp}/(2\sqrt{2})$.

After you have saved all three AC Sweeps, overlay the three small signal response curves and save the overlay as a jpeg file. Use log scale for the x scale and dB for the y scale, normalizing y to V_{in} (0.0353V_{rms} or 0.1V_{pp}). Before saving the overlay, measure the passband V_O , passband dB, dB @ f_{high} , and f_{high} for each value of R_2 . **DO NOT use decade box for R2** (the long leads are too noisy).

- Use the average of the three Gain-BW products to determine the small signal unity gain BW for your op-amp.

Print the overlay, write your name(s) on the print, label the print, label each gain plot, and staple the print to your lab report.

PART III: SLEW RATE

- Use the circuit in Figure 9-3. Let $R_1 = 10 k\Omega$, $R_2 = 10 k\Omega$, $R_L = 2.2 k\Omega$, $R_3 = 10 k\Omega$. Theoretical Gain $V_O/V_g = -1$

Set $V_i = 10V_{pp}$, 1 kHz, square wave. Adjust the scope vertical sensitivity and horizontal time base to display the rising edge of the output waveform over most of the screen. Use the computer to capture the waveform and save it as a jpeg file with the cursors positioned to measure ΔV and Δt .

***Print the jpeg file**, title the print(s), identify your ΔV and Δt , write your name(s) on the print, and

staple the print to your Data Sheet.

2. Change V_i to 1 V_{pp}, (still a 1 kHz square wave) and change R2 to 100 k Ω .
Theoretical Gain $V_o/V_g = -10$

Use the scope to measure ΔV and Δt . Adjust the scope vertical sensitivity and horizontal time base to display the rising edge of the output waveform over most of the screen. Keep the measurement cursors in the linear part of the waveform – avoid the rounded ends that result from the bandwidth limitation of the high gain amplifier. To measure ΔV and Δt , you may use the scope cursors or you may capture the waveform and use the buffer cursors.

3. (5 points) Shut down Windows, return cables to racks, return parts to correct drawer bins, return adapters to container, turn off bench power, clear bench, and place seat under bench.

100 points total

Names:

by first name: 1st alphabetically – wiring 2nd alphabetically – Labview 3rd alphabetically– data sheet

Part I: OUTPUT CIRCUIT LIMITATIONS

2. $V_g =$ _____ $V_{OC} = V_O =$ _____ $V_O / V_g =$ _____

From the prelab: Theoretical $V_O/V_g =$ _____

Is your measured gain close to your theoretical gain? _____ If not, troubleshoot your circuit until you find the problem.

Measured $I_{SC} =$ _____

From Pspice: Simulated $I_{sc} =$ _____

How does the measured I_{sc} compare to the Pspice simulation?

From the prelab: Short circuit current $I_{sc} =$ _____ typical

Is this op-amp short circuit current performance acceptable? Why or why not?

3.

Table 9-1

Load Resistance	Measured Load Voltage	Calculated Load Current
100Ω		
300Ω		
500Ω		
1000Ω		

Why is the load voltage lower than expected for smaller values of R_L ? (see prelab notes)

$R_{Lmin} =$ _____ $V_O =$ _____ How did the circuit perform with your R_{Lmin} ?

4. Measured V_o where the negative swing clips _____

Measured V_o where the positive swing clips _____

From Pspice: $V_{Omax} =$ _____, $V_{Omin} =$ _____

How does the measured voltage swing of your OpAmp compare to the Pspice simulation?

From the prelab: Data Sheet T_A (min to max) = \pm _____ minimum or \pm _____ typical

Is your OpAmp's output voltage swing performance acceptable? Why or why not?

PART II: GAIN BANDWIDTH PRODUCT

1. **Table 9-2**

R_2	Passband V_o		Passband dB		dB @ f_{high}	f_{high}	
	Prelab	Measured	Prelab	Measured		Prelab	Measured
47k Ω							
100k Ω							
470k Ω							

How do your measured values for V_o , passband dB, and f_{high} compare to the expected values calculated in the prelab?

Calculate the measured Gain = V_o / V_g and the Gain-BW product = $|Gain| \times f_{high}$ for each R_2 and enter this information in Table 9-3.

Table 9-3

R_2	Gain V_o/V_g		Gain-BW product
	Prelab	Measured	
47k Ω			
100k Ω			
470k Ω			

How do your measured gains compare to your expected values from the prelab?

Is the small signal gain-bandwidth product reasonably constant for your amplifier? Should it be?

2. Your predicted unity gain bandwidth = _____

From the prelab: Unity Gain Bandwidth Spec _____

Is this op-amp bandwidth performance acceptable? Why or why not?

PART III: SLEW RATE

1. $\Delta V =$ _____, $\Delta t =$ _____, Slew Rate = $\Delta V / \Delta t =$ _____

2. $\Delta V =$ _____, $\Delta t =$ _____, Slew Rate = $\Delta V / \Delta t =$ _____

Are the slew rates for part 1 and 2 close to the same? _____

Should the slew rates be the same? _____ (hint: see the prelab notes)

What causes the rounding of the waveform at the end of the voltage swing of the large gain amplifier?
(hint: see the prelab notes about bandwidth)

From Pspice: Slew Rate = _____

How does the measured slew Rate compare to the Pspice simulation?

From the Prelab: Slew Rate Specification from data sheet _____ typical

Is your OpAmp's Slew Rate performance acceptable? Why or why not?