

ENGR-2300
Electronic Instrumentation
Quiz 2
Fall 2021

Name _____

Section ____

Question I (20 points) _____

Question II (20 points) _____

Question III (20 points) _____

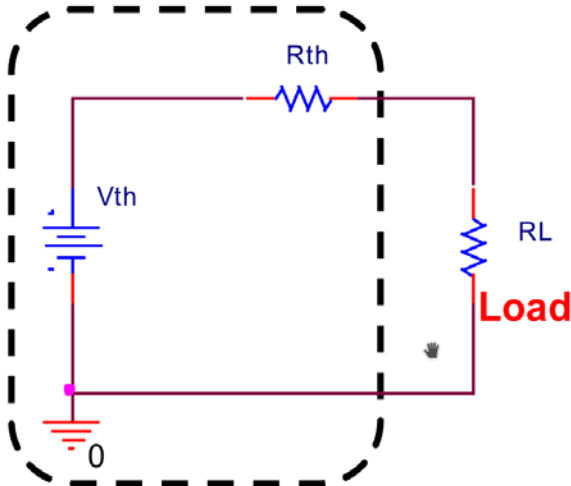
Question IV (20 points) _____

LMS Question is worth an additional 20pts

Total (80 points) _____

On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS. No credit will be given for numbers that appear without justification. Read the entire quiz before answering any questions. Also it may be easier to answer parts of questions out of order. **If you run out of room to write your answers on the printed quiz, please attach scratch paper with additional answers rather than writing on the back of the exam pages.**

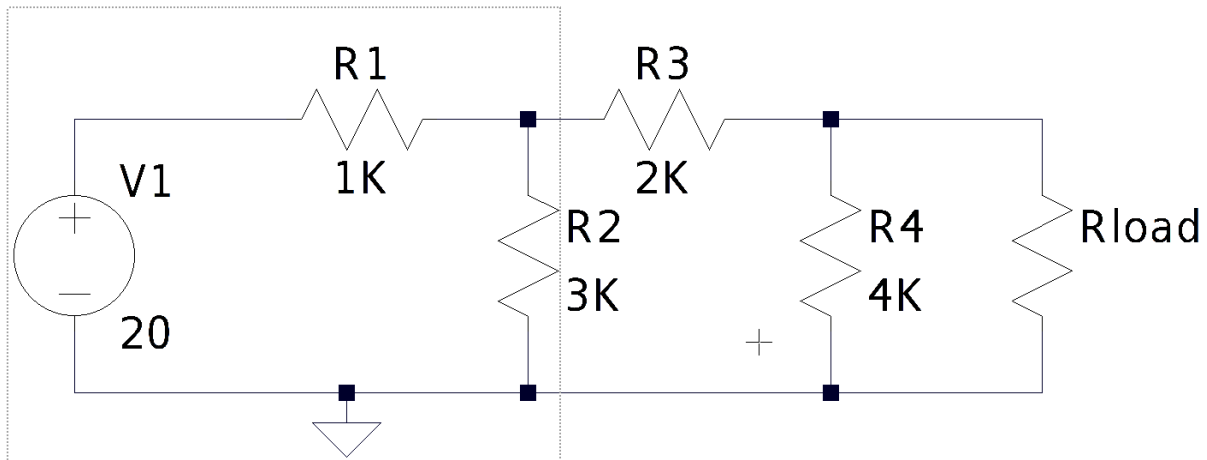
I. Thevenin Equivalent And Voltage Follower (20 points)



The Thevenin Equivalent Circuit consists of a voltage source in series with a resistor, which provides a very simple replacement for much more complex circuits. If we have this simple source, analyzing complex loads becomes quite easy.

- a) (5 pts) Two measurements are performed in order to determine the unknowns, V_{th} and R_{th} . In the first measurement, the load resistor R_L is $1\text{ k}\Omega$. A second measurement is made in which R_L is changed to $8\text{ k}\Omega$. For these two measurements, the voltage across the load resistor, V_L , is experimentally found to 1.0V and 4V respectively as shown in the table below. Using these two measurements, find the two unknowns, R_{th} and V_{th} .

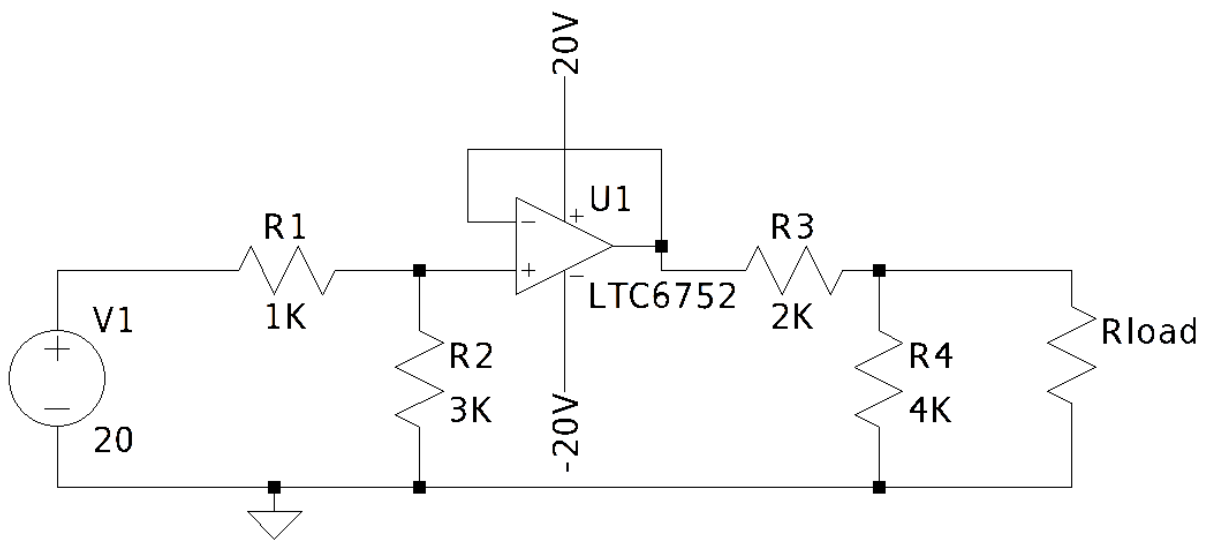
R_L (in ohms)	V_L (in volts)
1k	1.0
8k	4



b) (4 pts) Now consider a different circuit, shown above. Find and sketch the Thévenin equivalent voltage source (which will include V_{th} and R_{th}) for the part of the circuit inside the gray dotted box. (This includes R_1 , R_2 , and V_1).

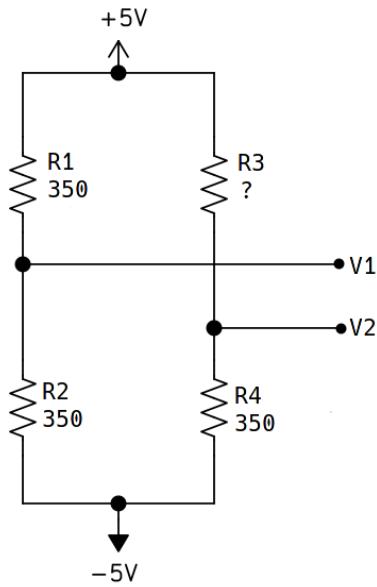
c) (4 pts) Now find and sketch the Thévenin equivalent voltage source for the entire circuit. (This includes V_1 , R_1 , R_2 , R_3 , and R_4 .)

- d) (3 pts) Using the Thévenin equivalent circuit obtained in part c, find the current through the load resistor when $R_L = 1 \text{ k}\Omega$.

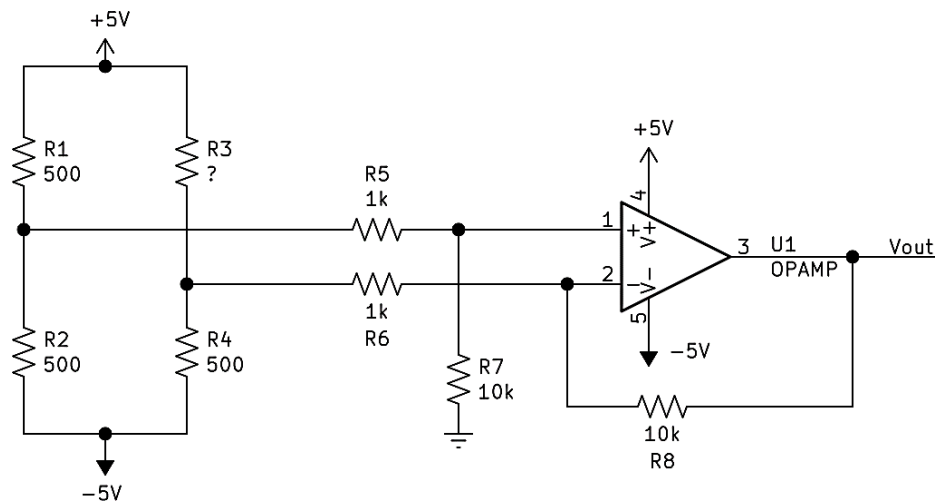


- e) (4 pts) An ideal voltage follower is now placed between R2 and R3 as shown above. What is the new current through the load resistor?

II. Strain Gauges and Bridges (20 points)

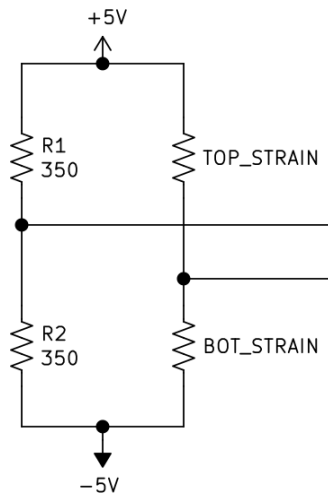


- a. (3 pts) In the strain gauge above, suppose that $R3$ has a value of 320Ω . What is the differential voltage output ($V1 - V2$)?



- b. (7 pts) Now we look at a new strain gauge connected to a differential amplifier as shown on the bottom of the previous page. If the voltage V_{out} is 800mV, find the value of R_3 . (*Assume that the op amp is a rail-to-rail chip, meaning that the output can reach the voltage of the power supplies; otherwise assume it is ideal.*)
- c. (4 pts) Suppose that the value of R_3 in part b varies from 450Ω to 550Ω during normal operation. Assuming that you keep the values of R_7 and R_8 equal, what is the maximum resistance that can be chosen for R_7 and R_8 without causing saturation of the op amp output?

- d. (2 pts) In Experiment 5 and Project 2, you were asked to consistently use the same cantilever beam and strain gauge each time you came to class or open shop. Why was this the case?
- e. (2 pts) In Experiment 5 and Project 2, the bridge had two strain gauges in it, as shown below. One was on the top of the beam and the other was on the bottom. What is the usefulness in having two strain gauges?

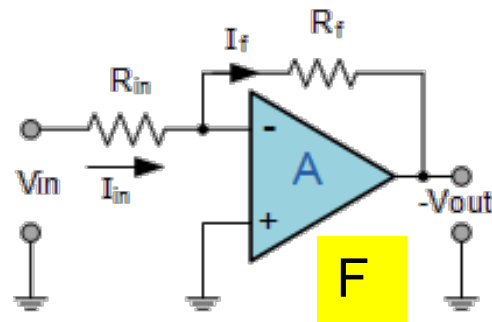
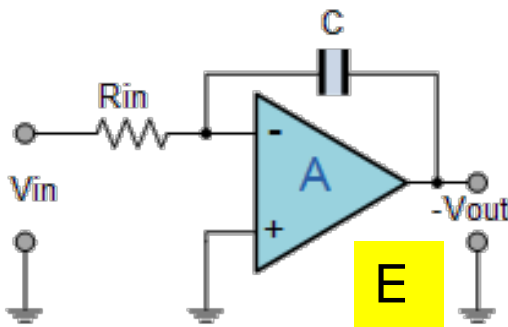
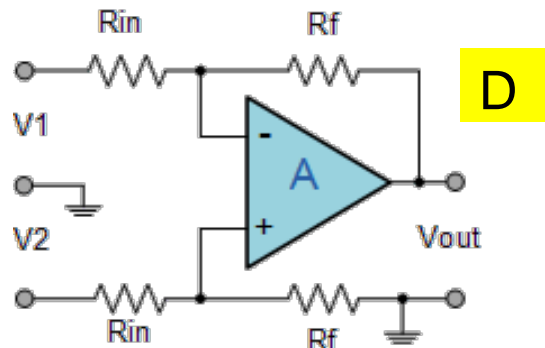
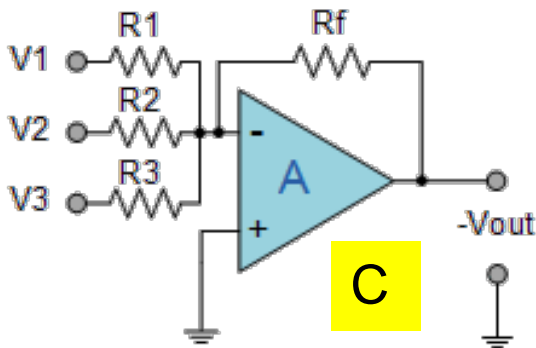
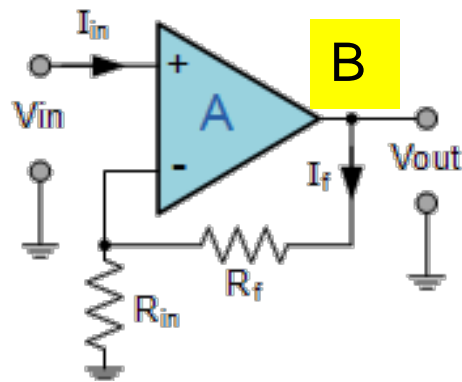
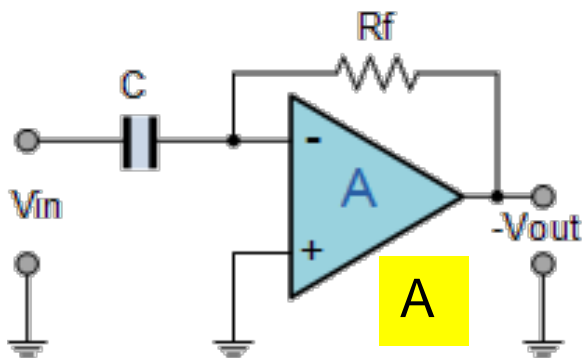


- f. (2 pts) Suppose that the voltage output of the circuit described in part b needs to be “re-zeroed” – specifically, the beam is at rest but the circuit is outputting a small positive voltage and you need to make the voltage read 0V. Describe a change you would make to the circuit to achieve this.

III. Operational Amplifier Applications (20 points)

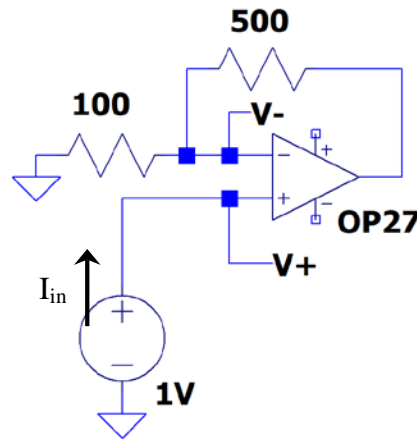
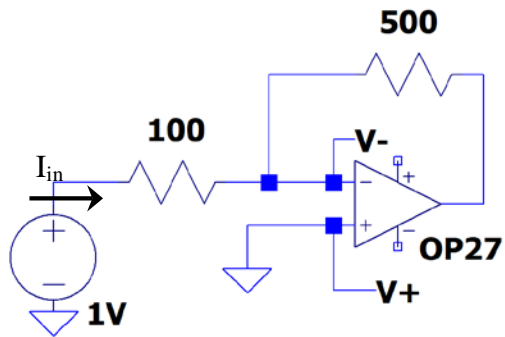
a. (3 pts) What type of amplifier is each circuit?

A	B
C	D
E	F



- b. (6 pts) Design a non-inverting amplifier circuit with a **gain of 20**, specify resistor values, the resistors must have values of $\geq 1\text{k}\Omega$. Draw the circuit schematic. Be sure to label the input and the output. You can assume any resistor value is available.

- c. (6 pts) Using the ideal op amp rules, “Op Amp Analysis Rules”, determine for each circuit below the values for V_+ , V_- , and I_{in} . These circuits aren’t connected to each other in any way. As with all problems, include units.



Left Circuit:

$V_+ = \underline{\hspace{2cm}}$

$V_- = \underline{\hspace{2cm}}$

$I_{in} = \underline{\hspace{2cm}}$

Right Circuit:

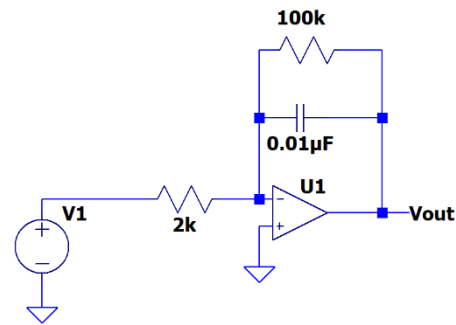
$V_+ = \underline{\hspace{2cm}}$

$V_- = \underline{\hspace{2cm}}$

$I_{in} = \underline{\hspace{2cm}}$

d. (5 pts) For the circuit shown on the right:

i) (1pt) For what range of frequencies will this behave as an integrator? Provide the answer in Hertz.

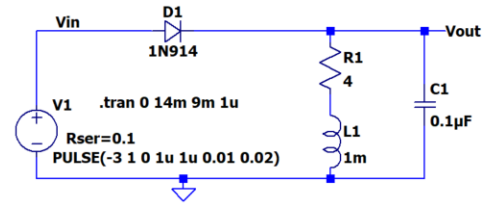


ii) (1pt) Will it be a reasonable integrator if V_1 is a sinewave at 2kHz?

iii) (3pts) For this part assume it is a good integrator. If V_1 is a sinewave with an amplitude of 0.5V and a frequency of 2kHz and a phase angle at $t=0$ or 0 degrees, what is V_{out} in the form of $V_{out}=V_{amp}\sin(\omega t+\theta)$. In other words: Give V_{amp} , ω , and θ of the output.

IV. Concepts, Troubleshooting and Data Analysis (20 points)

a. (7 pts) Real components compared to ideal: In Experiment 5 you built and modeled the circuit on the right.



i. (1 pt) For the LTspice model you included R1. But you didn't put a resistor there when you built the circuit. Why not?

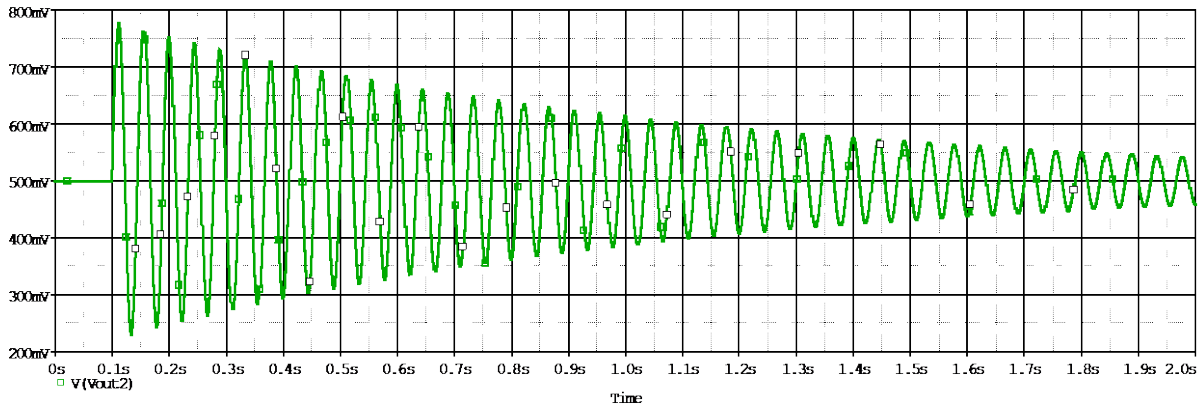
ii. (1 pt) Energy is lost as a function of time in the harmonic oscillator circuit as V_{out} was oscillating. Which component in the circuit shown in part i. of this problem causes the energy loss?

iii. (2 pts) Continuing with the energy loss question, will the energy loss be most rapid when the current in the inductor is at the maximum, or at 0A or energy loss doesn't depend on which part of the oscillation? Circle one.

peak energy loss at:

I_L is at a peak $I_L=0$ doesn't depend on which part of an oscillation (circle one)

iv. (3 pts) The inductor used for this circuit was a 1mH inductor. If by mistake your partner used a 10mH inductor, would the resonant frequency go up or down, and by what percentage would the frequency change, to the nearest 1%?



- b. (4 pts) The plot shown above represents data taken from the accelerometer on a beam after it has been integrated by an op-amp circuit. Note that there is a dc offset, typical of integration. Find the decay constant α and the angular frequency ω for this data. **You must mark the data points on the plot that you use for your answer.**

- c. (4 pts) Classroom Knowledge and Tasks: **True or False, circle one.**

- i. Before beginning a lab, at least one team member must read over and be generally acquainted with the experiment or project write-up and the other **required reading** materials listed on the EILinks page.

True or False

- ii. The velocity of the beam can be measured by using a differentiator op amp circuit with the accelerometer.

True or False

- iii. When asking for a signature on a check off page you show the instructor a live simulation or instrumentation board measurement. Live refers to it running on your computer at the time of the check off.

True or False

- iv. You don't need to have done hand-drawn schematics for the first checkoff of an experiment.

True or False

$V_S = \pm 15\text{ V}$, $T_A = 25^\circ\text{C}$, unless otherwise noted.

Table 1.

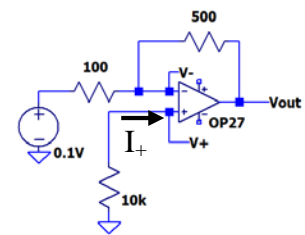
Parameter	Symbol	Test Conditions	OP27A/OP27E			OP27G			Unit
			Min	Typ	Max	Min	Typ	Max	
INPUT OFFSET VOLTAGE ¹	V_{OS}		10	25		30	100	μV	
LONG-TERM V_{OS} STABILITY ^{2,3}	V_{OS}/Time		0.2	1.0		0.4	2.0	$\mu\text{V}/\text{Mo}$	
INPUT OFFSET CURRENT	I_{OS}		7	35		12	75	nA	
INPUT BIAS CURRENT	I_B		± 10	± 40		± 15	± 80	nA	
INPUT NOISE VOLTAGE ^{3,4}	$e_{n,p-p}$	0.1 Hz to 10 Hz	0.08	0.18		0.09	0.25	$\mu\text{V p-p}$	
INPUT NOISE Voltage Density ³	e_n	$f_0 = 10\text{ Hz}$	3.5	5.5		3.8	8.0	$\text{nV}/\sqrt{\text{Hz}}$	
		$f_0 = 30\text{ Hz}$	3.1	4.5		3.3	5.6	$\text{nV}/\sqrt{\text{Hz}}$	
		$f_0 = 1000\text{ Hz}$	3.0	3.8		3.2	4.5	$\text{nV}/\sqrt{\text{Hz}}$	
INPUT NOISE Current Density ³	i_n	$f_0 = 10\text{ Hz}$	1.7	4.0		1.7	4.0	$\text{pA}/\sqrt{\text{Hz}}$	
		$f_0 = 30\text{ Hz}$	1.0	2.3		1.0	2.3	$\text{pA}/\sqrt{\text{Hz}}$	
		$f_0 = 1000\text{ Hz}$	0.4	0.6		0.4	0.6	$\text{pA}/\sqrt{\text{Hz}}$	
INPUT RESISTANCE Differential Mode ⁵	R_{IN}		1.3	6		0.7	4	M Ω	
		Common Mode		3		2		G Ω	
INPUT VOLTAGE RANGE	IVR		± 11.0	± 12.3		± 11.0	± 12.3	V	
COMMON-MODE REJECTION RATIO	CMRR	$V_{CM} = \pm 11\text{ V}$	114	126		100	120	dB	
POWER SUPPLY REJECTION RATIO	PSRR	$V_S = \pm 4\text{ V to } \pm 18\text{ V}$		1	10		2	20	$\mu\text{V}/\text{V}$
LARGE SIGNAL VOLTAGE GAIN	A_{VO}	$R_L \geq 2\text{ k}\Omega$, $V_O = \pm 10\text{ V}$	1000	1800		700	1500	V/mV	
		$R_L \geq 600\ \Omega$, $V_O = \pm 10\text{ V}$	800	1500		600	1500	V/mV	
OUTPUT VOLTAGE SWING	V_O	$R_L \geq 2\text{ k}\Omega$	± 12.0	± 13.8		± 11.5	± 13.5	V	
		$R_L \geq 600\ \Omega$	± 10.0	± 11.5		± 10.0	± 11.5	V	
SLEW RATE ⁶	SR	$R_L \geq 2\text{ k}\Omega$	1.7	2.8		1.7	2.8	V/ μs	
GAIN BANDWIDTH PRODUCT ⁶	GBW		5.0	8.0		5.0	8.0	MHz	
OPEN-LOOP OUTPUT RESISTANCE	R_O	$V_O = 0$, $I_O = 0$		70			70	Ω	
POWER CONSUMPTION	P_d	V_O		90	140		100	170	mW
OFFSET ADJUSTMENT RANGE		$R_p = 10\text{ k}\Omega$		± 4.0			± 4.0	mV	

d. (5 pts) Part of the data sheet for the OP27 is shown. Use this to answer the following questions. Look at typical values for the G version, OP27G.

i. If the OP27G is powered by $\pm 15\text{ V}$ supplies and has a $10\text{ k}\Omega$ load, what are the expected maximum and minimum output voltages you can expect to achieve? (1pt)

ii. If the load is changed to $600\ \Omega$, what is the expected max and min output voltages? (1pt)

iii. For the ideal op amp model what are the value of I_+ and V_+ as shown in the figure on the right?(1pt)



iv. The data sheet lists the actual expected values of I_+ as something called INPUT BIAS CURRENT. Using the largest **typical** value of the INPUT BIAS CURRENT, what would be the value of V_+ for this circuit? (2pt)

v. (2pt) Extra credit: Given your answer above, what would be the error in V_{out} due to the INPUT Bias Current?