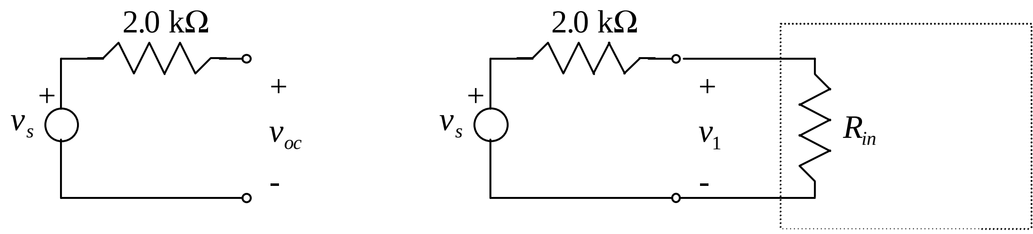
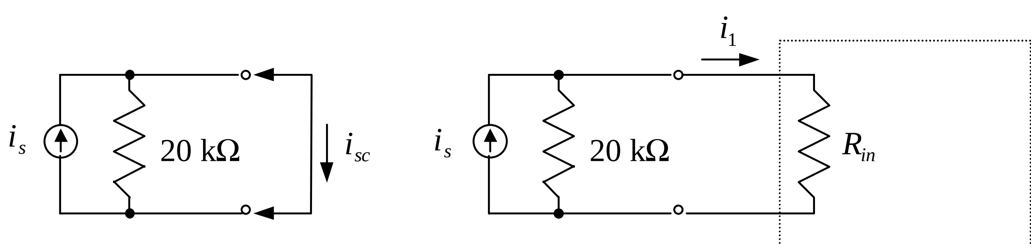
3. Problems

1. The circuit on the left below shows a sensor whose open-circuit voltage v_{oc} has a maximum value of 0.5 V. The circuit on the right shows this sensor connected to the input of an amplifier.



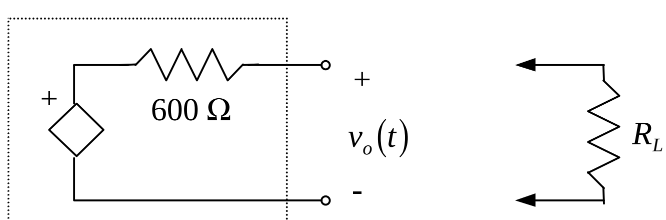
   Find the minimum value of amplifier input resistance R_{in} so that the voltage v_1 will have a maximum value of at least 0.4 V.

2. The circuit on the left below shows a sensor whose short-circuit current i_{sc} has a maximum value of 2.0 mA. The circuit on the right shows this sensor connected to the input of an amplifier.



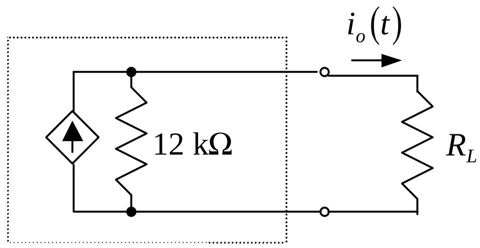
   Find the maximum value of amplifier input resistance R_{in} so that the input current i_1 will have a maximum value of at least 1.5 mA.

3. The output of an amplifier is modelled below. When output is terminated in an open circuit, the output voltage is $v_o(t) = 5\cos\left(2\pi 250t + \frac{\pi}{6}\right)$ V.



Suppose a load resistor R_L is to be connected across the amplifier output. Find the minimum value of R_L so that the output voltage will have a peak value of at least 3.5 V.

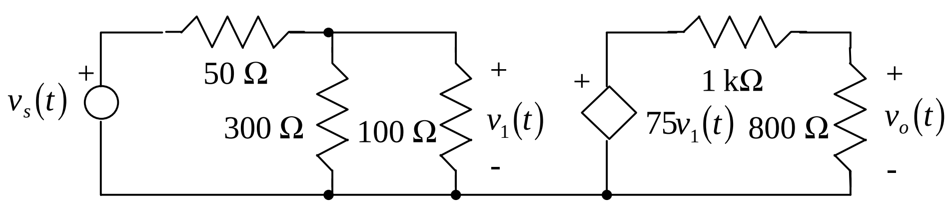
4. The circuit shown below models the output of an amplifier. The amplifier is driving a load resistor R_L. When $R_L = 10\ \text{k}\Omega$ the load current is found to be $i_o(t) = 2.50\cos(2\pi 300\times 10^5 t)$ mA.



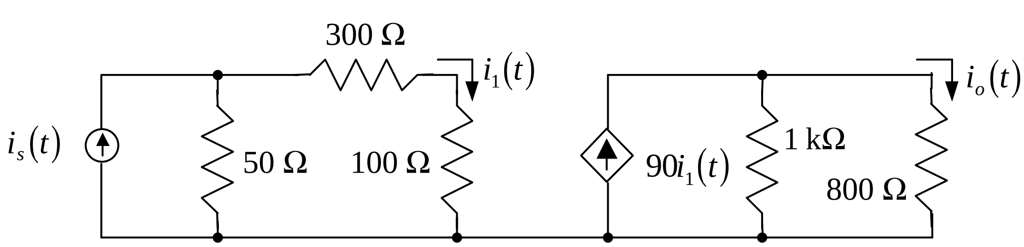
A. Find the maximum value of R_L if the load current is to have a peak value of at least 4.00 mA.

B. What is the maximum possible value of the peak load current?

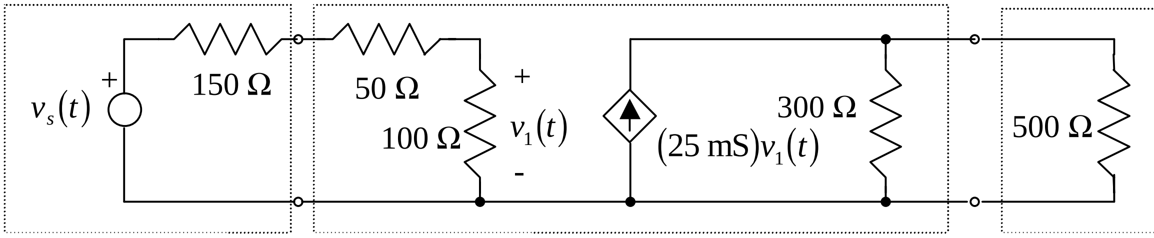
5. Find the loaded voltage gain $A_V = \frac{v_o}{v_s}$ of the amplifier whose model is shown below.



6. Find the loaded current gain $A_I = \frac{i_o}{i_s}$ of the amplifier whose model is shown below.

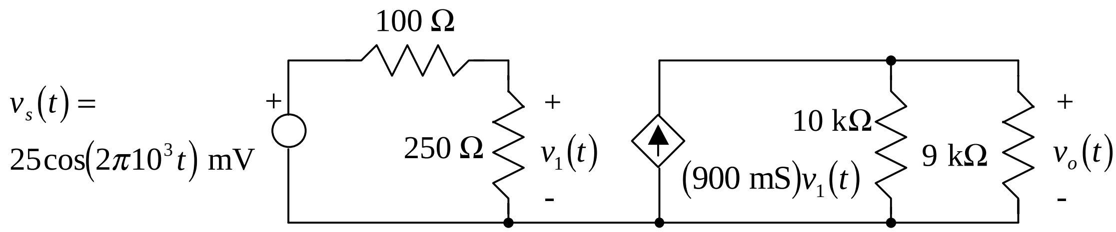


7. The diagram below shows a non-ideal source driving an amplifier, which in turn drives a $500\ \Omega$ load resistor.



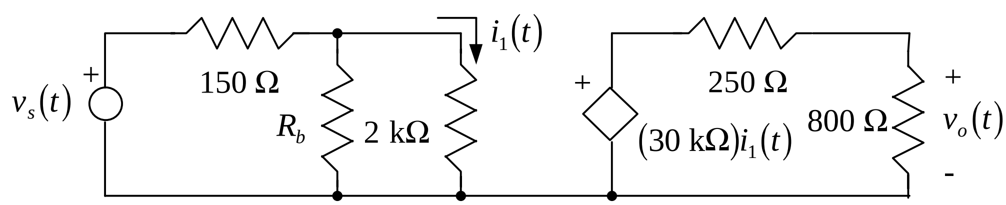
A. Find the power p_S that the non-ideal source provides to the amplifier. Your answer will be expressed in terms of $v_s(t)$.
B. Find the power p_L that the amplifier provides to the load. Your answer will again be expressed in terms of $v_s(t)$.
C. Find the power gain $A_P = \frac{p_L}{p_S}$.
D. Express the power gain in decibels, where $A_P\big|_{dB} = 10\log(A_P)$.

8. The diagram below shows an amplifier driven by a sinusoidal voltage source.

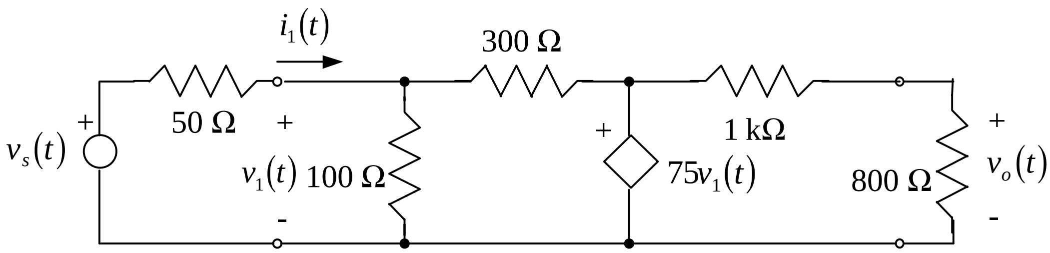


A. Find the output voltage $v_o(t)$.
B. Plot $v_s(t)$ and $v_o(t)$.
C. What is the phase difference between the input and output voltages?

9. Find the minimum value of R_b in the amplifier whose model is shown below so that the voltage gain $A = \frac{v_o}{v_s}$ is at least ten.



10. The amplifier model shown below contains a 300 Ω feedback resistor.

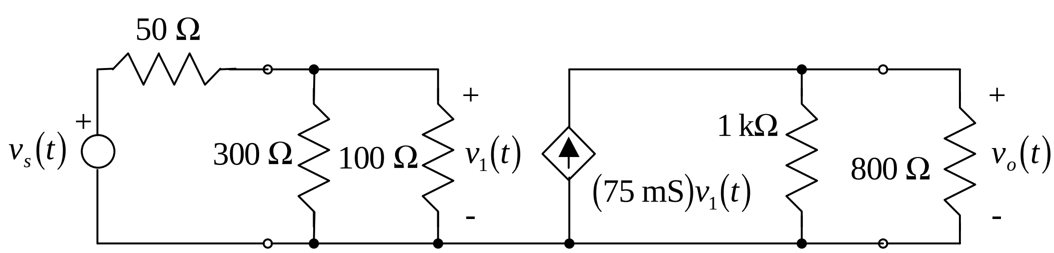


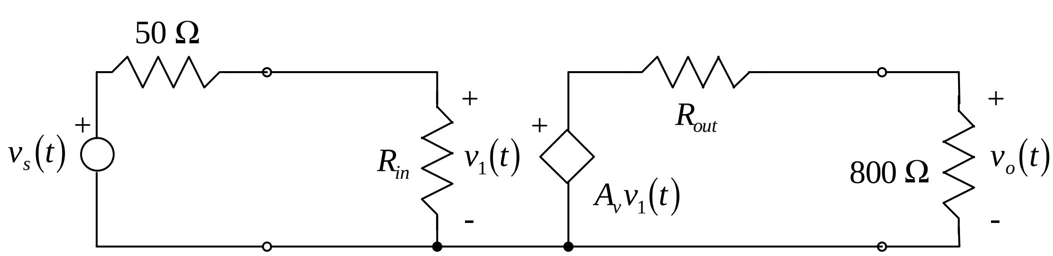
A. Find the voltage gain $A_v = \frac{v_o}{v_1}$.

B. Find the input resistance $R_{in} = \frac{v_1}{i_1}$ seen by the voltage source.

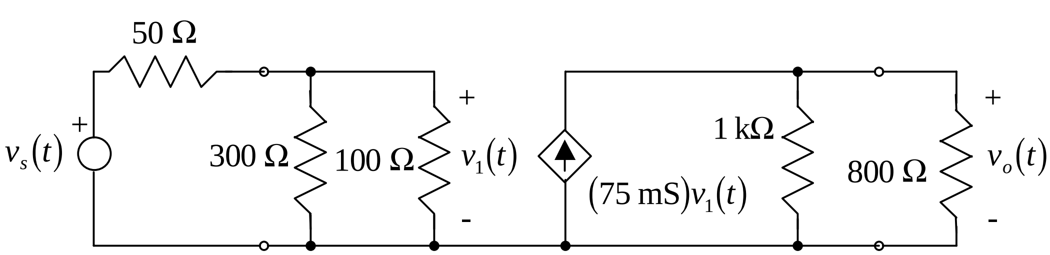
C. Find a Thevenin equivalent model for the amplifier as seen looking back from the 800 Ω load resistor.

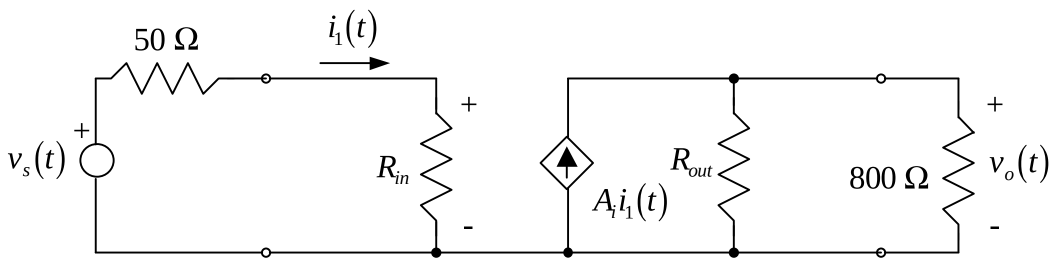
11. The schematic diagram below is a model of an amplifier. A simpler model for the same amplifier is also shown. Find values for R_{in}, R_{out}, and A_v so that the two models are equivalent.



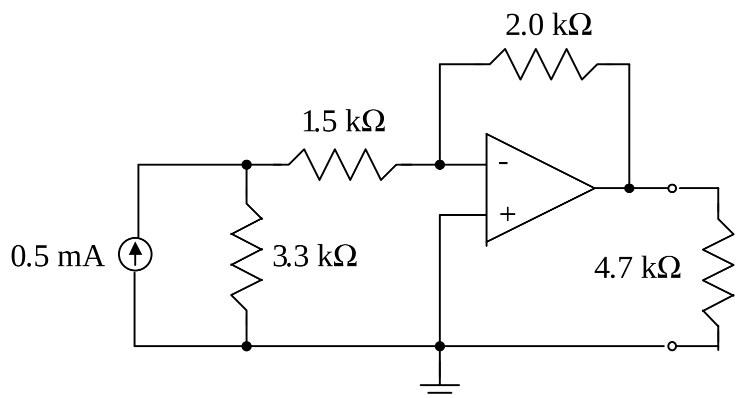


12. The schematic diagram below is a model of an amplifier. A simpler model for the same amplifier is also shown. Find values for R_{in}, R_{out}, and A_v so that the two models are equivalent.

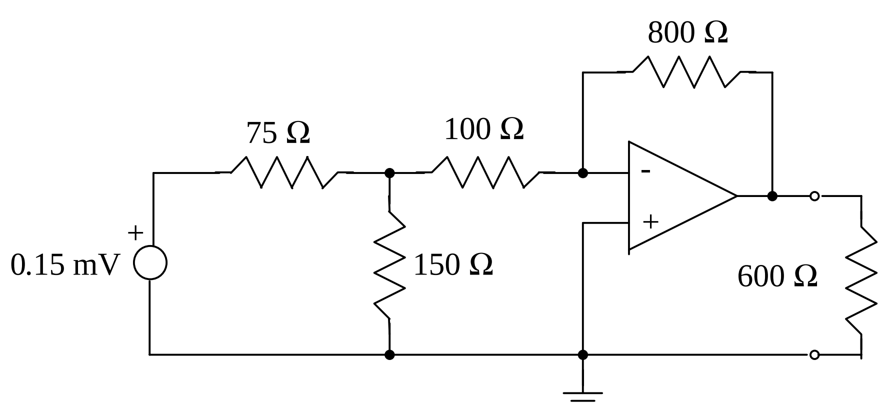




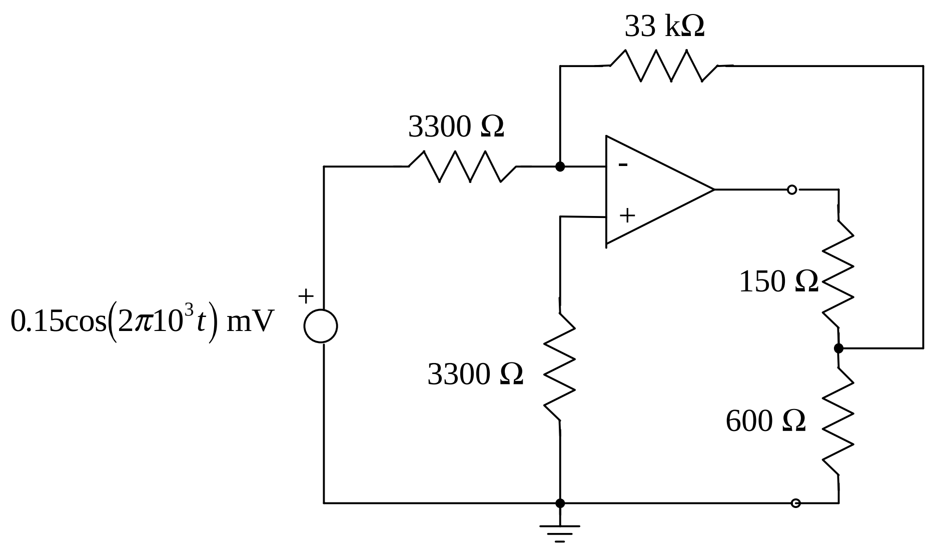
13. The circuit shown below contains an ideal op-amp. Find all of the voltages and currents.



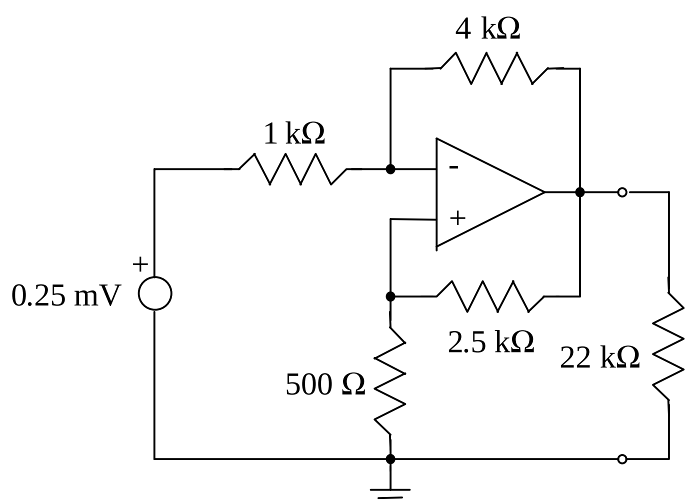
14. The circuit shown below contains an ideal op-amp. Find all of the voltages and currents.



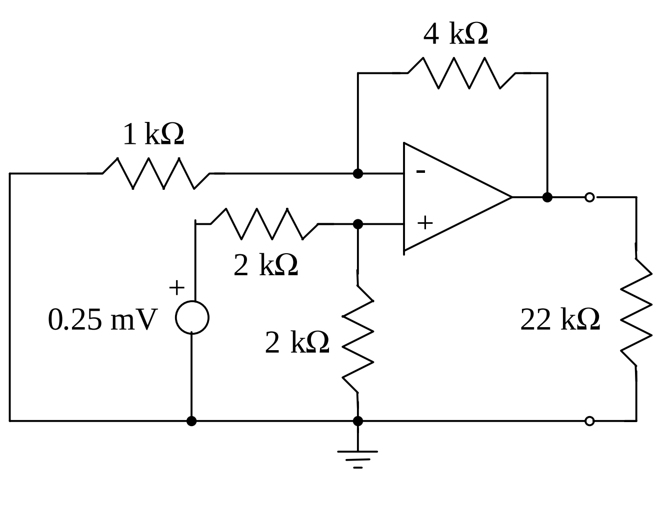
15. The circuit shown below contains an ideal op-amp. Find all of the voltages and currents.



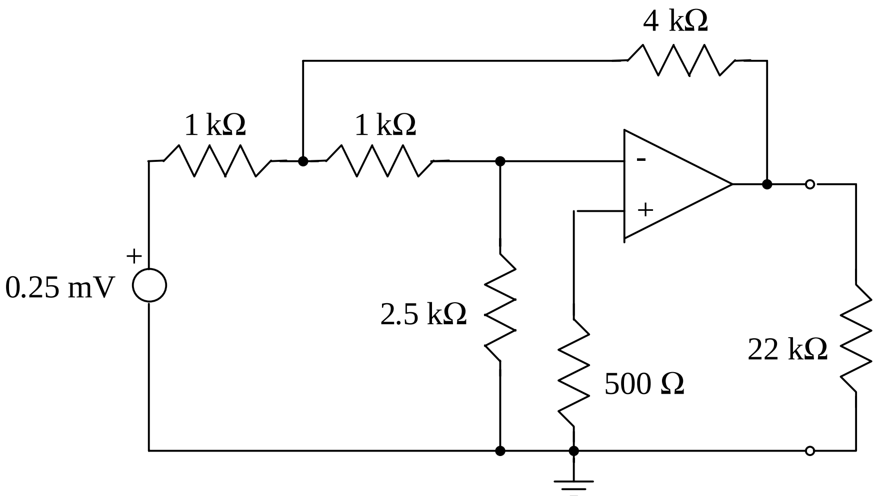
16. The circuit shown below contains an ideal op-amp. Find all of the voltages and currents.



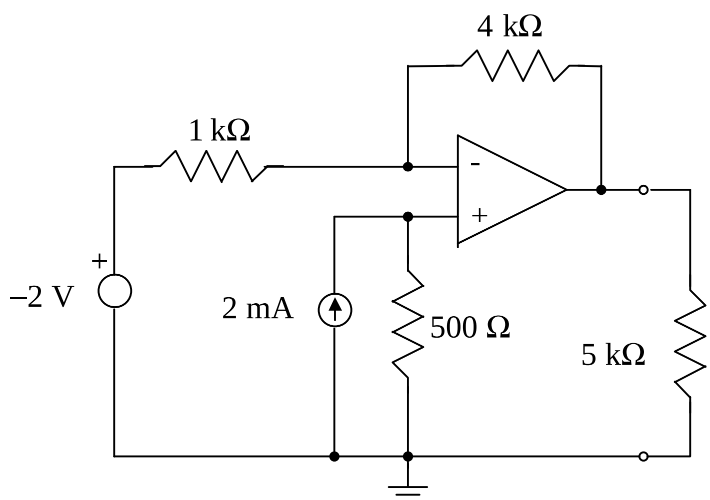
17. The circuit shown below contains an ideal op-amp. Find all of the voltages and currents.



18. The circuit shown below contains an ideal op-amp. Find all of the voltages and currents.

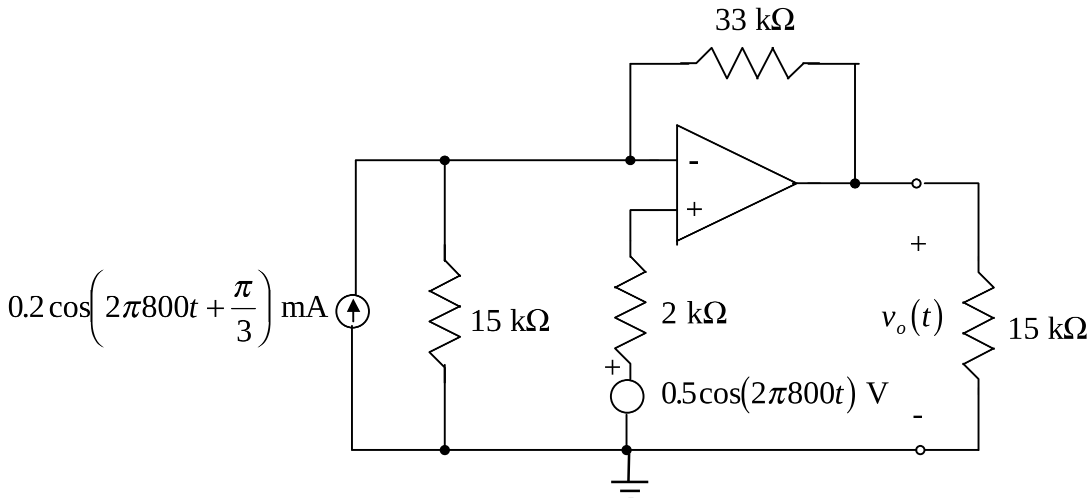


19. The circuit shown below contains an ideal op-amp. Find all of the voltages and currents.

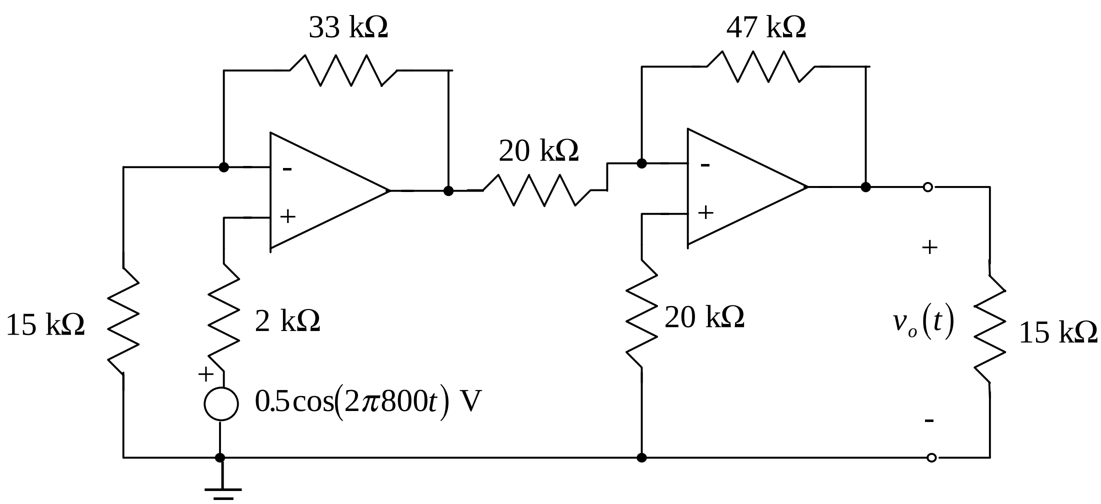


20. The circuit shown below contains an ideal op-amp.

A. Find all of the voltages and currents.
B. Plot several cycles of the output voltage $v_o(t)$. Determine from your plot the peak output voltage V_{oP}.

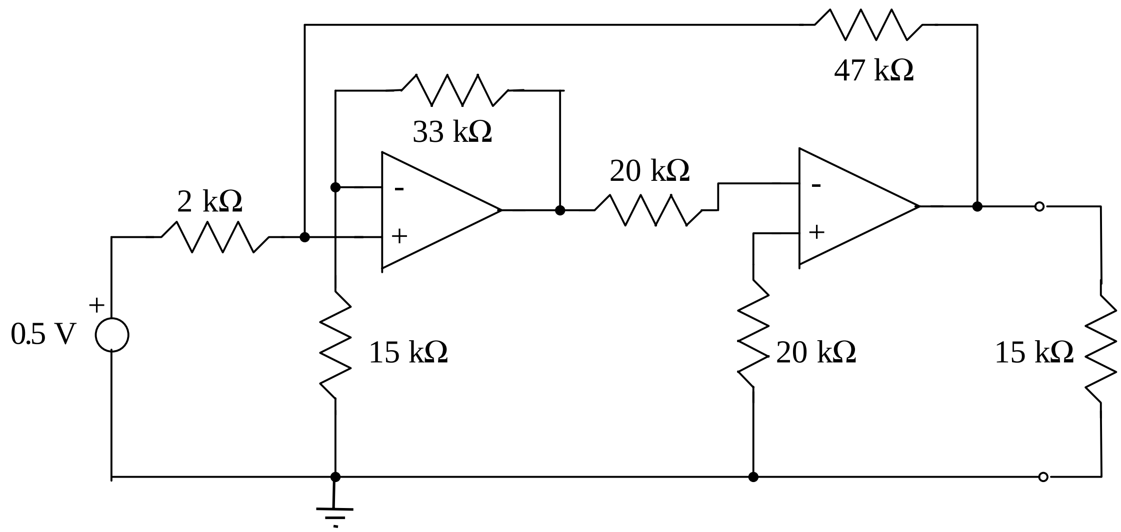


21. The circuit shown below contains ideal op-amps.

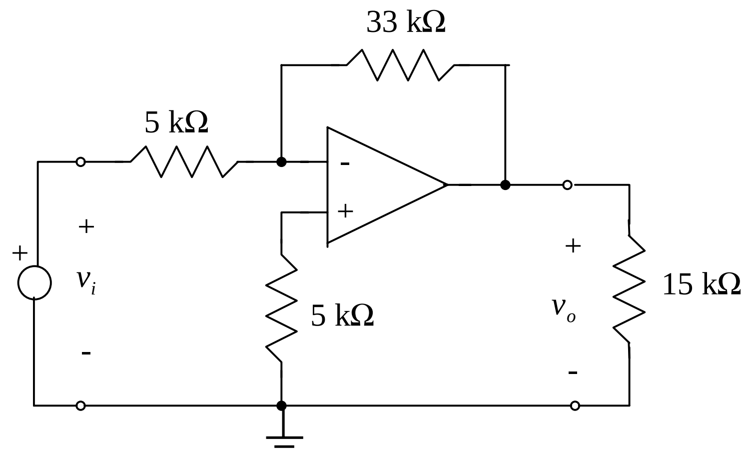


A. Find all of the voltages and currents.
B. Plot the source voltage and the output voltage $v_o(t)$ on the same axes. If the source voltage is used as a reference, what is the phase of the output voltage?

22. The circuit shown below contains ideal op-amps. Find all of the voltages and currents.



23. The amplifier shown below contains an ideal op-amp.



A. Find the voltage gain $A = \frac{v_o}{v_i}$.

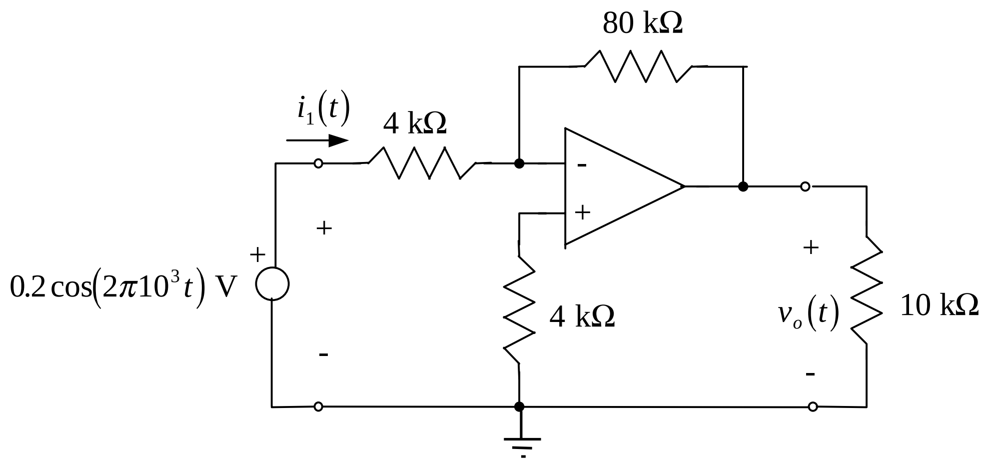
B. Find the input impedance seen by the independent source.

24. The amplifier below contains an ideal op-amp.

A. Find the output voltage $v_o(t)$.

B. Plot the output voltage and the input source voltage on the same set of axes. Find the phase of the output voltage if the source voltage is used as a reference.

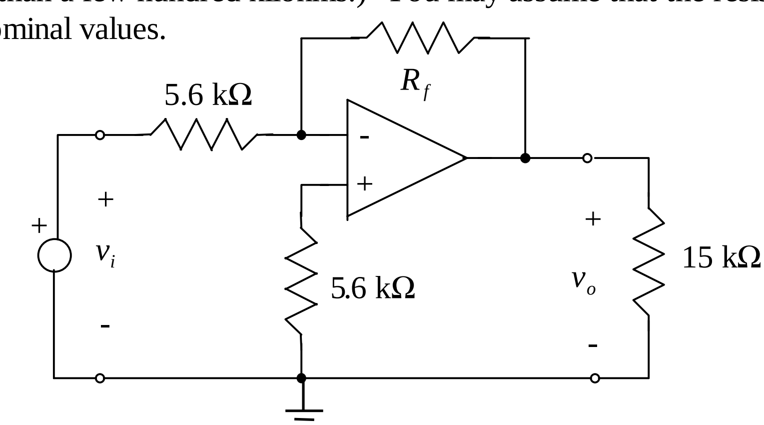
C. Find the input current $i_1(t)$.



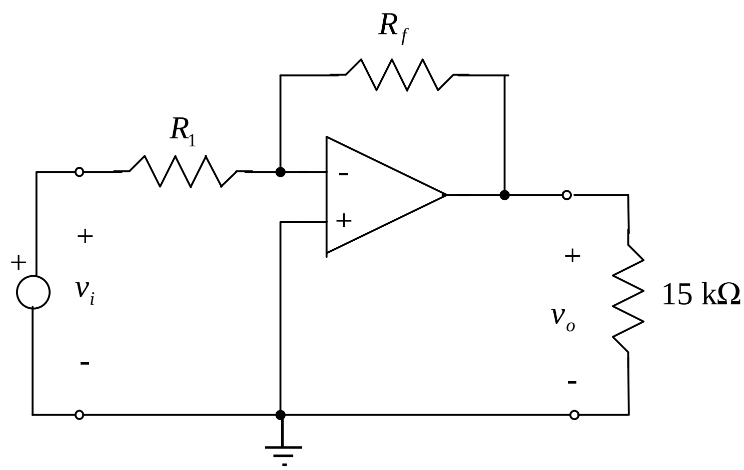
The next few problems require standard resistor values. Nominal values of resistors available in ±10 % tolerance are

10Ω	12Ω	15Ω	18Ω	22Ω	27Ω	33Ω	39Ω	47Ω	56Ω	68Ω	82Ω
100Ω	120Ω	150Ω	180Ω	220Ω	270Ω	330Ω	390Ω	470Ω	560Ω	680Ω	820Ω
1.0kΩ	1.2kΩ	1.5kΩ	1.8kΩ	2.2kΩ	2.7kΩ	3.3kΩ	3.9kΩ	4.7kΩ	5.6kΩ	6.8kΩ	8.2kΩ
10kΩ	12kΩ	15kΩ	18kΩ	22kΩ	27kΩ	33kΩ	39kΩ	47kΩ	56kΩ	68kΩ	82kΩ
100kΩ	120kΩ	150kΩ	180kΩ	220kΩ	270kΩ	330kΩ	390kΩ	470kΩ	560kΩ	680kΩ	820kΩ
1.0MΩ	1.2MΩ	1.5MΩ	1.8MΩ	2.2MΩ	2.7MΩ	3.3MΩ	3.9MΩ	4.7MΩ	5.6MΩ	6.8MΩ	8.2MΩ

25. The amplifier below uses an ideal op-amp. Find a value of feedback resistance R_f that will produce a voltage gain whose magnitude is at least fifteen. Then find the actual voltage gain of your amplifier. (A good design practice is to limit the range of resistors in op-amp circuits to a minimum not much smaller than one kilohm and a maximum not much larger than a few hundred kilohms.) You may assume that the resistors actually have their nominal values.

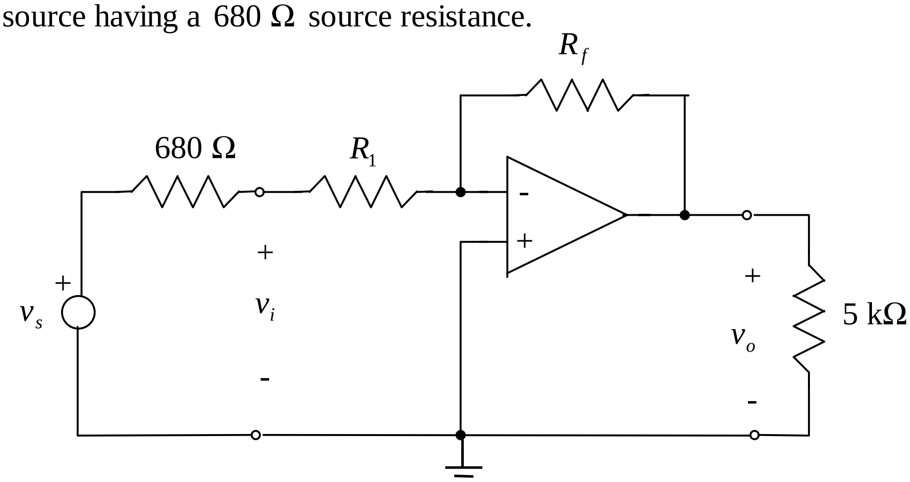


26. The amplifier below uses an ideal op-amp.



A. Using standard resistors, select values for R_1 and R_f so that the amplifier will have an input resistance of at least $2\ \text{k}\Omega$ and a gain whose magnitude is at least five. (A good design practice is to limit the range of resistors in op-amp circuits to a minimum not much smaller than one kilohm and a maximum not much larger than a few hundred kilohms.) Assume that the resistors actually have their nominal values.
B. Now suppose that the resistor values deviate from their nominal values by 10%. Either show that your design meets the given specifications even in the worst case, or redsign the amplifier so that it will meet the specifications in the worst case.

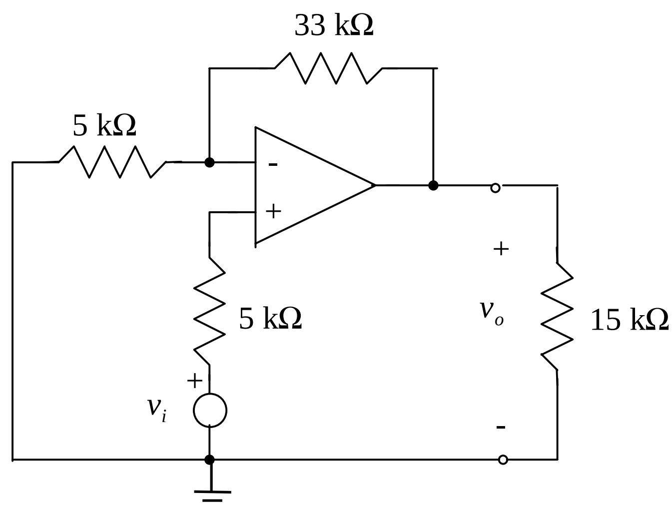
27. The amplifier shown below uses an ideal op-amp. The amplifier is driven by a non-ideal source having a $680\ \Omega$ source resistance.



A. Using standard resistors, select values for R_1 and R_f so that the amplifier's input resistance is *matched* (equal) to the source resistance, and the voltage gain $A = \frac{v_o}{v_s}$ has a magnitude at least fifteen.

B. Find the voltage gain $\frac{v_o}{v_i}$.

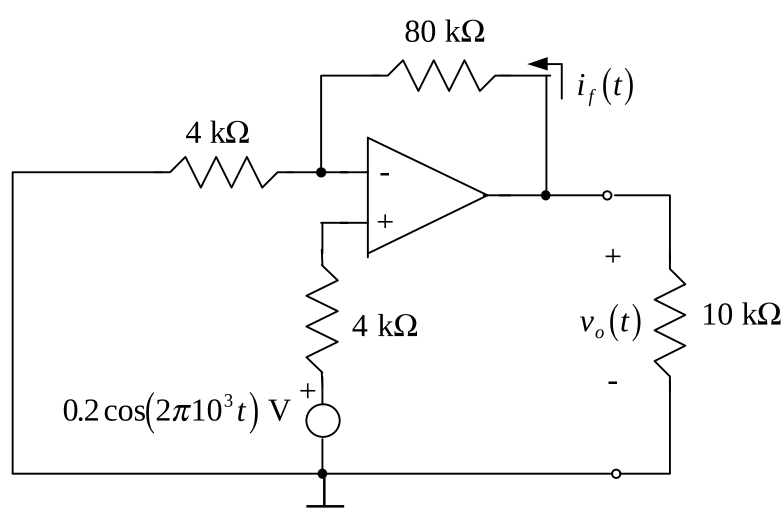
28. The amplifier shown below contains an ideal op-amp.



A. Find the voltage gain $A = \frac{v_o}{v_i}$.

B. Find the input impedance seen by the independent source.

29. The amplifier below contains an ideal op-amp.

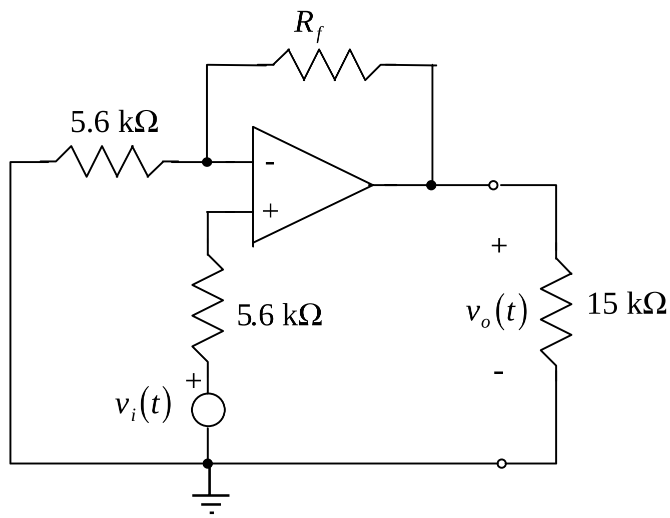


A. Find the output voltage $v_o(t)$.

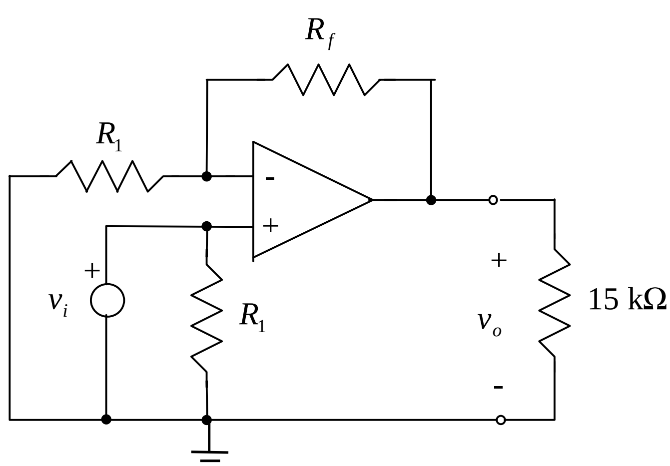
B. Plot the output voltage and the input source voltage on the same set of axes. Find the phase of the output voltage if the source voltage is used as a reference.

C. Find the feedback current $i_f(t)$. (Can you do it without the Big Gun?)

30. The amplifier below uses an ideal op-amp and standard 10% tolerance resistors (see the table just before problem 25). Find a value of feedback resistance R_f that will produce a voltage gain whose magnitude is at least fifteen. Then find the actual voltage gain of your amplifier. (A good design practice is to limit the range of resistors in op-amp circuits to a minimum not much smaller than one kilohm and a maximum not much larger than a few hundred kilohms.) You may assume that the resistors actually have their nominal values.



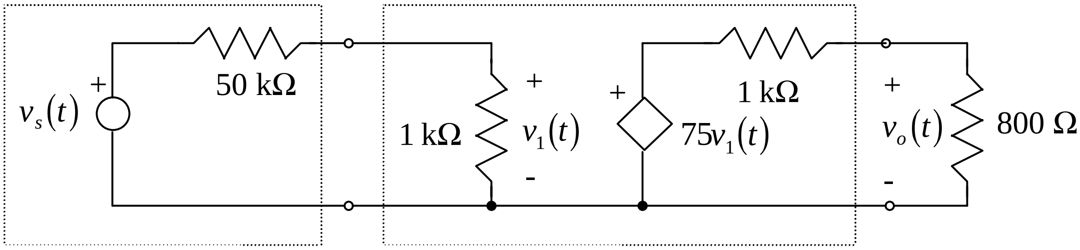
31. The amplifier below uses an ideal op-amp.



A. Using standard resistors, select values for R_1 and R_f so that the amplifier will have an input resistance of at least $2\ \text{k}\Omega$ and a gain whose magnitude is at least five. (A good design practice is to limit the range of resistors in op-amp circuits to a minimum not much smaller than one kilohm and a maximum not much larger than a few hundred kilohms.) Assume that the resistors actually have their nominal values.

B. Now suppose that the resistor values deviate from their nominal values by 10%. Either show that your design meets the given specifications even in the worst case, or redsign the amplifier so that it will meet the specifications in the worst case.

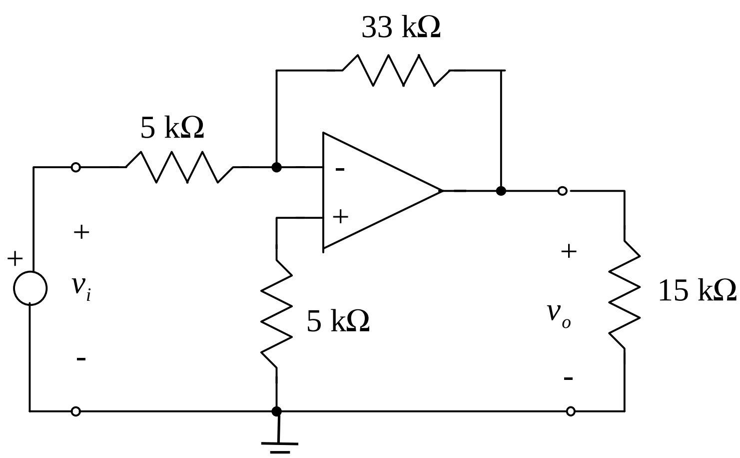
32. The circuit below shows a transducer connected to an amplifier.



A. Find the voltage gain $A = \frac{v_o}{v_s}$.

B. Suppose a voltage gain of $A = 150$ is needed. Design a non-inverting buffer to be placed between the transducer and the amplifier so that the required gain can be realized. Use standard resistance values as given in the table just before problem 25. (A good design practice is to limit the range of resistors in op-amp circuits to a minimum not much smaller than one kilohm and a maximum not much larger than a few hundred kilohms.) Assume that the resistors actually have their nominal values.

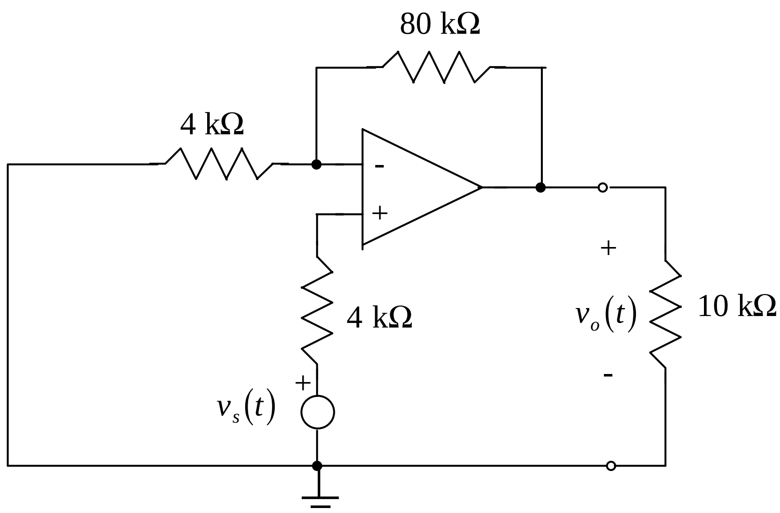
33. In the amplifier below $V_{SAT+} = -V_{SAT-} = 13.6$ V. Find the maximum and minimum values of v_i for which the op-amp will operate in its linear active region.



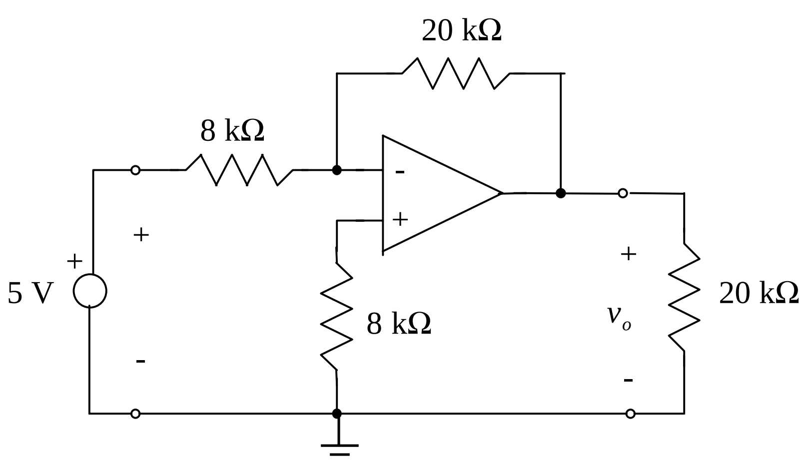
34. The amplifier circuit shown below operates from a ±12 V power supply.

A. Find the maximum and minimum values of the output voltage $v_o(t)$.

B. Find the maximum and minimum values of the input voltage $v_s(t)$ for which the op-amp will operate in its linear active region.

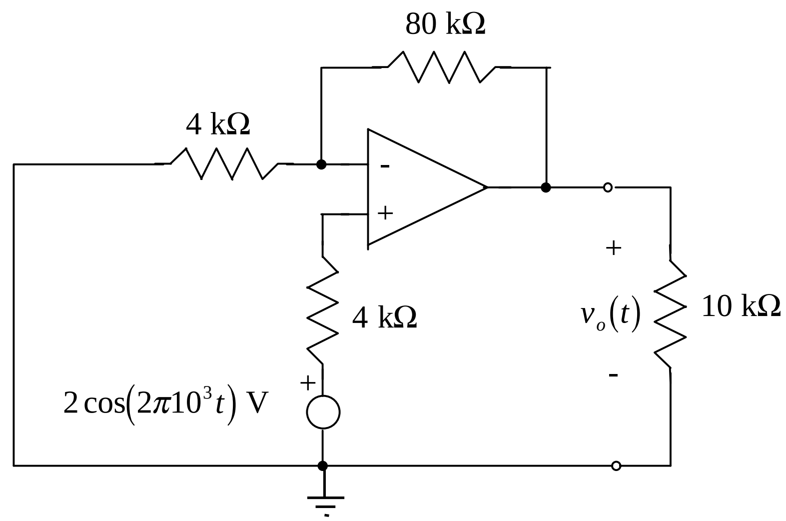


35. The amplifier shown below operates from a ±10 V power supply.

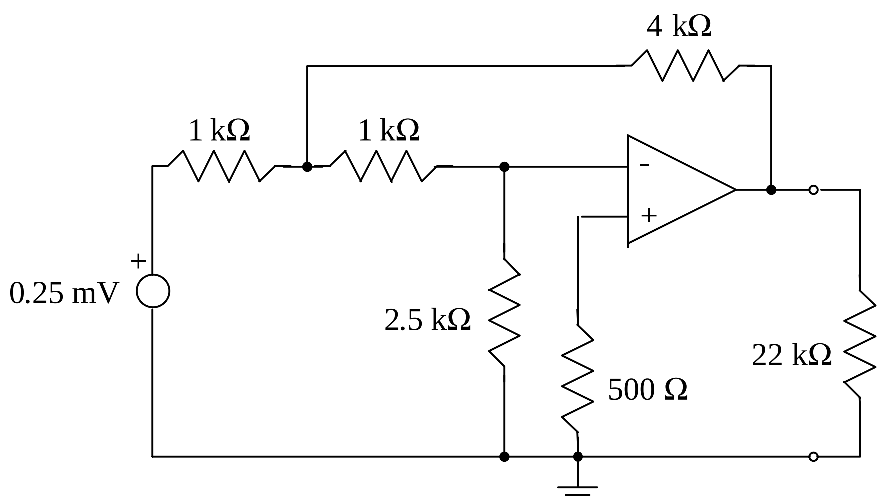


A. Determine whether the op-amp is saturated.
B. Find the output voltage v_o.

36. The amplifier shown below operates from a ±15 V power supply. Plot the output voltage $v_o(t)$ as a function of time. Include the effects of saturation, if there are any.

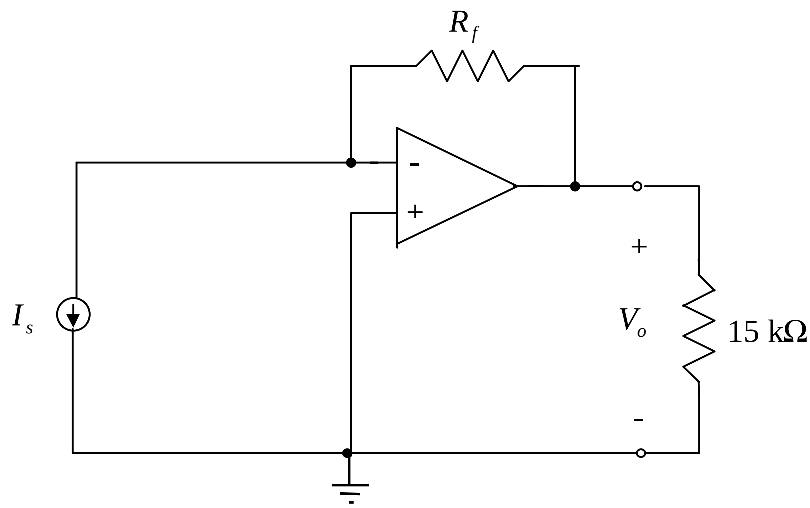


37. The amplifier below operates from a ±12 V power supply.



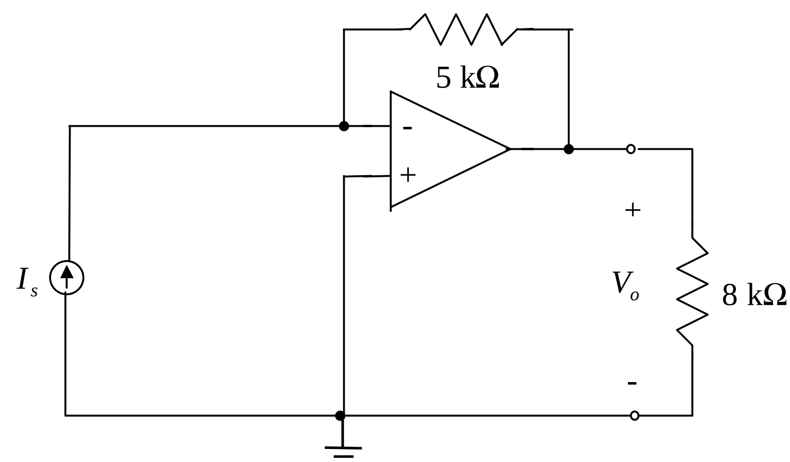
A. Determine whether the op-amp is saturated.
B. Find the maximum and minimum values that the independent source voltage can take if the op-amp is to operate in its linear active region.

38. The circuit shown below contains an ideal op-amp. The current source I_s takes values between zero and 1 mA. Find the value of feedback resistor R_f so that the output voltage V_o will take values between zero and 5 V.

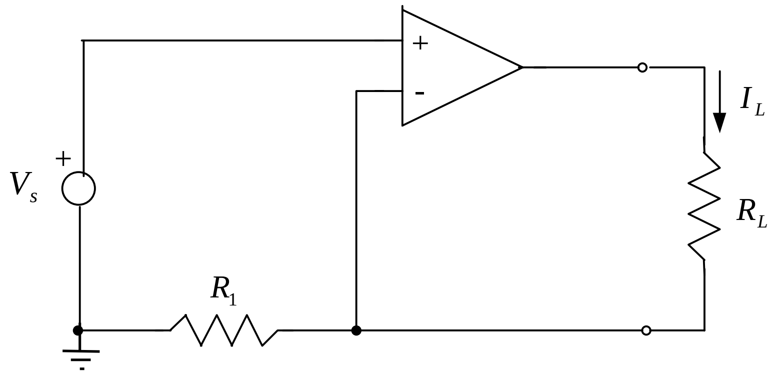


39. A phototransistor can be modeled as an ideal current source. The current produced is zero when no light shines on the phototransistor, and 250 μA under "full" illumination. Design a current-to-voltage converter that will produce an output voltage with a range from zero to one volt.

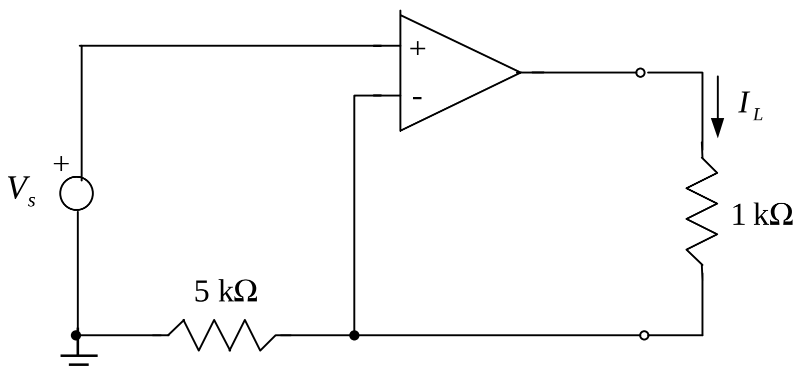
40. The op-amp in the circuit show below uses a ±12 V power supply. Find the range of the input current I_s for which the op-amp will remain in its linear active region.



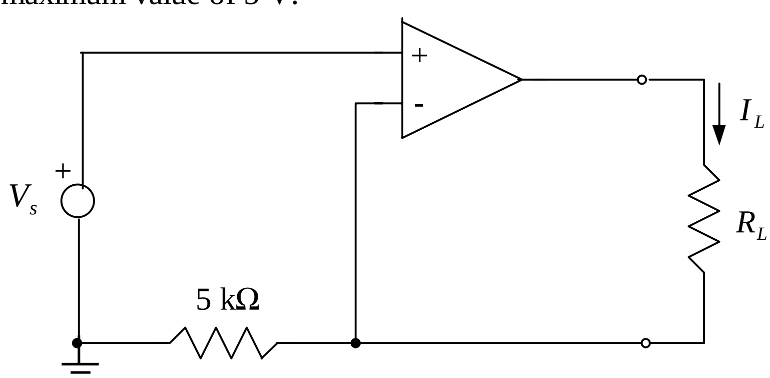
41. Show that the circuit shown below is a *voltage-to-current converter*. That is, show that the load current I_L is proportional to the source voltage V_s. Find the constant of proportionality. Show that the load current does not depend on the value of load resistor R_L. Assume that the op-amp is ideal.



42. In the circuit shown below the load current I_L is to range from zero to 10 mA. Find the corresponding range of input voltages V_s.

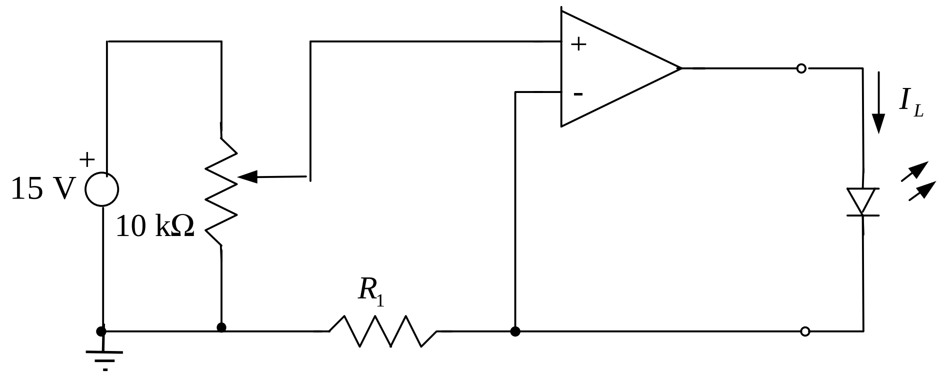


43. The op-amp in the circuit show below uses a ±15 V power supply. The source voltage V_s has a maximum value of 5 V.

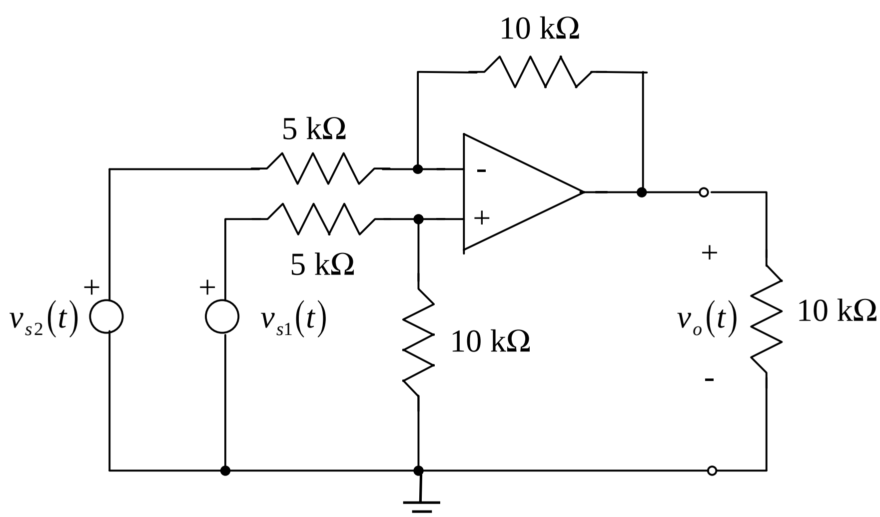


A. Find the largest value of R_L for which the op-amp will remain in its linear active region.
B. In normal operation the load current I_L is independent of the value of load resistor R_L. What happens if the load resistor is removed ($R_L = \infty$)?

44. The circuit shown below can be used to vary the brightness of a light-emitting diode (LED). The LED reaches full illumination when the load current $I_L = 15\text{ mA}$. The $10\text{ k}\Omega$ *potentiometer* ("pot") is a $10\text{ k}\Omega$ resistor with an adjustable tap that can be controlled by a knob on the front panel. Find the value of resistor R_1 that will allow full illumination when the pot is set all the way to its $10\text{ k}\Omega$ limit.



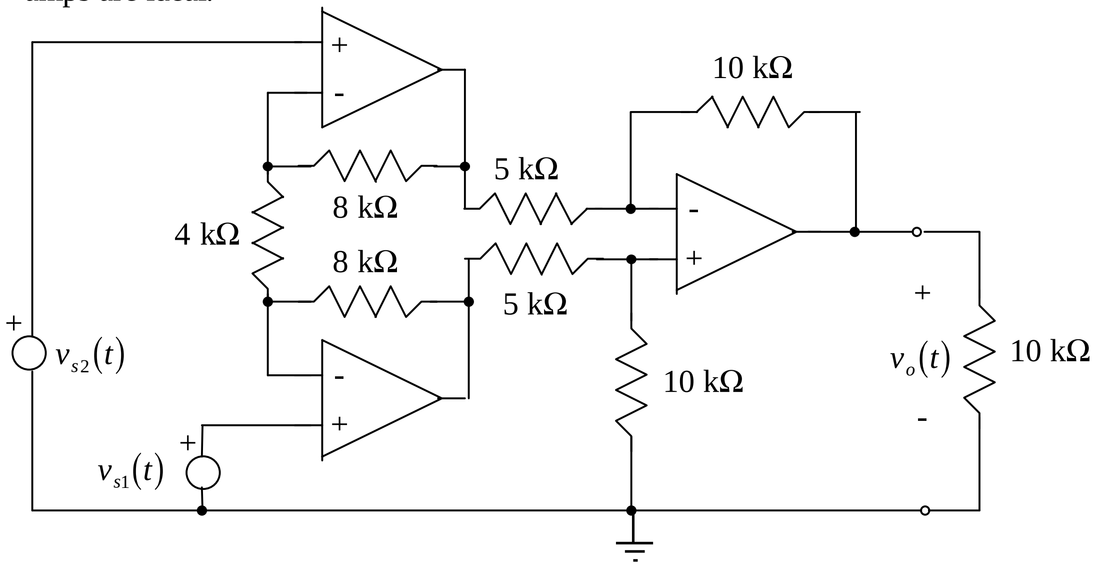
45. The circuit shown below is an example of a *difference amplifier*. Assume that the op-amp is ideal.



A. Find the output $v_o(t)$ as a function of the inputs $v_{s1}(t)$ and $v_{s2}(t)$. Show that $v_o(t) = K(v_{s1}(t) - v_{s2}(t))$ and find the constant K.

B. Find the input impedance of the amplifier as seen by $v_{s1}(t)$ when $v_{s2}(t) = 0$. Find the input impedance of the amplifier as seen by $v_{s2}(t)$ when $v_{s1}(t) = 0$. Are these input impedances equal?

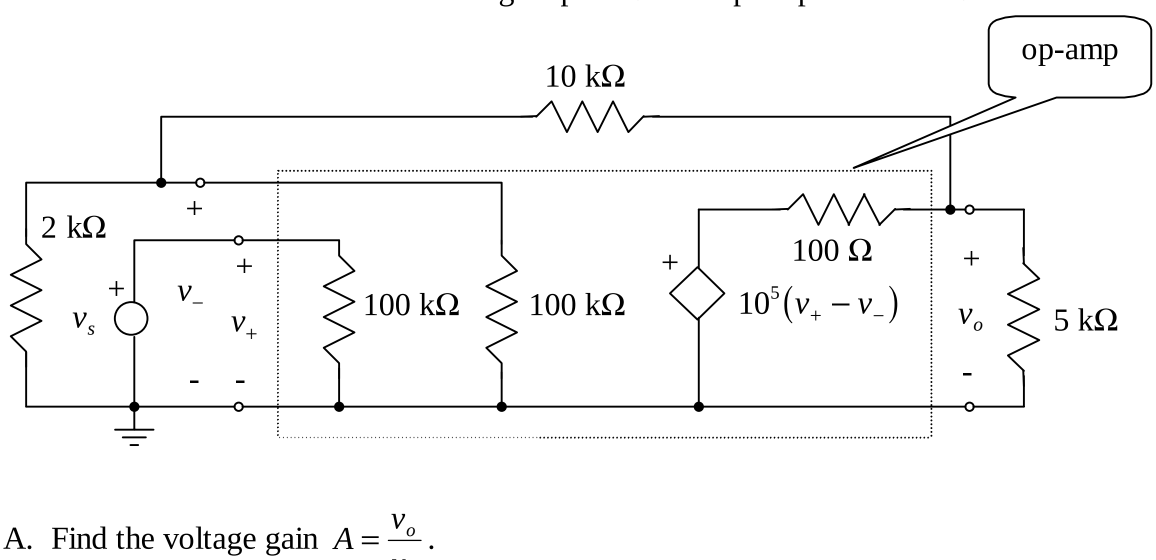
46. The circuit shown below is an example of a *difference amplifier*. Assume that the op-amps are ideal.



A. Find the output $v_o(t)$ as a function of the inputs $v_{s1}(t)$ and $v_{s2}(t)$. Show that $v_o(t) = K(v_{s1}(t) - v_{s2}(t))$ and find the constant K.

B. Find the input impedance of the amplifier as seen by $v_{s1}(t)$ when $v_{s2}(t) = 0$. Find the input impedance of the amplifier as seen by $v_{s2}(t)$ when $v_{s1}(t) = 0$. Are these input impedances equal?

47. The circuit below shows a non-inverting amplifier. The op-amp is not ideal.



A. Find the voltage gain $A = \frac{v_o}{v_s}$.

B. Find the input resistance seen by the independent source.

C. How do the gain and input resistance compare with the values that you would have obtained if the op-amp had been ideal?