ECE 65: Components & Circuits Lab

Lecture 3

Operational Amplifier limitations

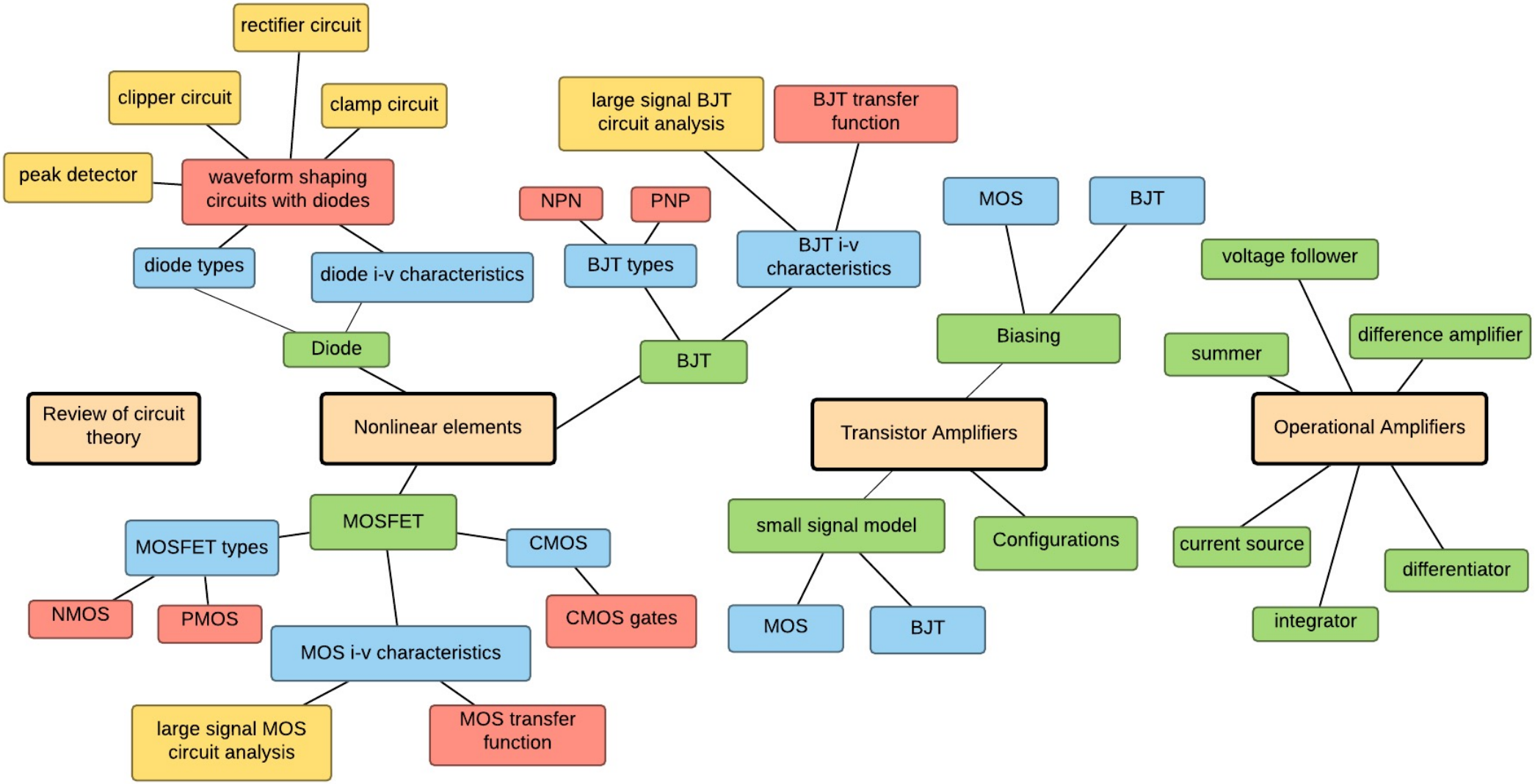
Reference notes: sections 7.5

Sedra & Smith (7th Ed): sections 2-2.3

Saharnaz Baghdadchi

Course map

7. Operational amplifiers

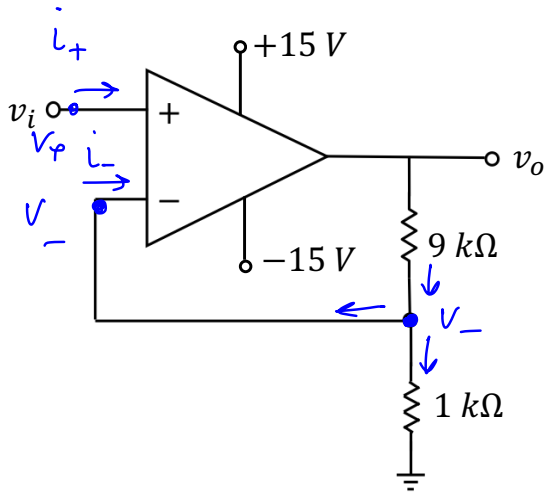


Voltage-supply limit or Saturation

As we saw before, the maximum output voltage of op-amps is limited by the positive and negative voltage sources (V_{S+} and V_{S-}) used to power up the op-amp chip.

$$V_{s^-} < V_o < V_{s^+}$$

$$V_{sat^-} \lesssim V_o \lesssim V_{sat^+}$$



$V_{sat+} = 14\ V$

$V_{sat-} = -14\ V$

Assume an ideal op-amp $\Rightarrow i_+ = i_- = 0$

Because of negative feedback : $v_+ = v_-$

here, $V_+ = V_i$, $\frac{V_-}{1k\Omega} = \frac{V_o - V_-}{9k\Omega} \Rightarrow V_o = 10\ V_- \Rightarrow \boxed{V_o = 10\ V_i}$

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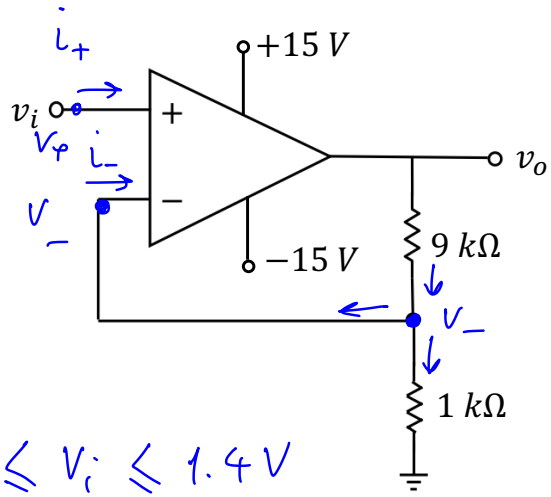
$$V_{sat^-} \leq V_o \leq V_{sat^+}$$



$V_{sat+} = 14\ V$

$V_{sat-} = -14\ V$

$V_o = 10\ v_i \Rightarrow \frac{-14V}{10} \leq V_i \leq \frac{14}{10}\ V \Rightarrow -1.4\ V \leq V_i \leq 1.4\ V$

Voltage-supply limit or Saturation

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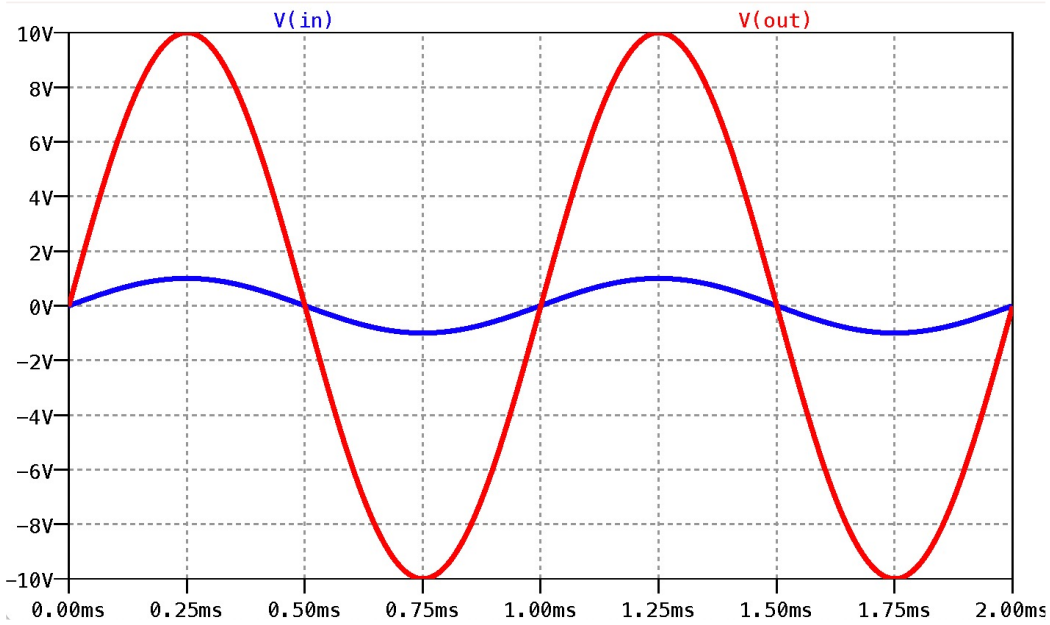

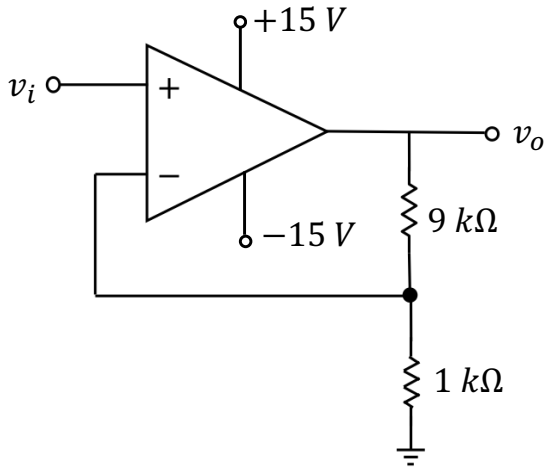

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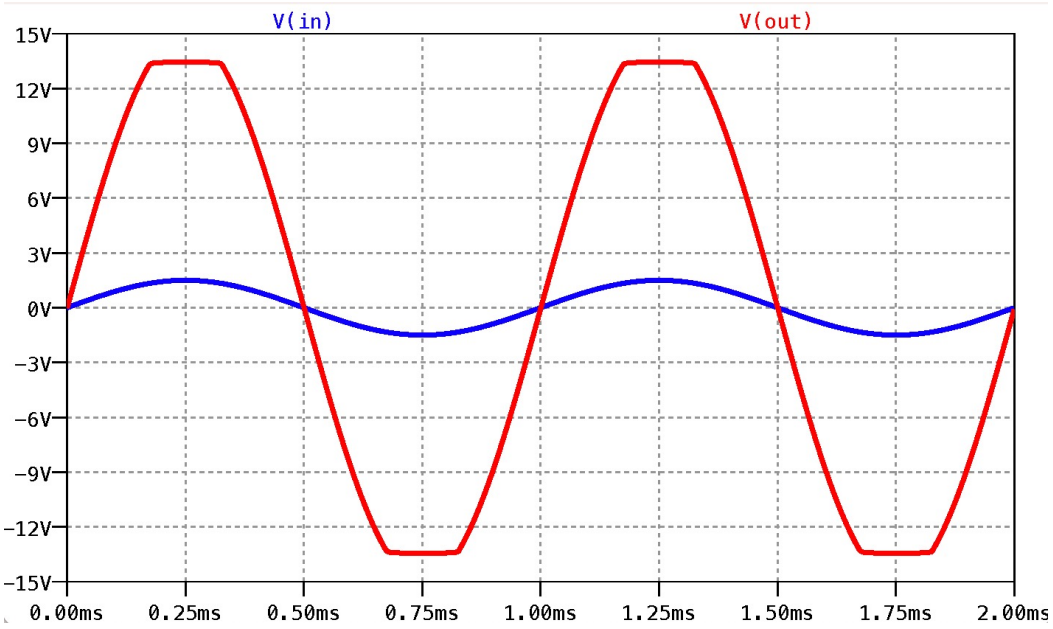
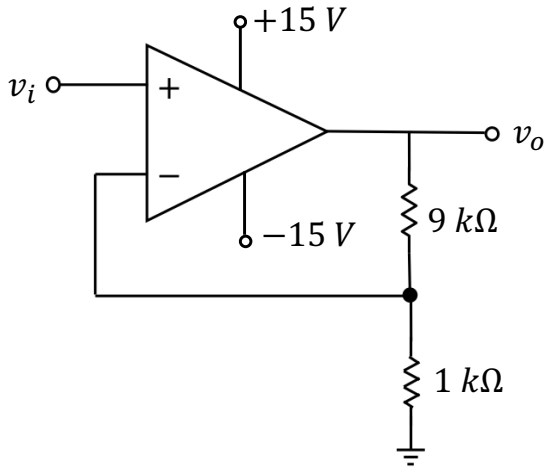
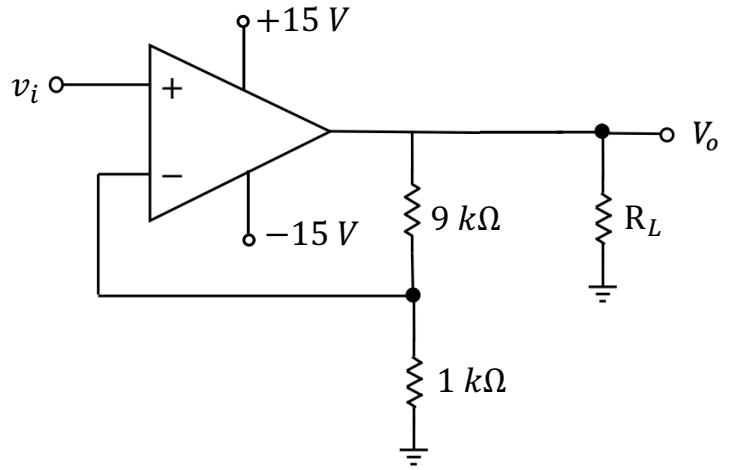




Maximum Output Current

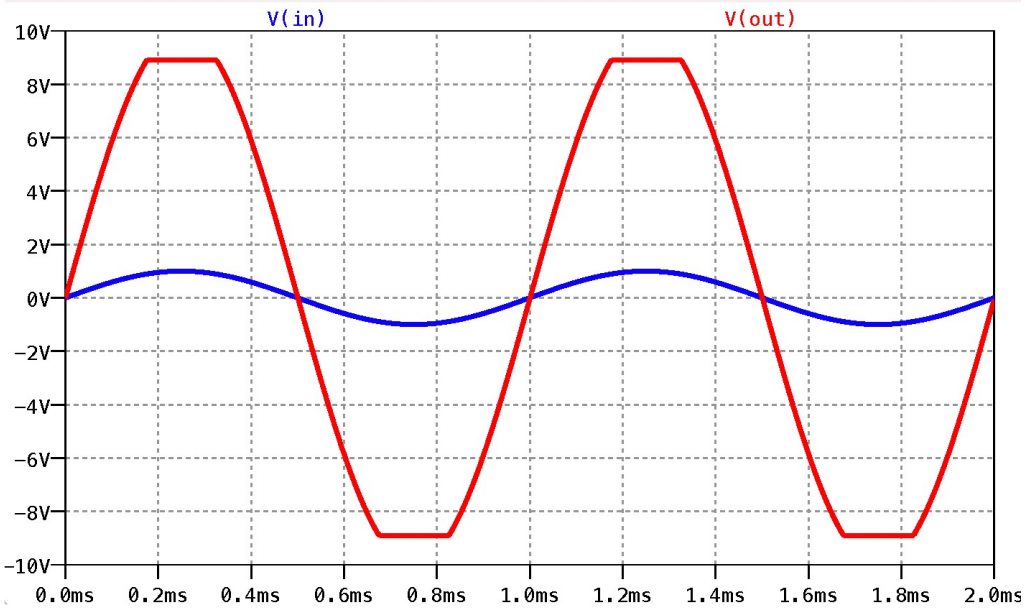
The output current of an op-amp is limited to a specified maximum value.

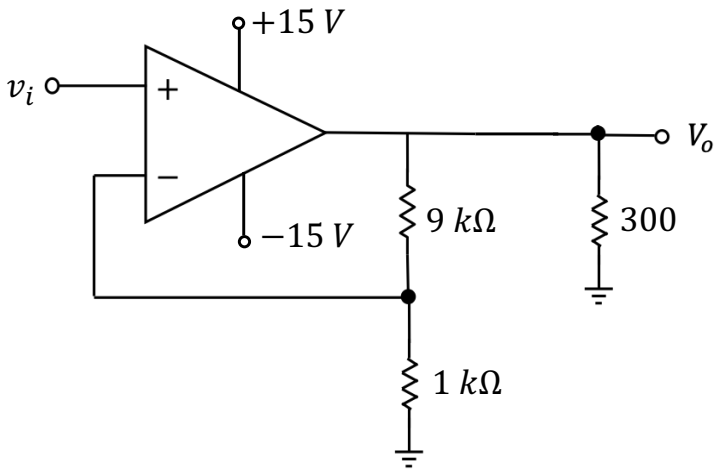
For example, in the 741 op-amp, the maximum output current is ±20mA.



Maximum Output Current

If the circuit requires a current larger than the maximum output current, in either direction, the output voltage will saturate at a level corresponding to the maximum allowed output current.

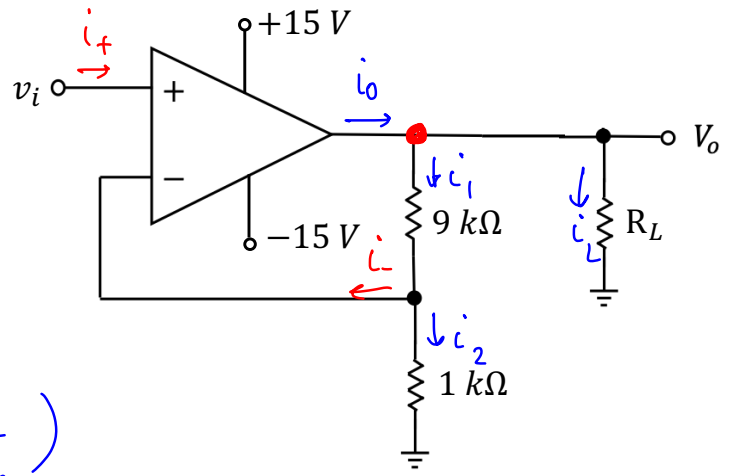




Maximum Output Current - Example

The following op-amp circuit is fed with a low-frequency sinusoidal signal with peak amplitude of $1\ V$. The maximum output current is $\pm 20mA$. If $\mathrm{R_L} = 1\ k\Omega$, specify and sketch the output voltage.

assume an ideal op-amp: $i_+ = i_- = 0 \Rightarrow i_1 = i_2$



KCL: $i_0 = i_1 + i_L$

$$i_0 = \frac{V_o}{9k\Omega + 1k\Omega} + \frac{V_o}{R_L}$$

$$i_0 = \frac{V_o}{10k\Omega} + \frac{V_o}{1k\Omega} = V_o\left(\frac{1}{10k\Omega} + \frac{1}{1k\Omega}\right)$$

$$= V_o \times 1.1$$

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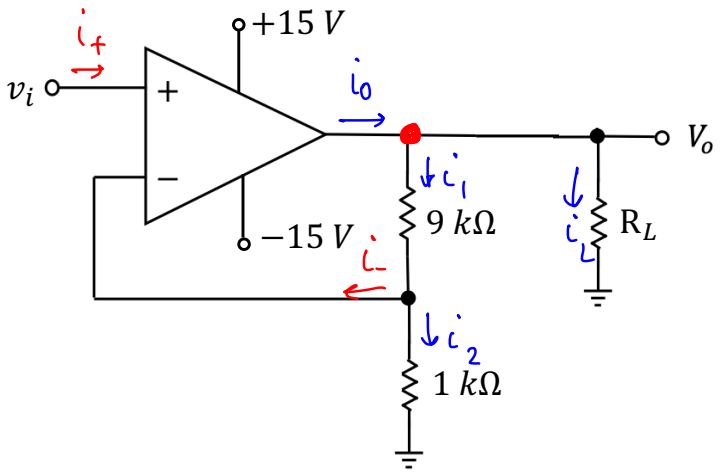


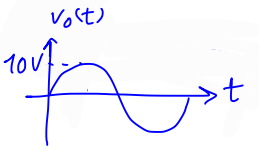
$i_0 = V_o \times 1.1$

Assume linear amplification:

$\frac{V_o}{V_i} = 10\ V/V \Rightarrow$ if $V_{i_{max}} = 1V \Rightarrow V_{o_{max}} = 10\ V$

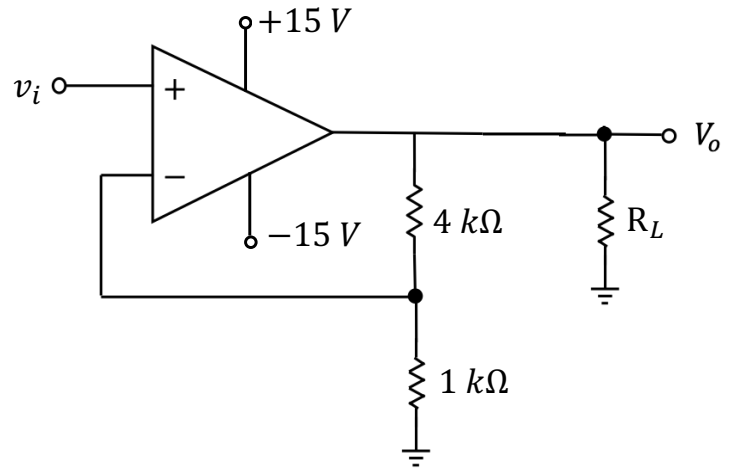
$\Rightarrow i_{o_{max}} = 10 \times 1.1 = 11\ mA < +20mA$

$\Rightarrow$ We are not limited by the maximum output current $\Rightarrow V_{o_{max}} = 10\ V$



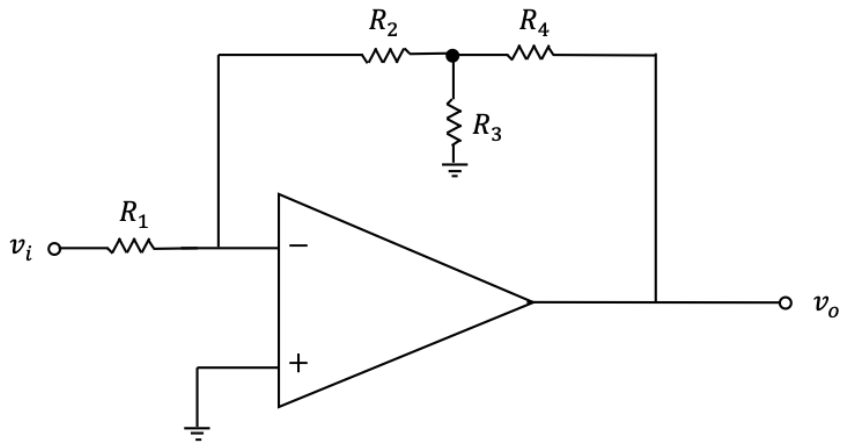
Lecture 3 reading quiz.

The following op-amp circuit is fed with a low-frequency sinusoidal signal with the peak amplitude of $\mathrm{V_P}$. The output saturation voltage is $\pm 13\ V$, and the maximum output current is $\pm 20\ mA$. If $\mathrm{R_L} = 0.5\ k\Omega$, find the maximum value of $\mathrm{V_P}$ for which an undistorted sinusoidal signal is obtained at the output?



Discussion question 1.

What is v_o/v_i in this op-amp circuit? Assume an ideal op-amp.

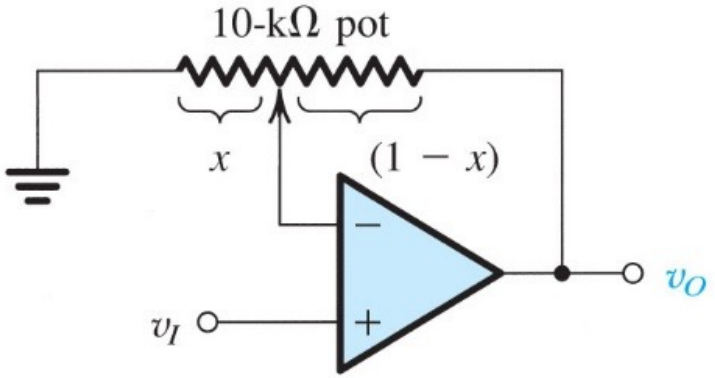


Discussion question 2.

The following circuit uses a $10\ k\Omega$ potentiometer to obtain an adjustable gain amplifier.

a) Derive an expression for the gain as a function of the potentiometer setting x.
b) What is the range of the gain obtained?
c) Show how to add a fixed resistor so that the gain range can be 1 to 11 V/V. What is the value of that resistor?

Assume an ideal op-amp.



Discussion question 2.

a) Derive an expression for the gain as a function of the potentiometer setting x.

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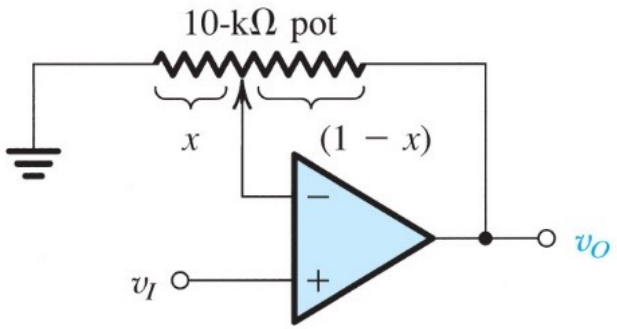

Discussion question 2.

a) What is the range of the gain obtained?
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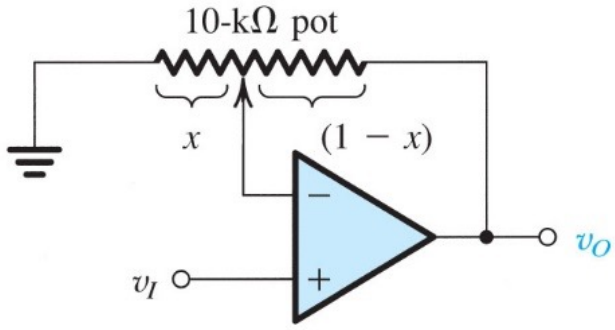

Discussion question 2.

a) Show how to add a fixed resistor so that the gain range can be 1 to 11 V/V. What is the value of that resistor?

Assume an ideal op-amp.