EECS16A DIS10B

email: moseswon@
OH: W 10AM-12PM PT (HWP)

Playlist: (bit.ly/16ajukebox)
1. Never Gonna Give you up (Anonymous)
2. Sweet Home Alabama (Vaibhav Agrawal)
3. Sofia - Clairo (Anonymous)

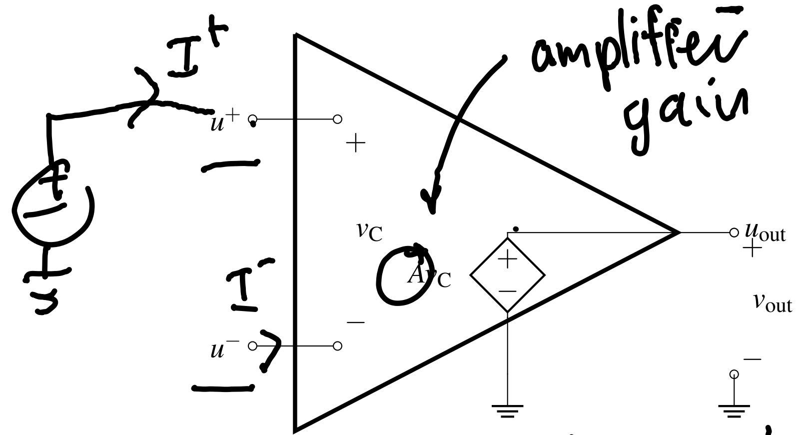
Learning Objectives

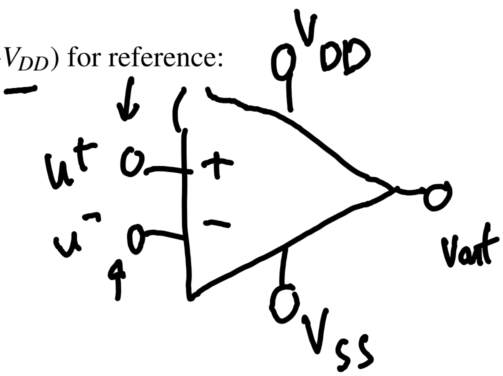
1. Implications of op amp model on analysis (don't look at node voltage on output) → comes from a voltage source
2. First op amp module: Buffer (aka voltage buffer/ unity gain buffer)
3. Comparator behavior and practice
4. Vocabulary: "gain" - multiplier/scaling factor
5. Golden Rules - application

EECS 16A Designing Information Devices and Systems I
Fall 2020 Discussion 10B

1. Op-Amp Rules and Negative Feedback Rules

Here is an equivalent circuit of an op-amp (where we are assuming that $V_{SS} = -V_{DD}$) for reference:



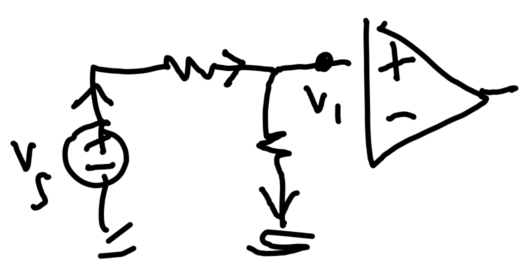


gain

$V_{out} = Av_c = A(u^+ - u^-)$

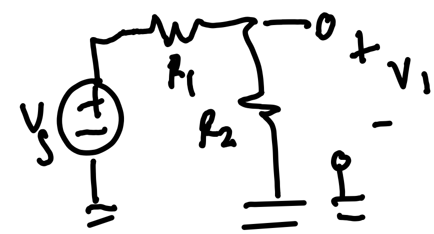
(a) What are the currents flowing into the positive and negative terminals of the op-amp (i.e., what are I^+ and I^-)? Based on this answer, what are some of the advantages of using an op-amp in your circuit designs?

$I^+ = I^- = 0A$



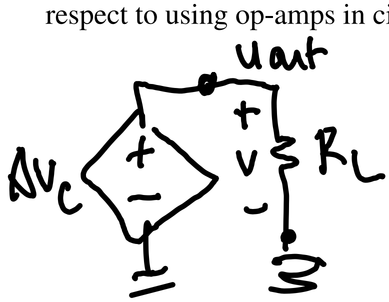
Drawing no current means volts stay the same

EX



$V_1 = \frac{R_2}{R_1+R_2} V_S$

(b) Suppose we add a resistor of value R_L between u_{out} and ground. What is the value of v_{out}? Does your answer depend on R_L? In other words, how does R_L affect Av_C? What are the implications of this with respect to using op-amps in circuit design?



$R_L = 1\Omega$ $V = u_{out} = Av_c$

$R_L = 1k\Omega$ $V = Av_c$

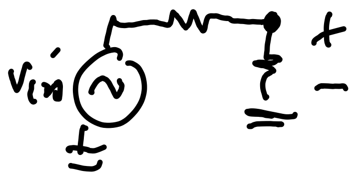
$R_L = ?$ $V = Av_c$

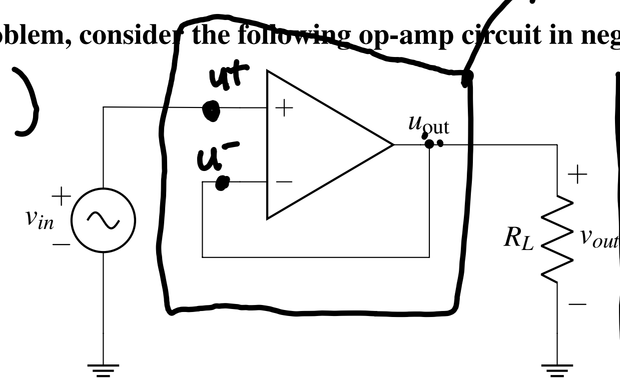
Can put voltages into next circuit w/o change

NFB - Negative Feedback buffer

For the rest of the problem, consider the following op-amp circuit in negative feedback:

$u_{out} = A(u^+ - u^-)$





Ideal op amp ($A = \infty$)
→ ($I^+ = I^- = 0$)
Golden rules
① $I^+ = I^- = 0$
② If in NFB
→ $u^+ = u^-$

(c) Assuming that this is an ideal op-amp, what is v_{out}?

$u^+ = V_{in}$

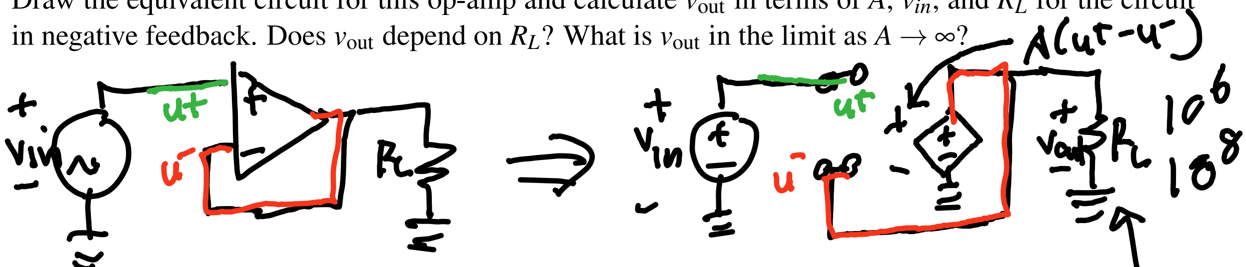
$u^- = u_{out}$

$V_{in} = u^+ = u^- = u_{out}$

GR ②

$u_{out} = V_{in}$

(d) Draw the equivalent circuit for this op-amp and calculate v_{out} in terms of A, v_{in}, and R_L for the circuit in negative feedback. Does v_{out} depend on R_L? What is v_{out} in the limit as $A \to \infty$?



$u^- = A(u^+ - u^-)$

$u^- = Au^+ - Au^-$

$u^- + A\cancel{u^-} = Au^+$

$u^-(1+A) = Au^+ = Av_{in}$

$u^- = \frac{A}{1+A} v_{in}$

$A \to \infty \quad \frac{A}{1+A} \to 1$

$V_{out} = 1 \cdot v_{in}$

$V_{out} = u^- = V_{in}$

Q: $A(u^+ - u^-) \Rightarrow \infty$?

$A \to \infty \quad u^- \to v_{in} = u^+$

$\infty(u^+ - u^+)$

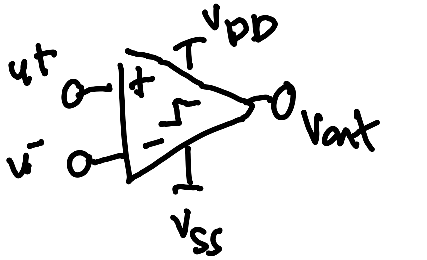
$\infty \cdot 0 = ?$

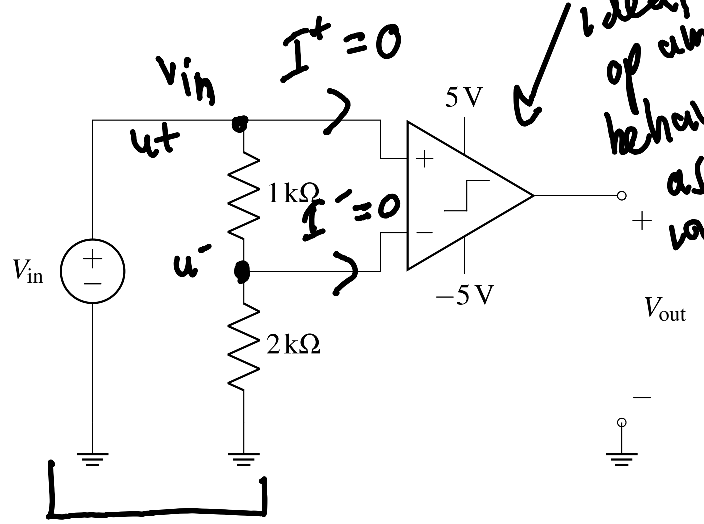
{ R_L doesn't not change V_{out}

2. Comparators

For each of the circuits shown below, plot V_{out} for V_{in} ranging from $-10\,\mathrm{V}$ to $10\,\mathrm{V}$ for part (a) and from $0\,\mathrm{V}$ to $10\,\mathrm{V}$ for part (b).

(a)





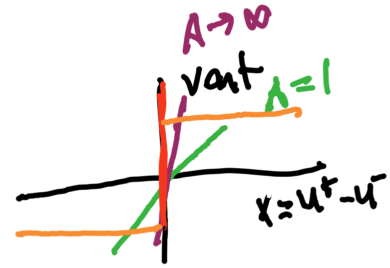
ideal op amp behaving as comparator

$u^+ - u^- > 0$ $V_{out} = V_{DD}$

$u^+ - u^- < 0$ $V_{out} = V_{SS}$

$u^+ > u^-$

$u^+ < u^-$



$u^+ = V_{in}$

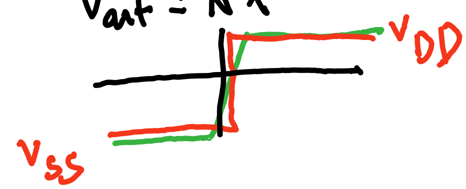
$u^- = \frac{2}{3} V_{in}$

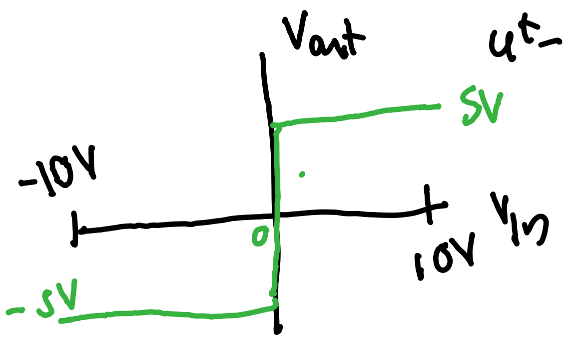
$u^+ - u^- = V_{in} - \frac{2}{3} V_{in}$

$= \frac{1}{3} V_{in}$

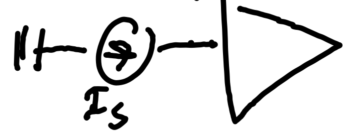
$V_{out} = A(u^+ - u^-)$

$V_{out} = AX$

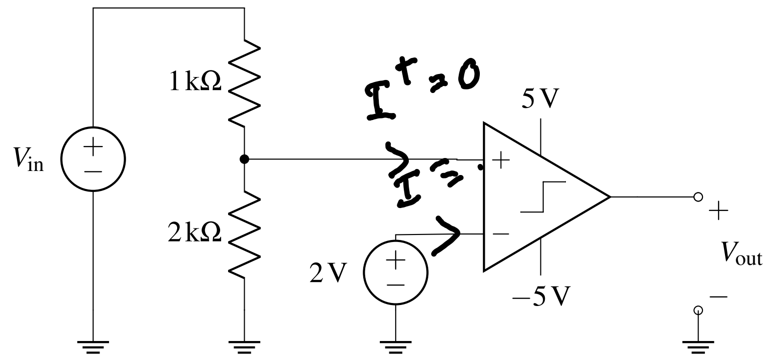




✓ issue



(b)



$u^+ = \frac{2}{3}V_{in}$

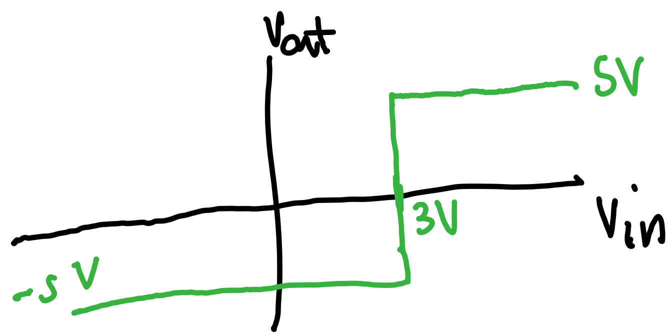
$u^- = 2V$

$u^+ - u^- = \frac{2}{3}V_{in} - 2V$

$\frac{2}{3}V_{in} - 2V \geq 0 \quad V_{out} = 5V$

$\frac{2}{3}V_{in} > 2V$

$V_{in} > 3V \quad V_{out} = 5V$



$\frac{2}{3}V_{in} - 2V < 0 \quad V_{out} = -5V$

$\frac{2}{3}V_{in} < 2V$

$V_{in} < 3V \quad V_{out} = -5V$