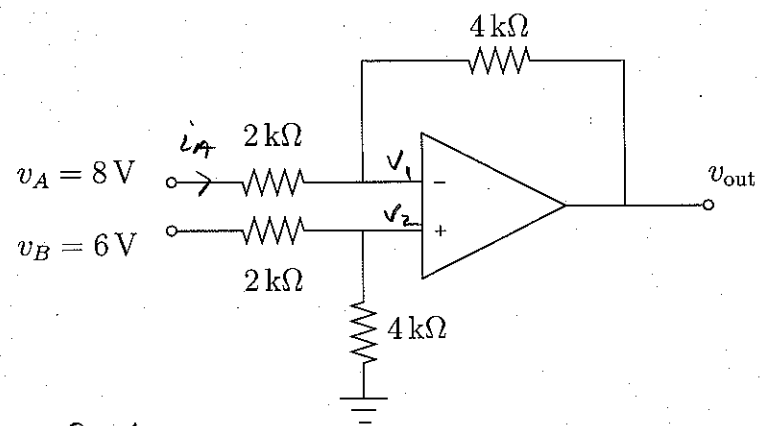
PHYS 235 — Exam #2

Thursday, March 5, 2009

Name: KEY

1. (18 pts) Consider the illustrated circuit containing an ideal op-amp (powered from $\pm 15\,\text{V}$ supplies) and resistors. Determine the numerical value of output voltage v_{out}. Be sure to include all reasoning and/or derivations.



Negative feedback $\Rightarrow$ $V_2 = V_1$

$$V_2 = \frac{4}{2+4} \cdot V_B = \frac{4}{6} \times 6 = 4\,V$$

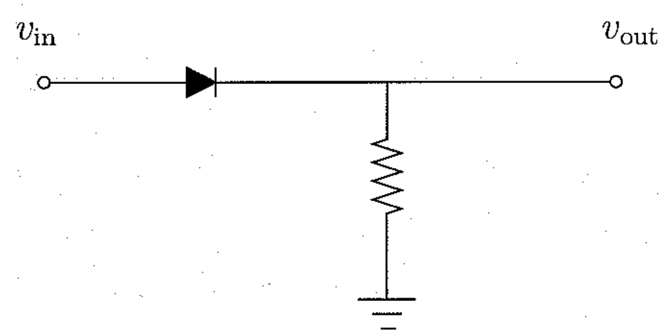
$$\Rightarrow V_1 = 4\,V$$

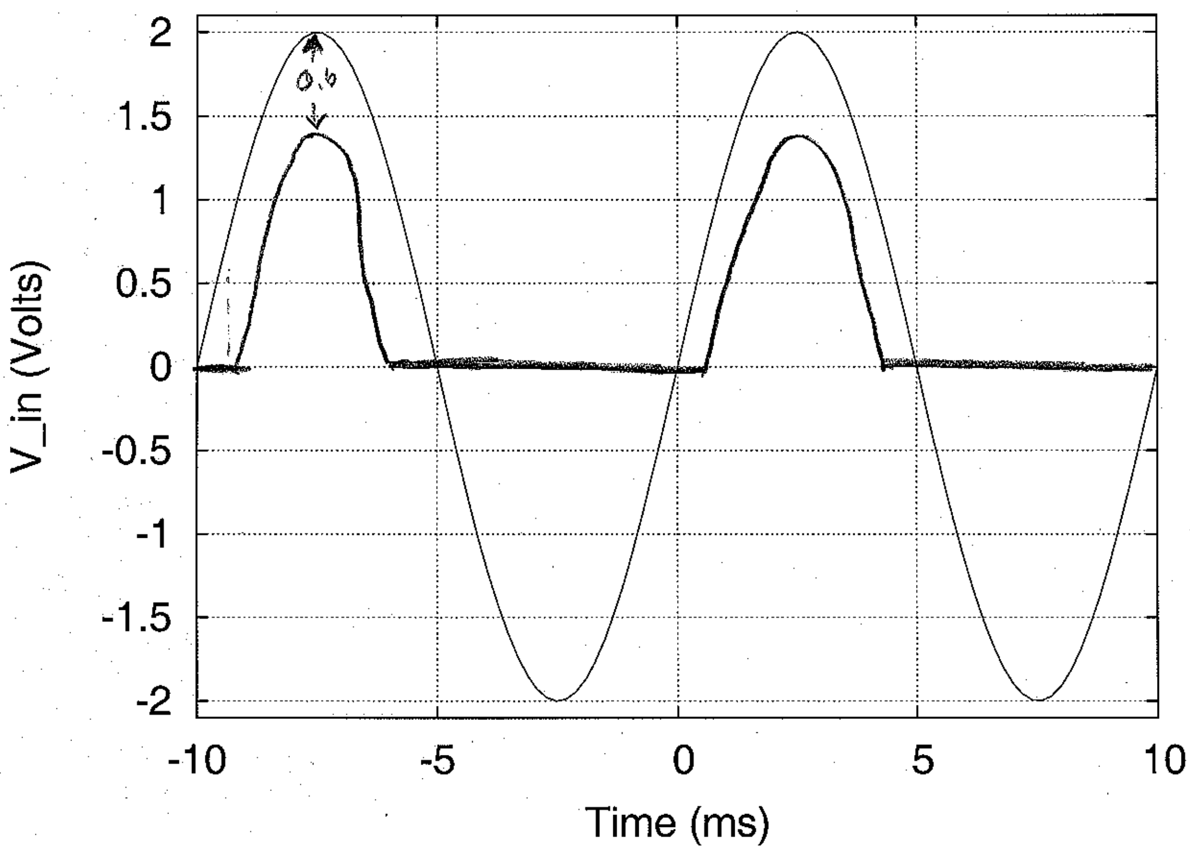
$$i_A = \frac{\Delta V}{2\,k\Omega} = \frac{8-4}{2\,k\Omega} = 2\,mA$$

$$V_{out} = V_1 - i_A \times 2 = 4 - 2 \times 4 = -4\,V$$

2. (18 pts)

(a) Consider the illustrated circuit with an ideal silicon diode and a resistor, and the illustrated input signal v_{in}. Sketch the output signal you would observe on an oscilloscope. (Draw your sketch on the same set of axes as the input.)

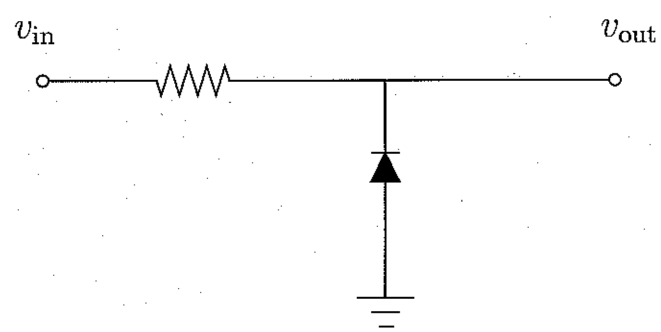


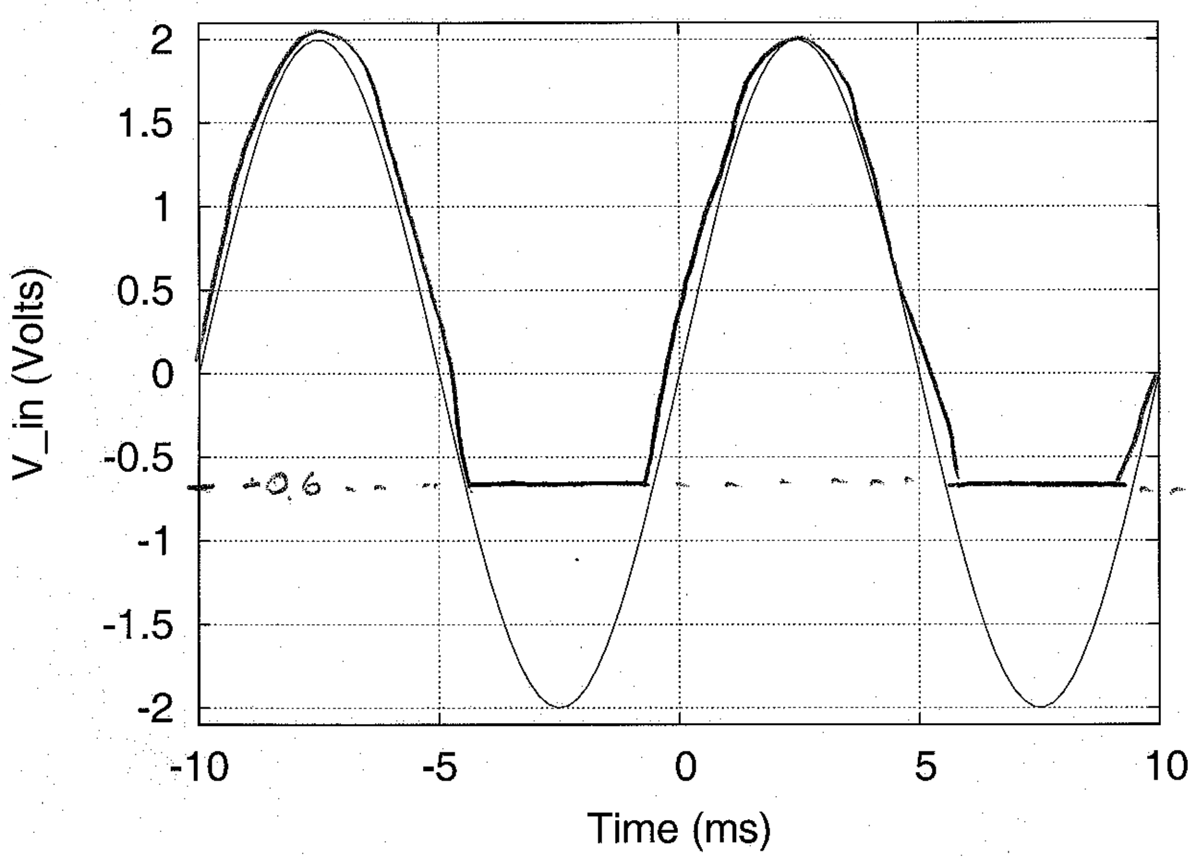


When forward biased $V_{out} = V_{in} - 0.6\,V$

when reversed biased $i_R = 0 \Rightarrow V_{out} = 0$

(b) Consider the illustrated circuit with an ideal silicon diode and a resistor, and the illustrated input signal v_{in}. Sketch the output signal you would observe on an oscilloscope. (Draw your sketch on the same set of axes as the input.)





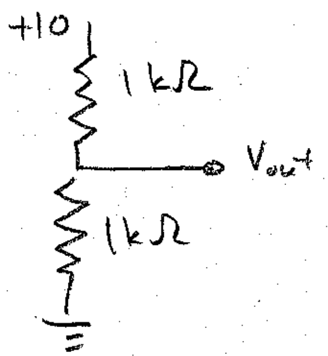
When forward biased $V_{out} = 0 - 0.6 = -0.6\,V$

When reverse biased $i_R = 0 \Rightarrow V_{out} = V_{in}$

3. (10 pts) Why is an amplifier with a voltage gain of 1, i.e., with $v_{\text{out}} = v_{\text{in}}$, of any use to anyone? (Specific examples may help your explanation.)

An amplifier with a gain of 1 can be very useful if it has a high input impedance and a low output impedance. This can turn a poor voltage source into a much better approximation of an ideal voltage source, where the output voltage is (approximately) independent of the current drawn from the source.

Example: Consider the following voltage divider.

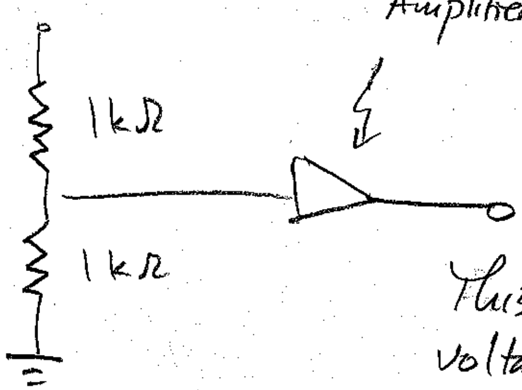


For $R_{load} \gg 1\,k\Omega$ $V_{out} \approx 5\,V$

but for $R_{load} \approx 500\,\Omega$ $V_{out} \approx 2.5\,V$

Not a great voltage source!

Fix:



Amplifier with $R_{input} \gg 1\,k\Omega$, say $1\,M\Omega$

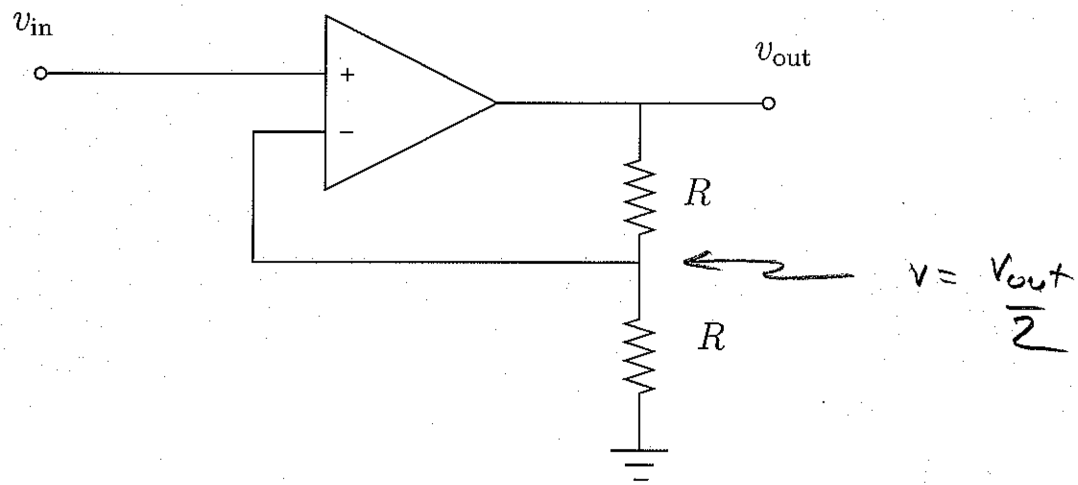
$R_{output} \sim 10\,\Omega$

Gain $= 1$

This will give a constant voltage output of 5V down to load resistances near $10\,\Omega$.

4. (a) Assume that the op-amp is ideal and determine an expression for the gain of the illustrated circuit.

(b) Assume the that illustrated op-amp is **not** ideal in one respect: the open-loop gain A_0 is **not** infinite. Determine an expression for the gain of the circuit. (This result should reduce to your previous result in the limit $A_0 \to \infty$.)



a) Negative feedback $\Rightarrow$ $V_2 = V_1$

or $V_{in} = \frac{V_{out}}{2}$

$\Rightarrow$ $V_{out} = 2V_{in}$

b)

$$V_{out} = A_0(V_2 - V_1)$$

$$= A_0\left(V_{in} - \tfrac{1}{2}V_{out}\right)$$

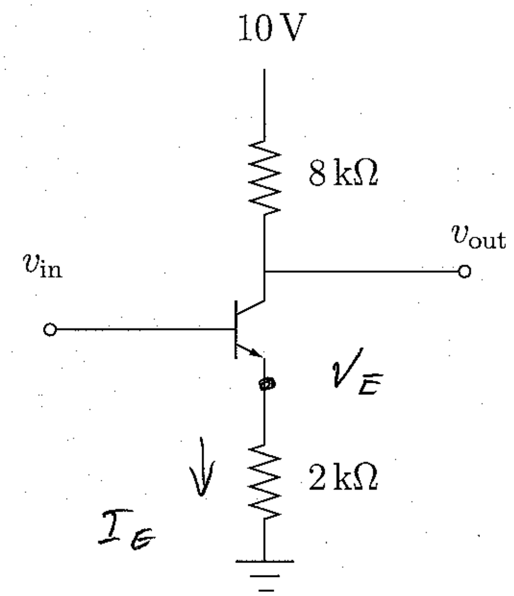
$$= A_0 V_{in} - \tfrac{1}{2}A_0 V_{out}$$

$$\Rightarrow \quad V_{out}\left(1 + \tfrac{1}{2}A_0\right) = A_0 V_{in}$$

$$V_{out} = \frac{A_0}{1+\frac{1}{2}A_0} V_{in} = \frac{2A_0}{2+A_0} V_{in}$$

$$\xrightarrow[A_0 \to \infty]{} 2V_{in} \quad ✓$$

5. (18 pts) Consider the illustrated circuit with a transistor and two resistors. You may use the "simplest" model of transistor behavior in this problem, i.e., $I_B \simeq 0$.



(a) Determine the output when $v_{in} = 2\,\text{V}$.

(b) Determine the output when $v_{in} = 4\,\text{V}$.

a) $V_E = V_{in} - 0.6 = 1.4$

$I_E = \frac{V_E}{2k\Omega} = 0.7\,mA$

$V_{out} = 10 - I_C \times 8k\Omega$

$= 10 - I_E \times 8k\Omega$

$= 10 - 0.7mA \times 8k\Omega$

$= 10 - 5.6\,V$

$= 4.4V$

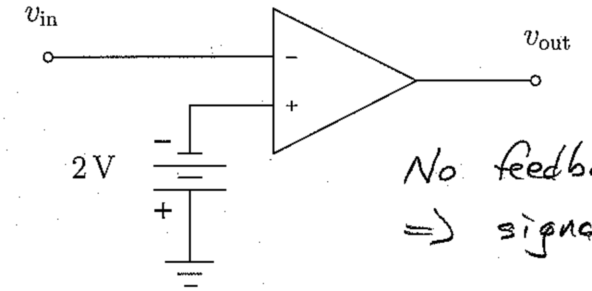
b) Rules would give $I_E = \frac{3.4V}{2k\Omega} = 1.7\,mA$

$$V_{out} = 10 - I_E \times 8\,k\Omega$$
$$= 10 - 1.7\,mA \times 8\,k\Omega$$
$$= 10 - 13.6$$
$$= -3.6\,V$$

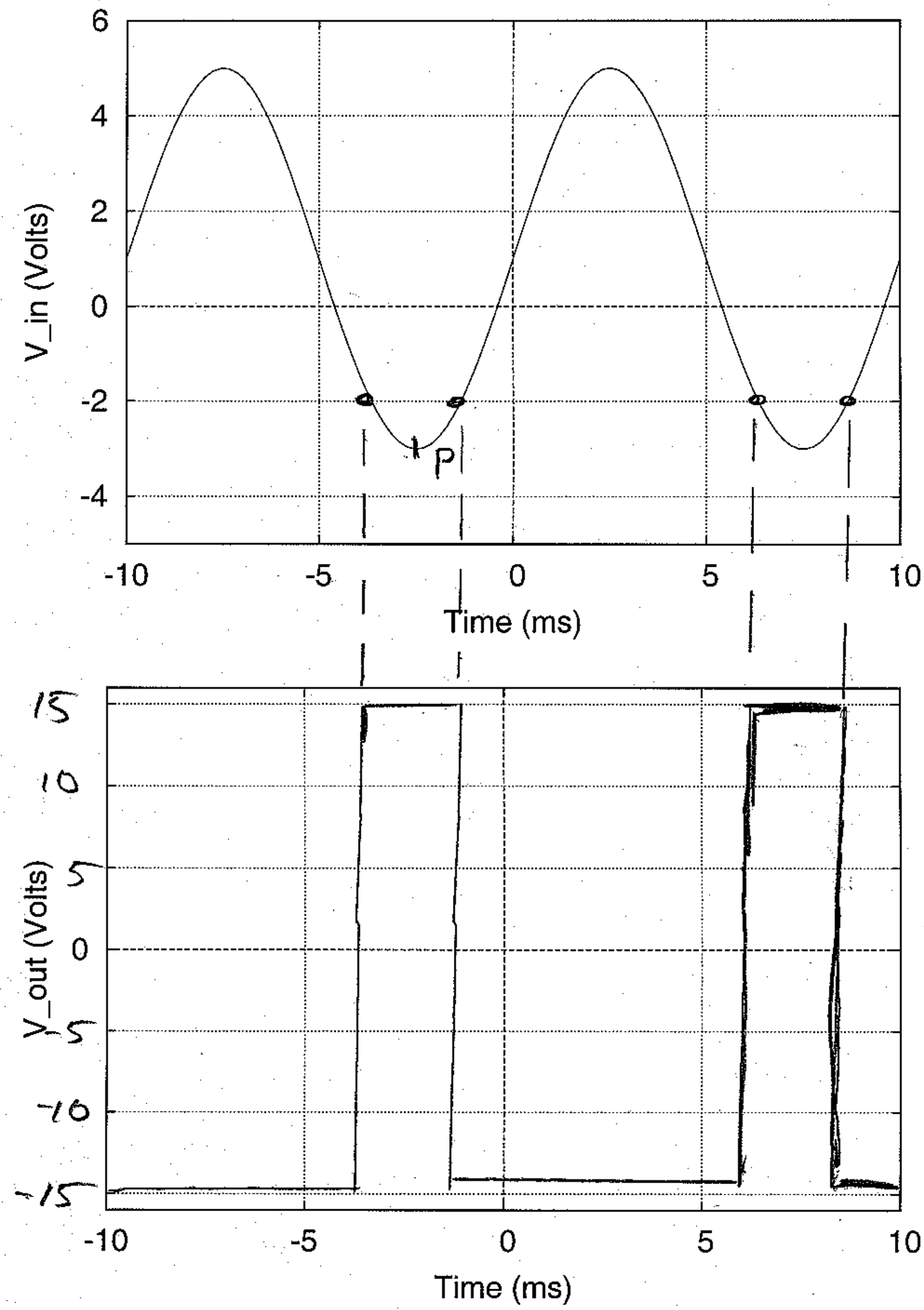
But this is impossible. The low potential end of the emitter resistor can't go below 0, nor can anything else in the collector-emitter chain, so

$$(V_{out})_{min} \approx 0$$

6. (18 pts) Sketch the output of the illustrated circuit for the given input.



No feedback
⇒ signal w/ clipping



At P $\quad V_{out} = A_0[-2-(-3)] = +A_0 \rightarrow$ Positive saturation