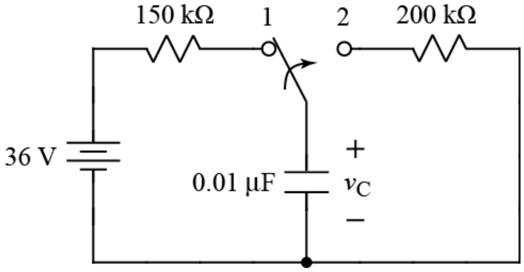
ECE 1250

Practice Exam #2 Solution

1.



After being on side 1 for a long time, the switch moves from side 1 to side 2 at $t = 0$.

a) Find the value of $v_C(t = 0)$.

b) Find an expression for $v_C(t > 0)$.

c) Find the value of the energy stored by the capacitor at time $t = 3\tau$ where τ = time constant for circuit after $t = 0$.

SOL'N: a) $v_C(t = 0) = 36$ V. C charges to voltage of power supply.

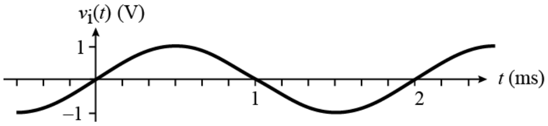
b) $v_C(t \to \infty) = 0\,\mathrm{V}$, $R_{\mathrm{Thev}} = 200\ \mathrm{k\Omega}$ for $t > 0$. $\tau = R_{\mathrm{Thev}}C = 2$ ms.

$$v_C(t > 0) = 0\,\mathrm{V} + [36\,\mathrm{V} - 0\,\mathrm{V}]e^{-t/2\,\mathrm{ms}}$$

c) $v_C(t = 3\tau) = 36\,\mathrm{V}\,e^{-3} \approx 1.8\,\mathrm{V}$, $w_C = \frac{1}{2}CV^2 = \frac{1}{2}(0.01\mu)(1.8)^2\,\mathrm{J} = 16\,\mathrm{nJ}$

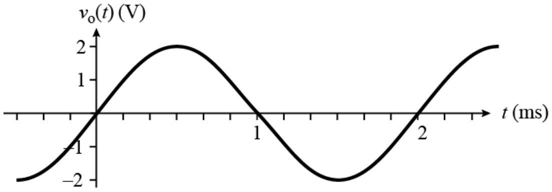
2.

A function generator outputs the following signal, $v_i(t)$.



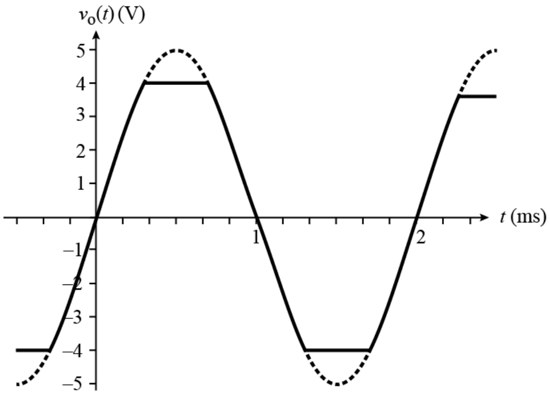
Design op-amp circuits to output each of the following waveforms when $v_i(t)$ is the input. You may use either one or two op-amps in each case.

a)



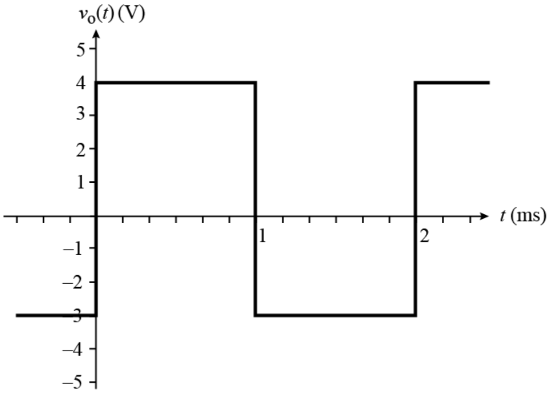
sol'n: Non-inverting amp, $R_f = R_s > 1\ \mathrm{k\Omega}$

b)



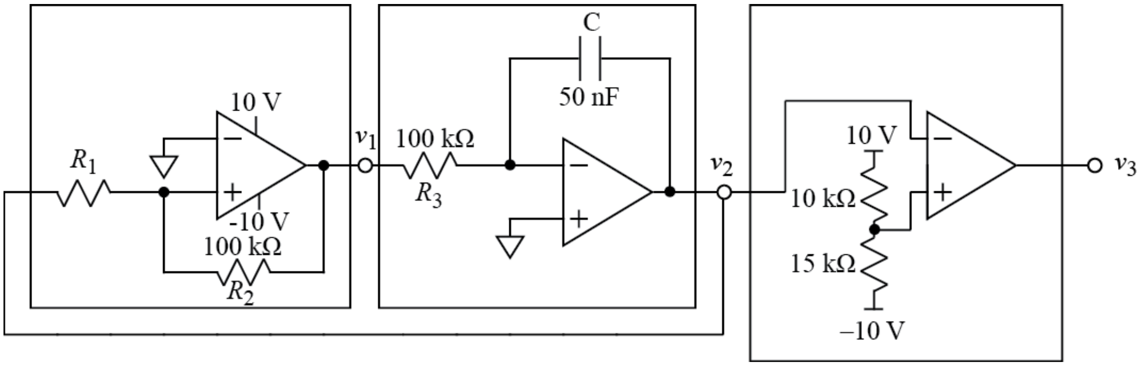
sol'n: Non-inverting amp, $R_f = 4R_s > 1$ kΩ
clipped, so use pwr supply ±5 V.

c)



sol'n: Use comparator v_i vs 0V,
pwr supply ±5 V, then summing
amp to add 1V.

3.



The above circuit is from Lab 4, but some of the component values have been changed.

a) Find the minimum and maximum values allowed for R_1 in order to achieve proper operation: 1) successfully generating a triangle wave (which requires that v_1 switches from high to low and back), and 2) avoiding clipping that would occur if v_2 exceeded the rail voltage for the op-amp.

SOL'N: a) R_1 and R_2 form V-divider between v_1 and v_2. v_2 must pull v_+ of 1st op-amp below 0 V in order to switch v_1 when v_1 is $-v_{\text{rail}}$ and v_2 is $+v_{\text{rail}}$. Need $R_1 < R_2$ for that to happen. So R_1 = 100 kΩ is the maximum. The other condition cannot occur, since if v_2 hits the rail voltage, it will just stay there. v_1 and v_2 will then stay the same and switching will never occur.

b) Choose an allowed value for R_1 and calculate the period of $v_2(t)$.

SOL'N: b) Many solutions. Key equations are:

$$0\,\text{V} = v_+ = \frac{v_1 R_1 + v_2 R_2}{R_1 + R_2} = \frac{-v_{\text{rail}} R_1 + v_2 R_2}{R_1 + R_2} \quad \text{solve for peak } v_2.$$

$$v_{2\text{peak}} = \frac{v_{\text{rail}} R_1}{R_2} = \frac{9\,\text{V} \cdot R_1}{100\ \text{k}\Omega}$$

$$\text{slope of } v_2 = -\frac{I}{C} = -\frac{v_1}{R_3 C} = -\frac{v_{\text{rail}}}{R_3 C} = \frac{-9\,\text{V}}{5\,\text{ms}} = -1.8\ \text{kV/s}$$

Half of period = time for v_2 to go from -pk to +pk = $2v_{2\ \text{pk}}$

or half period = $2v_{2\ \text{pk}}$/slope of v_2.

c) Draw a graph of $v_2(t)$ and $v_3(t)$ for at least one period of $v_2(t)$. Label all important times and voltages on the graph.

SOL'N: b) $v_2(t)$ = triangle wave with slope and max v_2 and period from (b).

$$0\,\text{V} = v_+ = \frac{v_1 R_1 + v_2 R_2}{R_1 + R_2} = \frac{-v_{\text{rail}} R_1 + v_2 R_2}{R_1 + R_2} \quad \text{solve for peak } v_2.$$

$v_3(t)$ is rectangular waveform. High voltage = $+\text{v}_{\text{rail}}$ = 9V, low V = -9 V.

$v_3(t)$ is high when $v_2 > +2$ V = v_+ of third op-amp.