EECS 16A Designing Information Devices and Systems I
Fall 2018 Homework 11

This homework is due November 9, 2018, at 23:59.
Self-grades are due November 13, 2018, at 23:59.

Submission Format
Your homework submission should consist of **one** file.

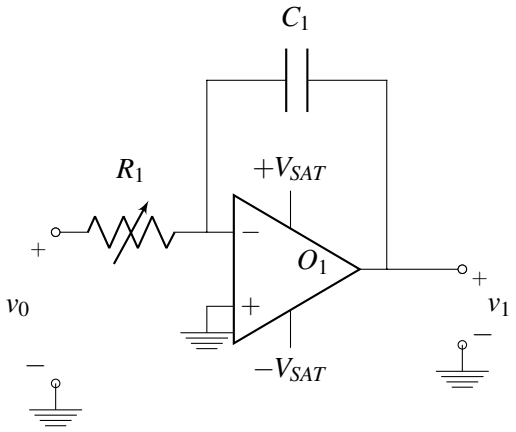
- `hw11.pdf`: A single PDF file that contains all of your answers (any handwritten answers should be scanned).

Submit each file to its respective assignment on Gradescope.

1. Jumpbot

In this problem, you will be designing circuits allowing a robot named Jumpbot to execute a set of commands that will be described below. Specifically, the output voltages produced by your circuits are interpreted by Jumpbot as setting its vertical position in meters in free space (both positive and negative values will be used). You will be generating an oscillating triangular waveform with a controllable time period.

(a) One of the circuit blocks you will use to generate the triangular waveform is the integrator. An integrator integrates the input signal. For the circuit given below express v_1 in terms of R_1, C_1, and v_0. You may assume the capacitor C_1 has $0V$ across it at time $t = 0$.
Hint: You will have to apply KCL, and the current flowing through a capacitor is given by $I = C\frac{dV}{dt}$.

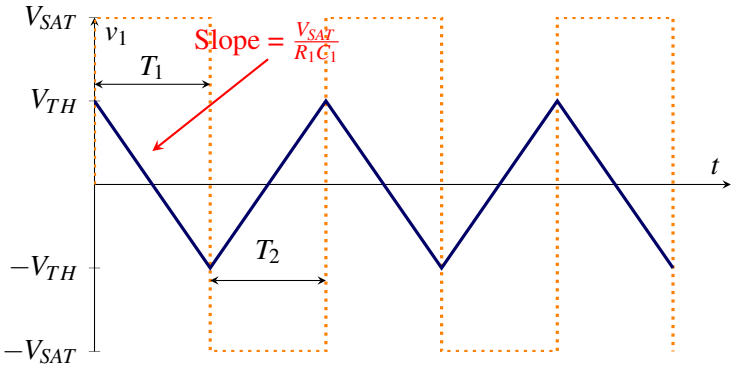


Solution:

Let's write the KCL equation at V^- assuming all currents are leaving.

$$\begin{aligned} i_{R_1} &= -i_{C_1} \\ i_{C_1} &= C_1 \frac{d(0-v_1(t))}{dt} \\ \frac{0-v_0}{R_1} &= C_1 \frac{d(v_1(t)-0)}{dt} \\ -\frac{v_0}{R_1 C_1} &= \frac{dv_1(t)}{dt} \\ v_1(t) &= -\frac{1}{R_1 C_1} \int_0^t v_0 d\tau \end{aligned}$$

(b) Suppose for a specific v_0, shown by the dotted orange line below, v_1 looks as shown by the blue line. Derive an expression for T_1 and T_2 as a function R_1, C_1, V_{TH}, and V_{SAT}.



Solution:

Note that the indicated slope is the magnitude of the slope.

For T_1, using the waveform of v_1:

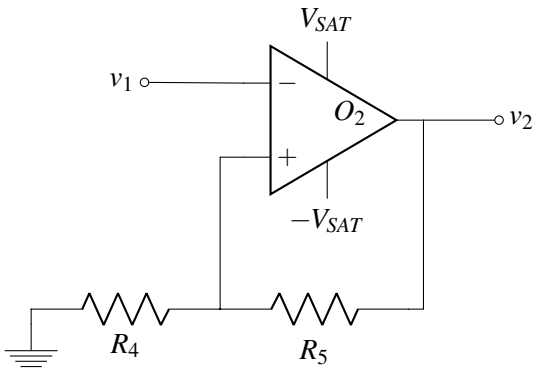
$$\begin{aligned} \frac{-V_{TH}-V_{TH}}{T_1} &= -\frac{V_{SAT}}{R_1 C_1} \\ T_1 &= R_1 C_1 \frac{2V_{TH}}{V_{SAT}} \end{aligned}$$

Similarly for T_2, using the waveform of v_1:

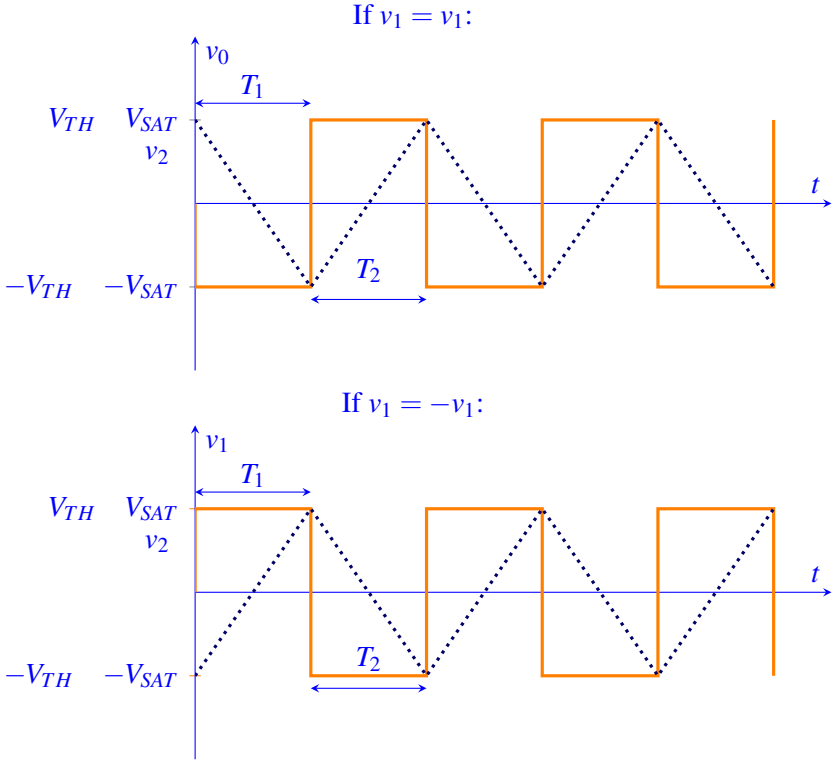
$$\begin{aligned} \frac{V_{TH}-(-V_{TH})}{T_2} &= \frac{V_{SAT}}{R_1 C_1} \\ T_2 &= R_1 C_1 \frac{2V_{TH}}{V_{SAT}} \end{aligned}$$

(c) We have a circuit that generates a triangle wave from a square wave. However, we need to create the initial signal (v_0) that helped us to create the triangular waveform (v_1). For the circuit below, draw the waveform (v_2) if we use v_1 from part (b) as the input. Now, draw the waveform (v_2) if we use $-v_1$. Which v_2 (v_1 as input or $-v_1$ as input) matches v_0 from part (b)?

$$\begin{aligned} +V_{TH} &= \frac{R_4}{R_4+R_5} V_{SAT} \\ -V_{TH} &= \frac{R_4}{R_4+R_5} (-V_{SAT}) \end{aligned}$$



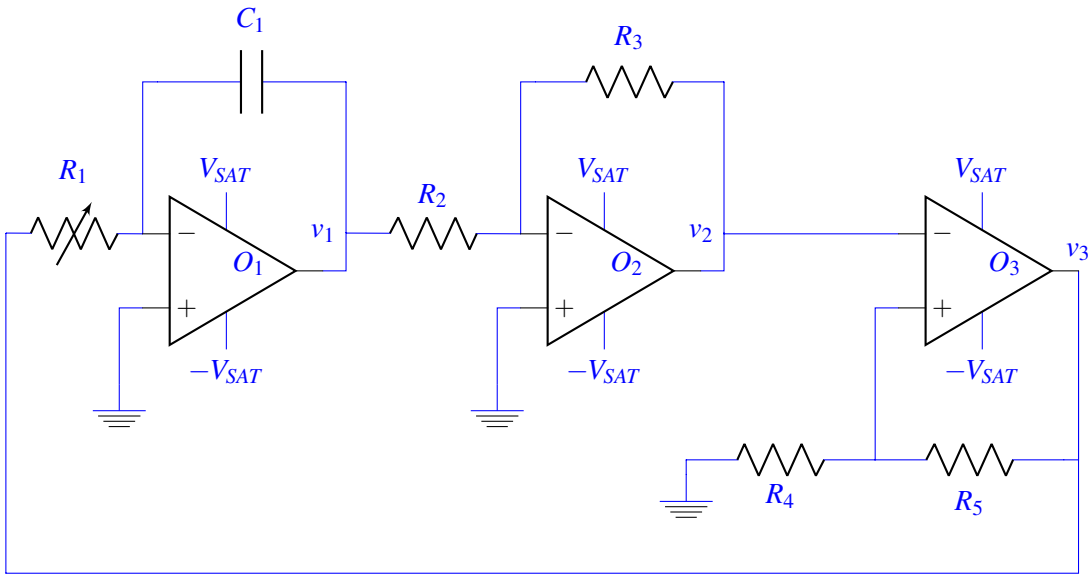
Solution:



If $-v_1$ is used as the input, the output matches v_0 from part (a).

(d) Now let's put it all together. The circuit from part (a) generates a triangle wave (v_1) from a square wave (v_0). The circuit above takes an input triangle wave and creates a square wave. Connect the two circuits together so that the circuit keeps generating a triangle wave on it's own. You will use the circuits from part (a) and part (c), in addition you can use any opamps and resistors.

Solution:



We've added an inverting amplifier, O2, with a gain of 1, so that v_2 has the polarity that we want as we saw in part (c).

(e) In your circuit, if $\pm V_{SAT} = \pm 10\,\text{V}$, $C_1 = 0.01\,\text{mF}$, and $R_4 = 10\,\text{k}\Omega$, find the values for R_1 and R_5, so that the jumpbot jumps with 10 V peak-to-peak amplitude ($\pm V_{TH} = \pm 5\,\text{V}$) with 1 kHz frequency (period = 1 / frequency).

Solution:

10 V peak-to-peak amplitude means $\pm V_{TH} = \pm 5\,\text{V}$. Therefore,

$$V_{TH} = \frac{R_4}{R_4 + R_5} V_{SAT}$$
$$5\,\text{V} = \frac{10\,\text{k}\Omega}{10\,\text{k}\Omega + R_5} 10\,\text{V}$$
$$R_5 = 10\,\text{k}\Omega$$

To find R_1, we can use the relationship derived in part (b). However, here $T_1 = 0.5\,\text{ms}$ because $T_1 + T_2 = T = 1\,\text{ms}$ (oscillation frequency 1 kHz).

$$T_1 = R_1 C_1 \frac{2V_{TH}}{V_{SAT}}$$
$$0.5\,\text{ms} = R_1 \cdot 0.01\,\text{mF} \cdot \frac{2 \cdot 5\,\text{V}}{10\,\text{V}}$$
$$R_1 = 50\,\Omega$$

2. Midterm Problem 3

Redo Midterm Problem 3.

(a) **Solution:** See midterm solutions.

(b) **Solution:** See midterm solutions.

(c) **Solution:** See midterm solutions.

(d) **Solution:** See midterm solutions.

3. **Midterm Problem 4**
Redo Midterm Problem 4.

(a) **Solution:** See midterm solutions.

(b) **Solution:** See midterm solutions.

(c) **Solution:** See midterm solutions.

(d) **Solution:** See midterm solutions.

4. **Midterm Problem 5**
Redo Midterm Problem 5.

(a) **Solution:** See midterm solutions.

(b) **Solution:** See midterm solutions.

5. **Midterm Problem 6**
Redo Midterm Problem 6.

(a) **Solution:** See midterm solutions.

(b) **Solution:** See midterm solutions.

(c) **Solution:** See midterm solutions.

(d) **Solution:** See midterm solutions.

6. **Midterm Problem 7**
Redo Midterm Problem 7.

(a) **Solution:** See midterm solutions.

(b) **Solution:** See midterm solutions.

(c) **Solution:** See midterm solutions.

7. **Midterm Problem 8**
Redo Midterm Problem 8.

(a) **Solution:** See midterm solutions.

(b) **Solution:** See midterm solutions.

(c) **Solution:** See midterm solutions.

(d) **Solution:** See midterm solutions.

(e) **Solution:** See midterm solutions.

(f) **Solution:** See midterm solutions.

(g) **Solution:** See midterm solutions.

8. Homework Process and Study Group

Who else did you work with on this homework? List names and student ID's. (In case of homework party, you can also just describe the group.) How did you work on this homework?

Solution:

I worked on this homework with...

I first worked by myself for 2 hours, but got stuck on problem 5, so I went to office hours on...

Then I went to homework party for a few hours, where I finished the homework.