EECS 16A Designing Information Devices and Systems I
Spring 2016 Elad Alon, Babak Ayazifar Homework 8

This homework is due March 29, 2016, at Noon.

We hope you have/had a lovely Spring Break!! Relax and recuperate :)

1. **Homework process and study group**

   Who else did you work with on this homework? List names and student ID's. (In case of hw party, you can also just describe the group.) How did you work on this homework?
   Working in groups of 3-5 will earn credit for your participation grade.

2. **IoT4eva Revisited**

   After guiding them to make an intelligent selection for their super-capacitors, IoT4eva was so happy with your performance that you got a promotion! The good news is that you're getting paid more, but the "bad" news is that you have more responsibilities too. In particular, you are now responsible not only for selecting the super-capacitors used to power the device, but also for building the rest of the circuitry associated with the power supply.

   In practice, many real circuits (especially sensors that are trying to detect very small signals) don't like to operate with supply voltages that vary substantially over time. Remembering that the voltage on our super capacitors drops linearly as we pull current out of them, this means that if we want to use these super capacitors for our device, we need to build another circuit. This circuit is powered by the super-capacitor and produces a constant voltage at its output, where this voltage will then be used to supply power to rest of the device. These circuits are often referred to as "voltage regulators", and in this problem we'll explore how to build the simplest form of such a voltage regulator.

   (a) The first problem we may have had to solve to realize such a voltage regulator is to figure out how to build a reference that would allow us to set the voltage at the output of our regulator to a known absolute value. Fortunately someone else in the company has already built one of those and made it available to you - you can model this circuit as a voltage source whose value is $0.8V$ with a source resistance of $1k\Omega$. (The internals of this voltage reference circuit aren't important for this problem, but as you should see shortly, this circuit by itself is not appropriate for supplying power to the rest of the device.)

   Now that we have a reference we can focus on the core of the voltage regulator itself. Using this reference circuit, an op-amp, and resistors, design a circuit that is powered by the super-capacitor voltage V_{sc} (which for now you can assume is always high enough for the circuit to work) and that would produce a constant $1.2V$ supply voltage for the rest of the device. Note that you can model the load from the rest of the device as a $10mA$ current source; please be sure to choose specific values for any resistors you use in your circuit as well.

   (b) Now that we've built the voltage regulator and we know that we want its output voltage to stay fixed at $1.2V$, what is the minimum voltage we need on our super capacitors $V_{sc,min}$ to ensure that the regulator can indeed produce a fixed $1.2V$ output?

(c) One of the most important things to evaluate about a voltage regulator is its efficiency - i.e., the power dissipated by the load circuits (in this case, the rest of the IoT4eva device) divided by the total amount of power delivered by the power supply. Continuing to model the rest of the IoT4eva device as a $10mA$ current source, how much power is dissipated by the $10mA$ current source? As a function of V_{sc} (and assuming V_{sc} is higher than the minimum you found in part b), how much power is actually delivered by the super-capacitor? What is therefore the efficiency of your voltage regulator circuit?

Note that you can assume that the op-amp does not dissipate any power except for what is required to supply the current to its output. (Hint: The op-amp itself can't generate any power, so you should think about where this current would have to originate from.) It is also worth noting that the voltage reference circuit that was given to you would actually dissipate some power from the super-capacitor as well, but you can ignore that for this problem.

(d) Still using only op-amps and resistors, is there anything you can do to improve the efficiency of your voltage regulator design?

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

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

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

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

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

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

9. **Midterm Problem 9**
Redo Midterm Problem 9.

10. **Midterm Problem 10**
Redo Midterm Problem 10.

11. **Your Own Problem** Write your own problem related to this week's material and solve it. You may still work in groups to brainstorm problems, but each student should submit a unique problem. What is the problem? How to formulate it? How to solve it? What is the solution?