Massachusetts Institute of Technology
Department of Aeronautics and Astronautics

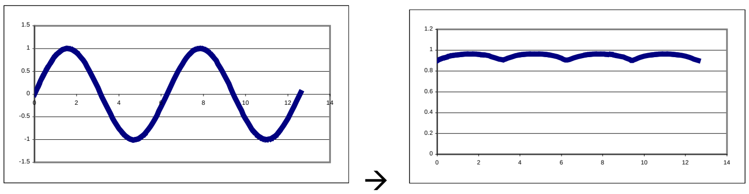
16.682 – Special Subjects in Aeronautics and Astronautics
"Prototyping Avionics"

<u>Homework #2</u>
Out: Mon Feb 27, 2006
Due: Wed Mar 8, 2006

Topics:
- Power supplies
- Transistors

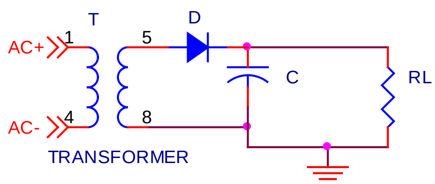
Problem 1 – Transformers and Bridges

In class we saw the use of a *full-wave bridge rectifier* to help convert an AC signal to a DC signal (with some ripple):



There are other types of rectifiers (half-wave, for example) and other ways to implement a full-wave rectifier. Lets take a quick look at these:

1) A half-wave rectifier looks like this:



Explain using a diagram that compares the input voltage (AC+/-) and the output voltage (V across R_L) why it is a *half* wave. The following steps could be useful:

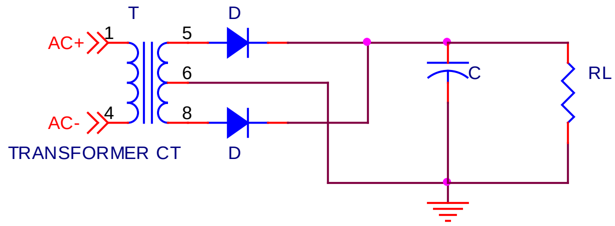
a) Assume the capacitor C is not there:

i) how does the current flow across R_L when the AC is on the positive side?

ii) how does the current flow across R_L when the AC is on the negative side?

b) Add the capacitor and show the approximate signal

2) Another way to implement a full wave rectifier is as follows (note it is *not* a *bridge*):



This is a great way to understand the concept that voltages are relative and at the same time how transformers can help us:

a) Since pin 6 is defined as ground, what is the AC polarity of pins 5 & 8? How about the DC polarity (after the diodes) of pins 5 & 8?
b) Ignoring the capacitor, show how the current flows when the AC voltage is positive and negative
c) Draw a picture of the output voltage before the capacitor, and compare it to the input voltage
d) What happens when you account for the capacitor?
e) ***Extra credit***: what is the main difference in the output voltage between a *bridge* rectifier (from lecture) and a *center-tap* rectifier?

Problem 2 – Regulators

After reducing the voltage with a transformer and rectifying any AC signals, you practically always want to use a regulator. Lets makes sure you understand the benefits and caveats of both linear and switching regulators.

1) Lets start with a linear regulator, and use it in two cases:

a) Assume that your rectifier output voltage is 12V and your load operates at 5V and utilizes:
i) 10mA of current
ii) 1A of current
What is the absolute/total wasted power in the regulator?
What is the efficiency for each case?
Does it make sense for a *linear* regulator?

b) Now assume the rectifier output voltage is 6V, and the current is 1A.
What is the wasted power?
What is the efficiency?

c) In which of these cases would you use a linear regulator? Why?

2) When you use a center-tap rectifier, or if you use batteries as your power-source, it is hard to get negative voltages. You could change your circuit to use a full-bridge and change your transformer, or could try to put “center taps” on batteries in series, but those are all ugly solutions. It would be nice to use a switching regulator!

a) Go online and find a switching regulator that can invert a voltage (recommended sites include: `http://www.digikey.com` or `http://www.maxim-ic.com`. I don't necessarily want to promote specific brands, but these have the following benefits:

- Typing "voltage regulator" in the Digikey search box gives you a great list of results with many ways to filter out the "specifications" you want
- Maxim provides very good datasheets with "typical application circuits" which show you how to implement a switching regulator, including all part numbers!

There are many others out there, but these give you good information.

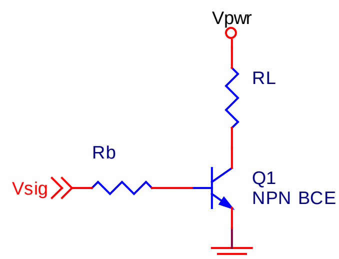
b) Once you find the specific regulator, get the datasheet and find:
   i) Maximum input voltage
   ii) Efficiency (maybe as a function of current?)
   III) Maximum power (W)

c) Copy a "typical application circuit" and label all the parts in it, with short explanations of the purpose of each part.

This problem intends to show you two things: understand the use of regulators, and realize that you don't have to know how to design a switching one, all you need to do is understand how they work and go find one that already exists!

Problem 3 – Transistors: NPN & PNP

For this problem we'll stick to the basic use of a transistor to amplify current of a digital circuit to drive a large load (such as a solenoid valve, a relay, etc). The circuit we presented in class is:



Reminder of something we covered in lecture too quickly: the voltage drop across a transistor (between the base and the emitter) is 0.6V in general, like in a diode.

Lets make sure you understand this circuit:

a) If you assume that V_{sig} comes from a digital micro-controller and is either 0V or 5V; that the load requires 250mA; and that the amplification of the transistor is h=100, then:
What should R_B be?
What happens if you make R_B larger?
What happens if you make R_B smaller?

b) If you know that V_{sig} is 5V and can provide a maximum of 20mA, and that the transistor has h=100 then:
i) What is the maximum current through the load?
II) What is the minimum value R_B can be?

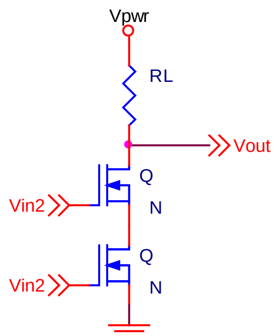
Problem 4 – Transistors: MOSFETs

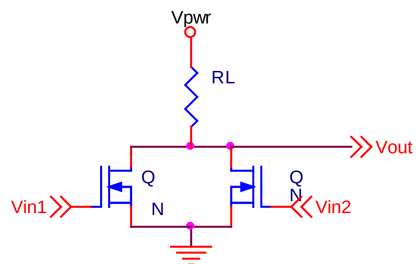
1) First, lets understand the difference between N-channel and P-channel MOSFETs – it is very similar to the difference between NPN and PNP transistors. In class we saw that the current flow from *drain* to the *source* of an N-channel MOSFET is a (non-linear) function of the voltage across the *gate* (+) and the *source*(-). A P-channel MOSFET is the compliment of the N-channel:

- The current flow from the *source* to the *drain* is a function of the voltage across the *source*(+) and the *gate*(-).

Draw the behavior of this current (show how current flows from one point to another) in a symbol of a P-MOSFET and draw the curve as a function of V_{gs} to I_{ds}.

2) In class we introduced MOSFETs to design digital circuits, but we only talked about the output as being "current on/off". A real circuit requires that all nodes be fully defined and loops are closed. Therefore, lets look at slightly modified versions of the networks that were introduced in class:





In these cases we no longer have "floating" voltages, but instead all nodes are tied to a voltage, like it should be.

Keeping in mind that when the voltage between the *gate* and the *source* is positive, MOSFETs transmit current across the *drain* and the *source*, fill out the truth tables (2 total) for each of the circuits.

What are the logic functions implemented by these circuits?

3) ***Extra Credit:*** Try to use P-channel MOSFETs to implement the opposite logic.

That implementation is the “complimentary” circuit, and a combination of both circuits is what is ultimately used in CMOS technology.