# ECE 320 - Homework #5

DC to DC Converters, Transistor Switches.  Due Monday, September 28tht

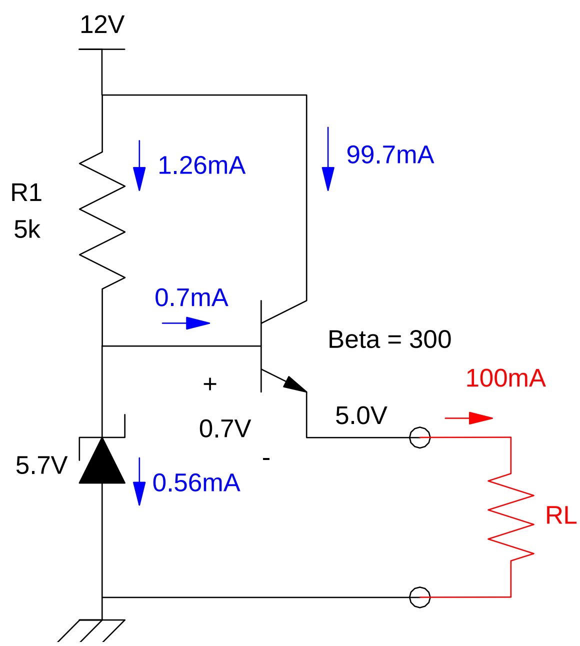
1)  Design a circuit which converts 12V DC to 5V DC using a transistor, with the output capable of driving 100mA @ 5V, with an efficiency more than 10%

- Use a Zener diode to create a voltage reference.
- Add a transistor with a current gain of 300 (Zetex 1051A).  This results in a base current of 0.7mA under full load.
- Add a resistor (R1) small enough to drive the base current.  (R1 = 9k).  Pick R1 slightly smaller than 9k to make sure there is enough current available to drive the base under full load.

R1 Calculations:  Under full load, you need 100mA to the load.  Assuming a current gain of 300, the base current is 0666uA  (100mA / 300).  R1 must supply at least this much current

$$R_1 < \frac{12V - 5.7V}{666uA} = 9.4k\Omega$$

To make sure there is enough current to turn on the Zener diode and provide current to the transistor, let R1 = 5k,




Efficiency:

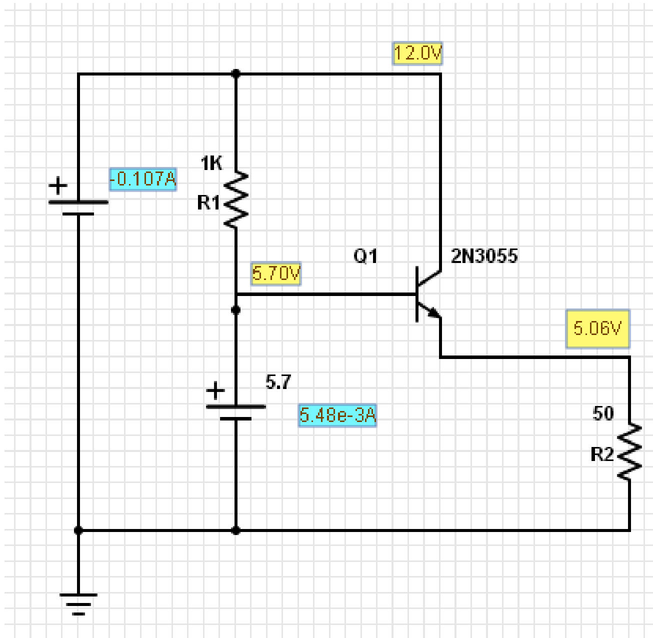
Power Out = 5V @ 100mA = 500mW

Power In = 12V @ (99.7mA + 1.26mA) = 1211mW

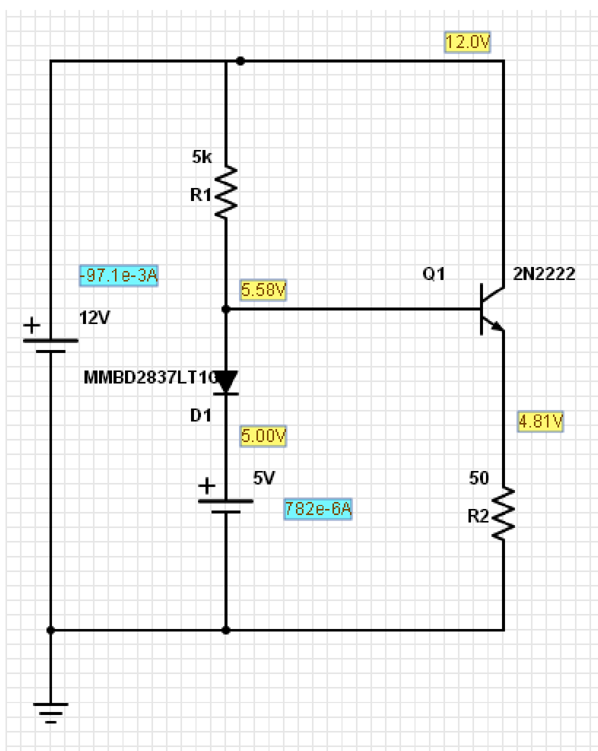
Efficiency = Power Out / Power In = 41%

2) Check your design in PartSim

Instead of a 5.7V Zener diode (which I couldn't find in PartSim), a 5.7V source is used.  It absorbs 0.56mA




You could also use a regular silicon diode along with a DC power supply so that it turns on at 5.7V:



3) Design a circuit which converts 12V DC to 5V DC, capable of driving 100mA @ 5V, with an efficiency more than 80% that results in a ripple of 500mV (ripple added)

Use a Buck converter. Assume a 1kHz switching frequency with a duty cycle of 5/12

To model the load, use a resistor

$$R_{load} = \frac{5V}{100mA} = 50\Omega$$

The voltage at the switching element is

$$V_{in}(t+T) = \begin{cases} 12V & 0 < t < 5/12ms \\ 0V & 5/12ms < t < 1ms \end{cases}$$

Approximately

$$V_{in}(t) = 5 + 12V_{pp}\sin(2000\pi t)$$

Option 1: C = 0

DC Analysis: $(\omega = 0)$

$$V_{out} = \left(\frac{R}{R+j\omega L}\right)V_{in}$$

$$V_{out} = \left(\frac{R}{R+j0}\right)5V = 5V$$

AC Analysis: $(\omega = 2000\pi)$

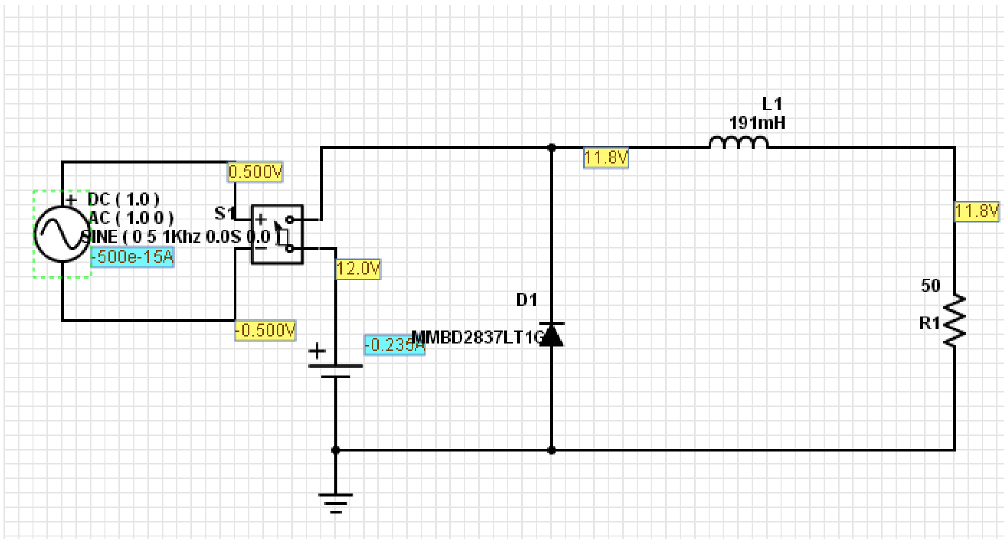
$$V_{out} = \left(\frac{R}{R+j\omega L}\right)V_{in}$$

For a 500mVpp output ripple

$$500mV_{pp} = \left(\frac{50}{50+j\omega L}\right)12V_{pp}$$

$$L = 191mH$$

4) Check your design in PartSim




A switch is used to simulate the on-off connection.  A sine wave drives it


Output Voltage:  5.09V < V < 5.927V

The DC level is a little off since the on/off cycle time is a little off for the switching regulator (plus the diode brings the minimum voltage in to -0.7V)

The ripple is 817mV - slightly larger than the desired 500mV

Problem 3) (take 2): Add a capacitor

Let L = 100mH

The ripple at the load is then

$$V_{out} = \left( \frac{R || \frac{1}{j\omega C}}{R || \frac{1}{j\omega C} + j\omega L} \right) V_{in}$$

Assume

$$R || \frac{1}{j\omega C} \approx \frac{1}{j\omega C}$$

$$R || \frac{1}{j\omega C} + j\omega L \approx j\omega L$$

then

$$V_{out} = \left( \frac{\frac{1}{j\omega C}}{j\omega L} \right) V_{in}$$

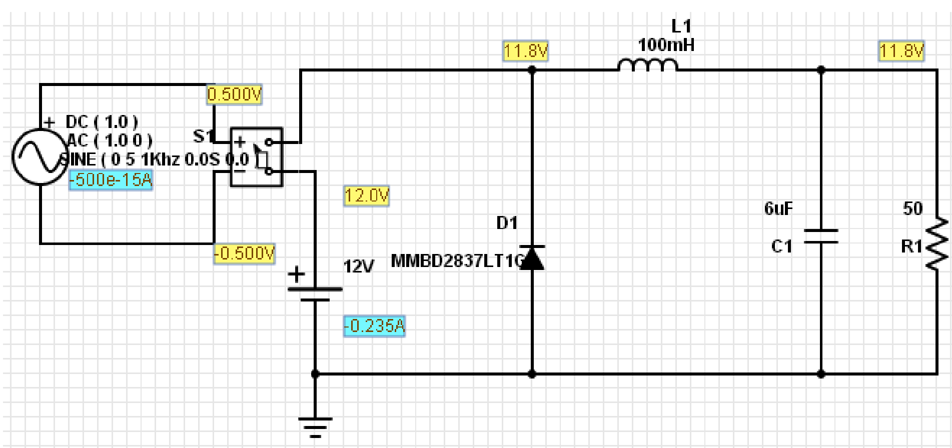
$$V_{out} = \left( \frac{1}{\omega^2 LC} \right) V_{in}$$

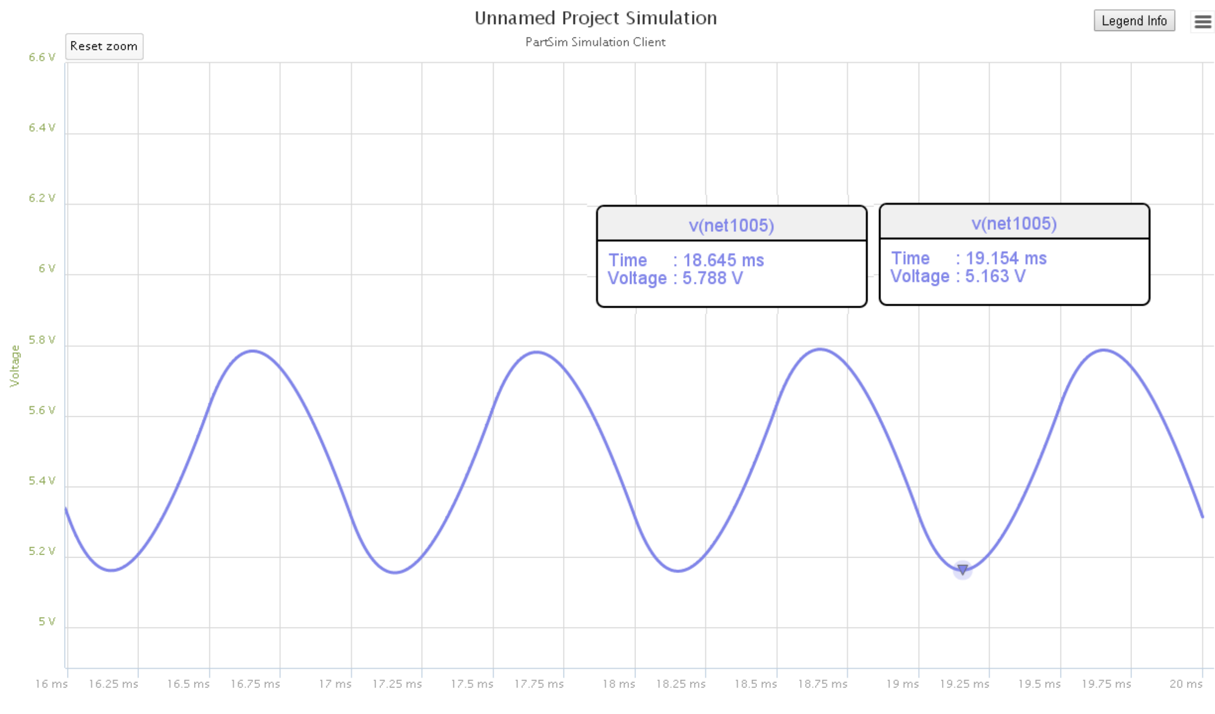
If L = 100mA

$$500mV_{pp} = \left( \frac{1}{(2000\pi)^2 (100mH) C} \right) 12V_{pp}$$

C = 6uF

Problem 4: Checking in PartSim






Output Voltage: 5.163V < Vout < 5.788V (ripple = 630mV)

5) Design a circuit which allows a function generator to drive an 8 Ohm speaker

Input:

- 0V / 5V TTL square wave, capable of driving 20mA

Output

- 8 Ohm speaker

Relationship:

- 0V in produces 0mA at the speaker
- 5V in produces 1A at the speaker (+/- 100mA)

Use a tansistor: Selecting a transistor from PartSim which can take 625mA

| | hfe | Icmax |
|---|---|---|
| 2n3055 | 20 | 15A |
| 2n3442 | 20 | 10A |
| 2n2222 | 100 | 800mA |

The collector current when the transistor is on is 625mA

$$I_c = \frac{5V}{8\Omega} = 625mA$$

The base current then needs to be

$$\beta I_b > I_c$$

$$I_b > \frac{625mA}{100} = 6.25mA$$

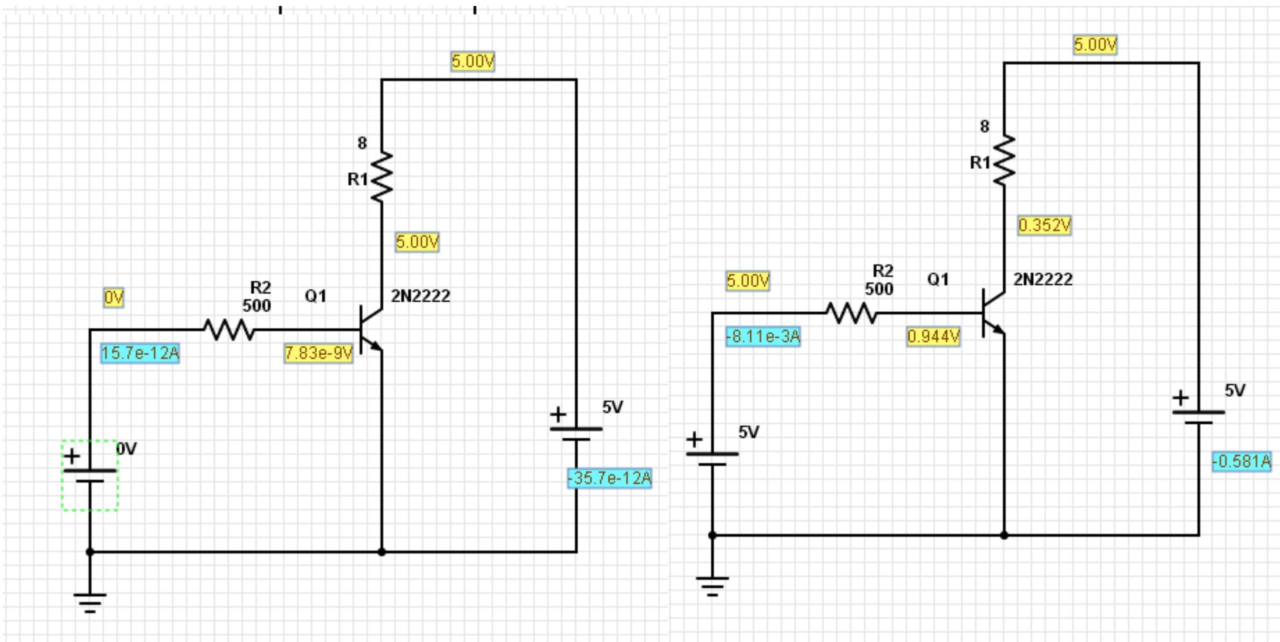
The base resistor is then

$$R_b < \frac{5V - 0.7V}{6.25mA} = 688\Omega$$

Let

Rb = 500 Ohms

6) Check your design in PartSim




PartSim Simulation for Vin = 0V (left) and Vin = 5V (right)

From PartSim:

When Vin = 0V, (left figure) the transistor is off (all currents zero)

When Vin = 5V (right figure),

Ic = 581mA (vs 625mA)

Vce = 0.352V ( the transistor is saturated - or pretty close )

Ibe = 8.11mA

Check for saturation:

$$\beta I_b > I_c$$

$$(100)(8.11mA) > 581mA$$

Lab)

7) Build one of the above circuits and verify the voltages and currents are as you calculated.