EE 322 Advanced Electronics, Spring 2013
Exam 1
Monday March 4, 2013

Rules: This is a closed-book exam. You may use only your brain, a calculator and pen/paper. Each numbered question counts equally toward your grade.

Note: The questions are designed to test your conceptual understanding, not your ability to do many pages of math. If you find yourself doing long calculations there is a high probability that you are doing something wrong.

Linear regulator

The LM317 linear regulator has 3 pins: a input pin, a output pin, and a adjust pin. The output voltage is selected through a voltage divider scheme involving the output, the adjust pin, and ground. The voltage between output and regulation is 1.25 V.

1. **Select resistors to create an output voltage of 5 V, with the smallest resistor being 10 kΩ. Show the circuit with component values.**

   Smallest resistor is between ADJ and output, call it $R_2 = 10\,\mathrm{k\Omega}$. We then have

$$1.25 = \frac{R_2}{R_1 + R_2} \times 5$$

$$1.25\,(R_1 + R_2) = 5R_2$$

$$R_1 = \frac{3.75\,R_2}{1.25} = 30\,\mathrm{k\Omega}$$

2. **Add a bypass BJT and resistor such that the bypass turns on when the power dissipation in the LM317 reaches 0.5 W for a 15 V input. Show the circuit with component values.**

   The voltage drop across the LM317 will be $15 - 5 - 0.5 = 9.5\,\mathrm{V}$ (the 0.5 from drop across current sense resistor). The maximum current comes from

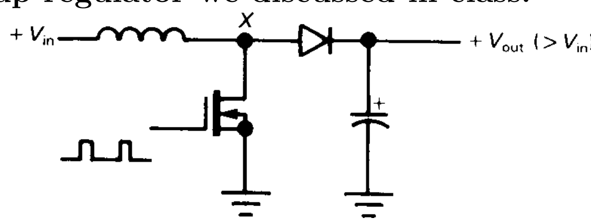
$$I = \frac{P}{V} = \frac{0.5}{9.5} = 53\,\mathrm{mA}$$

   That currene must produce 0.5 V across the current sense resistor, thus

$$R_S = \frac{0.5}{0.053} = 9.4\,\Omega$$

Switching regulator

3. Draw the step-up regulator we discussed in class.



4. What is the output voltage if the input voltage is 5 V and the inductor current ramps up for twice as long as it ramps down?

The slope is

$$\frac{dI}{dt} = \frac{\Delta V}{L}$$

and the down slope is twice the up slope, so the voltage while the current is decreasing is twice the voltage while it is increasing. The decreasing current voltage is $V_{\text{out}} - V_{\text{in}}$ and thus we must conclude that $V_{\text{out}} = 15\,\text{V}$.

5. Plot, for discontinuous mode, the voltage at the junction of the switch, diode, and inductor. Make sure to show the correct ratio between duration of up- and down-ramp. You may assume ideal components.

Electronic noise

Examine a inverting amplifier. You need to amplify a source signal by a $G_{vo} = -100$. The source has output resistance $1\,\mathrm{M\Omega}$. A amplifier with finite input resistance thus needs a gain (A_{vo}) larger than that to provide the specified G_{vo}. The op-amp noise is $e_{na} = 100\,\mathrm{nV}/\sqrt{\mathrm{Hz}}$. You may assume $T = 300\,\mathrm{K}$, $k = 1.4 \times 10^{-23}$, and $B = 1\,\mathrm{kHz}$.

6. **If the amplifier input resistance is $1\,\mathrm{M\Omega}$, select the appropriate feedback resistor and compute the output RMS noise.**

   Since the amplifier input resistance equals the source resistance the signal is cut in half at the amplifier input and we thus need a gain of -200 on the amplifier. That means that $R_2 = 200\,\mathrm{M\Omega}$. The noise on the output is then

$$
\begin{aligned}
v_n &= \sqrt{4kT\left(R_s + R_1\right)A^2 + e_{na}^2\left(|A| + 1\right)^2 + 4kTR_2}\sqrt{B} \\
&= \sqrt{\begin{array}{l} 4 \times 1.4 \times 10^{-23} \times 300 \times 2 \times 10^6 \times 200^2 \\ + \left(100 \times 10^{-9}\right)^2 \times 201^2 \\ + 4 \times 1.4 \times 10^{-23} \times 300 \times 200 \times 10^6 \end{array}} \times \sqrt{10^3} \\
&= 1.0\,\mathrm{mV}
\end{aligned}
$$

7. **Does the noise improve (get smaller) if you use a $100\,\mathrm{M\Omega}$ input resistance instead (and correspondingly smaller A_{vo})?**

   In this case the input resistance is MUCH larger than the source resistance so I will just approximate a gain of -100 and thus the feedback resistance is $10\,\mathrm{G\Omega}$. Use the same equation as in the prvious question but with $R_1 = 100\,\mathrm{M\Omega}$, $A = -100$, $R_2 = 10\,\mathrm{G\Omega}$.

$$
\begin{aligned}
v_n &= \sqrt{4kT\left(R_s + R_1\right)A^2 + e_{na}^2\left(|A| + 1\right)^2 + 4kTR_2}\sqrt{B} \\
&= \sqrt{\begin{array}{l} 4 \times 1.4 \times 10^{-23} \times 300 \times 101 \times 10^6 \times 100^2 \\ + \left(100 \times 10^{-9}\right)^2 \times 101^2 \\ + 4 \times 1.4 \times 10^{-23} \times 300 \times 10 \times 10^9 \end{array}} \times \sqrt{10^3} \\
&= 4.2\,\mathrm{mV}
\end{aligned}
$$

   Thus the answer is no, using larger input resistance does not improve the noise in this case.