Engineering 1620 – Spring 2016

Answers to Homework 2: SPICE Analysis of a Voltage Doubler

I assumed that the results of a SPICE run would be sufficiently obvious that the questions about it would be easy enough not to require my answers but some of the questions I have heard about those results have given me pause. Here is a partial set of answers based on my own run of SPICE.

2.) My final peak voltage was 8.05 volts after 3 msec. The output reached 7.98 volts on the 17th peak of the input signal at 1.63 msec after startup. Around 3 msec, the output varies from 8.05 volts at maximum to 7.92 volts minimum, a peak to peak variation of 0.13 volts. The mean or DC output is ½ (8.05 + 7.92) = 8.0 volts DC. The ripple frequency is the same as the source frequency, 10 KHz.

3.) The mean output current is 8.0/5e4 = 160 uA. On my SPICE plot, the peak current in D2 was 1.71 mA or a ratio of 10.7:1. In class I gave a rough estimate of 10 X. (I was prescient!)

4.) With no load but using a large signal model that imposes a forward voltage drop even with no diode current, the output will simply be $V_{OUT} = 2*(V_{SRC} – V_F) = 8.5$ volts.

5.) With 50 K ohms and 8.5 volts, the output current is 170 uA. The ripple in the output comes from this current discharging the capacitor during the 100 usec periods between peaks of the source signal. During that time the current does not change very much so the change in voltage is $v_{ripple} = \frac{I_{LOAD}T}{C} = \frac{I_{LOAD}}{Cf_{ripple}}$ Plug and chug gives a ripple voltage of 0.17 volts and a mean DC output of 8.5 – 0.085 = 8.41 volts DC.

6.) Both estimates in part 5 are high because we have neglected the current in the diodes being much higher than the output current. This is necessary so that the total charge into the output load resistor has to be the same as the charge passing through each diode on a cycle by cycle basis. The diodes conduct for much less time than the resistor, so the ratio is high. Estimating the peak current as 10 times the output current would mean a potential drop of 0.34 volts across the 200 ohms of the source resistance. Then the output is only expected to be 2*(5 - .34 - .75) = 7.97 volts peak. The DC output voltage would be 7.88 volts. This is 1 % agreement with SPICE with relatively little effort.

7.) Here are two variants on voltage multipliers. The left hand figure is a true voltage tripler. The right hand figure is actually a quadrupler but the drop in the source resistor is sufficient that SPICE shows it to have an output that is only 3 X the input peak voltage.