Lab 10 – Notes

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General Notes

- Lab 9 is an extra credit lab that you can do on your own if you would like to get a bump to your grade. We are not doing it in class.
- Please make sure to return back all the ALD chips if you haven’t already.

Procedures to compute the values for any converter

1. Start by using the simple equation (10.5/10.9/10.14)
2. Check the conditions after calculating the values using the simple equations.
3. Is the condition satisfied?
   - Yes? You are done.
   - No? You need to recompute again using the complicated equation (10.3 & 10.4/ 10.7 & 10.8 / 10.11 & 10.12).

Task 1

Task 10.5.1: Buck converter

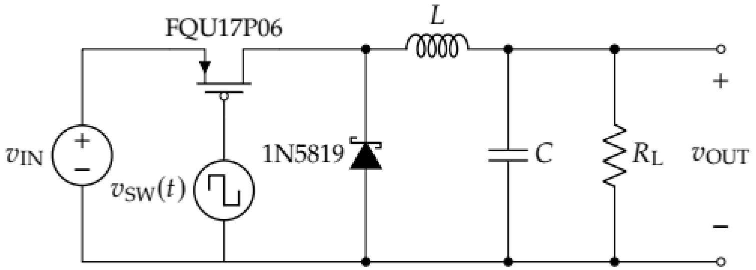


Figure 10.9: A buck converter circuit.

1. *Compute* the theoretical $v_{OUT,avg}$ given $L = 1\,\text{mH}$, $C = 10\,\mu\text{F}$, $R_L = 330\,\Omega$, $v_{IN} = 5\,\text{V}$, and $v_{SW}(t)$ is a −5 V to 5 V 100 kHz square wave with duty cycle $D = 50\%$.
2. *Construct* the circuit in figure 10.9 with the above values.
3. *Measure* the v_{pp} and $v_{OUT,avg}$ with the oscilloscope set to a vertical scale of 100 mV/div. *Calculate* the error for $v_{OUT,avg}$.
4. *Capture* two screenshots of output $v_{OUT}(t)$: One with a vertical scale of 100 mV/div and one with a vertical scale of 1V/div.
5. *Measure* the efficiency of the conversion P_{out}/P_{in}.[a]
6. *Measure* and *plot* $v_{OUT,avg}$ vs. duty cycle of the switch. For this circuit, the duty cycle of the switch is not the duty cycle of the function generator. Instead, $D_{SW} = 1 - D_{FG}$.

[a] Assume that P_{in} can be calculated from the voltage and current reading on the power supply unit. If your power supply unit does not indicate the output current, you should use a multimeter to measure current.

1. Compute the expected value first to compare with the value from the measurement.

3. It's important to understand that the $V_{OUT,avg}$ is the DC voltage that we are looking for, while v_{PP} is for the AC ripples/noise added to our signal, which we would like to be small. Measure and compute the error.

4. Take screenshots using 2 different scales.

5. $\eta = \dfrac{P_{out}}{P_{In}}$

**** You must use the benchtop power supply in this step**

- $P_{Out} = \dfrac{V_{OUT,avg}^2 \rightarrow \textit{should be close to the expected out.voltage}}{R_L}$
- $P_{In} = V_{In} * I_{In}$; $\mathrm{V_{In}} = 5$ & $\mathrm{I_{In}} \rightarrow$ Read the current drawn by the power supply.

6. Take at least 10 points.

Note: $D_{Sw} = 1 - D_{FG}$

Task 2

Task 10.5.2: Boost converter

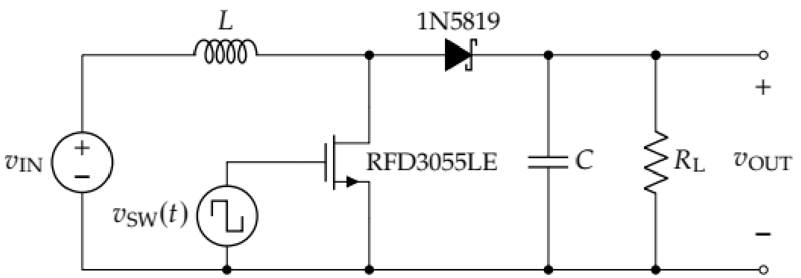


Figure 10.10: A boost converter circuit.

1. *Compute* the duty cycle of the switch needed for $v_{OUT} = 10\,V$ given $L = 1\,mH$, $C = 10\,\mu F$, $R_L = 680\,\Omega$, $v_{IN} = 5\,V$, and $v_{SW}(t)$ is a 0 V to 5 V 100 kHz square wave.
2. *Construct* the circuit in figure 10.10 using the above values.
3. *Measure* the v_{pp} and $v_{OUT,avg}$ with the oscilloscope set to a vertical scale of 200 mV/div. *Calculate* the error for $v_{OUT,avg}$.
4. *Capture* two screenshots of output $v_{OUT}(t)$: One with a vertical scale of 200 mV/div and one with a vertical scale of 1 V/div.
5. *Measure* the efficiency of the conversion P_{out}/P_{in}.[a]

[a] Assume that P_{in} can be calculated from the voltage and current reading on the power supply unit. If your power supply unit does not indicate the output current, you should use a multimeter to measure current.

**LEAVE this circuit built for task 4

**Only power up the circuit when R_L is connected.

1. Check your values with a TA.
2. Please turn on the wavegen (the square wave) first before turning on the supply (+5v) to avoid having short circuit issues.
3. Measure voltages and compute the error.
4. Take screenshots using 2 different scales.
5. $\eta = \frac{P_{out}}{P_{In}}$

**** You must use the benchtop power supply in this step**

- $P_{Out} = \frac{V^2_{OUT,avg} \rightarrow \textit{should be close to the expected out.voltage}}{R_L}$
- $P_{In} = V_{In} * I_{In}$; $V_{In} = 5$ & $I_{In} \rightarrow$ Read the current drawn by the power supply.

Task 3

Task 10.5.3: Inverted boost converter

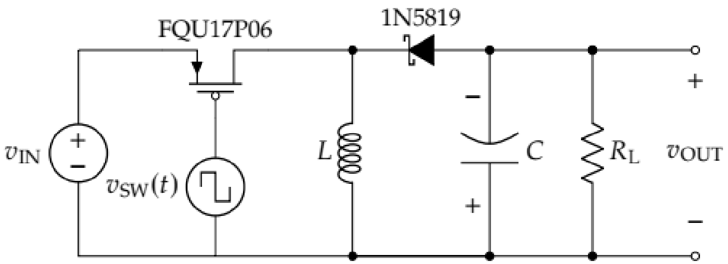


Figure 10.11: An inverted boost converter circuit.

1. *Compute* the duty cycle of the switch needed for $v_{OUT} = -10\,V$ given $L = 1\,mH$, $C = 10\,\mu F$, $R_L = 680\,\Omega$, $v_{IN} = 5\,V$, and $v_{SW}(t)$ is a $-5\,V$ to $5\,V$ 100 kHz square wave.
2. *Construct* the circuit in figure 10.11 using the above values. *Recall* that for the PMOS switch, $D_{SW} = 1 - D_{FG}$. Also *ensure* that any electrolytic capacitors are installed in the correct polarity, as shown in figure 10.11.
3. *Measure* the v_{pp} and $v_{OUT,avg}$ with the oscilloscope set to a vertical scale of 200 mV/div. *Calculate* the error for $v_{OUT,avg}$.
4. *Capture* two screenshots of output $v_{OUT}(t)$: One with a vertical scale of 200 mV/div and one with a vertical scale of 1 V/div.
5. *Measure* the efficiency of the conversion P_{out}/P_{in}.[a]

[a] Assume that P_{in} can be calculated from the voltage and current reading on the power supply unit. If your power supply unit does not indicate the output current, you should use a multimeter to measure current.

**LEAVE this circuit built for task 4

** Make sure that polarity of the capacitor is correct before powering up the circuit.

1. Check your values with a TA. (Note the this a p-MOS -> $D_{Sw} = 1 - D_{FG}$)
2. Please turn on the wavegen (the square wave) first before turning on the supply (+5v) to avoid having short circuit issues.
3. Measure voltages and compute the error.
4. Take screenshots using 2 different scales.
5. $\eta = \dfrac{P_{out}}{P_{In}}$

**** You must use the benchtop power supply in this step**

- $P_{Out} = \dfrac{V_{OUT,avg}^2 \rightarrow \textit{should be close to the expected out.voltage}}{R_L}$
- $P_{In} = V_{In} * I_{In}$; $\mathrm{V_{In}} = 5$ & $\mathrm{I_{In}} \rightarrow$ Read the current drawn by the power supply.

Task 4

Task 10.5.4: Dual rail power supply design

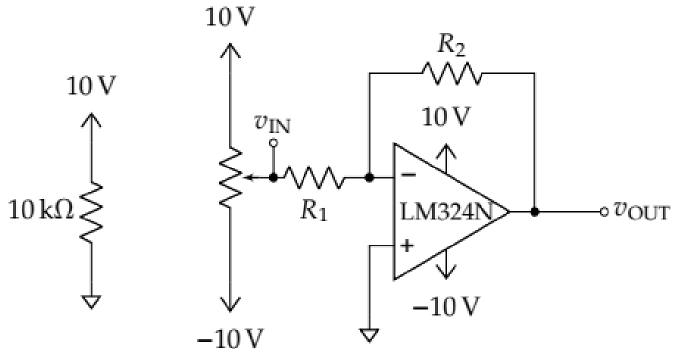


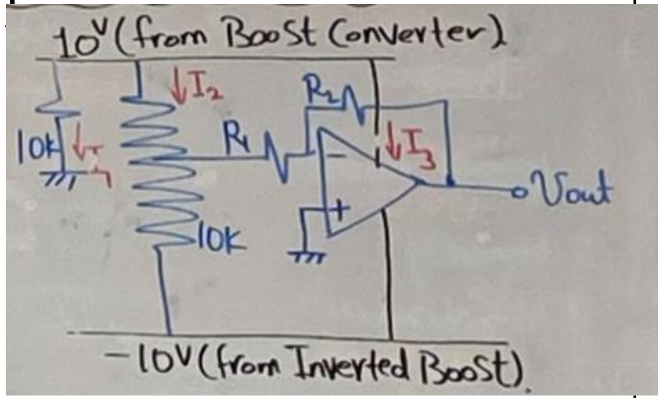
Figure 10.12: An inverting amplifier circuit.

In this task, you will design your own dual rail power supply to drive the operational amplifier in the inverting amplifier circuit from a 5 V USB power supply.

1. *Design* a dual rail power supply that outputs both 10 V and −10 V. The Low-Power Quad-Operational Amplifiers (LM324N) [3] draws approximately 4 mA. You will need both outputs of the function generator.
2. *Pick* an appropriate R_1 and R_2 so that the op-amp has a gain of −4.7. Pick R_1 and R_2 to both be greater than 10 kΩ.
3. *Construct* the designed circuit with the op amp connected. **Do not turn on the circuit without the opamp connected to the positive supply or the voltage will increase without bound!**
4. *Adjust* the duty cycles[a] on the function generator to fine tune the output voltages to the designed ±10 V.
5. *Measure* v_{IN} and v_{OUT} while varying the potentiometer. *Plot* v_{OUT} vs. v_{IN}.

[a] In a real switching power supply, there are circuits that automatically adjust the duty cycle based on a feedback system.

- You need to design a Boost converter (+10v) and an Inverted Boost converter (-10v)
- $I_{L_{Boost}} = I_1 + I_2 + I_3$
- $I_{L_{Inv\ Boost}} = I_2 + I_3$
- $R_L = \dfrac{10\ v}{I_L}$ (each converter)



* You need to compute values for D & $f = \frac{1}{T}$ using R_L for each converter.

* You may assume f (25kHz<f<100kHz) & compute D (0.3<D<0.7). Hint: f = 100 kHz can work.

** Do NOT forget to remove R_L from tasks 2 & 3.

4. Fine tune the Duty cycles from the designed values till you get exactly +10 and -10 v.

5. Vary the potentiometer and measure vin and vout.

(Take enough points to show the 3 regions in the curve).