Lab 11 – Notes

Spring 2024

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Task 1

Task 11.4.1: Buck regulator with PWM modulator control

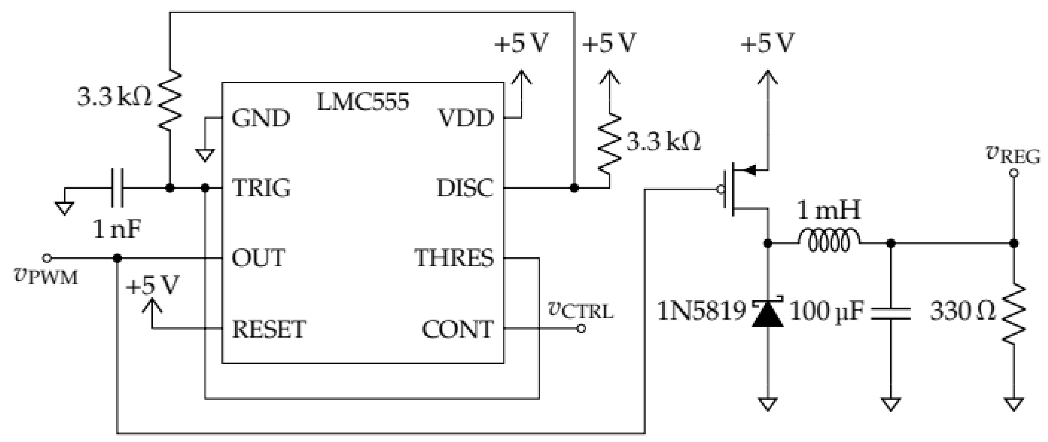

Figure 11.7: PWM Modulation Circuit

1. *Construct* the circuit in figure 11.7
2. *Connect* v_{CTRL} to the function generator and configure the function generator to output DC.
3. *Measure* and *Plot* the relationship between v_{CTRL}, the duty cycle of v_{PWM}, and v_{REG}.
4. What control voltage and duty cycle is needed for a 2.5 V output?
5. *Change* the supply voltage from 5 V to 4 V then *adjust* the control voltage until v_{REG} = 2.5 V. *Record* the control voltage and PWM duty cycle at this point and *compare* these values with the answer from step 4.
6. Is this method of controlling the regulated output voltage open loop or closed loop?

* Please LEAVE this part built for task 3.

* This is the same circuit as lab 10, but you are building a 555-timer circuit to generate the square wave instead of using the function generator.

2. The input is DC voltage (connect the wavegen to Vctrl and configure it to "offset" to generate a DC output).

3. Step up Vctrl from 0-5v (take at least 10 points). Measure the duty cycle of Vpwm and the DC voltage of Vreg at each step. (<u>Note: </u>you can use PosDuty in the AD2 to measure the duty cycle, but if the output of Vpwm looks very distorted, you are encouraged to measure it manually)

Plot 2 curves: Duty_cycle_Vpwm vs Vctrl & Vreg vs Vctrl.

5.6./ Change the supply (from 5 to 4v), now ALL the values will change. Why?!!

Re-adjust to get again Vreg = 2.5, record the new values and compare then compare with step 4.

Task 2

Task 11.4.2: Error amplifier

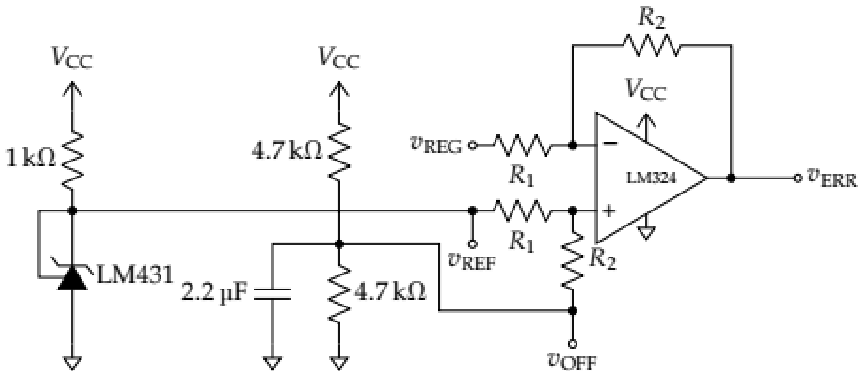

Figure 11.8: PWM Modulation Circuit

In this task, we will design and build an error amplifier that will measure how far from our target voltage of 2.5 V the output of the regulator is. Because this is a single supply design, we must supply an offset voltage to stay within the common mode input and output range of the op amp.

1. Pick R_1 and R_2 in figure 11.8 in order to make $v_{ERR} = v_{REF} - v_{REG} + v_{OFF}$. Choose values greater than 20 kΩ.
2. *Construct* the circuit in figure 11.8 with $V_{CC} = 5\,V$.
3. *Connect* v_{REG} to the function generator in DC mode.
4. *Sweep* the function generator from 1 V to 4 V and record v_{ERR} at each step.
5. *Set* $V_{CC} = 4\,V$ then *repeat* step 4.
6. Does the circuit implement the desired error measurement equation? What is the output voltage when the error is zero for each case?

* Please LEAVE this part built for task 3.

* Please note the following:

- v_{REF} *is always* $\sim 2.5\ v \rightarrow$ *zener diode* $\rightarrow$ *Always constant*
- $v_{OFF} = \frac{V_{CC}}{2} \rightarrow$ *It changes with the supply*
- v_{REG} should be the actual input that we need to compare with (it will be connected to the output of the regulator in task 3). In this task we will be connecting it to the wavegen with an input of DC voltage.

1. Check your values of R1 & R2 with a GTA.

4. Take a measurement at every 0.5v step.

5. Change Vcc=4, then sweep again as in step 4.

6. What is meant by the error here is the actual error $v_{ERR\,actual} = v_{REF} - v_{REG}$, v_{OFF} is just a DC added to the equation.

What is the output of $v_{ERR} = v_{REF} - v_{REG} + v_{OFF}$, when the actual error is zero?!

Task 3

Task 11.4.3: Closed loop buck controller

1. *Construct* the circuit in figure 11.9. Make sure to close the feedback loop by connecting both v_{CTRL} points together.
2. *Set* V_{CC} to 5 V and measure the average value of v_{CTRL} and v_{REG}.
3. *Sweep* V_{CC} from 4 V to 5 V. *Record* v_{REG} and v_{CTRL} at each step.
4. *Capture* an oscilloscope screenshot showing v_{REG} and v_{CTRL} during the power up sequence. That is, turn off V_{CC}, set the oscilloscope to single trigger mode, then turn on V_{CC} = 5 V.
5. *Replace* R_L with a 150 Ω resistor. What happens to v_{REG} and v_{CTRL}?
6. Is this control system able to effectively and automatically regulate v_{REG} over a variety of conditions? What is the relationship between V_{CC} and the control voltage? What is the relationship between R_L and the control voltage?
7. *Replace* the 33 kΩ resistor in the PI controller with a 2.2 kΩ resistor while still using R_L = 150 Ω. What happens to v_{CTRL} and v_{REG}? Obtain an oscilloscope screenshot showing both v_{CTRL} and v_{REG} in this configuration. Is the power supply still working correctly?

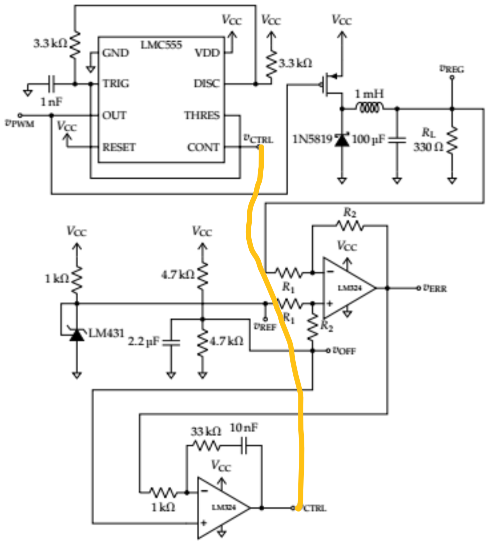

Figure 11.9: Buck Regulator Controller

* Use the circuits from tasks 1 & 2 to build the whole circuit.

* Please understand that this circuit is a closed loop, it is built to maintain v_{REG} to be always at the target value (~2.5v). For any change in the circuit, any values (e.g. v_{CTRL} *and* D_{PWM}) can change accordingly to fix v_{REG}, but v_{REG} should remain almost constant.

1. Make sure to close the loop (connect v_{CTRL}).

3. Here you are changing the supply. (Take at least 10 points)

4. Use "single run" (please check the demo of this part in the video): Turn off the supply -> click single run -> Turn on the supply.

5. Here you are changing RL.

6. What are your observations??

7. You need to change the resistance in the PI controller (NOT the load). You should see some oscillations in v_{REG} or/and v_{CTRL}.

No oscillations? Try to turn off the supply and turn it on again, or try to remove the load and place it back again.

<u>**Take screenshots and comment on the results.**</u>