ECEN321: Analogue Electronics
Assignment 2
Thermal Analysis and Voltage Regulation - Submission

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May 14, 2020

Question 1:

a) Heat Sinks are uses to lower the junction temperature by transferring heat from the junction to ambient. This provides mitigation of the degradation of characteristics and prevent failure due to thermal cycling. The insulating washer provides electrical insulation as well as thermal conductivity.

b) Both are three terminal, fixed voltage regulators.
The LM7806 provides an output of +6V for a minimum V_i of +8.3
The LM7912 provides an output of -12V for a minimum V_i of -14.6
i.e differences being 78XX is positive out for positive in, and 79XX is negative out for negative in.

c) The three types of switching regulators are step-up (boost), step-down (buck), and inverting:
Step-Up: V-out is always greater than V-in, Step-down: V-out always lower that V-in, Inverting inverted the polarity of the input voltage but can be at any relative level.
Switching have max efficiencies of $\geq 90\%$ where linear can only much less, especially when the output varies far from the input. Linear are cheaper, so used in lower current application, where efficiency/energy loss isn't that much an issue. Usually when the output is closer to the input. Switching is particularly good for high current applications due to high efficiencies but are harder to control the output noise.

d)
- Required input and out voltages
- Total current requirements of the supplied circuit
- Efficiency
- How much filtering is needed
- The noise allowances when using a switching supply

Question 2:

a) $115 - (90 - 25) * 0.657 = 72.295W$

b) **COMPONENTS:**

Chose STP16NF06 a 60V - 16A, Power MOSFET

Symbol	Parameter	Value	Unit
T_{stg}	Storage temperature	-55 to 175	°C
T_j	Max. operating junction temperature		
$R_{th-case}$	Thermal resistance junction-case max	3.33	°C/W
R_{th-amb}	Thermal resistance junction-ambient max	62.5	°C/W
T_J	Maximum lead temperature for soldering purpose	300	°C

Chose F series heatsink, FA-T220-64E (2.5" Height, 46g, 22,814mm^2)

ANALYSIS:

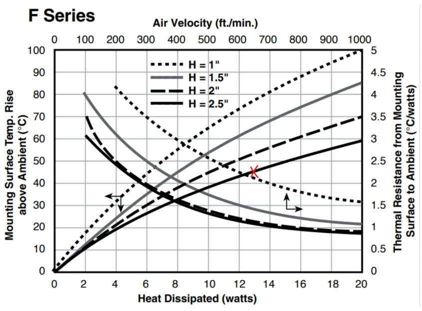
$P_d = 13W,\ T_{a-max} = 50°C,\ R_{\Theta jc} = 3.33°C/W,\ R_{\Theta ja} = 62.5°C/W$

Without heatsink:

$$\begin{aligned} T &= R_{\Theta ja} \cdot P_d + T_{a-max} \\ &= (62.5 \times 13) + 50 \\ T &= 862.5°C \end{aligned}$$

So definatly requires further thermal management.

With Heatsink (+thermal grease):



So for our power dissipation of 13W, the temperature rise corresponds to 45°C (i.e for the curve H=2.5").

For an included safety factor of 20%:

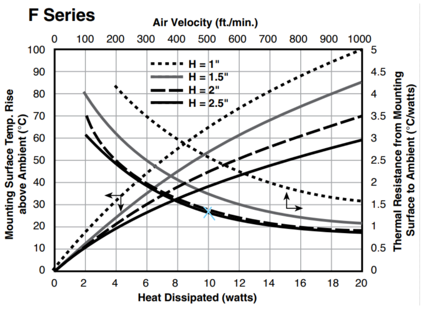
$$\begin{aligned} R_{\Theta sa} &= (T_r/P_d) \times 1.2 \\ &= (45/13) \times 1.2 \\ R_{\Theta sa} &= 4.153846°C/W \end{aligned}$$

Then using a thermal grease with an assumed $R_{\Theta cs} = 0.2°C/W$

$$\begin{aligned} T_s &= R_{\Theta sa} \times P_d + T_a \\ &= 4.15 * 13 + 50 = 103.95 \\ T_c &= R_{\Theta cs} \times P_d + T_s \\ &= 0.2 * 13 + 103.95 = 106.55 \\ T_j &= R_{\Theta jc} \times P_d + T_c \\ &= 3.33 * 13 + 106.55 \\ T &= 149.84°C \end{aligned}$$

So with a natural convection heatsink, the temperature is reduced to below the max operating temperature, but only just.

With Forced Convection:



Assume air velocity of 500 ft/min gives $1.4°C/W$, with a 20% safety factor.

$$\begin{aligned} R_{\Theta sa} &= 1.4°C/W \times 1.2 \\ &= 1.68°C/W \end{aligned}$$

With new $R_{\Theta sa}$:

$$\begin{aligned} T &= R_{\Theta jc} \times P_d + (R_{\Theta cs} \times P_d + (R_{\Theta sa} \times P_d + T_a)) \\ &= 3.33 * 13 + (0.2 * 13 + (1.68 * 13 + 50)) \\ &= 117.73°C \end{aligned}$$

As shown, with the above scenario of forced convection, the temperature is brought under control.

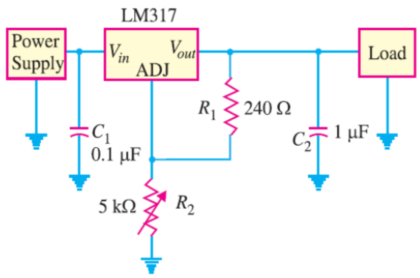
Question 3:

a) Load regulation $= (\frac{V_{NL}-V_{FL}}{V_{FL}}) \times 100\% = ((15-14.5)/14.5)*100 = 3.45\%$

b) Load regulation $= (\frac{V_{NL}-V_{FL}}{V_{FL}}) \times 100\% = ((8-7.996)/7.996)*100 = 0.05\%$

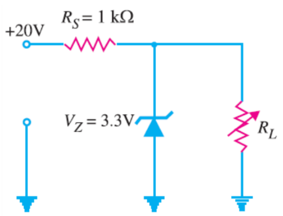
c) Line regulation $= \frac{(\Delta V_{OUT}/V_{OUT})\times 100\%}{\Delta V_{IN}} = (((12.6-12)/12.6)*100)/(235-218) = 0.28\%$

d) $R_2 = 1.68k\Omega,\ V_{ref} = 1.25V,\ I_{adj} = 100\mu A$



$$\begin{aligned} V_o &= V_{ref}(1+\frac{R_2}{R_1}) + I_{adj}R_2 \\ &= 1.25*(1+(1.68E3/240)) + 100E-6*1.68E3 \\ V_o &= 10.168V \end{aligned}$$

e) $I_{min} = 3mA,\ I_{max} = 100mA$



$$\begin{aligned} I &= 20/1 = 20 \\ I_{L-max} &= I - I_{Z-min} = 20-3 = 17 \\ R_{L-min} &= \frac{V_Z}{I_{L-max}} = 3.3/17 = 0.194118k\Omega \\ R_L &= 194\Omega \end{aligned}$$