Ecen 303

Q1. $V_{cc} = +10V$, $V_{ee} = -10V$, $R_E = 10\Omega$

$V_{ceq} = V_{cc}$, $I_{cq} \approx I_E = \frac{|V_{ee}|}{R_E} = 1A$

$P_{o(max)} = \frac{V_{ceq} I_{cq}}{2} = \frac{10(1)}{2} = \underline{5 \text{ watts}}$

$P_{DC} = |V_{cc}| + |V_{ee}| \cdot I_{cq}$

$= 10 + 10 I_{cq} = \underline{20 \text{ watts}}$

$\eta = \frac{5}{20} = 0.25 = \underline{25\%}$

Q2. a) $\%D_2 = \left|\frac{0.5}{5}\right| \times 100 = \underline{10\%}$

$\%D_3 = \left|\frac{0.3}{5}\right| \times 100 = \underline{6\%}$

$\%D_4 = \left|\frac{0.2}{5}\right| \times 100 = \underline{4\%}$

b) $THD = \sqrt{0.1^2 + 0.08^2 + 0.04^2} = \underline{0.12328} = 12.328\%$

c) $D_{2,3,4} = 0.2, 0.05, 0.06$

$I_1 = 4A$ $R_c = 8\Omega$

$THD = \sqrt{0.2^2 + 0.05^2 + 0.06^2} = 0.215$

$P_1 = \frac{I_1^2 \cdot R_c}{2} = \frac{16 \cdot 8}{2} = 64 \text{ watts}$

$P = (1 + THD^2)P_1 = (1 + 0.215^2)64 = 66.95 \text{ watts}$

Quest 3. a) 2N3904 $\quad T_{a(max)} = 65°$

derate: $5mW/°C$ above $t_a = 25°$

$(65-25) * 5 = 200mW$

Max dissipation $\Rightarrow$ @$T_a = 65°C \Rightarrow$ <u>425mW</u>

b) $R_{\theta JA} = 200°C/W$

$R_{\theta JC} = 83.3 °C/W$

$T_{J max} = -55°C \rightarrow 150°C$

$V_{CC} = 10$, $R_1 = 10K$, $R_2 = 2K2$

$P_{DC} = V_{CC} \cdot I_{CQ}$, $I_E \approx I_{CQ}$ $\quad I_E = \frac{V_E}{R_E}$

$V_E = V_B - 0.7$, $\quad V_B = \frac{R_2}{R_1 + R_2} V_{CC} = 1.8$

$V_E = 1.1$, $I_{CQ} = 0.001617 = 1.617mA$

$P_{DC} = 16.17mW$

$T = 200 * 16.17 \times 10^{-3} + 65 = \underline{68.234°C}$

This is within the operating temperature

∴ does not require a heatsink

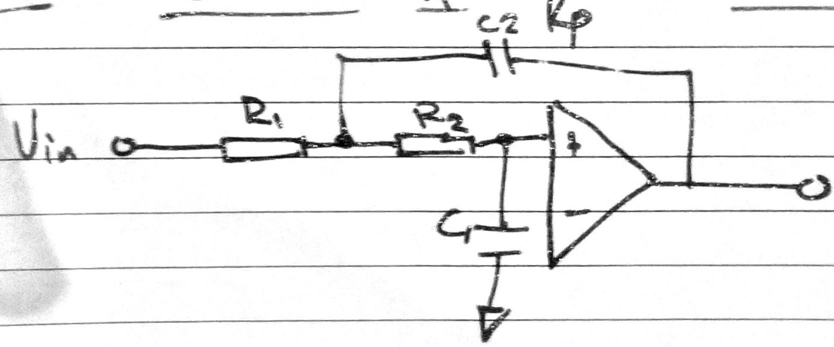
Question 4. Low pass filter

$f_c = 200Hz$, sourced from Techwell

I chose a 2nd Order Active filter to make use of high input Z

And a butterworth approximation to ~~reduce~~ eliminate passband ripple.

$Q = \frac{1}{\sqrt{2}}$ $K_c = 1$ $f_p = \frac{f_c}{K_p} = 200Hz$

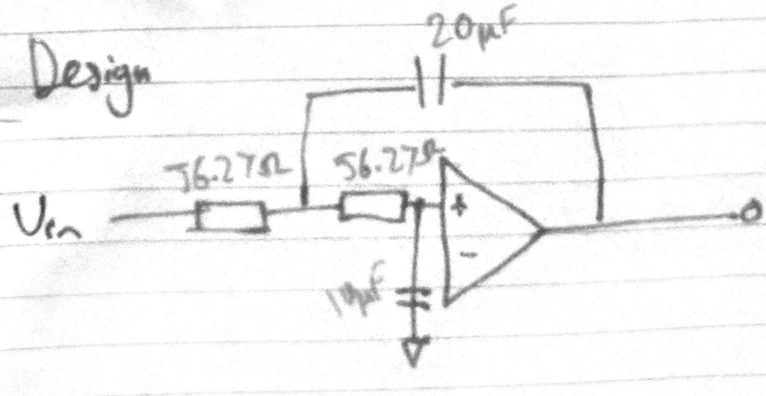


Next: Choose standard C_1 value = $10\mu F$

$Q = 0.5\sqrt{\frac{C_2}{C_1}} \Rightarrow C_1(2Q)^2 = 2C_1 = C_2$, $C_2 = 20\mu F$

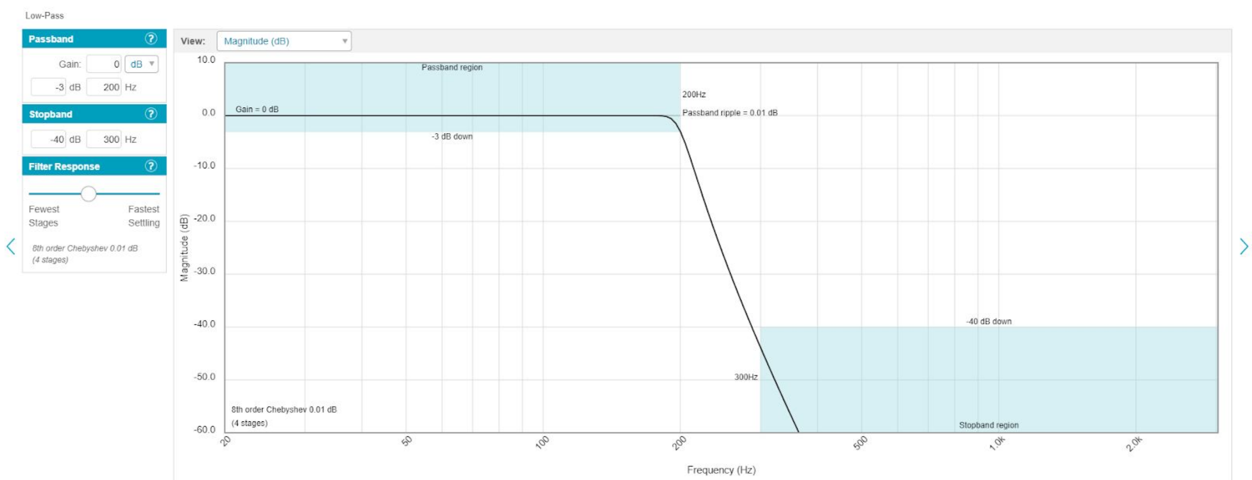
$f_p = \frac{1}{2\pi R\sqrt{C_1C_2}}$, $R = \frac{1}{f_p 2\pi\sqrt{C_1C_2}} = 56.269\,\Omega$

Final Design

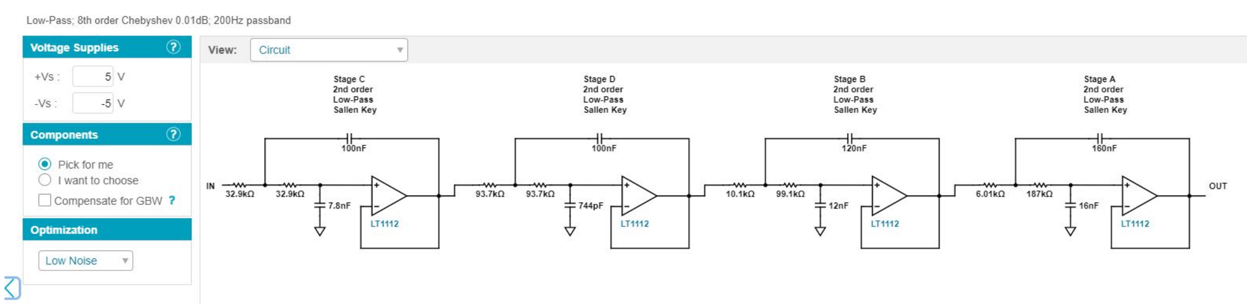


Question 5

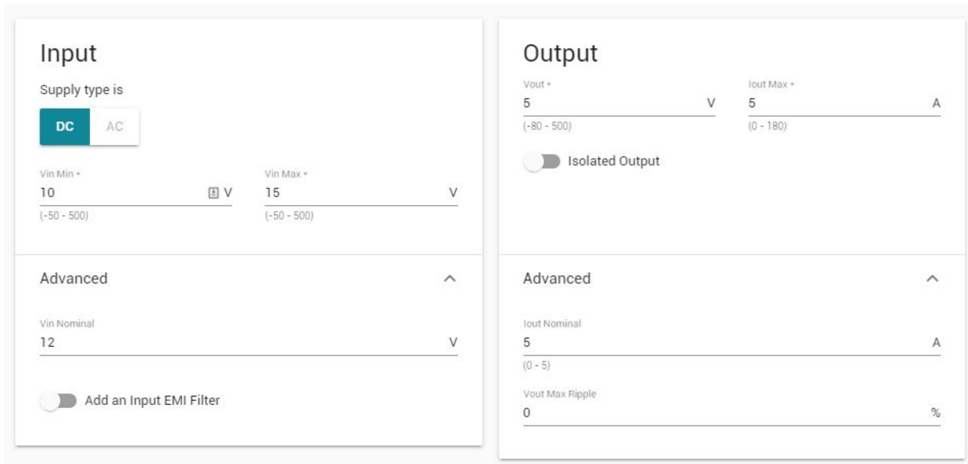
To keep from altering the passed signal a 0dB passband gain was chosen.
The passband ends at 200Hz with at -3dB.
The stop band was chosen to be as close as possible (300Hz) while retaining a unity gain in the passband.
Note due to a slight Chebyshev approximation there is a 0.01dB ripple at the end of the passband



The resultant filter is a 4 stage, 8th order active filter. This is supplied with +-5V as this is just signal filtering, but optimised for low noise output due to its audio application.



Question 6

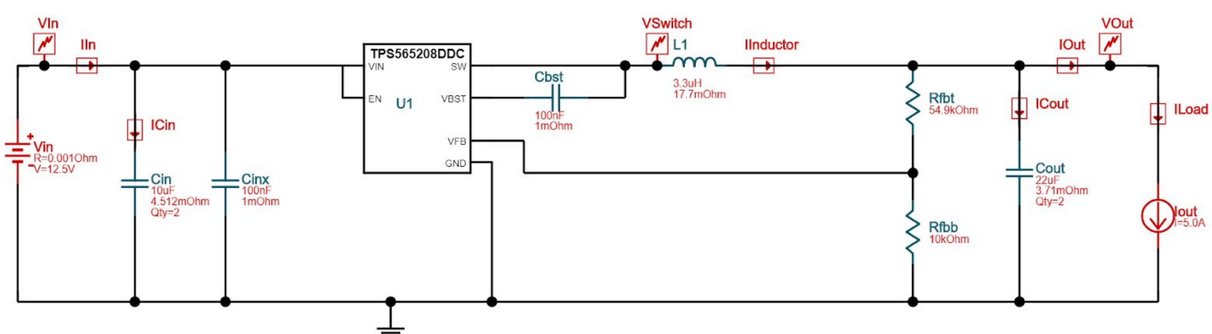


Design Decisions:

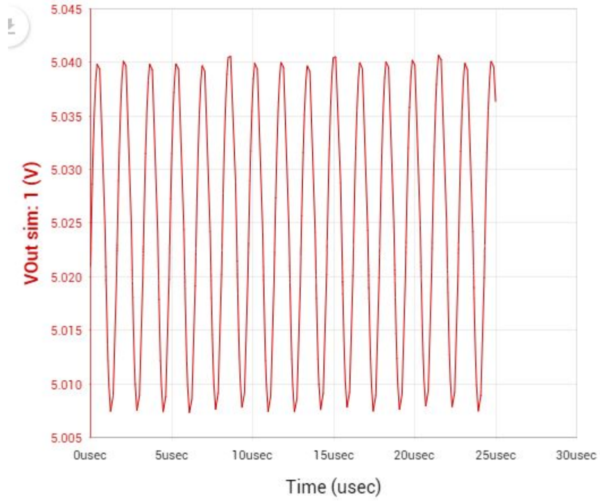
Given the required application of a charger. This was taken to be powered via an external DC voltage source, ie a large 12V battery etc. Also the closeness in input to out. The above figure shows a chosen voltage range of 10V - 15V but designed for a nominal 12V, this is the account for discharge voltage droop and accounting for issues with overvoltage

Output was selected to match 5V, 5A requirements and a aimed 0% Vout ripple to design for a minimised ripple.

This resulted in TI Power Designer providing the below design, which I then simulated and evaluated.



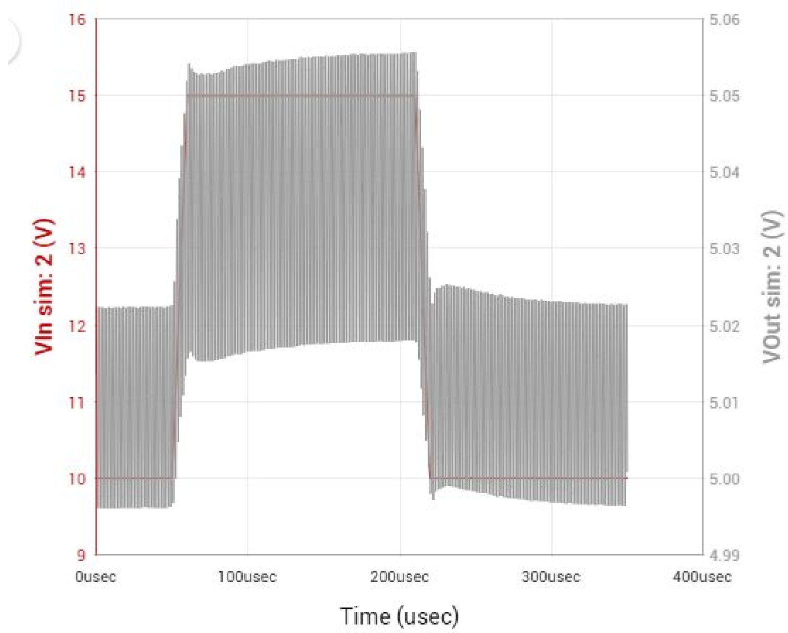
Design Evaluation:



Performance Summary

Sim ID	Vout Peak-to-Peak	Vout Average	Inductor Current Peak-To-Peak	Average Freq
1	33.30 mV	5.03 V	1.50 A	616.85 kHz

$$\% \text{ Ripple} = \frac{33.30mV}{5.03V} \times 100 = 0.66\%$$



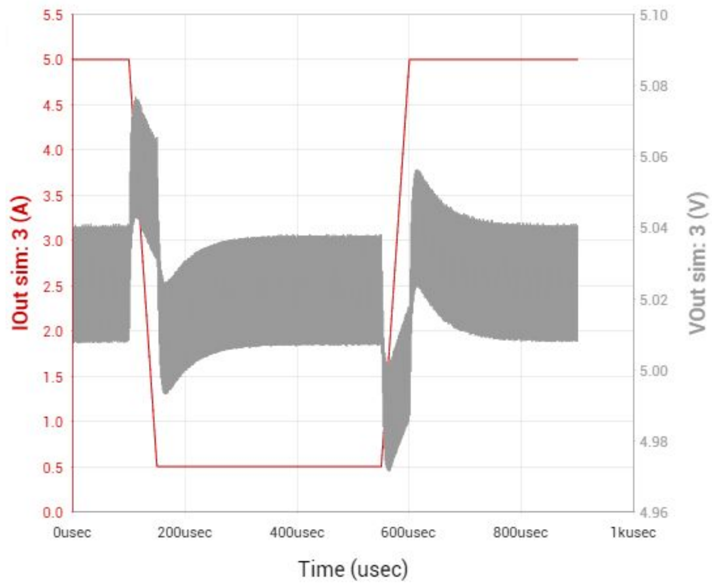
Performance Summary

Sim ID	Vout Maximum	Vout Minimum
2	5.06 V	5.00 V

Worst case line regulation:

$$= \frac{\Delta V\,out}{\Delta V\,i}$$

$$= \frac{0.06}{5} \times 100 = 1.2\%$$



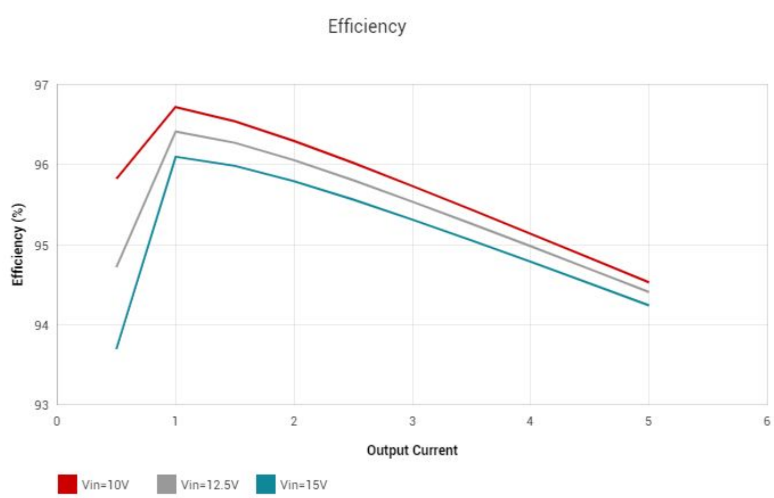
Performance Summary

Sim ID	Vout Maximum	Vout Minimum	Overshoot Settle Time	Undershoot Settle Time	Overshoot	Undershoot
3	5.08 V	4.97 V	0.15 ms	0.15 ms	0.05 V	0.05 V

Load regulation, looking the settled values from a load transient simulation:

$$= \frac{VNL - VFL}{VFL} \times 100$$

$$= \frac{5.015 - 5.03}{5.03} \times 100 \ = 0.298\%$$



This design provide great efficiency (93.5% ⇒ 97%) generally and ~94.5% at the required current for the full input voltage range.