Calculations 5V buck:

- Fs = 1MHz
- Cout = 50 uF DC derated
- Vin = 24V
- Vout = 5V
- Iout = 2A
- Fc = Fs/10 = 100KHz
- Vout = 10mV
- ESR = 10mΩ

$$L = \frac{0.7 * V_{out}}{F_s} = \frac{0.7 * 5}{1MHz} = 0.0000035H = 3.5\mu H => 4.7\mu H$$

$$D = \frac{V_{out}}{V_{in}} = \frac{5V}{24V} = 0.208$$

$$T = \frac{1}{F_s} = \frac{1}{1MHz} = 1\mu S$$

$$\Delta I_l = \frac{V_{in} - V_{out}}{L} * D * T = \frac{24 - 5}{4.7\mu H} * 0.208 * 1\mu S = 0.841\text{A}$$

$$C_{out} = \frac{\Delta Q}{\Delta V_{cout}} = \frac{\Delta I_l}{8 * F_s * \Delta V_{cout}} = \frac{0.841A}{8 * 1MHz * 10mV} = 1.5 * 10^{-5} = 10.5\mu F$$

$$\Delta V_{cout} = \frac{\Delta Q}{C_{out}} = \frac{\Delta I_l}{8 * F_s * C_{out}} = \frac{0.841A}{8 * 1MHz * 50\mu F} = 2.10 * 10^{-3} = 2.10mV$$

Met ESR:

$$\Delta V_{cout} = \Delta I_l \left(\frac{1}{8 * F_s * C_{out}} + ESR\right) = 0.841\left(\frac{1}{8 * 1MHz * 50\mu F} + 10m\Omega\right) = 0.0105 = 10.5mV$$

Calculations 8V buck:

- Fs = 1MHz
- Cout = 50 uF DC derated
- Vin = 24V
- Vout = 8V
- Iout = 2A
- Fc = Fs/10 = 100KHz
- Vout = 10mV
- ESR = 10mΩ

$$L = \frac{0.7 * V_{out}}{F_s} = \frac{0.7 * 8}{1MHz} = 5.6 * 10^{-6} = 5.6\mu H => 6.8\mu H$$

$$D = \frac{V_{out}}{V_{in}} = \frac{8V}{24V} = 0.3333$$

$$T = \frac{1}{F_s} = \frac{1}{1MHz} = 1\mu S$$

$$\Delta I_l = \frac{V_{in} - V_{out}}{L} * D * T = \frac{24 - 8}{6.8\mu H} * 0.3333 * 1\mu S = 0.784$$

$$C_{out} = \frac{\Delta Q}{\Delta V_{cout}} = \frac{\Delta I_l}{8 * F_s * \Delta V_{cout}} = \frac{0.784A}{8 * 1MHz * 10mV} = 9.8 * 10^{-6} = 9.8\mu F$$

$$\Delta V_{cout} = \frac{\Delta Q}{C_{out}} = \frac{\Delta I_l}{8 * F_s * C_{out}} = \frac{0.784A}{8 * 1MHz * 50\mu F} = 1.96 * 10^{-3} = 1.96mV$$

Met ESR:

$$\Delta V_{cout} = \Delta I_l \left(\frac{1}{8 * F_s * C_{out}} + ESR\right) = 0.784\left(\frac{1}{8 * 1MHz * 50\mu F} + 10m\Omega\right) = 9.8 * 10^{-3} = 9.8mV$$

Calculations 12V buck:

- Fs = 1MHz
- Cout = 50 uF DC derated
- Vin = 24V
- Vout = 12V
- Iout = 4A of 2A
- Fc = Fs/10 = 100KHz
- Vout = 10mV
- ESR = 10mΩ

$$L = \frac{0.7 * V_{out}}{F_s} = \frac{0.7 * 12}{1MHz} = 8.4 * 10^{-6} = 8.4\mu H => 10\mu H$$

$$D = \frac{V_{out}}{V_{in}} = \frac{12V}{24V} = 0.5$$

$$T = \frac{1}{F_s} = \frac{1}{1MHz} = 1\mu S$$

$$\Delta I_l = \frac{V_{in} - V_{out}}{L} * D * T = \frac{24 - 12}{10\mu H} * 0.5 * 1\mu S = 0.6$$

$$C_{out} = \frac{\Delta Q}{\Delta V_{cout}} = \frac{\Delta I_l}{8 * F_s * \Delta V_{cout}} = \frac{0.6A}{8 * 1MHz * 10mV} = 7.5 * 10^{-6} = 7.5\mu F$$

$$\Delta V_{cout} = \frac{\Delta Q}{C_{out}} = \frac{\Delta I_l}{8 * F_s * C_{out}} = \frac{0.6A}{8 * 1MHz * 50\mu F} = 1.5 * 10^{-3} = 1.5mV$$

Met ESR:

$$\Delta V_{cout} = \Delta I_l \left(\frac{1}{8 * F_s * C_{out}} + ESR\right) = 0.6\left(\frac{1}{8 * 1MHz * 50\mu F} + 10m\Omega\right) = 7.5 * 10^{-3} = 7.5mV$$

Calculations 15V buck:

- Fs = 1MHz
- Cout = 50 uF DC derated
- Vin = 24V
- Vout = 15V
- Iout = 2A
- Fc = Fs/10 = 100KHz
- Vout = 10mV
- ESR = 10mΩ

$$L = \frac{0.7 * V_{out}}{F_s} = \frac{0.7 * 15}{1MHz} = 10.5 * 10^{-6} = 10.5\mu H => 15\mu H$$

$$D = \frac{V_{out}}{V_{in}} = \frac{15V}{24V} = 0.625$$

$$T = \frac{1}{F_s} = \frac{1}{1MHz} = 1\mu S$$

$$\Delta I_l = \frac{V_{in} - V_{out}}{L} * D * T = \frac{24 - 15}{15\mu H} * 0.625 * 1\mu S = 0.375$$

$$C_{out} = \frac{\Delta Q}{\Delta V_{cout}} = \frac{\Delta I_l}{8 * F_s * \Delta V_{cout}} = \frac{0.375A}{8 * 1MHz * 10mV} = 4.68 * 10^{-6} = 4.68\mu F$$

$$\Delta V_{cout} = \frac{\Delta Q}{C_{out}} = \frac{\Delta I_l}{8 * F_s * C_{out}} = \frac{0.375A}{8 * 1MHz * 50\mu F} = 0.937 * 10^{-3} = 0.937mV$$

Met ESR:

$$\Delta V_{cout} = \Delta I_l \left(\frac{1}{8 * F_s * C_{out}} + ESR\right) = 0.375\left(\frac{1}{8 * 1MHz * 50\mu F} + 10m\Omega\right) = 4.7 * 10^{-3} = 4.7mV$$

Voltage divider 5V:

- Vout = 5V
- Feedback voltage = 0.9V

$$divison = \frac{5}{0.9} = 5.55$$

$$Vref = V_{out} * \frac{R2}{R2 + R1} = 5 * \frac{22}{100 + 22} = 0.901V$$

E12 : 100k and 22K for 0.1%

Voltage divider 8V:

- Vout = 8V
- Feedback voltage = 0.9V

$$divison = \frac{8}{0.9} = 8.88$$

$$Vref = V_{out} * \frac{R2}{R2 + R1} = 8 * \frac{15K}{120K + 15K} = 0.88V$$

E12 : 120k and 15K for 1.52%

Voltage divider 12V:

- Vout = 12V
- Feedback voltage = 0.9V

$$divison = \frac{12}{0.9} = 13.33$$

$$Vref = V_{out} * \frac{R2}{R2 + R1} = 12 * \frac{22K}{270K + 22K} = 0.904V$$

E12 : 270k and 22K for 0.47%

Voltage divider 15V:

- Vout = 15V
- Feedback voltage = 0.9V

$$divison = \frac{12}{0.9} = 16.66$$

$$Vref = V_{out} * \frac{R2}{R2 + R1} = 15 * \frac{30K}{470K + 30K} = 0.9V$$

E24 : 470k and 30K for 0.04%

$$C_{in} = \frac{I_{out(max)} * D * (1-D)}{\eta * F_{sw} * \Delta V_{in}} = \frac{2A * 0.208 * (1 - 0.208)}{0.9 * 1MHz * 200mV} = 1.83 * 10^{-6} = 1.83\ \mu F$$

Setting up UVLO. Datasheet recommends for R1 to be 3.3MΩ. Vinu needs to be higher than 0.8 * Vout to avoid hiccups during slow power-up. The highest Vout = 15V so the min Vinu should be 12V. since we want to use a Vout of 15V and we use a buck converter we should set this to more than 15V, let's say 18V

$$R_2 = \frac{R_1 * 1.215}{V_{inu} - 1.215} = \frac{3.3M\Omega * 1.215}{18\ - 1.215} = 238873\Omega\ \approx 220\text{K}$$

This will give a UVLO of:

$$V_{inu} = \frac{R_1 * 1.215}{R_2 - 1.215} = \frac{3.3M * 1.215}{220K - 1.215} = \ 18.225V$$

SS (Soft-Start) Soft-Start Capacitor Selection:

The device implements adjustable soft-start operation to reduce inrush current. A capacitor connected from the SS pin to SGND programs the soft-start time. The selected output capacitance (CSEL) and the output voltage (VOUT) determine the minimum required soft-start capacitor as follows:

$$C_{ss}\ \geq\ 28\ \times\ 10^{-6}\ \times\ C_{SEL}\ \times\ V_{OUT}$$

The soft-start time (tSS) is related to the capacitor connected at SS (CSS) by the following equation:

$$t_{SS}\ = \frac{C_{SS}}{5.55\ \times\ 10^{-6}}$$

Because of multiple output voltages, the SS with the highest output voltage is leading. Therefore 15V as the output voltage is the one to choose.

$$\begin{aligned} &\text{C}_{ss}\ \geq\ 28\ \times\ 10^{-6}\ \times 50\mu \times\ 15 = 28nF \\ &C_{ss} = 33nF \\ &t_{ss} = \frac{33n}{5.55 \times 10^{-6}} = 5.95\text{ms} \end{aligned}$$

The RT resistor selection:

The RT is responsible for the switching frequency of the buck converter. In the calculations the determined switching frequency is 1MHz.

$$\begin{aligned} &R_{RT(k\Omega)}\ \cong \frac{21000}{f_{SW(kHz)}} - 1.7 = \frac{21000}{1000} - 1.7 = 19.3k\Omega \\ &R_{RT} = 20k\Omega \end{aligned}$$