

JETSON Config:

a.) LTC4365: UV/OV Protection1.) Find $R_1 + R_2$

$$R_1 + R_2 = \frac{V_{OS(UV)}}{I_{UV}}$$

$$R_1 + R_2 = \frac{3mV}{10nA}$$

$$R_1 + R_2 = 300k$$

2.) Find R_3 using UV trip threshold

$$R_3 = \frac{V_{OS(UV)}}{I_{UV}} \cdot \left(\frac{UV_{TH} - 0.5V}{0.5V} \right)$$

$$\text{Let } UV_{TH} = 22V$$

$$R_3 = \left(\frac{3mV}{10nA} \right) \cdot \left(\frac{22 - 0.5}{0.5} \right) = 12.9M\Omega$$

3.) Find R_1 using OV trip threshold

$$\text{Let } OV = 35$$

$$R_1 = \left(\frac{V_{OV(UV)}}{I_{UV}} \right) + R_3 \cdot 0.5V$$

$$R_1 = \left(\left(\frac{3mV}{10nA} \right) + 12.9M\Omega \right) (0.5V) = 190k$$

$$R_1 \approx 190k$$

4.) Find R_2

$$R_1 + R_2 = 300k$$

$$R_1 = 190k$$

$$R_2 = 300k - 190k$$

$$R_2 = 110k$$

* Each UV/OV Threshold will be the same because each load switch is before each switching regulator

Recommended Parameters:

$$V_{OS(UV)} = 3mV$$

$$I_{UV} = 10nA$$

Set by me:

$$OV_{TH} = 35V$$

$$UV_{TH} = 22V$$

From LTC 4365 Data sheet
(Pg. 11)

Procedure for Selecting UV/OV External Resistor Values

The following 3-step procedure helps select the resistor values for the resistive divider of Figure 4. This procedure minimizes UV and OV offset errors caused by leakage currents at the respective pins.

- Choose maximum tolerable offset at the UV pin, $V_{OS(UV)}$. Divide by the worst case leakage current at the UV pin, I_{UV} (10nA). Set the sum of $R_1 + R_2$ equal to $V_{OS(UV)}$ divided by $10nA$. Note that due to the presence of R_3 , the actual offset at UV will be slightly lower:

$$R_1 + R_2 = \frac{V_{OS(UV)}}{I_{UV}}$$

- Select the desired V_{IN} UV trip threshold, UV_{TH} . Find the value of R_3 :

$$R_3 = \frac{V_{OS(UV)}}{I_{UV}} \cdot \left(\frac{UV_{TH} - 0.5V}{0.5V} \right)$$

- Select the desired V_{IN} OV trip threshold, OV_{TH} . Find the values of R_1 and R_2 :

$$R_1 = \frac{\left(\frac{V_{OS(UV)}}{I_{UV}} \right) + R_3}{OV_{TH}} \cdot 0.5V$$

$$R_2 = \frac{V_{OS(UV)}}{I_{UV}} - R_1$$

The example of Figure 4 uses standard 1% resistor values. The following parameters were selected:

$$V_{OS(UV)} = 3mV$$

$$I_{UV} = 10nA$$

$$UV_{TH} = 5V$$

$$OV_{TH} = 18V$$

For Jetson Load switch OV/UV

$$R_1 = 190k$$

$$R_2 = 110k$$

$$R_3 = 12.9M\Omega$$

* Each UV/OV Threshold will be the same because each load switch is before each switching regulator

JETSON Config: (Cont.) Switching Regulator

6.) LT8638SEV: Output Voltage, Default Switching Frequency and choke Inductor Selection

FB Resistor Network

$$R_1 = R_2 \left(\frac{V_{out}}{0.6V} - 1 \right)$$

$$R_1 = 3k \left(\frac{20}{0.6V} - 1 \right)$$

$$R_1 = 97000 \Omega$$

$$R_1 \approx 100k$$

Let $R_2 = 3k\Omega$
 $V_{out} = 20V$

From LT8638SEV Datasheet (Pg. 17)

FB Resistor Network

The output voltage is programmed with a resistor divider between the output and the FB pin. Choose the resistor values according to E1.

$$R_1 = R_2 \left(\frac{V_{out}}{0.6V} - 1 \right) \quad (1)$$

Reference designators refer to the Block Diagram. 1% resistors are recommended to maintain output voltage accuracy.

When using large FB resistors, a 4.7pF to 47pF phase-lead capacitor should be connected from V_{out} to FB.

FB Resistor Network for $V_{out} = 20V$

$$R_1 = 100k, R_2 = 3k$$

Default switching frequency RT calculations

$$f_{sw(max)} = \frac{V_{out} + V_{sw(BOT)}}{t_{on(min)}(V_{in} - V_{in_{sw(TOP)}} + V_{sw(BOT)})}$$

where V_{in} is the typical input voltage, V_{out} is the output voltage, $V_{sw(TOP)} = \sim 0.2V$, $V_{sw(BOT)} = \sim 0.8V$, $t_{on(min)}$ is the minimum top switch on time
 internal switch drops at max load

the higher your switching frequency, the lower your input voltage can be and lower efficiency

Let:

$$V_{sw(BOT)} = 0.8V$$

$$V_{sw(TOP)} = 0.2V$$

$$V_{out} = 20V$$

$$t_{on(min)} = 25\text{ ns}$$

↑ from electrical characteristics

$$f_{sw(max)} = \frac{20V + 0.8V}{(25 \times 10^{-9})(28V - 0.2 + 0.8)}$$

$$= 29090909.09 \text{ Hz}$$

$$\approx 30 \text{ MHz}$$

Super high, so not a huge concern.

Pick avg. value on table,

Switching Frequency @ 400 kHz Resistor

$$400 \text{ kHz} \Rightarrow RT = 105 \text{ k}\Omega$$

From LT8638SEV Datasheet (Pg. 18)

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table showing the necessary R_T value for a desired switching frequency is in Table 1.

The R_T resistor required for a desired switching frequency can be calculated using Equation 2.

$$R_T = \frac{44.8}{f_{sw}} \quad (2)$$

where R_T is in k Ω and f_{sw} is the desired switching frequency in MHz.

Table 1. SW Frequency vs R_T Value

f_{sw} (MHz)	R_T (Ω)
0.2	226
0.4	148
0.4	105
0.5	82.5
0.6	66.5
0.7	56.2
0.8	48.7
1.0	38.3
1.2	31.6
1.4	26.1
1.6	22.1
1.8	19.1
2.0	16.9
2.2	15.4
3.0	10.5

Operating Frequency Selection and Trade-Offs

Selection of the operating frequency is a trade-off between efficiency, component size, and input voltage range. The advantage of high frequency operation is that smaller inductor and capacitor values may be used. The disadvantages are lower efficiency and a smaller input voltage range.

The highest switching frequency ($f_{sw(max)}$) for a given application can be calculated as follows:

$$f_{sw(max)} = \frac{V_{out} + V_{sw(BOT)}}{t_{on(min)}(V_{in} - V_{sw(TOP)} + V_{sw(BOT)})} \quad (3)$$

where V_{in} is the typical input voltage, V_{out} is the output voltage, $V_{sw(TOP)}$ and $V_{sw(BOT)}$ are the internal switch

drops ($\sim 0.2V$, $\sim 0.08V$, respectively at maximum load) and $t_{on(min)}$ is the minimum top switch on-time (see the Electrical Characteristics). Equation 3 shows that a slower switching frequency is necessary to accommodate a high V_{in}/V_{out} ratio.

For transient operation, V_{in} may go as high as the absolute maximum rating of 42V regardless of the R_T value, however the V_{in} -to- V_{out} dropout is limited by the $R_{on(on)}$ of the top switch. In this mode the LT8638S skips switch cycles, resulting in a lower switching frequency than programmed by RT.

For applications that cannot allow deviation from the programmed switching frequency at low V_{in}/V_{out} ratios use Equation 4 to set switching frequency.

$$V_{in(min)} = \frac{V_{out} + V_{sw(BOT)}}{1 - f_{sw} \cdot t_{off(min)}} - V_{sw(BOT)} + V_{sw(TOP)} \quad (4)$$

where $V_{in(min)}$ is the minimum input voltage without skipped cycles, V_{out} is the output voltage, $V_{sw(TOP)}$ and $V_{sw(BOT)}$ are the internal switch drops ($\sim 0.2V$, $\sim 0.08V$, respectively at maximum load), f_{sw} is the switching frequency (set by R_T), and $t_{off(min)}$ is the minimum switch off-time. Note that higher switching frequency will increase the minimum input voltage below which cycles will be dropped to achieve higher duty cycle.

JETSON CONFIG: (cont.)

Inductor Selection and Maximum Output Current:

Due to power requirements, $I_{\text{load max}} \approx 8A$

1.) First Find L_{min} due to $\frac{V_o}{V_{\text{in}}} \geq 0.5$

$$\frac{V_o}{V_{\text{in}}} > 0.5$$

$$f_{\text{sw}} = 900 \text{ kHz}$$

$$L_{\text{min}} = \frac{V_{\text{in}} \left(2 \cdot \frac{V_o}{V_{\text{in}}} - 1 \right)}{5 \cdot f_{\text{sw}}}$$

$$L_{\text{min}} = \frac{28 \left(\left(2 \cdot \frac{20}{28} \right) - 1 \right)}{5 \cdot 4000000} = 6 \times 10^{-6} = 6 \mu\text{H}$$

2.) Find the Peak-to-Peak ripple current

$$\Delta I_L = \frac{V_{\text{out}}}{L \cdot f_{\text{sw}}} \cdot \left(1 - \frac{V_{\text{out}}}{V_{\text{in(max)}}} \right)$$

$$\Delta I_L = \left(\frac{20}{(6 \times 10^{-6})(400000)} \right) \left(1 - \frac{20V}{28V} \right)$$

$$\Delta I_L = 2.38075 \text{ A}$$

3.) Calculate $I_{\text{out(max)}}$

$$I_{\text{out max}} = I_{\text{lim}} - \frac{\Delta I_L}{2}$$

Duty Cycle Ratio

$$DC = 0.714$$

so $I_L \approx 15A$ at $DC \approx 0.8$

* $I_{\text{out(max)}}$ is max output current

$$I_{\text{out max}} = 15A - \frac{2.38075A}{2} = 13.809525A$$

some

4.) Find $I_L(\text{max})$ to pick inductor with high enough RMS

$$I_L(\text{peak}) = I_{\text{load(max)}} + \frac{1}{2} \Delta I_L$$

$$I_L(\text{peak}) = 13.809525 + \frac{1}{2} (2.38075)$$

$$I_L(\text{peak}) = 15A$$

$$I_{\text{load(max)}} = 13.809525A$$

$$\Delta I_L = 2.38075A$$

LT8638SEV Datasheet (P.g.19)

Inductor Selection and Maximum Output Current

The LT8638S is designed to minimize solution size by allowing the inductor to be chosen based on the output load requirements of the application. During overload or short-circuit conditions the LT8638S safely tolerates operation with a saturated inductor through the use of a high speed peak-current mode architecture.

A good first choice for the inductor value is given by Equation 5.

$$L = \left(\frac{V_{\text{OUT}} + V_{\text{SW(BOT)}}}{f_{\text{sw}}} \right) \cdot 0.2 \quad (5)$$

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where f_{sw} is the switching frequency in MHz, V_{OUT} is the output voltage, $V_{\text{SW(BOT)}}$ is the bottom switch drop (~0.08V) and L is the inductor value in μH .

To avoid overheating and poor efficiency, an inductor must be chosen with an RMS current rating that is greater than the maximum expected output load of the application. In addition, the saturation current (typically labeled I_{SAT}) rating of the inductor must be higher than the load current plus 1/2 of inductor ripple current (Equation 6)

$$I_{L(\text{PEAK})} = I_{\text{LOAD(MAX)}} + \frac{1}{2} \Delta I_L \quad (6)$$

where ΔI_L is the inductor ripple current as calculated in Equation 8 and $I_{\text{LOAD(MAX)}}$ is the maximum output load for a given application.

As a quick example, an application requiring 3A output should use an inductor with an RMS rating of greater than 3A and an I_{SAT} of greater than 4A. During long duration overload or short-circuit conditions, the inductor RMS rating requirement is greater to avoid overheating of the inductor. To keep the efficiency high, the series resistance (DCR) should be less than $8m\Omega$, and the core material should be intended for high frequency applications.

The LT8638S limits the peak switch current in order to protect the switches and the system from overload faults. The top switch current limit (I_{LIM}) is 20A at low duty cycles and decreases linearly to 15A at DC = 0.8. The inductor value must then be sufficient to supply the desired maximum output current ($I_{\text{OUT(MAX)}}$), which is a function of the switch current limit (I_{LIM}) and the ripple current (Equation 7).

$$I_{\text{OUT(MAX)}} = I_{\text{LIM}} - \frac{\Delta I_L}{2} \quad (7)$$

The peak-to-peak ripple current in the inductor can be calculated using Equation 8.

$$\Delta I_L = \frac{V_{\text{OUT}}}{L \cdot f_{\text{sw}}} \cdot \left(1 - \frac{V_{\text{OUT}}}{V_{\text{IN(MAX)}}} \right) \quad (8)$$

where f_{sw} is the switching frequency of the LT8638S, and L is the value of the inductor. Therefore, the maximum output current that the LT8638S will deliver depends on

$$\frac{V_o}{V_{\text{in}}} = \frac{20}{28} = 0.714$$

(9)

where DC is the duty cycle ratio ($V_{\text{OUT}}/V_{\text{IN}}$) and f_{sw} is the switching frequency.

* Due to $\frac{V_o}{V_{\text{in}}} \geq 0.5$,

a minimum inductance value must be calculated

5.) Finalize L value

$$L = \frac{V_{\text{OUT}} + V_{\text{SW(BOT)}}}{f_{\text{sw}}} \cdot 0.2$$

f_{sw} in MHz

$$L = \left(\frac{20 + 0.8}{0.4} \right) \cdot 0.2$$

$$L = 10.4 \mu\text{H}$$

* can use $10 \mu\text{H}$

OBC Config:

a.) LTC436S : UV/OV Protection

- The $V_{OS(UV)}$ is the max voltage deviation that you can get at the output. This is given by the highest leakage current at the $I(UV)$ pin.

1.) Find $R_1 + R_2$

$$R_1 + R_2 = \frac{V_{OS(UV)}}{I_{UV}}$$

Recommended Parameters :

$$\begin{aligned} V_{OS(UV)} &= 3mV \\ I_{UV} &= 10nA \end{aligned}$$

From LTC 436S Datasheet
(Pg. 11)

Procedure for Selecting UV/OV External Resistor Values

The following 3-step procedure helps select the resistor values for the resistive divider of Figure 4. This procedure minimizes UV and OV offset errors caused by leakage currents at the respective pins.

- Choose maximum tolerable offset at the UV pin, $V_{OS(UV)}$. Divide by the worst case leakage current at the UV pin, I_{UV} (10nA). Set the sum of $R_1 + R_2$ equal to $V_{OS(UV)}$ divided by 10nA. Note that due to the presence of R_3 , the actual offset at UV will be slightly lower.

$$R_1 + R_2 = \frac{V_{OS(UV)}}{I_{UV}}$$

- Select the desired V_{IN} UV trip threshold, UV_{TH} . Find the value of R_3 :

$$R_3 = \frac{V_{OS(UV)}}{I_{UV}} \cdot \left(\frac{UV_{TH} - 0.5V}{0.5V} \right)$$

- Select the desired V_{IN} OV trip threshold, OV_{TH} . Find the values of R_1 and R_2 :

$$\begin{aligned} R_1 &= \frac{\left(\frac{V_{OS(UV)}}{I_{UV}} + R_3 \right)}{OV_{TH}} \cdot 0.5V \\ R_2 &= \frac{V_{OS(UV)}}{I_{UV}} - R_1 \end{aligned}$$

The example of Figure 4 uses standard 1% resistor values. The following parameters were selected:

$$V_{OS(UV)} = 3mV$$

$$I_{UV} = 10nA$$

$$UV_{TH} = 5V$$

$$OV_{TH} = 18V$$

2.) Find R_3 using UV trip threshold

$$R_3 = \frac{V_{OS(UV)}}{I_{UV}} \cdot \left(\frac{UV_{TH} - 0.5V}{0.5V} \right)$$

$$\text{Let } UV_{TH} = 22V$$

$$R_3 = \left(\frac{3mV}{10nA} \right) \cdot \left(\frac{22 - 0.5}{0.5} \right) = 12.9M\Omega$$

3.) Find R_1 using OV trip threshold

$$\text{Let } OV = 35$$

$$R_1 = \left(\frac{\frac{V_{OV}(UV)}{I(UV)}}{OV} \right) + R_3 \cdot 0.5V$$

$$R_1 = \left(\left(\frac{3mV}{10nA} \right) + 12.9M\Omega \right) (0.5V) = 190k$$

$$R_1 \approx 190k$$

For OBC Load switch OV/UV

$$R_1 = 190k$$

$$R_2 = 110k$$

$$R_3 = 12.9M\Omega$$

* Each UV/OV Threshold will be the same because each load switch is before each switching regulator

4.) Find R_2

$$R_1 + R_2 = 300k$$

$$R_1 = 190k$$

$$\begin{aligned} R_2 &= 300k - 190k \\ R_2 &= 110k \end{aligned}$$

OBC Config: (Cont.) Switching Regulator

6) LT8638SEV: Output Voltage, Default Switching Frequency and choke Inductor selection

FB Resistor Network

$$R_1 = R_2 \left(\frac{V_{out}}{0.6V} - 1 \right)$$

Let $R_2 = 5.5k$

$$V_{out} = 3.3V$$

$$R_1 = 5.5k \left(\frac{3.3}{0.6V} - 1 \right)$$

$$R_1 = 24750$$

$$R_1 \approx 25k$$

FB Resistor Network for $V_{out} = 3.3V$

$$R_1 = 25k, R_2 = 5.5k$$

From LT8638SEV Datasheet (Pg 17)

FB Resistor Network

The output voltage is programmed with a resistor divider between the output and the FB pin. Choose the resistor values according to E1.

$$R_1 = R_2 \left(\frac{V_{out}}{0.6V} - 1 \right) \quad (1)$$

Reference designators refer to the Block Diagram. 1% resistors are recommended to maintain output voltage accuracy.

When using large FB resistors, a 4.7pF to 47pF phase-lead capacitor should be connected from V_{out} to FB.

Default switching frequency RT calculations

$$f_{sw(max)} = \frac{V_{out} + V_{sw(BOT)}}{t_{on(min)}(V_{in} - V_{in_{sw(TOP)}} + V_{sw(BOT)})}$$

where V_{in} is the typical input voltage, V_{out} is the output voltage, $V_{sw(TOP)} = \sim 0.2V$, $V_{sw(BOT)} = \sim 0.8V$, $t_{on(min)}$ is the minimum top switch on time, $\text{internal switch drops at max load}$

• The higher your switching frequency, the lower your input voltage can be and lower efficiency

From LT8638SEV Datasheet (Pg. 18)

APPLICATIONS INFORMATION

table showing the necessary R_T value for a desired switching frequency is in Table 1.

The R_T resistor required for a desired switching frequency can be calculated using Equation 2.

$$R_T = \frac{44.8}{f_{sw}} \quad (2)$$

where R_T is in kΩ and f_{sw} is the desired switching frequency in MHz.

Table 1. SW Frequency vs R_T Value

f_{sw} (MHz)	R_T (kΩ)
0.2	226
0.3	140
0.4	105
0.5	82.5
0.6	66.5
0.7	56.2
0.8	48.7
1.0	38.3
1.2	31.6
1.4	26.1
1.6	22.1
1.8	19.1
2.0	16.9
2.2	15.4
3.0	10.5

Operating Frequency Selection and Trade-Offs

Selection of the operating frequency is a trade-off between efficiency, component size, and input voltage range. The advantage of high frequency operation is that smaller inductor and capacitor values may be used. The disadvantages are lower efficiency and a smaller input voltage range.

The highest switching frequency ($f_{sw(max)}$) for a given application can be calculated as follows:

$$f_{sw(max)} = \frac{V_{out} + V_{sw(BOT)}}{t_{on(min)}(V_{in} - V_{sw(TOP)} + V_{sw(BOT)})} \quad (3)$$

where V_{in} is the typical input voltage, V_{out} is the output voltage, $V_{sw(TOP)}$ and $V_{sw(BOT)}$ are the internal switch

drops (-0.2V, -0.08V, respectively at maximum load) and $t_{on(min)}$ is the minimum top switch on-time (see the Electrical Characteristics). Equation 3 shows that a slower switching frequency is necessary to accommodate a high V_{in}/V_{out} ratio.

For transient operation, V_{in} may go as high as the absolute maximum rating of 42V regardless of the R_T value, however the LT8638S will reduce switching frequency as necessary to maintain control of inductor current to assure safe operation.

The LT8638S is capable of a maximum duty cycle of approximately 99%, and the V_{in} -to- V_{out} dropout is limited by the $R_{on(on)}$ of the top switch. In this mode the LT8638S skips switch cycles, resulting in a lower switching frequency than programmed by R_T .

For applications that cannot allow deviation from the programmed switching frequency at low V_{in}/V_{out} ratios use Equation 4 to set switching frequency.

$$V_{in(min)} = \frac{V_{out} + V_{sw(BOT)}}{1 - f_{sw} \cdot t_{off(min)}} - V_{sw(BOT)} + V_{sw(TOP)} \quad (4)$$

where $V_{in(min)}$ is the minimum input voltage without skipped cycles, V_{out} is the output voltage, $V_{sw(TOP)}$ and $V_{sw(BOT)}$ are the internal switch drops (-0.2V, -0.08V, respectively at maximum load), f_{sw} is the switching frequency (set by R_T), and $t_{off(min)}$ is the minimum switch off-time. Note that higher switching frequency will increase the minimum input voltage below which cycles will be dropped to achieve higher duty cycle.

$$f_{sw(max)} = \frac{3.3V + 0.8V}{(2 \times 10^{-9})(28V - 0.2V + 0.8V)} = 5734265.734 \text{ Hz}$$

$$t_{on(min)} = 25 \text{ ns}$$

$$\approx 5.7 \text{ MHz}$$

↑ from electrical characteristics

Super high, so not a huge concern.

Pick avg. value on table,

Switching Frequency @ 400 kHz Resistor

$$400 \text{ kHz} \rightarrow R_T = 105 \text{ k}\Omega$$

OBC config: (cont.)

Choke inductor selection

1. Choose appropriate first choice inductor

$$L = \frac{V_{out} + V_{sw(BOT)}}{f_{sw}} \cdot 0.2$$

$$L = \frac{3.3v + 0.8}{400\text{kHz}} \cdot 0.2$$

= 2.05 μH

Given:

$$V_{sw(BOT)} = 0.08V$$

L is in μH

$$V_{out} = 3.3$$

$$f_{sw} = 400\text{kHz}$$

LT8638 Datasheet (Pg. 11)

Inductor Selection and Maximum Output Current

The LT8638S is designed to minimize solution size by allowing the inductor to be chosen based on the output load requirements of the application. During overload or short-circuit conditions the LT8638S safely tolerates operation with a saturated inductor through the use of a high speed peak-current mode architecture.

A good first choice for the inductor value is given by Equation 5.

$$L = \left(\frac{V_{out} + V_{sw(BOT)}}{f_{sw}} \right) \cdot 0.2 \quad (5)$$

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For duty cycles greater than 50% ($V_{out}/V_{in} > 0.5$), a minimum inductance is required to avoid subharmonic oscillation (Equation 9). See Application Note 19 for more details.

$$L_{min} = \frac{V_{in}(2 \cdot DC - 1)}{5 \cdot f_{sw}} \quad (9)$$

where DC is the duty cycle ratio (V_{out}/V_{in}) and f_{sw} is the switching frequency.

2. Check duty cycle ratio for minimum inductance rating

$$\frac{V_{out}}{V_{in}} = \frac{3.3v}{28v} = 0.117 < 0.5$$

No minimum inductance necessary

3.) Confirm inductor value can support max current (3A) for 1Mx8

a.) First find the ripple current ΔI_L

$$\Delta I_L = \frac{V_{out}}{L \cdot f_{sw}} \cdot \left(1 - \frac{V_{out}}{V_{in(max)}} \right)$$

$$\Delta I_L = \left(\frac{3.3v}{2.05\mu H \cdot 400\text{kHz}} \right) \left(1 - \frac{3.3v}{28v} \right) = 3.55 A$$

$$I_{out(max)} = I_{lim} - \frac{\Delta I_L}{2}$$

$$I_{out(max)} = 15A - \frac{3.55}{2} = 13.225 A$$

$$I_{lim} = 15A$$

We only need 3A for this component, so our max I_{out} is more than enough

So in conclusion:

$$L = 2.05 \mu H$$

Peripheral Board (Sv conn.)

a.) LTC4365: UV/OV Protection

1.) Find $R_1 + R_2$

$$R_1 + R_2 = \frac{V_{OS(UV)}}{I_{UV}}$$

$$R_1 + R_2 = \frac{3mV}{10nA}$$

$$R_1 + R_2 = 300k$$

2.) Find R_3 using UV trip threshold

$$R_3 = \frac{V_{OS(UV)}}{I_{UV}} \cdot \left(\frac{UV_{TH} - 0.5V}{0.5V} \right)$$

$$\text{Let } UV_{TH} = 22V$$

$$R_3 = \left(\frac{3mV}{10nA} \right) \cdot \left(\frac{22 - 0.5}{0.5} \right) = 12.9M\Omega$$

3.) Find R_1 using OV trip threshold

$$\text{Let } OV = 35$$

$$R_1 = \left(\frac{V_{OV(UV)}}{I_{UV}} \right) + R_3 \cdot 0.5V$$

$$R_1 = \left(\left(\frac{3mV}{10nA} \right) + 12.9M\Omega \right) (0.5V) = 190k$$

$$R_1 \approx 190k$$

4.) Find R_2

$$R_1 + R_2 = 300k$$

$$R_1 = 190k$$

$$R_2 = 300k - 190k$$

$$R_2 = 110k$$

Recommended Parameters :

$$V_{OS(UV)} = 3mV$$

$$I_{UV} = 10nA$$

Set by me:

$$OV_{TH} = 35V$$

$$UV_{TH} = 22V$$

From LTC 4365 Data sheet
(Pg. 11)

Procedure for Selecting UV/OV External Resistor Values

The following 3-step procedure helps select the resistor values for the resistive divider of Figure 4. This procedure minimizes UV and OV offset errors caused by leakage currents at the respective pins.

- Choose maximum tolerable offset at the UV pin, $V_{OS(UV)}$. Divide by the worst case leakage current at the UV pin, I_{UV} (10nA). Set the sum of $R_1 + R_2$ equal to $V_{OS(UV)}$ divided by 10nA. Note that due to the presence of R_3 , the actual offset at UV will be slightly lower.

$$R_1 + R_2 = \frac{V_{OS(UV)}}{I_{UV}}$$

- Select the desired V_{IN} UV trip threshold, UV_{TH} . Find the value of R_3 :

$$R_3 = \frac{V_{OS(UV)}}{I_{UV}} \cdot \left(\frac{UV_{TH} - 0.5V}{0.5V} \right)$$

- Select the desired V_{IN} OV trip threshold, OV_{TH} . Find the values of R_1 and R_2 :

$$R_1 = \frac{\left(\frac{V_{OS(UV)}}{I_{UV}} + R_3 \right)}{OV_{TH}} \cdot 0.5V$$

$$R_2 = \frac{V_{OS(UV)}}{I_{UV}} - R_1$$

The example of Figure 4 uses standard 1% resistor values. The following parameters were selected:

$$V_{OS(UV)} = 3mV$$

$$I_{UV} = 10nA$$

$$UV_{TH} = 5V$$

$$OV_{TH} = 18V$$

For OBC

$$R_1 = 190k$$

$$R_2 = 110k$$

$$R_3 = 12.9M\Omega$$

* Each UV/OV Threshold will be the same because each load switch is before each switching regulator

Passive Config: (Cont.) Switching Regulator

6.) LT8638SEV: Output Voltage, Default Switching Frequency and choke Inductor Selection

FB Resistor Network

$$R_1 = R_2 \left(\frac{V_{out}}{0.6V} - 1 \right)$$

$$R_1 = 3k \left(\frac{5}{0.6V} - 1 \right)$$

$$R_1 = 22000$$

$$R_1 \approx 22k$$

Let $R_2 = 3k\Omega$
 $V_{out} = 5V$

From LT8638SEV Datasheet (Pg. 17)

FB Resistor Network

The output voltage is programmed with a resistor divider between the output and the FB pin. Choose the resistor values according to Eq.1.

$$R_1 = R_2 \left(\frac{V_{out}}{0.6V} - 1 \right) \quad (1)$$

Reference designators refer to the Block Diagram. 1% resistors are recommended to maintain output voltage accuracy.

When using large FB resistors, a 4.7pF to 47pF phase-lead capacitor should be connected from V_{out} to FB.

FB Resistor Network for $V_{out} = 5V$

$$R_1 = 22k, R_2 = 3k$$

Default Switching Frequency / RT calculations

$$f_{sw(max)} = \frac{V_{out} + V_{sw(BOT)}}{t_{on(min)}(V_{in} - V_{in_{sw(TOP)}} + V_{sw(BOT)})}$$

where V_{in} is the typical input voltage, V_{out} is the output voltage, $V_{sw(TOP)} = \sim 0.2V$, $V_{sw(BOT)} = \sim 0.8V$, $t_{on(min)}$ is the minimum top switch on time
 internal switch drops at max load

- The higher your switching frequency, the lower your input voltage can be and lower efficiency

From LT8638SEV Datasheet (Pg. 18)

APPLICATIONS INFORMATION

table showing the necessary R_T value for a desired switching frequency is in Table 1.

The R_T resistor required for a desired switching frequency can be calculated using Equation 2.

$$R_T = \frac{44.8}{f_{sw}} - 5.9 \quad (2)$$

where R_T is in kΩ and f_{sw} is the desired switching frequency in MHz.

Table 1. SW Frequency vs R_T Value

f_{sw} (MHz)	R_T (kΩ)
0.2	226
0.3	143
0.4	105
0.5	82.5
0.6	66.5
0.7	56.2
0.8	48.7
1.0	38.3
1.2	31.6
1.4	26.1
1.6	22.1
1.8	19.1
2.0	16.9
2.2	15.4
3.0	10.5

Operating Frequency Selection and Trade-Offs

Selection of the operating frequency is a trade-off between efficiency, component size, and input voltage range. The advantage of high frequency operation is that smaller inductor and capacitor values may be used. The disadvantages are lower efficiency and a smaller input voltage range.

The highest switching frequency ($f_{sw(max)}$) for a given application can be calculated as follows:

$$f_{sw(max)} = \frac{V_{out} + V_{sw(BOT)}}{t_{on(min)}(V_{in} - V_{sw(TOP)} + V_{sw(BOT)})} \quad (3)$$

where V_{in} is the typical input voltage, V_{out} is the output voltage, $V_{sw(TOP)}$ and $V_{sw(BOT)}$ are the internal switch

drops (-0.2V, -0.08V, respectively at maximum load) and $t_{on(min)}$ is the minimum top switch on-time (see the Electrical Characteristics). Equation 3 shows that a slower switching frequency is necessary to accommodate a high V_{in}/V_{out} ratio.

For transient operation, V_{in} may go as high as the absolute maximum rating of 42V regardless of the R_T value, however the LT8638S will reduce switching frequency as necessary to maintain control of inductor current to assure safe operation.

The LT8638S is capable of a maximum duty cycle of approximately 99%, and the V_{in} -to- V_{out} dropout is limited by the $R_{on(on)}$ of the top switch. In this mode the LT8638S skips switch cycles, resulting in a lower switching frequency than programmed by R_T .

For applications that cannot allow deviation from the programmed switching frequency at low V_{in}/V_{out} ratios use Equation 4 to set switching frequency.

$$V_{in(min)} = \frac{V_{out} + V_{sw(BOT)}}{1 - \frac{1}{f_{sw}} \cdot t_{off(min)}} - V_{sw(BOT)} + V_{sw(TOP)} \quad (4)$$

where $V_{in(min)}$ is the minimum input voltage without skipped cycles, V_{out} is the output voltage, $V_{sw(TOP)}$ and $V_{sw(BOT)}$ are the internal switch drops (-0.2V, -0.08V, respectively at maximum load), f_{sw} is the switching frequency (set by R_T), and $t_{off(min)}$ is the minimum switch off-time. Note that higher switching frequency will increase the minimum input voltage below which cycles will be dropped to achieve higher duty cycle.

Switching Frequency @ 400 kHz Resistor

$$400\text{ kHz} \Rightarrow R_T = 10\text{ k}\Omega$$

Perif config: (cont.)

Choke inductor selection

LT8638 Datasheet (P.g. 17)

1. Choose appropriate first choice inductor

$$L = \frac{V_{out} + V_{SW(BOT)}}{f_{sw}} \cdot 0.2$$

$$L = \frac{5V + 0.8}{400\text{kHz}} \cdot 0.2$$

$$= 2.9 \times 10^{-6} \text{ H} = 2.9 \mu\text{H}$$

Given:

$$V_{SW(BOT)} = 0.08V$$

L is in μH

$$V_{out} = 5$$

$$f_{sw} = 400\text{kHz}$$

Inductor Selection and Maximum Output Current

The LT8638S is designed to minimize solution size by allowing the inductor to be chosen based on the output load requirements of the application. During overload or short-circuit conditions the LT8638S safely tolerates operation with a saturated inductor through the use of a high speed peak-current mode architecture.

A good first choice for the inductor value is given by Equation 5.

$$L = \left(\frac{V_{out} + V_{SW(BOT)}}{f_{sw}} \right) \cdot 0.2 \quad (5)$$

Rev. A

2. Check duty cycle ratio for minimum inductance rating

$$\frac{V_{out}}{V_{in}} = \frac{5V}{28V} = 0.17 < 0.5$$

No minimum inductance necessary

For duty cycles greater than 50% ($V_{out}/V_{in} > 0.5$), a minimum inductance is required to avoid subharmonic oscillation (Equation 9). See Application Note 19 for more details.

$$L_{MIN} = \frac{V_{IN}(2 \cdot DC - 1)}{5 \cdot f_{sw}} \quad (9)$$

where DC is the duty cycle ratio (V_{out}/V_{in}) and f_{sw} is the switching frequency.

3.) Confirm inductor value can support max current (3A) for IMX8

a.) First find the ripple current ΔI_L

$$\Delta I_L = \frac{V_{out}}{L \cdot f_{sw}} \cdot \left(1 - \frac{V_{out}}{V_{in(\max)}} \right)$$

$$\Delta L = \left(\frac{5V}{2.9 \mu\text{H} \cdot 400\text{kHz}} \right) \left(1 - \frac{5V}{28V} \right) = 3.54\text{A}$$

$$I_{out(max)} = I_{lim} - \frac{\Delta I_L}{2}$$

$$I_{out(max)} = 1.5A - \frac{3.54}{2} = 13.23$$

$$I_{lim} = 1.5A$$

we only need 3A for this component, so our max limit is more than enough

So in conclusion:

$$L = 2.90 \mu\text{H}$$

LTC6902 Clock :

Frequency setting / Phase set / SSFM select

Step 1:

Selecting the phase:

3-phase \rightarrow 3 components

Leave PH open, M = 3

For SSFM
→

Step 2: Frequency range

Let desired freq be 400 kHz,
Based on datasheet this is at $200\text{kHz} < f < 2\text{MHz}$

so $N = 10$, leave div open

Step 3: Define Rset (For SSFM)

$$R_{\text{set}} = 20k \left(\frac{10\text{MHz}}{N \cdot M \cdot f_{\text{out}}} \right)$$

$$R_{\text{set}} = 20k \left(\frac{10\text{MHz}}{3 \cdot 10 \cdot (400\text{kHz})} \right) = 16.666 \text{ k}\Omega$$

$$f_{\text{out}} = \frac{10\text{MHz}}{N \cdot M} \cdot \left(\frac{20k\Omega}{R_{\text{set}}} \right)$$

in SSFM is f_{max}

Step 4: Define Rmod

$$R_{\text{mod}} = 20 \cdot \frac{R_{\text{set}}}{\text{spreading percentage}}$$

$$R_{\text{mod}} = 20 \cdot \left(\frac{16.666 \text{ k}\Omega}{25} \right) = 13.332 \text{ k}\Omega$$

where spreading percentage = $100 \left(\frac{f_{\text{max}} - f_{\text{min}}}{f_{\text{max}}} \right)$

$$= 100 \left(\frac{400\text{kHz} - 300\text{kHz}}{400\text{kHz}} \right) \\ = 25\% \text{ spreading}$$

LTC6902 Config.:

SSFM with 25% spreading

$$R_{\text{set}} = 16.666 \text{ k}\Omega \Rightarrow \text{set}$$

$$R_{\text{mod}} = 13.332 \text{ k}\Omega \Rightarrow \text{mod}$$

PH Open $\rightarrow M = 3$

Div Open $\rightarrow N = 10$

LTC6902 Datasheet (Pg.5)

By selecting the multiphase mode, a division parameter M is also chosen:

2-Phase: Connect PH Pin to GND	M = 1
3-Phase: Leave PH Open	M = 3
4-Phase: Connect PH Pin to V+	M = 4

DIVIDER SETTING	FREQUENCY RANGE ($f_{\text{OUT}} \cdot M$)
N = 1	Connect DIV Pin to GND 2MHz to 20MHz
N = 10	Leave DIV Open 200kHz to 2MHz
N = 100	Connect DIV Pin to V+ <200kHz

Note: The frequency range numbers are for a 5V supply where a 20MHz output is the maximum frequency supported. For low supply applications ($2.7V \leq V^* \leq 4V$), the maximum rated output frequency is 10MHz and all of the above numbers should be halved.

$$f_{\text{OUT}} = \frac{10\text{MHz}}{N \cdot M} \cdot \left(\frac{20k\Omega}{R_{\text{SET}}} \right); 5\text{kHz} \leq f_{\text{OUT}} \leq 20\text{MHz}$$

$$\text{Spreading Percentage} = 20 \cdot \frac{R_{\text{SET}}}{R_{\text{MOD}}}$$

All LT8638SEV Soft-Start Calculations

LT8638SEV Datasheet (P.g.22)

For OBC

- Shortest SS

SS formula:

$$T_{SS} = \frac{0.8 \times C_{SS}}{2mA}$$

let $C_{SS} = 100nF$

$$T_{SS} = \frac{0.8 \times 10nF}{2mA}$$

= 4ms

Checklist for calc's:

JETSON:

- Load Switch
 - OV/UV
- Switching reg.
 - ILT
 - Inductor
 - SS

OBC:

- Load Switch
 - OV/UV
- Switching reg.
 - ILT
 - Inductor
 - SS

Perif:

- Load Switch
 - OV/UV
- Switching reg.
 - ILT
 - Inductor
 - SS

Clock:

- SSFM
- fmax
- # of phases

R-Shunt Resistor Selection for INA230 :

82mV is the max vdrop across it

Jetson INA230 :

$$R_{shunt} = \frac{V_{shunt\ max}}{I_{max}}$$

$V_{shunt\ max} = 0.08$

$I_{max} = 10A$

$$R_{shunt} = \frac{0.08}{10} = 8m\Omega$$

OBC INA230 :

$$R_{shunt} = \frac{V_{shunt\ max}}{I_{max}}$$

$V_{shunt\ max} = 0.08$

$I_{max} = 3A$

$$R_{shunt} = \frac{0.08}{3A} \approx 26.7m\Omega$$

Go with 30mΩ

Peripheral INA230 :

$$R_{shunt} = \frac{V_{shunt\ max}}{I_{max}}$$

$V_{shunt\ max} = 0.08$

$I_{max} = 2A$

$$R_{shunt} = \frac{0.08}{2} = 40m\Omega$$

Output Voltage Tracking and Soft-Start

The LT8638S allows the user to program its output voltage ramp rate by means of the SS pin. An internal 2µA pulls up the SS pin to INTV_{CC}. Putting an external capacitor on SS enables soft starting the output to prevent current surge on the input supply. During the soft-start ramp the output voltage will proportionally track the SS pin voltage. For output tracking applications, SS can be externally driven by another voltage source. From 0V to 1V, the SS voltage will override the internal 0.6V reference input to the error amplifier, thus regulating the FB pin voltage to a function of the SS pin. See plot in the Typical Performance Characteristics section. When SS is above 1V, tracking is disabled and the feedback voltage

will regulate to the internal reference voltage. The SS pin may be left floating if the function is not needed.

An active pull-down circuit is connected to the SS pin which will discharge the external soft-start capacitor in the case of fault conditions and restart the ramp when the faults are cleared. Fault conditions that clear the soft-start capacitor are the EN/UV pin transitioning low, V_{IN} voltage falling too low, or thermal shutdown.