100W LED CC Driver using LM3409HV

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1 LED Calculation

1.1 Specifications

- Nominal input voltage: $V_{in} = 48\,\mathrm{V}$
- Maximum input voltage: $V_{in-max} = 48\,\mathrm{V}$
- Nominal output voltage: $V_o = 33\,\mathrm{V}$
- Led approx dynamic resistance: $r_D = 0.7\,\Omega$
- Switching frequency: $f_{sw} = 228\,\mathrm{kHz}$
- Average LED current: $I_{LED} = 2.5\,\mathrm{A}, 3\,\mathrm{A}, 3.5\,\mathrm{A}$
- Inductor current ripple: $\Delta i_{L-PP} = 1.28\,\mathrm{A}$
- LED current ripple: $\Delta i_{LED-PP} = 300\,\mathrm{mA}$
- Input voltage ripple: $\Delta V_{in-PP} = 1.4\,\mathrm{V}$
- UVLO characteristics: $V_{TURN-ON}, V_{HYS}$
- Expected efficiency: $\eta = 97\%$

1.2 Nominal Switching Frequency

$$D = \frac{V_o}{\eta \cdot V_{IN}} = \frac{33\,\mathrm{V}}{97\% \cdot 48\,\mathrm{V}} = 0.708 \tag{1}$$

$$R_{off} = -\frac{-(1 - \frac{V_o}{\eta \cdot V_{in}})}{(C_{off} + 20\,\mathrm{pF}) \cdot f_{sw} \cdot \ln(1 - \frac{1.24\,\mathrm{V}}{V_o})} = \frac{-(1 - \frac{33\,\mathrm{V}}{97\% \cdot 48\,\mathrm{V}})}{(470\,\mathrm{pF} + 20\,\mathrm{pF}) \cdot 241\,\mathrm{kHz} \cdot \ln(1 - \frac{1.24\,\mathrm{V}}{33\,\mathrm{V}})} = 64.4\,\mathrm{k\Omega} \tag{2}$$

The closest resistor value is $68.1\,\mathrm{k\Omega}$ so the switching frequency becomes $228\,\mathrm{kHz}$.

$$t_{off} = -R_{off} \cdot (C_{off} + 20\,\mathrm{pF}) \cdot \ln\left(1 - \frac{1.24\,\mathrm{V}}{V_o}\right) = -68.1\,\mathrm{k\Omega} \cdot (470\,\mathrm{pF} + 20\,\mathrm{pF}) \cdot \ln\left(1 - \frac{1.24\,\mathrm{V}}{33\,\mathrm{V}}\right) = 1.28\,\mathrm{\mu s} \tag{3}$$

1.3 Inductor Ripple Current

$$L = \frac{V_o \cdot t_{off}}{\Delta i_{L-PP}} = \frac{33\,\mathrm{V} \cdot 1.28\,\mathrm{\mu s}}{1.28\,\mathrm{A}} = 32.9\,\mathrm{\mu H} \approx 33\,\mathrm{\mu H} \tag{4}$$

1.4 Average LED Current

For constant 2.5A current...

$$I_{L\_MAX} = I_{LED} + \frac{\Delta i_{L-PP}}{2} = 2.5\,\mathrm{A} + \frac{1.28\,\mathrm{A}}{2} = 3.64\,\mathrm{A} \tag{5}$$

$$R_{SNS} = \frac{V_{ADJ}}{5 \cdot I_{L\_MAX}} = \frac{1.24\,\mathrm{V}}{5 \cdot 3.64\,\mathrm{A}} \approx 68\,\mathrm{m\Omega} \tag{6}$$

1.5 Output Capacitance

$$Z_c = \frac{r_D \cdot i_{LED-PP}}{i_{L-PP} - i_{LED-PP}} = \frac{0.7\,\Omega \cdot 300\,\mathrm{mA}}{1.28\,\mathrm{A} - 300\,\mathrm{mA}} = 0.214\,\Omega \tag{7}$$

$$C_{O\_MIN} = \frac{1}{2 \cdot \pi \cdot f_{sw} \cdot Z_c} = \frac{1}{2 \cdot \pi \cdot 228\,\mathrm{kHz} \cdot 0.214\,\Omega} = 3.2\,\mathrm{\mu F} \approx 3.3\,\mathrm{\mu F} \tag{8}$$

1.6 Input Capacitance

$$C_{IN\_MIN} = \frac{I_{LED} \cdot t_{on}}{V_{in-PP}} = \frac{3\,\mathrm{A} \cdot \left(\frac{1}{228\,\mathrm{kHz}} - 1.28\,\mathrm{\mu s}\right)}{1.4\,\mathrm{V}} = 6.6\,\mathrm{\mu F} \tag{9}$$

$$I_{N\_RMS} = I_{LED} \cdot f_{sw} \cdot \sqrt{t_{on} \cdot t_{off}} = 3\,\mathrm{A} \cdot 228\,\mathrm{kHz} \cdot \sqrt{\left(\frac{1}{228\,\mathrm{kHz}} - 1.28\,\mathrm{\mu s}\right) \cdot 1.28\,\mathrm{\mu s}} = 1.36\,\mathrm{A} \tag{10}$$

1.7 PFET

Note:

- Voltage 15% higher than V_{IN_MAX}
- Current 10% higher than I_T
- PMOS gate charge $\leq 30\,\mathrm{nC}$

$$I_T = D \cdot I_{LED} = 0.708 \cdot 3\,\mathrm{A} = 2.12\,\mathrm{A} \tag{11}$$

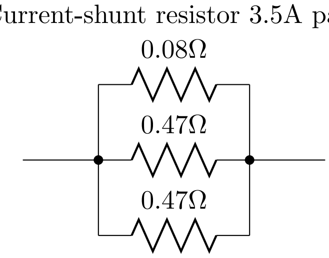
$$I_{T-RMS} = I_{LED} \cdot \sqrt{D \cdot \left(1 + 1/12 \cdot \left(\frac{\Delta i_{L-PP}}{I_{LED}}\right)^2\right)} = 3\,\mathrm{A} \cdot \sqrt{0.708 \cdot \left(1 + 1/12 \cdot \left(\frac{1.28\,\mathrm{A}}{3\,\mathrm{A}}\right)^2\right)} = 2.54\,\mathrm{A} \tag{12}$$

$$P_T = I_{T-RMS}^2 \cdot R_{DSON} = 2.32\,\mathrm{A}^2 \cdot 235\,\mathrm{m\Omega} = 598\,\mathrm{mW} \tag{13}$$

1.8 3.0A/3.5A Shunt Resistor Calculation

The current of the led is selected by soldering or de-soldering current shunt resistors. First the current shunt resistance value was calculated for 2.5A led current. A decrease in the equivalent shunt resistance increases the current through the led. A resistance value that could scale the current linearly in 500mA steps was found to be 0.47Ω. The actual led current was then calculated in table 1.

Figure 1: Current-shunt resistor 3.5A parallel circuit



$$\frac{1}{R_T} = \frac{1}{R1} + \frac{1}{R2} + \cdots + \frac{1}{R_n} \tag{14}$$

Table 1: Actual current and equiv. shunt resistance calculation

Constant	**2.5A**	**3.0A**	**3.5A**
I_{L_MAX}	$2.5\text{A} + \frac{1.28\text{A}}{2} = 3.14\text{A}$	$3.0\text{A} + \frac{1.28\text{A}}{2} = 3.64\text{A}$	$3.5\text{A} + \frac{1.28\text{A}}{2} = 4.14\text{A}$
Exact R_{SNS}	$\frac{1.24\text{V}}{5 \cdot 3.14\text{A}} = 0.0790\Omega$	$\frac{1.24\text{V}}{5 \cdot 3.64\text{A}} = 0.0681\Omega$	$\frac{1.24\text{V}}{5 \cdot 4.14\text{A}} = 0.0600\Omega$
Approx R_{SNS}	80mΩ Resistor	0.47Ω Resistor = 68.4mΩ	2 $\times$ 0.47Ω Resistor = 59.7mΩ
Actual I_{LED}	$\frac{1.24\text{V}}{5 \cdot 0.0800\Omega} - 0.64\text{A} = 2.46\text{A}$	$\frac{1.24\text{V}}{5 \cdot 0.0684\Omega} - 0.64\text{A} = 2.98\text{A}$	$\frac{1.24\text{V}}{5 \cdot 0.0590\Omega} - 0.64\text{A} = 3.51\text{A}$