1 Introduction

This wide range evaluation board showcases the LM3423 NFET controller used with a buck-boost current regulator. It is designed to drive 4 to 8 LEDs at a maximum average LED current of 700mA from a DC input voltage of 10 to 70V.

The evaluation board showcases most features of the LM3423 including PWM dimming, fault and LED status flags, output overvoltage protection and input under-voltage lockout. Note that there are two revisions of this PCB. The documentation for the latest revision (551600305-002 RevA) is shown first. The schematic, layout and bill of materials for the first revision (551600305-001 Rev1) can be found at the end of this document.

The buck-boost circuit can be easily redesigned for different specifications by changing only a few components (see the Alternate Designs section found at the end of this application note). Note that design modifications can change the system efficiency. See the LM3421/21Q1/21Q0 LM3423/23Q1/23Q0 N-Ch Controllers for Constant Current LED Drivers (SNVS574) data sheet for a comprehensive explanation of the device and application information.

![Figure 1. Efficiency with 6 Series LEDs at 700mA](image)

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Figure 2. Board Schematic
## 3 Pin Descriptions

<table>
<thead>
<tr>
<th>LM3423</th>
<th>LM3421</th>
<th>Name</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>$V_{IN}$</td>
<td>Input Voltage</td>
<td>Bypass with 100 nF capacitor to AGND as close to the device as possible in the circuit board layout.</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>EN</td>
<td>Enable</td>
<td>Connect to AGND for zero current shutdown or apply &gt; 2.4V to enable device.</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>COMP</td>
<td>Compensation</td>
<td>Connect a capacitor to AGND to set the compensation.</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>CSH</td>
<td>Current Sense High</td>
<td>Connect a resistor to AGND to set the signal current. For analog dimming, connect a controlled current source or a potentiometer to AGND as detailed in the Analog Dimming section.</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>RCT</td>
<td>Resistor Capacitor Timing</td>
<td>External RC network sets the predictive “off-time” and thus the switching frequency.</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>AGND</td>
<td>Analog Ground</td>
<td>Connect to PGND through the DAP copper pad to provide ground return for CSH, COMP, RCT, and TIMR.</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>OVP</td>
<td>Over-Voltage Protection</td>
<td>Connect to a resistor divider from $V_C$ to program output over-voltage lockout (OVLO). Turn-off threshold is 1.24V and hysteresis for turn-on is provided by 23 µA current source.</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>nDIM</td>
<td>Dimming Input / Under-Voltage Protection</td>
<td>Connect a PWM signal for dimming as detailed in the PWM Dimming section and/or a resistor divider from $V_C$ to program input under-voltage lockout (UVLO). Turn-on threshold is 1.24V and hysteresis for turn-off is provided by 23 µA current source.</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
<td>FLT</td>
<td>Fault Flag</td>
<td>Connect to pull-up resistor from $V_{IN}$ and N-channel MosFET open drain output is high when a fault condition is latched by the timer.</td>
</tr>
<tr>
<td>10</td>
<td>-</td>
<td>TIMR</td>
<td>Fault Timer</td>
<td>Connect a capacitor to AGND to set the time delay before a sensed fault condition is latched.</td>
</tr>
<tr>
<td>11</td>
<td>-</td>
<td>LRDY</td>
<td>LED Ready Flag</td>
<td>Connect to pull-up resistor from $V_{IN}$ and N-channel MosFET open drain output pulls down when the LED current is not in regulation.</td>
</tr>
<tr>
<td>12</td>
<td>-</td>
<td>DPOL</td>
<td>Dim Polarity</td>
<td>Connect to AGND if dimming with a series P-channel MosFET or leave open when dimming with series N-channel MosFET.</td>
</tr>
<tr>
<td>13</td>
<td>9</td>
<td>DDRV</td>
<td>Dim Gate Drive Output</td>
<td>Connect to the gate of the dimming MosFET.</td>
</tr>
<tr>
<td>14</td>
<td>10</td>
<td>PGND</td>
<td>Power Ground</td>
<td>Connect to AGND through the DAP copper pad to provide ground return for GATE and DDRV.</td>
</tr>
<tr>
<td>15</td>
<td>11</td>
<td>GATE</td>
<td>Main Gate Drive Output</td>
<td>Connect to the gate of the main switching MosFET.</td>
</tr>
<tr>
<td>16</td>
<td>12</td>
<td>$V_{CC}$</td>
<td>Internal Regulator Output</td>
<td>Bypass with 2.2 µF–3.3 µF ceramic capacitor to PGND.</td>
</tr>
<tr>
<td>17</td>
<td>13</td>
<td>IS</td>
<td>Main Switch Current Sense</td>
<td>Connect to the drain of the main N-channel MosFET switch for $R_{DS-ON}$ sensing or to a sense resistor installed in the source of the same device.</td>
</tr>
<tr>
<td>18</td>
<td>14</td>
<td>RPD</td>
<td>Resistor Pull Down</td>
<td>Connect the low side of all external resistor dividers ($V_{IN}$ UVLO, OVP) to implement “zero-current” shutdown.</td>
</tr>
<tr>
<td>19</td>
<td>15</td>
<td>HSP</td>
<td>LED Current Sense Positive</td>
<td>Connect through a series resistor to the positive side of the LED current sense resistor.</td>
</tr>
<tr>
<td>20</td>
<td>16</td>
<td>HSN</td>
<td>LED Current Sense Negative</td>
<td>Connect through a series resistor to the negative side of the LED current sense resistor.</td>
</tr>
<tr>
<td>DAP (21)</td>
<td>DAP (17)</td>
<td>DAP</td>
<td>Thermal PAD on bottom of IC</td>
<td>Star ground, connecting AGND and PGND.</td>
</tr>
<tr>
<td>Qty</td>
<td>Part ID</td>
<td>Part Value</td>
<td>Manufacturer</td>
<td>Part Number</td>
</tr>
<tr>
<td>-----</td>
<td>----------</td>
<td>------------</td>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>2</td>
<td>C1, C12</td>
<td>0.1 µF X7R 10% 50V</td>
<td>TDK</td>
<td>C1608X5R1H104K</td>
</tr>
<tr>
<td>2</td>
<td>C2, C8</td>
<td>1.0 µF X7R 10% 50V</td>
<td>MURATA</td>
<td>GRM21BR71H105KA12L KA01L</td>
</tr>
<tr>
<td>1</td>
<td>C3</td>
<td>68 µF 20% 100V</td>
<td>UCC</td>
<td>EMVY101ARA680MKE</td>
</tr>
<tr>
<td>1</td>
<td>C4</td>
<td>0.1 µF X7R 10% 100V</td>
<td>TDK</td>
<td>C2012X7R2A104M</td>
</tr>
<tr>
<td>4</td>
<td>C6(a-d)</td>
<td>10 µF X7R 10% 50V (4 installed for a total of 40 µF)</td>
<td>TDK</td>
<td>C5750X7R1H106</td>
</tr>
<tr>
<td>1</td>
<td>C7</td>
<td>1000 pF X5R 5% 100V</td>
<td>MURATA</td>
<td>GRM21BR2E102K</td>
</tr>
<tr>
<td>1</td>
<td>C9</td>
<td>2.2 µF X7R 10% 16V</td>
<td>MURATA</td>
<td>GRM21BR71C225KA01L</td>
</tr>
<tr>
<td>1</td>
<td>C10</td>
<td>10 nF X7R 10% 50V</td>
<td>PANASONIC</td>
<td>ECJ2VB1H103 KA12L</td>
</tr>
<tr>
<td>1</td>
<td>C11</td>
<td>47 pF COG/NPO 5% 50V</td>
<td>PANASONIC</td>
<td>ECJ2VG1H470 KA01L</td>
</tr>
<tr>
<td>1</td>
<td>D1</td>
<td>Schottky 100V 12A (or 6A)</td>
<td>VISHAY</td>
<td>12CWQ10FNPBF (or 6CWQ10FNPBF)</td>
</tr>
<tr>
<td>1</td>
<td>D2</td>
<td>Zener 10V</td>
<td>ON-SEMI</td>
<td>BZX84C10-V</td>
</tr>
<tr>
<td>4</td>
<td>J1, J2, J4, J5</td>
<td>banana jack</td>
<td>KEYSTONE</td>
<td>575-8</td>
</tr>
<tr>
<td>1</td>
<td>J3</td>
<td>1x2 male header (with shunt tab)</td>
<td>SAMTEC</td>
<td>TSW-102-07-T-S</td>
</tr>
<tr>
<td>1</td>
<td>L1</td>
<td>47 µH 20% 6.3A</td>
<td>COILCRAFT</td>
<td>MSS1260-473MLB</td>
</tr>
<tr>
<td>2</td>
<td>Q1, Q2</td>
<td>NMOS 150V 50A (or 100V 32A)</td>
<td>INFINEON</td>
<td>IPD200N15N3 (or FDD3682)</td>
</tr>
<tr>
<td>2</td>
<td>Q3, Q7</td>
<td>NMOS 60V 260 mA</td>
<td>ON-SEMI</td>
<td>2N7002ET1G</td>
</tr>
<tr>
<td>1</td>
<td>Q4</td>
<td>PNP 40V 200 mA</td>
<td>FAIRCHILD</td>
<td>MMBT3906</td>
</tr>
<tr>
<td>1</td>
<td>Q5</td>
<td>PNP 150V 600 mA</td>
<td>FAIRCHILD</td>
<td>MMBT5401</td>
</tr>
<tr>
<td>1</td>
<td>Q6</td>
<td>NPN 300V 500 mA</td>
<td>FAIRCHILD</td>
<td>MMBTA42</td>
</tr>
<tr>
<td>2</td>
<td>R1, R11</td>
<td>12.4 kΩ 1%</td>
<td>VISHAY</td>
<td>CRCW080512k4FKEA</td>
</tr>
<tr>
<td>1</td>
<td>R2</td>
<td>0Ω 1%</td>
<td>VISHAY</td>
<td>CRCW08050000Z0EA</td>
</tr>
<tr>
<td>2</td>
<td>R3, R20</td>
<td>10Ω 1%</td>
<td>VISHAY</td>
<td>CRCW080510R0FKEA</td>
</tr>
<tr>
<td>1</td>
<td>R4</td>
<td>16.9 kΩ 1%</td>
<td>VISHAY</td>
<td>CRCW080516k9FKEA</td>
</tr>
<tr>
<td>3</td>
<td>R5, R7, R8</td>
<td>1.40 kΩ 1%</td>
<td>VISHAY</td>
<td>CRCW08051k40FKEA</td>
</tr>
<tr>
<td>1</td>
<td>R6</td>
<td>0.06Ω 1% 1W</td>
<td>VISHAY</td>
<td>WSL2512R0600FEA</td>
</tr>
<tr>
<td>1</td>
<td>R9</td>
<td>0.20 kΩ 1W</td>
<td>PANASONIC</td>
<td>ERJ12RSFR20U</td>
</tr>
<tr>
<td>1</td>
<td>R10</td>
<td>35.7 kΩ 1%</td>
<td>VISHAY</td>
<td>CRCW080535k7FKEA</td>
</tr>
<tr>
<td>3</td>
<td>R12, R13, R19</td>
<td>10.0 kΩ 1%</td>
<td>VISHAY</td>
<td>CRCW080510k0FKEA</td>
</tr>
<tr>
<td>3</td>
<td>R14, R15, R17</td>
<td>100 kΩ 1%</td>
<td>VISHAY</td>
<td>CRCW0805100kFKEA</td>
</tr>
<tr>
<td>1</td>
<td>R18</td>
<td>432 kΩ 1%</td>
<td>VISHAY</td>
<td>CRCW0805432kFKEA</td>
</tr>
<tr>
<td>5</td>
<td>TP1, TP5, TP6, TP10</td>
<td>turret</td>
<td>KEYSTONE</td>
<td>1502-2</td>
</tr>
<tr>
<td>1</td>
<td>U1</td>
<td>Buck-boost controller</td>
<td>TI</td>
<td>LM3423</td>
</tr>
</tbody>
</table>
5 PCB Layout for 551600305-002 REVA

Figure 3. Top Layer

Figure 4. Bottom Layer
6 Design Procedure

Refer to the LM3421/21Q1/21Q0 LM3423/23Q1/23Q0 N-Ch Controllers for Constant Current LED Drivers (SNVS574) data sheet for design considerations.

6.1 Specifications

N = 6

\( V_{\text{LED}} = 3.5 \text{V} \)

\( r_{\text{LED}} = 325 \text{ m}\Omega \)

\( V_{\text{IN}} = 24 \text{V} \)

\( V_{\text{IN-MIN}} = 10 \text{V}; V_{\text{IN-MAX}} = 70 \text{V} \)

\( f_{\text{SW}} = 700 \text{ kHz} \)

\( V_{\text{SNS}} = 150 \text{ m}\text{V} \)

\( I_{\text{LED}} = 700 \text{ mA} \)

\( \Delta i_{\text{L-PP}} = 350 \text{ mA} \)

\( \Delta i_{\text{LED-PP}} = 50 \text{ mA} \)

\( \Delta v_{\text{IN-PP}} = 100 \text{ mV} \)

\( I_{\text{LIM}} = 4 \text{A} \)

\( V_{\text{TURN-ON}} = 10 \text{V}; V_{\text{HYS}} = 3.4 \text{V} \)

\( V_{\text{TURN-OFF}} = 44 \text{V}; V_{\text{HYSO}} = 10 \text{V} \)

6.2 Operating Point

Solve for \( V_0 \) and \( r_D \):

\[
V_0 = N \times V_{\text{LED}} = 6 \times 3.5 \text{V} = 21 \text{V}
\]

(1)

\[
r_D = N \times r_{\text{LED}} = 6 \times 325 \text{ m}\Omega = 1.95 \text{k}\Omega
\]

(2)

Solve for \( D, D', D_{\text{MAX}}, \) and \( D_{\text{MIN}} \):

\[
D = \frac{V_0}{V_0 + V_{\text{IN}}} = \frac{21 \text{V}}{21 \text{V} + 24 \text{V}} = 0.467
\]

(3)

\[
D' = 1 - D = 1 - 0.467 = 0.533
\]

(4)

\[
D_{\text{MIN}} = \frac{V_0}{V_0 + V_{\text{IN-MAX}}} = \frac{21 \text{V}}{21 \text{V} + 70 \text{V}} = 0.231
\]

(5)

\[
D_{\text{MAX}} = \frac{V_0}{V_0 + V_{\text{IN-MIN}}} = \frac{21 \text{V}}{21 \text{V} + 10 \text{V}} = 0.677
\]

(6)

6.3 Switching Frequency

Assume \( C_7 = 1 \text{nF} \) and solve for \( R_{10} \):

\[
R_{10} = \frac{25}{f_{\text{SW}} \times C_7} = \frac{25}{700 \text{ kHz} \times 1 \text{nF}} = 35.7 \text{k}\Omega
\]

(7)

The closest standard resistor is actually 35.7 k\Ω therefore the \( f_{\text{SW}} \) is:

\[
f_{\text{SW}} = \frac{25}{R_{10} \times C_7} = \frac{25}{35.7 \text{k}\Omega \times 1 \text{nF}} = 700 \text{ kHz}
\]

(8)
The chosen components from Section 6.3 are:

\[
\begin{align*}
C7 &= 1 \text{ nF} \\
R10 &= 35.7 \text{ k}\Omega
\end{align*}
\]  

(9)

### 6.4 Average LED Current

Solve for R9:

\[
R9 = \frac{V_{\text{SNS}}}{I_{\text{LED}}} = \frac{150 \text{ mV}}{700 \text{ mA}} = 0.214 \Omega
\]

Assume R1 = 12.4 k\Omega and solve for R8:

\[
R8 = \frac{i_{\text{LED}} \times R1 \times R9}{1.24V} = \frac{700 \text{ mA} \times 12.4 \text{ k}\Omega \times 0.2\Omega}{1.24V} = 1.4 \text{ k}\Omega
\]

(11)

The closest standard resistor for R9 is 0.2\Omega and the closest for R8 (and R7) is actually 1.4 k\Omega therefore \(I_{\text{LED}}\) is:

\[
I_{\text{LED}} = \frac{1.24V \times R8}{R9 \times R1} = \frac{1.24V \times 1.4 \Omega}{0.2\Omega \times 12.4 \text{ k}\Omega} = 700 \text{ mA}
\]

(12)

The chosen components from Section 6.4 are:

\[
\begin{align*}
R9 &= 0.2\Omega \\
R1 &= 12.4 \text{ k}\Omega \\
R8 &= R7 = 1.4 \text{ k}\Omega
\end{align*}
\]  

(13)

### 6.5 Inductor Ripple Current

Solve for L1:

\[
L1 = \frac{V_{\text{IN}} \times D}{\Delta i_{\text{PP}} \times f_{\text{SW}}} = \frac{24V \times 0.467}{350 \text{ mA} \times 700 \text{ kHz}} = 46 \mu\text{H}
\]

(14)

The closest standard inductor is 47 \mu\text{H} therefore the actual \(\Delta i_{\text{PP}}\) is:

\[
\Delta i_{\text{PP}} = \frac{V_{\text{IN}} \times D}{L1 \times f_{\text{SW}}} = \frac{24V \times 0.467}{47 \mu\text{H} \times 700 \text{ kHz}} = 340 \text{ mA}
\]

(15)

Determine minimum allowable RMS current rating:

\[
I_{\text{L-RMS}} = \frac{I_{\text{LED}}}{D^\frac{1}{2}} \times \sqrt{1 + \frac{1}{12} \times \left(\frac{\Delta i_{\text{PP}} \times D}{I_{\text{LED}}}\right)^2}
\]

\[
I_{\text{L-RMS}} = \frac{700 \text{ mA}}{0.533} \times \sqrt{1 + \frac{1}{12} \times \left(\frac{340 \text{ mA} \times 0.533}{700 \text{ mA}}\right)^2}
\]

\[
I_{\text{L-RMS}} = 1.32\text{A}
\]

(16)

The chosen component from Section 6.5 is:

\[
L1 = 47 \mu\text{H}
\]

(17)

### 6.6 Output Capacitance

Solve for \(C_O\):

\[
C_O = \frac{I_{\text{LED}} \times D}{D \times \Delta i_{\text{LED-PP}} \times f_{\text{SW}}}
\]

\[
C_O = \frac{700 \text{ mA} \times 0.467}{1.95\Omega \times 50 \text{ mA} \times 700 \text{ kHz}} = 4.79 \mu\text{F}
\]

(18)
A total value of 40 µF (using 4 10 µF X7R ceramic capacitors) is chosen therefore the actual ΔI_{LED,PP} is:

\[ \Delta I_{LED,PP} = \frac{I_{LED} \times D}{f_0 \times C_0 \times f_{SW}} \]

\[ \Delta I_{LED,PP} = \frac{700 \, \text{mA} \times 0.467}{1.95 \, \Omega \times 40 \, \mu F \times 700 \, \text{kHz}} = 6 \, \text{mA} \]  

(19)

Determine minimum allowable RMS current rating:

\[ I_{LED,\text{RMS}} = I_{LED} \times \sqrt{\frac{D_{\text{MAX}}}{1 - D_{\text{MAX}}}} = 700 \, \text{mA} \times \sqrt{\frac{0.677}{1 - 0.677}} = 1.01 \, \text{A} \]

(20)

The chosen components from Section 6.6 are:

\[ C_6 = 4 \times 10 \, \mu F \]  

(21)

6.7 Peak Current Limit

Solve for R6:

\[ R6 = \frac{245 \, \text{mV}}{I_{\text{LIM}}} = \frac{245 \, \text{mV}}{4 \, \text{A}} = 0.061 \, \Omega \]  

(22)

The closest standard resistor is 0.06 Ω therefore \( I_{\text{LIM}} \) is:

\[ I_{\text{LIM}} = \frac{245 \, \text{mV}}{R6} = \frac{245 \, \text{mV}}{0.06 \, \Omega} = 4.1 \, \text{A} \]  

(23)

The chosen component from Section 6.7 is:

\[ R6 = 0.06 \, \Omega \]  

(24)

6.8 Loop Compensation

\( \omega_{p1} \) is approximated:

\[ \omega_{p1} = \frac{1 + D}{f_0 \times C_0} = \frac{1.467}{1.95 \Omega \times 40 \, \mu F} = 19k \, \text{rad/sec} \]  

(25)

\( \omega_{z1} \) is approximated:

\[ \omega_{z1} = \frac{f_0 \times D^2}{D \times L_1} = \frac{1.95 \Omega \times 0.533^2}{0.467 \times 47 \, \mu H} = 25k \, \text{rad/sec} \]  

(26)

\( T_{U0} \) is approximated:

\[ T_{U0} = \frac{D \times 620 \, \text{V}}{(1 + D) \times I_{\text{LED}} \times R6} = \frac{0.533 \times 620 \, \text{V}}{1.467 \times 700 \, \text{mA} \times 0.06 \, \Omega} = 5360 \]  

(27)

To ensure stability, calculate \( \omega_{p2} \):

\[ \omega_{p2} = \frac{\min(\omega_{p1}, \omega_{z1})}{5 \times T_{U0}} = \frac{\omega_{p1}}{5 \times 5360} = \frac{19k}{5 \times 5360} = 0.709 \, \text{rad/sec} \]  

(28)

Solve for \( C_8 \):

\[ C_8 = \frac{1}{\omega_{p2} \times 5 \times 10^6 \Omega} = \frac{1}{0.709 \times 5 \times 10^6 \Omega} = 0.28 \, \mu F \]  

(29)

To attenuate switching noise, calculate \( \omega_{p3} \):

\[ \omega_{p3} = \max(\omega_{p1}, \omega_{z1}) \times 10 = \omega_{z1} \times 10 \]

\[ \omega_{p3} = 25k \, \text{rad/sec} \times 10 = 250k \, \text{rad/sec} \]  

(30)
Assume $R_{20} = 10\,\Omega$ and solve for $C_{12}$:

$$C_{12} = \frac{1}{10\,\Omega \times \omega_{P3}} = \frac{1}{10\,\Omega \times 250\,\text{rad} / \text{sec}} = 0.4\,\mu\text{F}$$  \hspace{1cm} (31)

Since PWM dimming can be evaluated with this board, a much larger compensation capacitor $C_8 = 1.0\,\mu\text{F}$ is chosen and a smaller high frequency capacitor $C_{12} = 0.1\,\mu\text{F}$ is chosen.

The chosen components from Section 6.8 are:

- $C_8 = 1.0\,\mu\text{F}$
- $R_{20} = 10\,\Omega$
- $C_{12} = 0.1\,\mu\text{F}$  \hspace{1cm} (32)

### 6.9 Input Capacitance

Solve for the minimum $C_{\text{IN}}$:

$$C_{\text{IN}} = \frac{I_{\text{LED}} \times D}{\Delta V_{\text{IN-PP}} \times f_{\text{SW}}} = \frac{700\,\text{mA} \times 0.467}{100\,\text{mV} \times 700\,\text{kHz}} = 4.67\,\mu\text{F}$$  \hspace{1cm} (33)

To minimize power supply interaction a much larger capacitance of $68\,\mu\text{F}$ is used, therefore the actual $\Delta V_{\text{IN-PP}}$ is much lower.

Determine minimum allowable RMS current rating:

$$I_{\text{CO-RMS}} = I_{\text{LED}} \times \sqrt{\frac{D_{\text{MAX}}}{1 - D_{\text{MAX}}}} = 700\,\text{mA} \times \sqrt{\frac{0.677}{1 - 0.677}} = 1.01\,\text{A}$$  \hspace{1cm} (34)

The chosen components from Section 6.9 are:

- $C_3 = 68\,\mu\text{F}$  \hspace{1cm} (35)

### 6.10 NFET

Determine minimum Q1 voltage rating and current rating:

$$V_{\text{T-MAX}} = V_{\text{IN-MAX}} + V_D = 70\,\text{V} + 21\,\text{V} = 91\,\text{V}$$  \hspace{1cm} (36)

$$I_{\text{T-MAX}} = \frac{0.677}{1 - 0.677} \times 700\,\text{mA} = 1.46\,\text{A}$$  \hspace{1cm} (37)

A 100V NFET is chosen with a current rating of 40A due to the low $R_{\text{DS-ON}} = 50\,\text{m}\Omega$. Determine $I_{\text{T-RMS}}$ and $P_T$:

$$I_{\text{T-RMS}} = \frac{I_{\text{LED}}}{D'} \times \sqrt{D} = \frac{700\,\text{mA}}{0.533} \times \sqrt{0.467} = 897\,\text{mA}$$  \hspace{1cm} (38)

$$P_T = I_{\text{T-RMS}}^2 \times R_{\text{DSON}} = 897\,\text{mA}^2 \times 50\,\text{m}\Omega = 40\,\text{mW}$$  \hspace{1cm} (39)

The chosen component from Section 6.10 is:

- Q1 $\rightarrow 40\,\text{A}, 100\,\text{V}, \text{DPAK}$  \hspace{1cm} (40)

### 6.11 DIODE

Determine minimum D1 voltage rating and current rating:

$$V_{\text{RD-MAX}} = V_{\text{IN-MAX}} + V_D = 70\,\text{V} + 21\,\text{V} = 91\,\text{V}$$  \hspace{1cm} (41)

$$I_{\text{D-MAX}} = I_{\text{LED}} = 700\,\text{mA}$$  \hspace{1cm} (42)

A 100V diode is chosen with a current rating of 12A and $V_D = 600\,\text{mV}$. Determine $P_D$:

$$P_D = I_D \times V_FD = 700\,\text{mA} \times 600\,\text{mV} = 420\,\text{mW}$$  \hspace{1cm} (43)
The chosen component from Section 6.11 is:

\[ D1 \rightarrow 12A, 100V, DPAK \]  

(44)

### 6.12 Input UVLO

Since PWM dimming will be evaluated, a three resistor network will be used. Assume \( R_{13} = 10\, \text{k}\Omega \) and solve for \( R_{5} \):

\[ R_{5} = \frac{1.24V \times R_{13}}{V_{\text{TURN-ON}} - 1.24V} = \frac{1.24V \times 10\, \text{k}\Omega}{10V - 1.24V} = 1.42\, \text{k}\Omega \]  

(45)

The closest standard resistor is 1.4 kΩ therefore \( V_{\text{TURN-ON}} \) is:

\[ V_{\text{TURN-ON}} = \frac{1.24V \times (R_{5} + R_{13})}{R_{5}} \]  

\[ V_{\text{TURN-ON}} = \frac{1.24V \times (1.4\, \text{k}\Omega + 10\, \text{k}\Omega)}{1.4\, \text{k}\Omega} = 10.1V \]  

(46)

Solve for \( R_{4} \):

\[ R_{4} = \frac{R_{5} \times (V_{\text{HYS}} - 23\, \mu A \times R_{13})}{23\, \mu A \times (R_{5} + R_{13})} \]  

\[ R_{4} = \frac{1.4\, \text{k}\Omega \times (3.4V - 23\, \mu A \times 10\, \text{k}\Omega)}{23\, \mu A \times (1.4\, \text{k}\Omega + 10\, \text{k}\Omega)} = 16.9\, \text{k}\Omega \]  

(47)

The closest standard resistor is 16.9 kΩ making \( V_{\text{HYS}} \):

\[ V_{\text{HYS}} = \frac{23\, \mu A \times R_{4} \times (R_{5} + R_{13})}{R_{5}} + 23\, \mu A \times R_{13} \]  

\[ V_{\text{HYS}} = \frac{23\, \mu A \times 16.9\, \text{k}\Omega \times (1.4\, \text{k}\Omega + 10\, \text{k}\Omega)}{1.4\, \text{k}\Omega} + 23\, \mu A \times 10\, \text{k}\Omega = 3.4V \]  

(48)

The chosen components from Section 6.12 are:

\[ R_{5} = 1.4\, \text{k}\Omega \]  

\[ R_{13} = 10\, \text{k}\Omega \]  

\[ R_{4} = 16.9\, \text{k}\Omega \]  

(49)

### 6.13 Output OVLO

Solve for \( R_{18} \):

\[ R_{18} = \frac{V_{\text{HYSO}}}{23\, \mu A} = \frac{10V}{23\, \mu A} = 435\, \text{k}\Omega \]  

(50)

The closest standard resistor is 432 kΩ therefore \( V_{\text{HYSO}} \) is:

\[ V_{\text{HYSO}} = R_{18} \times 23\, \mu A = 432\, \text{k}\Omega \times 23\, \mu A = 9.9V \]  

(51)

Solve for \( R_{11} \):

\[ R_{11} = \frac{1.24V \times R_{18}}{V_{\text{TURN-OFF}} - 620\, \text{mV}} = \frac{1.24V \times 432\, \text{k}\Omega}{44V - 620\, \text{mV}} = 12.3\, \text{k}\Omega \]  

(52)

The closest standard resistor is 12.4 kΩ making \( V_{\text{TURN-OFF}} \):

\[ V_{\text{TURN-OFF}} = \frac{1.24V \times (R_{11} + R_{18})}{R_{11}} \]  

\[ V_{\text{TURN-OFF}} = \frac{1.24V \times (0.5 \times 12.4\, \text{k}\Omega + 432\, \text{k}\Omega)}{12.4\, \text{k}\Omega} = 44V \]  

(53)
The chosen components from Section 6.13 are:

\[
\begin{align*}
R_{11} & = 12.4 \, \text{k}\Omega \\
R_{18} & = 432 \, \text{k}\Omega
\end{align*}
\]

(54)

6.14 PWM Dimming

The LM3423 Buck-boost Evaluation board is configured to demonstrate PWM dimming of the LEDs. For best operation, use a PWM signal that has greater than 3V amplitude at a frequency between 120Hz and 5kHz. Apply the PWM signal to the BNC connector (J6) and the inverted signal (seen by the nDIM pin) can be monitored at TP5.

The output PWM drive signal (DDRV) is level shifted to the floating LED stack using several components (R19, R17, Q4, Q6, Q7, and D2) and ultimately controls the series dimming FET (Q2). This level shift adds a several microsecond delay from input to output as seen in the Typical Waveforms section. This delay, along with the time it takes to slew the LED current from zero to its nominal value, limits the contrast ratio for a given dimming frequency.

Using the evaluation board (24V input, 21V output), at 5kHz dimming frequency the best case contrast ratio is approximately 40:1, but at 200Hz the same system is more like 1000:1 ratio. In general, contrast ratios much above 2000:1 are not possible for any operating point using the LM3423 buck-boost evaluation board.

6.15 Fault and LED Current Monitoring

The LM3423 has a fault detection flag in the form of an open-drain NFET at the FLT pin. Using the external pull-up resistor (R14) to VIN, the fault status can be monitored at the FLT pin (high = fault). The fault timer interval is set with the capacitor (C10) from TIMR to GND (10nF yields roughly 1ms). If a fault is detected that exceeds the programmed timer interval, such as an output over-voltage condition, the FLT pin transitions from high to low and internally GATE and DDRV are latched off. To reset the device once the fault is removed, either the input power must be cycled or the EN pin must be toggled.

This can be tested directly with the evaluation board by opening the LED load. An OVP fault will occur which disables GATE and DDRV. Then if the LEDs are reconnected, the EN pin jumper (J3) can be removed and reinserted to restart normal operation of the LM3423.

The LED status flag (LRDY) can be seen by monitoring TP4. LRDY is also an open-drain NFET connection which has an external pull-up resistor (R15) to VIN. If the LED current is in regulation the voltage at TP4 will be high, but when it falls out of regulation the NFET turns on and pulls TP4 low. The LM3423 datasheet lists all of the conditions that affect LRDY, FLT, and TIMR.
Typical Waveforms

$T_A = +25^\circ C$, $V_{\text{IN}} = 24V$ and $V_O = 21V$.

**Figure 5.** 1kHz 50% PWM DIMMING
TP5 dim voltage ($V_{\text{DIM}}$)
LED current ($I_{\text{LED}}$)

**Figure 6.** 1kHz 50% PWM DIMMING (Rising Edge)
TP5 dim voltage ($V_{\text{DIM}}$)
LED current ($I_{\text{LED}}$)
Figure 7. Top Layer

Figure 8. Bottom Layer
### Bill of Materials for 551600305-001 REV1

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<tr>
<th>Qty</th>
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<th>Part Value</th>
<th>Manufacturer</th>
<th>Part Number</th>
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<tr>
<td>2</td>
<td>C1, C12</td>
<td>0.1 µF X7R 10% 50V</td>
<td>TDK</td>
<td>C1608X5R1H104K</td>
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<tr>
<td>2</td>
<td>C2, C8</td>
<td>1.0 µF X7R 10% 50V</td>
<td>MURATA</td>
<td>GRM21BR71H105KA12L KA01L</td>
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<td>1</td>
<td>C3</td>
<td>68 µF 20% 100V</td>
<td>UCC</td>
<td>EMVY101ARA680MKE</td>
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<tr>
<td>1</td>
<td>C4</td>
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<td>TDK</td>
<td>C2012X7R2A104M</td>
</tr>
<tr>
<td>4</td>
<td>C6</td>
<td>10 µF X7R 10% 50V (4 installed for a total of 40 µF)</td>
<td>TDK</td>
<td>C5750X7R1H106</td>
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<tr>
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<td>1000 pF X5R 5% 100V</td>
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<td>C2012X5R2E102K</td>
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<td>C9</td>
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<td>GRM21BR71C225KA01L</td>
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<td>C10</td>
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<td>ECJ2VB1H103 KA12L</td>
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<td>C11</td>
<td>47 pF COG/NPO 5% 50V</td>
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<td>ECJ2VG1H470 KA01L</td>
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<td>1</td>
<td>D1</td>
<td>Schottky 100V 7A</td>
<td>VISHAY</td>
<td>6CWQ10FNPBF</td>
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<tr>
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<td>D2</td>
<td>Zener 10V</td>
<td>ON-SEMI</td>
<td>BZX84C10-V</td>
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<tr>
<td>4</td>
<td>J1, J2, J4, J5</td>
<td>banana jack</td>
<td>KEYSTONE</td>
<td>575-8</td>
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<td>1</td>
<td>J3</td>
<td>1x2 male header (with shunt tab)</td>
<td>SAMTEC</td>
<td>TSW-102-07-T-S</td>
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<td>BNC connector</td>
<td>AMPHENOL</td>
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<td>J7</td>
<td>DNP</td>
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<tr>
<td>1</td>
<td>L1</td>
<td>47 µH 20% 6.3A</td>
<td>COILCRAFT</td>
<td>MSS1260-473MLB</td>
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<tr>
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<td>Q1, Q2</td>
<td>NMOS 100V 40A</td>
<td>VISHAY</td>
<td>SUD40N10-25</td>
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<tr>
<td>2</td>
<td>Q3, Q7</td>
<td>NMOS 60V 260 mA</td>
<td>ON-SEMI</td>
<td>2N7002ET1G</td>
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<td>Q4</td>
<td>PNP 40V 200 mA</td>
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<td>MMBT3906</td>
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<tr>
<td>1</td>
<td>Q5</td>
<td>PNP 150V 600 mA</td>
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<tr>
<td>1</td>
<td>Q6</td>
<td>NPN 300V 500 mA</td>
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<td>2</td>
<td>R1, R11</td>
<td>12.4 kΩ 1%</td>
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<td>1</td>
<td>R2</td>
<td>0Ω 1%</td>
<td>VISHAY</td>
<td>CRCW08050000Z0EA</td>
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<tr>
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<td>R4</td>
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<tr>
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<td>R9</td>
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<td>PANASONIC</td>
<td>ERJ12RSFR20U</td>
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<td>1</td>
<td>R10</td>
<td>35.7 kΩ 1%</td>
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<td>R12, R13, R19</td>
<td>10.0 kΩ 1%</td>
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<tr>
<td>3</td>
<td>R14, R15, R17</td>
<td>100 kΩ 1%</td>
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<td>R16</td>
<td>DNP</td>
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<tr>
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<td>R18</td>
<td>432 kΩ 1%</td>
<td>VISHAY</td>
<td>CRCW0805432kFKEA</td>
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<td>5</td>
<td>TP1, TP4, TP5, TP7, TP10</td>
<td>turret</td>
<td>KEYSTONE</td>
<td>1502-2</td>
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<tr>
<td>1</td>
<td>U1</td>
<td>Buck-boost controller</td>
<td>TI</td>
<td>LM3423</td>
</tr>
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</table>
11 Alternate Designs

Alternate designs with the LM3423 evaluation board are possible with very few changes to the existing hardware. The evaluation board FETs and diodes are already rated higher than necessary for design flexibility. The input UVLO, output OVP, input and output capacitance can remain the same for the designs shown below. These alternate designs can be evaluated by changing only R9, R10, and L1.

Table 1 gives the main specifications for four different designs and the corresponding values for R9, R10, and L1. PWM dimming can be evaluated with any of these designs.

Table 1. Alternate Designs Specifications

<table>
<thead>
<tr>
<th>Specification / Component</th>
<th>Design 1</th>
<th>Design 2</th>
<th>Design 3</th>
<th>Design 4</th>
</tr>
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<tbody>
<tr>
<td>$V_{IN}$</td>
<td>10V - 45V</td>
<td>15V - 50V</td>
<td>20V - 55V</td>
<td>25V - 60V</td>
</tr>
<tr>
<td>$V_O$</td>
<td>14V</td>
<td>21V</td>
<td>28V</td>
<td>35V</td>
</tr>
<tr>
<td>$f_{SW}$</td>
<td>600kHz</td>
<td>700kHz</td>
<td>500kHz</td>
<td>700kHz</td>
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<tr>
<td>$I_{LED}$</td>
<td>2A</td>
<td>500mA</td>
<td>2.5A</td>
<td>1.25A</td>
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<tr>
<td>R9</td>
<td>0.05Ω</td>
<td>0.2Ω</td>
<td>0.04Ω</td>
<td>0.08Ω</td>
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<tr>
<td>R10</td>
<td>41.2 kΩ</td>
<td>35.7 kΩ</td>
<td>49.9 kΩ</td>
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<tr>
<td>L1</td>
<td>22µH</td>
<td>68µH</td>
<td>15µH</td>
<td>33µH</td>
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Applications

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