LM26420-Q1 デュアル2A、車載用認定済み、高効率同期整流
DC/DCコンバータ

1 特長
- 車載アプリケーションに対応
- 以下の結果でAEC Q100認定済み
  - デバイス温度グレード0 (Q0): 動作時周囲温度範囲-40℃～+150℃
  - デバイス温度グレード1 (Q1): 動作時周囲温度範囲-40℃～+125℃
- CISPR25 Class 5 伝導エミッションに準拠
- 入力電圧範囲: 3V～5.5V
- 出力電圧範囲: 0.8V～4.5V
- レギュレータごとに2Aの出力電流
- 2.2MHz 固定のスイッチング周波数
- 0.8V、1.5% 精度の内部基準電圧
- 内部ソフト・スタート
- 出力ごとに独立のパワーグリッドと高精度のインターパル
- 電流モード、PWM 動作
- サーマル・シャットダウン
- 過電圧保護
- 出力負荷をプリバイアスして起動可能
- レギュレータは180°の位相差
- WEBENCH® Power Designer により、LM26420-Q1を使用するカスタム設計を作成

2 アプリケーション
- 車載用ヘッド・ユニットおよびクラスタ
- ADAS カメラ・システム
- 車載用レーダー・システム
- 高度に統合されたPOL電源

LM26420デュアル降圧DC/DCコンバータ

3 概要
LM26420-Q1レギュレータはモノリシック、高効率のデュアルPWM降圧型DC/DCコンバータです。このデバイスは、先端のBICMOSテクノロジを使用して、内蔵の75mΩ PMOS上部スイッチと、内蔵の50mΩ NMOS下部スイッチにより2つの2A負荷を駆動し、可能な最高の電力密度を実現しています。世界最高レベルの制御回路により、最短で30nsのオン時間が可能なため、3V～5.5Vの入力動作範囲全体から、最小出力電圧の0.8Vへ、非常に高周波の変換が可能です。

動作周波数が高いにもかかわらず、93%までの高い効率を簡単に実現できます。外部からのシャットダウン機能を備えており、非常に低いスタンバイ電流が特長です。

LM26420-Q1は電流モード制御と内部補償を活用して、広範な動作条件において高性能のレギュレーションを行います。

LM26420-Q1はスイッチング周波数が2MHzを超えることが保証されているため、AM周波数帯域に干渉を引き起こすおそれなしに車載用アプリケーションで使用できます。

製品情報(1)

<table>
<thead>
<tr>
<th>型番</th>
<th>パッケージ</th>
<th>本体サイズ(公称)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM26420-Q1</td>
<td>HTSSOP (20)</td>
<td>6.50mm×4.40mm</td>
</tr>
<tr>
<td></td>
<td>WQFN (16)</td>
<td>4.00mm×4.00mm</td>
</tr>
</tbody>
</table>

(1) 提供されているすべてのパッケージについては、巻末の注文情報参照してください。

LM26420の効率(最高93%)

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4 改訂履歴
資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

2018年5月発行のものから更新

- Updated Power Supply Recommendations ……………………………………………………… 28
5 Pin Configuration and Functions

Pin Functions: 16-Pin WQFN

<table>
<thead>
<tr>
<th>PIN</th>
<th>TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMBER</td>
<td>NAME</td>
<td>Description</td>
</tr>
<tr>
<td>1,2</td>
<td>VIND</td>
<td>Power input supply for Buck 1.</td>
</tr>
<tr>
<td>3</td>
<td>SW</td>
<td>Output switch for Buck 1. Connect to the inductor.</td>
</tr>
<tr>
<td>4</td>
<td>PGND</td>
<td>Power ground pin for Buck 1.</td>
</tr>
<tr>
<td>5</td>
<td>FB</td>
<td>Feedback pin for Buck 1. Connect to external resistor divider to set output voltage.</td>
</tr>
<tr>
<td>6</td>
<td>PG</td>
<td>Power Good Indicator for Buck 1. Pin is connected through a resistor to an external supply (open drain output).</td>
</tr>
<tr>
<td>7</td>
<td>PG</td>
<td>Power Good Indicator for Buck 2. Pin is connected through a resistor to an external supply (open drain output).</td>
</tr>
<tr>
<td>8</td>
<td>FB</td>
<td>Feedback pin for Buck 2. Connect to external resistor divider to set output voltage.</td>
</tr>
<tr>
<td>9</td>
<td>PGND</td>
<td>Power ground pin for Buck 2.</td>
</tr>
<tr>
<td>10</td>
<td>SW</td>
<td>Output switch for Buck 2. Connect to the inductor.</td>
</tr>
<tr>
<td>11, 12</td>
<td>VIND</td>
<td>Power input supply for Buck 2.</td>
</tr>
<tr>
<td>13</td>
<td>EN</td>
<td>Enable control input. Logic high enable operation for Buck 2. Do not allow this pin to float or be greater than ( V_{IN} + 0.3 ) V.</td>
</tr>
<tr>
<td>14</td>
<td>AGND</td>
<td>Signal ground pin. Place the bottom resistor of the feedback network as close as possible to pin.</td>
</tr>
<tr>
<td>15</td>
<td>VINC</td>
<td>Input supply for control circuitry.</td>
</tr>
<tr>
<td>16</td>
<td>EN</td>
<td>Enable control input. Logic high enable operation for Buck 1. Do not allow this pin to float or be greater than ( V_{IN} + 0.3 ) V.</td>
</tr>
<tr>
<td>DAP</td>
<td>—</td>
<td>Connect to system ground for low thermal impedance and as a primary electrical GND connection.</td>
</tr>
</tbody>
</table>
## Pin Functions 20-Pin HTSSOP

<table>
<thead>
<tr>
<th>PIN</th>
<th>NUMBER</th>
<th>NAME</th>
<th>TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VINC</td>
<td>A</td>
<td>Input supply for control circuitry.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>EN₁</td>
<td>A</td>
<td>Enable control input. Logic high enable operation for Buck 1. Do not allow this pin to float or be greater than V&lt;sub&gt;IN&lt;/sub&gt; + 0.3 V.</td>
<td></td>
</tr>
<tr>
<td>3, 4</td>
<td>VIND₁</td>
<td>A</td>
<td>Power Input supply for Buck 1.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>SW₁</td>
<td>P</td>
<td>Output switch for Buck 1. Connect to the inductor.</td>
<td></td>
</tr>
<tr>
<td>6, 7</td>
<td>PGND₁</td>
<td>G</td>
<td>Power ground pin for Buck 1.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>FB₁</td>
<td>A</td>
<td>Feedback pin for Buck 1. Connect to external resistor divider to set output voltage.</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>PG₁</td>
<td>G</td>
<td>Power Good Indicator for Buck 1. Pin is connected through a resistor to an external supply (open drain output).</td>
<td></td>
</tr>
<tr>
<td>10, 11, DAP</td>
<td>PG₂</td>
<td>G</td>
<td>Connect to system ground for low thermal impedance, but it cannot be used as a primary GND connection.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>FB₂</td>
<td>A</td>
<td>Feedback pin for Buck 2. Connect to external resistor divider to set output voltage.</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>PGND₂</td>
<td>G</td>
<td>Power ground pin for Buck 2.</td>
<td></td>
</tr>
<tr>
<td>14, 15</td>
<td>SW₂</td>
<td>P</td>
<td>Output switch for Buck 2. Connect to the inductor.</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>VIND₂</td>
<td>A</td>
<td>Power Input supply for Buck 2.</td>
<td></td>
</tr>
<tr>
<td>17, 18</td>
<td>EN₂</td>
<td>A</td>
<td>Enable control input. Logic high enable operation for Buck 2. Do not allow this pin to float or be greater than V&lt;sub&gt;IN&lt;/sub&gt; + 0.3 V.</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>AGND</td>
<td>G</td>
<td>Signal ground pin. Place the bottom resistor of the feedback network as close as possible to pin.</td>
<td></td>
</tr>
</tbody>
</table>
6 Specifications

6.1 Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted)\(^{(1)}\)

<table>
<thead>
<tr>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIN</td>
<td>–0.5</td>
<td>7 V</td>
</tr>
<tr>
<td>FB</td>
<td>–0.5</td>
<td>3 V</td>
</tr>
<tr>
<td>EN</td>
<td>–0.5</td>
<td>7 V</td>
</tr>
<tr>
<td>SW</td>
<td>–0.5</td>
<td>7 V</td>
</tr>
</tbody>
</table>

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

<table>
<thead>
<tr>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>±2000 V</td>
<td></td>
</tr>
<tr>
<td>±750 V</td>
<td></td>
</tr>
<tr>
<td>±750 V</td>
<td></td>
</tr>
</tbody>
</table>

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

6.3 Recommended Operating Conditions

Over operating free-air temperature range (unless otherwise noted)

<table>
<thead>
<tr>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIN</td>
<td>3</td>
<td>5.5 V</td>
</tr>
<tr>
<td>Junction temperature (Q1)</td>
<td>–40</td>
<td>125 °C</td>
</tr>
<tr>
<td>Junction temperature (Q0)</td>
<td>–40</td>
<td>150 °C</td>
</tr>
</tbody>
</table>

6.4 Thermal Information

<table>
<thead>
<tr>
<th>THERMAL METRIC(^{(1)})</th>
<th>LM26420-Q1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PWP (HTSSOP)</td>
</tr>
<tr>
<td></td>
<td>20 PINS</td>
</tr>
<tr>
<td>Junction-to-ambient thermal resistance</td>
<td>38.5</td>
</tr>
<tr>
<td>Junction-to-case thermal resistance</td>
<td>21.0</td>
</tr>
<tr>
<td>Junction-to-board thermal resistance</td>
<td>19.9</td>
</tr>
<tr>
<td>Junction-to-top characterization parameter</td>
<td>0.7</td>
</tr>
<tr>
<td>Junction-to-board characterization parameter</td>
<td>19.7</td>
</tr>
<tr>
<td>Junction-to-case (bottom) thermal resistance</td>
<td>3.5</td>
</tr>
</tbody>
</table>

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report.
## 6.5 Electrical Characteristics Per Buck

Over operating free-air temperature range (unless otherwise noted)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{FB}$ Feedback Voltage</td>
<td></td>
<td>0.788</td>
<td>0.8</td>
<td>0.812</td>
<td>V</td>
</tr>
<tr>
<td>$\Delta V_{FB}/V_{IN}$ Feedback Voltage Line Regulation</td>
<td>$V_{IN} = 3$ V to 5.5 V</td>
<td>0.05</td>
<td>%/V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_B$ Feedback Input Bias Current</td>
<td></td>
<td>0.4</td>
<td>100</td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td>UVLO Undervoltage Lockout</td>
<td>$V_{IN}$ Rising</td>
<td>2.628</td>
<td>2.9</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>$V_{IN}$ Falling</td>
<td>2</td>
<td>2.3</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>UVLO Hysteresis</td>
<td></td>
<td>330</td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>$F_{SW}$ Switching Frequency</td>
<td></td>
<td>2.01</td>
<td>2.2</td>
<td>2.65</td>
<td>MHz</td>
</tr>
<tr>
<td>$F_{FB}$ Frequency Foldback</td>
<td></td>
<td>300</td>
<td></td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td>$D_{MAX}$ Maximum Duty Cycle</td>
<td></td>
<td>86%</td>
<td>91.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_{DSON_TOP}$ TOP Switch On Resistance</td>
<td>WQFN-16 Package</td>
<td>75</td>
<td>135</td>
<td></td>
<td>mΩ</td>
</tr>
<tr>
<td></td>
<td>HTSSOP-20 Package</td>
<td>70</td>
<td>135</td>
<td></td>
<td>mΩ</td>
</tr>
<tr>
<td>$R_{DSON_BOT}$ BOTTOM Switch On Resistance</td>
<td>WQFN-16 Package</td>
<td>55</td>
<td>100</td>
<td></td>
<td>mΩ</td>
</tr>
<tr>
<td></td>
<td>TSSOP-20 Package</td>
<td>45</td>
<td>80</td>
<td></td>
<td>mΩ</td>
</tr>
<tr>
<td>$I_{CL_TOP}$ TOP Switch Current Limit</td>
<td>$V_{IN} = 3.3$ V</td>
<td>2.4</td>
<td>3.3</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>$I_{CL_BOT}$ BOTTOM Switch Reverse Current Limit</td>
<td>$V_{IN} = 3.3$ V</td>
<td>0.4</td>
<td>0.75</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>$\Delta \Phi$ Phase Shift Between SW₁ and SW₂</td>
<td></td>
<td>160</td>
<td>180</td>
<td>200</td>
<td>°</td>
</tr>
<tr>
<td>$V_{EN_TH}$ Enable Threshold Voltage</td>
<td></td>
<td>0.97</td>
<td>1.04</td>
<td>1.12</td>
<td>V</td>
</tr>
<tr>
<td>$V_{EN_TH}$ Enable Threshold Hysteresis</td>
<td></td>
<td>0.15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{SW_TOP}$ Switch Leakage</td>
<td></td>
<td>-0.7</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>$I_{EN}$ Enable Pin Current</td>
<td>Sink/Source</td>
<td>5</td>
<td></td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td>$V_{PG_TH_U}$ Upper Power Good Threshold</td>
<td>FB Pin Voltage Rising</td>
<td>848</td>
<td>925</td>
<td>1,008</td>
<td>mV</td>
</tr>
<tr>
<td>$V_{PG_TH_U}$ Upper Power Good Hysteresis</td>
<td></td>
<td>40</td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>$V_{PG_TH_L}$ Lower Power Good Threshold</td>
<td>FB Pin Voltage Rising</td>
<td>656</td>
<td>710</td>
<td>791</td>
<td>mV</td>
</tr>
<tr>
<td>$V_{PG_TH_L}$ Lower Power Good Hysteresis</td>
<td></td>
<td>40</td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>$I_{QVINC}$ VINC Quiescent Current (non-switching) with both outputs on</td>
<td>$V_{FB} = 0.9$ V</td>
<td>3.3</td>
<td>5</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>$I_{QVINC}$ VINC Quiescent Current (switching) with both outputs on</td>
<td>$V_{FB} = 0.7$ V</td>
<td>4.7</td>
<td>6.2</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>$I_{QVINC}$ VINC Quiescent Current (shutdown)</td>
<td>$V_{EN} = 0$ V</td>
<td>0.05</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>$I_{QVIND}$ VIND Quiescent Current (non-switching)</td>
<td>$V_{FB} = 0.9$ V</td>
<td>0.9</td>
<td>1.5</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>$I_{QVIND}$ VIND Quiescent Current (switching)</td>
<td>$V_{FB} = 0.7$ V</td>
<td>11</td>
<td>15</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>$I_{QVIND}$ VIND Quiescent Current (shutdown)</td>
<td>$V_{EN} = 0$ V</td>
<td>0.1</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>$T_{SD}$ Thermal Shutdown Temperature</td>
<td></td>
<td>165</td>
<td></td>
<td></td>
<td>°C</td>
</tr>
</tbody>
</table>
6.6 Typical Characteristics

All curves taken at $V_{IN} = 5\, \text{V}$ with configuration in typical application circuits shown in Application and Implementation. $T_J = 25^\circ\text{C}$, unless otherwise specified.

Figure 1. Efficiency vs Load

Figure 2. Efficiency vs Load

Figure 3. Efficiency vs Load

Figure 4. Efficiency vs Load

Figure 5. Efficiency vs Load

Figure 6. Load Regulation
Typical Characteristics (continued)

All curves taken at $V_{IN} = 5$ V with configuration in typical application circuits shown in *Application and Implementation*. $T_J = 25^\circ$C, unless otherwise specified.

**Figure 7. Load Regulation**

$V_{IN} = 3$ V  $V_{OUT} = 1.8$ V

**Figure 8. Line Regulation**

$V_{OUT} = 1.8$ V  $I_{OUT} = 1000$ mA

**Figure 9. Oscillator Frequency vs Temperature,**

**Figure 10. $R_{DS\text{ON}}$ Top Vs Temperature (WQFN-16 Package)**

**Figure 11. $R_{DS\text{ON}}$ Bottom Vs Temperature (WQFN-16 Package)**

**Figure 12. $R_{DS\text{ON}}$ Top Vs Temperature (TSSOP-20 Package)**
Typical Characteristics (continued)

All curves taken at $V_{IN} = 5$ V with configuration in typical application circuits shown in Application and Implementation. $T_J = 25^\circ$C, unless otherwise specified.

Figure 13. $R_{DS(ON)}$ Bottom vs Temperature (TSSOP-20 Package)

Figure 14. $I_Q$ (Quiescent Current Switching)

Figure 15. $V_{FB}$ vs Temperature

Figure 16. Current Limit vs Temperature

Figure 17. Reverse Current Limit vs Temperature

Figure 18. Short Circuit Waveforms

$V_{IN} = 5$ V and 3.3 V
Typical Characteristics (continued)

All curves taken at $V_{IN} = 5$ V with configuration in typical application circuits shown in Application and Implementation. $T_J = 25^\circ$C, unless otherwise specified.

![Graph 1: IQ (Quiescent Current) vs Temperature (Q0 Grade)]

![Graph 2: $V_{FB}$ vs Temperature (Q0 Grade)]

![Graph 3: Current Limit vs Temperature (Q0 Grade)]

![Graph 4: Reverse Current Limit vs Temperature (Q0 Grade)]

![Graph 5: $R_{DSON}$ Top vs Temperature (Q0 Grade)]

![Graph 6: $R_{DSON}$ Bottom vs Temperature (Q0 Grade)]
Typical Characteristics (continued)

All curves taken at \( V_{IN} = 5 \) V with configuration in typical application circuits shown in *Application and Implementation*. \( T_J = 25^\circ C \), unless otherwise specified.

![Oscillator Frequency vs Temperature (Q0 Grade)](image)

*Figure 25. Oscillator Frequency vs Temperature (Q0 Grade)*
7 Detailed Description

7.1 Overview

The LM26420-Q1 is a constant frequency dual PWM buck synchronous regulator device that can supply two loads at up to 2 A each. The regulator has a preset switching frequency of 2.2 MHz. This high frequency allows the LM26420-Q1 to operate with small surface mount capacitors and inductors, resulting in a DC/DC converter that requires a minimum amount of board space. The LM26420-Q1 is internally compensated, so it is simple to use and requires few external components. The LM26420-Q1 uses current-mode control to regulate the output voltage. The following operating description of the LM26420-Q1 refers to the Functional Block Diagram, which depicts the functional blocks for one of the two channels, and to the waveforms in Figure 26. The LM26420-Q1 supplies a regulated output voltage by switching the internal PMOS and NMOS switches at constant frequency and variable duty cycle. A switching cycle begins at the falling edge of the reset pulse generated by the internal clock. When this pulse goes low, the output control logic turns on the internal PMOS control switch (TOP Switch). During this on-time, the SW pin voltage ($V_{SW}$) swings up to approximately $V_{IN}$, and the inductor current ($I_L$) increases with a linear slope. $I_L$ is measured by the current sense amplifier, which generates an output proportional to the switch current. The sense signal is summed with the regulator's corrective ramp and compared to the error amplifier's output, which is proportional to the difference between the feedback voltage and $V_{REF}$. When the PWM comparator output goes high, the TOP Switch turns off and the NMOS switch (BOTTOM Switch) turns on after a short delay, which is controlled by the Dead-Time-Control Logic, until the next switching cycle begins. During the top switch off-time, inductor current discharges through the BOTTOM Switch, which forces the SW pin to swing to ground. The regulator loop adjusts the duty cycle (D) to maintain a constant output voltage.

![Figure 26. LM26420-Q1 Basic Operation of the PWM Comparator](image-url)
7.3 Feature Description

7.3.1 Soft Start

This function forces \( V_{OUT} \) to increase at a controlled rate during start-up in a controlled fashion, which helps reduce inrush current and eliminate overshoot on \( V_{OUT} \). During soft start, reference voltage of the error amplifier ramps from 0 V to its nominal value of 0.8 V in approximately 600 µs. If the converter is turned on into a pre-biased load, then the feedback begins ramping from the prebias voltage but at the same rate as if it had started from 0 V. The two outputs start up ratiometrically if enabled at the same time, see Figure 27 below.
Feature Description (continued)

Figure 27. LM26420 Soft-Start

7.3.2 Power Good
The LM26420-Q1 features an open drain power good (PG) pin to sequence external supplies or loads and to provide fault detection. This pin requires an external resistor (R_{PG}) to pull PG high when the output is within the PG tolerance window. Typical values for this resistor range from 10 k\(\Omega\) to 100 k\(\Omega\).

7.3.3 Precision Enable
The LM26420-Q1 features independent precision enables that allow the converter to be controlled by an external signal. This feature allows the device to be sequenced either by a external control signal or the output of another converter in conjunction with a resistor divider network. It can also be set to turn on at a specific input voltage when used in conjunction with a resistor divider network connected to the input voltage. The device is enabled when the EN pin exceeds 1.04 V and has a 150-mV hysteresis.

7.4 Device Functional Modes

7.4.1 Output Overvoltage Protection
The overvoltage comparator compares the FB pin voltage to a voltage that is approximately 15% greater than the internal reference V_{REF}. Once the FB pin voltage goes 15% above the internal reference, the internal PMOS switch is turned off, which allows the output voltage to decrease toward regulation.

7.4.2 Undervoltage Lockout
Undervoltage lockout (UVLO) prevents the LM26420-Q1 from operating until the input voltage exceeds 2.628 V (typical). The UVLO threshold has approximately 330 mV of hysteresis, so the device operates until \(V_{IN}\) drops below 2.3 V (typical). Hysteresis prevents the part from turning off during power up if \(V_{IN}\) is non-monotonic.

7.4.3 Current Limit
The LM26420-Q1 uses cycle-by-cycle current limiting to protect the output switch. During each switching cycle, a current limit comparator detects if the output switch current exceeds 3.3 A (typical), and turns off the switch until the next switching cycle begins.

7.4.4 Thermal Shutdown
Thermal shutdown limits total power dissipation by turning off the output switch when the device junction temperature exceeds 165°C. After thermal shutdown occurs, the output switch does not turn on until the junction temperature drops to approximately 150°C.
8 Application and Implementation

NOTE
Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI’s customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

8.1.1 Programming Output Voltage

The output voltage is set using Equation 1 where R2 is connected between the FB pin and GND, and R1 is connected between \( V_{\text{OUT}} \) and the FB pin. A good value for R2 is 10 k\( \Omega \). When designing a unity gain converter (\( V_{\text{OUT}} = 0.8 \text{ V} \)), R1 must be between 0 \( \Omega \) and 100 \( \Omega \), and R2 must be on the order of 5 k\( \Omega \) to 50 k\( \Omega \). 10 k\( \Omega \) is the suggested value where R1 is the top feedback resistor and R2 is the bottom feedback resistor.

\[
R_1 = \left( \frac{V_{\text{OUT}}}{V_{\text{REF}}} - 1 \right) \times R_2
\]

\( V_{\text{REF}} = 0.80 \text{ V} \)

\( \text{Equation 1} \)

\( \text{Equation 2} \)

To determine the maximum allowed resistor tolerance, use Equation 3:

\[
\sigma = \left( \frac{1}{1 + 2x} \left( \frac{1}{1 - \frac{V_{\text{FB}}}{V_{\text{OUT}}}} \right) \right)
\]

where

- TOL is the set point accuracy of the regulator, is the tolerance of \( V_{\text{FB}} \).

Example:

\( V_{\text{OUT}} = 2.5 \text{ V} \), with a setpoint accuracy of ±3.5%.

\[
\sigma = \left( \frac{1}{1 + 2x} \left( \frac{1}{1 - \frac{0.8 \text{ V}}{2.5 \text{ V}}} \right) \right) = 1.4%
\]

Choose 1% resistors. If R2 = 10 k\( \Omega \), then R1 is 21.25 k\( \Omega \).
Application Information (continued)

8.1.2 VINC Filtering Components

Additional filtering is required between VINC and AGND in order to prevent high frequency noise on VIN from disturbing the sensitive circuitry connected to VINC. A small RC filter can be used on the VINC pin as shown in Figure 29.

![Figure 29. RC Filter On VINC](image)

In general, $R_F$ is typically between 1 Ω and 10 Ω so that the steady state voltage drop across the resistor due to the VINC bias current does not affect the UVLO level. $C_F$ can range from 0.22 µF to 1 µF in X7R or X5R dielectric, where the RC time constant should be at least 2 µs. $C_F$ must be placed as close to the device as possible with a direct connection from VINC and AGND.

8.1.3 Using Precision Enable and Power Good

The LM26420-Q1 device precision EN and PG pins address many of the sequencing requirements required in today's challenging applications. Each output can be controlled independently and have independent power good. This allows for a multitude of ways to control each output. Typically, the enables to each output are tied together to the input voltage and the outputs ratiometrically ramp up when the input voltage reaches above UVLO rising threshold. There may be instances where it is desired that the second output ($V_{OUT2}$) does not turn on until the first output ($V_{OUT1}$) has reached 90% of the desired setpoint. This is easily achieved with an external resistor divider attached from $V_{OUT1}$ to $EN_2$, see Figure 30.

![Figure 30. V_{OUT1} Controlling V_{OUT2} with Resistor Divider](image)

If it is not desired to have a resistor divider to control $V_{OUT2}$ with $V_{OUT1}$, then the PG1 can be connected to the $EN_2$ pin to control $V_{OUT2}$, see Figure 31. $R_{PG1}$ is a pullup resistor on the range of 10 kΩ to 100 kΩ, 50 kΩ is the suggested value. This turns on $V_{OUT2}$ when $V_{OUT1}$ is approximately 90% of the programmed output.

**NOTE**

This also turns off $V_{OUT2}$ when $V_{OUT1}$ is outside the ±10% of the programmed output.
Another example might be that the output is not to be turned on until the input voltage reaches 90% of desired voltage setpoint. This verifies that the input supply is stable before turning on the output. Select $R_{EN1}$ and $R_{EN2}$ such that the voltage at the EN pin is greater than 1.12 V when reaching the 90% desired set-point.

The power good feature of the LM26420-Q1 is designed with hysteresis in order to ensure no false power good flags are asserted during large transient. Once power good is asserted high, it is not pulled low until the output voltage exceeds ±14% of the setpoint for a duration of approximately 7.5 μs (typical), see Figure 33.
Application Information (continued)

8.1.4 Overcurrent Protection

When the switch current reaches the current limit value, it is turned off immediately. This effectively reduces the duty cycle and therefore the output voltage dips and continues to droop until the output load matches the peak current limit inductor current. As the FB voltage drops below 480 mV the operating frequency begins to decrease until it hits full on frequency foldback, which is set to approximately 300 kHz. Frequency foldback helps reduce the thermal stress in the device by reducing the switching losses and to prevent runaway of the inductor current when the output is shorted to ground.

It is important to note that when recovering from a overcurrent condition the converter does not go through the soft-start process. There may be an overshoot due to the sudden removal of the overcurrent fault. The reference voltage at the non-inverting input of the error amplifier always sits at 0.8 V during the overcurrent condition, therefore when the fault is removed the converter bring the FB voltage back to 0.8 V as quickly as possible. The overshoot depend on whether there is a load on the output after the removal of the overcurrent fault, the size of the inductor, and the amount of capacitance on the output. The smaller the inductor and the larger the capacitance on the output the smaller the overshoot.

NOTE
Overcurrent protection for each output is independent.

8.2 Typical Applications

8.2.1 2.2-MHz, 0.8-V Typical High-Efficiency Application Circuit

Figure 34. LM26420-Q1 (2.2 MHz): \(V_{IN} = 5\) V, \(V_{OUT1} = 1.8\) V at 2 A and \(V_{OUT2} = 0.8\) V at 2 A
Typical Applications (continued)

8.2.1.1 Design Requirements

Example requirements for typical synchronous DC/DC converter applications:

Table 1. Design Parameters

<table>
<thead>
<tr>
<th>DESIGN PARAMETER</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{OUT}$</td>
<td>Output voltage</td>
</tr>
<tr>
<td>$V_{IN}$ (minimum)</td>
<td>Maximum input voltage</td>
</tr>
<tr>
<td>$V_{IN}$ (maximum)</td>
<td>Minimum input voltage</td>
</tr>
<tr>
<td>$I_{OUT}$ (maximum)</td>
<td>Maximum output current</td>
</tr>
<tr>
<td>$f_{SW}$</td>
<td>Switching frequency</td>
</tr>
</tbody>
</table>

8.2.1.2 Detailed Design Procedure

8.2.1.2.1 Custom Design With WEBENCH® Tools

Click here to create a custom design using the LM26420-Q1 device with the WEBENCH® Power Designer.

1. Start by entering the input voltage ($V_{IN}$), output voltage ($V_{OUT}$), and output current ($I_{OUT}$) requirements.
2. Optimize the design for key parameters such as efficiency, footprint, and cost using the optimizer dial.
3. Compare the generated design with other possible solutions from Texas Instruments.

The WEBENCH Power Designer provides a customized schematic along with a list of materials with real-time pricing and component availability.

In most cases, these actions are available:
- Run electrical simulations to see important waveforms and circuit performance
- Run thermal simulations to understand board thermal performance
- Export customized schematic and layout into popular CAD formats
- Print PDF reports for the design, and share the design with colleagues

Get more information about WEBENCH tools at www.ti.com/WEBENCH.

Table 2. Bill Of Materials

<table>
<thead>
<tr>
<th>PART ID</th>
<th>PART VALUE</th>
<th>MANUFACTURER</th>
<th>PART NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1</td>
<td>2-A buck regulator</td>
<td>TI</td>
<td>LM26420-Q1</td>
</tr>
<tr>
<td>C3, C4</td>
<td>15 µF, 6.3 V, 1206, X5R</td>
<td>TDK</td>
<td>C3216X5R0J156M</td>
</tr>
<tr>
<td>C1</td>
<td>33 µF, 6.3 V, 1206, X5R</td>
<td>TDK</td>
<td>C3216X5R0J336M</td>
</tr>
<tr>
<td>C2, C6</td>
<td>22 µF, 6.3 V, 1206, X5R</td>
<td>TDK</td>
<td>C3216X5R0J226M</td>
</tr>
<tr>
<td>C5</td>
<td>0.47 µF, 10 V, 0805, X7R</td>
<td>Vishay</td>
<td>VJ0805Y474KXQCW1BC</td>
</tr>
<tr>
<td>L1</td>
<td>1.0 µH, 7.9 A</td>
<td>TDK</td>
<td>RLF7030T-1R0M6R4</td>
</tr>
<tr>
<td>L2</td>
<td>0.7 µH, 3.7 A</td>
<td>Coilcraft</td>
<td>LPS4414-701ML</td>
</tr>
<tr>
<td>R3, R4</td>
<td>10.0 kΩ, 0603, 1%</td>
<td>Vishay</td>
<td>CRCW060310K0F</td>
</tr>
<tr>
<td>R5, R6</td>
<td>49.9 kΩ, 0603, 1%</td>
<td>Vishay</td>
<td>CRCW060649K9F</td>
</tr>
<tr>
<td>R1</td>
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<td>Vishay</td>
<td>CRCW060312K7F</td>
</tr>
<tr>
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<td>4.99 Ω, 0603, 1%</td>
<td>Vishay</td>
<td>CRCW06034R99F</td>
</tr>
</tbody>
</table>
8.2.1.2.2 Inductor Selection

The duty cycle (D) can be approximated as the ratio of output voltage ($V_{OUT}$) to input voltage ($V_{IN}$):

$$D = \frac{V_{OUT}}{V_{IN}}$$

The voltage drop across the internal NMOS (SW_BOT) and PMOS (SW_TOP) must be included to calculate a more accurate duty cycle. Calculate D by using the following formulas:

$$D = \frac{V_{OUT} + V_{SW,BOT}}{V_{IN} + V_{SW,BOT} - V_{SW, TOP}}$$

$V_{SW, TOP}$ and $V_{SW, BOT}$ can be approximated by:

$$V_{SW, TOP} = I_{OUT} \times R_{DSON, TOP} \quad (7)$$

$$V_{SW, BOT} = I_{OUT} \times R_{DSON, BOT} \quad (8)$$

The inductor value determines the output ripple voltage. Smaller inductor values decrease the size of the inductor, but increase the output ripple voltage. An increase in the inductor value decreases the output ripple current.

One must ensure that the minimum current limit (2.4 A) is not exceeded, so the peak current in the inductor must be calculated. The peak current ($I_{LPK}$) in the inductor is calculated by:

$$I_{LPK} = I_{OUT} + \Delta i_L$$

In general,

$$\Delta i_L = 0.1 \times (I_{OUT}) \rightarrow 0.2 \times (I_{OUT}) \quad (11)$$

If $\Delta i_L = 20\%$ of 2 A, the peak current in the inductor is 2.4 A. The minimum ensured current limit over all operating conditions is 2.4 A. One can either reduce $\Delta i_L$, or make the engineering judgment that zero margin is safe enough. The typical current limit is 3.3 A.

The LM26420-Q1 operates at frequencies allowing the use of ceramic output capacitors without compromising transient response. Ceramic capacitors allow higher inductor ripple without significantly increasing output ripple voltage. See Output Capacitor section for more details on calculating output voltage ripple. Now that the ripple current is determined, the inductance is calculated by:

$$L = \frac{2\Delta i_L}{(V_{IN} - V_{OUT})} \times \left( \frac{DT_s}{2\Delta i_L} \right)$$

Where

$$T_s = \frac{1}{f_s}$$
When selecting an inductor, make sure that it is capable of supporting the peak output current without saturating. Inductor saturation results in a sudden reduction in inductance and prevent the regulator from operating correctly. The peak current of the inductor is used to specify the maximum output current of the inductor and saturation is not a concern due to the exceptionally small delay of the internal current limit signal. Ferrite based inductors are preferred to minimize core losses when operating with the frequencies used by the LM26420-Q1. This presents little restriction because the variety of ferrite-based inductors is huge. Lastly, inductors with lower series resistance \( R_{DC} \) provides better operating efficiency. For recommended inductors see Table 2.

8.2.1.2.3 Input Capacitor Selection

The input capacitors provide the AC current needed by the nearby power switch so that current provided by the upstream power supply does not carry a lot of AC content, generating less EMI. To the buck regulator in question, the input capacitor also prevents the drain voltage of the FET switch from dipping when the FET is turned on, therefore providing a healthy line rail for the LM26420-Q1 to work with. Because typically most of the AC current is provided by the local input capacitors, the power loss in those capacitors can be a concern. In the case of the LM26420-Q1 regulator, because the two channels operate 180° out of phase, the AC stress in the input capacitors is less than if they operated in phase. The measure for the AC stress is called input ripple RMS current. It is strongly recommended that at least one 10µF ceramic capacitor be placed next to each of the VIND pins. Bulk capacitors such as electrolytic capacitors or OSCON capacitors can be added to help stabilize the local line voltage, especially during large load transient events. As for the ceramic capacitors, use X7R or X5R types. They maintain most of their capacitance over a wide temperature range. Try to avoid sizes smaller than 0805. Otherwise significant drop in capacitance may be caused by the DC bias voltage. See Output Capacitor section for more information. The DC voltage rating of the ceramic capacitor should be higher than the highest input voltage.

Capacitor temperature is a major concern in board designs. While using a 10-µF or higher MLCC as the input capacitor is a good starting point, it is a good idea to check the temperature in the real thermal environment to make sure the capacitors are not overheated. Capacitor vendors may provide curves of ripple RMS current vs. temperature rise, based on a designated thermal impedance. In reality, the thermal impedance may be very different. So it is always a good idea to check the capacitor temperature on the board.

Because the duty cycles of the two channels may overlap, calculation of the input ripple RMS current is a little tedious — use Equation 14:

\[
I_{\text{rms}} = \sqrt{(I_1 - I_{\text{avg}})^2 d1 + (I_2 - I_{\text{avg}})^2 d2 + (I_1 + I_2 - I_{\text{avg}})^2 d3}
\]

where
- \( I_1 \) is Channel 1’s maximum output current
- \( I_2 \) is Channel 2’s maximum output current
- \( d1 \) is the non-overlapping portion of Channel 1’s duty cycle \( D_1 \)
- \( d2 \) is the non-overlapping portion of Channel 2’s duty cycle \( D_2 \)
- \( d3 \) is the overlapping portion of the two duty cycles.
- \( I_{\text{avg}} \) is the average input current

\[
I_{\text{avg}} = I_1 \times D_1 + I_2 \times D_2
\]

To quickly determine the values of \( d1, d2 \) and \( d3 \), refer to the decision tree in Figure 36. To determine the duty cycle of each channel, use \( D = V_{\text{OUT}}/V_{\text{IN}} \) for a quick result or use the following equation for a more accurate result.

\[
D = \frac{V_{\text{OUT}} + V_{\text{SW,BOT}} + I_{\text{OUT}} \times R_{\text{DC}}}{V_{\text{IN}} + V_{\text{SW,BOT}} \cdot V_{\text{SW,TOP}}}
\]

where
- \( R_{\text{DC}} \) is the winding resistance of the inductor.

Example:

\( V_{\text{IN}} = 5 \text{ V}, V_{\text{OUT1}} = 3.3 \text{ V}, I_{\text{OUT1}} = 2 \text{ A}, V_{\text{OUT2}} = 1.2 \text{ V}, I_{\text{OUT2}} = 1.5 \text{ A}, R_{\text{DS}} = 170 \text{ m}\Omega, R_{\text{DC}} = 30 \text{ m}\Omega, \) \( I_{\text{OUT1}} \) is the same as \( I_1 \) in the input ripple RMS current equation, \( I_{\text{OUT2}} \) is the same as \( I_2 \).

First, find out the duty cycles. Plug the numbers into the duty cycle equation and we get \( D_1 = 0.75 \), and \( D_2 = 0.33 \). Next, follow the decision tree in Figure 36 to find out the values of \( d1, d2 \) and \( d3 \). In this case, \( d_1 = 0.5, d_2 = D_2 + 0.5 - D_1 = 0.08, \) and \( d3 = D_1 - 0.5 = 0.25 \). \( I_{\text{avg}} = I_{\text{OUT1}} \times D_1 + I_{\text{OUT2}} \times D_2 = 1.995 \text{ A} \). Plug all the numbers into the input ripple RMS current equation and the result is \( I_{\text{IR(rms)}} = 0.77 \text{ A} \).
8.2.1.2.4 Output Capacitor

The output capacitor is selected based upon the desired output ripple and transient response. The initial current of a load transient is provided mainly by the output capacitor. The output ripple of the converter is approximately:

\[ \Delta V_{OUT} = \Delta L \left( \frac{1}{8} F_{SW} \times C_{OUT} \right) \]  

(16)

When using MLCCs, the ESR is typically so low that the capacitive ripple may dominate. When this occurs, the output ripple is approximately sinusoidal and 90° phase shifted from the switching action. Given the availability and quality of MLCCs and the expected output voltage of designs using the LM26420-Q1, there is really no need to review any other capacitor technologies. Another benefit of ceramic capacitors is their ability to bypass high frequency noise. A certain amount of switching edge noise couples through parasitic capacitances in the inductor to the output. A ceramic capacitor bypasses this noise while a tantalum capacitor does not. Because the output capacitor is one of the two external components that control the stability of the regulator control loop, most applications require a minimum of 22 µF of output capacitance. Capacitance often, but not always, can be increased significantly with little detriment to the regulator stability. Like the input capacitor, recommended multilayer ceramic capacitors are X7R or X5R types.

8.2.1.2.5 Calculating Efficiency and Junction Temperature

The complete LM26420-Q1 DC/DC converter efficiency can be estimated in the following manner.

\[ \eta = \frac{P_{OUT}}{P_{IN}} \]  

(17)

Or

\[ \eta = \frac{P_{OUT}}{P_{OUT} + P_{LOSS}} \]  

(18)

Calculations for determining the most significant power losses follow here. Other losses totaling less than 2% are not discussed.

Power loss \( (P_{LOSS}) \) is the sum of two basic types of losses in the converter: switching and conduction. Conduction losses usually dominate at higher output loads, whereas switching losses remain relatively fixed and dominate at lower output loads. The first step in determining the losses is to calculate the duty cycle (D):

\[ D = \frac{V_{OUT} + V_{SW_BOT}}{V_{IN} + V_{SW_BOT} - V_{SW_TOP}} \]  

(19)

\( V_{SW_TOP} \) is the voltage drop across the internal PFET when it is on, and is equal to:

\[ V_{SW_TOP} = I_{OUT} \times R_{DSON_TOP} \]  

(20)
\[ V_{SW\_BOT} = I_{OUT} \times R_{DS\_ON\_BOT} \]  

(21)

If the voltage drop across the inductor \((V_{DCR})\) is accounted for, the equation becomes:

\[
D = \frac{V_{OUT} + V_{SW\_BOT} + V_{DCR}}{V_{IN} + V_{SW\_BOT} + V_{DCR} - V_{SW\_TOP}}
\]

(22)

Another significant external power loss is the conduction loss in the output inductor. The equation can be simplified to:

\[
P_{IND} = I_{OUT}^2 \times R_{DCR}
\]

(23)

The LM26420-Q1 conduction loss is mainly associated with the two internal FETs:

\[
P_{COND\_TOP} = (I_{OUT}^2 \times D) \left(1 + \frac{1}{3} \times \frac{\Delta L}{I_{OUT}}\right) R_{DS\_ON\_TOP}
\]

\[
P_{COND\_BOT} = (I_{OUT}^2 \times (1-D)) \left(1 + \frac{1}{3} \times \frac{\Delta L}{I_{OUT}}\right) R_{DS\_ON\_BOT}
\]

(24)

If the inductor ripple current is fairly small, the conduction losses can be simplified to:

\[
P_{COND\_TOP} = (I_{OUT}^2 \times R_{DS\_ON\_TOP} \times D)
\]

\[
P_{COND\_BOT} = (I_{OUT}^2 \times R_{DS\_ON\_BOT} \times (1-D))
\]

(25)  

(26)

(27)

Switching losses are also associated with the internal FETs. They occur during the switch on and off transition periods, where voltages and currents overlap resulting in power loss. The simplest means to determine this loss is to empirically measuring the rise and fall times (10% to 90%) of the switch at the switch node.

Switching Power Loss is calculated as follows:

\[
P_{SWR} = \frac{1}{2}(V_{IN} \times I_{OUT} \times F_{SW} \times T_{RISE})
\]

(28)

\[
P_{SWF} = \frac{1}{2}(V_{IN} \times I_{OUT} \times F_{SW} \times T_{FALL})
\]

(29)

\[
P_{SW} = P_{SWR} + P_{SWF}
\]

(30)

Another loss is the power required for operation of the internal circuitry:

\[
P_{Q} = I_{Q} \times V_{IN}
\]

(31)

\(I_{Q}\) is the quiescent operating current, and is typically around 8.4 mA \((I_{Q\_VINC} = 4.7 \text{ mA} + I_{Q\_VIND} = 3.7 \text{ mA})\) for the 550-kHz frequency option.

Due to Dead-Time-Control Logic in the converter, there is a small delay (~4 nsec) between the turn ON and OFF of the TOP and BOTTOM FET. During this time, the body diode of the BOTTOM FET is conducting with a voltage drop of \(V_{BDIODE} (~0.65 \text{ V})\). This allows the inductor current to circulate to the output, until the BOTTOM FET is turned ON and the inductor current passes through the FET. There is a small amount of power loss due to this body diode conducting and it can be calculated as follows:

\[
P_{BDIODE} = 2 \times (V_{BDIODE} \times I_{OUT} \times F_{SW} \times T_{BDIODE})
\]

(32)

Typical Application power losses are:

\[
P_{LOSS} = \Sigma P_{COND} + P_{SW} + P_{BDIODE} + P_{IND} + P_{Q}
\]

(33)

\[
P_{INTERNAL} = \Sigma P_{COND} + P_{SW} + P_{BDIODE} + P_{Q}
\]

(34)
Table 3. Power Loss Tabulation

<table>
<thead>
<tr>
<th>DESIGN PARAMETER</th>
<th>VALUE</th>
<th>DESIGN PARAMETER</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IN}$</td>
<td>5 V</td>
<td>$V_{OUT}$</td>
<td>1.2 V</td>
</tr>
<tr>
<td>$I_{OUT}$</td>
<td>2 A</td>
<td>$P_{OUT}$</td>
<td>2.4 W</td>
</tr>
<tr>
<td>$F_{SW}$</td>
<td>550 kHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{BDIODE}$</td>
<td>0.65 V</td>
<td>$P_{BDIODE}$</td>
<td>5.7 mW</td>
</tr>
<tr>
<td>$I_{Q}$</td>
<td>8.4 mA</td>
<td>$P_{Q}$</td>
<td>42 mW</td>
</tr>
<tr>
<td>$T_{RISE}$</td>
<td>1.5 nsec</td>
<td>$P_{SWR}$</td>
<td>4.1 mW</td>
</tr>
<tr>
<td>$T_{FALL}$</td>
<td>1.5 nsec</td>
<td>$P_{SWF}$</td>
<td>4.1 mW</td>
</tr>
<tr>
<td>$R_{DSON_TOP}$</td>
<td>75 mΩ</td>
<td>$P_{COND_TOP}$</td>
<td>81 mW</td>
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<tr>
<td>$R_{DSON_BOT}$</td>
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<td>$P_{COND_BOT}$</td>
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<tr>
<td>$IND_DCR$</td>
<td>20 mΩ</td>
<td>$P_{IND}$</td>
<td>80 mW</td>
</tr>
<tr>
<td>$D$</td>
<td>0.262</td>
<td>$P_{LOSS}$</td>
<td>384 mW</td>
</tr>
<tr>
<td>$\eta$</td>
<td>86.2%</td>
<td>$P_{INTERNAL}$</td>
<td>304 mW</td>
</tr>
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These calculations assume a junction temperature of 25°C. The $R_{DSON}$ values are larger due to internal heating; therefore, the internal power loss ($P_{INTERNAL}$) must be first calculated to estimate the rise in junction temperature.
8.2.1.3 Application Curves

Figure 37. Load Transient Response

Figure 38. Start-Up (Soft Start)

Figure 39. Enable - Disable
8.2.2 2.2-MHz, 1.8-V Typical High-Efficiency Application Circuit

Figure 40. LM26420-Q1 (2.2 MHz): $V_{IN} = 5$ V, $V_{OUT1} = 3.3$ V at 2 A and $V_{OUT2} = 1.8$ V at 2 A

8.2.2.1 Design Requirements

See Design Requirements above.

8.2.2.2 Detailed Design Procedure

Table 4. Bill Of Materials

<table>
<thead>
<tr>
<th>PART ID</th>
<th>PART VALUE</th>
<th>MANUFACTURER</th>
<th>PART NUMBER</th>
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<tr>
<td>U1</td>
<td>2-A Buck Regulator</td>
<td>TI</td>
<td>LM26420-Q1</td>
</tr>
<tr>
<td>C3, C4</td>
<td>15 µF, 6.3 V, 1206, X5R</td>
<td>TDK</td>
<td>C3216X5R0J156M</td>
</tr>
<tr>
<td>C1</td>
<td>22 µF, 6.3 V, 1206, X5R</td>
<td>TDK</td>
<td>C3216X5R0J226M</td>
</tr>
<tr>
<td>C2</td>
<td>33 µF, 6.3 V, 1206, X5R</td>
<td>TDK</td>
<td>C3216X5R0J336M</td>
</tr>
<tr>
<td>C5</td>
<td>0.47 µF, 10 V, 0805, X7R</td>
<td>Vishay</td>
<td>VJ0805Y474KXQCW1BC</td>
</tr>
<tr>
<td>L1, L2</td>
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<td>TDK</td>
<td>RLF7030T-1R0M6R4</td>
</tr>
<tr>
<td>R3, R4</td>
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<td>Vishay</td>
<td>CRCW060310K0F</td>
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<td>CRCW060331K6F</td>
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<tr>
<td>R7</td>
<td>4.99 Ω, 0603, 1%</td>
<td>Vishay</td>
<td>CRCW06034R99F</td>
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</table>
Also see *Detailed Design Procedure* above.

### 8.2.2.3 Application Curves

See *Application Curves* above.

#### 8.2.3 LM26420-Q1 2.2-MHz, 2.5-V Typical High-Efficiency Application Circuit

![Diagram](https://www.ti.com/lit/ds/symlink/lm26420-q1.pdf)

**Figure 41.** LM26420-Q1 (2.2 MHz): $V_{IN} = 5\, \text{V}$, $V_{OUT1} = 1.2\, \text{V}$ at 2 A and $V_{OUT2} = 2.5\, \text{V}$ at 2 A

### 8.2.3.1 Design Requirements

See *Design Requirements* above.

### 8.2.3.2 Detailed Design Procedure

*Table 5. Bill Of Materials*

<table>
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<tr>
<th>PART ID</th>
<th>PART VALUE</th>
<th>MANUFACTURER</th>
<th>PART NUMBER</th>
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<td>LM26420-Q1</td>
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<td>C3, C4</td>
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<td>TDK</td>
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<td>Vishay</td>
<td>VJ0805Y474KXQCW1BC</td>
</tr>
<tr>
<td>L1</td>
<td>1.0 µH, 7.9A</td>
<td>TDK</td>
<td>RLF7030T-1R0M6R4</td>
</tr>
<tr>
<td>L2</td>
<td>1.5 µH, 6.5A</td>
<td>TDK</td>
<td>RLF7030T-1R5M6R1</td>
</tr>
<tr>
<td>R3, R4</td>
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<td>Vishay</td>
<td>CRCW060310K0F</td>
</tr>
<tr>
<td>R1</td>
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<td>Vishay</td>
<td>CRCW06034K99F</td>
</tr>
<tr>
<td>R5, R6</td>
<td>49.9 kΩ, 0603, 1%</td>
<td>Vishay</td>
<td>CRCW060649K9F</td>
</tr>
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<td>Vishay</td>
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<tr>
<td>R7</td>
<td>4.99 Ω, 0603, 1%</td>
<td>Vishay</td>
<td>CRCW06034R99F</td>
</tr>
</tbody>
</table>

Also see *Detailed Design Procedure* above.

### 8.2.3.3 Application Curves

See *Application Curves* above.
9 Power Supply Recommendations

The LM26420-Q1 is designed to operate from an input voltage supply range between 3 V and 5.5 V. This input supply must be well regulated and able to withstand maximum input current and maintain a stable voltage. The resistance of the input supply rail must be low enough that an input current transient does not cause a high enough drop at the LM26420-Q1 supply voltage that can cause a false UVLO fault triggering and system reset. If the input supply is located more than a few inches from the LM26420-Q1, additional bulk capacitance may be required in addition to the ceramic bypass capacitors. The amount of bulk capacitance is not critical, but a 47-μF or 100-μF electrolytic capacitor is a typical choice.

LM26420-Q1 contains a high side PMOS FET and a low side NMOS FET as shown in Figure 42. The source nodes of the high side PMOS FETs are connected to VIND₁ and VIND₂ respectively. VINC is the power source for the high and low side gate drivers. Ideally, VINC is connected to VIND₁ and VIND₂ by an RC filter as detailed in VINC Filtering Components. If VINC is allowed to be lower than VIND₁ or VIND₂, the high side PMOS FETs may be turned on regardless of the state of the respective gate drivers. Under this condition, shoot through will occur when the low side NMOS FET is turned on and permanent damage may result. When applying input voltage to VINC, VIND₁ and VIND₂, VINC must not be less than VIND₁,₂ – VTH to avoid shoot through and FET damage.

10 Layout

10.1 Layout Guidelines

When planning layout there are a few things to consider when trying to achieve a clean, regulated output. The most important consideration is the close coupling of the GND connections of the input capacitor and the PGND pin. These ground ends must be close to one another and be connected to the GND plane with at least two through-holes. Place these components as close to the device as possible. Next in importance is the location of the GND connection of the output capacitor, which must be near the GND connections of VIND and PGND. There must be a continuous ground plane on the bottom layer of a two-layer board except under the switching node island. The FB pin is a high impedance node, and care must be taken to make the FB trace short to avoid noise pickup and inaccurate regulation. The feedback resistors must be placed as close as possible to the device as possible, with the GND of R1 placed as close to the GND of the device as possible. The VOUT trace to R2 must be routed away from the inductor and any other traces that are switching. High AC currents flow through the VIN, SW, and VOUT traces, so they must be as short and wide as possible. However, making the traces wide increases radiated noise, so the designer must make this trade-off. Radiated noise can be decreased by choosing a shielded inductor. The remaining components must also be placed as close as possible to the device. See AN-1229 SIMPLE SWITCHER® PCB Layout Guidelines for further considerations, and the LM26420-Q1 demo board as an example of a four-layer layout.
Layout Guidelines (continued)

For certain high power applications, the PCB land may be modified to a *dog bone* shape (see Figure 44). By increasing the size of ground plane, and adding thermal vias, the $R_{\text{JA}}$ for the application can be reduced.

### 10.2 Layout Example

![Figure 44. Typical Layout For DC/DC Converter](image-url)

**Figure 43. Internal Connection**

**Figure 44. Typical Layout For DC/DC Converter**

### 10.3 Thermal Considerations

$T_J =$ Chip junction temperature  
$T_A =$ Ambient temperature  
$R_{\text{JUC}} =$ Thermal resistance from chip junction to device case  
$R_{\text{JA}} =$ Thermal resistance from chip junction to ambient air  

Heat in the LM26420-Q1 due to internal power dissipation is removed through conduction and/or convection.  

Conduction: Heat transfer occurs through cross sectional areas of material. Depending on the material, the transfer of heat can be considered to have poor to good thermal conductivity properties (insulator vs conductor).  

Heat Transfer goes as:
Thermal Considerations (continued)

Silicon → package → lead frame → PCB

Convection: Heat transfer is by means of airflow. This could be from a fan or natural convection. Natural convection occurs when air currents rise from the hot device to cooler air.

Thermal impedance is defined as:

$$R_b = \frac{\Delta T}{\text{Power}} \quad (35)$$

Thermal impedance from the silicon junction to the ambient air is defined as:

$$R_{\text{JJA}} = \frac{T_J - T_A}{P_{\text{INTERNAL}}} \quad (36)$$

The PCB size, weight of copper used to route traces and ground plane, and number of layers within the PCB can greatly affect $R_{\text{JJA}}$. The type and number of thermal vias can also make a large difference in the thermal impedance. Thermal vias are necessary in most applications. They conduct heat from the surface of the PCB to the ground plane. Five to eight thermal vias must be placed under the exposed pad to the ground plane if the WQFN package is used. Up to 12 thermal vias must be used in the HTSSOP-20 package for optimum heat transfer from the device to the ground plane.

Thermal impedance also depends on the thermal properties of the application's operating conditions ($V_{\text{IN}}$, $V_{\text{OUT}}$, $I_{\text{OUT}}$, etc.), and the surrounding circuitry.

10.3.1 Method 1: Silicon Junction Temperature Determination

To accurately measure the silicon temperature for a given application, two methods can be used. The first method requires the user to know the thermal impedance of the silicon junction to top case temperature.

Some clarification needs to be made before we go any further.

$R_{\text{JJC}}$ is the thermal impedance from silicon junction to the exposed pad.

$R_{\text{JUT}}$ is the thermal impedance from top case to the silicon junction.

In this data sheet $R_{\text{JUT}}$ is used so that it allows the user to measure top case temperature with a small thermocouple attached to the top case.

$R_{\text{JUT}}$ is approximately 20°C/W for the 16-pin WQFN package with the exposed pad. Knowing the internal dissipation from the efficiency calculation given previously, and the case temperature, which can be empirically measured on the bench we have:

$$R_{\text{JUT}} = \frac{T_J - T_T}{P_{\text{INTERNAL}}} \quad (37)$$

Therefore:

$$T_J = (R_{\text{JUT}} \times P_{\text{INTERNAL}}) + T_C \quad (38)$$

From the previous example:

$$T_J = 20^\circ\text{C/W} \times 0.304\text{W} + T_C \quad (39)$$

10.3.2 Thermal Shutdown Temperature Determination

The second method, although more complicated, can give a very accurate silicon junction temperature.

The second step is to determine $R_{\text{JJA}}$ of the application. The LM26420-Q1 has over-temperature protection circuitry. When the silicon temperature reaches 165°C, the device stops switching. The protection circuitry has a hysteresis of about 15°C. Once the silicon junction temperature has decreased to approximately 150°C, the device starts to switch again. Knowing this, the $R_{\text{JJA}}$ for any application can be characterized during the early stages of the design one may calculate the $R_{\text{JJA}}$ by placing the PCB circuit into a thermal chamber. Raise the ambient temperature in the given working application until the circuit enters thermal shutdown. If the SW pin is monitored, it is obvious when the internal FETs stop switching, indicating a junction temperature of 165°C. Knowing the internal power dissipation from the above methods, the junction temperature, and the ambient temperature $R_{\text{JJA}}$ can be determined.
Thermal Considerations (continued)

\[ R_{\text{JJA}} = \frac{165^\circ - T_A}{304 \text{ mW}} \]  

(40)

Once this is determined, the maximum ambient temperature allowed for a desired junction temperature can be found.

An example of calculating \( R_{\text{JJA}} \) for an application using the LM26420-Q1 WQFN demonstration board is shown below.

The four layer PCB is constructed using FR4 with 1 oz copper traces. The copper ground plane is on the bottom layer. The ground plane is accessed by eight vias. The board measures 3 cm \( \times \) 3 cm. It was placed in an oven with no forced airflow. The ambient temperature was raised to 152°C, and at that temperature, the device went into thermal shutdown.

From the previous example:

\[ P_{\text{INTERNAL}} = 304 \text{ mW} \]  

(41)

\[ R_{\text{JJA}} = \frac{165^\circ \text{C} - 152^\circ \text{C}}{304 \text{ mW}} = 42.8^\circ \text{ C/W} \]  

(42)

If the junction temperature was to be kept below 125°C, then the ambient temperature could not go above 112°C.

\[ T_J - (R_{\text{JJA}} \times P_{\text{INTERNAL}}) = T_A \]  

(43)

\[ 125^\circ \text{C} - (42.8^\circ \text{C/W} \times 304 \text{ mW}) = 112.0^\circ \text{C} \]  

(44)
11 デバイスおよびドキュメントのサポート

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1. 最初に、入力電圧(V_in)、出力電圧(V_out)、出力電流(I_out)の要件を入力します。
2. オプティマイザのダイヤルを使用して、効率、占有面積、コストなどの主要なパラメータについて設計を最適化します。
3. 生成された設計を、テキサス・インスツルメンツが提供する他の方式と比較します。
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通常、次の操作を実行可能です。
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• 熱シミュレーションを実行し、基板の熱特性を把握する。
• カスタマイズされた回路図やレイアウトを、一般的なCADフォーマットで出力する。
• 設計のレポートをPDFで印刷し、設計を共有する。
WEBENCHツールの詳細は、www.ti.com/WEBENCHでご覧になれます。

11.2 ドキュメントのサポート

11.2.1 関連資料
『AN-1229 SIMPLE SWITCHER®のPCBレイアウト・ガイドライン』(SNVA054)

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11.7 Glossary

SLYZ022 — Ti Glossary.
This glossary lists and explains terms, acronyms, and definitions.

12 メカニカル、パッケージ、および注文情報

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## Packaging Information

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<td>ACTIVE</td>
<td>HTSSOP</td>
<td>PWP</td>
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<td>2500</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>SN</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 125</td>
<td>LM26420Q1MXH</td>
<td>Samples</td>
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<tr>
<td>LM26420Q1XSQ/NOPB</td>
<td>ACTIVE</td>
<td>WQFN</td>
<td>RUM</td>
<td>16</td>
<td>1000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>SN</td>
<td>Level-3-260C-168HR</td>
<td>-40 to 125</td>
<td>L26420Q</td>
<td>Samples</td>
</tr>
<tr>
<td>LM26420Q1XSQX/NOPB</td>
<td>ACTIVE</td>
<td>WQFN</td>
<td>RUM</td>
<td>16</td>
<td>4500</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>SN</td>
<td>Level-3-260C-168HR</td>
<td>-40 to 125</td>
<td>L26420Q</td>
<td>Samples</td>
</tr>
</tbody>
</table>

(1) The marketing status values are defined as follows:
- **ACTIVE**: Product device recommended for new designs.
- **LIFEBUY**: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
- **NRND**: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
- **PREVIEW**: Device has been announced but is not in production. Samples may or may not be available.
- **OBSOLETE**: TI has discontinued the production of the device.

(2) **RoHS**: TI defines “RoHS” to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, “RoHS” products are suitable for use in specified lead-free processes. TI may reference these types of products as “Pb-Free”.

**RoHS Exempt**: TI defines “RoHS Exempt” to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green**: TI defines “Green” to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) **MSL, Peak Temp.** - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.
Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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TAPE AND REEL INFORMATION

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Reel Diameter (mm)</th>
<th>Reel Width W1 (mm)</th>
<th>A0 (mm)</th>
<th>B0 (mm)</th>
<th>K0 (mm)</th>
<th>P1 (mm)</th>
<th>W (mm)</th>
<th>Pin1 Quadrant</th>
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<tbody>
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<td>LM26420Q0XMHX/NOPB</td>
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<td>16.0</td>
<td>Q1</td>
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<tr>
<td>LM26420Q1XMHX/NOPB</td>
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<td>8.0</td>
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<td>Q1</td>
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<tr>
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<td>Q1</td>
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*All dimensions are nominal.
**TAPE AND REEL BOX DIMENSIONS**

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<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Height (mm)</th>
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</thead>
<tbody>
<tr>
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<td>PWP</td>
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<td>35.0</td>
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<td>367.0</td>
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*All dimensions are nominal*
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