This user’s guide contains information for the TPS54824EVM-779 evaluation module (PWR779) as well as for the TPS54824 dc/dc converter. Also included are the performance specifications, the schematic, and the bill of materials for the TPS54824EVM-779.

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1 Introduction

1.1 Background

The TPS54824 dc/dc converter is a synchronous buck converter designed to provide up to an 8-A output. The input (VIN) is rated for 4.5 V to 17 V. Rated input voltage and output current range for the evaluation module are given in Table 1. This evaluation module is designed to demonstrate the small printed-circuit-board areas that may be achieved when designing with the TPS54824 regulator. The RT/CLK pin is configured for 700-kHz switching frequency. The high-side and low-side MOSFETs are incorporated inside the TPS54824 package along with the gate-drive circuitry. The low drain-to-source on-resistance of the MOSFET allows the TPS54824 to achieve high efficiencies and helps keep the junction temperature low at high output currents. An external divider allows for an adjustable output voltage. Additionally, the TPS54824 provides adjustable soft start and undervoltage lockout inputs and a power good output.

<table>
<thead>
<tr>
<th>EVM</th>
<th>Input Voltage Range</th>
<th>Output Current Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS54824EVM-779</td>
<td>V_IN = 4.5 V to 17 V</td>
<td>0 A to 8 A</td>
</tr>
</tbody>
</table>

1.2 Performance Specification Summary

A summary of the TPS54824EVM-779 performance specifications is provided in Table 2. Specifications are given for an input voltage of \( V_{IN} = 12 \) V and an output voltage of 1.8 V, unless otherwise specified. The TPS54824EVM-779 is designed and tested for \( V_{IN} = 4.5 \) V to 17 V. The ambient temperature is 25°C for all measurements, unless otherwise noted.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Test Conditions</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{IN} ) voltage range</td>
<td></td>
<td>4.5</td>
<td>12</td>
<td>17</td>
<td>V</td>
</tr>
<tr>
<td>( V_{IN} ) start voltage</td>
<td></td>
<td>4.4</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>( V_{IN} ) stop voltage</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Output voltage setpoint</td>
<td></td>
<td>1.8</td>
<td></td>
<td></td>
<td>V</td>
</tr>
</tbody>
</table>

Trademarks

All trademarks are the property of their respective owners.
Table 2. TPS54824EVM-779 Performance Specification Summary (continued)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Test Conditions</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output current range</td>
<td>( V_{IN} = 4.5 \text{ V to 17 V} )</td>
<td>0</td>
<td>8</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Load regulation</td>
<td>( V_{IN} = 4.5 \text{ V to 17 V, } I_o = 8 \text{ A} )</td>
<td>Voltage change</td>
<td>–0.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load transient response</td>
<td>( I_o = 2 \text{ A to 6 A} )</td>
<td>Recovery time</td>
<td>75</td>
<td>µs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( I_o = 6 \text{ A to 2A} )</td>
<td>Voltage change</td>
<td>55</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recovery time</td>
<td>75</td>
<td>µs</td>
<td></td>
</tr>
<tr>
<td>Loop bandwidth</td>
<td>( V_{IN} = 12 \text{ V, } I_{O} = 4 \text{ A} )</td>
<td>116</td>
<td>kHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase margin</td>
<td>( V_{IN} = 12 \text{ V, } I_{O} = 4 \text{ A} )</td>
<td>58</td>
<td>degree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input ripple voltage</td>
<td>( I_o = 8 \text{ A} )</td>
<td>270</td>
<td>mVPP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output ripple voltage</td>
<td>( I_o = 8 \text{ A} )</td>
<td>11</td>
<td>mVPP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output rise time</td>
<td></td>
<td>1.1</td>
<td>ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating frequency ( f_{SW} )</td>
<td>TPS54824EVM-779, ( V_{IN} = 5 \text{ V, } I_{O} = 2 \text{ A} )</td>
<td>700</td>
<td>kHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum efficiency</td>
<td></td>
<td>94.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.3 Evaluating the TPS54824EVM-779 at -40 °C

The TPS54824EVM-779 was designed and optimized at room temperature of 25 °C. For evaluation down to -40 °C, the compensation must be adjusted to provide sufficient gain and phase margin. Recommended compensation changes for -40 °C evaluation are: \( R_5 = 5.36 \text{ kΩ} \), \( C_{18} = 5.6 \text{ nF} \) and \( C_{17} = 68 \text{ pF} \).

1.4 Modifications

These evaluation modules are designed to provide access to the features of the TPS54824. Some modifications can be made to this module. When modifications are made to the components on the EVM, the compensation components connected to the COMP pin may need to be changed. Changes to the \( f_{SW} \), output voltage, output inductor, and output capacitors may require a change in the external compensation. Table 3 gives some example values for different applications.

1.4.1 Output Voltage Setpoint

The output voltage is set by the resistor divider network of \( R_8 \) and \( R_6 \). \( R_6 \) is fixed at 6.04 kΩ. To change the output voltage of the EVM, it is necessary to change the value of resistor \( R_8 \). Changing the value of \( R_6 \) can change the output voltage above the 0.6-V reference voltage \( V_{REF} \). The value of \( R_8 \) for a specific output voltage can be calculated using Equation 1.

\[
R_8 = R_6 \times \left( \frac{V_{OUT}}{0.6 \text{ V}} - 1 \right)
\]  

(1)

1.4.2 Adjustable UVLO

The undervoltage lockout (UVLO) can be adjusted externally using \( R_2 \) and \( R_9 \). See the TPS54824 datasheet (SLVSDC9) for detailed instructions for setting the external UVLO.
1.4.3 Example Component Values For Common Output Voltages

Table 3 shows recommended modifications to the EVM for evaluating different output voltages. Depending on the load step response requirements in the application, the output capacitors may need to be different from the values shown in this table. More or less output capacitance can be used. If the output capacitors are changed, the compensation may need to be adjusted. Additionally if a different $f_{SW}$ is needed, the inductance value (L) may need to be changed. The TPS54824 datasheet equations or WEBENCH can be used to calculate the output capacitor value, compensation, $f_{SW}$ and inductance.

<table>
<thead>
<tr>
<th>$V_{OUT}$ (V)</th>
<th>$f_{SW}$ (kHz)</th>
<th>$R_T$ (R7) (kΩ)</th>
<th>L (µH)</th>
<th>$C_{OUT}$ (µF)</th>
<th>$R_{FBT}$ (R8) (kΩ)</th>
<th>$R_C$ (R5) (kΩ)</th>
<th>$C_C$ (C18) (nF)</th>
<th>$C_P$ (C17) (pF)</th>
<th>$C_{FF}$ (C19) (pF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>500</td>
<td>100</td>
<td>1.0</td>
<td>4x 47</td>
<td>4.02</td>
<td>3.32</td>
<td>10</td>
<td>180</td>
<td>470</td>
</tr>
<tr>
<td>1.8</td>
<td>500</td>
<td>100</td>
<td>1.5</td>
<td>4x 47</td>
<td>12.1</td>
<td>5.36</td>
<td>5.6</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>3.3</td>
<td>500</td>
<td>100</td>
<td>2.2</td>
<td>2x 47</td>
<td>27.4</td>
<td>3.32</td>
<td>10</td>
<td>180</td>
<td>68</td>
</tr>
</tbody>
</table>
2 Test Setup and Results

This section describes how to properly connect, set up, and use the TPS54824EVM-779 evaluation module. The section also includes test results typical for the evaluation module and covers efficiency, output voltage regulation, load transients, loop response, output ripple, input ripple, start-up, and current limit modes.

2.1 Input/Output Connections

The TPS54824EVM-779 is provided with input/output connectors and test points as shown in Table 4. A power supply capable of supplying greater than 5 A must be connected to J1 through a pair of 20-AWG wires or better. The load must be connected to J2 through a pair of 20-AWG wires or better. The maximum load current capability is 12 A. Wire lengths must be minimized to reduce losses in the wires. Test point TP1 provides a place to monitor the $V_{IN}$ input voltages with TP7 providing a convenient ground reference. TP4 is used to monitor the output voltage with TP9 as the ground reference.

Table 4. TPS54824EVM-779 EVM Connectors and Test Points

<table>
<thead>
<tr>
<th>Reference Designator</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>J1</td>
<td>VIN input voltage connector (see Table 1 for $V_{IN}$ range)</td>
</tr>
<tr>
<td>J2</td>
<td>VOUT terminal to connect load</td>
</tr>
<tr>
<td>J3</td>
<td>2-pin header for enable. Add shunt to connect EN to ground and disable device.</td>
</tr>
<tr>
<td>J4</td>
<td>2-pin header for power good resistor pullup connection. Add a shunt to pull up to VOUT.</td>
</tr>
<tr>
<td>TP1</td>
<td>VIN test point</td>
</tr>
<tr>
<td>TP2</td>
<td>EN test point</td>
</tr>
<tr>
<td>TP3</td>
<td>SW node test point</td>
</tr>
<tr>
<td>TP4</td>
<td>1.8-V test point</td>
</tr>
<tr>
<td>TP5</td>
<td>PGOOD pullup test point</td>
</tr>
<tr>
<td>TP6</td>
<td>PGOOD test point</td>
</tr>
<tr>
<td>TP7</td>
<td>PGND test point</td>
</tr>
<tr>
<td>TP8</td>
<td>SS/TRK test point</td>
</tr>
<tr>
<td>TP9</td>
<td>PGND test point</td>
</tr>
<tr>
<td>TP10</td>
<td>Test point between voltage divider network and output of TPS54824 converter. Used for loop response measurements.</td>
</tr>
<tr>
<td>TP11</td>
<td>PGND test point</td>
</tr>
<tr>
<td>TP12</td>
<td>AGND test point</td>
</tr>
<tr>
<td>TP13</td>
<td>AGND test point</td>
</tr>
<tr>
<td>TP14</td>
<td>PGND test point</td>
</tr>
<tr>
<td>TP15</td>
<td>Test point for supplying external CLK for synchronization. C20 and R10 should be populated to use.</td>
</tr>
</tbody>
</table>
2.2 Efficiency

The efficiency of this EVM peaks at a load current of about 4 A and then decreases as the load current increases toward full load. Figure 1 shows the efficiency for the TPS54824EVM-779 at an ambient temperature of 25°C.

![Figure 1. TPS54824EVM-779 Efficiency - Cyntec Inductor](image1)

Figure 1 shows the efficiency for the TPS54824EVM-779 using a semi-log scale to more easily show efficiency at lower output currents. The ambient temperature is 25°C.

![Figure 2. TPS54824EVM-779 Low Current Efficiency - Cyntec Inductor](image2)
Figure 3 shows the efficiency for the TPS54824EVM-779 with a WE 744311100 inductor. The ambient temperature is 25°C.

The efficiency may be lower at higher ambient temperatures, due to temperature variation in the drain-to-source resistance of the internal MOSFETs.
2.3 **Output Voltage Load Regulation**

Figure 4 shows the load regulation for the TPS54824EVM-779.

![Figure 4. TPS54824EVM-779 Load Regulation](image)

Measurements are given for an ambient temperature of 25°C.

2.4 **Output Voltage Line Regulation**

Figure 5 shows the line regulation for the TPS54824EVM-779.

![Figure 5. TPS54824EVM-779 Line Regulation](image)
2.5 Load Transients

Figure 6 shows the TPS54824EVM-779 response to load transients. The current step is from 2 A to 6 A. The current step slew rate is 1 A/µs. Total peak-to-peak voltage variation is as shown, including ripple and noise on the output.

![Figure 6. TPS54824EVM-779 Transient Response](image)

2.6 Loop Characteristics

Figure 7 shows the TPS54824EVM-779 loop-response characteristics. Gain and phase plots are shown for $V_{IN}$ voltage of 12 V. Load current for the measurement is 4 A.

![Figure 7. TPS54824EVM-779 Loop Response](image)
2.7 Output Voltage Ripple

Figure 8 and Figure 9 show the TPS54824EVM-779 output voltage ripple. The load currents are no load and 8 A. $V_{IN} = 12$ V. The ripple voltage is measured directly across TP9 and TP4.

![Figure 8. TPS54824EVM-779 Output Ripple, No Load](image1)

![Figure 9. TPS54824EVM-779 Output Ripple, 8-A Load](image2)
2.8 Input Voltage Ripple

Figure 10 and Figure 11 show the TPS54824EVM-779 input voltage ripple. The load currents are no load and 8 A. \( V_{\text{IN}} = 12 \text{ V} \). The ripple voltage is measured directly across TP1 and TP7.

![Figure 10. TPS54824EVM-779 Input Ripple, No Load](image1)

![Figure 11. TPS54824EVM-779 Input Ripple, 8-A Load](image2)
2.9 Powering Up

Figure 12 and Figure 13 show the start-up waveforms for the TPS54824EVM-779. In Figure 12, the output voltage ramps up as soon as the input voltage reaches the UVLO threshold. In Figure 13, the input voltage is initially applied and the output is inhibited by pulling EN to GND using an external function generator. When the EN voltage is increased above the enable-threshold voltage, the start-up sequence begins and the output voltage ramps up to the externally set value of 1.8 V. The input voltage for these plots is 12 V and the load is 1 Ω. Alternatively, a jumper at J3 to tie EN to GND can also be used. When the jumper is removed, EN is released and the start-up sequence will begin.

![Figure 12. TPS54824EVM-779 Start-Up Relative to V_{IN}](image1)

![Figure 13. TPS54824EVM-779 Start-Up Relative to Enable](image2)
2.10 Powering Down

Figure 14 and Figure 15 show the TPS54824EVM-779 shutdown. The input voltage for these plots is 12 V and the load is 1 Ω.

![Figure 14. TPS54824EVM-779 Shutdown Relative to V_{IN}](image1)

![Figure 15. TPS54824EVM-779 Shutdown Relative to Enable](image2)
2.11 Start-Up Into Pre-Bias

Figure 16 shows the TPS54824EVM-779 start up into a pre-biased output. The output voltage is pre-biased to 1 V.

![Figure 16. TPS54824EVM-779 Start-Up Into Pre-Bias](image)

2.12 Hiccup Mode Current Limit

Figure 17, Figure 18, and Figure 19 show the TPS54824EVM-779 hiccup mode current limit feature. When an overcurrent event occurs, the TPS54824EVM-779 shuts down and restarts. Figure 17 shows the restart sequence in an overcurrent condition. Figure 18 shows TPS54824EVM-779 entering hiccup mode and Figure 19 shows TPS54824EVM-779 exiting hiccup mode.
Figure 17. TPS54824EVM-779 Hiccup Mode Current Limit

Figure 18. TPS54824EVM-779 Hiccup Mode Start
Figure 19. TPS54824EVM-779 Hiccup Mode Stop
3 Board Layout

This section provides a description of the TPS54824EVM-779 board layout and layer illustrations.

3.1 Layout

The board layout for the TPS54824EVM-779 is shown in Figure 20 through Figure 23. The top-side layer of the EVM is laid out in a manner typical of a user application. The top, bottom, and internal layers are 2-oz. copper.

The top layer contains the main power traces for VIN, VOUT, and SW. Also on the top layer are connections for the remaining pins of the TPS54824 and the majority of the signal traces. The top layer has dedicated ground plane for quiet analog ground that is connected to the main power ground plane at a single point. The internal layer-1 is a large ground plane and also routes signals to test points. The internal layer-2 contains an additional large ground copper area as well as an additional VIN and VOUT copper fill. The bottom layer is another ground plane with two additional traces for the output voltage feedback. The top-side ground traces are connected to the bottom and internal ground planes with multiple vias placed around the board.

The input decoupling capacitors and bootstrap capacitor are all located as close to the IC as possible. Additionally, the voltage set point resistor divider components are kept close to the IC. The voltage divider network ties to the output voltage at the point of regulation, the copper V_{OUT} trace at the TP4 test point. An additional input bulk capacitor is used to limit the noise entering the converter from the input supply. Critical analog circuits such as the voltage set point divider, EN resistor, SS/TRK capacitor, RT/CLK resistor, and COMP pin are terminated to the quiet analog ground island on the top layer.
Figure 20. TPS54824EVM-779 Top-Side Layout

Figure 21. TPS54824EVM-779 Internal Layer-1 Layout
Figure 22. TPS54824EVM-779 Internal Layer-2 Layout

Figure 23. TPS54824EVM-779 Bottom-Side Layout
4 Schematic and Bill of Materials

This section presents the TPS54824EVM-779 schematic and bill of materials.

4.1 Schematic

Figure 24 is the schematic for the TPS54824EVM-779.

Figure 24. TPS54824EVM-779 Schematic
## 4.2 Bill of Materials

Table 5 presents the bill of materials for the TPS54824EVM-779.

<table>
<thead>
<tr>
<th>Designator</th>
<th>Qty</th>
<th>Value</th>
<th>Description</th>
<th>Package Reference</th>
<th>Part Number</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>C3, C4</td>
<td>2</td>
<td>10uF</td>
<td>CAP, CERM, 10 µF, 35 V, +/- 20%, X5R, 1206</td>
<td>1206</td>
<td>C3216XR1V106M160AB</td>
<td>TDK</td>
</tr>
<tr>
<td>C5, C6, C8</td>
<td>3</td>
<td>0.1uF</td>
<td>CAP, CERM, 0.1uF, 25V, +/-10%, X7R, 0603</td>
<td>0603</td>
<td>06033C104KAT2A</td>
<td>AVX</td>
</tr>
<tr>
<td>C7</td>
<td>1</td>
<td>100uF</td>
<td>CAP, AL, 100 µF, 50 V, +/- 20%, 0.18 ohm, TH</td>
<td>Cap, 10x12.5mm</td>
<td>UBT1H101MPD1TD</td>
<td>Nichicon</td>
</tr>
<tr>
<td>C9, C10, C11, C12</td>
<td>4</td>
<td>47uF</td>
<td>CAP, CERM, 47 µF, 6.3 V, +/-20%, X5R, 1206</td>
<td>1206</td>
<td>GRM31CR60J476ME19L</td>
<td>Murata</td>
</tr>
<tr>
<td>C16</td>
<td>1</td>
<td>8200pF</td>
<td>CAP, CERM, 8200 pF, 25 V, +/- 10%, X7R, 0603</td>
<td>0603</td>
<td>GRM188R71E822KA01D</td>
<td>Murata</td>
</tr>
<tr>
<td>C17</td>
<td>1</td>
<td>27pF</td>
<td>CAP, CERM, 27 pF, 50 V, +/- 5%, C0G/NP0, 0603</td>
<td>0603</td>
<td>GRM1885C1H270J01D</td>
<td>Murata</td>
</tr>
<tr>
<td>C18</td>
<td>1</td>
<td>2200pF</td>
<td>CAP, CERM, 2200 pF, 25 V, +/- 10%, X7R, 0603</td>
<td>0603</td>
<td>GRM188R71E222KA01D</td>
<td>Murata</td>
</tr>
<tr>
<td>C19</td>
<td>1</td>
<td>100pF</td>
<td>CAP, CERM, 100 pF, 50 V, +/- 5%, C0G/NP0, 0603</td>
<td>0603</td>
<td>885012006057</td>
<td>Wurth Elektronik</td>
</tr>
<tr>
<td>J1, J2</td>
<td>2</td>
<td></td>
<td>Terminal Block, 5.08 mm, 2X1, Brass, TH</td>
<td>2X1 5.08 mm Terminal Block</td>
<td>ED120/2DS</td>
<td>On-Shore Technology</td>
</tr>
<tr>
<td>J3, J4</td>
<td>2</td>
<td></td>
<td>Header, 100mil, 2x1, Gold, TH</td>
<td>Header, 100mil, 2x1, TH</td>
<td>HTSW-102-07-G-S</td>
<td>Samtec</td>
</tr>
<tr>
<td>L1</td>
<td>1</td>
<td>1uH</td>
<td>Inductor, 1 µH, 14.4 A, 0.0064 ohm, SMD</td>
<td>6.95x2.8x6.6mm</td>
<td>CMLE063T-1R0MS</td>
<td>Cynitec</td>
</tr>
<tr>
<td>LBL1</td>
<td>1</td>
<td></td>
<td>Thermal Transfer Printable Labels, 0.650&quot; W x 0.200&quot; H - 10,000 per roll</td>
<td>PCB Label 0.650&quot;H x 0.200&quot;W</td>
<td>THT-14-423-10</td>
<td>Brady</td>
</tr>
<tr>
<td>R1</td>
<td>1</td>
<td>100k</td>
<td>RES, 100 k, 5%, 0.1 W, 0603</td>
<td>0603</td>
<td>CRCW0603100KJNEA</td>
<td>Vishay-Dale</td>
</tr>
<tr>
<td>R2</td>
<td>1</td>
<td>86.6k</td>
<td>RES, 86.6 k, 1%, 0.1 W, 0603</td>
<td>0603</td>
<td>CRCW060386K6FKEA</td>
<td>Vishay-Dale</td>
</tr>
<tr>
<td>R4</td>
<td>1</td>
<td>10</td>
<td>RES, 10, 5%, 0.1 W, 0603</td>
<td>0603</td>
<td>CRCW060310R0JNEA</td>
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</tr>
<tr>
<td>R5</td>
<td>1</td>
<td>9.53k</td>
<td>RES, 9.53 k, 1%, 0.1 W, 0603</td>
<td>0603</td>
<td>CRCW06039K53FKEA</td>
<td>Vishay-Dale</td>
</tr>
<tr>
<td>R6</td>
<td>1</td>
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<td>RES, 6.04 k, 1%, 0.1 W, 0603</td>
<td>0603</td>
<td>CRCW06036K04FKEA</td>
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<tr>
<td>R7</td>
<td>1</td>
<td>69.8k</td>
<td>RES, 69.8 k, 1%, 0.1 W, 0603</td>
<td>0603</td>
<td>CRCW060369K8FKEA</td>
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<tr>
<td>R8</td>
<td>1</td>
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<td>RES, 12.1 k, 1%, 0.1 W, 0603</td>
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<td>CRCW060312K1FKEA</td>
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<tr>
<td>R9</td>
<td>1</td>
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<td>RES, 30.9 k, 1%, 0.1 W, 0603</td>
<td>0603</td>
<td>CRCW060330K9FKEA</td>
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<td>SH-J1, SH-J2</td>
<td>2</td>
<td>1x2</td>
<td>Shunt, 100mil, Gold plated, Black</td>
<td>Shunt, 100mil, Gold plated, Black</td>
<td>SNT-100-BK-G</td>
<td>Samtec</td>
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<td>15</td>
<td>Test Point, Miniature, SMT</td>
<td>Testpoint_Keystone_Miniature</td>
<td>S015</td>
<td>Keystone</td>
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<tr>
<td>U1</td>
<td>1</td>
<td></td>
<td>4.5-V to 17-V Input, 8-A Synchronous Step-Down Voltage Regulator, RNV0018B (VQFN-HR-18)</td>
<td>RNV0018B</td>
<td>TPSS54824RNV</td>
<td>Texas Instruments</td>
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<tr>
<td>C1, C2</td>
<td>0</td>
<td>22uF</td>
<td>CAP, CERM, 22 µF, 35 V, +/-20%, X5R, 1206</td>
<td>1206</td>
<td>C3216XR1V226M160AC</td>
<td>TDK</td>
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<td>47pF</td>
<td>CAP, CERM, 47 pF, 50 V, +/-5%, C0G/NP0, 0603</td>
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<td>06033A470JAT2A</td>
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<td>FID1, FID2, FID3</td>
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<td></td>
<td>Fiducial mark. There is nothing to buy or mount.</td>
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<td>N/A</td>
</tr>
<tr>
<td>R10</td>
<td>0</td>
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<td>0603</td>
<td>CRCW060320K0FKEA</td>
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Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (November 2016) to A Revision

- Added Section: Evaluating the TPS54824EVM-779 at -40 °C ................................................................. 3
- Added Text: When modifications are made... .................................................................................................. 3
- Added Section: Example Component Values For Common Output Voltages .................................................. 4
STANDARD TERMS FOR EVALUATION MODULES

1. **Delivery:** TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software.

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 **Limited Warranty and Related Remedies/Disclaimers:**

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3 **Regulatory Notices:**

   3.1 **United States**

      3.1.1 **Notice applicable to EVMs not FCC-Approved:**

         **FCC NOTICE:** This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

      3.1.2 **For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:**

         **CAUTION**

         This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. Changes or modifications not expressly approved by the party responsible for compliance could void the user’s authority to operate the equipment.

         **FCC Interference Statement for Class A EVM devices**

         **NOTE:** This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.
FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning off and on the device, the user is encouraged to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

1. This device may not cause interference, and
2. This device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

3.2 Canada

For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247

3.3 Japan

Notice for EVMs delivered in Japan: Please see http://www.tij.co.jp/lfds/ti_ja/general/eStore/notice_01.page

Notice for Users of EVMs Considered “Radio Frequency Products” in Japan: EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan.

2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or

3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.
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3.3.3 Notice for EVMs for Power Line Communication: Please see http://www.tij.co.jp/ltsd/ti_ja/general/eStore/notice_02.page
電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。http://www.tij.co.jp/ltsd/ti_ja/general/eStore/notice_02.page

3.4 European Union
3.4.1 For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive):
This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 EVM Use Restrictions and Warnings:
4.1 EVMs are not for use in functional safety and/or safety critical evaluations, including but not limited to evaluations of life support applications.
4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.
4.3 Safety-Related Warnings and Restrictions:
4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.
4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.
4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

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8.1 **General Limitations.** IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS, REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

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