TPS61085T 650-kHz and 1.2-MHz, 18.5-V Step-Up DC-DC Converter

1 Features
- 2.3-V to 6-V Input Voltage Range
- 18.5-V Boost Converter With 2-A Switch Current
- 650-kHz or 1.2-MHz Selectable Switching Frequency
- Adjustable Soft Start
- Thermal Shutdown
- Undervoltage Lockout
- 8-Pin VSSOP and TSSOP Packages

2 Applications
- Handheld Devices
- GPS Receiver
- Digital Still Camera
- Portable Applications
- DSL Modem
- PCMCIA Card
- TFT LCD Bias Supply

3 Description
The TPS61085 device is a high-frequency high-efficiency DC-to-DC boost converter with an integrated 2-A, 0.13-Ω power switch capable of providing an output voltage up to 18.5 V. The selectable frequency of 650 kHz or 1.2 MHz allows the use of small external inductors and capacitors, and provides fast transient response. The external compensation allows optimizing the regulator for application conditions. A capacitor connected to the specific soft-start pin minimizes inrush current at start-up.

Device Information

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PACKAGE</th>
<th>BODY SIZE (NOM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS61085T</td>
<td>VSSOP (8)</td>
<td>3.00 mm × 3.00 mm</td>
</tr>
<tr>
<td></td>
<td>TSSOP (8)</td>
<td>3.00 mm × 4.40 mm</td>
</tr>
</tbody>
</table>

(1) For all available packages, see the orderable addendum at the end of the data sheet.
Table of Contents

1 Features .......................................................... 1
2 Applications ..................................................... 1
3 Description ......................................................... 1
4 Revision History .................................................. 2
5 Pin Configuration and Functions .......................... 3
6 Specifications ..................................................... 3
   6.1 Absolute Maximum Ratings ........................... 3
   6.2 ESD Ratings .................................................. 3
   6.3 Recommended Operating Conditions .............. 4
   6.4 Thermal Information ...................................... 4
   6.5 Electrical Characteristics .............................. 4
   6.6 Typical Characteristics ................................ 5
7 Detailed Description ........................................... 7
   7.1 Overview .................................................... 7
   7.2 Functional Block Diagram .............................. 7
   7.3 Feature Description ....................................... 8
   7.4 Device Functional Modes ............................... 8
8 Application and Implementation .......................... 9
   8.1 Application Information ................................. 9
   8.2 Typical Application ...................................... 9
   8.3 System Examples ......................................... 14
9 Power Supply Recommendations .......................... 18
10 Layout ............................................................ 19
   10.1 Layout Guidelines ....................................... 19
   10.2 Layout Example ......................................... 19
11 Device and Documentation Support ...................... 20
   11.1 Device Support .......................................... 20
   11.2 Receiving Notification of Documentation Updates 20
   11.3 Community Resources .................................. 20
   11.4 Trademarks ............................................... 20
   11.5 Electrostatic Discharge Caution .................... 20
   11.6 Glossary .................................................. 20
12 Mechanical, Packaging, and Orderable Information .. 20

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

Changes from Revision A (December 2009) to Revision B  Page

• Added ESD Ratings table, Feature Description section, Device Functional Modes, Application and Implementation section, Power Supply Recommendations section, Layout section, Device and Documentation Support section, and Mechanical, Packaging, and Orderable Information section. ................................................................. 1
• Removed Ordering Information table, see POA at the end of the data sheet ......................................................... 1
• Removed Dissipation Ratings table .................................................. 1
• Added minimum voltage to SW pin in Absolute Maximum Ratings ................................................................. 3
• Changed SW leakage current value from 10 µA to 2 µA .................................................. 4
• Changed SW leakage current maximum from 10 µA to 2 µA .................................................. 4
• Changed x-axis of Figure 5 from V \text{CC} - Supply Current to V \text{CC} - Supply Voltage ................................................................. 6
• Changed I_{\text{OUT}} value from mA to A of Figure 6 ................................................................. 6
• Connected FREQ pin to VIN and removed FREQ pin connection to GND on Figure 18 ................................................................. 17

Changes from Original (November 2009) to Revision A  Page

• Added maximum load current graphs ........................................................................ 5
5 Pin Configuration and Functions

![Pin Configuration Diagram]

<table>
<thead>
<tr>
<th>PIN</th>
<th>TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO.</td>
<td>NAME</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>COMP</td>
<td>I/O Compensation pin</td>
</tr>
<tr>
<td>2</td>
<td>FB</td>
<td>I Feedback pin</td>
</tr>
<tr>
<td>3</td>
<td>EN</td>
<td>I Shutdown control input. Connect this pin to logic high level to enable the device.</td>
</tr>
<tr>
<td>4</td>
<td>PGND</td>
<td>— Power ground</td>
</tr>
<tr>
<td>5</td>
<td>SW</td>
<td>I Switch pin</td>
</tr>
<tr>
<td>6</td>
<td>IN</td>
<td>PWR Input supply pin</td>
</tr>
<tr>
<td>7</td>
<td>FREQ</td>
<td>I Frequency select pin. The power switch operates at 650 kHz if FREQ is connected to GND and at 1.2 MHz if FREQ is connected to IN.</td>
</tr>
<tr>
<td>8</td>
<td>SS</td>
<td>O Soft-start control pin. Connect a capacitor to this pin if soft-start required. Open = no soft start</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>IN(^{(2)})</td>
<td>–0.3</td>
<td>7 V</td>
</tr>
<tr>
<td>Voltage on pins EN, FB, SS, FREQ, COMP</td>
<td>–0.3</td>
<td>7 V</td>
</tr>
<tr>
<td>Voltage on pin SW</td>
<td>–0.3</td>
<td>20 V</td>
</tr>
<tr>
<td>Continuous power dissipation</td>
<td>See Thermal Information</td>
<td></td>
</tr>
<tr>
<td>Lead temperature (soldering, 10 s)</td>
<td>260 °C</td>
<td></td>
</tr>
<tr>
<td>Operating junction temperature</td>
<td>–40 150 °C</td>
<td></td>
</tr>
<tr>
<td>Storage temperature, (T_{stg})</td>
<td>–65 150 °C</td>
<td></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, and functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

\(^{(2)}\) All voltage values are with respect to network ground terminal.

6.2 ESD Ratings

<table>
<thead>
<tr>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(^{(1)})</td>
<td>±2000 V</td>
</tr>
<tr>
<td>Charged-device model (CDM), per JEDEC specification JESD22-C101(^{(2)})</td>
<td>±500</td>
</tr>
<tr>
<td>Machine model</td>
<td>±200</td>
</tr>
</tbody>
</table>

\(^{(1)}\) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

\(^{(2)}\) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.
6.3 Recommended Operating Conditions

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IN}$</td>
<td>2.3</td>
<td>6</td>
<td>V</td>
</tr>
<tr>
<td>$V_S$</td>
<td>$V_{IN} + 0.5$</td>
<td>18.5</td>
<td>V</td>
</tr>
<tr>
<td>$T_A$</td>
<td>–40</td>
<td>105</td>
<td>°C</td>
</tr>
<tr>
<td>$T_J$</td>
<td>–40</td>
<td>125</td>
<td>°C</td>
</tr>
</tbody>
</table>

6.4 Thermal Information

<table>
<thead>
<tr>
<th>THERMAL METRIC(1)</th>
<th>DGK (VSSOP)</th>
<th>PW (TSSOP)</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{JA}$</td>
<td>189.3</td>
<td>183.3</td>
<td>°C/W</td>
</tr>
<tr>
<td>$R_{JC(top)}$</td>
<td>57.1</td>
<td>66.7</td>
<td>°C/W</td>
</tr>
<tr>
<td>$R_{JB}$</td>
<td>109.9</td>
<td>112.0</td>
<td>°C/W</td>
</tr>
<tr>
<td>$\psi_{JT}$</td>
<td>3.5</td>
<td>8.3</td>
<td>°C/W</td>
</tr>
<tr>
<td>$\psi_{JB}$</td>
<td>108.3</td>
<td>110.3</td>
<td>°C/W</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

$V_{IN} = 3.3$ V, $EN = IN$, $V_S = 12$ V, $T_A = –40$°C to +105°C, typical values are at $T_A = 25$°C (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>$V_{IN}$</td>
<td>Input voltage range</td>
<td>2.3</td>
<td></td>
<td>6</td>
<td>V</td>
</tr>
<tr>
<td>$I_Q$</td>
<td>Operating quiescent current into IN</td>
<td>Device not switching, $V_{FB} = 1.3$ V</td>
<td>70</td>
<td>100</td>
<td>µA</td>
</tr>
<tr>
<td>$I_{SDVIN}$</td>
<td>Shutdown current into IN</td>
<td>$EN = GND$</td>
<td>1</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>UVLO</td>
<td>Undervoltage lockout threshold</td>
<td>$V_{IN}$ falling</td>
<td>2.2</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$T_SD$</td>
<td>Thermal shutdown</td>
<td>Temperature rising, $T_J$</td>
<td>150</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>$T_{SD(HYS)}$</td>
<td>Thermal shutdown hysteresis</td>
<td>14</td>
<td></td>
<td>°C</td>
<td></td>
</tr>
</tbody>
</table>

LOGIC SIGNALS EN, FREQ

<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>$V_{IH}$</td>
<td>High level input voltage</td>
<td>$V_{IN} = 2.3$ V to 6 V</td>
<td>2</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$V_L$</td>
<td>Low level input voltage</td>
<td>$V_{IN} = 2.3$ V to 6 V</td>
<td>0.5</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$I_{IL}$</td>
<td>Input leakage current</td>
<td>$EN = FREQ = GND$</td>
<td>0.1</td>
<td></td>
<td>µA</td>
</tr>
</tbody>
</table>

BOOST CONVERTER

<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>$V_S$</td>
<td>Boost output voltage</td>
<td>$V_{IN} + 0.5$</td>
<td>18.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$V_{FB}$</td>
<td>Feedback regulation voltage</td>
<td>1.230</td>
<td>1.238</td>
<td>1.246</td>
<td>V</td>
</tr>
<tr>
<td>$g_m$</td>
<td>Transconductance error amplifier</td>
<td>107</td>
<td></td>
<td>µA/V</td>
<td></td>
</tr>
<tr>
<td>$I_{FB}$</td>
<td>Feedback input bias current</td>
<td>$V_{FB} = 1.238$ V Ω</td>
<td>0.1</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>$R_{DS(on)}$</td>
<td>N-channel MOSFET ON-resistance</td>
<td>$V_{IN} = V_{GS} = 5$ V, $I_{SW} =$ current limit</td>
<td>0.13</td>
<td>0.2</td>
<td>Ω</td>
</tr>
<tr>
<td>$I_{SS}$</td>
<td>Soft-start current</td>
<td>$V_{SS} = 1.238$ V</td>
<td>7</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>$f_{osc}$</td>
<td>Oscillator frequency</td>
<td>$FREQ = high$</td>
<td>0.9</td>
<td>1.2</td>
<td>1.5</td>
</tr>
<tr>
<td>Line regulation</td>
<td>$V_{IN} = 2.3$ V to 6 V, $I_{OUT} = 10$ mA</td>
<td>0.000</td>
<td>2</td>
<td>%/V</td>
<td></td>
</tr>
<tr>
<td>Load regulation</td>
<td>$V_{IN} = 3.3$ V, $I_{OUT} = 1$ mA to 400 mA</td>
<td>0.11</td>
<td></td>
<td>%/A</td>
<td></td>
</tr>
</tbody>
</table>
6.6 Typical Characteristics

The typical characteristics are measured with the 3.3-µH inductor for high-frequency (part number-7447789003) or 6.8-µH inductor for low frequency (part number-B82464G4) and the rectifier diode with part number SL22.

Table 1. Table of Graphs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Graph Description</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>I_{OUT(max)}</td>
<td>Maximum load current vs Input voltage at high frequency (1.2 MHz)</td>
<td>Figure 1</td>
</tr>
<tr>
<td></td>
<td>Maximum load current vs Input voltage at low frequency (650 kHz)</td>
<td>Figure 2</td>
</tr>
<tr>
<td>\eta</td>
<td>Efficiency vs Load current, ( V_S = 12 \text{ V}, V_{IN} = 3.3 \text{ V} )</td>
<td>Figure 3</td>
</tr>
<tr>
<td></td>
<td>Efficiency vs Load current, ( V_S = 9 \text{ V}, V_{IN} = 3.3 \text{ V} )</td>
<td>Figure 4</td>
</tr>
<tr>
<td>Supply current</td>
<td>vs Supply voltage</td>
<td>Figure 5</td>
</tr>
<tr>
<td>Frequency</td>
<td>vs Load current</td>
<td>Figure 6</td>
</tr>
<tr>
<td></td>
<td>vs Supply voltage</td>
<td>Figure 7</td>
</tr>
</tbody>
</table>

Figure 1. Maximum Load Current vs Input Voltage

Figure 2. Maximum Load Current vs Input Voltage

Figure 3. Efficiency vs Load Current, \( V_S = 12 \text{ V}, V_{IN} = 3.3 \text{ V} \)

Figure 4. Efficiency vs Load Current, \( V_S = 9 \text{ V}, V_{IN} = 3.3 \text{ V} \)
Figure 5. Supply Current vs Supply Voltage

Figure 6. Frequency vs Load Current

Figure 7. Frequency vs Supply Voltage
7 Detailed Description

7.1 Overview

The TPS61085T boost converter is designed for output voltages up to 18.5 V with a switch-peak current limit of 2 A minimum. The device, which operates in a current mode scheme with quasi-constant frequency, is externally compensated for maximum flexibility and stability. The switching frequency is selectable between 650 kHz or 1.2 MHz and the minimum input voltage is 2.3 V. To control the inrush current at start-up, a soft-start pin is available.

The TPS61085T’s boost converter’s novel topology using adaptive OFF-time provides superior load and line transient responses and operates also over a wider range of applications than conventional converters.

The selectable switching frequency offers the possibility to optimize the design either for the use of small sized components (1.2 MHz) or for higher system efficiency (650 kHz). However, the frequency changes slightly because the voltage drop across the $R_{DS(on)}$ has some influence on the current and voltage measurement and thus on the ON-time (the OFF-time remains constant).

Depending on the load current, the converter operates in continuous conduction mode (CCM), discontinuous conduction mode (DCM), or pulse skip mode to maintain the output voltage.

7.2 Functional Block Diagram
7.3 Feature Description

7.3.1 Soft Start
The boost converter has an adjustable soft start to prevent high inrush current during start-up. To minimize the inrush current during start-up an external capacitor connected to the soft-start pin SS is used to slowly ramp up the internal current limit of the boost converter when charged with a constant current. When the EN pin is pulled high, the soft-start capacitor ($C_{SS}$) is immediately charged to 0.3 V. The capacitor is then charged at a constant current of 10 µA typically until the output of the boost converter $V_S$ has reached its power good threshold (90% of $V_S$ nominal value). During this time, the SS voltage directly controls the peak inductor current, starting with 0 A at $V_{SS} = 0.3$ V up to the full current limit at $V_{SS} \approx 800$ mV. The maximum load current is available after the soft start is completed. The larger the capacitor the slower the ramp of the current limit and the longer the soft-start time. A 100-nF capacitor is usually sufficient for most of the applications. When the EN pin is pulled low, the soft-start capacitor is discharged to ground.

7.3.2 Frequency Select Pin (FREQ)
The frequency select pin FREQ allows to set the switching frequency of the device to 650 kHz (FREQ = low) or 1.2 MHz (FREQ = high). Higher switching frequency improves load transient response but reduces slightly the efficiency. The other benefits of higher switching frequency are a lower output ripple voltage and smaller inductor size. Usually, TI recommends using 1.2-MHz switching frequency unless light-load efficiency is a major concern.

7.3.3 Undervoltage Lockout (UVLO)
To avoid misoperation of the device at low input voltages an undervoltage lockout is included that disables the device, if the input voltage falls below 2.2 V.

7.3.4 Thermal Shutdown
A thermal shutdown is implemented to prevent damages due to excessive heat and power dissipation. Typically the thermal shutdown threshold is at $T_J = 150^\circ$C. When the thermal shutdown is triggered the device stops switching until the temperature falls below typically $T_J = 136^\circ$C. Then the device starts switching again.

7.3.5 Overvoltage Prevention
If overvoltage is detected on the FB pin (typically 3% above the nominal value of 1.238 V) the part stops switching immediately until the voltage on this pin drops to its nominal value. This prevents overvoltage on the output and secures the circuits connected to the output from excessive overvoltage.

7.4 Device Functional Modes
The converter operates in continuous conduction mode (CCM) as soon as the input current increases above half the ripple current in the inductor. For lower load currents it switches into discontinuous conduction mode (DCM). If the load is further reduced, the part starts to skip pulses to maintain the output voltage.
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
With the TPS61085T device, a boost regulator with an output voltage of up to 18.5 V can be designed with input voltage ranging from 2.3 V to 6 V. The TPS61085T device has a peak switch current limit of 2 A minimum. The device, which operates in a current mode scheme and uses simple external compensation scheme for maximum flexibility and stability. Selectable switching frequency allows the regulator to be optimized either for smaller size (1.2 MHz) or for higher system efficiency (650 KHz). A dedicated soft-start (SS) pin allows the designer to control the inrush current at start-up.

The following section provides a step-by-step design approach for configuring the TPS61085T as a voltage regulating boost converter.

8.2  Typical Application

![Diagram of typical application](image)

Figure 8. Typical Application, 3.3 V to 12 V (\(f_{\text{sw}} = 1.2 \text{ MHz}\))

8.2.1  Design Requirements
Table 2 lists the design parameters for this application example.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage</td>
<td>3.3 V ± 20%</td>
</tr>
<tr>
<td>Output voltage</td>
<td>12 V</td>
</tr>
<tr>
<td>Output current</td>
<td>600 mA</td>
</tr>
<tr>
<td>Switching frequency</td>
<td>1.2 MHz</td>
</tr>
</tbody>
</table>
8.2.2 Detailed Design Procedure

The first step in the design procedure is to verify that the maximum possible output current of the boost converter supports the specific application requirements. A simple approach is to estimate the converter efficiency, by taking the efficiency numbers from the provided efficiency curves or to use a worst-case assumption for the expected efficiency, for example, 90%.

1. Duty cycle:

\[ D = 1 - \frac{V_{IN} \times \eta}{V_S} \]  

(1)

2. Maximum output current:

\[ I_{out} = \left( I_{swpeak} - \frac{\Delta I_L}{2} \right) \times (1 - D) \]  

(2)

3. Peak switch current:

\[ I_{swpeak} = \frac{\Delta I_L}{2} + \frac{I_{out}}{1 - D} \]

where

\[ \Delta I_L = \frac{V_{IN} \times D}{f_s \times L} \]

- \( I_{swpeak} \) = converter switch current (minimum switch current limit = 2 A)
- \( f_s \) = Converter switching frequency (typically 1.2 MHz)
- \( L \) = Selected inductor value
- \( \eta \) = Estimated converter efficiency (please use the number from the efficiency plots or 90% as an estimation)
- \( \Delta I_L \) = Inductor peak-to-peak ripple current

The peak switch current is the steady-state peak switch current that the integrated switch, inductor, and external Schottky diode must be able to handle. The calculation must be done for the minimum input voltage where the peak switch current is the highest.

8.2.2.1 Inductor Selection

The TPS61085T is designed to work with a wide range of inductors. The main parameter for the inductor selection is the saturation current of the inductor which must be higher than the peak switch current as calculated in Detailed Design Procedure with additional margin to cover for heavy load transients. An alternative, more conservative option is to choose an inductor with a saturation current at least as high as the maximum switch current limit of 3.2 A. The other important parameter is the inductor DC resistance. Usually, the lower the DC resistance the higher the efficiency. It is important to note that the inductor DC resistance is not the only parameter determining the efficiency. Especially for a boost converter where the inductor is the energy storage element, the type and core material of the inductor influences the efficiency as well. At high switching frequencies of 1.2-MHz inductor core losses, proximity effects and skin effects become more important. Usually, an inductor with a larger form factor gives higher efficiency. The efficiency difference between different inductors can vary between 2% to 10%. For the TPS61085T, inductor values between 3 µH and 6 µH are a good choice with a switching frequency of 1.2 MHz, typically 3.3 µH. At 650 kHz, TI recommends inductors between 6 µH and 13 µH, typically 6.8 µH. Table 3 shows a few inductors. Customers must verify and validate these components for suitability with their application before using them.

Typically, TI recommends the inductor current ripple is below 20% of the average inductor current. Calculate the inductor value using Equation 4.
\[ L = \left( \frac{V_{IN}}{V_S} \right)^2 \times \left( \frac{V_S - V_{IN}}{I_{out\_max} \times f} \right) \times \left( \frac{\eta}{0.35} \right) \]

where
- L is the inductor value
- \( V_{IN} \) is input voltage
- \( V_S \) is boost output voltage
- \( \eta \) is efficiency
- \( I_{out\_max} \) is the maximum output current
- \( f \) is frequency

### Table 3. Inductor Selection

<table>
<thead>
<tr>
<th>( L ) (( \mu )H)</th>
<th>SUPPLIER</th>
<th>COMPONENT CODE</th>
<th>SIZE (L×W×H mm)</th>
<th>DCR TYP (mΩ)</th>
<th>Isat (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3</td>
<td>Sumida</td>
<td>CDH38D09</td>
<td>4 x 4 x 1</td>
<td>240</td>
<td>1.25</td>
</tr>
<tr>
<td>4.7</td>
<td>Sumida</td>
<td>CDPH36D13</td>
<td>5 x 5 x 1.5</td>
<td>155</td>
<td>1.36</td>
</tr>
<tr>
<td>3.3</td>
<td>Sumida</td>
<td>CDPH4D19F</td>
<td>5.2 x 5.2 x 2</td>
<td>33</td>
<td>1.5</td>
</tr>
<tr>
<td>3.3</td>
<td>Sumida</td>
<td>CDRH6D12</td>
<td>6.7 x 6.7 x 1.5</td>
<td>62</td>
<td>2.2</td>
</tr>
<tr>
<td>4.7</td>
<td>Würth Elektronik</td>
<td>7447785004</td>
<td>5.9 x 6.2 x 3.3</td>
<td>60</td>
<td>2.5</td>
</tr>
<tr>
<td>5</td>
<td>Coilcraft</td>
<td>MSS7341</td>
<td>7.3 x 7.3 x 4.1</td>
<td>24</td>
<td>2.9</td>
</tr>
</tbody>
</table>

### 8.2.2.2 Rectifier Diode Selection

To achieve high efficiency, a Schottky type must be used for the rectifier diode. The reverse voltage rating must be higher than the maximum output voltage of the converter. The averaged rectified forward current \( I_{avg} \), the Schottky diode requirement is rated for, is equal to the output current \( I_{out} \):

\[ I_{avg} = I_{out} \]

Usually a Schottky diode with 2-A maximum average rectified forward current rating is sufficient for most applications. The Schottky rectifier can be selected with lower forward current capability depending on the output current \( I_{out} \) but must be able to dissipate the power. The dissipated power is the average rectified forward current times the diode forward voltage.

\[ P_D = I_{avg} \times V_{forward} \]

Typically the diode must be able to dissipate around 500 mW depending on the load current and forward voltage. See Table 4 for few diode options. Customers must verify and validate these components for suitability with their application before using them.
### Table 4. Rectifier Diode Selection

<table>
<thead>
<tr>
<th>CURRENT RATING (Iavg)</th>
<th>Vf</th>
<th>Vforward / Iavg</th>
<th>SUPPLIER</th>
<th>COMPONENT CODE</th>
<th>PACKAGE TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>750 mA</td>
<td>20 V</td>
<td>0.425 V / 750 mA</td>
<td>Fairchild Semiconductor</td>
<td>FYV0704S</td>
<td>SOT-23</td>
</tr>
<tr>
<td>1 A</td>
<td>20 V</td>
<td>0.39 V / 1 A</td>
<td>NXP</td>
<td>PMEG2010AEH</td>
<td>SOD-123</td>
</tr>
<tr>
<td>1 A</td>
<td>20 V</td>
<td>0.52 V / 1 A</td>
<td>Vishay Semiconductor</td>
<td>B120</td>
<td>SMA</td>
</tr>
<tr>
<td>1 A</td>
<td>20 V</td>
<td>0.5 V / 1 A</td>
<td>Vishay Semiconductor</td>
<td>SS12</td>
<td>SMA</td>
</tr>
<tr>
<td>1 A</td>
<td>20 V</td>
<td>0.44 V / 1 A</td>
<td>Vishay Semiconductor</td>
<td>MSS1P2L</td>
<td>μ-SMP (Low Profile)</td>
</tr>
</tbody>
</table>

#### 8.2.2.3 Setting the Output Voltage

The output voltage is set by an external resistor divider. Typically, a minimum current of 50 μA flowing through the feedback divider gives good accuracy and noise covering. A standard low-side resistor of 18 kΩ is typically selected. The resistors are then calculated as:

\[
R_2 = \frac{V_{ref}}{70 \mu A} \approx 18 k\Omega \\
R_1 = R_2 \times \left( \frac{V_s}{V_{ref}} - 1 \right)
\]  

#### 8.2.2.4 Compensation (COMP)

The regulator loop must be compensated by adjusting the external components connected to the COMP pin. The COMP pin is the output of the internal transconductance error amplifier. Standard values of \(R_{COMP} = 13 k\Omega\) and \(C_{COMP} = 3.3 \text{nF}\) works for the majority of the applications.

See Table 5 for dedicated compensation networks giving an improved load transient response. Equation 8 can be used to calculate \(R_{COMP}\) and \(C_{COMP}\):

\[
R_{COMP} = \frac{110 \cdot V_s \cdot V_s \cdot C_{OUT}}{L \cdot I_{OUT}} \\
C_{COMP} = \frac{V_s \cdot C_{OUT}}{7.5 \cdot I_{OUT} \cdot R_{COMP}}
\]  

### Table 5. Recommended Compensation Network Values at High/Low Frequency

<table>
<thead>
<tr>
<th>FREQUENCY</th>
<th>L</th>
<th>(V_s)</th>
<th>(V_{in} \pm 20%)</th>
<th>(R_{COMP})</th>
<th>(C_{COMP})</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High (1.2 MHz)</strong></td>
<td>3.3 μH</td>
<td>15 V</td>
<td>5 V</td>
<td>82 kΩ</td>
<td>1.1 nF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.3 V</td>
<td>75 kΩ</td>
<td>1.6 nF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>12 V</td>
<td>51 kΩ</td>
<td>1.1 nF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.3 V</td>
<td>47 kΩ</td>
<td>1.6 nF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9 V</td>
<td>30 kΩ</td>
<td>1.1 nF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.3 V</td>
<td>27 kΩ</td>
<td>1.6 nF</td>
</tr>
<tr>
<td><strong>Low (650 kHz)</strong></td>
<td>6.8 μH</td>
<td>15 V</td>
<td>5 V</td>
<td>43 kΩ</td>
<td>2.2 nF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.3 V</td>
<td>39 kΩ</td>
<td>3.3 nF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>12 V</td>
<td>27 kΩ</td>
<td>2.2 nF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.3 V</td>
<td>24 kΩ</td>
<td>3.3 nF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9 V</td>
<td>15 kΩ</td>
<td>2.2 nF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.3 V</td>
<td>13 kΩ</td>
<td>3.3 nF</td>
</tr>
</tbody>
</table>
Table 5 gives conservatives $R_{\text{COMP}}$ and $C_{\text{COMP}}$ values for certain inductors, input and output voltages providing a very stable system. For a faster response time, a higher $R_{\text{COMP}}$ value can be used to enlarge the bandwidth, as well as a slightly lower value of $C_{\text{COMP}}$ to keep enough phase margin. These adjustments must be performed in parallel with the load transient response monitoring of TPS61085T.

8.2.2.5 Input Capacitor Selection

For good input voltage filtering, TI recommends low-ESR ceramic capacitors. TPS61085T has an analog input (IN). Therefore, TI highly recommends placing a 1-uF bypass capacitor as close as possible to the IC from IN to GND.

One 10-µF ceramic input capacitor is sufficient for most of the applications. For better input voltage filtering, this value can be increased. Refer to Table 6 and typical applications for input capacitor recommendations. Customers must verify and validate these components for suitability with their application before using them.

8.2.2.6 Output Capacitor Selection

For best output voltage filtering, TI recommends a low ESR output capacitor like ceramic capacitor. Two 10-µF ceramic output capacitors (or one 22-µF) work for most of the applications. Higher capacitor values can be used to improve the load transient response.

Pay attention to the derating of capacitor value with the DC voltage.

### Table 6. Rectifier Input and Output Capacitor Selection

<table>
<thead>
<tr>
<th>CAPACITOR</th>
<th>VOLTAGE RATING</th>
<th>SUPPLIER</th>
<th>COMPONENT CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_{\text{IN}}$</td>
<td>10 µF/1206</td>
<td>16 V</td>
<td>Taiyo Yuden</td>
</tr>
<tr>
<td>IN bypass</td>
<td>1 µF/0603</td>
<td>16 V</td>
<td>Taiyo Yuden</td>
</tr>
<tr>
<td>$C_{\text{OUT}}$</td>
<td>10 µF/1206</td>
<td>25 V</td>
<td>Taiyo Yuden</td>
</tr>
</tbody>
</table>

8.2.3 Application Curves

![Figure 9. PWM Switching Discontinuous Conduction Mode](image1)

![Figure 10. PWM Switching Continuous Conduction Mode](image2)
8.3 System Examples

Figure 14 to Figure 21 show application circuit examples using the TPS61085T device. These circuits must be fully validated and tested by customers before using these circuits in their designs. TI does not warrant the accuracy or completeness of these circuits, nor does TI accept any responsibility for them.
System Examples (continued)

Figure 14. Typical Application, 3.3 V to 12 V ($f_{sw} = 650$ kHz)

Figure 15. Typical Application, 3.3 V to 9 V ($f_{sw} = 1.2$ MHz)
System Examples (continued)

Figure 16. Typical Application, 3.3 V to 9 V (f_{sw} = 650 kHz)

Figure 17. Typical Application With External Load Disconnect Switch
Figure 18. Typical Application 3.3 V to 9 V (f_{sw} = 1.2 MHz) for TFT LCD With External Charge Pumps (VGH, VGL)

Figure 19. Simple Application (3.3-V Input – f_{sw} = 650 kHz) for wLED Supply (3S3P) (With Optional Clamping Zener Diode)
System Examples (continued)

Figure 20. Simple Application (3.3-V Input \( f_{SW} = 650 \text{ kHz} \)) for wLED Supply (3S3P) With Adjustable Brightness Control using a PWM Signal on the Enable Pin (With Optional Clamping Zener Diode)

Figure 21. Simple Application (3.3-V Input \( f_{SW} = 650 \text{ kHz} \)) for wLED Supply (3S3P) With Adjustable Brightness Control Using an Analog Signal on the Feedback Pin (With Optional Clamping Zener Diode)

9 Power Supply Recommendations

The TPS61085T is designed to operate from an input voltage supply range from 2.3 V to 6 V. The required power supply for the TPS61085T must have a current rating according to the output voltage and output current of the TPS61085T.
10 Layout

10.1 Layout Guidelines

For all switching power supplies, the layout is an important step in the design, especially at high peak currents and high switching frequencies. If the layout is not carefully done, the regulator could show stability problems as well as EMI problems.

provides an example of layout design with the TPS61085T device.

• Use wide and short traces for the main current path and for the power ground tracks.
• The input capacitor, output capacitor, and the inductor must be placed as close as possible to the IC.
• Use a common ground node for power ground and a different one for control ground to minimize the effects of ground noise. Connect these ground nodes at the GND terminal of the IC.
• The most critical current path for all boost converters is from the switching FET, through the rectifier diode, then the output capacitors, and back to ground of the switching FET. Therefore, the output capacitors and their traces must be placed on the same board layer as the IC and as close as possible between the SW pin and the GND terminal of the IC.

10.2 Layout Example

Figure 22. TPS61085T Layout Example

www.ti.com
SLVSA418—NOVEMBER 2009–REVISED JULY 2016

Product Folder Links: TPS61085T
11 Device and Documentation Support

11.1 Device Support

11.1.1 Third-Party Products Disclaimer
TI'S PUBLICATION OF INFORMATION REGARDING THIRD-PARTY PRODUCTS OR SERVICES DOES NOT
CONSTITUTE AN ENDORSEMENT REGARDING THE SUITABILITY OF SUCH PRODUCTS OR SERVICES
OR A WARRANTY, REPRESENTATION OR ENDORSEMENT OF SUCH PRODUCTS OR SERVICES, EITHER
ALONE OR IN COMBINATION WITH ANY TI PRODUCT OR SERVICE.

11.2 Receiving Notification of Documentation Updates
To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper
right corner, click on Alert me to register and receive a weekly digest of any product information that has
changed. For change details, review the revision history included in any revised document.

11.3 Community Resources
The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective
contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of
Use.

TI E2E™ Online Community TI's Engineer-to-Engineer (E2E) Community. Created to foster collaboration
among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help
solve problems with fellow engineers.

Design Support TI's Design Support Quickly find helpful E2E forums along with design support tools and
contact information for technical support.

11.4 Trademarks
E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

11.5 Electrostatic Discharge Caution
These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam
during storage or handling to prevent electrostatic damage to the MOS gates.

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

12 Mechanical, Packaging, and Orderable Information
The following pages include mechanical, packaging, and orderable information. This information is the most
current data available for the designated devices. This data is subject to change without notice and revision of
this document. For browser-based versions of this data sheet, refer to the left-hand navigation.
## PACKAGING INFORMATION

<table>
<thead>
<tr>
<th>Orderable Device</th>
<th>Status</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Package Qty</th>
<th>Eco Plan</th>
<th>Lead/Ball Finish</th>
<th>MSL Peak Temp</th>
<th>Op Temp (°C)</th>
<th>Device Marking</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS61085TDGKR</td>
<td>ACTIVE</td>
<td>VSSOP</td>
<td>DGK</td>
<td>8</td>
<td>2000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 105</td>
<td>PTQI</td>
<td>Samples</td>
</tr>
<tr>
<td>TPS61085TPWR</td>
<td>ACTIVE</td>
<td>TSSOP</td>
<td>PW</td>
<td>8</td>
<td>2000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 105</td>
<td>61085T</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.

**OBSOLUTE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check [http://www.ti.com/productcontent](http://www.ti.com/productcontent) for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material).

(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.

(6) 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.

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.
### TAPE AND REEL INFORMATION

#### TAPE DIMENSIONS

- **A0**: Dimension designed to accommodate the component width
- **B0**: Dimension designed to accommodate the component length
- **K0**: Dimension designed to accommodate the component thickness
- **W**: Overall width of the carrier tape
- **P1**: Pitch between successive cavity centers

**Reel Width (W1)**

**Pocket Quadrants**

**Sprocket Holes**

**User Direction of Feed**

---

### PACKAGE MATERIALS 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>
</tr>
</thead>
<tbody>
<tr>
<td>TPS61085TDGKR</td>
<td>VSSOP</td>
<td>DGK</td>
<td>8</td>
<td>2000</td>
<td>330.0</td>
<td>12.4</td>
<td>5.3</td>
<td>3.4</td>
<td>1.4</td>
<td>8.0</td>
<td>12.0</td>
<td>Q1</td>
</tr>
<tr>
<td>TPS61085TPWR</td>
<td>TSSOP</td>
<td>PW</td>
<td>8</td>
<td>2000</td>
<td>330.0</td>
<td>12.4</td>
<td>7.0</td>
<td>3.6</td>
<td>1.6</td>
<td>8.0</td>
<td>12.0</td>
<td>Q1</td>
</tr>
</tbody>
</table>

*All dimensions are nominal.*
<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS61085TDGKR</td>
<td>VSSOP</td>
<td>DGK</td>
<td>8</td>
<td>2000</td>
<td>367.0</td>
<td>367.0</td>
<td>35.0</td>
</tr>
<tr>
<td>TPS61085TPWR</td>
<td>TSSOP</td>
<td>PW</td>
<td>8</td>
<td>2000</td>
<td>367.0</td>
<td>367.0</td>
<td>35.0</td>
</tr>
</tbody>
</table>

*All dimensions are nominal*
DGK (S-PDSO-G8) PLASTIC SMALL-OUTLINE PACKAGE

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
E. Falls within JEDEC MO-187 variation AA, except interlead flash.

4073329/E 05/06

Texas Instruments
www.ti.com
NOTES:  
A. All linear dimensions are in millimeters. 
B. This drawing is subject to change without notice. 
C. Publication IPC-7351 is recommended for alternate designs. 
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations. 
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.
NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153, variation AA.
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.
Texas Instruments Incorporated (TI) reserves the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. TI's published terms of sale for semiconductor products (http://www.ti.com/sc/docs/stdterms.htm) apply to the sale of packaged integrated circuit products that TI has qualified and released to market. Additional terms may apply to the use or sale of other types of TI products and services.

Reproduction of significant portions of TI information in TI data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such reproduced documentation. Information of third parties may be subject to additional restrictions. Resale of TI products or services with statements differing from or beyond the parameters stated by TI for that product or service voids all express and/or implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyers and others who are developing systems that incorporate TI products (collectively, “Designers”) understand and agree that Designers remain responsible for using their independent analysis, evaluation and judgment in designing their applications and that Designers have full and exclusive responsibility to assure the safety of Designers’ applications and compliance of their applications (and of all TI products used in or for Designers’ applications) with all applicable regulations, laws and other applicable requirements. Designer represents that, with respect to their applications, Designer has all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. Designer agrees that prior to using or distributing any applications that include TI products, Designer will thoroughly test such applications and the functionality of such TI products as used in such applications.

TI's provision of technical, application or other design advice, quality characterization, reliability data or other services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, “TI Resources”) are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using TI Resources in any way, Designer (individually or, if Designer is acting on behalf of a company, Designer's company) agrees to use any particular TI Resource solely for this purpose and subject to the terms of this Notice.

TI’s provision of TI Resources does not expand or otherwise alter TI’s applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

Designer is authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY TECHNOLOGY, INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED “AS IS” AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS. TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY DESIGNER AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

Unless TI has explicitly designated an individual product as meeting the requirements of a particular industry standard (e.g., ISO/TS 16949 and ISO 26262), TI is not responsible for any failure to meet such industry standard requirements.

Where TI specifically promotes products as facilitating functional safety or as compliant with industry functional safety standards, such products are intended to help enable customers to design and create their own applications that meet applicable functional safety standards and requirements. Using products in an application does not by itself establish any safety features in the application. Designers must ensure compliance with safety-related requirements and standards applicable to their applications. Designers may not use any TI products in life-critical medical equipment unless authorized officers of the parties have executed a special contract specifically governing such use. Life-critical medical equipment is medical equipment where failure of such equipment would cause serious bodily injury or death (e.g., life support, pacemakers, defibrillators, heart pumps, neurostimulators, and implantables). Such equipment includes, without limitation, all medical devices identified by the U.S. Food and Drug Administration as Class III devices and equivalent classifications outside the U.S.

TI may expressly designate certain products as completing a particular qualification (e.g., Q100, Military Grade, or Enhanced Product), Designers agree that it has the necessary expertise to select the product with the appropriate qualification designation for their applications and that proper product selection is at Designers’ own risk. Designers are solely responsible for compliance with all legal and regulatory requirements in connection with such selection.

Designer will fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of Designer’s non-compliance with the terms and provisions of this Notice.