28V, 0.5A Step-Down Converter with Sleep Mode

Check for Samples: TPS62175, TPS62177

FEATURES

- **DCS-Control™ Topology**
- **Input Voltage Range 4.75 to 28V**
- **Quiescent Current typ. 4.8µA (Sleep Mode)**
- **100% Duty Cycle Mode**
- **Active Output Discharge**
- **Power Good Output**
- **Output Current of 500mA**
- **Output Voltage Range 1V to 6V**
- **Switching Frequency of Typically 1MHz**
- **Seamless Power Save Mode Transition**
- **Undervoltage Lockout**
- **Short Circuit Protection**
- **Over Temperature Protection**
- **Available in 2 x 3 mm 10-pin WSON Package**

APPLICATIONS

- **General 12V/24V Point Of Load Supply**
- **Ultra Mobile PC, Embedded PC**
- **Low Power Supply for Microprocessor**
- **High Efficiency LDO Alternative**
- **Industrial Sensors**

DESCRIPTION

The TPS62175/7 is a high efficiency synchronous step-down DC-DC converter, based on the DCS-Control™ topology.

With a wide operating input voltage range of 4.75 to 28V, the device is ideally suited for systems powered from multi cell Li-Ion as well as 12V and even higher intermediate supply rails, providing up to 500mA output current.

The TPS62175/7 automatically enters Power Save Mode at light loads, to maintain high efficiency across the whole load range. As well, it features a Sleep Mode to supply applications with advanced power save modes like ultra low power micro controllers. The Power Good output may be used for power sequencing and/or Power On Reset.

The device features a typical quiescent current of 22uA in normal mode and 4.8uA in Sleep Mode. In Sleep Mode, the efficiency at very low load currents can be increased by as much as 20%. In shutdown mode, the shutdown current is less than 2uA and the output is actively discharged.

The TPS62175/7, available in an adjustable and a fixed output voltage version, is packaged in a small 2x3mm 10-pin WSON package.

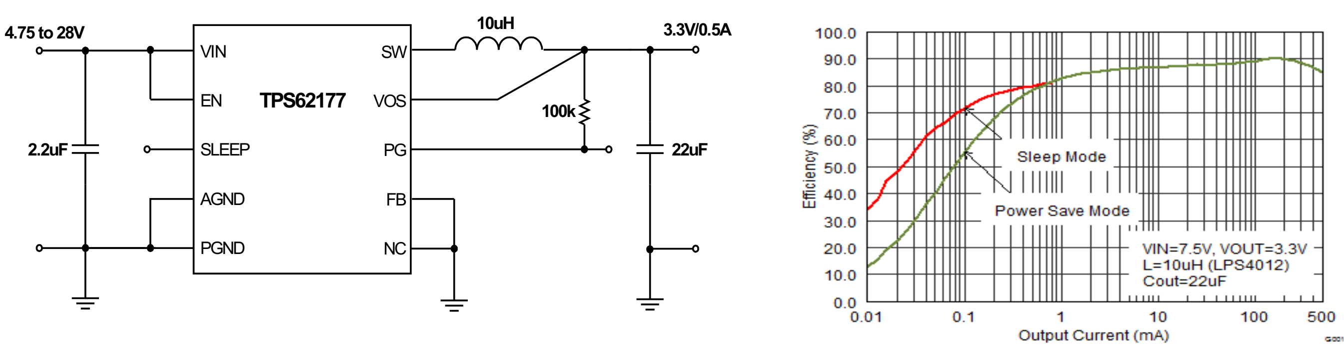


Figure 1. Typical Application and Efficiency

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

DCS-Control is a trademark of Texas Instruments.

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.

ORDERING INFORMATION(1)(2)

T_A	OUTPUT VOLTAGE (2)	PART NUMBER	PACKAGE	ORDERING	PACKAGE MARKING
-40°C to 85°C	adjustable	TPS62175	10-Pin WSON	TPS62175DQC	62175
	3.3 V	TPS62177		TPS62177DQC	62177

(1) For detailed ordering information please check the PACKAGE OPTION ADDENDUM section at the end of this datasheet.
(2) Contact the factory to check availability of other output voltage or current limit versions.

ABSOLUTE MAXIMUM RATINGS(1)

		MIN	MAX	UNIT
Pin Voltage Range(2)	VIN	-0.3	30	V
	EN, SW	-0.3	V_{IN}+0.3	V
	FB, PG, VOS, SLEEP, NC	-0.3	7	V
Power Good Sink Current	PG		10	mA
Temperature Range	Operating junction temperature, T_J	-40	125	°C
	Storage temperature, T_{stg}	-65	150	
ESD rating(3)	HBM Human body model		2	kV
	CDM Charge device model		0.5	kV

(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 my affect device reliability.
(2) All voltages are with respect to network ground terminal.
(3) ESD testing is performed according to the respective JESD22 JEDEC standard.

THERMAL INFORMATION

THERMAL METRIC(1)		TPS62175/7	UNITS
		DQC (10) PINS	
θ_{JA}	Junction-to-ambient thermal resistance	61.6	°C/W
$\theta_{JC(TOP)}$	Junction-to-case(top) thermal resistance	65.5	
θ_{JB}	Junction-to-board thermal resistance	22.5	
ψ_{JT}	Junction-to-top characterization parameter	1.4	
ψ_{JB}	Junction-to-board characterization parameter	22.4	
$\theta_{JC(BOTTOM)}$	Junction-to-case(bottom) thermal resistance	5.3	

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.

RECOMMENDED OPERATING CONDITIONS

	MIN	MAX	UNIT
Supply Voltage, V_{IN}	4.75	28	V
Operating free air temperature, T_A	–40	85	°C
Operating junction temperature, T_J	–40	125	°C

ELECTRICAL CHARACTERISTICS

over free-air temperature range (T_A=-40°C to +85°C) and V_{IN}=4.75 to 28V. Typical values at V_{IN}=12V and T_A=25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
SUPPLY						
V_{IN}	Input Voltage Range		4.75		28	V
I_Q	Operating Quiescent Current	EN=High, SLEEP=High, I_{OUT}=0mA, device not switching		22	36	µA
I_{Q_SLEEP}	Sleep Mode Quiescent Current	EN=High, SLEEP=Low, I_{OUT}=0mA, device not switching		4.8	10	µA
I_{SD}	Shutdown Current	EN=Low, current into VIN pin		1.5	5	µA
V_{UVLO}	Undervoltage Lockout Threshold	Rising Input Voltage	4.5	4.6	4.7	V
		Falling Input Voltage		2.9		V
T_{SD}	Thermal Shutdown Temperature	Rising Junction Temperature		150		°C
	Thermal Shutdown Hysteresis			20		
CONTROL (EN, PG, SLEEP)						
V_H	High Level Input Threshold Voltage (EN, SLEEP)		0.9			V
V_L	Low Level Input Threshold Voltage (EN, SLEEP)				0.3	V
I_{LKG_EN}	Input Leakage Current (EN)	EN=V_{IN}		5	300	nA
I_{LKG_SLEEP}	Input Leakage Current (SLEEP)	V_{SLEEP} = 3.3V		1.4		µA
V_{TH_PG}	Power Good Threshold Voltage	Rising (%V_{OUT})	93	96	99	%
		Falling (%V_{OUT})	87	90	93	
V_{OL_PG}	Power Good Output Low Voltage	I_{PG} = -2mA			0.3	V
I_{LKG_PG}	Input Leakage Current (PG)	V_{PG} = 5V		5	300	nA
POWER SWITCH						
$R_{DS(ON)}$	High-Side MOSFET ON-Resistance	V_{IN} ≥ 6V		850	1430	mΩ
	Low-Side MOSFET ON-Resistance	V_{IN} ≥ 6V		320	530	mΩ
I_{LIMF}	High-Side MOSFET Current Limit	Normal Operation	800	1000	1200	mA
		Startup Mode	450	525	600	
OUTPUT						
V_{OUT}	Output Voltage Range (TPS62175)	V_{IN} ≥ V_{OUT}	1		6	V
V_{REF}	Internal Reference Voltage			0.8		V
I_{OUT_SLEEP}	Output Current in Sleep Mode	SLEEP= Low, V_{OUT}=3.3V, L=10µH	15			mA
I_{LKG_FB}	Input Leakage Current (FB)	V_{FB}= 0.8V		1	100	nA

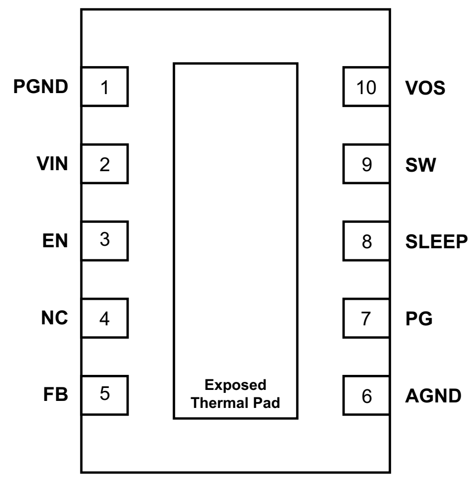
ELECTRICAL CHARACTERISTICS (continued)

over free-air temperature range (T_A=-40°C to +85°C) and V_{IN}=4.75 to 28V. Typical values at V_{IN}=12V and T_A=25°C (unless otherwise noted)

<table>
<tr><th colspan="2">PARAMETER</th><th colspan="3">TEST CONDITIONS</th><th>MIN</th><th>TYP</th><th>MAX</th><th>UNIT</th></tr>
<tr><td rowspan="10">V_{OUT}</td><td rowspan="7">Output Voltage Accuracy(1)</td><td rowspan="4">TPS62175 (adjustable Vout), $V_{IN} \geq V_{OUT}$ +1V</td><td colspan="2">PWM Mode</td><td>-1.8</td><td></td><td>1.8</td><td rowspan="7">%</td></tr>
<tr><td rowspan="2">Power Save Mode, L=10µH</td><td>$V_{OUT} \geq$ 2.5V, C_{OUT}=22µF</td><td>-1.8</td><td></td><td>3</td></tr>
<tr><td>V_{OUT} < 2.5V, C_{OUT}=44µF</td><td>-1.8</td><td></td><td>3.7</td></tr>
<tr><td>Sleep Mode, $I_{OUT} \leq$15mA</td><td>C_{OUT}=22µF, L=10µH</td><td>-1.6</td><td></td><td>2.9</td></tr>
<tr><td rowspan="3">TPS62177 (3.3V fixed Vout)</td><td colspan="2">PWM Mode</td><td>-2</td><td></td><td>2</td></tr>
<tr><td>Power Save Mode,</td><td rowspan="2">C_{OUT}=22µF, L=10µH</td><td>-2</td><td></td><td>2.9</td></tr>
<tr><td>Sleep Mode, $I_{OUT} \leq$15mA</td><td>-1.6</td><td></td><td>2.7</td></tr>
<tr><td>Output Discharge Resistance</td><td colspan="3">EN=Low</td><td></td><td>175</td><td></td><td>Ω</td></tr>
<tr><td>Load Regulation</td><td colspan="3">V_{OUT}=3.3V, PWM mode operation</td><td></td><td>0.02</td><td></td><td>%/A</td></tr>
<tr><td>Line Regulation</td><td colspan="3">V_{OUT}=3.3V, I_{OUT}= 500mA, PWM mode operation</td><td></td><td>0.015</td><td></td><td>%/V</td></tr>
</table>

(1) The output voltage accuracy in Power Save and Sleep Mode can be improved by increasing the output capacitor value, reducing the output voltage ripple (see APPLICATION INFORMATION section).

DEVICE INFORMATION

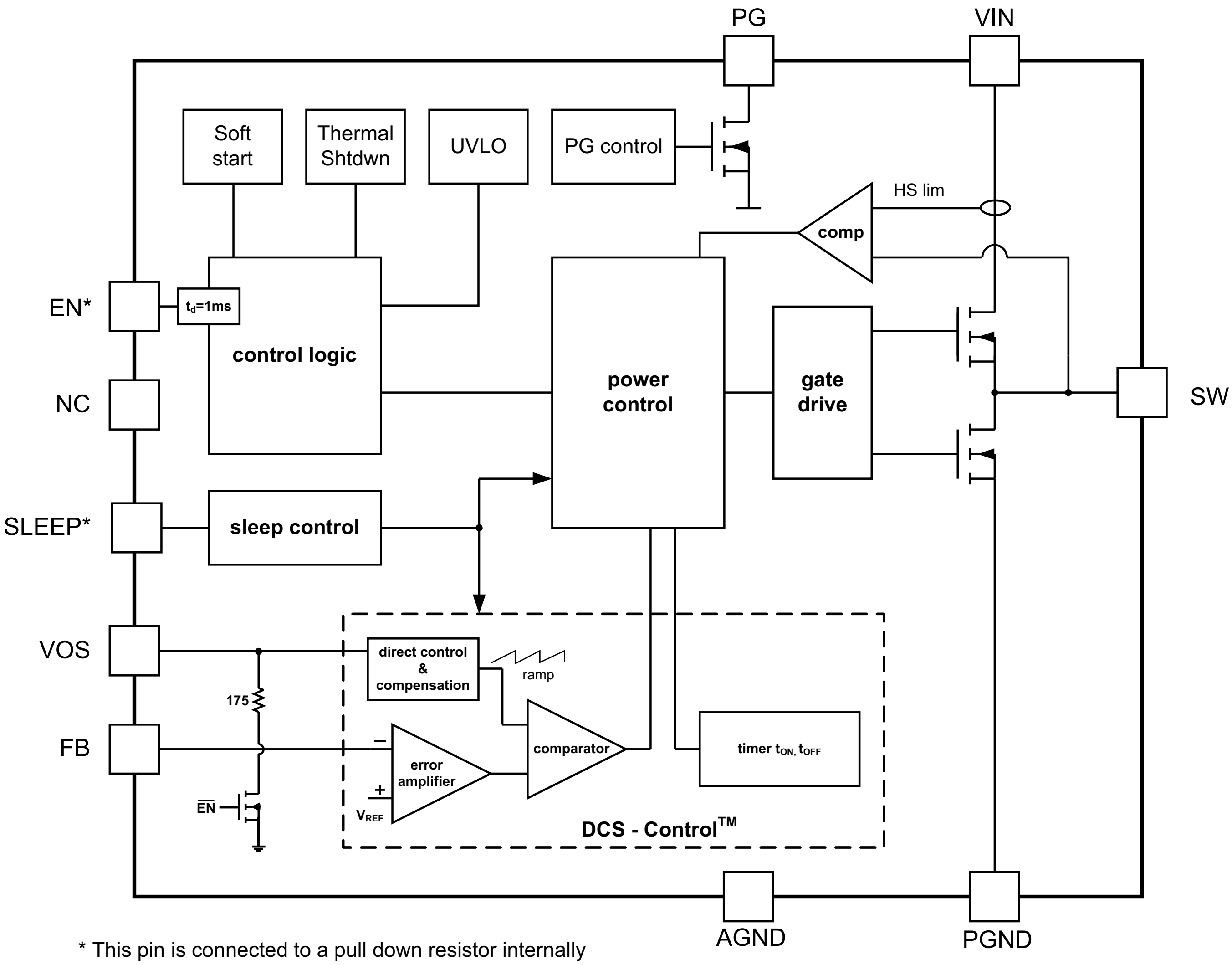


TERMINAL FUNCTIONS

PIN [(1)]		I/O	DESCRIPTION
NAME	NO.		
PGND	1		Power ground connection.
VIN	2	I	Supply voltage for the converter.
EN	3	I	Enable input (High=Enabled, Low= Disabled)
NC	4		This pin is recommended to be connected to AGND but can left be floating.
FB	5	I	Voltage feedback of adjustable version. Connect resistive divider to this pin. It is recommended to connect FB to AGND for fixed voltage versions for improved thermal performance.
AGND	6		Analog ground connection.
PG	7	O	Output power good. (open drain, requires pull-up resistor)
SLEEP	8	I	Sleep mode input (High=Normal Operation, Low=Sleep mode Operation). Can be operated dynamically during operation.
SW	9	O	Switch node, connected to the internal MOSFET switches. Connect inductor between SW and output capacitor.
VOS	10	I	Output voltage sense pin and connection for the control loop circuitry.
Exposed Thermal Pad			Must be connected to AGND and PGND. Must be soldered to achieve appropriate power dissipation and mechanical reliability.

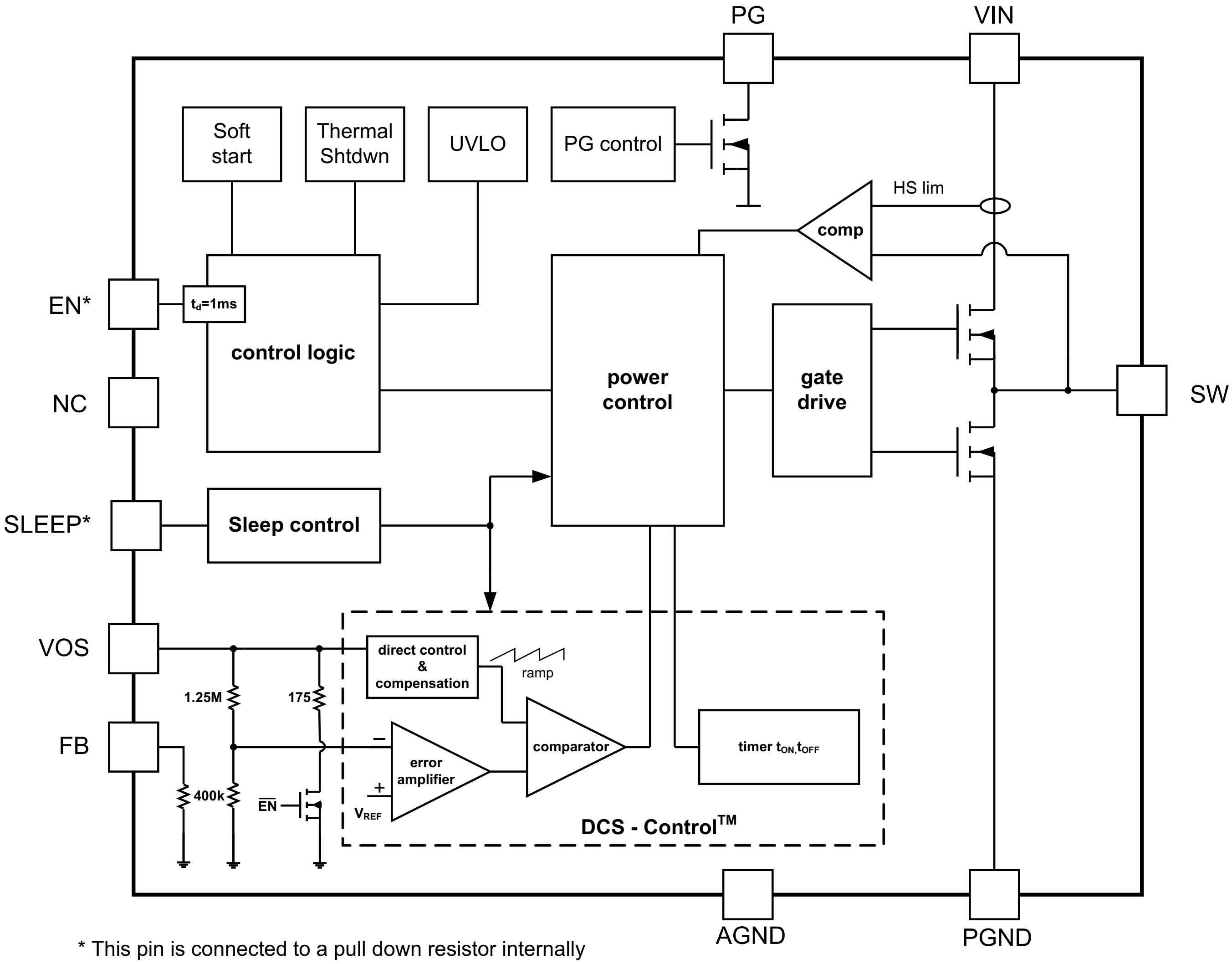
(1) For more information about connecting pins, see DETAILED DESCRIPTION and APPLICATION INFORMATION sections.

FUNCTIONAL BLOCK DIAGRAM



* This pin is connected to a pull down resistor internally (see Detailed Description section).

Figure 2. TPS62175 (adjustable output voltage)



* This pin is connected to a pull down resistor internally (see Detailed Description section).

Figure 3. TPS62177 (fixed output voltage)

PARAMETER MEASUREMENT INFORMATION

List of Components

REFERENCE	DESCRIPTION	MANUFACTURER
IC	28V, 0.5A Step-Down Converter, WSON	TPS62175DQC, Texas Instruments
L1	10uH, (4 x 4 x 1.2) mm	LPS4012, Coilcraft
Cin	2.2µF, 50V, Ceramic, 0805, X5R	Standard
Cout	22µF, 6.3V, Ceramic, 0805, X5R	Standard
R1	depending on Vout	
R2	depending on Vout	
R3	100kΩ, Chip, 0603, 1/16W, 1%	Standard

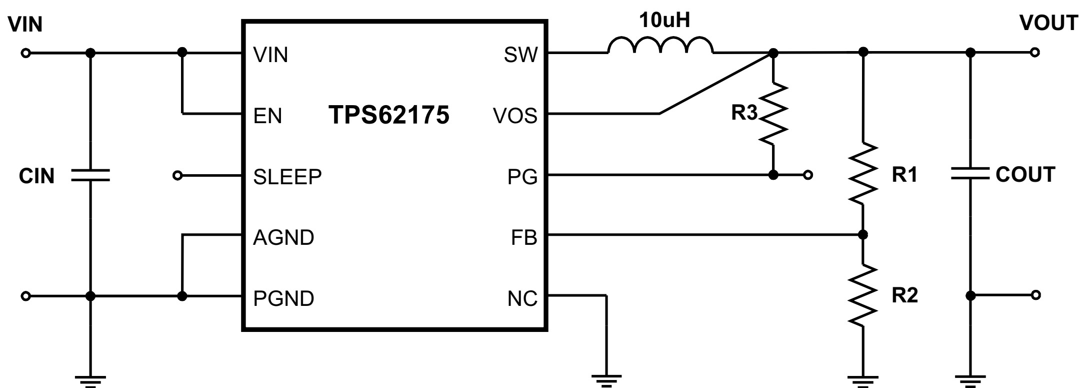


Figure 4. Measurement Setup

TYPICAL CHARACTERISTICS

Table of Graphs

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	Startup	41 - 43
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	Typical Operation (PWM Mode, Power Save Mode, Sleep Mode, Short Circuit)	45 - 52
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EFFICIENCY vs OUTPUT CURRENT

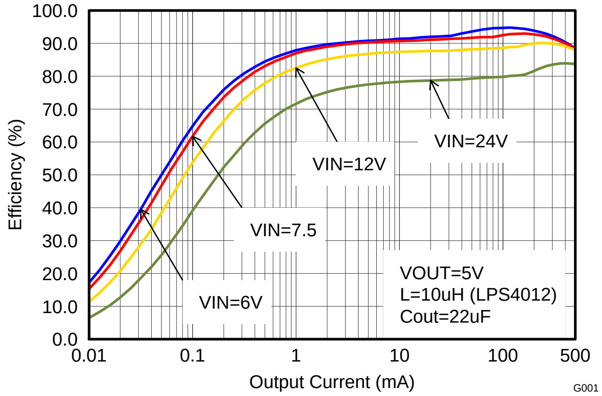

Figure 5. Vout=5V

EFFICIENCY vs INPUT VOLTAGE

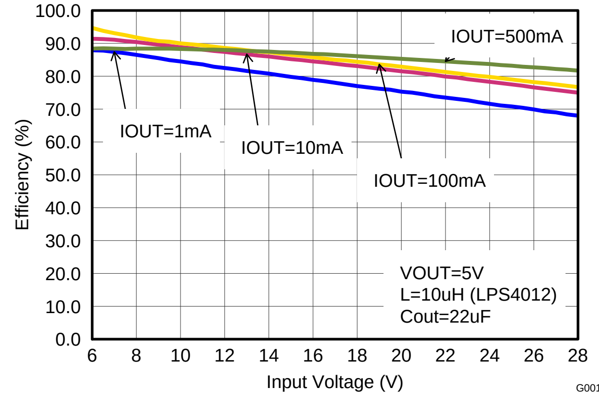

Figure 6. Vout=5V

EFFICIENCY vs OUTPUT CURRENT

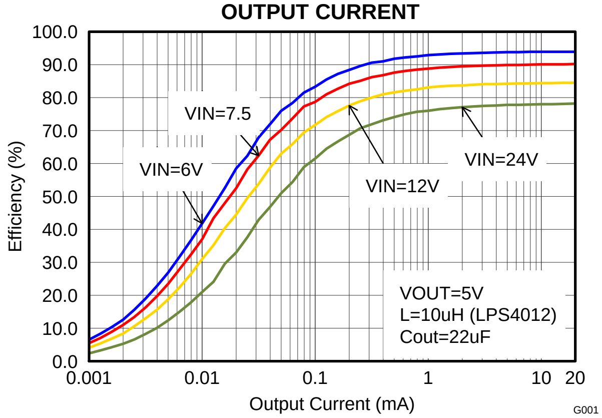

Figure 7. Vout=5V (Sleep Mode)

EFFICIENCY vs INPUT VOLTAGE

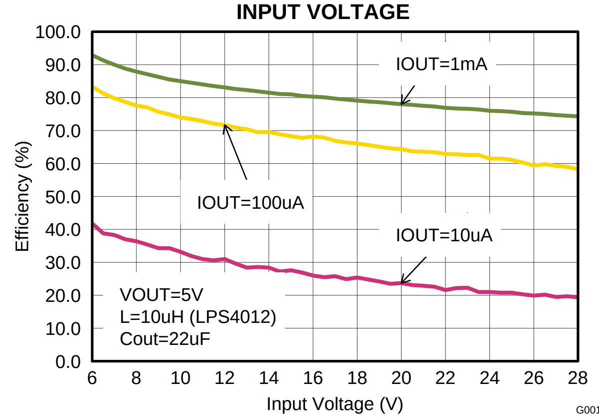

Figure 8. Vout=5V (Sleep Mode)

EFFICIENCY vs OUTPUT CURRENT

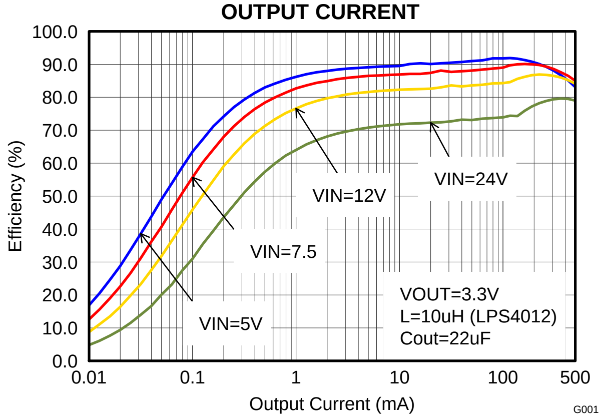

Figure 9. Vout=3.3V

EFFICIENCY vs INPUT VOLTAGE

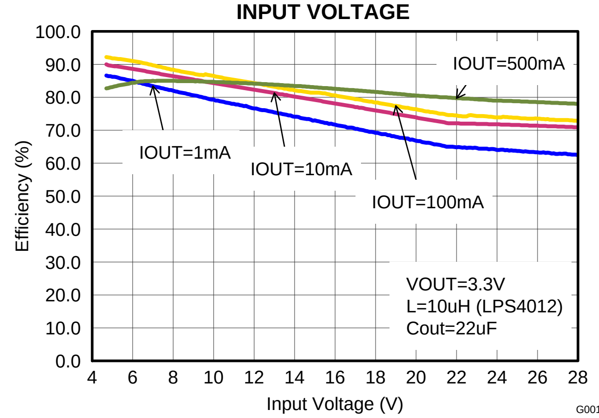

Figure 10. Vout=3.3V

EFFICIENCY
vs
OUTPUT CURRENT

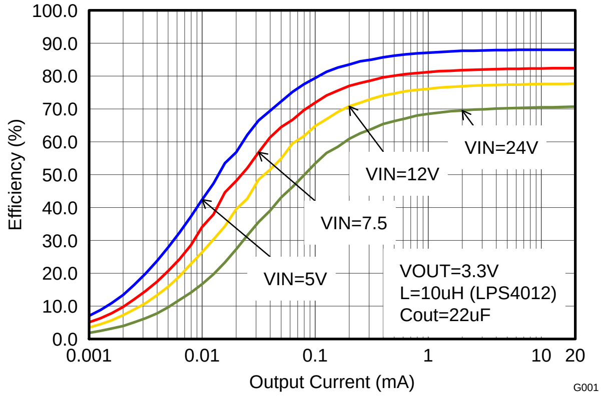

Figure 11. Vout=3.3V (Sleep Mode)

EFFICIENCY
vs
INPUT VOLTAGE

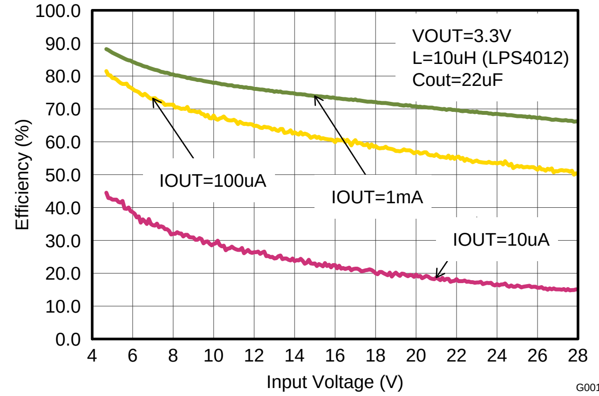

Figure 12. Vout=3.3V (Sleep Mode)

EFFICIENCY
vs
OUTPUT CURRENT

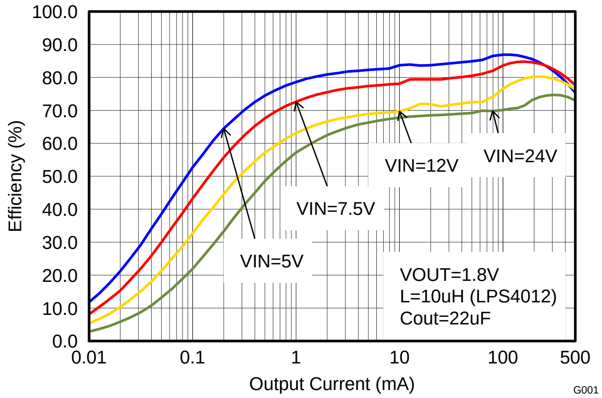

Figure 13. Vout=1.8V

EFFICIENCY
vs
INPUT VOLTAGE

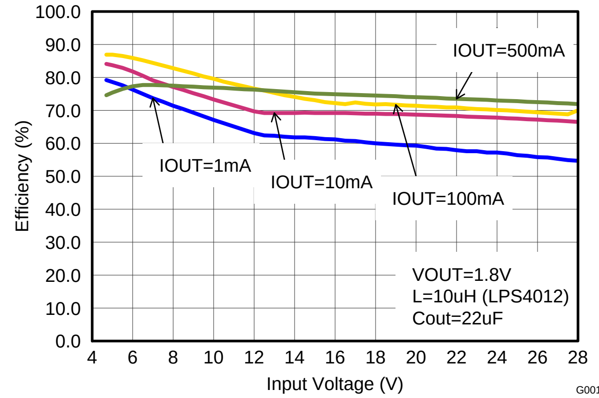

Figure 14. Vout=1.8V

EFFICIENCY
vs
OUTPUT CURRENT

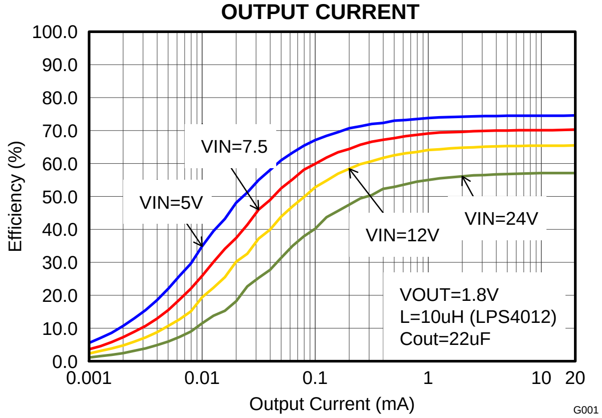

Figure 15. Vout=1.8V (Sleep Mode)

EFFICIENCY
vs
INPUT VOLTAGE

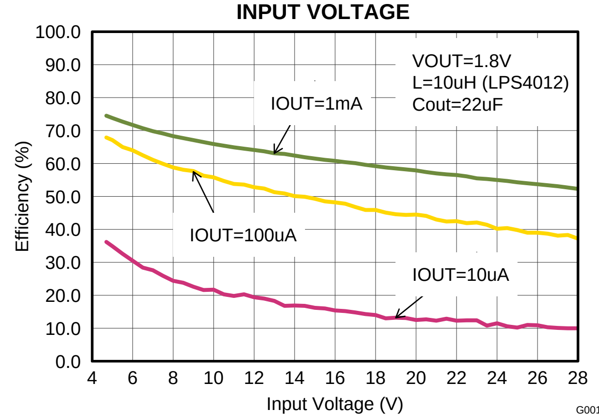

Figure 16. Vout=1.8V (Sleep Mode)

EFFICIENCY
vs
OUTPUT CURRENT

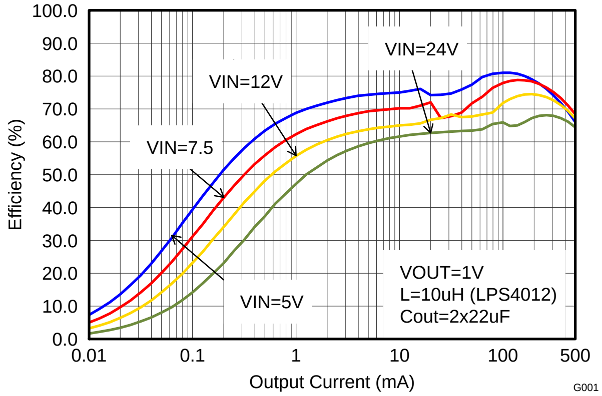

Figure 17. Vout=1V

EFFICIENCY
vs
INPUT VOLTAGE

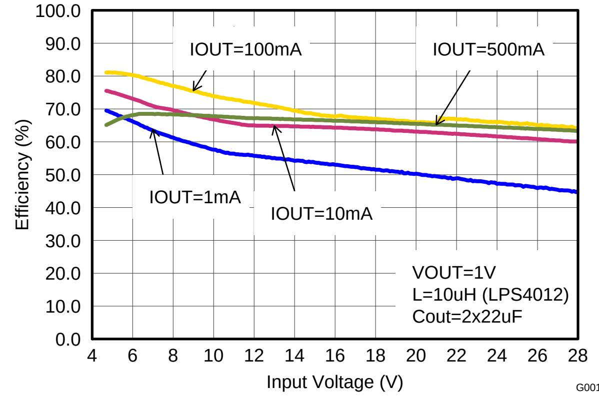

Figure 18. Vout=1V

EFFICIENCY
vs
OUTPUT CURRENT

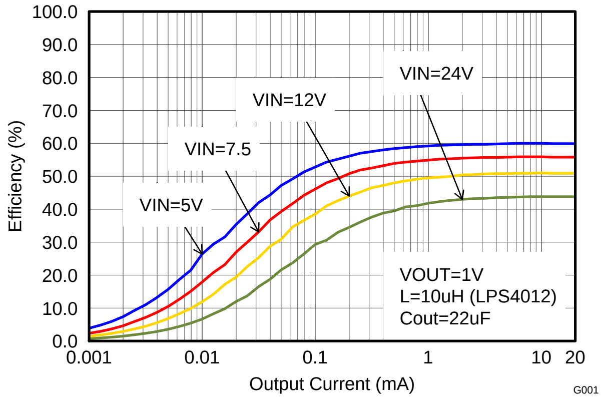

Figure 19. Vout=1V (Sleep Mode)

EFFICIENCY
vs
INPUT VOLTAGE

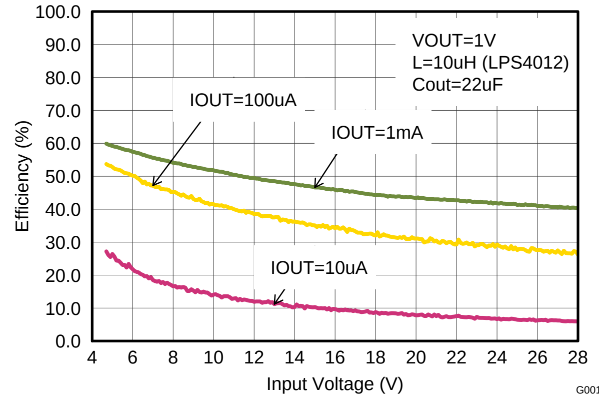

Figure 20. Vout=1V (Sleep Mode)

OUTPUT VOLTAGE
vs
OUTPUT CURRENT

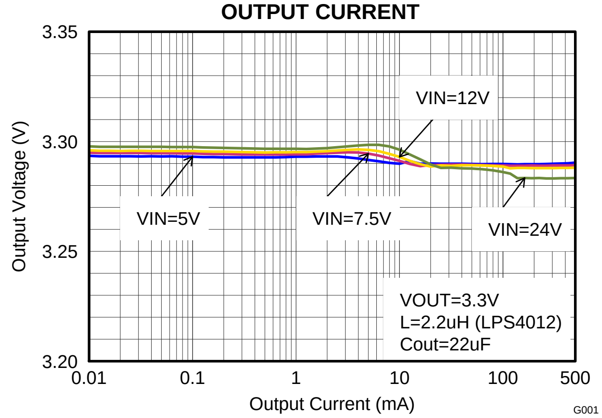

Figure 21. Output Voltage Accuracy (Load Regulation)

OUTPUT VOLTAGE
vs
INPUT VOLTAGE

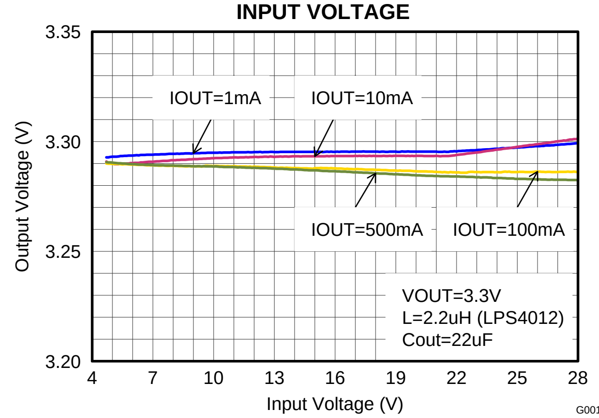

Figure 22. Output Voltage Accuracy (Line Regulation)

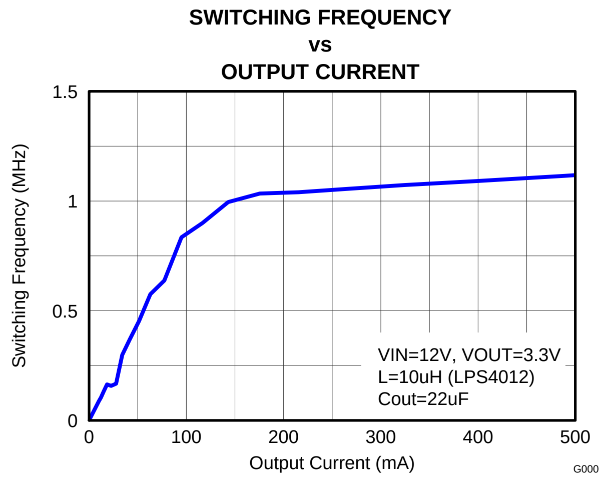

Figure 23. Switching Frequency

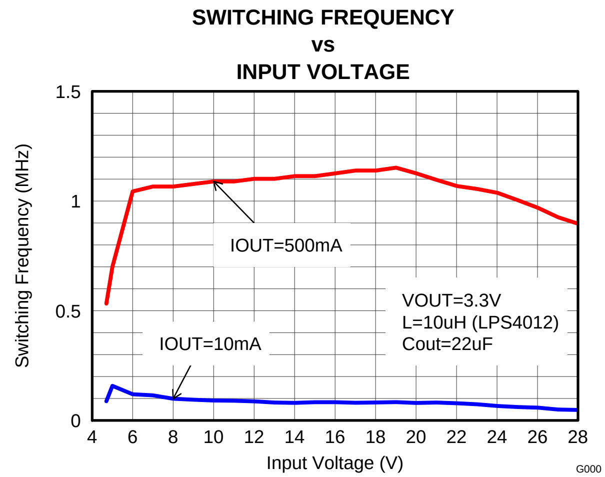

Figure 24. Switching Frequency

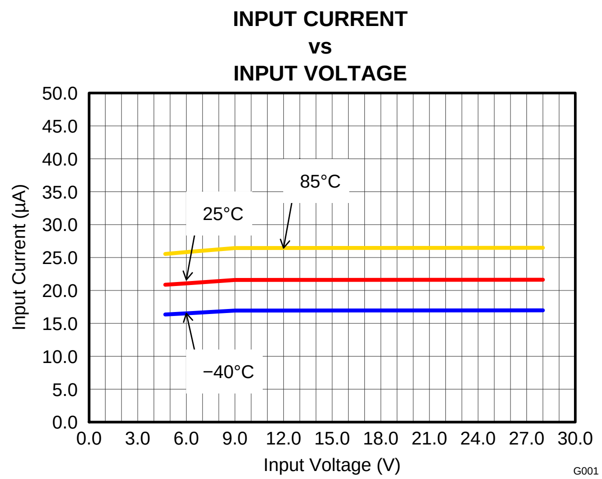

Figure 25. Quiescent Current

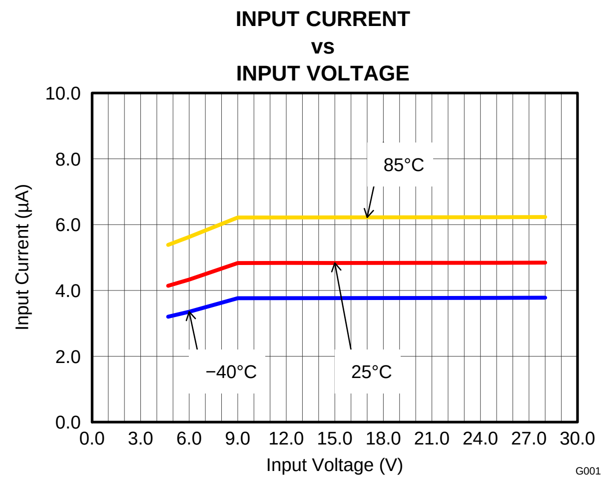

Figure 26. Quiescent Current (Sleep Mode)

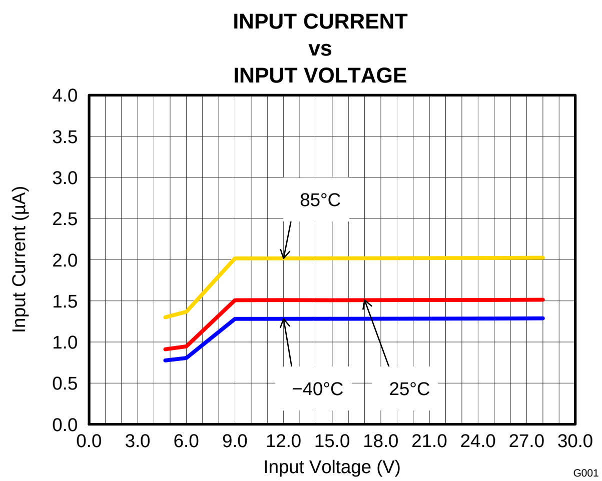

Figure 27. Shutdown Current

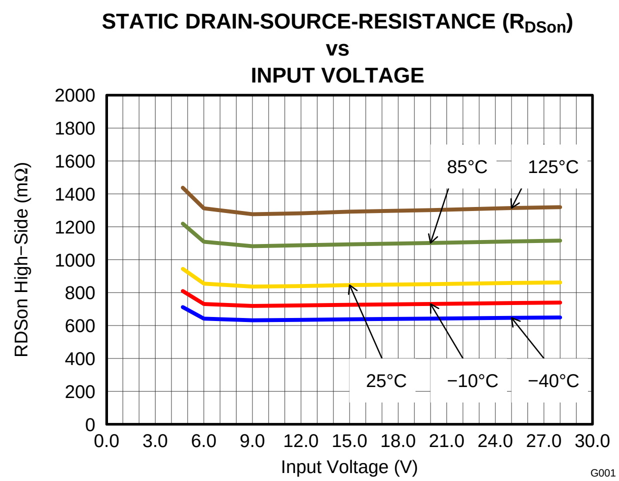

Figure 28. High-Side Switch

**STATIC DRAIN-SOURCE-RESISTANCE (R_{DSon})
vs
INPUT VOLTAGE**

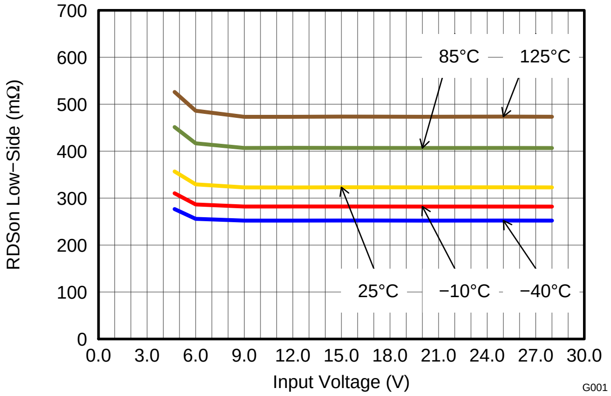

Figure 29. Low-Side Switch

**OUTPUT CURRENT
vs
INPUT VOLTAGE**

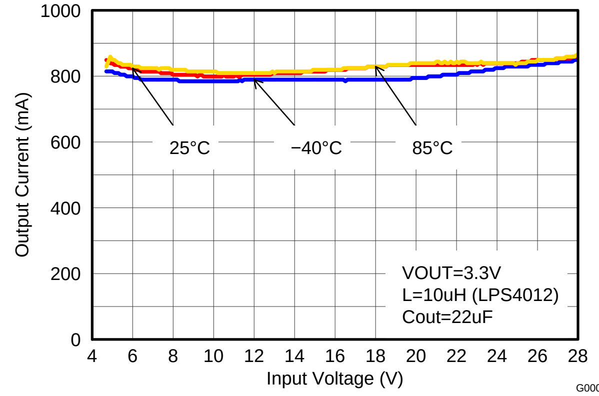

Figure 30. Maximum Output Current

SLEEP MODE ENTRY/EXIT

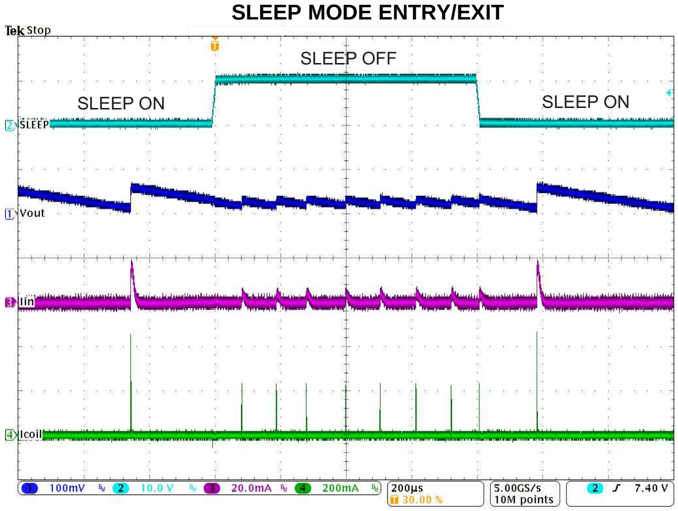

Figure 31. V_{IN}=12V, V_{OUT}=3.3V, Iout=1mA

SLEEP MODE ENTRY/EXIT

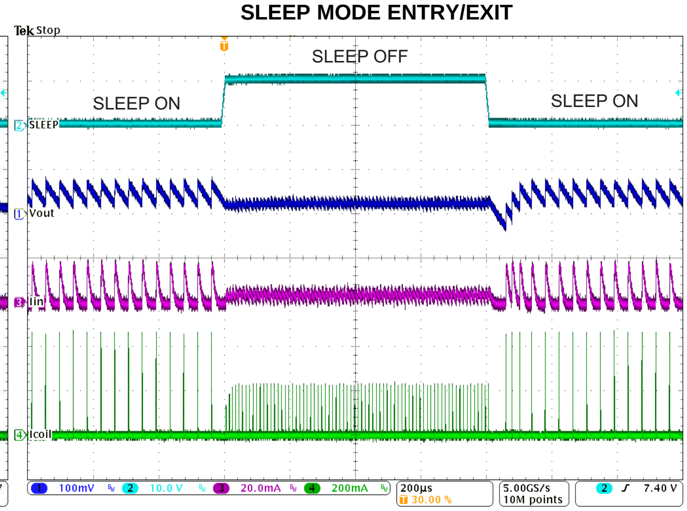

Figure 32. V_{IN}=12V, V_{OUT}=3.3V, Iout=10mA

LOAD TRANSIENT RESPONSE

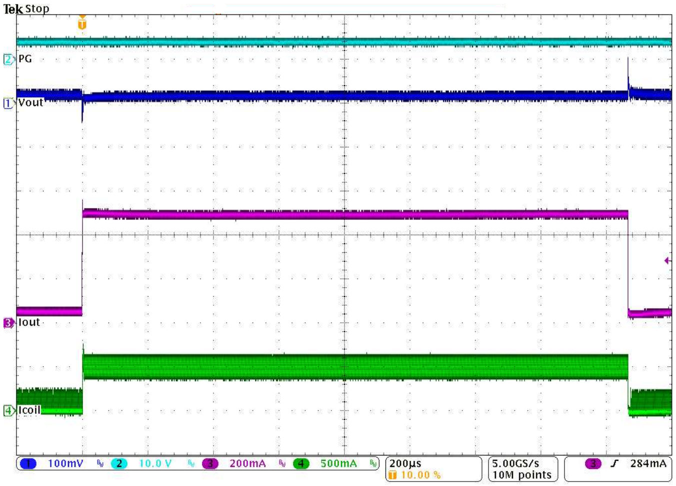

Figure 33. PWM Mode, V_{IN}=12V, V_{OUT}=3.3V, Iout (200mA to 500mA)

LOAD TRANSIENT RESPONSE

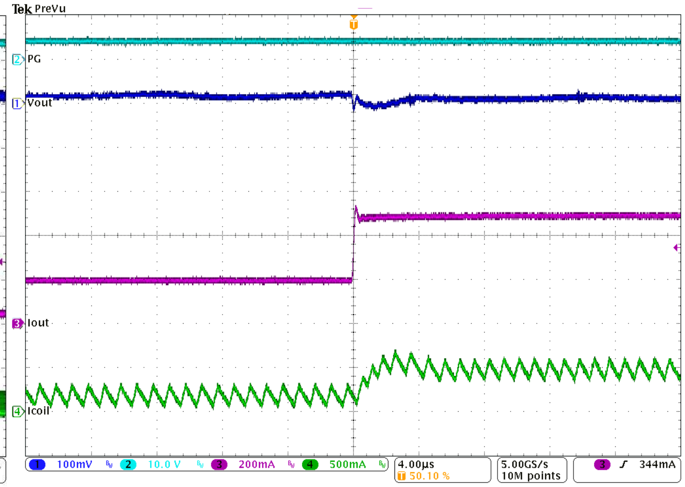

Figure 34. PWM Mode, V_{IN}=12V, V_{OUT}=3.3V, Iout (200mA to 500mA), rising edge

LOAD TRANSIENT RESPONSE

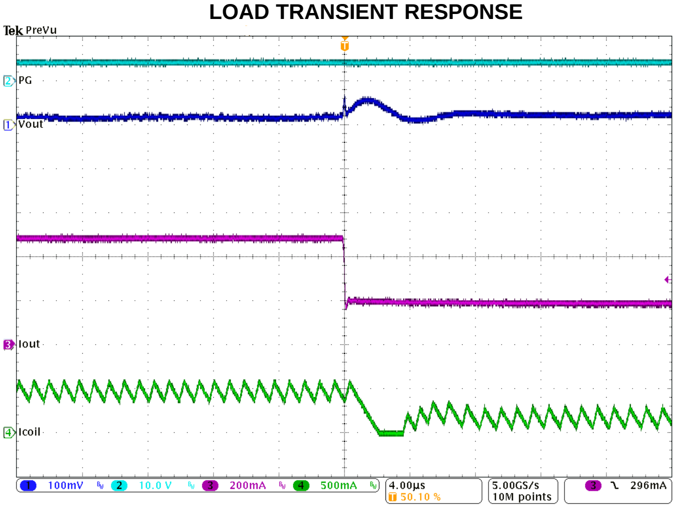

Figure 35. PWM Mode, V_{IN}=12V, V_{OUT}=3.3V, Iout (200mA to 500mA), falling edge

LOAD TRANSIENT RESPONSE

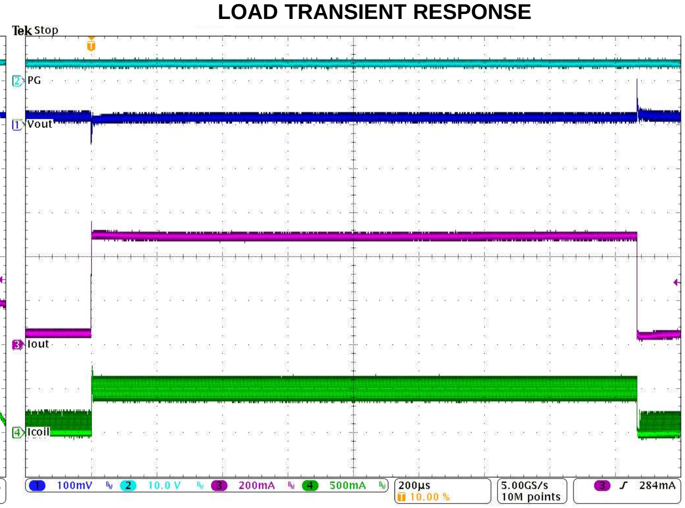

Figure 36. Power Save Mode, V_{IN}=12V, V_{OUT}=3.3V, Iout (50mA to 500mA)

LOAD TRANSIENT RESPONSE

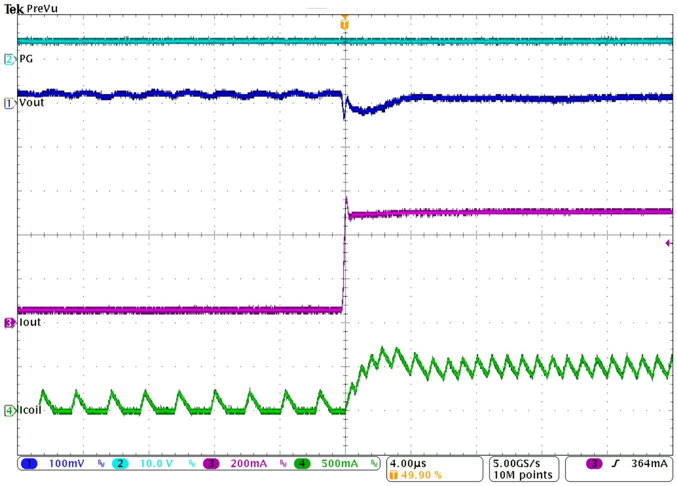

Figure 37. Power Save Mode, V_{IN}=12V, V_{OUT}=3.3V, Iout (50mA to 500mA), rising edge

LOAD TRANSIENT RESPONSE

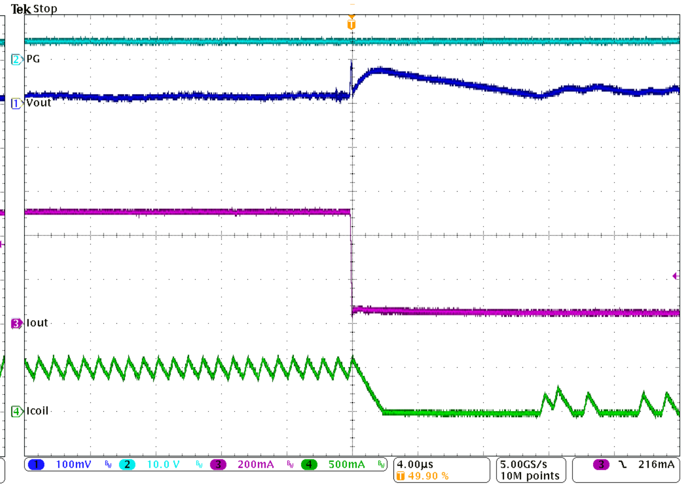

Figure 38. Power Save Mode, V_{IN}=12V, V_{OUT}=3.3V, Iout (50mA to 500mA), falling edge

LINE TRANSIENT RESPONSE

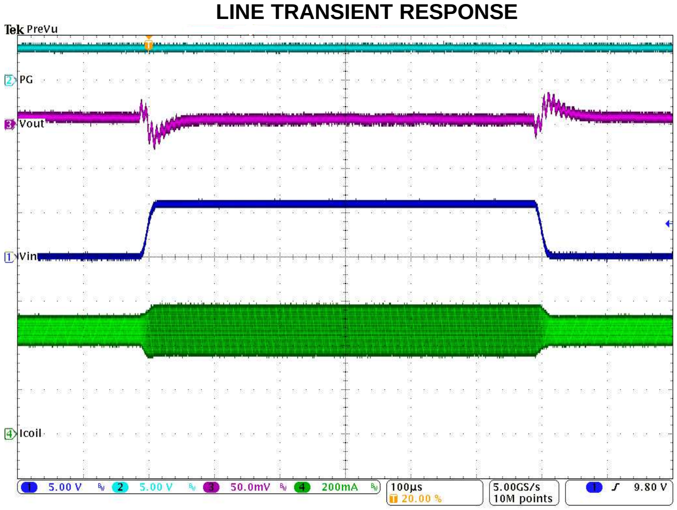

Figure 39. PWM Mode, V_{IN} (6V to 12V), Iout=500mA

LINE TRANSIENT RESPONSE

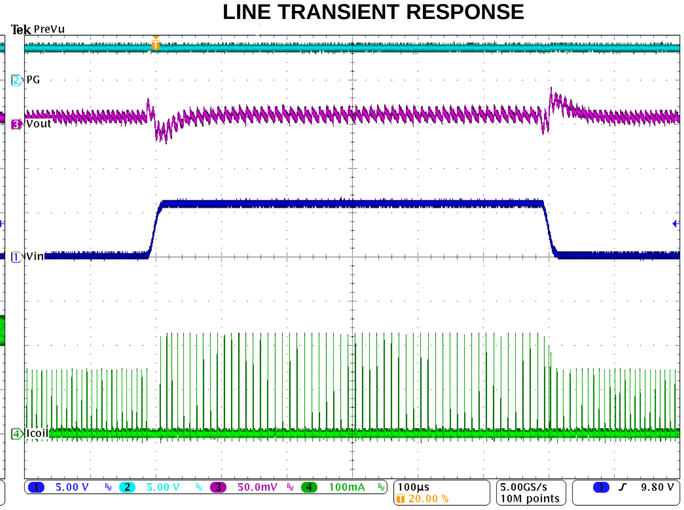

Figure 40. Power Save Mode, V_{IN} (6V to 12V), Iout=10mA

STARTUP TO VOUT=3.3V

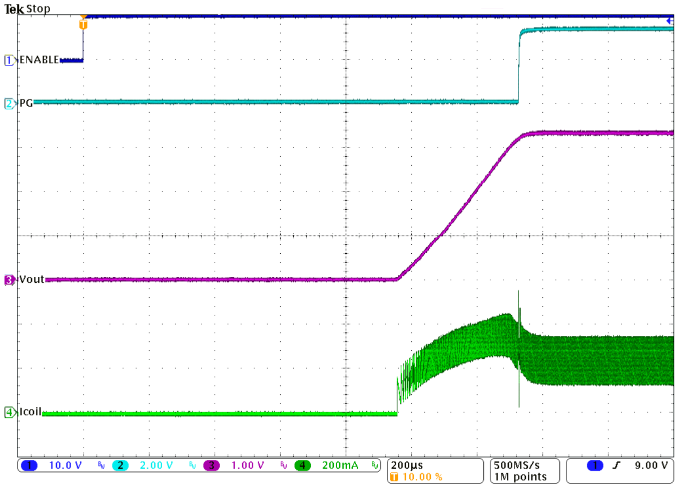

Figure 41. PWM Mode, V_{IN}=12V, Iout=250mA

STARTUP CURRENT LIMIT

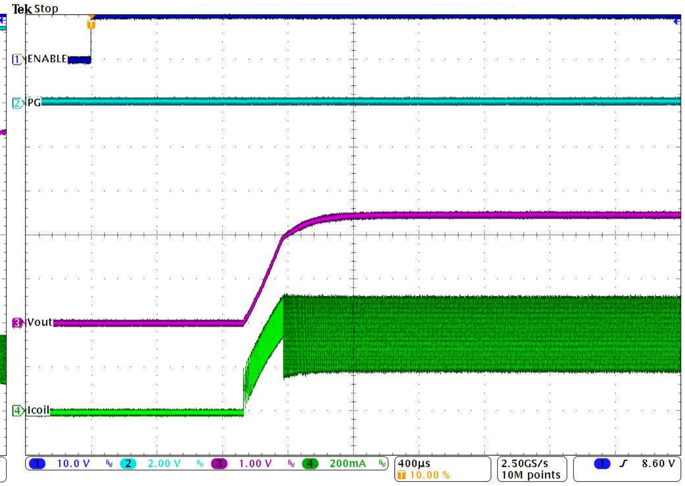

Figure 42. Startup Current Limit, V_{IN}=12V, Rload=6.6Ω

STARTUP TO VOUT=3.3V

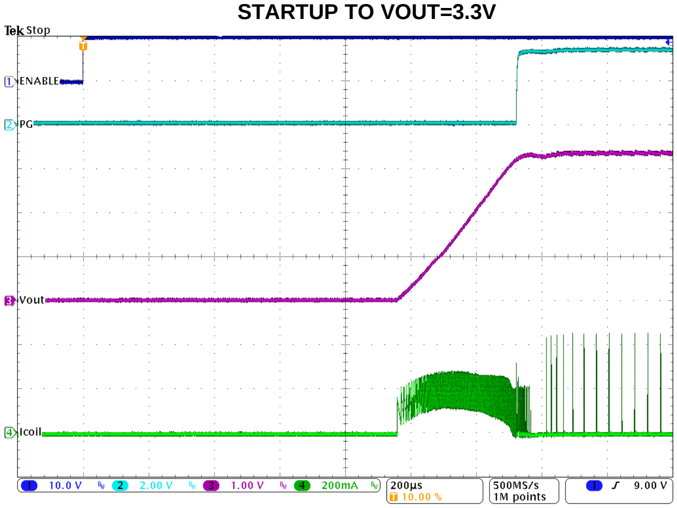

Figure 43. Sleep Mode, VIN=12V, Iout=10mA

OUTPUT VOLTAGE DISCHARGE

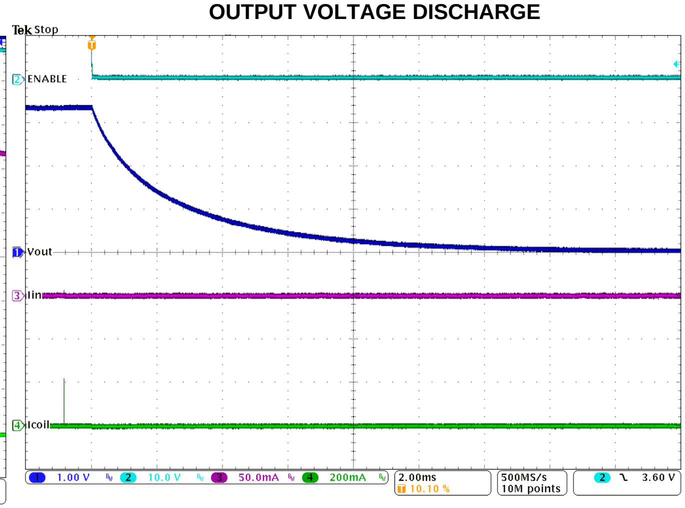

Figure 44. Output Discharge Function (Vout=3.3V, no load)

PWM MODE OPERATION

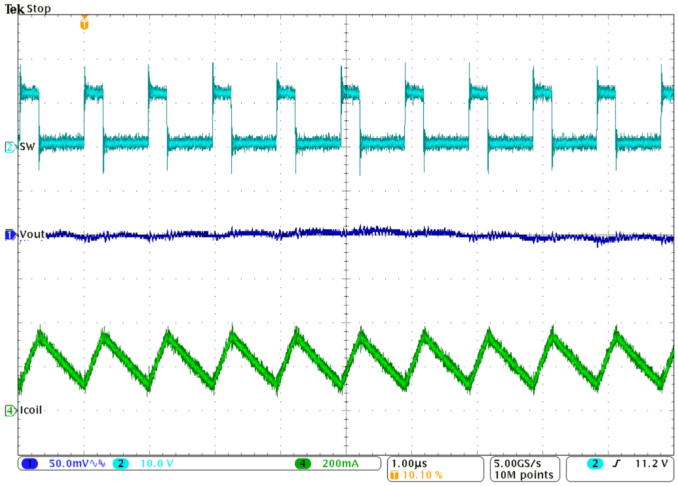

Figure 45. Typical Operation in PWM Mode, V_{IN}=12V, V_{OUT}=3.3V, Iout=250mA

POWER SAVE MODE OPERATION

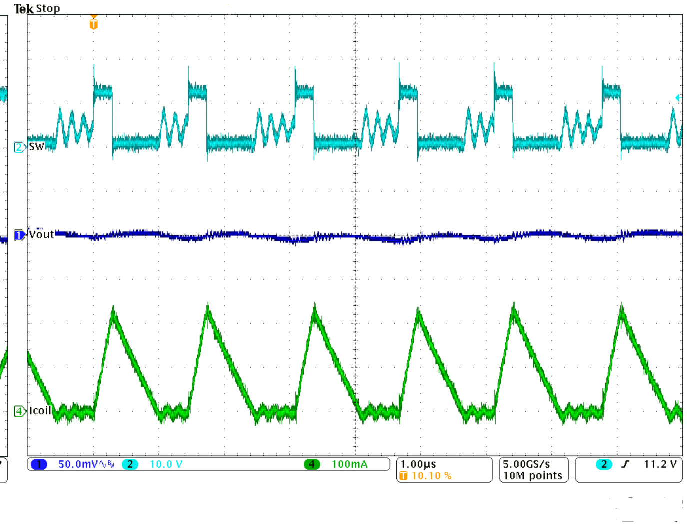

Figure 46. Typical Operation in Power Save Mode, V_{IN}=12V, V_{OUT}=3.3V, Iout=75mA

POWER SAVE MODE OPERATION

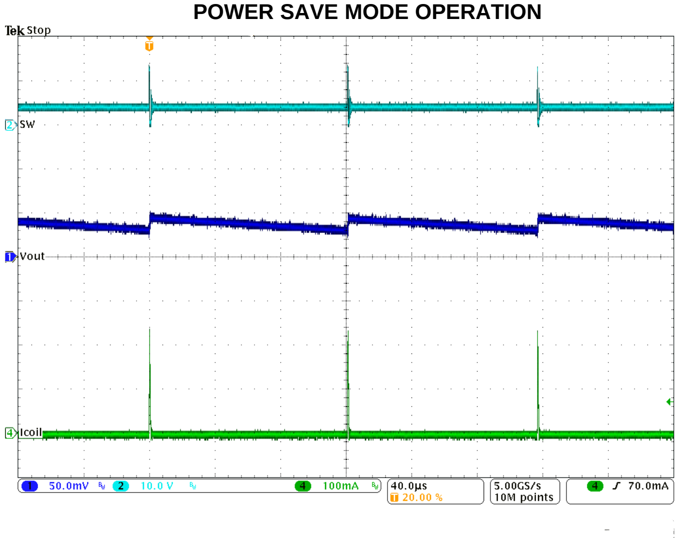

Figure 47. Typical Operation in Power Save Mode, V_{IN}=12V, V_{OUT}=3.3V, Iout=1mA

SLEEP MODE OPERATION

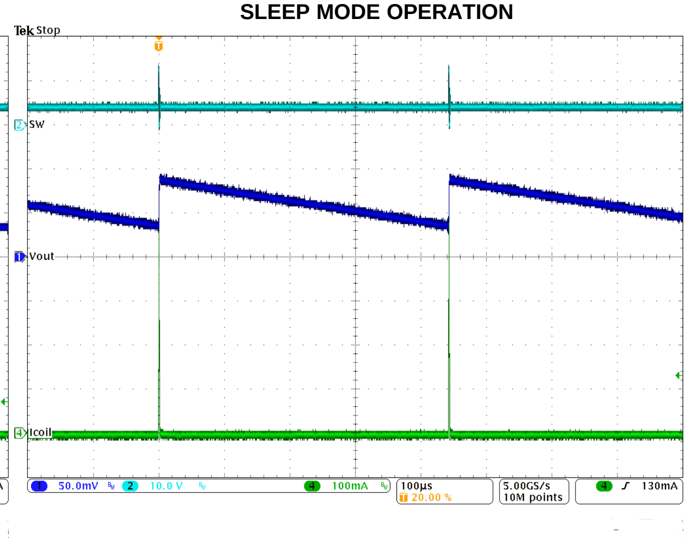

Figure 48. Typical Operation in Sleep Mode, V_{IN}=12V, V_{OUT}=3.3V, Iout=1mA

POWER SAVE MODE OPERATION

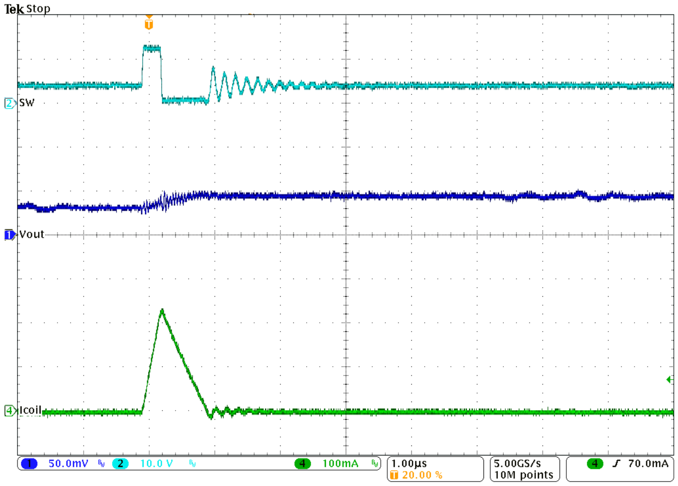

Figure 49. Typical Operation in Power Save Mode, V_{IN}=12V, V_{OUT}=3.3V, Iout=1mA (single pulse)

SLEEP MODE OPERATION

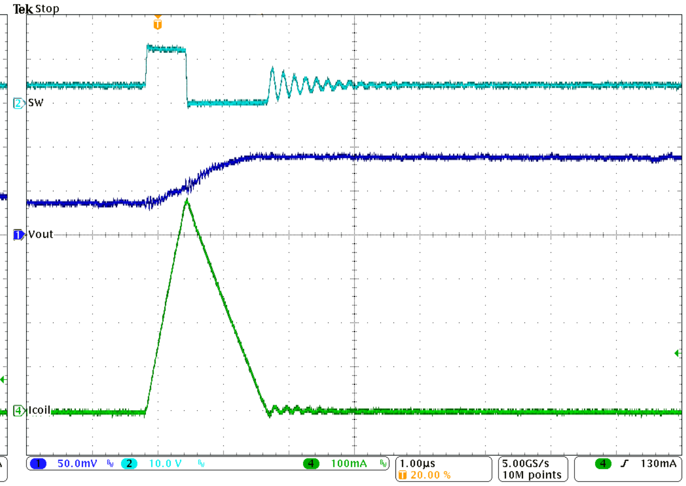

Figure 50. Typical Operation in Sleep Mode, V_{IN}=12V, V_{OUT}=3.3V, Iout=1mA (single pulse)

SHORT CIRCUIT OPERATION

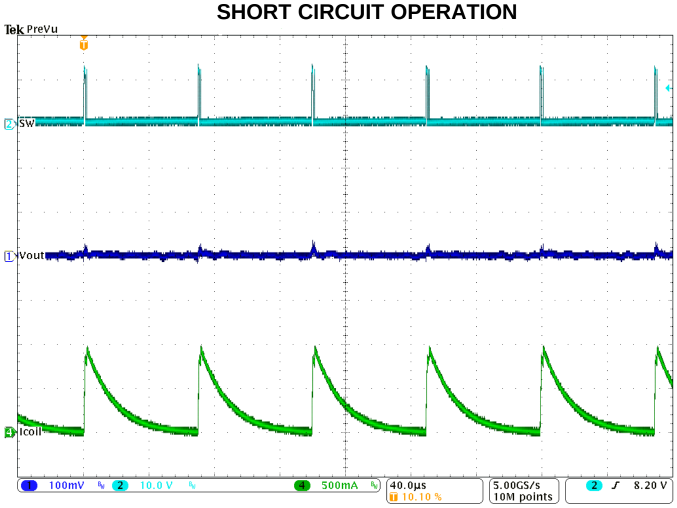

Figure 51. Short circuit while running, V_{IN}=12V

SHORT CIRCUIT OPERATION

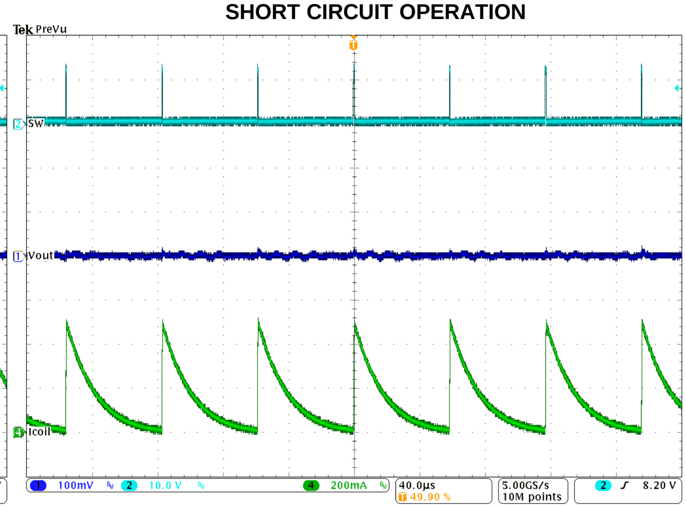

Figure 52. Short circuit from startup, V_{IN}=12V

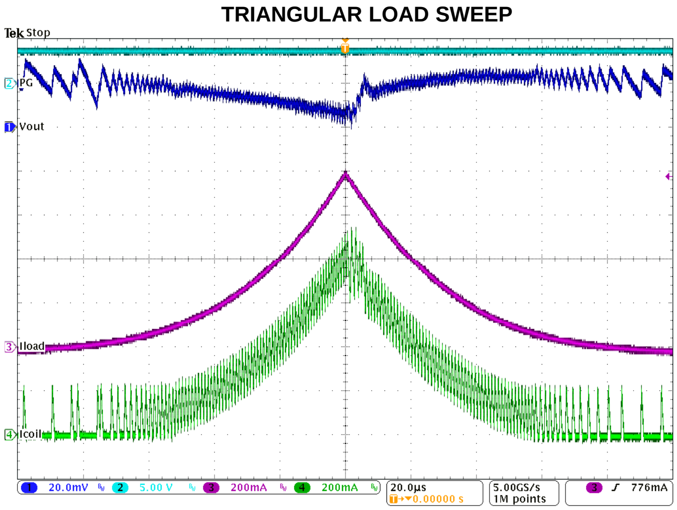

Figure 53. Triangular Load Sweep with Mode Transitions (Power Save Mode - PWM Mode - Power Save Mode), V_{IN}=12V, V_{OUT}=3.3V

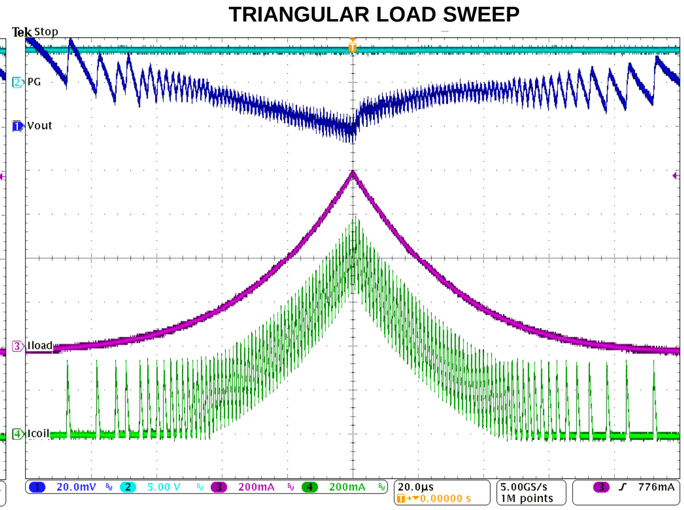

Figure 54. Triangular Load Sweep with Mode Transitions (Power Save Mode - PWM Mode - Power Save Mode), V_{IN}=24V, V_{OUT}=3.3V

DETAILED DESCRIPTION

Device Operation

The TPS62175/7 synchronous switch mode power converters are based on DCS-Control™ (**D**irect **C**ontrol with **S**eamless Transition into Power Save Mode), an advanced regulation topology, that combines the advantages of hysteretic, voltage mode and current mode control including an AC loop directly associated to the output voltage. This control loop takes information about output voltage changes and feeds it directly to a fast comparator stage. It sets the switching frequency, which is constant for steady state operating conditions, and provides immediate response to dynamic load changes. To get accurate DC load regulation, a voltage feedback loop is used. The internally compensated regulation network achieves fast and stable operation with small external components and low ESR capacitors.

The DCS-Control™ topology supports PWM (Pulse Width Modulation) mode for medium and heavy load conditions and a Power Save Mode at light loads. During PWM, it operates at its nominal switching frequency in continuous conduction mode. This frequency is typically about 1MHz with a controlled frequency variation depending on the input voltage. If the load current decreases, the converter enters Power Save Mode to sustain high efficiency down to very light loads. In Power Save Mode the switching frequency decreases linearly with the load current. Since DCS-Control™ supports both operation modes within one single building block, the transition from PWM to Power Save Mode is seamless without effects on the output voltage. Fixed output voltage versions provide smallest solution size and lowest current consumption, requiring only 3 external components. An internal current limit supports nominal output currents of up to 500mA. The TPS62175/7 offer both excellent DC voltage and superior load transient regulation, combined with very low output voltage ripple, minimizing interference with RF circuits.

Pulse Width Modulation (PWM) Operation

The TPS62175/7 operates with pulse width modulation in continuous conduction mode (CCM) with a nominal switching frequency of about 1MHz. The switching frequency in PWM is set by an internal timer circuit. The frequency variation is controlled and depends on V_{IN} and V_{OUT}. The device operates in PWM mode as long the output current is higher than half the inductor's ripple current. To maintain high efficiency at light loads, the device enters Power Save Mode at the boundary to discontinuous conduction mode (DCM).

Power Save Mode Operation

The TPS62175/7's built in Power Save Mode is entered seamlessly, if the load current decreases. This secures a high efficiency in light load operation by keeping the on-time and reducing the switching frequency. The device remains in Power Save Mode as long as the inductor current is discontinuous. The on-time, in steady-state operation, can be estimated as:

$$t_{ON} = \frac{V_{OUT}}{V_{IN}} \cdot 1\mu s \quad (1)$$

While the peak inductor current in Power Save Mode can be approximated by:

$$I_{LPSM(peak)} = \frac{(V_{IN} - V_{OUT})}{L} \cdot t_{ON} \quad (2)$$

The switching frequency is calculated as follows:

$$f_{PSM} = \frac{2 \cdot I_{OUT}}{t_{ON}^2 \frac{V_{IN}}{V_{OUT}} \left[\frac{V_{IN} - V_{OUT}}{L}\right]} \quad (3)$$

Sleep Mode Operation

In Sleep Mode operation, the typical quiescent current is reduced from 22µA to 4.8µA to significantly increase the efficiency at load currents of typically less than 1mA (see Figure 1). The output voltage is regulated with a fixed on-time, which is adjusted according to V_{IN}. A new pulse is initiated once the output voltage falls below its regulation threshold. Sleep Mode is limited with its dynamic response and current capabilities. It is designed to be enabled and disabled by pulling the SLEEP pin High or Low.

As a safety feature, the device returns to normal operation automatically, if too much current is drawn, avoiding a complete collapse of Vout. Once the load current decreases again, the device re-enters Sleep mode operation. However, this is not a recommended operation mode.

Ultra low power micro controllers in deep sleep or hibernating mode might have floating output pins. Therefore, TPS62175/7 have a pull-down resistor internally connected to the Sleep pin, to keep a logic low level, when the Sleep input signal goes High Impedance. If the Sleep signal goes directly from logic High to High Impedance, the low level detection must be ensured considering the leakage of the micro controller's Sleep signal. An external pull-down resistor, shown in Figure 62, may be required. The device can deliver temporarily more than 15mA, to allow micro controllers to wake up and drive the Sleep signal High, exiting Sleep Mode.

100% Mode Operation

The duty cycle of the buck converter is given by D=Vout/Vin and increases as the input voltage comes close to the output voltage. In this case, the device starts 100% duty cycle operation turning on the high-side switch 100% of the time. The high-side switch stays turned on as long as the output voltage is below the internal setpoint. This allows the conversion of small input to output voltage differences, e.g. for longest operation time of battery-powered applications.

The minimum input voltage to maintain output voltage regulation can be calculated as:

$$V_{IN(min)} = V_{OUT(min)} + I_{OUT}\left(R_{DS(on)} + R_L\right) \tag{4}$$

where

I_{OUT} is the output current,
$R_{DS(on)}$ is the $R_{DS(on)}$ of the high-side FET and
R_L is the DC resistance of the inductor used.

Enable/Shutdown (EN)

The device can be switched on/off by pulling the EN pin to High (operation) or Low (shutdown). If EN is pulled to High, the device starts operation after a delay of about 1ms (typ.). This helps to ensure a monotonic startup sequence, which makes the device ideally suited to control the power on sequence of micro controllers.

During Shutdown, the internal MOSFETs as well as the entire control circuitry are turned off and the current consumption is typically 1.5µA. The EN pin is connected via a 400kΩ pull-down resistor, keeping the logic level low, if the pin is floating.

Output Discharge

The output is actively discharged through a 175Ω (typ.) resistor on the VOS pin when the device is turned off by EN, UVLO or thermal shutdown.

Softstart

The internal soft start circuitry controls the output voltage slope during startup. This avoids excessive inrush current and ensures a controlled output voltage rise time. It also prevents unwanted voltage drops from high-impedance power sources or batteries. When EN is set to High and the device starts switching, V_{OUT} rises with a slope of typically 10mV/µs. The internal current limit is reduced to typically 525mA during startup. Thereby the output current is less than 500mA during hat time (see Figure 42). The startup sequence ends, when device achieves regulation, then, the device runs with the full current limit of typically 1A, providing full output current.

The TPS62175/7 can monotonically start into a pre-biased output.

Current Limit And Short Circuit Protection

The TPS62175/7 devices are protected against heavy load and short circuit events. If a current limit situation is detected, the device switches off. The off time is maintained longer as the output voltage becomes lower. At heavy overloads the low side MOSFET stays on until the inductor current returns to zero. Then the high side MOSFET turns on again (see Figure 51 and Figure 52).

Power Good (PG)

The TPS62175/7 has a built in power good (PG) function to indicate that the output reached regulation. The PG signal can be used for startup sequencing of multiple rails. The PG pin is an open-drain output that requires a pull-up resistor (to any voltage below 7V). It can sink 2mA of current and maintain its specified logic Low level of 0.3V. It is held Low when the device is turned off by EN, UVLO or thermal shutdown.

If the PG pin is not used, it may be left floating or connected to AGND.

Under Voltage Lockout (UVLO)

If the input voltage drops, the under voltage lockout function prevents misoperation by turning the device off. The under voltage lockout threshold is set to 4.6V (typically) for rising V_{IN}. To cover for possible input voltage drops, when using high impedance sources or batteries, the falling threshold is set to typically 2.9V, allowing monotonic startup sequence under such conditions. For input voltages below the minimum VIN of 4.75V and above the falling UVLO threshold of 2.9V, the device still functions with a current limit and regulation capability but the electrical characteristics are no longer specified.

Thermal Shutdown

The junction temperature (Tj) of the device is monitored by an internal temperature sensor. If Tj exceeds 150°C (typ), the device goes into thermal shutdown. Both the high-side and low-side power FETs are turned off and PG goes Low. When Tj decreases below the hysteresis amount, the converter resumes normal operation, beginning with Soft Start. To avoid unstable conditions, a hysteresis of typically 20°C is implemented on the thermal shutdown temperature.

APPLICATION INFORMATION

Programming The Output Voltage

While the output voltage of the TPS62175 is adjustable, the TPS62177 is programmed to a fixed output voltage of 3.3V. For the fixed output voltage version, the FB pin is pulled low internally by a 400kΩ resistor. It is recommended to connect the FB pin to AGND to improve thermal resistance. The adjustable version can be programmed for output voltages from 1V to 6V by using a resistive divider. The voltage at the FB pin is regulated to 800mV. The value of the output voltage is set by the selection of the resistive divider from Equation 5. It is recommended to choose resistor values which allow a current of at least 5uA. Lower resistor values are recommended to increase noise immunity. For applications requiring lowest current consumption, the use of the fixed output voltage version is recommended.

$$R_1 = R_2 \left(\frac{V_{OUT}}{V_{REF}} - 1 \right) \tag{5}$$

As a safety feature, the device clamps the output voltage at the VOS pin to typically 7.4V, if the FB pin gets opened.

External Component Selection

The external components have to fulfill the needs of the application, but also the stability criteria of the devices control loop. The TPS62175/7 is optimized to work within a wide range of external components. The LC output filter's inductance and capacitance have to be considered together, while creating a double pole that is responsible for the corner frequency of the converter. Table 1 shows the recommended output filter components.

Table 1. Recommended LC Output Filter Combinations[1]

	10µF	22µF	47µF	100µF	200µF	400µF
6.8µH						
10µH		√[2]	√	√	√	
22µH				√	√	
33µH						

(1) The values in the table are nominal values. Variations of typically ±20% due to tolerance, saturation and DC bias are assumed.
(2) This LC combination is the standard value and recommended for most applications. For output voltages of ≤2V, an output capacitance of at least 2x22uF is recommended.

Output Filter And Loop Stability

The TPS62175/7 devices are internally compensated and are stable with LC output filter combinations recommended in Table 1. Further information on other values and loop stability can be found in SLVA543.

Inductor Selection

The inductor selection is determined by several effects like inductor ripple current, output ripple voltage, PWM-to-Power Save Mode transition point and efficiency. In addition, the inductor selected has to be rated for appropriate saturation current and DC resistance (DCR). Equation 6 and Equation 7 calculate the maximum inductor current under static load conditions.

$$I_{L(\max)} = I_{OUT(\max)} + \frac{\Delta I_{L(\max)}}{2} \tag{6}$$

$$\Delta I_{L(\max)} = \frac{V_{OUT}}{\eta} \cdot \left(\frac{1 - \dfrac{V_{OUT}}{V_{IN(\max)} \cdot \eta}}{L_{(\min)} \cdot f_{SW}} \right) \tag{7}$$

where

ΔI_L is the Peak to Peak Inductor Ripple Current,
η is the converter efficiency (see efficiency figures),
L(min) is the minimum inductor value and
f_{SW} is the actual PWM Switching Frequency.

Calculating the maximum inductor current using the actual operating conditions gives the minimum saturation current of the inductor needed. A margin of about 20% is recommended to cover possible load transient overshoot. A larger inductor value is also useful to get lower ripple current, but increases the transient response time and solution size as well. The following inductors have been tested with the TPS62175/7:

Table 2. List of Inductors

Type	Inductance [µH]	Current [A][1]	DCR [mΩ]	Dimensions [L x B x H] mm	MANUFACTURER
LPS4012-103MLC	10µH, ±20%	1.1A	350 (max)	4.0 x 4.0 x 1.2	Coilcraft
LPS4018-103MLC	10µH, ±20%	1.3A	200 (max)	4.0 x 4.0 x 1.8	Coilcraft
VLS4012ET-100M	10µH, ±20%	0.99A	190 (typ)	4.0 x 4.0 x 1.2	TDK
VLCF4020T-100MR85	10µH, ±20%	0.85A	168 (typ)	4.0 x 4.0 x 2.0	TDK
74437324100	10µH, ±20%	1.5 A	215 (typ)	4.5 x 4.1 x 1.8	Wuerth
IFSC-1515AH-01	10µH, ±20%	1.3A	135 (typ)	3.8 x 3.8 x 1.8	Vishay
ELL-4LG100MA	10µH, ±20%	0.8A	200 (typ)	3.8 x 3.8 x 1.8	Panasonic

(1) I_{RMS} at 40°C rise or I_{SAT} at 30% drop.

Output Capacitor

The recommended value for the output capacitor is 22uF. To maintain low output voltage ripple during large load transients, for output voltages below 2V, 2x 22µF is recommended. The architecture of the TPS62175/7 allows the use of ceramic output capacitors with low equivalent series resistance (ESR). These capacitors provide low output voltage ripple and are recommended with an X7R or X5R dielectric. Larger capacitance values have the advantage of smaller output voltage ripple and a tighter DC output accuracy in Power Save Mode.

Note: In Power Save Mode, the output voltage ripple and accuracy depends on the output capacitance and the inductor value. The larger the capacitance the lower the output voltage ripple and the better the output voltage accuracy. The same relation applies to the inductor value.

Input Capacitor

Typically, 2.2µF is sufficient and is recommended, though a larger value reduces input current ripple further. The input capacitor buffers the input voltage during transient events and also decouples the converter from the supply. A low ESR, multilayer, X5R or X7R dielectric, ceramic capacitor is recommended for best filtering and should be placed between VIN and PGND as close as possible to those pins.

NOTE

DC Bias effect: High capacitance ceramic capacitors have a DC Bias effect, which has a strong influence on the final effective capacitance. Therefore the right capacitor value has to be chosen carefully. Package size and voltage rating in combination with dielectric material are responsible for differences between the rated capacitor value and the effective capacitance.

Layout Considerations

The input capacitor needs to be placed as close as possible to the IC pins (VIN, PGND). The inductor should be placed close to the SW pin and connect directly to the output capacitor - minimizing the loop area between the SW pin, inductor, output capacitor and PGND pin. Also, sensitive nodes like FB and VOS should be connected with short wires, not nearby high dv/dt signals (e.g. SW). The feedback resistors, R_1 and R_2, should be placed close to the IC and connect directly to the AGND and FB pins.

A proper layout is critical for the operation of a switch mode power supply, even more at high switching frequencies. Therefore the PCB layout of the TPS62175/7 demands careful attention to ensure operation and to get the performance specified. A poor layout can lead to issues like poor regulation (both line and load), stability and accuracy weaknesses, increased EMI radiation and noise sensitivity. See Figure 55 for the recommended layout of the TPS62175, which is implemented on the EVM. Information can be found in the EVM Users Guide, SLVU743. Alternatively, the EVM Gerber data are available for download here, SLVC453.

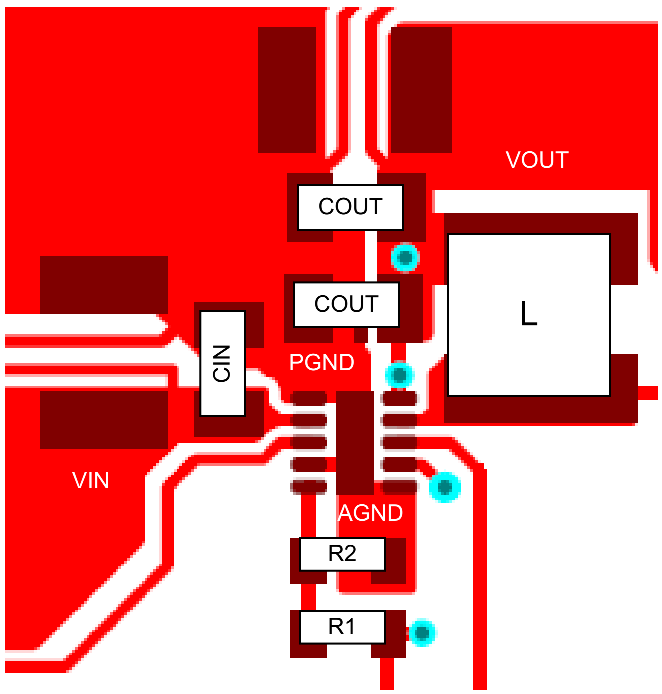

Figure 55. Layout Example

The Exposed Thermal Pad must be soldered to AGND and on the circuit board for mechanical reliability and to achieve appropriate power dissipation.

THERMAL INFORMATION

The TPS62175/7 is designed for a maximum operating junction temperature (T_j) of 125°C. Therefore the maximum output power is limited by the power losses. Since the thermal resistance of the package is given, the size of the surrounding copper area and a proper thermal connection of the IC can reduce the thermal resistance. To get an improved thermal behavior, it's recommended to use top layer metal to connect the device with wide and thick metal lines (see Figure 55 above). Internal ground layers can connect to vias directly under the IC for improved thermal performance.

For more details on how to use the thermal parameters, see the application notes: Thermal Characteristics Application Note (SZZA017), and (SPRA953).

Typical Applications

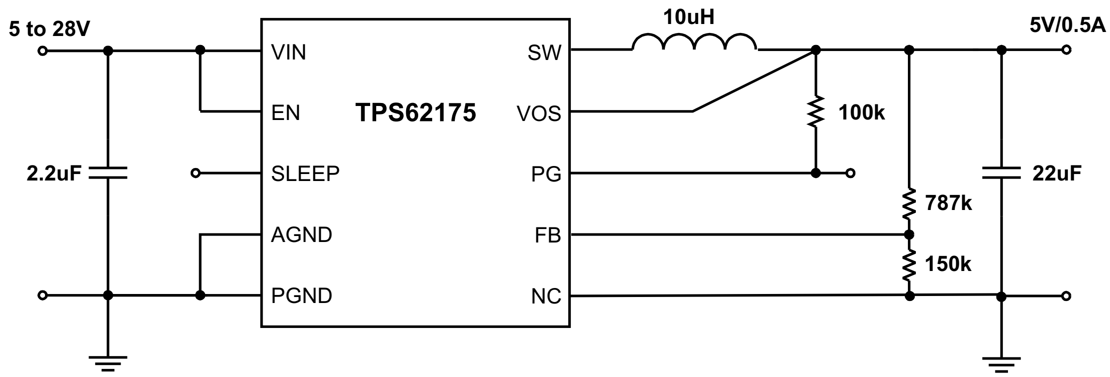

Figure 56. 5V/0.5A Power Supply

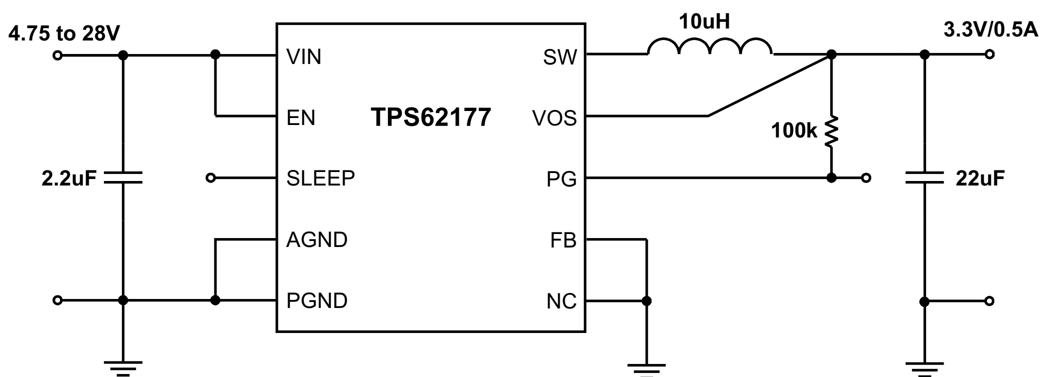

Figure 57. 3.3V/0.5A Power Supply

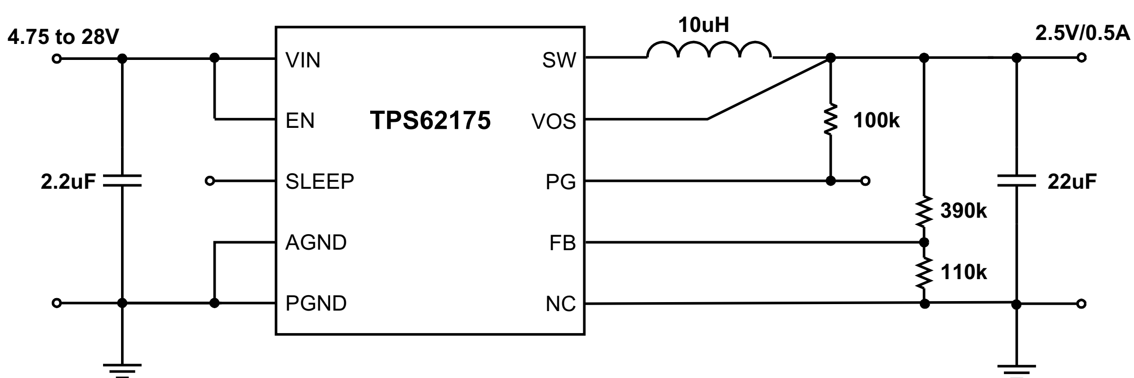

Figure 58. 2.5V/0.5A Power Supply

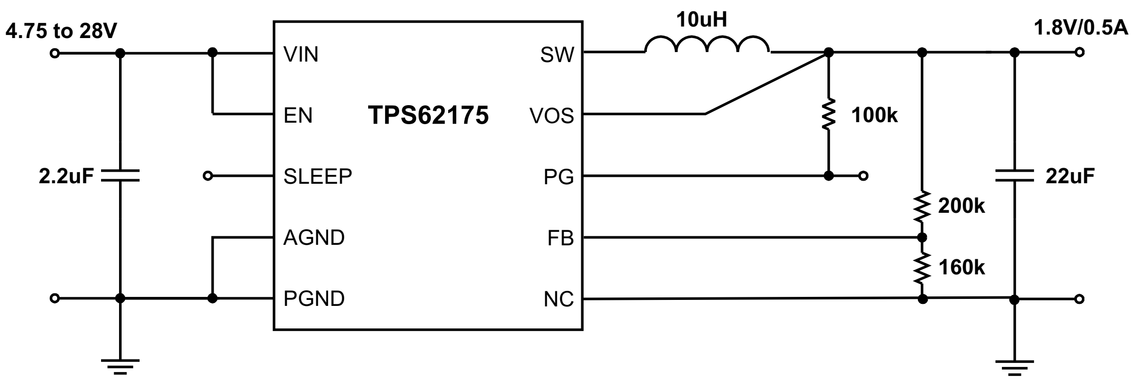

Figure 59. 1.8V/0.5A Power Supply

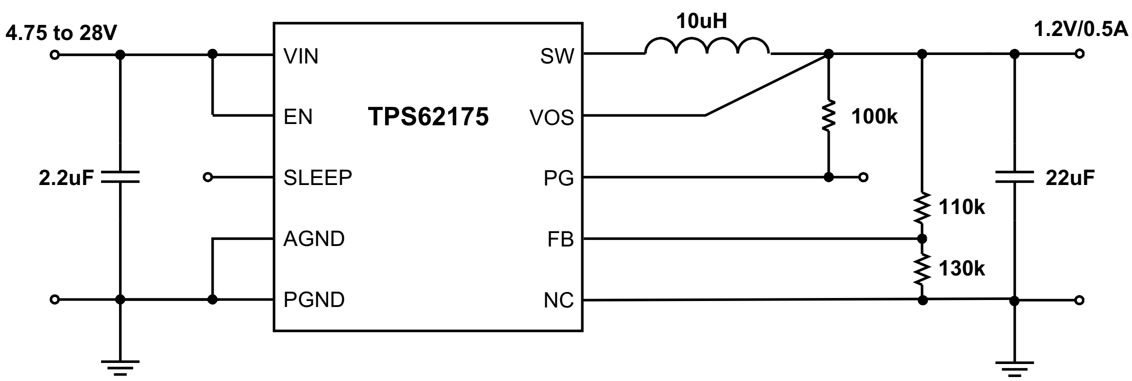

Figure 60. 1.2V/0.5A Power Supply

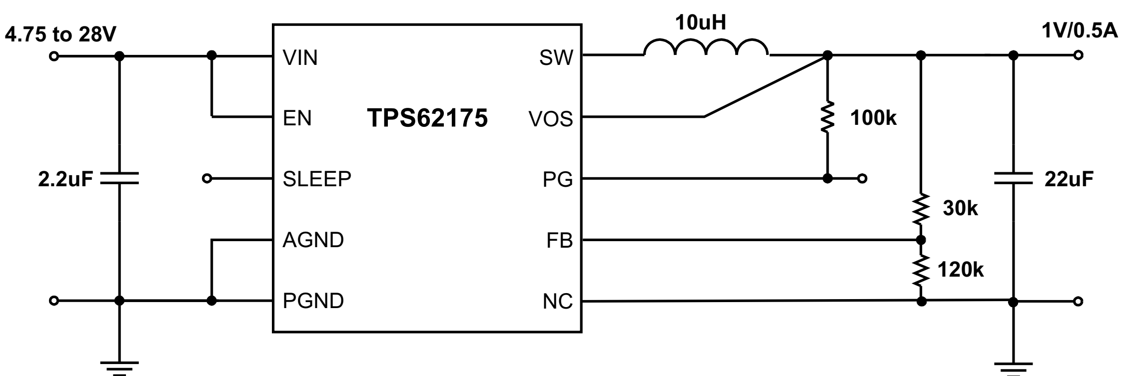

Figure 61. 1V/0.5A Power Supply

Application Examples

Micro Controller Power Supply

The TPS6215/7 can be used advantageously as the power supply rail for micro-controllers with low current power save modes. Figure 62 shows the connection of TPS62177 to the Stellaris Cortex M4 micro-controller (LM4F), using its Hibernate Mode signal to control Sleep Mode operation.

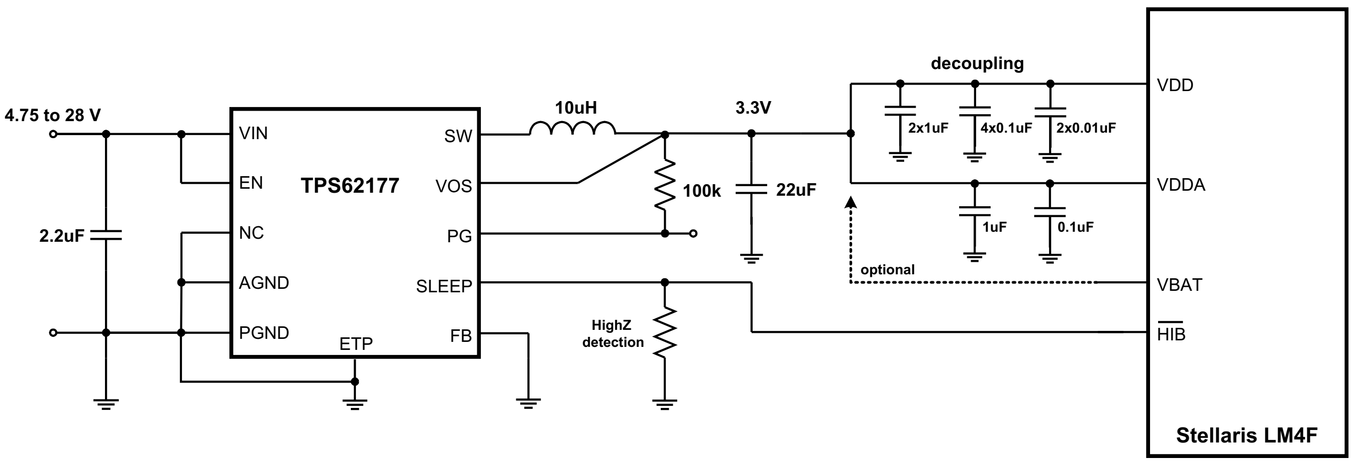

Figure 62. Micro-Controller Power Supply with Sleep Mode

Inverting Power Supply

The TPS62175/7 can be used as inverting power supply by rearranging external circuitry as shown in Figure 63. As the former GND node now represents a voltage level below system ground, the voltage difference between V_{IN} and V_{OUT} has to be limited to the maximum operating voltage of 28V.

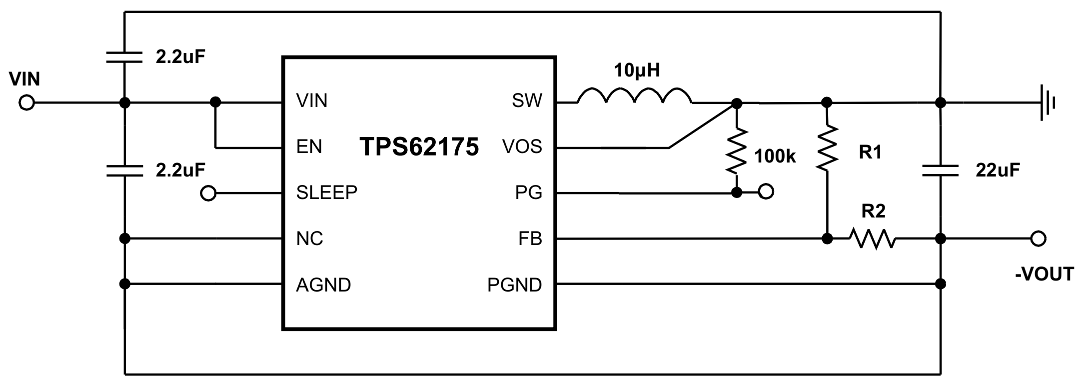

Figure 63. Inverting Buck-Boost Converter

More information about using TPS62175 as inverting buck-boost converter can be found in the Application Note SLVA542.

REVISION HISTORY

Changes from Original (October 2012) to Revision A	Page
• Added Startup Mode to High-Side MOSFET Current Limit in ELECTRICAL CHARACTERISTICS	3
• Changed Table 1	23

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Samples (Requires Login)
TPS62175DQCR	ACTIVE	WSON	DQC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	
TPS62175DQCT	ACTIVE	WSON	DQC	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	
TPS62177DQCR	ACTIVE	WSON	DQC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	
TPS62177DQCT	ACTIVE	WSON	DQC	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	

(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) 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 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.

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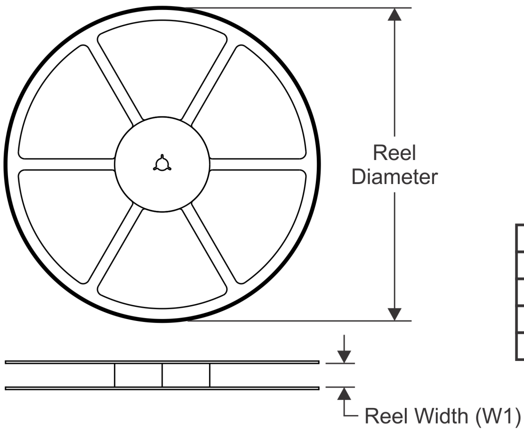
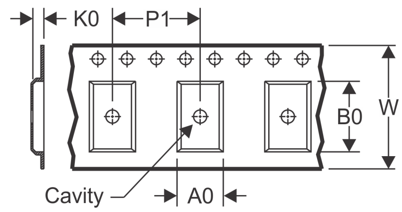
TAPE AND REEL INFORMATION

REEL DIMENSIONS

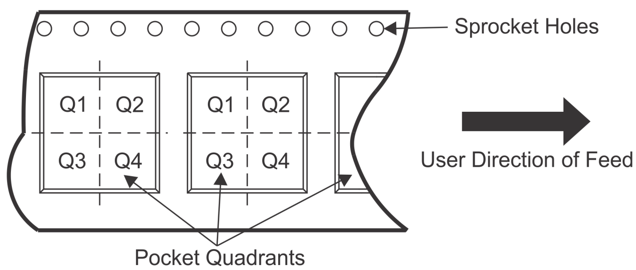


TAPE DIMENSIONS



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

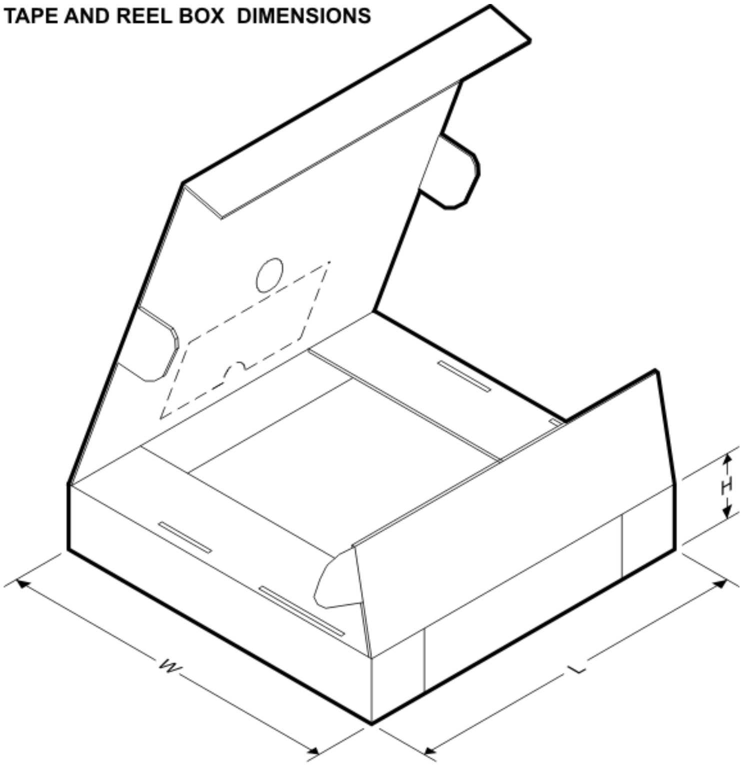
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPS62175DQCR	WSON	DQC	10	3000	330.0	12.4	2.3	3.3	0.85	4.0	12.0	Q1
TPS62175DQCT	WSON	DQC	10	250	180.0	12.4	2.3	3.3	0.85	4.0	12.0	Q1
TPS62177DQCR	WSON	DQC	10	3000	330.0	12.4	2.3	3.3	0.85	4.0	12.0	Q1
TPS62177DQCT	WSON	DQC	10	250	180.0	12.4	2.3	3.3	0.85	4.0	12.0	Q1

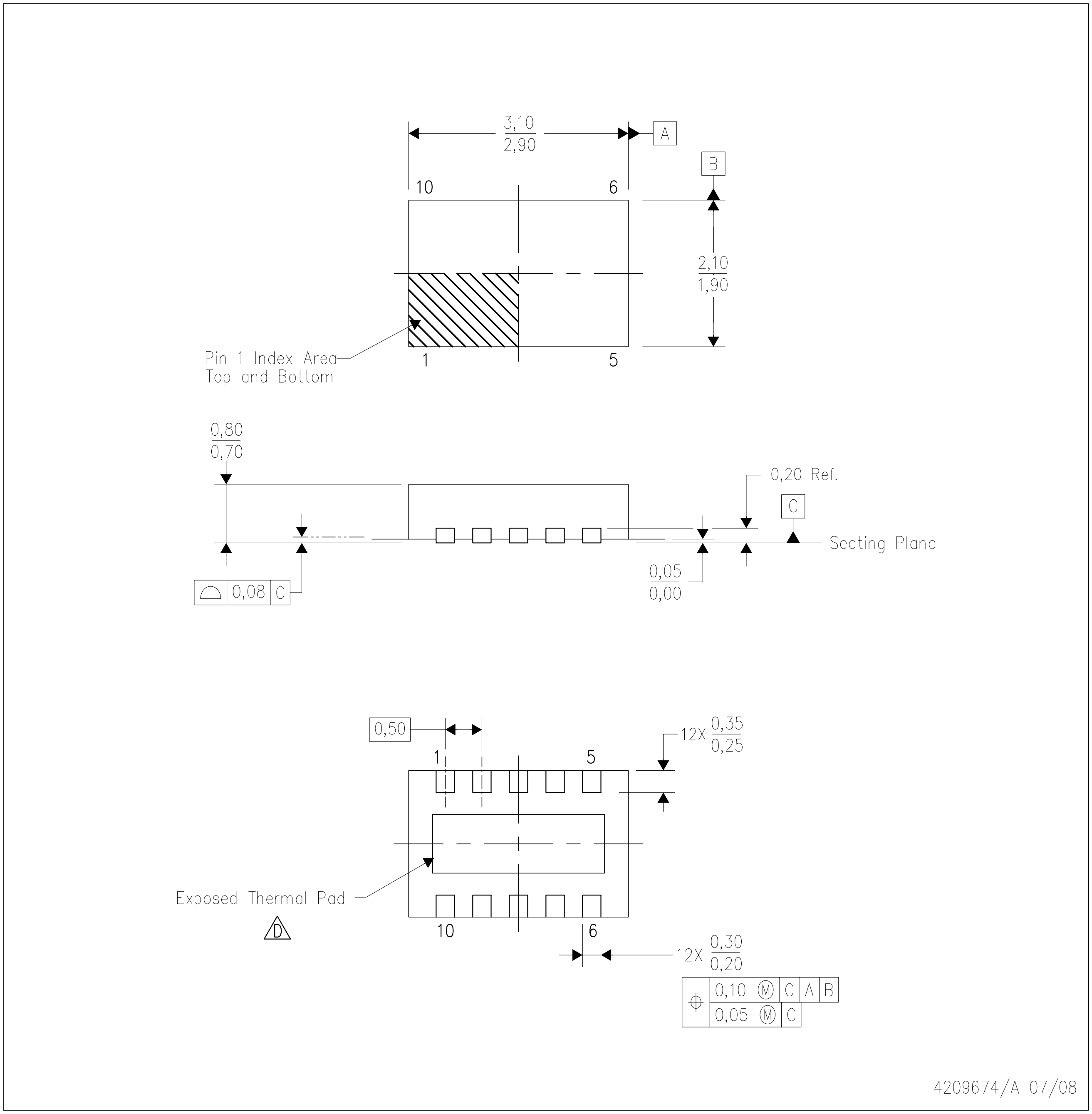
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS62175DQCR	WSON	DQC	10	3000	367.0	367.0	35.0
TPS62175DQCT	WSON	DQC	10	250	210.0	185.0	35.0
TPS62177DQCR	WSON	DQC	10	3000	367.0	367.0	35.0
TPS62177DQCT	WSON	DQC	10	250	210.0	185.0	35.0

DQC (R–PWSON–N10) PLASTIC SMALL OUTLINE NO–LEAD



NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
- B. This drawing is subject to change without notice.
- C. SON (Small Outline No–Lead) package configuration.
- D. The package thermal pad must be soldered to the board for thermal and mechanical performance. See the Product Data Sheet for details regarding the exposed thermal pad dimensions.

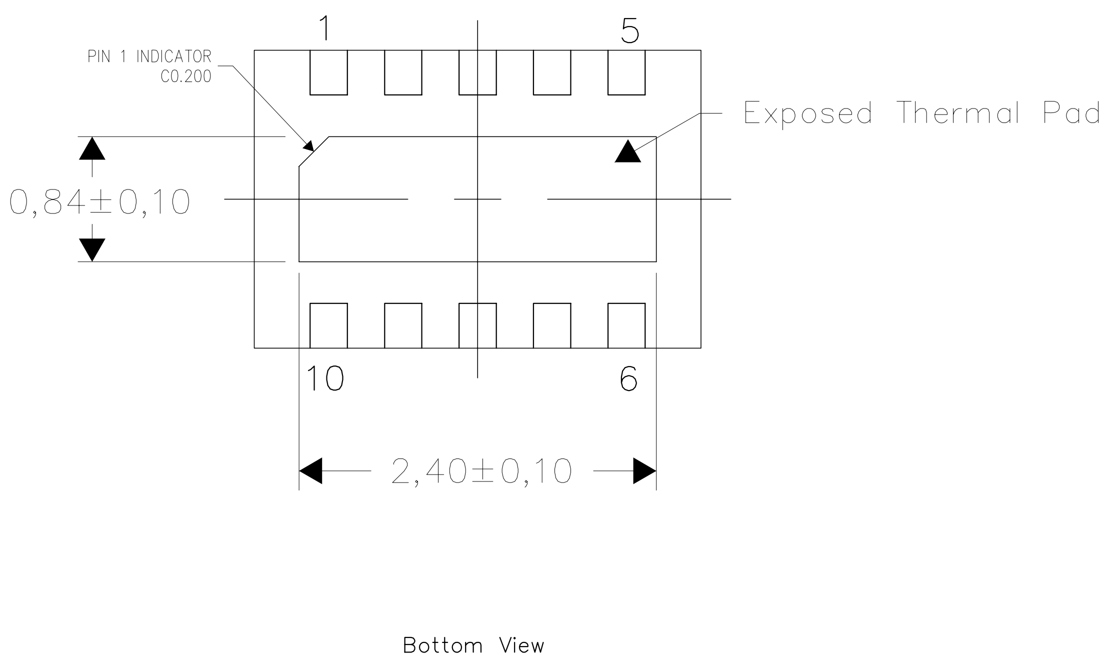
DQC (R–PWSON–N10) PLASTIC SAMLL OUTLINE NO–LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No–Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



Exposed Thermal Pad Dimensions

4209909/C 12/11

NOTE: A. All linear dimensions are in millimeters

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