

# TPS62000-Q1, TPS62001-Q1, TPS62002-Q1, TPS62003-Q1 TPS62004-Q1, TPS62005-Q1, TPS62006-Q1, TPS62007-Q1, TPS62008-Q1 HIGH-EFFICIENCY STEP-DOWN LOW POWER DC-DC CONVERTER

SGLS243 – APRIL 2004

## FEATURES

- Qualification in Accordance With AEC-Q100†
- Qualified for Automotive Applications
- Customer-Specific Configuration Control Can Be Supported Along With Major-Change Approval
- High-Efficiency Synchronous Step-Down Converter With Greater Than 95% Efficiency
- 2-V to 5.5-V Operating Input Voltage Range
- Adjustable Output Voltage Range From 0.8 V to  $V_I$
- Fixed Output Voltage Options Available in 0.9 V, 1 V, 1.2 V, 1.5 V, 1.8 V, 1.9 V, 2.5 V, and 3.3 V
- Synchronizable to External Clock Signal up to 1 MHz
- Up to 600-mA Output Current
- Pin-Programmable Current Limit

† Contact Texas Instruments for details. Q100 qualification data available on request.

- High Efficiency Over a Wide Load Current Range in Power Save Mode
- 100% Maximum Duty Cycle for Lowest Dropout
- Low-Noise Operation Antiringing Switch and PFM/PWM Operation Mode
- Internal Softstart
- 50- $\mu$ A Quiescent Current (TYP)
- Available in the 10-Pin Microsmall Outline Package (MSOP)
- Evaluation Module Available

## APPLICATIONS

- Low-Power CPUs and DSPs
- Cellular Phones
- Organizers, PDAs, and Handheld PCs
- MP-3 Portable Audio Players
- Digital Cameras
- USB-Based DSL Modems and Other Network Interface Cards

## description/ordering information

The TPS6200x devices are a family of low-noise synchronous step-down dc-dc converters that are ideally suited for systems powered from a 1-cell Li-ion battery or from a 2- to 3-cell NiCd, NiMH, or alkaline battery. The TPS6200x operates typically down to an input voltage of 1.8 V, with a specified minimum input voltage of 2 V.

### ORDERING INFORMATION

$T_J$	VOLTAGE OPTIONS	MSOP PACKAGE	MARKING
–40°C to 125°C	Adjustable	TPS62000QDGSRQ1	AOQ
	0.9 V	TPS62001QDGSRQ1†	
	1 V	TPS62002QDGSRQ1†	
	1.2 V	TPS62003QDGSRQ1†	
	1.5 V	TPS62004QDGSRQ1	AOR
	1.8 V	TPS62005QDGSRQ1	ALY
	1.9 V	TPS62008QDGSRQ1†	
	2.5 V	TPS62006QDGSRQ1	AOS
	3.3 V	TPS62007QDGSRQ1	AOT

† Indicates Product Preview. Contact Texas Instruments for details.



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**TEXAS  
INSTRUMENTS**

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SGLS243 – APRIL 2004

## description (continued)

The TPS6200x is a synchronous current-mode PWM converter with integrated N- and P-channel power MOSFET switches. Synchronous rectification is used to increase efficiency and to reduce external component count. To achieve the highest efficiency over a wide load current range, the converter enters a power-saving pulse-frequency modulation (PFM) mode at light load currents. Operating frequency is typically 750 kHz, allowing the use of small inductor and capacitor values. The device can be synchronized to an external clock signal in the range of 500 kHz to 1 MHz. For low-noise operation, the converter can be operated in the PWM mode and the internal antiringing switch reduces noise and EMI. In the shutdown mode, the current consumption is reduced to less than 1  $\mu$ A. The TPS6200x is available in the 10-pin (DGS) microsmall outline package (MSOP). The devices operate over a junction temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

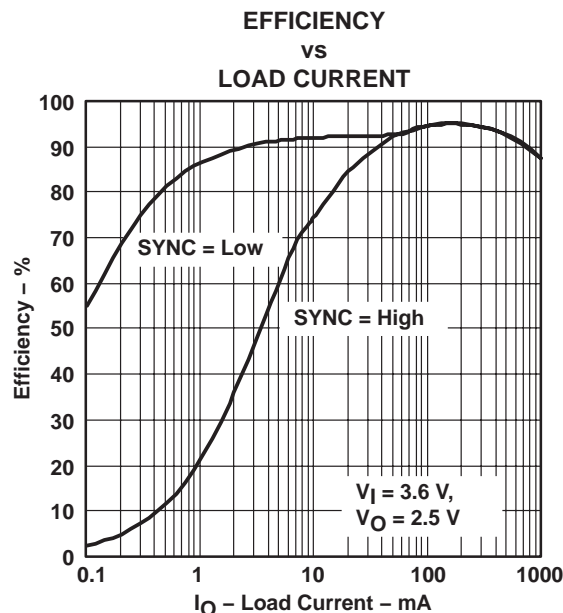


Figure 1

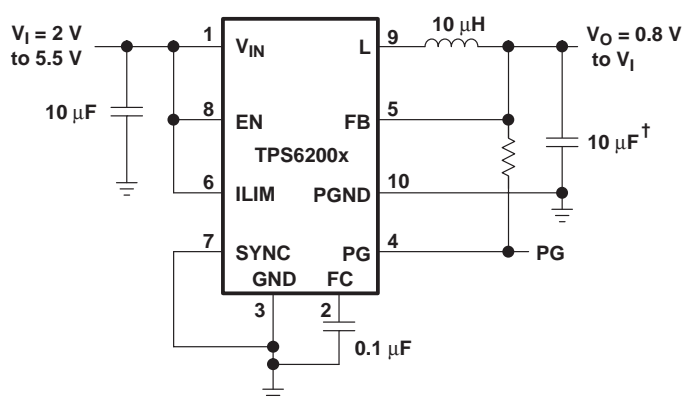
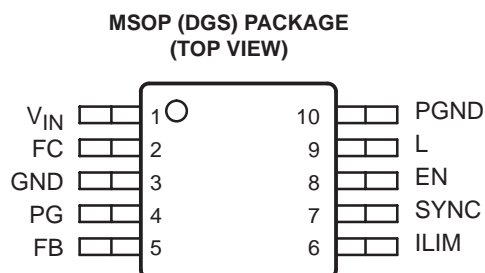


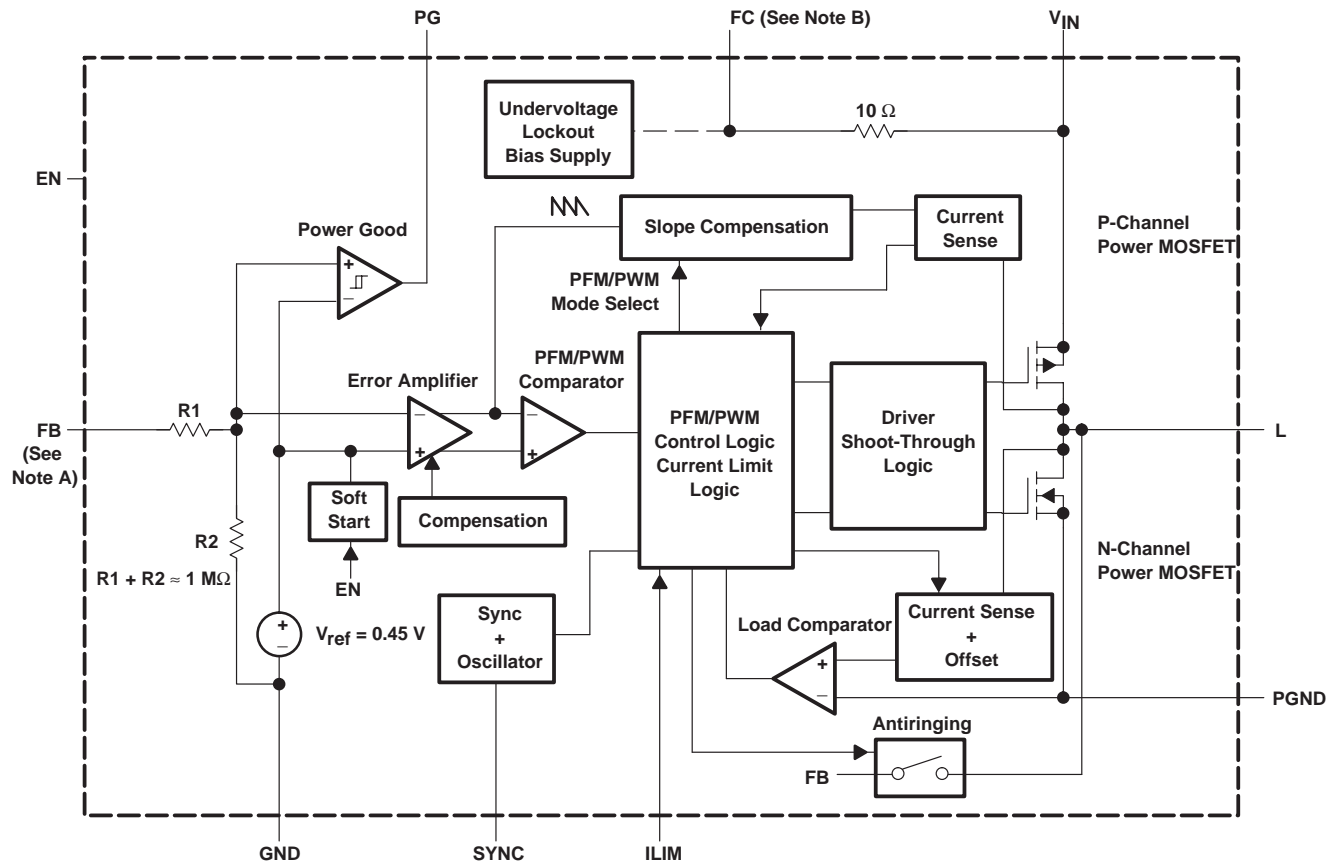
Figure 2. Typical Application Circuit for Fixed Output Voltage Option



**TPS62000-Q1, TPS62001-Q1, TPS62002-Q1, TPS62003-Q1  
TPS62004-Q1, TPS62005-Q1, TPS62006-Q1, TPS62007-Q1, TPS62008-Q1  
HIGH-EFFICIENCY STEP-DOWN LOW POWER DC-DC CONVERTER**

SGLS243 – APRIL 2004

**functional block diagram**



- NOTES: A. The adjustable output voltage version does not use the internal feedback resistor divider. The FB pin is directly connected to the error amplifier.
- B. Do not connect the FC pin to an external power source.

**TPS62000-Q1, TPS62001-Q1, TPS62002-Q1, TPS62003-Q1  
TPS62004-Q1, TPS62005-Q1, TPS62006-Q1, TPS62007-Q1, TPS62008-Q1  
HIGH-EFFICIENCY STEP-DOWN LOW POWER DC-DC CONVERTER**

SGLS243 – APRIL 2004

## Terminal Functions

TERMINAL NAME	NO.	I/O	DESCRIPTION
EN	8	I	Enable. A logic high enables the converter and a logic low forces the device into shutdown mode reducing the supply current to less than 1 $\mu$ A.
FB	5	I	Feedback pin for the fixed output voltage option. For the adjustable version, an external resistive divider is connected to FB. The internal voltage divider is disabled for the adjustable version.
FC	2		Supply bypass pin. A 0.1- $\mu$ F coupling capacitor should be connected as close as possible to this pin for good high frequency input voltage supply filtering.
GND	3		Ground
ILIM	6	I	Switch current limit. Connect ILIM to GND to set the switch current limit to typically 600 mA, or connect this pin to $V_{IN}$ to set the current limit to typically 1200 mA.
L	9	I/O	Connect the inductor to this pin. L is the switch pin connected to the drain of the internal power MOSFETS.
PG	4	O	Power good comparator output. This is an open-drain output. A pullup resistor should be connected between PG and $V_O$ . The output goes active high when the output voltage is greater than 92% of the nominal value.
PGND	10		Power ground. Connect all power grounds to PGND.
SYNC	7	I	Input for synchronization to external clock signal. Synchronizes the converter switching frequency to an external clock signal with CMOS level: SYNC = High: Low-noise mode enabled, fixed frequency PWM operation is forced SYNC = Low (GND): Power-save mode enabled, PFM/PWM mode enabled.
$V_{IN}$	1	I	Supply voltage input
NC			Not connected

## detailed description

### operation

The TPS6200x is a step down converter operating in a current mode PFM/PWM scheme with a typical switching frequency of 750 kHz.

At moderate to heavy loads, the converter operates in the pulse width modulation (PWM) and at light loads the converter enters a power save mode (pulse frequency modulation) to keep the efficiency high.

In the PWM mode operation, the device operates at a fixed frequency of 750 kHz. At the beginning of each clock cycle, the high side P-channel MOSFET is turned on. The current in the inductor ramps up and is sensed via an internal circuit. The high side switch is turned off when the sensed current causes the PFM/PWM comparator to trip when the output voltage is in regulation or when the inductor current reaches the current limit (set by ILIM). After a minimum dead time preventing shoot through current, the low side N-channel MOSFET is turned on and the current ramps down again. As the clock cycle is completed, the low side switch is turned off and the next clock cycle starts.

In discontinuous conduction mode (DCM), the inductor current ramps to zero before the end of each clock cycle. In order to increase the efficiency the load comparator turns off the low side MOSFET before the inductor current becomes negative. This prevents reverse current flowing from the output capacitor through the inductor and low side MOSFET to ground that would cause additional losses.

As the load current decreases and the peak inductor current does not reach the power save mode threshold of typically 120 mA for more than 15 clock cycles, the converter enters a pulse frequency modulation (PFM) mode.



#### **operation (continued)**

In the PFM mode, the converter operates with:

- Variable frequency
- Constant peak current that reduces switching losses
- Quiescent current at a minimum

Thus maintaining the highest efficiency at light load currents. In this mode, the output voltage is monitored with the error amplifier. As soon as the output voltage falls below the nominal value, the high side switch is turned on and the inductor current ramps up. When the inductor current reaches the peak current of typical:  $150\text{ mA} + 50\text{ mA/V} \times (V_I - V_O)$ , the high side switch turns off and the low side switch turns on. As the inductor current ramps down, the low side switch is turned off before the inductor current becomes negative which completes the cycle. When the output voltage falls below the nominal voltage again, the next cycle is started.

The converter enters the PWM mode again as soon as the output voltage can not be maintained with the typical peak inductor current in the PFM mode.

The control loop is internally compensated reducing the amount of external components.

The switch current is internally sensed and the maximum current limit can be set to typical 600 mA by connecting ILIM to ground or to typically 1.2 A connecting ILIM to  $V_{IN}$ .

#### **100% duty cycle operation**

As the input voltage approaches the output voltage and the duty cycle exceeds typical 95%, the converter turns the P-channel high side switch continuously on. In this mode, the output voltage is equal to the input voltage minus the voltage drop across the P-channel MOSFET.

#### **synchronization, power save mode and forced PWM mode**

If no clock signal is applied, the converter operates with a typical switching frequency of 750 kHz. It is possible to synchronize the converter to an external clock within a frequency range from 500 kHz to 1000 kHz. The device automatically detects the rising edge of the first clock and is synchronizes immediately to the external clock. If the clock signal is stopped, the converter automatically switches back to the internal clock and continues operation without interruption. The switch over is initiated if no rising edge on the SYNC pin is detected for a duration of four clock cycles. Therefore, the maximum delay time can be 8  $\mu\text{s}$  in case the internal clock has a minimum frequency of 500 kHz.

In case the device is synchronized to an external clock, the power save mode is disabled and the device stays in forced PWM mode.

Connecting the SYNC pin to the GND pin enables the power save mode. The converter operates in the PWM mode at moderate to heavy loads and in the PFM mode during light loads maintaining high efficiency over a wide load current range.

Connecting the SYNC pin to the  $V_{IN}$  pin forces the converter to operate permanently in the PWM mode, even at light or no load currents. The advantage is the converter operates with a fixed switching frequency that allows simple filtering of the switching frequency for noise sensitive applications. In this mode, the efficiency is lower compared to the power save mode during light loads (see Figure 1).

It is possible to switch from forced PWM mode to the power save mode during operation.

The flexible configuration of the SYNC pin during operation of the device allows efficient power management by adjusting the operation of the TPS6200x to the specific system requirements.

# TPS62000-Q1, TPS62001-Q1, TPS62002-Q1, TPS62003-Q1 TPS62004-Q1, TPS62005-Q1, TPS62006-Q1, TPS62007-Q1, TPS62008-Q1 HIGH-EFFICIENCY STEP-DOWN LOW POWER DC-DC CONVERTER

SGLS243 – APRIL 2004

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## low noise antiringing switch

An *antiringing* switch is implemented in order to reduce the EMI radiated from the converter during discontinuous conduction mode (DCM). In DCM, the inductor current ramps to zero before the end of each switching period. The internal load comparator turns off the low side switch at that instant thus preventing the current flowing backward through the inductance which increases the efficiency. An antiringing switch across the inductor prevents parasitic oscillation caused by the residual energy stored in the inductance (see Figure 12).

### NOTE:

The *antiringing* switch is only activated in the fixed output voltage versions. It is not enabled for the adjustable output voltage version TPS62000.

## soft start

As the enable pin (EN) goes high, the soft-start function generates an internal voltage ramp. This causes the start-up current to slowly rise preventing output voltage overshoot and high inrush currents. The soft-start duration is typical 1 ms (see Figure 13). When the soft-start function is completed, the error amplifier is connected directly to the internal voltage reference.

## enable

Logic low on EN forces the TPS6200x into shutdown. In shutdown, the power switch, drivers, voltage reference, oscillator, and all other functions are turned off. The supply current is reduced to less than 1  $\mu$ A in the shutdown mode.

## undervoltage lockout

An undervoltage lockout circuit provides the save operation of the device and it prevents the converter from turning on when the voltage on  $V_{IN}$  is less than 1.6 V typical.

## power good comparator

The power good (PG) comparator has an open drain output capable of sinking typically 10  $\mu$ A. The PG is only active when the device is enabled (EN = high). When the device is disabled (EN = low), the PG pin is high impedance.

The PG output is only valid after a 100  $\mu$ s delay after the device is enabled and the supply voltage is greater than 1.2 V. This is only important in cases where the pullup resistor of the PG pin is connected to an external voltage source, which might cause an initial spike (false high signal) within the first 100  $\mu$ s after the input voltage exceeds 1.2 V. This initial spike can be filtered with a small R-C filter to avoid false power good signals during start-up.

If the PG pin is connected to the output of the TPS62000 with a pullup resistor, no initial spike (false high signal) occurs and no precautions have to be taken during start-up.

The PG pin becomes active high when the output voltage exceeds typically 94.5% of its nominal value. Leave the PG pin unconnected when not used.

## no load operation

In case the converter operates in the forced PWM mode and there is no load connected to the output, the converter regulates the output voltage by allowing the inductor current to reverse for a short period of time.



**TPS62000-Q1, TPS62001-Q1, TPS62002-Q1, TPS62003-Q1  
TPS62004-Q1, TPS62005-Q1, TPS62006-Q1, TPS62007-Q1, TPS62008-Q1  
HIGH-EFFICIENCY STEP-DOWN LOW POWER DC-DC CONVERTER**

SGLS243 – APRIL 2004

**absolute maximum ratings over operating free-air temperature (unless otherwise noted)<sup>†</sup>**

Supply voltages on pin $V_{IN}$ and FC (see Note 1)	–0.3 V to 6 V
Voltages on pins EN, ILIM, SYNC, PG, FB, L (see Note 1)	–0.3 V to $V_{IN} + 0.3$ V
Peak switch current	1.6 A
Continuous power dissipation	See Dissipation Rating Table
Operating junction temperature range, $T_J$	–40°C to 150°C
Storage temperature range, $T_{stg}$	–65°C to 150°C
Lead temperature (soldering, 10 sec)	260°C

<sup>†</sup> 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.

NOTE 1: All voltage values are with respect to network ground terminal.

**DISSIPATION RATING TABLE**

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 85^\circ\text{C}$ POWER RATING
10 pin MSOP	555 mW	5.56 mW/°C	305 mW	221 mW

NOTE: The thermal resistance junction to ambient of the 10-pin MSOP is 180°C/W. The device will not run into thermal limitations, provided it is operated within the specified range.

**recommended operating conditions**

	MIN	TYP	MAX	UNIT
Supply voltage, $V_I$	2		5.5	V
Output voltage range for adjustable output voltage version, $V_O$	0.8		$V_I$	V
Output current for 3-cell operation, $I_O$ ( $V_I \geq 2.5$ V; $L = 10$ $\mu$ H, $f = 750$ kHz)			600	mA
Output current for 2-cell operation, $I_O$ ( $V_I \geq 2$ V; $L = 10$ $\mu$ H, $f = 750$ kHz)			200	mA
Inductor, L (see Note 2)		10		$\mu$ H
Input capacitor, $C_i$ (see Note 2)	10			$\mu$ F
Output capacitor, $C_O$ (see Note 2) $V_O \geq 1.8$ V)	10			$\mu$ F
Output capacitor, $C_O$ (see Note 2) $V_O < 1.8$ V)	47			$\mu$ F
Operating junction temperature, $T_J$	–40		125	°C

NOTE 2: See the *Application Information* section for further information.

**electrical characteristics over recommended operating free-air temperature range,  $V_I = 3.6$  V,  $V_O = 2.5$  V,  $I_O = 300$  mA,  $EN = V_{IN}$ ,  $ILIM = V_{IN}$ ,  $T_J = -40^\circ\text{C}$  to  $125^\circ\text{C}$  (unless otherwise noted)**

**supply current**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_I$ Input voltage range	$I_O = 0$ mA to 600 mA	2.5		5.5	V
	$I_O = 0$ mA to 200 mA	2		5.5	
$I_{(Q)}$ Operating quiescent current	$I_O = 0$ mA, SYNC = GND (PFM-mode enabled)		50	75	$\mu$ A
$I_{(SD)}$ Shutdown current	EN = GND		0.1	1	$\mu$ A

**enable**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{IH}$ EN high-level input voltage		1.3			V
$V_{IL}$ EN low level input voltage				0.4	V
$I_{lkg}$ EN input leakage current	EN = GND or $V_{IN}$		0.01	0.1	$\mu$ A
$V_{(UVLO)}$ Undervoltage lockout threshold		1.2	1.6	1.95	V





**TPS62000-Q1, TPS62001-Q1, TPS62002-Q1, TPS62003-Q1  
TPS62004-Q1, TPS62005-Q1, TPS62006-Q1, TPS62007-Q1, TPS62008-Q1  
HIGH-EFFICIENCY STEP-DOWN LOW POWER DC-DC CONVERTER**

SGLS243 – APRIL 2004

electrical characteristics over recommended operating free-air temperature range,  $V_I = 3.6\text{ V}$ ,  $V_O = 2.5\text{ V}$ ,  $I_O = 300\text{ mA}$ ,  $EN = V_{IN}$ ,  $ILIM = V_{IN}$ ,  $T_J = -40^\circ\text{C}$  to  $125^\circ\text{C}$  (unless otherwise noted) (continued)

**power switch and current limit**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$r_{DS(on)}$	P-channel MOSFET on-resistance	$V_I = V_{GS} = 3.6\text{ V}$ , $I = 200\text{ mA}$	150	280	600	$m\Omega$
		$V_I = V_{GS} = 2\text{ V}$ , $I = 200\text{ mA}$		480		
	P-channel leakage current	$V_{DS} = 5.5\text{ V}$			1	$\mu\text{A}$
	N-channel MOSFET on-resistance	$V_I = V_{GS} = 3.6\text{ V}$ , $I_O = 200\text{ mA}$	150	280	600	$m\Omega$
		$V_I = V_{GS} = 2\text{ V}$ , $I_O = 200\text{ mA}$		500		
	N-channel leakage current	$V_{DS} = 5.5\text{ V}$			1	$\mu\text{A}$
$I_{(LIM)}$	P-channel current limit	$2.5\text{ V} \leq V_I \leq 5.5\text{ V}$ , $ILIM = V_{IN}$	800	1200	1600	$\text{mA}$
		$2\text{ V} \leq V_I \leq 5.5\text{ V}$ , $ILIM = GND$	390	600	900	
$V_{IH}$	ILIM high-level input voltage		1.3			$\text{V}$
$V_{IL}$	ILIM low-level input voltage				0.4	$\text{V}$
$I_{lkg}$	ILIM input leakage current	$ILIM = GND$ or $V_{IN}$		0.01	0.1	$\mu\text{A}$

**power good output (see Note 3)**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(PG)}$	Power good threshold	Feedback voltage falling	88% $V_O$	92% $V_O$	94% $V_O$	$\text{V}$
	Power good hysteresis			2.5% $V_O$		$\text{V}$
$V_{OL}$	PG output low voltage	$V_{(FB)} = 0.8 \times V_O$ nominal, $I_{(sink)} = 10\text{ }\mu\text{A}$			0.3	$\text{V}$
$I_{lkg}$	PG output leakage current	$V_{(FB)} = V_O$ nominal		0.01	1	$\mu\text{A}$
Minimum supply voltage for valid power good signal			1.2			$\text{V}$

NOTE 3: Power good is not valid for the first 100  $\mu\text{s}$  after EN goes high. Please refer to the application section for more information.

**oscillator**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$f_s$	Oscillator frequency		500	750	1000	$\text{kHz}$
$f_{(SYNC)}$	Synchronization range	CMOS-logic clock signal on SYNC pin	500		1000	$\text{kHz}$
$V_{IH}$	SYNC high level input voltage		1.3			$\text{V}$
$V_{IL}$	SYNC low level input voltage				0.4	$\text{V}$
$I_{lkg}$	SYNC input leakage current	$SYNC = GND$ or $V_{IN}$		0.01	0.1	$\mu\text{A}$
Duty cycle of external clock signal			20%		60%	



**TPS62000-Q1, TPS62001-Q1, TPS62002-Q1, TPS62003-Q1  
TPS62004-Q1, TPS62005-Q1, TPS62006-Q1, TPS62007-Q1, TPS62008-Q1  
HIGH-EFFICIENCY STEP-DOWN LOW POWER DC-DC CONVERTER**

SGLS243 – APRIL 2004

electrical characteristics over recommended operating free-air temperature range,  $V_I = 3.6\text{ V}$ ,  $V_O = 2.5\text{ V}$ ,  $I_O = 300\text{ mA}$ ,  $EN = V_{IN}$ ,  $ILIM = V_{IN}$ ,  $T_J = -40^\circ\text{C}$  to  $125^\circ\text{C}$  (unless otherwise noted) (continued)

**output**

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
V <sub>O</sub>	Adjustable output voltage range	TPS62000		0.8		5.5	V
V <sub>ref</sub>	Reference voltage	TPS6200x		0.45			V
V <sub>O</sub>	Fixed output voltage (see Note 4)	TPS62000 adjustable	V <sub>I</sub> = 2.5 V to 5.5 V; 0 mA ≤ I <sub>O</sub> ≤ 600 mA	−4%		4%	V
			10 mA < I <sub>O</sub> ≤ 600 mA	−4%		3%	
		TPS62001 0.9 V	V <sub>I</sub> = 2.5 V to 5.5 V; 0 mA ≤ I <sub>O</sub> ≤ 600 mA	−4%		4%	
			10 mA < I <sub>O</sub> ≤ 600 mA	−4%		3%	
		TPS62002 1 V	V <sub>I</sub> = 2.5 V to 5.5 V; 0 mA ≤ I <sub>O</sub> ≤ 600 mA	−4%		4%	
			10 mA < I <sub>O</sub> ≤ 600 mA	−4%		3%	
		TPS62003 1.2 V	V <sub>I</sub> = 2.5 V to 5.5 V; 0 mA ≤ I <sub>O</sub> ≤ 600 mA	−4%		4%	
			10 mA < I <sub>O</sub> ≤ 600 mA	−4%		3%	
		TPS62004 1.5 V	V <sub>I</sub> = 2.5 V to 5.5 V; 0 mA ≤ I <sub>O</sub> ≤ 600 mA	−4%		4%	
			10 mA < I <sub>O</sub> ≤ 600 mA	−4%		3%	
		TPS62005 1.8 V	V <sub>I</sub> = 2.5 V to 5.5 V; 0 mA ≤ I <sub>O</sub> ≤ 600 mA	−4%		4%	
			10 mA < I <sub>O</sub> ≤ 600 mA	−4%		3%	
		TPS62008 1.9 V	V <sub>I</sub> = 2.5 V to 5.5 V; 0 mA ≤ I <sub>O</sub> ≤ 600 mA	−4%		4%	
			10 mA < I <sub>O</sub> ≤ 600 mA	−4%		3%	
		TPS62006 2.5 V	V <sub>I</sub> = 2.7 V to 5.5 V; 0 mA ≤ I <sub>O</sub> ≤ 600 mA	−4%		4%	
			10 mA < I <sub>O</sub> ≤ 600 mA	−4%		3%	
		TPS62007 3.3 V	V <sub>I</sub> = 3.6 V to 5.5 V; 0 mA ≤ I <sub>O</sub> ≤ 600 mA	−4%		4%	
			10 mA < I <sub>O</sub> ≤ 600 mA	−4%		3%	
Line regulation			V <sub>I</sub> = V <sub>O</sub> + 0.5 V (min. 2 V) to 5.5 V, I <sub>O</sub> = 10 mA	0.05		%/V	
Load regulation			V <sub>I</sub> = 5.5 V; I <sub>O</sub> = 10 mA to 600 mA	0.6%			
η	Efficiency	V <sub>I</sub> = 5 V; V <sub>O</sub> = 3.3 V; I <sub>O</sub> = 300 mA		95%			
		V <sub>I</sub> = 3.6 V; V <sub>O</sub> = 2.5 V; I <sub>O</sub> = 200 mA					
Start-up time			I <sub>O</sub> = 0 mA, time from active EN to V <sub>O</sub>	0.4	2	ms	

NOTE 4: The output voltage accuracy includes line and load regulation over the full temperature range,  $T_J = -40^\circ\text{C}$  to  $125^\circ\text{C}$ .

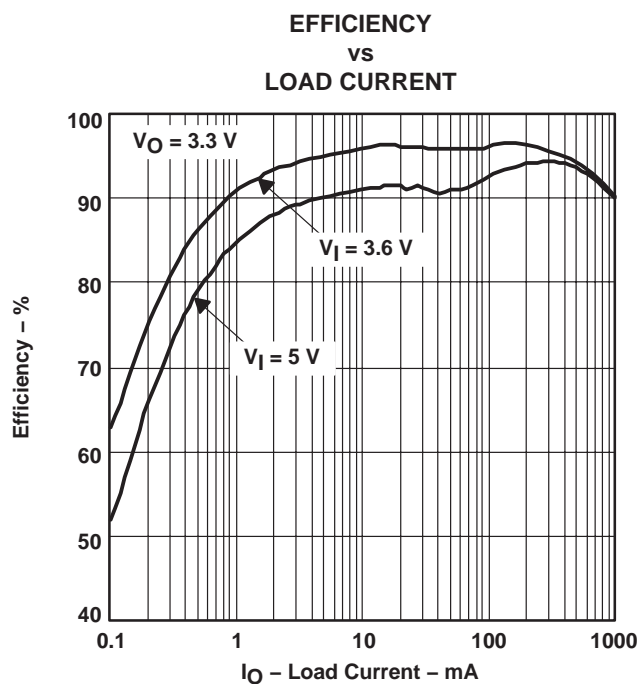
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TPS62004-Q1, TPS62005-Q1, TPS62006-Q1, TPS62007-Q1, TPS62008-Q1  
HIGH-EFFICIENCY STEP-DOWN LOW POWER DC-DC CONVERTER**

SGLS243 – APRIL 2004

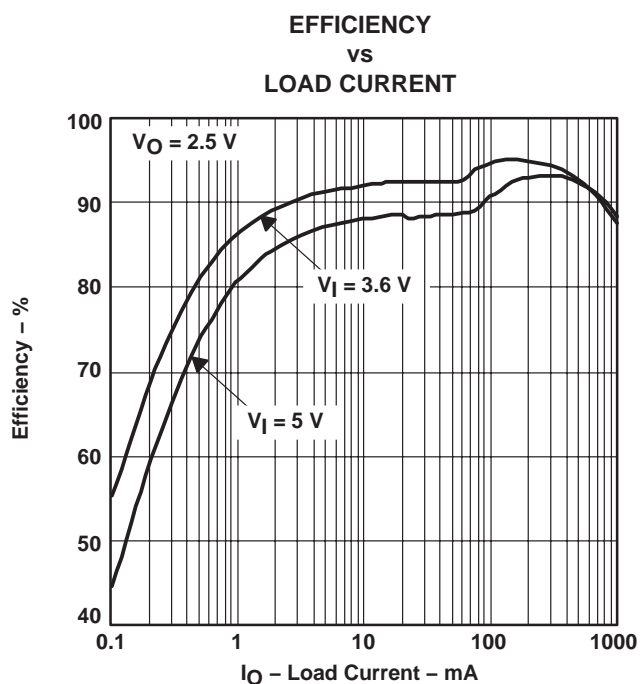
**TYPICAL CHARACTERISTICS**

**Table of Graphs**

			FIGURE
$\eta$	Efficiency	vs Load current	3, 4, 5
$V_{(\text{drop})}$	Dropout voltage	vs Load current	6
$I_Q$	Operating quiescent current	vs Input voltage (power save mode)	7
		vs Input voltage (forced PWM)	8
$f_{\text{osc}}$	Oscillator frequency	vs Free-air temperature	9
	Load transient response		10
	Line transient response		11
	Power save mode operation		12
	Start-up	vs Time	13
$V_O$	Output voltage	vs Load current	14



**Figure 3**



**Figure 4**

# TYPICAL CHARACTERISTICS

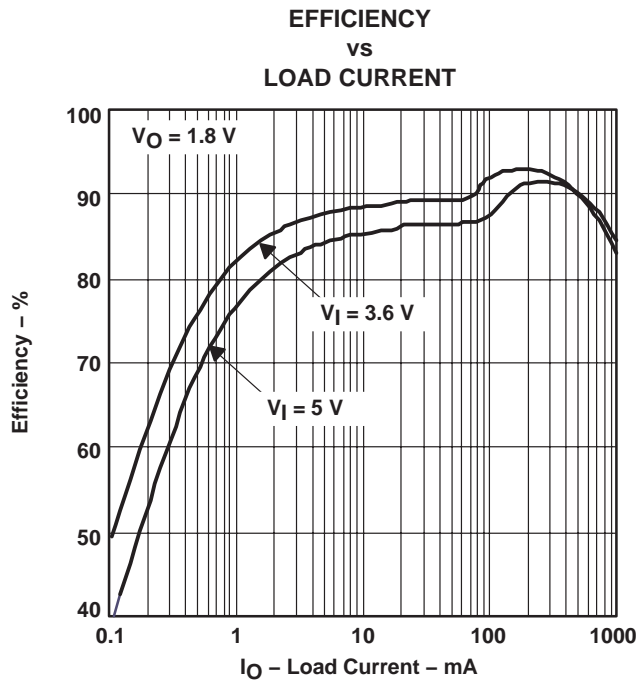


Figure 5

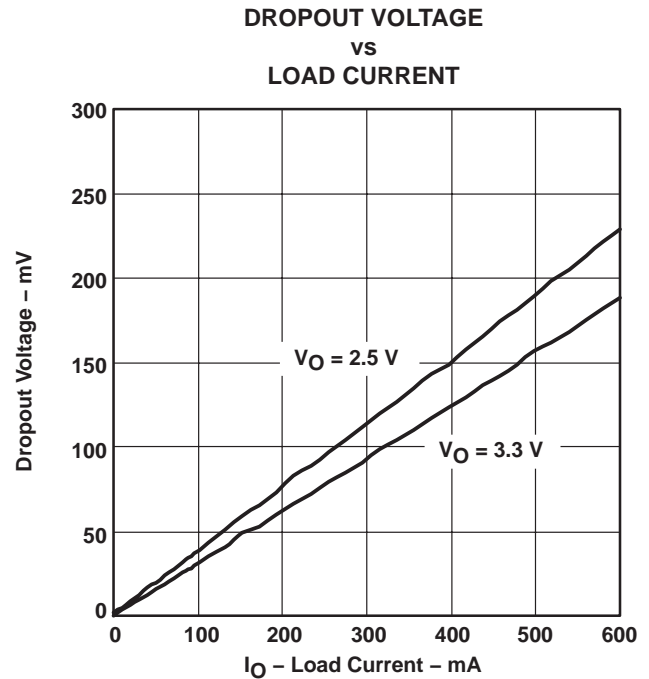


Figure 6

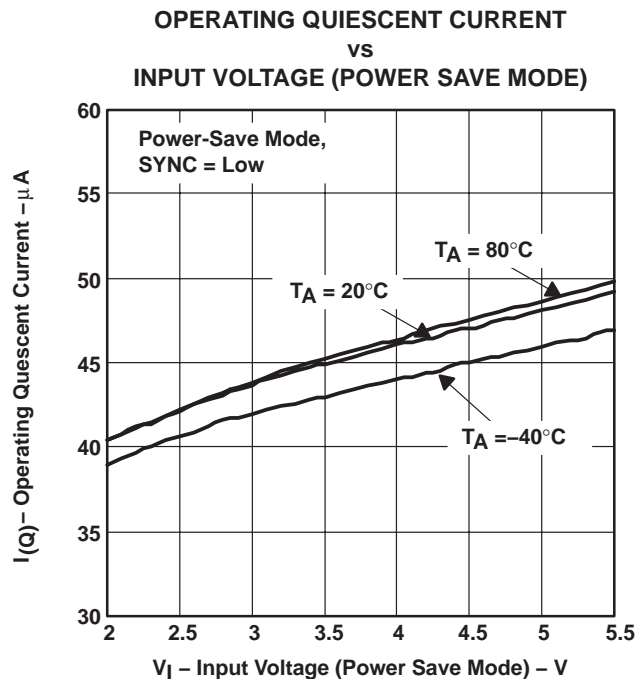


Figure 7

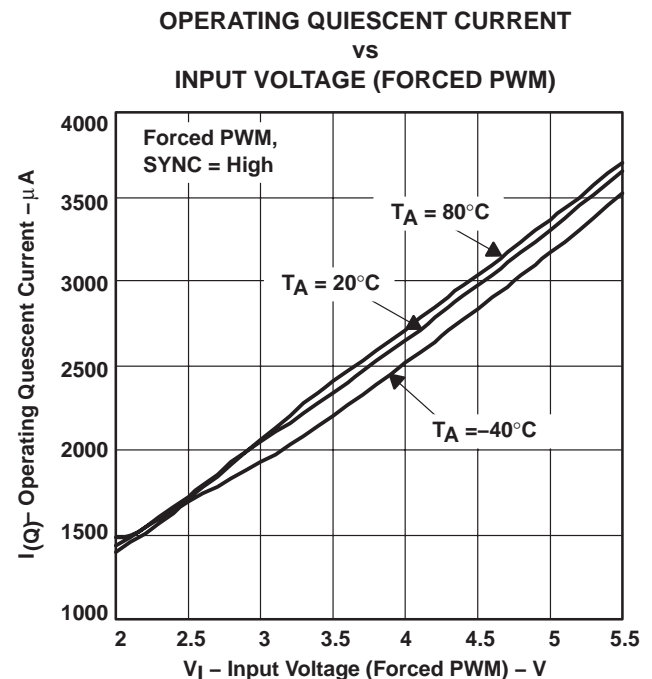
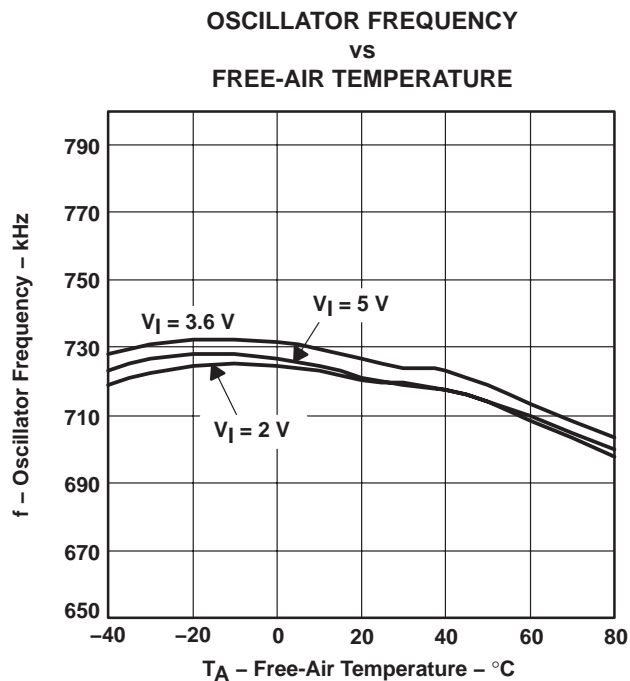


Figure 8

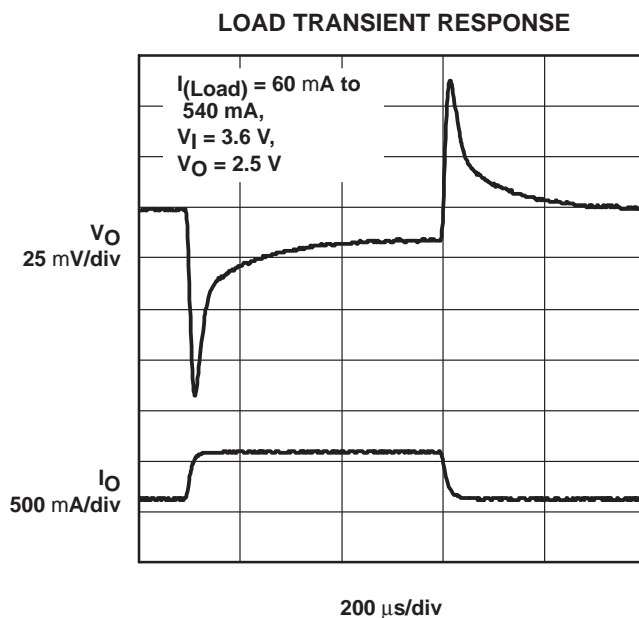
**TPS62000-Q1, TPS62001-Q1, TPS62002-Q1, TPS62003-Q1  
TPS62004-Q1, TPS62005-Q1, TPS62006-Q1, TPS62007-Q1, TPS62008-Q1  
HIGH-EFFICIENCY STEP-DOWN LOW POWER DC-DC CONVERTER**

SGLS243 – APRIL 2004

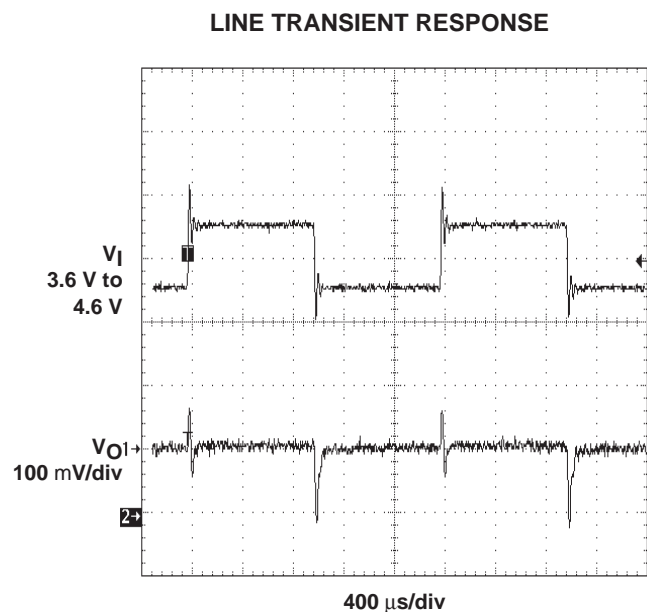
**TYPICAL CHARACTERISTICS**



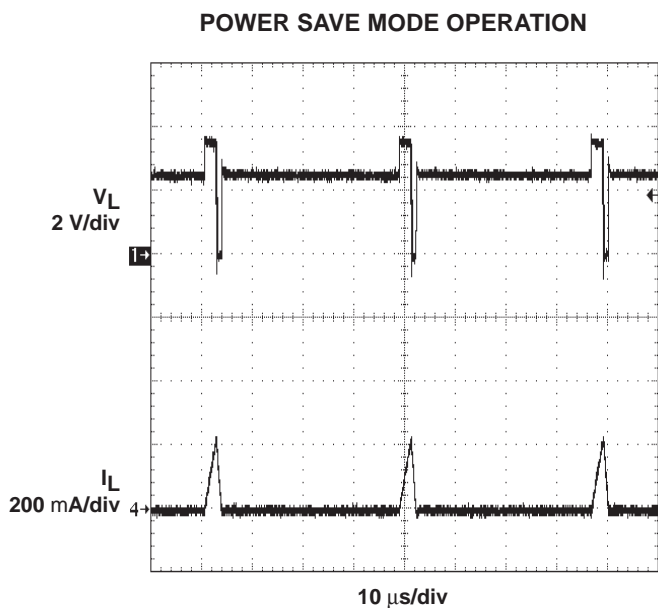
**Figure 9**



**Figure 10**



**Figure 11**



**Figure 12**

## TYPICAL CHARACTERISTICS

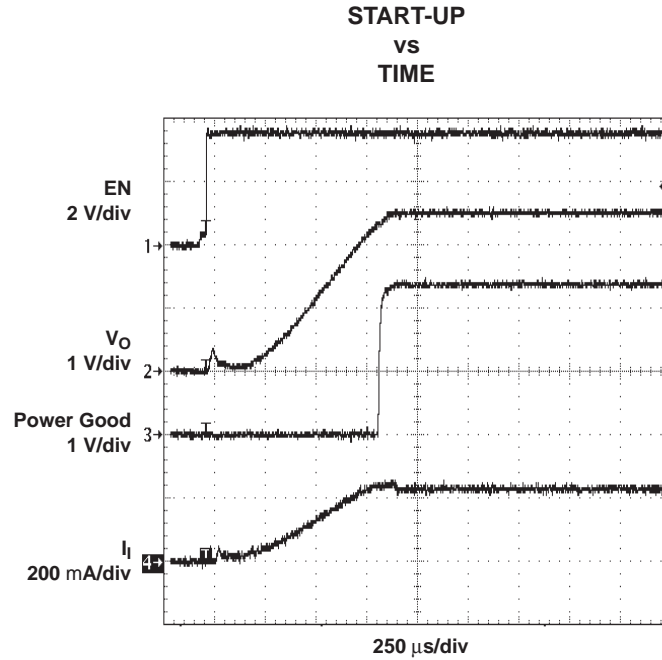


Figure 13

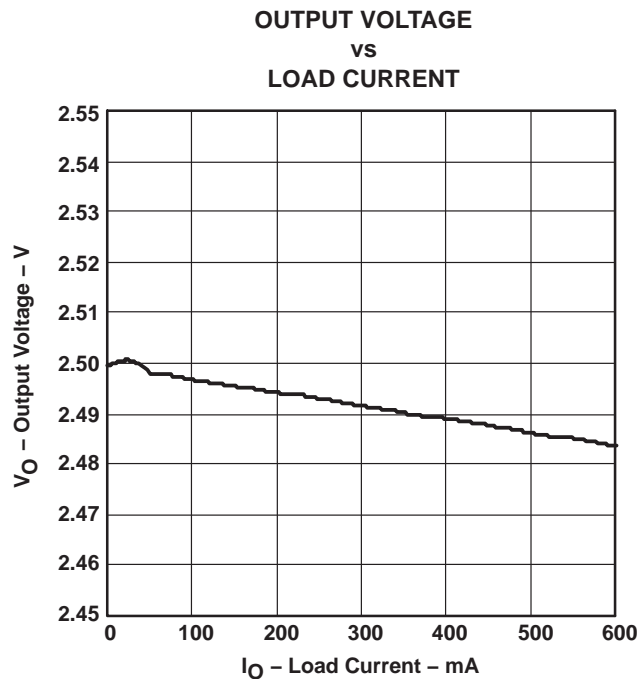


Figure 14



## APPLICATION INFORMATION

### inductor selection (continued)

In order to avoid saturation of the inductor, the inductor should be rated at least for the maximum output current plus the inductor ripple current which is calculated as:

$$\Delta I_L = V_O \times \frac{1 - \frac{V_O}{V_I}}{L \times f} \quad I_{L(max)} = I_{O(max)} + \frac{\Delta I_L}{2}$$

Where:

$f$  = Switching frequency (750 kHz typical)

$L$  = Inductor value

$\Delta I_L$  = Peak-to-peak inductor ripple current

$I_{L(max)}$  = Maximum inductor current

The highest inductor current occurs at maximum  $V_I$ .

A more conservative approach is to select the inductor current rating just for the maximum switch current of the TPS6200x which is 1.6 A with  $ILIM = V_{IN}$  and 900 mA with  $ILIM = GND$ . See Table 1 for recommended inductors.

**Table 1. Tested Inductors**

OUTPUT CURRENT	INDUCTOR VALUE	COMPONENT SUPPLIER	COMMENTS
0 mA to 600 mA	10 $\mu$ H	Coilcraft DO3316P-103	High efficiency
		Coilcraft DT3316P-103	
		Sumida CDR63B-100	Smallest solution
		Sumida CDRH5D28-100	
0 mA to 300 mA	10 $\mu$ H	Coilcraft DO1608C-103	High efficiency
		Sumida CDRH4D28-100	
		muRata LQH4C100K04	Smallest solution

### output capacitor selection

For best performance, a low ESR output capacitor is needed. At output voltages greater than 1.8 V, ceramic output capacitors can be used to show the best performance. Output voltages below 1.8 V require a larger output capacitor and ESR value to improve the performance and stability of the converter.

**Table 2. Capacitor Selection**

OUTPUT VOLTAGE RANGE	OUTPUT CAPACITOR	OUTPUT CAPACITOR ESR
$1.8 \text{ V} \leq V_I \leq 5.5 \text{ V}$	$C_O \geq 10 \mu\text{F}$	$\text{ESR} \leq 120 \text{ m}\Omega$
$0.8 \text{ V} \leq V_I < 1.8 \text{ V}$	$C_O \geq 47 \mu\text{F}$	$\text{ESR} > 50 \text{ m}\Omega$

See Table 3 for recommended capacitors.



## APPLICATION INFORMATION

### output capacitor selection (continued)

If an output capacitor is selected with an ESR value  $\leq 120 \text{ m}\Omega$ , its RMS ripple current rating always meets the application requirements. The RMS ripple current is calculated as:

$$I_{\text{RMS}(C_O)} = V_O \times \frac{1 - \frac{V_O}{V_I}}{L \times f} \times \frac{1}{2 \times \sqrt{3}}$$

The overall output ripple voltage is the sum of the voltage spike caused by the output capacitor ESR plus the voltage ripple caused by charge and discharging the output capacitor:

$$\Delta V_O = V_O \times \frac{1 - \frac{V_O}{V_I}}{L \times f} \times \left( \frac{1}{8 \times C_O \times f} + \text{ESR} \right)$$

Where the highest output voltage ripple occurs at the highest input voltage  $V_I$ .

**Table 3. Tested Capacitors**

CAPACITOR VALUE	ESR/m $\Omega$	COMPONENT SUPPLIER	COMMENTS
10 $\mu\text{F}$	50	Taiyo Yuden JMK316BJ106KL	Ceramic
47 $\mu\text{F}$	100	Sanyo 6TPA47M	POSCAP
68 $\mu\text{F}$	100	Sprague 594D686X0010C2T	Tantalum

### input capacitor selection

Because of the nature of the buck converter having a pulsating input current, a low ESR input capacitor is required for best input voltage filtering and minimizing the interference with other circuits caused by high input voltage spikes.

The input capacitor should have a minimum value of 10  $\mu\text{F}$  and can be increased without any limit for better input voltage filtering.

The input capacitor should be rated for the maximum input ripple current calculated as:

$$I_{\text{RMS}} = I_{O(\text{max})} \times \sqrt{\frac{V_O}{V_I} \times \left( 1 - \frac{V_O}{V_I} \right)}$$

The worst case RMS ripple current occurs at  $D = 0.5$  and is calculated as:  $I_{\text{RMS}} = \frac{I_O}{2}$ .

Ceramic capacitors show a good performance because of their low ESR value and they are less sensitive against voltage transients compared to tantalum capacitors.

Place the input capacitor as close as possible to the input pin of the IC for best performance.

## APPLICATION INFORMATION

### layout considerations

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

Therefore, use wide and short traces for the main current paths as indicated in bold in Figure 16. The input capacitor should be placed as close as possible to the IC pins, as well as the inductor and output capacitor. Place the bypass capacitor, C3, as close as possible to the FC pin. The analog ground, GND, and the power ground, PGND, need to be separated. Use a common-ground node, as shown in Figure 16, to minimize the effects of ground noise.

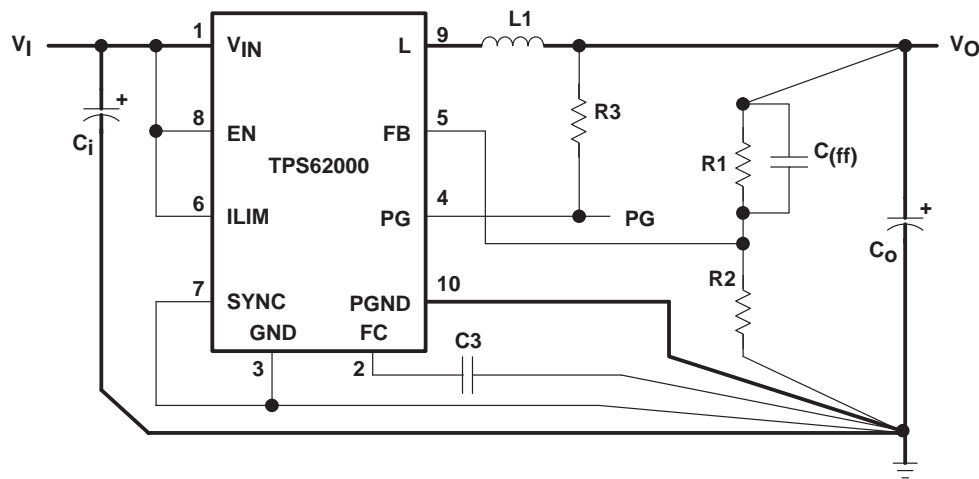


Figure 16. Layout Diagram

### typical application

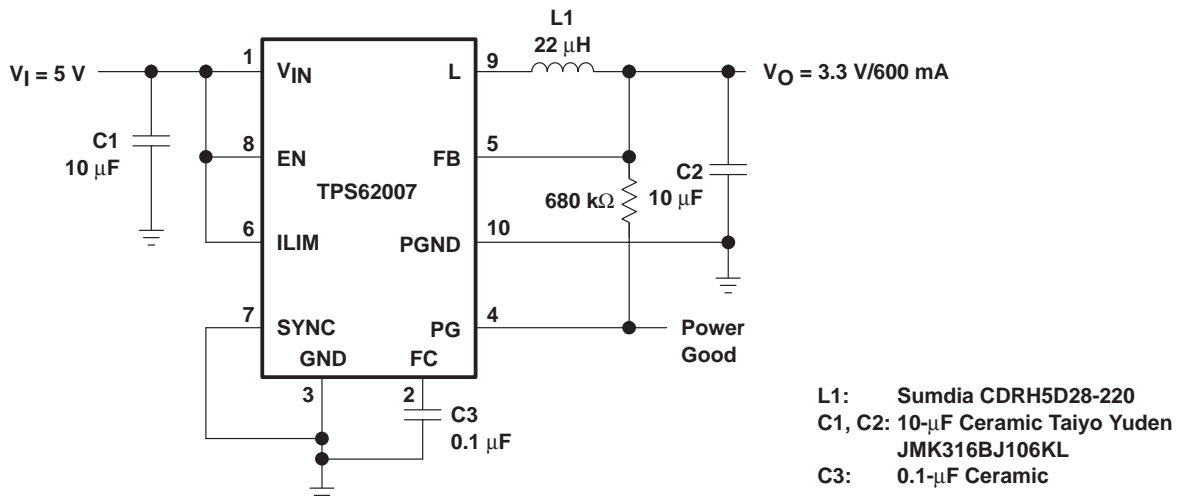


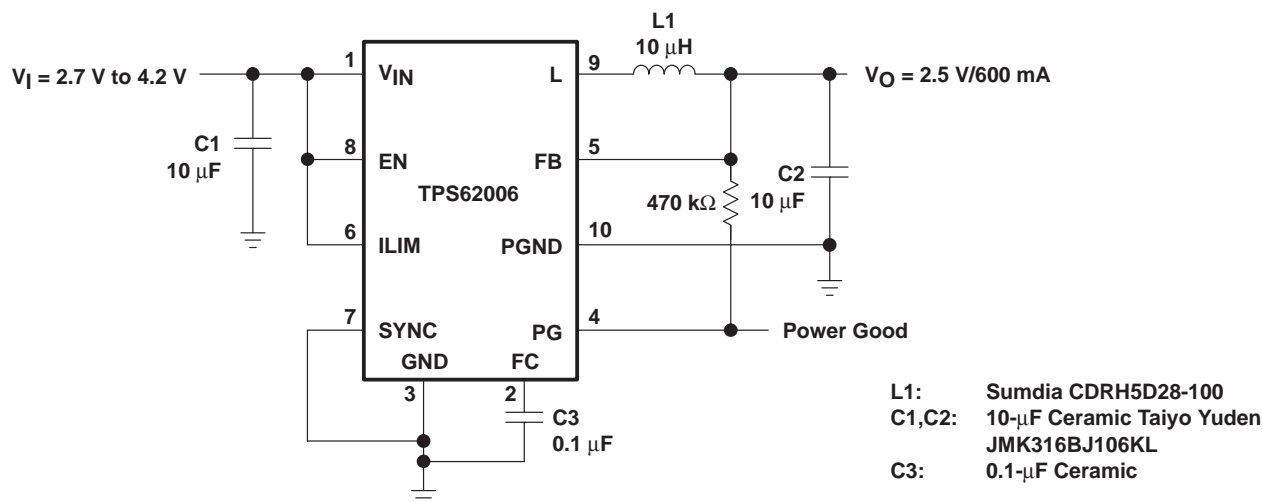
Figure 17. Standard 5 V to 3.3 V/600 mA Conversion – High Efficiency

**TPS62000-Q1, TPS62001-Q1, TPS62002-Q1, TPS62003-Q1  
TPS62004-Q1, TPS62005-Q1, TPS62006-Q1, TPS62007-Q1, TPS62008-Q1  
HIGH-EFFICIENCY STEP-DOWN LOW POWER DC-DC CONVERTER**

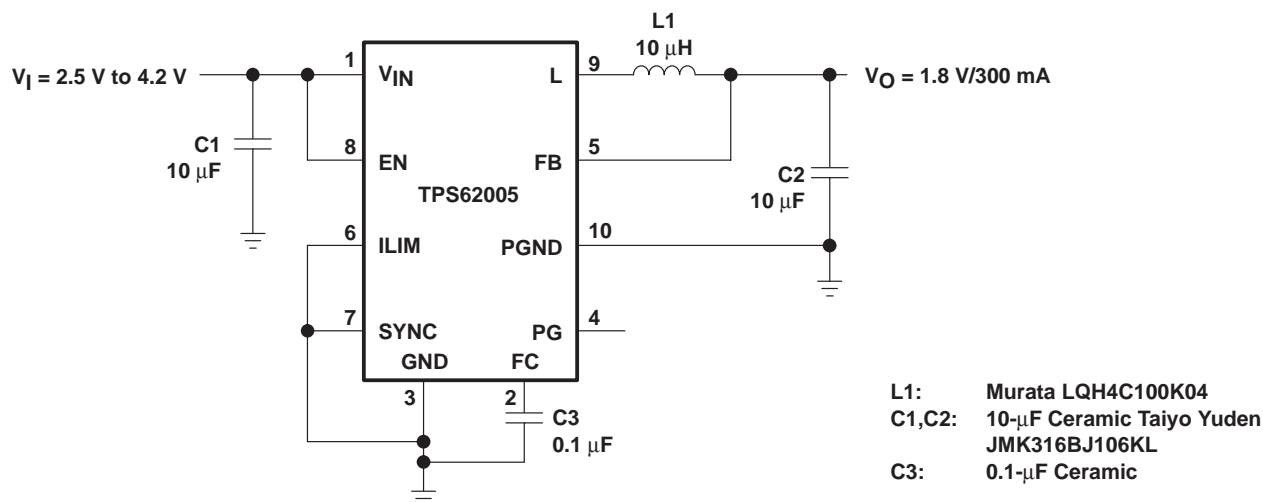
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**APPLICATION INFORMATION**

**typical application (continued)**



**Figure 18. Single Li-on to 2.5 V/600 mA Using Ceramic Capacitors Only**



NOTE: For low noise operation, connect SYNC to  $V_{IN}$ .

**Figure 19. Single Li-on to 1.8 V/300 mA – Smallest Solution Size**

## APPLICATION INFORMATION

typical application (continued)

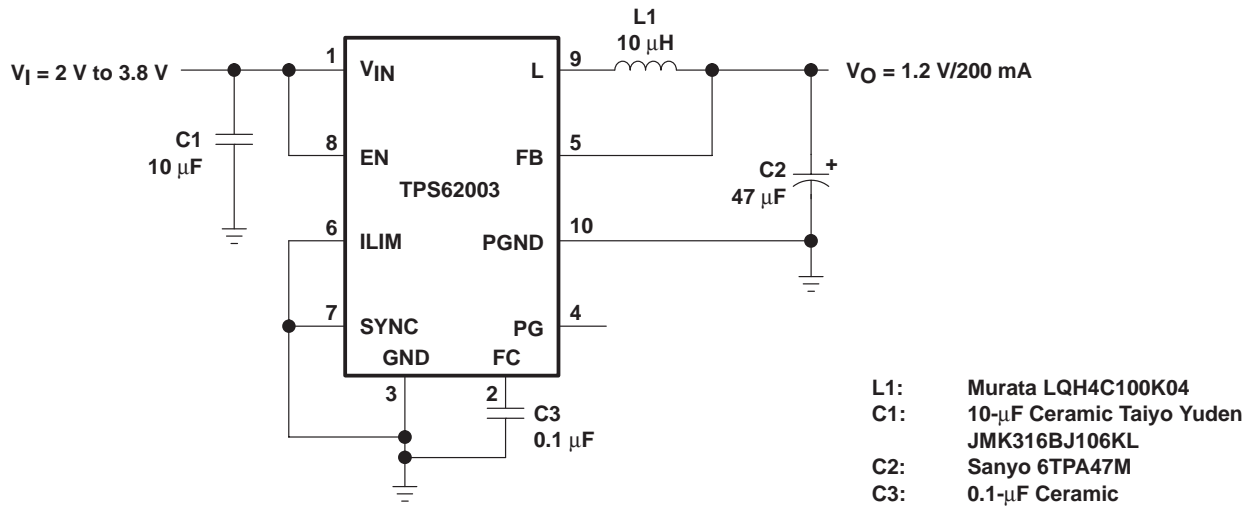
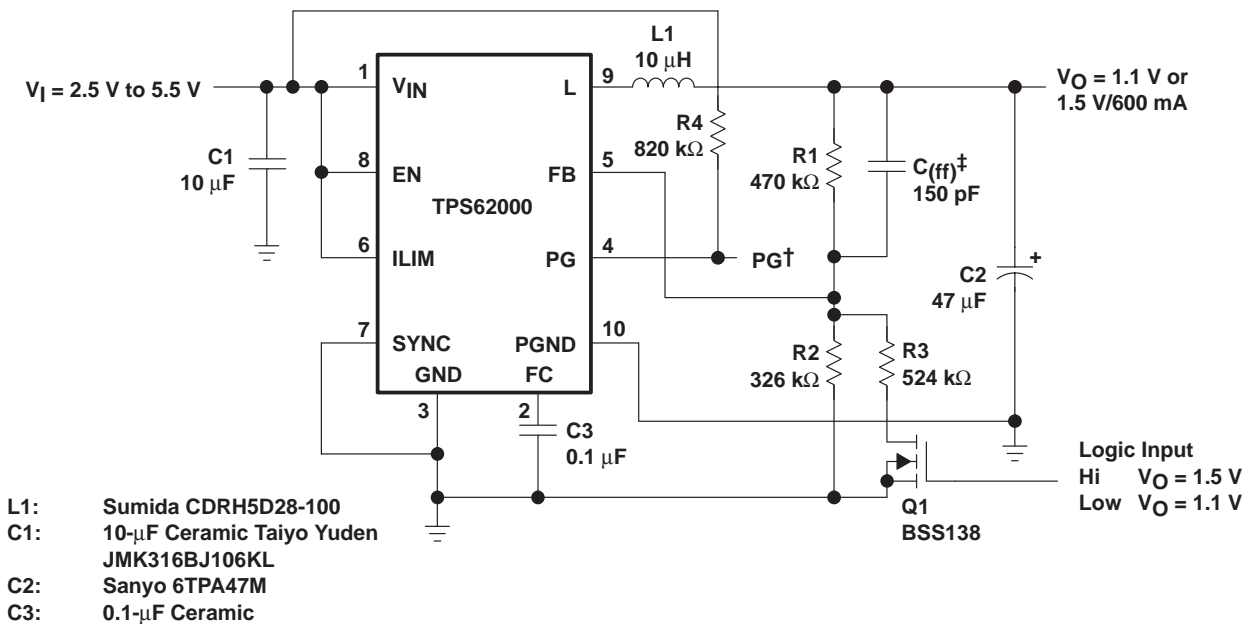


Figure 20. Dual Cell NiMH or NiCd to 1.2 V/200 mA – Smallest Solution Size



† Use a small R-C filter to filter wrong reset signals during output voltage transitions.

‡ A large value is used for  $C_{(ff)}$  to compensate for the parasitic capacitance introduced into the regulation loop by Q1.

Figure 21. Dynamic Output Voltage Programming As Used in Low Power DSP Applications

## PACKAGING INFORMATION

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
TPS62000QDGSRQ1	ACTIVE	MSOP	DGS	10	2500	None	Call TI	Level-1-235C-UNLIM
TPS62004QDGSRQ1	ACTIVE	MSOP	DGS	10	2500	None	Call TI	Level-1-235C-UNLIM
TPS62005QDGSRQ1	ACTIVE	MSOP	DGS	10	2500	None	Call TI	Level-1-235C-UNLIM
TPS62006QDGSRQ1	ACTIVE	MSOP	DGS	10	2500	None	Call TI	Level-1-235C-UNLIM
TPS62007QDGSRQ1	ACTIVE	MSOP	DGS	10	2500	None	Call TI	Level-1-235C-UNLIM

<sup>(1)</sup> The marketing status values are defined as follows:

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**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.

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

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## DGS (S-PDSO-G10)

## PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
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  - This drawing is subject to change without notice.
  - Body dimensions do not include mold flash or protrusion.
  - Falls within JEDEC MO-187 variation BA.

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