HIGH-EFFICIENCY SINGLE INDUCTOR BUCK-BOOST CONVERTER In Tiny WCSP

Check for Samples: TPS63036

FEATURES

- **Input Voltage Range: 1.8V to 5.5V**
- **Real Buck or Boost operation**
- **Adjustable and fixed output voltage version**
- **Up to 94% Efficiency**
- **Device Quiescent Current less than 50μA**
- **Fixed and Adjustable Output Voltage Options**
- **Power Save Mode for Improved Efficiency at Low Output Power**
- **Forced Fixed Frequency Operation and Synchronization Possible**
- **Load Disconnect During Shutdown**
- **Over-Temperature Protection**
- **Available in Small 1.854 mm x 1.076 mm, WCSP-8 Package**

APPLICATIONS

- **All Two-Cell and Three-Cell Alkaline, NiCd or NiMH or Single-Cell Li Battery Powered Products**
- **Portable Audio Players**
- **PDAs**
- **Cellular Phones**
- **Personal Medical Products**
- **White LEDs**

DESCRIPTION

The TPS63036 is a non inverting buck-boost converter able to provide a regulated output voltage from an input supply that can be higher or lower than the output voltage. The buck-boost converter is based on a fixed frequency, pulse-width-modulation (PWM) controller using synchronous rectification to obtain maximum efficiency. At low load currents, the converter enters Power Save Mode to maintain high efficiency over a wide load current range. The Power Save mode can be disabled, forcing the converter to operate at a fixed switching frequency. The maximum average current in the switches is limited to a typical value of 1000 mA. The output voltage is programmable using an external resistor divider. The converter can be disabled to minimize battery drain. During shutdown, the load is disconnected from the battery. The device is packaged 8-pin WCSP package measuring 1.854 mm x 1.076 mm (YFG).

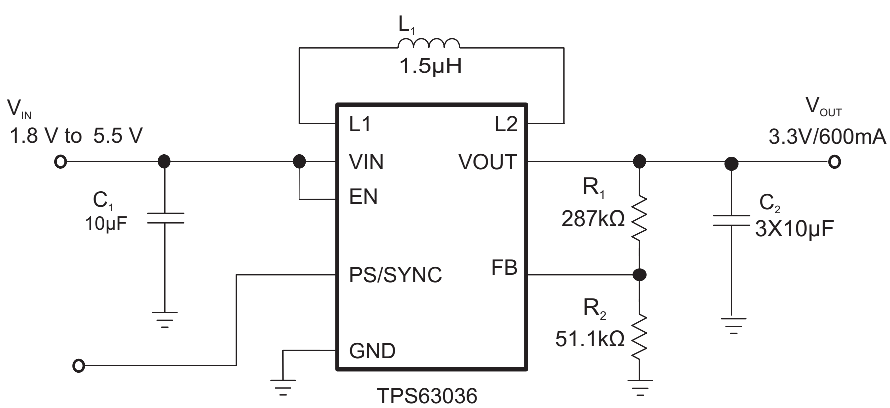


Figure 1. Typical Circuit

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.

AVAILABLE OUTPUT VOLTAGE OPTIONS [1]

T_A	OUTPUT VOLTAGE DC/DC	PACKAGE MARKING	PACKAGE	PART NUMBER
–40°C to 85°C	Adjustable	S63036	8-WCSP	TPS63036YFG

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com

ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range (unless otherwise noted)[1]

	TPS63036
Input voltage range on VIN, L1, L2, VOUT, PS/SYNC, EN, FB	–0.3 V to 7 V
Operating virtual junction temperature range, T_J	–40°C to 150°C
Storage temperature range T_{stg}	–65°C to 150°C

(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.

DISSIPATION RATINGS TABLE

PACKAGE[1]	THERMAL RESISTANCE Θ_{JA}	POWER RATING $T_A \leq 25°C$	DERATING FACTOR ABOVE $T_A = 25°C$
YFG	84 °C/W	1190 mW	12 mW/°C

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com.

RECOMMENDED OPERATING CONDITIONS

	MIN	NOM	MAX	UNIT
Supply voltage at VIN	1.8		5.5	V
Operating free air temperature range, T_A	–40		85	°C
Operating virtual junction temperature range, T_J	–40		125	°C

ELECTRICAL CHARACTERISTICS

over recommended free-air temperature range and over recommended input voltage range (typical at an ambient temperature range of 25°C) (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
DC/DC STAGE						
V_{IN}	Input voltage range		1.8(1)		5.5	V
V_{OUT}	TPS63036 output voltage range		1.2		5.5	V
	Duty cycle in step down conversion		20%			
V_{FB}	TPS63036 feedback voltage	PS/SYNC = VIN Io<5mA	495	500	505	mV
V_{FB}	TPS63036 feedback voltage	PS/SYNC = GND Referenced to 500mV Io<5mA	-3%		+6%	
	Load Regulation	PS/SYNC = GND		0.008		%/mA
f	Oscillator frequency		1800	2000	2200	kHz
	Frequency range for synchronization		2200	2400	2600	kHz
I_{SW}	Average input current limit	V_{IN} = 3.6 V, T_A = 25°C(2)		1000		mA
	High side switch on resistance	V_{IN} = 3.6 V		200		mΩ
	Low side switch on resistance	V_{IN} = 3.6 V		200		mΩ
	Line regulation			0.5%		
I_q	Quiescent current VIN	I_O = 0 mA, V_{EN} = V_{IN} = 3.6 V, V_{OUT} = 3.3 V		25	35	μA
I_q	Quiescent current VOUT	I_O = 0 mA, V_{EN} = V_{IN} = 3.6 V, V_{OUT} = 3.3 V		4	6	μA
I_S	Shutdown current	V_{EN} = 0 V, V_{IN} = 3.6 V		0.1	0.9	μA
CONTROL STAGE						
V_{UVLO}	Under voltage lockout threshold falling		1.4	1.5	1.6	V
V_{UVLO}	Under voltage lockout threshold raising		1.6	1.8	2.0	V
V_{IL}	EN, PS/SYNC input low voltage				0.4	V
V_{IH}	EN, PS/SYNC input high voltage		1.2			V
	EN, PS/SYNC input current	Clamped on GND or VIN		0.01	0.1	μA
	Overtemperature protection			140		°C
	Overtemperature hysteresis			20		°C

(1) The typical required supply voltage for startup is 2V. The part is functional down to 1.8V.
(2) For the minimum specified average input current limit at V_{OUT} = 2.5V, 3.3V and 4.5V refer to curve in Figure 3. For the maximum specified average input current limit at V_{OUT} = 2.5V, 3.3V and 4.5V refer to curve in Figure 4.

PIN ASSIGNMENTS

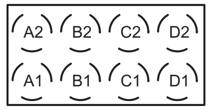
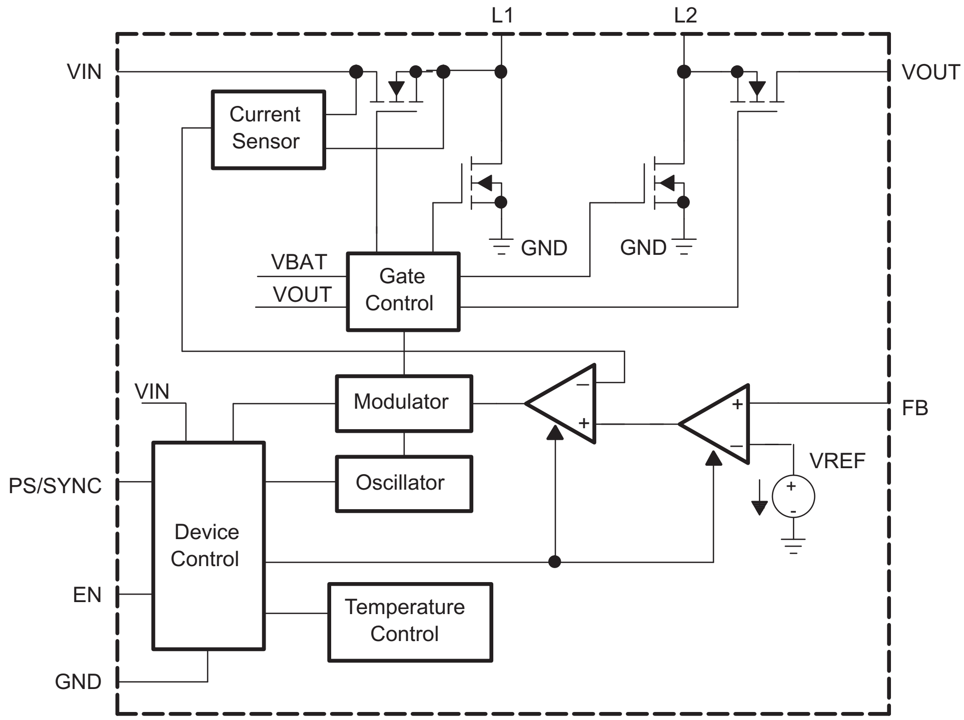


Figure 2. WCSP (YFG) Package - Top view

Terminal Functions

TERMINAL NAME	TERMINAL NO.	I/O	DESCRIPTION
EN	A2	I	Enable input. (1 enabled, 0 disabled)
FB	D2	I	Voltage feedback of adjustable versions, must be connected to VOUT on fixed output voltage versions
GND	C2		Control / logic ground
PS/SYNC	B2	I	Enable / disable power save mode (1 disabled, 0 enabled, clock signal for synchronization)
L1	B1	I	Connection for Inductor
L2	C1	I	Connection for Inductor
VIN	A1	I	Supply voltage for power stage
VOUT	D1	O	Buck-boost converter output

FUNCTIONAL BLOCK DIAGRAM (TPS63036)



TYPICAL CHARACTERISTICS

TABLE OF GRAPHS

DESCRIPTION1		FIGURE
Minimum input current	vs Input voltage (TPS63036, V_{OUT} = 2.5 V V_{OUT} = 3.3V V_{OUT} = 4.5 V)	3
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Efficiency	vs Output current (TPS63036, Power Save Enabled, V_{OUT} = 2.5 V / V_{OUT} = 4.5 V)	5
	vs Output current (TPS63036, Power Save Disabled, V_{OUT} = 2.5 V / V_{OUT} = 4.5 V)	6
	vs Output current (TPS63036, Power Save Enabled, V_{OUT} = 3.3 V)	7
	vs Output current (TPS63036, Power Save Disabled, V_{OUT} = 3.3 V)	8
	vs Input voltage (TPS63036, Power Save Enabled, V_{OUT} = 2.5V, I_{OUT} = {10; 100; 500 mA})	9
	vs Input voltage (TPS63036, Power Save Disabled, V_{OUT} = 2.5V, I_{OUT} = {10; 100; 500 mA})	10
	vs Input voltage (TPS63036, Power Save Enabled, V_{OUT} = 3.3V, I_{OUT} = {10; 100; 500 mA})	11
	vs Input voltage (TPS63036, Power Save Disabled, V_{OUT} = 3.3V, I_{OUT} = {10; 100; 500 mA})	12
	vs Input voltage (TPS63036, Power Save Enabled, V_{OUT} = 4.5V, I_{OUT} = {10; 100; 500 mA})	13
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Output voltage	vs Output current (TPS63036,Power Save Disabled, V_{OUT} = 2.5 V)	15
	vs Output current (TPS63036, Power Save Disabled, V_{OUT} = 3.3 V)	16
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Waveforms	Load transient response (TPS63036, $V_{IN} < V_{OUT}$, Load change from 0 mA to 150 mA)	18
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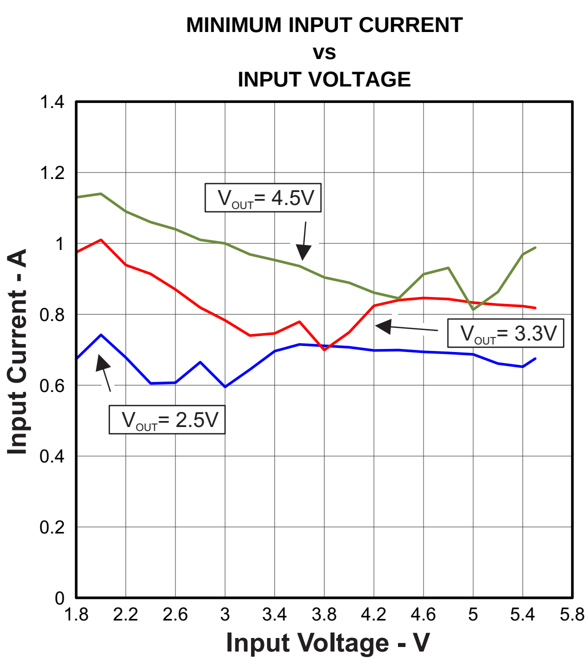


Figure 3.

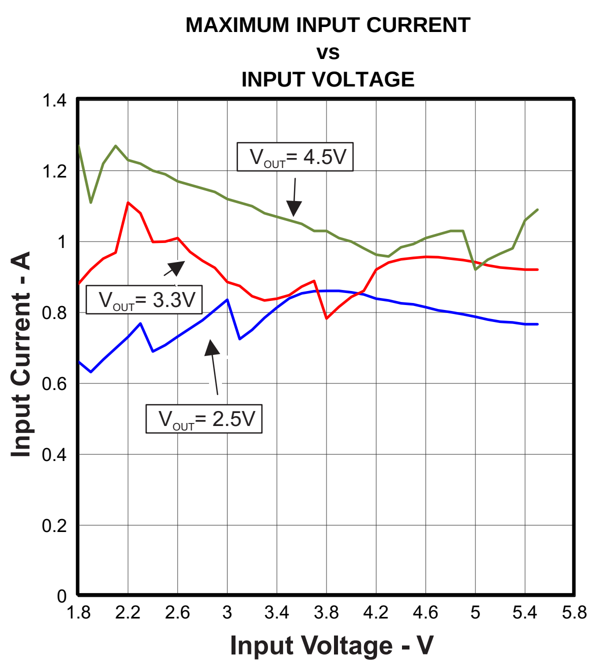


Figure 4.

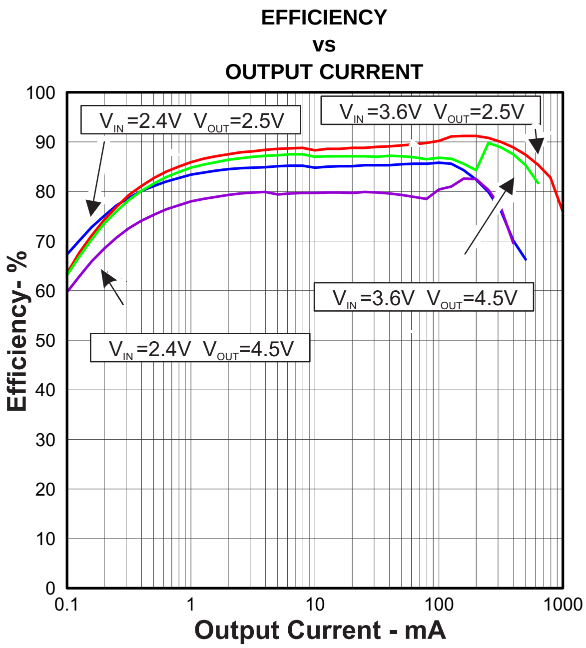


Figure 5.

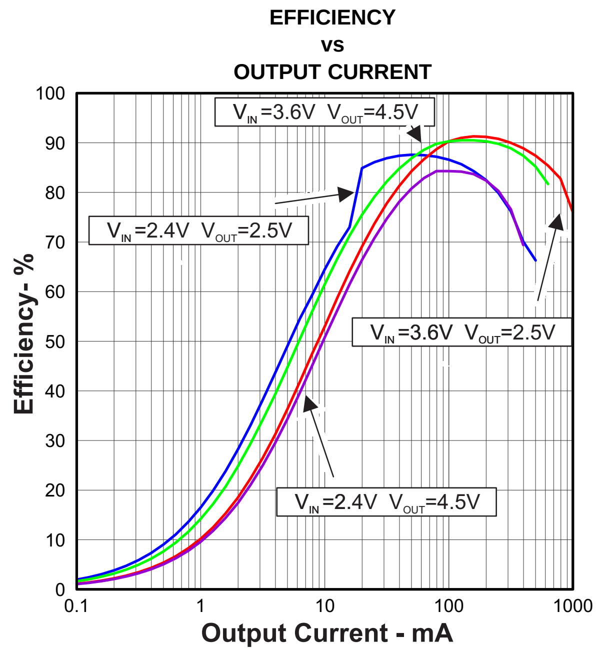


Figure 6.

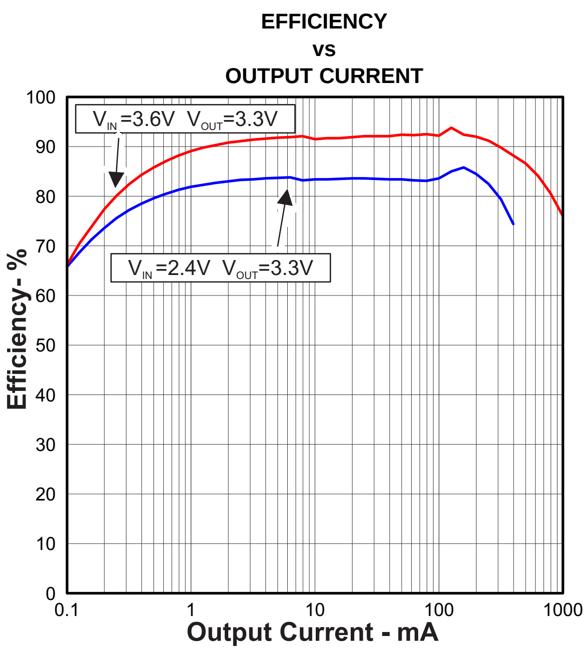


Figure 7.

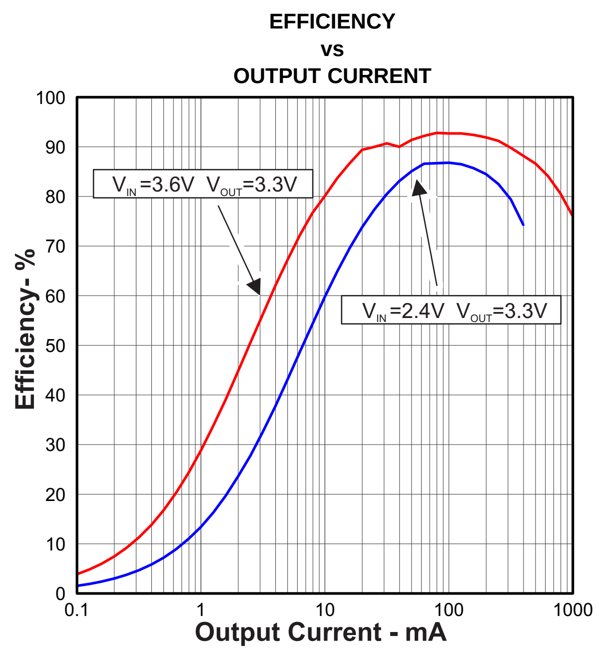


Figure 8.

EFFICIENCY
vs
INPUT VOLTAGE

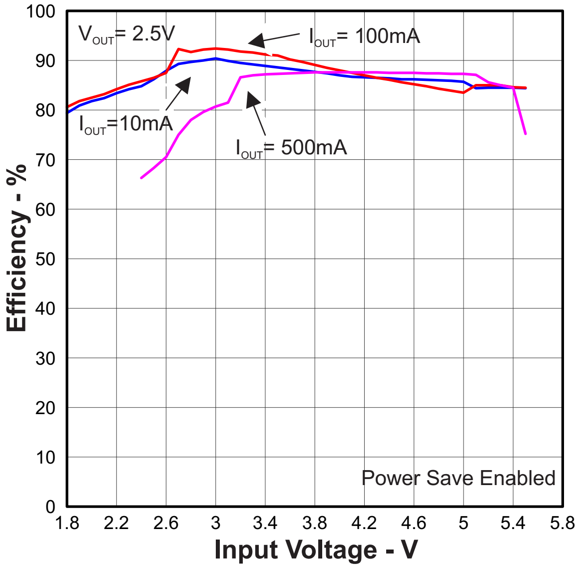


Figure 9.

EFFICIENCY
vs
INPUT VOLTAGE

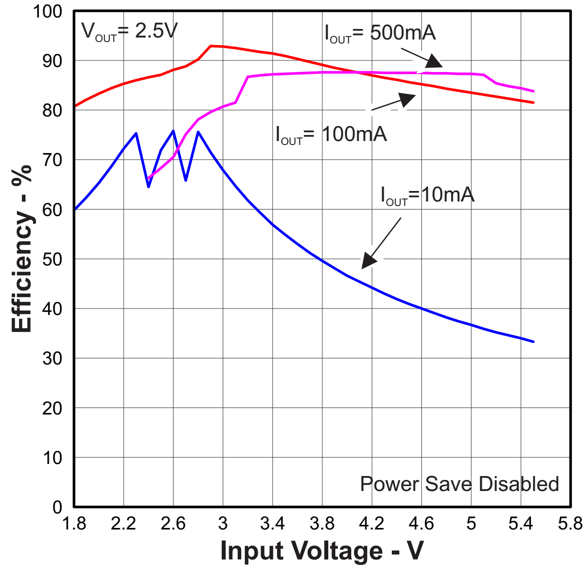


Figure 10.

EFFICIENCY
vs
INPUT VOLTAGE

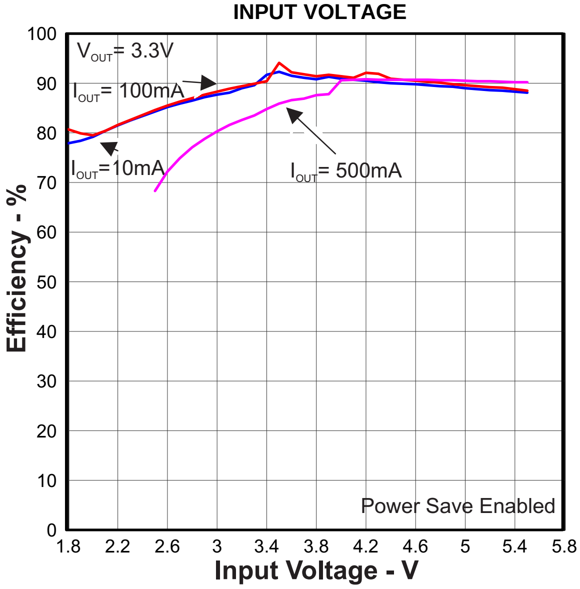


Figure 11.

EFFICIENCY
vs
INPUT VOLTAGE

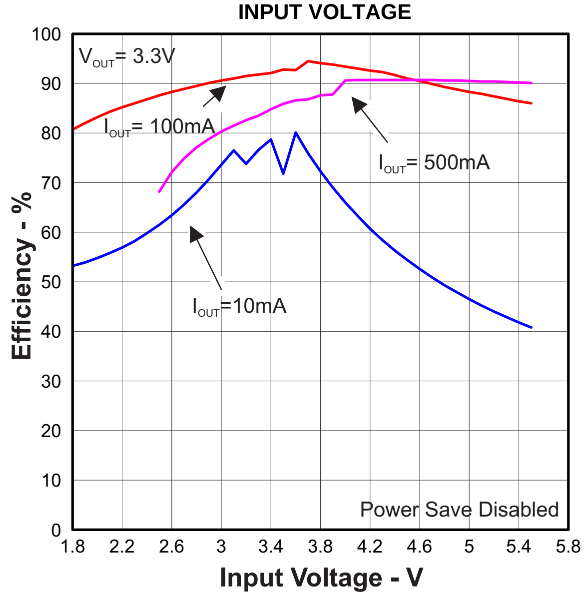


Figure 12.

EFFICIENCY vs INPUT VOLTAGE

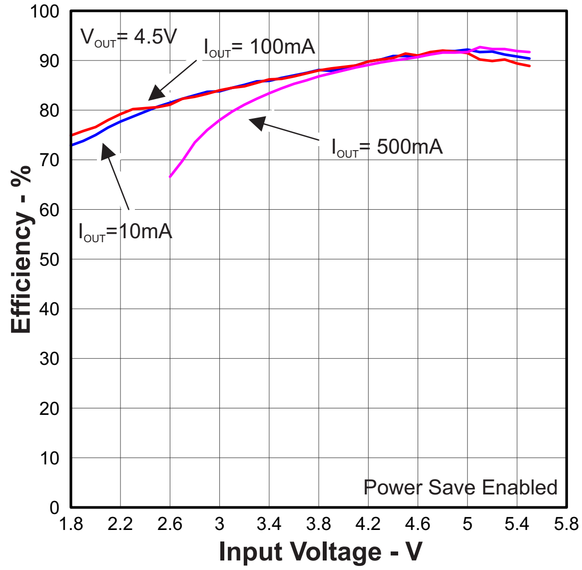


Figure 13.

EFFICIENCY vs INPUT VOLTAGE

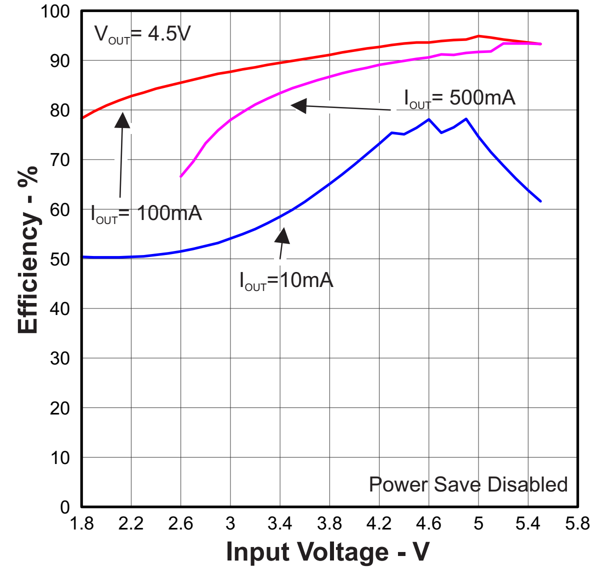


Figure 14.

OUTPUT VOLTAGE vs OUTPUT CURRENT

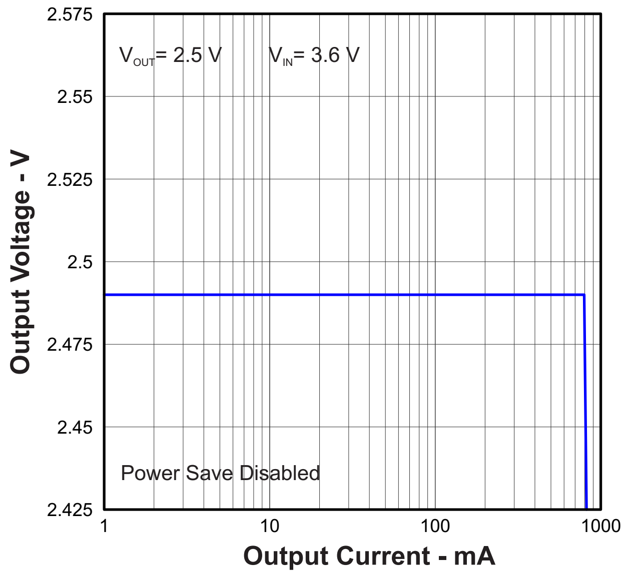


Figure 15.

OUTPUT VOLTAGE vs OUTPUT CURRENT

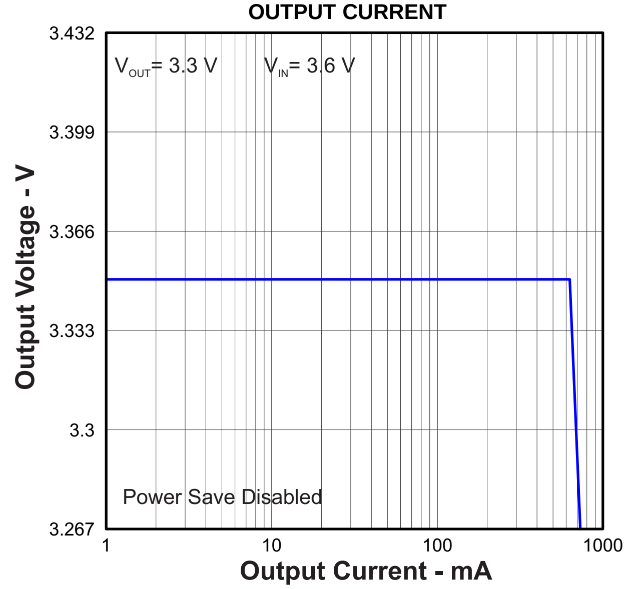


Figure 16.

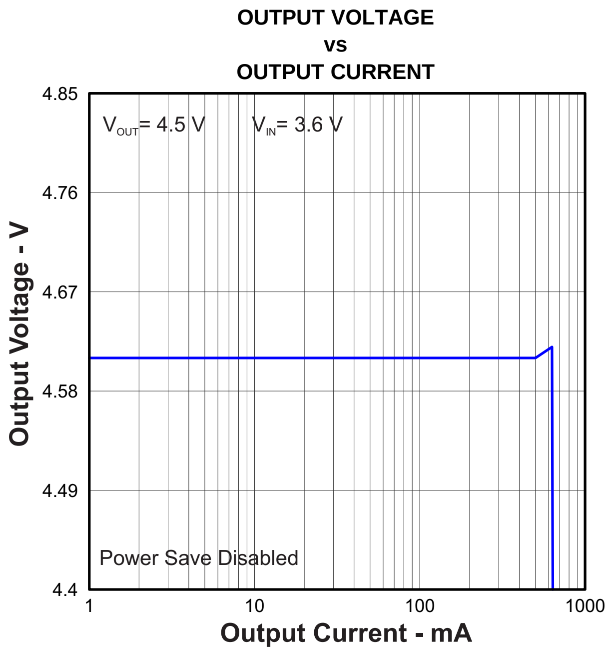


Figure 17.

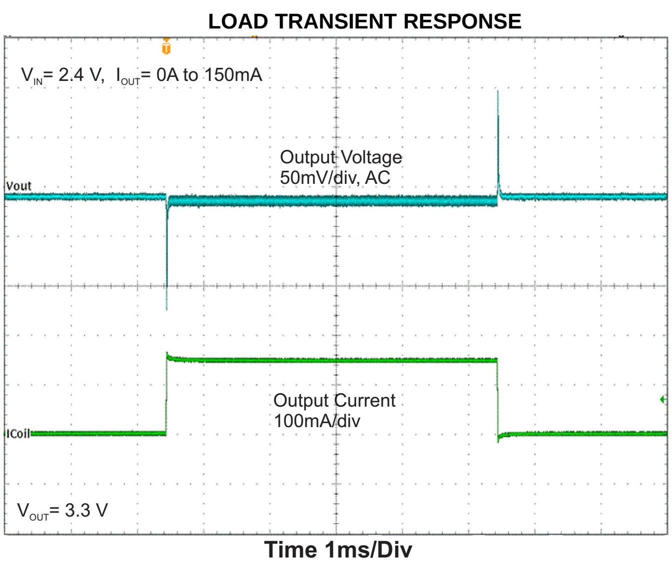


Figure 18.

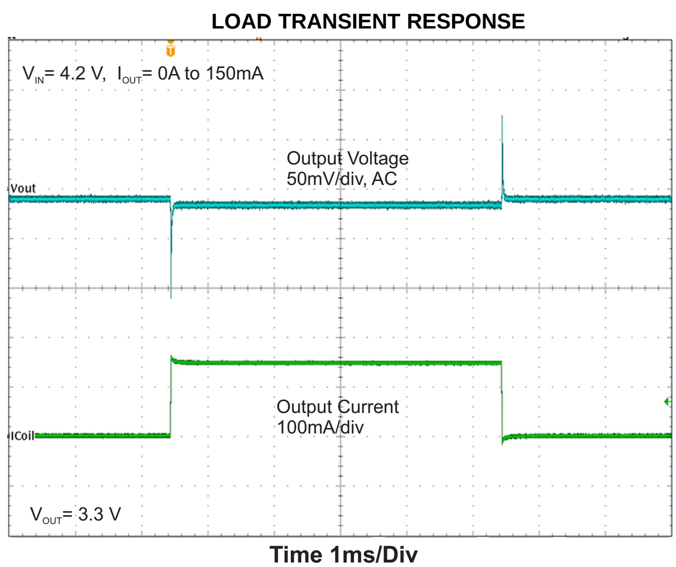


Figure 19.

LINE TRANSIENT RESPONSE

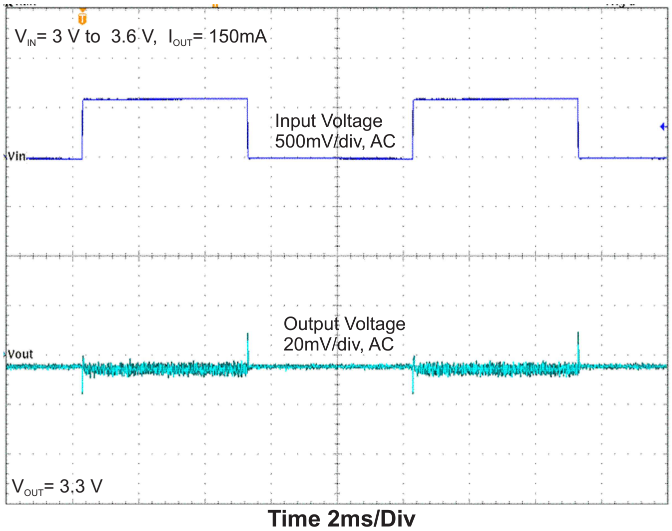


Figure 20.

STARTUP AFTER ENABLE

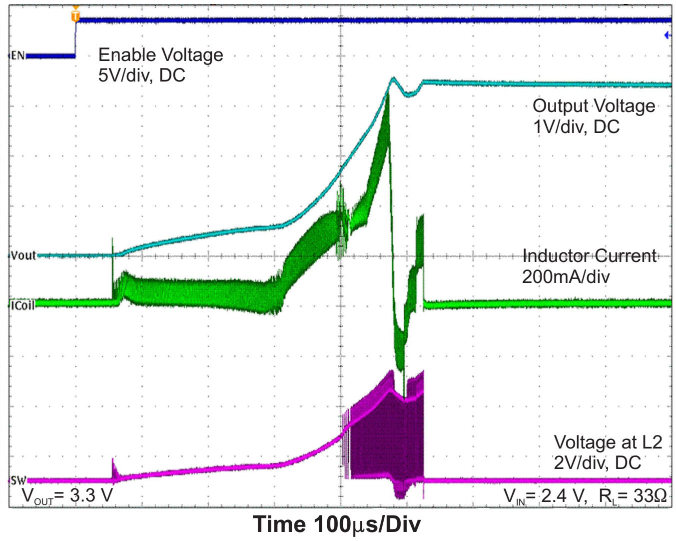


Figure 21.

STARTUP AFTER ENABLE

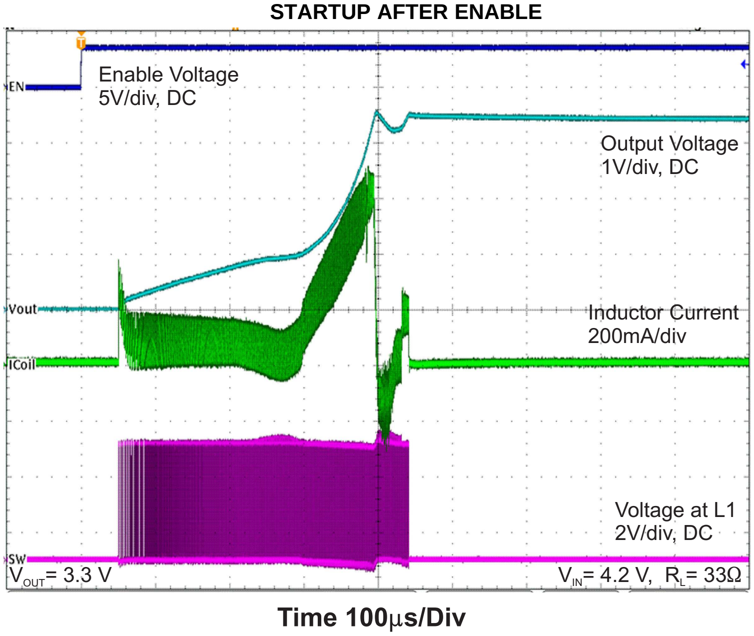


Figure 22.

PARAMETER MEASUREMENT INFORMATION

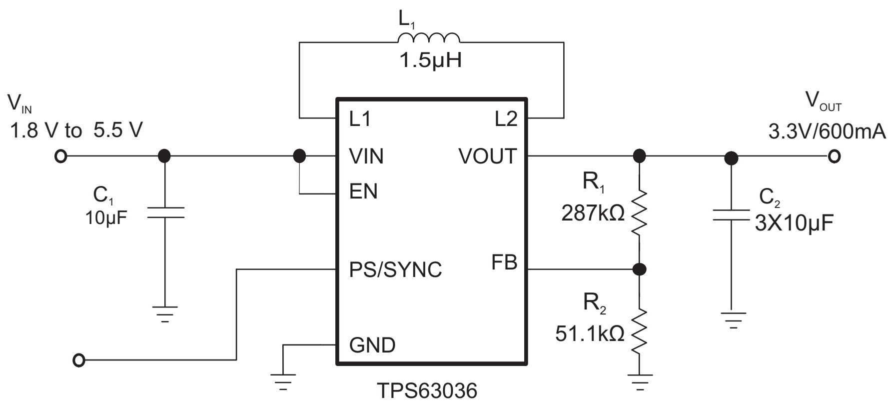


Figure 23. Parameter Measurement Circuit

Table 1. List of Components

REFERENCE	DESCRIPTION	MANUFACTURER
	TPS63036	Texas Instruments
L1	1.5 µH, 3 mm x 3 mm x 1.5 mm	Coilcraft, LPS3015-152MLC
C1	10 µF 6.3V, 0603, X7R ceramic	GRM188R60J106KME84D, Murata
C2	3 × 10 µF 6.3V, 0603, X7R ceramic	GRM188R60J106KME84D, Murata
R1, R2	Depending on the output voltage at TPS63036	

DETAILED DESCRIPTION

The controller circuit of the device is based on an average current mode topology. The controller also uses input and output voltage feedforward. Changes of input and output voltage are monitored and immediately can change the duty cycle in the modulator to achieve a fast response to those errors. The voltage error amplifier gets its feedback input from the FB pin. A resistive voltage divider must be connected to that pin. The feedback voltage will be compared with the internal reference voltage to generate a stable and accurate output voltage.

The device uses 4 internal N-channel MOSFETs to maintain synchronous power conversion at all possible operating conditions. This enables the device to keep high efficiency over a wide input voltage and output power range. Due to the 4-switch topology, the load is always disconnected from the input during shutdown of the converter. To protect the device from overheating an internal temperature sensor is implemented.

Buck-Boost Operation

To regulate the output voltage at all possible input voltage conditions, the device automatically switches from step down operation to boost operation and back as required by the configuration. It always uses one active switch, one rectifying switch, one switch permanently on, and one switch permanently off. Therefore, it operates as a step down converter (buck) when the input voltage is higher than the output voltage, and as a boost converter when the input voltage is lower than the output voltage. There is no mode of operation in which all 4 switches are permanently switching. Controlling the switches this way allows the converter to maintain high efficiency at the most important point of operation, when input voltage is close to the output voltage. The RMS current through the switches and the inductor is kept at a minimum, to minimize switching and conduction losses. For the remaining 2 switches, one is kept permanently on and the other is kept permanently off, thus causing no switching losses.

Control loop description

The average inductor current is regulated by a fast current regulator loop which is controlled by a voltage control loop. Figure 1 shows the control loop.

The non inverting input of the transconductance amplifier Gmv can be assumed to be constant. The output of Gmv defines the average inductor current. The inductor current is reconstructed measuring the current through the high side buck MOSFET. This current corresponds exactly to the inductor current in boost mode. In buck mode the current is measured during the on time of the same MOSFET. During the off time the current is reconstructed internally starting from the peak value reached at the end of the on time cycle. The average current is then compared to the desired value and the difference, or current error, is amplified and compared to the sawtooth ramp of either the Buck or the Boost.

The Buck-Boost Overlap Control™ makes sure that the classical buck-boost function, which would cause two switches to be on every half a cycle, is avoided. Thanks to this block whenever all switches becomes active during one clock cycle, the two ramps are shifted away from each other, on the other hand when there is no switching activities because there is a gap between the ramps, the ramps are moved closer together. As a result the number of classical buck-boost cycles or no switching is reduced to a minimum and high efficiency values has been achieved.

Slope compensation is not required to avoid subharmonic oscillation which are otherwise observed when working with peak current mode control with $D > 0.5$.

Nevertheless the amplified inductor current downslope at one input of the PWM comparator must not exceed the oscillator ramp slope at the other comparator input. This purpose is reached limiting the gain of the current amplifier.

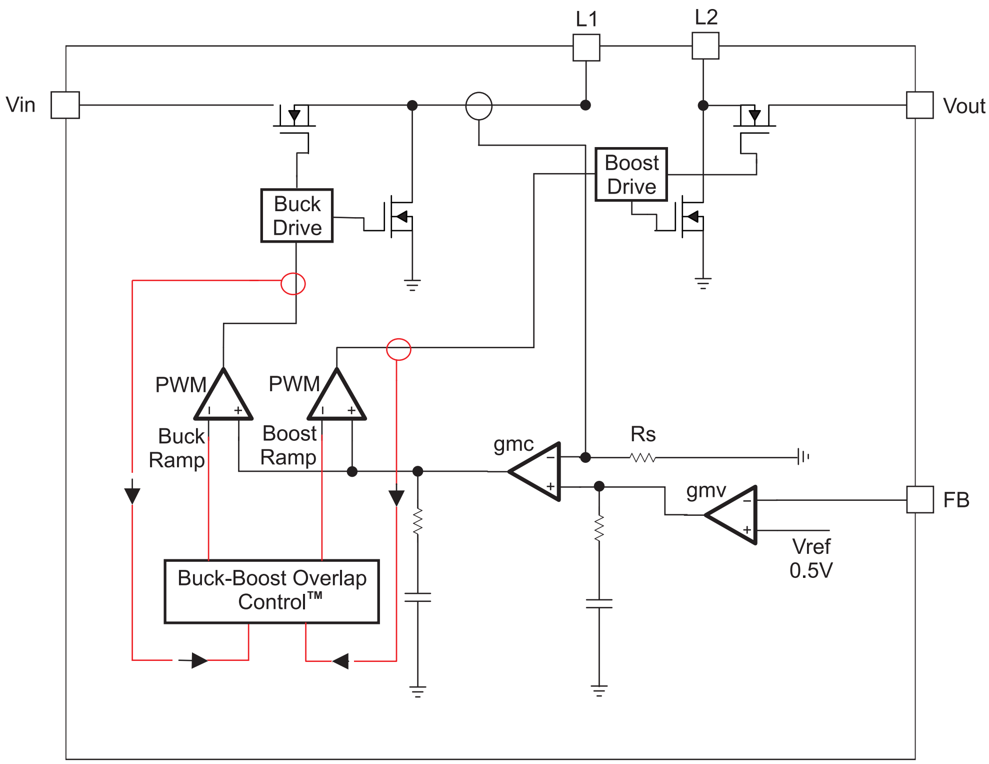


Figure 24. Average Current Mode Control

Power-save mode and synchronization

The PS/SYNC pin can be used to select different operation modes. Power Save Mode is used to improve efficiency at light load. To enable Power Save Mode, PS/SYNC must be set low. If PS/SYNC is set low then Power Save Mode is entered when the average inductor current gets lower then about 100mA. At this point the converter operates with reduced switching frequency and with a minimum quiescent current to maintain high efficiency.

During the Power Save Mode, the output voltage is monitored with a comparator by the threshold comp low and comp high. When the device enters Power Save Mode, the converter stops operating and the output voltage drops. The slope of the output voltage depends on the load and the value of output capacitance. As the output voltage falls below the comp low threshold, the device ramps up the output voltage again, by starting operation using a programmed average inductor current higher than required by the current load condition. Operation can last one or several pulses. The converter continues these pulses until the comp high threshold, is reached and the average inductance current gets lower than about 100mA. When the load increases above the minimum forced inductor current of about 100mA, the device will automatically switch to PWM mode.

The Power Save Mode can be disabled by programming high at the PS/SYNC. Connecting a clock signal at PS/SYNC forces the device to synchronize to the connected clock frequency.

Synchronization is done by a PLL, so synchronizing to lower and higher frequencies compared to the internal clock works without any issues. The PLL can also tolerate missing clock pulses without the converter malfunctioning. The PS/SYNC input supports standard logic thresholds.

Current Limit

To protect the device and the application, the average input current is limited internally on the IC. At nominal operating conditions, this current limit is constant. The current limit value can be found in the electrical characteristics table. The current limit varies depending on the input voltage. A curve of the input current varying with the input voltage is shown in figure 3 and figure 4 respectively showing the minimum and the maximum current limit expected depending on input and output voltage.

Given the average input current in figure 3 is then possible to calculate the output current reached in boost mode using Equation 1 and Equation 2 and in buck mode using Equation 3 and Equation 4.

Duty Cycle Boost $$D = \frac{V_{OUT} - V_{IN}}{V_{OUT}} \quad (1)$$

Maximum Output Current Boost $$I_{OUT} = \eta \times I_{SW} \times (1 - D) \quad (2)$$

Duty Cycle Buck $$D = \frac{V_{OUT}}{V_{IN}} \quad (3)$$

Maximum Output Current Buck $$Iout = \frac{\eta \times Isw}{D} \quad (4)$$

With,

η = Estimated converter efficiency (use the number from the efficiency curves or 0.80 as an assumption)
f = Converter switching frequency (typical 2MHz)
L = Selected inductor value
I_{SW}=Minimum average input current (Figure 3)

Device Enable

The device is put into operation when EN is set high. It is put into a shutdown mode when EN is set to GND. In shutdown mode, the regulator stops switching, all internal control circuitry is switched off, and the load is disconnected from the input. This means that the output voltage can drop below the input voltage during shutdown. During start-up of the converter, the duty cycle and the peak current are limited in order to avoid high peak currents flowing from the input.

Softstart and Short Circuit Protection

After being enabled, the device starts operating. The average input current limit ramps up from an initial 400mA following the output voltage increasing. At an output voltage of about 1.2V, the current limit is at its nominal value. If the output voltage does not increase, the current limit will not increase. The device ramps up the output voltage in a controlled manner even if a large capacitor is connected at the output. When the output voltage does not increase above 1.2V, the device assumes a short circuit at the output, and keeps the current limit low to protect itself and the application. At a short on the output during operation, the current limit also is decreased accordingly.

Overvoltage Protection

If, for any reason, the output voltage is not fed back properly to the input of the voltage amplifier, control of the output voltage will not work anymore. Therefore overvoltage protection is implemented to avoid the output voltage exceeding critical values for the device and possibly for the system it is supplying. The implemented overvoltage protection circuit monitors the output voltage internally as well. In case it reaches the overvoltage threshold the voltage amplifier regulates the output voltage to this value.

Undervoltage Lockout

An undervoltage lockout function prevents device start-up if the supply voltage on VIN is lower than approximately its threshold (see electrical characteristics table). When in operation, the device automatically enters the shutdown mode if the voltage on VIN drops below the undervoltage lockout threshold. The device automatically restarts if the input voltage recovers to the minimum operating input voltage.

Overtemperature Protection

The device has a built-in temperature sensor which monitors the internal IC temperature. If the temperature exceeds the programmed threshold (see electrical characteristics table) the device stops operating. As soon as the IC temperature has decreased below the programmed threshold, it starts operating again. There is a built-in hysteresis to avoid unstable operation at IC temperatures at the overtemperature threshold.

APPLICATION INFORMATION

DESIGN PROCEDURE

The TPS63036 buck-boost converter has internal loop compensation. Therefore, the external L-C filter has to be selected to work with the internal compensation. As a general rule of thumb, the product L×C should not move over a wide range when selecting a different output filter. However, when selecting the output filter a low limit for the inductor value exists to avoid subharmonic oscillation which could be caused by a far too fast ramp up of the amplified inductor current. For the TPS63036 the minimum inductor value should be kept at 1uH. To simplify this process Table 2 outlines possible inductor and capacitor value combinations.

Table 2. Output Filter Selection (Average Inductance current up to 1A)

INDUCTOR VALUE [µH](1)	OUTPUT CAPACITOR VALUE [µF](2)		
	30	44	66
1.0	√	√	√
1.5	√(3)	√	√
2.2			√

(1) Inductor tolerance and current de-rating is anticipated. The effective inductance can vary by 20% and –30%.
(2) Capacitance tolerance and bias voltage de-rating is anticipated. The effective capacitance can vary by 20% and –50%.
(3) Typical application. Other check mark indicates recommended filter combinations

Inductor Selection

For high efficiencies, the inductor should have a low dc resistance to minimize conduction losses. Especially at high-switching frequencies the core material has a higher impact on efficiency. When using small chip inductors, the efficiency is reduced mainly due to higher inductor core losses. This needs to be considered when selecting the appropriate inductor. The inductor value determines the inductor ripple current. The larger the inductor value, the smaller the inductor ripple current and the lower the conduction losses of the converter. Conversely, larger inductor values cause a slower load transient response. To avoid saturation of the inductor, with the chosen inductance value, the peak current for the inductor in steady state operation can be calculated. Only the equation which defines the switch current in boost mode is reported because this is providing the highest value of current and represents the critical current value for selecting the right inductor.

Duty Cycle Boost $$D = \frac{Vout - Vin}{Vout} \quad (5)$$

$$I_{PEAK} = I_{SW\_MAX} + \frac{Vin \times D}{2 \times f \times L} \quad (6)$$

With,

- D =Duty Cycle in Boost mode
- f = Converter switching frequency (typical 2 MHz)
- L = Selected inductor value
- η = Estimated converter efficiency (use the number from the efficiency curves or 0.80 as an assumption)
- I_{SW_MAX}=Maximum average input current (Figure 4)
- **Note:** The calculation must be done for the minimum input voltage which is possible to have in boost mode

Consideration must be given to the load transients and error conditions that can cause higher inductor currents. This must be taken into consideration when selecting an appropriate inductor. Please refer to Table 3 for typical inductors.

The size of the inductor can also affect the stability of the feedback loop. In particular the boost transfer function exhibits a right half-plane zero, whose frequency is inverse proportional to the inductor value and the load current. This means higher is the value of inductance and load current more possibilities has the right plane zero to be moved at lower frequency. This could degrade the phase margin of the feedback loop. It is recommended to choose the inductor's value in order to have the frequency of the right half plane zero >400KHz. The frequency of the RHPZ can be calculated using equation (3)

$$f_{RHPZ} = \frac{(1 - D)^2 \times Vout}{2\pi \times Iout \times L} \quad (7)$$

With,

D =Duty Cycle in Boost mode

Note: The calculation must be done for the minimum input voltage which is possible to have in boost mode

Table 3. Inductor Selection

INDUCTOR VALUE	COMPONENT SUPPLIER	SIZE (LxWxH mm)	Isat/DCR
1 µH	TOKO 1286AS-H-1R0M	2x1.6x1.2	2.3A/78mΩ
1 µH	Coilcraft XFL4020-102	4 x 4 x 2.1	5.1A/10.8 mΩ
1 µH	Coilcraft XFL3012-102	3 x 3 x 1.2	2.2 A/35 mΩ
1.5µH	TOKO, 1286AS-H-1R5M	2 x 1.6 x 1.2	4.4A/ 14.40mΩ
1.5µH	Coilcraft, LPS3015-152MLC	3 x 3 x 1.5	2.1A/100mΩ
1.5µH	TOKO, 1269AS-H-1R5M	2.5 x 2 x 1	2.1A/108mΩ
2.2µH	TOKO D1286AS-H-2R2M	2 x 1.6 x 1.2	1.6A/192mΩ

Capacitor selection

Input Capacitor

At least a 10µF input capacitor is recommended to improve transient behavior of the regulator and EMI behavior of the total power supply circuit. A ceramic capacitor placed as close as possible to the VIN and GND pins of the IC is recommended.

Output Capacitor

For the output capacitor, use of a small ceramic capacitors placed as close as possible to the VOUT and GND pins of the IC is recommended. If, for any reason, the application requires the use of large capacitors which can not be placed close to the IC, use a smaller ceramic capacitor in parallel to the large capacitor. The small capacitor should be placed as close as possible to the VOUT and GND pins of the IC. The recommended typical output capacitor value is 30 µF.

There is also no upper limit for the output capacitance value. Larger capacitors will cause lower output voltage ripple as well as lower output voltage drop during load transients.

When choosing input and output capacitors, it needs to be kept in mind, that the value of capacitance experiences significant losses from their rated value depending on the operating temperature and the operating DC voltage. It's not uncommon for a small surface mount ceramic capacitor to lose 50% and more of it's rated capacitance. For this reason could be important to use a larger value of capacitance or a capacitor with higher voltage rating in order to ensure the required capacitance at the full operating voltage.

Setting the Output Voltage

The output voltage of the TPS63036 is set by an external resistor divider. The resistor divider must be connected between VOUT, FB and GND. When the output voltage is regulated, the typical value of the voltage at the FB pin is 500mV. The maximum recommended value for the output voltage is 5.5V. The typical current into the FB pin is 0.01µA, and the voltage across the resistor between FB and GND, R_2, is typically 500 mV. Based on these two values, the recommended value for R2 should be lower than 100kΩ, in order to set the divider current at 5µA or higher. From that, the value of the resistor connected between VOUT and FB, R1, depending on the needed output voltage (V_{OUT}), can be calculated using Equation 8:

$$R1 = R2 \times \left(\frac{V_{OUT}}{V_{FB}} - 1 \right) \quad (8)$$

A small capacitor C3=10pF, in parallel with R1 needs to be placed when using the Power Save Mode, to improve considerably the output voltage ripple.

LAYOUT CONSIDERATIONS

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. Therefore, use wide and short traces for the main current path and for the ground tracks. The input capacitor, output capacitor, and the inductor should be placed as close as possible to the IC.

The feedback divider should be placed as close as possible to the ground pin of the IC.

THERMAL INFORMATION

Implementation of integrated circuits in low-profile and fine-pitch surface-mount packages typically requires special attention to power dissipation. Many system-dependent issues such as thermal coupling, airflow, added heat sinks and convection surfaces, and the presence of other heat-generating components affect the power-dissipation limits of a given component.

Three basic approaches for enhancing thermal performance are listed below.

1. Improving the power dissipation capability of the PCB design
2. Improving the thermal coupling of the component to the PCB by soldering all pins to traces as wide as possible.
3. Introducing airflow in the system

The maximum recommended junction temperature (T_J) of the TPS63036 device is 125°C. The thermal resistance of this 8-pin chip-scale package (YFG) is $R_{\theta JA}$ = 84°C/W, if all pins are soldered. Specified regulator operation is assured to a maximum ambient temperature T_A of 85°C. Therefore, the maximum power dissipation is about 476 mW, as calculated in Equation 9. More power can be dissipated if the maximum ambient temperature of the application is lower.

$$P_{D(MAX)} = \frac{T_{J(MAX)} - T_A}{R_{\theta JA}} = \frac{125°C - 85°C}{84\ °C/W} = 476\ mW \tag{9}$$

PACKAGE INFORMATION

Package Dimensions

The package dimensions for this YFG package are shown in the table below. See the package drawing at the end of this data sheet for more details.

Table 4. YFG Package Dimensions

Packaged Devices	D	E
TPS63036YFG	1.854 ± 0.03mm	1.076±0.03mm

TYPICAL APPLICATION

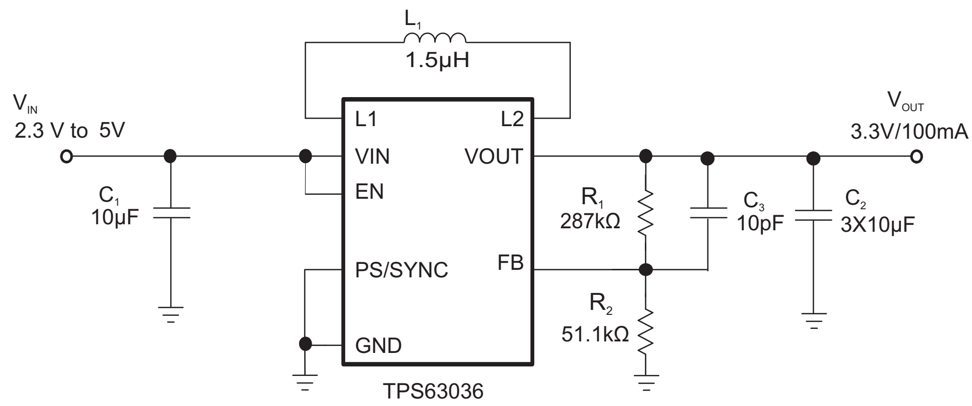
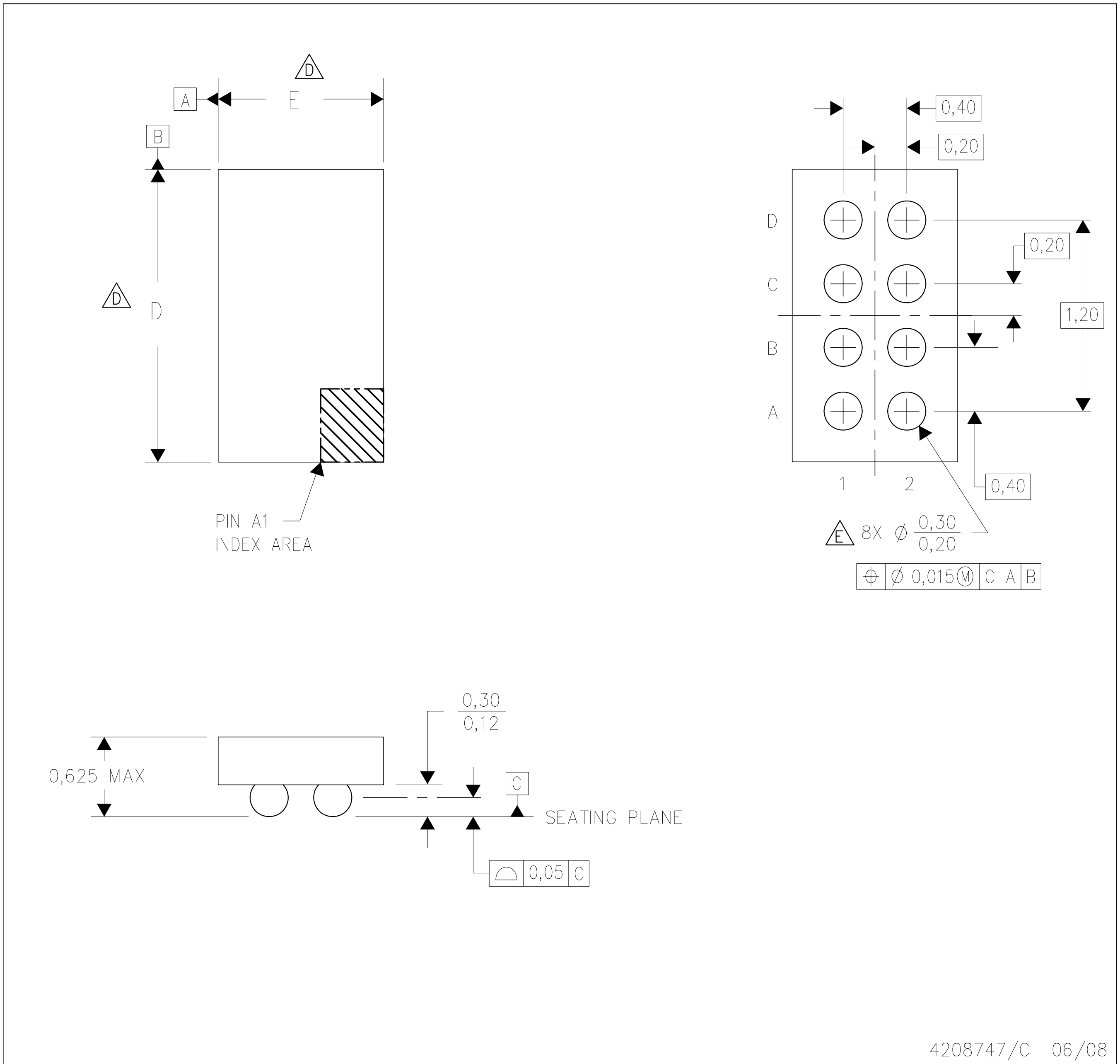


Figure 25. Typical Application Circuit for LCD-Bias

YFG (R–XBGA–N8) DIE–SIZE BALL GRID ARRAY



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Die size package configuration.
D. Devices in YFG package can have dimensions D ranging from 1.56 to 2.25 mm and E ranging from 0.76 to 1.45 mm. To determine the exact package size of a particular device, refer to the datasheet.
E. Reference Product Data Sheet for array population. 4 x 2 matrix pattern is shown for illustration only.
F. This package is Lead Free.

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)
TPS63036YFGR	PREVIEW	DSBGA	YFG	8	3000	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	
TPS63036YFGT	PREVIEW	DSBGA	YFG	8	250	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	

(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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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.

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