



LM2623 General-Purpose, Gated-Oscillator-Based DC/DC Boost Converter

1 Features

- Good Efficiency Over a Very Wide Load Range
- Very Low Output Voltage Ripple
- Up to 2-MHz Switching Frequency
- 0.8-V to 14-V Operating Voltage
- 1.1-V Start-up Voltage
- 1.24-V to 14-V Adjustable Output Voltage
- Up to 2-A Load Current at Low Output Voltages
- 0.17-Ω Internal MOSFET
- Up to 90% Regulator Efficiency
- 80-μA Typical Operating Current (Into V_{DD} Pin of Supply)
- < 2.5-μA Ensured Supply Current In Shutdown
- Small 8-Pin VSSOP Package (Half the Footprint of Standard 8-Pin SOIC Package); 1.09-mm Package Height
- 4-mm x 4-mm Thermally Enhanced WSON Package Option

2 Applications

- Cameras, Pagers and Cell Phones
- PDAs, Palmtop Computers, GPS devices
- White LED Drive, TFT, or Scanned LCDs
- Flash Memory Programming
- Hand-Held Instruments
- 1, 2, 3, or 4 Cell Alkaline Systems
- 1, 2, or 3 Cell Lithium-ion Systems

3 Description

The LM2623 is a high-efficiency, general-purpose, step-up DC-DC switching regulator for battery-powered and low input voltage systems. It accepts an input voltage between 0.8 V and 14 V and converts it into a regulated output voltage between 1.24 V and 14 V. Efficiencies up to 90% are achievable with the LM2623.

In order to adapt to a number of applications, the LM2623 allows the designer to vary the output voltage, the operating frequency (300 kHz to 2 MHz) and duty cycle (17% to 90%) to optimize the part's performance. The selected values can be fixed or can vary with battery voltage or input to output voltage ratio. The LM2623 uses a very simple, on/off regulation mode to produce good efficiency and stable operation over a wide operating range. It normally regulates by skipping switching cycles when it reaches the regulation limit (Pulse Frequency Modulation).

Note: Please read the [Non-Linear Effect](#) and [Choosing the Correct C3 Capacitor](#) sections so that any challenges with designing with this part can be taken into account before a board design/layout is finalized.

For alternative solutions, See Also: LM2700, LM2622, LM2731, LM2733, and LM2621.

Device Information⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM2623	WSON (14)	4.00 mm x 4.00 mm
	VSSOP (8)	3.00 mm x 3.00 mm

(1) For all available packages, see the orderable addendum at the end of the datasheet.

Typical Application Circuit

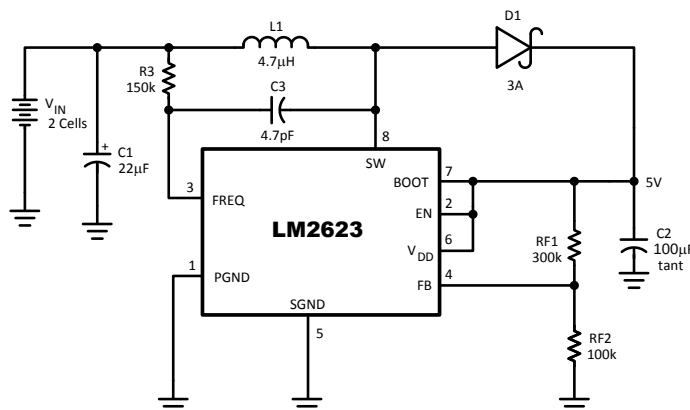


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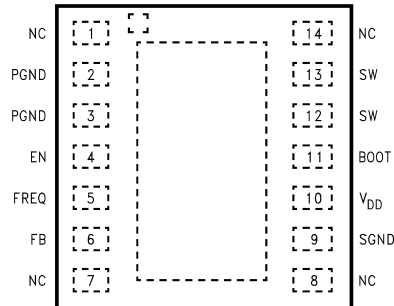
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4 Revision History

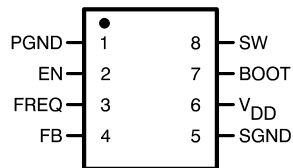
Changes from Revision G (December 2005) to Revision H	Page
Added <i>Device Information</i> and <i>Handling Rating</i> tables, <i>Feature Description</i>, <i>Device Functional Modes</i>, <i>Application and Implementation</i>, <i>Power Supply Recommendations</i>, <i>Layout</i>, <i>Device and Documentation Support</i>, and <i>Mechanical, Packaging, and Orderable Information</i> sections; moved some curves to <i>Application Curves</i> section	1

5 Pin Configuration and Functions

**WSOP Package
14 Pins
Top View**



**VSSOP Package
8 Pins
Top View**



Pin Functions

PIN			TYPE	DESCRIPTION
WSOP	VSSOP	NAME		
1	—	NC	N/A	No Connect
2, 3	1	PGND	GND	Power Ground (WSOP Pins 2 & 3 must be shorted together).
4	2	EN	Digital	Active-Low Shutdown Input
5	3	FREQ	Analog	Frequency Adjust. An external resistor connected between this pin and a voltage source sets the switching frequency of the LM2623.
6	4	FB	Analog	Output Voltage Feedback
7	—	NC	N/A	No Connect
8	—	NC	N/A	No connect
9	5	SGND	GND	Signal Ground
10	6	V _{DD}	Power	Power Supply for Internal Circuitry
11	7	BOOT	Analog	Bootstrap Supply for the Gate Drive of Internal MOSFET Power Switch
12, 13	8	SW	Analog	Drain of the Internal MOSFET Power Switch. (WSOP Pins 12 & 13 must be shorted together.)
14	—	NC	N/A	No Connect
DAP	—	DAP	Thermal	To be soldered to board for enhanced thermal dissipation. To be electrically isolated/floating.

6 Specifications

6.1 Absolute Maximum Ratings⁽¹⁾⁽²⁾

	MIN	MAX	UNIT
SW pin voltage	–0.5	14.5	V
BOOT, V _{DD} , EN and FB pins	–0.5	10	V
FREQ pin		100	μA
T _{Jmax} ⁽³⁾		150	°C
Lead temp. (soldering, 5 sec)		260	°C
Power dissipation (T _A =25°C) ⁽³⁾		500	mW

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.
- (3) The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{Jmax} (maximum junction temperature), R_{θJA} (junction-to-ambient thermal resistance), and T_A (ambient temperature). The maximum allowable power dissipation at any temperature is P_{dmax} = (T_{Jmax} – T_A) / R_{θJA} or the number given in the *Absolute Maximum Ratings*, whichever is lower.

6.2 Handling Ratings

	MIN	MAX	UNIT
T _{stg}	–65	150	°C
V _(ESD)	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins ⁽¹⁾	2	kV
	Charged device model (CDM), per JEDEC specification JESD22-C101, all pins ⁽²⁾	0.5	

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions⁽¹⁾

	MIN	MAX	UNIT
V _{DD} pin	3	5	V
FB, EN pins	0	V _{DD}	
BOOT pin	0	10	V
Ambient temperature (T _A)	–40	85	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.4 Thermal Information

THERMAL METRIC ⁽¹⁾	LM2623		UNIT
	NHE	DGK	
	14 PINS	8 PINS	
R _{θJA} Junction-to-ambient thermal resistance	40 – 56	240	°C/W

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

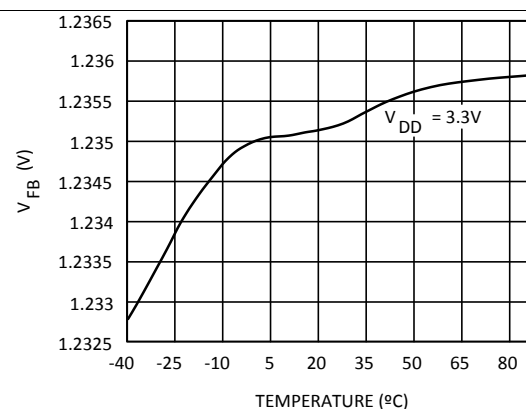
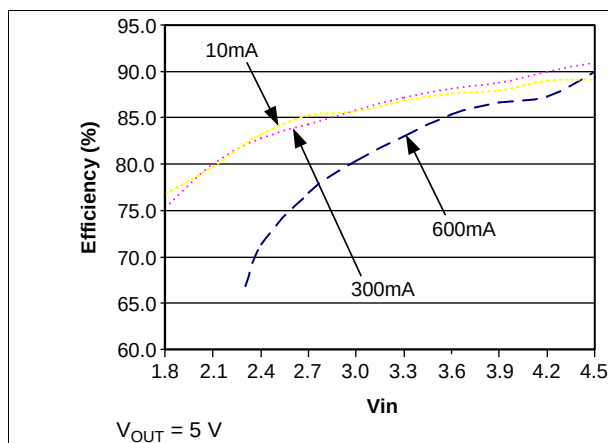
6.5 Electrical Characteristics

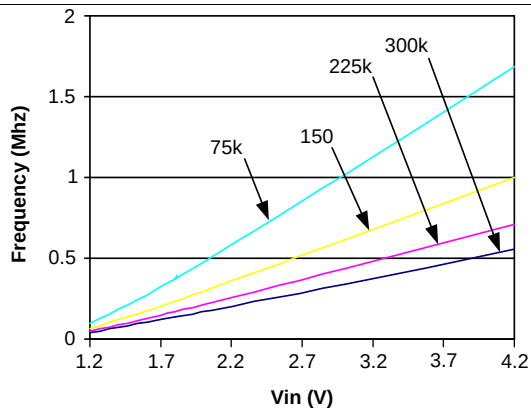
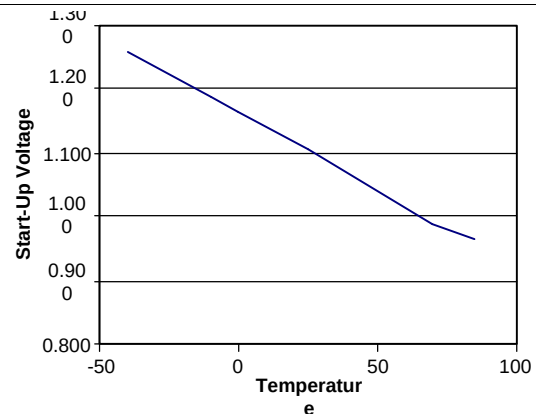
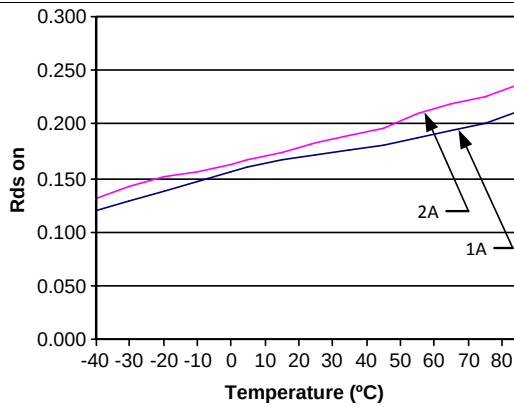
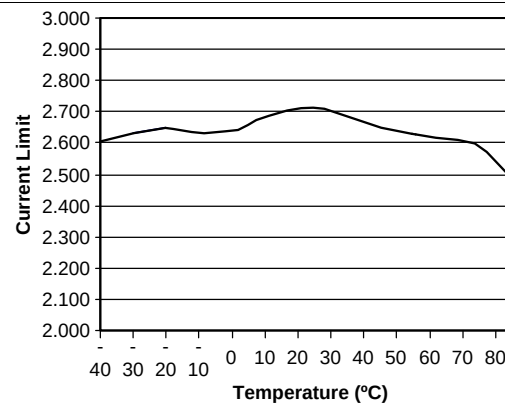
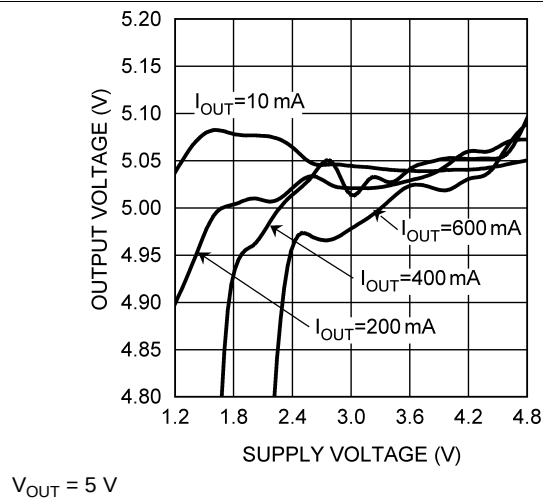
Limits apply for $T_J = 25^\circ\text{C}$ and $V_{DD} = V_{OUT} = 3.3\text{ V}$, unless otherwise specified.

PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT
V _{DD_ST}	Start-up supply voltage 25°C	I _{LOAD} = 0 mA ⁽¹⁾			1.1	V
V _{IN_OP}	Minimum operating supply voltage (once started)	I _{LOAD} = 0 mA		0.65	0.8	V
V _{FB}	FB pin voltage			1.24		V
		−40°C to 85°C	1.2028	1.2772		
V _{OUT_MAX}	Maximum output voltage			14		V
η	Efficiency	V _{IN} = 3.6 V; V _{OUT} = 5 V; I _{LOAD} = 500 mA		87%		
		V _{IN} = 2.5 V; V _{OUT} = 3.3 V; I _{LOAD} = 200 mA		87%		
D	Switch duty cycle			17		
I _{DD}	Operating quiescent current ⁽²⁾	FB Pin > 1.3 V; EN Pin at V _{DD}		80		μA
		FB Pin > 1.3 V; EN Pin at V _{DD} , −40°C to 85°C		110		
I _{SD}	Shutdown quiescent current ⁽³⁾	V _{DD} , BOOT and SW Pins at 5 V; EN Pin < 200 mV		0.01		μA
		V _{DD} , BOOT and SW Pins at 5 V; EN Pin < 200 mV, −40°C to 85°C		2.5		
I _{CL}	Switch peak current limit	LM2623A	2.2	2.85		A
I _C	Switch peak current limit	LM2623	1.2			
R _{DS_ON}	MOSFET switch on resistance			0.17		Ω
		−40°C to 85°C		0.26		
ENABLE SECTION						
V _{EN_LO}	EN pin voltage low ⁽⁴⁾	−40°C to 85°C			0.15 V _{DD}	V
V _{EN_HI}	EN pin voltage high ⁽⁴⁾	−40°C to 85°C	0.7 V _{DD}			

- (1) V_{DD} tied to BOOT and EN pins. Frequency pin tied to V_{DD} through 121K resistor. $V_{DD_ST} = V_{DD}$ when start-up occurs. V_{IN} is $V_{DD} + D1$ voltage (usually 10 mV to 50 mV at start-up).
- (2) This is the current into the V_{DD} pin.
- (3) This is the total current into pins V_{DD} , BOOT, SW and FREQ.
- (4) When the EN pin is below V_{EN_LO} , the regulator is shut down; when it is above V_{EN_HI} , the regulator is operating.

6.6 Typical Characteristics



Typical Characteristics (continued)

Figure 3. Frequency vs V_{IN}

Figure 4. Maximum Start-Up Voltage vs Temperature

Figure 5. Typical $R_{DS(ON)}$ vs Temperature

Figure 6. Typical Current Limit vs Temperature

Figure 7. Output Voltage vs Supply Voltage

7 Detailed Description

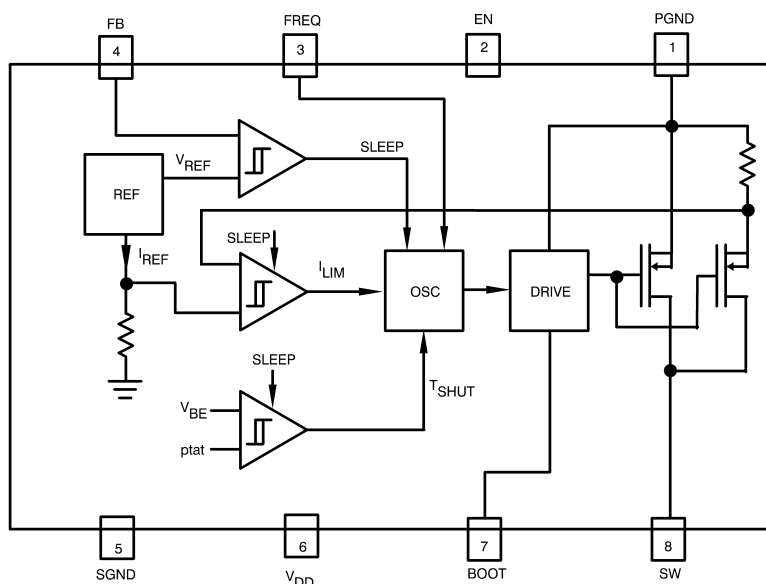
7.1 Overview

The LM2623 is designed to provide step-up DC-DC voltage regulation in battery-powered and low-input voltage systems. It combines a step-up switching regulator, N-channel power MOSFET, built-in current limit, thermal limit, and voltage reference in a single 8-pin VSSOP package [Functional Block Diagram](#). The switching DC-DC regulator boosts an input voltage between 0.8 V and 14 V to a regulated output voltage between 1.24 V and 14 V. The LM2623 starts from a low 1.1 V input and remains operational down to below 0.8 V.

This device is optimized for use in cellular phones and other applications requiring a small size, low profile, as well as low quiescent current for maximum battery life during stand-by and shutdown. A high-efficiency gated-oscillator topology offers an output of up to 2 A at low output voltages.

Additional features include a built-in peak switch current limit, and thermal protection circuitry.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Gated Oscillator Control Scheme.

The on/off regulation mode of the LM2623, along with its ultra-low quiescent current, results in good efficiency over a very wide load range. The internal oscillator frequency can be programmed using an external resistor to be constant or vary with the battery voltage. Adding a capacitor to program the frequency allows the designer to adjust the duty cycle and optimize it for the application. Adding a resistor in addition to the capacitor allows the duty cycle to dynamically compensate for changes to the input/output voltage ratio. We call this a Ratio Adaptive Gated Oscillator circuit. See the [Typical Application](#) for sample application circuits. Using the correct RC components to adjust the oscillator allows the part to run with low ripple and high efficiency over a wide range of loads and input/output voltages.

Feature Description (continued)

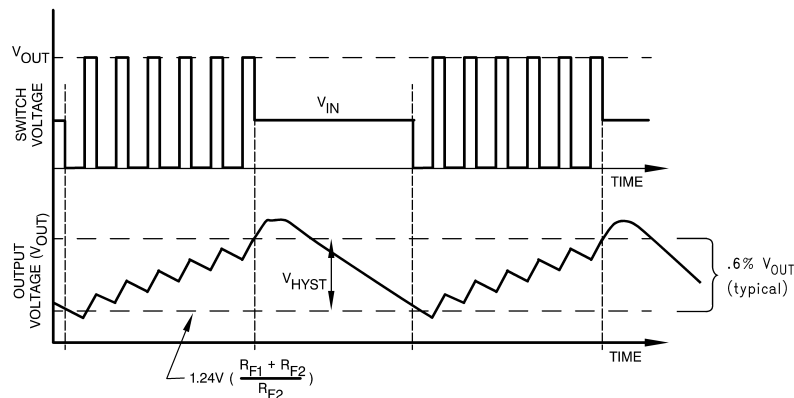


Figure 8. Typical Step-Up Regulator Waveforms

7.3.2 Cycle-to-Cycle PFM

When the load doesn't vary over a wide range (like zero to full load), ratio adaptive circuit techniques can be used to achieve cycle to cycle PFM regulation and lower ripple (or smaller output capacitors). The key to success here is matching the duty cycle of the circuit closely to what is required by the input to output voltage ratio. This ratio then needs to be dynamically adjusted for input voltage changes (usually caused by batteries running down). The chosen ratio should allow most of the energy in each switching cycle to be delivered to the load and only a small amount to be stored. When the regulation limit is reached, the overshoot will be small and the system will settle at an equilibrium point where it adjusts the off time in each switching cycle to meet the current requirements of the load. The off time adjustment is done by exceeding the regulation limit during each switching cycle and waiting until the voltage drops below the limit again to start the next switching cycle. The current in the coil never goes to zero like it frequently does in the hysteretic operating mode of circuits with wide load variations or duty cycles that aren't matched to the input/output voltage ratio. Optimizing the duty cycle for a given set of input/output voltages conditions can be done by using the circuit values in the Application Notes.

7.3.3 Shutdown

The LM2623 features a shutdown mode that reduces the quiescent current to less than an ensured 2.5 μA over temperature. This extends the life of the battery in battery powered applications. During shutdown, all feedback and control circuitry is turned off. The regulator's output voltage drops to one diode drop below the input voltage. Entry into the shutdown mode is controlled by the active-low logic input pin EN (pin-2). When the logic input to this pin is pulled below 0.15 V_{DD} , the device goes into shutdown mode. The logic input to this pin should be above 0.7 V_{DD} for the device to work in normal stepup mode.

7.3.4 Internal Current Limit and Thermal Protection

An internal cycle-by-cycle current limit serves as a protection feature. This is set high enough (2.85 A typical, approximately 4 A maximum) so as not to come into effect during normal operating conditions. An internal thermal protection circuit disables the MOSFET power switch when the junction temperature (T_J) exceeds about 160°C. The switch is re-enabled when T_J drops below approximately 135°C.

7.4 Device Functional Modes

7.4.1 Pulse Frequency Modulation (PFM)

Pulse Frequency Modulation is typically accomplished by switching continuously until the voltage limit is reached and skipping cycles after that to just maintain it. This results in a somewhat hysteretic mode of operation. The coil stores more energy each cycle as the current ramps up to high levels. When the voltage limit is reached, the system usually overshoots to a higher voltage than required, due to the stored energy in the coil (see [Figure 8](#)). The system will also undershoot somewhat when it starts switching again because it has depleted all the stored energy in the coil and needs to store more energy to reach equilibrium with the load. Larger output capacitors

Device Functional Modes (continued)

and smaller inductors reduce the ripple in these situations. The frequency being filtered, however, is not the basic switching frequency. It is a lower frequency determined by the load, the input/output voltage and the circuit parameters. This mode of operation is useful in situations where the load variation is significant. Power managed computer systems, for instance, may vary from zero to full load while the system is on and this is usually the preferred regulation mode for such systems.

7.4.2 Low Voltage Start-Up

The LM2623 can start up from voltages as low as 1.1 V. On start-up, the control circuitry switches the N-channel MOSFET continuously until the output reaches 3 V. After this output voltage is reached, the normal step-up regulator feedback and gated oscillator control scheme take over. Once the device is in regulation, it can operate down to below 0.8 V input, since the internal power for the IC can be boot-strapped from the output using the V_{DD} pin.

8 Applications and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The LM2623 features a shutdown mode, entry into the shutdown mode is controlled by the active-low logic input pin EN (pin 2). When the logic input to this pin is pulled below $0.15 V_{DD}$, the device goes into shutdown mode. The logic input to this pin should be above $0.7 V_{DD}$ for the device to work in normal start-up mode.

8.2 Typical Application

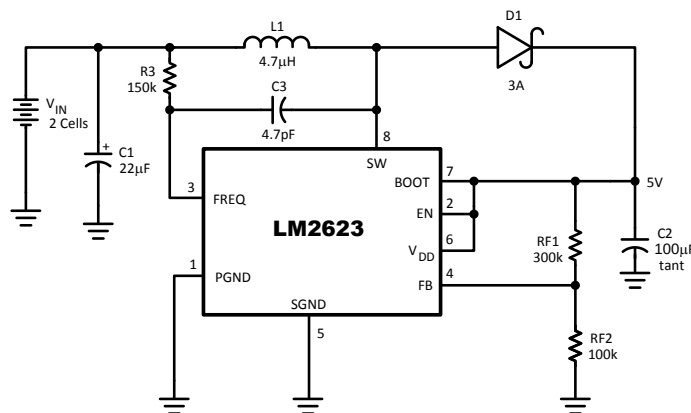


Figure 9. LM2623 Typical Application

8.2.1 Design Requirements

The LM2623 allows the designer to vary output voltage, operating frequency and duty cycle to optimize the part performance, please read [Detailed Design Procedure](#) for details.

8.2.2 Detailed Design Procedure

8.2.2.1 Non-Linear Effect

The LM2623 is very similar to the LM2621. The LM2623 is based on the LM2621, except for the fact that the LM2623 takes advantage of a non-linear effect that allows for the duty cycle to be programmable. The C3 capacitor is used to dump charge on the FREQ pin in order to manipulate the duty cycle of the internal oscillator. The part is being tricked to behave in a certain manner, in the effort to make this Pulse Frequency Modulated (PFM) boost switching regulator behave as a Pulse Width Modulated (PWM) boost switching regulator.

8.2.2.2 Choosing the Correct C3 Capacitor

The C3 capacitor allows for the duty cycle of the internal oscillator to be programmable. Choosing the correct C3 capacitor to get the appropriate duty cycle for a particular application circuit is a trial and error process. The non-linear effect that C3 produces is dependent on the input voltage and output voltage values. The correct C3 capacitor for particular input and output voltage values cannot be calculated. Choosing the correct C3 capacitance is best done by trial and error, in conjunction with the checking of the inductor peak current to make sure your not too close to the current limit of the device. As the C3 capacitor value increases, so does the duty cycle. And conversely as the C3 capacitor value decreases, the duty cycle decreases. An incorrect choice of the C3 capacitor can result in the part prematurely tripping the current limit and/or double pulsing, which could lead to the output voltage not being stable.

Typical Application (continued)

8.2.2.3 Setting the Output Voltage

The output voltage of the step-up regulator can be set by connecting a feedback resistive divider made of R_{F1} and R_{F2} . The resistor values are selected as follows:

$$R_{F1} = R_{F2} * [(V_{OUT}/1.24) - 1] \quad (1)$$

A value of 50k to 100k is suggested for R_{F2} . Then, R_{F1} can be selected using [Equation 1](#).

8.2.2.4 V_{DD} Supply

The V_{DD} supply must be between 3 V to 5 V for the LM2623. This voltage can be bootstrapped from a much lower input voltage by simply connecting the V_{DD} pin to V_{OUT} . In the event that the V_{DD} supply voltage is not a low ripple voltage source (less than 200 millivolts), it may be advisable to use an RC filter to clean it up. Excessive ripple on V_{DD} may reduce the efficiency.

8.2.2.5 Setting the Switching Frequency

The switching frequency of the oscillator is selected by choosing an external resistor ($R3$) connected between V_{IN} and the FREQ pin. See [Figure 3](#) in the [Typical Characteristics](#) section of the data sheet for choosing the $R3$ value to achieve the desired switching frequency. A high switching frequency allows the use of very small surface mount inductors and capacitors and results in a very small solution size. A switching frequency between 300 kHz and 2 MHz is recommended.

8.2.2.6 Output Diode Selection

A Schottky diode should be used for the output diode. The forward current rating of the diode should be higher than the peak input current, and the reverse voltage rating must be higher than the output voltage. Do not use ordinary rectifier diodes, since slow switching speeds and long recovery times cause the efficiency and the load regulation to suffer.

8.2.3 Application Curves

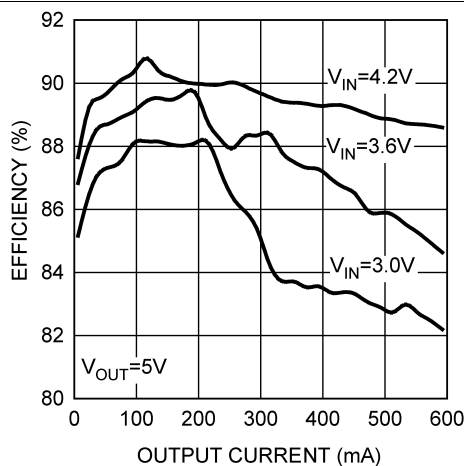


Figure 10. Efficiency vs Output Current

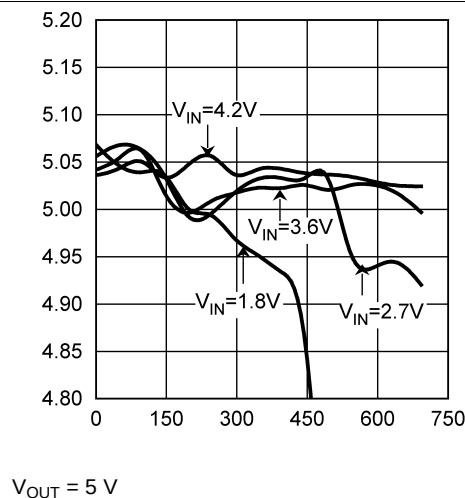


Figure 11. Output Voltage vs Output Current

9 Power Supply Recommendations

The LM2623 can start up from voltages as low as 1.1 V. On start-up, the control circuitry switches the N-channel MOSFET continuously until the output reaches 3 V. After this output voltage is reached, the normal step-up regulator feedback and gated oscillator control scheme take over. Once the device is in regulation, it can operate down to below 0.8 V input, since the internal power for the IC can be boot-strapped from the output using the V_{DD} pin.

10 Layout

10.1 Layout Guidelines

The example layouts below follow proper layout guidelines and should be used as a guide for laying out the LM2623 circuit. The LM2623 inductive boost converter sees a high switched voltage at the SW pin, and a step current through the Schottky diode and output capacitor each switching cycle. The high switching voltage can create interference into nearby nodes due to electric field coupling ($I = C \times dV/dt$). The large step current through the diode and the output capacitor can cause a large voltage spike at the SW and BOOST pins due to parasitic inductance in the step current conducting path ($V = L \times di/dt$). Board layout guidelines are geared towards minimizing this electric field coupling and conducted noise.

[Boost Output Capacitor Placement](#), [Schottky Diode Placement](#), and [Boost Input / \$V_{DD}\$ Capacitor Placement](#) detail the main (layout sensitive) areas of the LM2623 inductive boost converter in order of decreasing importance:

10.1.1 Boost Output Capacitor Placement

Because the output capacitor is in the path of the inductor current discharge path, it will see a high-current step from 0 to IPEAK each time the switch turns off and the Schottky diode turns on. Any inductance along this series path from the diodes cathode, through COUT, and back into the LM2623 GND pin will contribute to voltage spikes at SW. These spikes can potentially over-voltage the SW and BOOST pins, or feed through to GND. To avoid this, COUT+ must be connected as close as possible to the cathode of the Schottky diode, and COUT– must be connected as close as possible to the LM2623 GND bumps. The best placement for COUT is on the same layer as the LM2623 to avoid any vias that can add excessive series inductance.

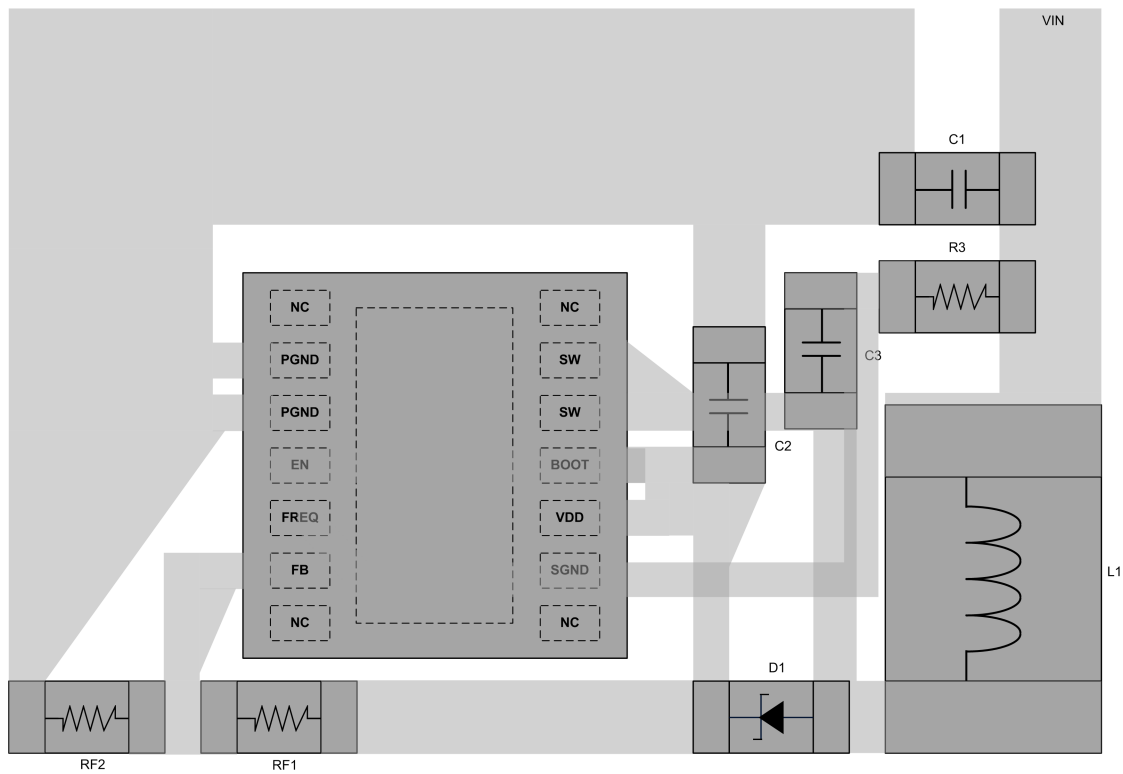
10.1.2 Schottky Diode Placement

In the LM2623 device boost circuit the Schottky diode is in the path of the inductor current discharge. As a result the Schottky diode sees a high-current step from 0 to IPEAK each time the switch turns off, and the diode turns on. Any inductance in series with the diode will cause a voltage spike at SW. This can potentially over-voltage the SW pin, or feed through to VOUT and through the output capacitor, into GND. Connecting the anode of the diode as close as possible to the SW pin, and connecting the cathode of the diode as close as possible to COUT+, will reduce the inductance ($LP_{_}$) and minimize these voltage spikes.

10.1.3 Boost Input / V_{DD} Capacitor Placement

The LM2623 input capacitor filters the inductor current ripple and the internal MOSFET driver currents. The inductor current ripple can add input voltage ripple due to any series resistance in the input power path. The MOSFET driver currents can add voltage spikes on the input due to the inductance in series with the VIN/ V_{DD} and the input capacitor. Close placement of the input capacitor to the V_{DD} pin and to the GND pin is critical since any series inductance between VIN/ V_{DD} and CIN+ or CIN– and GND can create voltage spikes that could appear on the VIN/ V_{DD} supply line and GND.

10.2 Layout Example



10.3 WSON Package Devices

The LM2623 is offered in the 14-lead WSON surface mount package to allow for increased power dissipation compared to the VSSOP-8. For details of the thermal performance as well as mounting and soldering specifications, refer to Application Note AN-1187 *Leadless Leadframe Package (LLP)* ([SNOA401](#)).

11 Device and Documentation Support

11.1 Device Support

11.1.1 Third-Party Products Disclaimer

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

11.2 Documentation Support

11.2.1 Related Documentation

For related documentation, see the following:

Application Note AN-1187 *Leadless Leadframe Package (LLP)* ([SNOA401](#)).

11.3 Trademarks

All trademarks are the property of their respective owners.

11.4 Electrostatic Discharge Caution



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

11.5 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

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

IMPORTANT NOTICE

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