National Semiconductor

LM2651
1.5A High Efficiency Synchronous Switching Regulator

General Description

The LM2651 switching regulator provides high efficiency power conversion over a 100:1 load range (1.5A to 15mA). This feature makes the LM2651 an ideal fit in battery-powered applications that demand long battery life in both run and standby modes.

Synchronous rectification is used to achieve up to 97% efficiency. At light loads, the LM2651 enters a low power hysteretic or "sleep" mode to keep the efficiency high. In many applications, the efficiency still exceeds 80% at 15mA load. A shutdown pin is available to disable the LM2651 and reduce the supply current to less than 10µA.

The LM2651 contains a patented current sensing circuitry for current mode control. This feature eliminates the external current sensing resistor required by other current-mode DC-DC converters.

The LM2651 has a 300 kHz fixed frequency internal oscillator. The high oscillator frequency allows the use of extremely small, low profile components.

A programmable soft-start feature limits current surges from the input power supply at start up and provides a simple means of sequencing multiple power supplies.

Other protection features include input undervoltage lockout, current limiting, and thermal shutdown.

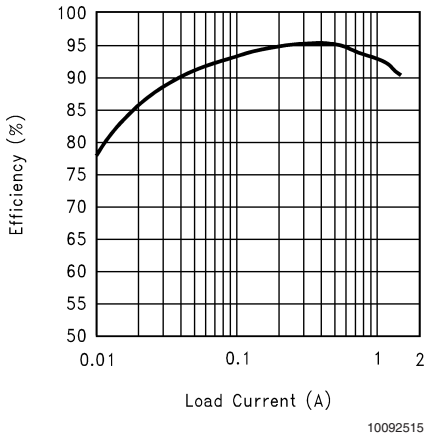
Features

- Ultra high efficiency up to 97%
- High efficiency over a 1.5A to milliamperes load range
- 4V to 14V input voltage range
- 1.8V, 2.5V, 3.3V, or ADJ output voltage
- Internal MOSFET switch with low $R_{DS(on)}$ of 75mΩ
- 300kHz fixed frequency internal oscillator
- 7µA shutdown current
- Patented current sensing for current mode control
- Input undervoltage lockout
- Adjustable soft-start
- Current limit and thermal shutdown
- 16-pin TSSOP package

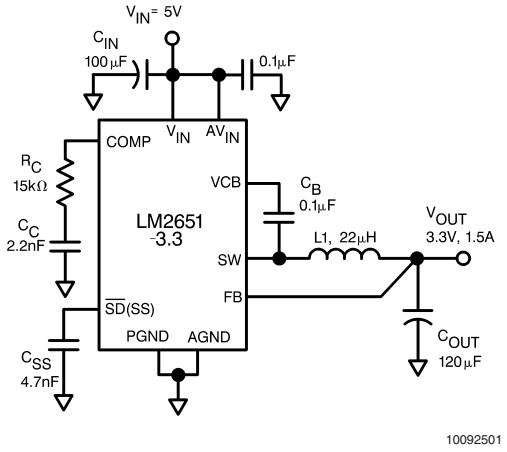
Applications

- Personal digital assistants (PDAs)
- Computer peripherals
- Battery-powered devices
- Handheld scanners
- High efficiency 5V conversion

Typical Application

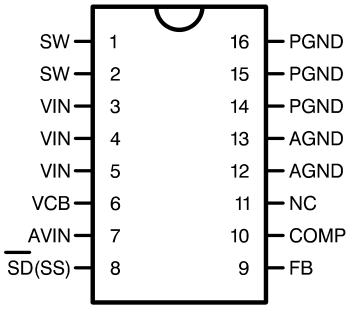


Efficiency vs Load Current (V_{IN} = 5V, V_{OUT} = 3.3V



Connection Diagram

16-Lead TSSOP (MTC)



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Ordering Information

V_{OUT}	Part Number		Package Type	NSC Package Drawing
	Supplied as 94 Units, Rail	Supplied as 2.5k Units, Tape and Reel		
1.8	LM2651MTC-1.8	LM2651MTCX-1.8	TSSOP-16	MTC16
2.5	LM2651MTC-2.5	LM2651MTCX-2.5		
3.3	LM2651MTC-3.3	LM2651MTCX-3.3		
ADJ	LM2651MTC-ADJ	LM2651MTCX-ADJ		

Pin Description

Pin	Name	Function
1, 2	SW	Switched-node connection, which is connected with the source of the internal high-side MOSFET.
3-5	VIN	Main power supply pin.
6	VCB	Bootstrap capacitor connection for high-side gate drive.
7	AVIN	Input supply voltage for control and driver circuits.
8	$\overline{SD}$(SS)	Shutdown and Soft-start control pin. Pulling this pin below 0.3V shuts off the regulator. A capacitor connected from this pin to ground provides a control ramp of the input current. Do not drive this pin with an external source or erroneous operation may result.
9	FB	Output voltage feedback input. Connected to the output voltage.
10	COMP	Compensation network connection. Connected to the output of the voltage error amplifier.
11	NC	No internal connection.
12-13	AGND	Low-noise analog ground.
14-16	PGND	Power ground.

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Input Voltage	15V
Feedback Pin Voltage	$-0.4V \le V_{FB} \le 5V$
Power Dissipation (T_A =25˚C), (Note 2)	893 mW
Junction Temperature Range	$-40˚C \le T_J \le +125˚C$
Storage Temperature Range	−65˚C to +150˚C
ESD Susceptibility	
Human Body Model (Note 3)	1kV

Operating Ratings (Note 1)

Supply Voltage	$4V \le V_{IN} \le 14V$

LM2651-1.8 System Parameters

Specifications in standard type face are for T_J = 25˚C and those with **boldface type** apply over **full operating junction temperature range.** V_{IN} =10V unless otherwise specified.

Symbol	Parameter	Conditions	Typical	Limit	Units
V_{OUT}	Output Voltage	I_{LOAD} = 900 mA	1.8	1.761/**1.719** 1.836/**1.854**	V V(min) V(max)
V_{OUT}	Output Voltage Line Regulation	V_{IN} = 4V to 14V I_{LOAD} = 900 mA	0.2		%
V_{OUT}	Output Voltage Load Regulation	I_{LOAD} = 10 mA to 1.5A V_{IN} = 5V	1.3		%
V_{OUT}	Output Voltage Load Regulation	I_{LOAD} = 200 mA to 1.5A V_{IN} = 5V	0.3		%
V_{HYST}	Sleep Mode Output Voltage Hysteresis		35		mV

LM2651-2.5 System Parameters

Symbol	Parameter	Conditions	Typical	Limit	Units
V_{OUT}	Output Voltage	I_{LOAD} = 900 mA	2.5	2.43/**2.388** 2.574/**2.575**	V V(min) V(max)
V_{OUT}	Output Voltage Line Regulation	V_{IN} = 4V to 12V I_{LOAD} = 900 mA	0.2		%
V_{OUT}	Output Voltage Load Regulation	I_{LOAD} = 10 mA to 1.5A V_{IN} = 5V	1.3		%
V_{OUT}	Output Voltage Load Regulation	I_{LOAD} = 200 mA to 1.5A V_{IN} = 5V	0.3		%
V_{HYST}	Sleep Mode Output Voltage Hysteresis		48		mV

LM2651-3.3 System Parameters

Symbol	Parameter	Conditions	Typical	Limit	Units
V_{OUT}	Output Voltage	I_{LOAD} = 900 mA	3.3	3.265/**3.201** 3.379/**3.399**	V V(min) V(max)
V_{OUT}	Output Voltage Line Regulation	V_{IN} = 4V to 14V I_{LOAD} = 900 mA	0.2		%
V_{OUT}	Output Voltage Load Regulation	I_{LOAD} = 10 mA to 1.5A V_{IN} = 5V	1.3		%
V_{OUT}	Output Voltage Load Regulation	I_{LOAD} = 200 mA to 1.5A V_{IN} = 5V	0.3		%
V_{HYST}	Sleep Mode Output Voltage Hysteresis		60		mV

LM2651-ADJ System Parameters

(V_{OUT} = 2.5V unless otherwise specified)

Symbol	Parameter	Conditions	Typical	Limit	Units
V_{FB}	Feedback Voltage	I_{LOAD} = 900 mA	1.238	**1.200** **1.263**	V V(min) V(max)
V_{OUT}	Output Voltage Line Regulation	V_{IN} = 4V to 14V I_{LOAD} = 900 mA	0.2		%
V_{OUT}	Output Voltage Load Regulation	I_{LOAD} = 10 mA to 1.5A V_{IN} = 5V	1.3		%
V_{OUT}	Output Voltage Load Regulation	I_{LOAD} = 200 mA to 1.5A V_{IN} = 5V	0.3		%
V_{HYST}	Sleep Mode Output Voltage Hysteresis		24		mV

All Output Voltage Versions

Specifications in standard type face are for T_J = 25˚C and those with **boldface type** apply over **full operating junction temperature range.** V_{IN} =10V unless otherwise specified.

Symbol	Parameter	Conditions	Typical	Limit	Units
I_Q	Quiescent Current		1.6	**2.0**	mA mA(max)
I_{QSD}	Quiescent Current in Shutdown Mode	Shutdown Pin Pulled Low	7	12/**20**	µA µA(max)
$R_{SW(ON)}$	High-Side or Low-Side Switch On Resistance (MOSFET On Resistance + Bonding Wire Resistance)	I_{SWITCH} = 1A	110		mΩ
$R_{DS(ON)}$	MOSFET On Resistance (High-Side or Low-Side)	I_{SWITCH} = 1A	75	**130**	mΩ mΩ(max)
I_L	Switch Leakage Current - High Side		130		nA
	Switch Leakage Current - Low Side		130		nA
V_{BOOT}	Bootstrap Regulator Voltage	I_{BOOT} = 1 mA	6.75	6.45/**6.40** 6.95/**7.00**	V V(min) V(max)
G_M	Error Amplifier Transconductance		1250		µmho
V_{INUV}	V_{IN} Undervoltage Lockout Threshold Voltage	Rising Edge	3.8	**3.95**	V V(max)
$V_{UV-HYST}$	Hysteresis for the Undervoltage Lockout		210		mV
I_{CL}	Switch Current Limit	V_{IN} = 5V	2	**1.55** **2.60**	A A(min) A(max)
I_{SM}	Sleep Mode Threshold Current	V_{IN} = 5V	100		mA
A_V	Error Amplifier Voltage Gain		100		V/V
I_{EA_SOURCE}	Error Amplifier Source Current		40	25/**15**	µA µA(min)
I_{EA_SINK}	Error Amplifier Sink Current		65	**30**	µA µA(min)
V_{EAH}	Error Amplifier Output Swing Upper Limit		2.70	2.50/**2.40**	V V(min)

All Output Voltage Versions (Continued)

Specifications in standard type face are for T_J = 25˚C and those with **boldface type** apply over **full operating junction temperature range.** V_{IN} =10V unless otherwise specified.

Symbol	Parameter	Conditions	Typical	Limit	Units
V_{EAL}	Error Amplifier Output Swing Lower Limit		1.25	1.35/**1.50**	V V(max)
V_D	Body Diode Voltage	I_{DIODE} = 1.5A	1		V
f_{OSC}	Oscillator Frequency	V_{IN} = 4V	300	280/**255** 330/**345**	kHz kHz(min) kHz(max)
D_{MAX}	Maximum Duty Cycle	V_{IN} = 4V	95	**92**	% %(min)
I_{SS}	Soft-Start Current	Voltage at the SS pin = 1.4V	11	**7** **14**	µA µA(min) µA(max)
$I_{SHUTDOWN}$	Shutdown Pin Current	Shutdown Pin Pulled Low	2.2	0.8/**0.5** 3.7/**4.0**	µA µA(min) µA(max)
$v_{SHUTDOWN}$	Shutdown Pin Threshold Voltage	Falling Edge	0.6	**0.3** **0.9**	V V(min) V(max)
T_{SD}	Thermal Shutdown Temperature		165		˚C
T_{SD_HYST}	Thermal Shutdown Hysteresis Temperature		25		˚C

Note 1: Absolute maximum ratings indicate limits beyond which damage to the device may occur. Operating ratings indicate conditions for which the device is intended to be functional, but device parameter specifications may not be guaranteed under these conditions. For guaranteed specifications and test conditions, see the Electrical Characteristics.

Note 2: The maximum allowable power dissipation is calculated by using $P_{Dmax} = (T_{Jmax} - T_A)/\theta_{JA}$, where T_{Jmax} is the maximum junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction-to-ambient thermal resistance of the specified package. The 893 mW rating results from using 150˚C, 25˚C, and 140˚C/W for T_{Jmax}, T_A, and θ_{JA} respectively. A θ_{JA} of 140˚C/W represents the worst-case condition of no heat sinking of the 16-pin TSSOP package. Heat sinking allows the safe dissipation of more power. The Absolute Maximum power dissipation must be derated by 7.14mW per ˚C above 25˚C ambient. The LM2651 actively limits its junction temperature to about 165˚C.

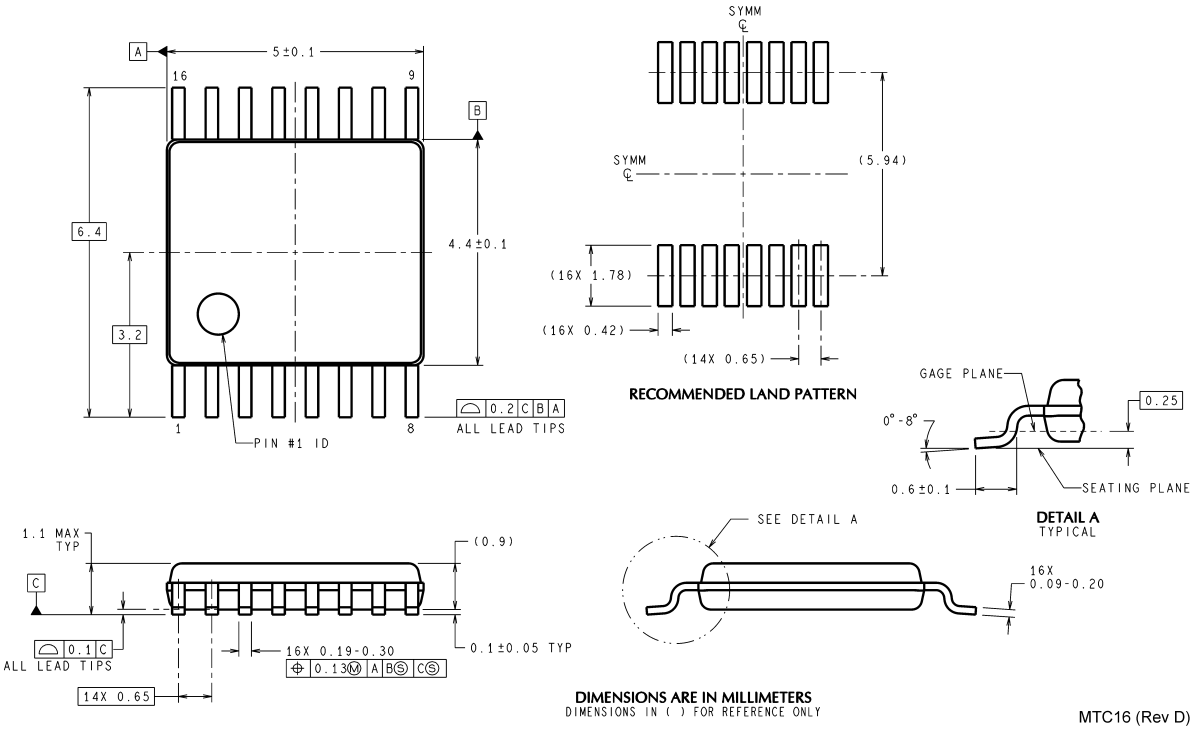
Note 3: The human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin.

Note 4: Typical numbers are at 25˚C and represent the most likely norm.

Note 5: All limits are guaranteed at room temperature (standard typeface) and at **temperature extremes (boldface type)**. All room temperature limits are 100% production tested. All limits at **temperature extremes** are guaranteed via correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).

Physical Dimensions inches (millimeters)

unless otherwise noted



16-Lead TSSOP (MTC)
For ordering, refer to Ordering Information Table
See NS Package Number MTC16