High-efficiency Synchronous Step-up DC/DC Converter

PRODUCT SUMMARY

High efficiency boost converter
Output current up to 500mA
No external diode required

FEATURES

- Quiescent supply current of 20μA.
- Power-saving shutdown mode (0.1μA typical).
- Internal synchronous rectifier
- On-chip low-battery detector.
- Low battery hysteresis
- **Pb-free, RoHS compliant MSOP-8**

APPLICATIONS

- Palmtop and notebook computers.
- PDAs
- Wireless phones
- Pocket organizers.
- Digital cameras.
- Hand-held devices with 1 to 3 cells of NiMH/NiCd batteries.

DESCRIPTION

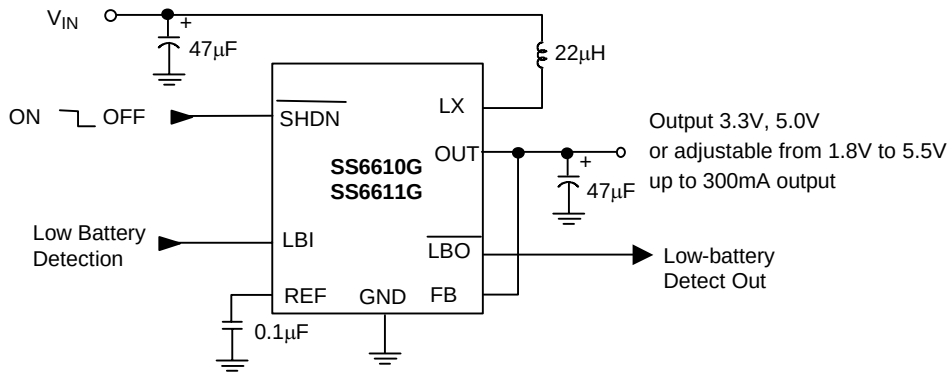
The SS6610/11G are high-efficiency step-up DC/DC converters, with a start-up voltage as low as 0.8V, and an operating voltage down to 0.7V. Consuming only 20μA of quiescent current, these devices include a built-in synchronous rectifier that reduces size and cost by eliminating the need for an external Schottky diode, and improves overall efficiency by minimizing losses.

The switching frequency can range up to 500KHz depending on the load and input voltage. The output voltage can be easily set by:

1) two external resistors for 1.8V to 5.5V;
2) connecting FB to OUT to get 3.3V; or
3) connecting FB to GND to get 5.0V.

The peak current of the internal switch is fixed at 1A (SS6610G) or 0.65A (SS6611G) for design flexibility.

TYPICAL APPLICATION CIRCUIT



ORDERING INFORMATION

SS6610GO TR
SS6611GO TR

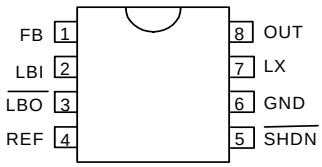
- TR: Packing — Tape and reel
- GO: Package type — RoHS-compliant MSOP-8

Example: SS6610GO TR

→ SS6610 in RoHS-compliant MSOP-8 package, shipped on tape and reel

PIN CONFIGURATION

MSOP-8
TOP VIEW



ABSOLUTE MAXIMUM RATINGS

Supply voltage (OUT to GND)	8.0V
Switch voltage (LX to GND)	V_{OUT}+ 0.3V
$\overline{SHDN}$, LBO to GND	6.0V
LBI, REF, FB, to GND	V_{OUT}+0.3V
Switch current (LX)	-1.5A to +1.5A
Output current (OUT)	-1.5A to +1.5A
Operating temperature range	-40°C ~ +85°C
Storage temperature range	-65°C ~150°C

TEST CIRCUIT

Refer to the typical application circuit on page 1.

ELECTRICAL CHARACTERISTICS

(V_{IN} = 2.0V, V_{OUT} = 3.3V (FB = V_{OUT}),R_L = ∞ , unless otherwise specified.)

PARAMETER	TEST CONDITIONS		MIN.	TYP.	MAX.	UNIT
Minimum input voltage				0.7		V
Operating voltage			1.1		5.5	V
Start-up voltage	R_L=3kΩ (Note1)			0.8	1.1	V
Start-up voltage temp. coeff.				-2		mV/°C
Output voltage range	V_{IN}<V_{OUT}		1.8		5.5	
Output voltage	FB = V_{OUT}		3.17	3.3	3.43	V
Steady-state output current (Note 2)	FB=OUT (V_{OUT} =3.3V)	SS6610G	300	350		mA
		SS6611G	150	300		
	FB=GND (V_{OUT} =5.0V)	SS6610G	180	230		
		SS6611G	90	160		
Reference voltage	I_{REF}= 0		1.199	1.23	1.261	V
Reference voltage temp. coeff.				0.024		mV/°C
Reference load regulation	I_{REF} = 0 to 100μA			10	30	mV
Reference line regulation	V_{OUT} = 1.8V to 5.5V			5	10	mV/V
FB , LBI input threshold			1.199	1.23	1.261	V
Internal switch on-resistance	I_{LX} = 100mA			0.3	0.6	Ω
LX switch current limit	SS6610G		0.80	1.0	1.25	A
	SS6611G		0.50	0.65	0.85	
LX leakage current	V_{LX}=0V~4V; V_{OUT}=5.5V			0.05	1	μA
Operating current into OUT (Note 3)	V_{FB} = 1.4V , V_{OUT} = 3.3V			20	35	μA
Shutdown current into OUT	$\overline{SHDN}$ = GND			0.1	1	μA
Efficiency	V_{OUT}= 3.3V ,I_{LOAD} = 200mA			90		%
	V_{OUT} = 2V ,I_{LOAD} = 1mA			85		

ELECTRICAL CHARACTERISTICS (Continued)

PARAMETER	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
LX switch on-time	V_{FB} =1V , V_{OUT} = 3.3V	2	4	7	μs
LX switch off-time	V_{FB} =1V , V_{OUT} = 3.3V	0.6	0.9	1.4	μs
FB input current	V_{FB} = 1.4V		0.03	50	nA
LBI input current	V_{LBI} = 1.4V		1	50	nA
$\overline{SHDN}$ input current	$V_{\overline{SHDN}}$ = 0 or V_{OUT}		0.07	50	nA
$\overline{LBO}$ low output voltage	V_{LBI} = 0, I_{SINK} = 1mA		0.2	0.4	μA
$\overline{LBO}$ off leakage current	$V_{\overline{LBO}}$ = 5.5V, V_{LBI} = 5.5V		0.07	1	μA
LBI hystereisis			50		mV
$\overline{SHDN}$ input voltage	V_{IL}			0.2V_{OUT}	V
	V_{IH}	0.8V_{OUT}			

Note 1: Start-up voltage operation is guaranteed without the addition of an external Schottky diode between the input and output.
Note 2: Steady-state output current indicates that the device maintains output voltage regulation under load.
Note 3: Device is bootstrapped (power to the IC comes from OUT). This correlates directly with the actual battery supply.

TYPICAL PERFORMANCE CHARACTERISTICS

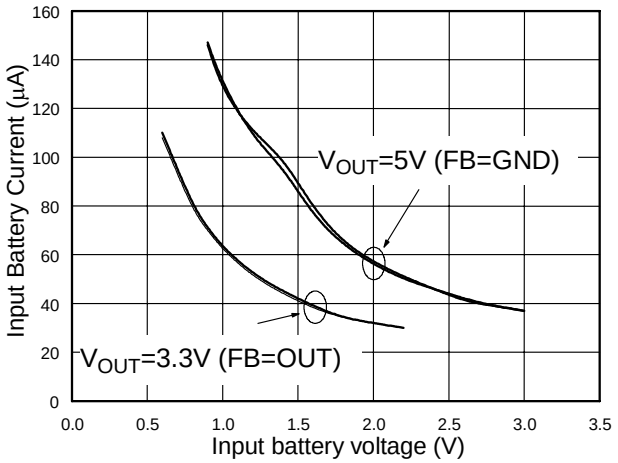


Fig. 1 No-Load Battery Current vs. Input Battery

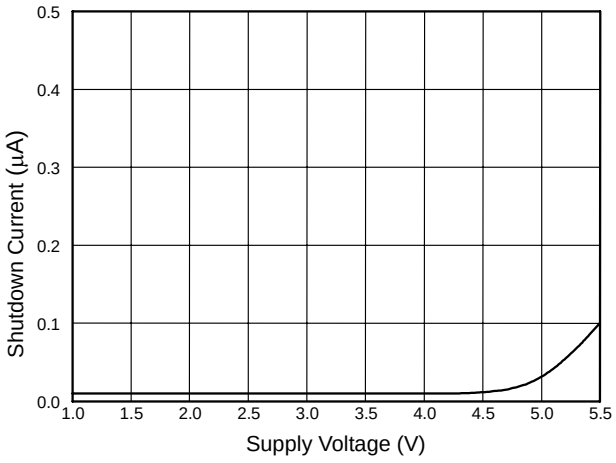


Fig. 2 Shutdown Current vs. Supply Voltage

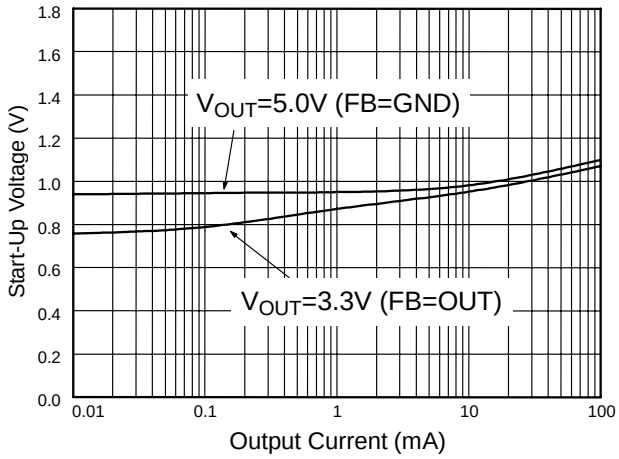


Fig. 3 Start-Up Voltage vs. Output Current

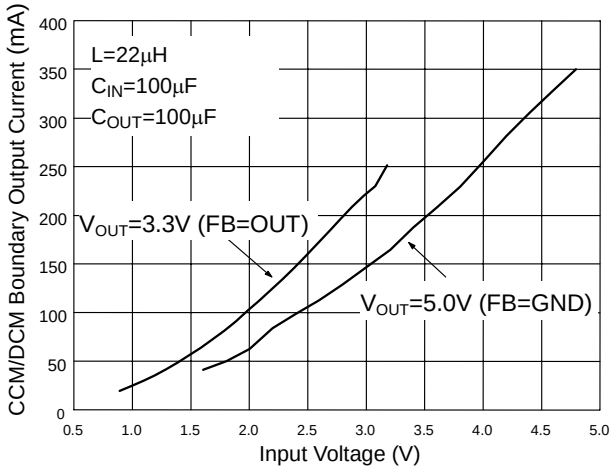


Fig. 4 Turning Point between CCM & DCM

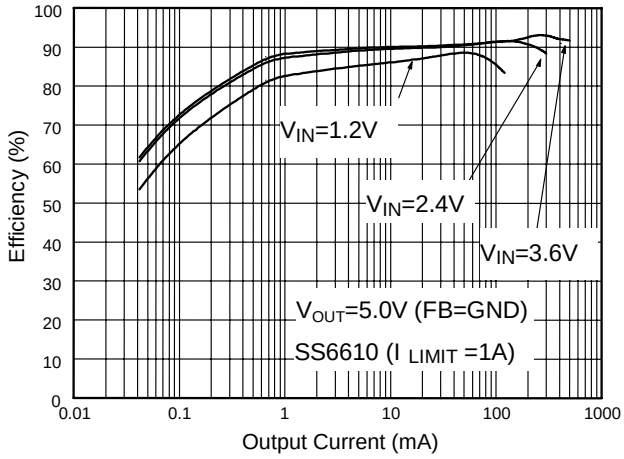


Fig. 5 Efficiency vs. Load Current (ref. to Fig.33)

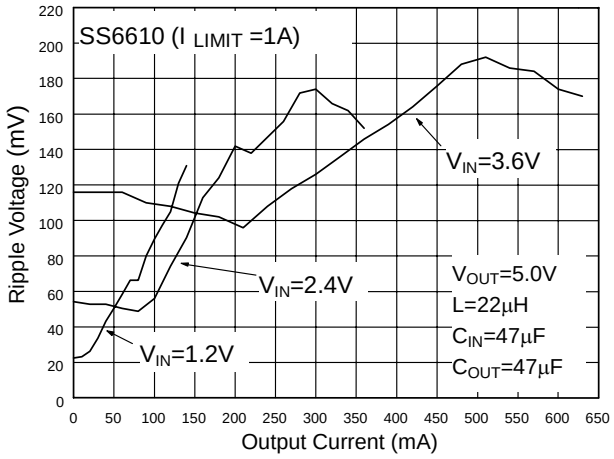


Fig. 6 Ripple Voltage (ref. to Fig.33)

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

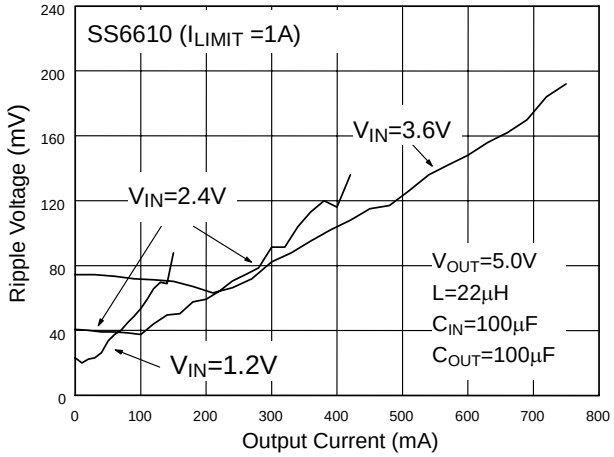


Fig. 7 Ripple Voltage (ref. to Fig.33)

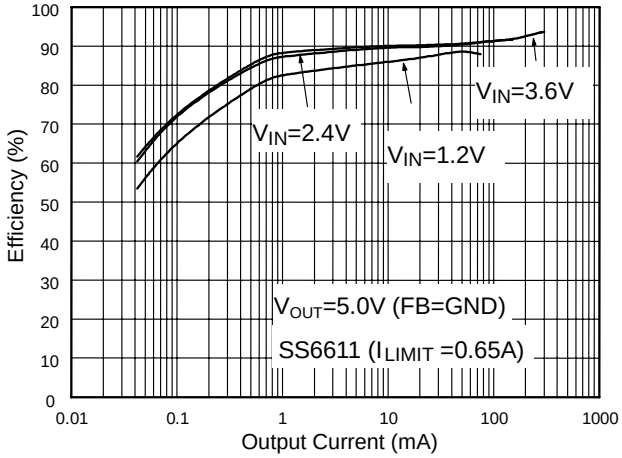


Fig. 8 Efficiency vs. Load Current (ref. to Fig.33)

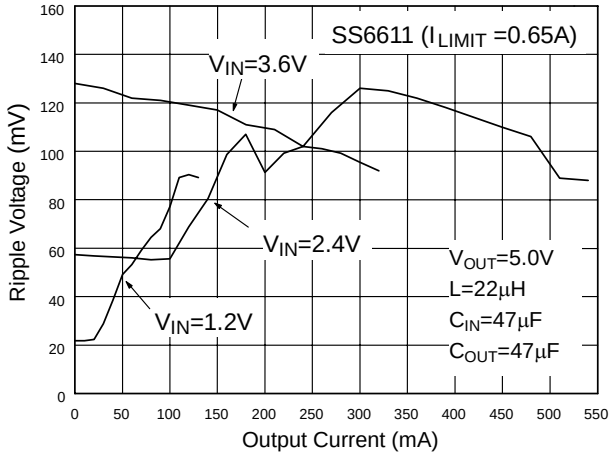


Fig. 9 Ripple Voltage (ref. to Fig.33)

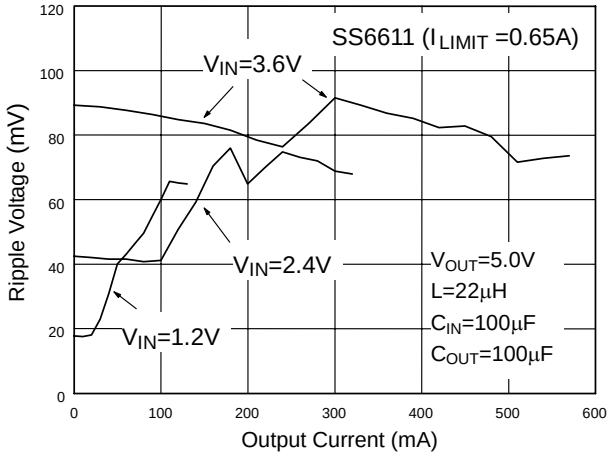


Fig. 10 Ripple Voltage (ref. to Fig.33)

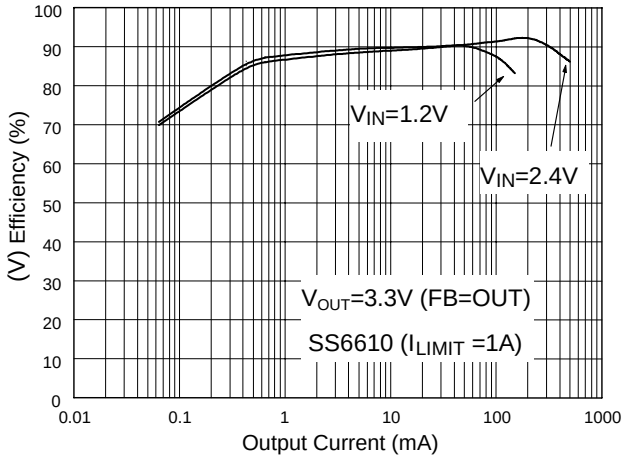


Fig. 11 Efficiency vs. Load Current (ref. to Fig.32)

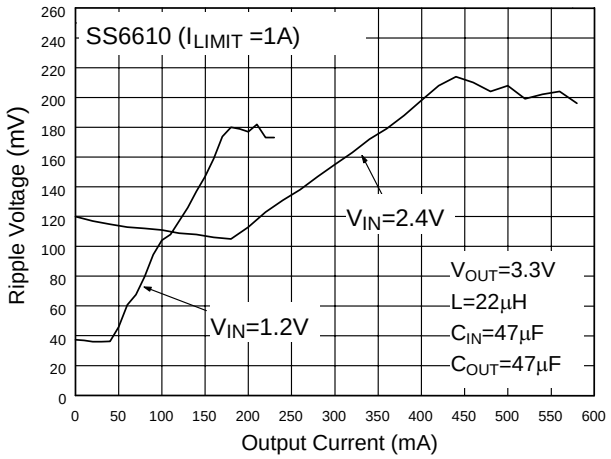


Fig. 12 Ripple Voltage (ref. to Fig.32)

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

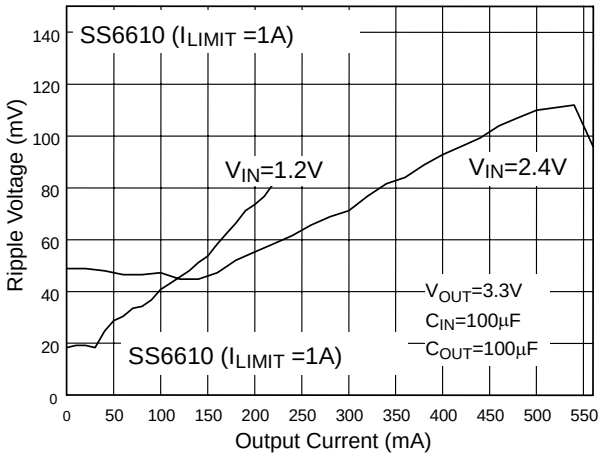


Fig. 13 Ripple Voltage (ref. to Fig.32)

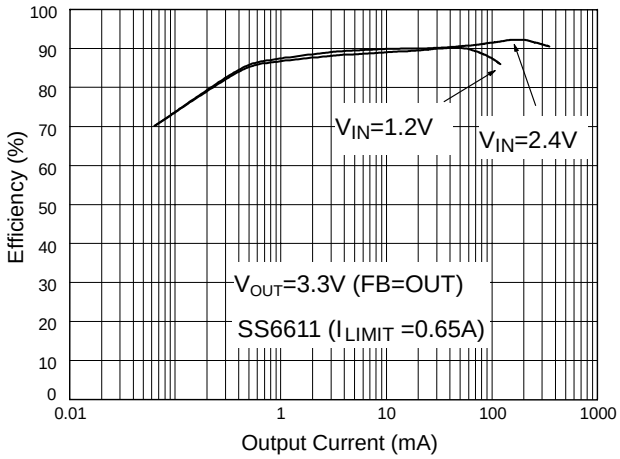


Fig. 14 Efficiency vs. Load Current (ref. to Fig.32)

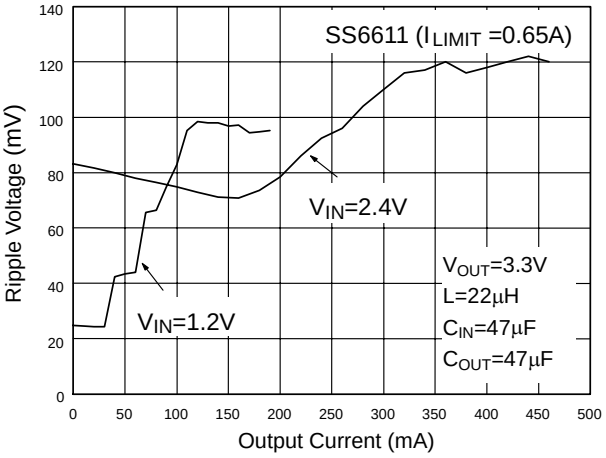


Fig. 15 Ripple Voltage (ref. to Fig.32)

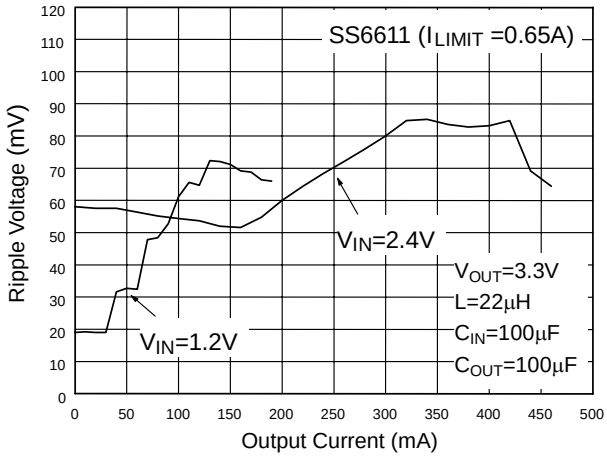


Fig. 16 Ripple Voltage (ref. to Fig.32)

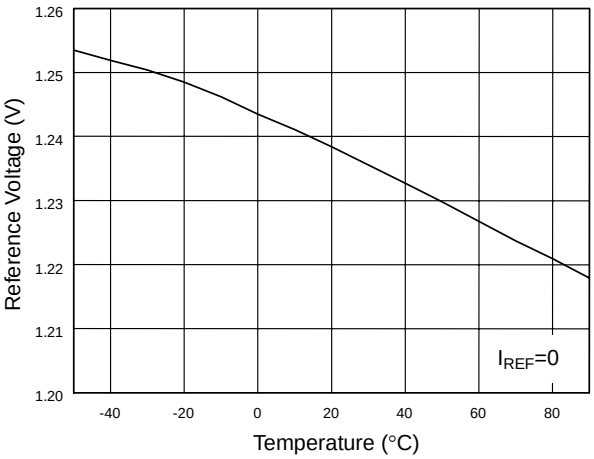


Fig. 17 Reference Voltage vs. Temperature

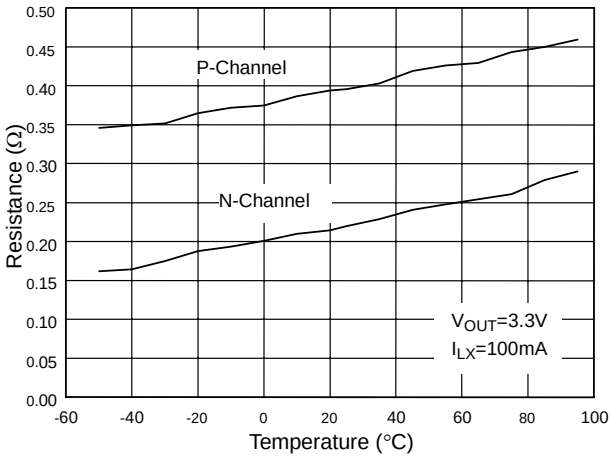


Fig. 18 Switch Resistance vs. Temperature

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

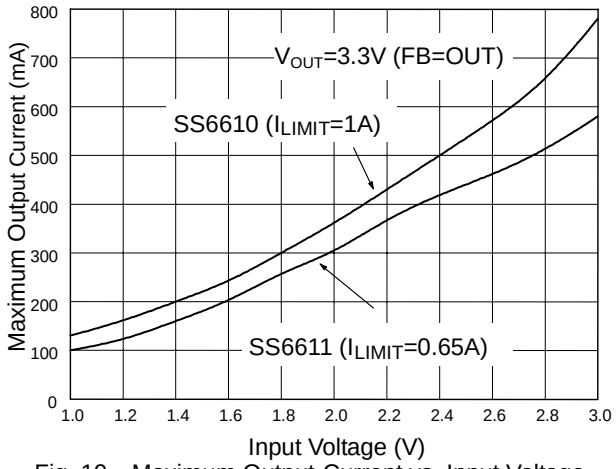


Fig. 19 Maximum Output Current vs. Input Voltage

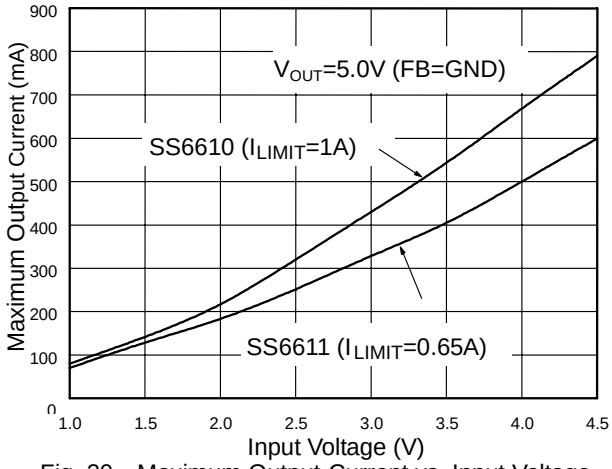


Fig. 20 Maximum Output Current vs. Input Voltage

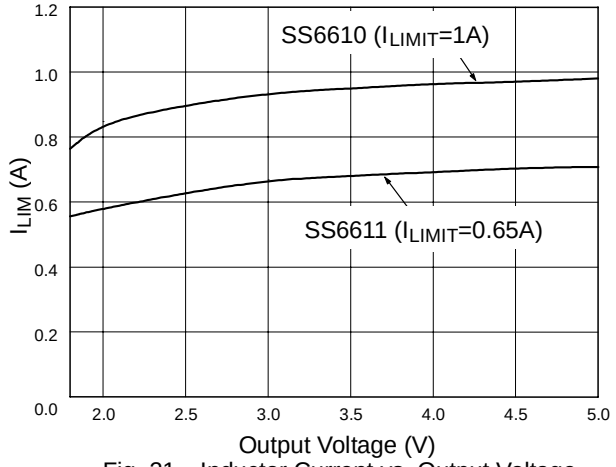


Fig. 21 Inductor Current vs. Output Voltage

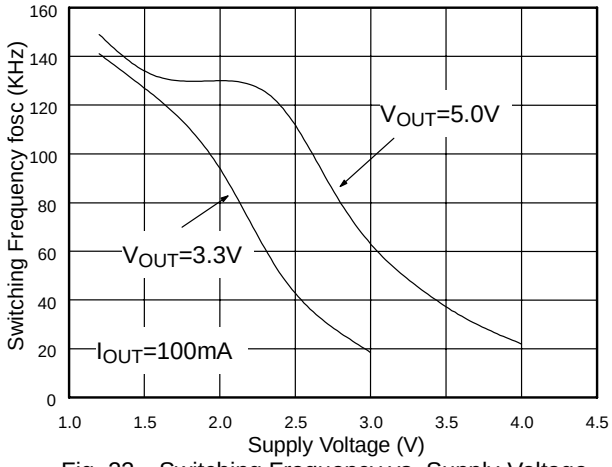


Fig. 22 Switching Frequency vs. Supply Voltage

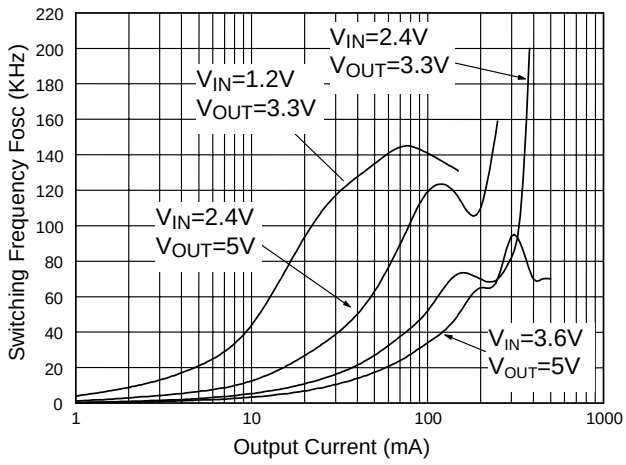


Fig. 23 Switching Frequency vs. Output Current

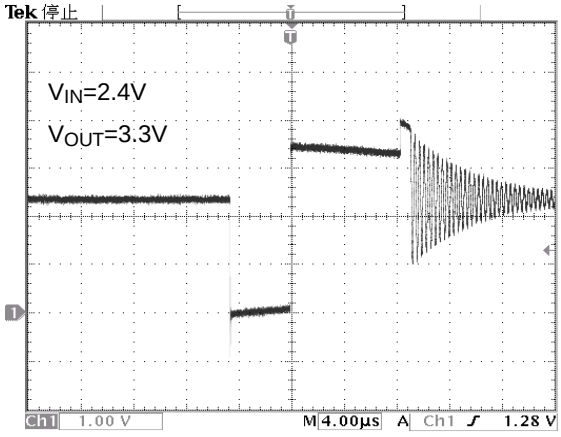


Fig. 24 LX Switching Waveform

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

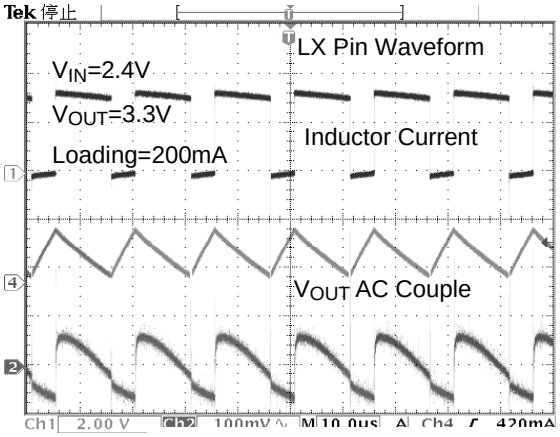


Fig. 25 Heavy Load Waveform

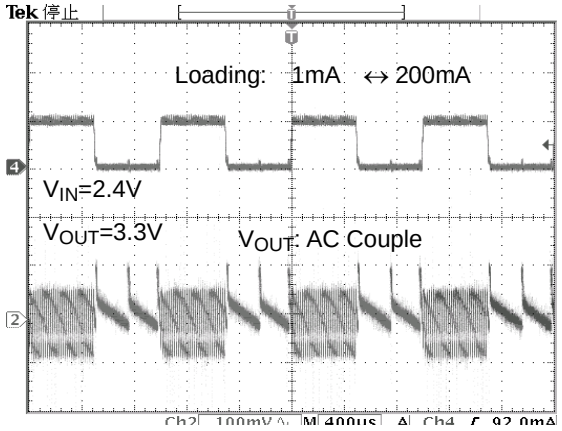


Fig. 26 Load Transient Response

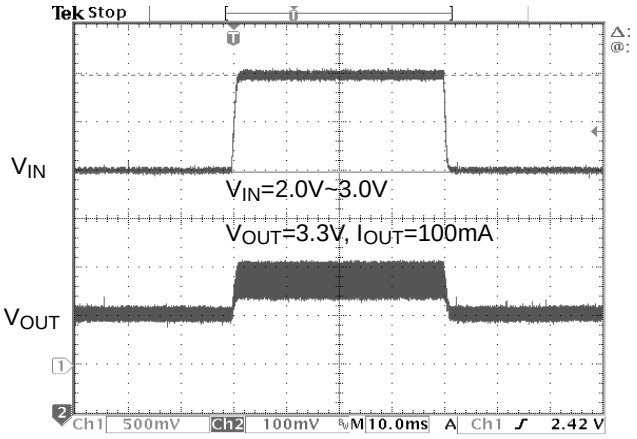


Fig. 27 Line Transient Response

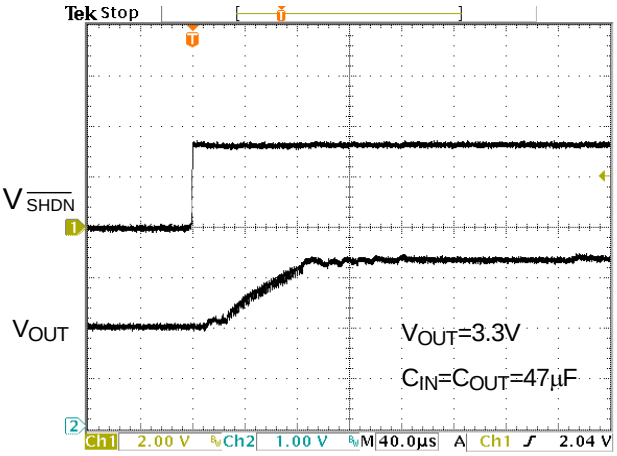


Fig. 28 Exiting Shutdown

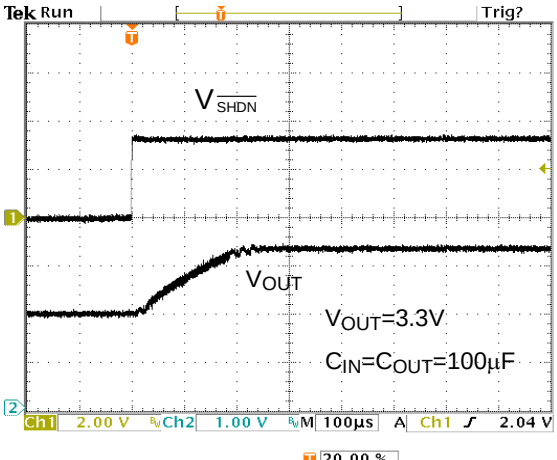


Fig. 29 Exiting Shutdown

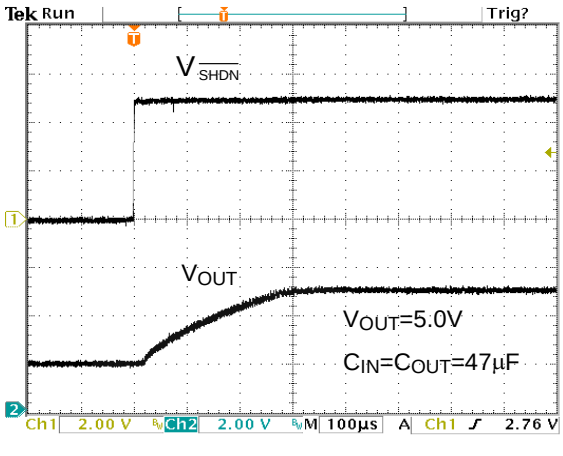


Fig. 30 Exiting Shutdown

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

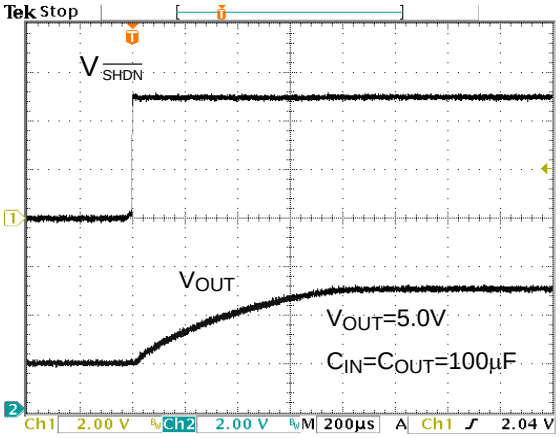
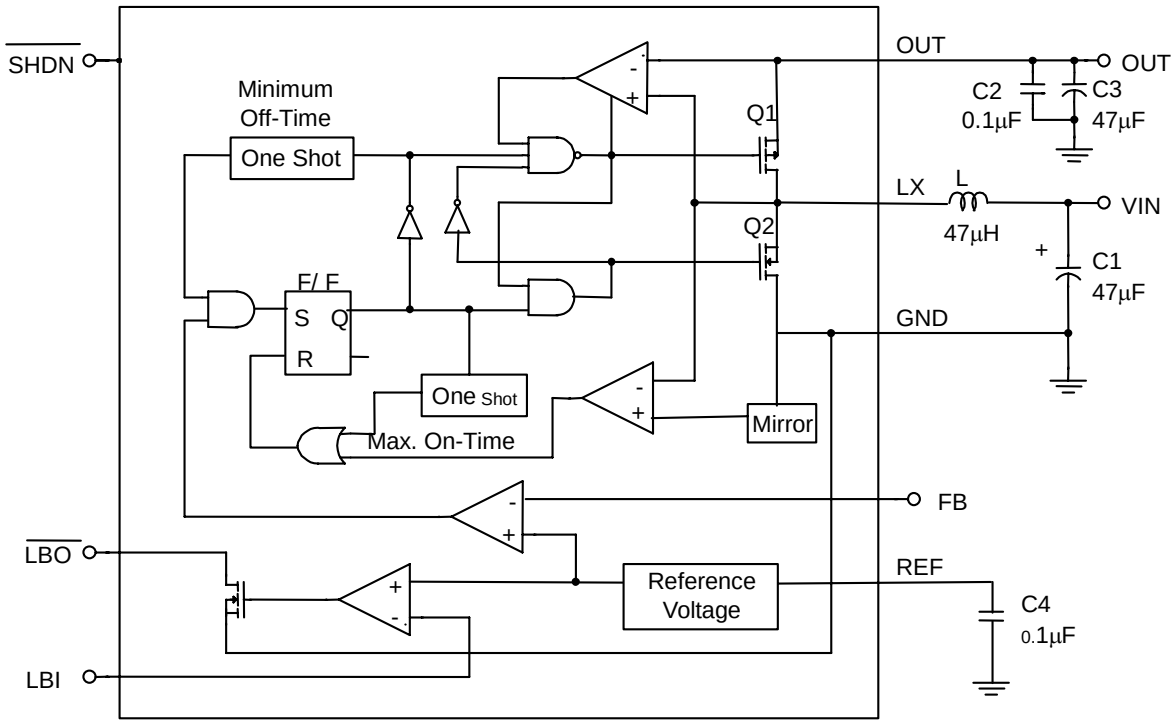


Fig. 31 Exiting Shutdown

BLOCK DIAGRAM



PIN DESCRIPTIONS

PIN 1: FB Connect to pin 8:OUT to get +3.3V output, connect to pin 6:GND to get +5.0V output, or use a resistor network to set the output voltage between +1.8V and +5.5V.

PIN 2: LBI Low-battery comparator input. Internally set at +1.23V to trip.

PIN 3: $\overline{\text{LBO}}$ Open-drain low-battery comparator output. Output is low when V_{LBI} is <1.23V. $\overline{\text{LBO}}$ is high-impedance during shutdown.

PIN 4: REF 1.23V reference voltage. Bypass with a 0.1μF capacitor.

PIN 5: $\overline{\text{SHDN}}$ Shutdown input. High = operating, low = shutdown.

PIN 6: GND Ground

PIN 7: LX N-channel and P-channel power MOSFET drain.

PIN 8: OUT Power output. OUT provides the bootstrap power to the IC.

APPLICATION INFORMATION

Overview

The SS6610/11 series are high-efficiency, step-up DC/DC converters, featuring a built-in synchronous rectifier, which reduces size and cost by eliminating the need for an external Schottky diode. The start-up voltage of the SS6610 and SS6611 is as low as 0.8V and they operate with an input voltage down to 0.7V. Quiescent supply current is only 20μA.

The internal P-MOSFET on-resistance is typically 0.3Ω to improve overall efficiency by minimizing AC losses. The output voltage can be easily set using two external resistors for 1.8V to 5.5V; connecting FB to OUT to get 3.3V; or connecting to GND to get 5.0V. The peak current of the internal switch is fixed at 1.0A (SS6610) or 0.65A (SS6611) for design flexibility. The current limits of the SS6610 and SS6611 are 1.0A and 0.65A respectively. The lower current limit allows the use of a physically smaller inductor in space-sensitive applications.

PFM Control Scheme

A key feature of the SS6610 series is a unique minimum-off-time, constant-on-time, current-limited, pulse-frequency-modulation (PFM) control scheme (see BLOCK DIAGRAM) with ultra-low quiescent current. The peak current of the internal N-MOSFET power switch can be fixed at 1.0A (SS6610) or 0.65A (SS6611). The switch frequency depends on either loading conditions or input voltage, and can range up to 500KHz. It is governed by a pair of one-shots that set a minimum off-time (1μs) and a maximum on-time (4μs).

Synchronous Rectification

Using the internal synchronous rectifier eliminates the need for an external Schottky diode, reducing the cost and board space. During the cycle of off-time, the P-MOSFET turns on and shuts the N-MOSFET off. Due to the low turn-on resistance of the MOSFET, the synchronous rectifier significantly improves efficiency without an additional external Schottky diode. Thus, the conversion efficiency can be as high as 93%.

Reference Voltage

The reference voltage (REF) is nominally 1.23V for excellent T.C. performance. In addition, the REF pin can source up to 100μA to an external circuit with good load regulation (<10mV). A bypass capacitor of 0.1μF is required for proper operation and good performance.

Shutdown

The whole circuit is shutdown when $V_{\overline{SHDN}}$ is low. In shutdown mode, the current can flow from the battery to the output due to the body diode of the P-MOSFET. V_{OUT}falls to approximately (Vin - 0.6V) and LX remains high impedance. The capacitance and load at OUT determine the rate at which V_{OUT} decays. Shutdown can be pulled as high as 6V. Regardless of the voltage at OUT.

Selecting the Output Voltage

V_{OUT} can be simply set to 3.3V/5.0V by connecting the FB pin to OUT/GND due to the use of an internal resistor divider in the IC (Fig.32 and Fig.33). In order to adjust output voltage, a resistor divider is connected to V_{OUT}, FB, GND (Fig.34). Vout can be calculated by the following equation:

$R5=R6\ [(V_{OUT} / V_{REF})-1]$ .....(1)

where V_{REF} =1.23V and V_{OUT} ranges from 1.8V to 5.5V. The recommended R6 is 240kΩ.

Low-Battery Detection

The SS6610 series contains an on-chip comparator with 50mV internal hysteresis (REF, REF+50mV) for low battery detection. If the voltage at LBI falls below the internal reference voltage, LBO (an open-drain output) sinks current to GND.

Component Selection

1. **Inductor Selection**

   An inductor value of 22μH performs well in most applications. The SS6610 series also work with inductors in the 10μH to 47μH range. An inductor with higher peak inductor current creates a higher output voltage ripple (I_{PEAK} x output filter capacitor ESR). The inductor's DC resistance significantly affects efficiency. We can calculate the maximum output current as follows:

$$I_{OUT(MAX)} = \frac{V_{IN}}{V_{OUT}}\left[I_{LIM} - t_{OFF}\left(\frac{V_{OUT} - V_{IN}}{2 \times L}\right)\right]\eta$$

.....(2)

where $I_{OUT(MAX)}$=maximum output current in amps

V_{IN}=input voltage

L=inductor value in μH

η =efficiency (typically 0.9)

t_{OFF}=LX switch' off-time in μs

I_{LIM}=1.0A or 0.65A

2. **Capacitor Selection**

   The output ripple voltage is related to the peak inductor current and the output capacitor ESR. Besides output ripple voltage, the output ripple current may also be of concern. A filter capacitor with low ESR is helpful to the efficiency and the steady state output current of the SS6610 series. Therefore a NIPPON MCM Series tantalum capacitor of 100μF/6V is recommended. A smaller capacitor (down to 47 μF with higher ESR) is acceptable for light loads or in applications that can tolerate higher output ripple.

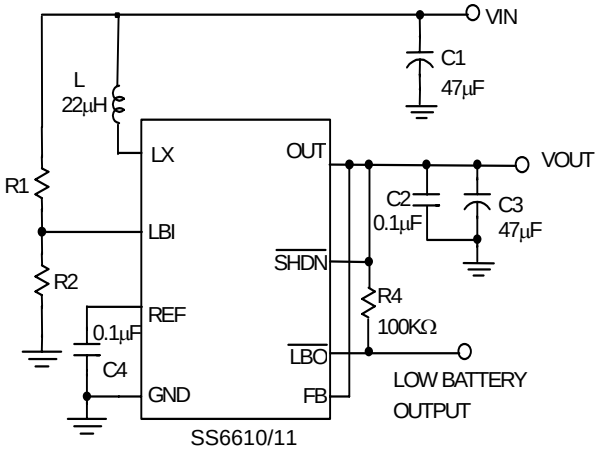
3. **PCB Layout and Grounding**

   Since the SS6610/11's switching frequency can range up to 500kHz, the SS6610/11 can be very sensitive. Careful printed circuit layout is important for minimizing ground bounce and noise. The OUT pin should be as clear as possible, and the GND pin should be placed close to the ground plane. Keep the IC's GND pin and the ground leads of the input and output filter capacitors less than 0.2in (5mm) apart. In addition, keep all connections to the FB and LX pins as short as possible. In particular, when using external feedback resistors, locate them as close to the FB pin as possible. To maximize output power and efficiency, and minimize output ripple voltage, use a ground plane and solder the IC's GND directly to the ground plane. Fig. 35 to 37 are the recommended layout diagrams.

Ripple Voltage Reduction

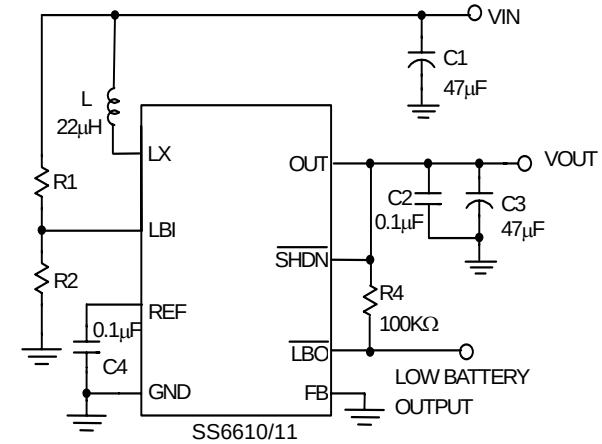
Two or three parallel output capacitors can significantly improve the output ripple voltage of the SS6610/11. The addition of an extra input capacitor results in a stable output voltage. Fig.38 shows the application circuit with the above features. Figures 39 to 46 show the performance of the circuit in Figure 38.

APPLICATION EXAMPLES



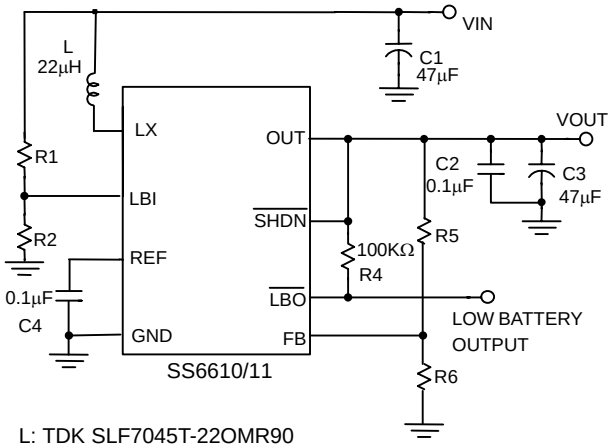
L: TDK SLF7045T-22OMR90
C1, C3: NIPPON Tantalum Capacitor 6MCM476MB2TER

Fig. 32. V_{OUT} = 3.3V Application Circuit.



L: TDK SLF7045T-22OMR90
C1, C3: NIPPON Tantalum Capacitor 6MCM476MB2TER

Fig. 33. V_{OUT} = 5.0V Application Circuit.



L: TDK SLF7045T-22OMR90
C1, C3: NIPPON Tantalum Capacitor 6MCM476MB2TER
$V_{OUT}=V_{REF}*(1+R5/R6)$

Fig. 34 An Adjustable Output Application Circuit

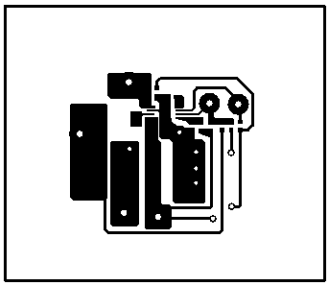


Fig. 35. Top layer

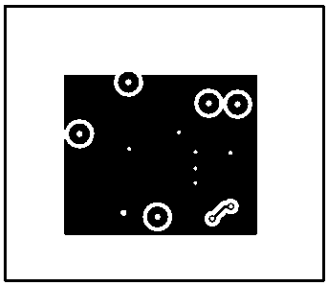


Fig. 36. Bottom layer

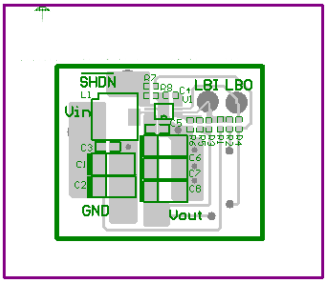
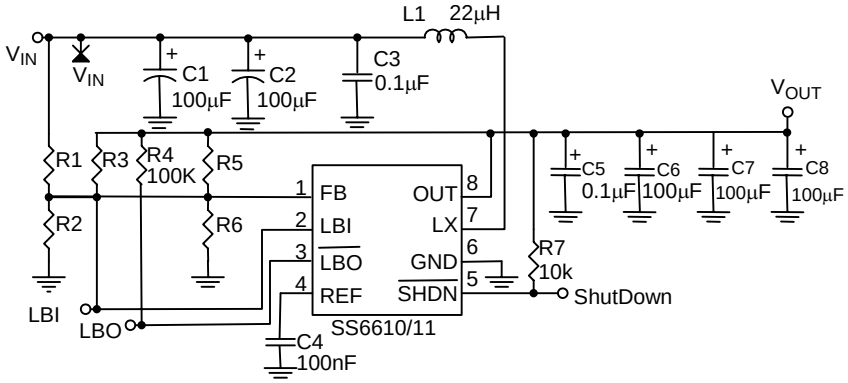


Fig. 37. Placement



R5=0Ω, R6=open; for V_{OUT}=3.3V
R5=open, R6=0Ω; for V_{OUT}=5.0V
V_{OUT}=1.23(1+R5/R6); for adjustable output voltage

L1: TDK SLF7045T-22OMR90

C1~C2, C6~8: NIPPON Tantalum Capacitor 6MCM107MCTER

Fig. 38 SS6610/11 application circuit with small ripple voltage.

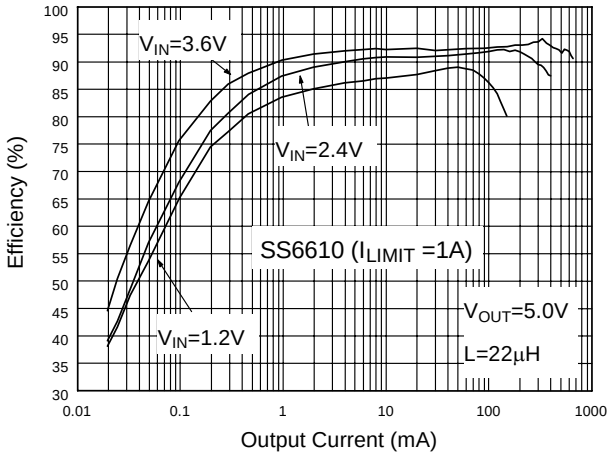


Fig. 39 Efficiency (ref. to Fig.38)

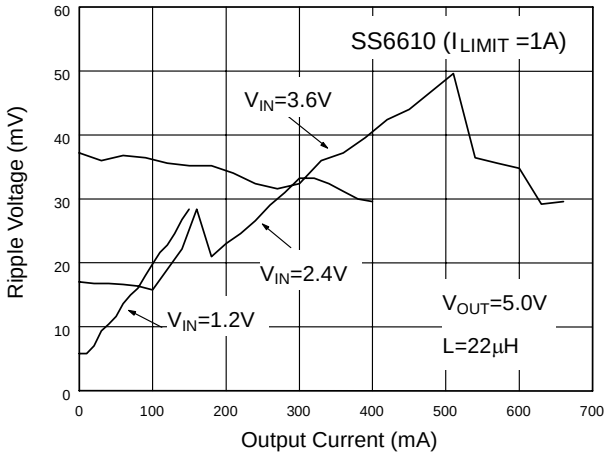


Fig. 40 Ripple Voltage (ref. to Fig.38)

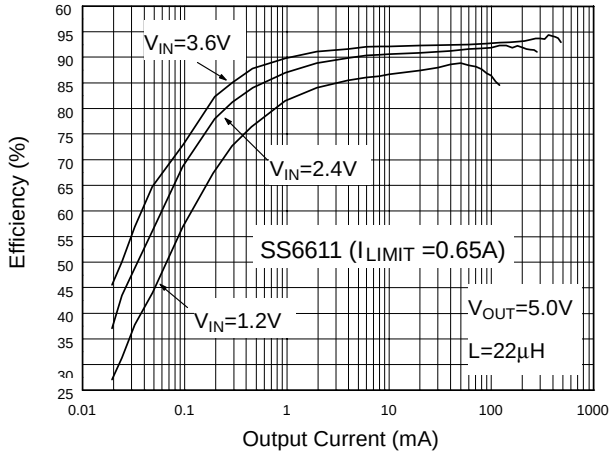


Fig. 41 Efficiency (ref. to Fig.38)

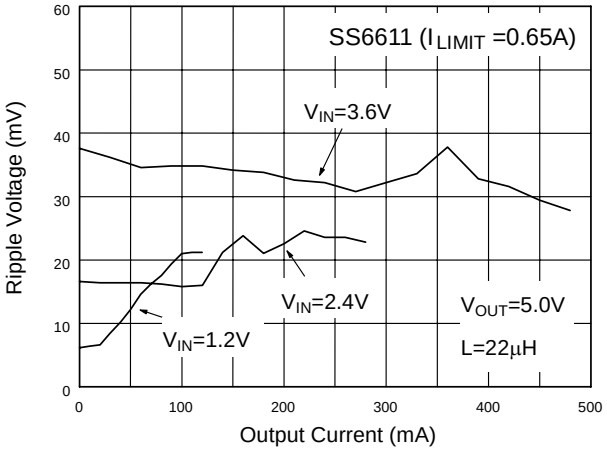


Fig. 42 Ripple Voltage (ref. to Fig.38)

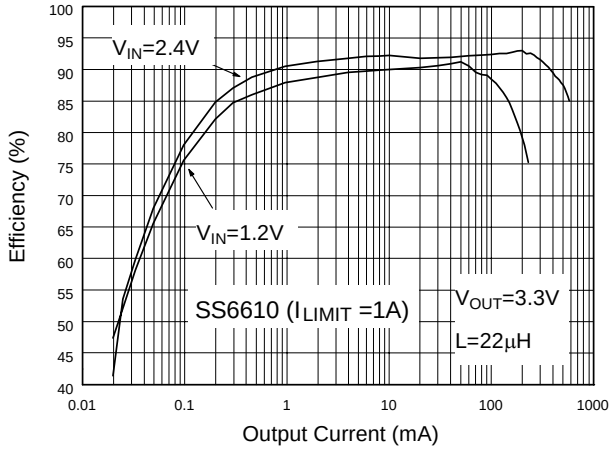


Fig. 43 Efficiency (ref. to Fig.38)

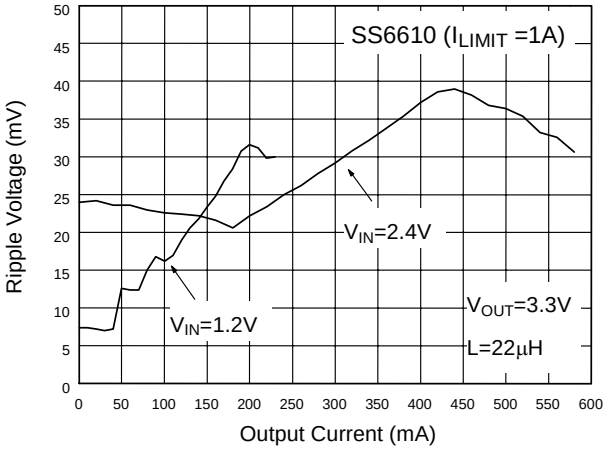


Fig. 44 Ripple Voltage (ref. to Fig.38)

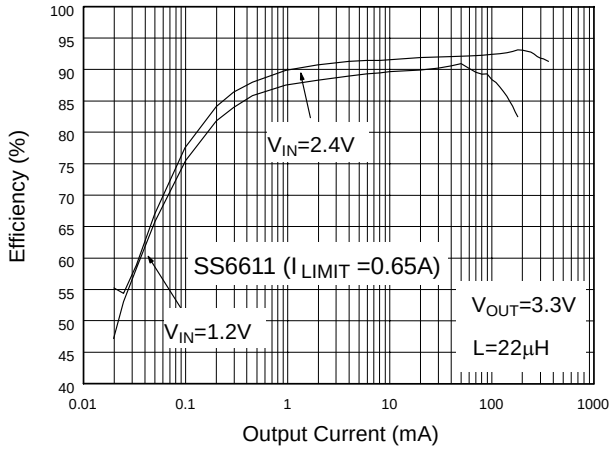


Fig. 45 Efficiency (ref. to Fig.38)

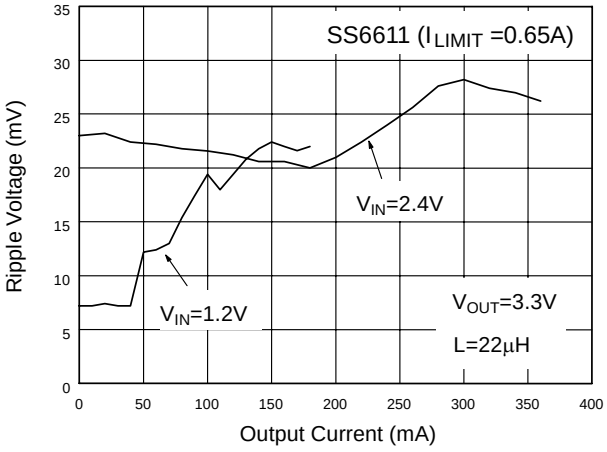
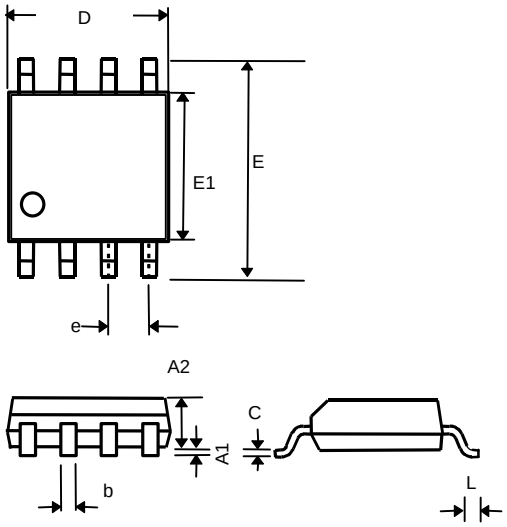


Fig. 46 Ripple Voltage (ref. to Fig.38)

PHYSICAL DIMENSIONS

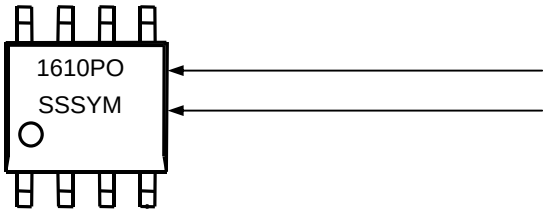
8 LEAD MSOP



SYMBOL	MIN	MAX
A1	--	0.20
A2	0.76	0.97
b	0.28	0.38
C	0.13	0.23
D	2.90	3.10
E	4.80	5.00
E1	2.90	3.10
e	0.65	
L	0.40	0.66

All dimensions in millimeters.
Dimensions do not include mold protrusions.

PART MARKING



SS6610G = 1610PO, SS6611G = 1611PO

Date/lot code:

SSS = lot code sequence

Y = year (C=2005, I=2006, D=2007...)

M = month (1-9,A,B,C)

PACKING:

Moisture sensitivity level MSL3

3000 pcs in antistatic tape on a 13 inch (330mm) reel packed in a moisture barrier bag (MBB).

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