1-Cell, 3-Pin, Step-Up DC/DC Controller

■ FEATURES

- Guaranteed start-up from less than 0.9 V.
- High efficiency.
- Low quiescent current.
- Fewer external components needed.
- Low ripple and low noise.
- Fixed output voltage: 2.7, 3.0V, 3.3V, and 5V.
- Driver for external transistor.
- Space-saving package: SOT-89 and TO-92.

■ APPLICATIONS

- Pagers.
- Cameras.
- Wireless Microphones.
- Pocket Organizers.
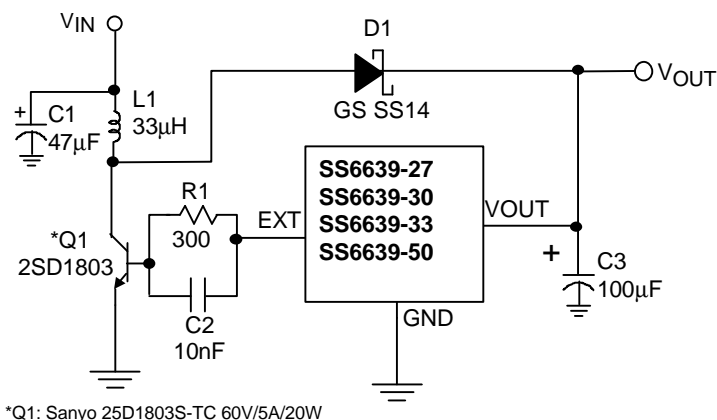- Battery Backup Suppliers.
- Portable Instruments.

■ GENERAL DESCRIPTION

The SS6639 is a high efficiency step-up DC/DC controller for applications using 1 to 4 battery cells. Only three external components are required to deliver a fixed output voltage of 2.7, 3.0V, 3.3V, or 5V. The SS6639 starts up from less than 0.9V input with a 1mA load. The Pulse Frequency Modulation scheme offers optimized performance for applications with light output loading and low input voltages. The output ripple and noise are lower than with circuits operating in PSM mode.

The PFM control circuit operating up to 100 KHz switching rate results in smaller passive components. The space-saving SOT-89 and TO-92 packages make the SS6639 an ideal choice of DC/DC controller for space-conscious applications, such as pagers, electronic cameras, and wireless microphones.
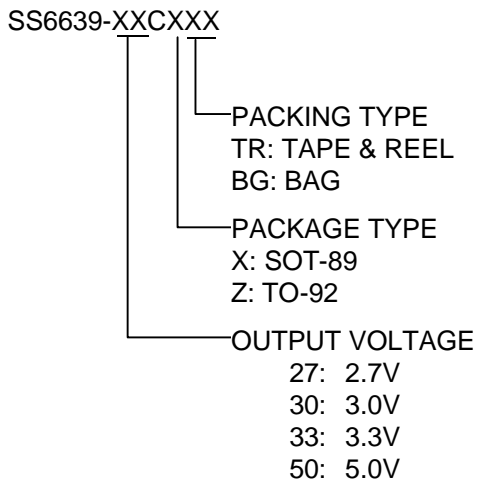
Using an external transistor driver pin (EXT), the SS6639 is recommended for applications requiring currents from several tens to several hundreds of milliamperes.
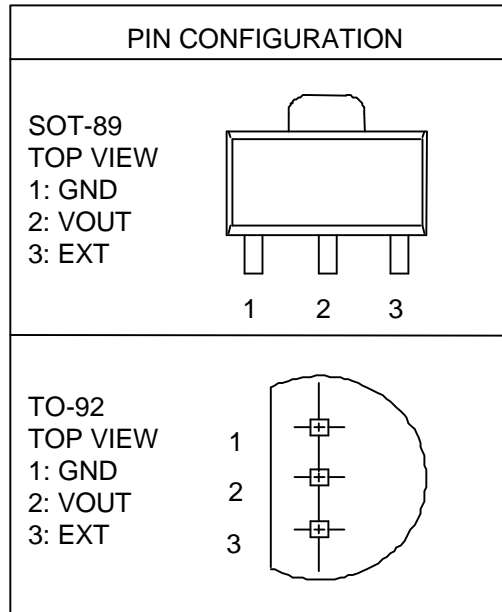
■ TYPICAL APPLICATION CIRCUIT

**100mA Load Current Step-Up Converter**

■ ORDERING INFORMATION

SS6639-XXCXXX

PACKING TYPE
TR: TAPE & REEL
BG: BAG

PACKAGE TYPE
X: SOT-89
Z: TO-92

OUTPUT VOLTAGE
27: 2.7V
30: 3.0V
33: 3.3V
50: 5.0V

EX: SS6639-27CXTR

→ 2.7V Version, in SOT-89 Package in

Tape and Reel Packing

PIN CONFIGURATION

SOT-89
TOP VIEW
1: GND
2: VOUT
3: EXT

1   2   3

TO-92
TOP VIEW
1: GND
2: VOUT
3: EXT

1
2
3

■ ABSOLUTE MAXIMUM RATINGS

Supply Voltage (VOUT Pin) ……………….……………………………………………………12V

EXT pin Voltage ……………………………………………….………-0.3V to Vout+0.3V

EXT pin Current ……………………………………………………..…………………….± 50mA

Operating Temperature Range ……………………………..……………..-40°C to 85°C

Storage Temperature Range ……………………………….…..………… -65°C to 150 °C

Lead Temperature (Soldering 10 Sec.) ……………….…….……………………260°C

■ TEST CIRCUIT

SS6639

2.5V O—— VOUT   EXT —O F$_{OUT}$

GND
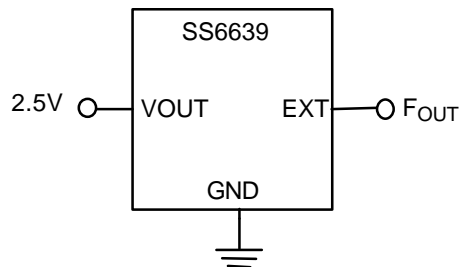
Oscillator Test Circuit

■ ELECTRICAL CHARACTERISTICS

(T_A=25°C, I_O=10mA, unless otherwise specified)

PARAMETER	TEST CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
Output Voltage	SS6639-27 V_{IN}=1.8V SS6639-30 V_{IN}=1.8V SS6639-33 V_{IN}=2.0V SS6639-50 V_{IN}=3.0V	V_{OUT}	2.633 2.925 3.218 4.875	2.700 3.000 3.300 5.000	2.767 3.075 3.382 5.125	V
Input Voltage		V_{IN}			8	V
Start-Up Voltage	I_{OUT}=1mA, V_{IN}:0→2V	V_{START}		0.8	0.9	V
Hold-on Voltage	I_{OUT}=1mA, V_{IN}:2→0V	V_{HOLD}	0.6			V
No-Load Input Current	I_{OUT}=0mA	I_{IN}		18		μA
Supply Current 1	SS6639-27 SS6639-30 SS6639-33 SS6639-50 EXT at no load, V_{IN}=V_{OUT} x 0.95 Measurement of the IC input current (VOUT Pin)	I_{DD1}		45 50 60 80		μA
Supply Current 2	SS6639-27 SS6639-30 SS6639-33 SS6639-50 EXT at no load, V_{IN}=V_{OUT} + 0.95 Measurement of the IC input current (VOUT Pin)	I_{DD2}		7 7 7 7		μA
EXT "H" On-Resistance	SS6639-27 SS6639-30 SS6639-33 SS6639-50 V_{EXT}=V_{OUT} − 0.4V	R_{EXTH}		300 200 185 130		Ω
EXT "L" On-Resistance	SS6639-27 SS6639-30 SS6639-33 SS6639-50 V_{EXT}= 0.4V	R_{EXTL}		110 80 70 60		Ω

■ ELECTRICAL CHARACTERISTICS (Continued)

PARAMETER	TEST CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
Oscillator Duty Cycle	$V_{IN}=V_{OUT}$ x 0.95 Measurement of the EXT Pin Waveform	DUTY	65	75	85	%
Max. Oscillator Freq.	$V_{IN}=V_{OUT}$ x 0.95 Measurement of the EXT Pin Waveform	F_{OSC}	80	105	130	KHz
Efficiency		η		80		%

■ TYPICAL PERFORMANCE CHARACTERISTICS

Inductor (L1): 33µH (Pin Type)   Capacitor (C1): 47µF (Tantalum Type)

Diode   (D1): 1N5819 Schottky Type   Transistor (Q1): 2SD1803
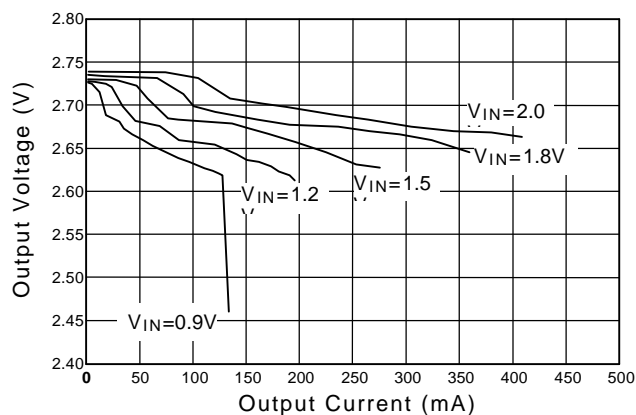
Fig. 1 SS6639-27 Load Regulation (L=33 H)
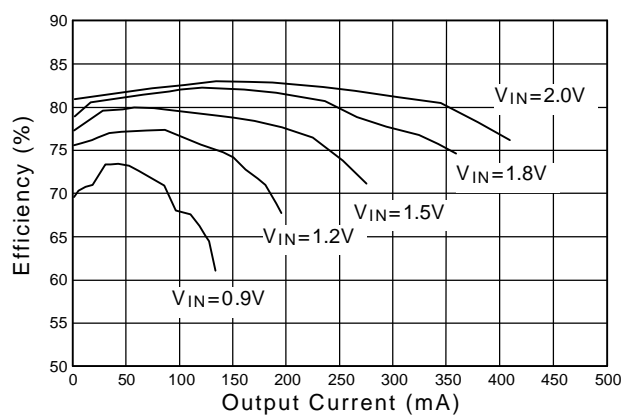
Fig. 2 SS6639-27 Efficiency (L=33uH)
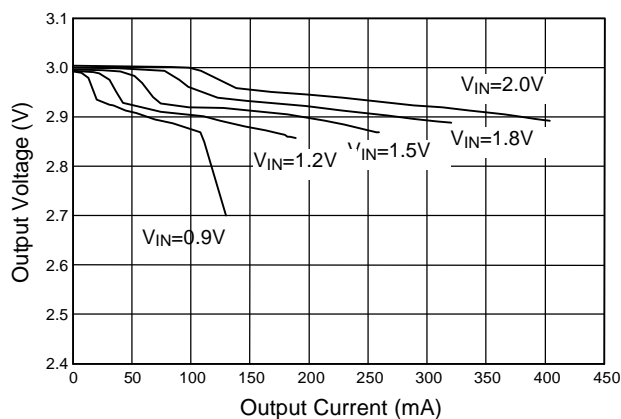
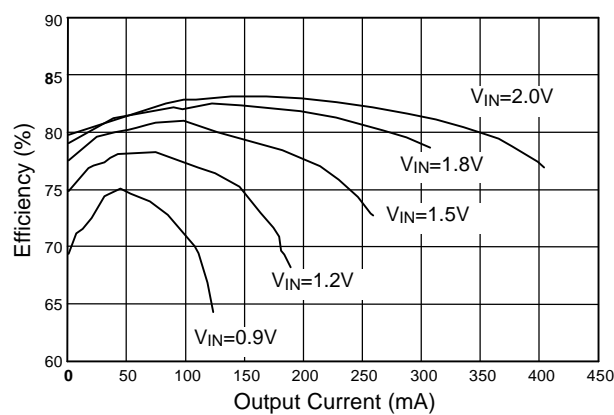Fig. 3 SS6639-30 Load Regulation (L=33 H)

Fig. 4 SS6639-30 Efficiency (L=33 H)
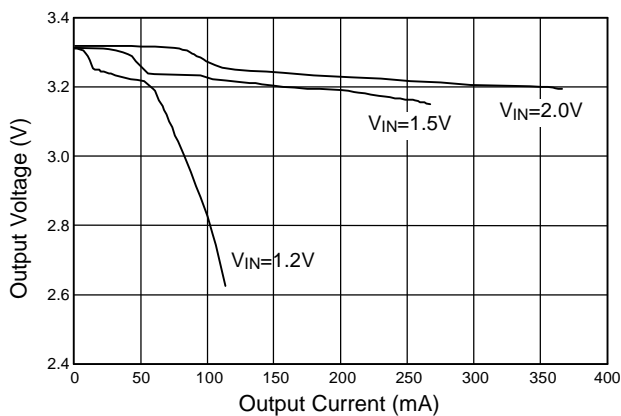
■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

Fig. 5 SS6639-33 Loading Regulation (L=33 H)
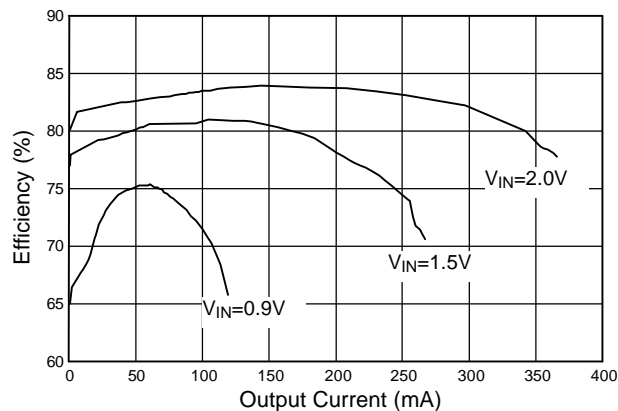
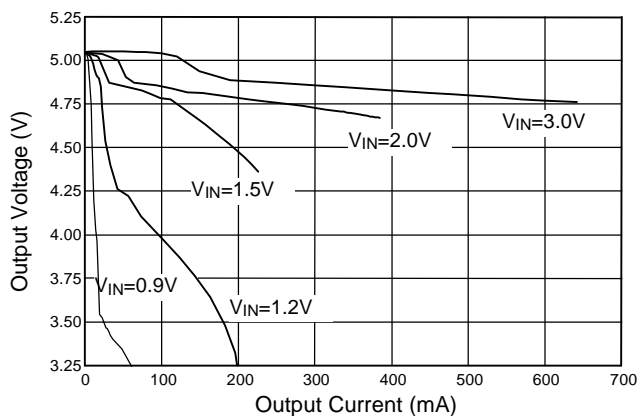Fig. 6 SS6639-33 Efficiency (L=33 H)
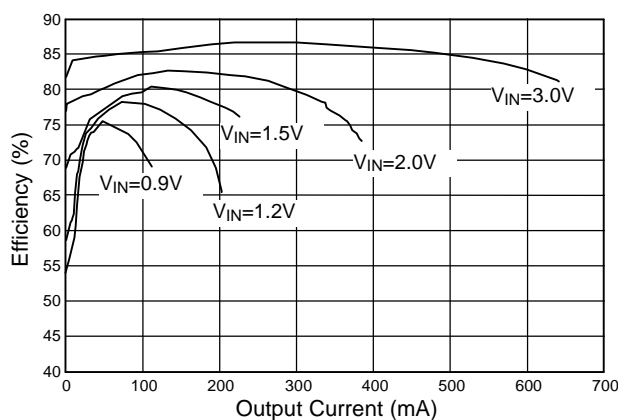
Fig. 7 SS6639-50 Load Regulation (L=33µH)
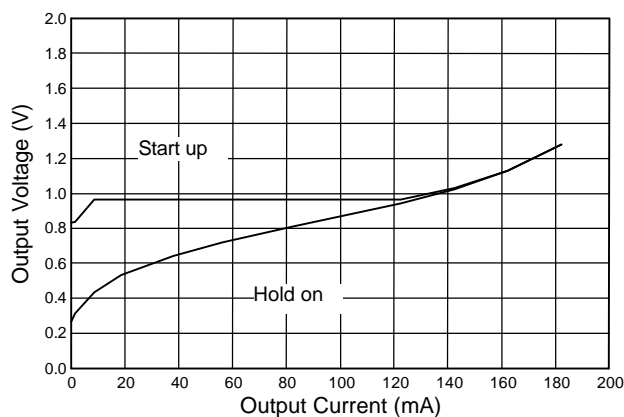
Fig. 8 SS6639-50 Efficiency (L=33 H)

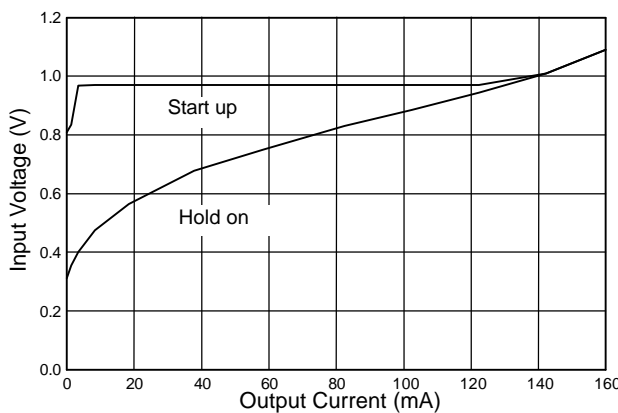Fig. 9 SS6639-27 Start-up & Hold-on Voltage (L=33µH)

Fig. 10 SS6639-30 Start-up & Hold-on Voltage (L=33 H)

■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)
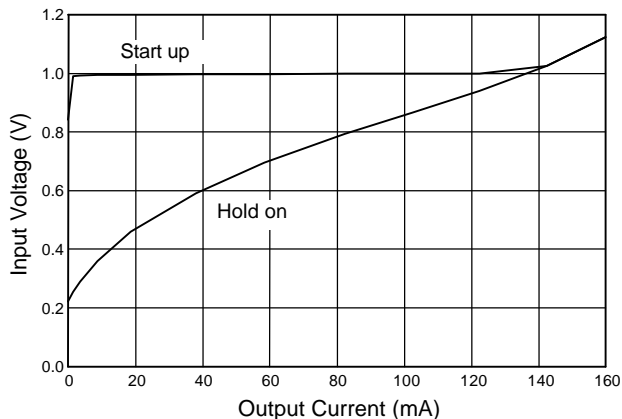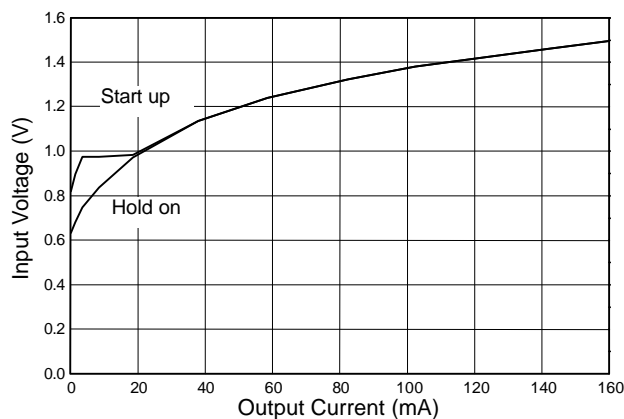
Fig. 11 SS6639-33 Start-up & Hold-on Voltage (L=33µH)
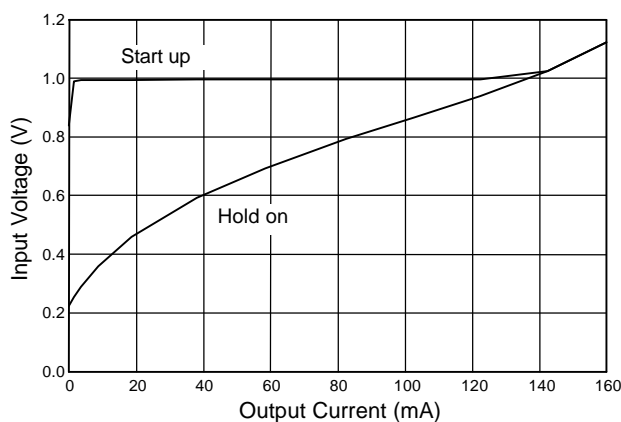
Fig. 12 SS6639-50 Start-up & Hold-on Voltage (L=33uH)

Fig. 13 SS6639-33 Start-up & Hold-on Voltage (L=33µH)

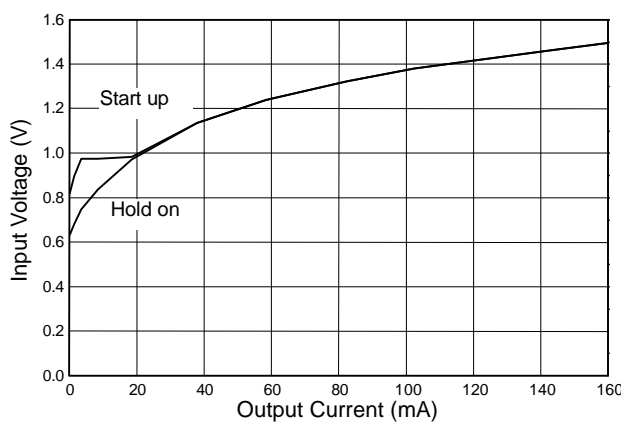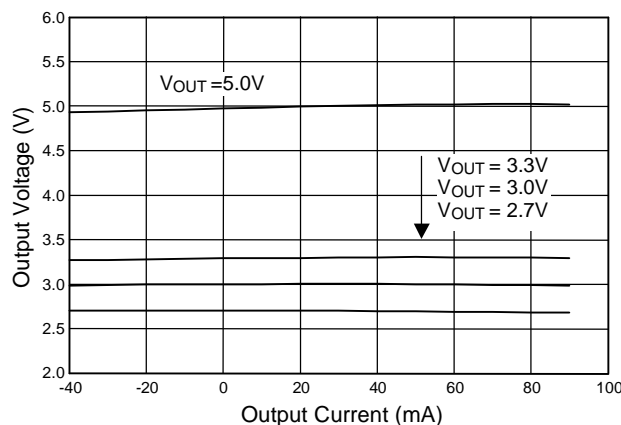Fig. 14 S6639-50 Start-up & Hold-on Voltage (L=33uH)

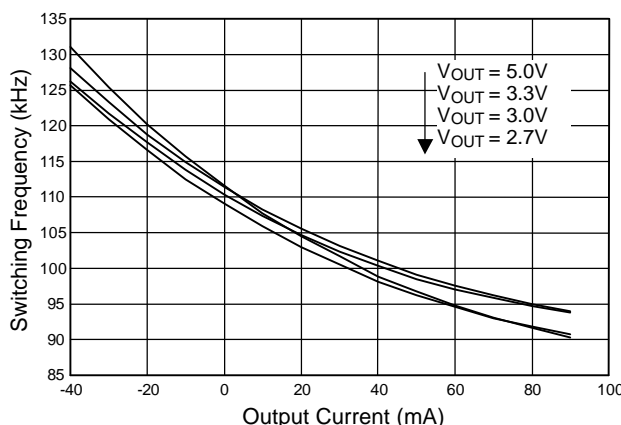Fig. 15 SS6639 Output Voltage vs. Temperature

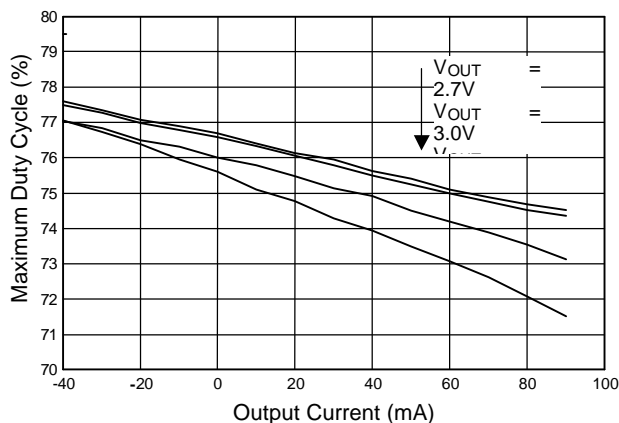Fig. 16 SS6639 Switching Frequency vs.Temperature

■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

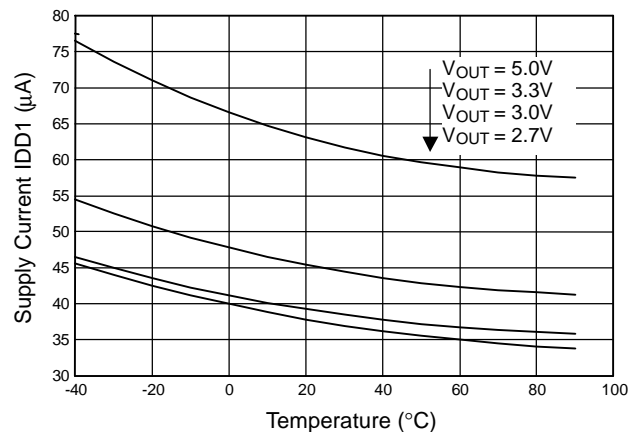Fig. 17 SS6639 Maximum Duty Cycle vs. Temperature
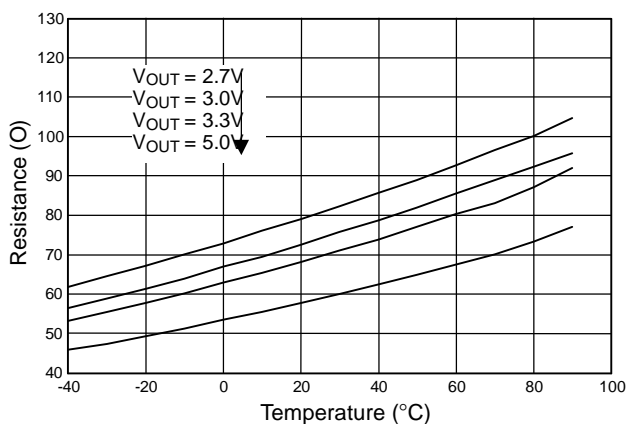
Fig. 18 SS6639 Supply Current vs. Temperature
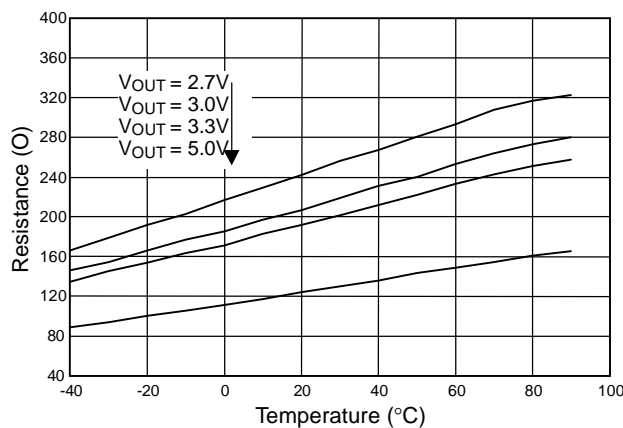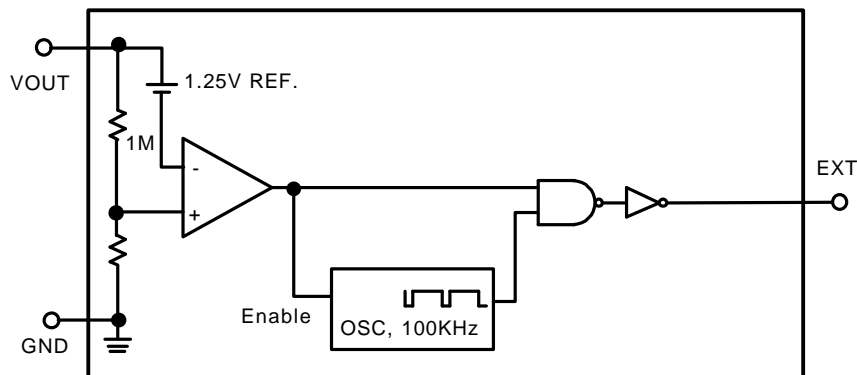
Fig. 19 SS6639 EXT "L" On-Resistance

Fig. 20 SS6639 EXT "H" On-Resistance

■ BLOCK DIAGRAM

■ PIN DESCRIPTIONS

Pin 1:   GND: Ground. Must be low impedance; solder directly to ground plane.

Pin 2:   VOUT: IC supply pin. Connect Vout to the regular output.

Pin 3:   EXT: Push-pull driver output for external power. Switch.

■ APPLICATION INFORMATION

General Description

The SS6639 PFM (pulse frequency modulation) controller IC combines a switch mode regulator, a push-pull driver, a precision voltage reference, and a voltage detector in a single monolithic device. It offers extremely low quiescent current, high efficiency, and very low gate-threshold voltage to ensure start-up with low battery voltage (0.8V typ.). Designed to maximize battery life in portable products, it minimizes switching losses by only switching as needed to service the load.

PFM controllers transfer a discrete amount of energy per cycle and regulate the output voltage by modulating the switching frequency with a constant turn-on time. Switching frequency depends on load, input voltage, and inductor value and can range up to 100 KHz.

When the output voltage drops, the error comparator enables the 100 kHz oscillator which turns the MOSFET on for around 7.5us and off for 2.5µs. Turning on the MOSFET allows inductor current to ramp up, storing energy in the magnetic field.

When the MOSFET turns off, the inductor forces current through the diode to the output capacitor and the load. As the stored energy is depleted, the current ramps down until the diode turns off. At this point, the inductor may ring due to residual energy and stray capacitance. The output capacitor stores charge when current flowing through the diode is high, and releases it when current is low, thereby maintaining a steady voltage across the load.

As the load increases, the output capacitor discharges faster and the error comparator initiates cycles sooner, increasing the switching frequency. The maximum duty cycle ensures adequate time for energy transfer to the output during the second half of each cycle. Depending on the circuit, PFM controllers can operate in either discontinuous mode or continuous conduction mode. The continuous conduction mode means that the inductor current does not ramp to zero during each cycle.
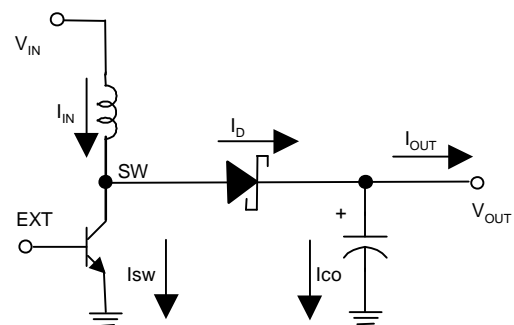
Discontinuous Conduction Mode
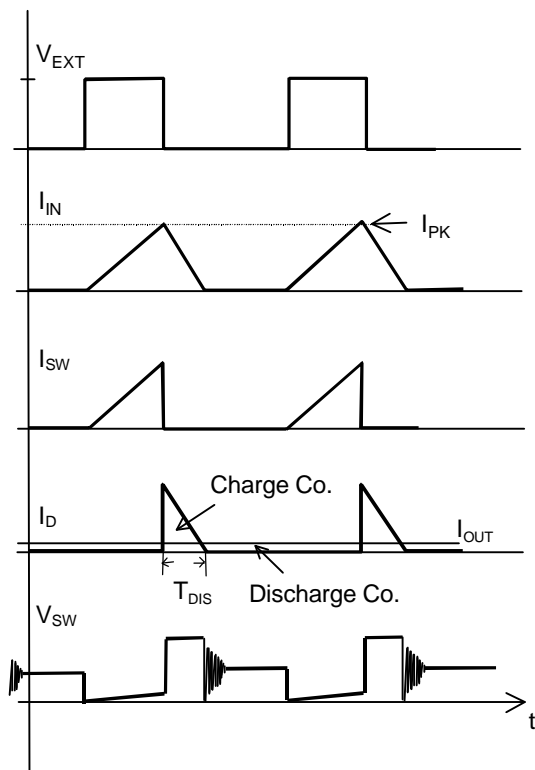
Discontinuous Conduction Mode
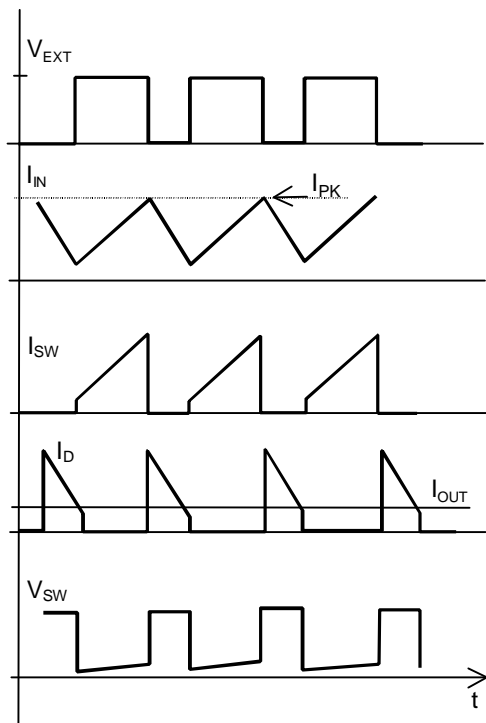
Continuous Conduction Mode

At the boundary between continuous and discontinuous modes, the output current (IOB) is determined by

$$I_{OB} = \left(\frac{V_{IN}}{V_{OUT} + V_D} \right) * \frac{1}{2} * \frac{V_{IN}}{L} * T_{ON} * (1 - x)$$

where V_D is the diode drop,

$$X = (R_{ON} + R_S) * \frac{T_{ON}}{L}$$

R_{ON}= Switch turn on resistance, R_S= Inductor DC resistance

T_{ON} = Switch ON time

In the discontinuous mode, the switching frequency (Fsw) is

$$F_{SW} = \frac{2(L) * (V_{OUT} + V_D - V_{IN}) * (I_{OUT})}{V_{IN}^2 * T_{ON}^2} * (1 + x)$$

In the continuous mode, the switching frequency is

$$f_{sw} = \frac{1}{T_{ON}} * \frac{(V_{OUT} + V_D - V_{IN})}{(V_{OUT} + V_D - V_{SW})}$$

$$* [1 + \frac{x}{2}(\frac{V_{IN} - V_{SW}}{V_{OUT} + V_D - V_{SW}})]$$

$$\cong \frac{1}{T_{ON}} * \left(\frac{V_{OUT} + V_D - V_{IN}}{V_{OUT} + V_D - V_{SW}} \right)$$

where Vsw = switch drop and is proportional to output current.

INDUCTOR SELECTION

To operate as an efficient energy transfer element, the inductor must fulfill three requirements. First, the inductance must be low enough for the inductor to store adequate energy under the worst case condition of minimum input voltage and switch ON time. Second, the inductance must also be high enough so the maximum current rating of the SS6639 and the inductor are not exceeded at the other worst case condition of maximum input voltage and ON time. Lastly, the inductor must have sufficiently low DC resistance so excessive power is not lost as heat in the windings. Unfortunately this is inversely related to physical size.

Minimum and maximum input voltage, output voltage and output current must be established before an inductor can be selected.

In discontinuous mode operation, at the end of the switch ON time, peak current and energy in the inductor build according to

$$I_{PK} = \left(\frac{V_{IN}}{R_{ON}+R_S}\right) * \left(1 - \exp(-\frac{R_{ON}+R_S}{L} * T_{ON})\right)$$

$$\cong \left(\frac{V_{IN}}{L}\right) * (T_{ON}) * \left(1 - \frac{x}{2}\right)$$

$$\cong \frac{V_{IN}}{L} * T_{ON}$$

(simple lossless equation), where

$$X = (R_{ON} + R_S) * \frac{T_{ON}}{L}$$

$$EL = \frac{1}{2}L * I_{PK}^2$$

Power required from the inductor per cycle must be equal to, or greater than

$$\frac{P_L}{f_{SW}} = (V_{OUT} + V_D - V_{IN}) * (I_{OUT}) * (\frac{1}{f_{SW}})$$

in order for the converter to regulate the output.

When the loading exceeds IOB, the PFM controller operates in continuous mode. Inductor peak current can be derived from

$$I_{PK} = \left(\frac{V_{OUT} + V_D - V_{SW}}{V_{IN} - V_{SW}} - \frac{x}{2}\right)$$
$$* I_{OUT} + \left(\frac{V_{IN} - V_{SW}}{2L}\right) * T_{ON} * \left(1 - \frac{x}{2}\right)$$

Valley current (Iv) is

$$I_V = \left(\frac{V_{OUT} + V_D - V_{SW}}{V_{IN} - V_{SW}} - \frac{x}{2}\right) * I_{OUT}$$
$$* \left(\frac{V_{IN} - V_{DE}}{2L}\right) * T_{ON} * \left(1 - \frac{x}{2}\right)$$

Table 1 Indicates resistance and height for each coil.

Power Inductor Type	Inductance (μH)	Resistance (Ω)	Rated Current (A)	height (mm)
Sumida SMT Type CD54	47	0.25	0.7	4.5
	100	0.50	0.5	
Hold SMT Type PM54	47	0.25	0.7	4.5
	100	0.50	0.5	
Hold SMT Type PM75	33	0.11	1.2	5.0
Huan Feng PIN Type V0810	33	40m	2	10.0

CAPACITOR SELECTION

A poor choice for an output capacitor can result in poor efficiency and high output ripple. Ordinary aluminum electrolytic capacitors, while inexpensive, may have unacceptably poor ESR and ESL. There are low ESR aluminum capacitors for switch mode DC-DC converters which work much better than general-purpose components. Tantalum capacitors provide still better performance but are more expensive. OS-CON capacitors have extremely low ESR in a small size. If the capacitance is reduced, the output ripple will increase.

As most of the input supply is applied across the input bypass capacitor, the capacitor voltage rating should be at least 1.25 times greater than the maximum input voltage.

DIODE SELECTION

Speed, forward drop, and leakage current are three main considerations in selecting a rectifier diode. The best performance is obtained with a Schottky rectifier

diode such as the 1N5819. Motorola makes the MBR0530 for surface mount. For lower output power a 1N4148 can be used although efficiency and start-up voltage will suffer substantially.

COMPONENT POWER DISSIPATION

Operating in discontinuous mode, the power loss in the winding resistance of the inductor is approximately equal to

$$PD_L = \frac{2}{3} * \left(\frac{T_{ON}}{L}\right) * (R_S) * \left(\frac{V_{OUT} + V_D}{V_{OUT}}\right) * (P_{OUT})$$

where $P_{OUT} = V_{OUT} * I_{OUT}$; R_S = Inductor DC R;

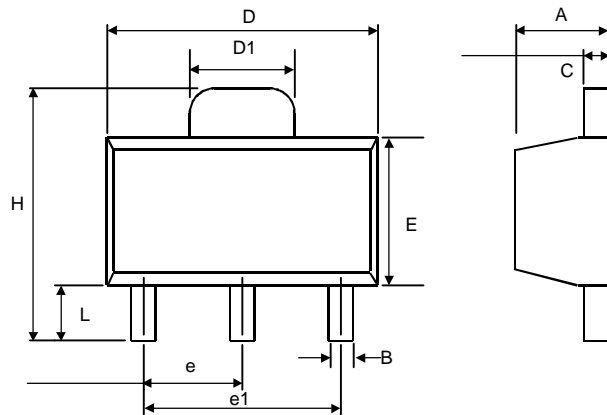V_D = Diode drop.

The power dissipated in switching losses is

$$PD_{SW} = \frac{2}{3} * \left(\frac{T_{ON}}{L}\right) * (R_{ON}) * (I_{OUT}) * (P_{OUT})$$

The power dissipated in the rectifier diode is

$$PD_D = \left(\frac{V_D}{V_{OUT}}\right) * (P_{OUT})$$
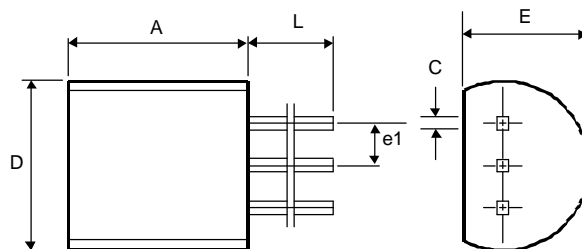
PHYSICAL DIMENSIONS

- **SOT-89 (unit: mm)**

SYMBOL	MIN	MAX
A	1.40	1.60
B	0.36	0.48
C	0.35	0.44
D	4.40	4.60
D1	1.62	1.83
E	2.29	2.60
e	1.50 (TYP.)	
e1	3.00 (TYP.)	
H	3.94	4.25
L	0.89	1.20

- **SOT-89 MARKING**

Part No.	Marking
SS6639-27	AU27
SS6639-30	AU30
SS6639-33	AU33
SS6639-50	AU50

- **TO-92 (unit: mm)**

SYMBOL	MIN	MAX
A	4.32	5.33
C	0.38 (TYP.)	
D	4.40	5.20
E	3.17	4.20
e1	1.27 (TYP.)	
L	12.7	-

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