Simple 3-Pin Step-Up DC/DC Converter

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: 2.7V, 3.0V, 3.3V, 4.5V and 5V.
- Space saving packages: SOT-23, SOT-89 and TO-92.
- **Pb-free, RoHS compliant.**

APPLICATIONS

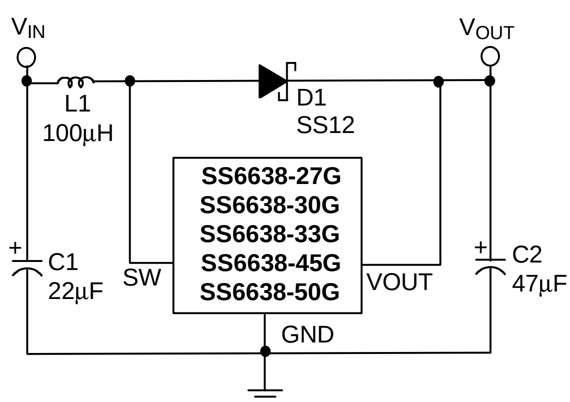
- Pagers.
- Cameras.
- Wireless Microphones.
- Pocket Organizers.
- Battery Backup Supplies.
- Portable Instruments.

DESCRIPTION

The SS6638G is a high-efficiency step-up DC/DC converter for applications using 1 to 4 NiMH battery cells. Only three external components are required to deliver a fixed output voltage of 2.7V, 3.0V, 3.3V, 4.5V or 5V. The SS6638G starts up from less than 0.9V input with 1mA load. A Pulse Frequency Modulation scheme brings optimized performance for applications with light output loading and low input voltages. The output ripple and noise are lower compared with circuits operating in PSM mode.

The PFM control circuit operating at a maximum 100kHz switching rate results in smaller passive components. The space saving SOT-23, SOT-89 and TO-92 packages make the SS6638G an ideal choice of DC/DC converter for space-conscious applications, like pagers, electronic cameras, and wireless microphones.

TYPICAL APPLICATION CIRCUIT



Simple Step-Up DC/DC Converter

ORDERING INFORMATION

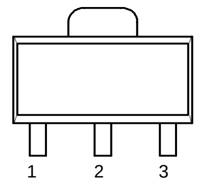
SS6638-XX X X XX

- Packing
  TR: Tape and reel
- Package type
  X: SOT-89
  Z: TO-92
  U: SOT-23
- G: Pb-free, RoHS-compliant
- Output voltage
  27: 2.7V
  30: 3.0V
  33: 3.3V
  45: 4.5V
  50: 5.0V

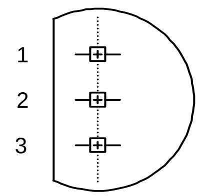
Example: SS6638-27GXTR
→ 2.7V output in RoHS-compliant SOT-89, shipped on tape and reel

PIN CONFIGURATION

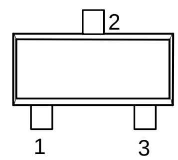
SOT-89
TOP VIEW
1: GND
2: VOUT
3: SW



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



SOT-23
TOP VIEW
1: GND
2: VOUT
3: SW



SOT-23 MARKING

Part No.	
SS6638-27GU	DA27P
SS6638-30GU	DA30P
SS6638-33GU	DA33P
SS6638-45GU	DA45P
SS6638-50GU	DA50P

SOT-89 MARKING

Part No.	
SS6638-27GX	AN27P
SS6638-30GX	AN30P
SS6638-33GX	AN33P
SS6638-45GX	AN45P
SS6638-50GX	AN50P

ABSOLUTE MAXIMUM RATINGS

Supply Voltage (VOUT pin) 6V
SW pin Voltage 6V
SW pin Switch Current 0.6A
Operating Temperature Range .... -40°C to 85°C
Maximum Junction Temperature .... 125°C
Storage Temperature Range .... -65°C to 150 °C
Lead Temperature (Soldering 10 Sec.) .... 260°C

Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

TEST CIRCUIT

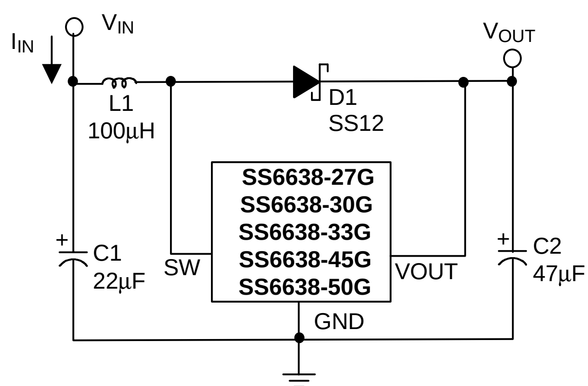


Fig. 1 Test Circuit 1

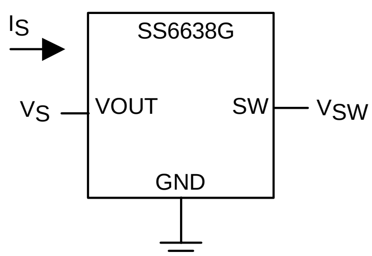


Fig. 2 Test Circuit 2

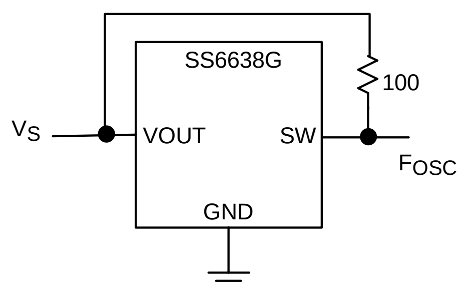


Fig. 3 Test Circuit 3

ELECTRICAL CHARACTERISTICS

(T_A=25°C, I_{OUT}=10mA, unless otherwise specified) (Note1)

PARAMETER	TEST CONDITIONS	TEST CKT	SYMBOL	MIN.	TYP.	MAX.	UNIT
Output Voltage	SS6638-27G V_{IN}=1.8V	1	V_{OUT}	2.633	2.700	2.767	V
	SS6638-30G V_{IN}=1.8V			2.925	3.000	3.075	
	SS6638-33G V_{IN}=2.0V			3.218	3.300	3.382	
	SS6638-45G V_{IN}=3.0V			4.387	4.500	4.613	
	SS6638-50G V_{IN}=3.0V			4.875	5.000	5.125	
Input Voltage	Normal Operation	1	V_{IN}			6	V
Start-Up Voltage	I_{OUT}=1mA, V_{IN}:0→2V	1	V_{START}		0.8	0.9	V
Min. Hold-on Voltage	I_{OUT}=1mA, V_{IN}:2→0V	1	V_{HOLD}			0.7	V
No-Load Input Current	I_{OUT}=0mA	1	I_{IN}		15		µA
Supply Current	SS6638-27G	2	I_{S1}		42		µA
	SS6638-30G				50		
	SS6638-33G				60		
	SS6638-45G				70		
	SS6638-50G				90		
	V_S=V_{OUT} x 0.95						
	Measurement of the IC input current (VOUT pin)						
Supply Current	SS6638-27G	2	I_{S2}		7		µA
	SS6638-30G				7		
	SS6638-33G				7		
	SS6638-45G				7		
	SS6638-50G				7		
	V_S=V_{OUT} + 0.5V						
	Measurement of the IC input current (VOUT pin)						
SW Leakage Current	V_{SW}=6V, V_S=V_{OUT} + 0.5V	2				0.5	µA
SW Switch-On Resistance	SS6638-27G	2	R_{ON}		1.3		Ω
	SS6638-30G				1.2		
	SS6638-33G				1.1		
	SS6638-45G				1		
	SS6638-50G				1		
	V_S=V_{OUT} x 0.95, V_{SW}=0.4V						

ELECTRICAL CHARACTERISTICS (Continued)

PARAMETER	TEST CONDITIONS	TEST CKT	SYMBOL	MIN.	TYP.	MAX.	UNIT
Oscillator Duty Cycle	V_S=V_{OUT} x 0.95 Measurement of the SW pin waveform	3	DUTY	65	75	85	%
Max. Oscillator Freq.	V_S=V_{OUT} x 0.95 Measurement of the SW pin waveform	3	F_{OSC}	80	105	130	kHz
Efficiency		1	η		85		%

Note 1: Specifications are production tested at T_A=25°C. Specifications over the -40°C to 85°C operating temperature range are assured by design, characterization and correlation with Statistical Quality Controls (SQC).

TYPICAL PERFORMANCE CHARACTERISTICS (Refer to Typical Application)

Capacitor (C2) : 47μF (Tantalum Type)
Diode (D1) : 1N5819 Schottky Type

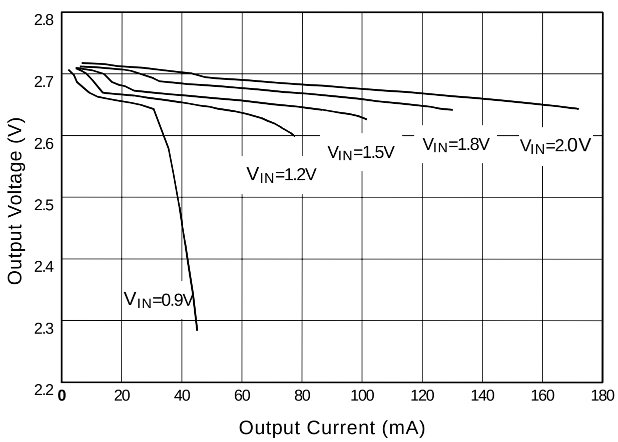


Fig. 4 SS6638-27G Load Regulation (L=100μH CD54)

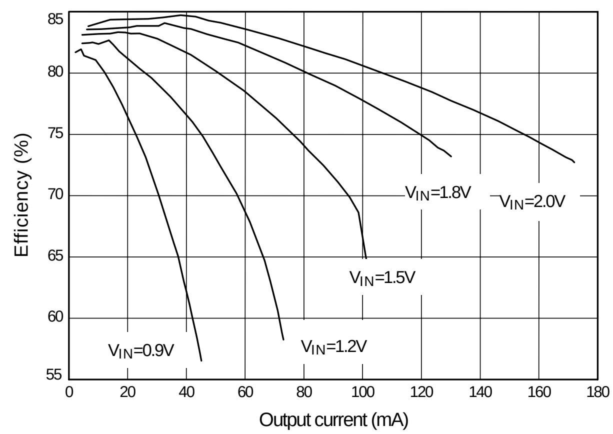


Fig. 5 SS6638-27G Efficiency (L=100μH CD54)

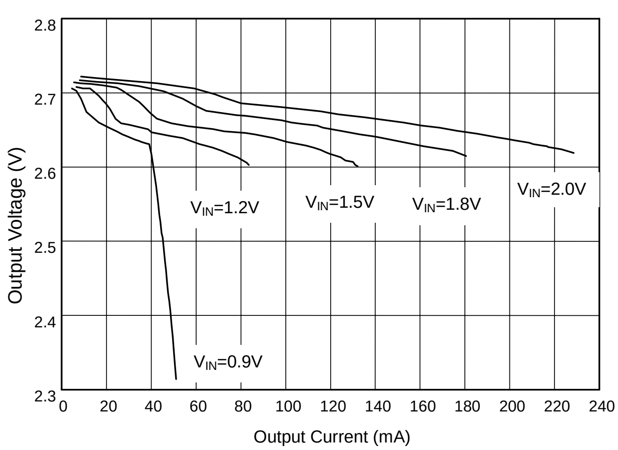


Fig. 6 SS6638-27G Load Regulation (L=47μH CD54)

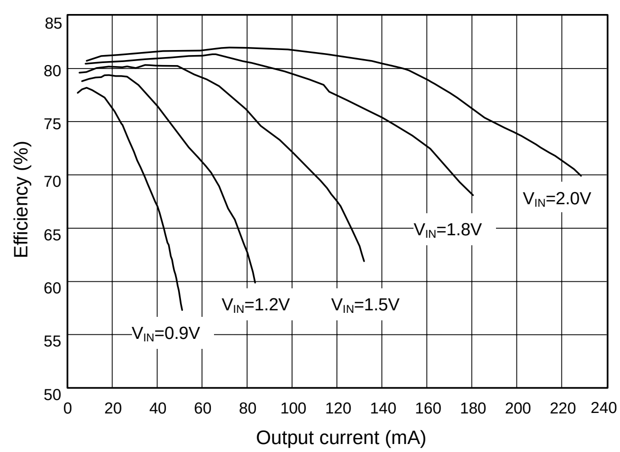


Fig. 7 SS6638-27G Efficiency (L=47μH CD54)

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

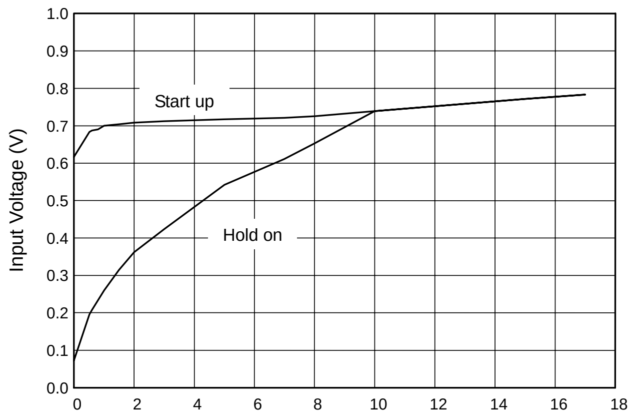


Fig. 8 SS6638-27G Start-Up & Hold-ON Voltage (L=47µH CD54)

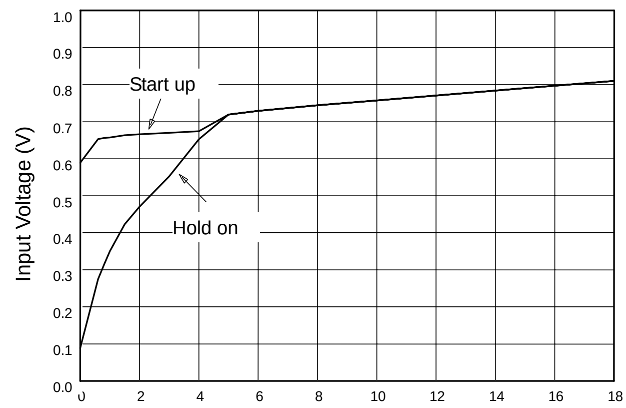


Fig. 9 SS6638-27G Start-Up & Hold-ON Voltage (L=100µH CD54)

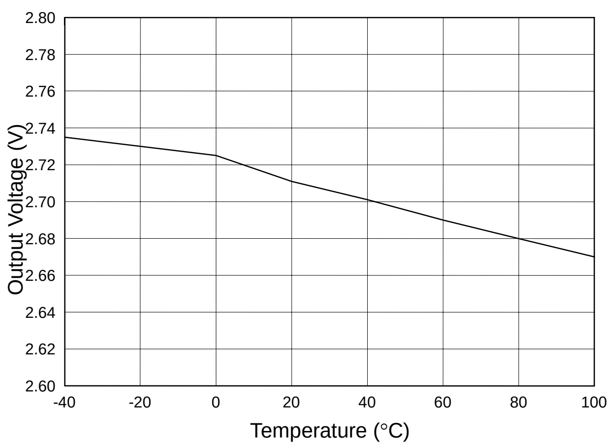


Fig. 10 SS6638-27G Output Voltage vs. Temperature

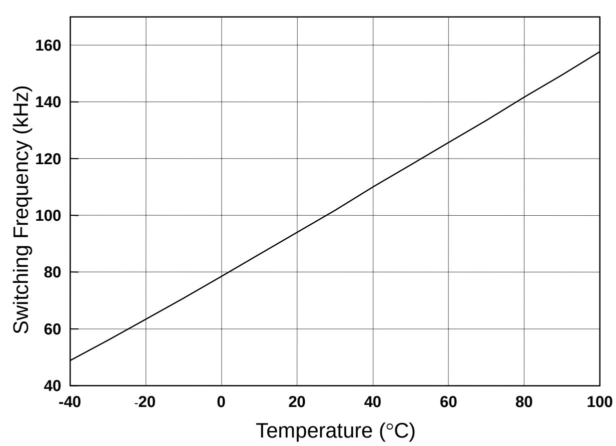


Fig. 11 SS6638-27G Switching Frequency vs. Temperature

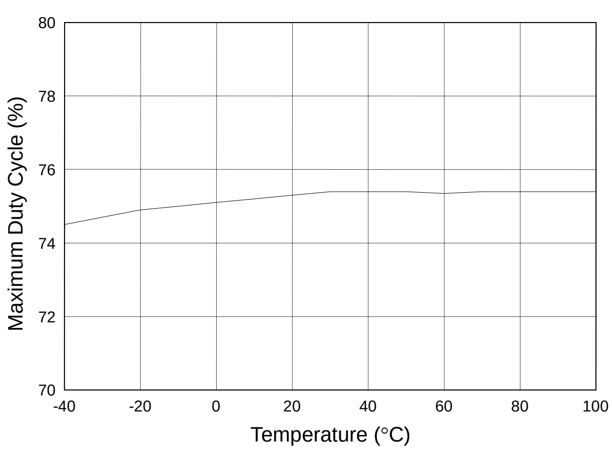


Fig. 12 SS6638-27G Maximum Duty Cycle vs. Temperature

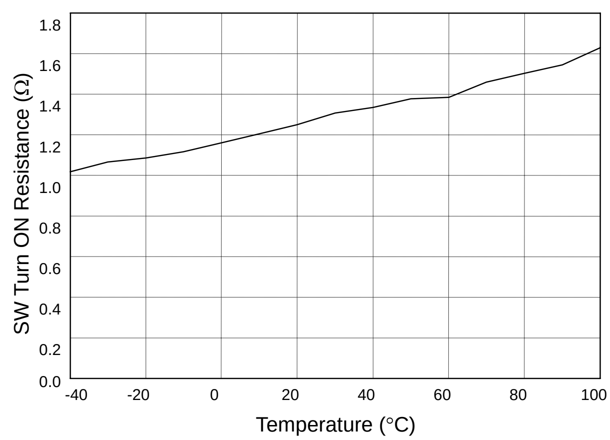


Fig. 13 SS6638-27G SW Turn ON Resistance vs. Temperature

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

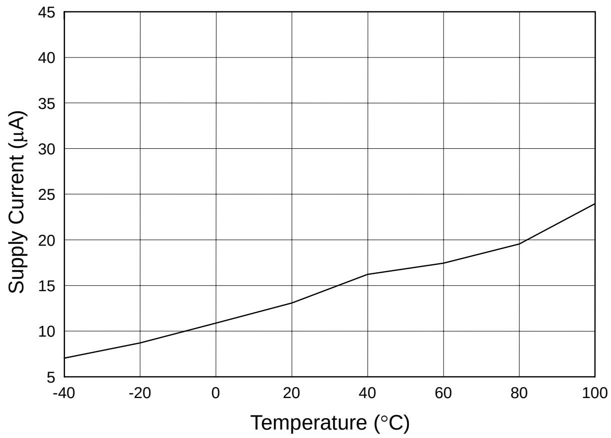


Fig. 14 SS6638-27G Supply Current vs. Temperature

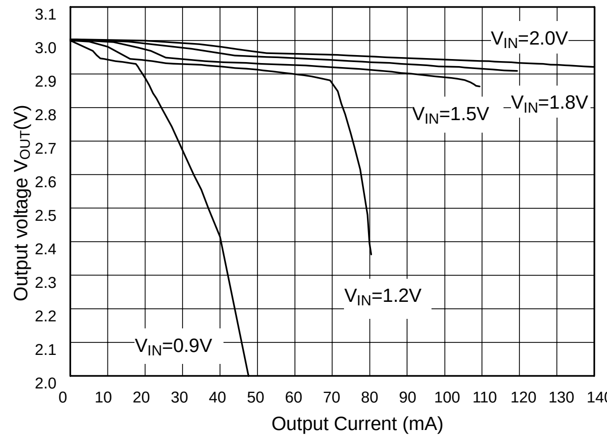


Fig. 15 SS6638-30G Load Regulation (L=100µH, CD54)

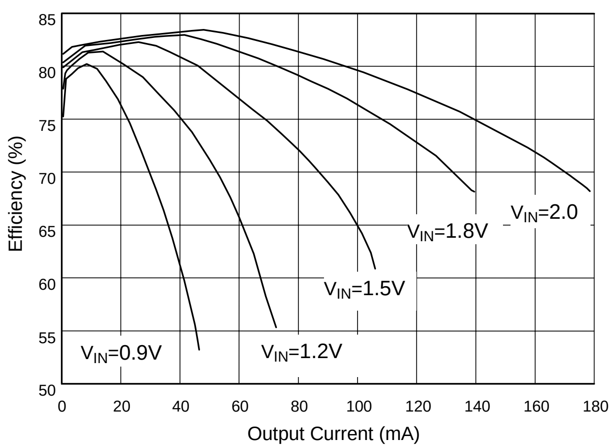


Fig. 16 SS6638-30G Efficiency (L=100µH, CD54)

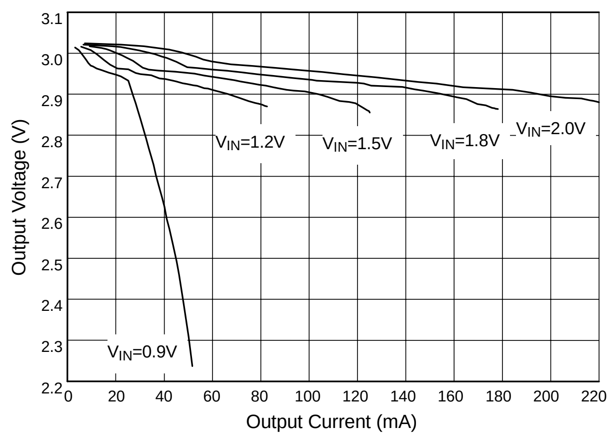


Fig. 17 SS6638-30G Load Regulation (L=47µH CD54)

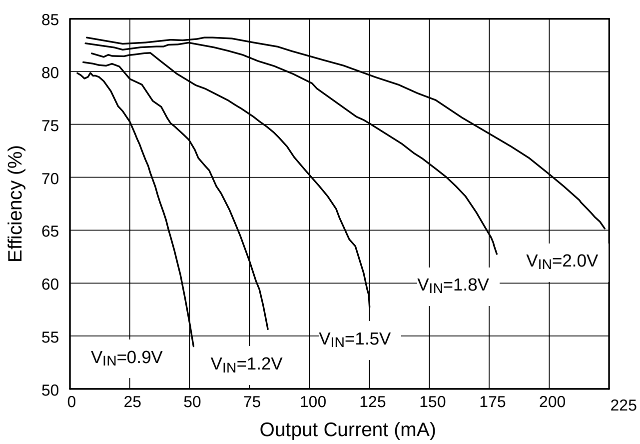


Fig. 18 SS6638-30G Efficiency (L=47µH CD54)

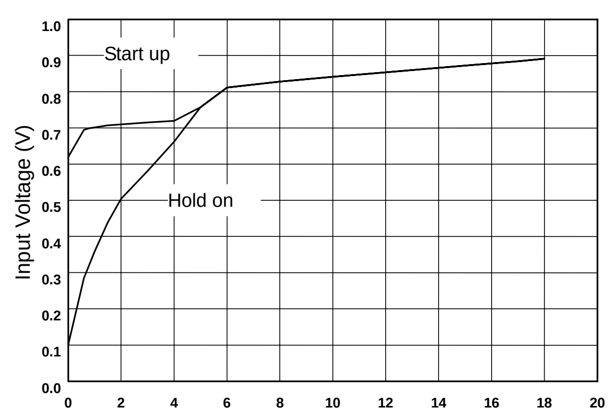


Fig. 19 SS6638-30G Start-up & Hold-on Voltage (L=100µH CD54)

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

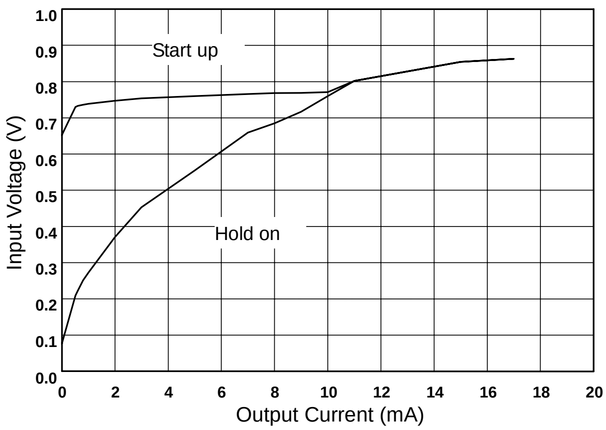


Fig. 20 SS6638-30G Start-up & Hold-on Voltage (L=47μH CD54)

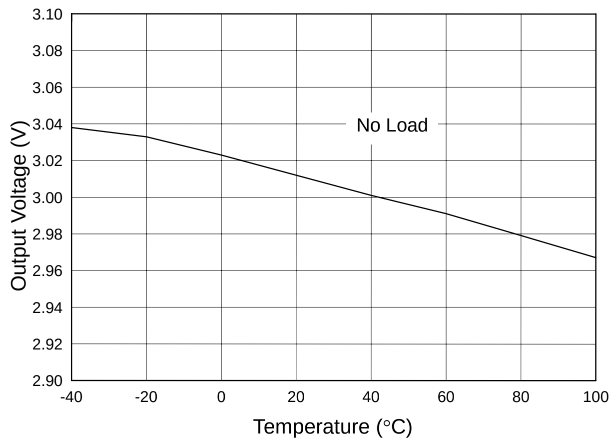


Fig. 21 SS6638-30G Output Voltage vs. Temperature

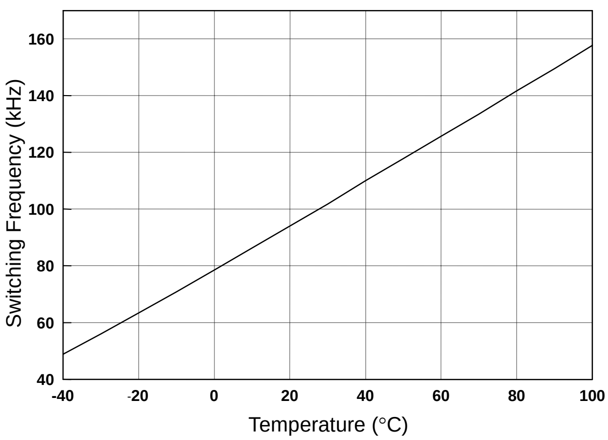


Fig. 22 SS6638-30G Switching Frequency vs. Temperature

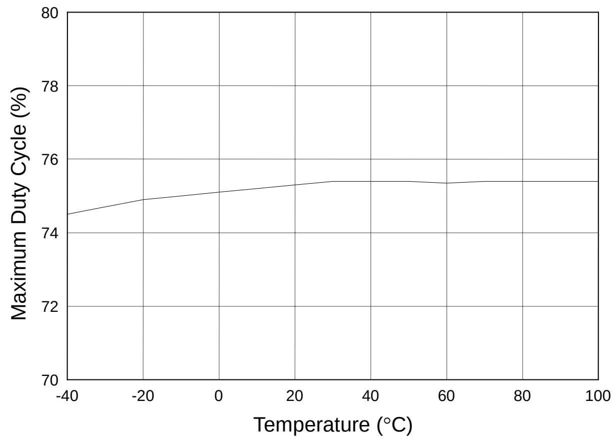


Fig. 23 SS6638-30G Maximum Duty Cycle vs. Temperature

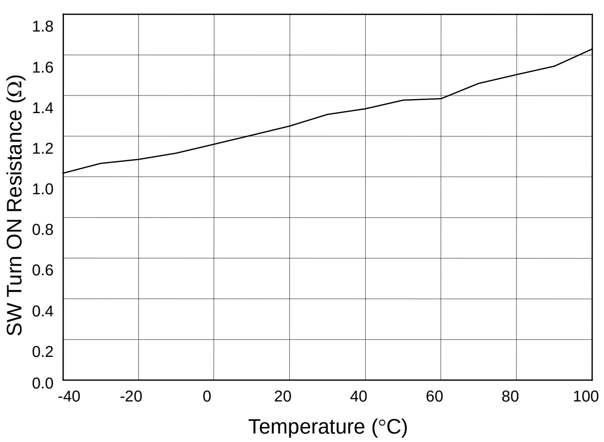


Fig. 24 SS6638-30G SW Turn ON Resistance vs. Temperature

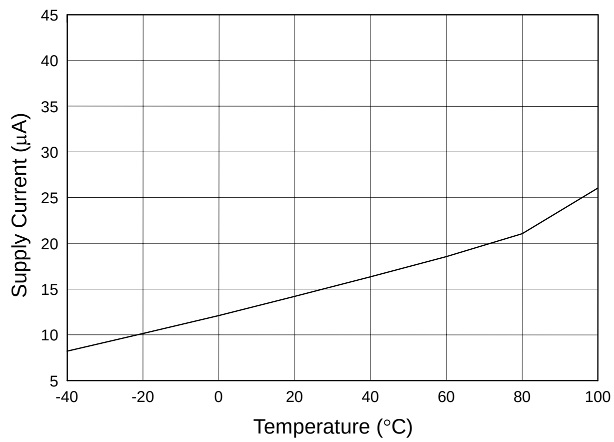


Fig. 25 SS6638-30G Supply Current vs. Temperature

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

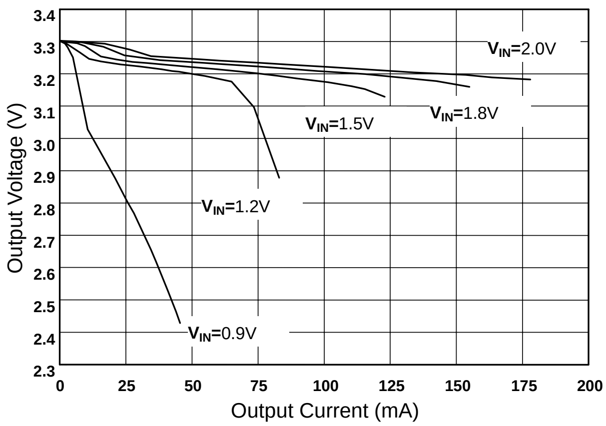


Fig. 26 SS6638-33G Load Regulation (L=100µH, CD54)

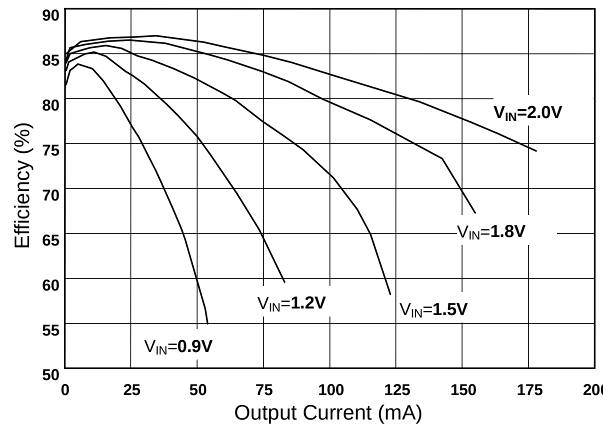


Fig. 27 SS6638-33G Efficiency (L=100µH, CD54)

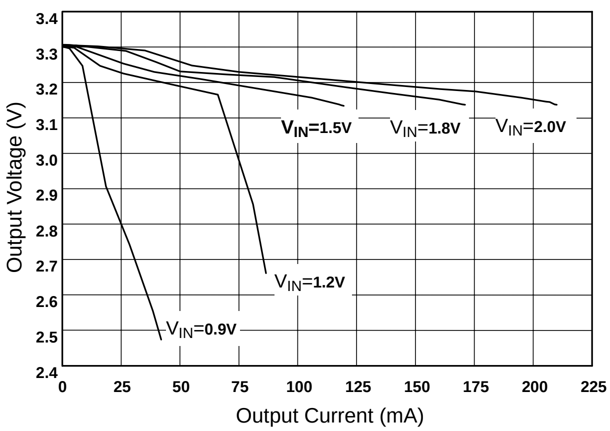


Fig. 28 SS6638-33G Load Regulation (L=47µH, CD54)

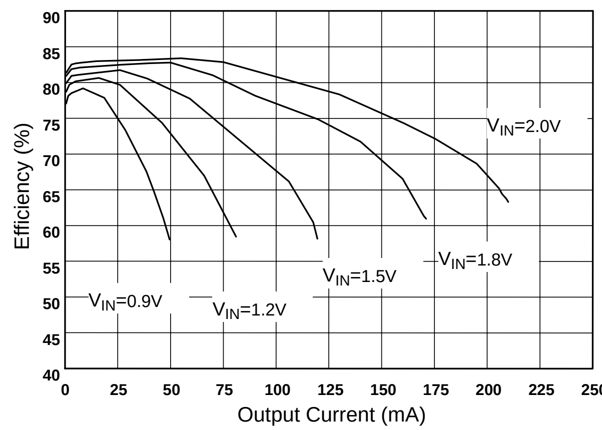


Fig. 29 SS6638-33G Efficiency (L=47µH,CD54)

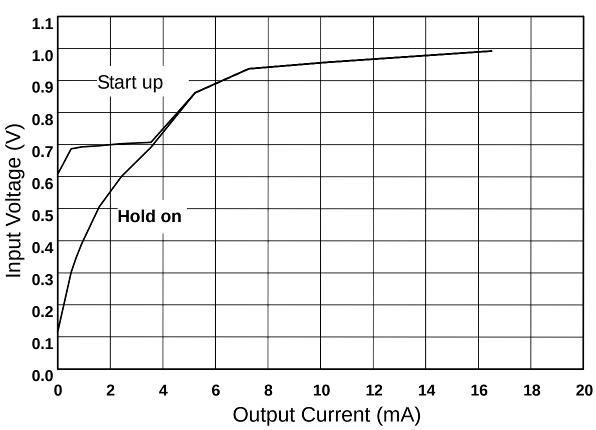


Fig. 30 SS6638-33G Start-up & Hold-on Voltage (L=100µH CD54)

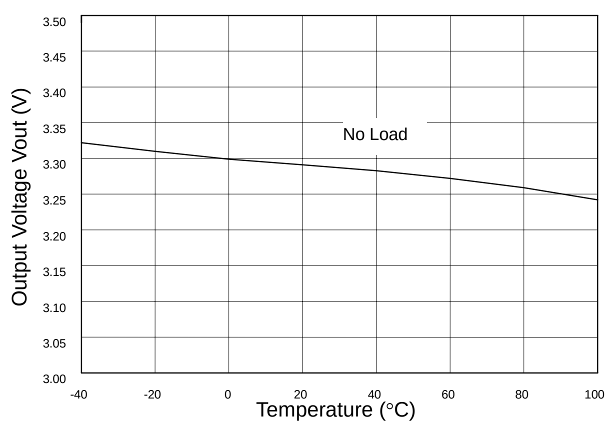


Fig. 31 SS6638-33G Output Voltage vs. Temperature

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

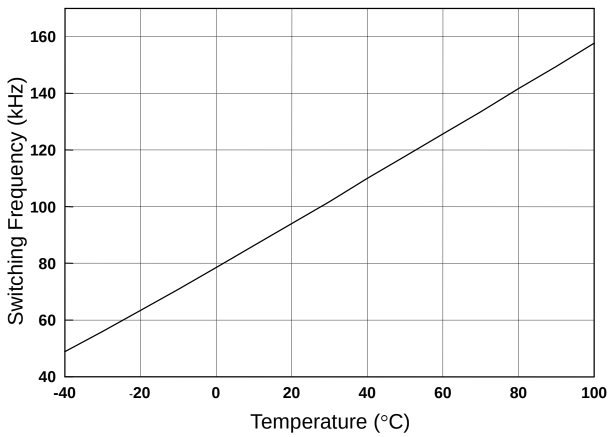


Fig. 32 SS6638-33G Switching Frequency vs. Temperature

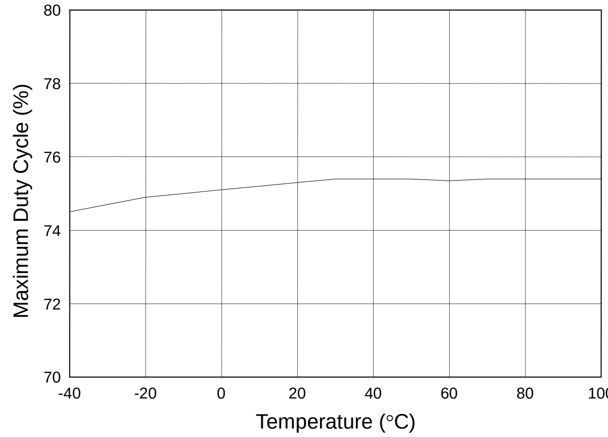


Fig. 33 SS6638-33G Maximum Duty Cycle vs. Temperature

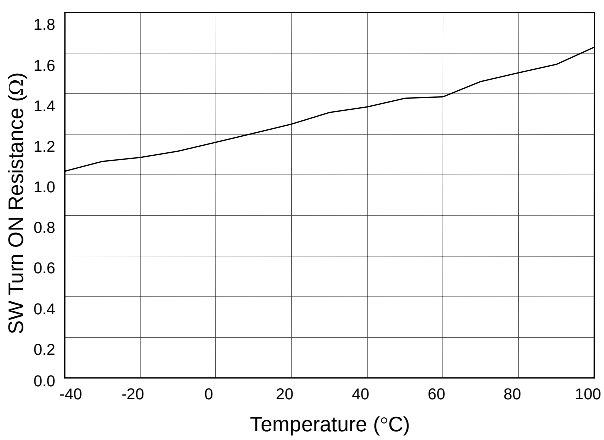


Fig. 34 SS6638-33G SW Turn ON Resistance vs. Temperature

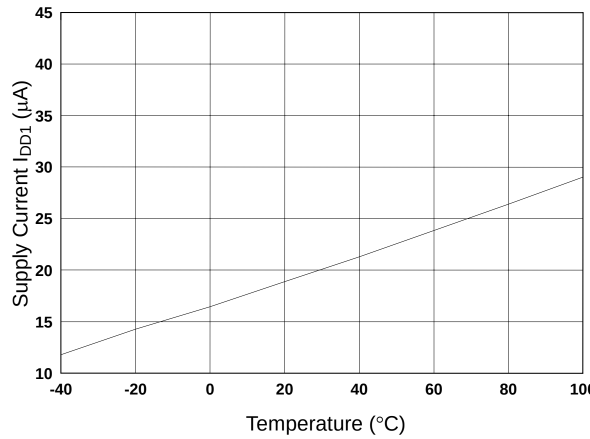


Fig. 35 SS6638-33G Supply Current vs. Temperature

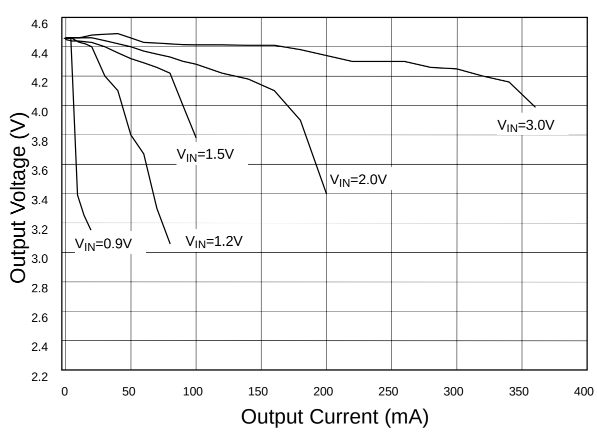


Fig. 36 SS6638-45G Load Regulation (L=100μH)

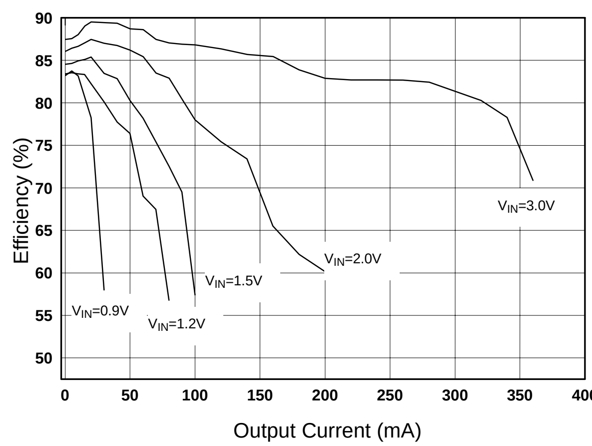


Fig. 37 SS6638-45G Efficiency (L=100μH)

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

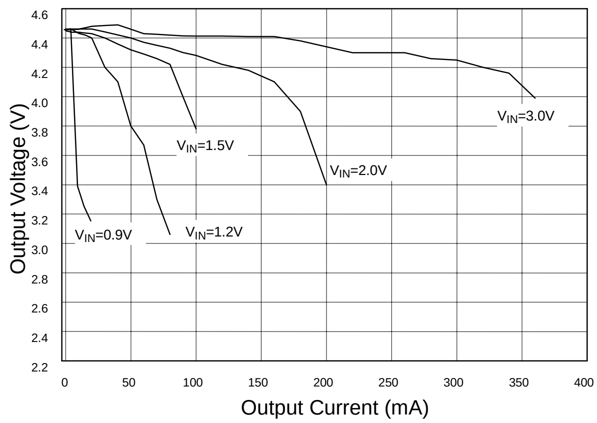


Fig. 38 SS6638-45G Load Regulation (L=100µH)

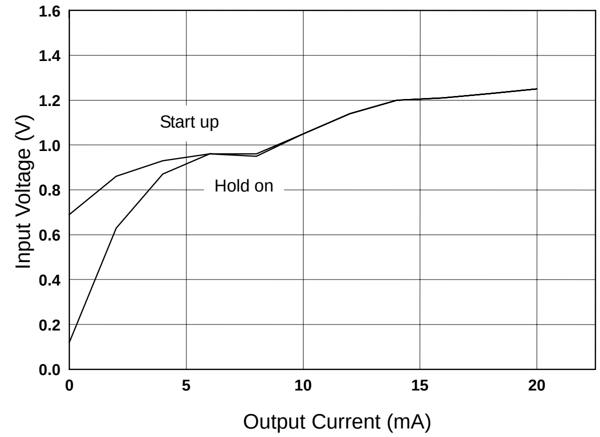


Fig. 39 SS6638-45G Start-up & Hold-On Voltage (L=100µH)

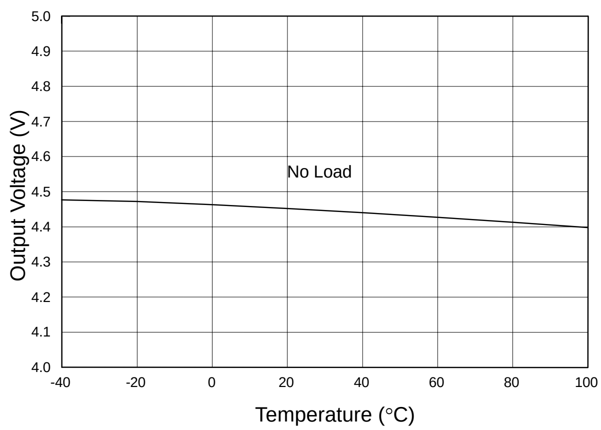


Fig. 40 SS6638-45G Output Voltage vs. Temperature

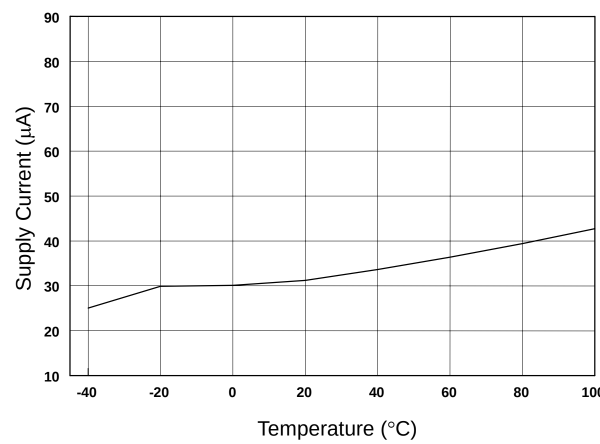


Fig. 41 SS6638-45G Supply Current vs. Temperature

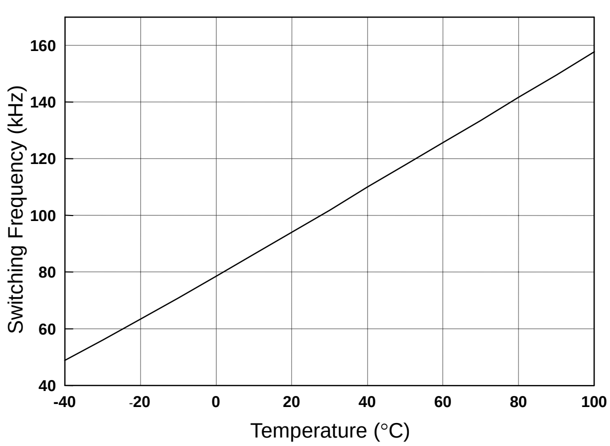


Fig. 42 SS6638-45G Switching Frequency vs. Temperature

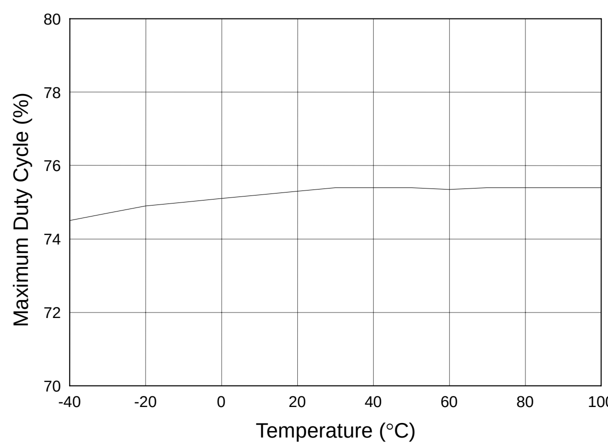


Fig. 43 SS6638-45G Maximum Duty Cycle vs. Temperature

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

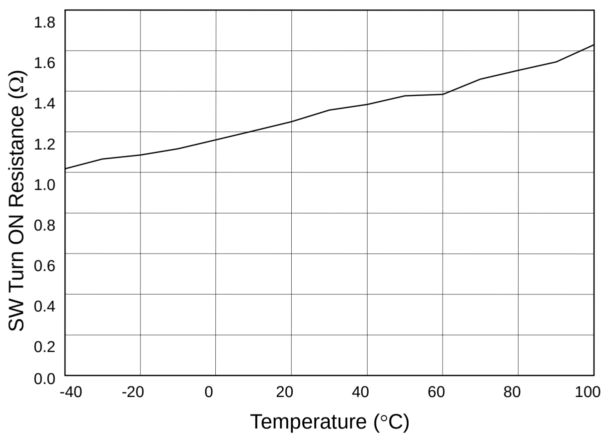


Fig. 44 SS6638-45G SW Turn ON Resistance vs. Temperature

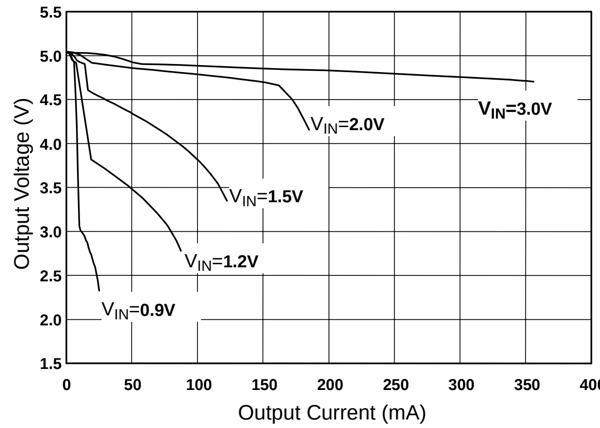


Fig. 45 SS6638-50G Load Regulation (L=100µH CD54)

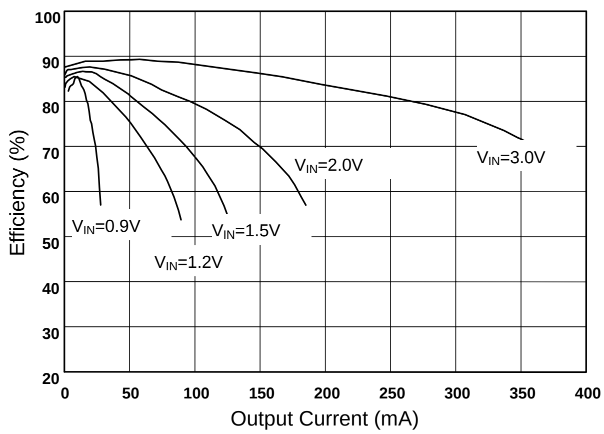


Fig. 46 SS6638-50G Efficiency (L=100µH CD54)

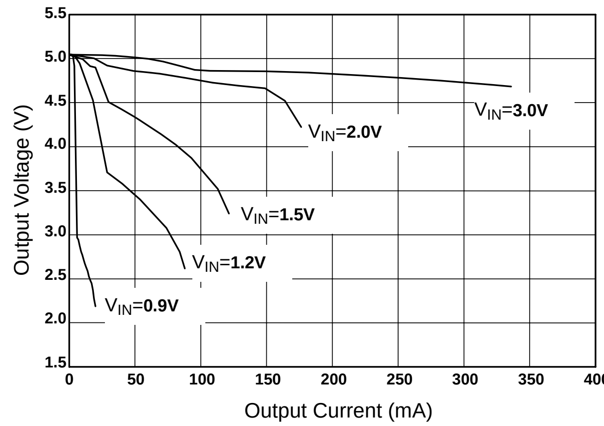


Fig. 47 SS6638-50G Load Regulation (L=47µH CD54)

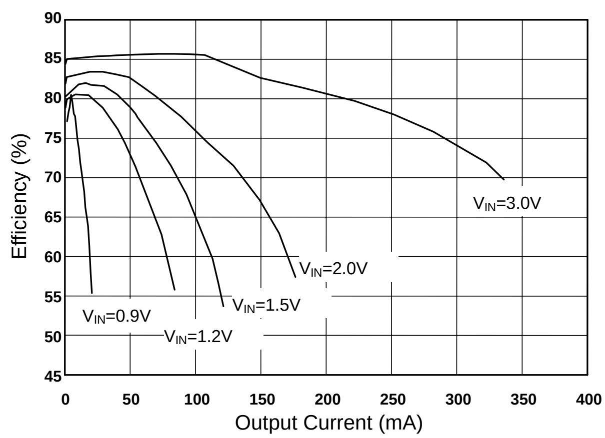


Fig. 48 SS6638-50G Efficiency (L=47µH CD54)

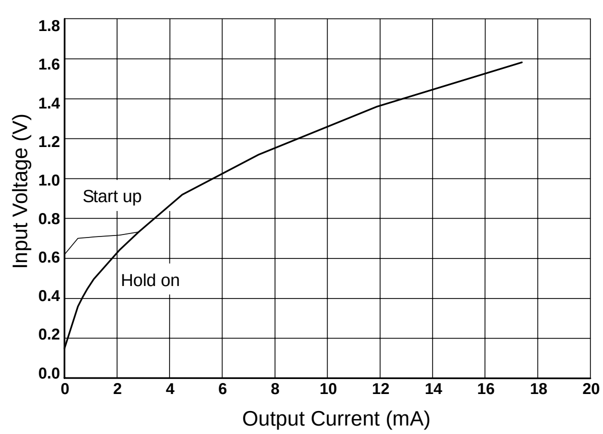


Fig. 49 SS6638-50G Start-up & Hold-on Voltage (L=100µH CD50)

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

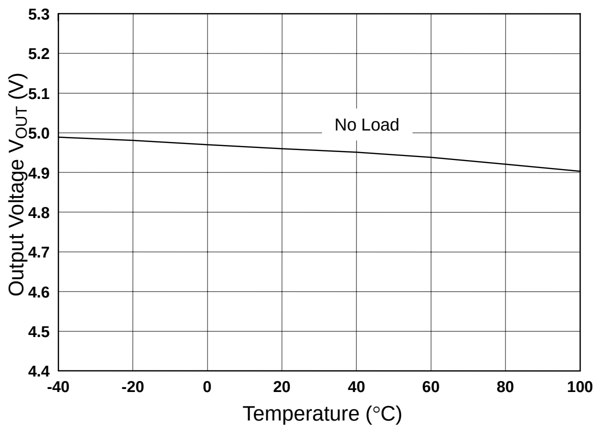


Fig. 50 SS6638-50G Output Voltage vs. Temperature

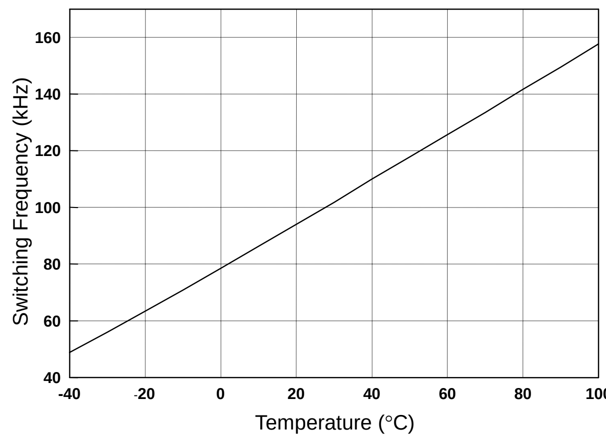


Fig. 51 SS6638-50G Switching Frequency vs. Temperature

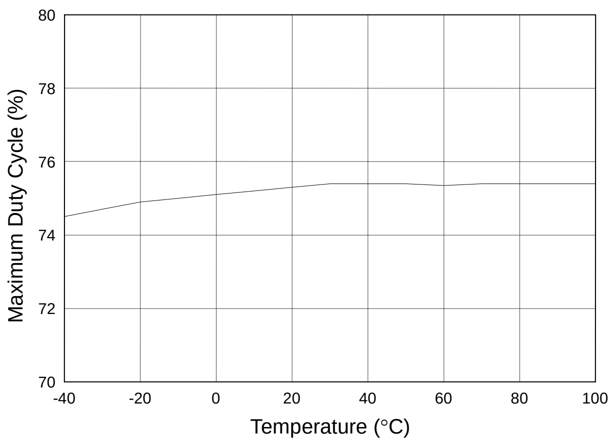


Fig. 52 SS6638-50G Maximum Duty Cycle vs. Temperature

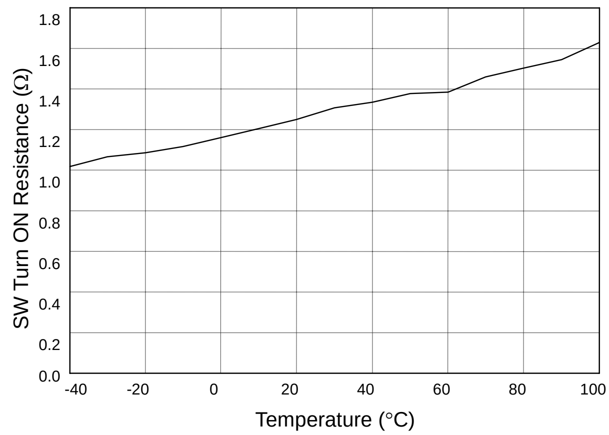


Fig. 53 SS6638-50G SW Turn ON Resistance vs. Temperature

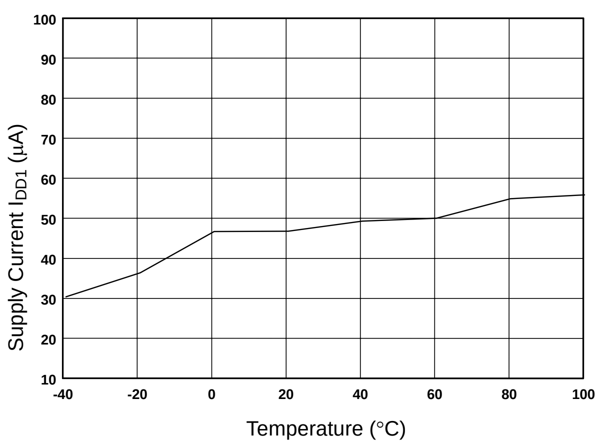


Fig. 54 SS6638-50G Supply Current vs. Temperature

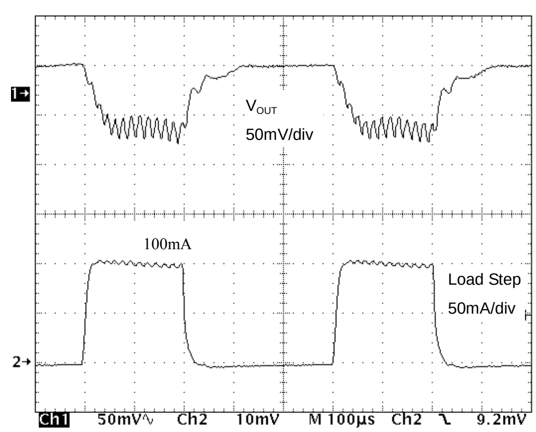


Fig. 55 Load Transient Response

(L_1=100μH, C_2=47μF, V_{IN}=2V)

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

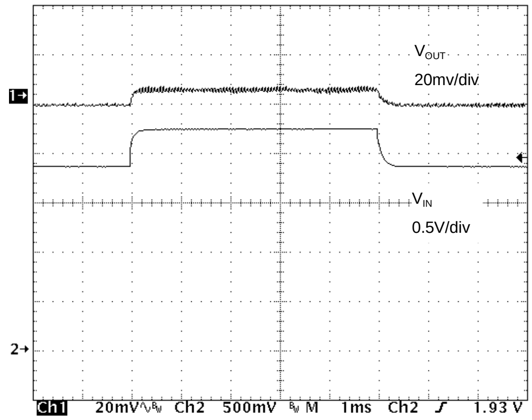
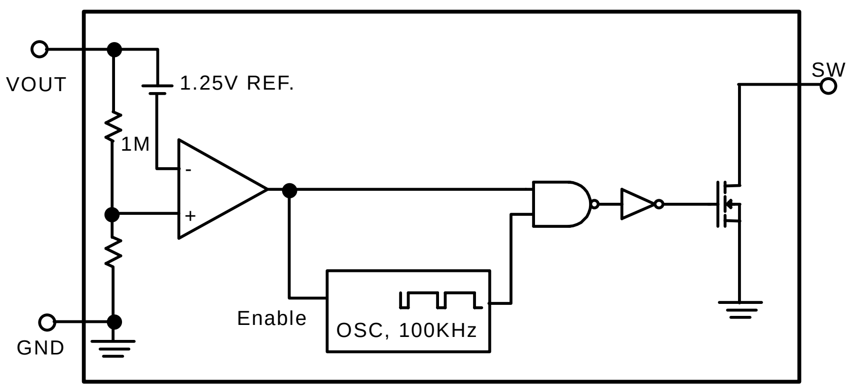


Fig. 56 Line Transient Response
(L_1=100µH, C_2=47µF)

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 converter output.

PIN 3 : SW - Internal drain of N-MOSFET switch.

APPLICATION INFORMATION

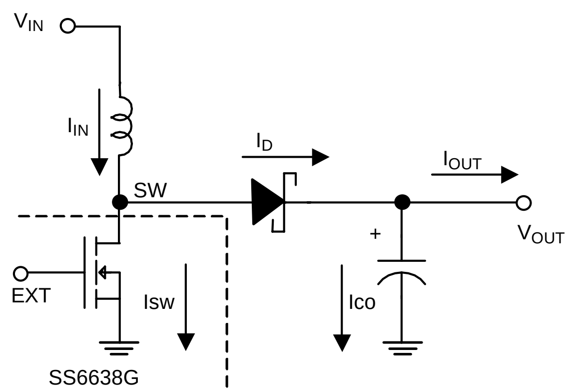
GENERAL DESCRIPTION

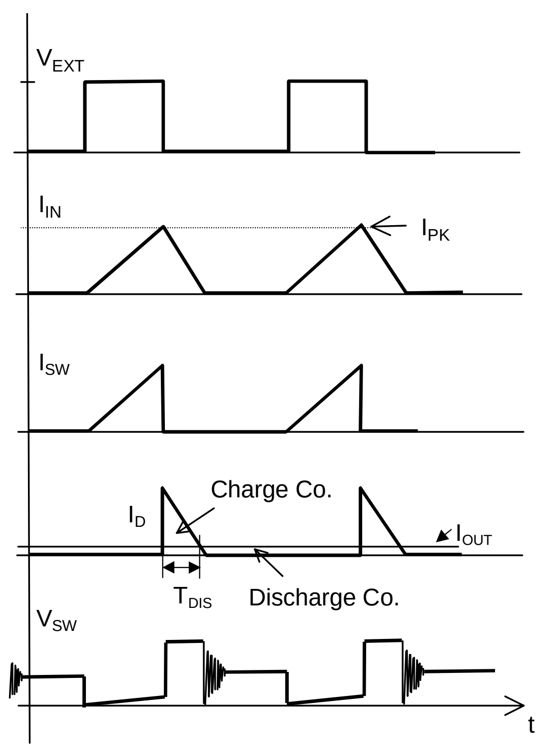
The SS6638G PFM (pulse frequency modulation) converter IC combines a switch mode converter, N-channel power MOSFET, precision voltage reference, and voltage detector in a single monolithic device. It offers both extreme low quiescent current, high efficiency, and very low gate threshold voltage to ensure 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 converters transfer a discrete amount of energy per cycle and regulate the output voltage by modulating the switching frequency with a constant pulse width. Switching frequency depends on load, input voltage, and inductor value, and it can range up to 100kHz. The SW on-resistance is typically 1 to 1.5Ω to minimize switching losses.

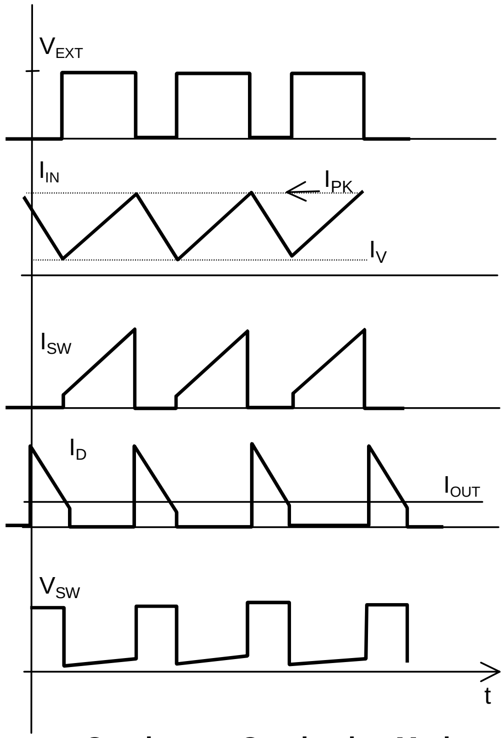
When the output voltage drops, the error comparator enables the 100KHz oscillator that turns the MOSFET on for about 7.5µs and off for 2.5µs. Turning on the MOSFET allows inductor current to ramp up, storing energy in a magnetic field. When The MOSFET turns off, inductor current is forced through the diode to the output capacitor and 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 the 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 converters operate in either discontinuous mode or continuous conduction mode. Continuous conduction mode means that the inductor current does not ramp to zero during each cycle.





Discontinuous Conduction Mode



Continuous Conduction Mode

At the boundary between continuous and discontinuous mode, output current (I_{OB}) 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}+Rs)Ton/L.

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

T_{ON} = Switch ON time

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

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

In the continuous mode, the switching frequency is

$$f_{SW}=\frac{1}{T_{ON}}\frac{(V_{OUT}+V_D-V_{IN})}{(V_{OUT}+V_D-V_{SW})}\times\left[1+\frac{x}{2}\left(\frac{V_{IN}-V_{SW}}{V_{OUT}+V_D-V_{SW}}\right)\right]$$

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

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 SS6638 and 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

$$I_{PK}=\left(\frac{Vin}{Ron+Rs}\right)\left(1-\exp\left(-\frac{Ron+Rs}{L}Ton\right)\right)$$

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

$$\cong\frac{V_{IN}}{L}T_{ON}\quad\text{(Simple losses equation)},$$

where x=(R_{ON}+R_S)T_{ON}/L

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

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

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

in order for the converter to regulate the output.

When loading is over I_{OB}, PFM converter 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

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

Table 1 Indicates resistance and height for each coil.

Power Inductor Type		Inductance (μH)	Resistance (Ω)	Rated Current (A)	Height (mm)
Coilcraft SMT Type (www.coilcraft.com)	DS1608	22	0.10	0.7	2.9
		47	0.18	0.5	
		100	0.38	0.3	
	DO3316	22	0.08	2.7	5.2
		47	0.14	1.8	
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

CAPACITOR SELECTION

A poor choice for an output capacitor can result in poor efficiency and high output ripple. Ordinary aluminum electrolytics, 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 proposetypes. Tantalum capacitors provide still better performance but are more expensive. OS-CON capacitors have extremely low ESR in a small size. If capacitance is reduced, output ripple will increase.

Most of the input supply is provided by 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 the three main considerations in selecting a rectifier diode. Best performance is obtained with a Schottky rectifier diode, such as the 1N5818, or the SS13 and B0530W in surface mount packages. 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, power loss in the winding resistance of inductor can be approximated to

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

where $P_{OUT}=V_{OUT}\times I_{OUT}$; Rs=Inductor DC R;

V_D = Diode drop.

The power dissipated due to the switch loss is

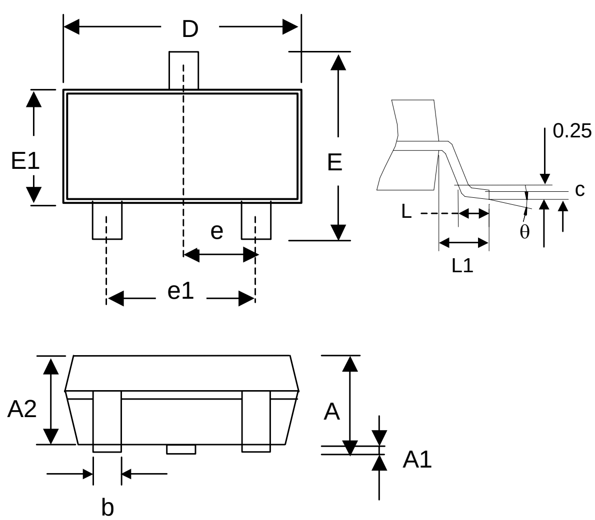
$$PDsw = \frac{2}{3}\left(\frac{T_{ON}}{L}\right)(R_{ON})\left(\frac{V_{OUT}+V_D-V_{IN}}{V_{OUT}}\right)(P_{OUT})$$

The power dissipated in the rectifier diode is

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

PHYSICAL DIMENSIONS (unit: mm)

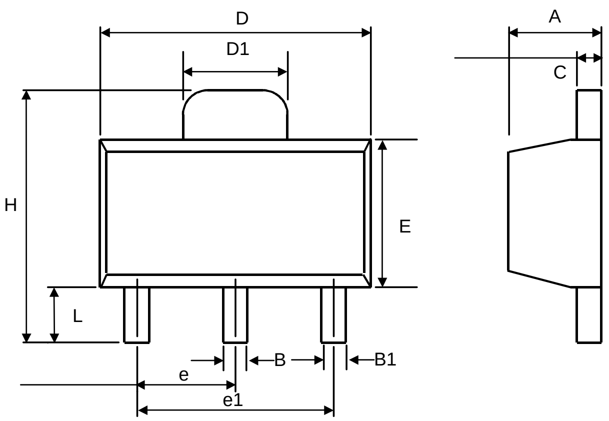
SOT-23-3 (GU)



SYMBOL	MIN	MAX
A	0.95	1.45
A1	0.05	0.15
A2	0.90	1.30
b	0.30	0.50
c	0.08	0.22
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.70
e	0.95 BSC	
e1	1.90 BSC	
L	0.30	0.60
L1	0.60 REF	
θ	0°	8°

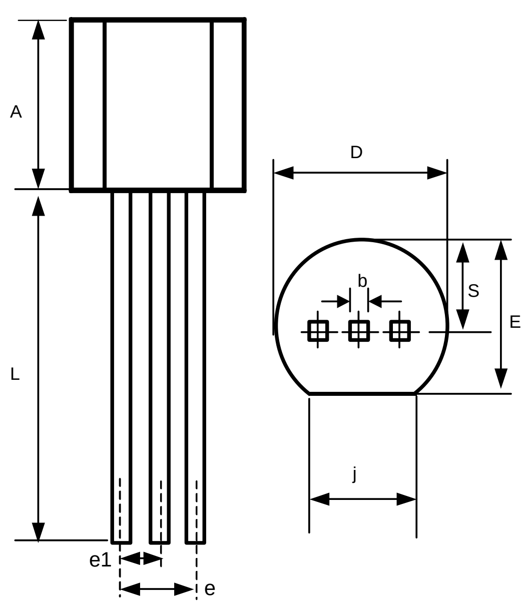
PHYSICAL DIMENSIONS (unit: mm) (Continued)

SOT-89-3 (GX)



SYMBOL	MIN	MAX
A	1.40	1.60
B	0.44	0.56
B1	0.36	0.48
C	0.35	0.44
D	4.40	4.60
D1	1.50	1.83
E	2.29	2.60
e	1.50 BSC	
e1	3.00 BSC	
H	3.94	4.25
L	0.89	1.20

TO-92 (GZ)



SYMBOL	MIN	MAX
A	4.32	5.33
b	0.36	0.47
D	4.45	5.20
E	3.18	4.19
e	2.42	2.66
e1	1.15	1.39
j	3.43	-
L	12.70	-
S	2.03	2.66