1.5MHz, 1A Synchronous Step-Down Converter

❖ GENERAL DESCRIPTION

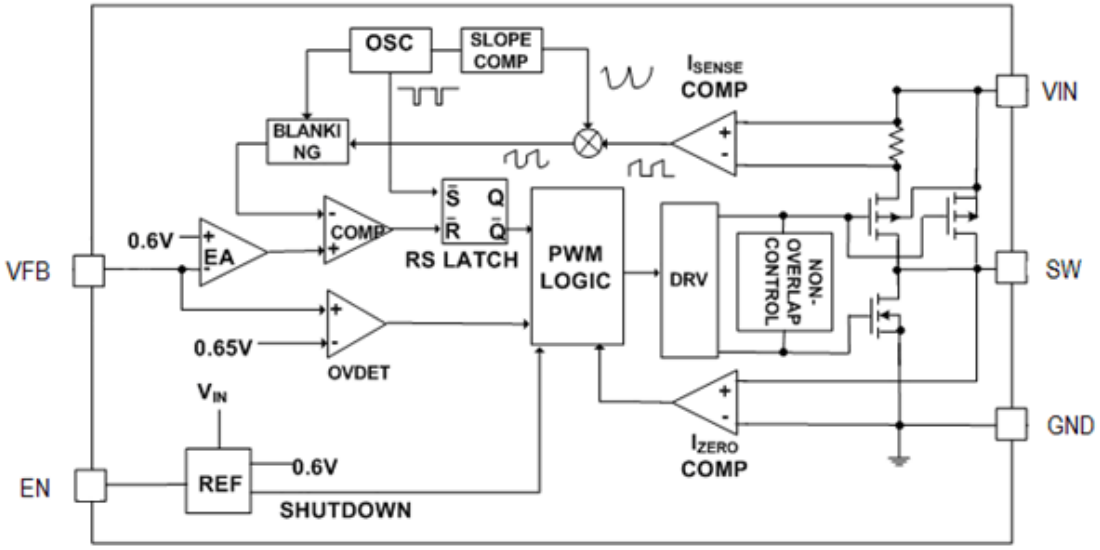
AX3503 is a high efficiency monolithic synchronous buck regulator using a constant frequency, current mode architecture. The device is available in an adjustable version. Supply current with no load is 35uA and drops to <1uA in shutdown. The 2.5V to 6V input voltage range makes AX3503 ideally suited for single Li-Ion, two to four AA battery-powered applications. 100% duty cycle provides low dropout operation, extending battery life in portable systems. PWM pulse skipping mode operation provides very low output ripple voltage for noise sensitive applications. Switching frequency is internally set at 1.5MHz, allowing the use of small surface mount inductors and capacitors. The internal synchronous switch increases efficiency and decreases need of an external Schottky diode. Low output voltages are easily supported with the 0.6V feedback reference voltage. AX3503 is available in small SOT-23-5L and TDFN-6L (2*2) packages.

❖ FEATURES

- 2.5V to 6V Input Voltage Range
- High Efficiency: Up to 94%
- 1.5MHz Constant Frequency Operation
- 1A Output Current at V_{IN}=3.6V and V_{OUT}=1.8V
- Quiescent Current: 35uA (input < 4.2V)
- No Schottky Diode Required
- 100% Duty Cycle in Dropout
- 0.6V Reference Allows Low Output Voltages
- Current Mode Operation for Excellent Line and Load Transient Response
- Current limit, Enable function
- Short Circuit Protect (SCP)
- ≤ 1μA Shutdown Current
- SOT-23-5L and TDFN-6L (2*2) Pb-Free packages

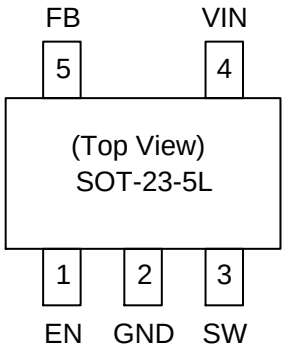
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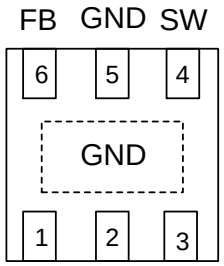
❖ BLOCK DIAGRAM



❖ PIN ASSIGNMENT

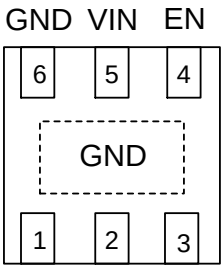
The packages of AX3503 are SOT-23-5L and TDFN-6L (2*2); the pin assignment is given by:





TDFN-6L (2*2) **A Type**

Name	Description
EN	Enable pin H：normal operation L：Shutdown
VIN	Power Supply Input Pin
SW	Switch output pin. Connect external inductor here. Minimize trace area at this pin to reduce EMI.
GND	Ground Pin
FB	Output Feedback pin

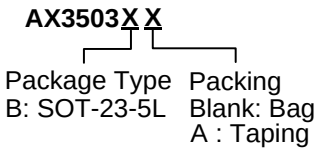


TDFN-6L (2*2) **B Type**

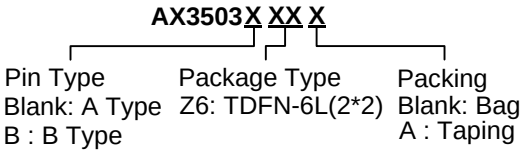
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❖ ORDER/MARKING INFORMATION

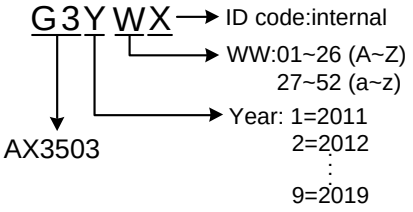
Order Information (SOT-23-5L)



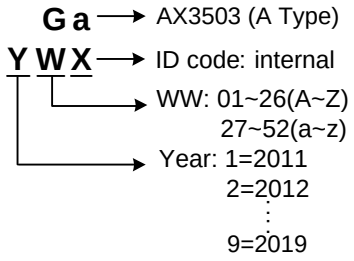
Order Information (TDFN-6L) A/B Type



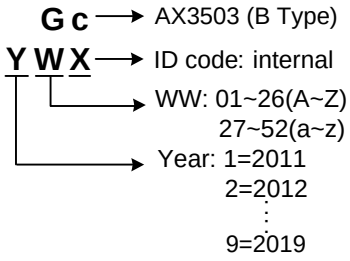
Top Marking (SOT-23-5L)



Top Marking (TDFN-6L) A Type



Top Marking (TDFN-6L) B Type



❖ ABSOLUTE MAXIMUM RATINGS (at T_A = 25°C)

Characteristics		Symbol	Rating	Unit
VIN Pin Voltage		V_{IN}	V_{SS} - 0.3 to V_{SS} + 7	V
Feedback Pin Voltage		V_{FB}	V_{SS} - 0.3 to V_{CC} + 0.3	V
EN Pin Voltage		V_{EN}	V_{SS} - 0.3 to V_{CC} + 0.3	V
Switch Pin Voltage		V_{SW}	V_{SS} - 0.3 to V_{CC} + 0.3	V
Peak SW Sink & Source Current		I_{PSW}	1.4	A
Power Dissipation		PD	(T_J-T_A) / θ_{JA}	mW
Storage Temperature Range		T_{ST}	-40 to +150	°C
Operating Temperature Range		T_{OP}	-40 to +85	°C
Junction Temperature		T_J	+125	°C
Thermal Resistance from Junction to case	TDFN-6L	θ_{JC}	25	°C/W
	SOT-23-5L		110	
Thermal Resistance from Junction to ambient	TDFN-6L	θ_{JA}	120	°C/W
	SOT-23-5L		250	

Note: θ_{JA} is measured with the PCB copper area of approximately 1 in^2(Multi-layer). That need connect to GND pin of the AX3503.

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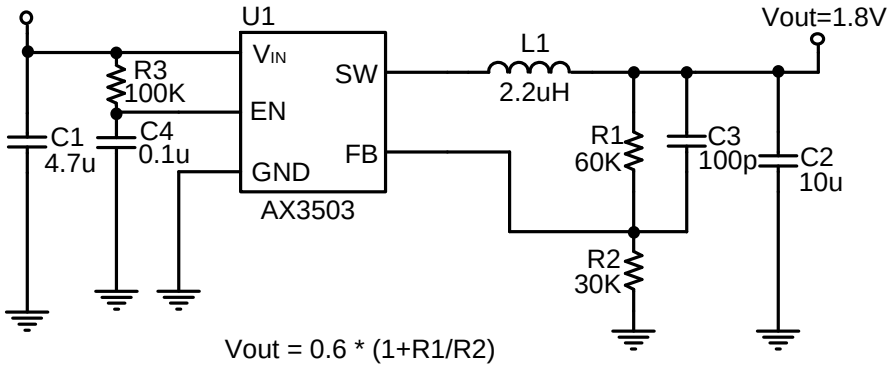
❖ ELECTRICAL CHARACTERISTICS

(V_{IN} = V_{EN}=3.6V, T_A =25°C, unless otherwise specified) (Note)

Characteristics	Symbol	Conditions	Min	Typ	Max	Units
Input Voltage Range	V_{IN}		2.5	-	6	V
Feedback Voltage	V_{FB}	T_A= +25°C	0.588	0.600	0.612	V
		T_A=0°C ≤T_A≤ 85°C	0.587	0.600	0.614	
		T_A=-40°C≤T_A≤ 85°C	0.582	0.600	0.618	
Feedback Bias Current	I_{FB}	V_{FB}=0.65V	-	-	±30	nA
Input DC Supply Current	I_{CC}	V_{FB}=0V	-	35	45	uA
Shutdown Supply Current	I_{SD}	V_{EN} =0V	-	0.1	1	uA
Switching Current Limit	I_{LIMIT}		1.2	1.4	-	A
Line Regulation	$\Delta V_{OUT}/V_{OUT}$	V_{IN} = 2.5V~5.5V	-	0.04	0.4	%/V
Load Regulation	$\Delta V_{OUT}/V_{OUT}$	I_{OUT} = 0.01 to 1A	-	1	-	%
Oscillation Frequency	F_{OSC}	SW pin, V_{IN}=3.6V to V_{OUT} =1.2V	1.2	1.5	2.0	MHz
$R_{DS(ON)}$ of P-CH MOSFET	R_{DSON}	I_{SW}= 300mA	-	0.35	0.50	Ω
$R_{DS(ON)}$ of N-CH MOSFET	R_{DSON}	I_{SW}= -300mA	-	0.30	0.45	Ω
EN pin logic input threshold voltage	V_{ENL}		0.6	-	-	V
	V_{ENH}		-	-	1.2	
EN Pin Input Current	I_{EN}		-	±0.1	±1	uA
Efficiency	EFFI	V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=0.5A	-	92	-	%

Note: 100% production test at +25°C. Specifications over the temperature range are guaranteed by design and characterization.

❖ APPLICATION CIRCUIT



Vout = 0.6 * (1+R1/R2)

R2=10K~30K

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❖ FUNCTION DESCRIPTIONS

Operation

AX3503 is a monolithic switching mode step-down DC-DC converter. It utilizes internal MOSFETs to achieve high efficiency and can generate very low output voltage by using internal reference at 0.6V. It operates at a fixed switching frequency, and uses the slope compensated current mode architecture. This step-down DC-DC Converter supplies 1000mA output current at V_{OUT} = 1.8V with input voltage range from 2.5V to 6V.

Current Mode PWM Control

Slope compensated current mode PWM control provides stable switching and cycle-by-cycle current limit for excellent load and line responses and protection of the internal main switch (P-Ch MOSFET) and synchronous rectifier (N-CH MOSFET). During normal operation, the internal P-Ch MOSFET is turned on for a certain time to ramp the inductor current at each rising edge of the internal oscillator, and switched off when the peak inductor current is above the error voltage. The current comparator, $I_{COMP,}$ limits the peak inductor current. When the main switch is off, the synchronous rectifier will be turned on immediately and stay on until either the inductor current starts to reverse, as indicated by the current reversal comparator, I_{ZERO}, or the beginning of the next clock cycle. The OVDET comparator controls output transient overshoots by turning the main switch off and keeping it off until the fault is no longer present.

Idle Mode Operation

At very light loads, AX3503 automatically enters pulse skipping Mode. In the pulse skipping Mode, the inductor current may reach zero or reverse on each pulse. The PWM control loop will automatically skip pulses to maintain output regulation. The bottom MOSFET is turned off by the current reversal comparator, $I_{ZERO,}$ and the switch voltage will ring. This is discontinuous mode operation, and is normal behavior for the switching regulator.

Maximum Load Current

AX3503 will operate with input supply voltage as low as 2.5V, however, the maximum load current decreases at lower input due to large IR drop on the main switch and synchronous rectifier. The slope compensation signal reduces the peak inductor current as a function of the duty cycle to prevent sub-harmonic oscillations at duty cycles greater than 50%. Conversely the current limit increases as the duty cycle decreases.

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❖ APPLICATION INFORMATION

Setting the Output Voltage

Application circuit item shows the basic application circuit with AX3503 adjustable output version. The external resistor sets the output voltage according to the following equation:

$$V_{OUT} = 0.6V \times \left(1 + \frac{R1}{R2}\right)$$

Table 1 Resistor select for output voltage setting

V_{OUT}	R2	R1
1.2V	30K	30K
1.5V	30K	45K
1.8V	30K	60K
2.5V	30K	95K

Inductor Selection

For most designs, the AX3503 operates with inductors of 1µH to 2.2µH. Low inductance values are physically smaller but require faster switching, which results in some efficiency loss. The inductor value can be derived from the following equation:

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times f_{OSC}}$$

Where is inductor Ripple Current. Large value inductors lower ripple current and small value inductors result in high ripple currents. Choose inductor ripple current approximately 35% of the maximum load current 1000mA, ΔI_L=350mA.

Table 2 Inductor select for output voltage setting (V_{CC}=3.6V)

V_{OUT}	1.2V	1.5V	1.8V	2.5V
Inductor	2.2uH	2.2uH	2.2uH	2.2uH
Part Number WE-TPC	7440430027	7440430027	7440430027	7440430022

Note: Part type MH or M (www.we-online.com)

For output voltages above 2.0V, when light-load efficiency is important, the minimum recommended inductor is 2.2µH. For optimum voltage-positioning load transients, choose an inductor with DC series resistance in the 50mΩ to 150mΩ range. For higher efficiency at heavy loads (above 200mA), or minimal load regulation (but some transient overshoot), the resistance should be kept below 100mΩ. The DC current rating of the inductor should be at least equal to the maximum load current plus half the ripple current to prevent core saturation (1000mA+170mA).

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Input Capacitor Selection

The input capacitor reduces the surge current drawn from the input and switching noise from the device. The input capacitor impedance at the switching frequency shall be less than input source impedance to prevent high frequency switching current passing to the input. A low ESR input capacitor sized for maximum RMS current must be used. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. A 4.7μF ceramic capacitor for most applications is sufficient.

Output Capacitor Selection

The output capacitor is required to keep the output voltage ripple small and to ensure regulation loop stability. The output capacitor must have low impedance at the switching frequency. Ceramic capacitors with X5R or X7R dielectrics are recommended due to their low ESR and high ripple current.

Compensation Capacitor Selection

The compensation capacitors for increasing phase margin provide additional stability. It is required and more than 22p, Refer to Demo Board Schematic, The optimum values for C3 is 100pF.

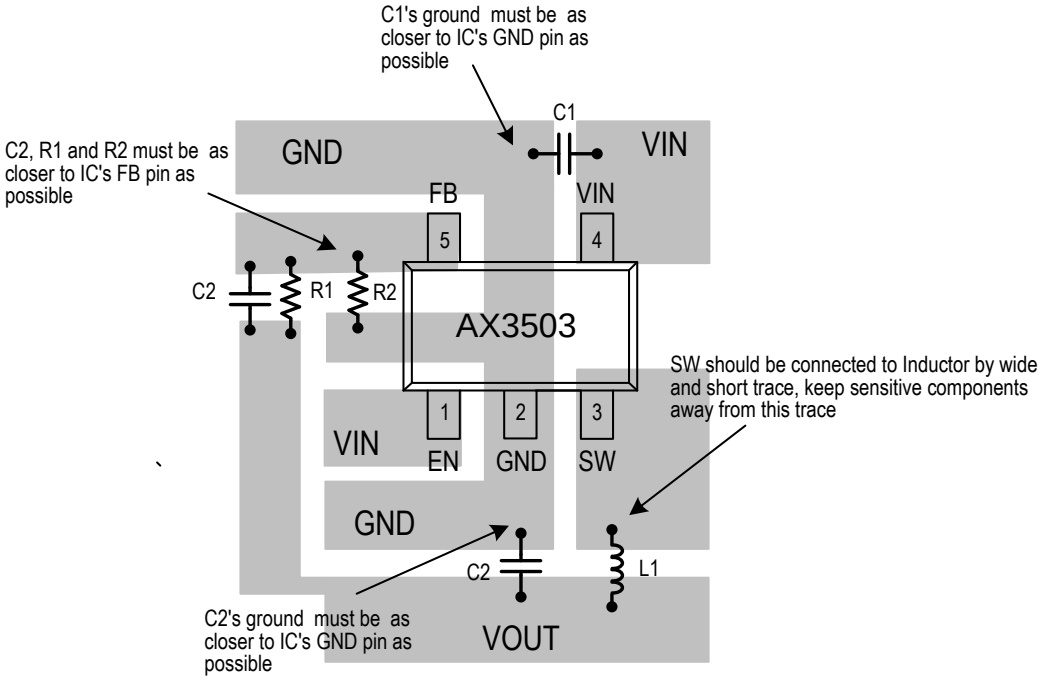
Layout Guidance

When laying out the PC board, the following suggestions should be taken to ensure proper operation of the AX3503. These items are also illustrated graphically in below.

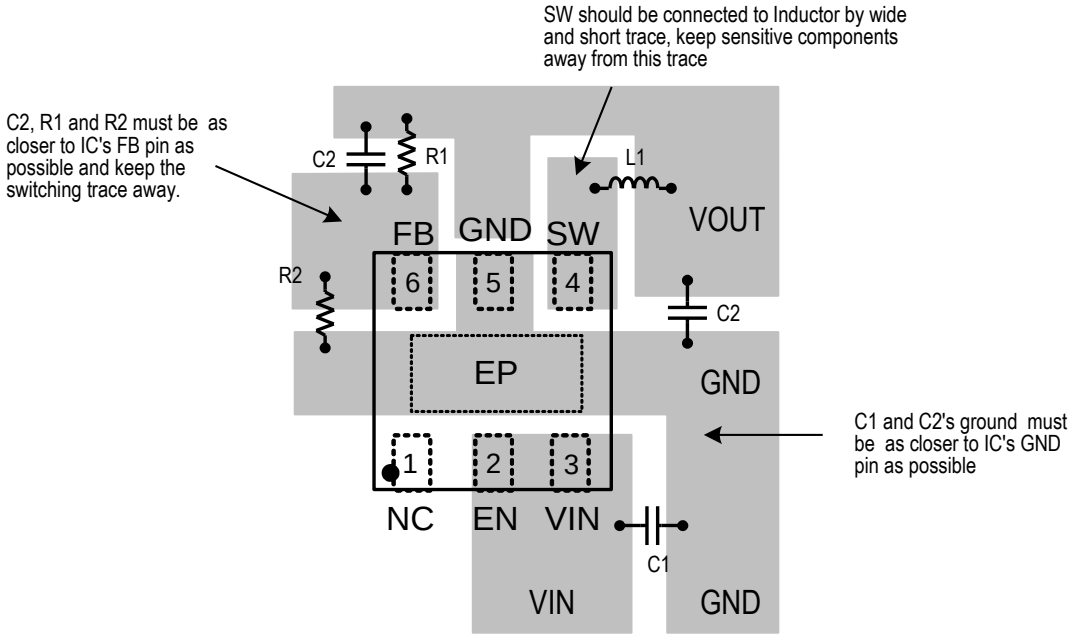
1. The power traces, including the GND trace, the SW trace and the V_{IN} trace should be kept short, direct and wide to allow large current flow. Put enough multiply-layer pads when they need to change the trace layer.
2. Connect the input capacitor C1 to the V_{IN} pin as closely as possible to get good power filter effect.
3. Keep the switching node, SW, away from the sensitive FB node.
4. Do not trace signal line under inductor.

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TSOT-23-5L Layout Guide



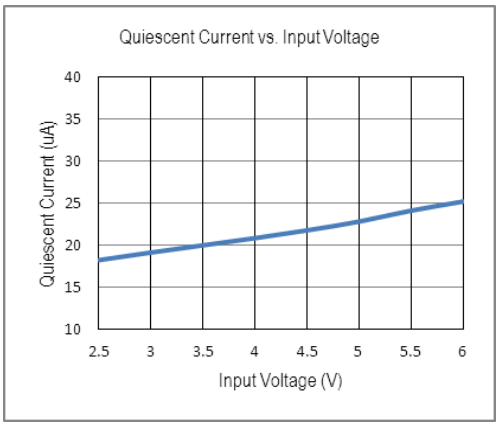
TDFN-6L Layout Guide



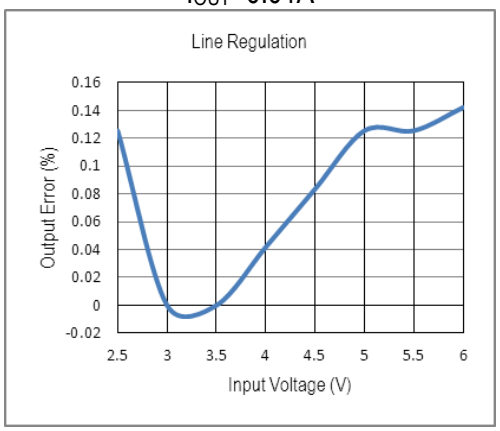
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❖ TYPICAL CHARACTERISTICS

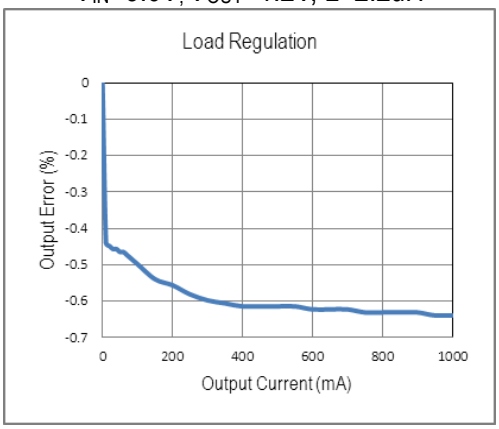
Quiescent Current vs. Input Voltage



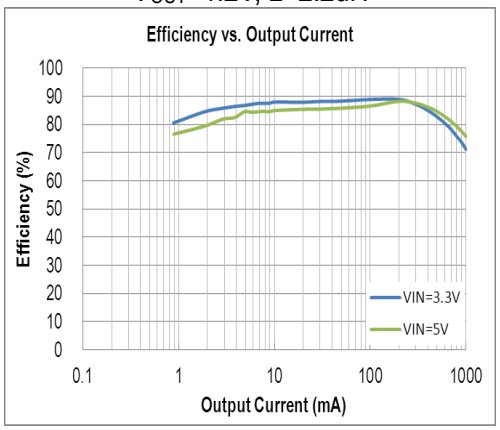
Line Regulation
I_{OUT}=0.01A



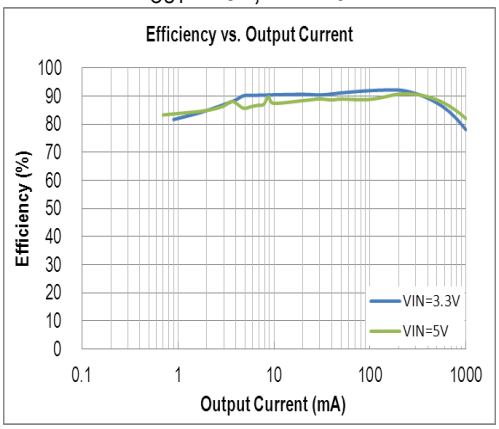
Load Regulation
V_{IN}=3.6V, V_{OUT}=1.2V, L=2.2uH



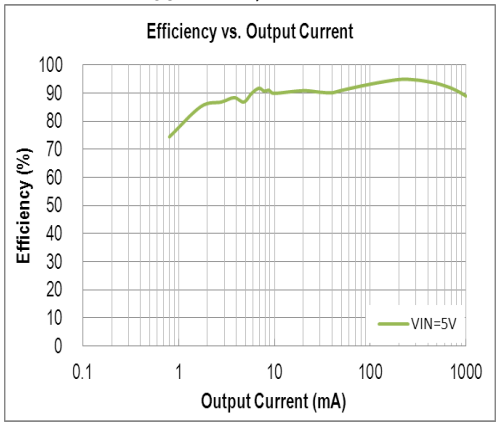
Efficiency vs. Output Current
V_{OUT}=1.2V, L=2.2uH



Efficiency vs. Output Current
V_{OUT}=1.8V, L=2.2uH



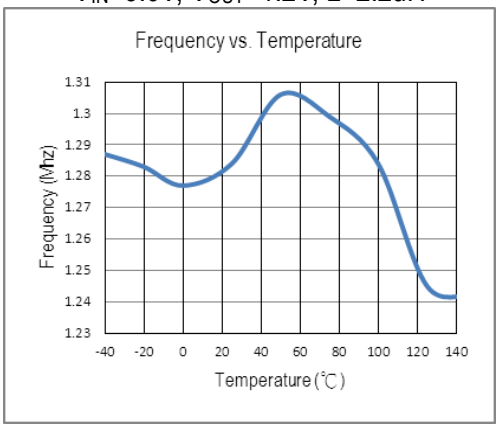
Efficiency vs. Output Current
V_{OUT}=3.3V, L=2.2uH



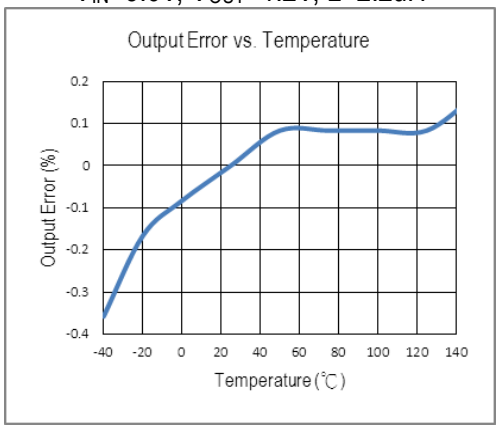
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❖ TYPICAL CHARACTERISTICS (CONTINUES)

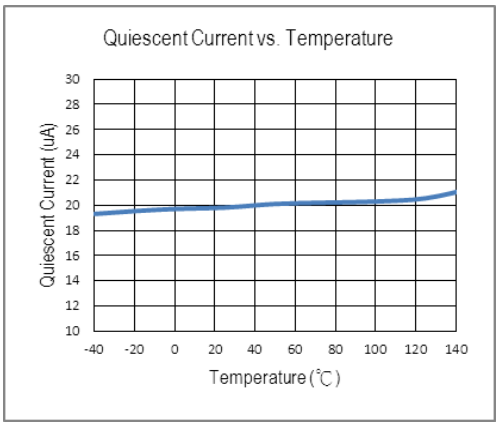
Frequency vs. Temperature
V_{IN}=3.6V, V_{OUT}=1.2V, L=2.2uH



Output Error vs. Temperature
V_{IN}=3.6V, V_{OUT}=1.2V, L=2.2uH



Quiescent Current vs. Temperature
V_{IN}=3.6V

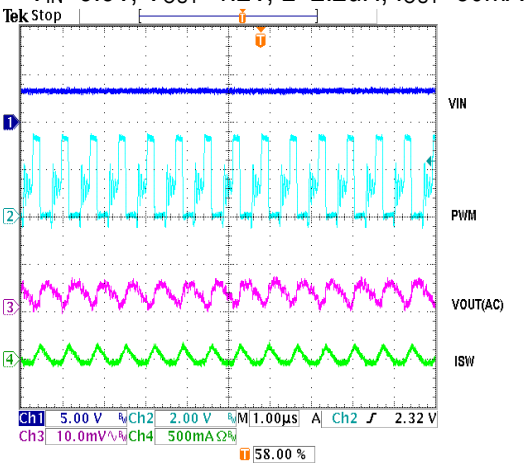


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❖ TYPICAL CHARACTERISTICS (CONTINUES)

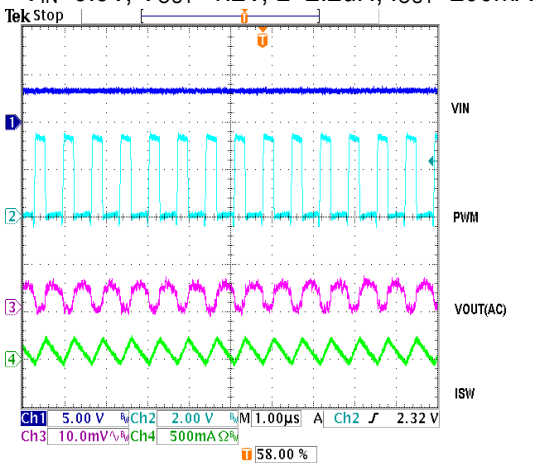
Output Ripple(light Load)

V_{IN}=3.3V, V_{OUT}=1.2V, L=2.2uH, I_{OUT}=80mA



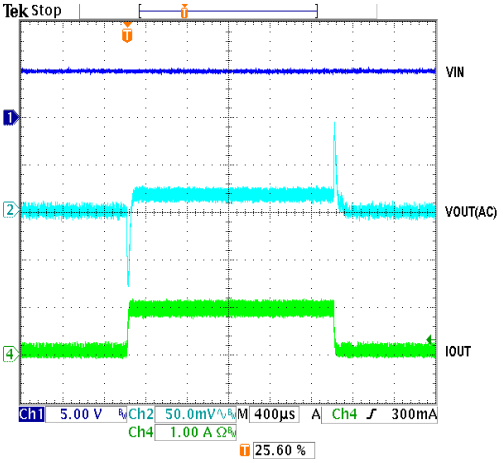
Output Ripple(Heavy Load)

V_{IN}=3.3V, V_{OUT}=1.2V, L=2.2uH, I_{OUT}=200mA



Transient

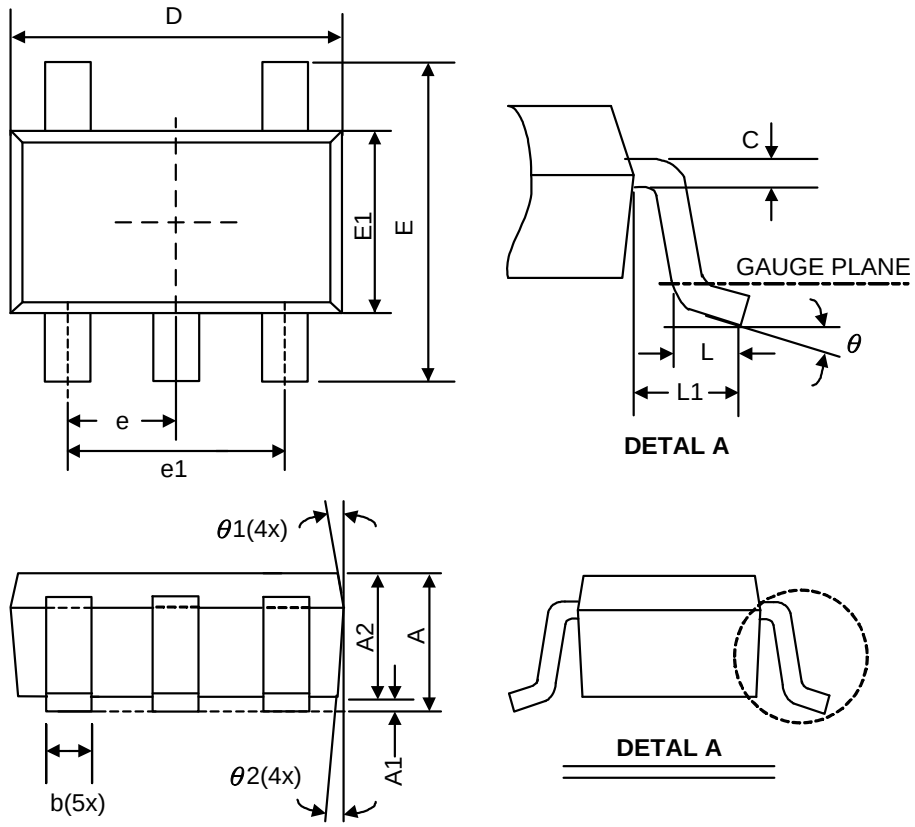
V_{IN}=3.3V, V_{OUT}=1.2V, L=2.2uH, I_{OUT}=0A~1A



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❖ PACKAGE OUTLINES

(1) SOT-23-5L

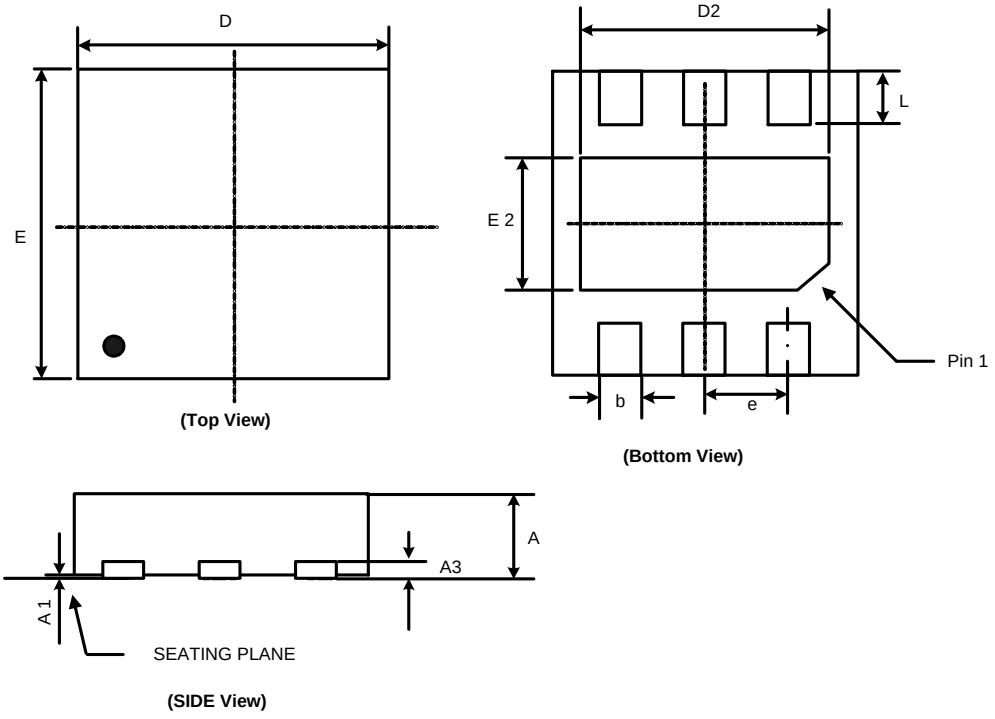


Symbol	Dimensions in Millimeters			Dimensions in Inches		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	-	-	1.45	-	-	0.057
A1	0	0.08	0.15	0	0.003	0.006
A2	0.9	1.1	1.3	0.035	0.043	0.051
b	0.3	0.4	0.5	0.012	0.016	0.02
C	0.08	0.15	0.22	0.003	0.006	0.009
D	2.7	2.9	3.1	0.106	0.114	0.122
E1	1.4	1.6	1.8	0.055	0.063	0.071
E	2.6	2.8	3	0.102	0.11	0.118
L	0.3	0.45	0.6	0.012	0.018	0.024
L1	0.5	0.6	0.7	0.02	0.024	0.028
e1	1.9 BSC			0.075 BSC		
e	0.95 BSC			0.037 BSC		
θ	0°	4°	8°	0°	4°	8°
θ 1	5°	10°	15°	5°	10°	15°
θ 2	5°	10°	15°	5°	10°	15°

JEDEC outline: MO-178 AA

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(2) TDFN-6L (2*2 0.75mm)



Symbol	Dimensions in Millimeters			Dimensions in Inches		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.7	0.75	0.8	0.028	0.03	0.031
A1	0	0.02	0.05	0	0.001	0.002
A3		0.203 REF.			0.008 REF.	
b	0.2	0.28	0.35	0.009	0.011	0.013
D	1.95	2	2.05	0.077	0.079	0.081
D2	1.0	1.5	1.7	0.039	0.059	0.067
E	1.95	2	2.05	0.077	0.079	0.081
E2	0.5	0.9	1.1	0.02	0.035	0.043
e		0.65 BSC.			0.026 BSC.	
L	0.2	0.3	0.4	0.008	0.012	0.016

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