5V Input 2.5A/3A 1.5MHz Synchronous Step-Down DC/DC Converter

❖ GENERAL DESCRIPTION

AX3703A can operate with input voltage from 2.5V to 5.5V and provide output range from 0.6V to input level, thanks to its 100% duty cycle operation. AX3703A is a 1.5MHz, 2.5A/3A constant on-time (COT) controlled synchronous step-down converter.

AX3703A consumes extremely low 15μA quiescent current hence achieves superior light load efficiency. The constant on-time control scheme simplifies loop compensation and offers excellent load transient response.

AX3703A has cycle-by-cycle current limit and hiccup mode to protect over-load or short circuit fault conditions. The high gain error amplifier in the control loop provides excellent load and line regulation. Proprietary adaptive on-time helps AX3703A to achieve nearly constant switching frequency across load range.

AX3703A is available in low profile SOT23-5L, SOT23-6L and 8 leads DFN 2mm x 2mm packages.

❖ FEATURES

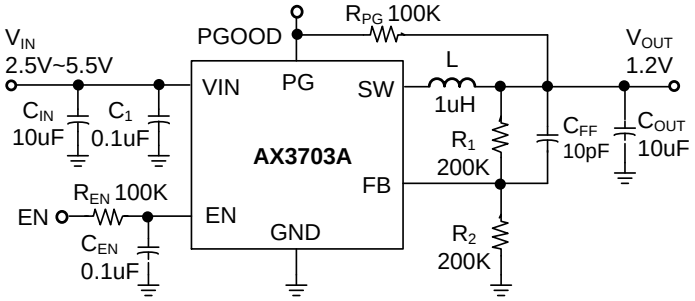
- AX3703AZ8A: Built-in 90mΩ/60mΩ Power Switches
- AX3703AZ8A: 3A Continuous Output Current
- AX3703ACA: 2.5A Continuous Output Current , 3A Peak Output Current
- AX3703ACA: Built-in 94mΩ/76mΩ Power Switches
- Wide Input Range from 2.5V to 6V
- Proprietary Fast Transient Constant On Time Architecture Stable with low ESR Ceramic Output Capacitors
- 1.5MHz Switching Frequency
- 15μA Low Quiescent Current
- +/- 2% 0.6V Feedback Voltage
- 1.21V Accurate Enable Threshold
- Up to 95% Efficiency
- 100% Duty Cycle Operation
- Thermal Shutdown Protection
- Internal 1msec Soft-Start

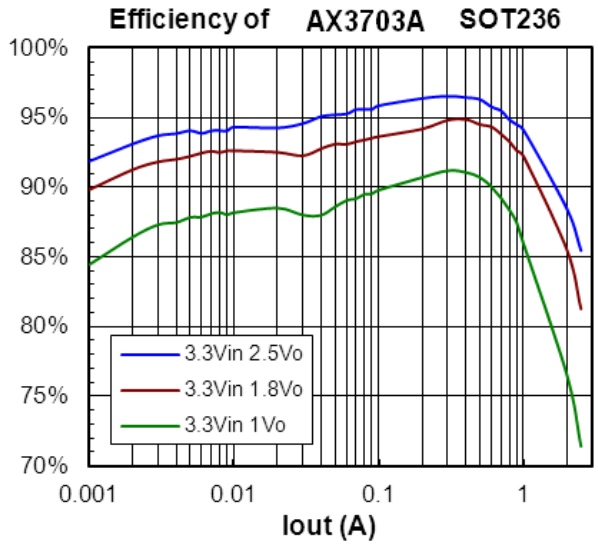
- Cycle-by-cycle Current Limit Protection
- Over-Load and Short Circuit Hiccup Mode
- Open Drain Power Good Indication
- Output Discharge
- Available in Small SOT23_5L, SOT23_6L and DFN2x2_8L
- Pb-Free RoHS Compliant
- RoHS and Halogen free compliance.

❖ APPLICATION

- WiFi RF Moudules
- Smart Phone and Tablets
- Solid-State and Hard Disk Drives
- DC/DC Micro Modules

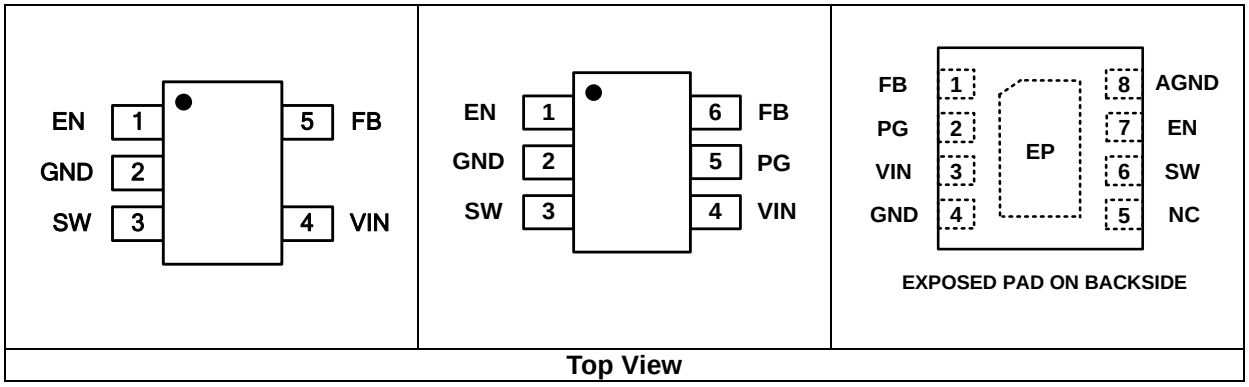
❖ TYPICAL APPLICATION





❖ PIN ASSIGNMENT

The package of AX3703A ; the pin assignment is given by:

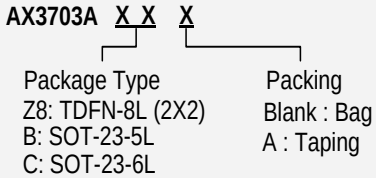
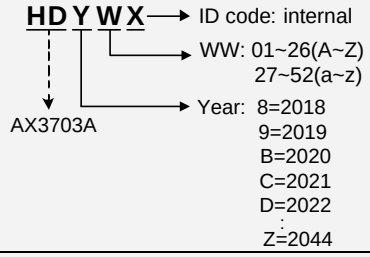


Top View

Pin Description

SOT235 Pin No.	OT236 Pin No.	DFN2x2_8L Pin No.	Symbol	Description
1	1	7	EN	Regulator Enable Control Input with accurate 1.21V enable threshold which can be used to build precision R-C turn-on delay and input under-voltage lockout. Don't float this pin. This pin has a pull-down resistor of typically 1MΩ to GND. • Drive EN above 1.21V to turn on the converter • Drive EN below 1.11V to turn off the converter and discharge output
2	2	4, EP	GND	Ground
3	3	6	SW	Power Switch Node
4	4	3	VIN	Input Supply Voltage
-	5	2	PG	Power Good Open-drain Output. Connect a 100kΩ pull-up resistor to V_{IN} or V_{OUT}.
5	6	1	FB	Voltage Feedback Input. Connect a resistor divider between output and FB to program the output voltage. VFB is regulated to 0.6V.
-		8	AGND	Analog Ground

❖ ORDER/MARKING INFORMATION

<table>
<tr><th>Order Information</th><th>Top Marking (SOT-23-5L)</th></tr>
<tr><td> 
</td><td> 
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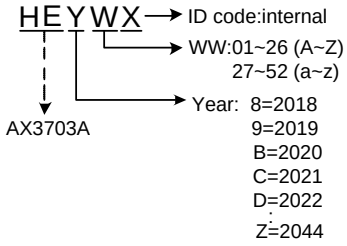
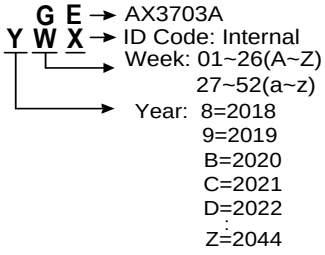
<tr><th>Top Marking (SOT-23-6L)</th><th>Top Marking (TDFN-8L)</th></tr>
<tr><td> 
</td><td> 
</td></tr>
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❖ ABSOLUTE MAXIMUM RATINGS

V_{IN} …….. …….. -0.3V to +6.5V
V_{SW} …….. … -0.3V to V_{IN} +0.3V
Dynamic V_{SW} in 10ns Duration -2V to V_{IN} +2V
The other Pins …… ……. -0.3V to +6.5V

Junction Temperature Range … -40°C to +150°C
Storage Temperature Range . . -65°C to +150°C
Lead Temperature(Soldering 10s) … …. … 260°C
ESD …….. ….. Class 2

Recommend Operating Conditions (Note2)

Input Voltage (V_{BAT}) …… ….. +2.5V to 5.5V
Output Voltage (V_{OUT}) …… … … +0.6V to V_{IN}

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

Thermal information (Note3, 4)

Maximum Power Dissipation(T_A=25°C)
SOT235(6) 0.48W
DFN2x2_8L 2.1W

Thermal Resistance(θ_{JA}) SOT235(6) ….. …. 210°C/W
Thermal Resistance(θ_{JC}) SOT235(6) ……. …. 32°C/W
Thermal Resistance(θ_{JA}) DFN2x2_8L ….. …. 46°C/W
Thermal Resistance(θ_{JC}) DFN2x2_8L ……. .. 10°C/W

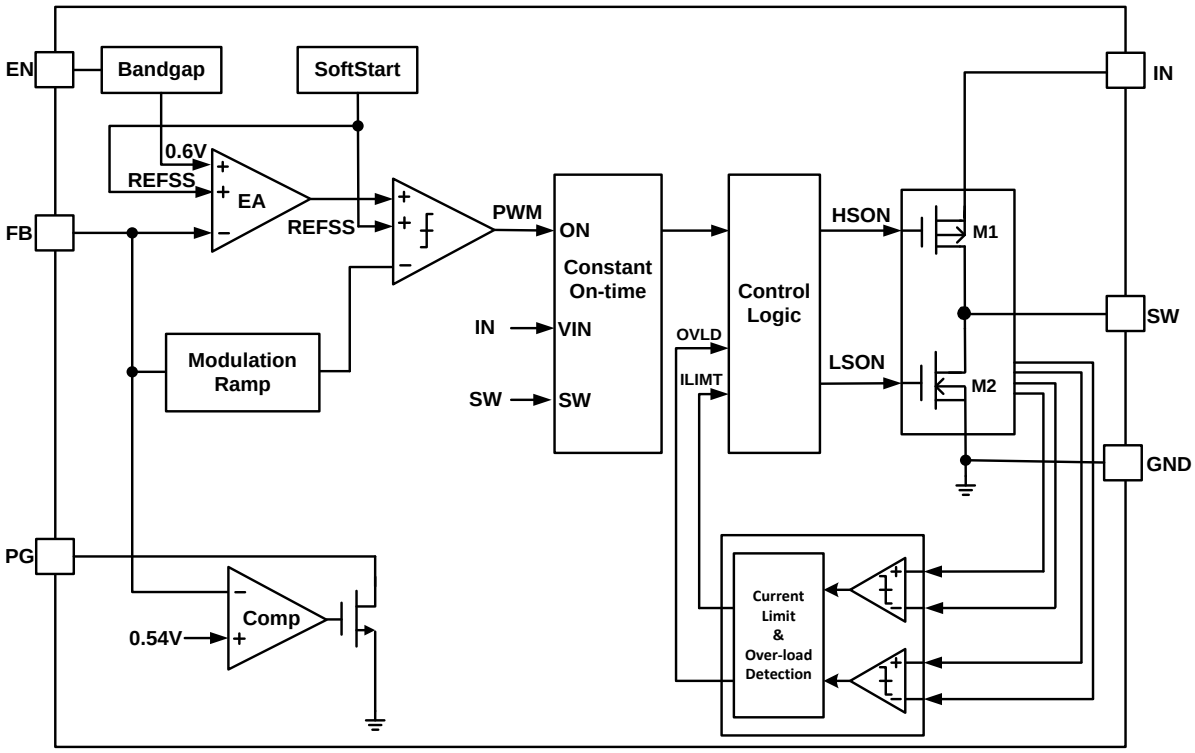
Note (1): Stress exceeding those listed “Absolute Maximum Ratings” may damage the device.
Note (2): The device is not guaranteed to function outside of the recommended operating conditions.
Note (3): Measured on JESD51-7, 4-Layer PCB.
Note (4): The maximum allowable power dissipation is a function of the maximum junction temperature T_{J_MAX}, the junction to ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by $P_{D\_MAX}= (T_{J\_MAX}-T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.

❖ ELECTRICAL CHARACTERISTICS

TA = 25°C, VIN=5V, unless otherwise noted. Typical values are at VIN = VEN = 5V.

Characteristics	Conditions	Min	Typ	Max	Units
Input Voltage Range V_{IN}		2.5		6.0	V
Shutdown Current	V_{EN} = 0V, V_{IN} = 5.5V		0.1	1	μA
Input Under Voltage Lockout Threshold	V_{IN} Increasing	2.3	2.4	2.5	V
Input Under Voltage Lockout Hysteresis			280		mV
Quiescent Current I_Q	V_{FB} = 0.63V		15	20	μA
Feedback Voltage V_{FB}		588	600	612	mV
Feedback Current I_{FB}		-50	1	+50	nA
HS Switch Current Limit			5		A
HS Main Switch On Resistance	AX3703ACA, V_{IN}=5V		94		mΩ
LS Synchronous Switch On Resistance	AX3703ACA, V_{IN}=5V		76		mΩ
HS Main Switch On Resistance	AX3703AZ8A, V_{IN}=5V		90		mΩ
LS Synchronous Switch On Resistance	AX3703AZ8A, V_{IN}=5V		60		mΩ
HS Leakage Current	V_{IN} = 5.5V, V_{EN} = V_{SW} = 0V		0.1	2	μA
LS Leakage Current	V_{IN} = V_{SW} = 5.5V, V_{EN} = 0V		0.1	2	μA
Min Off Time	AX3703ACA		95		ns
Min Off Time	AX3703AZ8A		70		ns
PWM Switching Frequency	I_{IOUT} = 1A		1.5		MHz
PGOOD Output Low Voltage	V_{FB} =0.5V, sink 1mA		0.2	0.3	V
PGOOD Output Leakage Current	V_{FB} = 0.63V , VPGOOD = V_{IN} = 5.5V		0.01	0.2	μA
PGOOD Under Voltage Rise Threshold	V_{FB} ramp up from under voltage	-13	-10	-7	%
PGOOD Under Voltage Fall Threshold	V_{FB} ramp down from regulation		-15		%
PGOOD Delay	PGOOD going High to Low		30		μs
EN On Threshold	V_{EN} ramp up	1.18	1.21	1.24	V
EN Off Threshold	V_{EN} ramp down		1.11		
EN Internal Pull Down Resistor		700	1000	1300	kΩ
Thermal Shutdown			160		℃
Thermal Shutdown Hysteresis			30		℃

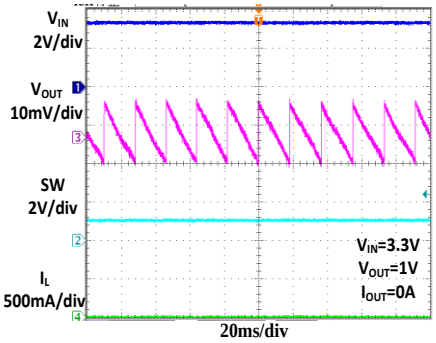
❖ Functional Block Diagram



❖ TYPICAL PERFORMANCE CHARACTERISTICS

CIN=10uF, COUT=10uF, L=1uH, TA=+25℃.

Steady State Test



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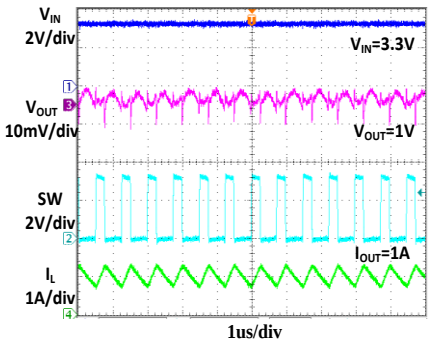

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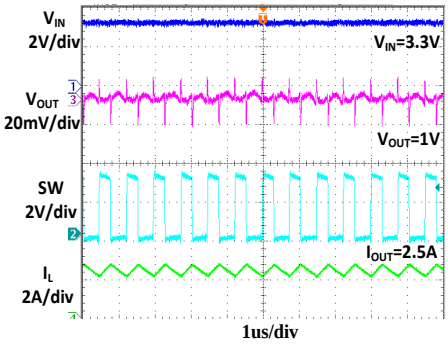

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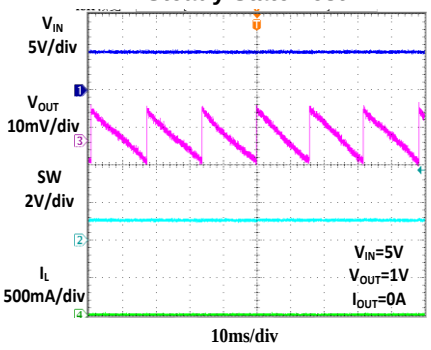

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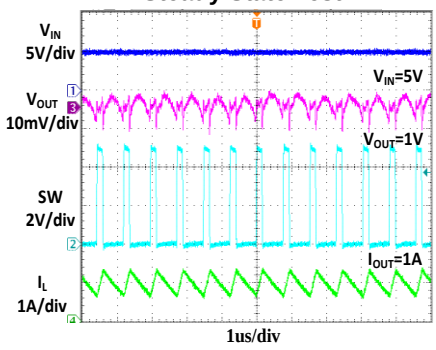

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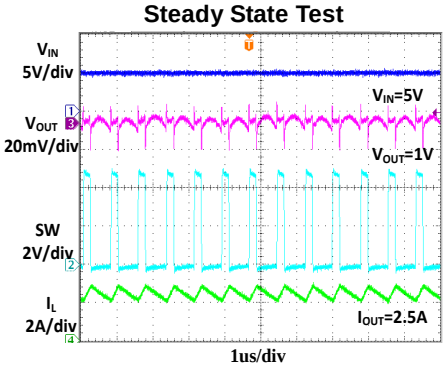

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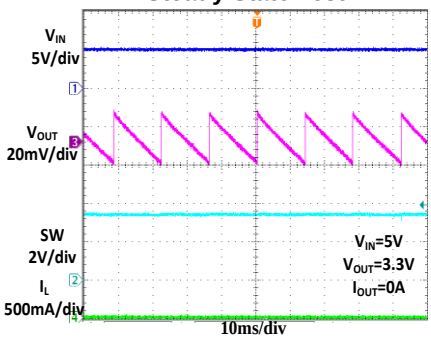

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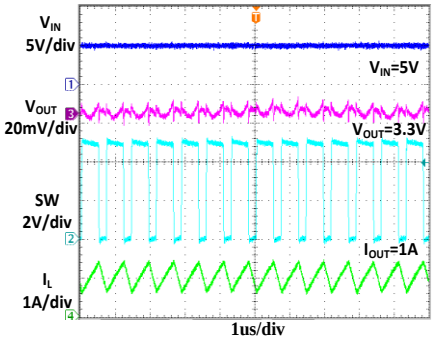

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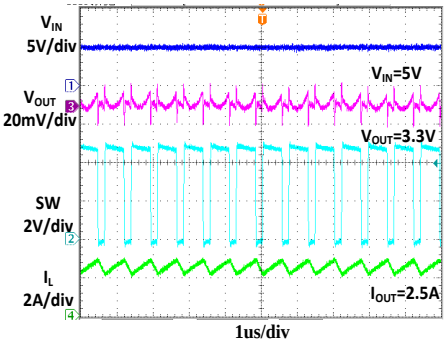
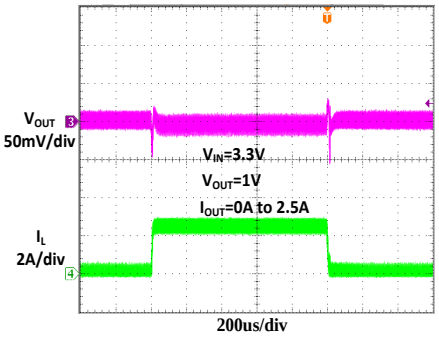
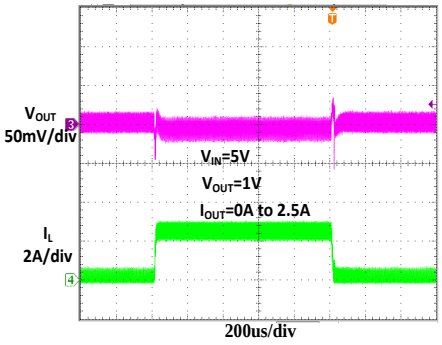


CIN=10uF, COUT=10uF, L=1uH, TA=+25℃

Load Transient Response



Load Transient Response



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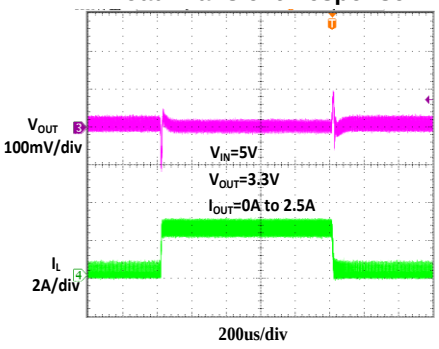
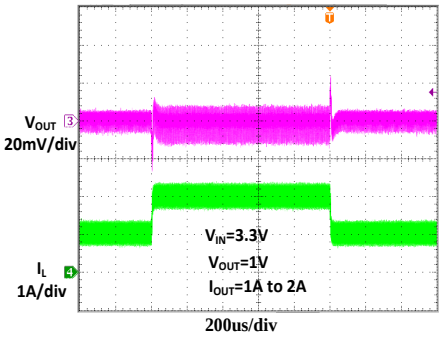
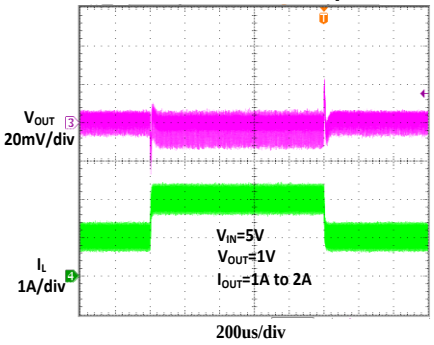


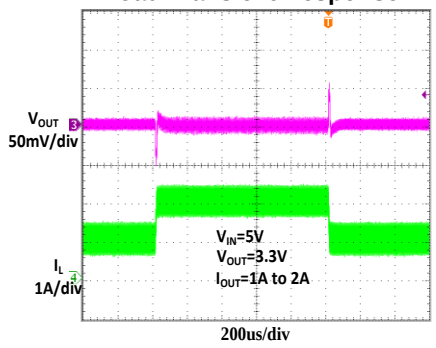
Load Transient Response



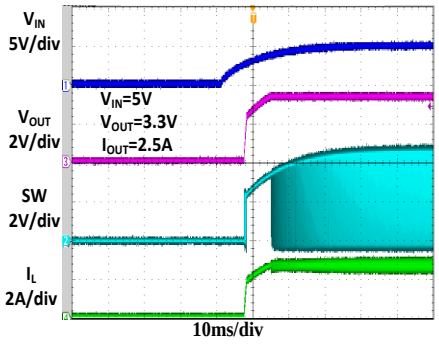
Load Transient Response



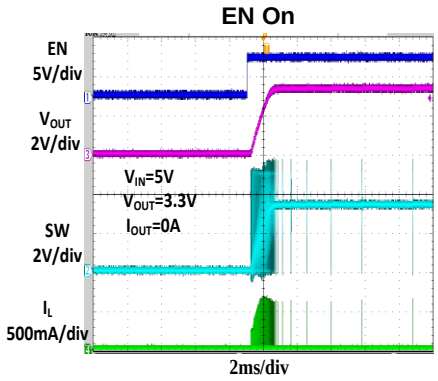
Load Transient Response



Vin Power On



EN On



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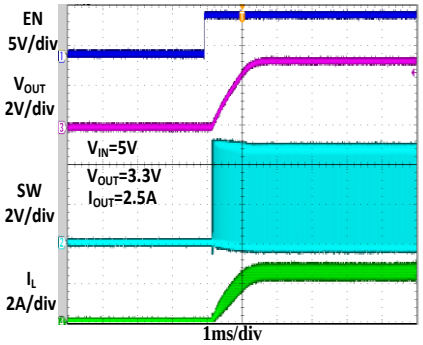
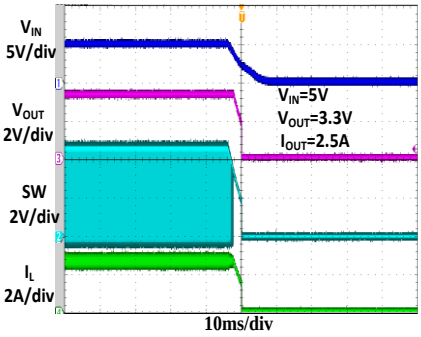


CIN=10uF, COUT=10uF, L=1uH, TA=+25℃

Vin Power Off



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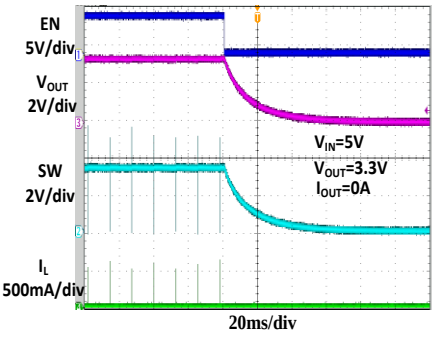
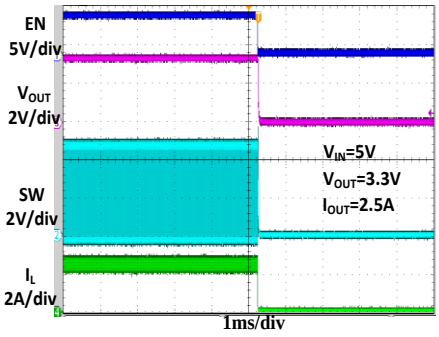
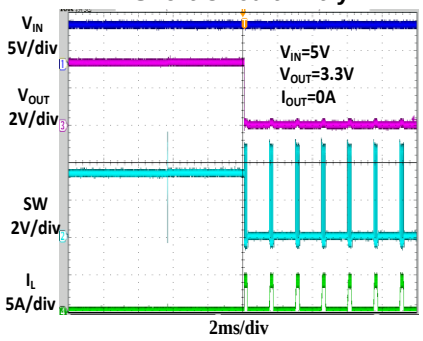


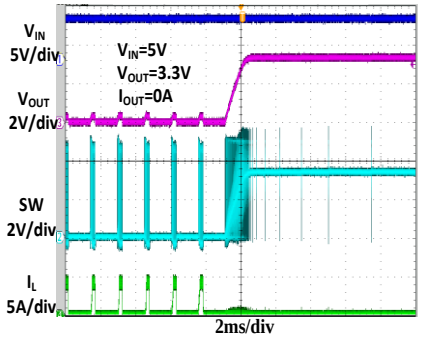
EN Off



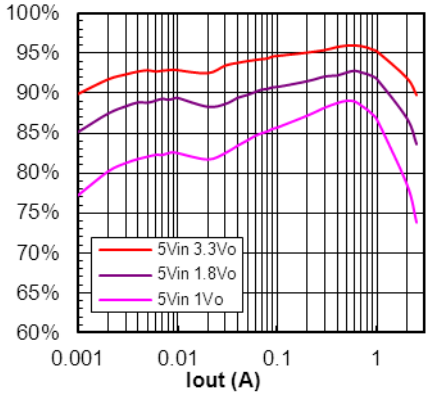
Short Circuit Entry



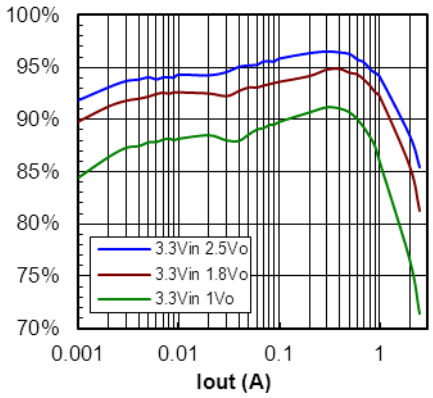
Short Circuit Recovery



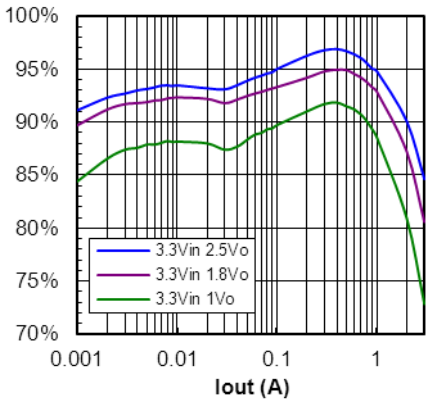
Efficiency of AX3703ACA SOT23



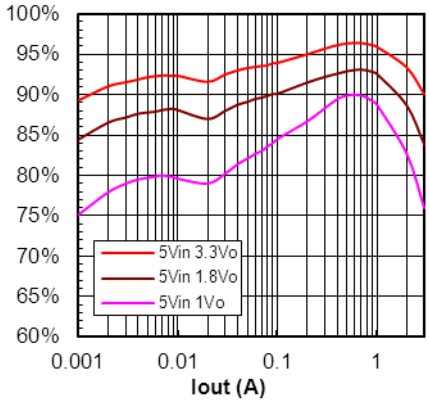
Efficiency of AX3703ACA SOT23



Efficiency of AX3703AZ8A DFN2x2_8L



Efficiency of AX3703AZ8A DFN2x2_8L



Enable

When input voltage is above the under voltage lock-out threshold, AX3703A can be enabled by pulling the EN pin to above 1.21V. AX3703A is disabled if the EN pin is pulled below 1.1V. The enable/disable threshold for EN pin is accurately designed to be 1.21V and 1.11V respectively, so one can also use external resistor divider to program the desired input under-voltage lockout level.

Soft Start

AX3703A has built-in soft start of 1ms. During the soft start period, output voltage is ramped up linearly to the regulation voltage, independent of the load current level and output capacitor value.

Light Load Operation

In light load condition where the converter operates in discontinuous mode, AX3703A cuts down its quiescent current to as low as 15uA and achieves excellent light load efficiency.

Theory of Operation

AX3703A is a constant on-time control synchronous step-down converter that offers excellent transient response over a wide range of input voltage. It achieves superior light-load efficiency with extremely low quiescent current.

Constant On-time Control

Constant on-time control step-down converters turn on HS immediately when FB droops below reference. The HS is turned on for a pre-determined period (on-time) of time to ramp up the inductor current, and then the LS will be turned on to ramp down the inductor current. The cycle repeats itself if FB droops below reference again. AX3703A uses proprietary technique to take into account the load current impact and adjusts the on-time accordingly to achieve a constant switching frequency over entire load current range.

For AX3703A, the on-time is approximately:

$$T_{ON} = \frac{V_{OUT}}{V_{IN}} \cdot 0.66\mu$$

Due to its immediate response on FB voltage droop and simplified loop compensation, constant on-time offers a superior transient response compare to traditional fixed frequency PWM control step-down converters.

Current Limit and Hiccup Mode

AX3703A has cycle-by-cycle HS current limit protection to prevent inductor current from running away. Once HS current limit is triggered, AX3703A will turn on LS and wait for the inductor to drop down to a pre-determined level before the HS can be turned on again. If this current limit condition is repeated for a sustained long period of time, AX3703A will consider it over-load or short circuit. Either way, AX3703A will enter hiccup mode, where it stop switching for a pre-determined period of time before automatically re-try to start up again. It always starts up with soft-start to limit inrush

current and avoid output overshoot.

Power Good Indication

AX3703A has open drain Power GOOD indicator PGOOD pin. When PGOOD is connected with external pull up resistor, it will be pulled up if output voltage is higher than 90% of regulation, otherwise PGOOD is pulled down by the internal open drain NMOS.

Application Information

Setting the Output Voltage

External feedback resistors are used to set the output voltage. Refer to typical application circuit on page1, the top feedback resistor R1 has some impact on the loop stability, so its recommended range is between 100kΩ-300kΩ. For any chosen R1, the bottom feedback resistor R2 can be calculated as:

$$R_2 = \frac{R_1}{\frac{V_{OUT}}{0.6} - 1}$$

Inductor Selection

The recommended inductor value for AX3703A is between 0.33uH to 1uH. Usually the inductor value is chosen to satisfy a desired ripple current:

$$L = \frac{V_{OUT} \cdot (V_{IN} - V_{OUT})}{V_{IN} \cdot f_{SW} \cdot \Delta I}$$

where ΔI is the inductor ripple current.

With the chosen ΔI, the peak inductor current will be:

$$I_{PK} = I_{LOAD} + \frac{1}{2} \cdot \Delta I$$

Input Bypass Capacitor Selection

The input current to the step-down converter is discontinuous with very sharp edges, therefore an input bypass capacitor is required. For best performance, it's recommended to use low ESR ceramic capacitors and place them as close to the input pin as possible. For lowest temperature variations, use X5R or X7R dielectric ceramic capacitors.

The RMS current of the input capacitor is approximately:

$$I_{CIN\_RMS} = I_{OUT}\sqrt{D(1-D)}$$

From the equation, it can be seen that the highest RMS current occurs when D is 0.5:

$$I_{CIN\_RMS} = \frac{1}{2} I_{OUT}$$

Choose the capacitor with RMS current rating higher than 1/2 I_{OUT}

The power dissipation on the input capacitor can be estimated with the RMS current and the ESR resistor. Electrolytic or tantalum capacitors can also be used, but due to their significantly higher ESR, a small size ceramic capacitor should be placed as close to the IC as possible.

The voltage ripple on the input capacitor, neglecting the ESR impact, can be calculated as:

$$\Delta V_{CIN} = \frac{I_{LOAD}}{f_{SW} \cdot C_{IN}} \cdot \frac{V_{OUT}}{V_{IN}} \cdot (1 - \frac{V_{OUT}}{V_{IN}})$$

Output Capacitor Selection

An output capacitor is required to obtain a stable output voltage. To minimize the output voltage ripple, ceramic capacitors should be used, and the ripple voltage can be estimated as:

$$\Delta V_{OUT} = \frac{1}{8} \cdot (1 - \frac{V_{OUT}}{V_{IN}}) \cdot \frac{V_{OUT}}{L} \cdot \frac{1}{(f_{SW})^2 \cdot C_{OUT}}$$

If electrolytic or tantalum capacitors are used, the ESR will dominate the output voltage ripple:

$$\Delta V_{OUT} = (1 - \frac{V_{OUT}}{V_{IN}}) \cdot \frac{V_{OUT}}{f_{SW} \cdot L} \cdot R_{ESR}$$

PCB Layout Recommendation

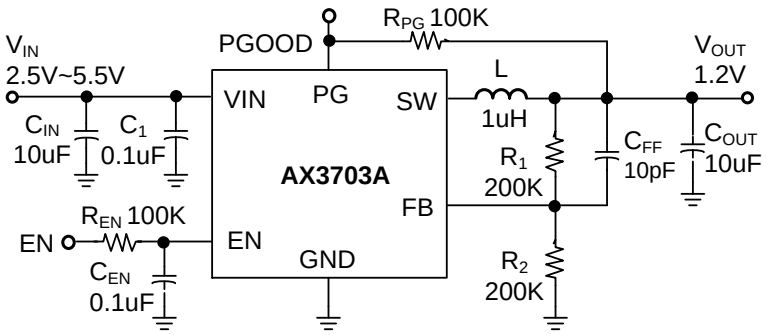
The physical design of the PCB is the final stage in the design of power converter. If designed improperly, the PCB could radiate excessive EMI and contribute instability to the power converter. Therefore, following the PCB layout guidelines below can ensure better performance of AX3703A.

(1). The loop (Vin-SW-L-Cout-GND) indicates a high current path. The traces within the loop should be kept as wide and short as possible to reduce parasitic inductance and high-frequency loop area. It is also good for efficiency improvement.

(2). Input capacitor as close as possible to the IC Pins (Vin and GND) and the input loop area should be as small as possible to reduce parasitic inductance, input voltage spike and noise emission.

(3). Feedback components (R_1, R_2 and C_{FF}) should be routed as far away from the inductor and the SW Pin as possible to minimize noise and EMI issue.

❖ AX3703A Application Schematic



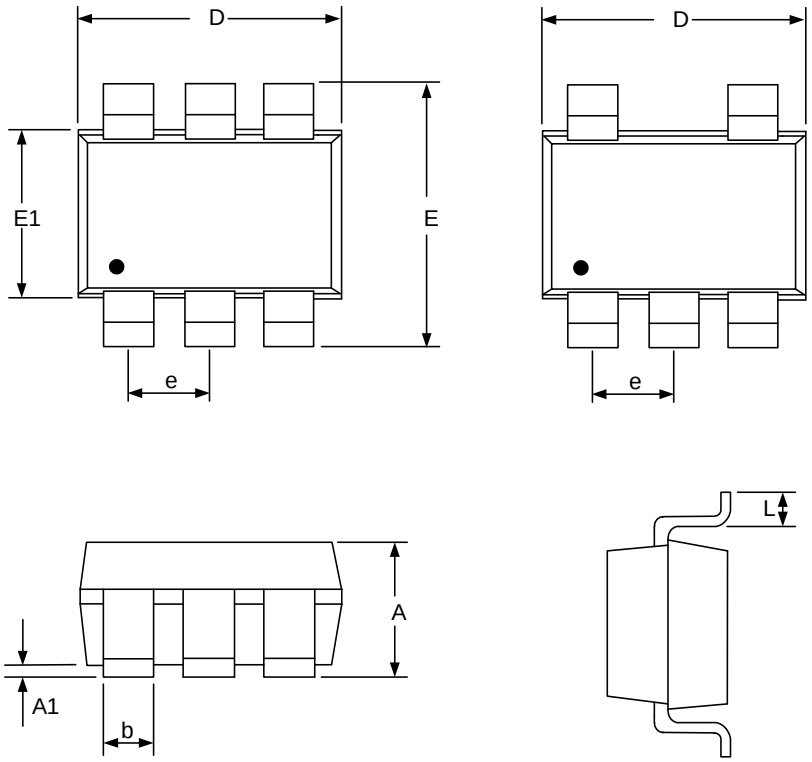
EVB BOM List

Qty	Ref	Value	Description	Package
1	C_{IN}	10μF	Ceramic Capacitor, 10V, X5R	0805
1	C_{OUT}	10μF	Ceramic Capacitor, 10V, X5R	0805

2	C1, C_{EN}	0.1μF		Ceramic Capacitor, 10V, X5R	0603
1	C_{FF}	10pF		Ceramic Capacitor, 10V, X5R	0603
1	L	1uH (0.47uH~1.5μH)		Inductor, GSTM4020P-1R0M, 22mΩ , 8.5A	SMD
1	R1	Vout=3.3V	200KΩ	Resistor, ±1%	0603
		Vout=2.5V	240KΩ		
		Vout=1.8V	200KΩ		
		Vout=1.2V	200KΩ		
		Vout=1.0V	100KΩ		
1	R2	Vout=3.3V	43KΩ	Resistor, ±1%	0603
		Vout=2.5V	75KΩ		
		Vout=1.8V	100KΩ		
		Vout=1.2V	200KΩ		
		Vout=1.0V	150KΩ		
2	R_{PG}, R_{EN}	100KΩ		Resistor, ±1%	0603
1	Power IC	AX3703A		Step-Down DC/DC Converter	SOT23_5(6)L DFN2x2_8L

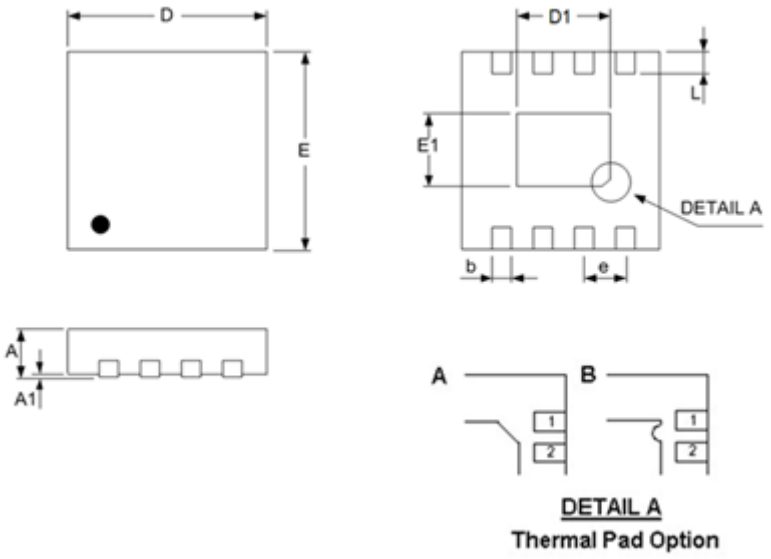
❖ PACKAGE OUTLINES

SOT23_5L and SOT23_6L Outline Dimensions
Unit: inches/mm



SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.89	1.45	0.035	0.057
A1	0.00	0.15	0.000	0.006
b	0.30	0.50	0.012	0.020
D	2.70	3.10	0.106	0.122
E1	1.40	1.80	0.055	0.071
e	0.95 BSC		0.037 BSC	
E	2.60	3.00	0.102	0.118
L	0.30	0.60	0.012	0.024

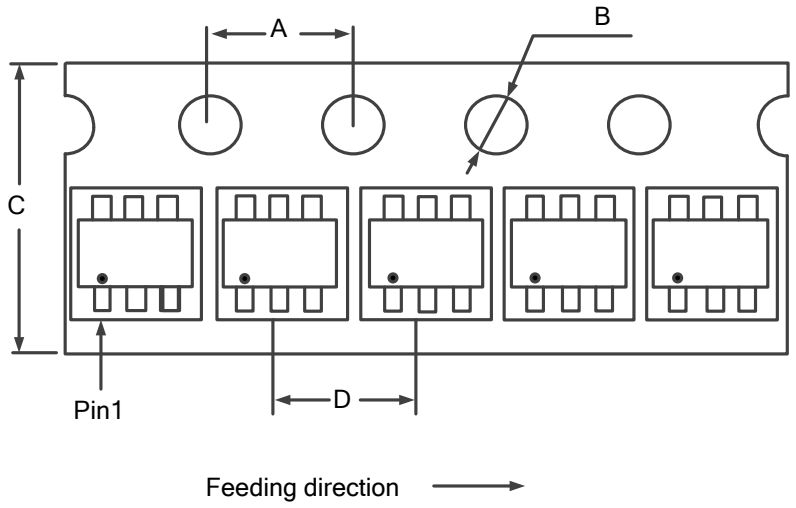
DFN 8L 2x2mm Outline Dimensions
Unit: inches/mm



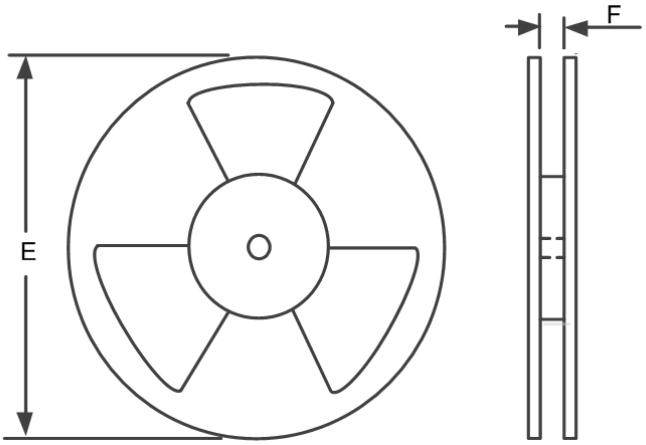
SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.70	0.80	0.028	0.031
A1	0.00	0.05	0.000	0.002
b	0.18	0.30	0.007	0.012
D	1.90	2.10	0.075	0.083
D1	1.10	1.40	0.043	0.055
E	1.90	2.10	0.075	0.083
E1	0.60	0.80	0.024	0.031
e	0.50		0.020	
L	0.25	0.45	0.010	0.018

❖ CARRIER TAPE DIMENSION

1. Orientation / Carrier Tape Information : SOT23_5L and SOT23_6L



1. Rokreel Information :

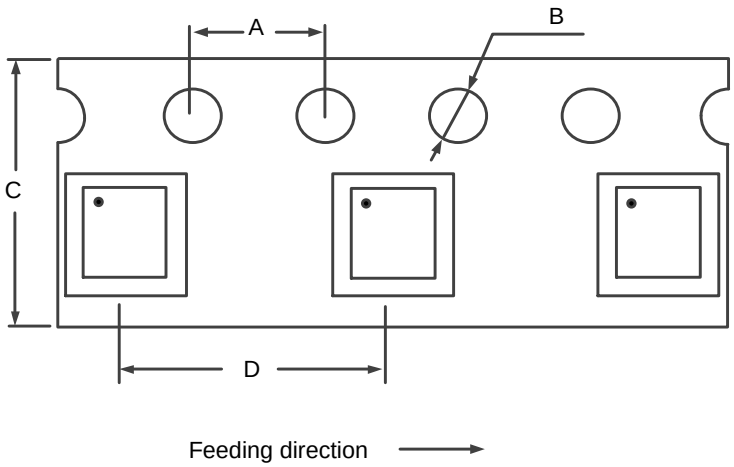


2. Dimension Details :

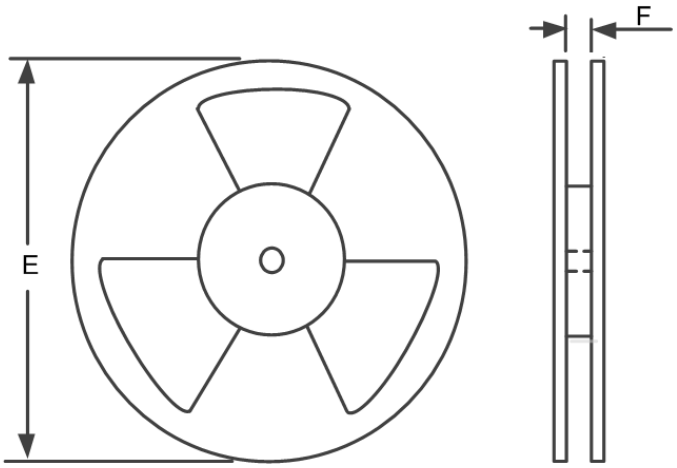
PKG Type	A	B	C	D	E	F	Q'ty/Reel
SOT23_6L	4.0 mm	1.5 mm	8.0 mm	4.0 mm	7 inches	9.0 mm	3,000

Carrier Tape & Reel Dimensions

1. Orientation / Carrier Tape Information : DFN 8L 2x2mm



2. Rokreel Information :



3. Dimension Details :

PKG Type	A	B	C	D	E	F	Q'ty/Reel
DFN2x2	4.0 mm	1.5 mm	8.0 mm	4.0 mm	7 inches	9.0 mm	3,000