18V 3A 500kHz Synchronous Step-Down DC/DC Converter

❖ GENERAL DESCRIPTION

The AX3903 is a high efficiency, 3A current mode synchronous step-down DC/DC converter with a wide input voltage range from 4.7V to 18V. The device integrates high side and low side MOSFETs to achieve high efficiency conversion. The current mode architecture supports fast transient response and internal compensation.

The AX3903 provides complete fault protection including input under-voltage lockout, output short circuit protection, over current protection, and thermal shutdown. The switching frequency is internally set at 500kHz.

To improve the light load efficiency, AX3903 has proprietary light load power saving mode (PSM) to minimize the switching loss by reducing the switching frequency.

The AX3903 is available in the SOT23_6L package.

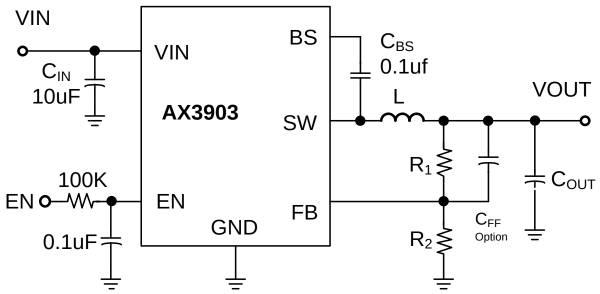
❖ FEATURES

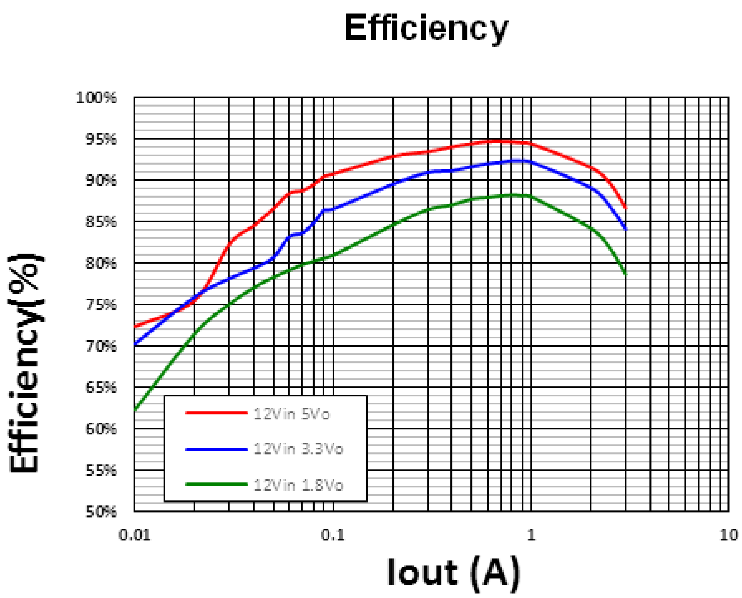
- Input Voltage Range from 4.7V to 18V
- Adjustable Output Voltage from 0.8V to 12V
- Support 100% Duty Cycle Operation
- 500kHz Switching Frequency
- Built-in 110mΩ/60mΩ Power Switch
- 3A Continuous Output Current
- High Efficiency up to 95%
- Internal 1msec Soft-Start
- Peak Current Mode Operation
- Over-temperature Protection
- Input Under Voltage Lockout (UVLO)
- Cycle-by-Cycle Current Limit Protection
- Over-Load and Short Circuit Protection
- Thermal Shutdown Protection
- Available in a Small SOT23_6L Package
- Pb-Free RoHS Compliant
- RoHS and Halogen free compliance

❖ APPLICATION

- Wireless and DSL Card
- Portable/Handheld Device
- STB, TV, Sound Bar, MP3 Player
- Microprocessor and DSP Core Supply

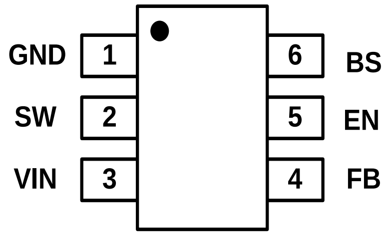
❖ TYPICAL APPLICATION





❖ PIN ASSIGNMENT

The package of AX3903 is SOT23_6L; the pin assignment is given by:



SOT23_6L

TOP VIEW

Name	Description
GND	Ground This is the reference of the ground connection for all components in the power supply.
SW	Power Switches Node
VIN	Main Input Supply Voltage
FB	Voltage Feedback
EN	Regulator Enable Control Input. There is an internal 1000kΩ from EN to GND. •Drive EN High Level to turn on the converter •Drive EN Low Level to turn off the converter
BS	Supply input for the high-side FET gate drive circuit. Connect a 0.1uF ceramic capacitor between BS and SW pins.

❖ ORDER/MARKING INFORMATION

Order Information	Top Marking
AX3903 XX X Package Type C: SOT-23-6L Packing Blank : Tube A : Taping	GI YWX X → ID code:internal W → WW:01~26 (A~Z) 27~52 (a~z) Y → Year: 8=2018, 9=2019, B=2020, C=2021, D=2022, :, Z=2044 GI → AX3903

❖ ABSOLUTE MAXIMUM RATINGS

VIN, SW Voltage ……………………….........+20V
Dynamic V_{SW} in 10ns Duration .... –3V to VIN+3V
BS-SW Voltage .... +6V
FB, EN Voltage .... +6V

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

Recommend Operating Conditions (Note2)

Input Voltage (V_{IN}) ………...….……....+ 4.7V V to +18V

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

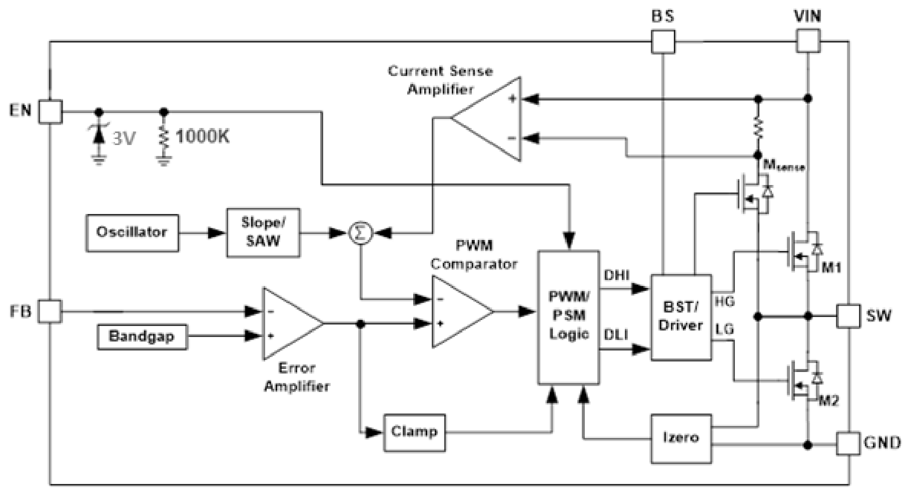
Thermal information (Note3)

Maximum Power Dissipation(T_A=+25°C)
SOT23_6L………………………………….......1.25W

Thermal Resistance (θ_{JA}) ……..……..…136.68°C/W
Thermal Resistance (θ_{JC}) …..…..…..…81.68°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)/θ_{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.

❖ Functional Block Diagram



❖ ELECTRICAL CHARACTERISTICS

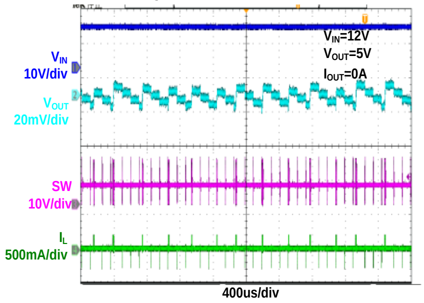
Recommended Operating Conditions, TA = +25°C, VIN=12V, unless otherwise noted.

PARAMETER	TEST CONTITIONS	MIN	TYP	MAX	UNIT
Input Supply Voltage		4.7		18	V
Shutdown Current	V_{EN} = 0V		0.1	5	μA
Regulated Feedback Voltage V_{REF}	4.7V≦V_{IN}≦18V	0.78	0.80	0.82	V
VIN Under Voltage Lockout Threshold	Rising Threshold		4.4		V
Input Under Voltage Lockout Hysteresis			310		mV
High Side MOSFET On Resistance	I_{SW}=0.2A		110		mΩ
Low Side MOSFET On Resistance	I_{SW}=0.2A		60		mΩ
Switch Current Limit			5.1		A
SW Leakage Current	V_{EN}=0V, V_{SW}=0V		1	10	μA
Oscillator Frequency		400	500	600	kHz
Short Circuit Oscillator Frequency	V_{FB}=0V		160		kHz
Min. On-Time for HS Switch			120		ns
Maximum Duty	V_{FB}=0.7V		100		%
EN On Threshold		1.2			V
EN Off Threshold				0.5	V
EN Pull Down Resister		400	1000		kΩ
EN Internal Voltage Clamp			3		V
Soft Start Time			1		msec
Thermal Shutdown Threshold			160		℃

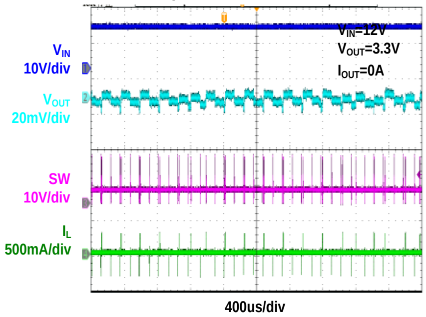
❖ TYPICAL PERFORMANCE CHARACTERISTICS

CIN=10μF, COUT=44μF, L=6.8μH for VOUT=5V; L=4.7μH for VOUT 3.3V; L=2.2μH for VOUT=1.2V, TA =+25℃

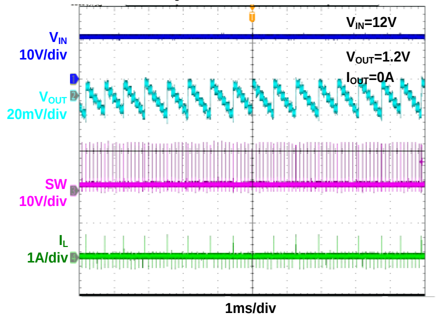
Steady State Test



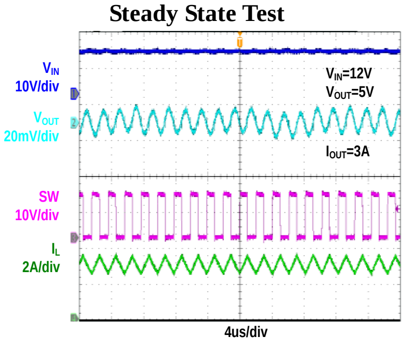
Steady State Test



Steady State Test



Steady State Test



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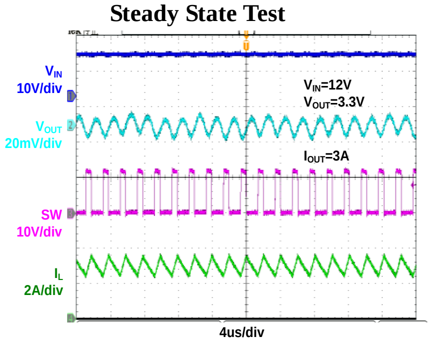
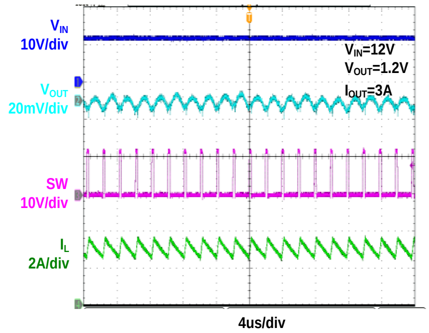
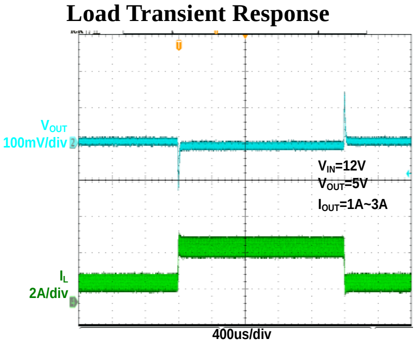


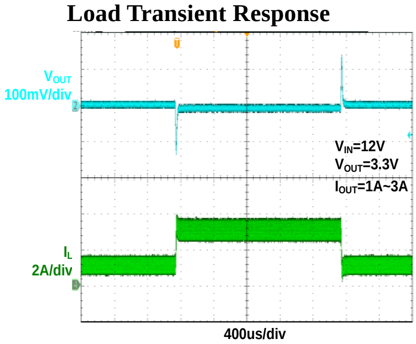
Steady State Test



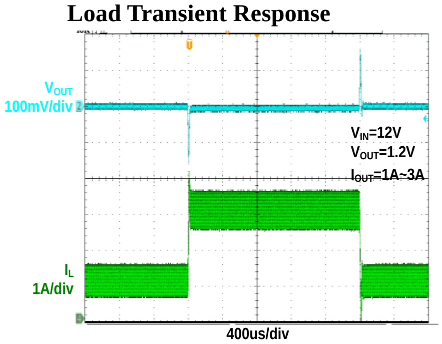
Load Transient Response



Load Transient Response

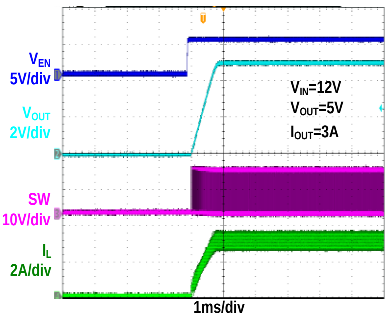


Load Transient Response

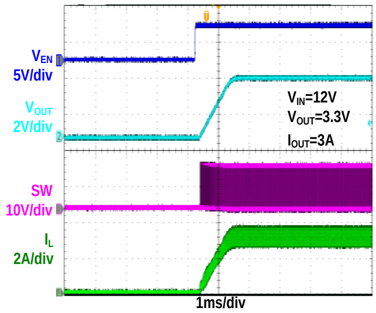


C_{IN}=10μF, C_{OUT}=44μF, L=6.8μH for V_{OUT}=5V; L=4.7μH for V_{OUT} 3.3V; L=2.2μH for V_{OUT}=1.2V, T_A =+25℃

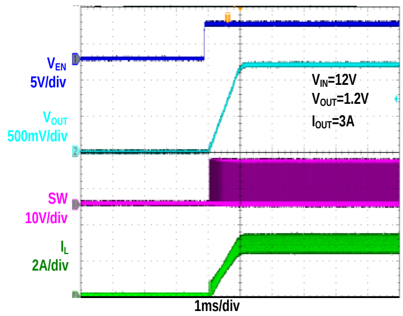
EN ON



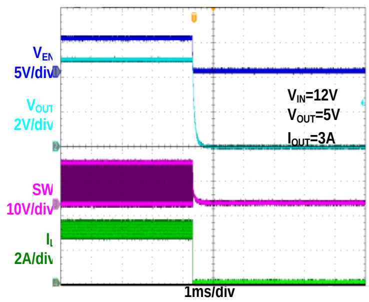
EN ON



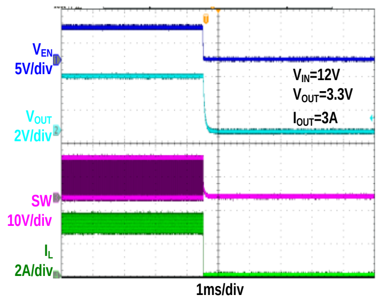
EN ON



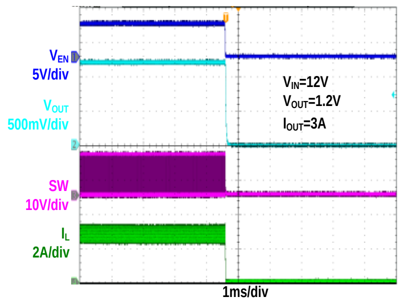
EN OFF



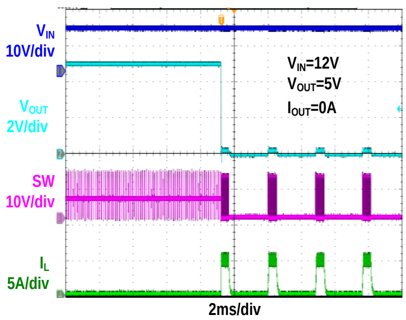
EN OFF



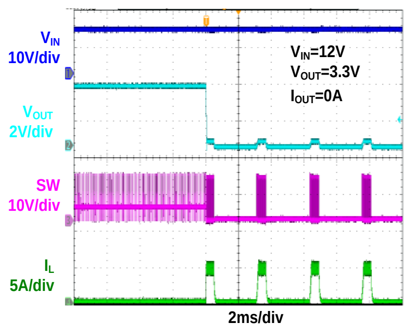
EN OFF



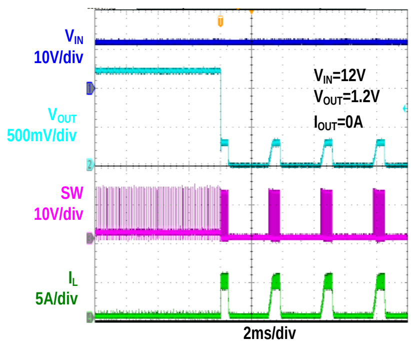
Short Circuit Protection



Short Circuit Protection



Short Circuit Protection



Theory of Operation

The AX3903 is a constant frequency current mode PWM step-down converter with integrated main switch and synchronous rectifier, which provides high efficiency operation and eliminates external Schottky diode.

Current Mode PWM Control

Current mode PWM control provides stable switching and cycle-by-cycle current limit for superior load and line response and protection of the internal main switch and synchronous rectifier. The AX3903 switches at a constant frequency and regulates the output voltage. During steady state operation, the high side switch is turned on at the beginning of a clock cycle driving the inductor current to ramp up. When the inductor current reaches the level defined by internal control voltage from the error amplifier, the high side switch is turned off and the low side switch is turned on to sustain the inductor current until the next clock cycle comes, when the high side switch is turned on again.

Power Saving Mode

AX3903 automatically reduces switching frequency to enter power saving mode (PSM) at light load. Its proprietary control provides seamless transition between PSM mode and PWM mode which gives minimal output voltage ripple over the full load current range.

Enable

The EN pin provides ON/OFF control of the regulator. Once the voltage of the EN pin exceeds the ON threshold voltage, the regulator starts operation and the internal soft-start begins to ramp. If the voltage of the EN pin is pulled below the OFF threshold, the regulator will stop switching and reset the internal soft-start.

Boost Capacitor

The BS pin and SW pin can be connected by a 100nF low ESR ceramic capacitor, providing the gate drive voltage for the high side MOSFET.

Input Under Voltage Lockout

The AX3903 features an Input Under-Voltage Lockout circuit, which shuts down the part when the input voltage drops below failing threshold to prevent unstable operation.

Internal Soft-start

The AX3903 comes with internal soft−start function, which reduces inrush current and overshoot of the output voltage. Soft−start is achieved by ramping up the reference voltage (V_{ref}) applied to the input of the error amplifier. The typical soft−start time is 1ms.

Short Circuit Protection

The AX3903 has short circuit protection. When the output is shorted, the oscillator's frequency is reduced to prevent the inductor's current from running away beyond the high side MOSFET current limit. The frequency will return to the normal level once the short circuit condition is removed and the feedback voltage > 0.25V.

Maximum Load Current

The AX3903 can operate down to 4.7V input voltage; 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 also reduces the inductor's peak current as a function of the duty cycle. For current mode control, slope compensation is needed to prevent sub-harmonic oscillations at duty cycles greater than 50%.

Application Information

Input Capacitor Selection

The input capacitor must sustain the ripple current produced during the period of "ON" state of the high side MOSFET, so a low ESR ceramic capacitor is required to minimize the loss. The input ripple current RMS value can be calculated by the following equation:

$$I_{INRMS} = I_{OUT}\sqrt{D \times (1-D)}$$

Where D is the duty cycle, I_{INRMS} is the input RMS current, and I_{OUT} is the load current. The equation reaches its maximum value with D = 0.5. The loss of the input capacitor can be calculated by the following equation:

$$P_{CIN} = ESR_{CIN} \times I_{INRMS}{}^2$$

Where P_{CIN} is the power loss of the input capacitor and ESR_{CIN} is the effective series resistance of the input capacitance. Due to large di/dt through the input capacitor, electrolytic or ceramics should be used.

Inductor Selection

The inductor selection is to meet the requirements of the output voltage ripple and affects the load transient response. The higher inductance can reduce the inductor's ripple current and induce the lower output ripple voltage. The ripple voltage and current are approximated by the following equations:

$$\Delta I = \frac{V_{IN} - V_{OUT}}{F_S \times L} \bullet \frac{V_{OUT}}{V_{IN}}$$

$$\Delta V_{OUT} = \Delta I \times ESR$$

Although the increase of the inductance reduces the ripple current and voltage, it contributes to the decrease of the response time for the regulator to load transient. The way to set a proper inductor value is to have the ripple current (ΔI) be approximately **20%~50%** of the maximum output current. Once the value has been determined, select an inductor capable of carrying the required peak current without going into saturation. It is also important to have the inductance tolerance specified to keep the accuracy of the system. 20% tolerance (at room temperature) is reasonable for the most inductor manufacturers. For some types of inductors, especially those with ferrite core, the ripple current will increase abruptly when it saturates, which will result in larger output ripple voltage.

Output Capacitor Selection

An output capacitor is required to filter the output and supply the load transient current. The high capacitor value and low ESR will reduce the output ripple and the load transient drop. In typical switching regulator design, the ESR of the output capacitor bank dominates the transient response. The number of output capacitors can be determined by the following equations:

$$ESR_{MAX} = \frac{\Delta V_{ESR}}{\Delta I_{OUT}}$$

$$\text{Number of capacitors} = \frac{ESR_{CAP}}{ESR_{MAX}}$$

ΔV_{ESR}= change in output voltage due to ESR
ΔI_{OUT} = load transient
ESR_{CAP} = maximum ESR per capacitor (specified in manufacturer's data sheet)
ESR_{MAX} = maximum allowable ESR

High frequency decoupling capacitors should be placed as closely to the power pins of the load as physically possible. For the decoupling requirements, please consult the capacitor manufacturers for confirmation.

Output Voltage

The output voltage is set using the FB pin and a resistor divider connected to the output as shown in AP circuit below. The output voltage (V_{OUT}) can be calculated according to the voltage of the FB pin (V_{FB}) and ratio of the feedback resistors by the following equation, where (V_{FB}) is 0.8V:

$$V_{FB} = V_{OUT} \times \frac{R_2}{(R_1 + R_2)}$$

Thus the output voltage is:

$$V_{OUT} = V_{FB} \times \left(\frac{R_1}{R_2} + 1 \right)$$

Choose R1=40kΩ~200kΩ to ensure feedback loop noise immunity. It is optional to add a feed-forward capacitor C_{FF}=4.7~22pF in parallel with R1 to achieve better transient response performance.

❖ Layout Consideration

The physical design of the PCB is the final stage in the design of power converter. The improperly designed PCB could radiate excessive EMI and contribute instability to the power converter. Follow the PCB layout guidelines below to ensure better performance of AX3903.

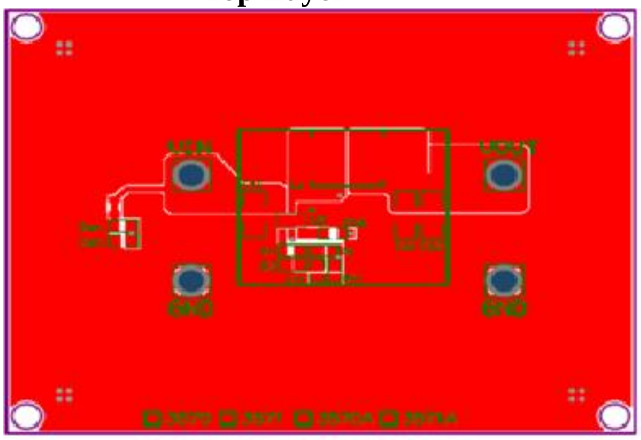
(1). The loop (Vin-SW-L-Cout-GND) indicates a high current path. The traces within the loop should be kept as wide and short as possible to reduce parasitic inductance and high-frequency loop area. It is also good for efficiency improvement.

(2). Place 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.

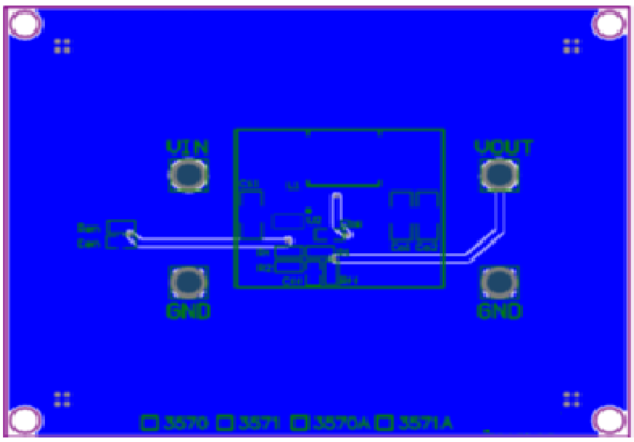
(3). Feedback components (R1, R2 and CFF) should be routed as far away from the inductor and the BS and SW pins to minimize noise and EMI issue.

SOT23_6L:

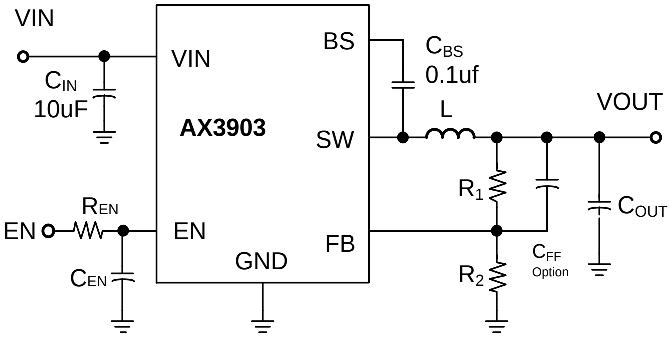
Top Layer



Bottom Layer



❖ Application 1 (without Rt Schematic):

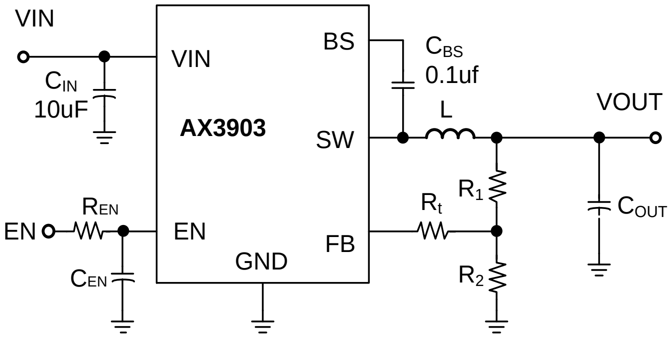


Application Circuit 1. and EVB BOM List

Qty	Ref	Value		Description	Package
1	C_{IN}	10μF		Ceramic Capacitor, 25V, X5R	0805
2	C_{OUT}	22μF		Ceramic Capacitor, 25V, X5R	0805
1	C_{EN}	0.1μF		Ceramic Capacitor, 16V, X5R	0603
1	C_{BS}	0.1μF		Ceramic Capacitor, 25V, X5R	0603
1	L	Vout=5V	6.8μH	Inductor,GSTM5030P 15mΩ, 6.5A	SMD
		Vout=3.3V	4.7μH		
		Vout=2.5V	3.3μH		
		Vout=1.8V	2.2μH		
		Vout=1.2V	2.2μH		
		Vout=1V	2.2μH		
1	R1	Vout=5V	150KΩ	Resistor, ±1%	0603
		Vout=3.3V	150KΩ		
		Vout=2.5V	150KΩ		
		Vout=1.8V	150KΩ		
		Vout=1.2V	150KΩ		
		Vout=1.05V	150KΩ		
1	R2	Vout=5V	28KΩ	Resistor, ±1%	0603
		Vout=3.3V	47KΩ		
		Vout=2.5V	69.8KΩ		
		Vout=1.8V	120KΩ		
		Vout=1.2V	300KΩ		
		Vout=1.05V	470KΩ		
1	C_{FF}	Vout=5V	10pF	Ceramic Capacitor, 50V, X5R	0603
		Vout=3.3V	10pF		
		Vout=2.5V	10pF		
		Vout=1.8V	10pF		
		Vout=1.2V	10pF		
		Vout=1.05V	10pF		
1	R_{EN}	10K~100KΩ		Resistor, ±1%	0603
1	Power IC	AX3903		Step-Down DC/DC Converter	SOT23_6L

❖ Application 2 (with Rt Schematic):

The T-type network shown in below figure can also be used.



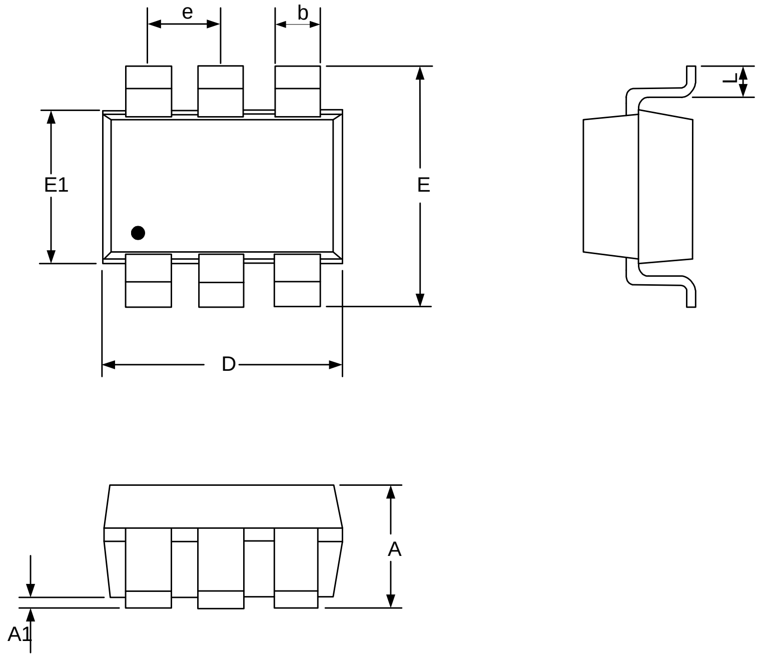
Application Circuit 2. with T-type Feedback Network and EVB BOM List

Qty	Ref	Value		Description	Package
1	C_{IN}	10μF		Ceramic Capacitor, 25V, X5R	0805
2	C_{OUT}	22μF		Ceramic Capacitor, 25V, X5R	0805
1	C_{EN}	0.1μF		Ceramic Capacitor, 16V, X5R	0603
1	C_{BS}	0.1μF		Ceramic Capacitor, 25V, X5R	0603
1	L	Vout=5V	6.8μH	Inductor,GSTM5030P 15mΩ, 6.5A	SMD
		Vout=3.3V	6.8μH		
		Vout=2.5V	4.7μH		
		Vout=1.8V	3.3μH		
		Vout=1.2V	2.2μH		
		Vout=1V	2.2μH		
1	R_T	Vout=5V	24.9KΩ	Resistor, ±1%	0603
		Vout=3.3V	40.2KΩ		
		Vout=2.5V	59KΩ		
		Vout=1.8V	75 KΩ		
		Vout=1.2V	120KΩ		
		Vout=1V	150KΩ		
1	R1	Vout=5V	40.2KΩ	Resistor, ±1%	0603
		Vout=3.3V	40.2KΩ		
		Vout=2.5V	40.2KΩ		
		Vout=1.8V	40.2KΩ		
		Vout=1.2V	20.5KΩ		
		Vout=1.05V	10KΩ		
1	R2	Vout=5V	7.68KΩ	Resistor, ±1%	0603
		Vout=3.3V	13KΩ		
		Vout=2.5V	19.1KΩ		
		Vout=1.8V	32.4KΩ		
		Vout=1.2V	41.2KΩ		
		Vout=1.05V	32.4KΩ		
1	R_{EN}	10K~100KΩ		Resistor, ±1%	0603
1	Power IC	AX3903		Step-Down DC/DC Converter	SOT23_6L

❖ PACKAGE OUTLINES

SOT23_6L Outline Dimensions

Unit: inches/mm

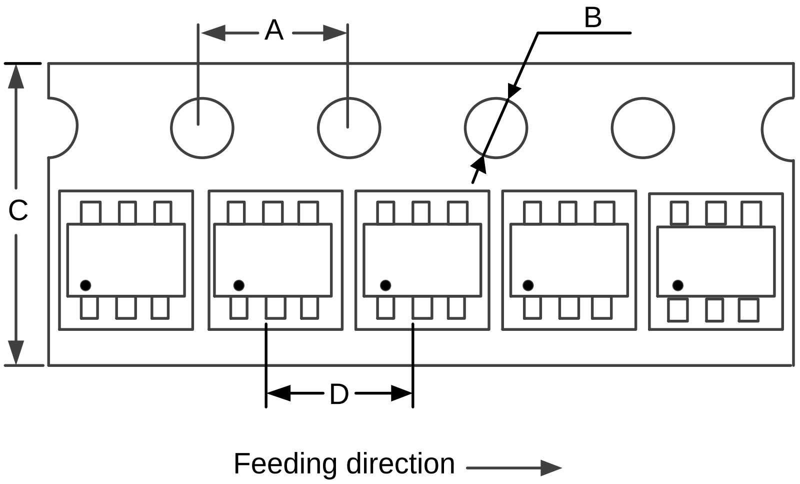


SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.89	1.45	0.035	0.057
A1	0.00	0.15	0.000	0.006
b	0.30	0.50	0.012	0.020
D	2.70	3.10	0.106	0.122
E1	1.40	1.80	0.055	0.071
e	0.84	1.04	0.033	0.041
E	2.60	3.00	0.102	0.118
L	0.30	0.60	0.012	0.024

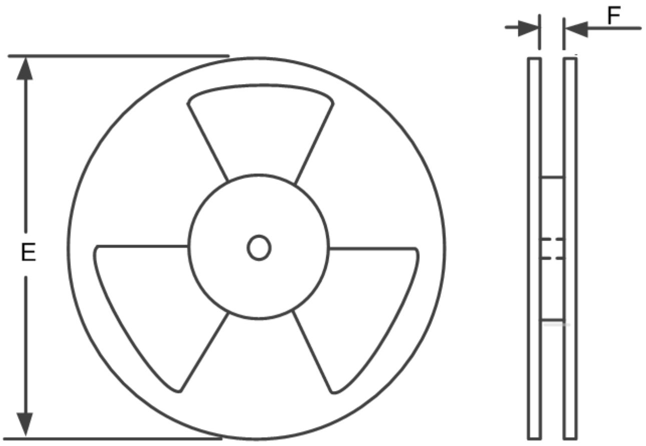
❖ CARRIER TAPE DIMENSION

SOT23_6L

1. Orientation / Carrier Tape Information :



2. Rokreel Information :



3. 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