axelite 亞瑟萊特科技股份有限公司 AXElite Technology Co.,Ltd

18V 2A 500kHz Synchronous Step-Down DC/DC Converter

❖ GENERAL DESCRIPTION

The AX3902 is a high efficiency, 2A current mode synchronous step-down DC/DC converter with a wide input voltage range from 4.5V 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 AX3902 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. AX3902 have different operation modes:

AX3902 is automatic PSM/PWM mode

To improve the light load efficiency, AX3902 has proprietary light load power saving mode (PSM) to minimize the switching loss by reducing the switching frequency.

The AX3902 is available in the SOT-23-6L package.

❖ FEATURES

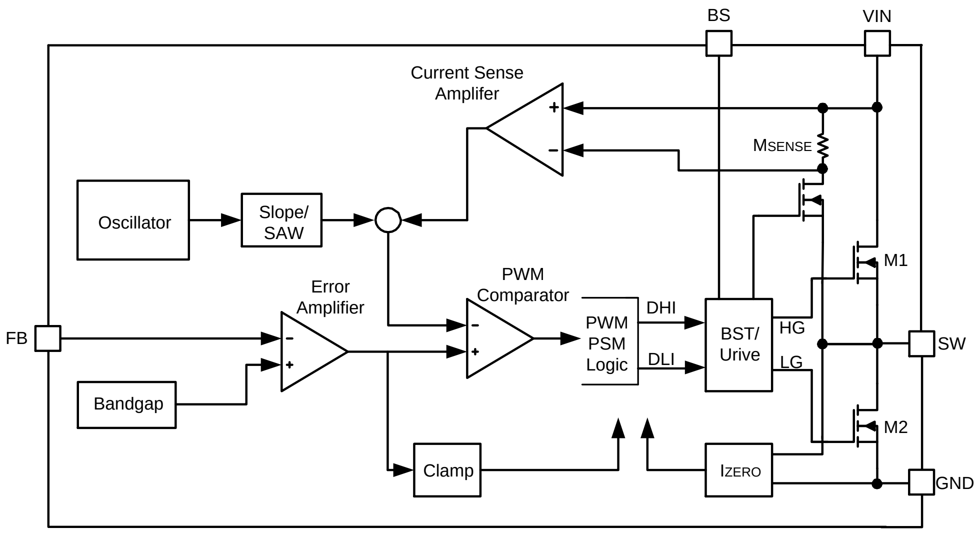
- Input Voltage Supply Range from 4.5V to 18V
- +/- 2% 0.8V Feedback Voltage Accuracy
- Adjustable Output Voltage from 0.8V to 12V
- 500kHz Constant Frequency Operation
- Built-in 120mΩ/80mΩ Power Switch
- Continuous Output Current up to 2A
- High Efficiency up to 95%
- Internal Soft-Start
- Current Mode Operation
- Input Under Voltage Lockout (UVLO)
- Over-temperature Protection
- Over-current Protection
- Over-Load and Short Circuit Protection
- Thermal Shutdown Protection
- Available in a Small SOT-23-6L Package
- RoHS and Halogen Free compliance

❖ Applications

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

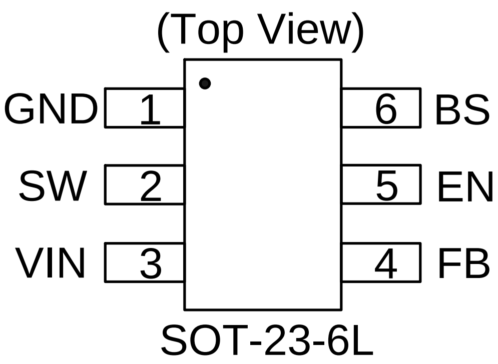
Rev.1.2 Nov.04, 2019

❖ BLOCK DIAGRAM



❖ PIN ASSIGNMENT

The packages of AX3902 are SOT-23-6L; the pin assignment is given by:



Name	Description
GND	Ground This is the reference of the ground connection for all components in the power supply.
SW	Power Switch Output This is the output of a power MOSFET switch.
VIN	Power Supply The input voltage for the power supply is connected to this pin.
FB	Voltage Feedback This is the input to an error amplifier, which drives the PWM controller. It is necessary to connect this pin to the actual output of power supply to set the DC output voltage.
EN	Enable (floating of this pin not recommended) This input provides an electrical ON/OFF control of the power supply.
BS	High Side Gate Drive Boost Input It is required to connect SW and BST by a capacitor, which is able to boost the gate drive to the internal NMOS above VIN to fully turn it ON.

❖ ORDER/MARKING INFORMATION

Order Information	Top Marking
AX3902 X X Package Type: C: SOT-23-6L Packing: Blank: Tube, A : Taping	dZYWX X → ID code: internal WW: 01~26(A~Z) 27~52(a~z) Year: 8=2018 9=2019 B=2020 C=2021 D=2022 … Z=2044 d → AX3902

❖ ABSOLUTE MAXIMUM RATINGS

Characteristics	Symbol	Rating	Unit
Absolute Maximum Rating(Note1)			
Input Supply Voltage	V_{IN}	20	V
SW,EN Voltage		20	V
Dynamic Vsw in 10ns Duration		-3 to Vin+3	V
BS-SW Voltage		6	V
FB Voltage	V_{FB}	6	V
Junction Temperature Range	T_J	-40 to 150	°C
Storage Temperature Range		-65 to 150	°C
Lead Temperature (Soldering 10s)		260	°C
Recommended Operating Conditions(Note2)			
Supply Input Voltage	V_{IN}	4.5 to 18	V
Operating Temperature Range		-40 to 85	°C
Thermal information(Note3,4)			
Maximum Power Dissipation(TA=+25℃)		1.25	W
Thermal Resistance	θ_{JA}	100	°C/W
Thermal Resistance	θ_{JC}	55	°C/W

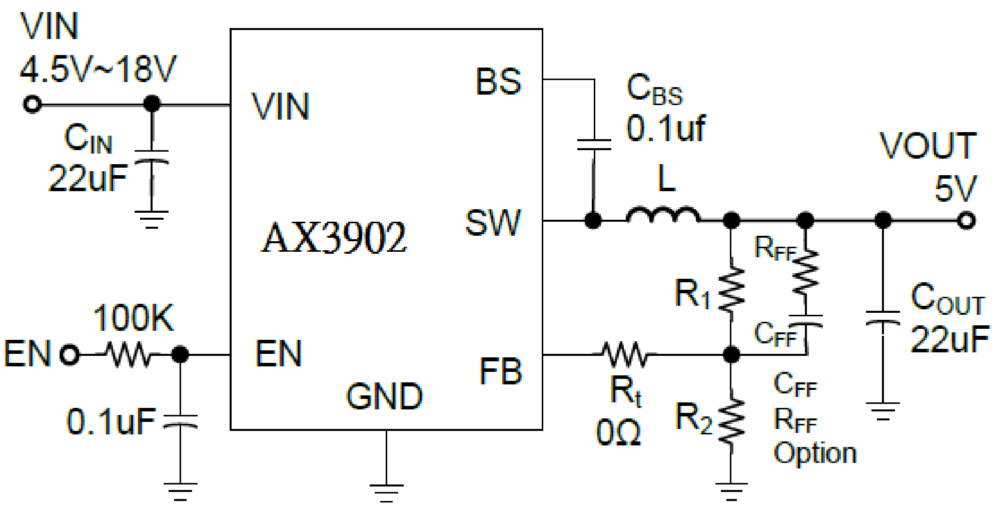
Note (1): Stress exceeding those listed “Absolute Maximum Ratings” may damage the device.
Note (2): The device is not guaranteed to function outside of the recommended operating conditions. Note (3): Measured on JESD51-7, 4-Layer PCB.
Note (4): The maximum allowable power dissipation is a function of the maximum junction temperature TJ_MAX, the junction to ambient thermal resistance θJA, and the ambient temperature TA. The maximum allowable continuous power dissipation at any ambient temperature is calculated by PD_MAX= (TJ_MAX-TA)/θJA. 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

(V_{IN} = 12V, T_A =25°C, unless otherwise specified)

Characteristics	Conditions	Min	Typ	Max	Units
Input Supply Voltage		4.5		18	V
Shutdown Current	V_{EN} = 0V		10		μA
Regulated Feedback Voltage V_{REF}	4.5V≦V_{IN}≦18V	0.784	0.8	0.816	V
VIN Under voltage Lockout Threshold		3.85	4.1	4.35	V
High Side MOSFET On Resistance	I_{SW}=0.2A		120		mΩ
Low Side MOSFET On Resistance	I_{SW}=0.2A		80		mΩ
Switch Current Limit			3.5		A
SW Leakage Current	V_{EN}=0V, VSW=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		99		%
EN On Threshold		1.2			V
EN Off Threshold				0.5	V
EN Input Current	V_{EN}=1V		1		μA
Soft Start Time			1		ms
Thermal Shutdown Threshold			160		°C

❖ APPLICATION CIRCUIT



❖ FUNCTION DESCRIPTIONS

Theory of Operation

The AX3902 is a constant frequency current mode PWM step-down converter with integrated main switch and synchronous rectifier, which provides high efficiency operation and eliminates an 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 AX3902 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

AX3902 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 threshold voltage, the regulator starts operation and the internal slow start begins to ramp. If the voltage of the EN pin is pulled below the threshold, the regulator will stop switching and reset the internal soft-start. Don't float this pin.

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 AX3902 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 AX3902 comes with an internal soft−start function, which reduces inrush current and overshoot of the output voltage. Soft−start is achieved by ramping up the reference voltage (Vref) applied to the input of the error amplifier. The typical soft−start time is 1ms.

Short Circuit Protection

The AX3902 has short circuit protection. When the output is shorted to ground, 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 AX3902 can operate down to 4.5V 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:t:

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

Where D is the duty cycle, IINRMS is the input RMS current, and IOUT 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 PCIN is the power loss of the input capacitor and ESRCIN 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 Capacitors 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 close to the power pins of the load as physically possible. For the decoupling requirements, please consult the capacitor manufacturers for confirmation.

Output Voltage

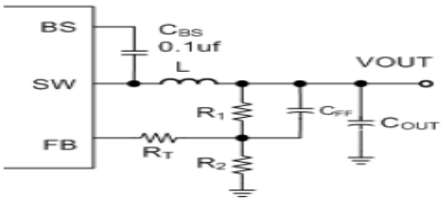
The output voltage is set using the FB pin and a resistor divider connected to the output as shown in AP Circuit below. The output voltage (V_{OUT}) can be calculated according to the voltage of the FB pin (V_{FB}) and ratio of the feedback resistors by the following equation, where (V_{FB}) is 0.8V:

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

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 CFF=4.7~33pF in parallel with R1 to achieve better transient response performance. The T-type network shown in below figure can also be used.

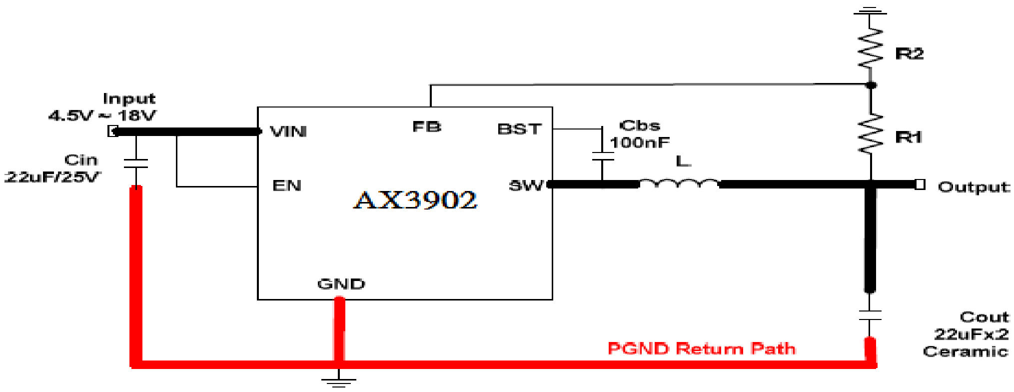


Resistor Selection for Common Output Voltage

V_{OUT} (V)	R1 (kΩ)	R2 (kΩ)	R_T (kΩ)	C_{FF} (pF)
1.05	49.9	160	0	-
1.2	49.9	100	0	10
1.8	49.9	40.2	0	33
2.5	51	24	0	47
3.3	47	15	0	47
5	51	9.76	0	47

Layout Consideration

For proper operation of the converter, some layout rules should be followed. It is necessary to understand which pin of AX3902 is sensitive and which is insensitive. Please refer the following for the location where noise comes from on the circuit and where the clear ground is for the small signal ground.

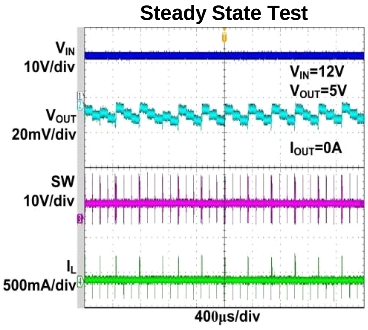


1.) First, put the input capacitor (CIN) as close as possible to the VIN pin.
2.) Secondly, place the Cs, Rs, Cp, Css and R2 as close as AX3902 and connect these analog grounds (Clear AGND) to AX3902 GND pin. It is recommended to use a dot short for these AGND pins or connect the GND pin via contact.
3.) The large current loop shown in bold lines in the above figure circuit should be routed as short and wide as possible and the switch node is a high dv/dt. It easily couples noise to other traces by the capacitive path. Therefore the sensitive signals like FB, COMP and AGND should be routed away with this noise source.
4.) The feedback network resistors (R1 & R2) should be routed away from the inductor and switch node to minimize noise and EMI issue. And the R1 resistor should be sensed the output capacitor or device loading, not the inductor's output node.

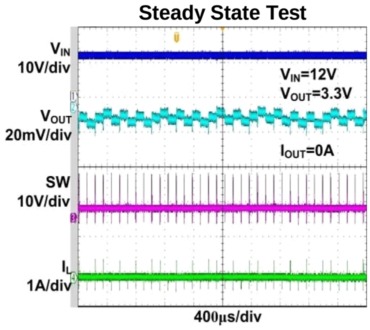
❖ TYPICAL CHARACTERISTICS

AX3902, CIN=22μF, COUT=44μF, L=6.8μH for VOUT=5V; L=4.7μH for VOUT 3.3V; L=2.2μH for VOUT=1.2V, TA =+25℃

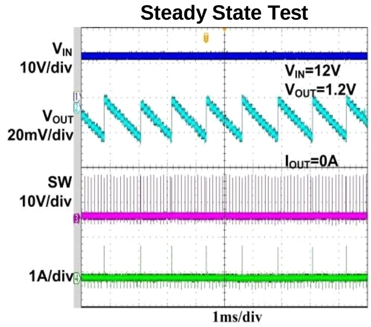
Steady State Test



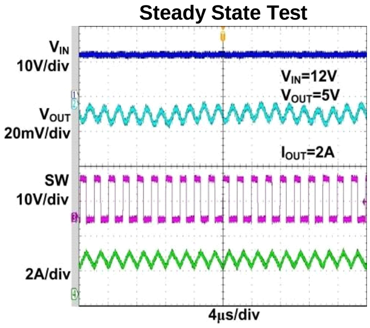
Steady State Test



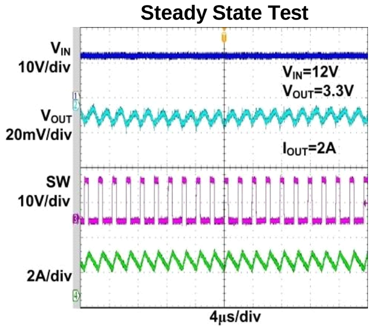
Steady State Test



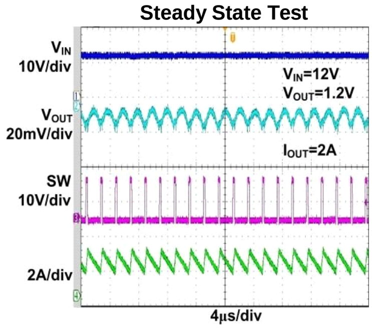
Steady State Test



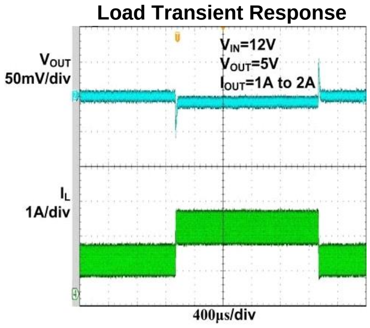
Steady State Test



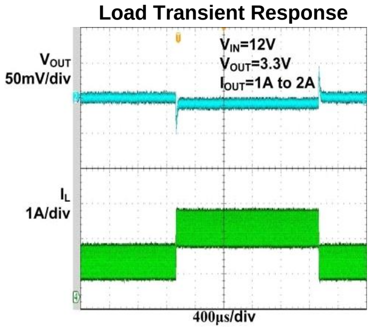
Steady State Test



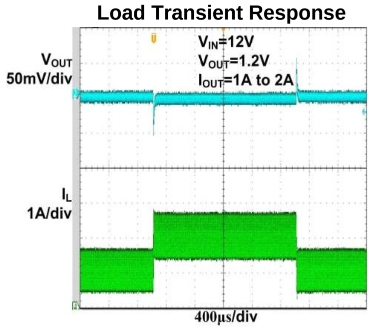
Load Transient Response



Load Transient Response



Load Transient Response



❖ TYPICAL CHARACTERISTICS

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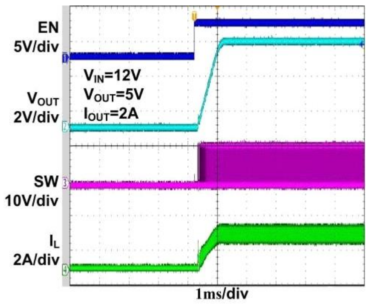
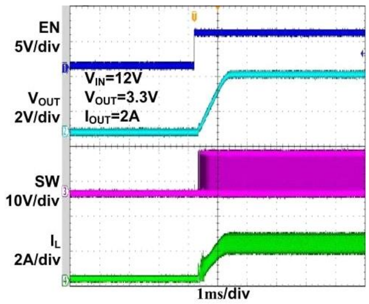
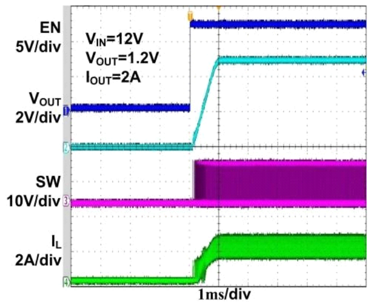
EN ON



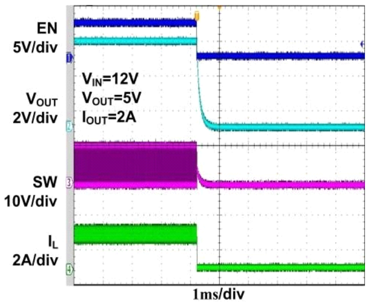
EN ON



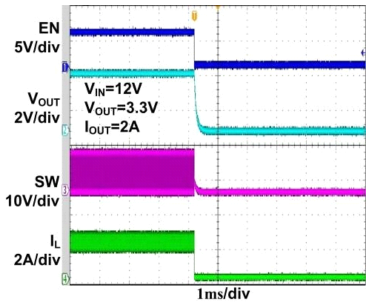
EN ON



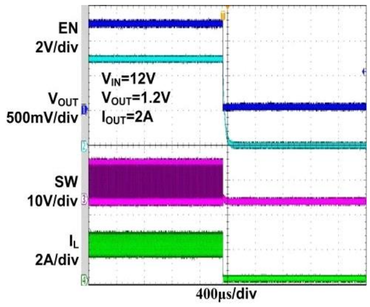
EN OFF



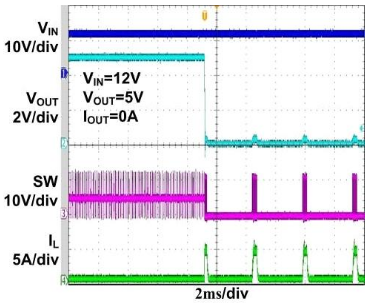
EN OFF



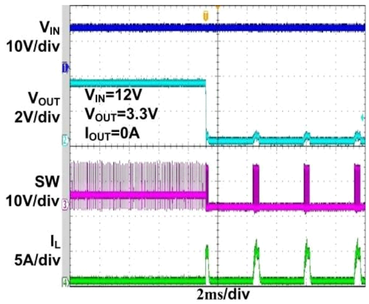
EN OFF



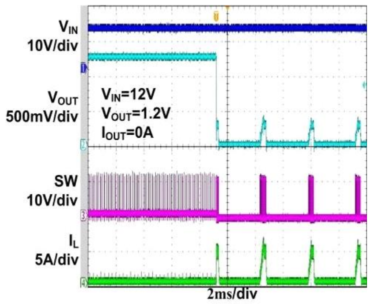
Short Circuit Protection



Short Circuit Protection

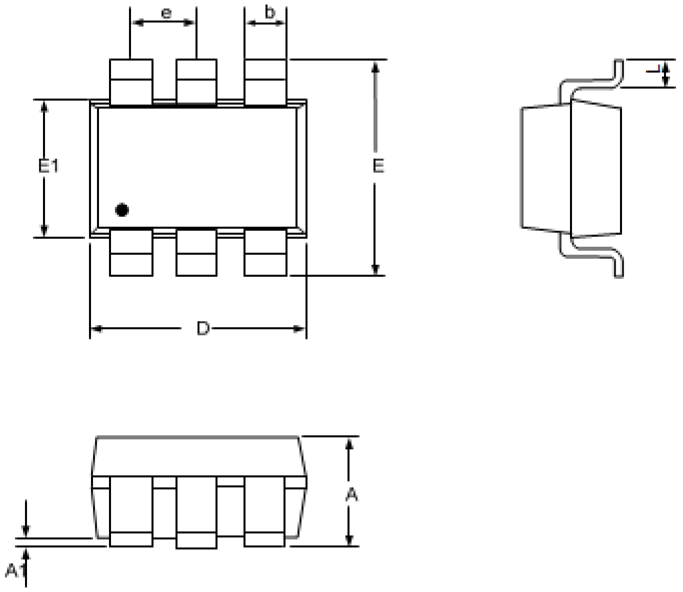


Short Circuit Protection



❖ PACKAGE OUTLINES

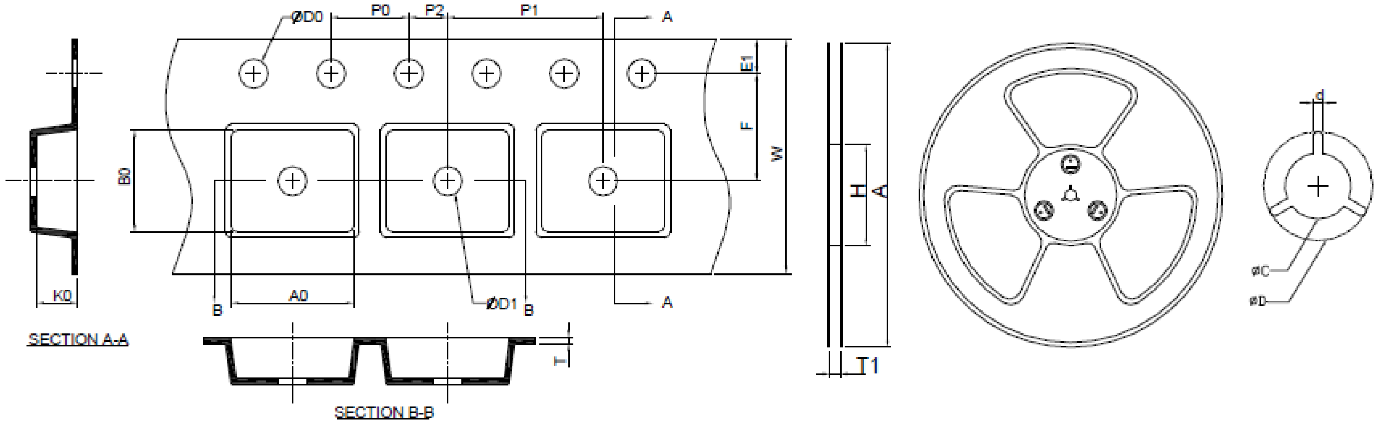
SOT-23-6L

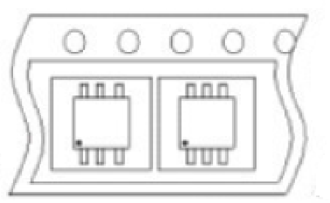


SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.89	1.45	0.035	0.057
A1	0.00	0.15	0.000	0.006
b	0.30	0.50	0.012	0.020
D	2.70	3.10	0.106	0.122
E1	1.40	1.80	0.055	0.071
e	0.84	1.04	0.033	0.041
E	2.60	3.00	0.102	0.118
L	0.30	0.60	0.012	0.024

❖ Carrier tape dimension

SOT-23-6L





A	H	T1	C	d	D	W	E1	F
178.0±2.00	50 MIN.	8.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	8.0±0.30	1.75±0.10	3.5±0.05
P0	**P1**	**P2**	**D0**	**D1**	**T**	**A0**	**B0**	**K0**
4.0±0.10	4.0±0.10	2.0±0.05	1.5+0.10 -0.00	1.0 MIN.	0.6+0.00 -0.40	3.20±0.20	3.10±0.20	1.50±0.20

(mm)