Low Input Voltage Step-up Converter with Low Quiescent Current

❖ GENERAL DESCRIPTION

The AX5070 family devices provide a power- supply solution for products powered by either a single, two or three-cell Alkaline, NiCd or NiMH, or one-cell Li-Ion or Li-polymer battery. Available output current depends on the input-to-output voltage ratio. The step-up converter is based on current–mode pulse-width-modulation (PWM) control using synchronous rectification to obtain maximum efficiency with the minimum quiescent current. The output voltage is programmable using an external resistor divider, The converter can be switched off to minimize battery drain in shutdown. In shutdown, the AX5070 connects the battery input to the output, allowing the input battery to be used as a backup or real-time clock supply when the converter is off. The devices are offered in a small 6-pin SOT23-6 package.

❖ FEATURES

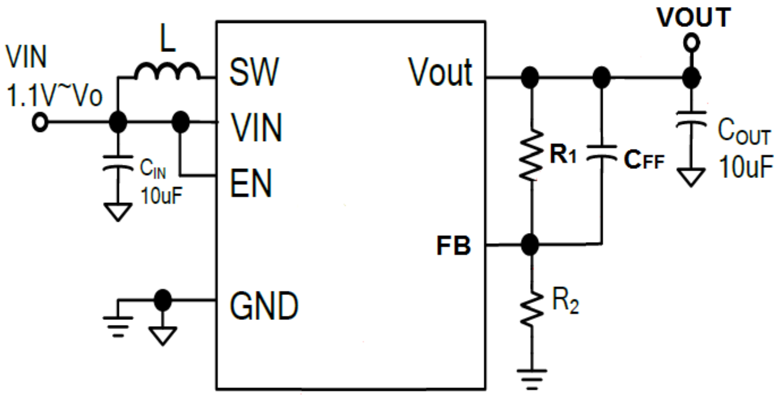
- Up to 92% Efficiency
- 12μA Quiescent Current
- Startup with 0.9V Minimum Input Voltage
- Operating Input Voltage from 0.9V to 5V
- Maximum Switch Current 450mA
- VOUT Pulled to VIN in Shutdown
- Adjustable Output Voltage from 2.5V to 5.5V
- Input Under-voltage Lockout
- Pb-Free (ROHS compliant)
- Small 6-pin SOT23_6L Package
- RoHS and Halogen free compliance.

❖ Applications

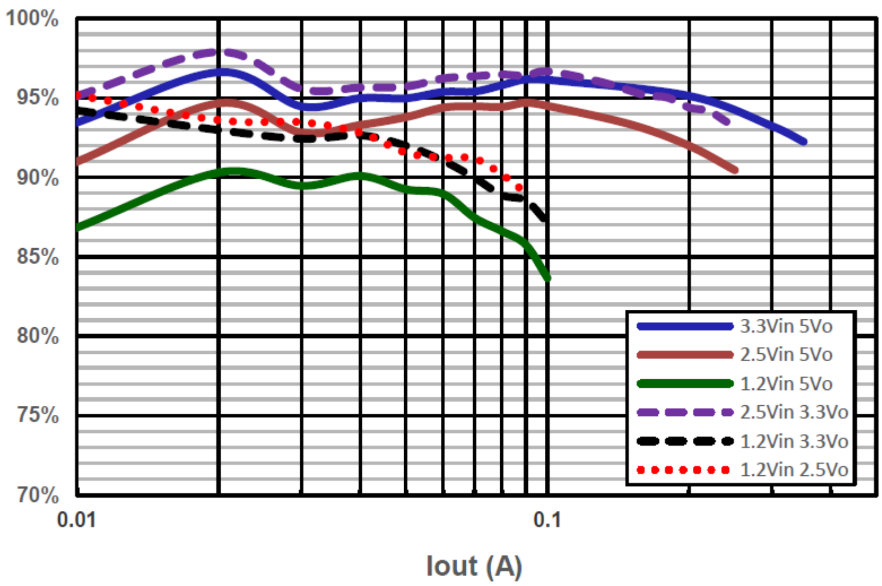
- Battery Powered Applications:
  - 1 to 3 Cell Alkaline, NiCd or NiMH
  - 1 cell Li-Ion
- Solar or Fuel Cell Powered Applications
- Consumer and Portable Medical Products
- Personal Care Products

❖ Typical Application

Adjustable Output Typical Application Circuit

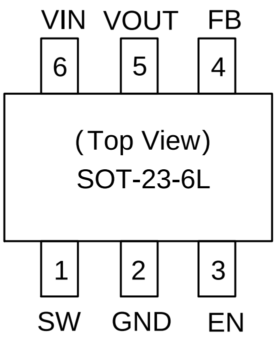


Efficiency



❖ PIN ASSIGNMENT

The packages of AX5070 is SOT-23-6L; the pin assignment is given by:



Name	Description
SW	Inductor Connection. NCH MOSFET switch drain and synchronous Rectifier PCH MOSFET switch drain.
GND	Control circuit and power switches ground.
EN	Enable input (1: enabled, 0: disabled). Must be actively tied high or low. When EN is low, the AX5070 both NCH and PCH switches are turned off.
FB	Adjustable VOUT Feedback Input. Set the output voltage through a resistor-divider network.
VOUT	Step-up converter output voltage. Bootstrapped supply for the device.
VIN	Step-up converter input voltage.

❖ ORDER/MARKING INFORMATION

Order Information

AX5070-X X

Package Type
C: SOT23-6L

Packing
Blank : Tube
A : Taping

Part No.	Marking	Package	Remark
AX5070C	5070 YWXX	SOT23-6L	Y: Year W: Week XX: Control Code

Absolute Maximum Rating (Reference to GND) (Note1)

Supply Voltage VIN and VOUT……………………………..…………….-0.3V to +6V
Dynamic VSW in 10ns Duration…………………………….…..…….. -2V to V_{OUT} +2V
The Other Pins……………………………………………………..…….. -0.3V to +6V
Power Switch Peak Current…………………………….……………….Internal Limited
Junction temperature range……………………………………………………. +150°C
Storage temperature range……………………………………………. -55°C to +150°C
Lead Temperature…………………………………………………………………+260°C
ESD Classification…………………………………………………………………Class 2

Recommended Operating Conditions (Note2)

Input Voltage V_{IN}…………………………………………….……………….0.9 V to 5V
Output Voltage V_{OUT}……………………………………….….…………….1.8 V to 5.5V
Ambient Temperature Range…………………………….…………..-40°C to +85°C

Thermal Information (Note3, 4)

Maximum Power Dissipation(T_A=+25°C)……………………………………….0.8W
Thermal Resistance (θ_{JA})……………………………….…...………………. 125°C/W
Thermal Resistance (θ_{JC})…………………………………………..…………..66°C/W

Note1: Stress exceeding those listed "Absolute Maximum Ratings" may damage the device.

Note2: The device is not guaranteed to function outside of the recommended operating conditions.

Note3: Measured on JESD51-7, 4-Layer PCB.

Note4: 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.

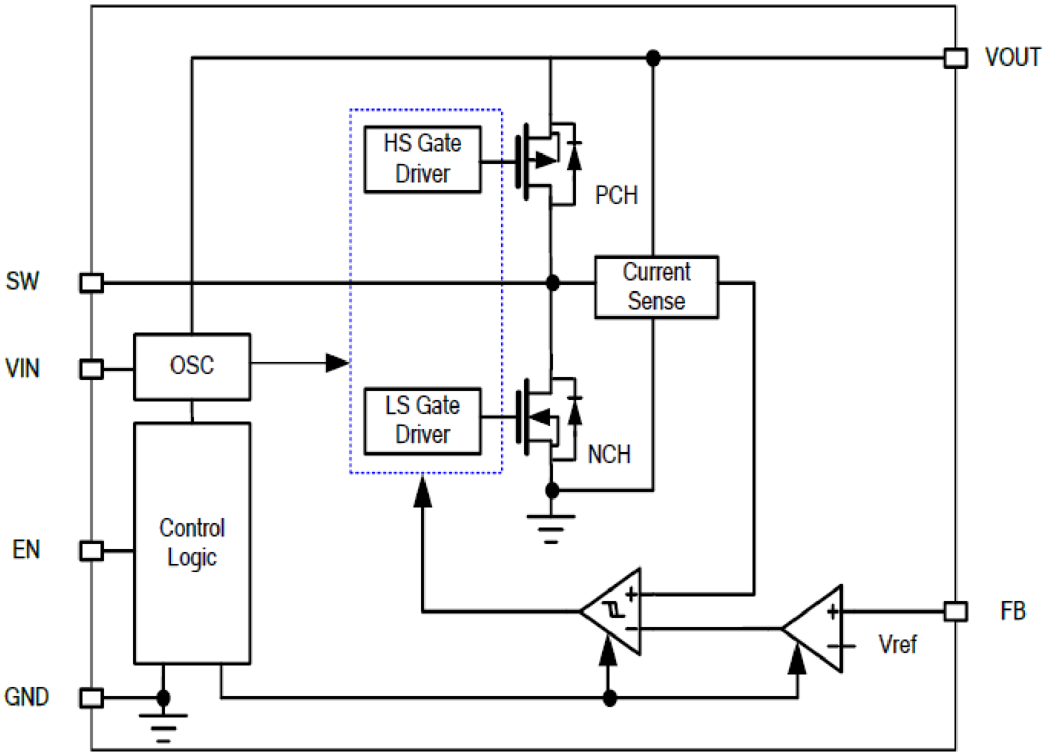
❖ ELECTRICAL CHARACTERISTICS

Unless otherwise noted, all parameter limits are established over the recommended operating conditions:
T_A = +25°C, 0.9V ≤ V_{IN} ≤ 5V, unless otherwise noted. Typical values are at V_{IN}= V_{EN} =1.2V

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IN}	Input voltage range			0.9		5	V
V_{IN}	Minimum input voltage at startup		I_{OUT}=1mA		0.7		V
V_{UVLO}	Input Under-voltage Lockout Threshold for Turn-off		V_{IN} decreasing		0.5		V
V_{OUT}	Adjustable Output voltage		V_{IN}<V_{OUT}	2.5		5.5	V
V_{FB}	Adjustable VOUT Feedback Voltage			485	500	515	mV
I_{FB}	Feedback Input Current		V_{FB} = 0.5V		3		nA
I_{SW}	Switch Current Limit		V_{OUT} = 3.3V		450		mA
R_{PCH}	Rectifier PCH switch on resistance		V_{OUT}=3.3V		300		mΩ
R_{NCH}	Main NCH switch on resistance		V_{OUT}=3.3V		270		mΩ
f_{SW}	Switching Frequency		V_{OUT}=3.3V and L=4.7μH		800		kHz
I_Q	Quiescent current	V_{IN}	V_{EN}=V_{IN}=1.2V,V_{OUT}=3.3V		2		μA
		V_{OUT}			10		μA
I_{SD}	Shutdown current	V_{IN}	V_{EN}=0V, V_{IN}=1.2V		0.01	1	μA
V_{IL}	EN Logic Low Threshold		1.1V ≤ V_{IN} ≤ 5V			0.4	V
V_{IH}	EN Logic High Threshold		1.1V ≤ V_{IN} ≤ 5V	0.5*V_{IN}			V
I_{EN}	EN Input Current		V_{EN}=0V or 5V	-1		1	μA

❖ Functional Block Diagram

Adjustable Version



❖ FUNCTION DESCRIPTIONS

Detailed Description

The AX5070 is compact, high-efficiency step-up converters feature 12μA quiescent supply current to ensure the highest possible efficiency over a wide load range. With a minimum +1.1V input voltage, these devices are well suited for applications with 1 to 3 alkaline cells, nickel-metal-hydride (NiMH) cells, or one lithium ion (Li+) cell.

The AX5070 is based on current mode pulse width modulation topology without an oscillator. The converter regulates the output voltage by keeping the inductor ripple current around 200 mA, and the error comparator senses that the output to adjust the offset of the inductor current depending on the output load current. If the required average input current is lower than the average inductor current defined by the constant 200mA ripple current, the inductor current becomes discontinuous to keep the efficiency high under the light load condition. The inductor current is limited by the internal 450mA NCH main switch current limit for over-load protection. An internal synchronous rectifier PCH switch eliminates the need for an external Schottky diode reducing cost and board space. While the inductor discharges, the PCH switch turns on and shunts the MOSFET body diode. As a result, the rectifier voltage drop is significantly reduced, improving efficiency without adding external components.

Shutdown

When EN is low, the AX5070 device is off and no current is drawn from the input. When EN is high, the device is on. EN is driven from a logic-level output, and connect EN to VIN If it is not used. In shutdown, the AX5070 connects the input to the output through the inductor and the internal synchronous rectifier PCH switch. This allows the input battery (rather than a separate backup battery) to provide backup power for devices such as an idled microcontroller, SRAM, or real-time clock (RTC), without the usual diode forward drop. If the output has a residual voltage during shutdown, a small amount of energy will be transferred from the output back to the input immediately after shutdown. This energy transfer may cause a slight momentary "bump" in the input voltage. The magnitude and duration of the input bump are related to the ratio of CIN and COUT and the ability of the input to sink current. With battery input sources, the bump will be negligible, but with power-supply inputs (typically cannot sink current), the bump may be 100s of mV.

Startup

When the EN pin is tied high, the device begins to operate. If the input voltage (AX5070 VIN<2.2V) is not high enough to supply the control circuit properly, a startup oscillator controls the main NCH switch to operate in Asynchronous mode (The synchronous rectifier PCH switch remains off). During this phase, the switching frequency is controlled by the startup oscillator, and the maximum switch current is limited. When the device has built up the output voltage to approximately 2.2V, high enough to supply the control circuit, the device switches to its normal current mode operation. The startup time depends on the minimum input voltage VIN_MIN and load current. For proper startup with low input voltage, recommend to limit load current as shown below.

$$I_{OUT\_Startup} \leq 80mA * \frac{V_{IN\_MIN}}{2.2V}$$

Input Under-Voltage Lockout

The input under-voltage lockout circuit prevents the device from malfunctioning at low input voltages and the battery from excessive discharge. It disables the output stage of the converter once the falling VIN trips the under-voltage lockout threshold VUVLO which is typically 0.5V. The device starts operation once the rising VIN trips VUVLO threshold plus its hysteresis of 50mV at typically 0.55V.

❖ Application Information

Design Procedure

The AX5070DC/DC converters are intended for systems powered by a single cell battery to up to three Alkaline, NiCd or NiMH cells with a typical terminal voltage between 0.9V and 4.5V. They can also be used in systems powered by one-cell Li-Ion or Li-Polymer batteries with a typical voltage between 2.5V and 4.2V. Additionally, any other voltage source with a typical output voltage between 1.8V and 5V can be used with the AX5070 family.

Setting the Output Voltage

The output voltage is set using the FB pin and a resistor divider connected to the output as shown in the typical application circuit on page1, The output voltage (VOUT) can be calculated according to the voltage of the FB pin (VFB) and ratio of the feedback resistors by the following equation, where VFB is0.5V:

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

Thus the output voltage is:

$$V_{OUT} = 0.5 \times \frac{(R_1 + R_2)}{R_2}$$

Choose R2=100kΩ~1000kΩ to ensure feedback loop noise immunity. It is optional to add a feed-forward capacitor CFF=22~33pF in parallel with R1 to achieve better transient response performance.

Inductor Selection

The AX5070 converters can operate with an effective inductance in the range of 3.3μH to 10μH. Inductor values of 4.7uH show good performance over the whole input and output voltage range. The switching frequency fSW is proportional to inductance value 1/L as shown below.

$$f_{SW} = \frac{1}{0.2A * L} * \frac{V_{IN} * (V_{OUT} - V_{IN})}{V_{OUT}}$$

The inductor should have low DCR (copper-wire resistance) to reduce I2R losses, and must be able to handle the maximum peak inductor current (internally limited to 450mA (TYP)) without saturating. The inductor DC current rating should be greater than the maximum input average current. The highest peak current through the inductor and the switch depends on the output load, converter efficiency η, the minimum input voltage (VIN_MIN), and the output voltage (VOUT). Estimation of the maximum average inductor current can be done using:

$$I_L = I_{OUT} * \frac{V_{OUT}}{V_{IN\_MIN} * \eta}$$

For example, for an output current of 100mA at 3.3VOUT with 85% efficiency, at least 323mA of average current flows through the inductor at a minimum input voltage of 1.2V.

Having selected an inductance value, the maximum output current depends on the steady-state operation mode. The maximum output current IOUT_MAX in continuous conduction mode can be estimated with the equation below.

$$I_{OUT\_MAX} \le 350mA * \frac{V_{IN\_MIN} * \eta}{V_{OUT}}$$

where η is the converter efficiency, and 350mA is average inductor current with ILMAX=450mA and ripple current

ΔIL=200mA. For example, the maximum output current is around 108mA at 3.3VOUT with 85% efficiency at a minimum input voltage of 1.2V.

Input Capacitor

An input capacitor value of at least 10μF is recommended to improve transient behavior of the regulator and EMI behavior of the total power supply circuit. A ceramic capacitor placed as close as possible to the VIN and GND pins of the IC is recommended.

Output Capacitor

The output capacitor must completely supply the load during the charging phase of the inductor. A reasonable value of the output capacitance depends on the speed of the load transients and the load current during the load change. It is recommended to use X7R ceramic capacitors placed as close as possible to the VOUT and GND pins of the IC. A recommended output capacitance value is around 4.7~10μF. Note that high capacitance ceramic capacitors have a DC Bias effect, which will have a strong influence on the final effective capacitance. A 10 V rated 0805 capacitor with 10μF can have an effective capacitance of less 5μF at an output voltage of 5V.

Thermal information

Implementation of integrated circuits in low-profile and fine-pitch surface-mount packages typically requires special attention to power dissipation. Many system-dependent issues such as thermal coupling, airflow, added heat sinks and convection surfaces, and the presence of other heat-generating components affect the power-dissipation limits of a given component. Three basic approaches for enhancing thermal performance are listed below:

★Improve the power dissipation capability of the PCB design

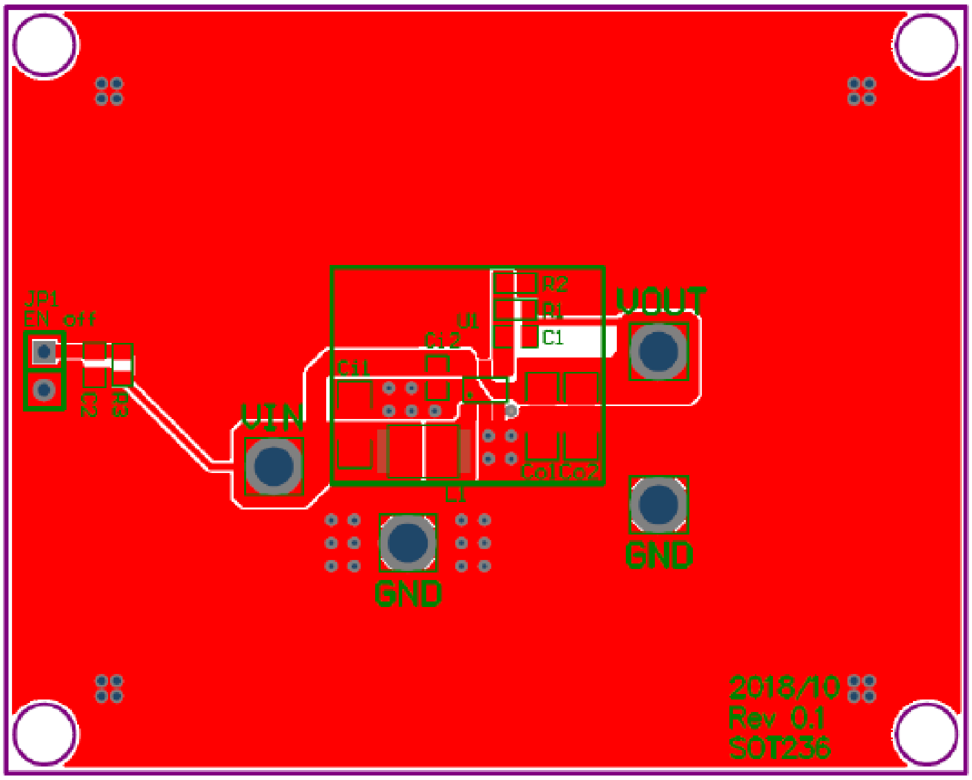
★High speed switching path (SW, GND and VOUT with wide PCB traces) must be kept as short as possible.

★Choose a bigger size 4.7uH Inductor with the lowest DCR value for given PCB space

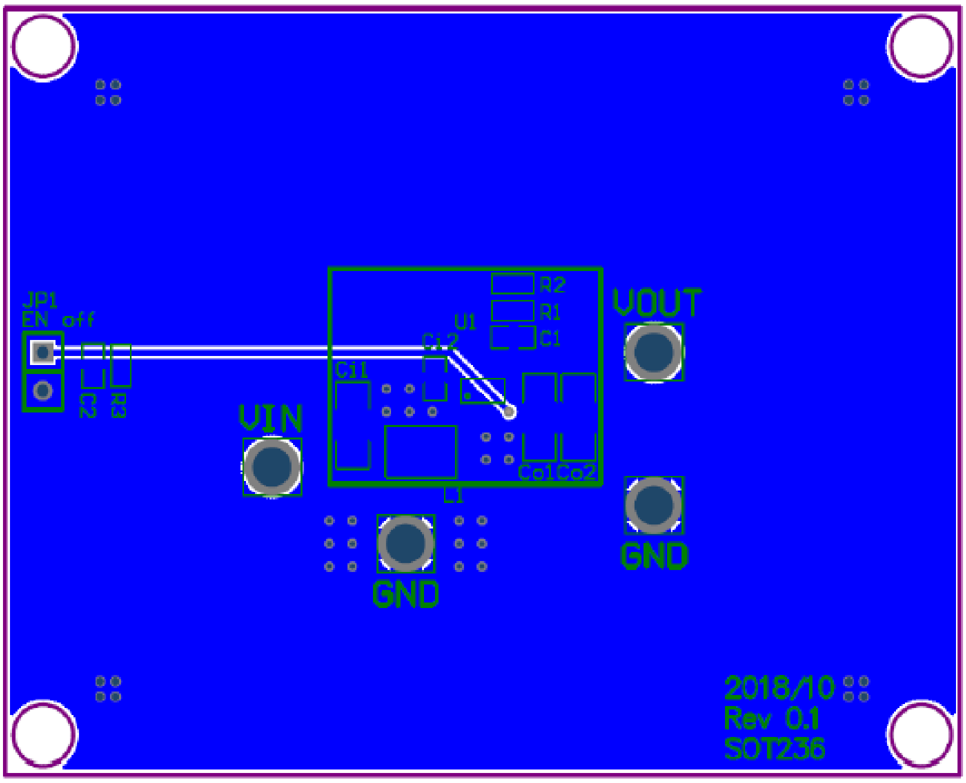
The recommended maximum junction temperature (TJ) of the AX5070devices is 125℃.The thermal resistance of the SOT23-5 package is RθJA=75℃/W. Specified regulator operation is assured to a maximum ambient temperature TA of +25℃. Therefore, the maximum power dissipation for the SOT23-6L package it is about 1.33W.

$$P_{D(MAX)} = \frac{T_{J(MAX)} - T_{A}}{R_{\theta JA}} = \frac{125°C - 25°C}{75°C/W} = 1.33W$$

❖ Layout Considerations

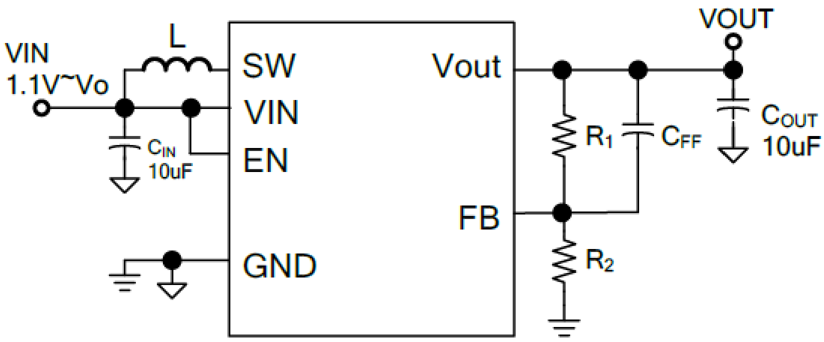


Top Layer



Bottom Layer

❖ Application Schematic

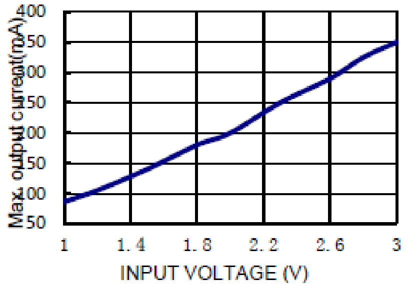


Qty	Ref	Value		Description	Package
1	C_{IN}	10µF		Ceramic Capacitor, 10V, X5R	0805
1	C_{OUT}	10µF		Ceramic Capacitor, 10V, X5R	0805
option	C_{FF}	22~33pF		Ceramic Capacitor, 10V, X5R	0603
1	L	4.7uH		Inductor, MHCI06030, 32mΩ, 5.5A	SMD
1	R1	Vout=5.0V	5.1M	Resistor, ±1%	0603
		Vout=3.3V	2.2M		
		Vout=2.5V	2M		
1	R2	Vout=5.0V	560K	Resistor, ±1%	0603
		Vout=3.3V	390K		
		Vout=2.5V	490K		
1	Power IC	AX5070		Step-Up Converter	SOT236

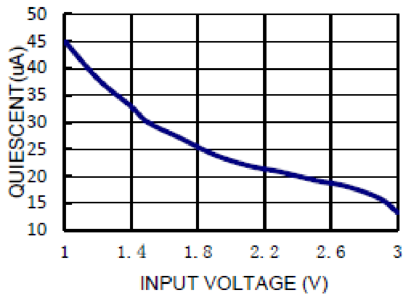
❖ TYPICAL CHARACTERISTICS

VIN =1.2V, VOUT =3.3V, AX5070typical application circuit (Figure 1.), TA = +25°C, unless otherwise noted.

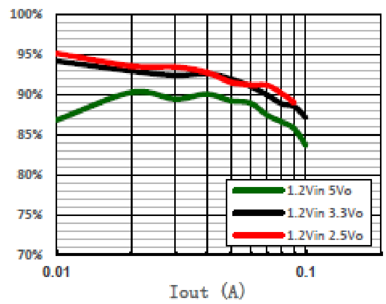
Maximum Output Current vs Input Voltage



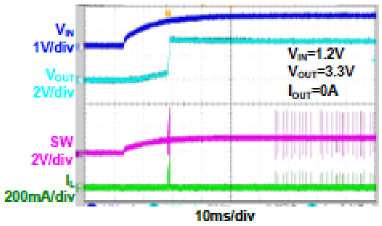
No Load Input Current vs Input Voltage, Device Enabled



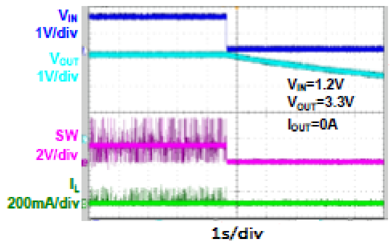
Efficiency vs Input Voltage and Output Current



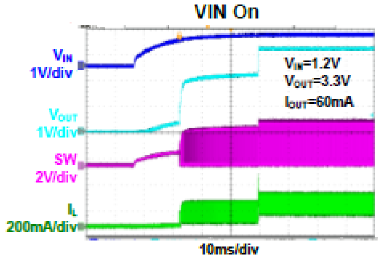
VIN On



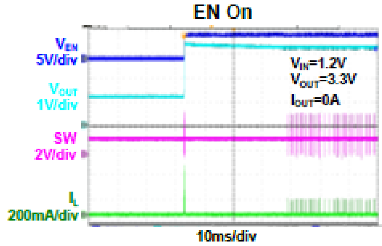
VIN Off



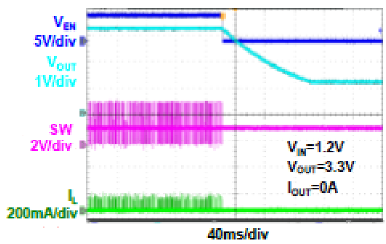
VIN On



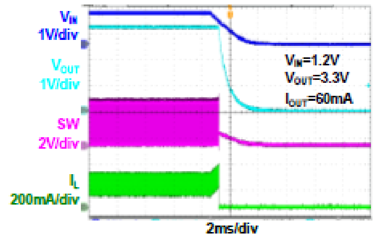
EN On



EN Off



VIN Off



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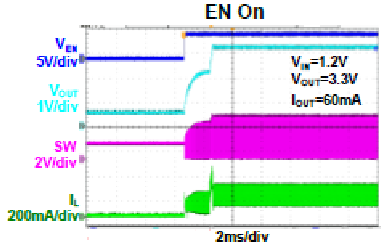
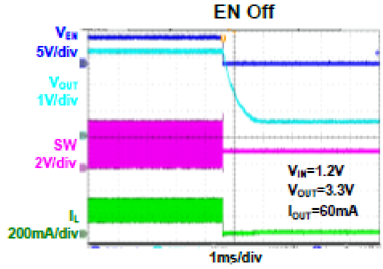
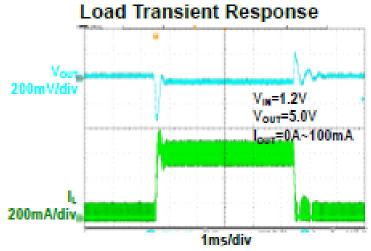


EN Off

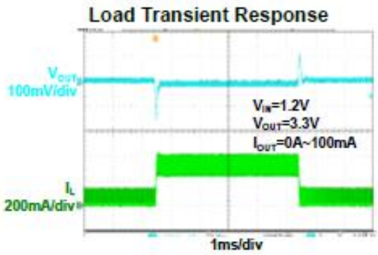


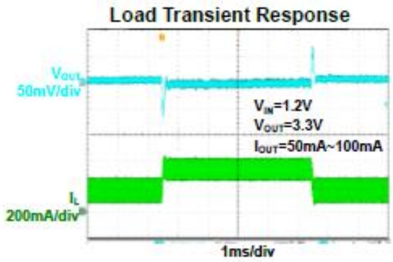
Load Transient Response

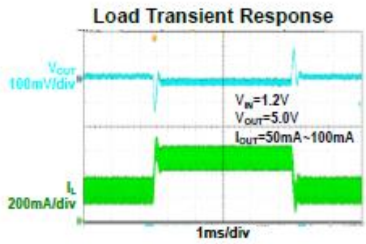


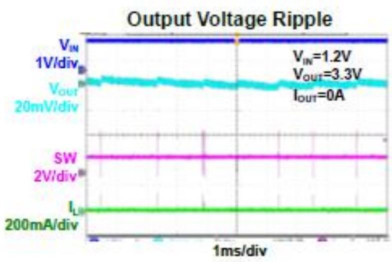
Typical Performance Characteristics

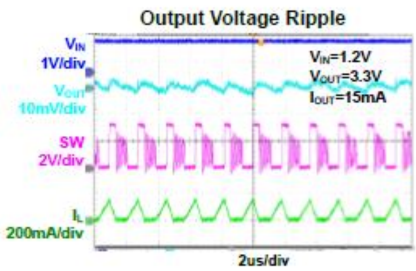
VIN =1.2V, VOUT =3.3V, AX5070typical application circuit (Figure 1.), TA = +25°C, unless otherwise noted.

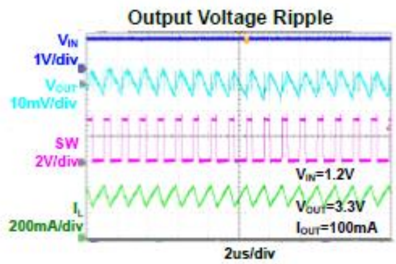


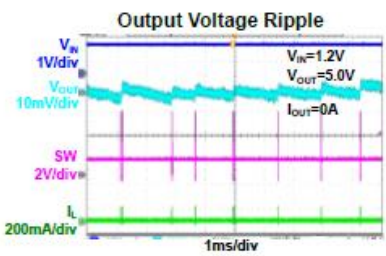


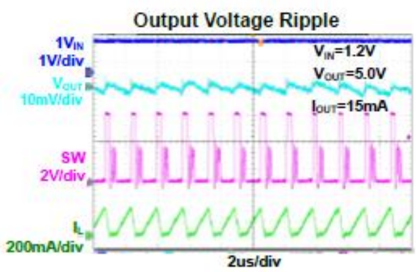


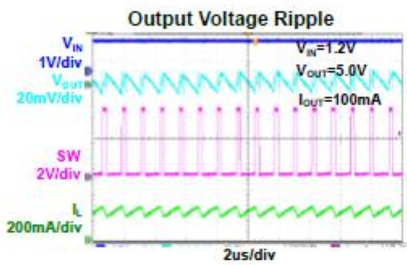






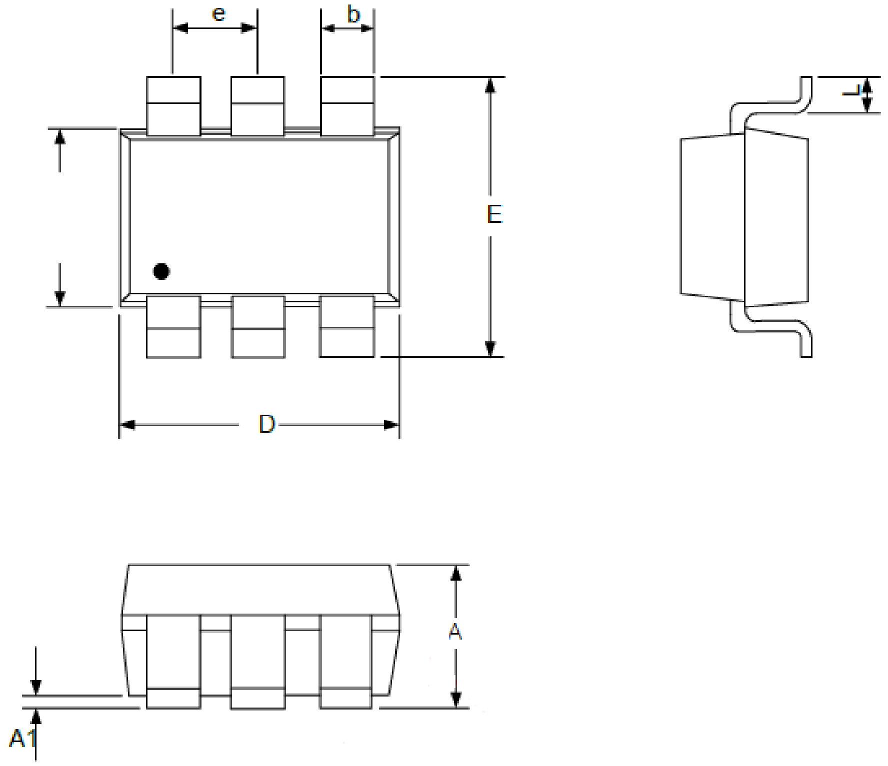






❖ PACKAGE OUTLINES

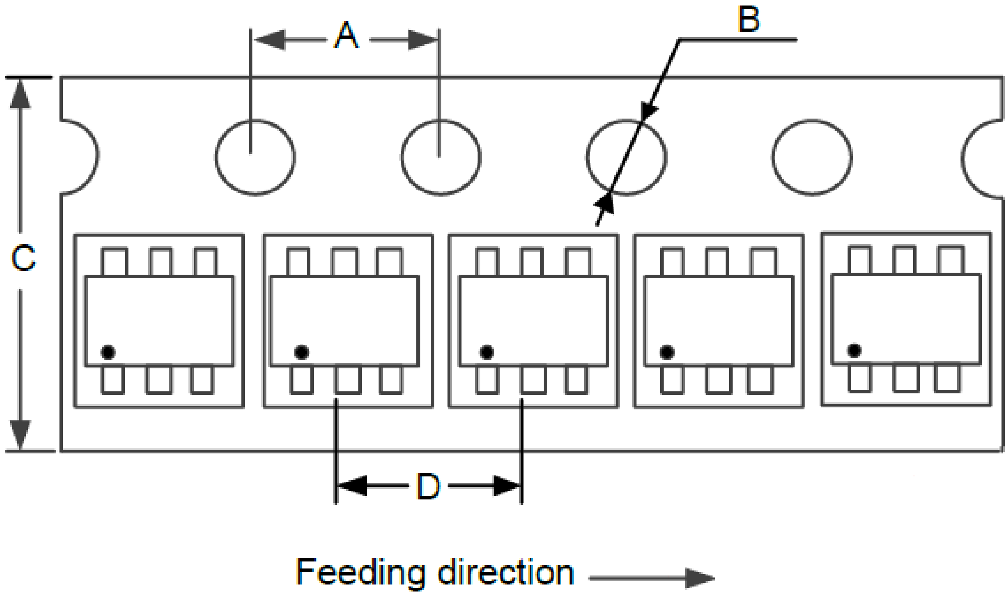
SOT23_6L Outline Dimensions Unit: inches/mm



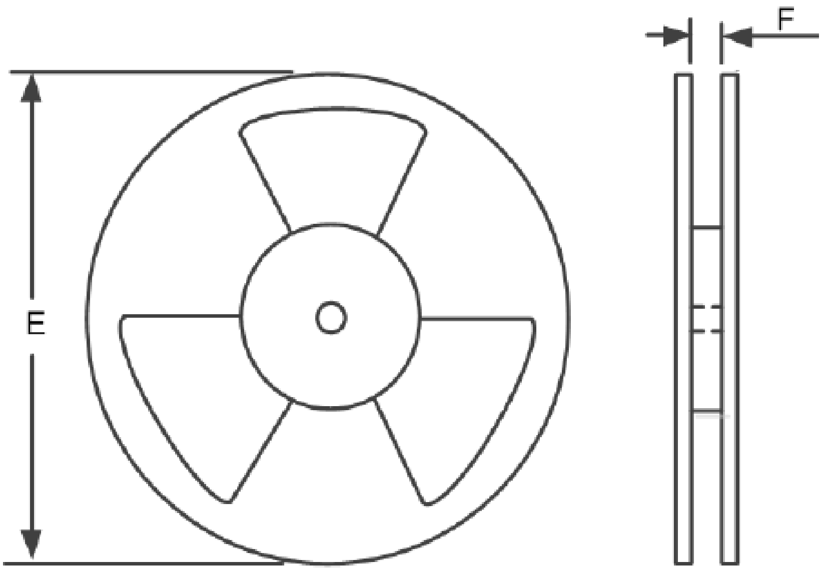
SYMBOLS	MILLIMETERS		INCHES	
	Min.	Max.	Min.	Max.
A	0.89	1.45	0.035	0.057
A1	0.00	0.15	0.000	0.006
b	0.30	0.50	0.012	0.020
D	2.70	3.10	0.106	0.122
E1	1.40	1.80	0.055	0.071
e	0.95 BSC		0.037 BSC	
E	2.60	3.00	0.102	0.118
L	0.30	0.60	0.012	0.024

❖ Carrier tape dimension

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