# 1.4MHz, 1.2A, VFB=0.6V Synchronous Step-Down Converter

## ❖ GENERAL DESCRIPTION

AX3701 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 about 200uA and drops to <1uA in shutdown. The 2.5V to 7.5V input voltage range makes AX3701 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. Pulse skipping mode operation provides very low output ripple voltage for noise sensitive applications. Switching frequency is internally set at 1.4MHz, 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. AX3701 is available in small SOT-23-5L, TDFN-6L (2*2) packages.

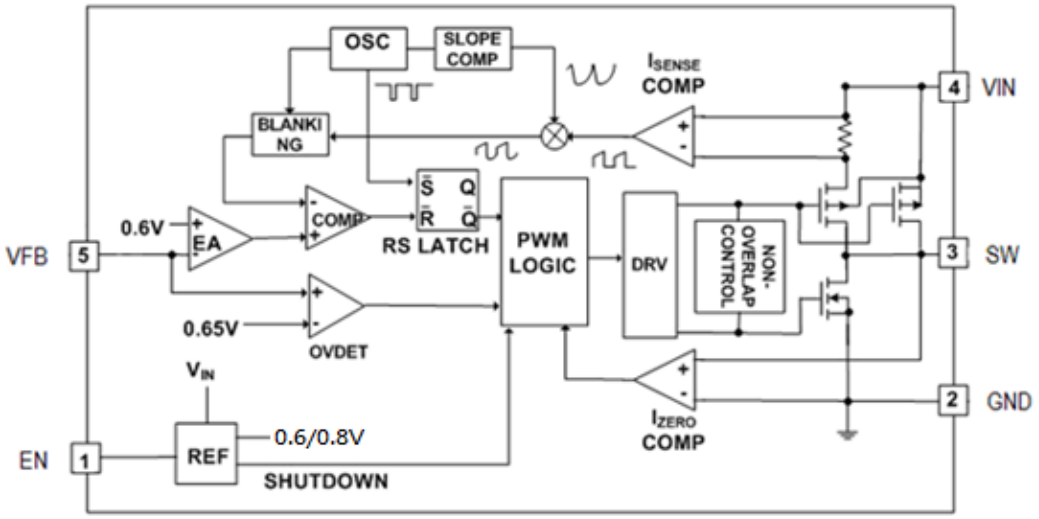
## ❖ FEATURES

- 2.5V to 7.5V Input Voltage Range
- Output Voltage from 0.6V to $V_{IN}$
- High Efficiency: Up to 92%
- 1.4MHz Constant Frequency Operation
- 1.2A Output Current
- Quiescent Current: 200uA (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, TDFN-6L (2*2)



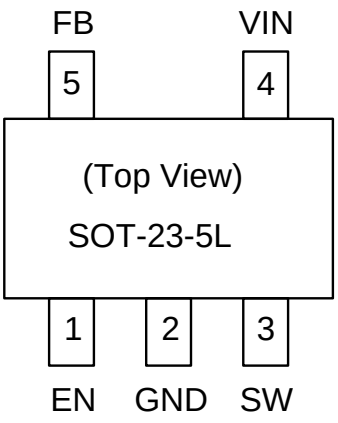
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## ❖ BLOCK DIAGRAM

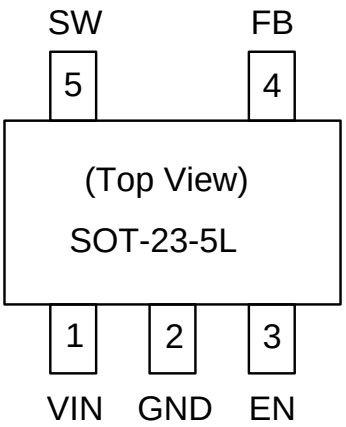



## ❖ PIN ASSIGNMENT

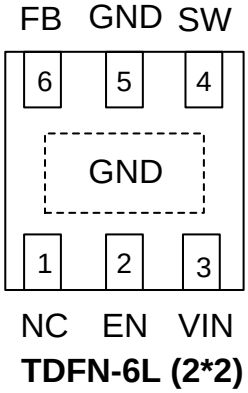
The packages of AX3701 are SOT-23-5L and TDFN-6L, the pin assignment is given by:




**SOT-23-5L (A Type)**




**SOT-23-5L (B Type)**




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

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



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## ❖ ORDER/MARKING INFORMATION

**Order Information**

AX3701 X X X X

- Pin Type: A: A Type; B: B Type (For SOT-23-5L Only)
- Package Type: B: SOT-23-5L; Z6: TDFN-6L (2X2)
- Packing: Blank : Bag; A : Taping

**Top Marking (TDFN-6L)**

Z a → Part Number

YWX → ID Code: Internal

- Week: 01~26(A~Z), 27~52(a~z)
- Year : A = 2010, 1 = 2011, ⋮, 9 = 2019

**Top Marking (SOT-23-5L A/B Type)**

XX Y WX → ID code: internal

- WW: 01~26(A~Z), 27~52(a~z)
- Year: A=2010, 1=2011, 2=2012, ⋮, 9=2019
- Za: AX3701 (A Type)
- Zf: AX3701 (B Type)

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

| Characteristics | | Symbol | Rating | Unit |
|---|---|---|---|---|
| VIN Pin Voltage | | $V_{IN}$ | $V_{SS}$ - 0.3 to $V_{SS}$ + 8 | V |
| 2ms Pulse width VIN tolerance | | $V_{PLUSE}$ | $V_{SS}$ - 0.3 to $V_{SS}$ + 10 | 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 and Source Current | | $I_{PSW}$ | 1.5 | A |
| Power Dissipation | | PD | ( $T_J$-$T_A$ ) / $\theta_{JA}$ | 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 |
| ESD HBM | | HBM | ±2 | KV |
| ESD MM | | MM | ±200 | V |
| Thermal Resistance from Junction to case | TDFN-6L(2*2) | $\theta_{JC}$ | 25 | °C/W |
| | SOT-23-5L | | 130 | |
| Thermal Resistance from Junction to ambient | TDFN-6L(2*2) | $\theta_{JA}$ | 120 | °C/W |
| | SOT-23-5L | | 250 | |

Note: $\theta_{JA}$ is measured with the PCB copper area of approximately 1 $in^2$(Multi-layer). That need connect to GND pin of the AX3701.



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## ❖ ELECTRICAL CHARACTERISTICS

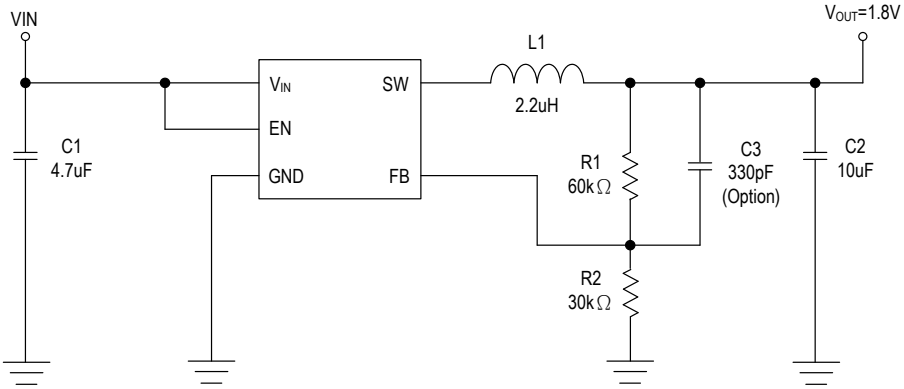
($V_{IN}$ = $V_{EN}$=3.6V, $T_A$ =25°C, unless otherwise specified) (Note)

| Characteristics | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Input Voltage Range (Note 2) | $V_{IN}$ | | 2.5 | - | 7.5 | V |
| Under Voltage Lock Out threshold | $V_{UVLO}$ | $V_{IN}$ Rising | 1.8 | 2.1 | 2.3 | V |
| | | Hysteresis | 100 | 250 | 400 | mV |
| Feedback Voltage | $V_{FB}$ | $V_{FB}$=0.6V | 0.5880 | 0.6000 | 0.6120 | V |
| Feedback Bias Current | $I_{FB}$ | $V_{FB}$=0.65V | -30 | - | +30 | nA |
| Quiescent Current | $I_{CC}$ | $V_{FB}$=1V | - | 200 | 400 | uA |
| Shutdown Supply Current | $I_{SD}$ | $V_{EN}$ =0V | - | 0.1 | 1 | uA |
| Switching Current Limit | $I_{LIMIT}$ | VIN=5V | | 1.8 | | 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 1.2A | - | 0.5 | 0.6 | % |
| Oscillation Frequency | $F_{OSC}$ | SW pin | 1.2 | 1.4 | 1.6 | MHz |
| $R_{DS(ON)}$ of P-CH MOSFET | $R_{DSON}$ | $I_{OUT}$=1.0A | - | 0.26 | 0.33 | Ω |
| $R_{DS(ON)}$ of N-CH MOSFET | $R_{DSON}$ | $I_{OUT}$=1.0A | - | 0.26 | 0.33 | Ω |
| Efficiency | EFFI | $V_{IN}$=5V, $V_{OUT}$=3.3V, $I_{OUT}$=0.5A | 92 | - | - | % |
| 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 |
| Soft-Start Interval | $T_{SS}$ | | - | 1.2 | - | ms |

Note 1: 100% production test at +25°C. Specifications over the temperature range are guaranteed by design and characterization.

Note 2: $V_{IN}$ (Min.) > $V_{OUT}$ (Max.) + $I_O$ (Max.) • (P-CH MOSFET $R_{DS(ON)}$+LDCR)

## ❖ APPLICATION CIRCUIT




$V_{OUT}$=0.6*(1+R1/R2)



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## ❖ FUNCTION DESCRIPTIONS

### Operation

AX3701 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 1.2A output current at $V_{OUT}$ = 1.8V with input voltage range from 2.5V to 7.5V.

### 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, AX3701 automatically enters pulse skipping mode. In the pulse skipping Mode, the inductor current may reach zero or reverse on each pulse. The 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

AX3701 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 AX3701 adjustable output version. The external resistor sets the output voltage according to the following equation:

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

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 |
| 3.3V | 30K | 135K |

We guarantee that the duty cycle range of 20% to 80% is able to work well.

### Inductor Selection

For most designs, the AX3701 operates with inductors of 1μH to 4.7μH. 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.

Table 2 Inductor select for output voltage setting ($V_{CC}$=3.3V)

| $V_{OUT}$ | 1.2V | 1.5V | 1.8V | 2.5V | 3.3V |
|---|---|---|---|---|---|
| Inductor | 2.2uH | 2.2uH | 2.2uH | 2.2uH | 2.2uH |

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.



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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

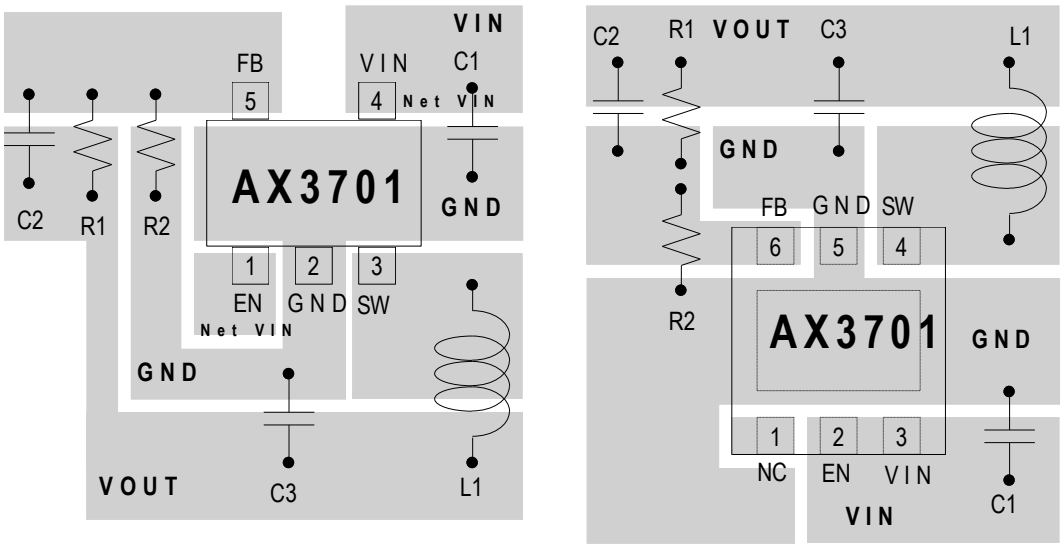
The compensation capacitors for increasing phase margin provide additional stability. It is required and more than 100pF, Refer to Demo Board Schematic, The optimum values for C3 (option) is 330pF.


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## PCB Layout Recommendations

When laying out the printed circuit board, the following checking should be used to ensure proper operation of the AX3701. Check the following in your layout:

1. The power traces, consisting of the GND trace, the SW trace and the $V_{IN}$ trace should be kept short, direct and wide.
2. Does the (+) plates of CIN connect to $V_{IN}$ as closely as possible. This capacitor provides the AC current to the internal power MOSFETs.
3. Keep the switching node SW away from the sensitive $V_{OUT}$ node.
4. Keep the (-) plates of $C_{IN}$ and $C_{OUT}$ as close as possible.

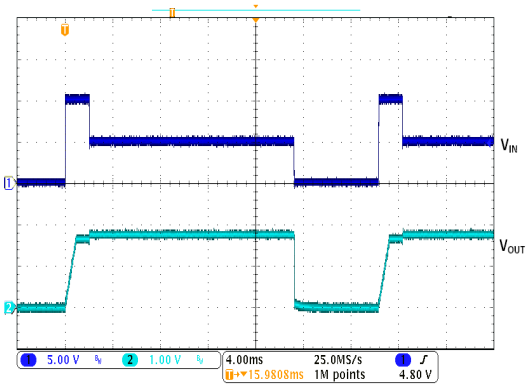




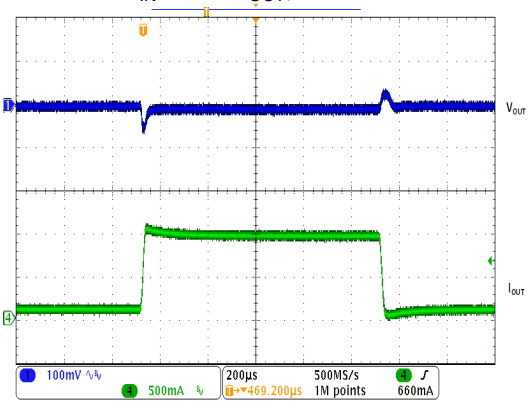

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## ❖ TYPICAL CHARACTERISTICS

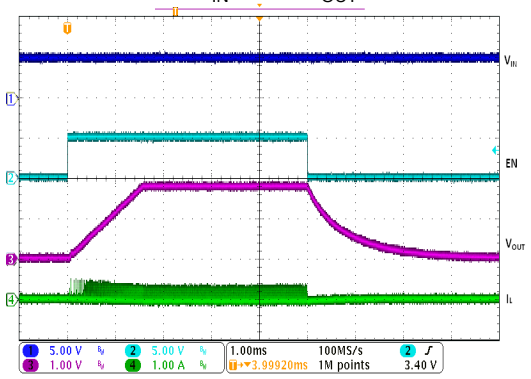
5V~10V $V_{IN}$ Overshoot Test,
No Load,1.8$V_{OUT}$



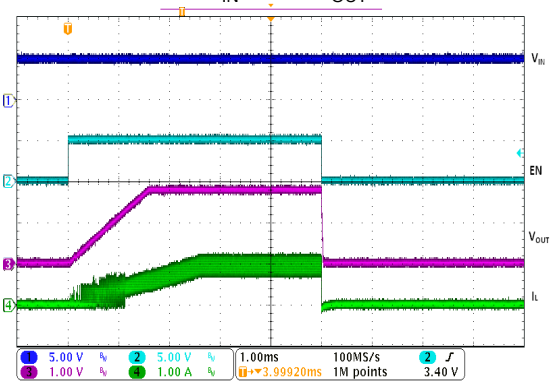

100mA~1A Load Transient Test,
5$V_{IN}$ to 1.8$V_{OUT}$, C3=330PF



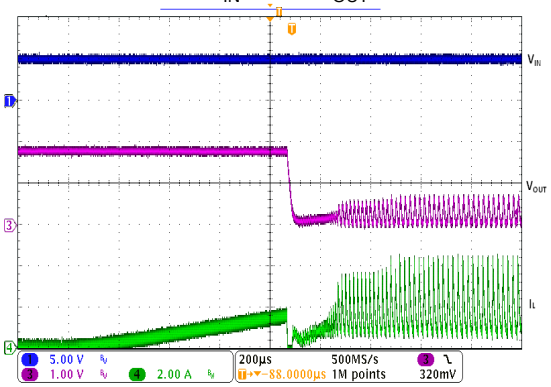

No Load Start Up and Shutdown,
5$V_{IN}$ to 1.8$V_{OUT}$



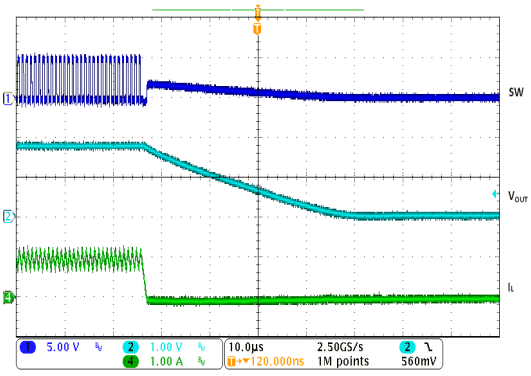

1A Load Start Up and Shutdown,
5$V_{IN}$ to 1.8$V_{OUT}$




Output Short Circuit Test,
5$V_{IN}$ to 1.8$V_{OUT}$




150°C Thermal Shutdown,
5$V_{IN}$ to 1.8$V_{OUT}$, 1A Load

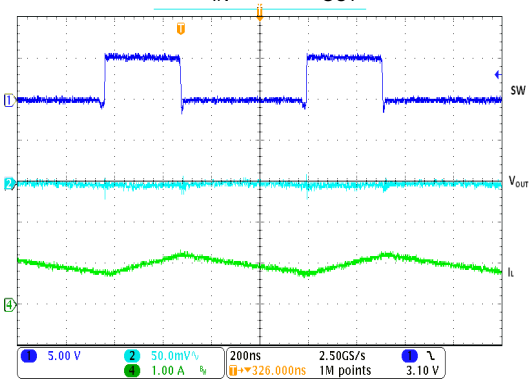




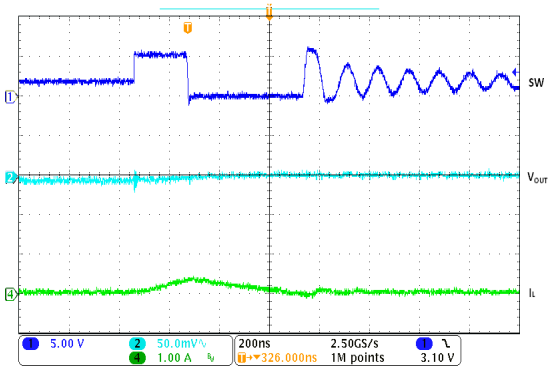

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## ❖ TYPICAL CHARACTERISTICS (CONTINUOUS)

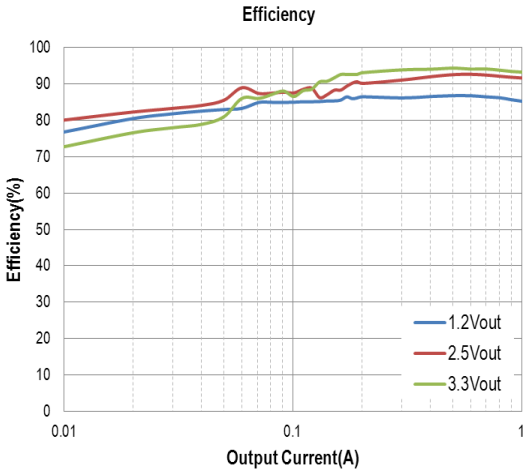
1A Load Switching Waveform,
$5V_{IN}$ to $1.8V_{OUT}$




No Load Switching Waveform,
$5V_{IN}$ to $1.8V_{OUT}$




$I_{OUT}$ vs Efficiency, $V_{IN}$=5V

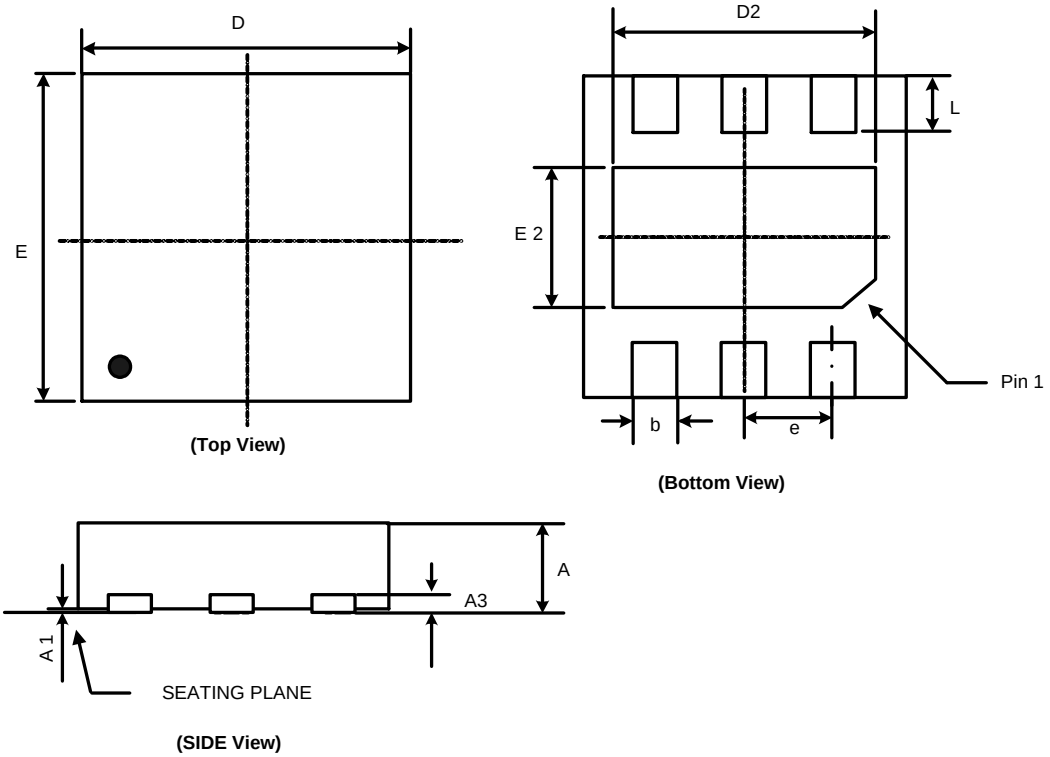





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## ❖ PACKAGE OUTLINES

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

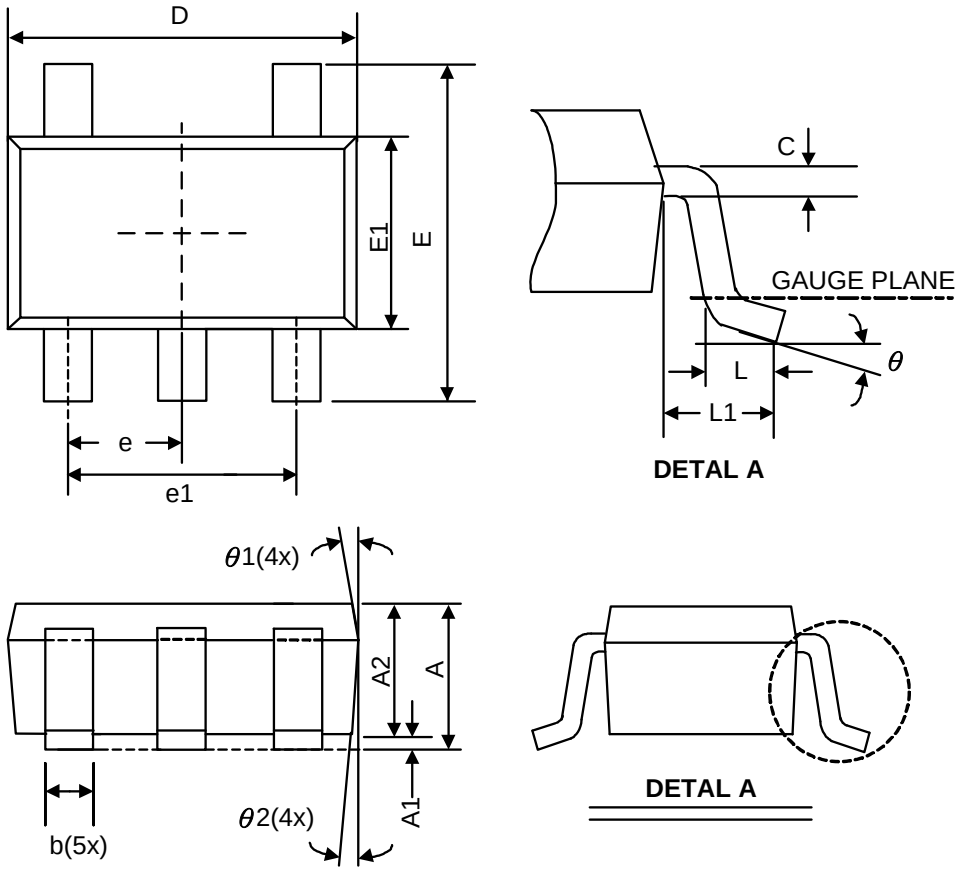



| Symbol | Dimensions in Millimeters | | | Dimensions in Inches | | |
|---|---|---|---|---|---|---|
| | Min. | Nom. | Max. | Min. | Nom. | Max. |
| A | 0.7 | 0.75 | 0.8 | 0.028 | 0.03 | 0.031 |
| A1 | 0 | 0.02 | 0.05 | 0 | 0.001 | 0.002 |
| A3 | | 0.203 REF. | | | 0.008 REF. | |
| b | 0.2 | 0.28 | 0.35 | 0.009 | 0.011 | 0.013 |
| D | 1.95 | 2 | 2.05 | 0.077 | 0.079 | 0.081 |
| D2 | 1.0 | 1.3 | 1.45 | 0.039 | 0.051 | 0.057 |
| E | 1.95 | 2 | 2.05 | 0.077 | 0.079 | 0.081 |
| E2 | 0.5 | 0.65 | 0.85 | 0.02 | 0.026 | 0.033 |
| e | | 0.65 BSC. | | | 0.026 BSC. | |
| L | 0.2 | 0.3 | 0.4 | 0.008 | 0.012 | 0.016 |



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## (2) SOT-23-5L




| Symbol | Dimensions in Millimeters | | | Dimensions in Inches | | |
|---|---|---|---|---|---|---|
| | Min. | Nom. | Max. | Min. | Nom. | Max. |
| A | - | - | 1.3 | - | - | 0.051 |
| 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: NA



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