1.5MHz, 1.2A, VFB=0.6V Synchronous Step-Down Converter

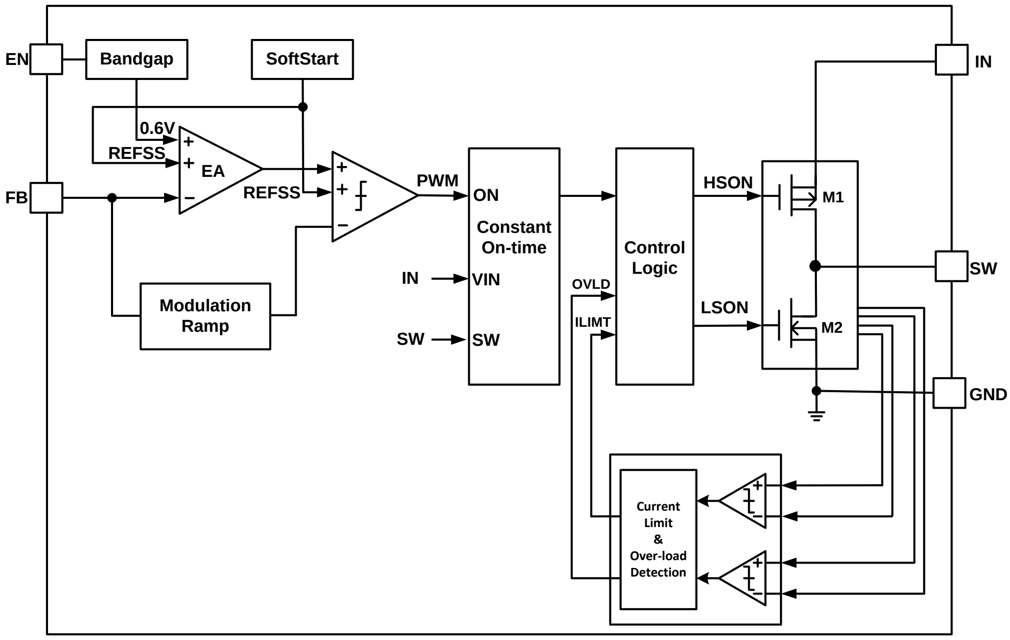
❖ GENERAL DESCRIPTION

AX3701 is a high efficiency monolithic synchronous buck regulator using a constant on-time (COT) architecture. The device is available in an adjustable version. Supply current with no load is about 30uA and drops to <1uA in shutdown. The 2.5V to 6.0V 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. The constant on-time control scheme simplifies loop compensation and offers excellent load transient response. The high gain error amplifier in the control loop provides excellent load and line regulation. Proprietary adaptive on-time helps AX3701 to achieve nearly constant switching frequency across load range. AX3701 has cycle-by-cycle current limit and hiccup mode to protect over-load or short circuit fault conditions. Switching frequency is internally set at 1.5MHz, 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

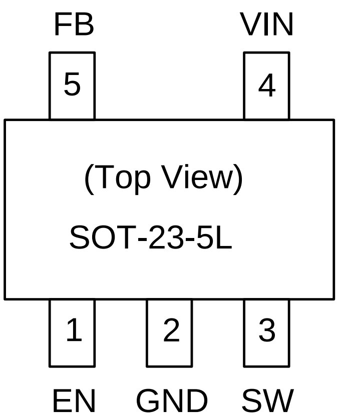
- 2.5V to 6.0V Input Voltage Range
- Output Voltage from 0.6V to V_{IN}
- High Efficiency: Up to 92%
- 1.5MHz Switching Frequency Operation
- 1.2A Output Current
- Quiescent Current: 30uA (input < 4.2V)
- No Schottky Diode Required
- 100% Duty Cycle in Dropout
- 0.6V Reference Allows Low Output Voltages
- Internal 1msec Soft-Start
- Proprietary Fast Transient Constant On Time Architecture Stable with low ESR Ceramic Output Capacitors
- Cycle-by cycle Current limit Protection
- Hiccup Mode for Short Circuit and Over-Load Protect
- ≤ 1µA Shutdown Current
- SOT-23-5L, TDFN-6L (2*2)
- RoHS and Halogen free compliance.

❖ BLOCK DIAGRAM

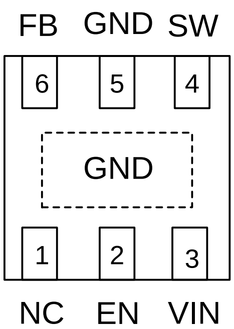


❖ PIN ASSIGNMENT

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



SOT-23-5L (A-Type)



TDFN-6L (2*2)

Name	Description
EN	Enable pin H：normal operation 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

❖ ORDER/MARKING INFORMATION

Order Information

AX3701 X X X X

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

Top Marking (TDFN-6L)	Top Marking SOT-23-5L(A-Type)
Z a → Part Number YWX → ID Code: Internal W → Week: 01~26(A~Z) 27~52(a~z) Y → Year: 8=2018 9=2019 B=2020 C=2021 D=2022 : Z=2044	XX Y W 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 XX → Za: AX3701 (A 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} +7	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)	θ_{JC}	25	°C/W
	SOT-23-5L		130	
Thermal Resistance from Junction to ambient	TDFN-6L(2*2)	θ_{JA}	120	°C/W
	SOT-23-5L		250	

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

❖ ELECTRICAL CHARACTERISTICS

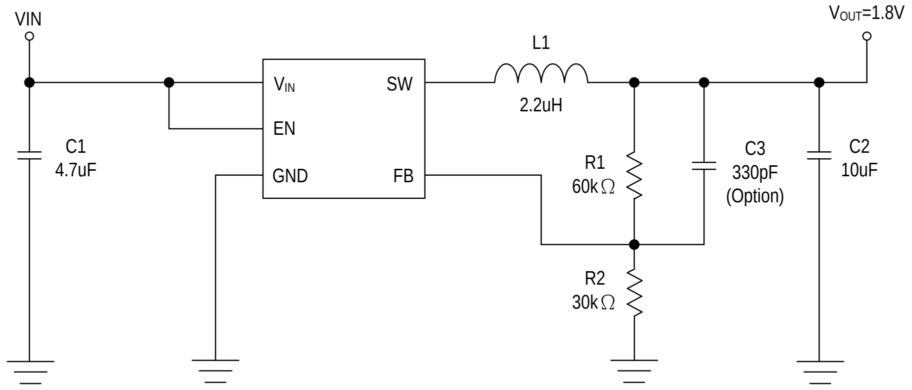
(V_{IN} = V_{EN}=3.6V, T_A =25°C, unless otherwise specified) (Note)

Characteristics	Symbol	Conditions	Min	Typ	Max	Units
Input Voltage Range (Note 2)	V_{IN}		2.5	-	6.0	V
Under Voltage Lock Out threshold	V_{UVLO}	V_{IN} Rising	2.3	2.4	2.5	V
		Hysteresis		280		mV
Input Over Voltage Lockout Threshold	V_{OVLO}	V_{IN} Rising		6.2		V
Input Over Voltage Lockout Hysteresis		Hysteresis		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	-	30	-	uA
Shutdown Supply Current	I_{SD}	V_{EN} =0V	-	0.1	1	uA
Switching Current Limit	I_{LIMIT}	VIN=5V	1.7	-		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	-	0.20	0.30	Ω
Efficiency	EFFI	V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=0.5A	92	-	-	%
EN pin logic input threshold voltage	V_{ENL}		-	-	0.4	V
	V_{ENH}		1.0	-	-	
EN Internal Pull Down Resistor	R_{EN}		700	1000	1300	kΩ
Soft-Start Interval	T_{SS}		-	1.0	-	ms
Thermal Shutdown	T_{SD}			160		°C
Thermal Shutdown Hysteresis	T_{SH}			30		°C
Output Discharging Resistor	R_{DISC}			50		Ω

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)

❖ FUNCTION DESCRIPTIONS

Theory of Operation

AX3701 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. AX3701 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 AX3701, 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.

Light Load Operation

In light load condition where the converter operates in discontinuous mode, AX3701 cuts down its quiescent current to as low as 15uA and achieves excellent light load efficiency.

Enable

When input voltage is above the under voltage lock-out threshold, AX3701 can be enabled by pulling the EN pin to above 1V. AX3701 is disabled if the EN pin is pulled below 0.4 V.

Soft Start

AX3701 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.

Current Limit and Hiccup Mode

AX3701 has cycle-by-cycle HS current limit protection to prevent inductor current from running away. Once HS current limit is triggered, AX3701 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, AX3701 will consider it over-load or short circuit. Either way, AX3701 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.

❖ 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.

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.

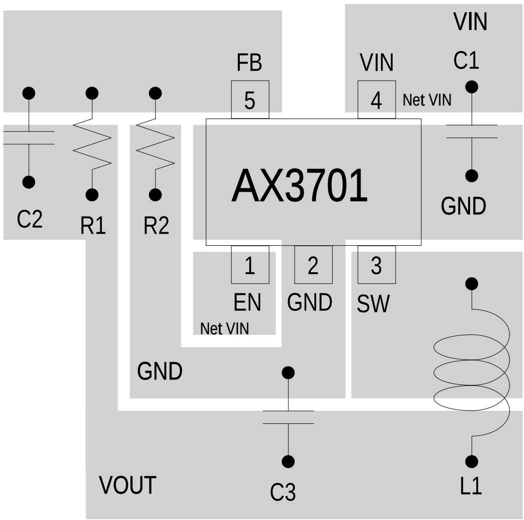
Compensation Capacitor Selection

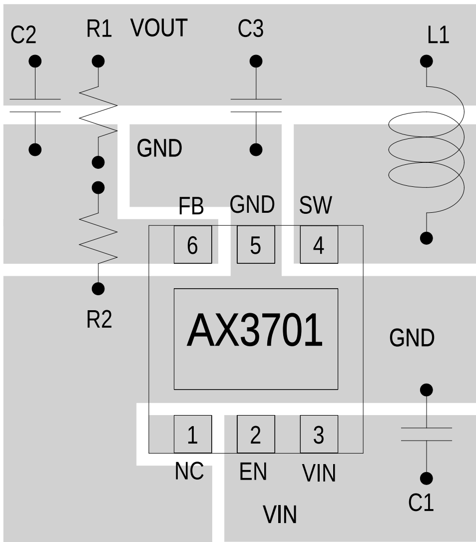
The compensation capacitors for increasing phase margin provide additional stability. It is required and more than 100pF, Refer to Demo Board Schematic, The optimum values for C3 (option) is 330pF.

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.

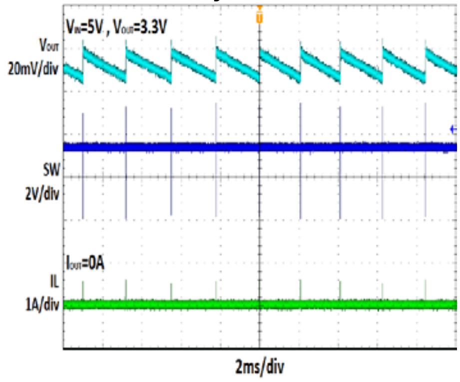




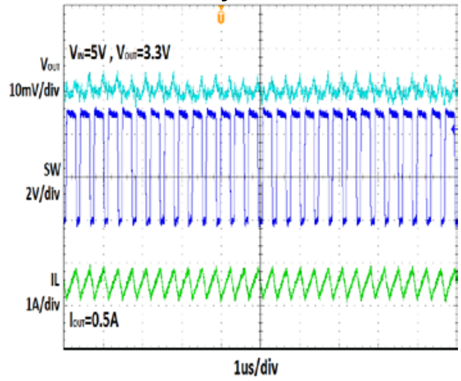
❖ TYPICAL CHARACTERISTICS

C_{IN}=10uF, C_{OUT}=10uF

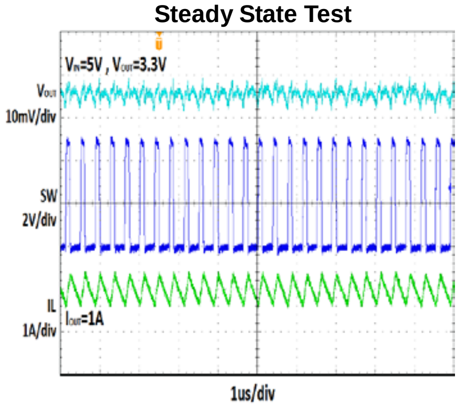
Steady State Test



Steady State Test



Steady State Test



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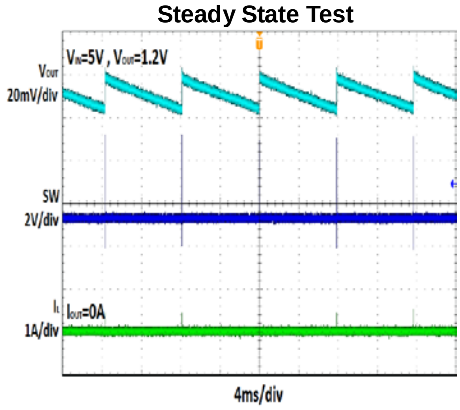

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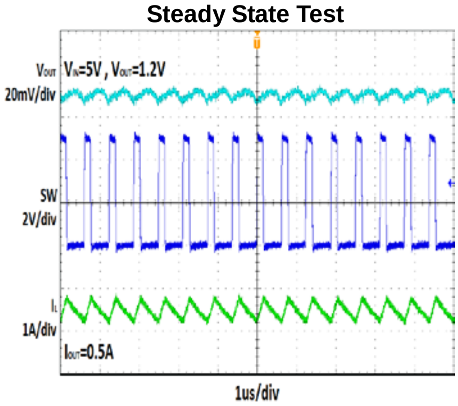

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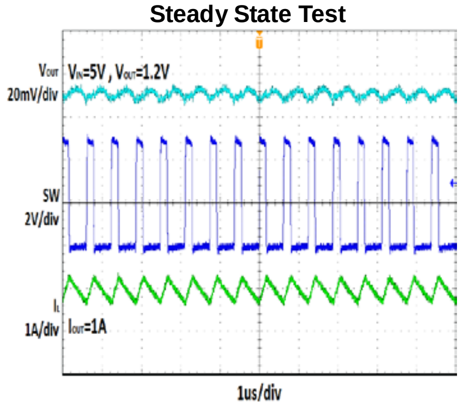
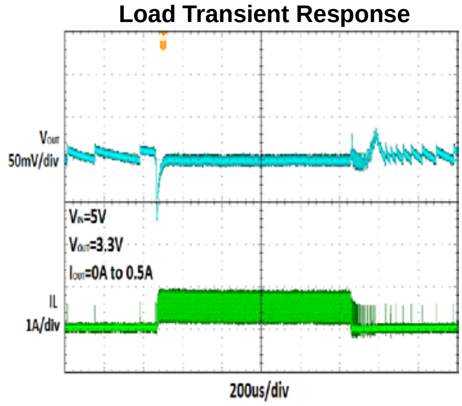
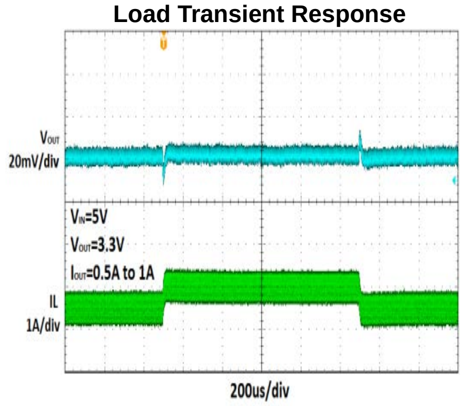


❖ TYPICAL CHARACTERISTICS (CONTINUOUS)

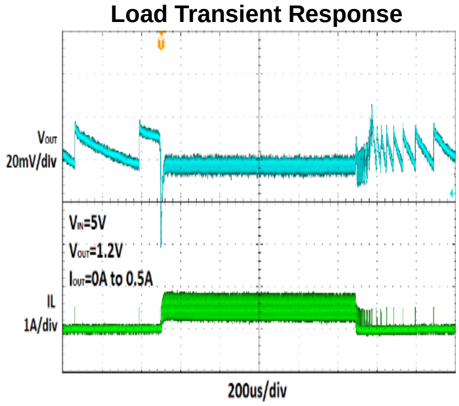
Load Transient Response



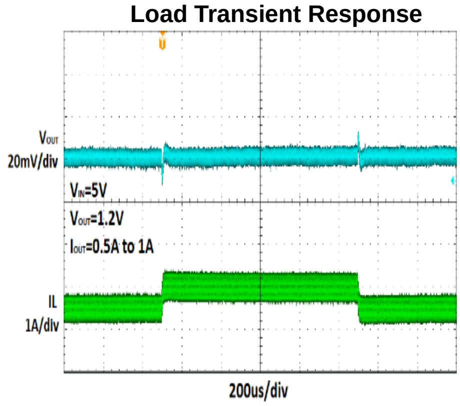
Load Transient Response



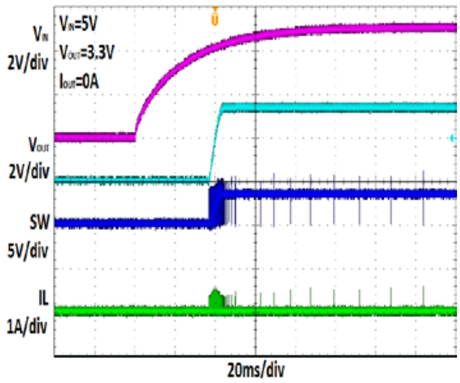
Load Transient Response



Load Transient Response



Vin Power On



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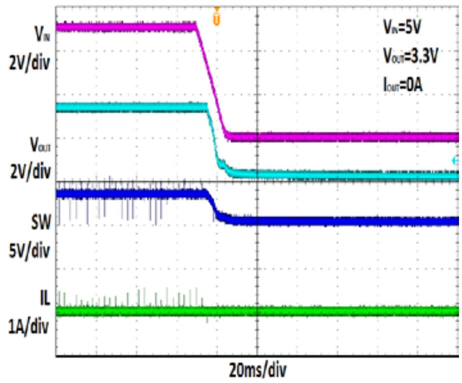
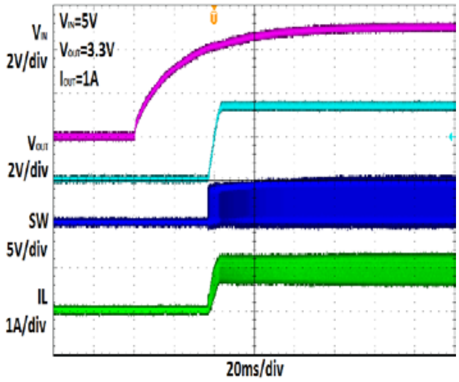


❖ TYPICAL CHARACTERISTICS (CONTINUOUS)

Vin Power On



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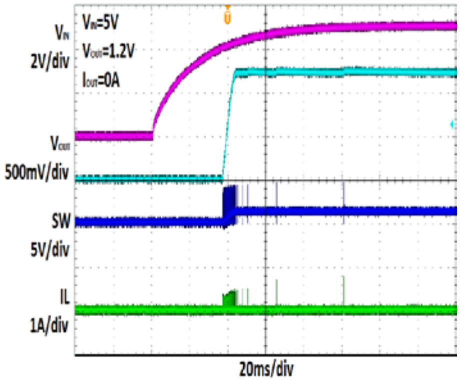

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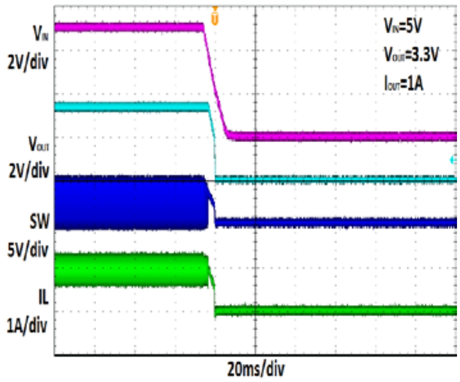

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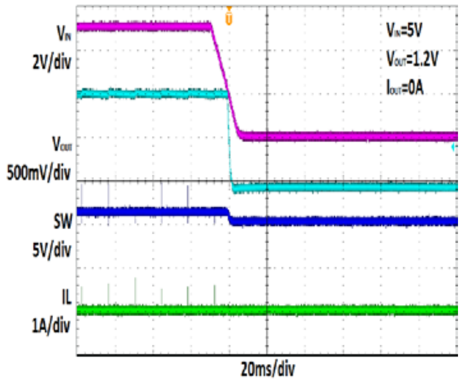
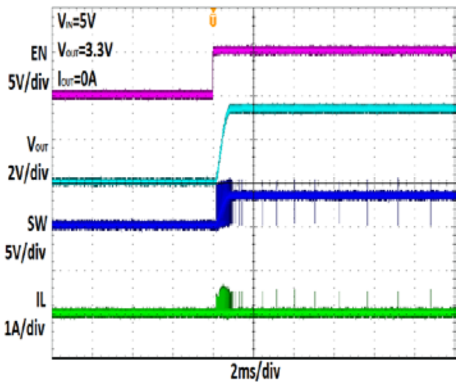


EN On



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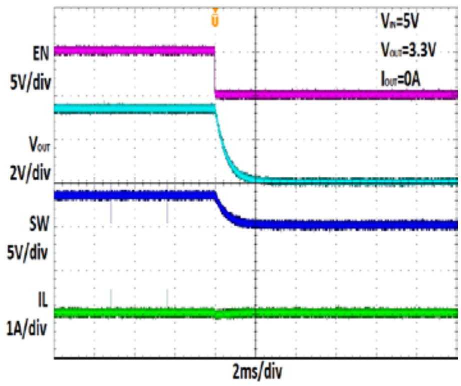
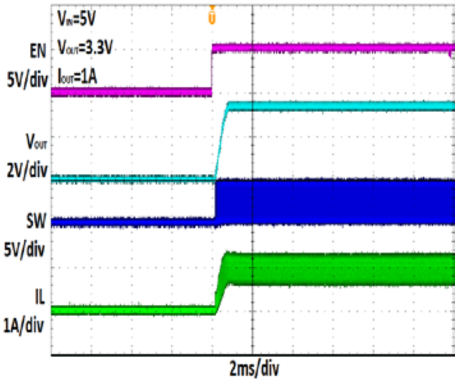


❖ TYPICAL CHARACTERISTICS (CONTINUOUS)

EN On



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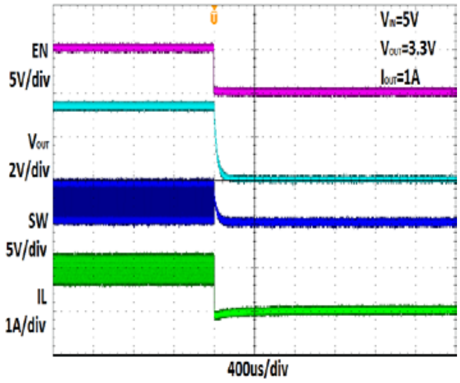

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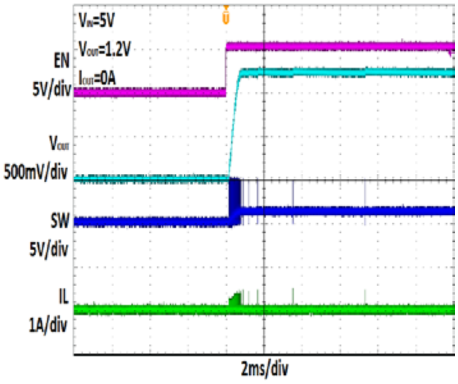

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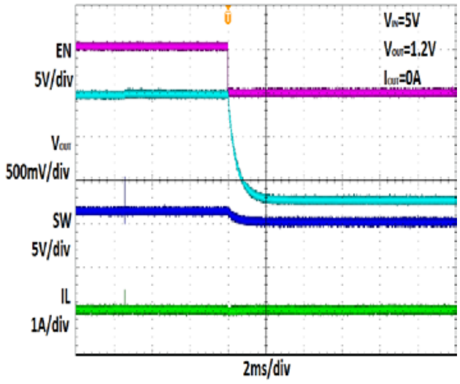

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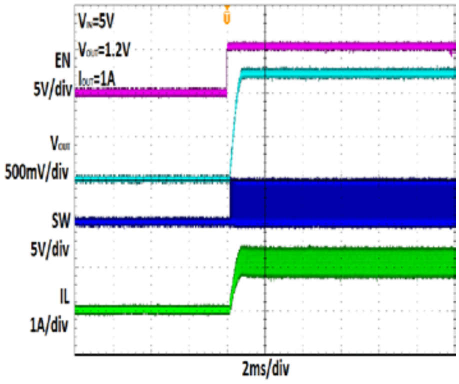
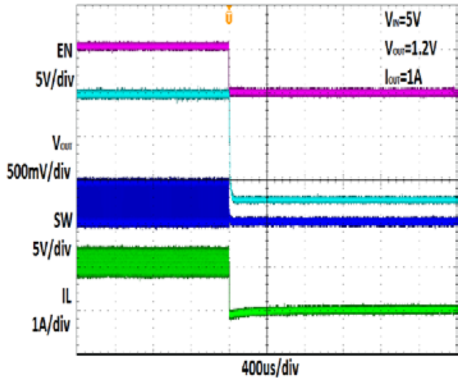
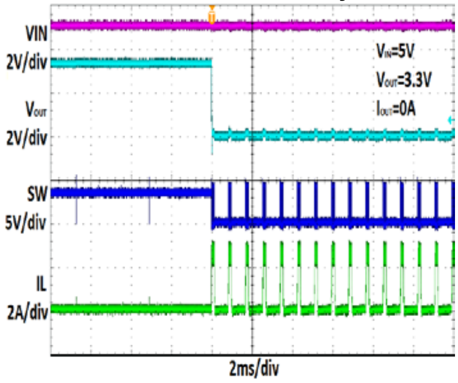


EN Off

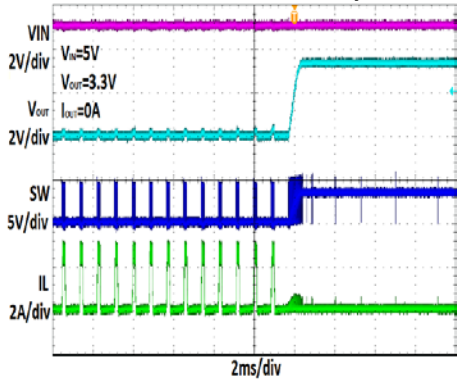


❖ TYPICAL CHARACTERISTICS (CONTINUOUS)

Short Circuit Entry



Short Circuit Entry



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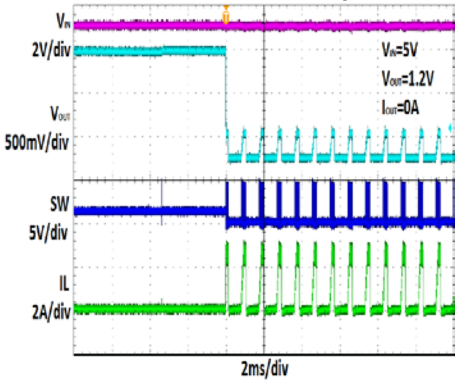

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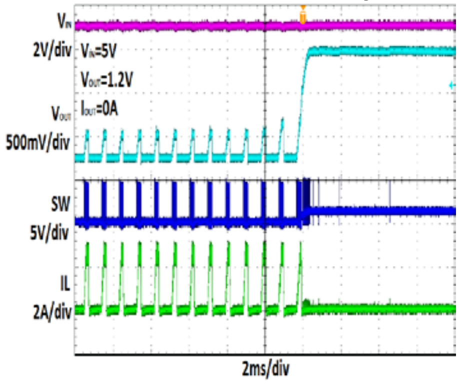
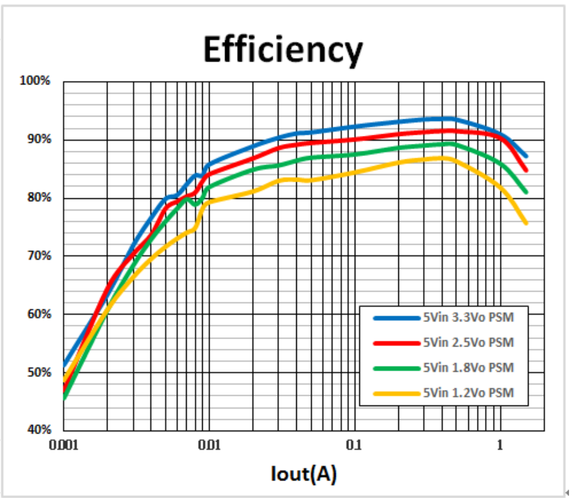
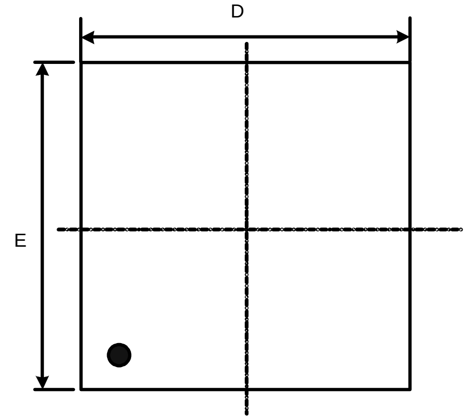


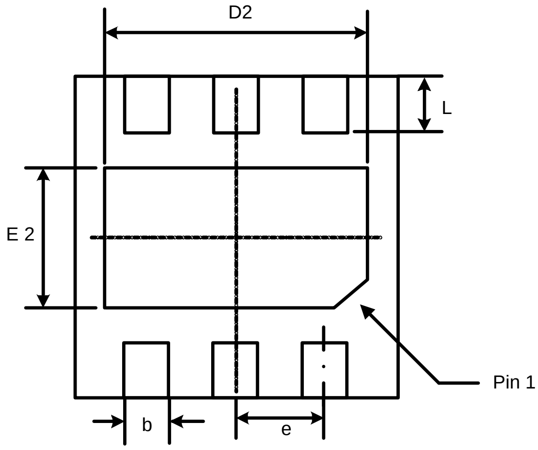


❖ PACKAGE OUTLINES

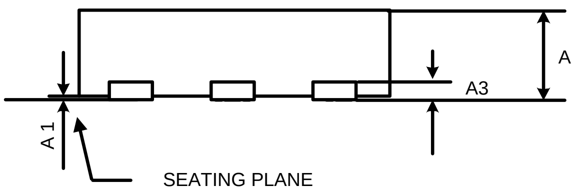
(1) TDFN-6L (2*2 0.75mm)



(Top View)



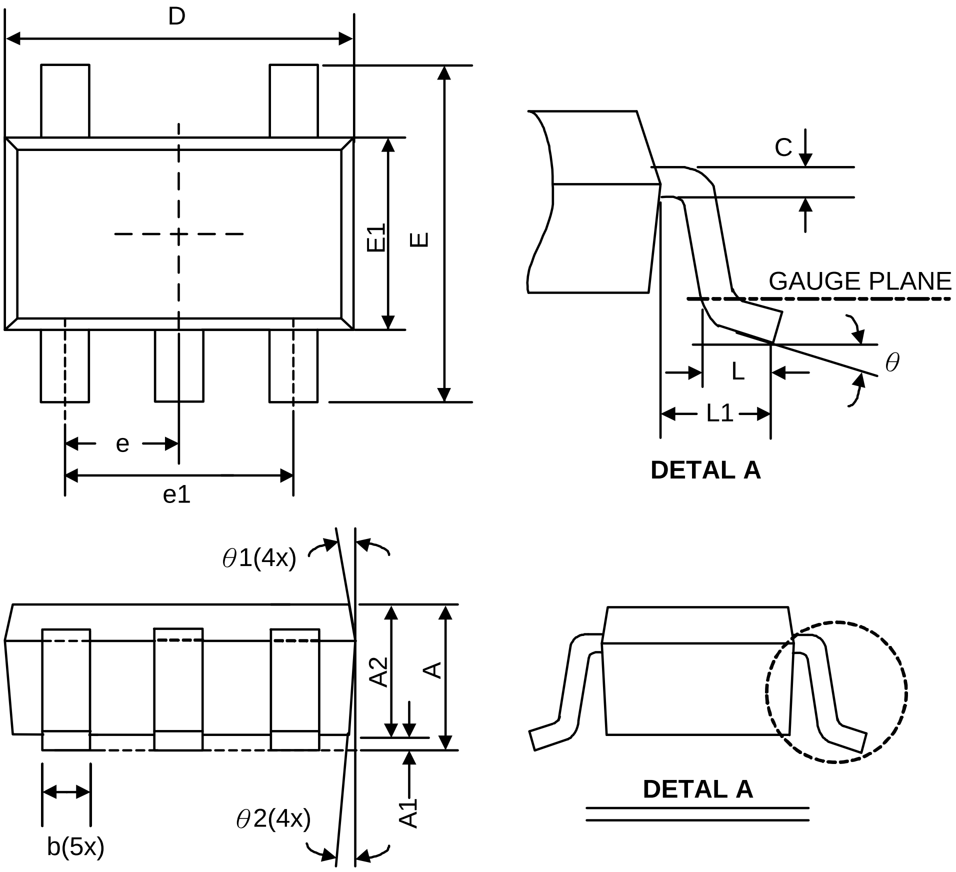
(Bottom View)



(SIDE View)

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

(2) SOT-23-5L

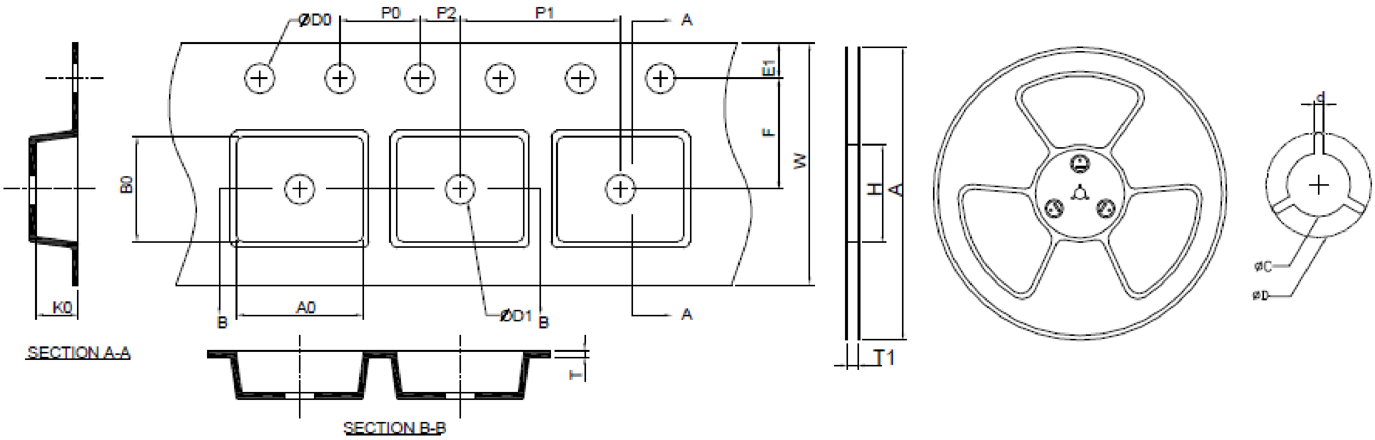


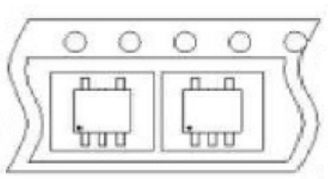
Symbol	Dimensions in Millimeters			Dimensions in Inches		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	-	-	1.3	-	-	0.051
A1	0	0.08	0.15	0	0.003	0.006
A2	0.9	1.1	1.3	0.035	0.043	0.051
b	0.3	0.4	0.5	0.012	0.016	0.02
C	0.08	0.15	0.22	0.003	0.006	0.009
D	2.7	2.9	3.1	0.106	0.114	0.122
E1	1.4	1.6	1.8	0.055	0.063	0.071
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°
θ1	5°	10°	15°	5°	10°	15°
θ2	5°	10°	15°	5°	10°	15°

JEDEC outline: NA

❖ Carrier tape dimension

SOT-23-5L

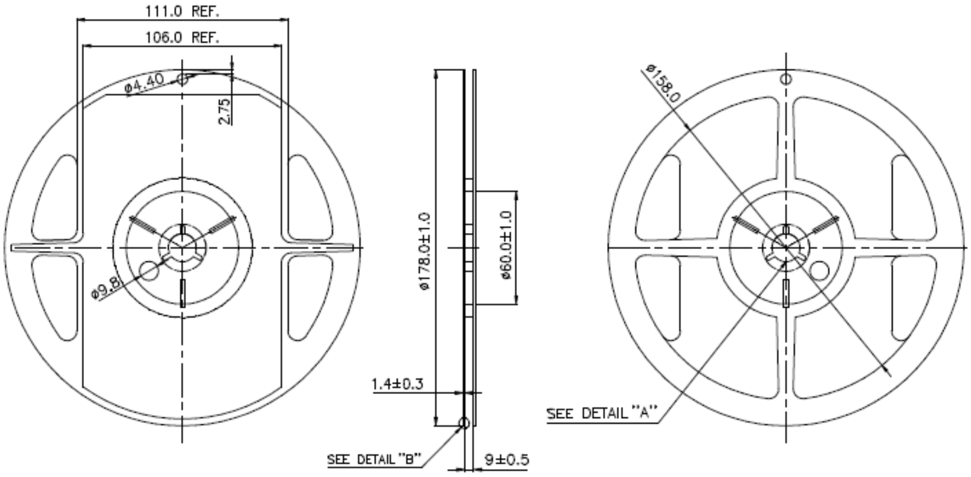


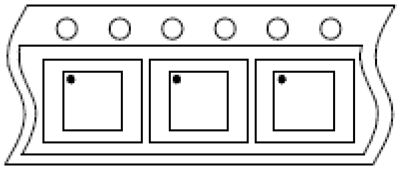


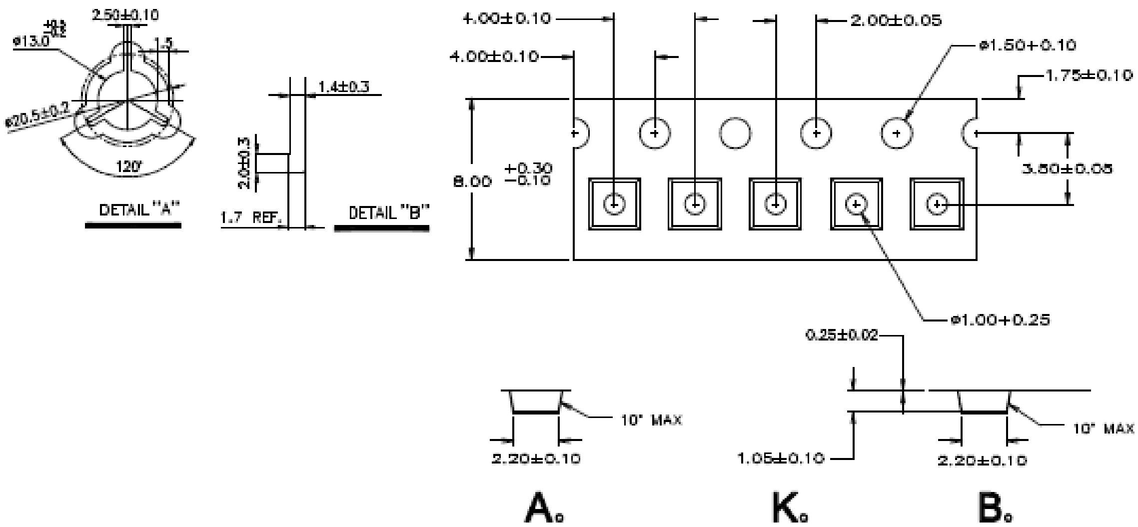
A	H	T1	C	d	D	W	E1	F
178.0±2.00	50 MIN.	8.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	8.0±0.30	1.75±0.10	3.5±0.05
P0	**P1**	**P2**	**D0**	**D1**	**T**	**A0**	**B0**	**K0**
4.0±0.10	4.0±0.10	2.0±0.05	1.5+0.10 -0.00	1.0 MIN.	0.6+0.00 -0.40	3.20±0.20	3.10±0.20	1.50±0.20

(mm)

TDFN-6L(2x2)


111.0 REF.
106.0 REF.
ø4.40
2.75
ø9.8
ø178.0±1.0
ø60.0±1.0
1.4±0.3
SEE DETAIL "B"
9±0.5
ø158.0
SEE DETAIL "A"




2.50±0.10
ø13.0
1.5
ø20.5±0.2
120°
DETAIL "A"
1.4±0.3
2.0±0.3
1.7 REF.
DETAIL "B"
4.00±0.10
4.00±0.10
2.00±0.05
ø1.50+0.10
1.75±0.10
8.00 +0.30 −0.10
3.50±0.05
ø1.00+0.25
0.25±0.02
10° MAX
2.20±0.10
1.05±0.10
10° MAX
2.20±0.10
A.
K.
B.