

5.5 V, 1 A, 1.65 MHz High-Efficiency, 20 μ A I_Q Constant On-Time Synchronous, Step-Down Converter

■ Features

- Low $R_{DS(ON)}$ for internal switches (top/bottom) 260 m Ω / 180 m Ω , 1.0 A
- 2.5 V ~ 5.5 V input voltage range
- 20 μ A typical quiescent current
- High light load efficiency
- High switching frequency 1.65 MHz minimizes the external components
- Output discharge function
- Operation mode:
DIO60011: Auto mode
DIO60011A: Forced PWM operation
- Fixed frequency COT architecture achieve ultra fast transient response
- Internal soft start limits the inrush current
- 100% dropout operation
- Operating temperature range: -40°C to 85°C

■ Applications

- Portable navigation devices
- Set top boxes
- USB dongle
- Media players
- Smart phones

■ Package Information

Part Number	Package	Body Size
DIO60011/A	SOT563	1.6 mm × 1.2 mm
	SOT23-6	1.6 mm × 2.9 mm

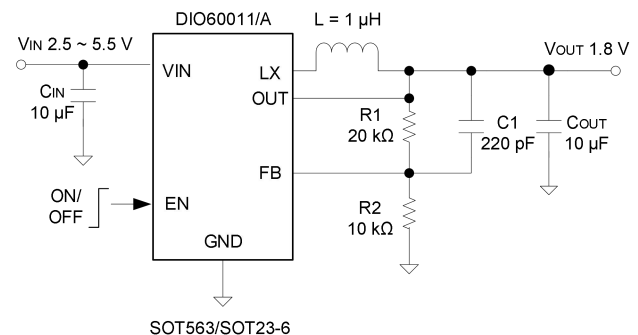
■ Description

The DIO60011/A is a high-efficiency synchronous step-down DC-DC regulator. The DIO60011/A can achieve up to 1 A continuous output current from a 2.5 V to 5.5 V input voltage with excellent load and line regulation. The output voltage can be regulated to as low as 0.6 V.

Constant-on-time (COT) control provides a fast transient response and eases loop stabilization. The DIO60011 includes an automatically entered power save mode to maintain high efficiency down to very light loads for extending the system battery run-time. The DIO60011A runs in Forced PWM maintaining a continuous conduction mode to ensure the least ripple in the output voltage and a quasi-fixed switching frequency.

The DIO60011/A is ideal for a wide range of applications, including portable navigation devices, set top boxes and media players.

■ Simplified Schematic



■ Ordering Information

Ordering Part No.	Top Marking	Operation Mode	MSL	RoHS	T _A	Package	
DIO60011SH3	W0L	Auto Mode	3	Green	-40 to 85°C	SOT563	Tape & Reel, 5000
DIO60011ST6	W00L	Auto Mode	3	Green	-40 to 85°C	SOT23-6	Tape & Reel, 3000
DIO60011ASH3	WLA	FPWM	3	Green	-40 to 85°C	SOT563	Tape & Reel, 5000
DIO60011AST6	W0LA	FPWM	3	Green	-40 to 85°C	SOT23-6	Tape & Reel, 3000

If you encounter any issue in the process of using the device, please contact our customer service at marketing@dioo.com or phone us at (+86)-21-62116882. If you have any improvement suggestions regarding the datasheet, we encourage you to contact our technical writing team at docs@dioo.com. Your feedback is invaluable for us to provide a better user experience.

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1. Pin Assignment and Functions

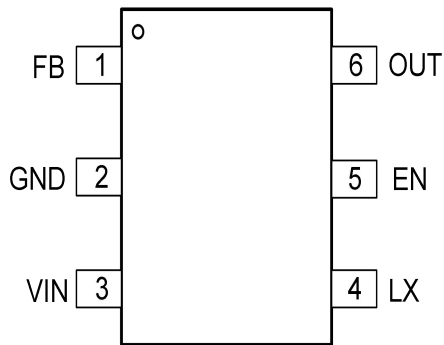


Figure 1. SOT563 (Top view)

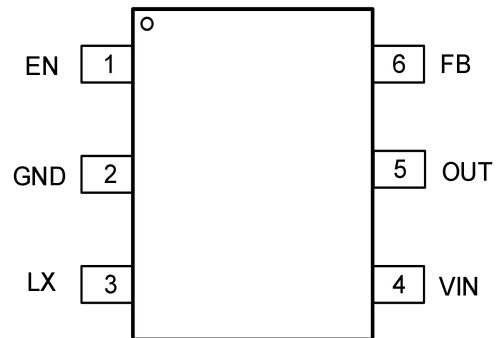


Figure 2. SOT23-6 (Top view)

Pin No.		Pin Name	I/O	Description
SOT563	SOT23-6			
5	1	EN	I	Enable control. Pull high to turn on. Do not float.
2	2	GND	G	Power ground.
4	3	LX	I/O	Inductor pin. Connect this pin to the switching node of inductor.
3	4	VIN	I	Power input.
1	6	FB	O	Output feedback pin. Connect this pin to the center point of the output resistor divider to program the output voltage: $V_{OUT} = 0.6 \times (1 + R1/R2)$. Add optional C1 (220 pF ~ 47 pF) to speed up the transient response.
6	5	OUT	O	Output voltage. Connect to the load to OUT. An output capacitor is required to decrease the output voltage ripple.

2. Absolute Maximum Ratings

Exceeding the maximum ratings listed under Absolute Maximum Ratings when designing is likely to damage the device permanently. Do not design to the maximum limits because long-time exposure to them might impact the device's reliability. The ratings are obtained over an operating free-air temperature range unless otherwise specified.

Symbol	Parameter	Rating	Unit
V_{CC}	Supply voltage ($V+$ ~ $V-$)	-0.3 ~ 6.0	V
	Enable / FB voltage	-0.3 to $V_{IN} + 0.2$	V
P_D	Power dissipation at $T_A = 25^{\circ}C$	0.6	W
T_{STG}	Storage temperature range	-65 ~ 150	$^{\circ}C$
T_J	Junction temperature range	150	$^{\circ}C$
T_L	Lead temperature range	260	$^{\circ}C$
	Dynamic LX voltage in 50 ns duration	$V_{IN} + 3$ to GND - 4	V

3. Recommended Operating Conditions

Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. The ratings are obtained over an operating free-air temperature range unless otherwise specified.

Symbol	Parameter	Rating	Unit
V_{CC}	Supply voltage ($V+$ ~ $V-$)	2.5 ~ 5.5	V
T_J	Junction temperature range	-40 ~ 125	$^{\circ}C$
T_A	Ambient temperature range	-40 ~ 85	$^{\circ}C$

4. ESD Ratings

When a statically-charged person or object touches an electrostatic discharge sensitive device, the electrostatic charge might be drained through sensitive circuitry in the device. If the electrostatic discharge possesses sufficient energy, damage might occur to the device due to localized overheating.

Model	Condition	Value	Unit
HBM	JEDEC:JS-001	± 2000	V
CDM	JEDEC:JS-002	± 2000	V

5. Electrical Characteristics

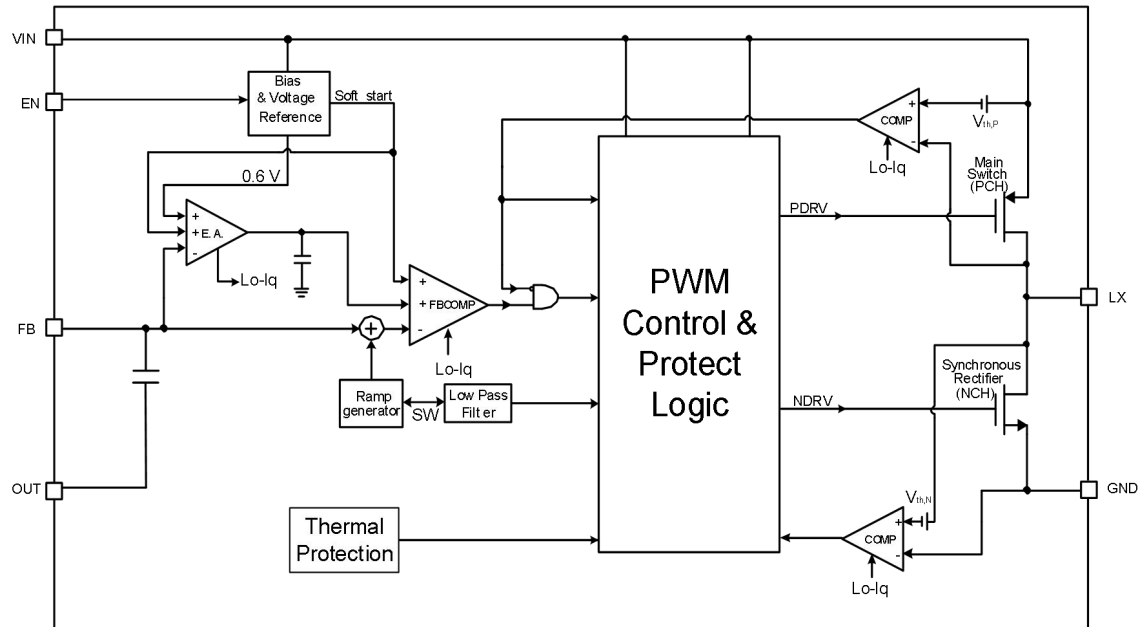
The values are obtained under these conditions unless otherwise specified: $V_{IN} = 5\text{ V}$, $V_{OUT} = 1.8\text{ V}$, $L = 1\text{ }\mu\text{H}$, $C_{OUT} = 10\text{ }\mu\text{F}$, $T_A = 25^\circ\text{C}$.

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V_{IN}	Input voltage range		2.5		5.5	V
I_Q	Quiescent current	$I_{OUT} = 0$, FB = 0.65 V PWM devices		20		μA
		$I_{OUT} = 0$, FB = 0.65 V FPWM devices		180		μA
I_{SHDN}	Shutdown current	EN = 0		0.1	1	μA
V_{REF}	Feedback reference voltage		0.588	0.6	0.612	V
$R_{DS(ON),P}$	PFET R_{ON}	$I_{OUT} = 100\text{ mA}$		260		m Ω
$R_{DS(ON),N}$	NFET R_{ON}	$I_{OUT} = 100\text{ mA}$		180		m Ω
I_{LIM}	PFET current limit		2			A
V_{ENH}	EN rising threshold		1			V
V_{ENL}	EN falling threshold				0.4	V
V_{UVLO}	Input undervoltage lockout threshold			2.15	2.3	V
V_{HYS}	undervoltage lockout hysteresis			0.15		V
f_{OSC}	Oscillator frequency	$I_{OUT} = 500\text{ mA}$		1.65		MHz
	Min ON time			80		ns
	Max Duty cycle		100			%
t_{SS}	Soft-start time	V_{OUT} rise from 10% to 90%		0.5		ms
T_{SD}	Thermal shutdown temperature			150		$^\circ\text{C}$
T_{HYS}	Thermal shutdown hysteresis			20		$^\circ\text{C}$

Note:

(1) Specifications subject to change without notice.

6. Block Diagram



7. Application Information

Important notice: Important notice: Validation and testing are the most reliable ways to confirm system functionality. The application information is not part of the specification and is for reference purposes only.

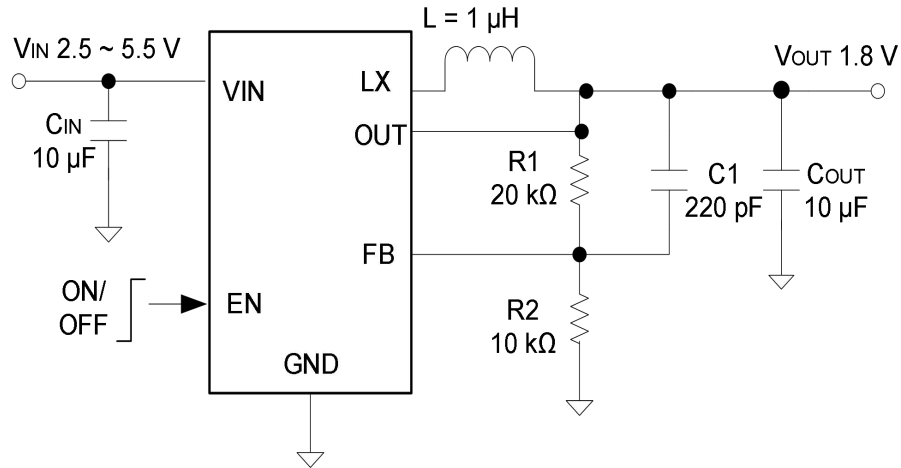


Figure 3. Typical application

The DIO60011/A is available in two versions, Forced Pulse Width Modulation (FPWM) and Auto Mode. The DIO60011/A is a synchronous buck regulator IC that integrates the adaptive constant on-time (COT) control, and top and bottom switches on the same die to minimize the switching transition loss and conduction loss. With ultra-low $R_{DS(ON)}$ power switches and proprietary COT control, this regulator IC can achieve the highest efficiency and the highest switch frequency simultaneously to minimize the external inductor and capacitor size, thus achieving the minimum solution footprint. Under PWM mode, the converter operates with a typical 1.65 MHz switching frequency to minimize the size of the inductor and capacitor. As the load current decreases, the converter enters PSM (Power Save Mode), reducing the switching frequency to keep high efficiency over the entire load current range.

Under Auto Mode, the DIO60011 enters PWM mode for medium to heavy load conditions or enters PSM (Power Save Mode) for a light load. Under FPWM mode, the converter maintains a continuous conduction mode operation and keeps the output voltage ripple very low across the whole load range.

Because of the high integration in the DIO60011/A IC, the application circuit based on this regulator IC is rather simple. Only the input capacitor, C_{IN} , output capacitor, C_{OUT} , output inductor, L , feedback capacitor, C_1 , and feedback resistors (R_1 and R_2) need to be selected for the targeted application specifications.

7.1. Enable

When disabled, the device shutdown supply current is only 0.1 μ A. When applying a voltage greater than the EN logic high threshold (typ 0.65 V, rising), the DIO60011/A enables all functions and the device initiates the soft-start phase. The DIO60011/A has a built-in 0.5 ms soft-start time to prevent output voltage overshoot and inrush current. When the EN voltage falls below its logic low threshold (typ 0.58 V, falling), the device operation is disabled and the 500 Ω active discharge is enabled to discharge the output voltage to ground.

7.2. Undervoltage lockout

Undervoltage lockout protects the IC from insufficient input voltages. The DIO60011/A is disabled if the input voltage falls below 2.15 V (typ). In this UVLO event, both the high-side and low-side power MOSFETs turn off.

7.3. Thermal shutdown

If the junction temperature of the device reaches the thermal shutdown limit of 150°C, the DIO60011/A shuts down both high-side and low-side power MOSFETs. When the junction temperature reduces to the required level (130°C typ), the device initiates a normal power-up cycle with soft-start.

7.4. Switch current limit and short-circuit protection

The protection function prevents the device from drawing excessive current in case of externally-caused overcurrent or short-circuit conditions. If the current limit threshold is reached, the device delivers its maximum output current. Detecting this condition for 32 switching cycles, the device turns off the high-side MOSFET for about 500 µs and then restarts again with a soft-start cycle. As long as the overload condition is present, the device hiccups that way, limiting the output power.

In FPWM devices, a negative current limit (I_{LIMN}) is enabled to prevent excessive current from flowing backward to the input. When the inductor current reaches I_{LIMN} , the low-side MOSFET turns off and the high-side MOSFET turns on and is kept on until t_{ON} time expires.

7.5. Feedback resistor dividers R1 and R2

Choose R1 and R2 to program the proper output voltage. To minimize the power consumption under light loads, choose large resistance values for both R1 and R2. It is recommended that the resistance value of R1 is below 30 kΩ, then R2 can be calculated from Equation (1).

$$R_2 = \frac{0.6V}{V_{OUT} - 0.6V} \times R_1 \quad (1)$$

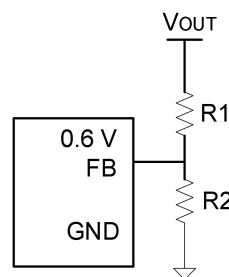


Figure 4. Feedback resistor dividers R1 and R2

7.6. Input capacitor C_{IN}

With the maximum load current at 1 A, the maximum ripple current through the input capacitor is about 0.5 A. A typical X7R or better grade ceramic capacitor with 6 V rating and greater than 10 µF capacitance can handle this ripple current well. To minimize the potential noise problem, place this ceramic capacitor really close to the IN and GND pins. Carefully minimize the loop area formed by C_{IN} , and IN/GND pins.

7.7. Output capacitor C_{OUT}

The output capacitor is selected to handle the output ripple noise requirements. Both steady-state ripple and transient requirements must be taken into consideration when selecting this capacitor. For the best performance, use X5R or a better grade ceramic capacitor with 6 V rating and greater than 10 μ F capacitance.

7.8. Output inductor L

There are several considerations in choosing this inductor.

(1) Choose the inductance to provide the desired ripple current. Choose the ripple current to be approximately 40% of the maximum output current. The inductance is calculated from Equation (2).

$$L = \frac{V_{OUT} \times (1 - V_{OUT} / V_{IN, MAX})}{f_{SW} \times I_{OUT, MAX} \times 40\%} \quad (2)$$

where f_{SW} is the switching frequency and $I_{OUT, MAX}$ is the maximum load current. The DIO60011/A regulator IC is quite tolerant of different ripple current amplitudes. Consequently, the final choice of inductance can be slightly off the calculation value without significantly impacting the performance.

(2) The saturation current rating of the inductor must be greater than the peak inductor current under full load conditions.

$$I_{SAT, MIN} > I_{OUT, MAX} + \frac{V_{OUT} \times (1 - V_{OUT} / V_{IN, MAX})}{2 \times f_{SW} \times L} \quad (3)$$

(3) The DC resistance (DCR) of the inductor and the core loss at the switching frequency must be low enough to achieve the desired efficiency requirement. Choose an inductor with a DCR lower than 50 m Ω to achieve a good overall efficiency.

7.9. Load transient considerations

The DIO60011/A regulator IC integrates the compensation components to achieve good stability and fast transient responses. In some applications, recommend using a 220 pF ceramic capacitor in parallel with R1 may further speed up the load transient responses and is thus recommended for applications with large load transient step requirements.

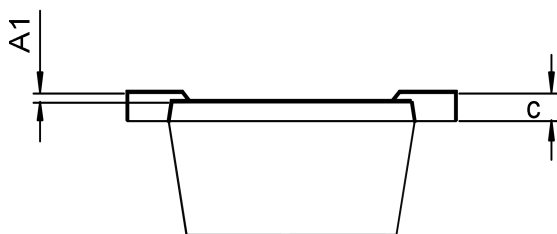
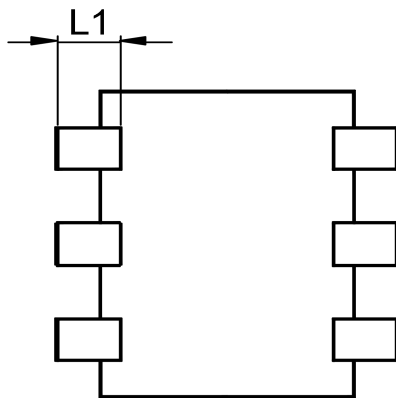
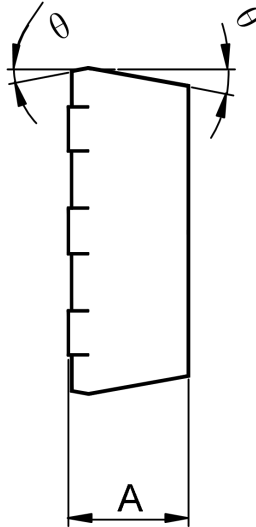
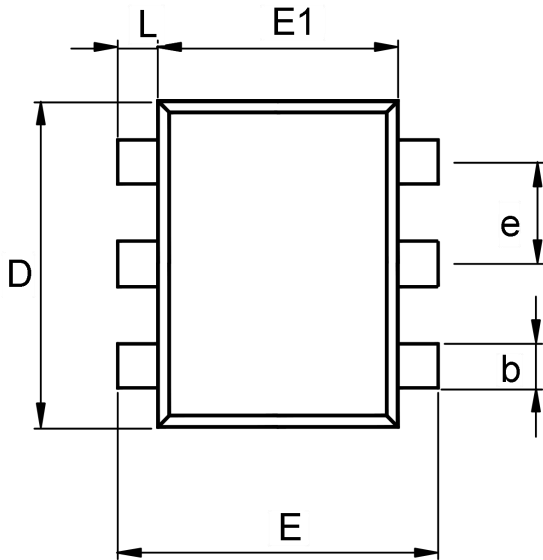
8. Layout Design

The layout design of the DIO60011/A regulator is relatively simple. For the best efficiency and minimum noise problems, place four components close to the IC: C_{IN} , L, R1, and R2.

- (1) Maximize the PCB copper area connected to the GND pin to achieve the best thermal and noise performance. If the board space allows, a ground plane is highly desirable.
- (2) Place C_{IN} close to pins IN and GND. Minimize the loop area formed by C_{IN} and GND.
- (3) Minimize the PCB copper area associated with LX pin to avoid the potential noise problem.
- (4) Avoid placing the components R1 and R2 and the trace connected to the FB pin adjacent to the LX net on the PCB layout to prevent the noise problem.
- (5) If the system chip interfaced with the EN pin has a high impedance state at shutdown mode and the IN pin is connected directly to a power source such as a Li-Ion battery, it is desirable to add a pull-down 1 M Ω resistor between the EN and GND pins to prevent the noise from falsely turning on the regulator at shutdown mode.

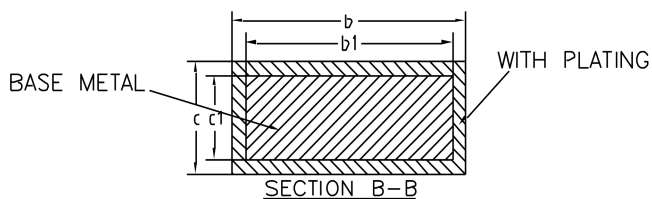
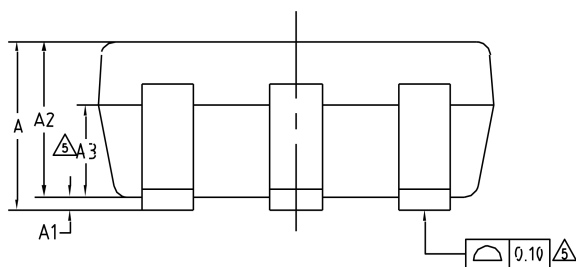
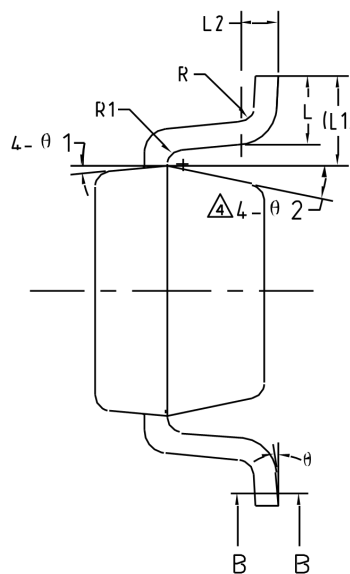
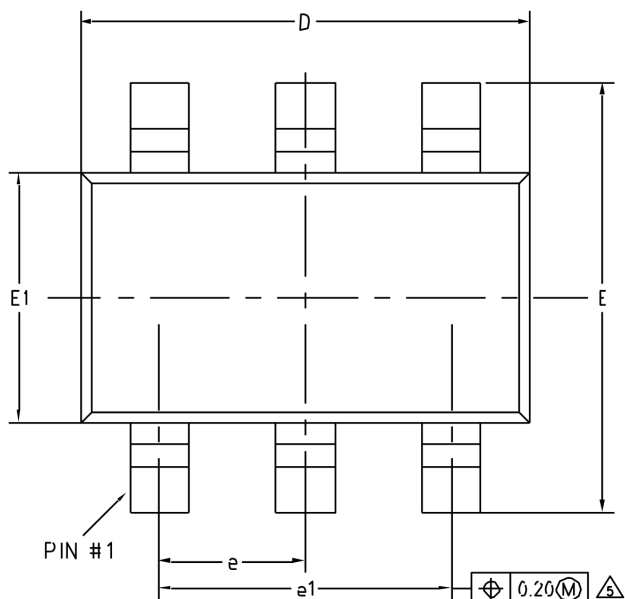
9. Physical Dimensions:

9.1. SOT563



Common Dimensions (Units of measure = Millimeter)		
Symbol	Min	Max
A	0.525	0.600
A1	0.000	0.050
e	0.450	0.550
c	0.090	0.180
D	1.500	1.700
b	0.170	0.270
E1	1.100	1.300
E	1.500	1.700
L	0.100	0.300
L1	0.200	0.400
θ	9° REF	

9.2. SOT23-6



Common Dimensions (Units of measure = Millimeter)			
Symbol	Min	Nom	Max
A	-	-	1.25
A1	0	-	0.15
A2	1.00	1.10	1.20
A3	0.60	0.65	0.70
b	0.34	-	0.45
b1	0.34	0.38	0.41
c	0.12	-	0.20
c1	0.12	0.15	0.16
D	2.826	2.926	3.026
E	2.60	2.80	3.00
E1	1.526	1.626	1.700
e	0.90	0.95	1.00
e1	1.80	1.90	2.00
L	0.30	0.40	0.60
L1	0.59 REF		
L2	0.25 BSC		
R	0.05	-	0.20
R1	0.05	-	0.20
θ	0°	-	8°
$\theta 1$	8°	10°	12°
$\theta 2$	10°	12°	14°

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