COT Mode 6.0V/2.0A Synchronous Step-Down Converter

General Description

The AS2309 is a high-efficiency monolithic synchronous buck regulator using a constant frequency, COT mode architecture. The device is available in an adjustable version. Supply current with no load is 35uA and drops to <1uA in shutdown. The 2.5V to 6.0V input voltage range makes the AS2309 ideally suited for single Li-Ion battery powered applications. 100% duty cycle provides low dropout operation, extending battery life in portable systems. DCM/CCM mode operation provides very low output ripple voltage for noise sensitive applications. Switching frequency is internally set at 1.2MHz, allowing the use of small surface mount inductors and capacitors. Low output voltages are easily supported with the 0.6V feedback reference voltage.

The AS2309 requires a minimal number of readily available, external components and is available in a small package.

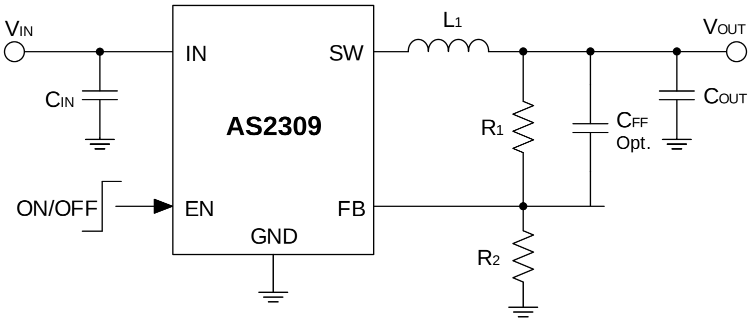
Features

- Wide 2.5V to 6.0V Operating Input Range
- 2.0A Continuous Output Current
- 1.2MHz Switching Frequency
- Short Protection with Hiccup-Mode
- Built-in Over Current Limit
- 10% To 100% load Transients, Output Change Less than 5%
- DCM for High Efficiency in Light Load
- Integrated internal Soft-Start
- 100/60mΩ Low RDS(ON) Internal MOSFETs
- Output Adjustable from 0.6V
- Low EMI Signature
- 100% Duty cycle
- Built-in 35Ω Discharge Resistor
- Thermal Shutdown
- COT Mode
- MSL3 Package Level

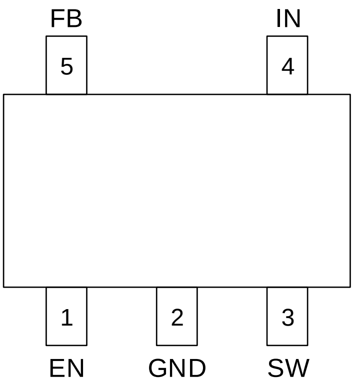
Applications

- Automotive Entertainment
- Wireless and DSL Modems
- Computer Entertainment
- IoT Applications
- Digital Still and Video Cameras
- Portable Instruments

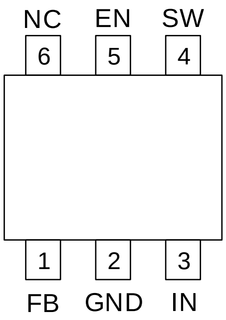
Typical Application Circuit



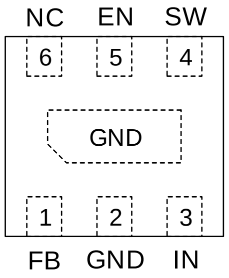
Pin Configuration



SOT23-5



SOT563



DFN1.6x1.6-6

Pin Descriptions

PIN NO.			PIN Name	Function
SOT23-5	SOT563	DFN 1.6*1.6		
5	1	1	FB	Output Voltage Feedback Pin. An internal resistive divider divides the output voltage down for comparison to the internal reference voltage.
2	2	2	GND	Ground Pin
4	3	3	IN	Power Supply Input. Must be closely decoupled to GND with a 10μF or greater ceramic capacitor.
3	4	4	SW	Power Switch Output. It is the switch node connection to Inductor. This pin connects to the drains of the internal P-ch and N-ch MOSFET switches.
1	5	5	EN	Chip Enable Pin. Drive EN above 1.2V to turn on the part. Drive EN below 0.4V to turn it off. Do not leave EN floating.
	6	6	NC	Not Connected

Ordering Information

PART No.	Package	Logo	Description	Tape&Reel
AS2309	SOT23-5	AS2309	DCM	3000PCS
AS2309A	SOT563	AS2309A	DCM	3000PCS
AS2309B	DFN1.6*1.6-6	AS2309B	DCM	3000PCS
AS2309C	SOT23-5	AS2309C	CCM	3000PCS
AS2309D	DFN1.6*1.6-6	AS2309D	CCM	3000PCS

Absolute Maximum Ratings (1)(2)

Item	Min	Max	Unit
V_{IN} voltage	-0.3	6.5	V
EN voltage	-0.3	6.5	V
SW voltage	-1.5V	V_{IN}+1.5V	V
FB voltage	–0.3	6.5	V
Power dissipation (3)	Internally Limited		
Operating junction temperature, T_J	-40	150	°C
Storage temperature, T_{stg}	–65	150	°C
Lead Temperature (Soldering, 10sec.)		260	°C

Note
(1) Exceeding these ratings may damage the device.
(2) The device is not guaranteed to function outside of its operating conditions.

Recommended Operating Conditions

Item	Min	Max	Unit
Operating junction temperature (1)	–40	125	°C
Operating temperature range	-40	85	°C
Input voltage V_{IN}	2.5	6.0	V
Output current	0	2.0	A

Note
(1) All limits specified at room temperature (T_A = 25°C) unless otherwise specified. All room temperature limits are 100% production tested. All limits at temperature extremes are ensured through correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).

Thermal Information

Item	Description	SOT23-5	SOT563	DFN1.6*1.6	Unit
$R_{\theta JA}$	Junction-to-ambient thermal resistance (1)(2)	170	147	175	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	130	153	88	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	42	75	120	°C/W

Note
(1) The package thermal impedance is calculated in accordance to JESD 51-7.
(2) Thermal Resistances were simulated on a 4-layer, JEDEC board

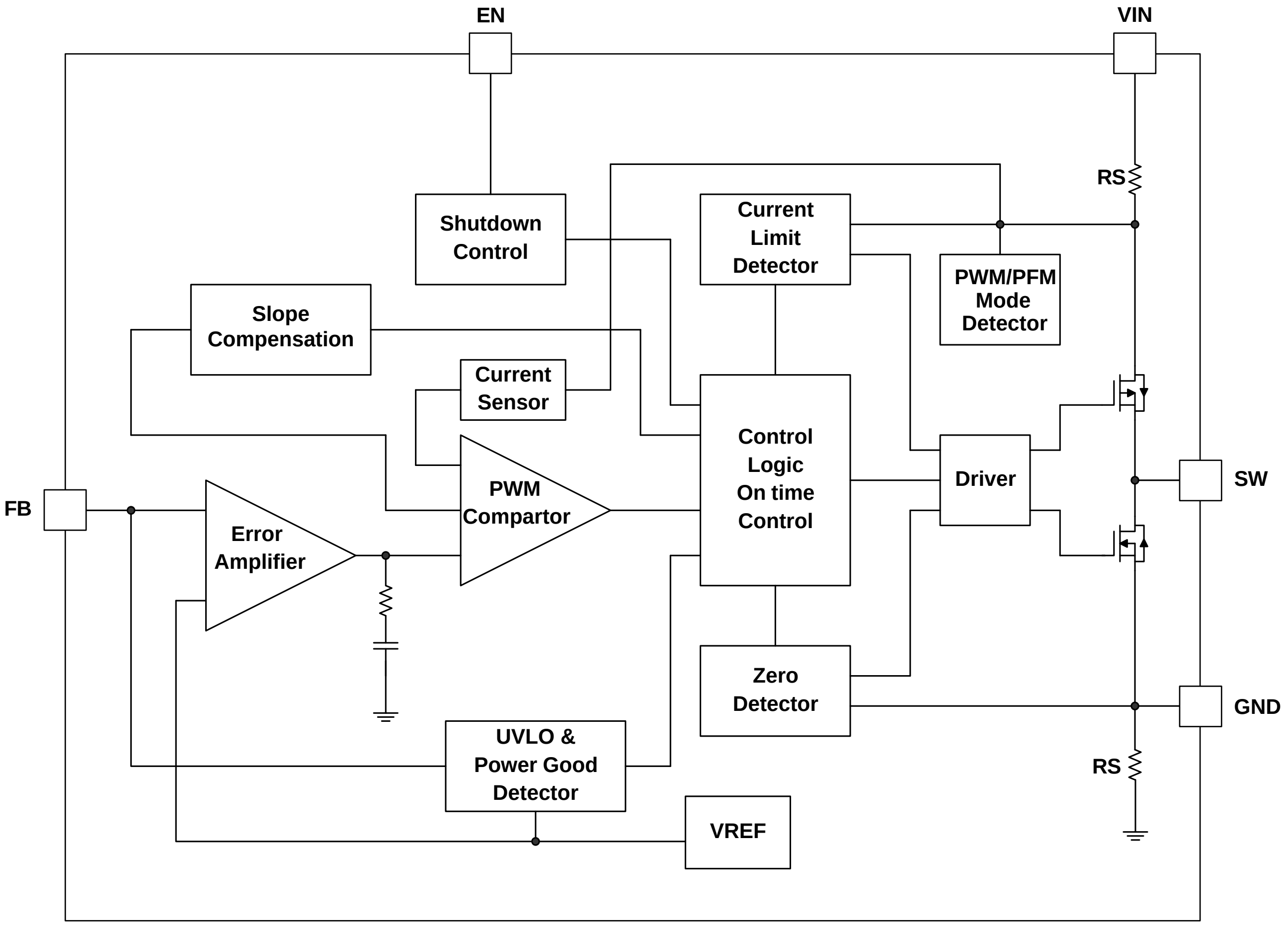
Electrical Characteristics (1)(2)

V_{IN}=5V, T_A=25°C, unless otherwise specified.

Parameter	Conditions	Min.	Typ.	Max.	Unit
Input Voltage Range		2.5		6.0	V
Quiescent current into VIN pin	AS2309/AS2309A/AS2309B	25	30	35	μA
	AS2309C/AS2309D	2	5	10	mA
Shutdown current into VIN pin	V_{EN} = 0V, V_{IN} = 5.0V			1	μA
Regulated Feedback Voltage	V_{IN} =5V, T_A =25°C	0.588	0.600	0.612	V
Output Voltage Line Regulation	V_{IN} = 2.5V to 5.5V			0.5	%
Output Voltage Load Regulation	V_{IN} =5V, Out=1.8V, ΔV_{LOAD} (0.-2A)			1.5	%
Oscillation Frequency1	V_{IN} =5V, Out=1.8V, Iload=1A	1.0	1.2	1.5	MHz
On Resistance of PMOS	I_{SW} = 100mA		100		mΩ
ON Resistance of NMOS	I_{SW} =-100mA		60		mΩ
High-Side Switch Current Limit	V_{IN} = 5.0V, FB=90%		3.3		A
Low-Side Switch Current Limit	V_{IN} = 5.0V, FB=90%		2.5		A
V_{IN} Under-Voltage Lockout Threshold			2.4		V
V_{IN} Under-Voltage Lockout Threshold-Hysteresis			200		mV
EN Rising Threshold		1.2			V
EN Falling Threshold				0.4	V
EN Threshold Hysteresis			200		mV
EN Leakage Current				200	nA
SW Leakage Current	V_{EN} =0V, V_{IN} =V_{SW} =5V			200	nA
Soft Start		0.8	1	1.2	mS
Thermal Shutdown			160		°C
Thermal Hysteresis			30		°C

Note
(1) MOSFET on-resistance specifications are guaranteed by correlation to wafer level measurements.
(2) Thermal shutdown specifications are guaranteed by correlation to the design and characteristics analysis.

Functional Block Diagram



Functions Description

Internal Regulator

The AS2309 is a COT mode step down DC/DC converter that provides excellent transient response with no extra external compensation components. This device contains an internal, low resistance, high voltage power MOSFET, and operates at a high 1.2MHz operating frequency to ensure a compact, high efficiency design with excellent AC and DC performance.

Error Amplifier

The error amplifier compares the FB pin voltage with the internal FB reference (VFB) and outputs a current proportional to the difference between the two. This output current is then used to charge or discharge the internal compensation network, which is used to control the power MOSFET current. The optimized internal compensation network minimizes the external component counts and simplifies the control loop design.

Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) protects the chip from operating at an insufficient supply voltage. UVLO protection monitors the internal regulator voltage. When the voltage is lower than UVLO threshold voltage, the device is shut off. When the voltage is higher than UVLO threshold voltage, the device is enabled again.

Thermal Shutdown

Thermal shutdown prevents the chip from operating at exceedingly high temperatures. When the silicon die temperature exceeds 160°C, it shuts down the whole chip. When the temperature falls below its lower threshold (Typ. 150°C) the chip is enabled again.

Internal Soft-Start

The soft-start is implemented to prevent the converter output voltage from overshooting during startup. When the chip starts, the internal circuitry generates a soft-start voltage (SS) ramping up from 0V to 0.6V. When it is lower than the internal reference (REF), SS overrides REF so the error amplifier uses SS as the reference. When SS is higher than REF, REF regains control. The SS time is internally max to 1ms.

Startup and Shutdown

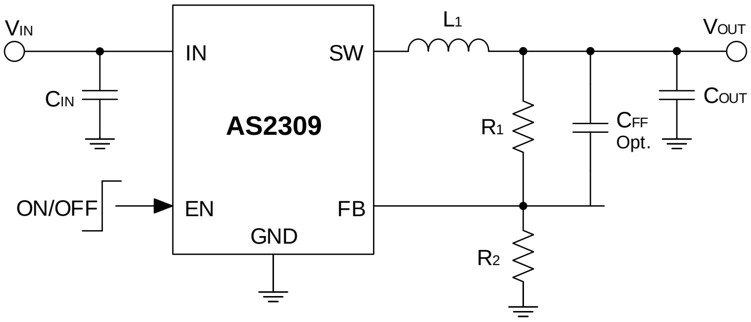
If both V_{IN} and EN are higher than their appropriate thresholds, the chip starts. The reference block starts first, generating stable reference voltage and currents, and then the internal regulator is enabled. The regulator provides stable supply for the remaining circuitries. Three events can shut down the chip: EN low, V_{IN} low and thermal shutdown. In the shutdown procedure, the signaling path is first blocked to avoid any fault triggering. The comp voltage and the internal supply rail are then pulled down. The floating driver is not subject to this shutdown command.

Applications Information

Setting the Output Voltage

AS2309 require an input capacitor, an output capacitor and an inductor. These components are critical to the performance of the device. AS2309 are internally compensated and do not require external components to achieve stable operation. The output voltage can be programmed by resistor divider.

$$V_{OUT} = V_{FB} \times \frac{R1 + R2}{R2}$$



V_{OUT}(V)	R1(KΩ)	R2(KΩ)	L1(μH)	C_{IN}(μF)	C_{OUT}(μF)	C_{FF} (pF) Opt.
1.0	6.67	10	1.0-4.7	4.7	10	C_{FF} Chapter
1.5	15.00	10	1.0-4.7	4.7	10	C_{FF} Chapter
1.8	20.00	10	1.0-4.7	4.7	10	C_{FF} Chapter
3.3	45.00	10	1.0-4.7	4.7	10	C_{FF} Chapter

Selecting the Inductor

The recommended inductor values are shown in the Application Diagram. It is important to guarantee the inductor core does not saturate during any foreseeable operational situation. The inductor should be rated to handle the peak load current plus the ripple current: Care should be taken when reviewing the different saturation current ratings that are specified by different manufacturers. Saturation current ratings are typically specified at 25°C, so ratings at maximum ambient temperature of the application should be requested from the manufacturer.

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times F_{OSC}}$$

Where ΔIL is the inductor ripple current. Choose inductor ripple current to be approximately 30% if the maximum load current. The maximum inductor peak current is:

$$I_{L(MAX)} = I_{LOAD} + \frac{\Delta I_L}{2}$$

Under light load conditions below 100mA, larger inductance is recommended for improved efficiency.

Selecting the Output Capacitor

Special attention should be paid when selecting these components. The DC bias of these capacitors can result in a capacitance value that falls below the minimum value given in the recommended capacitor specifications table. The ceramic capacitor's actual capacitance can vary with temperature. The capacitor type X7R, which operates over a temperature range of −55°C to +125°C, will only vary the capacitance to within ±15%. The capacitor type X5R has a similar tolerance over a reduced temperature range of −55°C to +85°C. Many large value ceramic capacitors, larger than 1uF are manufactured with Z5U or Y5V temperature characteristics. Their capacitance can drop by more than 50% as the temperature varies from 25°C to 85°C. Therefore X5R or X7R is recommended over Z5U and Y5V in applications where the ambient temperature will change significantly above or below 25°C. Tantalum capacitors are less desirable than ceramic for use as output capacitors because they are more expensive when comparing equivalent capacitance and voltage ratings in the 0.47uF to 44uF range. Another important consideration is that tantalum capacitors have higher ESR values than equivalent size ceramics. This means that while it may be possible to find a tantalum capacitor with an ESR value within the stable range, it would have to be larger in capacitance (which means bigger and more costly) than a ceramic capacitor with the same ESR value. It should also be noted that the ESR of a typical tantalum will increase about 2:1 as the temperature goes from 25°C down to −40°C, so some guard band must be allowed.

Feed-Forward Capacitor (C_{FF})

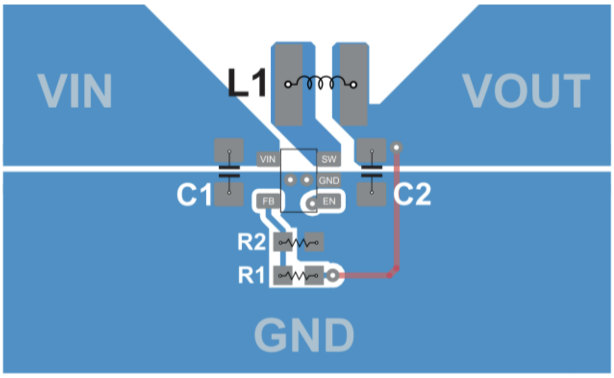
The use of a feed-forward capacitor (C_{FF}) in the feedback network is recommended to improve the transient response or higher phase margin. For optimizing the feed-forward capacitor, knowing the cross frequency is the first thing. The cross frequency (or the converter bandwidth) can be determined by using a network analyzer. When getting the cross frequency with no feed-forward capacitor identified, the value of feed-forward capacitor (C_{FF}) can be calculated with the following equation:

$$C_{FF} = \frac{1}{2\pi \times F_{CROSS}} \times \sqrt{\frac{1}{R1} \times \left(\frac{1}{R1} + \frac{1}{R2}\right)}$$

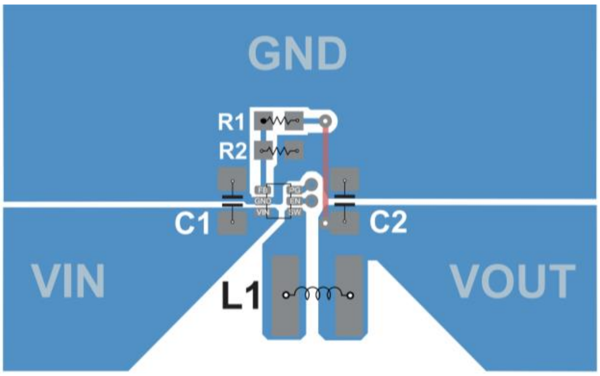
Where F_{CROSS} is the cross frequency.

To reduce transient ripple, the feed-forward capacitor value can be increased to push the cross frequency to higher region. Although this can improve transient response, it also decreases phase margin and cause more ringing. In the other hand, if more phase margin is desired, the feed-forward capacitor value can be decreased to push the cross frequency to lower region.

PC Board Layout Example & Guidelines



SOT23-5



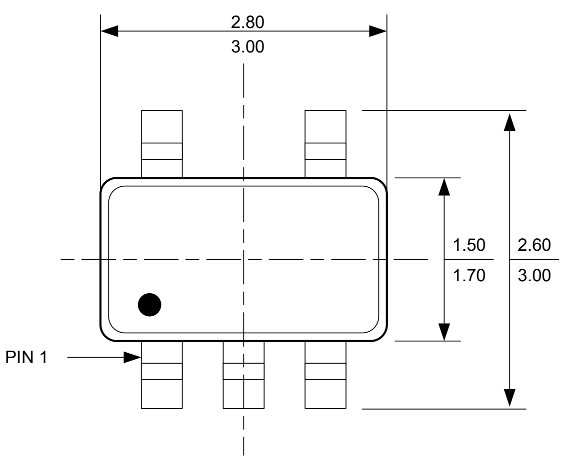
SOT563 & DFN1.6*1.6-6

The PCB layout is an important step to maintain the high performance of the AS2309 device.

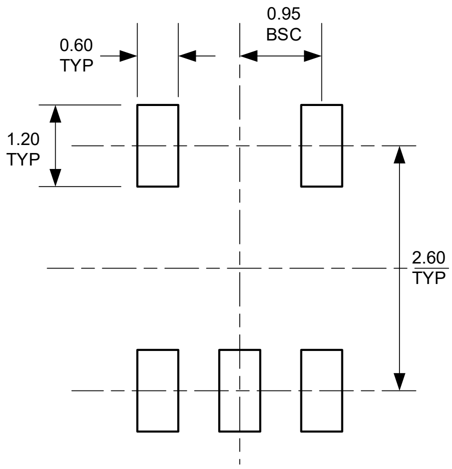
1. The input/output capacitors and the inductor should be placed as close as possible to the IC. This keeps the power traces short. Routing these power traces direct and wide results in low trace resistance and low parasitic inductance.
2. The low side of the input and output capacitors must be connected properly to the power GND to avoid a GND potential shift.
3. The sense traces connected to FB are signal traces. Special care should be taken to avoid noise being induced. Keep these traces away from SW nodes.
4. GND layers might be used for shielding.

Package Description

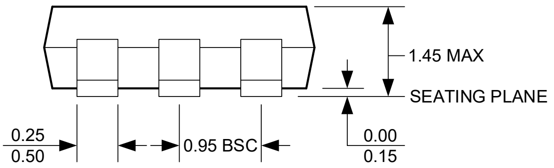
SOT23-5



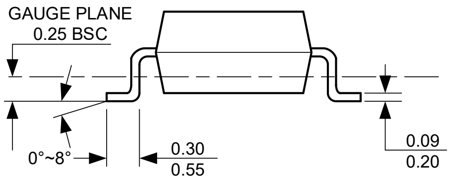
TOP VIEW



RECOMMENDED PAD LAYOUT



FRONT VIEW



SIDE VIEW

NOTE:

1. CONTROL DIMENSION IS IN INCHES. DIMENSION IN BRACKET IS IN MILLIMETERS.

2. PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.

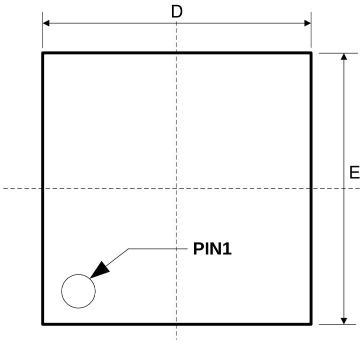
3. PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.

4. LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.004" INCHES MAX.

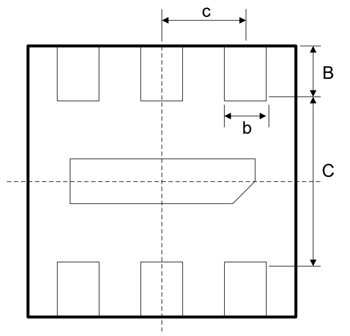
5. DRAWING CONFORMS TO JEDEC MS-012, VARIATION BA.

6. DRAWING IS NOT TO SCALE.

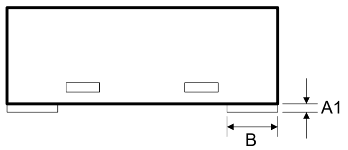
DFN1.6*1.6-6-0.55



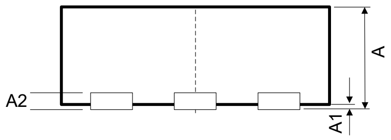
TOP VIEW



BOTTOM VIEW

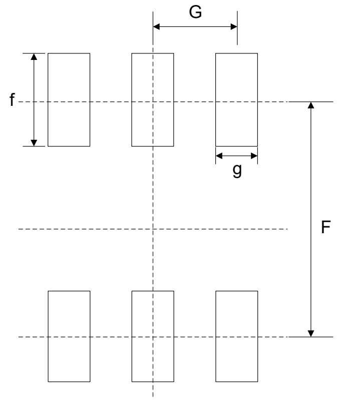


SIDE VIEW A



SIDE VIEW B

SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	0.50	0.55	0.60
A1	0.00	0.03	0.05
A2	0.08	0.13	0.18
B	0.30	0.35	0.40
b	0.20	0.25	0.30
C		1.00	
c		0.50	
D	1.50	1.60	1.70
E	1.50	1.60	1.70
F		1.48	
f		0.67	
G		0.50	
g		0.30	



RECOMMENDED LAND PATTERN

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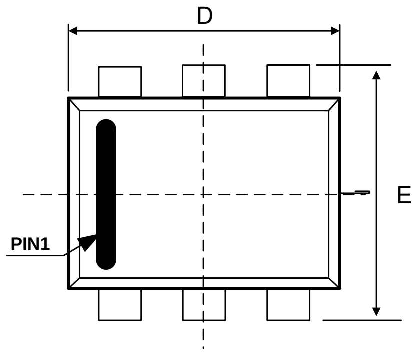
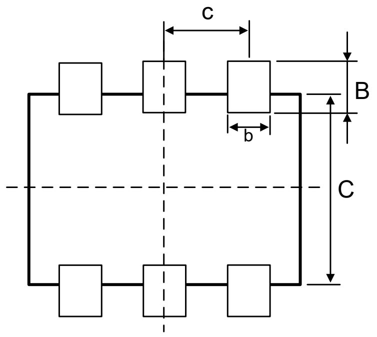
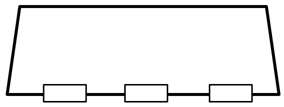
SOT563



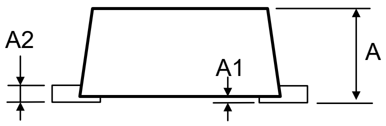
TOP VIEW



BOTTOM VIEW

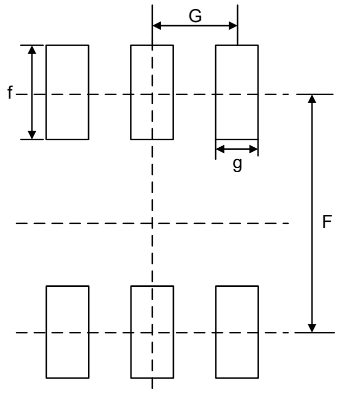


SIDE VIEW A



SIDE VIEW B

SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	0.50	0.55	0.60
A1	0.00		0.05
A2	0.08	0.13	0.18
B	0.20	0.30	0.40
b	0.15	0.20	0.27
C	1.10	1.20	1.30
c		0.50	
D	1.50	1.60	1.70
E	1.50	1.60	1.70
F		1.48	
f		0.67	
G		0.50	
g		0.30	



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