Compact, Small Package 1A Power-Distribution Switches

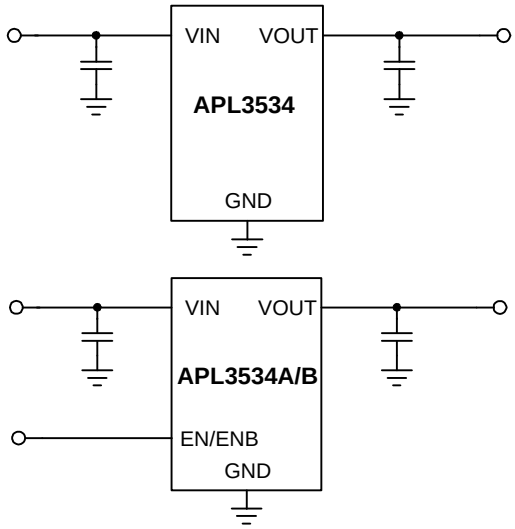
Features

- High Side N-MOSFET with Internal Charge Pump
- 1A Continuous Current
- Built-in Soft-Start
- Wide Supply Voltage Range
- Current-Limit and Short-Circuit Protections
- Input Voltage Under Voltage Lockout Protection
- Reverse Current Blocking when Switch Disabled
- Output OVP Protection
- Reverse Current-Limit Protection
- Output Discharge
- Over-Temperature Protection
- UL Approved-File No. E328191
- UL-CB Scheme IEC/EN62368-1 Certified
- TUV IEC/EN62368-1 Certified
- Lead Free and Green Devices Available (RoHS Compliant)

Applications

- HDMI Port Protection Switches
- Bluetooth Protection Switches
- High-side Power Protection Switches

Simplified Application Circuit



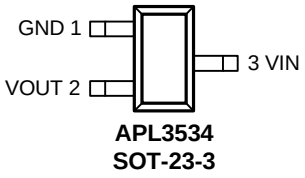
General Description

The APL3534/A/B is a power-distribution switch with current- limiting function and output OVP protections that can deliver current up to 1A. The device incorporates a 110mΩ N-channel MOSFET power switch.

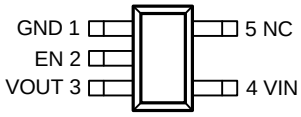
The device integrates some protection features, including current-limit protection, output over-voltage protection, over-temperature protection and UVLO. The current-limit protection can protect down-stream devices from catastrophic failure by limiting the output current at current-limit threshold during over-load or short-circuit events. The output over-voltage protection can prevent current flowing from VOUT to VIN when an abnormally high voltage exists in VOUT. The over-temperature protection function shuts down the N-channel MOSFET power switch when the junction temperature rises beyond 140°C and will automatically turns on the power switch when the temperature drops by 20°C. The UVLO function keeps the power switch in off state until there is a valid input voltage present.

The device is available in lead free SOT-23-3 and SOT-23-5 packages.

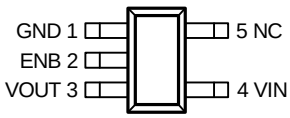
Pin Configuration



APL3534
SOT-23-3



APL3534A
SOT-23-5



APL3534B
SOT-23-5

Ordering and Marking Information

APL3534 □□□-□□□ Assembly Material Handling Code Temperature Range Package Code Enable Function	Enable Function Blank : No Enable Function A : Active High B : Active Low Package Code A : SOT-23-3 B : SOT-23-5 Operating Ambient Temperature Range I : -40 to 85 °C Handling Code TR : Tape & Reel Assembly Material G : Halogen and Lead Free Device

APL3534 A:	L34X	X - Date Code
APL3534A B:	L4AX	X - Date Code
APL3534B B:	L4BX	X - Date Code

Note: ANPEC lead-free products contain molding compounds/die attach materials and 100% matte tin plate termination finish; which are fully compliant with RoHS. ANPEC lead-free products meet or exceed the lead-free requirements of IPC/JEDEC J-STD-020D for MSL classification at lead-free peak reflow temperature. ANPEC defines “Green” to mean lead-free (RoHS compliant) and halogen free (Br or Cl does not exceed 900ppm by weight in homogeneous material and total of Br and Cl does not exceed 1500ppm by weight).

Absolute Maximum Ratings (Note 1)

Symbol	Parameter	Rating	Unit
V_{IN}	VIN to GND Voltage	-0.3 ~ 6.5	V
V_{OUT}	VOUT to GND Voltage	-0.3 ~ 6.5	V
V_{EN}, V_{ENB}	EN, ENB to GND Voltage	-0.3 ~ 6.5	V
T_J	Maximum Junction Temperature	-40 ~ 150	°C
T_{STG}	Storage Temperature	-65 ~ 150	°C
T_{SDR}	Maximum Lead Soldering Temperature (10 Seconds)	260	°C

Note1: Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Thermal Characteristics (Note 2)

Symbol	Parameter	Typical Value	Unit
θ_{JA}	Junction-to-Ambient Resistance in free air (SOT-23-3, SOT-23-5)	260	°C/W

Note 2: θ_{JA} is measured with the component mounted on a high effective thermal conductivity test board in free air.

Recommended Operating Conditions (Note 3)

Symbol	Parameter	Range	Unit
V_{IN}	VIN Input Voltage	2.7~ 5.4	V
I_{OUT}	OUT Output Current	0 ~ 1	A
T_A	Ambient Temperature	-40 ~ 85	°C
T_J	Junction Temperature	-40 ~ 125	°C

Note 3: Refer to the typical application circuit.

Electrical Characteristics

V_{IN}=5V, V_{EN}=5V or V_{ENB}=0V and T_A=25°C (unless otherwise noted).

Symbol	Parameter	Test Conditions	APL3534/A/B			Unit
			Min.	Typ.	Max.	
UNDER-VOLTAGE LOCKOUT						
	VIN UVLO Threshold Voltage	V_{IN} rising	2.35	2.5	2.65	V
	VIN UVLO Hysteresis		-	0.1	-	V
SUPPLY CURRENT						
I_{VIN}	VIN Supply Current	No load, V_{EN} = High (or V_{ENB} = Low)	-	100	150	µA
I_{SD}	VIN Shutdown Current	No load, V_{EN} = Low (or V_{ENB} = High)	-	-	1	µA
	OUT Leakage Current	VOUT tied to ground, V_{EN} =Low (or V_{ENB} = High)	-	-	1	µA
	OUT Input Current	V_{OUT}=5V, V_{IN} = 0V, no matter V_{EN} = Low or High	-	-	1	µA
POWER SWITCH						
$R_{DS(ON)}$	Power Switch On Resistance	V_{IN}=5V, I_{OUT}=1A, T_J=25°C	-	110	140	mΩ
		V_{IN}=5V, I_{OUT}=1A, T_J=-40~125°C	-	-	175	mΩ
		V_{IN}=3.3V, I_{OUT}=1A, T_J=25°C	-	120	155	mΩ
		V_{IN}=3.3V, I_{OUT}=1A, T_J=-40~125°C	-	-	195	mΩ
CURRENT-LIMIT PROTECTIONS						
I_{LIM}	Current-Limit Threshold	T_J=25°C,	1.3	1.6	1.9	A
		T_J=-40~125°C	1.05	-	-	A
I_{SHORT}	Short-Circuit Output Current	V_{OUT}<1.2V (This function is disabled during soft start interval)	0.3	0.6	1	A
OUTPUT OVER-VOLTAGE PROTECTS						
I_{RV}	Reverse Current Blocking Threshold	V_{OUT} - V_{IN}=1V, T_J=25°C	0.3	0.5	0.7	A
t_{RVDEG}	Reverse Current Blocking Deglitch Time	Guaranteed by Design	-	0.7	-	ms
V_{OVP}	Output OVP Threshold		5.5	5.75	6	V
T_{OVD}	Output OVP Delay Time		-	20	-	µs
SOFT-START CONTROL PIN						
t_{SS}	Soft-Start Time	V_{IN}=5V, V_{OUT}=10% to 90%	1	2.5	4	ms

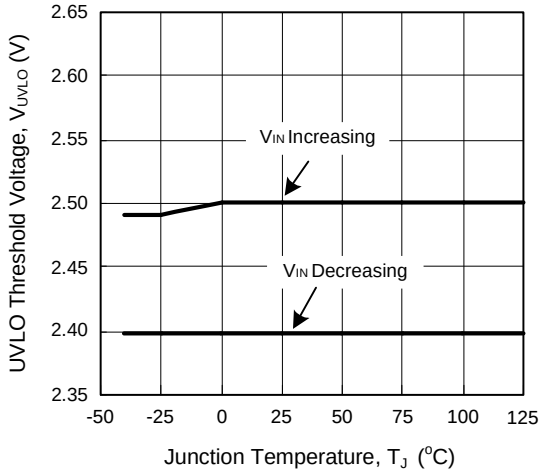
Electrical Characteristics (Cont.)

V_{IN}=5V, V_{EN}=5V or V_{ENB}=0V and T_A=25°C (unless otherwise noted).

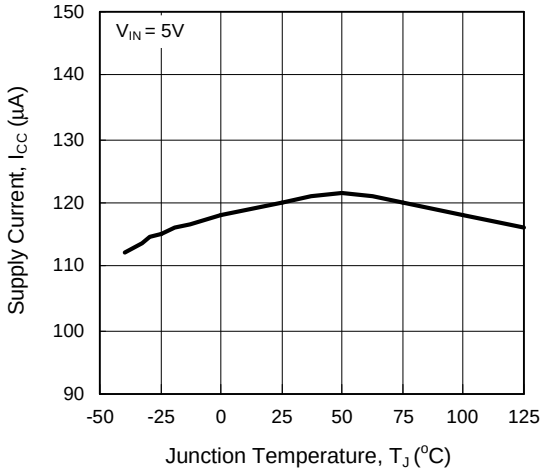
Symbol	Parameter	Test Conditions	APL3534/A/B			Unit
			Min.	Typ.	Max.	
OUTPUT DISCHARGE AND ENABLE						
	VOUT Discharge Resistance	V_{IN}=5V, V_{EN}=Low(or V_{ENB}=High), V_{OUT}=1V	-	40	-	Ω
V_{EN}, V_{ENB}	Input Logic High		2	-	-	V
	Input Logic Low		-	-	0.8	V
	EN, ENB Input Current	V_{EN}=5V or V_{ENB}=5V	-	-	1	μA
	EN, ENB Leakage	V_{EN}=0V or V_{ENB}=0V	-	-	1	μA
OUTPUT TEMPERATURE PROTECTION (OTP)						
T_{OTP}	Over-Temperature Threshold	T_J rising	-	140	-	°C
	Over-Temperature Hysteresis		-	20	-	°C

Typical Operating Characteristics

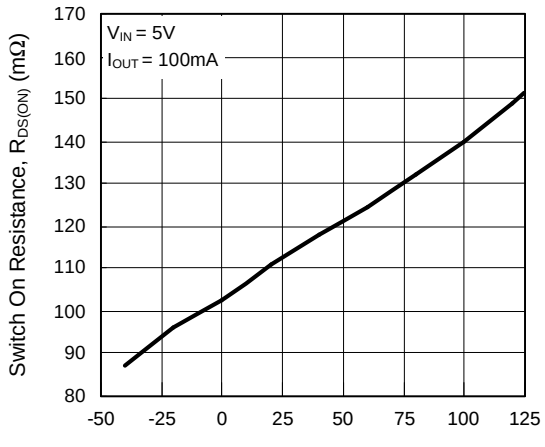
UVLO Threshold Voltage vs. Junction Temperature



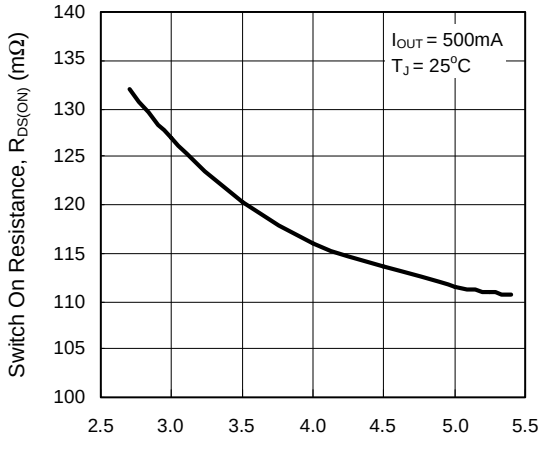
Supply Current vs. Junction Temperature



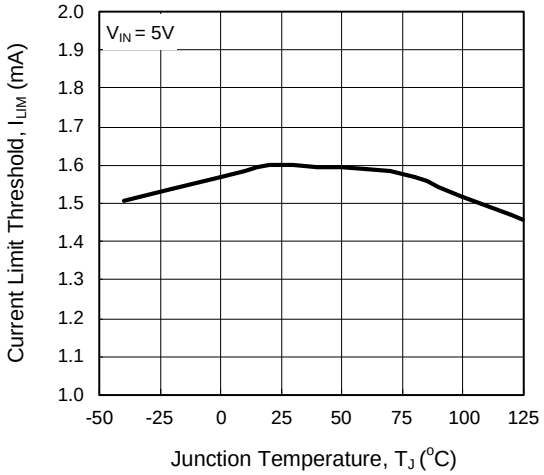
Switch On Resistance vs. Junction Temperature



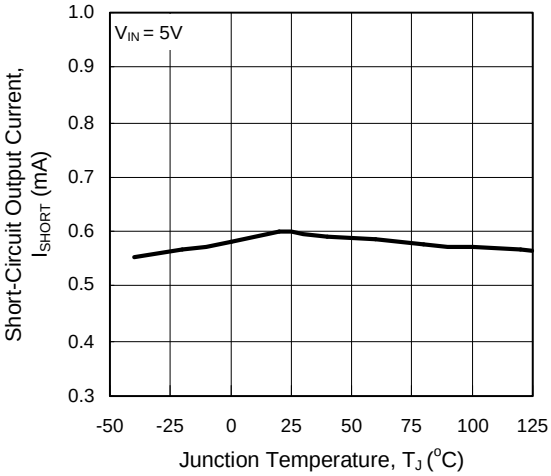
Switch On Resistance vs. Input Voltage



Current Limit Threshold vs. Junction Temperature

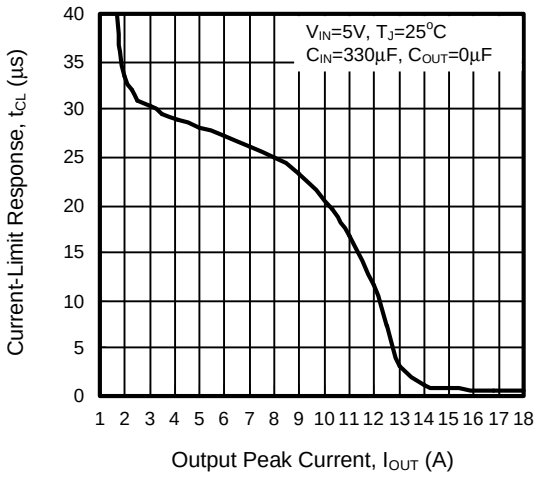


Short-Circuit Output Current vs. Junction Temperature

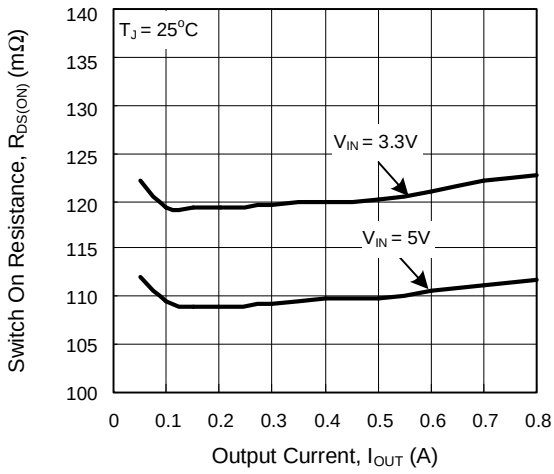


Typical Operating Characteristics

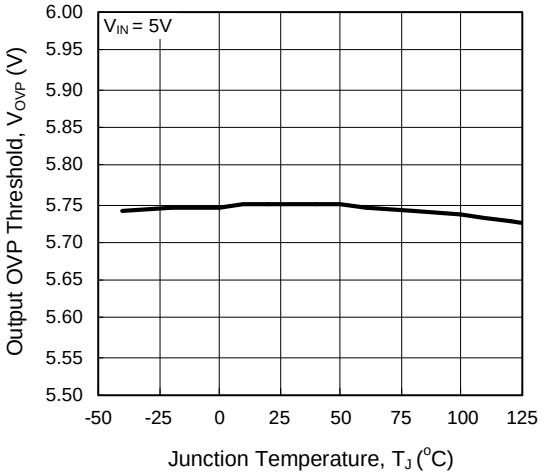
Current-Limit Response vs. Output Peak Current



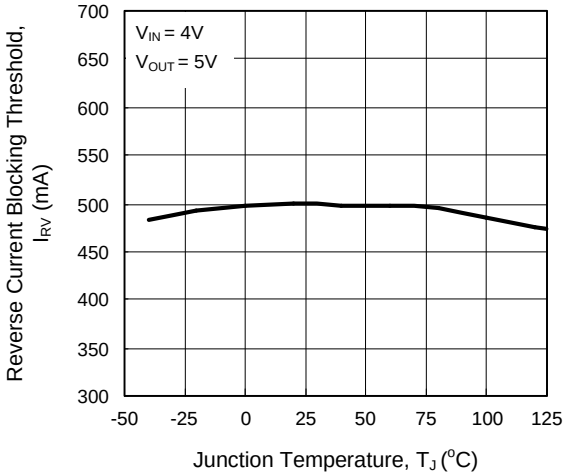
Switch On Resistance vs. Output Current



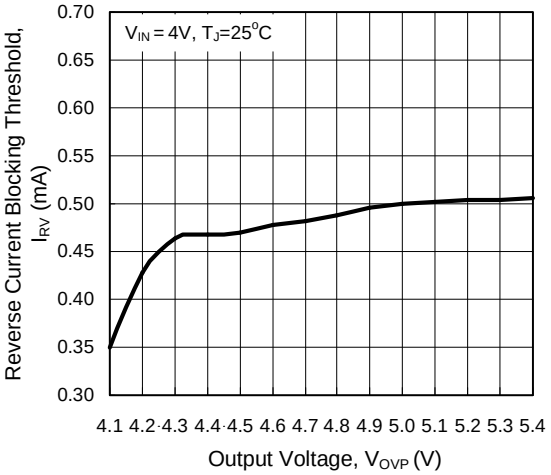
Output OVP Threshold vs. Junction Temperature



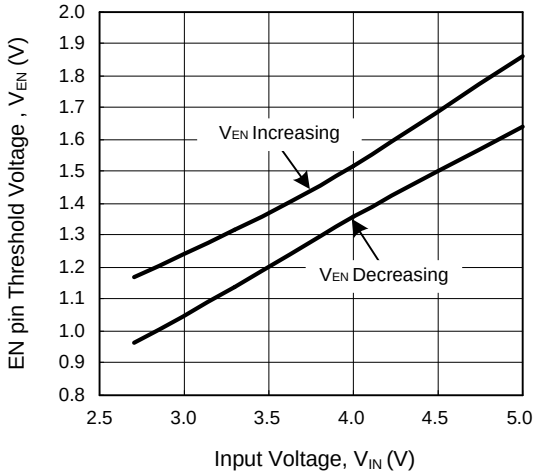
Reverse Current Blocking Threshold vs. Junction Temperature



Reverse Current Blocking Threshold vs. Output Voltage



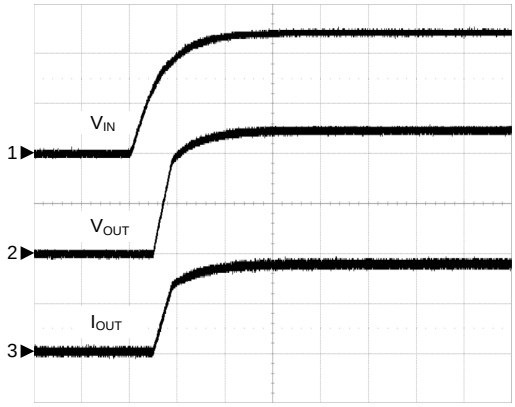
EN pin Threshold Voltage vs. Input Voltage



Operating Waveforms

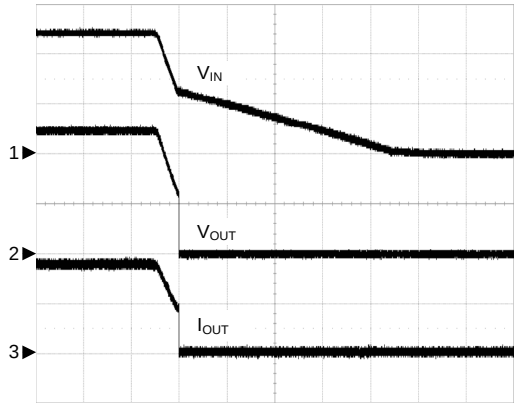
Refer to the typical application circuit. The test condition is V_{IN}=5V, T_A= 25°C unless otherwise specified.

Power On



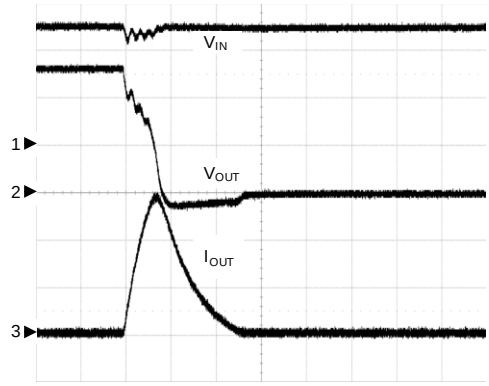
C_{IN}=0.1µF, C_{OUT}=0.1µF, R_{OUT}=5Ω
CH1: V_{IN}, 2V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: I_{OUT}, 0.5A/Div, DC
TIME: 5ms/Div

Power Off



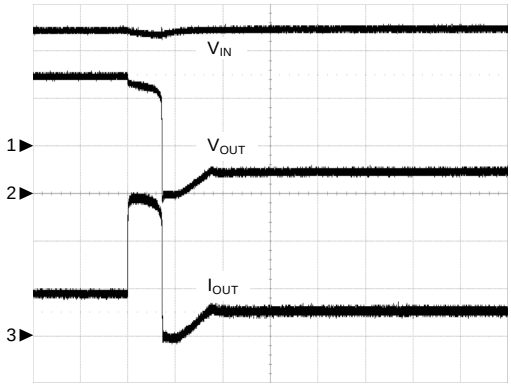
C_{IN}=0.1µF, C_{OUT}=0.1µF, R_{OUT}=5Ω
CH1: V_{IN}, 2V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: I_{OUT}, 0.5A/Div, DC
TIME: 5ms/Div

Short Circuit Response



C_{IN}=330µF, C_{OUT}=0µF, R_{OUT}=Open → 0Ω
CH1: V_{IN}, 2V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: I_{OUT}, 5A/Div, DC
TIME: 1µs/Div

Over-Current Protection

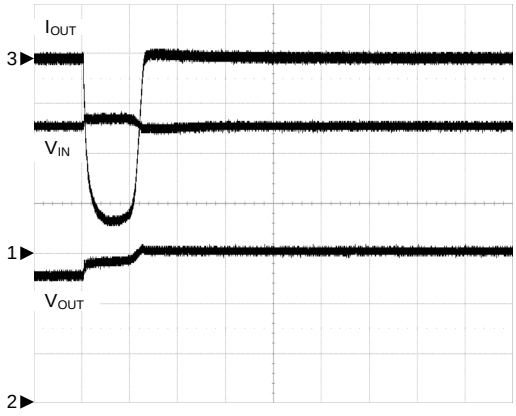


C_{IN}=330µF, C_{OUT}=0.1µF, I_{OUT}= 5Ω to 1.67Ω
CH1: V_{IN}, 2V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: I_{OUT}, 1A/Div, DC
TIME: 50µs/Div

Operating Waveforms

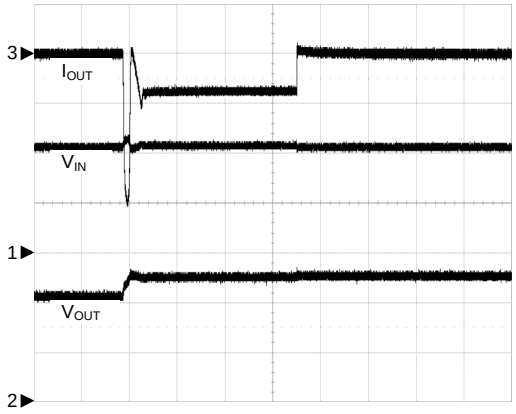
Refer to the typical application circuit. The test condition is V_{IN}=5V, T_A= 25°C unless otherwise specified.

Output Over-Voltage Protection



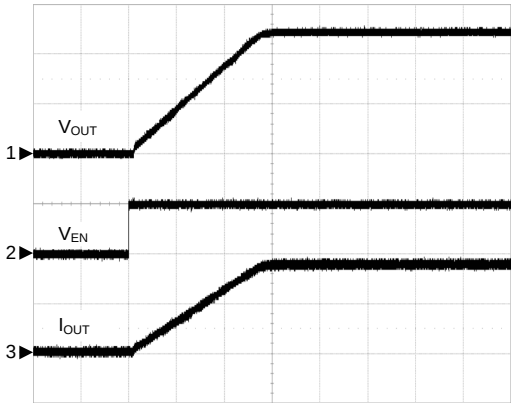
C_{IN}=0.1µF, C_{OUT}=0.1µF, V_{OUT}=open → 6V, R_{IN}=5Ω
CH1: V_{IN}, 2V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: I_{OUT}, 0.5A/Div, DC
TIME: 20µs/Div

Reverse Current Protection



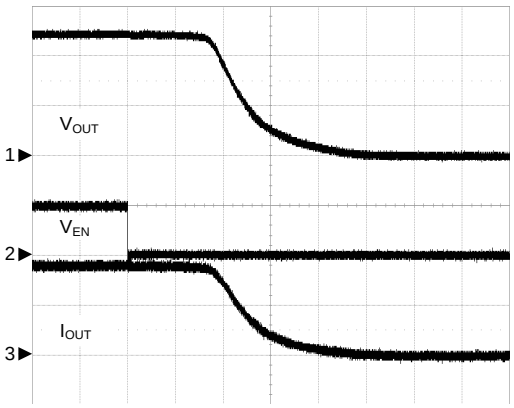
C_{IN}=0.1µF, C_{OUT}=0.1µF, R_{IN}=5Ω
V_{IN}=4.2V ,V_{OUT}=open →5V
CH1: V_{IN}, 2V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: I_{OUT}, 0.5A/Div, DC
TIME: 0.2ms/Div

Enable Response



C_{IN}=0.1µF, C_{OUT}=0.1µF, R_{OUT}=5Ω
CH1: V_{OUT}, 2V/Div, DC
CH2: V_{EN}, 5V/Div, DC
CH3: I_{OUT}, 500mA/Div, DC
TIME: 1ms/Div

Shutdown Response

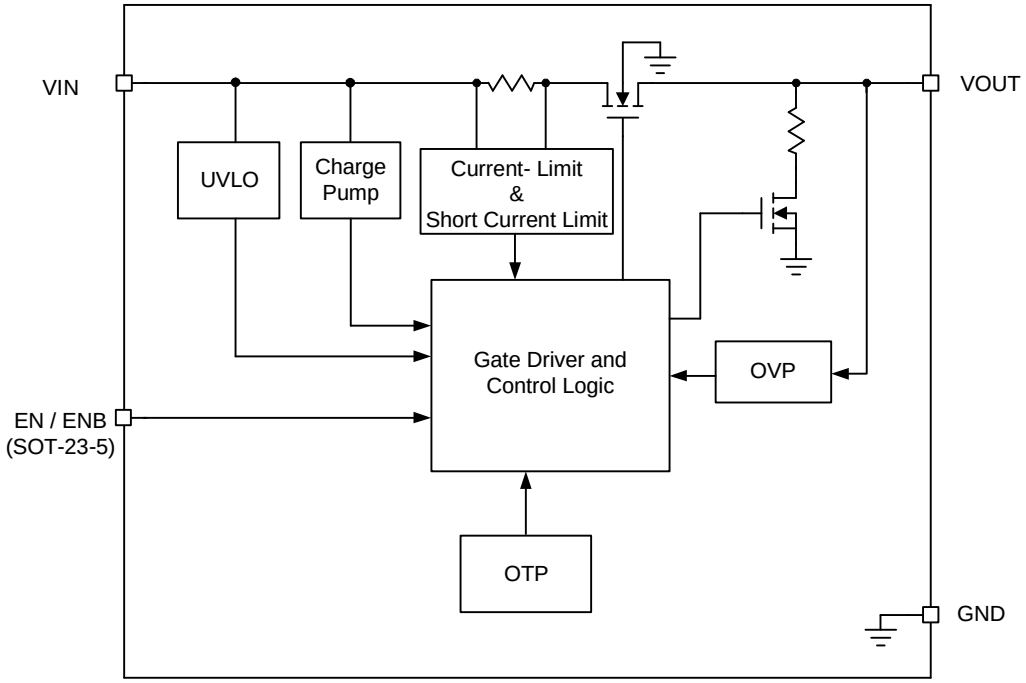


C_{IN}=0.1µF, C_{OUT}=0.1µF, R_{OUT}=5Ω
CH1: V_{OUT}, 2V/Div, DC
CH2: V_{ENB}, 5V/Div, DC
CH3: I_{OUT}, 500mA/Div, DC
TIME: 2µs/Div

Pin Description

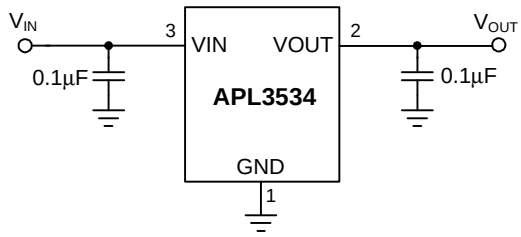
PIN		NAME	FUNCTION
NO.			
SOT-23-3	SOT-23-5		
1	1	GND	Ground.
2	3	VOUT	Output Voltage Pin. The output voltage follows the input voltage. When EN is low or V_{IN} is UVLO, the output voltage is discharged by an internal resistor.
3	4	VIN	Power Supply Input Connect this pin to external DC supply.
-	2	EN/ENB	Pulling the ENB above 2V or EN below 0.8V will disable the device, and pulling ENB pin below 0.8V or EN above 2V will enable the device. The EN and ENB pins cannot be left floating.
-	5	NC	Not Connected Internally.

Block Diagram

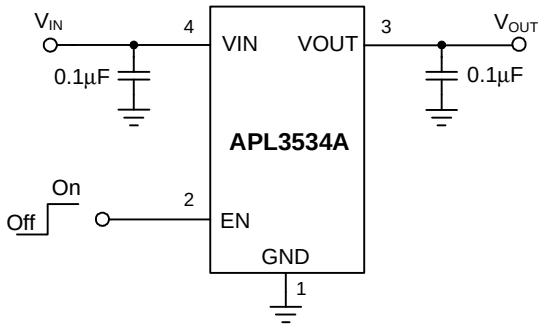


Typical Application Circuit

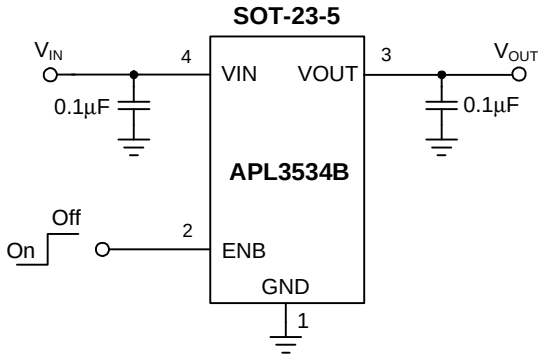
SOT-23-3



SOT-23-5



SOT-23-5



Function Description

VIN Under-voltage Lockout (UVLO)

The APL3534/A/B power switch has a built-in under-voltage lockout circuit to keep the output shut off until internal circuitry is operating properly. The UVLO circuit has hysteresis and a de-glitch feature so that it will typically ignore undershoot transients on the input. When input voltage exceeds the UVLO threshold, the output voltage starts a soft-start to reduce the inrush current.

Power Switch

The power switch is an N-channel MOSFET with a low $R_{DS(ON)}$. The internal power MOSFET does not have the body diode. When IC is in UVLO state, the MOSFET prevents a current flowing from the VOUT back to VIN and VIN to VOUT.

Current-Limit Protection

The APL3534/A/B power switch provides the current-limit protection function. During current-limit, the devices limit output current at current-limit threshold. For reliable operation, the device should not be operated in current-limit for extended period time.

Short-Circuit Protection

When the output voltage drops below 1.2V, which is caused by the over load or short-circuit, the devices limit the output current down to a safe level. The short-circuit current-limit is used to reduce the power dissipation during short-circuit condition. If the junction temperature is over the thermal shutdown temperature the device will enter the thermal shutdown. This Function is disabled during soft-start interval.

Soft-Start

The APLA3534/A/B has a built-in output soft-start control to limit the current surge during start-up. The soft-start interval is 2.5ms.

Output Over-Voltage Protection

The output over-voltage protection is implemented by 2 either sensing mechanisms. One is by sensing when V_{OUT} voltage is above V_{OVP} threshold, the internal power MOSFET is turned off. The other is by sensing when reverse current, flowing from VOUT to VIN, surpasses I_{RV}. When the reverse current reachers the reverse current Blocking threshold, the device limits the reveres current at I_{RV} threshold level. When the reverse current fault exists for more than 0.7ms, the internal power MOSFET is turned off. The internal power MOSFET is allowed to turn-on once the output voltage gose below V_{IN}-1.2V.

Output Discharge

When the input voltage is under VIN UVLO Threshold or V_{EN}=Low or V_{ENB}=High, the output discharge device is turned on to discharge the output voltage.

Enable/Disable (SOT-23-5)

Pulling the ENB above 2V or EN below 0.8V will disable the device, and pulling ENB pin below 0.8V or EN above 2V will enable the device.
When the IC is disabled the supply current is reduced to less than 1μA. The enable input is compatible with both TTL and CMOS logic levels. The EN/ENB pins cannot be left floating.

Over-temperature Protection

When the junction temperature exceeds 140°C, the internal thermal sense circuit turns off the power FET and allows the device to cool down. When the device's junction temperature cools by 20°C, the internal thermal sense circuit will enable the device, resulting in a pulsed output during continuous thermal protection. Thermal protection is designed to protect the IC in the event of over-temperature conditions. For normal operation, the junction temperature cannot exceed T_J=+125°C.

Application Information

Input Capacitor

A 1μF or higher ceramic bypass capacitor from VIN to GND, located near the APL3534/A/B, is strongly recommended to suppress the ringing during short circuit fault event. When the load current trips the SCP threshold in an over load condition such as a short circuit, hot plug-in or heavy load transient the IC immediately turns off the internal power switch that will cause VIN ringing due to the inductance between power source and VIN. Without the bypass capacitor, the output short may cause sufficient ringing on the input to damage internal control circuitry.
Input capacitor is especially important to prevent V_{IN} from ringing too high in some applications where the inductance between power source to VIN is large (ex, an extra bead is added between power source line to VIN for EMI reduction), additional input capacitance may be needed on the input to reduce voltage overshoot from exceeding the absolute maximum voltage of the device during over load conditions.

Thermal Consideration

The APL3534 maximum power dissipation depends on the differences of the thermal resistance and temperature between junction and ambient air. The power dissipation P_D across the device is:

$$P_D = (T_J - T_A) / \theta_{JA}$$

where $(T_J - T_A)$ is the temperature difference between the junction and ambient air. θ_{JA} is the thermal resistance between junction and ambient air. Assuming the T_A=25°C and maximum T_J=140°C (typical thermal limit threshold), the maximum power dissipation is calculated as:

$$P_{D(MAX)} = (140-25) / 260$$
$$= 0.44(W)$$

For normal operation, do not exceed the maximum operating junction temperature of T_J = 125°C. The calculated power dissipation should be less than:

$$P_D = (125-25) / 260$$
$$= 0.38(W) \text{ ----------} T_A=25°C$$

$$P_D = (125-85) / 260$$
$$= 0.15(W) \text{ ----------} T_A=85°C$$

The power dissipation depends on operating ambient temperature for fixed T_J=125°C and thermal resistance θ_{JA}. For APL3534 packages, the Figure 1 of derating curves allows the designer to see the effect of rising ambient temperature on the maximum power allowed.

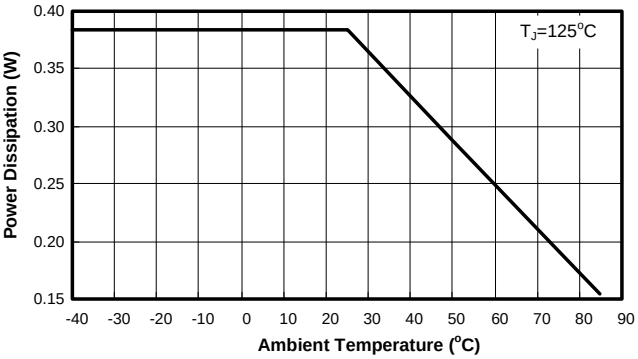


Figure 1. Derating Curves for APL3534 Package

Layout Consideration

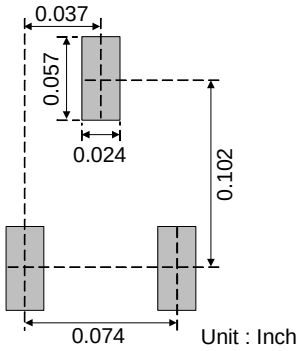
The PCB layout should be carefully performed to maximize thermal dissipation and to minimize voltage drop, droop and EMI. The following guidelines must be considered:

1. Please place the input capacitors near the VIN pin as close as possible.
2. Output decoupling capacitors for load must be placed near the load as close as possible for decoupling high-frequency ripples.

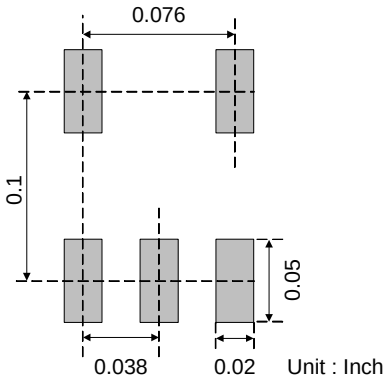
3. Locate APL3534/A/B and output capacitors near the load to reduce parasitic resistance and inductance for excellent load transient performance.
4. The negative pins of the input and output capacitors and the GND pin must be connected to the ground plane of the load.
5. Keep V_{IN} and V_{OUT} traces as wide and short as possible.

Application Information

Recommanded Minimum Footprit



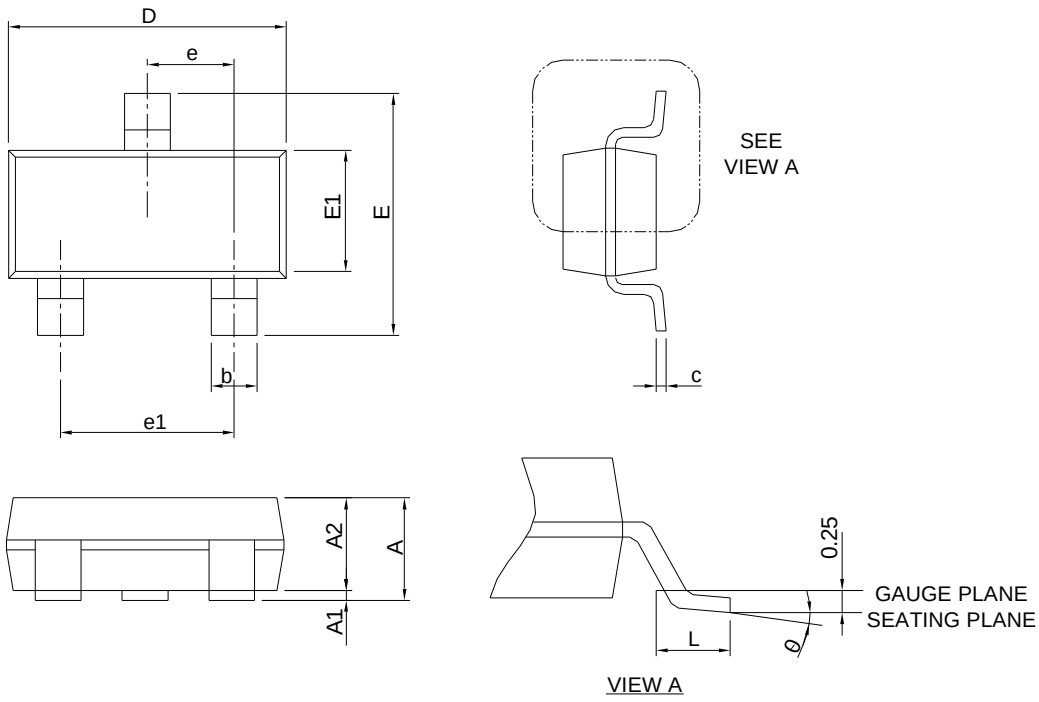
SOT-23-3



SOT-23-5

Package Information

SOT-23-3

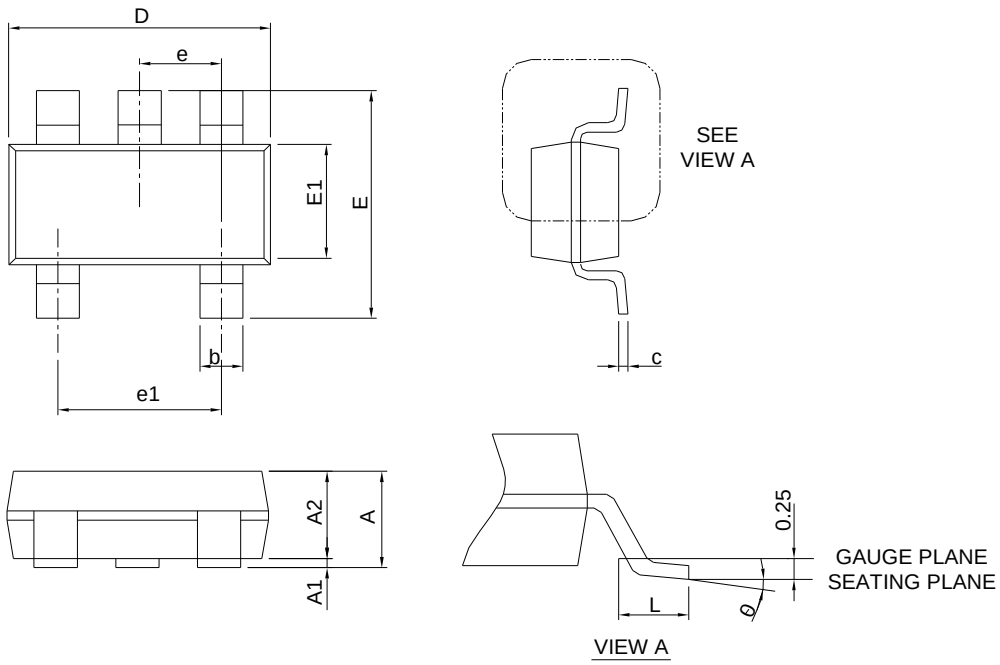


SYMBOL	SOT-23-3			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A		1.45		0.057
A1	0.00	0.15	0.000	0.006
A2	0.90	1.30	0.035	0.051
b	0.30	0.50	0.012	0.020
c	0.08	0.22	0.003	0.009
D	2.70	3.10	0.106	0.122
E	2.60	3.00	0.102	0.118
E1	1.40	1.80	0.055	0.071
e	0.95 BSC		0.037 BSC	
e1	1.90 BSC		0.075 BSC	
L	0.30	0.60	0.012	0.024
θ	0°	8°	0°	8°

Note : Dimension D and E1 do not include mold flash, protrusions or gate burrs. Mold flash, protrusion or gate burrs shall not exceed 10 mil per side.

Package Information

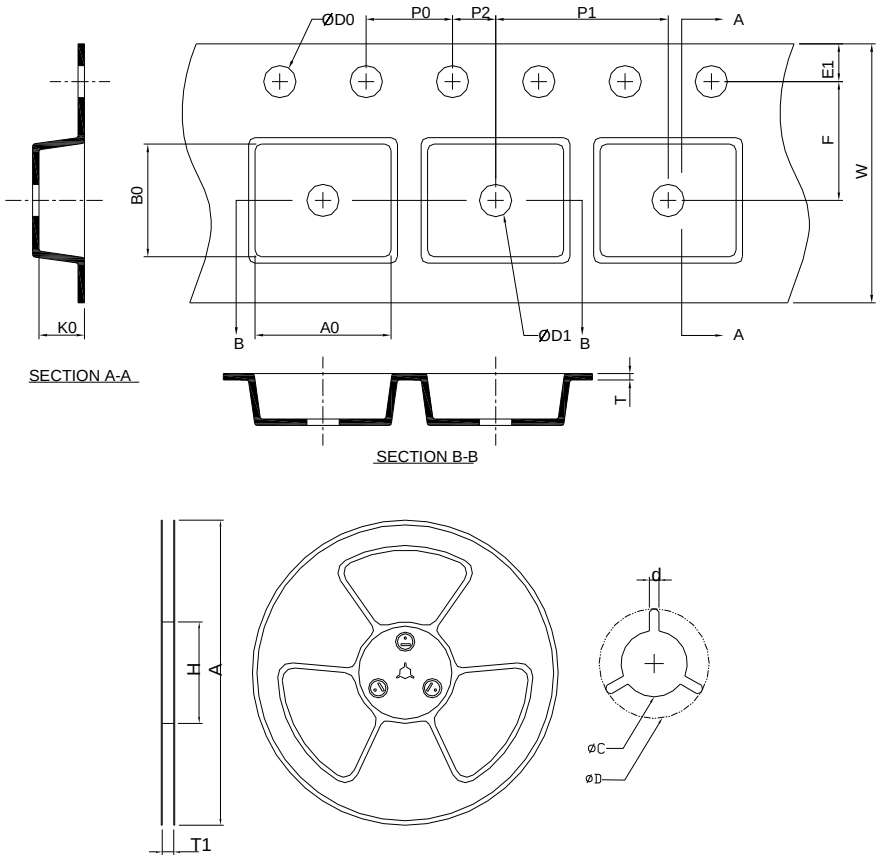
SOT-23-5



SYMBOL	SOT-23-5			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A		1.45		0.057
A1	0.00	0.15	0.000	0.006
A2	0.90	1.30	0.035	0.051
b	0.30	0.50	0.012	0.020
c	0.08	0.22	0.003	0.009
D	2.70	3.10	0.106	0.122
E	2.60	3.00	0.102	0.118
E1	1.40	1.80	0.055	0.071
e	0.95 BSC		0.037 BSC	
e1	1.90 BSC		0.075 BSC	
L	0.30	0.60	0.012	0.024
θ	0°	8°	0°	8°

Note : 1. Follow JEDEC TO-178 AA.
2. Dimension D and E1 do not include mold flash, protrusions or gate burrs. Mold flash, protrusion or gate burrs shall not exceed 10 mil per side.

Carrier Tape & Reel Dimensions



Application	A	H	T1	C	d	D	W	E1	F
SOT-23-3	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
Application	**A**	**H**	**T1**	**C**	**d**	**D**	**W**	**E1**	**F**
SOT-23-5	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

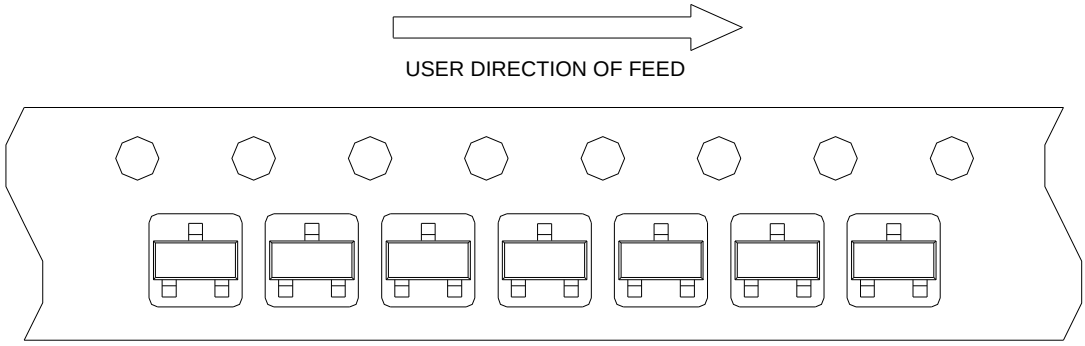
(mm)

Devices Per Unit

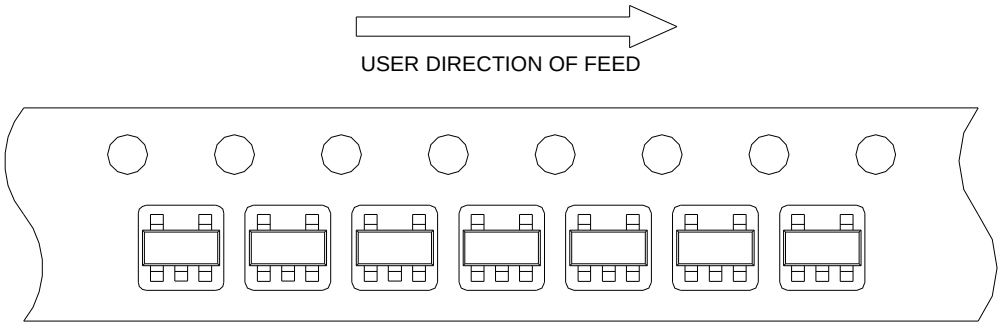
Package Type	Unit	Quantity
SOT-23-3	Tape & Reel	3000
SOT-23-5	Tape & Reel	3000

Taping Direction Information

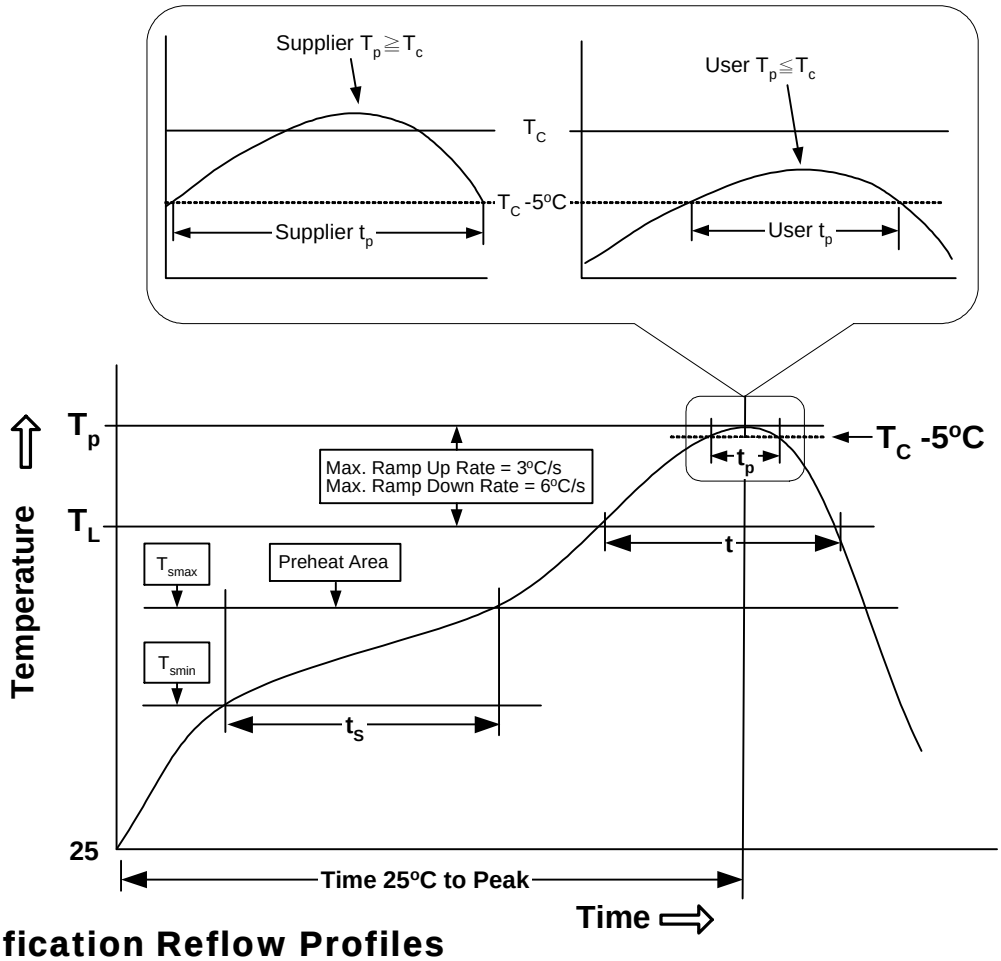
SOT-23-3



SOT-23-5



Classification Profile



Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
Preheat & Soak Temperature min (T_{smin}) Temperature max (T_{smax}) Time (T_{smin} to T_{smax}) (t_s)	 100 °C 150 °C 60-120 seconds	 150 °C 200 °C 60-120 seconds
Average ramp-up rate (T_{smax} to T_P)	3 °C/second max.	3 °C/second max.
Liquidous temperature (T_L) Time at liquidous (t_L)	183 °C 60-150 seconds	217 °C 60-150 seconds
Peak package body Temperature (T_p)*	See Classification Temp in table 1	See Classification Temp in table 2
Time (t_P)** within 5°C of the specified classification temperature (T_c)	20** seconds	30** seconds
Average ramp-down rate (T_p to T_{smax})	6 °C/second max.	6 °C/second max.
Time 25°C to peak temperature	6 minutes max.	8 minutes max.
* Tolerance for peak profile Temperature (T_p) is defined as a supplier minimum and a user maximum. ** Tolerance for time at peak profile temperature (t_p) is defined as a supplier minimum and a user maximum.		

Classification Reflow Profiles (Cont.)

Table 1. SnPb Eutectic Process – Classification Temperatures (Tc)

Package Thickness	Volume mm^3 <350	Volume mm^3 350
<2.5 mm	235 °C	220 °C
≥2.5 mm	220 °C	220 °C

Table 2. Pb-free Process – Classification Temperatures (Tc)

Package Thickness	Volume mm^3 <350	Volume mm^3 350-2000	Volume mm^3 >2000
<1.6 mm	260 °C	260 °C	260 °C
1.6 mm – 2.5 mm	260 °C	250 °C	245 °C
≥2.5 mm	250 °C	245 °C	245 °C

Reliability Test Program

Test item	Method	Description
SOLDERABILITY	JESD-22, B102	5 Sec, 245°C
HOLT	JESD-22, A108	1000 Hrs, Bias @ T_j=125°C
PCT	JESD-22, A102	168 Hrs, 100%RH, 2atm, 121°C
TCT	JESD-22, A104	500 Cycles, -65°C~150°C
HBM	MIL-STD-883-3015.7	VHBM≧2KV
MM	JESD-22, A115	VMM≧200V
Latch-Up	JESD 78	10ms, 1_{tr}≧100mA

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