USB Power-Distribution Switches

Features

- **62mΩ Power Switch On Resistance**
- **Wide Supply Voltage Range: 2.7V to 5.5V**
- **Fix Current Limit Protection**
- **Fast Over current Response: 2us (typ.)**
- **Over-Temperature Protection**
- **Fault Indication Output**
- **Enable Input**
- **Built-in Soft-Start**

Applications

- **Notebook and Desktop Computers**
- **USB Ports**
- **High-Side Power Protection Switchs**
- **MHL Ports**

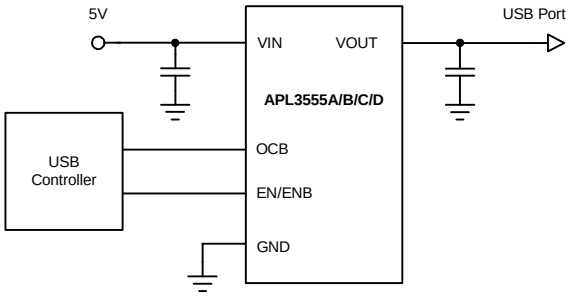
General Description

The APL3555 series of power switches are designed for USB applications. The 62mΩ N-channel MOSFET power switch satisfies the voltage drop requirements of USB specification.

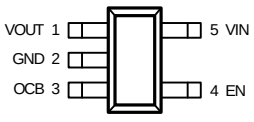
The protection features include current-limit protection, short-circuit protection, and over-temperature protection. The device limits the output current at current limit threshold level. When V_{OUT} drops below V_{IN}-1V, the devices limit the current to a lower and safe level. The over-temperature protection limits the junction temperature below 140°C in case of short circuit or over load conditions.

Other features include a deglitched OCB output to indicate the fault condition and an enable input to enable or disable the device.

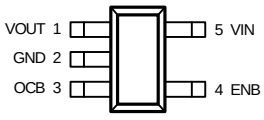
Simplified Application Circuit



Pin Configurations



SOT-23-5
APL3555A/C
(Top View)



SOT-23-5
APL3555B/D
(Top View)

Ordering and Marking Information

APL3555 □□□-□□□

- Assembly Material
- Handling Code
- Temperature Range
- Package Code
- Output Current/EN Function

Package Code
B : SOT-23-5
Operating Ambient Temperature Range
I : -40 to 85 °C
Handling Code
TR : Tape & Reel
Output Current/EN Function
A : 2A/Active High B : 2A/Active Low C : 1A/Active High
D : 1A/Active Low
Assembly Material
G : Halogen and Lead Free Device

APL3555O B: L5OX X - Date Code O-Output Current/EN Function 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 Input Voltage (VIN to GND)	-0.3 ~ 7	V
V_{OUT}	VOUT to GND Voltage	-0.3 ~ 7	V
V_{ENB}, V_{EN}	EN, ENB to GND Voltage	-0.3 ~ 7	V
V_{OCB}	OCB to GND Voltage	-0.3 ~ 7	V
T_J	Maximum Junction Temperature	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

Symbol	Parameter	Typical Value	Unit
θ_{JA}	Junction-to-Ambient Resistance in Free Air (Note 2) SOT-23-5	235	°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 ~ 5.5	V
I_{OUT}	OUT Output Current (APL3555A/B)	0 ~2	A
	OUT Output Current (APL3555C/D)	0 ~1	
T_A	Ambient Temperature	-40 ~ 85	°C
T_J	Junction Temperature	-40 ~ 125	°C

Note 3 : Refer to the typical application circuit

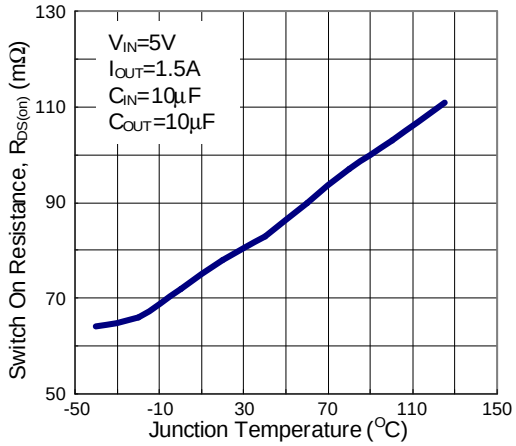
Electrical Characteristics

Unless otherwise specified, these specifications apply over V_{IN}=5V, V_{EN} =5V or V_{ENB}=0V and T_A= -40 ~ 85 °C. Typical values are at T_A=25°C.

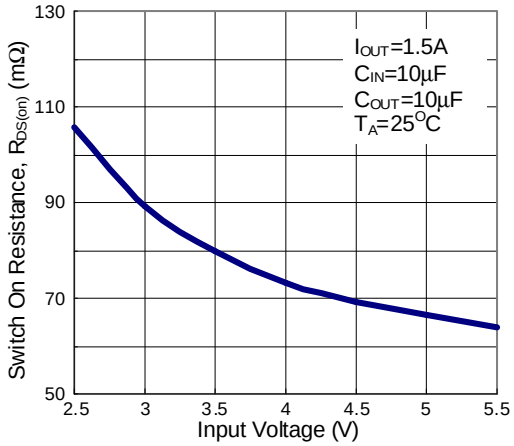
Symbol	Parameter	Test Conditions		APL3555			Unit
				Min.	Typ.	Max.	
SUPPLY CURRENT							
	VIN Supply Current	No load, V_{EN}=0V or V_{ENB}=5V		-	-	1	µA
		No load, V_{EN}=5V or V_{ENB}=0V		-	65	-	µA
	Leakage Current	VOUT=GND, V_{EN}=0V or V_{ENB}=5V		-	-	1	µA
	Reverse Leakage Current	VIN=GND, V_{OUT}=5V, V_{EN}=0V or V_{ENB}=5V		-	-	1	µA
POWER SWITCH							
$R_{DS(ON)}$	Power Switch On Resistance	I_{OUT}=1.5A, T_A= 25 °C	SOT-23-5 Package	-	62	78	mΩ
UNDER-VOLTAGE LOCKOUT (UVLO)							
	VIN UVLO Threshold Voltage	V_{IN} rising, T_A= -40 ~ 85 °C		1.7	-	2.65	V
	VIN UVLO Hysteresis			-	0.2	-	V
CURRENT-LIMIT AND SHORT-CIRCUIT PROTECTIONS							
I_{LIM}	Current Limit Threshold	APL3555A/B V_{IN}=2.7V to 5.5V, T_A= 25 °C		2.1	2.5	2.9	A
		APL3555C/D V_{IN}=2.7V to 5.5V, T_A= 25 °C		1.1	1.5	1.9	A
I_{SHORT}	Short-Circuit Output Current	APL3555A/B V_{IN}=2.7V to 5.5V		-	0.8	-	A
		APL3555C/D V_{IN}=2.7V to 5.5V		-	0.8	-	A
OCB OUTPUT PIN							
	OCB Output Low Voltage	I_{OCB}=5mA		-	0.2	0.4	V
	OCB Leakage Current	V_{OCB}=5V		-	-	1	µA
$t_{D(OCB)}$	OCB Deglitch Time	OCB assertion, T_A= -40 ~ 85 °C		5	12	20	ms
EN OR ENB INPUT PIN							
V_{IH}	Input Logic HIGH	V_{IN}=2.7V to 5V		2	-	-	V
V_{IL}	Input Logic LOW	V_{IN}=2.7V to 5V		-	-	0.8	V
	Input Current			-	-	1	µA
	VOUT Discharge Resistance	V_{EN}=0V or V_{ENB}=5V		-	150	-	Ω
$t_{D(ON)}$	Turn On Delay Time			-	80	-	µs
$t_{D(OFF)}$	Turn Off Delay Time			-	5	-	µs
t_{SS}	Soft-Start Time	No load, C_{OUT}=1µF, V_{IN}=5V		-	400	1000	µs
OVER-TEMPERATURE PROTECTION (OTP)							
T_{OTP}	Over-Temperature Threshold	T_J rising		-	140	-	°C
	Over-Temperature Hysteresis			-	20	-	°C

Typical Operating Characteristics

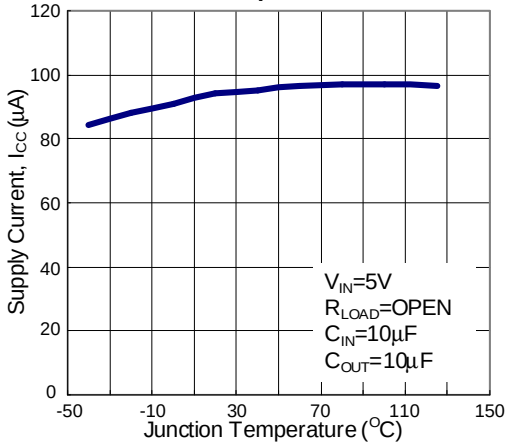
Switch On Resistance vs. Junction Temperature



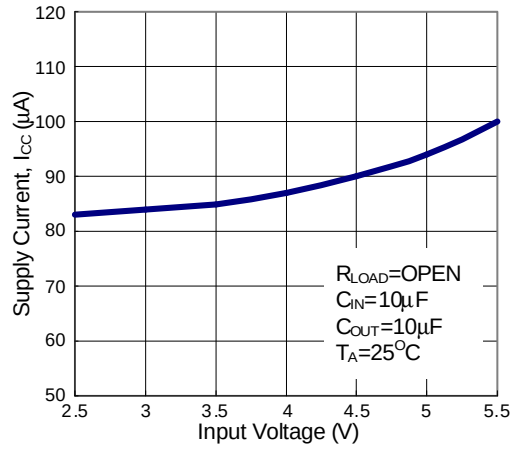
Switch On Resistance vs. Input Voltage



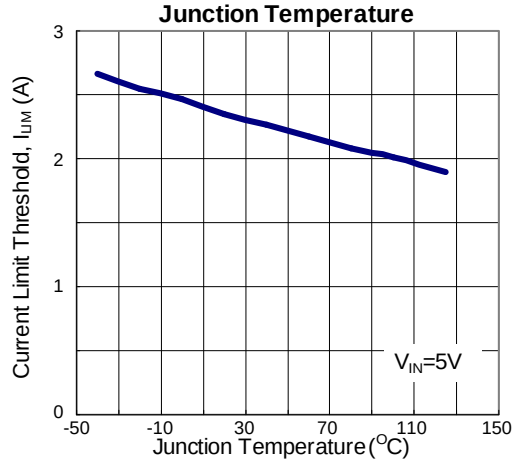
Supply Current vs. Junction Temperature



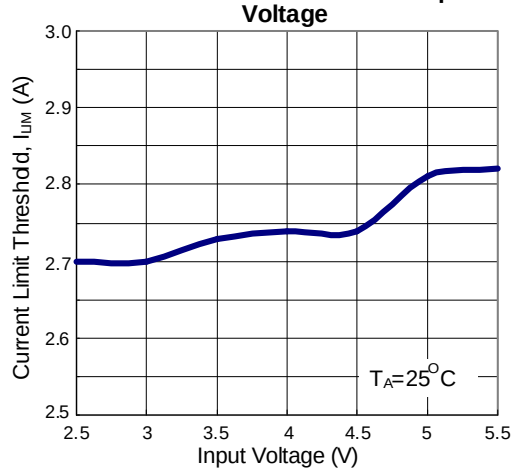
Supply Current vs. Input Voltage



Current Limit Threshold vs. Junction Temperature

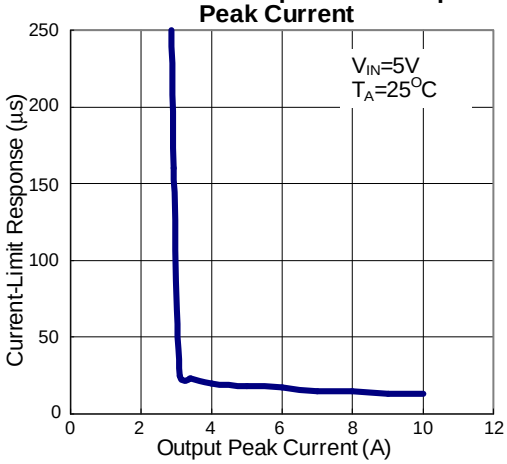


Current Limit Threshold vs. Input Voltage

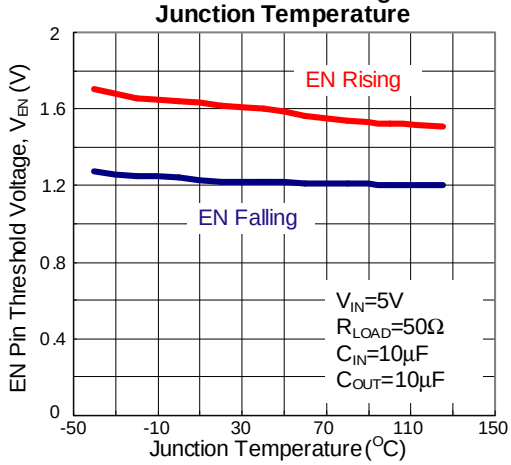


Typical Operating Characteristics (Cont.)

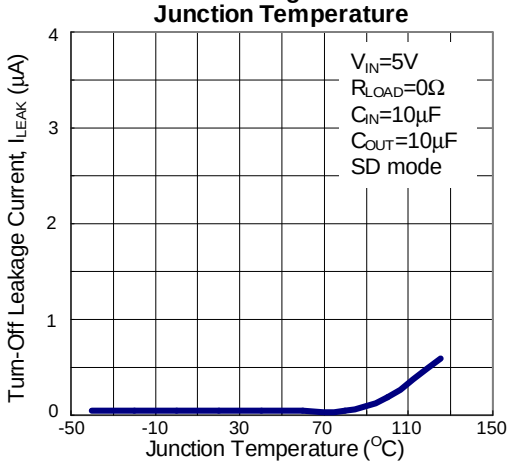
Current-Limit Response vs. Output Peak Current



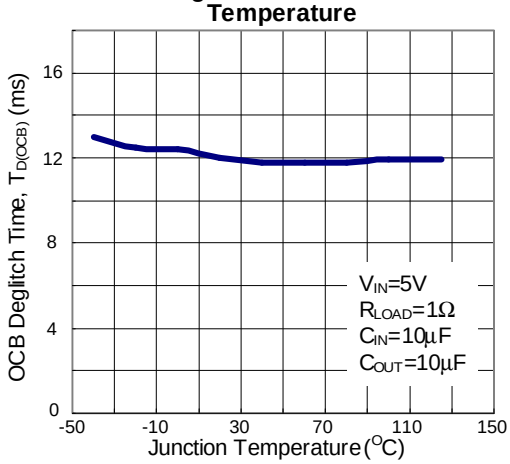
EN Pin Threshold Voltage vs . Junction Temperature



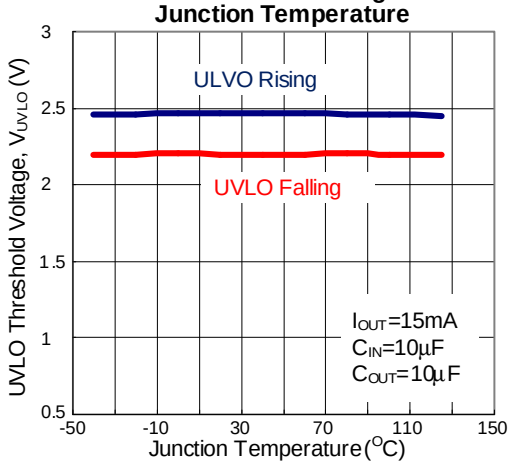
Turn-Off Leakage Current vs. Junction Temperature



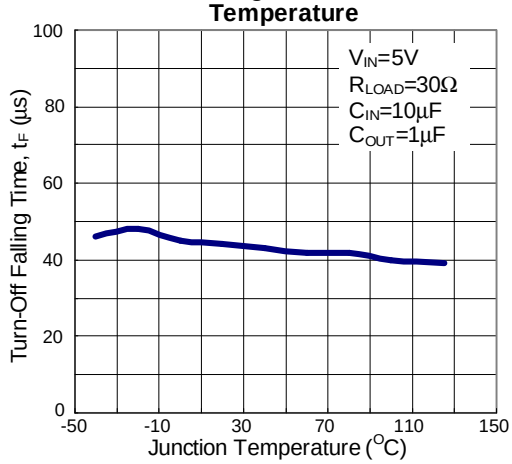
OCB Deglitch Time vs. Junction Temperature



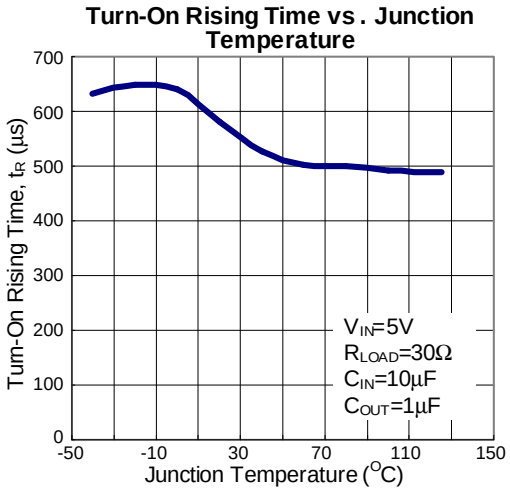
UVLO Threshold Voltage vs . Junction Temperature



Turn-Off Falling Time vs . Junction Temperature

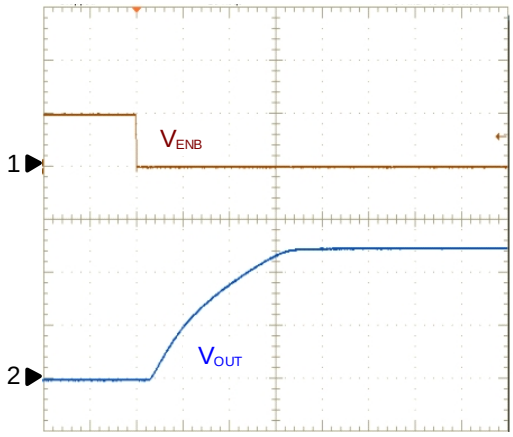


Typical Operating Characteristics (Cont.)



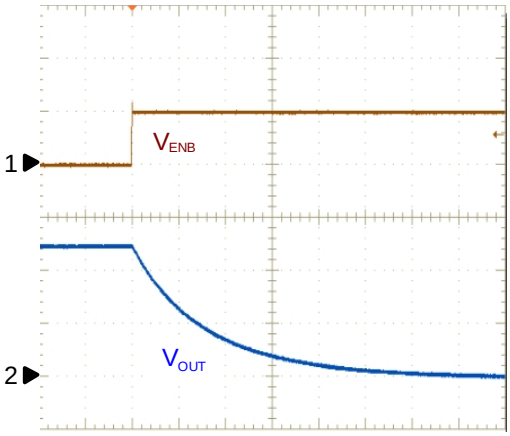
Operating Waveforms

Turn On Response



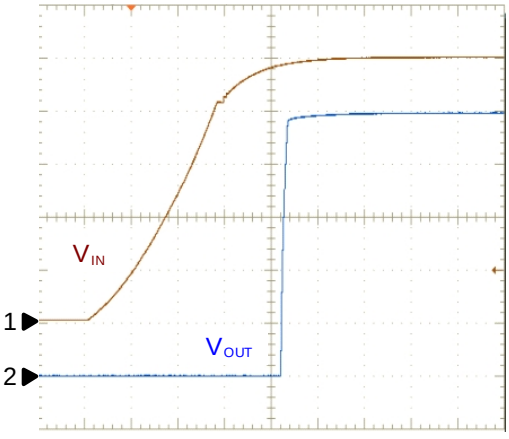
V_{IN}=5V,C_{OUT}=10µF/Electrolytic,
C_{IN}=10µF/Electrolytic,R_{LOAD}=30Ω
CH1:V_{ENB},5V/Div, DC
CH2:V_{OUT},2V/Div, DC
TIME:200µs/Div

Turn Off Response



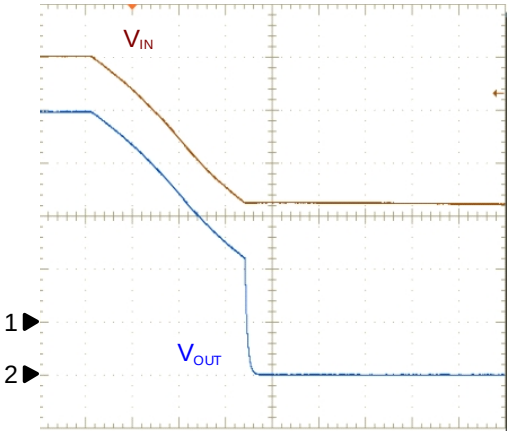
V_{IN}=5V,C_{OUT}=10µF/Electrolytic,
C_{IN}=10µF/Electrolytic,R_{LOAD}=30Ω
CH1:V_{ENB},5V/Div, DC
CH2:V_{OUT},2V/Div, DC
TIME:100µs/Div

UVLO at Rising



V_{IN}=5V,C_{OUT}=10µF/Electrolytic,
C_{IN}=10µF/Electrolytic,R_{LOAD}=30Ω
CH1:V_{IN},1V/Div, DC
CH2:V_{OUT},1V/Div, DC
TIME:4ms/Div

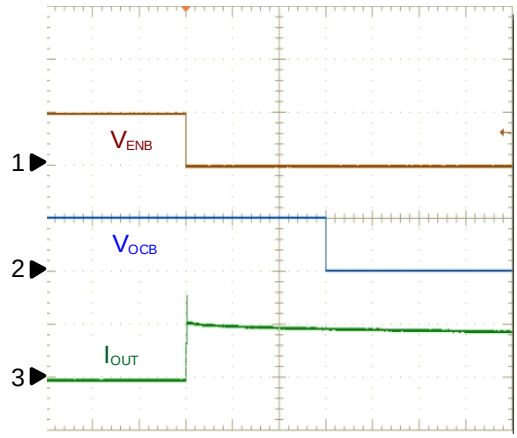
UVLO at Falling



V_{IN}=5V,C_{OUT}=10µF/Electrolytic,
C_{IN}=10µF/Electrolytic,R_{LOAD}=30Ω
CH1:V_{IN},1V/Div, DC
CH2:V_{OUT},1V/Div, DC
TIME:4ms/Div

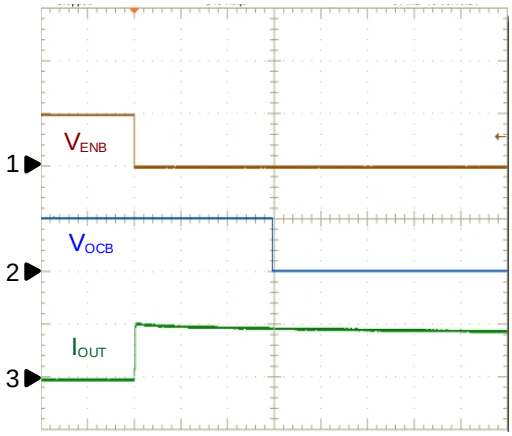
Operating Waveforms (Cont.)

OCB Response During Short Circuit



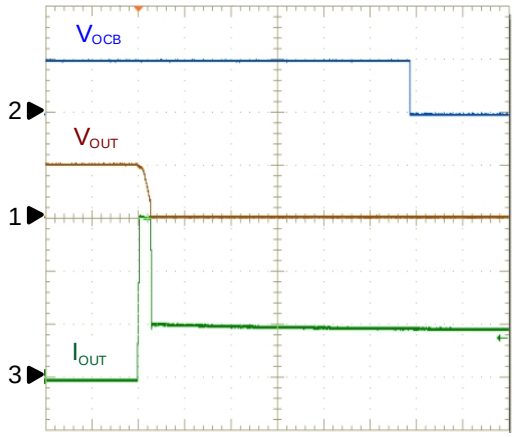
V_{IN}=5V,C_{OUT}=10µF/Electrolytic,
C_{IN}=10µF/Electrolytic,R_{LOAD}=0Ω
CH1:V_{ENB},5V/Div, DC
CH2:V_{OCB},5V/Div, DC
CH3:I_{OUT},1A/Div, DC
TIME:4ms/Div

OCB Response During Over Load



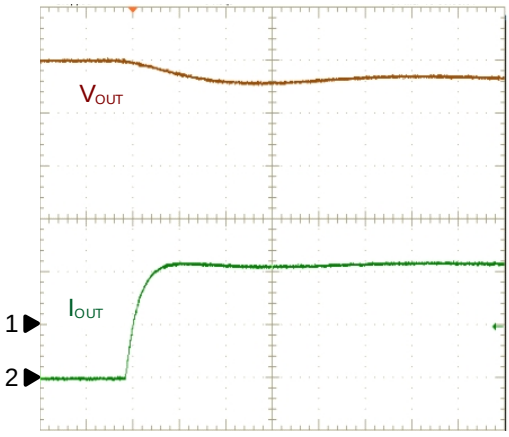
V_{IN}=5V,C_{OUT}=10µF/Electrolytic,
C_{IN}=10µF/Electrolytic,R_{LOAD}=1Ω
CH1:V_{ENB},5V/Div, DC
CH2:V_{OCB},5V/Div, DC
CH3:I_{OUT},1A/Div, DC
TIME:4ms/Div

OCB Response with Ramped Load



V_{IN}=5V,C_{OUT}=10µF/Electrolytic,
C_{IN}=10µF/Electrolytic
CH1:V_{OUT},5V/Div, DC
CH2:V_{OCB},5V/Div, DC
CH3:I_{OUT},1A/Div, DC
TIME:2ms/Div

Load-Transient Response

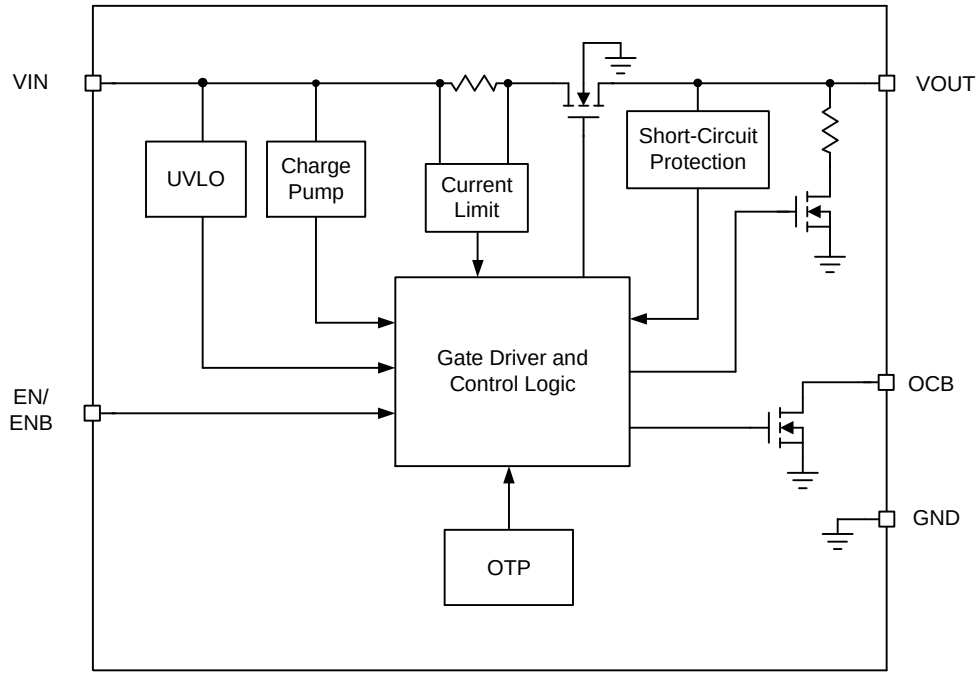


V_{IN}=5V,C_{OUT}=10µF/Electrolytic,
C_{IN}=10µF/Electrolytic,I_{OUT}=0 to 2A
CH1:V_{OUT},1V/Div, DC
CH2:I_{OUT},1A/Div, DC
TIME:2µs/Div

Pin Description

PIN		FUNCTION
NO.	NAME	
2	GND	Ground.
5	VIN	Power Supply Input. Connect this pin to external DC supply.
4	EN (A/C)	Enable Input. Pulling this pin to high will enable the device and pulling this pin to low will disable device. The EN pin cannot be left floating.
	ENB (B/D)	Enable Input. Pulling this pin to high will disable the device and pulling this pin to low will enable device. The ENB pin cannot be left floating.
3	OCB	Fault Indication Pin. This pin goes low when a current limit or an over-temperature condition is detected after a 12ms deglitch time.
1	VOUT	Output Voltage Pin. The output voltage follows the input voltage. When ENB is high or EN is low, the output voltage is discharged by an internal resistor.

Block Diagram



Parameter Measurement Information

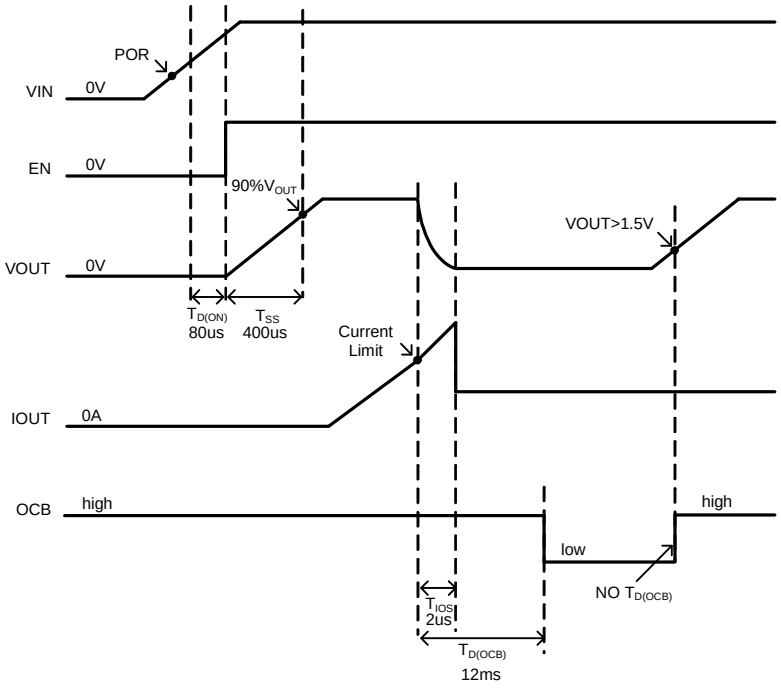
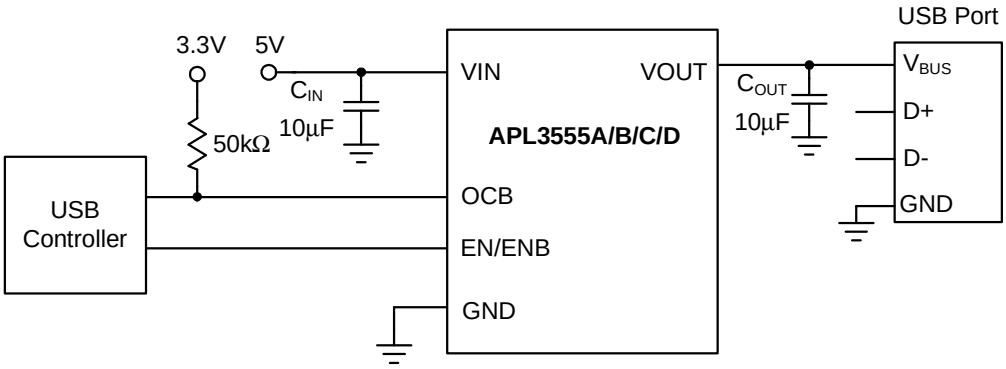


Figure 1. Sequence of Power On & Current Limit & OCB Indicate

Typical Application Circuit



Function Description

VIN Under-Voltage Lockout (UVLO)

The APL3555 series of power switches have a built-in under-voltage lockout circuit to keep the output shutting 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 off, the MOSFET prevents a current flowing from the VOUT back to VIN and VIN to VOUT.

Current-Limit Protection

The APL3555 series of power switches provide 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.

Short-Circuit Protection

When the output voltage drops below V_{IN}-1V, which is caused by an over-load or a 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 conditions. If the junction temperature reaches over-temperature threshold, the device will enter the thermal shutdown.

OCB Output

The APL3555 series of power switches provide an open-drain output to indicate that a fault has occurred. When any of current-limit or over-temperature protection occurs for a deglitch time of $t_{D(OCB)}$, the OCB goes low. If fault condition release, OCB will goes high when VOUT > 1.5V (see Figure 1). Since the OCB pin is an open-drain output, connecting a resistor to a pull high voltage is necessary.

Enable/Disable

Pull the ENB above 2V or EN below 0.8V will disable the device, and pull 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 pin 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 APL3555, 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.

Output Capacitor

A low-ESR 10µF aluminum electrolytic or tantalum between V_{OUT} and GND is strongly recommended to reduce the voltage droop during hot-attachment of downstream peripheral. (Per USB 2.0, output ports must have a minimum 120µF of low-ESR bulk capacitance per hub). Higher-value output capacitor is better when the output load is heavy.

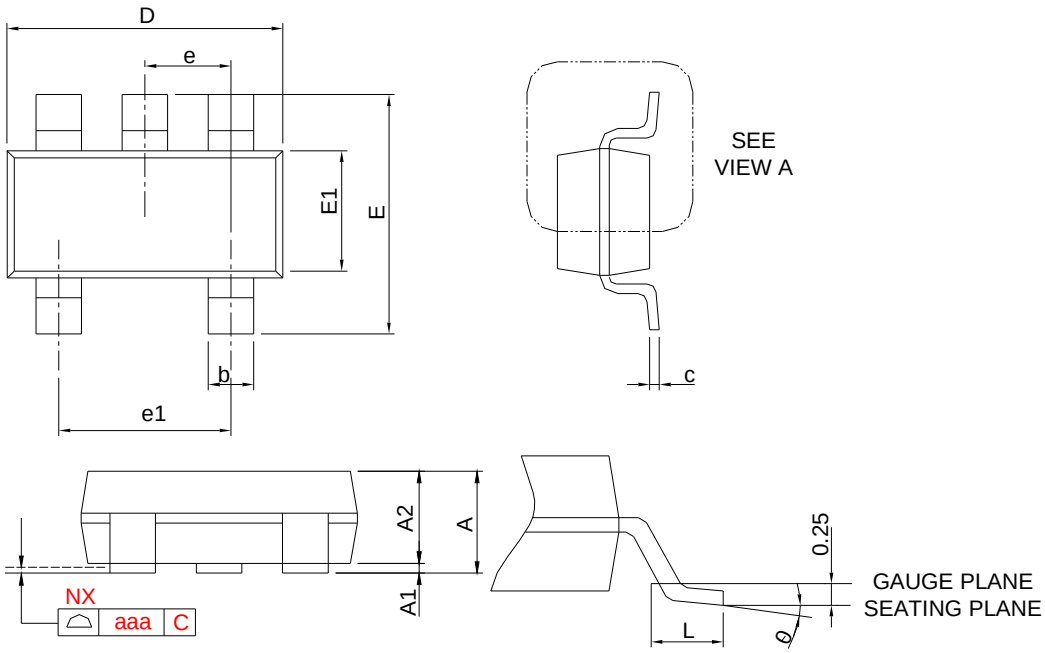
Layout Consideration

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 APL3555 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.

Package Information

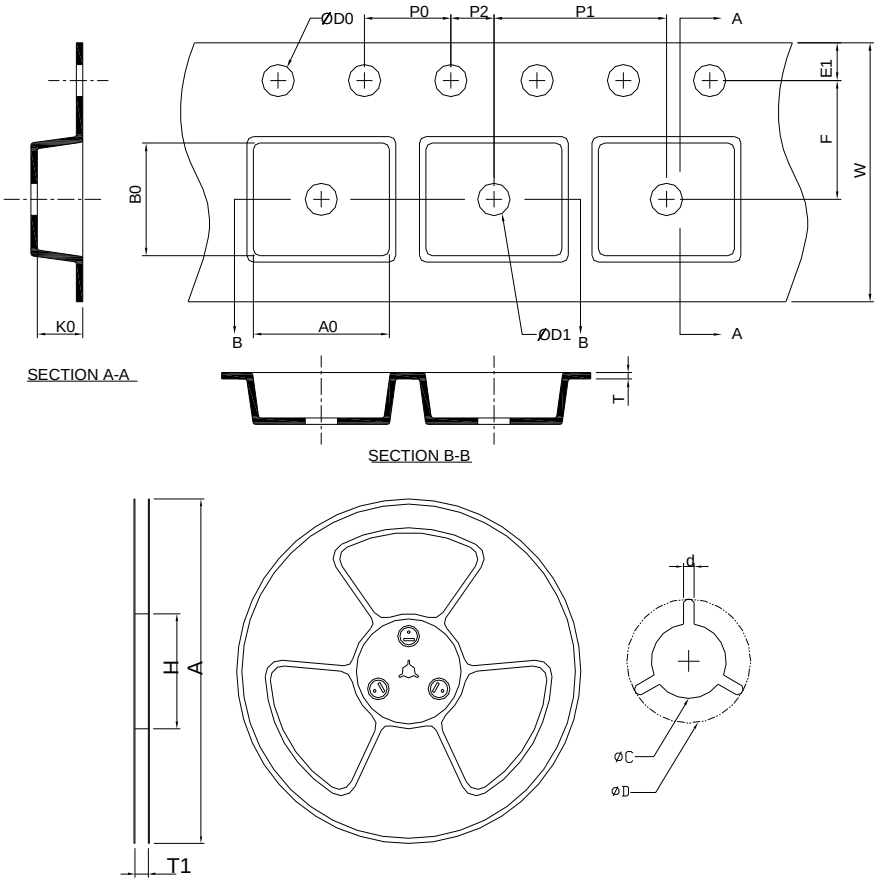
SOT-23-5



SYMBOL	SOT-23-5					
	MILLIMETERS			INCHES		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
A		1.16	1.45		0.046	0.057
A1	0.00	0.05	0.15	0.000	0.002	0.006
A2	0.90	1.10	1.30	0.035	0.043	0.051
b	0.30	0.38	0.50	0.012	0.015	0.020
c	0.08	0.17	0.22	0.003	0.007	0.009
D	2.70	2.93	3.10	0.106	0.115	0.122
E	2.60	2.83	3.00	0.102	0.111	0.118
E1	1.40	1.60	1.80	0.055	0.063	0.071
e	0.95 BSC			0.037BSC		
e1	1.90 BSC			0.075BSC		
K	0.30	0.45	0.60	0.012	0.018	0.024
θ	0	4	8	0	4	8
aaa	0.10			0.004		

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-23-5	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

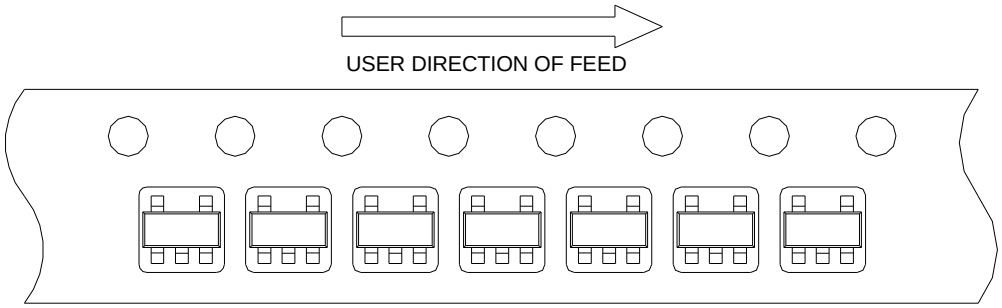
(mm)

Devices Per Unit

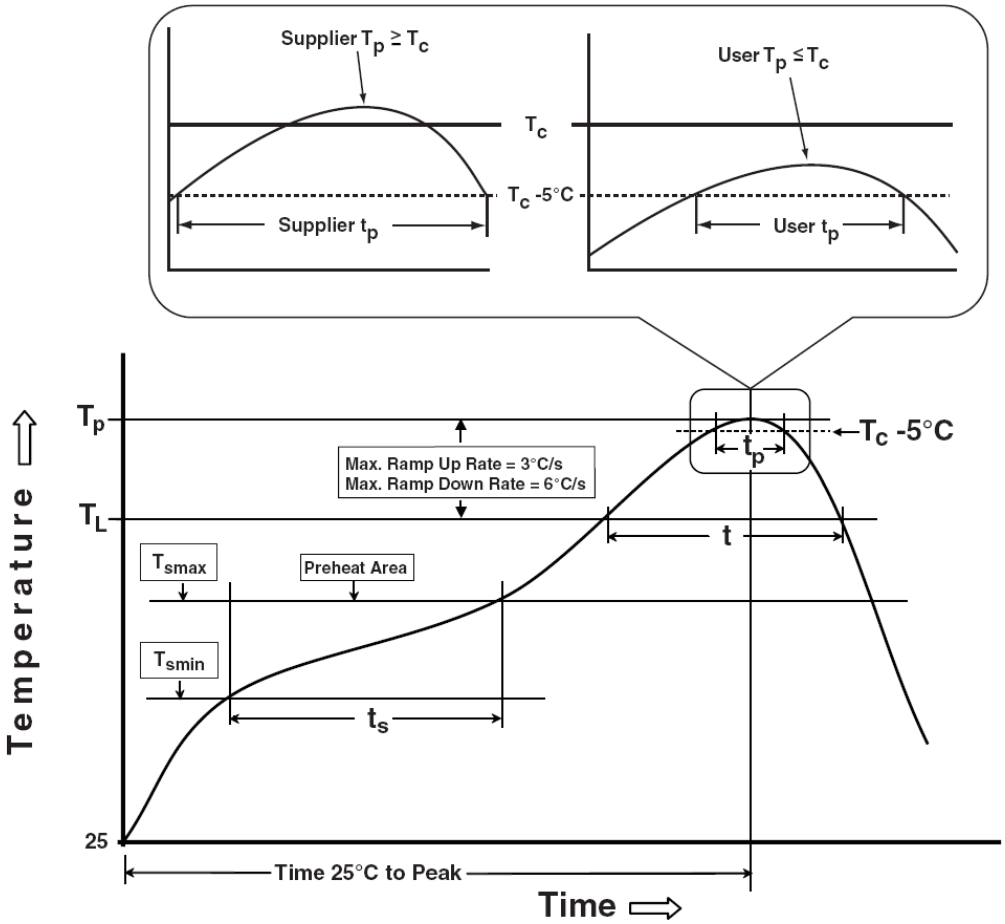
Package Type	Unit	Quantity
SOT-23-5	Tape & Reel	3000

Taping Direction Information

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 ³350
<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 @ Tj=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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