

Power-Distribution Switches with Discharge

Features

- **60mW High Side MOSFET**
- **2.5A Continuous Current**
- **Programmable VOUT Discharge Function by DIS Pin**
- **Wide Supply Voltage Range: 2.7V to 5.5V**
- **Current-Limit and Short-Circuit Protections**
- **Under-Voltage Lockout Protection**
- **Reverse Current Blocking when Switch Disabled**
- **Over-Temperature Protection**
- **Logic Level Enable Input**
APL3522A: Active High
APL3522B: Active Low
- **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)**

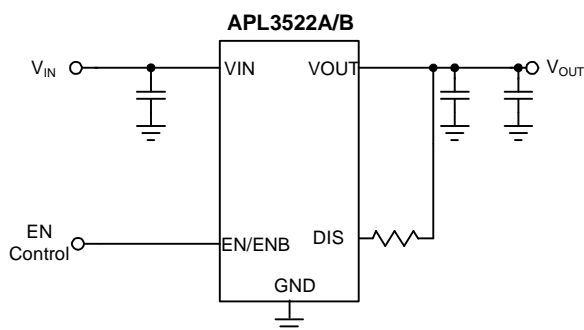
General Description

The APL3522A/B is a power-distribution switch with some protection functions that can deliver current up to 2.5A. The device incorporates a 60mΩ N-channel MOSFET power switch that is controlled by an enable logic pin and dedicated to soft-start ramp-up rate control that can be used in application where the inrush current is concerned. It can be programmable VOUT discharge function by DIS pin.

The device integrates some protection features, including current-limit protection, short-circuit protection, over-temperature protection, and UVLO. The current-limit and short-circuit 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. When V_{OUT} drops below $V_{IN} - 1.5V$ the devices limit the current to a lower and safe level. 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-23-5 packages with enable active-high(EN) and active-low(ENB) versions.

Simplified Application Circuit

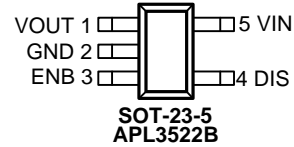
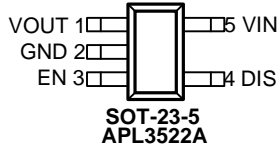


Applications

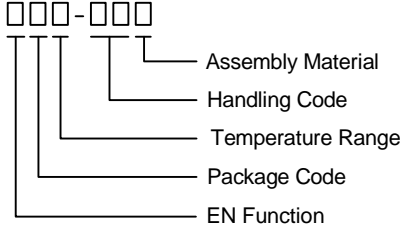
- **TFT LCD Modules**
- **Notebook and Desktop Computers**
- **USB Ports**
- **High-Side Power Protection Switches**

ANPEC reserves the right to make changes to improve reliability or manufacturability without notice, and advise customers to obtain the latest version of relevant information to verify before placing orders.

Pin Configuration



Ordering and Marking Information

| | | |
|-------------|--|---|
| APL3522 |  | EN Function A : Active High B : Active Low Package Code 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 |
| APL3522A B: | 22AX | X - Date Code |
| APL3522B B: | 22BX | 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 | V |
| V_{OUT} | VOUT to GND Voltage | -0.3 ~ 6 | V |
| V_{ENB}, V_{EN} | EN, ENB to GND Voltage | -0.3 ~ 6 | V |
| V_{DIS} | DIS to GND Voltage | -0.3 ~ 6 | V |
| I_{OUT} | Continuous Output Current | Internally Limited | A |
| 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

| Symbol | Parameter | Typical Value | Unit |
|---------------|--|---------------|------|
| θ_{JA} | Junction-to-Ambient Resistance in Free Air ^(Note 2) SOT-23-5 | 250 | °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 | $T_A = -40 \sim 25^\circ\text{C}$ | 0 ~ 2.5 |
| | | $T_A = 85^\circ\text{C}$ ^(Note 4) | 0 ~ 1.6 |
| T_A | Ambient Temperature | -40 ~ 85 | °C |
| T_J | Junction Temperature | -40 ~ 125 | °C |

Note 3: Refer to the typical application circuit.

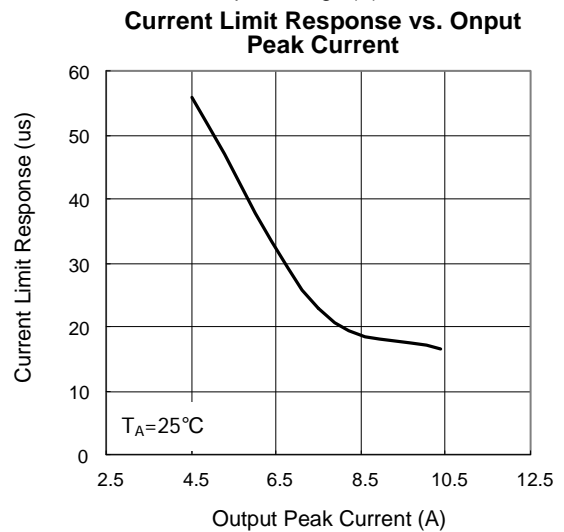
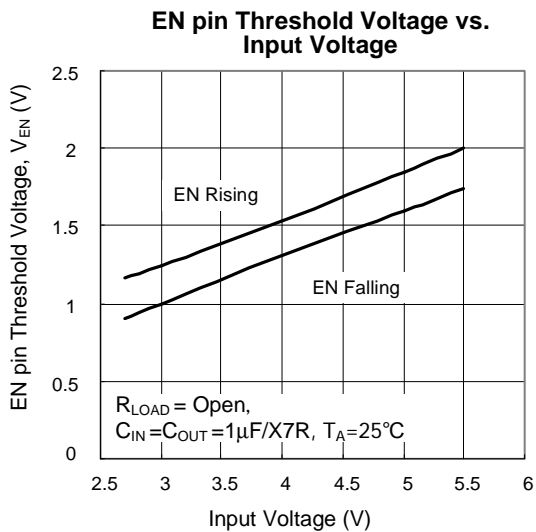
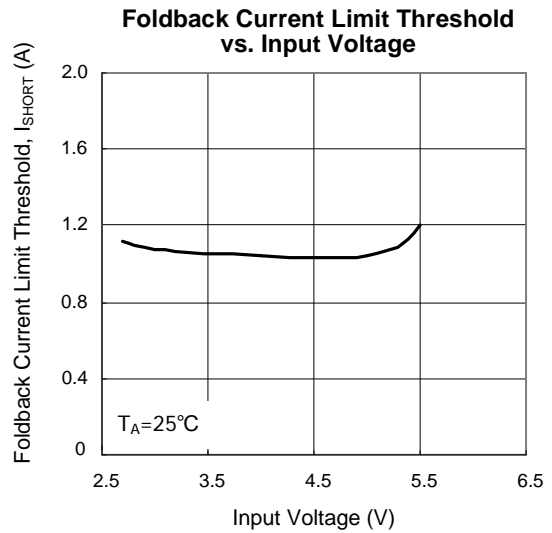
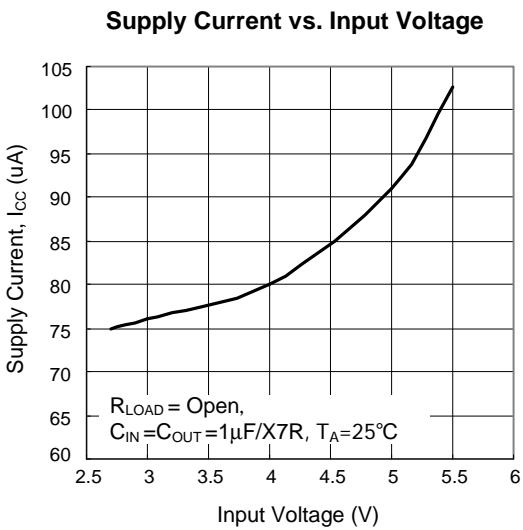
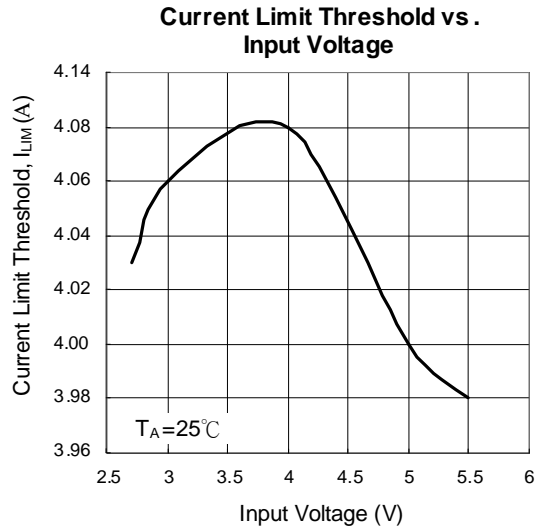
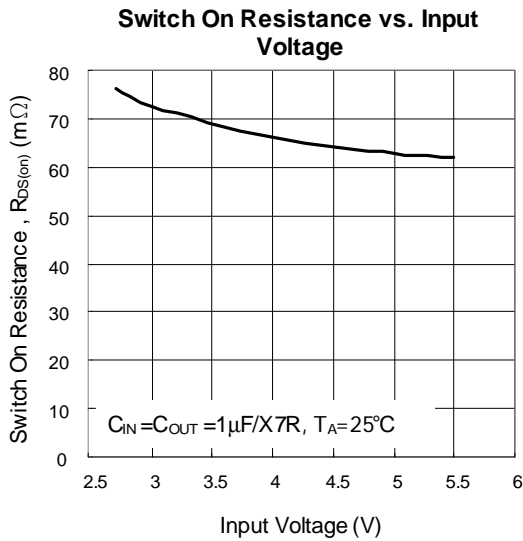
Note 4: When the ambient temperature rises, the output current should be reduced accordingly. Please see Application Information for more details.

Electrical Characteristics

Unless otherwise specified, these specifications apply over $V_{IN}=5V$, $V_{EN}=5V$ or $V_{ENB}=0V$ and $T_A=25^{\circ}C$.

| Symbol | Parameter | Test Conditions | APL3522A/B | | | 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 $V_{ENB}=0V$ | - | 60 | 100 | μA |
| | Leakage Current | $V_{OUT}=GND$, $V_{EN}=0V$ or $V_{ENB}=5V$ | - | - | 1 | μA |
| | Reverse Leakage Current | $V_{IN}=GND$, $V_{OUT}=5V$, $V_{EN}=0V$ or $V_{ENB}=5V$ | - | - | 1 | μA |
| POWER SWITCH | | | | | | |
| $R_{DS(ON)}$ | Power Switch On Resistance | $I_{OUT}=1.5A$, $T_A=25^{\circ}C$ | - | 60 | 70 | m Ω |
| UNDER-VOLTAGE LOCKOUT | | | | | | |
| | VIN UVLO Threshold Voltage | V_{IN} rising, $T_A=-40\sim 85^{\circ}C$ | 2.3 | - | 2.65 | V |
| | VIN UVLO Hysteresis | | - | 0.2 | - | V |
| CURRENT-LIMIT AND SHORT-CIRCUIT PROTECTIONS | | | | | | |
| I_{LIM} | Current-Limit Threshold | $V_{IN}=2.7V$ to $5.5V$, $T_A=-40\sim 85^{\circ}C$ | 3.5 | 4 | 4.9 | A |
| I_{SHORT} | Short-Circuit Output Current | $V_{IN}=2.7V$ to $5.5V$ | - | 0.8 | - | A |
| SOFT-START CONTROL PIN | | | | | | |
| t_{SS} | Soft-Start Time | $V_{IN}=3.3V$, No load, $C_{OUT}=1\mu F$ | 1 | 2 | 3 | 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 |
| | DIS Discharge Resistance | $V_{EN}=0V$ or $V_{ENB}=5V$ | - | 42 | - | Ω |
| OVER-TEMPERATURE PROTECTION (OTP) | | | | | | |
| T_{OTP} | Over-Temperature Threshold | T_J rising | - | 140 | - | $^{\circ}C$ |
| | Over-Temperature Hysteresis | | - | 20 | - | $^{\circ}C$ |

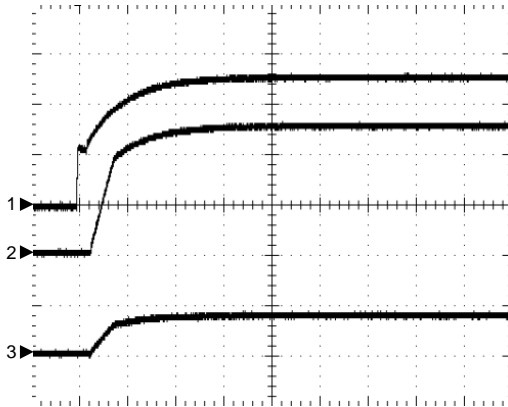
Typical Operating Characteristics



Operating Waveforms

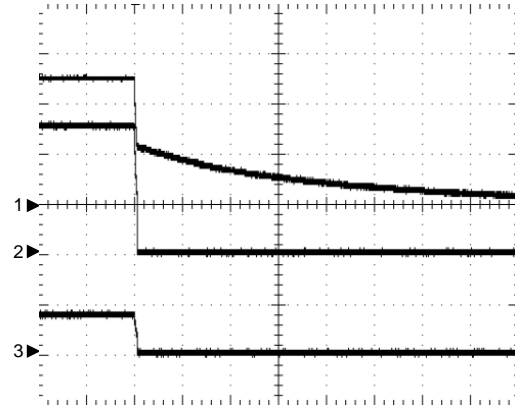
The test condition is $V_{IN}=5V$, $T_A=25^\circ C$ unless otherwise specified.

Power On



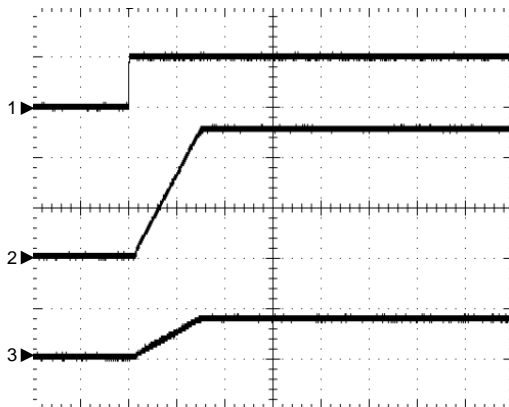
$V_{IN}=5V$, $R_{LOAD}=30\Omega$, $C_{IN}=1\mu F$, $C_{OUT}=10\mu F$
 CH1: V_{IN} , 2V/Div, DC
 CH2: V_{OUT} , 2V/Div, DC
 CH3: I_{OUT} , 0.2A/Div, DC
 TIME: 4ms/Div

Power Off



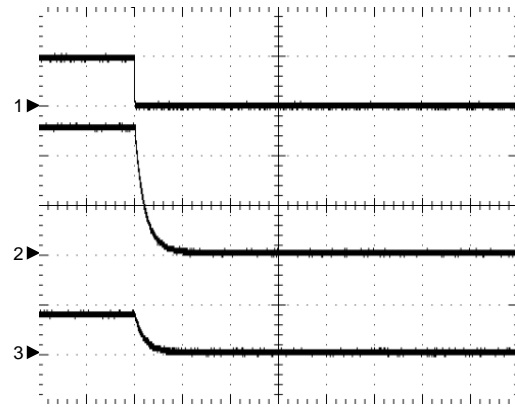
$V_{IN}=5V$, $R_{LOAD}=30\Omega$, $C_{IN}=1\mu F$, $C_{OUT}=10\mu F$,
 $R_{DIS}=100k\Omega$
 CH1: V_{IN} , 2V/Div, DC
 CH2: V_{OUT} , 2V/Div, DC
 CH3: I_{OUT} , 0.2A/Div, DC
 TIME: 200ms/Div

Turn On Response



$V_{IN}=5V$, $R_{LOAD}=30\Omega$, $C_{IN}=1\mu F$, $C_{OUT}=10\mu F$
 CH1: V_{EN} , 5V/Div, DC
 CH2: V_{OUT} , 2V/Div, DC
 CH3: I_{OUT} , 0.2A/Div, DC
 TIME: 2ms/Div

Turn Off Response

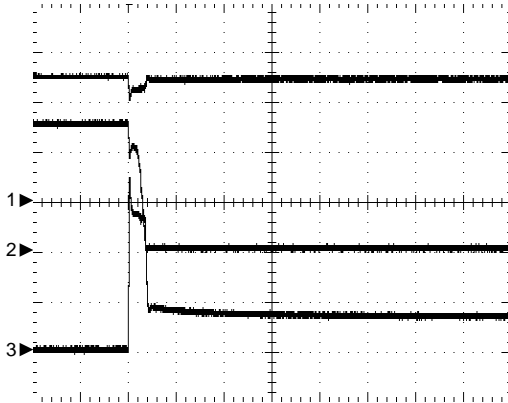


$V_{IN}=5V$, $R_{LOAD}=30\Omega$, $C_{IN}=1\mu F$, $C_{OUT}=10\mu F$,
 $R_{DIS}=100k\Omega$
 CH1: V_{EN} , 5V/Div, DC
 CH2: V_{OUT} , 2V/Div, DC
 CH3: I_{OUT} , 0.2A/Div, DC
 TIME: 2ms/Div

Operating Waveforms

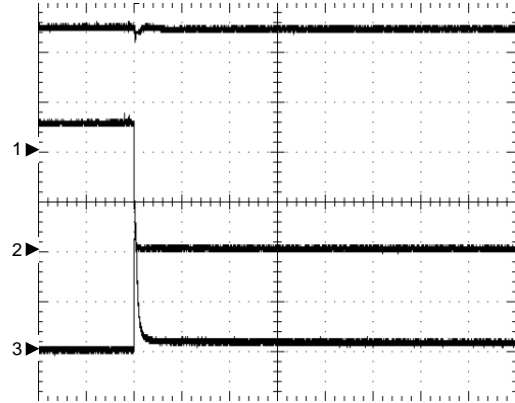
The test condition is $V_{IN}=5V$, $T_A=25^\circ C$ unless otherwise specified.

Current Limit Protection



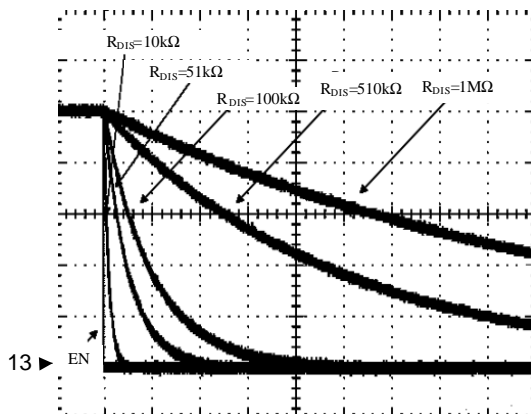
$V_{IN}=5V$, $C_{IN}=1\mu F$, $C_{OUT}=10\mu F$
 CH1: V_{IN} , 2V/Div, DC
 CH2: V_{OUT} , 2V/Div, DC
 CH3: I_{OUT} , 2A/Div, DC
 TIME: 0.4ms/Div

Short Circuit Protection



$V_{IN}=5V$, V_{OUT} short to ground, $C_{IN}=1\mu F$,
 $C_{OUT}=100\mu F$
 CH1: V_{IN} , 2V/Div, DC
 CH2: V_{OUT} , 2V/Div, DC
 CH3: I_{OUT} , 10A/Div, DC
 TIME: 100us/Div

V_{out} Discharge Time

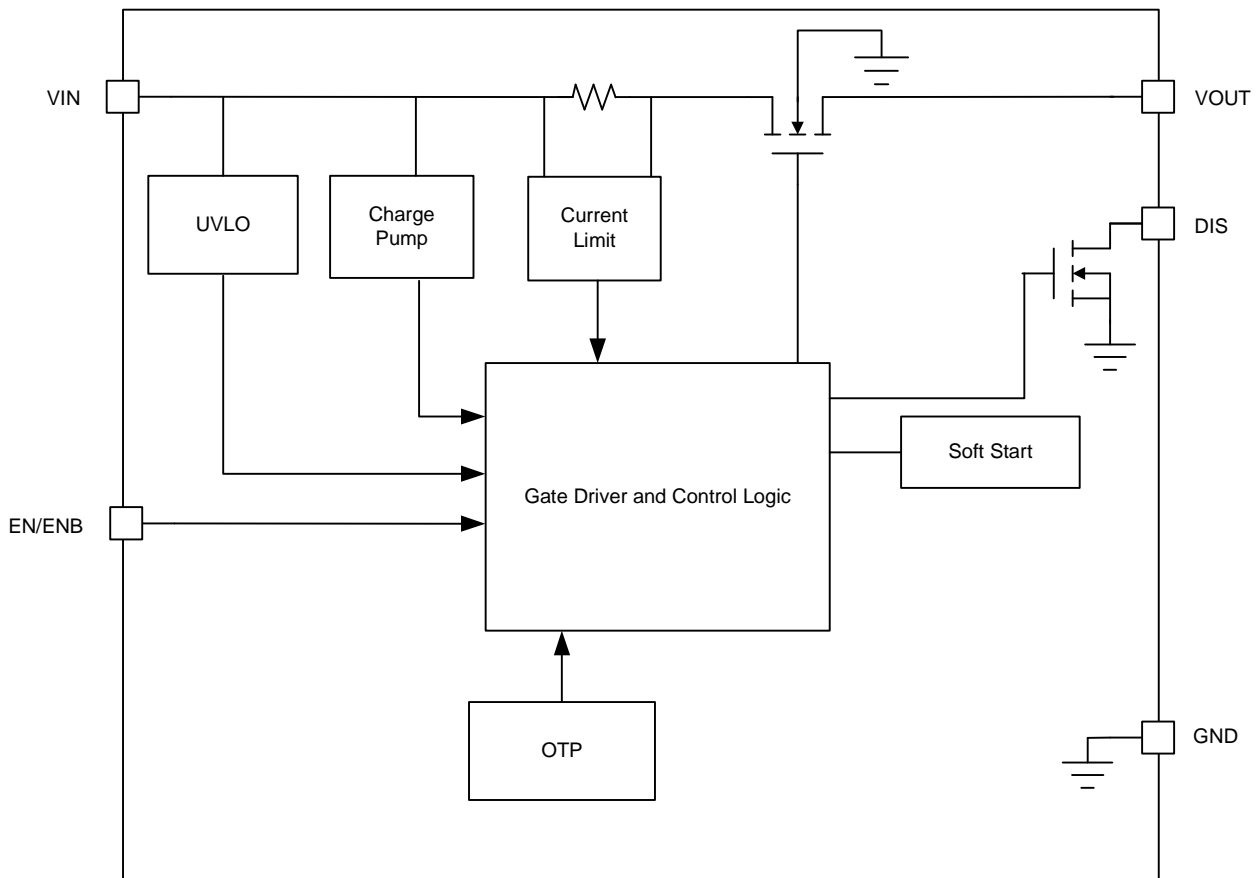


$V_{in}=5V$, $C_{in}=1\mu F$, $C_{out}=10\mu F$
 CH1: V_{out} (1V/Div)
 CH3: EN (1V/Div)
 Time: 1s/Div

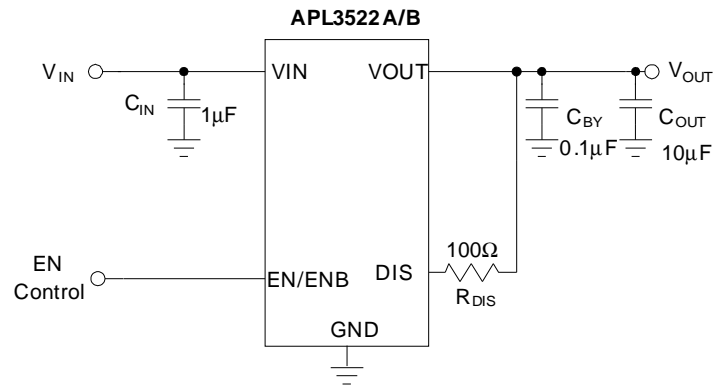
Pin Description

| PIN | | FUNCTION |
|-----|----------------|---|
| NO. | NAME | |
| 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. |
| 2 | GND | Ground |
| 3 | EN (APL3522A) | Enable Input. Pull this pin to high to enable the device and pull this pin to low to disable device. The EN pin cannot be left floating. |
| | ENB (APL3522B) | Enable Input. Pull this pin to high to disable the device and pull this pin to low to enable device. The ENB pin cannot be left floating. |
| 4 | DIS | Discharge Control Pin. Connect a resistor to VOUT to adjust discharge time. |
| 5 | VIN | Power Supply Input. Connect this pin to external DC supply. |

Block Diagram



Typical Application Circuit



Function Description

VIN Under-Voltage Lockout (UVLO)

The APL3522A/B power switch is built-in an 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 off, the MOSFET prevents a current flowing from the VOUT back to VIN and VIN to VOUT.

Current-Limit Protection

The APL3522A/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.

Short-Circuit Protection

When the output voltage drops below $V_{IN}-1.5V$, 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.

Soft-Start

The APL3522A/B provides an internal soft-start circuitry to control rise rate of the output voltage and limit the current surge during start-up.

Enable/Disable

Pull the ENB above 2V, or EN below 0.8V to disable the device and pull ENB pin below 0.8V or EN above 2V to enable the device. When the IC is disabled, the supply current is reduced to less than 1 μ A. 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 $T_J=+125^\circ\text{C}$.

Adjustable VOUT Discharge Function

It can be programmable VOUT discharge function by R_{DIS} . When ENB is high, or EN is low, It can be discharge from VOUT to DIS.

Application Information

Input Capacitor

A 1 μ F or higher ceramic bypass capacitor from VIN to GND, located near the APL3522, 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 10 μ F MLCC, aluminum electrolytic or tantalum between VOUT and GND is strongly recommended to reduce the voltage droop during hot-attachment of downstream peripheral. Higher-value output capacitor is better when the output load is heavy. Additionally, bypassing the output with a 0.1 μ F ceramic capacitor improves the immunity of the device to short-circuit transients.

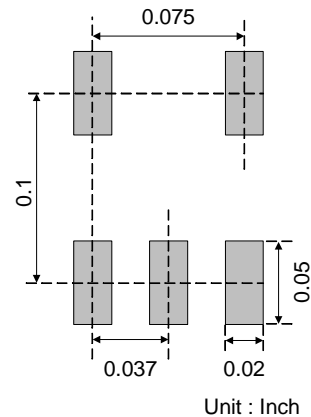
Layout Consideration

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 APL3522 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.

Recommended Minimum Footprint

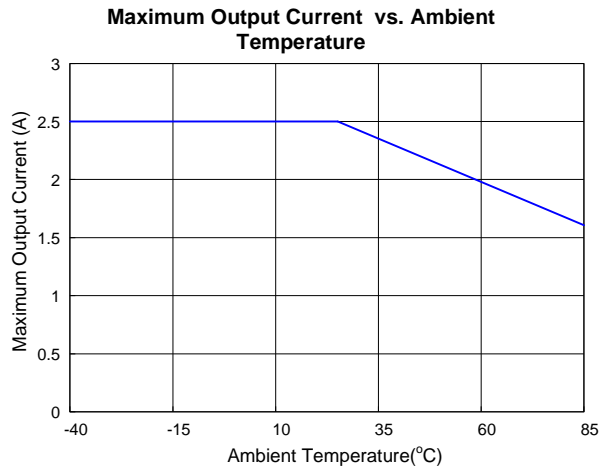


SOT-23-5

Maximum Output Current

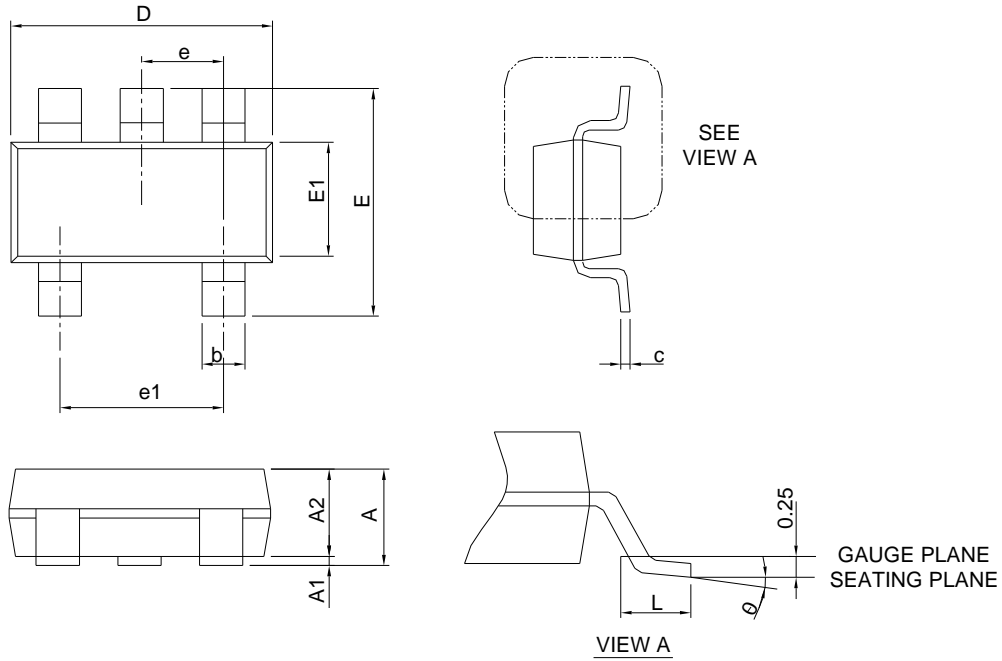
The APL3522 possesses a low on-resistance of power switch that makes it support load current up to 2.5A without causing junction temperature rising too much. However, heat dissipation is related to 2 external parameters, thermal resistance of package and ambient temperature. The thermal resistance θ_{JA} of SOT-23-5 is 250 $^{\circ}$ C/W that means 1 watt power generated on power switch of APL3522 will cause 250 $^{\circ}$ C rise of T_J referring to T_A . Higher ambient temperature will constrain heat dissipation. When the junction temperature rises too high, it has the likelihood to trigger OTP protection that will cause the output voltage cycle-by-cycle to turn-on and -off. The output current must be limited according to ambient temperature to avoid thermal shutdown, otherwise output voltage could not be a constant one. The following curve depicts the maximum output current versus ambient temperature. In $T_A < 25^{\circ}$ C condition, the output current can support up to 2.5A without any concern of OTP occurrence. In $T_A > 25^{\circ}$ C condition, the output current should be limited and the maximum allowable output current can be calculated by this equation: $2.875 - (0.015 * T_A)$. For Example, $T_A = 85^{\circ}$ C, the maximum output current is $2.875 - (0.015 * 85) = 1.6A$.

Application Information



Package Information

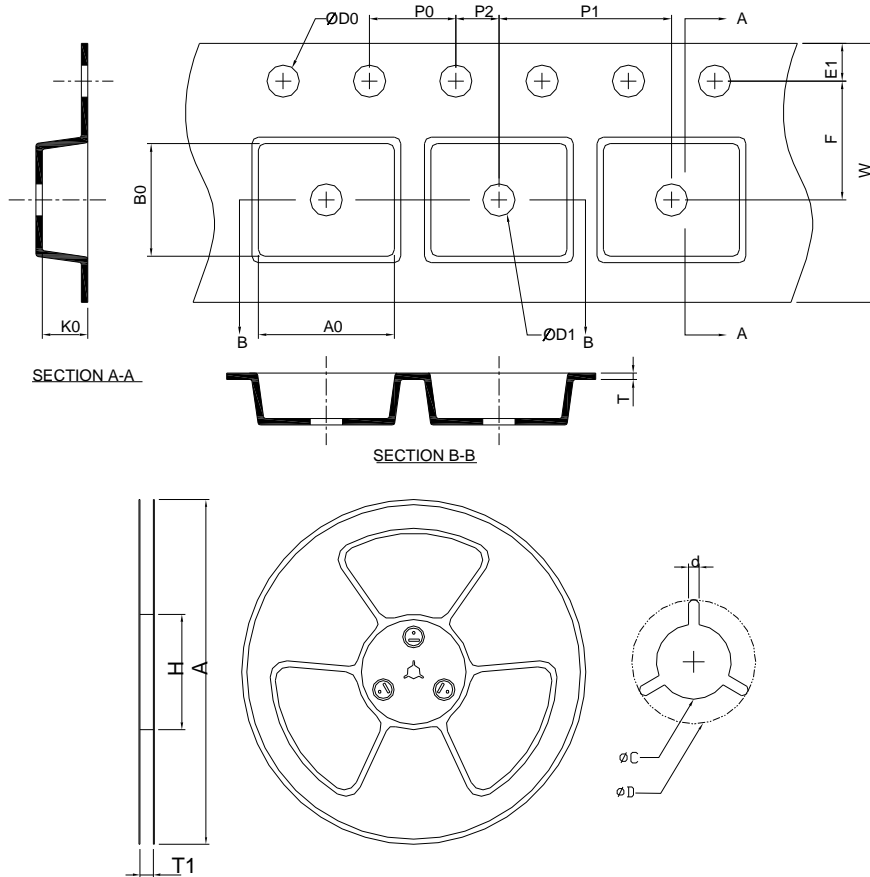
SOT-23-5



| 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-23-5 | 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 |

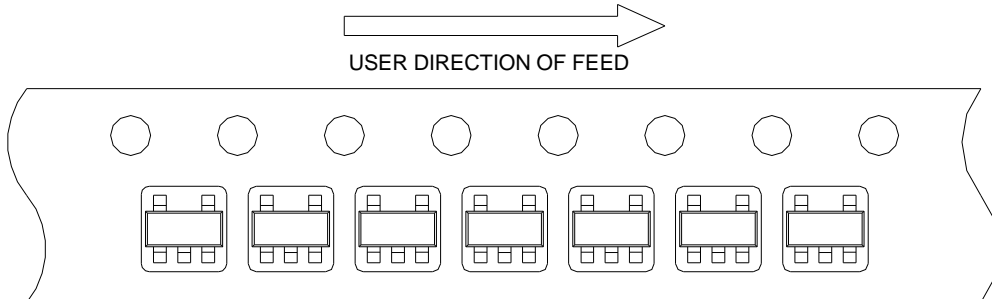
(mm)

Devices Per Unit

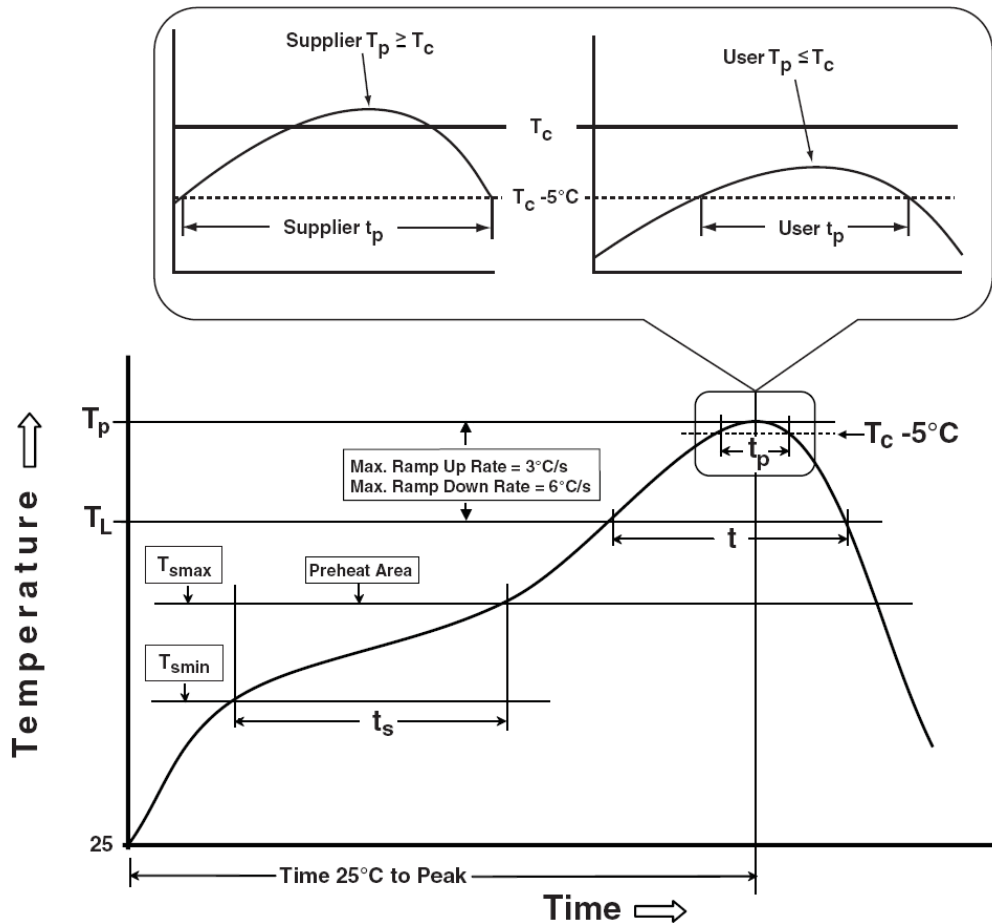
| Package Type | Unit | Quantity |
|--------------|-------------|----------|
| SOT-23-5 | Tape & Reel | 3000 |

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}) | 100 °C | 150 °C |
| Temperature max (T_{smax}) | 150 °C | 200 °C |
| Time (T_{smin} to T_{smax}) (t_s) | 60-120 seconds | 60-120 seconds |
| Average ramp-up rate (T_{smax} to T_p) | 3 °C/second max. | 3°C/second max. |
| Liquidous temperature (T_L) | 183 °C | 217 °C |
| Time at liquidous (t_L) | 60-150 seconds | 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. | | |

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

| 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 (T_c)

| 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 @ $T_j=125^\circ\text{C}$ |
| 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, $I_{tr} \geq 100\text{mA}$ |

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