

Features

- **40mW (3.3V Input) High Side MOSFET**
- **Current-Limit and Short Circuit Protections**
- **Over-Temperature Protection**
- **Under-Voltage Lockout Protection**
- **Reverse Current Blocking when Disabled**
- **Deglinted Fault Indication Output**
- **Internal Soft-Start Control**
- **Output Discharge when Disabled**
- **Logic Level Enable Input**
- **UL Approved-File No. E328191**
- **Nemko IEC/EN60950-1 CB Scheme Certified, No. 87387**
- **TUV IEC/EN60950-1 Certified, No. 44 780 15 406748-014**
- **Lead Free and Green Devices Available (RoHS Compliant)**

Applications

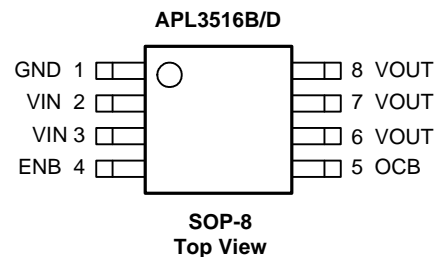
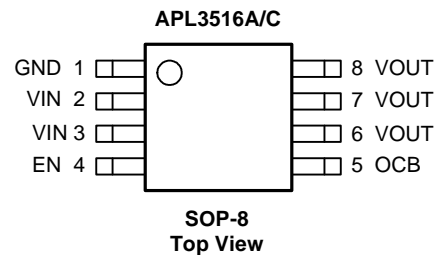
- **Display Ports**
- **Notebook and Desktop Computers**
- **High-Side Power Protection Switches**
- **Short-Circuit Protections**
- **Heavy Capacitive Loads Protections**

General Description

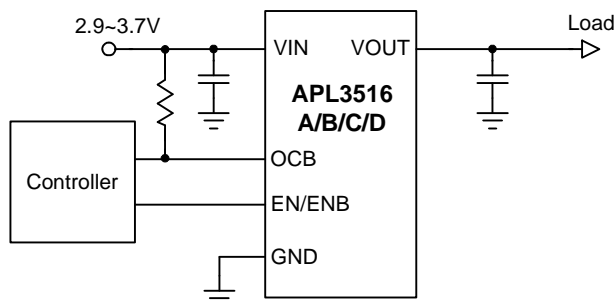
The APL3516A/B/C/D series are 40mΩ (3.3V input) high side load switches with an EN logic input and an OCB fault indication output.

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 1.5V, the devices limit the current to a lower and safe level. The OTP limits the junction temperature below 140°C in case of short circuit or over load conditions.

Pin Configuration

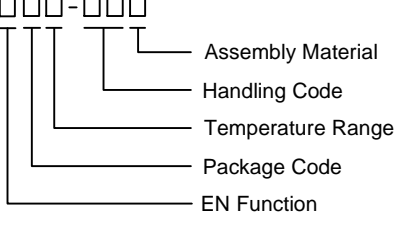


Simplified Application Circuit



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.

Ordering and Marking Information

| | | | |
|--|--|------------------------|-------------------|
| <p>APL3516 □□□-□□□</p>  <ul style="list-style-type: none"> — Assembly Material — Handling Code — Temperature Range — Package Code — EN Function | <p>Package Code K : SOP-8 Operating Ambient Temperature Range I : -40 to 85°C Handling Code TR : Tape & Reel EN Function A/C : Active High B/D : Active Low Assembly Material G : Halogen and Lead Free Device</p> | | |
| APL3516A K: | <table border="1" style="border-collapse: collapse;"> <tr> <td style="padding: 2px;">APL3516A XXXXX ●</td> <td style="padding: 2px;">XXXXX - Date Code</td> </tr> </table> | APL3516A XXXXX ● | XXXXX - Date Code |
| APL3516A XXXXX ● | XXXXX - Date Code | | |
| APL3516B K: | <table border="1" style="border-collapse: collapse;"> <tr> <td style="padding: 2px;">APL3516B XXXXX ●</td> <td style="padding: 2px;">XXXXX - Date Code</td> </tr> </table> | APL3516B XXXXX ● | XXXXX - Date Code |
| APL3516B XXXXX ● | XXXXX - Date Code | | |
| APL3516C K: | <table border="1" style="border-collapse: collapse;"> <tr> <td style="padding: 2px;">APL3516C XXXXX ●</td> <td style="padding: 2px;">XXXXX - Date Code</td> </tr> </table> | APL3516C XXXXX ● | XXXXX - Date Code |
| APL3516C XXXXX ● | XXXXX - Date Code | | |
| APL3516D K: | <table border="1" style="border-collapse: collapse;"> <tr> <td style="padding: 2px;">APL3516D XXXXX ●</td> <td style="padding: 2px;">XXXXX - Date Code</td> </tr> </table> | APL3516D XXXXX ● | XXXXX - Date Code |
| APL3516D XXXXX ● | XXXXX - 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 ~ 4 | V |
| V_{OUT} | VOUT to GND Voltage | -0.3 ~ 4 | V |
| V_{ENB}, V_{EN} | EN, ENB to GND Voltage | -0.3 ~ 4 | V |
| V_{OCB} | OCB to GND Voltage | -0.3 ~ 4 | 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 |

Note 1 : Absolute Maximum Ratings are those values beyond which the life of a device may be impaired. 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) SOP-8 | 160 | °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

| Symbol | Parameter | Range | Unit |
|-----------|----------------------|-----------|------|
| V_{IN} | VIN Input Voltage | 2.9 ~ 3.7 | V |
| I_{OUT} | OUT Output Current | 0 ~ 0.9 | A |
| T_A | Ambient Temperature | -40 ~ 85 | °C |
| T_J | Junction Temperature | -40 ~ 125 | °C |

Electrical Characteristics

Unless otherwise specified, these specifications apply over $V_{IN}=3.3V$, $V_{EN}=3.3V$ or $V_{ENB}=0V$ and $T_A=-40 \sim 85$ °C. Typical values are at $T_A=25$ °C.

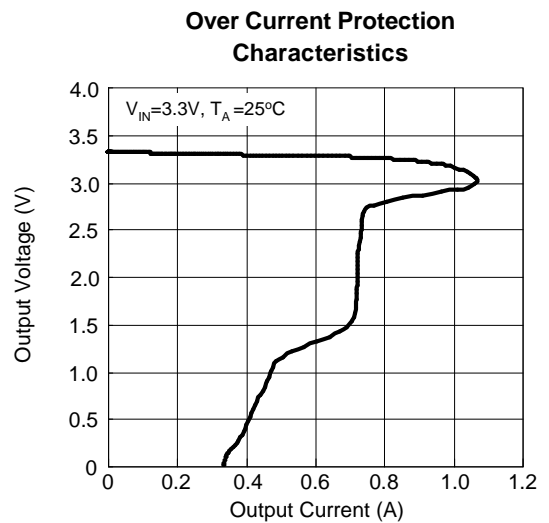
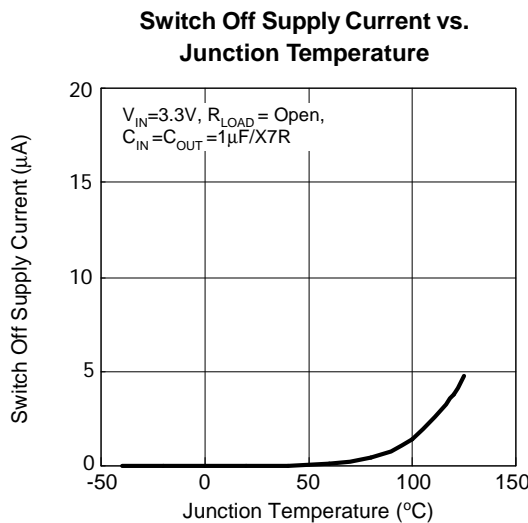
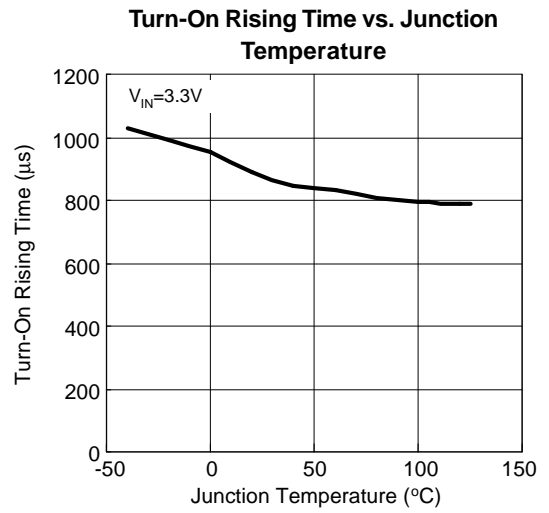
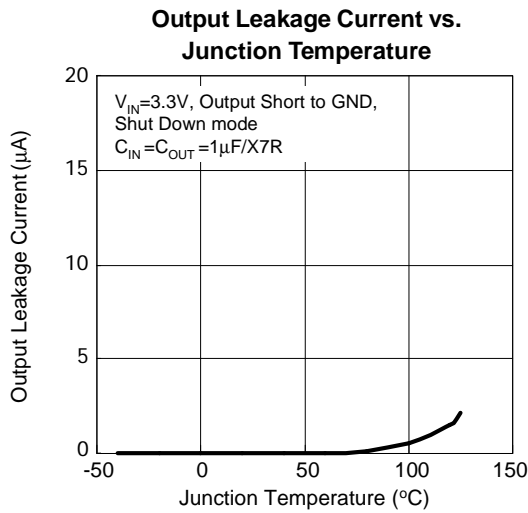
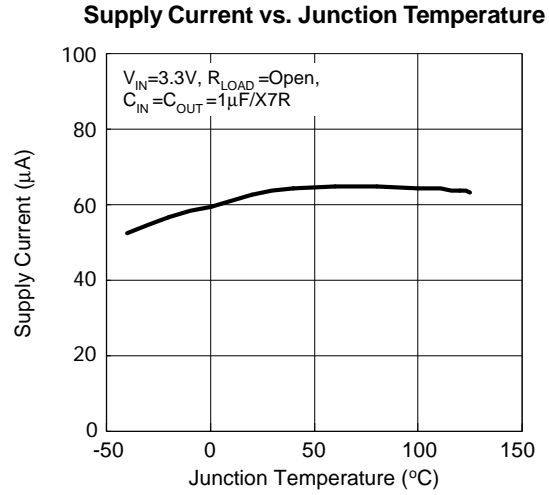
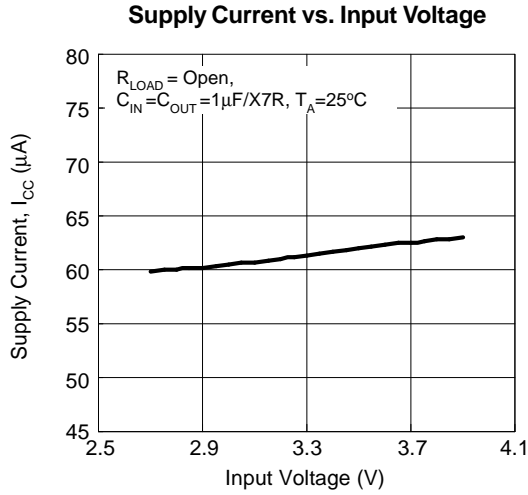
| Symbol | Parameter | Test Conditions | APL3516 | | | Unit | |
|--|------------------------------|---|------------|------|------|------------|---|
| | | | Min. | Typ. | Max. | | |
| SUPPLY CURRENT | | | | | | | |
| | VIN Supply Current | No load, $V_{EN}=0V$ or $V_{ENB}=3.3V$ | - | 0.5 | 1 | μA | |
| | | No load, $V_{EN}=3.3V$ or $V_{ENB}=0V$ | - | 70 | 150 | | |
| | Leakage Current | $V_{OUT}=GND$, $V_{EN}=0V$ or $V_{ENB}=3.3V$ | - | - | 1 | | |
| | Reverse Leakage Current | $V_{IN}=GND$, $V_{OUT}=3.3V$, $V_{EN}=0V$ or $V_{ENB}=3.3V$ | - | - | 1 | | |
| POWER SWITCH | | | | | | | |
| $R_{DS(ON)}$ | Power Switch On Resistance | $V_{IN}=3.3V$, $I_{OUT}=0.5A$, $T_A=25$ °C | - | 40 | 47 | m Ω | |
| | | $V_{IN}=3.3V$, $I_{OUT}=0.5A$, $T_A=-40 \sim 85$ °C | - | 46 | 54 | | |
| UNDER-VOLTAGE LOCKOUT | | | | | | | |
| | VIN UVLO Threshold Voltage | V_{IN} rising, $T_A=-40 \sim 85$ °C | 2.3 | - | 2.6 | V | |
| | VIN UVLO Hysteresis | | - | 0.2 | - | | |
| CURRENT-LIMIT AND SHORT CIRCUIT PROTECTIONS | | | | | | | |
| I_{LIM} | Current-Limit Threshold | $V_{IN}=2.9V$ to $3.7V$, $T_A=-40 \sim 85$ °C | APL3516A/B | 0.95 | - | 1.7 | A |
| | | | APL3516C/D | 1.1 | - | 1.7 | |
| I_{SHORT} | Short Circuit Output Current | $V_{IN}=2.9V$ to $3.7V$, $T_A=-40 \sim 85$ °C | - | 0.6 | - | | |
| OCB OUTPUT PIN | | | | | | | |
| | OCB Output Low Voltage | $I_{OCB}=5mA$ | - | 0.2 | 0.4 | V | |
| | OCB Leakage Current | $V_{OCB}=3.3V$ | - | - | 1 | μA | |
| $t_{D(OCB)}$ | OCB Deglitch Time | OCB assertion, $T_A=-40 \sim 85$ °C | 5 | 12 | 20 | ms | |
| EN OR ENB INPUT PIN | | | | | | | |
| V_{IH} | Input Logic HIGH | $V_{IN}=2.9V$ to $3.7V$ | 2 | - | - | V | |
| V_{IL} | Input Logic LOW | $V_{IN}=2.9V$ to $3.7V$ | - | - | 0.8 | V | |
| | Input Current | | - | - | 1 | μA | |
| | VOUT Discharge Resistance | $V_{EN}=0V$ or $V_{ENB}=3.3V$ | - | 150 | - | Ω | |
| $t_{D(ON)}$ | Turn on Delay Time | | - | 30 | - | μs | |
| $t_{D(OFF)}$ | Turn off Delay Time | | - | 30 | - | μs | |
| t_{SS} | Soft-Start Time | No load, $C_{OUT}=1\mu F$, $V_{IN}=3.3V$ | - | 1000 | - | μs | |

Electrical Characteristics (Cont.)

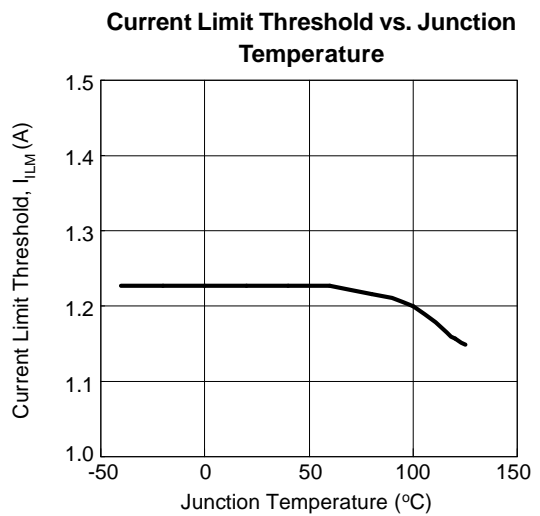
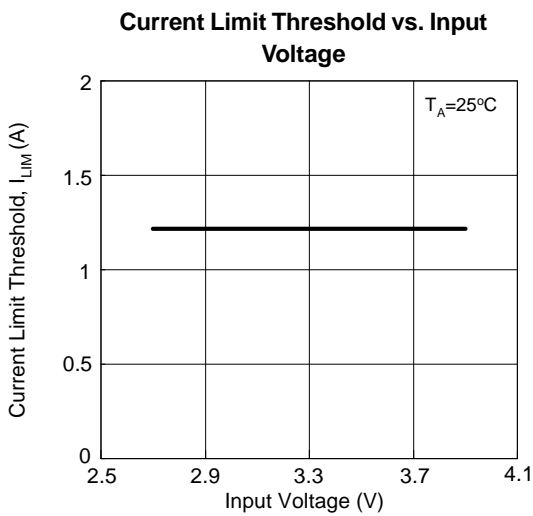
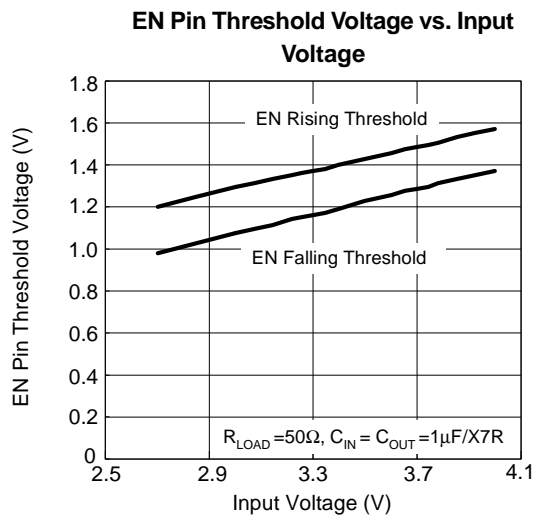
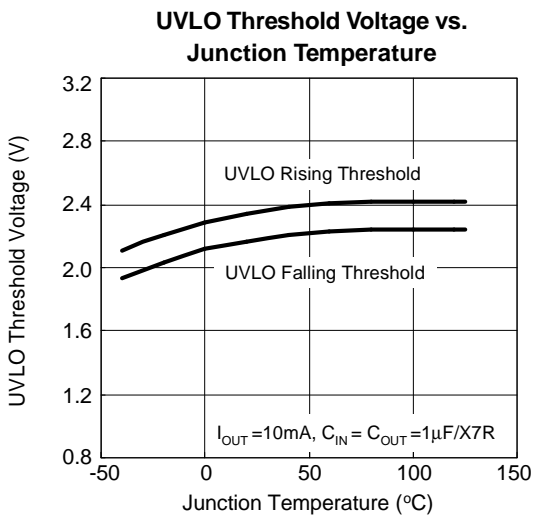
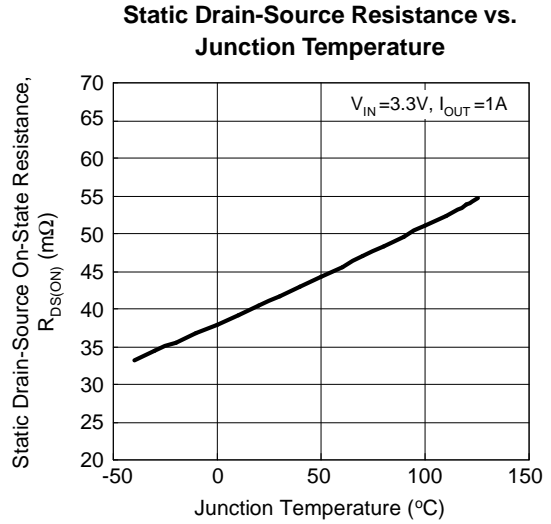
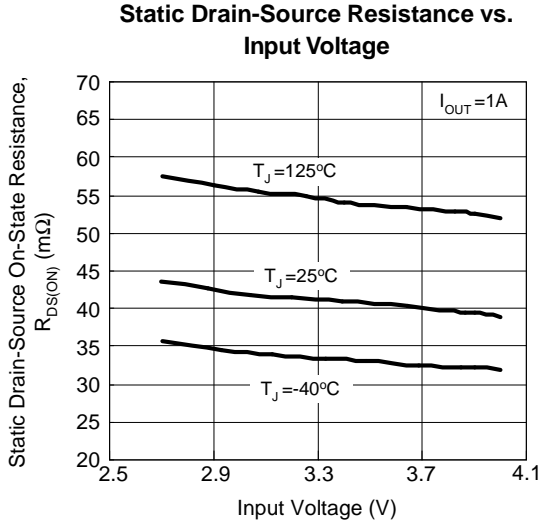
Unless otherwise specified, these specifications apply over $V_{IN}=3.3V$, $V_{EN}=3.3V$ or $V_{ENB}=0V$ and $T_A=-40 \sim 85 \text{ }^\circ\text{C}$. Typical values are at $T_A=25^\circ\text{C}$.

| Symbol | Parameter | Test Conditions | APL3516 | | | Unit |
|--|-----------------------------|-----------------|---------|------|------|------------------|
| | | | Min. | Typ. | Max. | |
| OVER-TEMPERATURE PROTECTION (OTP) | | | | | | |
| T_{OTP} | Over-Temperature Threshold | T_J rising | - | 140 | - | $^\circ\text{C}$ |
| | Over-Temperature Hysteresis | | - | 20 | - | $^\circ\text{C}$ |

Typical Operating Characteristics



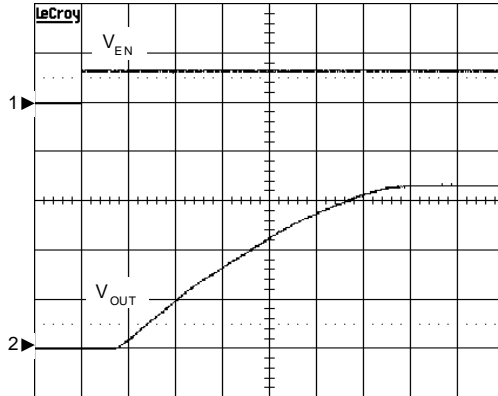
Typical Operating Characteristics (Cont.)



Operating Waveforms

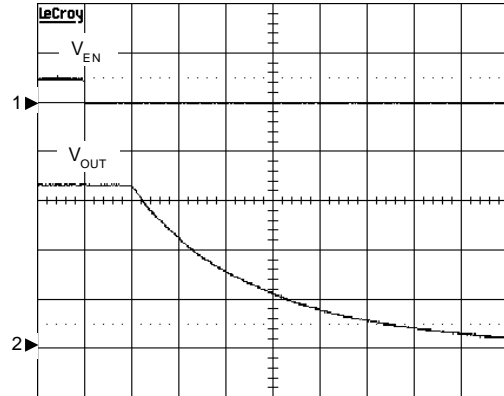
The test condition is $V_{IN}=3.3V$, $T_A=25^\circ C$ unless otherwise specified.

Turn On Response



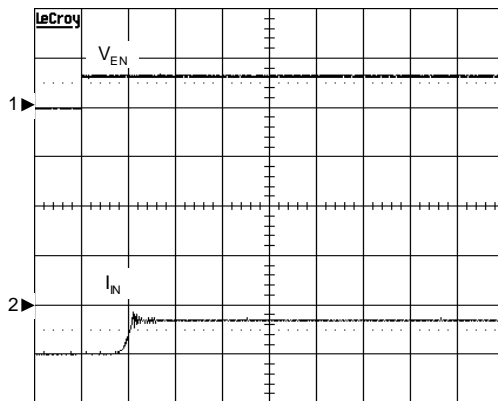
$V_{IN}=3.3V$, $R_{LOAD}=27\Omega$, $T_A=25^\circ C$
 CH1: V_{EN} , 5V/Div, DC
 CH2: V_{OUT} , 1V/Div, DC
 TIME: 200 μs /Div

Turn Off Response



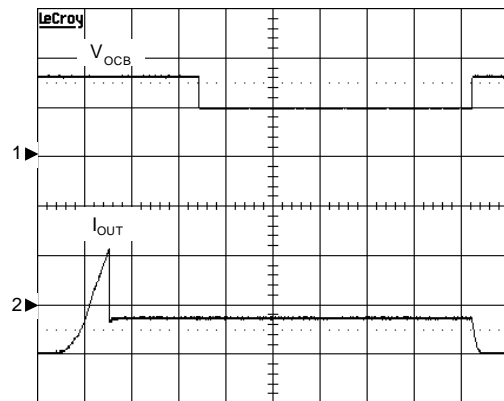
$V_{IN}=3.3V$, $R_{LOAD}=27\Omega$, $T_A=25^\circ C$
 CH1: V_{EN} , 5V/Div, DC
 CH2: V_{OUT} , 1V/Div, DC
 TIME: 20 μs /Div

Device Enabled into Short



$V_{IN}=3.3V$, Output Short to GND before Device Enabled, $T_A=25^\circ C$
 CH1: V_{EN} , 5V/Div, DC
 CH2: I_{IN} , 0.5A/Div, DC
 TIME: 200 μs /Div

Ramped Load on Enabled Device

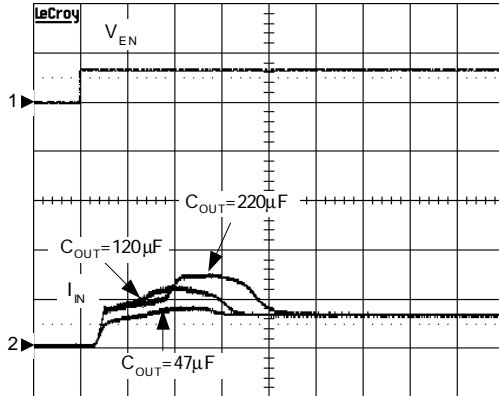


$V_{IN}=3.3V$, $C_{IN}=C_{OUT}=1\mu F/X7R$, $T_A=25^\circ C$
 CH1: V_{OCB} , 5V/Div, DC
 CH2: I_{OUT} , 0.5A/Div, DC
 TIME: 5ms/Div

Operating Waveforms (Cont.)

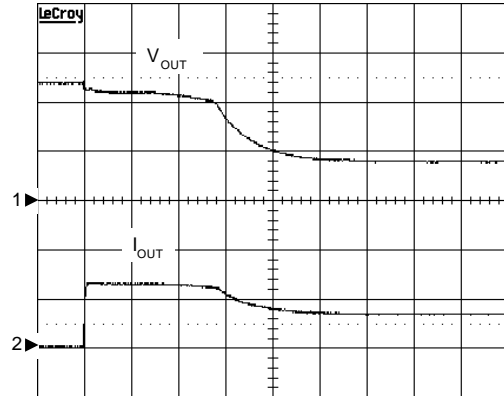
The test condition is $V_{IN}=3.3V$, $T_A=25^\circ C$ unless otherwise specified.

Harnessed Inrush Current



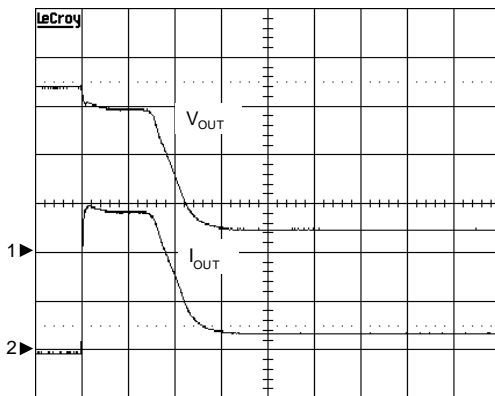
$V_{IN}=3.3V$, $R_{LOAD}=10\Omega$, $C_{IN}=1\mu F/X7R$,
 $C_{OUT}=47/120/220\mu F$, $T_A=25^\circ C$
 CH1: V_{EN} , 5V/Div, DC
 CH2: I_{IN} , 0.5A/Div, DC
 TIME: 0.5ms/Div

2.5W Load Connected to an Enabled Device



$V_{IN}=3.3V$, $R_{LOAD}=2.5\Omega$, $C_{IN}=C_{OUT}=1\mu F/X7R$,
 $T_A=25^\circ C$
 CH1: V_{OUT} , 1V/Div, DC
 CH2: I_{OUT} , 1A/Div, DC
 TIME: 10µs/Div

1W Load Connected to an Enabled Device

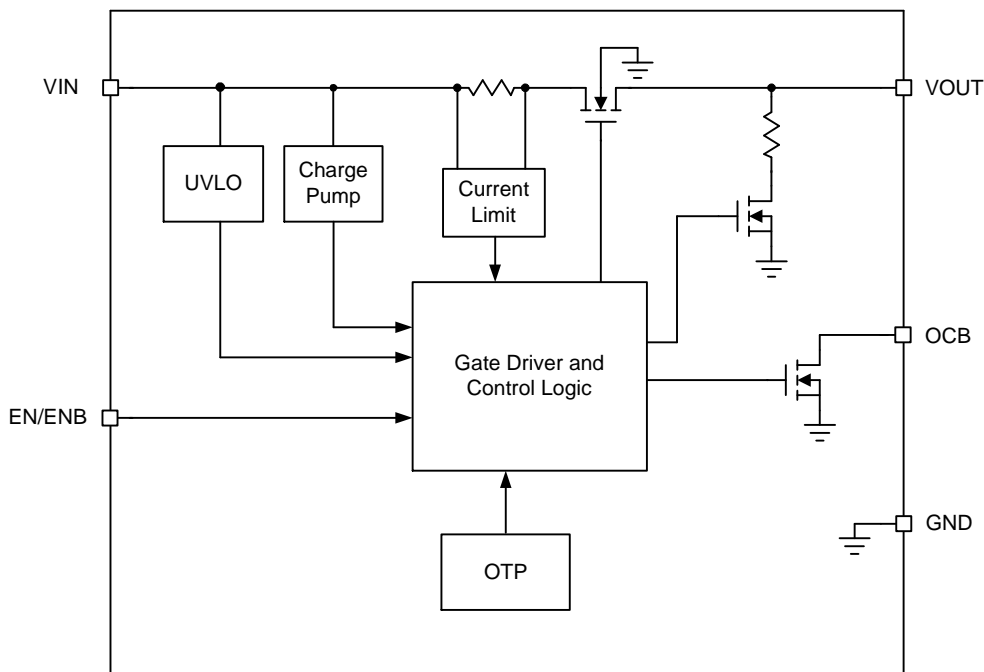


$V_{IN}=3.3V$, $R_{LOAD}=1\Omega$, $C_{IN}=C_{OUT}=1\mu F/X7R$,
 $T_A=25^\circ C$
 CH1: V_{OUT} , 1V/Div, DC
 CH2: I_{OUT} , 1A/Div, DC
 TIME: 10µs/Div

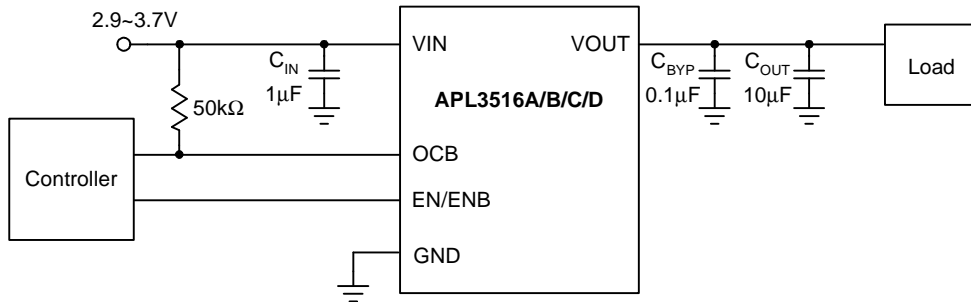
Pin Description

| PIN | | FUNCTION |
|---------|------------------|--|
| NO. | NAME | |
| 1 | GND | Ground. |
| 2, 3 | VIN | Power Supply Input. Connect this pin to external DC supply. |
| 4 | EN (APL3516A/C) | 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 (APL3516B/D) | 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. |
| 5 | OCB | Fault Indication Pin. This pin goes low when a current limit or an over-temperature condition is detected after a 8ms deglitch time. |
| 6, 7, 8 | 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



Typical Application Circuit



Function Description

VIN Under-Voltage Lockout (UVLO)

The APL3516A/B/C/D series of power switches are built-in an 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 APL3516A/B/C/D 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 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.

OCB Output

The APL3516A/B/C/D 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. 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 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 $T_{j,+125^{\circ}\text{C}}$.

Application Information

Input Capacitor

A 1 μ F or higher ceramic bypass capacitor from VIN to GND, located near the APL3516, 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 150 μ F 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

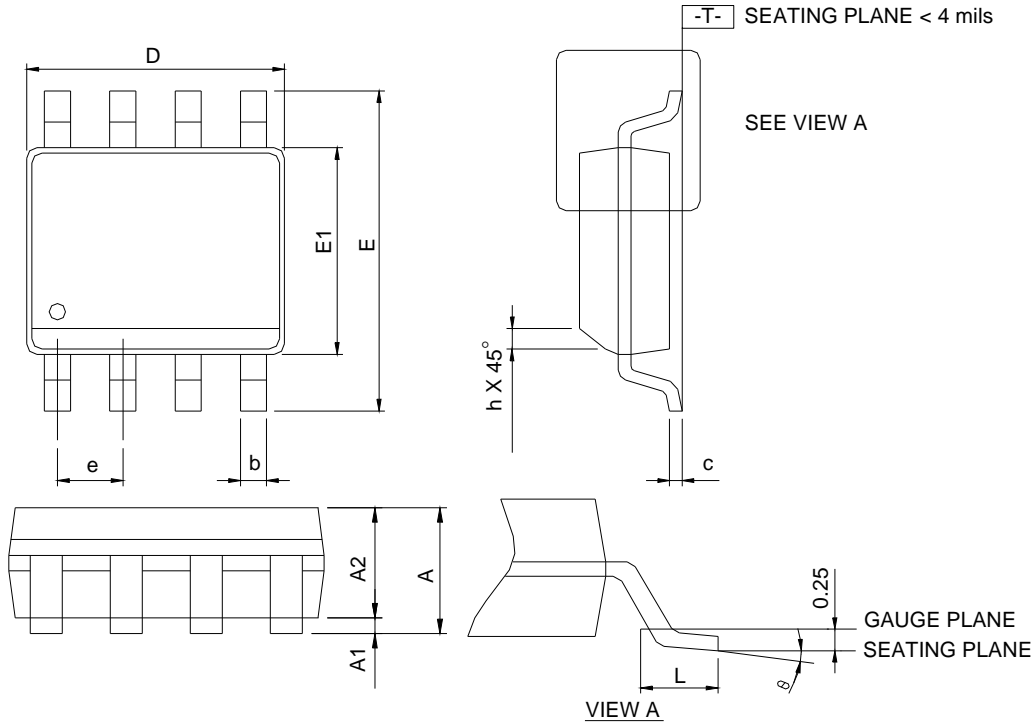
The PCB layout should be carefully performed to maximize thermal dissipation and to minimize voltage drop, droop and EMI. The following guidelines must be considered:

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 APL3516 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

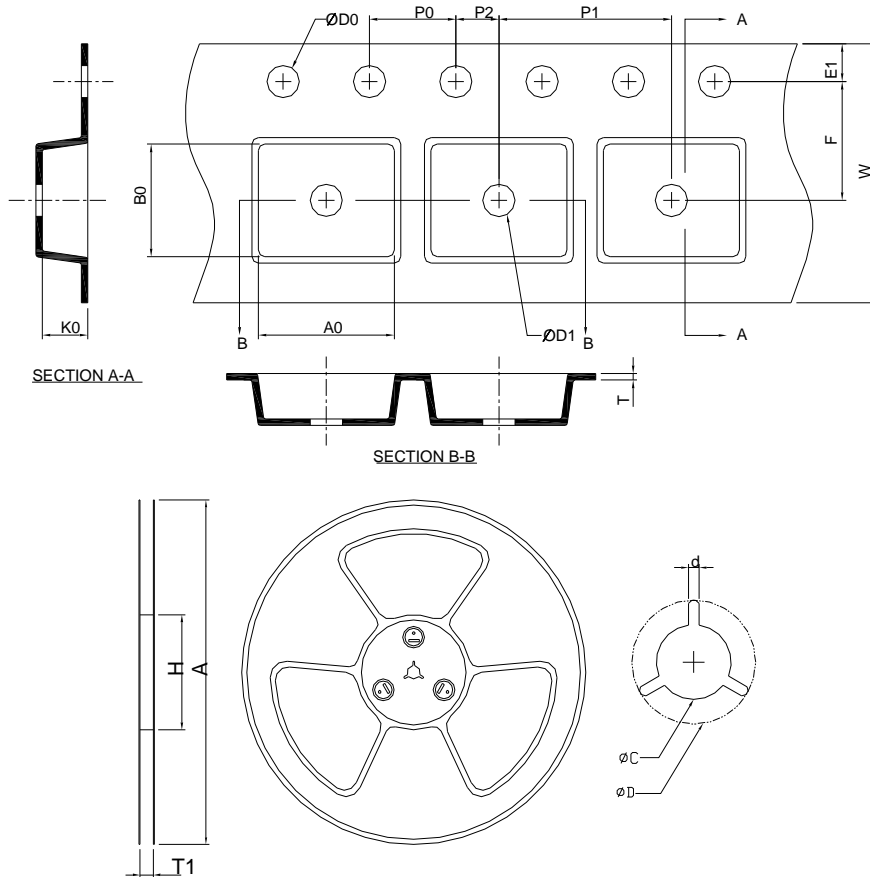
SOP-8



| SYMBOL | SOP-8 | | | |
|----------|-------------|------|-----------|-------|
| | MILLIMETERS | | INCHES | |
| | MIN. | MAX. | MIN. | MAX. |
| A | | 1.75 | | 0.069 |
| A1 | 0.10 | 0.25 | 0.004 | 0.010 |
| A2 | 1.25 | | 0.049 | |
| b | 0.31 | 0.51 | 0.012 | 0.020 |
| c | 0.17 | 0.25 | 0.007 | 0.010 |
| D | 4.80 | 5.00 | 0.189 | 0.197 |
| E | 5.80 | 6.20 | 0.228 | 0.244 |
| E1 | 3.80 | 4.00 | 0.150 | 0.157 |
| e | 1.27 BSC | | 0.050 BSC | |
| h | 0.25 | 0.50 | 0.010 | 0.020 |
| L | 0.40 | 1.27 | 0.016 | 0.050 |
| θ | 0° | 8° | 0° | 8° |

- Note: 1. Follow JEDEC MS-012 AA.
 2. Dimension "D" does not include mold flash, protrusions or gate burrs. Mold flash, protrusion or gate burrs shall not exceed 6 mil per side.
 3. Dimension "E" does not include inter-lead flash or protrusions. Inter-lead flash and protrusions shall not exceed 10 mil per side.

Carrier Tape & Reel Dimensions



| Application | A | H | T1 | C | d | D | W | E1 | F |
|-------------|------------|----------|--------------------|--------------------|----------|-------------------|-----------|-----------|-----------|
| SOP-8 | 330.0±2.00 | 50 MIN. | 12.4+2.00 -0.00 | 13.0+0.50 -0.20 | 1.5 MIN. | 20.2 MIN. | 12.0±0.30 | 1.75±0.10 | 5.5±0.05 |
| | P0 | P1 | P2 | D0 | D1 | T | A0 | B0 | K0 |
| | 4.0±0.10 | 8.0±0.10 | 2.0±0.05 | 1.5+0.10 -0.00 | 1.5 MIN. | 0.6+0.00 -0.40 | 6.40±0.20 | 5.20±0.20 | 2.10±0.20 |

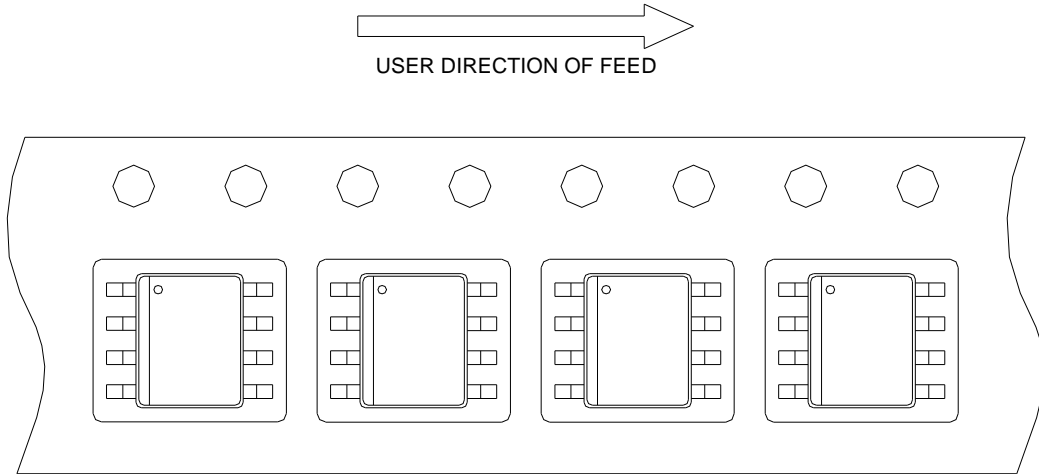
(mm)

Devices Per Unit

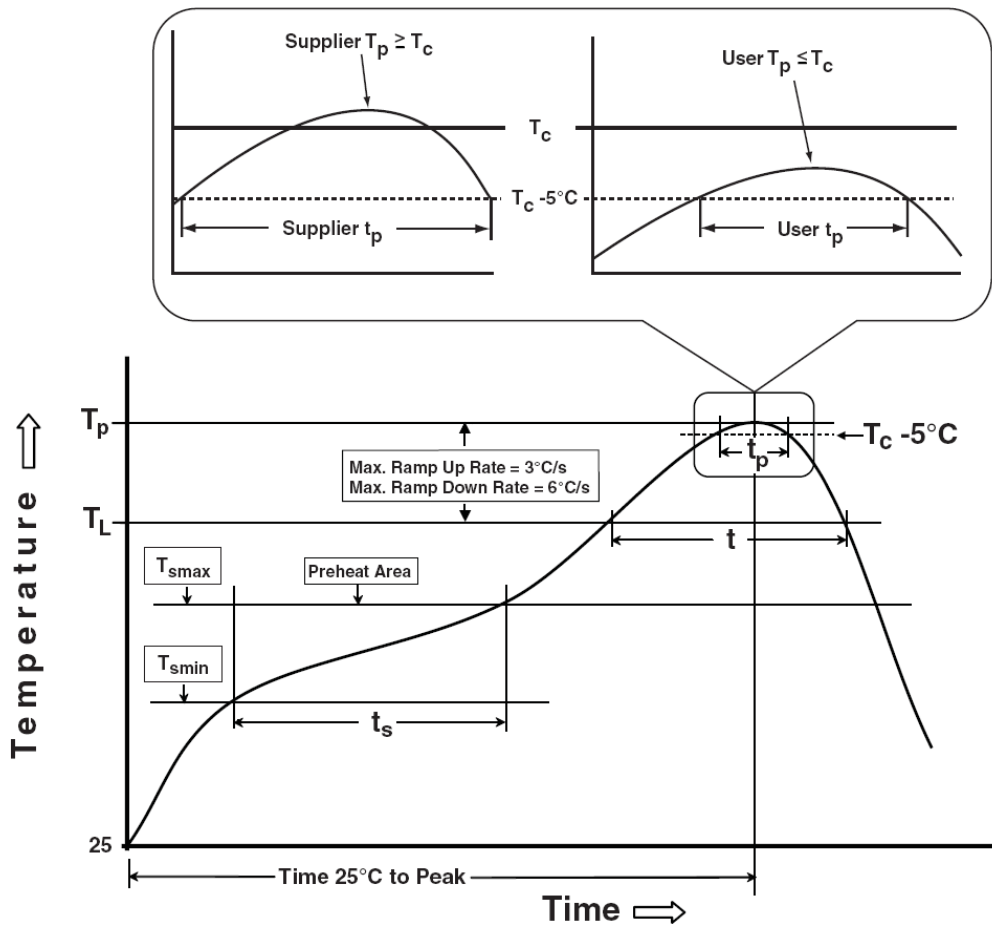
| Package Type | Unit | Quantity |
|--------------|-------------|----------|
| SOP-8 | Tape & Reel | 2500 |

Taping Direction Information

SOP-8



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, $1_{tr} \geq 100\text{mA}$ |

Customer Service

Anpec Electronics Corp.

Head Office :

No.6, Dusing 1st Road, SBIP,

Hsin-Chu, Taiwan, R.O.C.

Tel : 886-3-5642000

Fax : 886-3-5642050

Taipei Branch :

2F, No. 11, Lane 218, Sec 2 Jhongsing Rd.,

Sindian City, Taipei County 23146, Taiwan

Tel : 886-2-2910-3838

Fax : 886-2-2917-3838

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