

## Ultra-Low On-Resistance, Power Load Switch with Soft Start

### Features

- **Ultra-Low On-Resistance:**
  - $R_{DS(ON)} = 10.5m\Omega$  at  $V_{IN} = 5V$
  - $R_{DS(ON)} = 12m\Omega$  at  $V_{IN} = 3.6V$
  - $R_{DS(ON)} = 12.3m\Omega$  at  $V_{IN} = 2.5V$
  - $R_{DS(ON)} = 12.5m\Omega$  at  $V_{IN} = 1.8V$
  - $R_{DS(ON)} = 17.5m\Omega$  at  $V_{IN} = 1V$
- **Ultra-Low Quiescent Current:**  $V_{IN} = 1V$  Condition, 10mA (Max.)
- **3A Maximum Continuous Output Current**
- **Supply Voltage Range from 0.95V to 5.5V**
- **Built in Internal Charge Pump Function for Internal Gate Driver**
- **Built in Internal Soft-Start Function:**  $V_{IN} = 3.6V$  Condition, A: 96ms, B: 800ms (Typ.)
- **Built in Enable/Shutdown Control**
- **Built in Turn On Time:**  $V_{IN} = 3.6V$  Condition, A: 111ms, B: 860ms (Typ.)
- **Output Discharge when Switch Disabled**
- **Built in Reverse Current Block Function**
- **Tiny small WLCSP 0.9x1.4-6 Package**
- **Lead Free and Green Devices Available (RoHS Compliant)**

### Applications

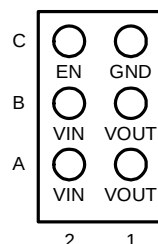
- Notebooks
- AIO PC
- Tablet PCs
- GPS Devices
- Smartphones

### General Description

The APL3537 is an ultra-low on-resistance, power-distribution switch with internal soft start control. The device is an N-channel MOSFET which needs only one input voltage from 0.95V to 5.5V. Built in internal charge pump function biases the N-MOS switch to achieve a minimum switch on-resistance. The APL3537 can be enabled by other power system. Pulling and holding the EN pin below 0.4V shuts off the output.

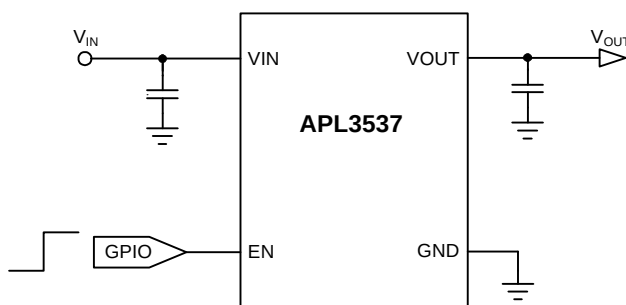
The device is available in lead free WLCSP 0.9x1.4-6 package.

### Pin Configuration



WLCSP 0.9x1.4-6  
(Top View)

### 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.



## Recommended Operating Conditions (Note 4)

| Symbol     | Parameter                                                                      | Range      | Unit             |
|------------|--------------------------------------------------------------------------------|------------|------------------|
| $V_{IN}$   | VIN Input Voltage                                                              | 0.95 ~ 5.5 | V                |
| $I_{OUT}$  | OUT Output Current                                                             | 0 ~ 3      | A                |
| $I_{PEAK}$ | Maximum Peak Current, 100 $\mu$ s pluse with 2% duty cycle                     | 4          | A                |
| $P_D$      | Maximum Power Dissipation, $T_A \leq 25^\circ\text{C}$ <small>(Note 2)</small> | 0.8        | W                |
|            | Maximum Power Dissipation, $T_A \leq 50^\circ\text{C}$ <small>(Note 2)</small> | 0.6        | W                |
|            | Maximum Power Dissipation, $T_A \leq 85^\circ\text{C}$ <small>(Note 2)</small> | 0.32       | W                |
| $V_{IH}$   | EN Logic High Input Voltage                                                    | 0.9 ~ 5.5  | V                |
| $V_{IL}$   | EN Logic Low Input Voltage                                                     | 0 ~ 0.4    | V                |
| $C_{OUT}$  | Output Capacitor                                                               | 0.1 ~ 10   | $\mu\text{F}$    |
| $T_A$      | Ambient Temperature                                                            | -40 ~ 85   | $^\circ\text{C}$ |
| $T_J$      | Junction Temperature                                                           | -40 ~ 125  | $^\circ\text{C}$ |

Note 4: Please refer to the typical application circuit.

## Electrical Characteristics

Unless otherwise specified, these specifications apply over  $V_{IN} = 1 \sim 5\text{V}$ ,  $V_{EN} = 3.6\text{V}$  and  $T_A = -40 \sim 85^\circ\text{C}$ . Typical values are at  $T_A = 25^\circ\text{C}$ .

| Symbol           | Parameter                      | Test Conditions                                                                              | APL3537 |     |     | Unit |
|------------------|--------------------------------|----------------------------------------------------------------------------------------------|---------|-----|-----|------|
|                  |                                |                                                                                              | Min     | Typ | Max |      |
| SUPPLY CURRENT   |                                |                                                                                              |         |     |     |      |
| I <sub>VIN</sub> | VIN Supply Current             | No load, V <sub>IN</sub> =5V                                                                 | -       | 50  | 90  | μA   |
|                  |                                | No load, V <sub>IN</sub> =3.6V                                                               | -       | 25  | 45  | μA   |
|                  |                                | No load, V <sub>IN</sub> =2.5V                                                               | -       | 17  | 32  | μA   |
|                  |                                | No load, V <sub>IN</sub> =1.8V                                                               | -       | 10  | 20  | μA   |
|                  |                                | No load, V <sub>IN</sub> =1.2V                                                               | -       | 7   | 15  | μA   |
|                  |                                | No load, V <sub>IN</sub> =1V                                                                 | -       | 5   | 10  | μA   |
| I <sub>SD</sub>  | VIN Supply Current at Shutdown | No load, V <sub>IN</sub> =5V, V <sub>EN</sub> =0V                                            | -       | 0.1 | 2   | μA   |
|                  |                                | No load, V <sub>IN</sub> =3.6V, V <sub>EN</sub> =0V                                          | -       | 0.1 | 1.8 | μA   |
|                  |                                | No load, V <sub>IN</sub> =2.5V, V <sub>EN</sub> =0V                                          | -       | -   | 1.7 | μA   |
|                  |                                | No load, V <sub>IN</sub> =1V, V <sub>EN</sub> =0V                                            | -       | 0.1 | 1.5 | μA   |
|                  |                                | No load, V <sub>EN</sub> =0V, V <sub>IN</sub> =1~5V, T <sub>J</sub> =25°C                    | -       | 0.1 | 1   | μA   |
|                  | VOUT Leakage Current           | No load, V <sub>IN</sub> =5V, V <sub>EN</sub> =0V                                            | -       | 0.1 | 1.5 | μA   |
|                  |                                | No load, V <sub>IN</sub> =3.6V, V <sub>EN</sub> =0V                                          | -       | 0.1 | 1.3 | μA   |
|                  |                                | No load, V <sub>IN</sub> =2.5V, V <sub>EN</sub> =0V                                          | -       | -   | 1.2 | μA   |
|                  |                                | No load, V <sub>IN</sub> =1V, V <sub>EN</sub> =0V                                            | -       | 0.1 | 1   | μA   |
|                  | Reverse Leakage Current        | V <sub>EN</sub> =0V, V <sub>IN</sub> =GND, V <sub>OUT</sub> =5V                              | -       | 0.1 | 2   | μA   |
|                  |                                | V <sub>EN</sub> =0V, V <sub>IN</sub> =GND, V <sub>OUT</sub> =3.6V                            | -       | 0.1 | 1.8 | μA   |
|                  |                                | V <sub>EN</sub> =0V, V <sub>IN</sub> =GND, V <sub>OUT</sub> =2.5V                            | -       | -   | 1.7 | μA   |
|                  |                                | V <sub>EN</sub> =0V, V <sub>IN</sub> =GND, V <sub>OUT</sub> =1V                              | -       | 0.1 | 1.5 | μA   |
|                  |                                | V <sub>EN</sub> =0V, V <sub>IN</sub> =GND, V <sub>OUT</sub> =3.3 or 5V, T <sub>J</sub> =25°C | -       | 0.1 | 1   | μA   |

## Electrical Characteristics

Unless otherwise specified, these specifications apply over  $V_{IN} = 1\sim 5V$ ,  $V_{EN} = 3.6V$  and  $T_A = -40\sim 85^\circ C$ . Typical values are at  $T_A = 25^\circ C$ .

| Symbol              | Parameter                                                                                         | Test Conditions                                                           | APL3537 |      |      | Unit |
|---------------------|---------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|---------|------|------|------|
|                     |                                                                                                   |                                                                           | Min     | Typ  | Max  |      |
| POWER SWITCH        |                                                                                                   |                                                                           |         |      |      |      |
| R <sub>DS(ON)</sub> | Power Switch On Resistance                                                                        | V <sub>IN</sub> =5V, I <sub>OUT</sub> =200mA, T <sub>J</sub> =25°C        | —       | 10.5 | 14   | mΩ   |
|                     |                                                                                                   | V <sub>IN</sub> =5V, I <sub>OUT</sub> =200mA, T <sub>J</sub> =-40~125°C   | —       | —    | 19   | mΩ   |
|                     |                                                                                                   | V <sub>IN</sub> =3.6V, I <sub>OUT</sub> =200mA, T <sub>J</sub> =25°C      | —       | 12   | 16   | mΩ   |
|                     |                                                                                                   | V <sub>IN</sub> =3.6V, I <sub>OUT</sub> =200mA, T <sub>J</sub> =-40~125°C | —       | —    | 21.5 | mΩ   |
|                     |                                                                                                   | V <sub>IN</sub> =2.5V, I <sub>OUT</sub> =200mA, T <sub>J</sub> =25°C      | —       | 12.3 | 16.3 | mΩ   |
|                     |                                                                                                   | V <sub>IN</sub> =2.5V, I <sub>OUT</sub> =200mA, T <sub>J</sub> =-40~125°C | —       | —    | 22.1 | mΩ   |
|                     |                                                                                                   | V <sub>IN</sub> =1.8V, I <sub>OUT</sub> =200mA, T <sub>J</sub> =25°C      | —       | 12.5 | 16.5 | mΩ   |
|                     |                                                                                                   | V <sub>IN</sub> =1.8V, I <sub>OUT</sub> =200mA, T <sub>J</sub> =-40~125°C | —       | —    | 22.5 | mΩ   |
|                     |                                                                                                   | V <sub>IN</sub> =1.2V, I <sub>OUT</sub> =200mA, T <sub>J</sub> =25°C      | —       | 16   | 19   | mΩ   |
|                     |                                                                                                   | V <sub>IN</sub> =1.2V, I <sub>OUT</sub> =200mA, T <sub>J</sub> =-40~125°C | —       | —    | 26   | mΩ   |
|                     |                                                                                                   | V <sub>IN</sub> =1.0V, I <sub>OUT</sub> =200mA, T <sub>J</sub> =25°C      | —       | 17.5 | 21   | mΩ   |
|                     |                                                                                                   | V <sub>IN</sub> =1.0V, I <sub>OUT</sub> =200mA, T <sub>J</sub> =-40~125°C | —       | —    | 28.5 | mΩ   |
| SOFT-START CONTROL  |                                                                                                   |                                                                           |         |      |      |      |
| t <sub>SS</sub>     | Soft-Start Time (APL3537A)<br>(V <sub>EN</sub> =0V, V <sub>IN</sub> =GND, V <sub>OUT</sub> =3.6V) | V <sub>IN</sub> =5V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 50   | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =3.6V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF       | —       | 55   | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =1.8 R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 60   | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =1.2 R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 112  | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =1V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 200  | —    | μs   |
|                     | Soft-Start Time (APL3537B)<br>(V <sub>EN</sub> =0V, V <sub>IN</sub> =GND, V <sub>OUT</sub> =3.6V) | V <sub>IN</sub> =5V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 950  | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =3.6V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF       | —       | 1065 | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =1.8 R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 730  | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =1.2 R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 1020 | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =1V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 1270 | —    | μs   |
| t <sub>F</sub>      | V <sub>OUT</sub> Fall Time (APL3537A) <sup>(Note 5)</sup>                                         | V <sub>IN</sub> =5V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 1.5  | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =3.6V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF       | —       | 1.5  | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =1V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 2    | —    | μs   |
|                     | V <sub>OUT</sub> Fall Time (APL3537B) <sup>(Note 5)</sup>                                         | V <sub>IN</sub> =5V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 1.5  | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =3.6V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF       | —       | 1.5  | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =1V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 2    | —    | μs   |
| t <sub>ON</sub>     | Turn On Time (APL3537A) <sup>(Note 5)</sup>                                                       | V <sub>IN</sub> =5V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 50   | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =3.6V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF       | —       | 60   | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =1.8 R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 75   | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =1.2 R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 140  | —    | μs   |
|                     |                                                                                                   | V <sub>IN</sub> =1V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF         | —       | 240  | —    | μs   |

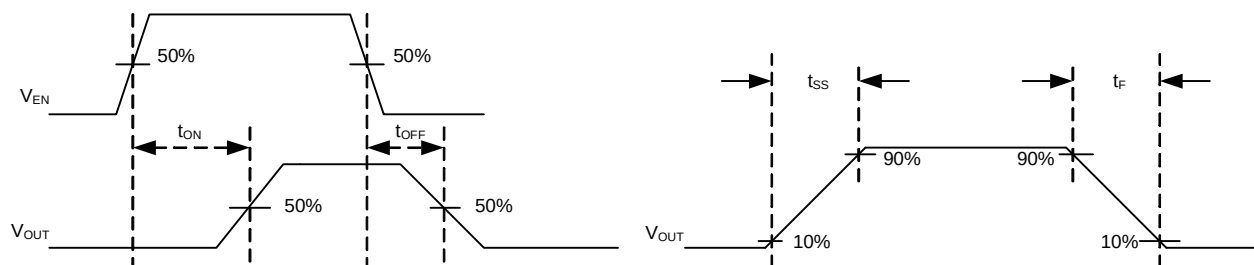
## Electrical Characteristics

Unless otherwise specified, these specifications apply over  $V_{IN} = 1\sim 5V$ ,  $V_{EN} = 3.6V$  and  $T_A = -40\sim 85^\circ C$ . Typical values are at  $T_A = 25^\circ C$ .

| Symbol           | Parameter                                    | Test Conditions                                                       | APL3537 |      |      | Unit |
|------------------|----------------------------------------------|-----------------------------------------------------------------------|---------|------|------|------|
|                  |                                              |                                                                       | Min     | Typ  | Max  |      |
| POWER SWITCH     |                                              |                                                                       |         |      |      |      |
| t <sub>ON</sub>  | Turn On Time (APL3537B) <sup>(Note 5)</sup>  | V <sub>IN</sub> =5 V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF    | —       | 850  | —    | μs   |
|                  |                                              | V <sub>IN</sub> =3.6V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF   | —       | 1080 | —    | μs   |
|                  |                                              | V <sub>IN</sub> =1.8 R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF     | —       | 840  | —    | μs   |
|                  |                                              | V <sub>IN</sub> =1.2 R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF     | —       | 1260 | —    | μs   |
|                  |                                              | V <sub>IN</sub> =1 V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF    | —       | 1600 | —    | μs   |
| t <sub>OFF</sub> | Turn Off Time (APL3537A) <sup>(Note 5)</sup> | V <sub>IN</sub> =5 V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF    | —       | 1    | —    | μs   |
|                  |                                              | V <sub>IN</sub> =3.6V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF   | —       | 1    | —    | μs   |
|                  |                                              | V <sub>IN</sub> =1 V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF    | —       | 3    | —    | μs   |
|                  | Turn Off Time (APL3537B) <sup>(Note 5)</sup> | V <sub>IN</sub> =5 V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF    | —       | 1    | —    | μs   |
|                  |                                              | V <sub>IN</sub> =3.6V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF   | —       | 1    | —    | μs   |
|                  |                                              | V <sub>IN</sub> =1 V, R <sub>L</sub> =10Ω, C <sub>OUT</sub> =0.1μF    | —       | 3    | —    | μs   |
| EN INPUT PIN     |                                              |                                                                       |         |      |      |      |
| V <sub>IH</sub>  | EN Input Logic High                          |                                                                       | 0.9     | —    | —    | V    |
| V <sub>IL</sub>  | EN Input Logic Low                           |                                                                       | —       | —    | 0.4  | V    |
|                  | EN Input Current                             | V <sub>EN</sub> =5.5V, V <sub>IN</sub> =0 V                           | —       | —    | 1    | μA   |
|                  | EN Leakage Current                           | V <sub>EN</sub> =0V, V <sub>IN</sub> =5.5V                            | —       | —    | 1    | μA   |
|                  | VOUT Discharge Resistance                    | V <sub>IN</sub> =5 V, V <sub>EN</sub> =0V, V <sub>OUT</sub> force 1V  | —       | 30   | 50   | Ω    |
|                  |                                              | V <sub>IN</sub> =3.6V, V <sub>EN</sub> =0V, V <sub>OUT</sub> force 1V | —       | 40   | 60   | Ω    |
|                  |                                              | V <sub>IN</sub> =1.8V, V <sub>EN</sub> =0V, V <sub>OUT</sub> force 1V | —       | 115  | 150  | Ω    |
|                  |                                              | V <sub>IN</sub> =1 V, V <sub>EN</sub> =0V, V <sub>OUT</sub> force 1V  | —       | 700  | 1200 | Ω    |

Note 5: Refer to the Timing Chart (See Figure 1).

## Timing Chart



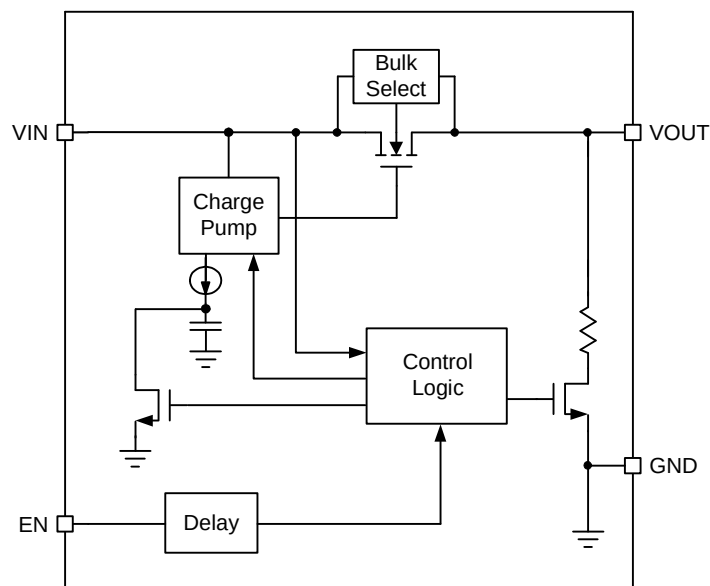
Note 6:  $t_{rise}$  and  $t_{fall}$  of the control signal is 100ns

Figure 1.  $t_{on}/t_{off}, t_{ss}/t_F$  Waveforms

## Pin Description

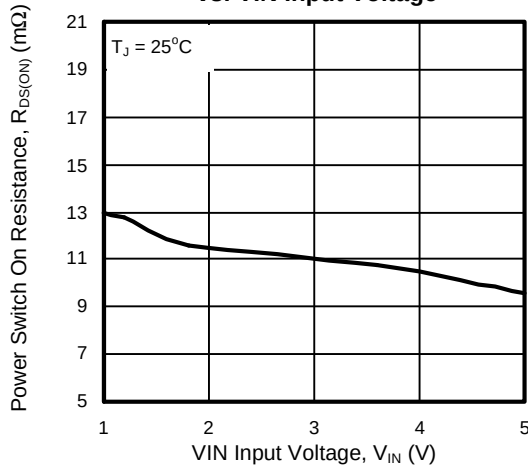
| PIN    |      | Function                                                                                |
|--------|------|-----------------------------------------------------------------------------------------|
| NO.    | NAME |                                                                                         |
| C1     | GND  | Ground pin of the circuitry. All voltage levels are measured with respect to this pin.  |
| C2     | EN   | Enable input of switch. Logic high turns on switch. The EN pin cannot be left floating. |
| A1, B1 | VOUT | Switch output.                                                                          |
| A2, B2 | VIN  | Power supply Input of switch. Connect this pin to an external DC supply.                |

## Block Diagram

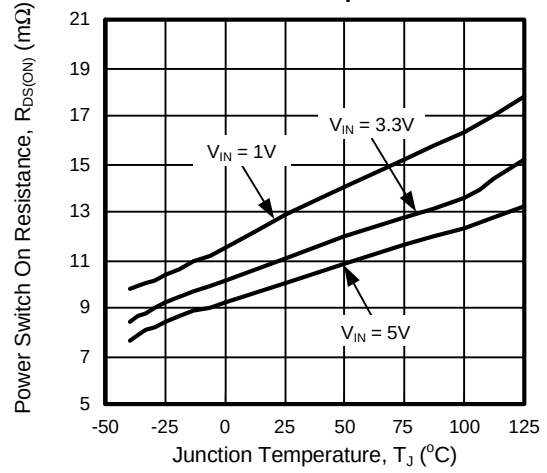


## Typical Operating Characteristics

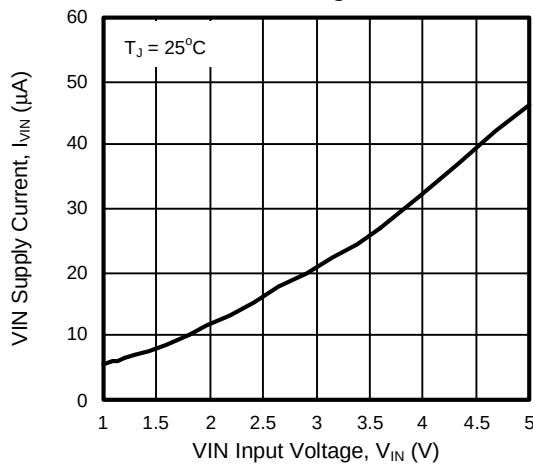
Power Switch On Resistance vs. VIN Input Voltage



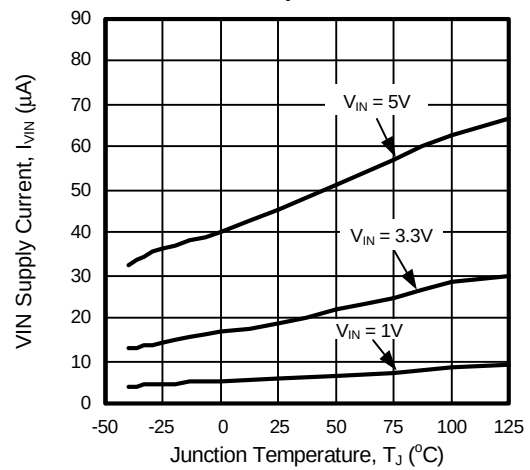
Power Switch On Resistance vs. Junction Temperature



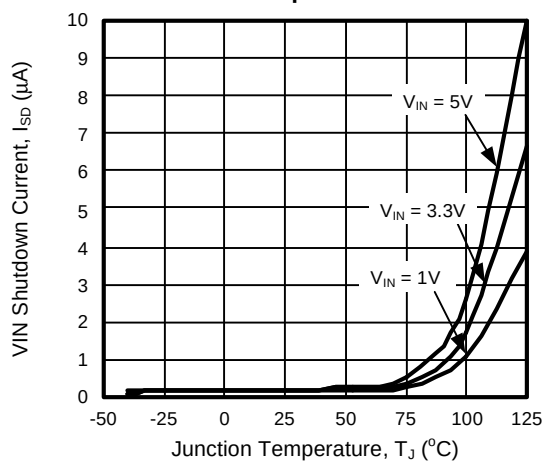
VIN Supply Current vs. VIN Input Voltage



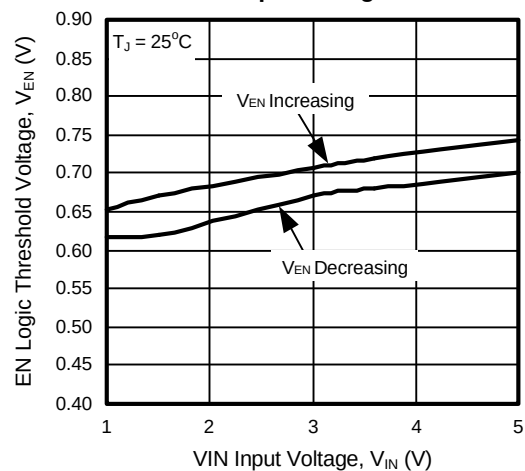
VIN Supply Current vs. Junction Temperature



VIN Shutdown Current vs. Junction Temperature

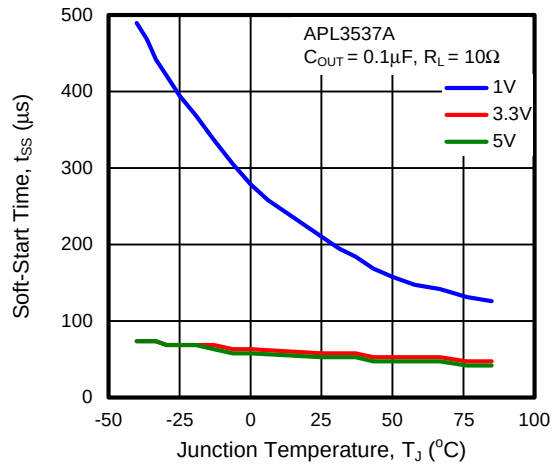


EN Logic Threshold Voltage vs. VIN Input Voltage

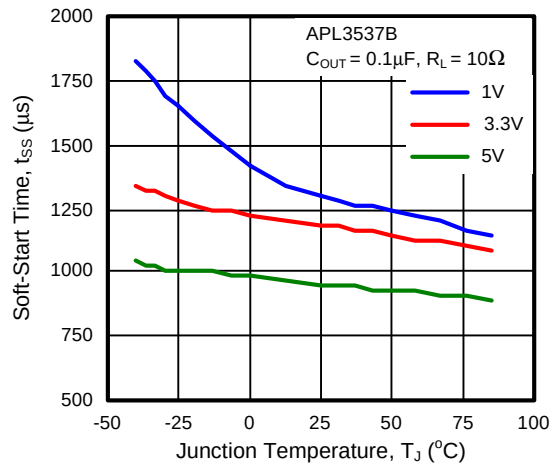


## Typical Operating Characteristics

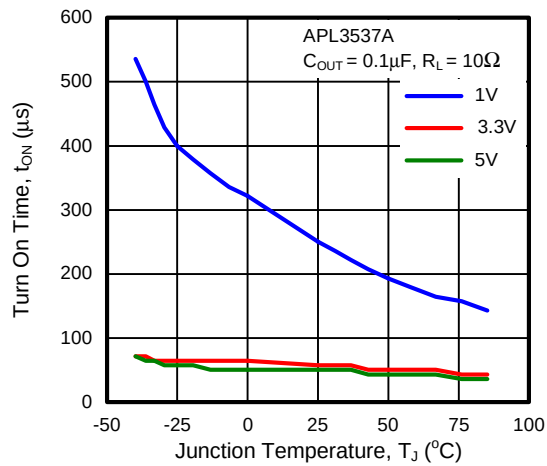
Soft-Start Time vs. Junction Temperature



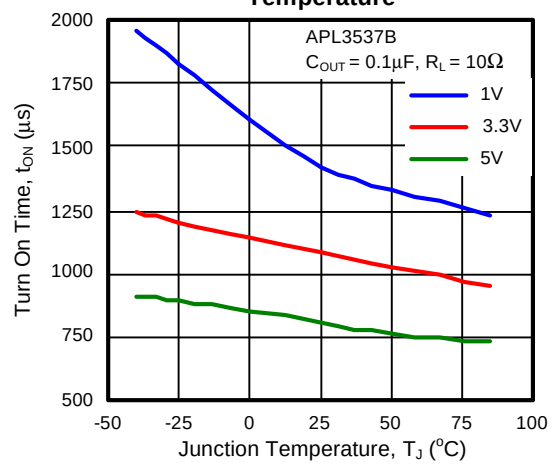
Soft-Start Time vs. Junction Temperature



Turn On Time vs. Junction Temperature



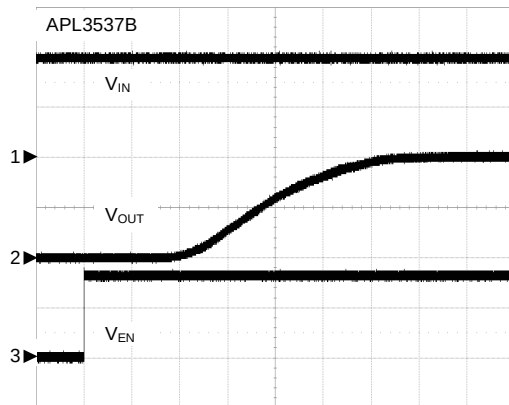
Turn On Time vs. Junction Temperature



## Operating Waveforms

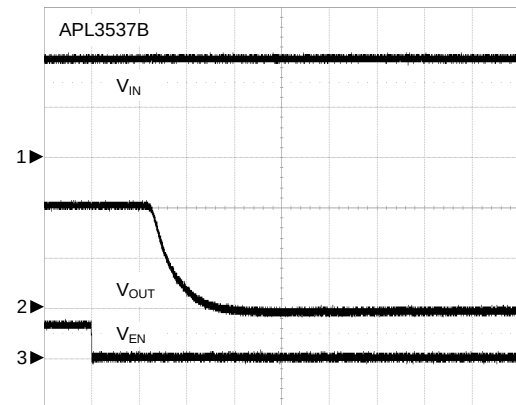
Refer to the typical application circuit.  $T_A = 25^\circ\text{C}$  unless otherwise specified.

Enable



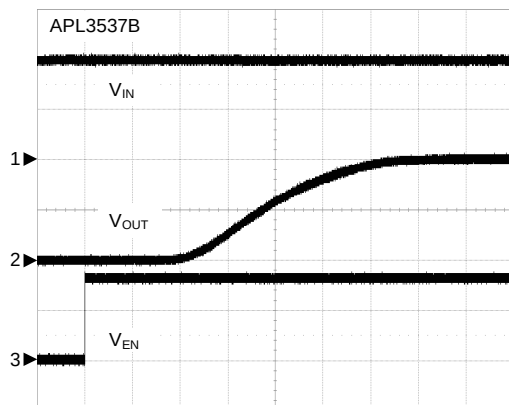
$V_{IN}=1\text{V}$ ,  $C_{OUT}=0.1\mu\text{F}$ ,  $R_L=10\Omega$   
 CH1:  $V_{IN}$ , 500mV/Div, DC  
 CH2:  $V_{OUT}$ , 500mV/Div, DC  
 CH3:  $V_{EN}$ , 2V/Div, DC  
 TIME: 0.5ms/Div

Shutdown



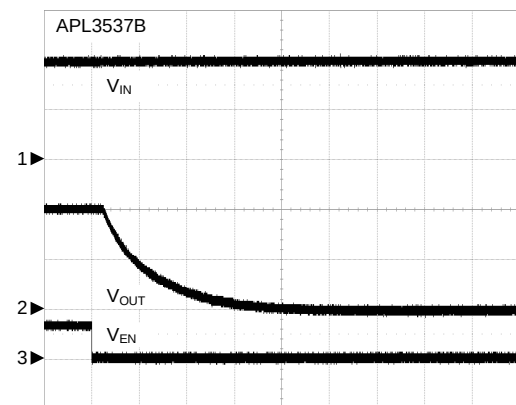
$V_{IN}=1\text{V}$ ,  $C_{OUT}=0.1\mu\text{F}$ ,  $R_L=10\Omega$   
 CH1:  $V_{IN}$ , 500mV/Div, DC  
 CH2:  $V_{OUT}$ , 500mV/Div, DC  
 CH3:  $V_{EN}$ , 5V/Div, DC  
 TIME: 2 $\mu\text{s}$ /Div

Enable



$V_{IN}=1\text{V}$ ,  $C_{OUT}=1\mu\text{F}$ ,  $R_L=10\Omega$   
 CH1:  $V_{IN}$ , 500mV/Div, DC  
 CH2:  $V_{OUT}$ , 500mV/Div, DC  
 CH3:  $V_{EN}$ , 2V/Div, DC  
 TIME: 0.5ms/Div

Shutdown

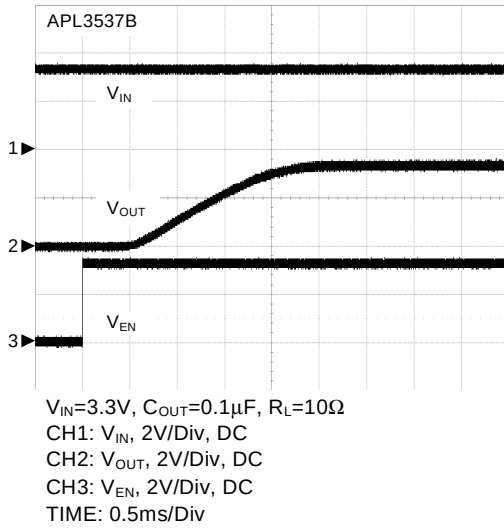


$V_{IN}=1\text{V}$ ,  $C_{OUT}=1\mu\text{F}$ ,  $R_L=10\Omega$   
 CH1:  $V_{IN}$ , 500mV/Div, DC  
 CH2:  $V_{OUT}$ , 500mV/Div, DC  
 CH3:  $V_{EN}$ , 5V/Div, DC  
 TIME: 10 $\mu\text{s}$ /Div

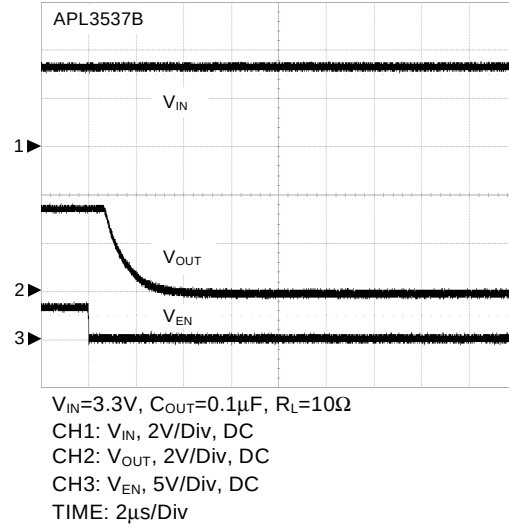
## Operating Waveforms

Refer to the typical application circuit.  $T_A = 25^\circ\text{C}$  unless otherwise specified.

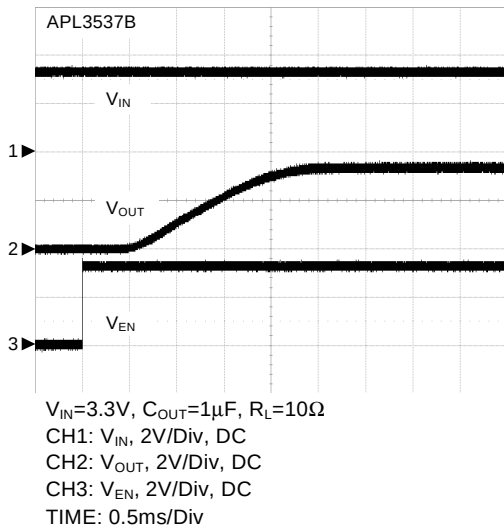
Enable



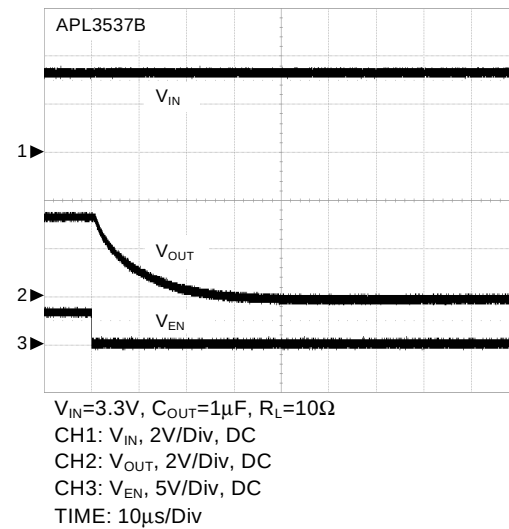
Shutdown



Enable



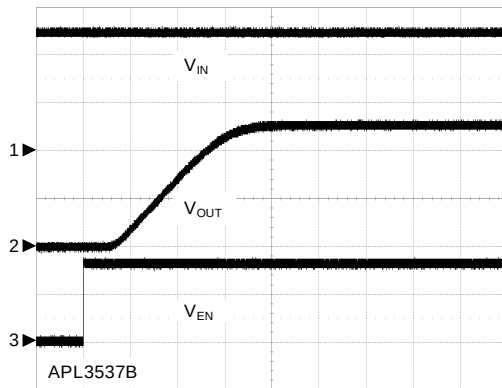
Shutdown



## Operating Waveforms

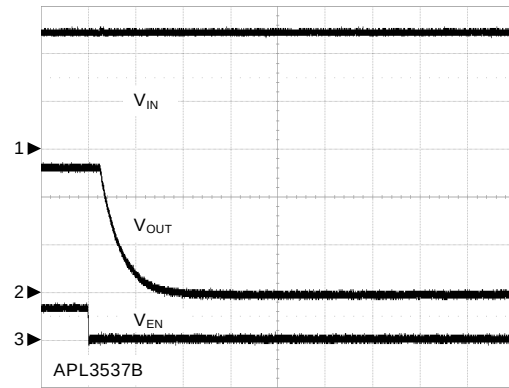
Refer to the typical application circuit.  $T_A = 25^\circ\text{C}$  unless otherwise specified.

Enable



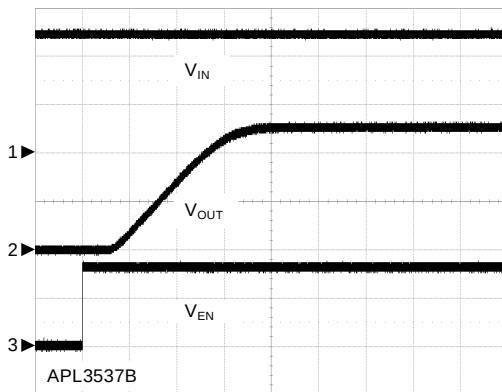
APL3537B  
 $V_{IN}=5\text{V}$ ,  $C_{OUT}=0.1\mu\text{F}$ ,  $R_L=10\Omega$   
 CH1:  $V_{IN}$ , 2V/Div, DC  
 CH2:  $V_{OUT}$ , 2V/Div, DC  
 CH3:  $V_{EN}$ , 2V/Div, DC  
 TIME: 0.5ms/Div

Shutdown



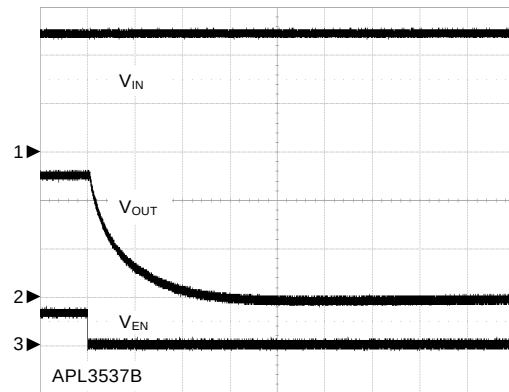
APL3537B  
 $V_{IN}=5\text{V}$ ,  $C_{OUT}=0.1\mu\text{F}$ ,  $R_L=10\Omega$   
 CH1:  $V_{IN}$ , 2V/Div, DC  
 CH2:  $V_{OUT}$ , 2V/Div, DC  
 CH3:  $V_{EN}$ , 5V/Div, DC  
 TIME: 2μs/Div

Enable



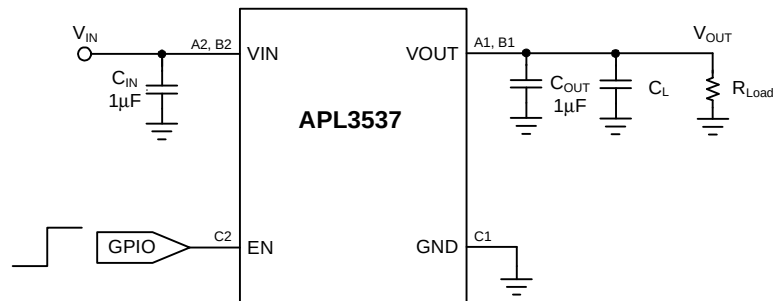
APL3537B  
 $V_{IN}=5\text{V}$ ,  $C_{OUT}=1\mu\text{F}$ ,  $R_L=10\Omega$   
 CH1:  $V_{IN}$ , 2V/Div, DC  
 CH2:  $V_{OUT}$ , 2V/Div, DC  
 CH3:  $V_{EN}$ , 2V/Div, DC  
 TIME: 0.5ms/Div

Shutdown



APL3537B  
 $V_{IN}=5\text{V}$ ,  $C_{OUT}=1\mu\text{F}$ ,  $R_L=10\Omega$   
 CH1:  $V_{IN}$ , 2V/Div, DC  
 CH2:  $V_{OUT}$ , 2V/Div, DC  
 CH3:  $V_{EN}$ , 5V/Div, DC  
 TIME: 10μs/Div

## Typical Application Circuit



## Function Description

### Soft-Start

The APL3537 Provides a soft-start circuitry to control rise rate of the output voltage during start-up.

### Enable Control

The APL3537 has a dedicated enable pin (EN). Pulling EN above 0.9V will enable the device, and pulling the EN below 0.4V will disable the device. Following a shutdown, a logic high signal re-enables the output through initiation of a new soft-start cycle. The enable input is compatible with standard GPIO logic threshold. (It can be used with any microcontroller with 1.2V, 1.8V, 2.5V, 3.3V GPIOs.) The EN pin cannot be left floating.

### Output Discharge

When the EN input voltage is under 0.4V, the output discharge device is turned on discharge the output voltage.

### Reverse Current Blocking Circuit

The APL3537 has a built-in reverse current blocking circuit to prevent a reverse current flowing through the body diode of power switch from the VOUT back VIN pin when power switch disabled.

## Application Information

### Power Sequencing

The power up/down sequence where VIN is already in steady state condition, and EN pin is asserted high or low to prevent wrong logic controls.

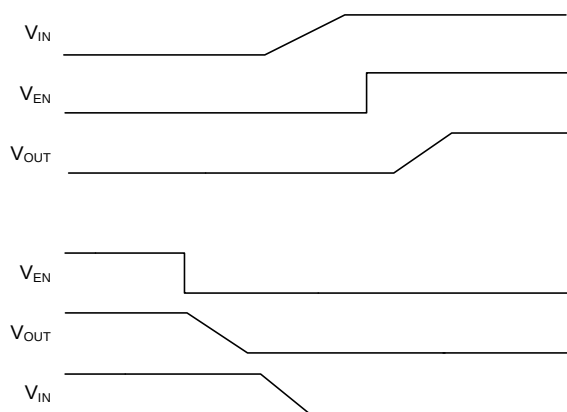


Figure 1. APL3537 Power Sequencing Diagram

### Input Capacitor

The APL3537 requires proper input capacitance to supply current surge during stepping load transients to prevent the input voltage rail from dropping. Because the parasitic inductor from the voltage sources or other bulk capacitors to the VIN pin limit the slew rate of the surge currents, more parasitic inductance needs more input capacitance.

A 1μF or higher ceramic input capacitor from VIN to GND, located near the APL3537, is strongly recommended to suppress the ringing during load transient event. Without the input capacitor, the load transient may cause sufficient ringing on the input (from supply lead inductance) to damage internal control circuitry.

Additional input capacitance may be needed on the input to reduce voltage overshoot from exceeding the absolute maximum voltage of the device during load transient conditions.

### Thermal Consideration

The APL3537 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 the  $(T_J - T_A)$  is the temperature difference between the junction and ambient air.  $\theta_{JA}$  is the thermal resistance between junction and ambient air. Assuming the  $T_A = 25^\circ\text{C}$  and maximum  $T_J = 150^\circ\text{C}$ , the maximum power dissipation is calculated as:

$$P_{D(\max)} = (150 - 25) / 125 = 1 \text{ (W)} \quad \text{----- for } T_A \leq 25^\circ\text{C}$$

For normal operation, do not exceed the maximum operating junction temperature of  $T_J = 125^\circ\text{C}$ . The calculated power dissipation should be less than:

$$P_D = (125 - 25) / 125 = 0.8 \text{ (W)} \quad \text{----- for } T_A \leq 25^\circ\text{C}$$

$$P_D = (125 - 85) / 125 = 0.32 \text{ (W)} \quad \text{----- for } T_A \leq 85^\circ\text{C}$$

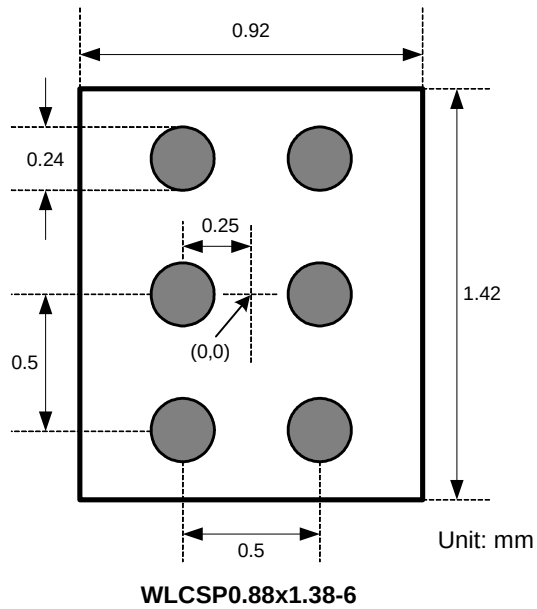
### Layout Consideration

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 APL3537 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 VIN and VOUT traces as wide and short as possible.

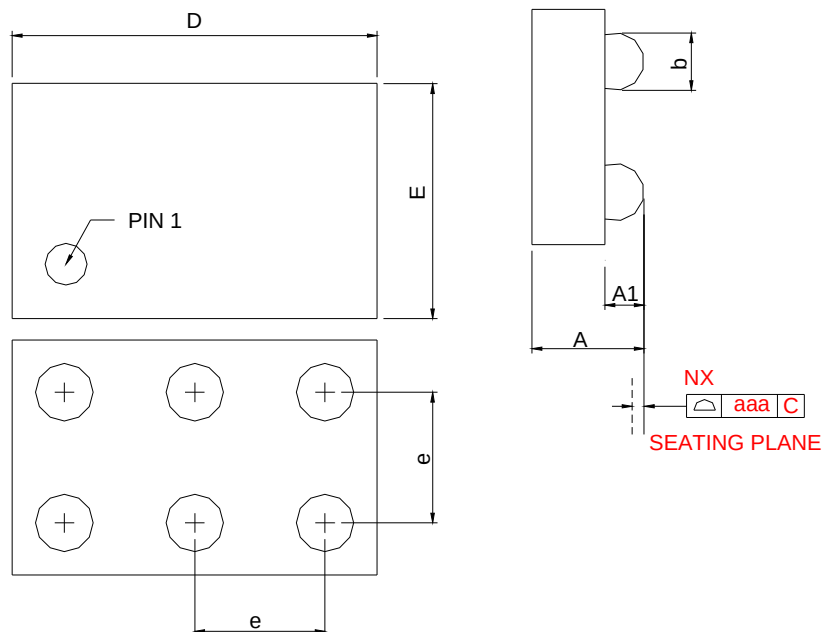
## Application Information (Cont.)

### Recommended Minimum Footprint



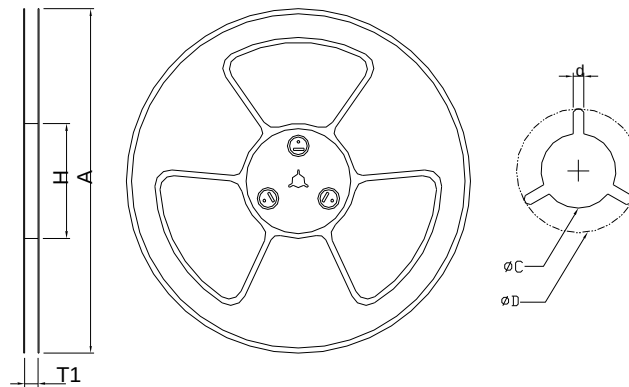
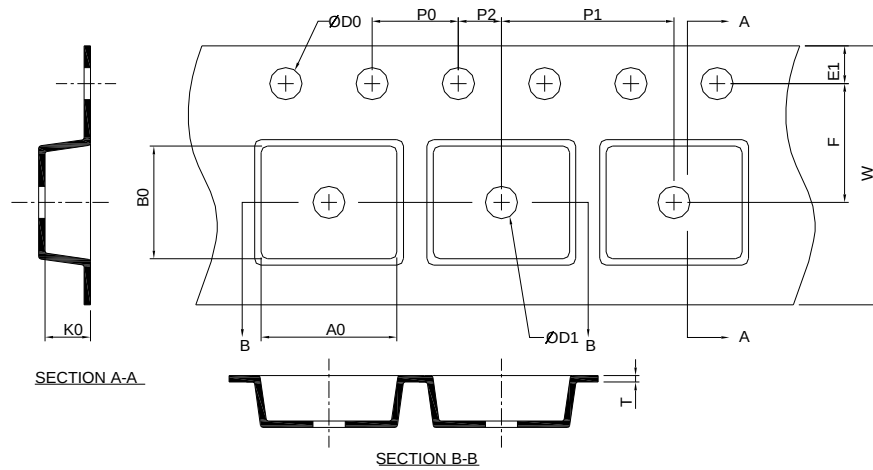
## Package Information

WLCSP0.88x1.38-6



| S<br>Y<br>M<br>B<br>O<br>L | WLCSP0.88*1.38-6 |      |           |       |
|----------------------------|------------------|------|-----------|-------|
|                            | MILLIMETERS      |      | INCHES    |       |
|                            | MIN.             | MAX. | MIN.      | MAX.  |
| A                          | 0.38             | 0.47 | 0.015     | 0.019 |
| A1                         | 0.13             | 0.17 | 0.005     | 0.007 |
| b                          | 0.20             | 0.24 | 0.008     | 0.009 |
| D                          | 1.38             | 1.46 | 0.054     | 0.057 |
| E                          | 0.88             | 0.96 | 0.035     | 0.038 |
| e                          | 0.50 BSC         |      | 0.020 BSC |       |
| aaa                        | 0.08             |      | 0.003     |       |

## Carrier Tape & Reel Dimensions



| Application  | A          | H         | T1                | C                  | d         | D                 | W         | E1        | F         |
|--------------|------------|-----------|-------------------|--------------------|-----------|-------------------|-----------|-----------|-----------|
| WLCSP0.9X1.4 | 178.0±2.00 | 50 MIN.   | 8.4+2.00<br>-0.00 | 13.0+0.50<br>-0.20 | 1.5 MIN.  | 20.2 MIN.         | 8.0±0.30  | 1.75±0.10 | 3.5±0.05  |
|              | <b>P0</b>  | <b>P1</b> | <b>P2</b>         | <b>D0</b>          | <b>D1</b> | <b>T</b>          | <b>A0</b> | <b>B0</b> | <b>K0</b> |
|              | 4.0±0.10   | 4.0±0.10  | 2.0±0.05          | 1.5+0.10<br>-0.00  | 1.5 MIN.  | 0.6+0.00<br>-0.40 | 1.10±0.10 | 1.60±0.10 | 0.56±0.10 |

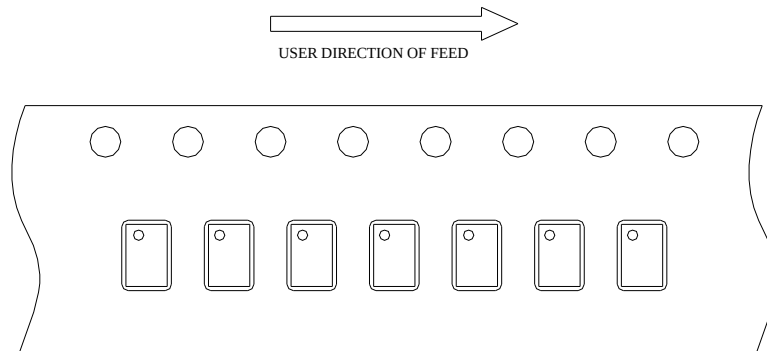
(mm)

## Devices Per Unit

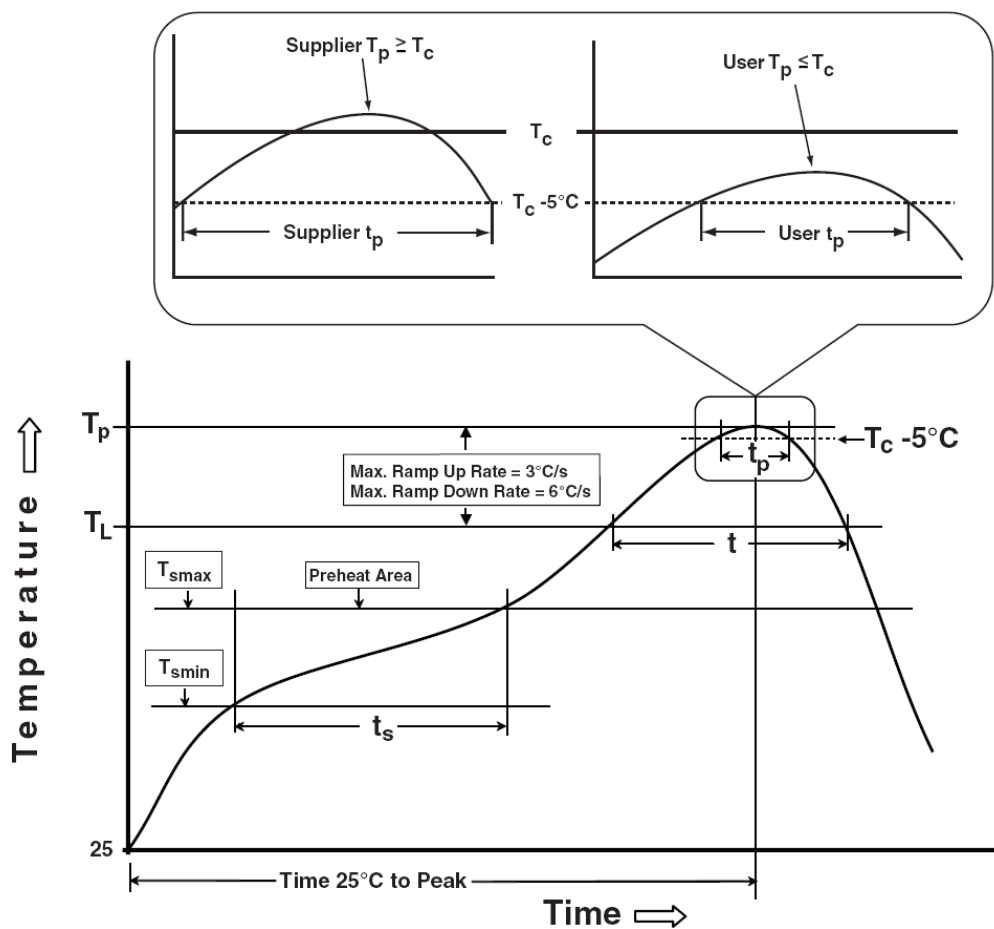
| Package Type | Unit        | Quantity |
|--------------|-------------|----------|
| WLCSP0.9x1.4 | Tape & Reel | 3000     |

## Taping Direction Information

WLCSP 0.9x1.4-6



## Classification Profile



## Classification Reflow Profiles

| Profile Feature                                                                                                                                                                                                             | Sn-Pb Eutectic Assembly            | Pb-Free Assembly                   |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|------------------------------------|
| <b>Preheat &amp; Soak</b><br>Temperature min ( $T_{smin}$ )<br>Temperature max ( $T_{smax}$ )<br>Time ( $T_{smin}$ to $T_{smax}$ ) ( $t_s$ )                                                                                | 100 °C<br>150 °C<br>60-120 seconds | 150 °C<br>200 °C<br>60-120 seconds |
| Average ramp-up rate ( $T_{smax}$ to $T_p$ )                                                                                                                                                                                | 3 °C/second max.                   | 3 °C/second max.                   |
| Liquidous temperature ( $T_L$ )<br>Time at liquidous ( $t_L$ )                                                                                                                                                              | 183 °C<br>60-150 seconds           | 217 °C<br>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.<br>** 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 <sup>3</sup><br><350 | Volume mm <sup>3</sup><br>≥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 <sup>3</sup><br><350 | Volume mm <sup>3</sup><br>350-2000 | Volume mm <sup>3</sup><br>>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, $I_{tr} \geq 100\text{mA}$           |

## Customer Service

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