

Adjustable Low Dropout 300mA Linear Regulator

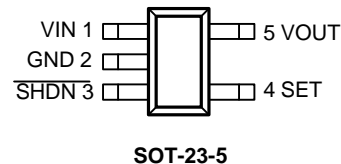
Features

- **Wide Operating Voltage: 2.7~6V**
- **Low Dropout Voltage:**
300mV(Typical) @ 300mA
- **Guaranteed 300mA Output Current**
- **Adjustable Output Voltage: 0.8~5.5V**
- **Current-Limit Protection with Foldback Current**
- **Over-Temperature Protection**
- **Stable with Low ESR Ceramic Capacitor**
- **SOT-23-5 Package**
- **Lead Free and Green Devices Available**
(RoHS Compliant)

General Description

The APL5324 is a P-channel low dropout linear regulator which needs only one input voltage from 2.7 to 6V, and delivers current up to 300mA to set output voltage. It also can work with low ESR ceramic capacitors and is ideal for using in the battery-powered applications such as notebook computers and cellular phones. Typical dropout voltage is only 300mV at 300mA loading. Current limit with current foldback and thermal shutdown functions protect the device against current over-loads and over temperature. The APL5324 is available in a SOT-23-5 package.

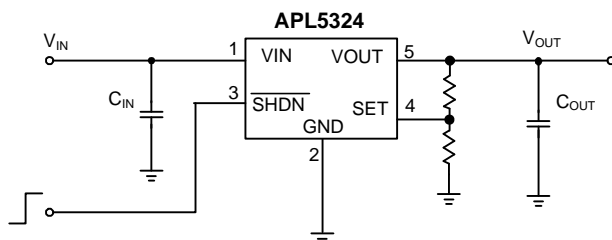
Pin Configuration



Applications

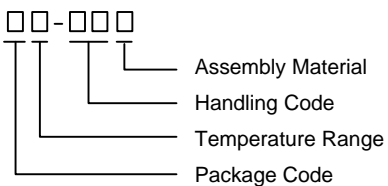
- **Cellular Phones**
- **Portable and Battery-Powered Equipment**
- **Notebook and Personal Computers**

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>APL5324 □□-□□□</p>  <p>Assembly Material Handling Code Temperature Range Package Code</p> | <p>Package Code B: SOT-23-5 Operating Ambient Temperature Range I: -40 to 85 °C Handling Code TR: Tape & Reel Assembly Material L: Lead Free Device G: Halogen and Lead Free Device</p> |
| <p>APL5324 B: 24RX</p> | <p>X - Date Code</p> |

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 Supply Voltage (VIN to GND) | -0.3 ~ 6.5 | V |
| $V_{\overline{SHDN}}$ | \overline{SHDN} Input Voltage (\overline{SHDN} to GND) | -0.3 ~ 6.5 | V |
| P_D | Power Dissipation | Internally Limited | W |
| T_J | 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} | Thermal Resistance-Junction to Ambient ^(Note 2) | 240 | °C/W |
| | SOT-23-5 | | |
| θ_{JC} | Thermal Resistance-Junction to Case | 130 | °C/W |
| | SOT-23-5 | | |

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 Supply Voltage | 2.7 ~ 6 | V |
| V_{OUT} | Output Voltage | 0.8 ~ 5.5 | V |
| I_{OUT} | VOUT Output Current | 0 ~ 300 | mA |
| C_{IN} | Input Capacitor | 0.22 ~ 100 | μF |
| C_{OUT} | Output Capacitor | 1.5 ~ 100 | μF |
| T_J | Junction Temperature | -40 ~ 125 | °C |

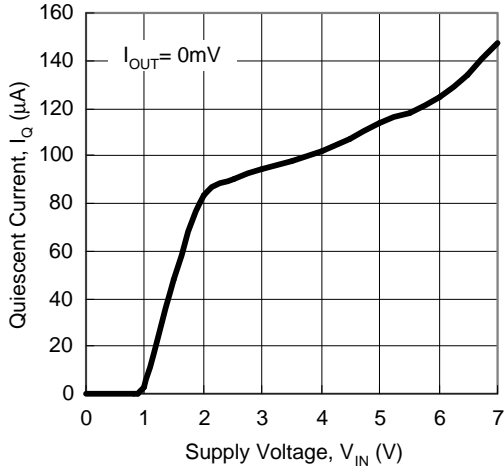
Electrical Characteristics

Unless otherwise specified, these specifications apply over $V_{IN} = V_{OUT} + 1V$, $I_{OUT} = 0 \sim 300mA$, $C_{IN} = 1\mu F$, $C_{OUT} = 2.2\mu F$, $T_A = -40$ to $85^\circ C$. Typical values are at $T_A = 25^\circ C$.

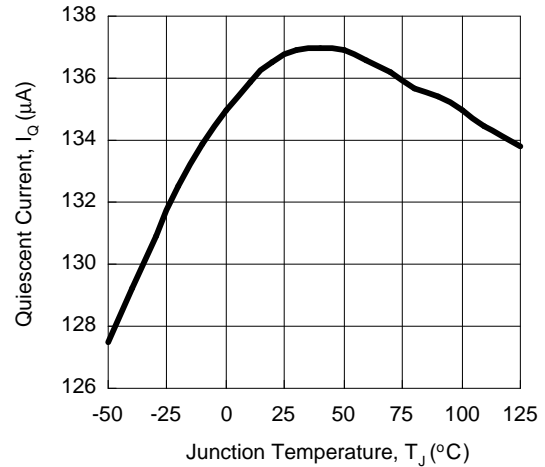
| Symbol | Parameter | Test Conditions | APL5324 | | | Unit |
|---------------------|---|--|--|------|-------|------------|
| | | | Min. | Typ. | Max. | |
| V_{IN} | Input Voltage | | 2.7 | - | 6 | V |
| V_{OUT} | Output Voltage Range | | 0.8 | - | 5.5 | V |
| I_Q | Quiescent Current | $I_{OUT} = 10mA \sim 300mA$ | - | 135 | 160 | μA |
| V_{REF} | Reference Voltage | Measured on SET, $V_{IN} = 3V$, $I_{OUT} = 10mA$ | - | 0.8 | - | V |
| | Output Voltage Accuracy | $I_{OUT} = 10mA$ | -2 | - | +2 | % |
| REG _{LINE} | Line Regulation | $\Delta V_{OUT} \% / \Delta V_{IN}$, $I_{OUT} = 10mA$ | -0.06 | - | +0.06 | %/V |
| REG _{LOAD} | Load Regulation | $\Delta V_{OUT} \% / \Delta I_{OUT}$ | -0.2 | - | +0.2 | %/A |
| V_{DROP} | Dropout Voltage | $V_{OUT} = 2.5V$, $I_{OUT} = 300mA$ | - | 500 | 650 | mV |
| | | $V_{OUT} = 3.3V$, $I_{OUT} = 300mA$ | - | 300 | 400 | |
| PSRR | Power Supply Ripple Rejection Ratio | $f = 10kHz$, $I_{OUT} = 300mA$ | - | 45 | - | dB |
| | | Noise | $f = 80Hz$ to $100kHz$, $I_{OUT} = 300mA$ | - | 160 | - |
| I_{LIMIT} | Current Limit | | 450 | 550 | - | mA |
| I_{SHORT} | Foldback Current | $V_{OUT} = 0V$ | - | 80 | - | mA |
| | SHDN Input Voltage High | | 1.6 | - | - | V |
| | SHDN Input Voltage Low | | - | - | 0.4 | |
| | V_{OUT} Discharge MOSFET $R_{DS(ON)}$ | SHDN = Low | - | 60 | - | Ω |
| | Shutdown VIN Supply Current | SHDN = Low, $V_{IN} = 6V$ | - | 0.1 | 1 | μA |
| | SHDN Pull Low Resistance | | - | 3 | - | $M\Omega$ |
| | Over Temperature Threshold | | - | 160 | - | $^\circ C$ |
| | Over Temperature Hysteresis | | - | 40 | - | $^\circ C$ |
| | SET Input Bias Current | $V_{SET} = 0.8V$ | -100 | - | 100 | nA |

Typical Operating Characteristics

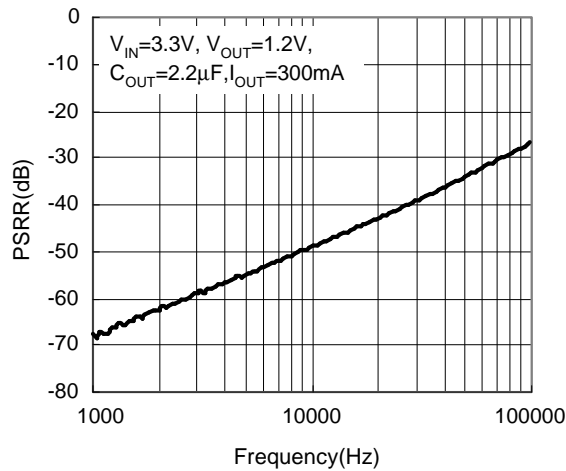
Quiescent Current vs. Supply Voltage



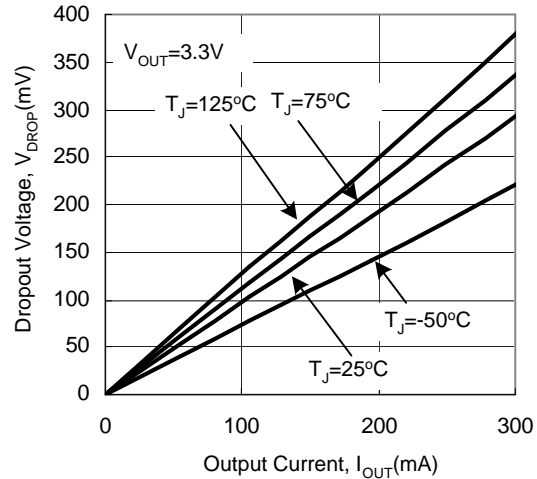
Quiescent Current vs. Junction Temperature



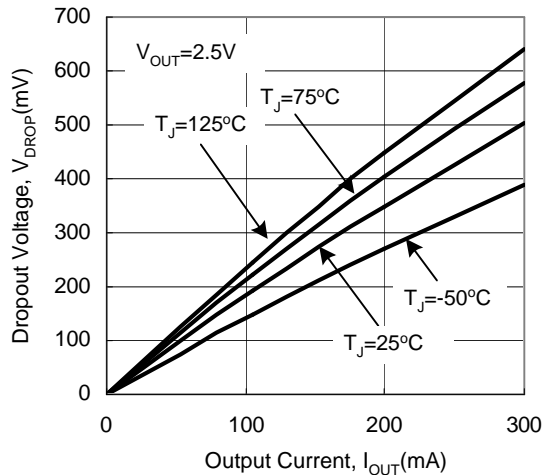
PSRR vs. Frequency



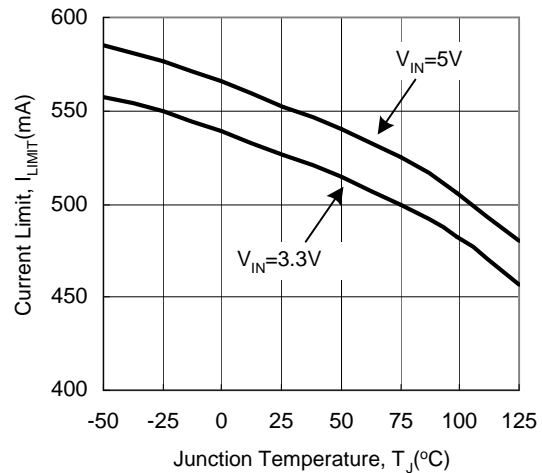
Dropout Voltage vs. Output Current



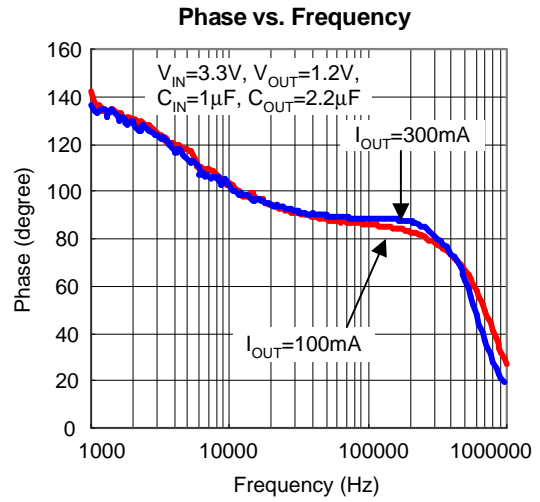
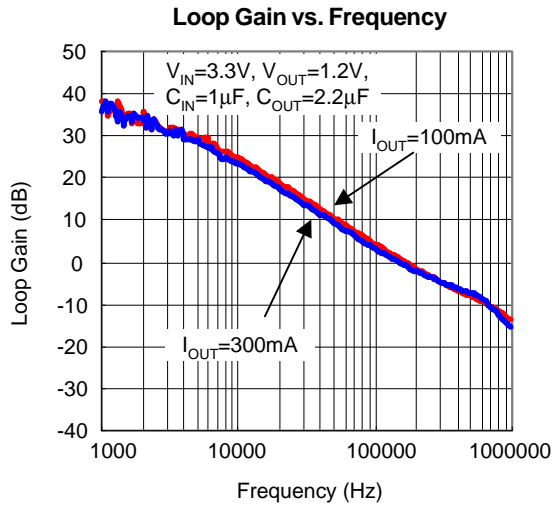
Dropout Voltage vs. Output Current



Current Limit vs. Junction Temperature

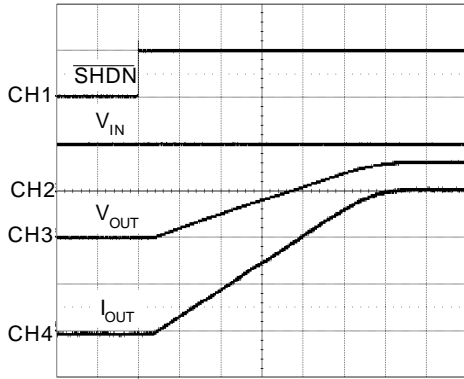


Typical Operating Characteristics (Cont.)



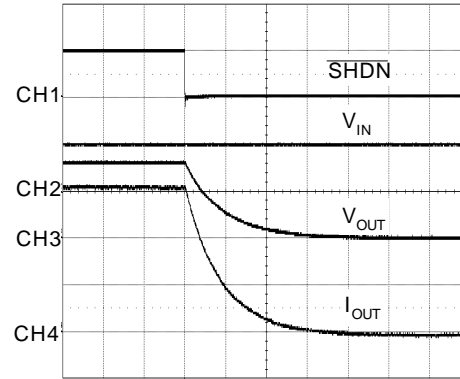
Operating Waveforms

Enable



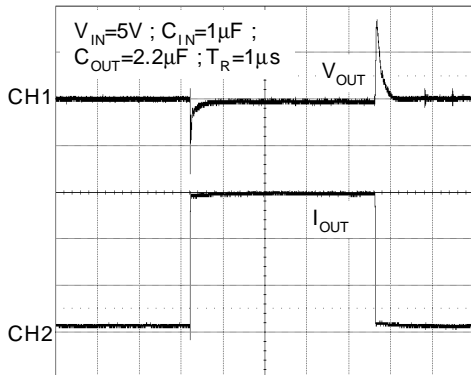
CH1 : $\overline{\text{SHDN}}$, 5V/div
 CH2 : V_{IN} , 5V/div
 CH3 : V_{OUT} , 2V/div
 CH4 : I_{OUT} , 100mA/div
 Time : 200 μ s/div

Shutdown



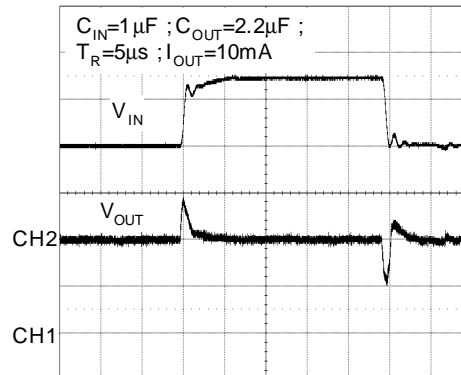
CH1 : $\overline{\text{SHDN}}$, 5V/div
 CH2 : V_{IN} , 5V/div
 CH3 : V_{OUT} , 2V/div
 CH4 : I_{OUT} , 100mA/div
 Time : 10 μ s/div

Load Transient



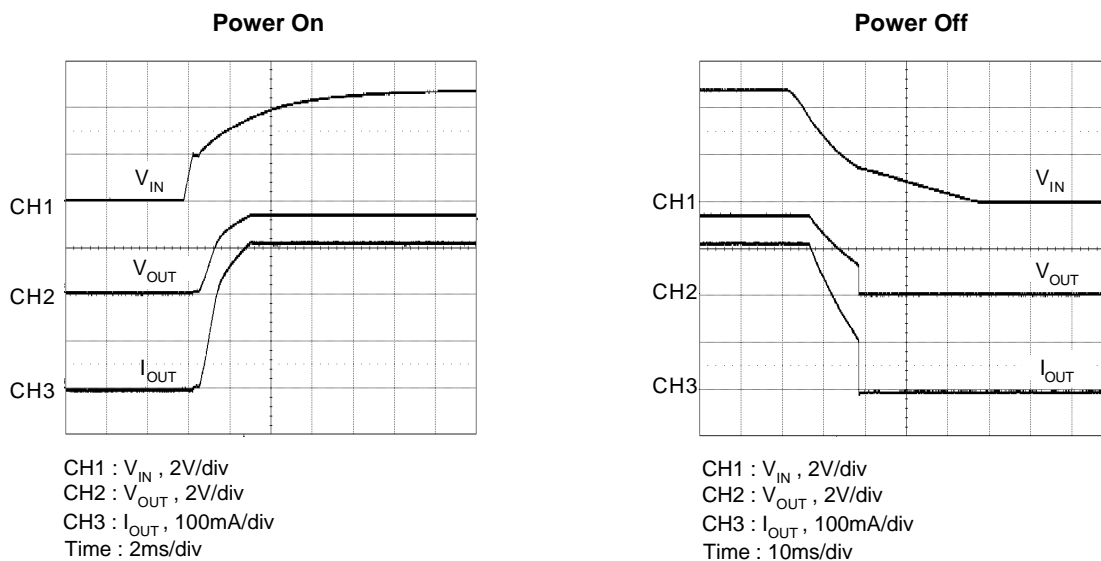
CH1 : V_{OUT} , 50mV/div AC
 CH2 : I_{OUT} , 100mA/div
 Time : 20 μ s/div

Line Transient



CH1 : V_{IN} , 1V/div DC
 CH2 : V_{OUT} , 50mV/div AC
 Time : 20 μ s/div

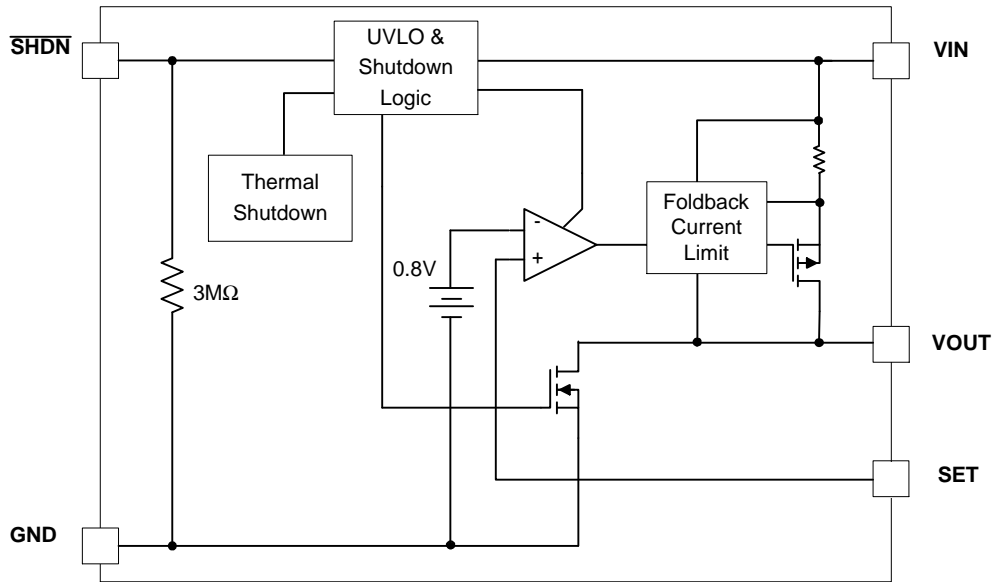
Operating Waveforms (Cont.)



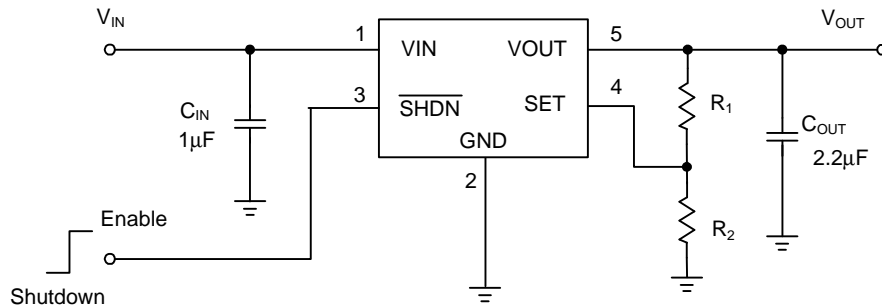
Pin Description

| PIN | | FUNCTION |
|-----|--------------------------|--|
| NO. | NAME | |
| 1 | VIN | Voltage supply input pin. |
| 2 | GND | Ground pin. |
| 3 | $\overline{\text{SHDN}}$ | Shutdown control pin, logic high: enable; logic low: shutdown. |
| 4 | SET | Connect this pin to an external resistor divider to adjust output voltage. |
| 5 | VOUT | Regulator output pin. |

Block Diagram



Typical Application Circuit



$$V_{OUT} = 0.8 \cdot \left(1 + \frac{R_1}{R_2} \right)$$

| Designation | Supplier | Part Number | Specification |
|------------------|----------|-------------------|-----------------------|
| C _{IN} | Murata | GRM185R61A105KE36 | 0603, X5R, 10V, 1μF |
| C _{IN} | Murata | GRM188R71A105KA61 | 0603, X7R, 10V, 1μF |
| C _{OUT} | Murata | GRM188R61A225KE34 | 0603, X5R, 10V, 2.2μF |
| C _{OUT} | Murata | GRM188R71A225KE15 | 0603, X7R, 10V, 2.2μF |

Reference: www.murata.com

Function Description

Output Voltage Regulation

The APL5324 is an adjustable low dropout linear regulator. The output voltage set by the resistor-divider is determined by:

$$V_{OUT} = 0.8 \cdot \left(1 + \frac{R1}{R2} \right)$$

Where R1 is connected from VOUT to SET with Kelvin sensing and R2 is connected from SET to GND. The recommended value of R2 is in the range of 100 to 100kΩ. An error amplifier works with a temperature compensated 0.8V reference and an output PMOS regulates the output to the presetting voltage. The error amplifier is designed with high bandwidth and DC gain provides very fast transient response and less load regulation. It compares the reference with the feedback voltage and amplifies the difference to drive the output PMOS which provides load current from VIN to VOUT.

Thermal Shutdown

A thermal shutdown circuit limits the junction temperature of APL5324. When the junction temperature exceeds +160°C, a thermal sensor turns off the output PMOS, allowing the device to cool down. The regulator regulates the output again through initiation of a new soft-start cycle after the junction temperature is cooled down by 40°C. The thermal shutdown is designed with a 40°C hysteresis to lower the average junction temperature during continuous thermal overload conditions, extending lifetime of the device.

For normal operation, device power dissipation should be externally limited so that junction temperature will not exceed 125°C.

Shutdown Control

The APL5324 has an active-low shutdown function. Force $\overline{\text{SHDN}}$ high (>1.6V) enables the V_{OUT} ; force $\overline{\text{SHDN}}$ low (<0.4V) disables the V_{OUT} . $\overline{\text{SHDN}}$ is internally pulled low by a resistor (3mΩ typical). If it is not used, connect to VIN for normal operation.

Application Information

Input Capacitor

The APL5324 requires proper input capacitors to supply surge current during stepping load transients to prevent the input rail from dropping. Because the parasitic inductor from the voltage sources or other bulk capacitors to the VIN limit the slew rate of the surge current, place the Input capacitors near VIN as close as possible. Input capacitors should be larger than 1μF and a minimum ceramic capacitor of 1μF is necessary.

Output Capacitor

The APL5324 needs a proper output capacitor to maintain circuit stability and to improve transient response over temperature and current. In order to insure the circuit stability, the proper output capacitor value should be larger than 2.2μF. With X5R and X7R dielectrics, 2.2μF is sufficient at all operating temperatures. Large output capacitor value can reduce noise and improve load-transient response and PSRR, however, it also affects power on issue. Equation (1) shows the relationship between the maximum C_{OUT} value and the V_{OUT}.

$$C_{OUT(max)} = 101 - \frac{19.5}{V_{OUT}}$$

Where the unit of C_{OUT} is μF and V_{OUT} is V. Figure 1 shows the curve of maximum output capacitor over the output voltage. The output voltage range is from 0.8 to 5.5V and the output capacitor value should under the line. Output capacitors must be placed at the load and the ground pin as close as possible and the impedance of the layout must be minimized.

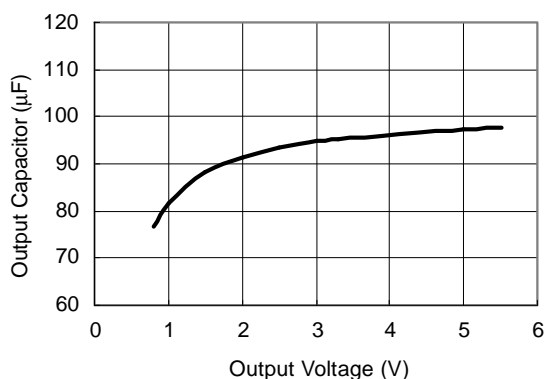


Figure 1

Operation Region and Power Dissipation

The APL5324 maximum power dissipation depends on the thermal resistance and temperature difference between the die junction and ambient air. The power dissipation P_D across the device is:

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

where (T_J-T_A) is the temperature difference between the junction and ambient air. θ_{JA} is the thermal resistance between Junction and ambient air. Assuming the T_A=25°C and maximum T_J=160°C (typical thermal limit threshold), the maximum power dissipation is calculated as:

$$P_{D(max)} = (160-25)/240 = 0.56(W)$$

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

$$P_D = (125-25)/240 = 0.41(W)$$

The GND provides an electrical connection to the ground and channels heat away. Connect the GND to the ground by using a large pad or a ground plane.

Layout Consideration

Figure 2 illustrates the layout. Below is a checklist for your layout:

1. Please place the input capacitors close to the VIN.
2. Ceramic capacitors for load must be placed near the load as close as possible.
3. To place APL5324 and output capacitors near the load is good for performance.
4. Large current paths, the bold lines in figure 2, must have wide tracks.
5. Divider resistor R1 and R2 must be placed near the SET as close as possible.

Application Information (Cont.)

Layout Consideration (Cont.)

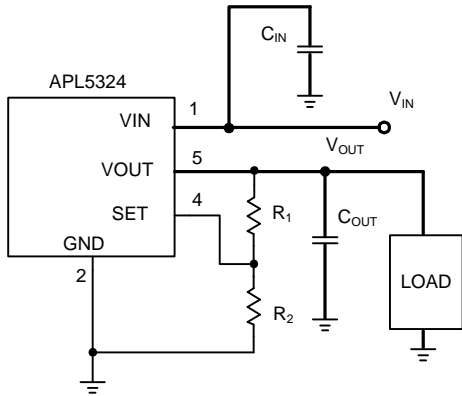
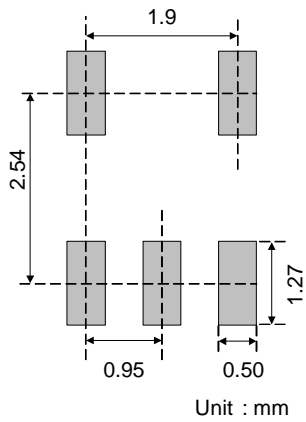


Figure 2

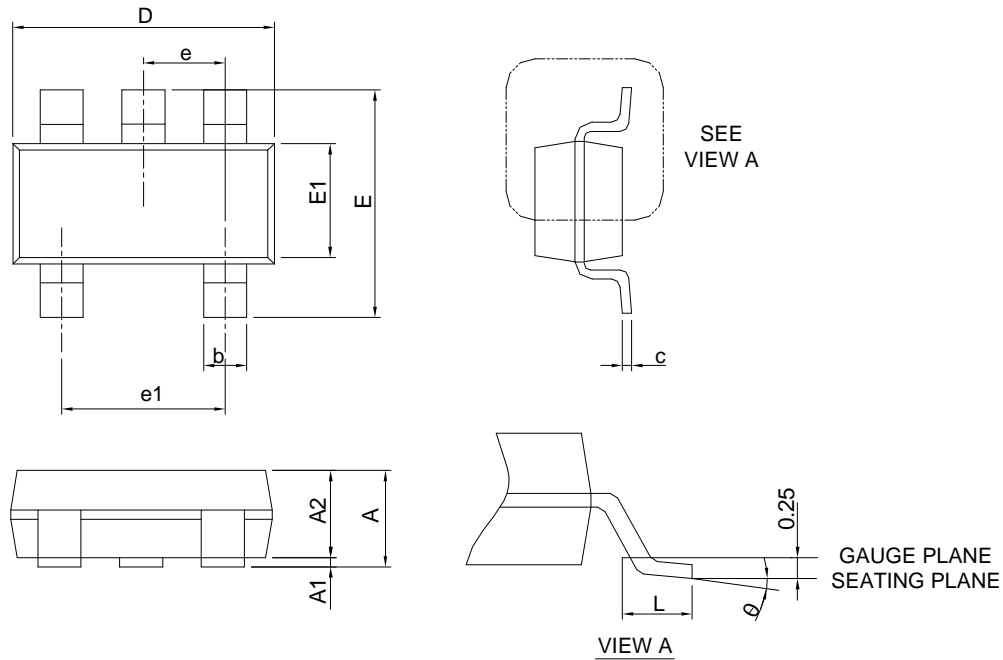
Recommended Minimum Footprint

SOT-23-5



Package Information

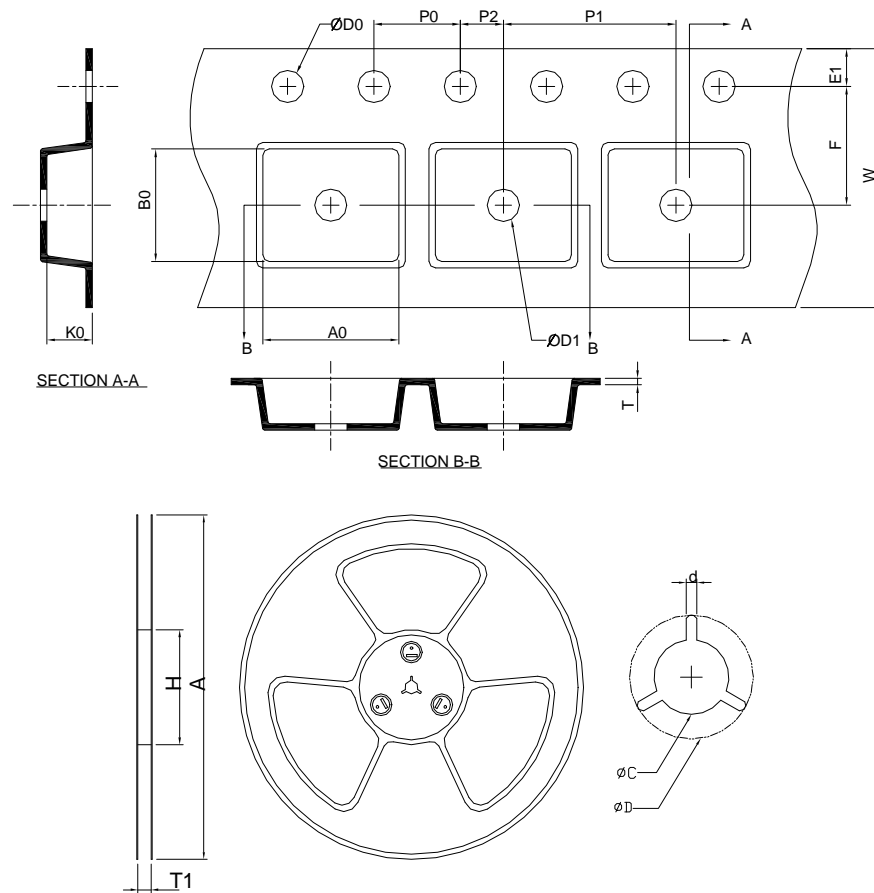
SOT-23-5



| DIMENSIONS | 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 |

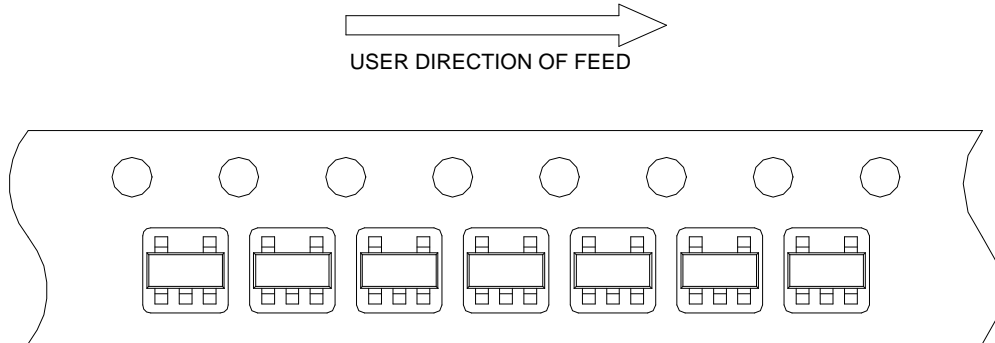
(mm)

Devices Per Unit

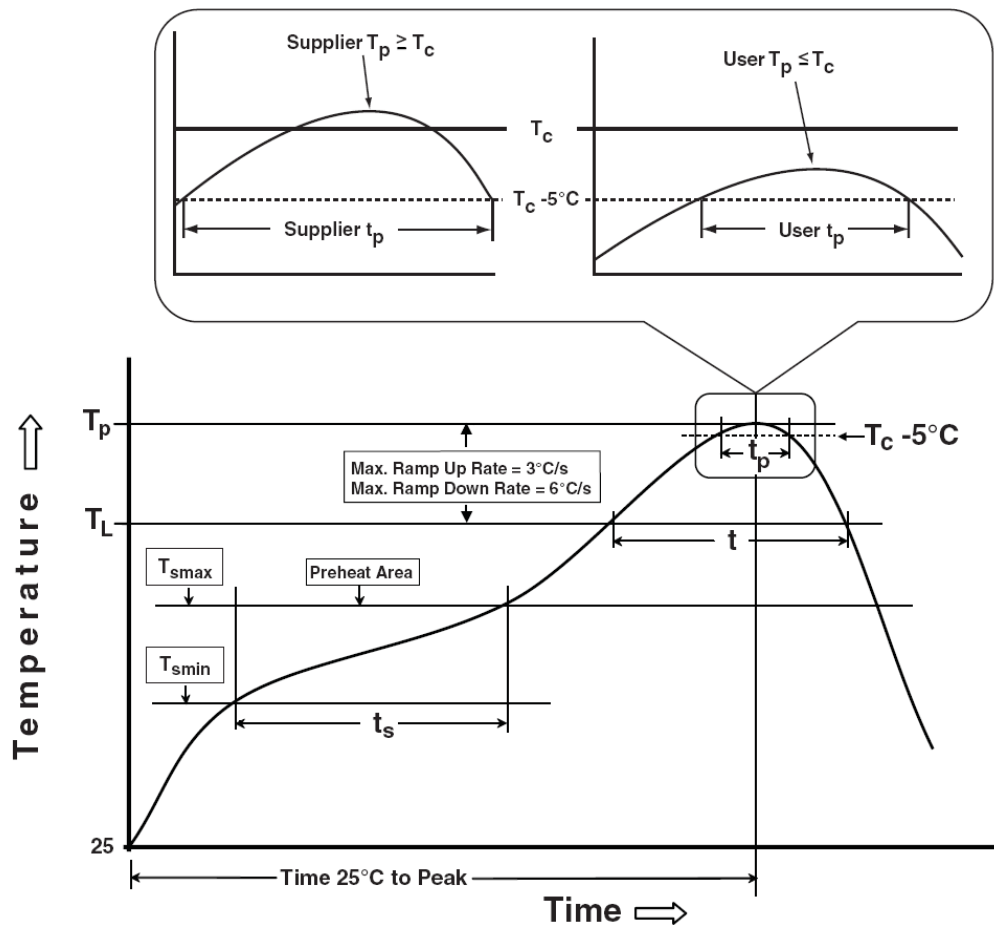
| Package Type | Unit | Quantity |
|--------------|-------------|----------|
| SOT-23-5 | Tape & Reel | 3000 |

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, 1 _{tr} 100mA |

Customer Service

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