# 500mA, Low Dropout, Low Noise Ultra-Fast Without Bypass Capacitor CMOS LDO Regulator

## General Description

The RT9013 is a high-performance, 500mA LDO regulator, offering extremely high PSRR and ultra-low dropout. Ideal for portable RF and wireless applications with demanding performance and space requirements.

The RT9013 quiescent current as low as 25μA, further prolonging the battery life. The RT9013 also works with low-ESR ceramic capacitors, reducing the amount of board space necessary for power applications, critical in hand-held wireless devices.

The RT9013 consumes typical 0.7μA in shutdown mode and has fast turn-on time less than 40μs. The other features include ultra-low dropout voltage, high output accuracy, current limiting protection, and high ripple rejection ratio. Available in the SC-82, SOT-23-5, SC-70-5 and WDFN-6L 2x2 package.

## Ordering Information

RT9013-□□□

Package Type
- Y : SC-82
- B : SOT-23-5
- U5 : SC-70-5
- QW : WDFN-6L 2x2 (W-Type)

Lead Plating System
- P : Pb Free
- G : Green (Halogen Free and Pb Free)

Fixed Output Voltage
- 12 : 1.2V
- 13 : 1.3V
- 15 : 1.5V
- 16 : 1.6V
- :
- 32 : 3.2V
- 33 : 3.3V
- 1B : 1.25V
- 1H : 1.85V
- 2H : 2.85V

Note :

Richtek products are :

- RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- Suitable for use in SnPb or Pb-free soldering processes.

## Features

- **Wide Operating Voltage Ranges : 2.2V to 5.5V**
- **Low Dropout : 250mV at 500mA**
- **Ultra-Low-Noise for RF Application**
- **Ultra-Fast Response in Line/Load Transient**
- **Current Limiting Protection**
- **Thermal Shutdown Protection**
- **High Power Supply Rejection Ratio**
- **Output Only 1μF Capacitor Required for Stability**
- **TTL-Logic-Controlled Shutdown Input**
- **RoHS Compliant and 100% Lead (Pb)-Free**

## Applications

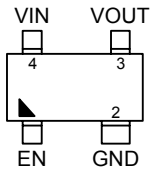
- CDMA/GSM Cellular Handsets
- Portable Information Appliances
- Laptop, Palmtops, Notebook Computers
- Hand-Held Instruments
- Mini PCI & PCI-Express Cards
- PCMCIA & New Cards

## Marking Information

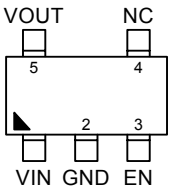
For marking information, contact our sales representative directly or through a Richtek distributor located in your area.

## Pin Configurations

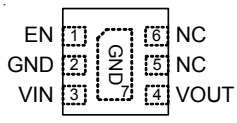
(TOP VIEW)




SC-82

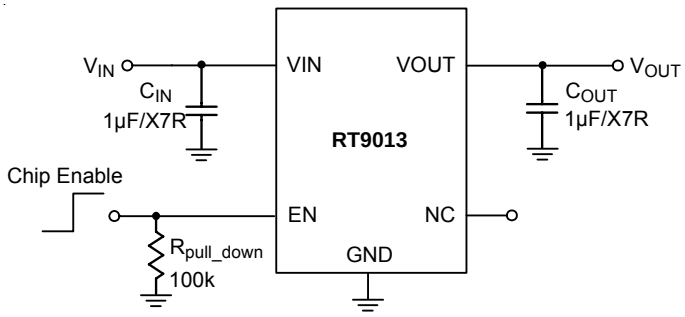



SOT-23-5 / SC-70-5




WDFN-6L 2x2

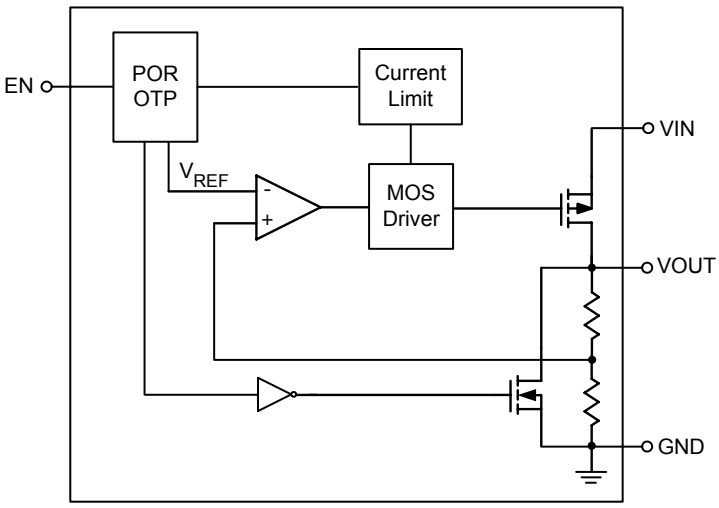
## Typical Application Circuit




## Functional Pin Description

| Pin Number | | | Pin Name | Pin Function |
|---|---|---|---|---|
| SC-82 | SOT-23-5 / SC-70-5 | WDFN-6L 2x2 | | |
| 3 | 5 | 4 | VOUT | Regulator Output. |
| -- | 4 | 5, 6 | NC | No Internal Connection. |
| 2 | 2 | 2, 7 (Exposed Pad) | GND | Common Ground. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation. |
| 1 | 3 | 1 | EN | Enable Input Logic, Active High. When the EN goes to a logic low, the device will be shutdown mode. |
| 4 | 1 | 3 | VIN | Supply Input. |

## Function Block Diagram



## Absolute Maximum Ratings (Note 1)

- Supply Input Voltage ---------- 6V
- EN Input Voltage ---------- 6V
- Power Dissipation, $P_D$ @ $T_A$ = 25°C
  - SOT-23-5 ---------- 0.4W
  - SC-70-5/ SC-82 ---------- 0.3W
  - WDFN-6L 2x2 ---------- 0.606W
- Package Thermal Resistance (Note 2)
  - SOT-23-5, $\theta_{JA}$ ---------- 250°C/W
  - SOT-23-5, $\theta_{JC}$ ---------- 25°C/W
  - SC-70-5/ SC-82, $\theta_{JA}$ ---------- 333°C/W
  - WDFN-6L 2x2, $\theta_{JA}$ ---------- 165°C/W
  - WDFN-6L 2x2, $\theta_{JC}$ ---------- 20°C/W
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Junction Temperature ---------- 150°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 3)
  - HBM ---------- 2kV
  - MM ---------- 200V

## Recommended Operating Conditions (Note 4)

- Supply Input Voltage ---------- 2.2V to 5.5V
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

## Electrical Characteristics

($V_{IN}$ = $V_{OUT}$ + 0.5V, $V_{EN}$ = $V_{IN}$, $C_{IN}$ = $C_{OUT}$ = 1µF (Ceramic, X7R), $T_A$ = 25°C unless otherwise specified)

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Input Voltage Range | $V_{IN}$ | | 2.2 | -- | 5.5 | V |
| Output Noise Voltage | $V_{ON}$ | $V_{OUT}$ = 1.5V, $C_{OUT}$ = 1µF, $I_{OUT}$ = 0mA | -- | 30 | -- | $\mu V_{RMS}$ |
| Output Voltage Accuracy (Fixed Output Voltage) | $\Delta V_{OUT}$ | $I_{OUT}$ = 10mA | –2 | 0 | +2 | % |
| Quiescent Current (Note 5) | $I_Q$ | $V_{EN}$ = 5V, $I_{OUT}$ = 0mA | -- | 25 | 50 | µA |
| Shutdown Current | $I_{SHDN}$ | $V_{EN}$ = 0V | -- | 0.7 | 1.5 | µA |
| Current Limit | $I_{LIM}$ | $R_{LOAD}$ = 0Ω, 2.2V ≤ $V_{IN}$ < 2.6V | 0.4 | 0.5 | 0.85 | A |
| | | $R_{LOAD}$ = 0Ω, 2.7V ≤ $V_{IN}$ ≤ 5.5V | 0.5 | 0.6 | 0.85 | A |
| Dropout Voltage (Note 6) | $V_{DROP}$ | $I_{OUT}$ = 400mA, 2.2V ≤ $V_{IN}$ < 2.7V | -- | 160 | 320 | mV |
| | | $I_{OUT}$ = 500mA, 2.7V ≤ $V_{IN}$ ≤ 5.5V | -- | 250 | 400 | |
| Load Regulation (Note 7) (Fixed Output Voltage) | $\Delta V_{LOAD}$ | 1mA < $I_{OUT}$ < 400mA 2.2V ≤ $V_{IN}$ < 2.7V | -- | -- | 0.6 | % |
| | | 1mA < $I_{OUT}$ < 500mA 2.7V ≤ $V_{IN}$ ≤ 5.5V | -- | -- | 1 | |

*To be continued*

| Parameter | | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| EN Threshold Voltage | Logic-Low | $V_{IL}$ | | 0 | -- | 0.6 | V |
| | Logic-High | $V_{IH}$ | | 1.6 | -- | 5.5 | |
| Enable Pin Current | | $I_{EN}$ | | -- | 0.1 | 1 | μA |
| Power Supply Rejection Rate | | PSRR | $I_{OUT}$ = 100mA, f = 10kHz | -- | –50 | -- | dB |
| Line Regulation | | $\Delta V_{LINE}$ | $V_{IN}$ = ($V_{OUT}$+0.5) to 5.5V, $I_{OUT}$ = 1mA | -- | 0.01 | 0.2 | %/V |
| Thermal Shutdown Temperature | | $T_{SD}$ | | -- | 170 | -- | °C |
| Thermal Shutdown Hysteresis | | $\Delta T_{SD}$ | | -- | 30 | -- | |

**Note 1.** Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

**Note 2.** $\theta_{JA}$ is measured in the natural convection at $T_A$ = 25°C on a low effective thermal conductivity test board of JEDEC 51-3 thermal measurement standard. The case position of $\theta_{JC}$ is on the exposed pad for the package.

**Note 3.** Devices are ESD sensitive. Handling precaution is recommended.

**Note 4.** The device is not guaranteed to function outside its operating conditions.

**Note 5.** Quiescent, or ground current, is the difference between input and output currents. It is defined by $I_Q = I_{IN} - I_{OUT}$ under no load condition ($I_{OUT}$ = 0mA). The total current drawn from the supply is the sum of the load current plus the ground pin current.

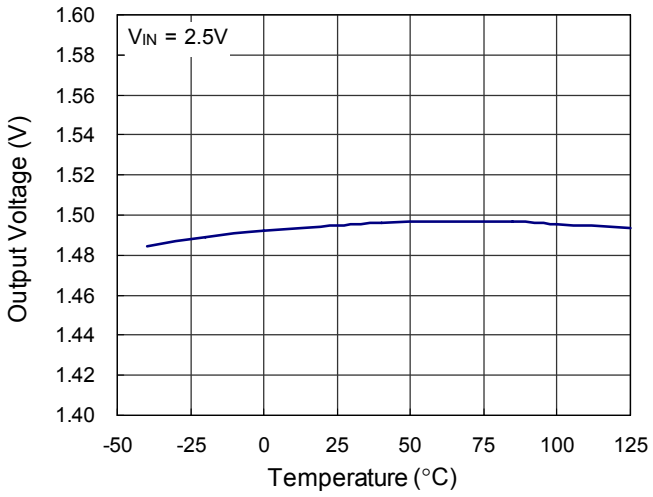
**Note 6.** The dropout voltage is defined as $V_{IN} - V_{OUT}$, which is measured when $V_{OUT}$ is $V_{OUT(NORMAL)}$ - 100mV.

**Note 7.** Regulation is measured at constant junction temperature by using a 2ms current pulse. Devices are tested for load regulation in the load range from 10mA to 500mA.

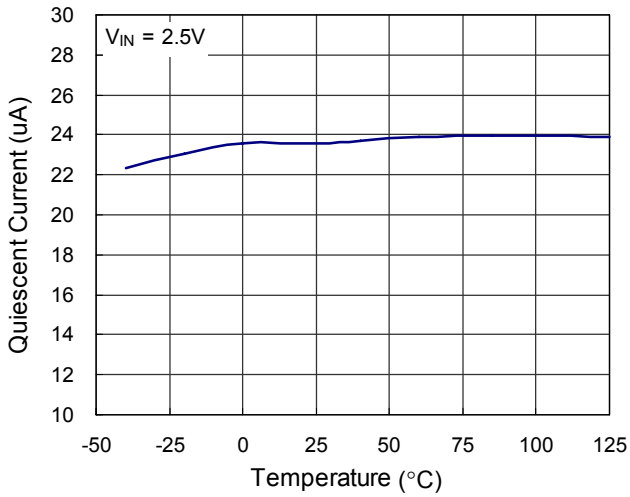
## Typical Operating Characteristics

($C_{IN}$ = $C_{OUT}$ = 1µ/X7R, unless otherwise specified)

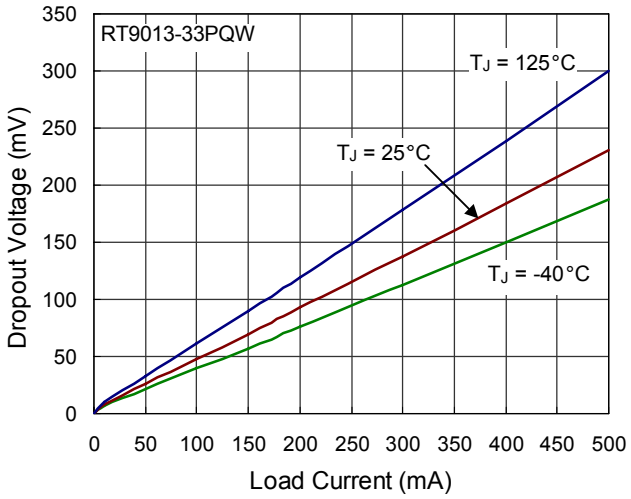
### Output Voltage vs. Temperature



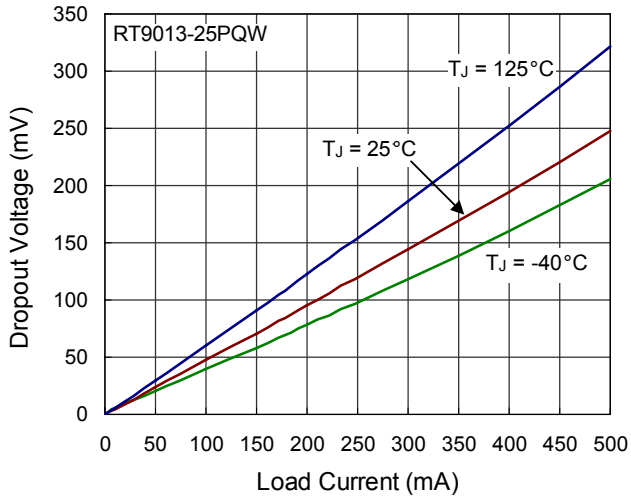

### Quiescent Current vs. Temperature



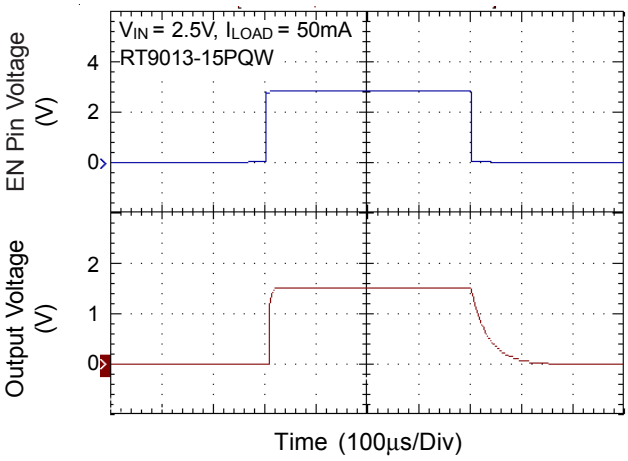

### Dropout Voltage vs. Load Current



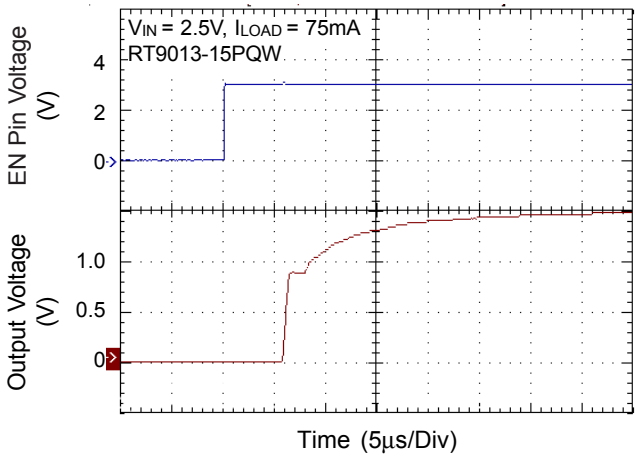

### Dropout Voltage vs. Load Current



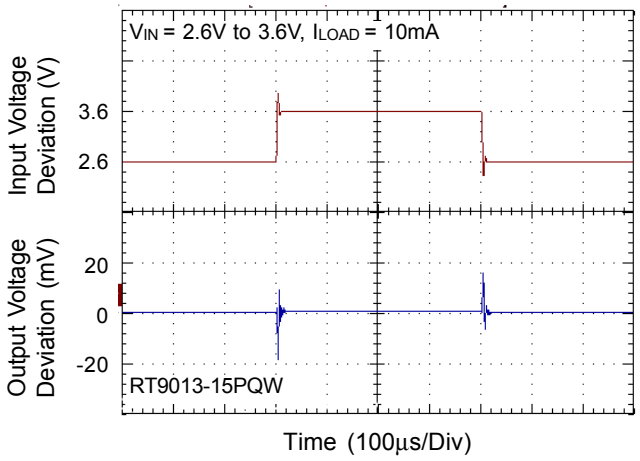

### EN Pin Shutdown Response



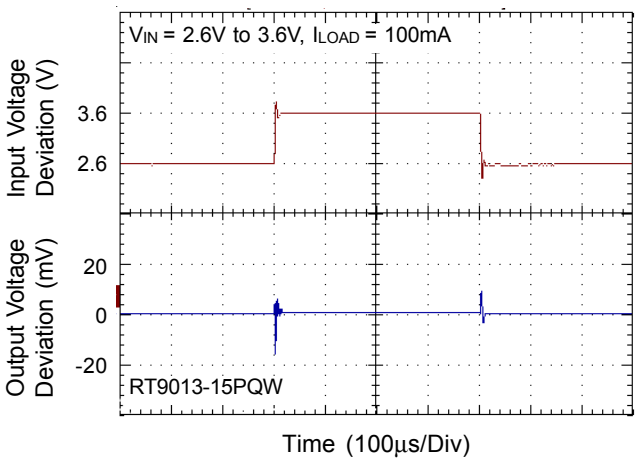

### Start Up



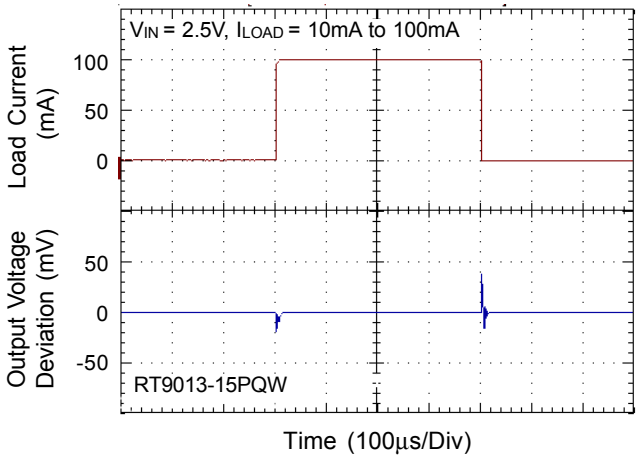
### Line Transient Response



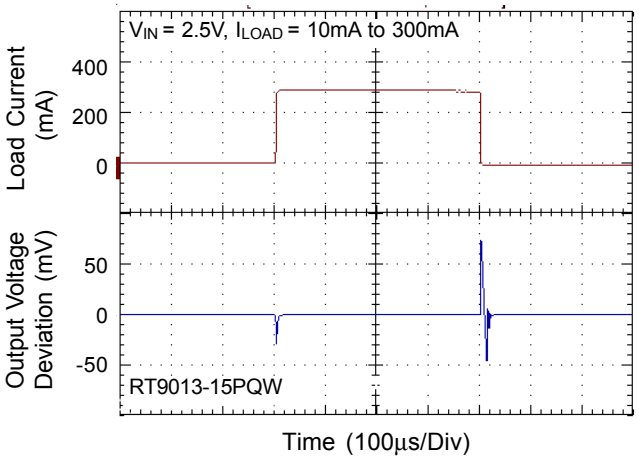

### Line Transient Response



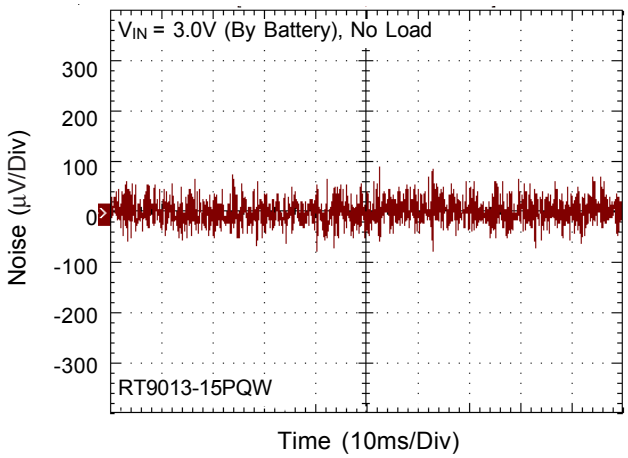

### Load Transient Response



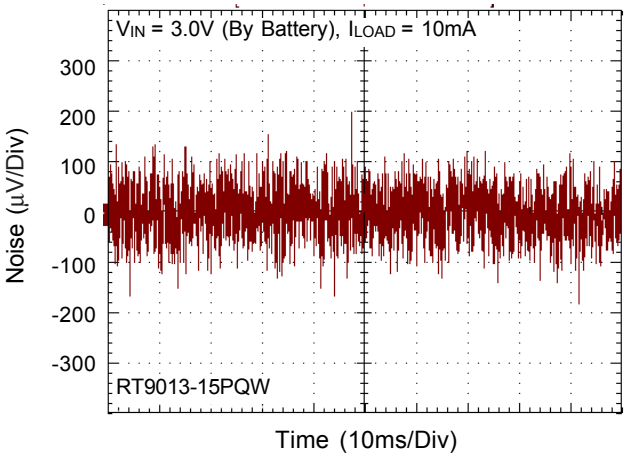

### Load Transient Response

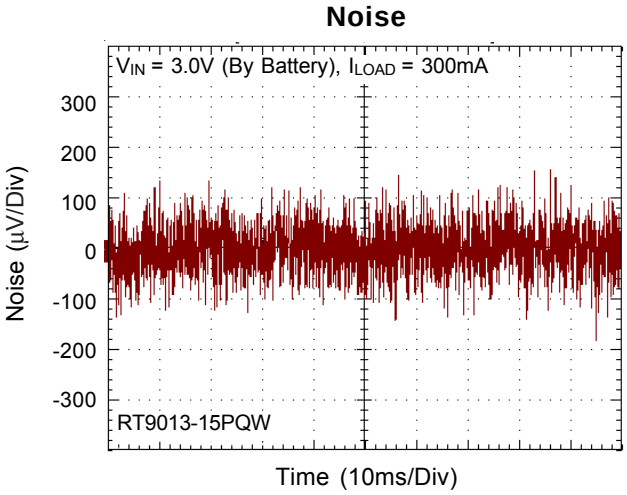


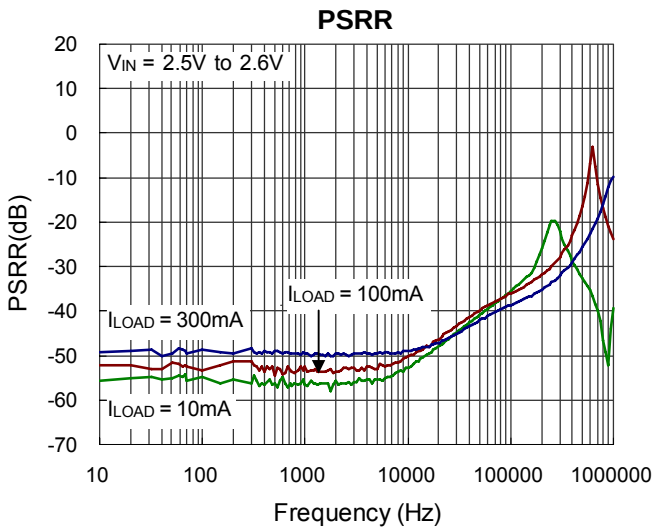

### Noise




### Noise




Noise
VIN = 3.0V (By Battery), ILOAD = 300mA
300
200
100
0
-100
-200
-300
Noise (μV/Div)
RT9013-15PQW
Time (10ms/Div)


PSRR
VIN = 2.5V to 2.6V
20
10
0
-10
-20
-30
-40
-50
-60
-70
PSRR(dB)
ILOAD = 100mA
ILOAD = 300mA
ILOAD = 10mA
10
100
1000
10000
100000
1000000
Frequency (Hz)

## Applications Information

Like any low-dropout regulator, the external capacitors used with the RT9013 must be carefully selected for regulator stability and performance. Using a capacitor whose value is > 1μF/X7R on the RT9013 input and the amount of capacitance can be increased without limit. The input capacitor must be located a distance of not more than 0.5 inch from the input pin of the IC and returned to a clean analog ground. Any good quality ceramic can be used for this capacitor. The capacitor with larger value and lower ESR (equivalent series resistance) provides better PSRR and line-transient response.

The output capacitor must meet both requirements for minimum amount of capacitance and ESR in all LDOs application. The RT9013 is designed specifically to work with low ESR ceramic output capacitor in space-saving and performance consideration. Using a ceramic capacitor whose value is at least 1μF with ESR is > 5mΩ on the RT9013 output ensures stability. The RT9013 still works well with output capacitor of other types due to the wide stable ESR range. Figure 1. shows the curves of allowable ESR range as a function of load current for various output capacitor values. Output capacitor of larger capacitance can reduce noise and improve load transient response, stability, and PSRR. The output capacitor should be located not more than 0.5 inch from the VOUT pin of the RT9013 and returned to a clean analog ground.

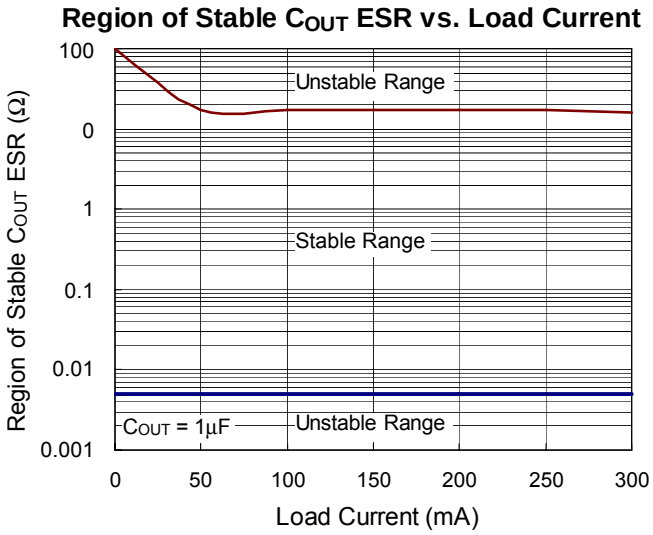



Figure 1

### Enable

The RT9013 goes into sleep mode when the EN pin is in a logic low condition. During this condition, the RT9013 has an EN pin to turn on or turn off regulator, When the EN pin is logic hight, the regulator will be turned on. The supply current to 0.7μA typical. The EN pin may be directly tied to $V_{IN}$ to keep the part on. The Enable input is CMOS logic and cannot be left floating.

### PSRR

The power supply rejection ratio (PSRR) is defined as the gain from the input to output divided by the gain from the supply to the output. The PSRR is found to be

$$PSRR = 20 \times \log\left(\frac{\Delta Gain\,Error}{\Delta Supply}\right)$$

Note that when heavy load measuring, Δsupply will cause Δtemperature. And Δtemperature will cause Δoutput voltage. So the heavy load PSRR measuring is include temperature effect.

### Current limit

The RT9013 contains an independent current limiter, which monitors and controls the pass transistor's gate voltage, limiting the output current to 0.6A (typ.). The output can be shorted to ground indefinitely without damaging the part.

### Thermal Considerations

Thermal protection limits power dissipation in RT9013. When the operation junction temperature exceeds 170°C, the OTP circuit starts the thermal shutdown function and turns the pass element off. The pass element turn on again after the junction temperature cools by 30°C.

For continuous operation, do not exceed absolute maximum operation junction temperature 125°C. The power dissipation definition in device is :

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT} + V_{IN} \times I_Q$$

The maximum power dissipation depends on the thermal resistance of IC package, PCB layout, the rate of surroundings airflow and temperature difference between junction to ambient. The maximum power dissipation can be calculated by following formula :

$P_{D(MAX)} = ( T_{J(MAX)} – T_A ) / \theta_{JA}$

Where $T_{J(MAX)}$ is the maximum operation junction temperature, $T_A$ is the ambient temperature and the $\theta_{JA}$ is the junction to ambient thermal resistance.

For recommended operating conditions specification of RT9013 the maximum junction temperature is 125°C and $T_A$ is the operated ambient temperature. The junction to ambient thermal resistance $\theta_{JA}$ ($\theta_{JA}$ is layout dependent) for WDFN-6L 2x2 package is 165°C/W, SOT-23-5 package is 250°C/W and SC-70-5/ SC-82 package is 333°C/W on the standard JEDEC 51-3 single-layer thermal test board. The maximum power dissipation at $T_A$ = 25°C can be calculated by following formula :

$P_{D(MAX)}$ = (125°C – 25°C) / 165°C/W = 0.606 W for WDFN-6L 2x2 packages

$P_{D(MAX)}$ = (125°C – 25°C) / 250°C/W = 0.400 W for SOT-23-5 packages

$P_{D(MAX)}$ = (125°C – 25°C) / 333°C/W = 0.300 W for SC-70-5/ SC-82 packages

The maximum power dissipation depends on operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance $\theta_{JA}$. For RT9013 package, the Figure 2 of derating curves allows the designer to see the effect of rising ambient temperature on the maximum power dissipation allowed.

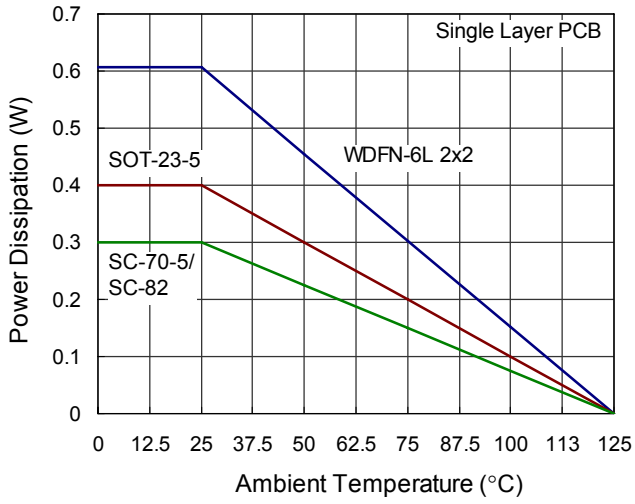
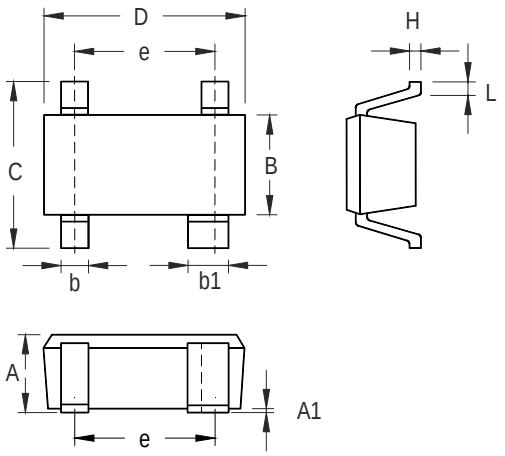


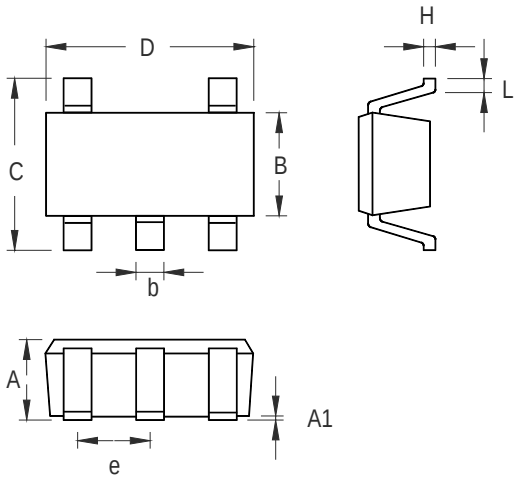

Figure 2. Derating Curves for RT9013 Packages

## Outline Dimension



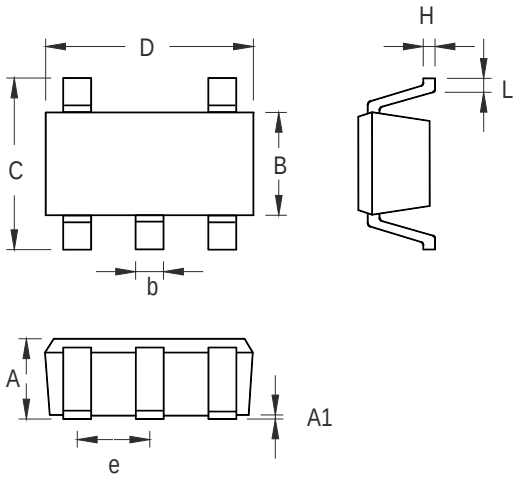

| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| A | 0.800 | 1.100 | 0.031 | 0.043 |
| A1 | 0.000 | 0.100 | 0.000 | 0.004 |
| B | 1.150 | 1.350 | 0.045 | 0.053 |
| b | 0.150 | 0.400 | 0.006 | 0.016 |
| b1 | 0.350 | 0.500 | 0.014 | 0.020 |
| C | 1.800 | 2.450 | 0.071 | 0.096 |
| D | 1.800 | 2.200 | 0.071 | 0.087 |
| e | 1.300 | | 0.051 | |
| H | 0.080 | 0.260 | 0.003 | 0.010 |
| L | 0.200 | 0.460 | 0.008 | 0.018 |

**SC-82 Surface Mount Package**



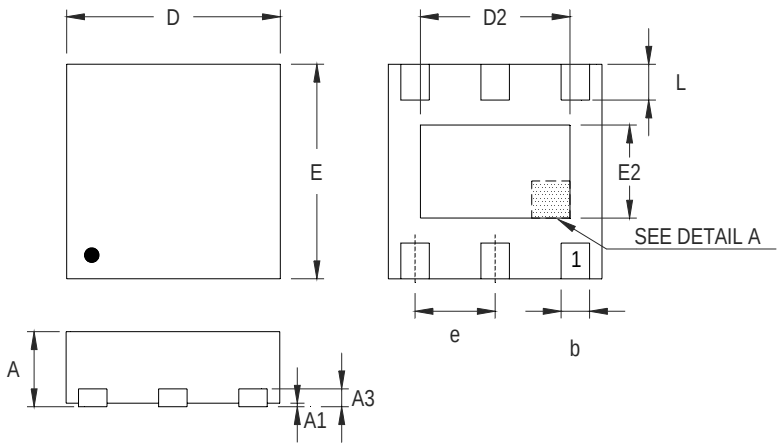

| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| A | 0.889 | 1.295 | 0.035 | 0.051 |
| A1 | 0.000 | 0.152 | 0.000 | 0.006 |
| B | 1.397 | 1.803 | 0.055 | 0.071 |
| b | 0.356 | 0.559 | 0.014 | 0.022 |
| C | 2.591 | 2.997 | 0.102 | 0.118 |
| D | 2.692 | 3.099 | 0.106 | 0.122 |
| e | 0.838 | 1.041 | 0.033 | 0.041 |
| H | 0.080 | 0.254 | 0.003 | 0.010 |
| L | 0.300 | 0.610 | 0.012 | 0.024 |

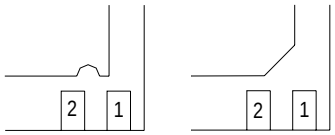
**SOT-23-5 Surface Mount Package**




| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| A | 0.800 | 1.100 | 0.031 | 0.044 |
| A1 | 0.000 | 0.100 | 0.000 | 0.004 |
| B | 1.150 | 1.350 | 0.045 | 0.054 |
| b | 0.150 | 0.400 | 0.006 | 0.016 |
| C | 1.800 | 2.450 | 0.071 | 0.096 |
| D | 1.800 | 2.250 | 0.071 | 0.089 |
| e | 0.650 | | 0.026 | |
| H | 0.080 | 0.260 | 0.003 | 0.010 |
| L | 0.210 | 0.460 | 0.008 | 0.018 |

**SC-70-5 Surface Mount Package**




**DETAIL A**

Pin #1 ID and Tie Bar Mark Options

Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| A | 0.700 | 0.800 | 0.028 | 0.031 |
| A1 | 0.000 | 0.050 | 0.000 | 0.002 |
| A3 | 0.175 | 0.250 | 0.007 | 0.010 |
| b | 0.200 | 0.350 | 0.008 | 0.014 |
| D | 1.950 | 2.050 | 0.077 | 0.081 |
| D2 | 1.000 | 1.450 | 0.039 | 0.057 |
| E | 1.950 | 2.050 | 0.077 | 0.081 |
| E2 | 0.500 | 0.850 | 0.020 | 0.033 |
| e | 0.650 | | 0.026 | |
| L | 0.300 | 0.400 | 0.012 | 0.016 |

**W-Type 6L DFN 2x2 Package**

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