

2A, 6.5V, Ultra-Low Noise, Ultra-Low Dropout Linear Regulator

1 General Description

The RTQ2538H is a high-current, low-noise, high accuracy, low-dropout linear regulator (LDO) capable of sourcing 2A with extremely low dropout (max. 90mV). The device supports single input supply voltage as low to 1.1V, enhancing its ease of use.

The low-noise, high PSRR and high output current capability makes the RTQ2538H ideal for powering noise-sensitive devices such as analog-to-digital converters (ADCs), digital-to-analog converters (DACs), and RF components. With very high accuracy, remote sensing, and soft-start capabilities to reduce inrush current, the RTQ2538H is suitable for powering digital loads such as FPGAs, DSPs, and ASICs.

The external enable control and power good indicator function make the control sequence easier. The output noise immunity is enhanced by adding external bypass capacitor on the NR/SS pin. The device is fully specified over the temperature range of $T_J = -40^{\circ}\text{C}$ to 125°C and is offered in the WQFN-12L 2.2x2.5 (FC).

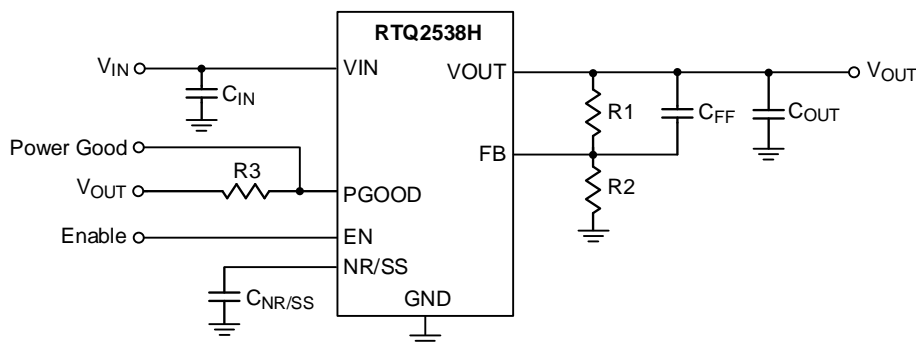
2 Features

- **Input Voltage Range: 1.1V to 6.5V**
- **Output Voltage Range: 0.8 V to 5.5V**
- **Accurate Output Voltage Accuracy (1%) Over Line, Load and Temperature**
- **Ultra-High PSRR: 43dB at 500kHz**
- **Excellent Noise Immunity**
 - ▶ **7.8 μVRMS at 0.8V Output**
 - ▶ **12.8 μVRMS at 5V Output**
- **Ultra-Low Dropout Voltage: 90mV Max. at 2A**
- **Enable Control**
- **Programmable Soft-Start Output**
- **Stable with a 47 μF or Larger Ceramic Output Capacitor**
- **Supports Power-Good Indicator Function**

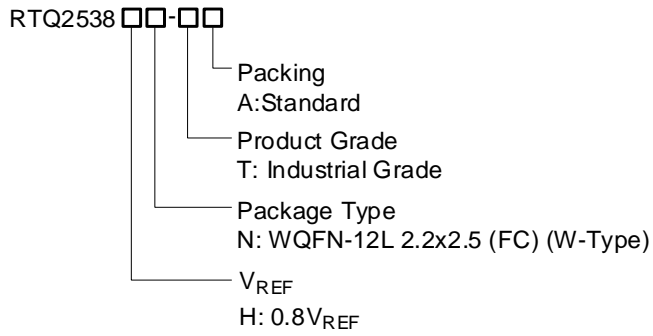
3 Applications

- Portable Electronic Devices
- Wireless Infrastructures: SerDes, FPGA, DSP
- RD, IF, Components: VCO, ADC, DAC, LVDS

4 Simplified Application Circuit



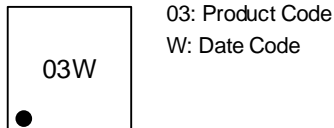
5 Ordering Information



Note:

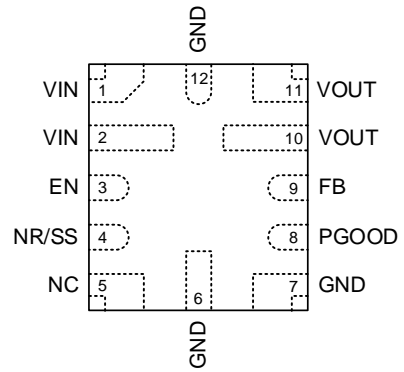
Richtek products are Richtek Green Policy compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.

6 Marking Information



7 Pin Configuration

(TOP VIEW)



WQFN-12L 2.2x2.5 (FC)

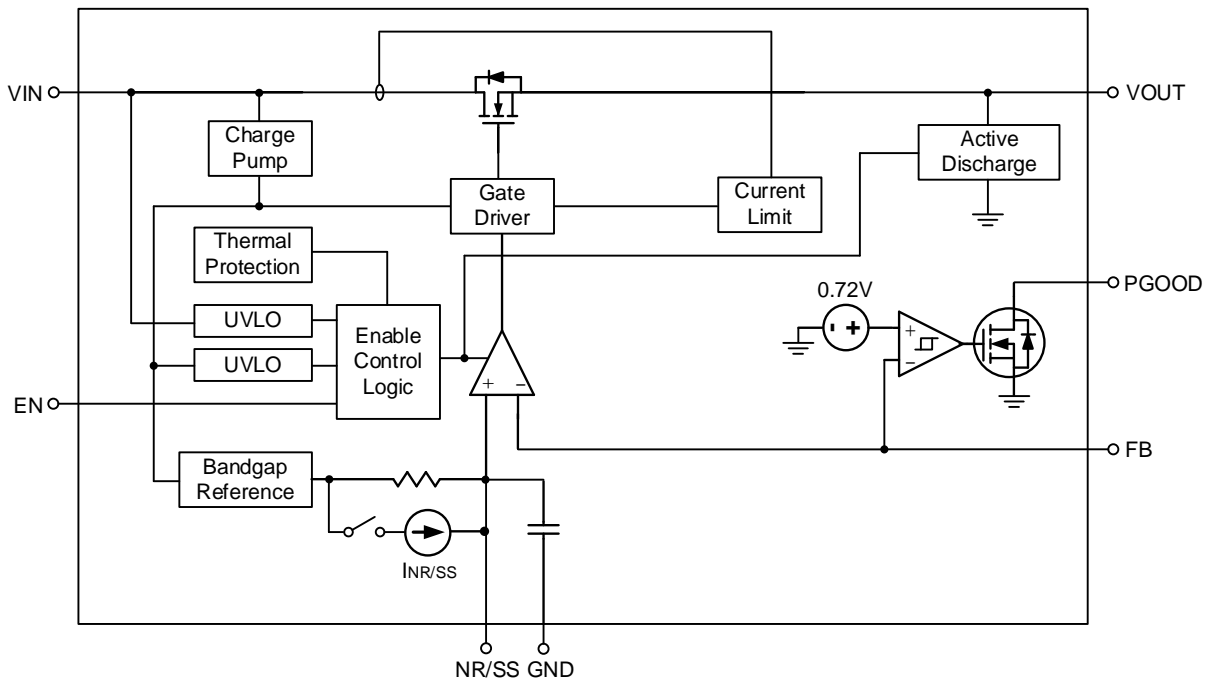
Table of Contents

| | | |
|-----------|---|-----------|
| 1 | General Description | 1 |
| 2 | Features | 1 |
| 3 | Applications | 1 |
| 4 | Simplified Application Circuit | 1 |
| 5 | Ordering Information | 2 |
| 6 | Marking Information | 2 |
| 7 | Pin Configuration | 2 |
| 8 | Functional Pin Description | 4 |
| 9 | Functional Block Diagram | 5 |
| 10 | Absolute Maximum Ratings | 6 |
| 11 | ESD Ratings | 6 |
| 12 | Recommended Operating Conditions | 6 |
| 13 | Thermal Information | 6 |
| 14 | Electrical Characteristics | 7 |
| 15 | Typical Application Circuit | 9 |
| 16 | Typical Operating Characteristics | 10 |
| 17 | Operation | 13 |
| 17.1 | Enable and Shutdown | 13 |
| 17.2 | Programmable Soft-Start | 13 |
| 17.3 | Power Good | 13 |
| 17.4 | Undervoltage Lockout (UVLO)..... | 13 |
| 17.5 | Internal Current Limit (I _{LIM}) | 13 |
| 17.6 | Over-Temperature Protection (OTP)..... | 14 |
| 17.7 | Output Active Discharge | 14 |
| 18 | Application Information | 15 |
| 18.1 | Output Voltage Setting | 15 |
| 18.2 | Dropout Voltage | 15 |
| 18.3 | C _{IN} and C _{OUT} Selection | 15 |
| 18.4 | Feed-Forward Capacitor (C _{FF})..... | 16 |
| 18.5 | Soft-Start and Noise Reduction (C _{NR/SS})..... | 16 |
| 18.6 | Input Inrush Current | 16 |
| 18.7 | Undervoltage Lockout (UVLO)..... | 16 |
| 18.8 | Power-Good (PGOOD) Function | 17 |
| 18.9 | Reverse Current Protection | 18 |
| 18.10 | Thermal Considerations | 18 |
| 18.11 | Layout Considerations | 20 |
| 19 | Outline Dimension | 21 |
| 20 | Footprint Information | 22 |
| 21 | Packing Information | 23 |
| 21.1 | Tape and Reel Data | 23 |
| 21.2 | Tape and Reel Packing | 24 |
| 21.3 | Packing Material Anti-ESD Property | 25 |
| 22 | Datasheet Revision History | 26 |

8 Functional Pin Description

| Pin No. | Pin Name | Pin Function |
|----------|----------|---|
| 1, 2 | VIN | Supply input. A general 47 μ F ceramic capacitor should be placed as close as possible to this pin for better noise rejection. |
| 3 | EN | Enable control input. Connecting this pin to logic high enables the regulator, and driving this pin low puts it into shutdown mode. The device can have V _{IN} and V _{EN} sequenced in any order without causing damage. However, to ensure that the soft-start function work as intended, certain sequencing rules must be applied. It is suggested to enable the device after V _{IN} is present. |
| 4 | NR/SS | Noise-reduction and soft-start pin. Decoupling this pin to GND with an external capacitor C _{NR/SS} not only reduces output noise to very low levels but also slows down the rising of V _{OUT} , resulting a soft-start behavior. For low-noise applications, a 10nF to 1 μ F C _{NR/SS} is suggested. |
| 5 | NC | No internal connection. Leaving these pins floating does not affect the functionality of the chip. By connecting this pin to GND, design engineers can extend the GND copper coverage on the PCB top layer to enhance the thermal convection. |
| 6, 7, 12 | GND | Ground. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation. |
| 8 | PGOOD | Power good indicator output. This pin is an open-drain output and is active high when the output voltage reaches 88% of the target. The pin is pulled to ground when the output voltage is lower than its specified thresholds, including EN shutdown, OCP and OTP. |
| 9 | FB | Feedback voltage input. This pin is used to set the desired output voltage via an external resistive divider. The feedback reference voltage is 0.8V, typically. |
| 10, 11 | VOUT | LDO output pins. A 47 μ F or larger ceramic capacitor (22 μ F or greater effective capacitance) is required for stability. Place the output capacitor as close to the device as possible and minimize the impedance between the V _{OUT} pin and load. |

9 Functional Block Diagram



10 Absolute Maximum Ratings

(Note 1)

- VIN, PGOOD, EN ----- -0.3V to 7V
- VOUT ----- -0.3V to 7V
- NR/SS, FB ----- -0.3V to 3.6V
- Lead Temperature (Soldering, 10 sec.) ----- 260°C
- Junction Temperature ----- 150°C
- Storage Temperature Range ----- -65°C to 150°C

11 ESD Ratings

(Note 2)

- ESD Susceptibility
- HBM (Human Body Model) ----- 2kV

12 Recommended Operating Conditions

(Note 3)

- Supply Input Voltage ----- 1.1V to 6.5V
- Junction Temperature Range ----- -40°C to 125°C

13 Thermal Information

(Note 4 and Note 5)

| Thermal Parameter | | WQFN-12L 2.2x2.5 (FC) | Unit |
|-----------------------|---|-----------------------|------|
| θ_{JA} | Junction-to-ambient thermal resistance (JEDEC standard) | 54.8 | °C/W |
| $\theta_{JC(Top)}$ | Junction-to-case (top) thermal resistance | 53 | °C/W |
| $\theta_{JC(Bottom)}$ | Junction-to-case (bottom) thermal resistance | 16.1 | °C/W |
| $\theta_{JA(EVB)}$ | Junction-to-ambient thermal resistance (specific EVB) | 49.7 | °C/W |
| $\Psi_{JC(Top)}$ | Junction-to-top characterization parameter | 1.7 | °C/W |
| Ψ_{JB} | Junction-to-board characterization parameter | 27.2 | °C/W |

14 Electrical Characteristics

Over operating temperature range ($T_J = -40^{\circ}\text{C}$ to 125°C), ($1.1\text{V} \leq V_{IN} \leq 6.5\text{V}$ and $V_{IN} \geq V_{OUT(\text{TARGET})} + 0.3\text{V}$, $V_{OUT(\text{TARGET})} = 0.8\text{V}$, V_{OUT} connected to 50Ω to GND, $V_{EN} = 1.1\text{V}$, $C_{IN} = 10\mu\text{F}$, $C_{OUT} = 47\mu\text{F}$, $C_{NR/SS} = 0\text{nF}$, $C_{FF} = 0\text{nF}$, and PGOOD pin pulled up to V_{IN} with $100\text{k}\Omega$ unless otherwise noted. (Note 6)

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|------------------------------------|-------------------|---|-----------------------|------------------------|-----------------------|---------------|
| Operating Input Voltage Range | V_{IN} | | 1.1 | -- | 6.5 | V |
| Feedback Reference Voltage | V_{REF} | | -- | 0.8 | -- | V |
| NR/SS Pin Voltage | $V_{NR/SS}$ | | -- | 0.8 | -- | V |
| Undervoltage Lockout | V_{UVLO} | V_{IN} increasing | -- | 1.02 | 1.085 | V |
| | ΔV_{UVLO} | Hysteresis | -- | 100 | -- | mV |
| Output Voltage Range | | Using external resistors | 0.8 | -- | 5.5 | V |
| Output Voltage Accuracy (Note 7) | V_{OUT} | $V_{IN} = V_{OUT} + 0.3\text{V}$, $0.8\text{V} \leq V_{OUT} \leq 5.5\text{V}$, $1\text{mA} \leq I_{OUT} \leq 2\text{A}$ | -1 | -- | 1 | % |
| Line Regulation | V_{LINE_REG} | $I_{OUT} = 1\text{mA}$, $1.1\text{V} \leq V_{IN} \leq 6.5\text{V}$ | -- | 0.05 | -- | %/V |
| Load Regulation | V_{LOAD_REG} | $1\text{mA} \leq I_{OUT} \leq 2\text{A}$ | -- | 0.08 | -- | %/A |
| Dropout Voltage | V_{DROP} | $V_{IN} = 1.1\text{V}$ to 6.5V , $I_{OUT} = 2\text{A}$, $V_{FB} = 0.8\text{V} - 3\%$ | -- | 34 | 90 | mV |
| Output Current Limit | I_{LIM} | $V_{OUT} = 90\%V_{OUT(\text{TARGET})}$, $V_{IN} = V_{OUT(\text{TARGET})} + 400\text{mV}$ | 2.2 | 3.3 | 3.8 | A |
| Short-Circuit Current Limit | I_{SC} | $R_{LOAD} = 20\text{m}\Omega$, under foldback operation | -- | 1 | -- | A |
| Ground Pin Current | I_{GND} | Minimum load, $V_{IN} = 6.5\text{V}$, $I_{OUT} = 5\text{mA}$ | -- | 2.8 | 4 | mA |
| | | Maximum load, $V_{IN} = 1.4\text{V}$, $I_{OUT} = 2\text{A}$ | -- | 3.7 | 5.5 | mA |
| | | Shutdown, PGOOD = Open, $V_{IN} = 6.5\text{V}$, $V_{EN} = 0.5\text{V}$ | -- | -- | 25 | μA |
| EN Pin Current | I_{EN} | $V_{IN} = 6.5\text{V}$, $V_{EN} = 0\text{V}$ and 6.5V | -0.1 | -- | 0.1 | μA |
| EN Pin High-Level Input Voltage | V_{EN_H} | Enable device | 1.1 | -- | 6.5 | V |
| EN Pin Low-Level Input Voltage | V_{EN_L} | Disable device | 0 | -- | 0.5 | V |
| PGOOD Pin Threshold | V_{IT_PGOOD} | For the direction of PGOOD signal falling with decreasing V_{OUT} | $0.82 \times V_{OUT}$ | $0.883 \times V_{OUT}$ | $0.93 \times V_{OUT}$ | V |
| PGOOD Pin Hysteresis | V_{PGOOD_HYS} | For PGOOD signal rising | -- | $2\% \times V_{OUT}$ | -- | V |
| PGOOD Pin Low-Level Output Voltage | V_{PGOOD_L} | $V_{OUT} < V_{IT_PGOOD}$, $I_{PGOOD} = -1\text{mA}$ (current into device) | -- | -- | 0.4 | V |
| PGOOD Pin Leakage Current | I_{PGOOD_LK} | $V_{OUT} > V_{IT_PGOOD}$, $V_{PGOOD} = 6.5\text{V}$ | -- | -- | 1 | μA |
| NR/SS Pin Charging Current | $I_{NR/SS}$ | $V_{NR/SS} = \text{GND}$, $V_{IN} = 6.5\text{V}$ | 4 | -- | 9 | μA |

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit | |
|------------------------------|-----------------|---|--|------|-----|-------|----|
| FB Pin Leakage Current | I _{FB} | V _{IN} = 6.5V | -100 | -- | 100 | nA | |
| Power Supply Rejection Ratio | PSRR | V _{IN} – V _{OUT} = 0.4V, I _{OUT} = 2A, C _{NR/SS} = 100nF, C _{FF} = 10nF, C _{OUT} = 47μF//10μF//10μF | f = 10kHz, V _{OUT} = 0.8V | -- | 47 | -- | dB |
| | | | f = 500kHz, V _{OUT} = 0.8V | -- | 43 | -- | |
| | | | f = 10kHz, V _{OUT} = 5V | -- | 48 | -- | |
| | | | f = 500kHz, V _{OUT} T = 5V | -- | 35 | -- | |
| Output Noise Voltage | e _{NO} | BW = 10Hz to 100kHz, V _{IN} = 1.1V, V _{OUT} = 0.8V, I _{OUT} = 2A, C _{NR/SS} = 100nF, C _{FF} = 10nF, C _{OUT} = 47μF//10μF//10μF | -- | 7.8 | -- | μVRMS | |
| | | BW = 10Hz to 100kHz, V _{OUT} = 5V, I _{OUT} = 2A, C _{NR/SS} = 100nF, C _{FF} = 10nF, C _{OUT} = 47μF//10μF//10μF | -- | 12.8 | -- | | |
| Thermal Shutdown Threshold | T _{SD} | Temperature increasing | -- | 160 | -- | °C | |
| | | Temperature decreasing | -- | 140 | -- | | |

Note 1. 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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

Note 2. Devices are ESD sensitive. Handling precautions are recommended.

Note 3. The device is not guaranteed to function outside its operating conditions.

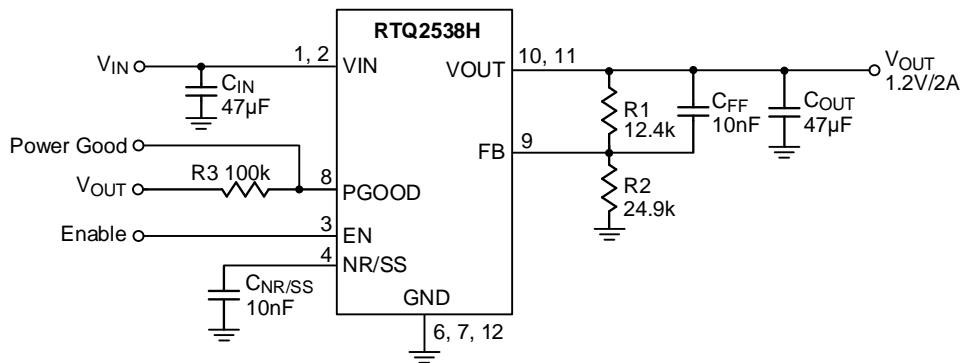
Note 4. For more information about thermal parameter, see the Application and Definition of Thermal Resistances report, [AN061](#).

Note 5. θ_{JA(EVB)}, Ψ_{JC(Top)} and Ψ_{JB} are measured on a high effective-thermal-conductivity four-layer test board which is in size of 70mm x 50mm; furthermore, all layers with 1 oz. Cu. Thermal resistance/parameter values may vary depending on the PCB material, layout, and test environmental conditions.

Note 6. V_{OUT(TARGET)} is the expected V_{OUT} value set by the external feedback resistors. The 50Ω load is disconnected when the test conditions specify an I_{OUT} value.

Note 7. External resistor tolerance is not taken into consideration.

15 Typical Application Circuit



$$V_{OUT} = V_{REF} \times \left(1 + \frac{R1}{R2}\right) = 0.8V \times \left(1 + \frac{12.4k}{24.9k}\right) = 1.2V$$

Figure 1. Configuration Circuit for V_{OUT} Adjusted by a Resistor Divider.

Table 1. Recommended Feedback-Resistor Values

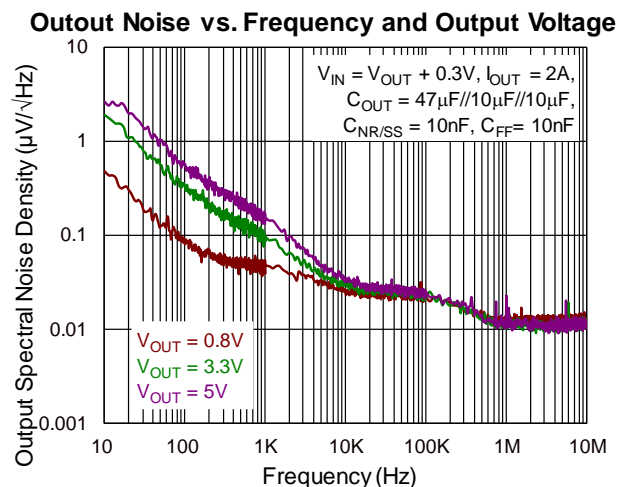
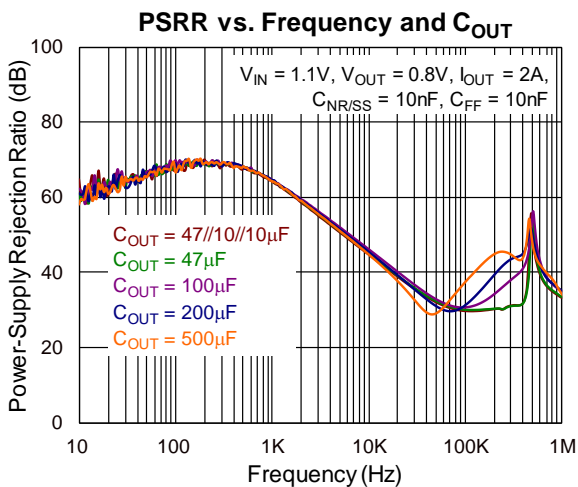
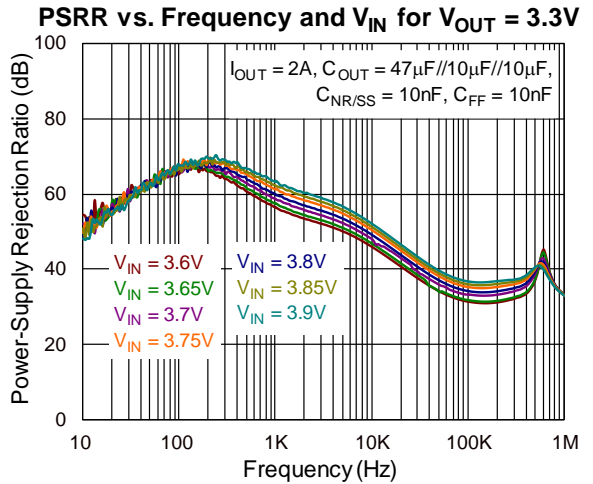
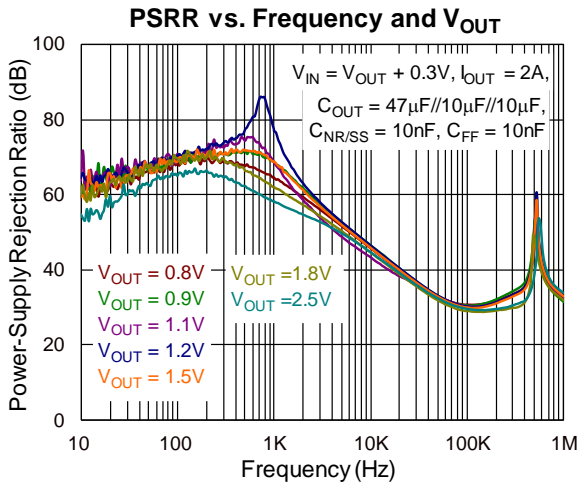
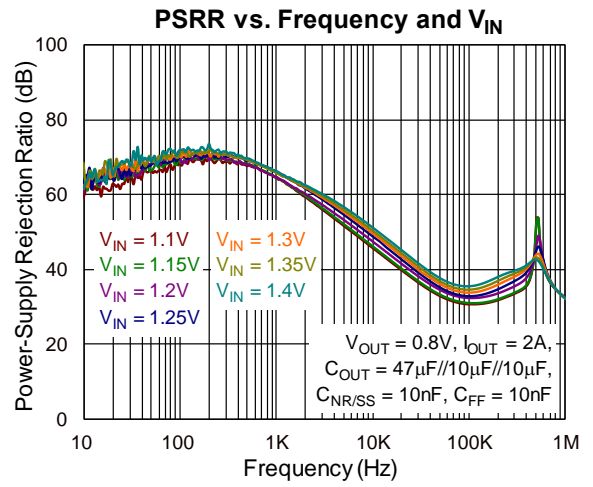
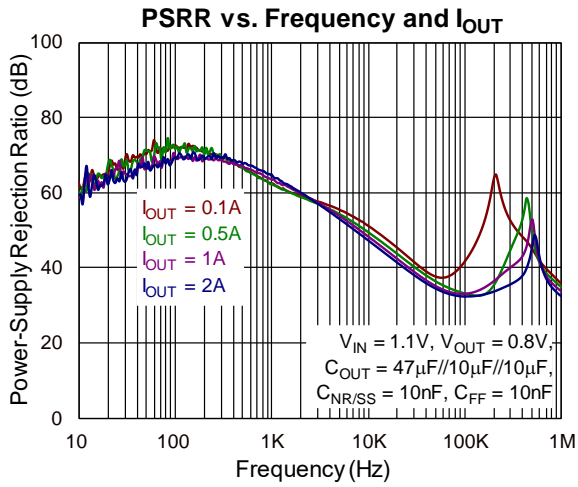
| Output Voltage (V) | External Resistor Divider Combination | |
|--------------------|---------------------------------------|--------|
| | R1(kΩ) | R2(kΩ) |
| 0.9 | 12.4 | 100 |
| 1 | 12.4 | 49.9 |
| 1.2 | 12.4 | 24.9 |
| 1.5 | 12.4 | 14.3 |
| 1.8 | 12.4 | 10 |
| 2.5 | 12.4 | 5.9 |
| 3.3 | 11.8 | 3.74 |
| 4.5 | 11.8 | 2.55 |
| 5 | 12.4 | 2.37 |

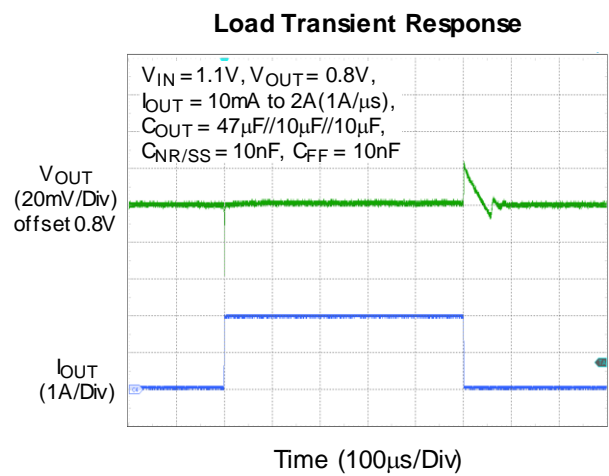
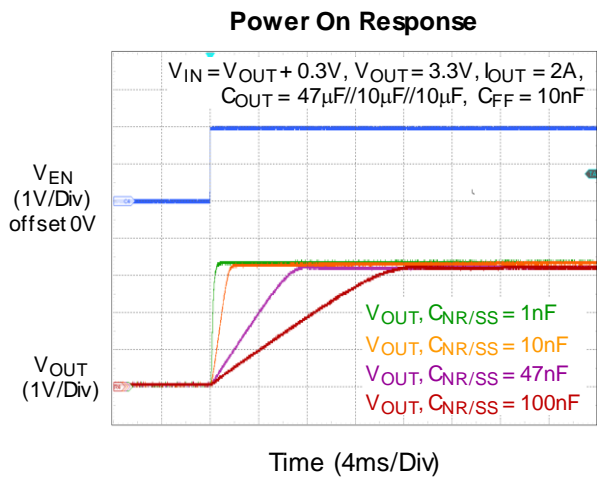
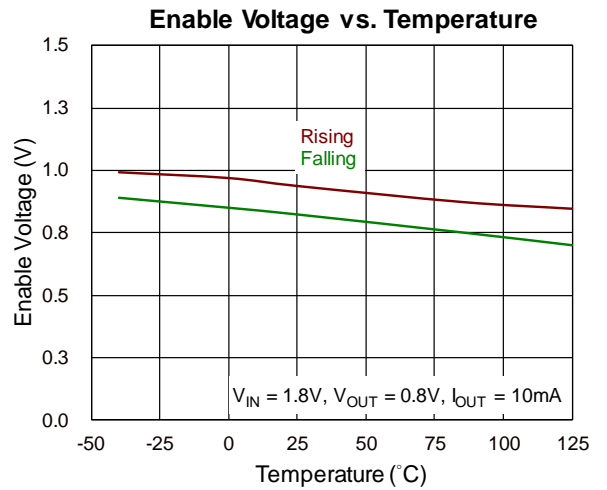
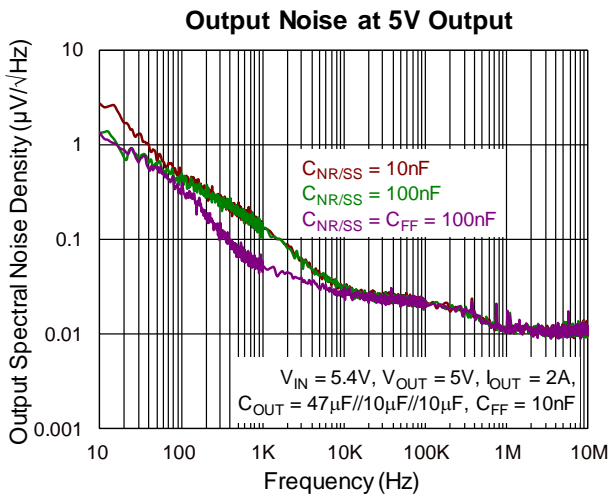
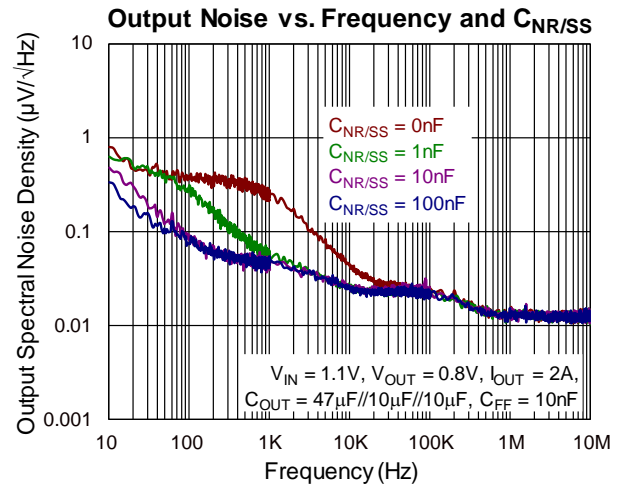
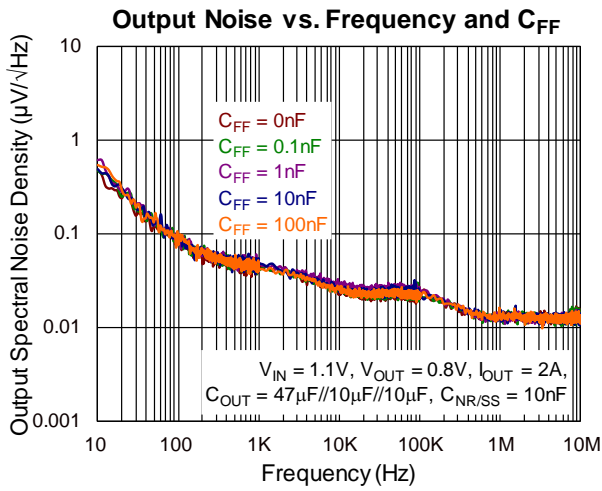
Table 2. Recommended External Components

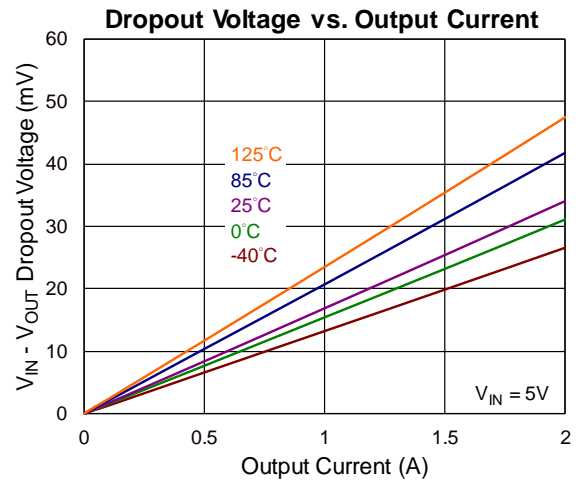
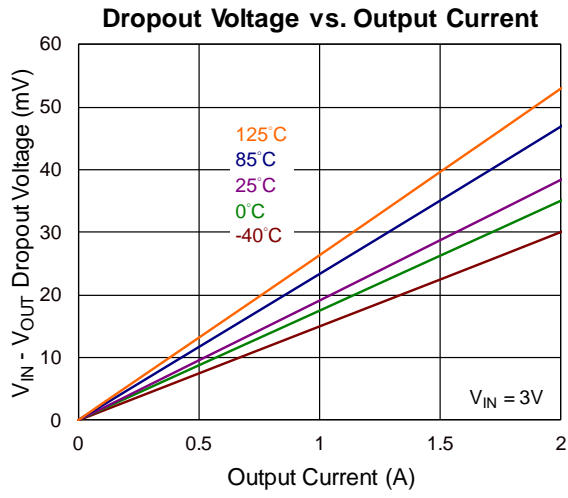
| Component | Description | Vendor P/N |
|--------------------------------------|----------------------|-----------------------------|
| C _{FF} , C _{NR/SS} | 10nF, 50V, X7R, 0603 | GRM033R71E103KE14 (Murata) |
| C _{IN} , *C _{OUT} | 47µF, 16V, X6S, 1210 | GRT32EC81C476KE13L (Murata) |

*: Considering the effective capacitance de-rated with biased voltage level, the C_{OUT} component needs to satisfy the effective capacitance at least 22µF or above at targeted output level for stable and normal operation.

16 Typical Operating Characteristics







17 Operation

The RTQ2538H operates with single supply input ranging from 1.1V to 6.5V and is capable of delivering up to 2A current to the output. The device features high PSRR and low noise to provide a clean supply to the application.

A low-noise reference and error amplifier are included to reduce device noise. The NR/SS capacitor filters the noise from the reference, and the feed-forward capacitor filters the noise from the error amplifier. The high power-supply rejection ratio (PSRR) of the RTQ2538H minimizes the coupling of input supply noise to the output.

17.1 Enable and Shutdown

The RTQ2538H provides an EN pin, as an external chip enable control, to enable or disable the device. V_{EN} below 0.5V turns the regulator off and enters the shutdown mode, while V_{EN} above 1.1V turns the regulator on. When the regulator is shut down, the ground current is reduced to a maximum of 25 μ A. The enable circuitry has hysteresis (typically 50mV) for use with relatively slowly ramping analog signals.

If not used, connect the EN pin as close as possible to the largest capacitance on the input to prevent voltage droops on the VIN line from triggering the enable circuit.

17.2 Programmable Soft-Start

The noise-reduction capacitor ($C_{NR/SS}$) reduces noise and programs the soft-start ramp time during turn-on. When EN and UVLO exceed the respective threshold voltage, the RTQ2538H activates a quick-start circuit to charge the noise reduction capacitor ($C_{NR/SS}$) and then the output voltage ramps up.

17.3 Power Good

The power-good circuit monitors the feedback pin voltage to indicate the status of the output voltage. The open-drain PGOOD pin requires an external pull-up resistor to an external supply, and any downstream device can receive power-good as a logic signal to be used for sequencing. A pull-up resistor from 10k Ω to 100k Ω is recommended. Make sure that the external pull-up supply voltage results in a valid logic signal for the receiving devices.

After start-up, the PGOOD pin becomes high impedance when the feedback voltage exceeds V_{PGOOD_HYS} (typically 90% of 0.8V reference voltage level). The PGOOD is pulled to GND when the feedback pin voltage falls below the V_{IT_PGOOD} . When EN is low, the current limit or OTP levels are reached.

17.4 Undervoltage Lockout (UVLO)

The UVLO circuit monitors the input voltage to prevent the device from turning on before V_{IN} rises above the V_{UVLO} threshold. The UVLO circuit also disables the output of the device when V_{IN} falls below the lockout voltage ($V_{UVLO} - \Delta V_{UVLO}$). The UVLO circuit responds quickly to the glitches on VIN and attempts to disable the output of the device if VIN collapses.

17.5 Internal Current Limit (I_{LIM})

The RTQ2538H continuously monitors the output current to protect the device against high load current faults or short events. The current limit circuitry is not intended to allow operation above the rated current of the device. Continuously running the RTQ2538H above the rated current degrades the reliability of the device.

During current limit, the output voltage falls when load impedance decreases. If the output voltage is low, excessive power may cause the output thermal shutdown.

A foldback feature limits the short-circuit current to protect the regulator from damage under all load conditions. If the load current demand exceeds the foldback current limit before EN goes high, the device does not turn on.

17.6 Over-Temperature Protection (OTP)

The RTQ2538H implements thermal shutdown protection. The device is disabled when the junction temperature (T_J) exceeds 160°C (typical). The LDO automatically turns on again when the temperature falls below 140°C (typical).

For reliable operation, limit the junction temperature to a maximum of 125°C. Continuously running the RTQ2538H into thermal shutdown or above a junction temperature of 125°C reduces long-term reliability.

17.7 Output Active Discharge

When the device is disabled, the RTQ2538H discharges the LDO output (via VOUT pins) through an internal current sink to ground. Do not rely on the active discharge circuit for discharging a large amount of output capacitance after the input supply collapses because reverse current can possibly flow from the output to the input. External current protection should be added if the device works at reverse voltage state.

18 Application Information

Richtek's component specification does not include the following information in the Application Information section. Thereby no warranty is given regarding its validity and accuracy. Customers should take responsibility to verify their own designs and reserve suitable design margin to ensure the functional suitability of their components and systems.

The RTQ2538H is a high-current, low-noise, high-accuracy, low-dropout linear regulator capable of sourcing 2A with maximum dropout of 90mV. The input voltage operating range is 1.1V to 6.5V, and the adjustable output voltage is 0.8V to 5.5V according to the external resistor setting to obtain the required output target.

18.1 Output Voltage Setting

The output voltage of the RTQ2538H can be set by external resistors to achieve different output targets.

By using external resistors, the output voltage is determined by the values of R1 and R2 as shown in Figure 2. The values of R1 and R2 can be calculated for any voltage value using the following formula:

$$V_{OUT} = 0.8 \times \frac{R1 + R2}{R2}$$

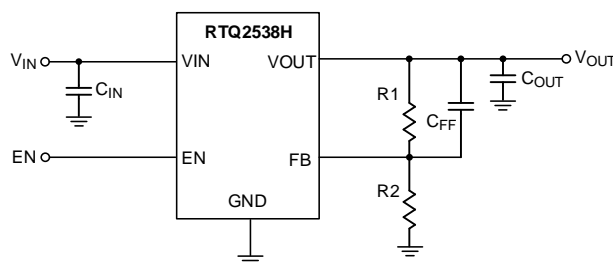


Figure 2. Output Voltage Set by External Resistors

18.2 Dropout Voltage

The dropout voltage refers to the voltage difference between the VIN and VOUT pins while operating at a specific output current. The dropout voltage V_{DROP} can also be expressed as the voltage drop on the pass-FET at a specific output current (I_{RATED}). This is when the pass-FET is fully operating in the ohmic region, where the pass-FET can be characterized as a resistance $R_{DS(ON)}$. Thus, the dropout voltage can be defined as ($V_{DROP} = V_{IN} - V_{OUT} = R_{DS(ON)} \times I_{RATED}$).

For normal operation, the suggested LDO operating range is $V_{IN} > V_{OUT} + V_{DROP}$ for good transient response and PSRR performance. However, operation in the ohmic region will degrade the performance severely.

18.3 CIN and COUT Selection

The RTQ2538H is designed to support low equivalent-series-resistance (ESR) ceramic capacitors. X7R, X5R, and COG rated ceramic capacitors are recommended due to its good capacitive stability across different temperatures, whereas the use of Y5V-rated capacitors is not recommended because of large capacitance variations.

However, the capacitance of ceramic capacitors varies with operating voltages and temperatures, and design engineers must be aware of these characteristics. Ceramic capacitors are usually recommended to be de-rated by 50%. A 47 μ F or greater output ceramic capacitor (or 22 μ F effective capacitance) is suggested to ensure stability. Input capacitance is selected to minimize transient input drop during load current steps. For general applications, an input capacitor of at least 47 μ F is highly recommended for minimal input impedance. If the trace inductance between the RTQ2538H input pin and power supply is high, a fast load transient can cause VIN voltage level ringing above

the absolute maximum voltage rating which damages the device. Adding more input capacitors can help restrict the ringing and keep it below the device absolute maximum ratings.

Generally, a 47 μ F 1210-sized ceramic capacitor in parallel with two 10 μ F 0805-sized ceramic capacitor ensure the minimum effective capacitance at high input voltage and high output voltage requirement. Place these capacitors as close to the pins as possible for optimum performance and to ensure stability.

18.4 Feed-Forward Capacitor (CFF)

The RTQ2538H is designed to be stable without the external feed-forward capacitor (CFF). However, a 10nF external feed-forward capacitor optimizes the transient, noise, and PSRR performances. A higher capacitance of CFF can also be used, but the start-up time will be longer and the power-good signal will incorrectly indicate that the output voltage is settled.

18.5 Soft-Start and Noise Reduction (CNR/SS)

The RTQ2538H is designed for a programmable, monotonic soft-start time during the output rising, which can be achieved via an external capacitor (CNR/SS) on the NR/SS pin. Using an external CNR/SS is recommended for general applications; it is not only for the in-rush current minimization but also to help reduce the noise component from the internal reference.

During the monotonic start-up procedure, the error amplifier of the RTQ2538H tracks the voltage ramp of the external soft-start capacitor (CNR/SS) until the voltage approaches the internal reference 0.8V. The soft-start ramp time can be calculated with Equation (a1), which depends on the soft-start charging current (I_{NR/SS}), the soft-start capacitance (C_{NR/SS}), and the internal reference 0.8V (V_{REF}).

$$t_{SS} = \frac{(V_{REF} \times C_{NR/SS})}{I_{NR/SS}} \quad (a1)$$

For noise-reduction, CNR/SS in conjunction with an internal noise-reduction resistor forms a low-pass filter (LPF) and filters out the noise from the internal bandgap reference before being amplified via the error amplifier, thus reducing the total device noise floor.

18.6 Input Inrush Current

During start-up, the input Inrush current into the VIN pin consists of the sum of load current and the charging current of the output capacitor. The inrush current is difficult to measure because the input capacitor must be removed, which is not recommended. Generally, the soft-start inrush current can be estimated by Equation (b1), where V_{OUT}(t) is the instantaneous output voltage of the power-on ramp, dV_{OUT}(t)/dt is the slope of the V_{OUT} ramp, and R_{LOAD} is the resistive load impedance.

$$I_{OUT}(t) = \frac{(C_{OUT} \times dV_{OUT}(t))}{dt} + \left(\frac{V_{OUT}(t)}{R_{LOAD}} \right) \quad (b1)$$

18.7 Undervoltage Lockout (UVLO)

The Undervoltage Lockout (UVLO) threshold is the minimum input operational voltage range that ensures the device stays disabled. Figure 3 shows that the UVLO circuits are triggered between three different input voltage events (duration a, b and c), assuming V_{EN} \geq V_{EN_H} all the time. For duration “a”, the input voltage starts rising. When VIN is over the UVLO rising threshold, V_{OUT} starts the power-on process. Then when V_{OUT} reaches the target level, it is under regulation. During “b”, although the power line has a voltage drop, it does not drop below the UVLO low threshold (falling threshold). As a result, the device maintains normal operation, and V_{OUT} is still regulated. At duration “c”, VIN drops below the UVLO falling threshold, so the control loop is disabled and there is no regulation.

Meanwhile, V_{OUT} drops. For general applications, instant power line transient with long power trace at the V_{IN} pin may have V_{IN} level unstable and force a trap as shown in duration “c”, which makes V_{OUT} collapse. In this case, adding more input capacitance or improving input trace layout on PCB are effective to improve input power stabilization.

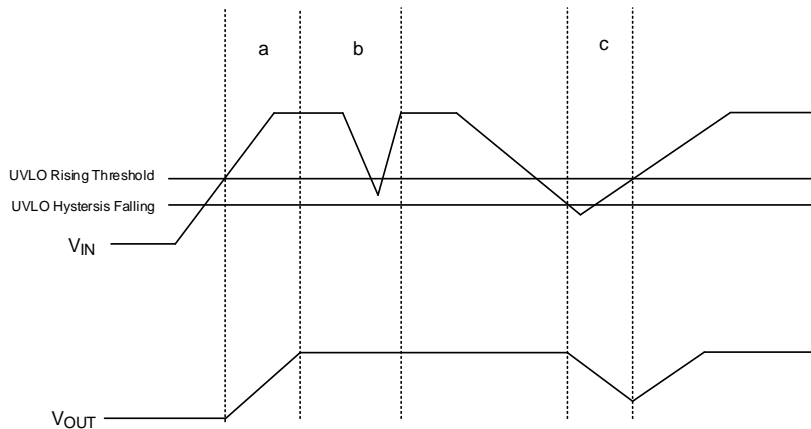


Figure 3. Undervoltage Lockout Trigger Conditions and Output Variation

18.8 Power-Good (PGOOD) Function

The power-good function monitors the voltage level at the feedback pin to indicate whether the output voltage status is normal or not. This function enables other devices to receive the RTQ2538H's power-good signal as a logic signal that can be used for the sequence design of the system application. The PGOOD pin is an open-drain structure and an external pull-up resistor connected to an external supply is necessary. The pull-up resistor value between 10kΩ to 100kΩ is recommended for proper operation. The lower limit of 10kΩ results from the maximum pull-down strength of the power-good transistor, and the upper limit of 100kΩ results from the maximum leakage current at the power-good node.

Figure 4 demonstrates different PGOOD scenarios versus V_{IN} , V_{EN} and protection status. During “a”, V_{EN} is higher than the V_{EN_H} threshold, and the device is under operation. In this period, V_{OUT} starts rising (the rising time is related to the soft-start capacitor $C_{NR/SS}$). When V_{OUT} is over the PGOOD hysteresis threshold, the reflected feedback voltage V_{FB} exceeds V_{PGOOD_HYS} threshold. Consequently, the PGOOD pin becomes a high impedance node. The duration “b” indicates some unpredictable operation (e.g., OTP, OCP or severe output voltage drop caused by very fast load variation). When V_{FB} is lower than the V_{IT_PGOOD} threshold, V_{PGOOD} is pulled to GND, which indicates that the output voltage is not ready. In duration “c”, V_{OUT} has a small drop which is not lower than the PGOOD falling threshold; the PGOOD pin remains in high impedance. After V_{EN} becomes logic “0”, V_{PGOOD} is pulled to GND as shown in duration “d”.

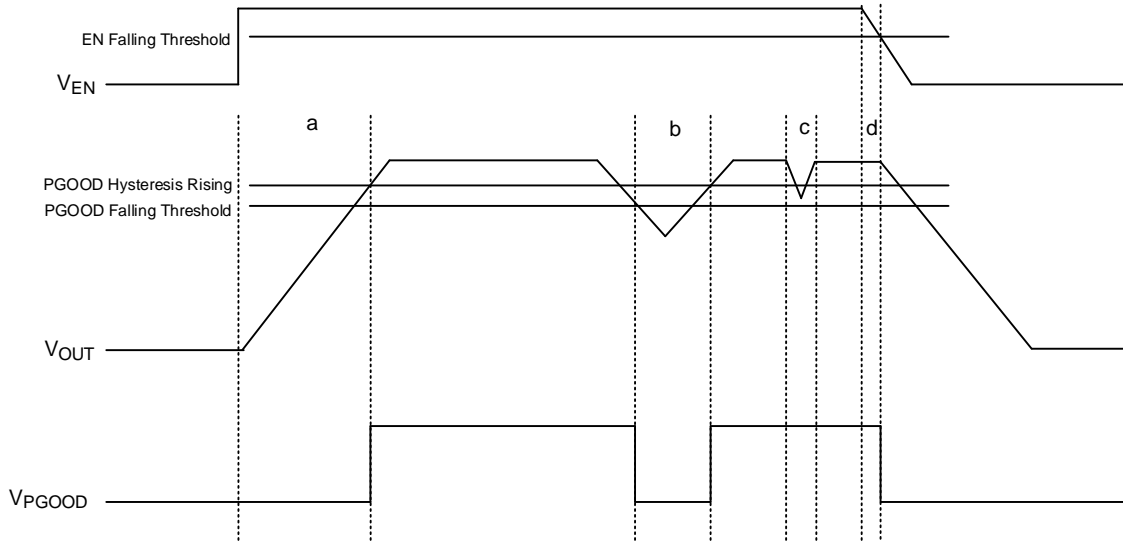


Figure 4. PGOOD Trigger Scenarios with Different Operating Status

18.9 Reverse Current Protection

The reverse current from V_{OUT} to V_{IN} that flows through the body diode of the pass element instead of the normal conducting channel can happen if the maximum V_{OUT} exceeds V_{IN} + 0.3V; in this case, the pass element may be damaged.

Such situation can arise if the output is biased above the input supply voltage level or the input supply has an instant drop at light load operation that makes V_{IN} < V_{OUT}. As shown in Figure 5, an external Schottky diode can be added to prevent the pass element from being damaged by the reverse current.

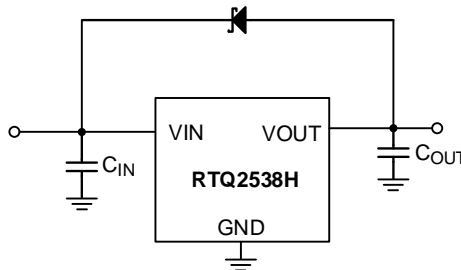


Figure 5. Application Circuit for Reverse Current Protection

18.10 Thermal Considerations

The junction temperature should never exceed the absolute maximum junction temperature T_{J(MAX)}, listed under Absolute Maximum Ratings, to avoid permanent damage to the device. The maximum allowable power dissipation depends on the thermal resistance of the IC package, the PCB layout, the rate of surrounding airflow, and the difference between the junction and ambient temperatures. The maximum power dissipation can be calculated using the following formula:

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

where T_{J(MAX)} is the maximum junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction-to-ambient thermal resistance.

For continuous operation, the maximum operating junction temperature indicated under Recommended Operating Conditions is 125°C. The junction-to-ambient thermal resistance, $\theta_{JA(EVB)}$, is highly package dependent. For a WQFN-12L 2.2x2.5 (FC) package, the thermal resistance, $\theta_{JA(EVB)}$, is 49.7°C/W on a standard high effective-

thermal- conductivity four-layer test board.

The maximum power dissipation at $T_A = 25^\circ\text{C}$ can be calculated as below:

$$P_{D(\text{MAX})} = (125^\circ\text{C} - 25^\circ\text{C}) / (49.7^\circ\text{C}/\text{W}) = 2.01\text{W for a WQFN-12L 2.2x2.5 (FC) package.}$$

The maximum power dissipation depends on the operating ambient temperature for the fixed $T_{J(\text{MAX})}$ and the thermal resistance, $\theta_{JA \text{ EVB}}$. The derating curves in Figure 6 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

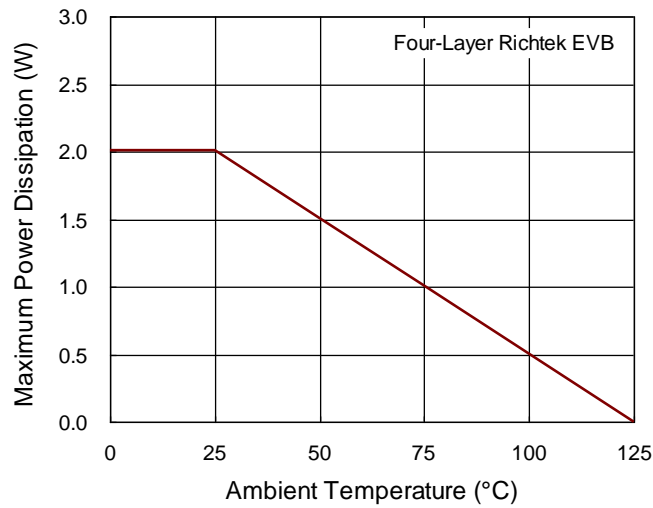


Figure 6. Derating Curve of Maximum Power Dissipation

18.11 Layout Considerations

For best performance of the RTQ2538H, it is recommended to follow the PCB layout suggestions below.

1. All circuit components should be placed on the same side and as close to the respective LDO pin as possible.
2. Place the ground return path connection to the input and output capacitors.
3. Connect the ground plane with a wide copper surface for good thermal dissipation.
4. Using vias and long power traces for the input and output capacitor connections is not recommended and has negative effects on performance.
5. Figure 7 shows a layout example that reduces conduction trace loops, helping to minimize inductive parasitic and load transient effects while improving the circuit stability.

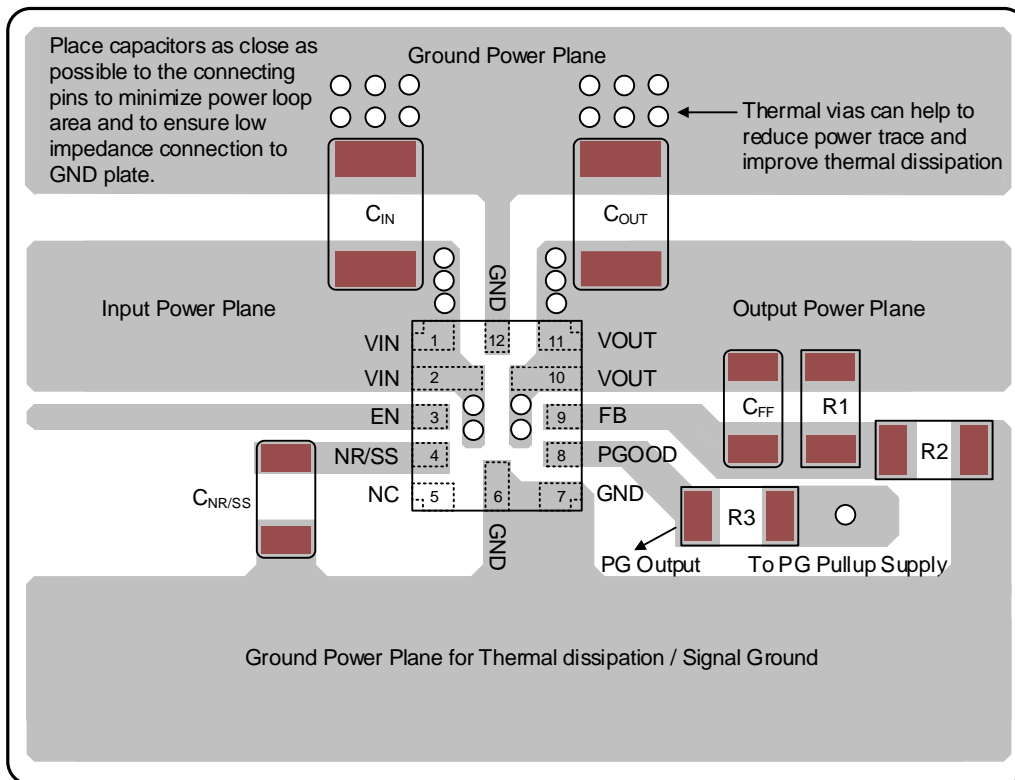
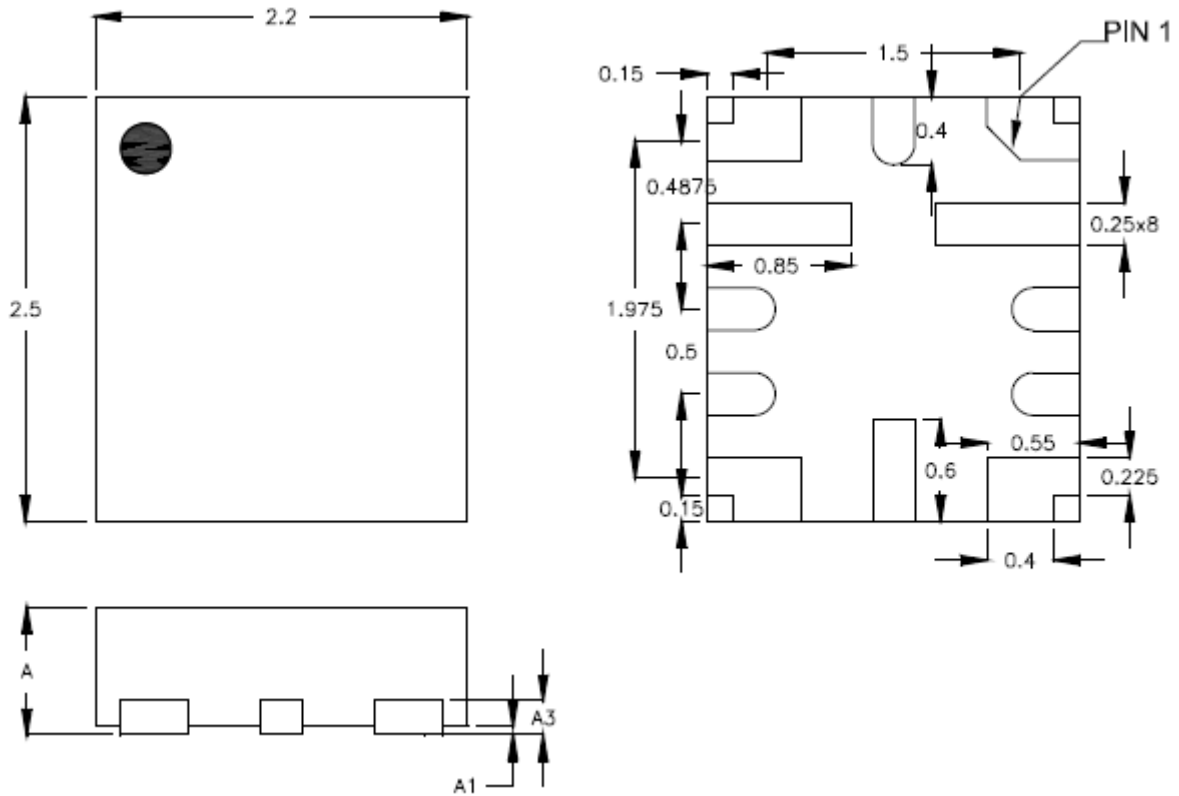


Figure 7. PCB Layout Guide

19 Outline Dimension

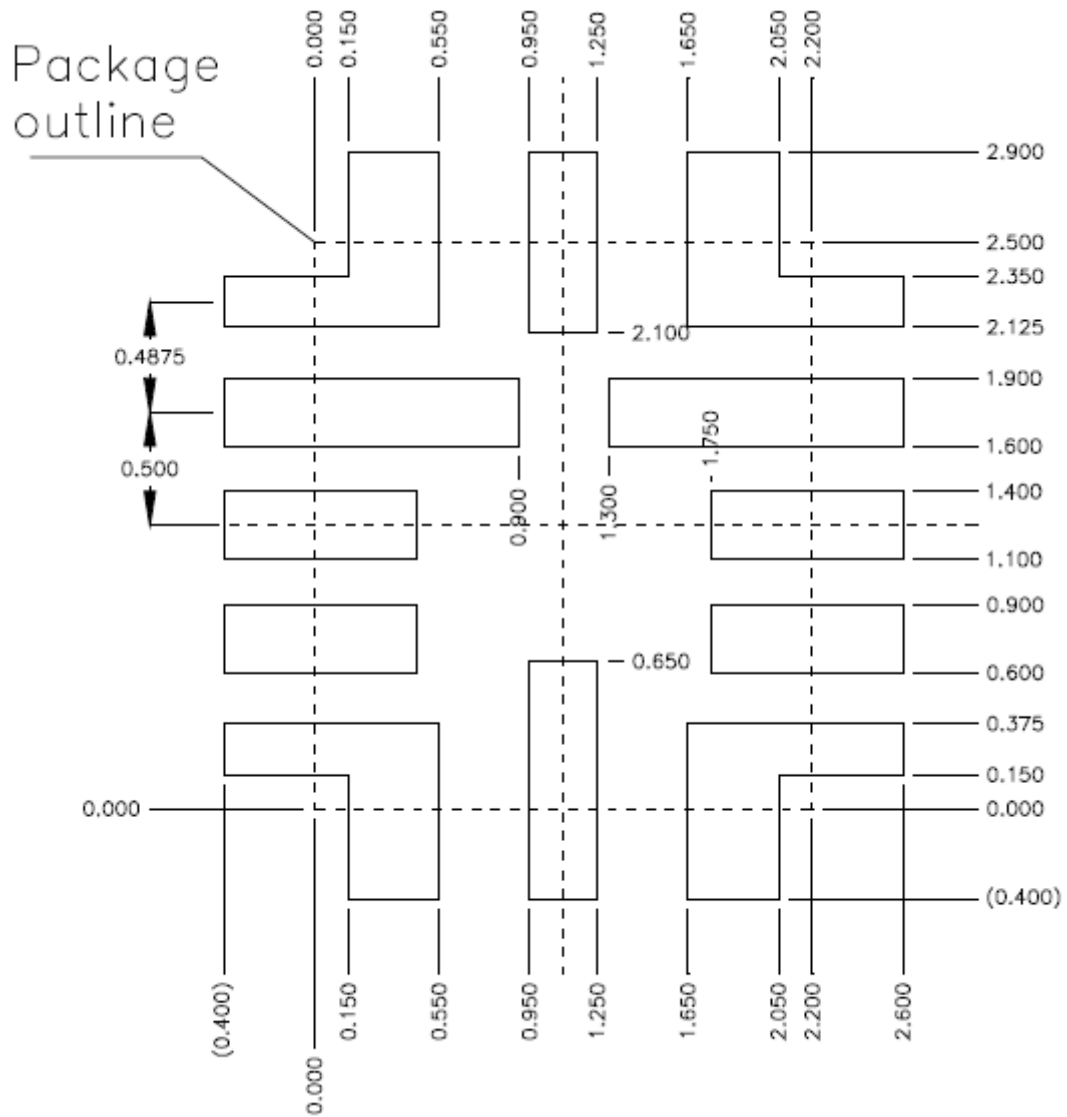


| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|--------|---------------------------|-------|----------------------|-------|
| | Min | Max | Min | Max |
| A | 0.700 | 0.800 | 0.028 | 0.031 |
| A1 | 0.000 | 0.050 | 0.000 | 0.002 |
| A3 | 0.175 | 0.250 | 0.007 | 0.010 |

| |
|-----------|
| Tolerance |
| ±0.050 |

W-Type 12L QFN 2.2x2.5 Package (FC)

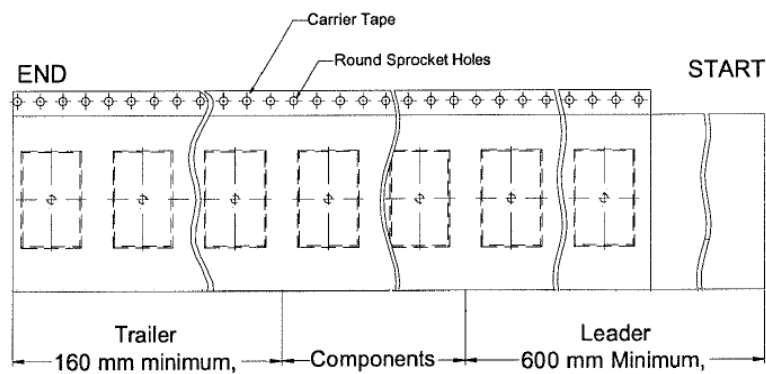
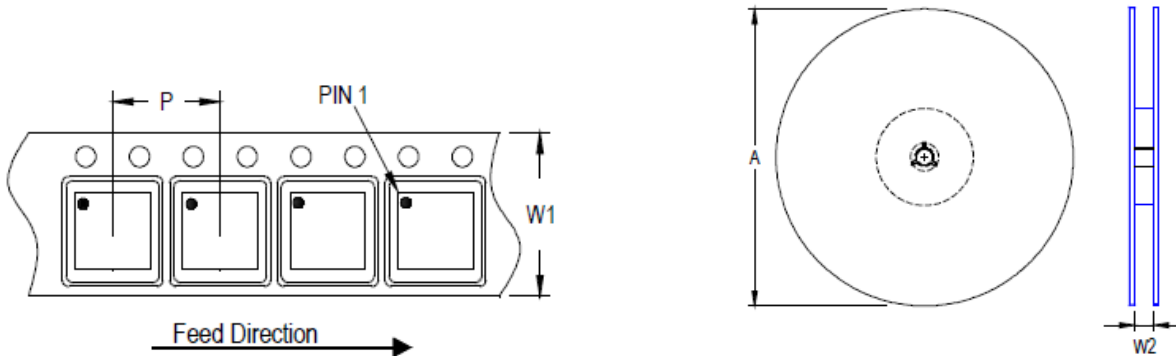
20 Footprint Information



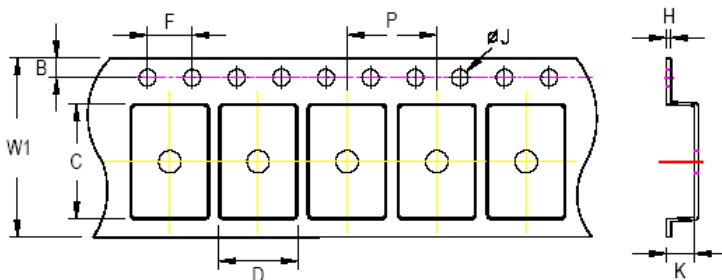
| Package | Number of Pins | Tolerance |
|--------------------------|----------------|-----------|
| V/W/U/XQFN2.2x2.5-12(FC) | 12 | ±0.05 |

21 Packing Information

21.1 Tape and Reel Data









| Package Type | Tape Size (W1) (mm) | Pocket Pitch (P) (mm) | Reel Size (A) | | Units per Reel | Trailer (mm) | Leader (mm) | Reel Width (W2) Min./Max. (mm) |
|-----------------|---------------------|-----------------------|---------------|------|----------------|--------------|-------------|--------------------------------|
| | | | (mm) | (in) | | | | |
| QFN/DFN 2.2x2.5 | 12 | 8 | 180 | 7 | 1,500 | 160 | 600 | 12.4/14.4 |



C, D and K are determined by component size.
The clearance between the components and the cavity is as follows:
- For 12mm carrier tape: 0.5mm max.

| Tape Size | W1 | | P | | B | | F | | ØJ | | H |
|-----------|--------|-------|-------|--------|--------|-------|-------|-------|-------|-------|---|
| | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Max. | |
| 12mm | 12.3mm | 7.9mm | 8.1mm | 1.65mm | 1.85mm | 3.9mm | 4.1mm | 1.5mm | 1.6mm | 0.6mm | |

21.2 Tape and Reel Packing

| Step | Photo/Description | Step | Photo/Description |
|------|---|------|--|
| 1 |  <p>Reel 7"</p> | 4 |  <p>3 reels per inner box Box A</p> |
| 2 |  <p>HIC & Desiccant (1 Unit) inside</p> | 5 |  <p>12 inner boxes per outer box</p> |
| 3 |  <p>Caution label is on backside of Al bag</p> | 6 |  <p>Outer box Carton A</p> |

| Package | Reel | | Box | | | | Carton | | | |
|--------------------|------|-------|-------|---------------|-------|-------|-------------------------------|----------------|-------|--------|
| | Size | Units | Item | Size(cm) | Reels | Units | Item | Size(cm) | Boxes | Unit |
| QFN/DFN 2.2x2.5 | 7" | 1,500 | Box A | 18.3*18.3*8.0 | 3 | 4,500 | Carton A | 38.3*27.2*38.3 | 12 | 54,000 |
| | | | Box E | 18.6*18.6*3.5 | 1 | 1,500 | For Combined or Partial Reel. | | | |

21.3 Packing Material Anti-ESD Property

| Surface Resistance | Aluminum Bag | Reel | Cover tape | Carrier tape | Tube | Protection Band |
|----------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Ω/cm^2 | 10^4 to 10^{11} | 10^4 to 10^{11} | 10^4 to 10^{11} | 10^4 to 10^{11} | 10^4 to 10^{11} | 10^4 to 10^{11} |

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Datasheet Revision History

| Version | Date | Description | Item |
|---------|-----------|-------------|---|
| 00 | 2023/9/27 | Final | Features on P1 Marking Information on P2 Electrical Characteristics on P7 |