RICHTEK®

RTQ2539C

3A, 6.5V, Low Noise, Low Dropout Linear Regulator

1 General Description

The RTQ2539C is a high-current (3A), low-noise (6.8μVRMS), high accuracy (1% over line, load, and temperature), low-dropout linear regulator (LDO) capable of sourcing 3A with extremely low dropout (max. 180mV for RTQ2539CGQV and max. 130mV for RTQ2539CGQWF). The device supports single input supply voltage as low to 1.1V, which makes it easy to use.

The low-noise, high PSRR and high output current capability makes the RTQ2539C ideal to power 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 RTQ2539C is ideal 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°C to 125°C and is offered in the WQFN-12L 2.2x2.5(FC) and VQFN-20L 3.5x3.5 packages.

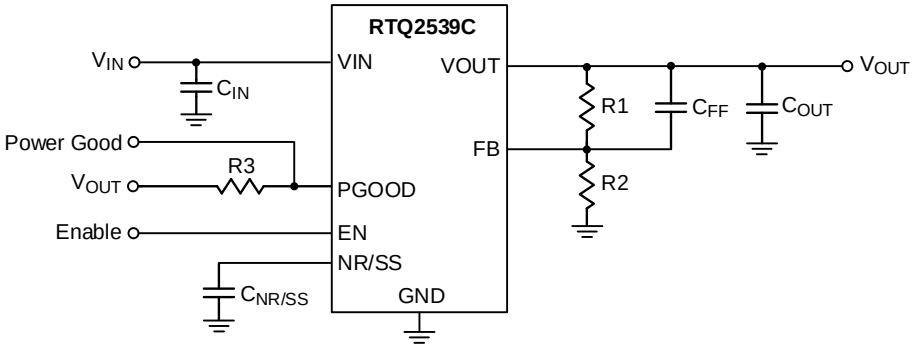
2 Features

- **Input Voltage Range: 1.1V to 6.5V**
- **Two Output Voltage Modes**
  - **0.5V to 5.5V (Set by a Resistive Divider)**
  - **0.5V to 3.65V (For RTQ2539CGQV only, Set via PCB Layout, No External Resistor Required)**
- **Accurate Output Voltage Accuracy (1%) Over Line, Load and Temperature**
- **PSRR: 40dB at 500kHz**
- **Noise Immunity**
  - **6.8μVRMS at 0.8V Output**
  - **10μVRMS at 3.3V Output**
- **Dropout Voltage:**
  - **180mV Max. at 3A for VQFN-20L 3.5x3.5**
  - **130mV Max. at 3A for WQFN-12L 2.2x2.5**
- **Enable Control**
- **Programmable Soft-Start Output**
- **Stable with a 47μF or Larger Ceramic Output Capacitor**
- **Support 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

RTQ2539C □□

Package Type
QWF: WQFN-12L 2.2x2.5 (FC) (W-Type)
QV: VQFN-20L 3.5x3.5 (V-Type)

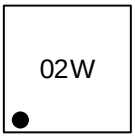
Lead Plating System
G: Richtek Green Policy Compliant

Note:

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

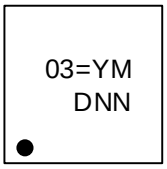
6 Marking Information

RTQ2539CGQWF



02: Product Code
W: Date Code

RTQ2539CGQV



03=: Product Code
YMDNN: Date Code

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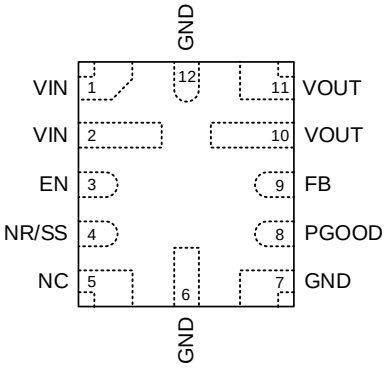
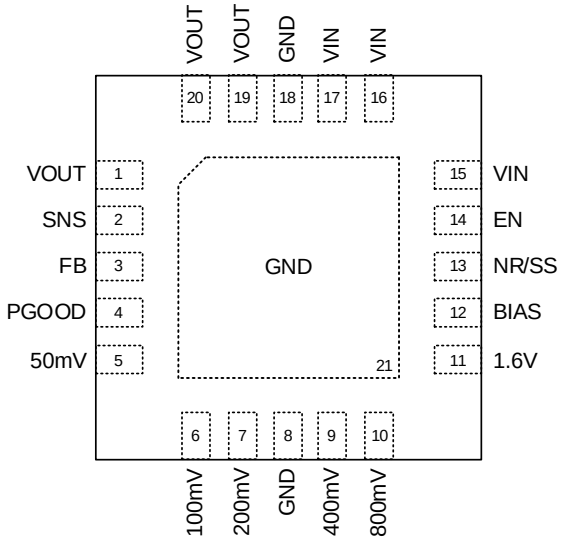
7 Pin Configuration

(TOP VIEW)



WQFN-12L 2.2x2.5 (FC)



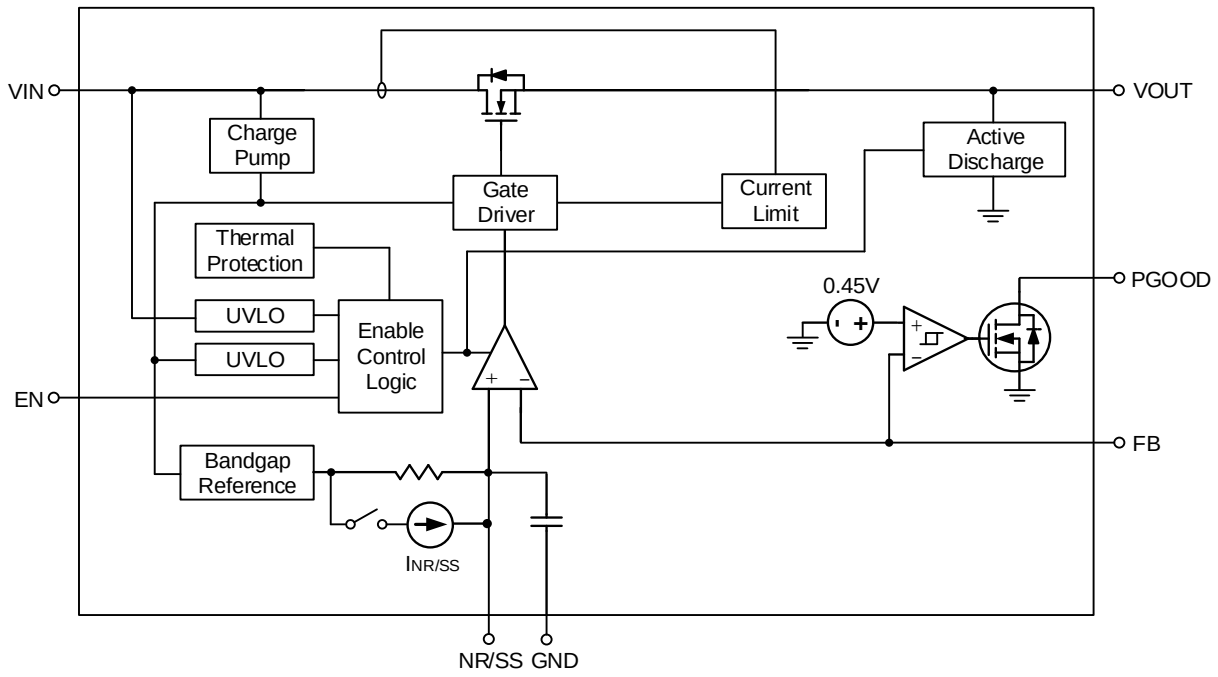
VQFN-20L 3.5x3.5

8 Functional Pin Description

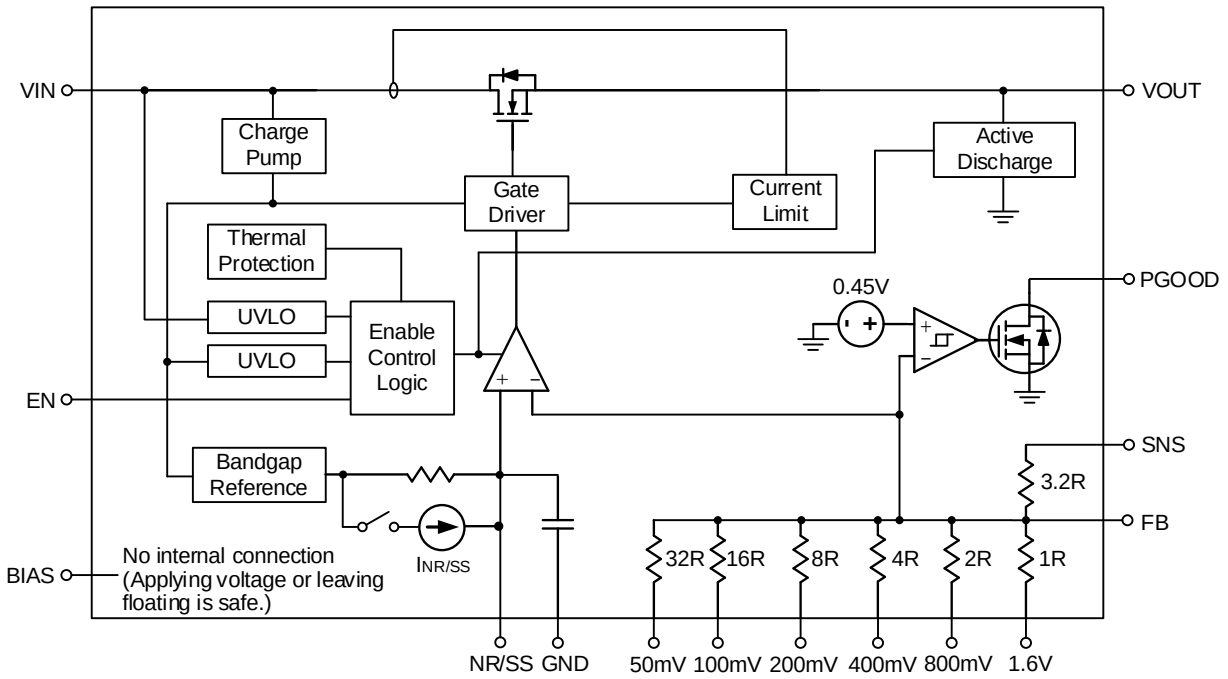
Pin No.		Pin Name	Pin Function
WQFN-12L 2.2x2.5(FC)	VQFN-20L 3.5x3.5		
--	5, 6, 7, 9, 10, 11	50mV, 100mV, 200mV, 400mV, 800mV, 1.6V	Output voltage setting pins. Connect these pins to ground or leave floating. Connecting these pins to ground increases the output voltage by the value of the pin name; multiple pins can be simultaneously connected to GND to select the desired output voltage. Leave these pins floating (open) if the VOUT voltage is set by external resistor.
1, 2	15, 16, 17	VIN	Supply input. A general 47μF ceramic capacitor should be placed as close as possible to this pin for better noise rejection.
3	14	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 to the device. However, to ensure the soft-start function to work as intended, certain sequencing rules must be applied. Enabling the device after V_{IN} is present is preferred. For the power-off conditions, it is recommended to set the falling slew rate of EN pin voltage to be higher than 0.1V/ms to ensure correct operation.
4	13	NR/SS	Noise-reduction and soft-start pin. Decoupling this pin to GND with an external capacitor $C_{NR/SS}$ can not only reduce output noise to very low levels but also slow down the rising of VOUT, providing a soft-start behavior. For low-noise applications, a 10nF to 1μF $C_{NR/SS}$ is suggested.
5	--	NC	No internal connection. Leaving these pins floating does not affect the functionality of the chip. By connecting these pins to GND, design engineers can extend the GND copper coverage on the PCB top layer to enhance the thermal convection.
6, 7, 12	8, 18, 21 (Exposed Pad)	GND	Ground. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.
8	4	PGOOD	Power good indicator output. An open-drain output and 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	3	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	1, 19, 20	VOUT	LDO output pins. A 47μF or larger ceramic capacitor (22μF or greater effective capacitance) is required for stability. Place the output capacitor as close to the device as possible and minimize the impedance between VOUT pin and load.
--	2	SNS	Output voltage sense input pin. Connect this pin only if using the configuration without external resistors. Keep the SNS pin floating if the VOUT voltage is set by external resistor.
--	12	BIAS	This pin has no internal IC connection. A BIAS input voltage below 6.5V can be applied to this pin (for compatibility with other vendors) or this pin can be left open (floating). Either option is safe and will not affect IC operation.

9 Functional Block Diagram

9.1 For WQFN-12L 2.2x2.5 (FC) package



9.2 For VQFN-20L 3.5x3.5 package



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

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.

11 ESD Ratings

(Note 2)

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

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

12 Recommended Operating Conditions

(Note 3)

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

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

13 Thermal Information

(Note 4 and Note 5)

Thermal Parameter		WQFN-12L 2.2x2.5 (FC)	VQFN-20L 3.5x3.5	Unit
θ_{JA}	Junction-to-ambient thermal resistance (JEDEC standard)	54.8	38.5	°C/W
$\theta_{JC(Top)}$	Junction-to-case (top) thermal resistance	53	50.57	°C/W
$\theta_{JC(Bottom)}$	Junction-to-case (bottom) thermal resistance	16.1	2.47	°C/W
$\theta_{JA(EVB)}$	Junction-to-ambient thermal resistance (specific EVB)	49.7	39.33	°C/W
$\Psi_{JC(Top)}$	Junction-to-top characterization parameter	1.7	5.79	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	27.2	24.06	°C/W

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

Note 5. $\theta_{JA(EVB)}$, $\Psi_{JC(Top)}$ 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.

14 Electrical Characteristics

Over operating temperature range (T_J = –40°C to 125°C), (1.1V ≤ V_{IN} ≤ 6.5V and V_{IN} ≥ $V_{OUT(TARGET)}$ + 0.3 V, $V_{OUT(TARGET)}$ = 0.5V, VOUT connected to 50Ω to GND, V_{EN} = 1.1 V, C_{IN} = 10µF, C_{OUT} = 47µF, $C_{NR/SS}$ = 0nF, C_{FF} = 0nF, and PGOOD pin pulled up to V_{IN} with 100kΩ unless otherwise noted. (Note 6)

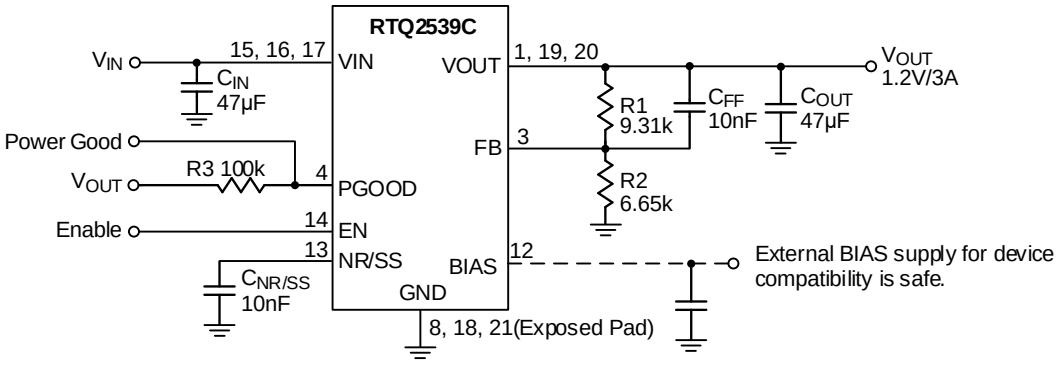
Parameter	Symbol	Test Conditions		Min	Typ	Max	Unit
VIN Supply Input Voltage	V_{IN}			1.1	--	6.5	V
Reference Voltage	V_{REF}			--	0.5	--	V
NR/SS Pin Voltage	$V_{NR/SS}$			--	0.5	--	V
Undervoltage Lockout Rising Threshold	V_{UVLO_R}	V_{IN} increasing		--	1.02	1.085	V
Undervoltage Lockout Hysteresis	V_{UVLO_HYS}	Hysteresis		--	100	--	mV
Output Voltage	V_{OUT}	RTQ2539CGQWF	Using external resistors	0.5	--	5.5	V
		RTQ2539CGQV	Using external resistors	0.5	--	5.5	V
			Using voltage setting pins (50mV, 100mV, 200mV, 400mV, 800mV, 1.6V)	0.5	--	3.65	V
Output Voltage Accuracy (Note 7)	V_{OUT_ACC}	V_{IN} = V_{OUT} + 0.3V, 0.5V ≤ V_{OUT} ≤ 5.5V, 1mA ≤ I_{OUT} ≤ 3A		–1	--	1	%
Line Regulation	V_{LINE_REG}	I_{OUT} = 1mA, 1.1V ≤ V_{IN} ≤ 6.5V		--	0.05	--	%/V
Load Regulation	V_{LOAD_REG}	1mA ≤ I_{OUT} ≤ 3A		--	0.08	--	%/A
Dropout Voltage	V_{DROP}	V_{IN} = 1.1V to 6.5V, I_{OUT} = 3A, V_{FB} = 0.5V – 3%	RTQ2539CGQV	--	80	180	mV
			RTQ2539CGQWF	--	55	130	
Current Limit	I_{LIM}	V_{OUT} = 90%$V_{OUT(TARGET)}$, V_{IN} = $V_{OUT(TARGET)}$ + 400mV		3.5	4.2	4.8	A
Short-Circuit Current Limit	I_{SC}	R_{LOAD} = 20mΩ, under foldback operation		--	1.5	--	A
Ground Pin Current	I_{GND}	Minimum load, V_{IN} = 6.5V, I_{OUT} = 5mA		--	3	4	mA
		Maximum load, V_{IN} = 1.4V, I_{OUT} = 3A		--	4.3	5.5	mA
Shutdown Current	I_{SHDN}	Shutdown, PGOOD = Open, V_{in} = 6.5V, V_{EN} = 0.5V		--	1.2	25	µA
EN Pin Current	I_{EN}	V_{IN} = 6.5V, V_{EN} = 0V and 6.5V		–0.1	--	0.1	µA
EN Input Voltage Rising threshold	V_{EN_R}	Enable device		1.1	--	6.5	V
EN Input Voltage Falling threshold	V_{EN_F}	Disable device		0		0.5	V
Power-Good Voltage Threshold	V_{PGOOD}	For the direction PGOOD signal falling with decreasing VOUT		0.82 x V_{OUT}	0.883 x V_{OUT}	0.93 x V_{OUT}	V

Parameter	Symbol	Test Conditions		Min	Typ	Max	Unit
Power-Good Voltage Hysteresis	V_{PGOOD_HYS}	For PGOOD signal rising		--	2% x V_{OUT}	--	V
PGOOD Pin Low-Level Output Voltage	V_{PGOOD_L}	V_{OUT} < V_{PGOOD}, I_{PGOOD} = –1mA (current into device)		--	--	0.4	V
PGOOD Pin Leakage Current	I_{PGOOD_LK}	V_{OUT} > V_{PGOOD}, V_{PGOOD} = 6.5V		--		1	μA
NR/SS Pin Charging Current	$I_{NR/SS}$	$V_{NR/SS}$ = GND, V_{IN} = 6.5V		4	--	9	μA
FB Pin Current	I_{FB}	V_{IN} = 6.5V		–100	--	100	nA
Power Supply Rejection Ratio	PSRR	V_{IN} – V_{OUT} = 0.7V, I_{OUT} = 3A, $C_{NR/SS}$ = 100nF, C_{FF} = 10nF, C_{OUT} = 47μF//10μF//10μF	f = 10kHz, V_{OUT} = 0.5V	--	50	--	dB
			f = 500kHz, V_{OUT} = 0.5V	--	40	--	
			f = 10kHz, V_{OUT} = 5V	--	49	--	
			f = 500kHz, V_{OUT} = 5V	--	34	--	
Output Noise	V_n	BW = 10Hz to 100kHz, I_{OUT} = 3A, $C_{NR/SS}$ = 100nF, C_{FF} = 10nF, C_{OUT} = 47μF//10μF//10μF	V_{IN} = 1.1V, V_{OUT} = 0.5V	--	6.8	--	μV_{RMS}
			V_{IN} = 3.6V, V_{OUT} = 3.3V	--	10	--	
			V_{OUT} = 5V	--	16	--	
Over-Temperature Protection Threshold	T_{OTP}			--	160	--	°C
Over-Temperature Protection Hysteresis	T_{OTP_HYS}			--	20	--	

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 account.

15 Typical Application Circuit



$$V_{OUT} = V_{REF} \times \left(1 + \frac{R1}{R2}\right) = 0.5V \times \left(1 + \frac{9.31k}{6.65k}\right) = 1.2V$$

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

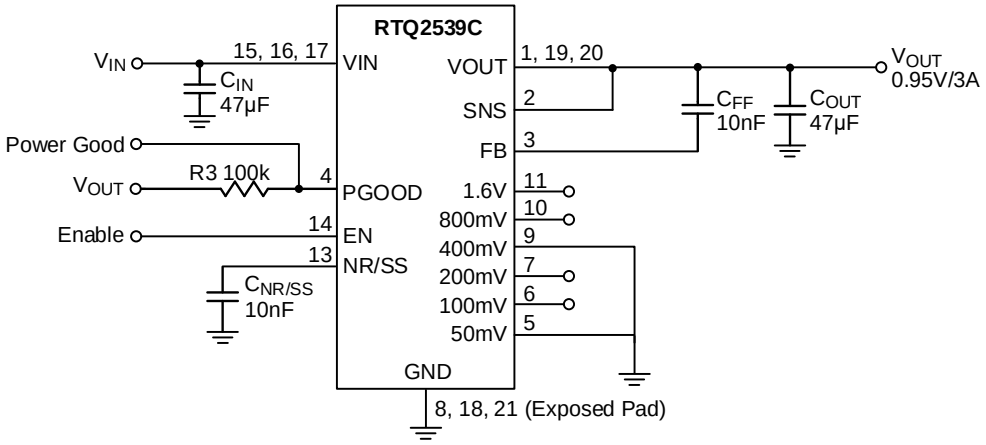
Table 1. Recommended Feedback-Resistor Values

Output Voltage (V)	External Resistor Divider Combination	
	R1(kΩ)	R2(kΩ)
0.8	12	20
0.9	12	15
1	12.4	12.4
1.2	9.31	6.65
1.5	12.4	6.2
1.8	10.2	3.92
2.5	10.2	2.55
3.3	10.7	1.91
4.5	12	1.5
5	10.2	1.13
5.5	10.2	1.02

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 derated 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.



$V_{OUT} = V_{REF} + 50mv + 400mV = 0.5V + 50mV + 400mV = 0.95V$

(Table 3. provides a full list for different V_{OUT} targets and the corresponding pin settings.)

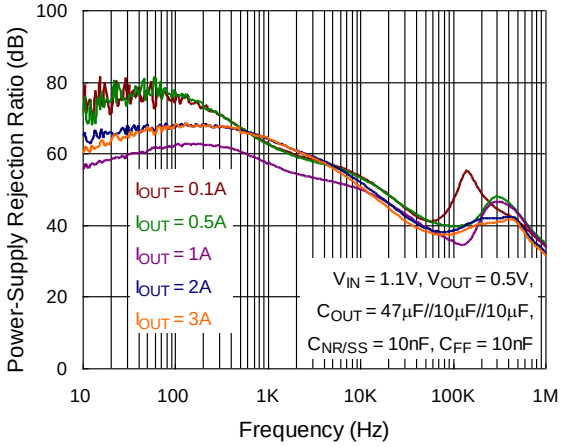
Figure 2. Configuration Circuit for Adjusted V_{OUT} via PCB Layout

Table 3. V_{OUT} Select Pin Settings for Different Targets

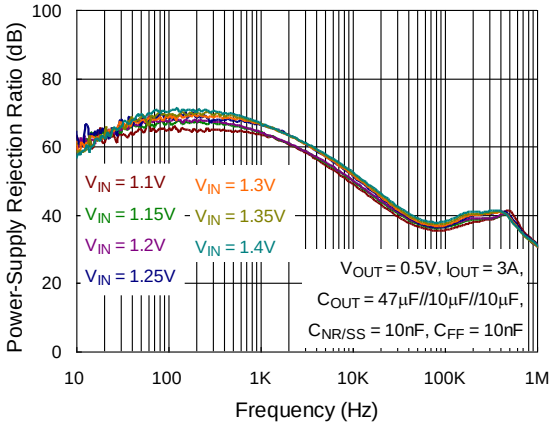
V_{OUT} (V)	50mV	100mV	200mV	400mV	800mV	1.6V	V_{OUT} (V)	50mV	100mV	200mV	400mV	800mV	1.6V
0.5	Open	Open	Open	Open	Open	Open	2.1	Open	Open	Open	Open	Open	GND
0.55	GND	Open	Open	Open	Open	Open	2.15	GND	Open	Open	Open	Open	GND
0.6	Open	GND	Open	Open	Open	Open	2.2	Open	GND	Open	Open	Open	GND
0.65	GND	GND	Open	Open	Open	Open	2.25	GND	GND	Open	Open	Open	GND
0.7	Open	Open	GND	Open	Open	Open	2.3	Open	Open	GND	Open	Open	GND
0.75	GND	Open	GND	Open	Open	Open	2.35	GND	Open	GND	Open	Open	GND
0.8	Open	GND	GND	Open	Open	Open	2.4	Open	GND	GND	Open	Open	GND
0.85	GND	GND	GND	Open	Open	Open	2.45	GND	GND	GND	Open	Open	GND
0.9	Open	Open	Open	GND	Open	Open	2.5	Open	Open	Open	GND	Open	GND
0.95	GND	Open	Open	GND	Open	Open	2.55	GND	Open	Open	GND	Open	GND
1	Open	GND	Open	GND	Open	Open	2.6	Open	GND	Open	GND	Open	GND
1.05	GND	GND	Open	GND	Open	Open	2.65	GND	GND	Open	GND	Open	GND
1.1	Open	Open	GND	GND	Open	Open	2.7	Open	Open	GND	GND	Open	GND
1.15	GND	Open	GND	GND	Open	Open	2.75	GND	Open	GND	GND	Open	GND
1.2	Open	GND	GND	GND	Open	Open	2.8	Open	GND	GND	GND	Open	GND
1.25	GND	GND	GND	GND	Open	Open	2.85	GND	GND	GND	GND	Open	GND
1.3	Open	Open	Open	Open	GND	Open	2.9	Open	Open	Open	Open	GND	GND
1.35	GND	Open	Open	Open	GND	Open	2.95	GND	Open	Open	Open	GND	GND
1.4	Open	GND	Open	Open	GND	Open	3	Open	GND	Open	Open	GND	GND
1.45	GND	GND	Open	Open	GND	Open	3.05	GND	GND	Open	Open	GND	GND
1.5	Open	Open	GND	Open	GND	Open	3.1	Open	Open	GND	Open	GND	GND
1.55	GND	Open	GND	Open	GND	Open	3.15	GND	Open	GND	Open	GND	GND
1.6	Open	GND	GND	Open	GND	Open	3.2	Open	GND	GND	Open	GND	GND
1.65	GND	GND	GND	Open	GND	Open	3.25	GND	GND	GND	Open	GND	GND
1.7	Open	Open	Open	GND	GND	Open	3.3	Open	Open	Open	GND	GND	GND
1.75	GND	Open	Open	GND	GND	Open	3.35	GND	Open	Open	GND	GND	GND
1.8	Open	GND	Open	GND	GND	Open	3.4	Open	GND	Open	GND	GND	GND
1.85	GND	GND	Open	GND	GND	Open	3.45	GND	GND	Open	GND	GND	GND
1.9	Open	Open	GND	GND	GND	Open	3.5	Open	Open	GND	GND	GND	GND
1.95	GND	Open	GND	GND	GND	Open	3.55	GND	Open	GND	GND	GND	GND
2	Open	GND	GND	GND	GND	Open	3.6	Open	GND	GND	GND	GND	GND
2.05	GND	GND	GND	GND	GND	Open	3.65	GND	GND	GND	GND	GND	GND

16 Typical Operating Characteristics

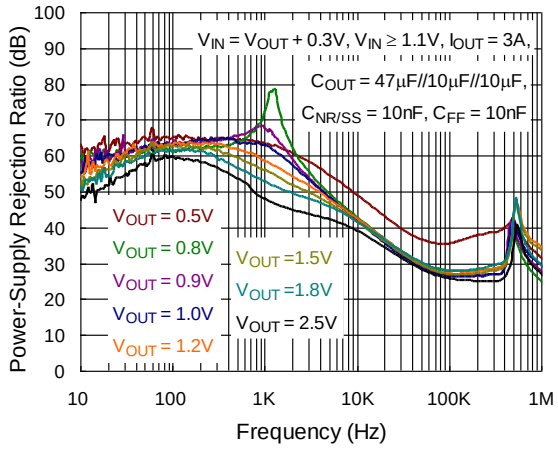
PSRR vs. Frequency and I_{OUT}



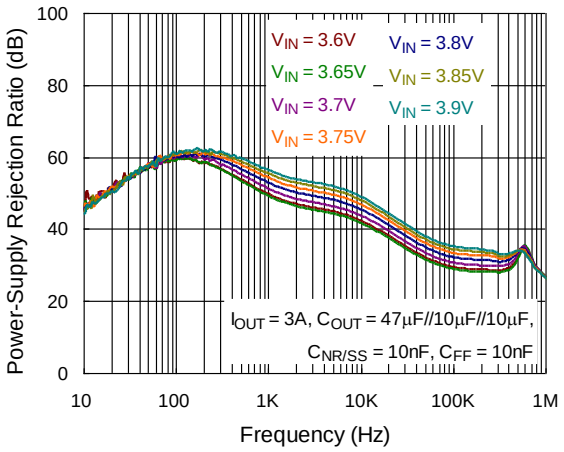
PSRR vs. Frequency and V_{IN}



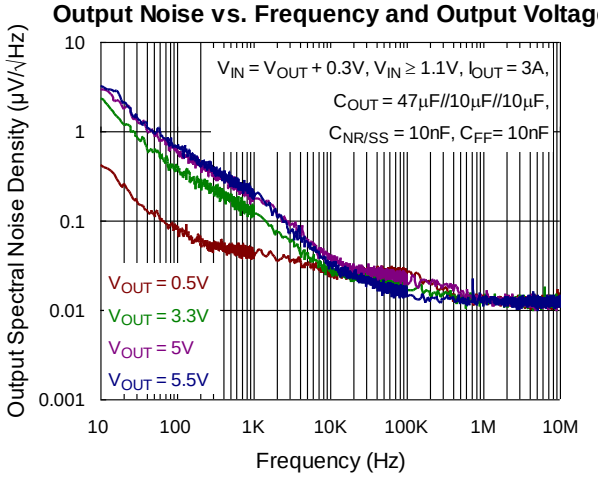
PSRR vs. Frequency and V_{OUT}



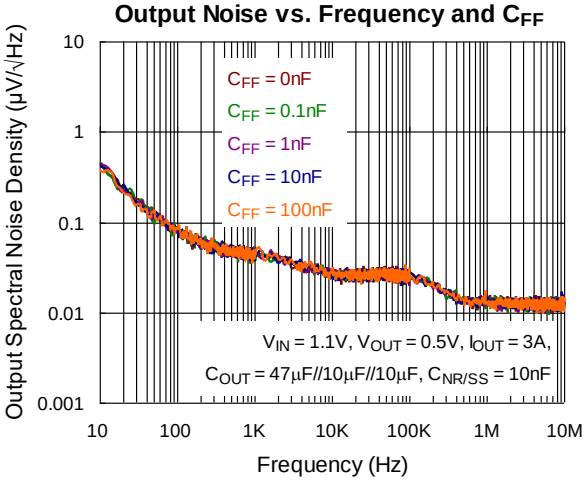
PSRR vs. Frequency and V_{IN} for V_{OUT} = 3.3V



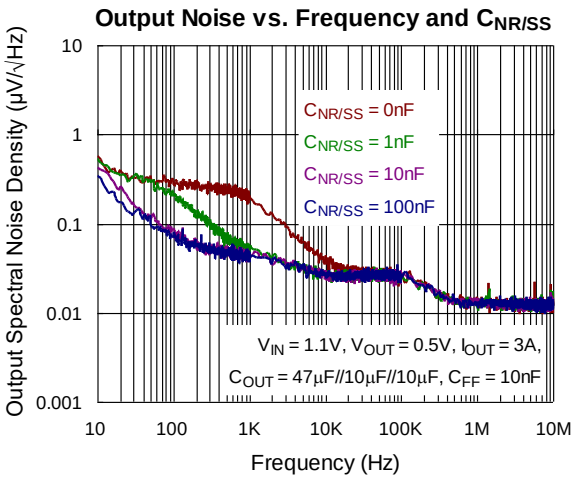
Output Noise vs. Frequency and Output Voltage



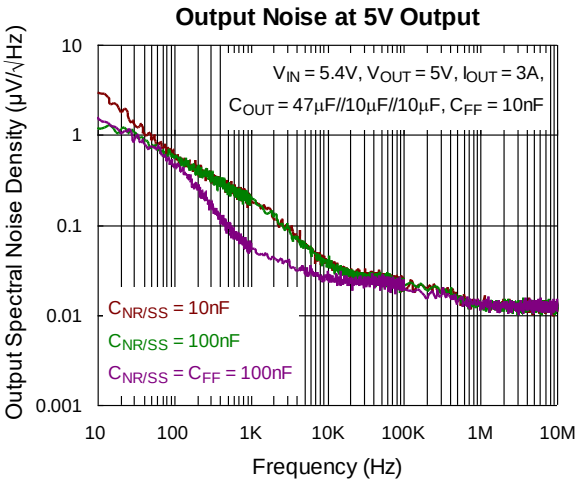
Output Noise vs. Frequency and C_{FF}



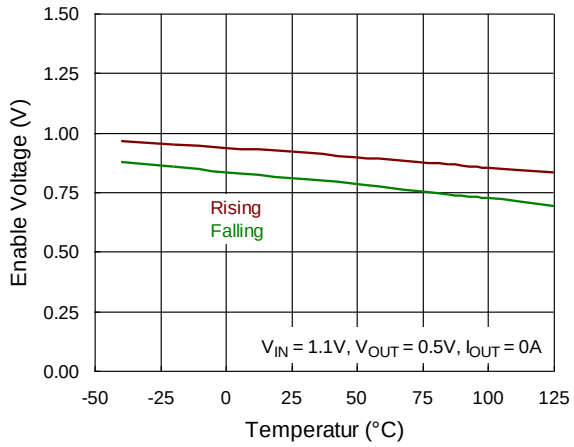
Output Noise vs. Frequency and $C_{NR/SS}$



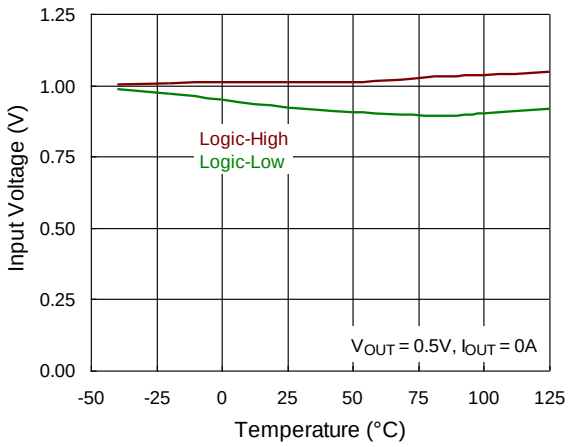
Output Noise at 5V Output



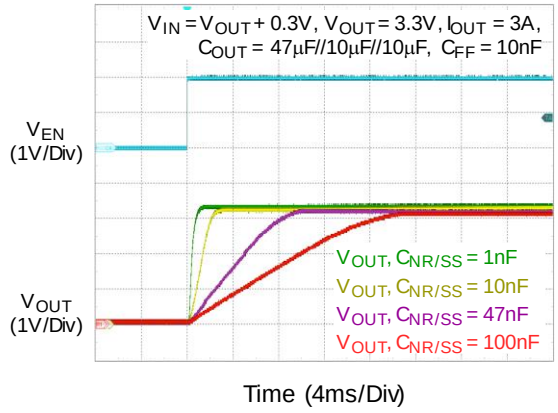
Enable Voltage vs. Temperature



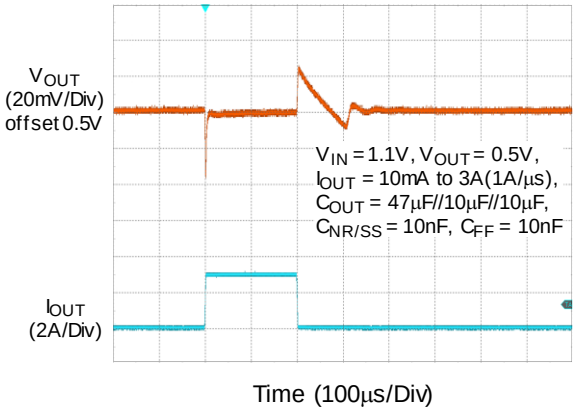
Input Voltage UVLO vs. Temperature

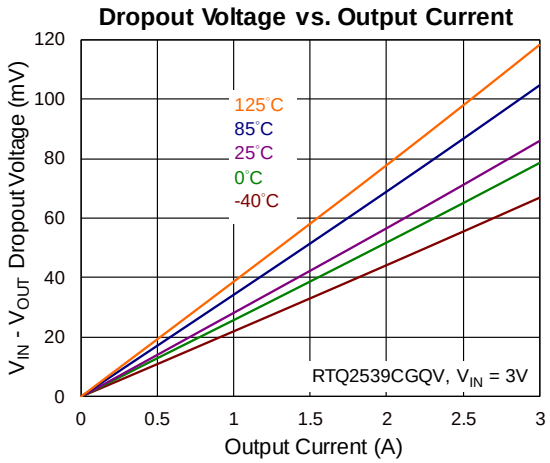


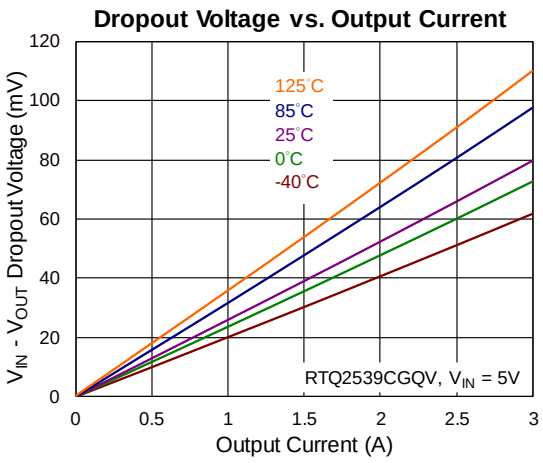
Power On Response

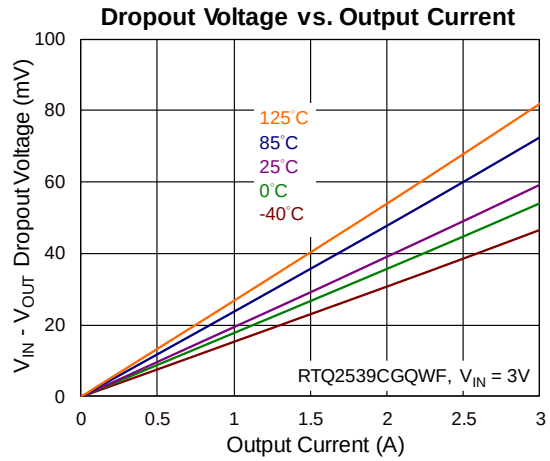


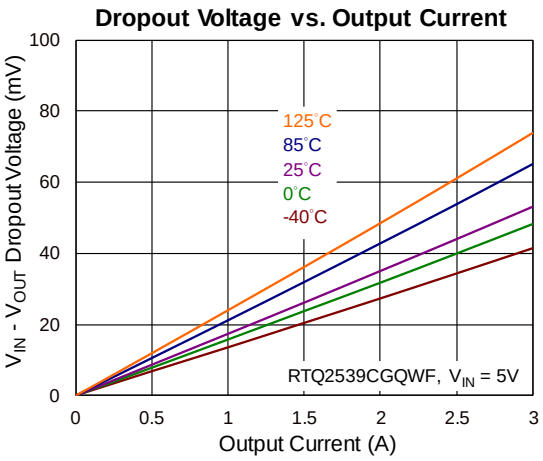
Load Transient Response











17 Operation

The RTQ2539C operates with single supply input ranging from 1.1V to 6.5V and is capable of delivering up to 3A 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 RTQ2539C minimizes the coupling of input supply noise to the output.

17.1 Enable and Shutdown

The RTQ2539C 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 25μA. The enable circuitry has hysteresis (typically 50mV) for use with relatively slowly ramping analog signals.

Furthermore, during the power-off conditions, it is recommended to set the falling slew rate of EN pin voltage to be higher than 0.1V/ms to ensure correct operation.

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 VOUT Programming Pins

The built-in matched feedback resistor network of the RTQ2539CGQV can set the output voltage. The output voltage can be programmed from 0.5V to 3.65V in 50mV steps when tying these programming pins 5, 6, 7, 9, 10, and 11 to ground. Tying any of the VOUT programming pins to SNS can lower the value of the upper resistor divider. Hence the VOUT programming resolution is increased.

17.3 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 RTQ2539C activates a quick-start circuit to charge the noise reduction capacitor ($C_{NR/SS}$) and then the output voltage ramps up.

17.4 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 that can be used for sequencing. A pull-up resistor from 10kΩ to 100kΩ is recommended. Make sure that the external pull-up supply voltage results in a valid logic signal for the receiving device or devices.

After start-up, the PGOOD pin becomes high impedance when the feedback voltage exceeds V_{PGOOD_HYS} (typically 90% of 0.5V reference voltage level). The PGOOD is pulled to GND when the feedback pin voltage falls below the V_{PGOOD}. When EN is low, the current limit or OTP levels are reached.

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 ($V_{UVLO\_R} – V_{UVLO\_HYS}$). The UVLO circuit responds quickly to glitches on VIN and attempts to disable the output of the device if V_{IN} collapses.

17.5 Internal Current Limit (I_{LIM})

The RTQ2539C 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 RTQ2539C 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 RTQ2539C implements over-temperature 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 RTQ2539C 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 RTQ2539C 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 RTQ2539C is a high-current, low-noise, high-accuracy, low-dropout linear regulator which is capable of sourcing 3A with maximum dropout of 180mV for VQFN-20L 3.5x3.5 package and 130mV for WQFN-12L 2.2x2.5 package. The input voltage operating range is 1.1V to 6.5V, and the adjustable output voltage is 0.5V to 5.5V according to the external resistor setting or 0.5V to 3.65V via PCB Layout to short specific pins and get the required output target.

18.1 Output Voltage Setting

The output voltage of the RTQ2539C 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 3. The values of R1 and R2 can be calculated for any voltage value using the following formula:

$$V_{OUT} = 0.5 \times \frac{R1 + R2}{R2}$$

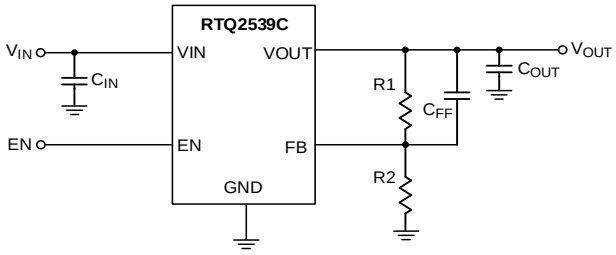


Figure 3. Output Voltage Set by External Resistors

The RTQ2539CGQV with VQFN-20L 3.5x3.5 can also short pins 5, 6, 7, 9, 10, 11 to ground and program the regulated output voltage level without external resistors after the SNS pin is connected to the VOUT. pins 5, 6, 7, 9, 10, and 11 are connected with internal resistor pairs. Each pin is either connected to ground (active) or left open (floating).

Voltage programming is set as the sum of the internal reference voltage (V_{REF} = 0.5V) plus the accumulated sum of the respective voltages assigned to each active pin as illustrated in Figure 4.

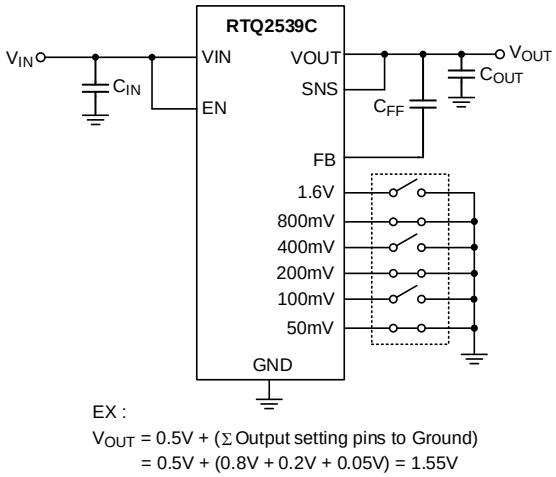


Figure 4. Output Setting without External Resistors

Table 3. summarizes these voltage values associated with each active pin setting for reference. By leaving all programming pins open, or floating, the output is thereby programmed to the minimum possible output voltage which equals to V_{REF} (0.5V). The maximum output target can be supported up to 3.65V after all pins 5, 6, 7, 9, 10, and 11 are shorted with ground at the same time.

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}) while the pass-FET is fully operating in the ohmic region, and 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 C_{IN} and C_{OUT} Selection

The RTQ2539C is designed to support low-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 voltage and temperature, and design engineers must be aware of these characteristics. Ceramic capacitors are usually recommended to be derated by 50%. A 47μF or greater output ceramic capacitor (or 22μF 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 47μF is highly recommended for minimal input impedance. If the trace inductance between the RTQ2539C 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 is available to restrict the ringing and keep it below the device absolute maximum ratings.

Generally, a 47μF 1210-sized ceramic capacitor in parallel with two 10μF 0805-sized ceramic capacitor ensures 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 (C_{FF})

The RTQ2539C is designed to be stable without the external feed-forward capacitor (C_{FF}). However, a 10nF external feed-forward capacitor optimizes the transient, noise, and PSRR performances. A higher capacitance of C_{FF} 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 ($C_{NR/SS}$)

The RTQ2539C is designed for a programmable, monotonic soft-start time during the output rising, which can be achieved via an external capacitor ($C_{NR/SS}$) on NR/SS pin. Using an external $C_{NR/SS}$ is recommended for general application; 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 RTQ2539C tracks the voltage ramp of the external soft-start capacitor ($C_{NR/SS}$) until the voltage approaches the internal reference 0.5V. 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 0.5V (V_{REF}).

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

For noise-reduction, $C_{NR/SS}$ 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.

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

18.7 Undervoltage Lockout (UVLO)

The Undervoltage Lockout (UVLO) threshold is the minimum input operational voltage range that ensures the device stays disabled. Figure 5 explains that the UVLO circuits are triggered between three different input voltage events (duration a, b and c), assuming $V_{EN} \geq V_{EN\_R}$ all the time. For duration "a, the input voltage starts rising. When V_{IN} is over the UVLO rising threshold, VOUT 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", V_{IN} drops below the UVLO falling threshold, so the control loop is disabled and there is no regulation. Meanwhile, V_{OUT} drops. For general application, instant power line transient with long power

trace at the VIN 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.

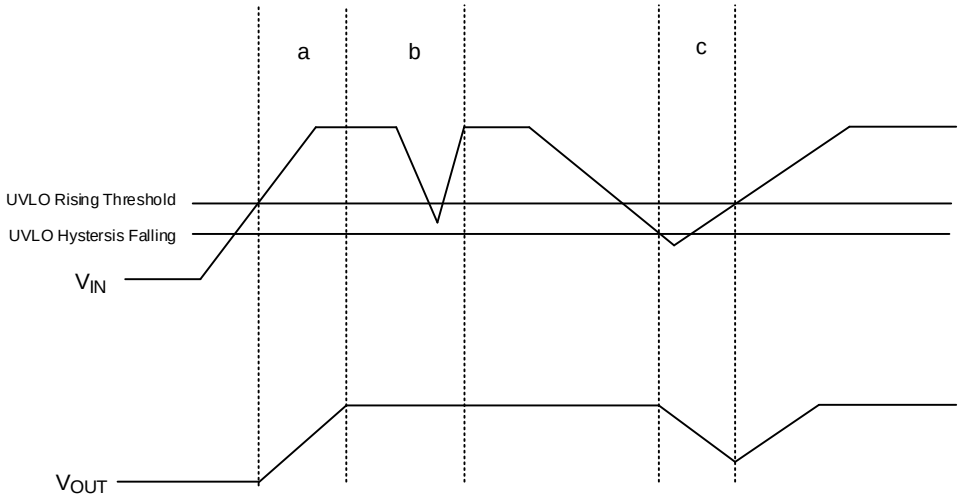


Figure 5. Under Voltage Lockout Trigging Conditions and Output Variation

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 RTQ2539C'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 6 demonstrates some PGOOD scenarios versus VIN, EN and protection status. During "a", V_{EN} is higher than the V_{EN_R} 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_{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”, VPGOOD is pulled to GND as shown in duration “d”.

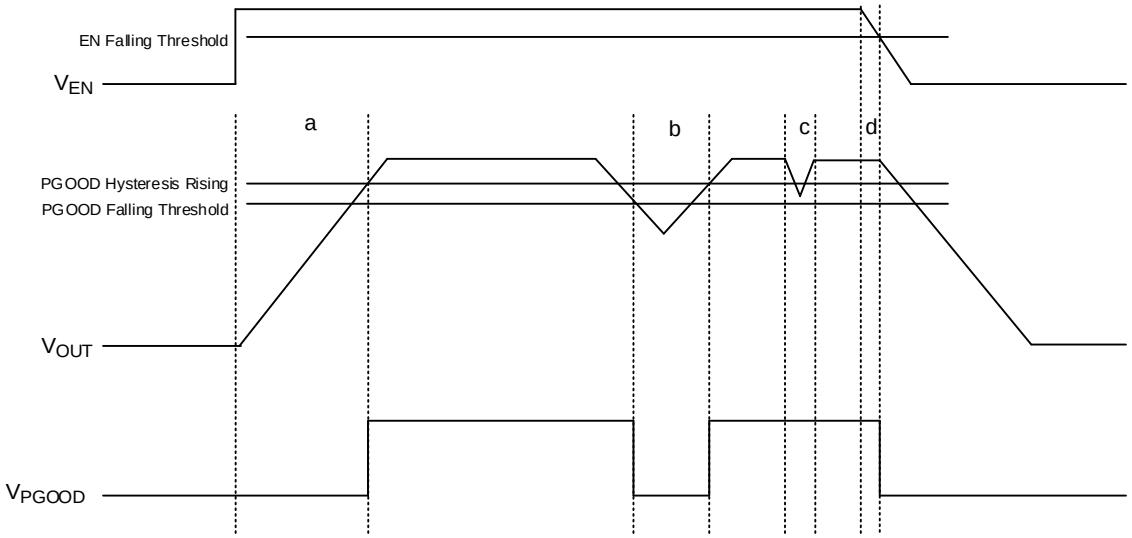


Figure 6. PGOOD Trigger Scenario with Different Operating Status

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.

For example, 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 7, an external Schottky diode can be added to prevent the pass element from being damaged by the reverse current.

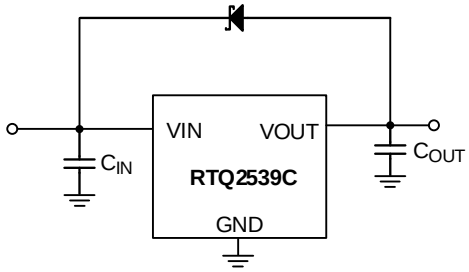


Figure 7. Application Circuit for Reverse Current Protection

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.

For a VQFN-20L 3.5x3.5 package, the thermal resistance, $\theta_{JA\ (EVB)}$, is 39.33°C/W on a standard high effective-thermal- conductivity four-layer test board. The maximum power dissipation at T_A = 25°C can be calculated as below:

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

$P_{D(MAX)}$ = (125°C – 25°C)/(39.33°C/W) = 2.54W for a VQFN-20L 3.5x3.5 package.

The maximum power dissipation depends on the operating ambient temperature for the fixed $T_{J(MAX)}$ and the thermal resistance, $\theta_{JA\ EVB)}$. The derating curves in Figure 8 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

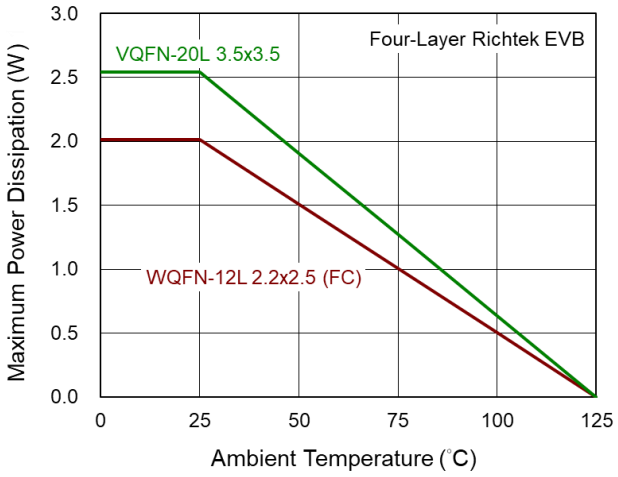


Figure 8. Derating Curve of Maximum Power Dissipation

18.11 Layout Considerations

For best performance of the RTQ2539C, the PCB layout suggestions below are highly recommended.

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 capacitor.
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 capacitors connections is not recommended and has negative effects on performance.
5. Figure 9 and Figure 10 show a layout example that reduces conduction trace loops, helping to minimize inductive parasitic and load transient effects while improving the circuit stability.

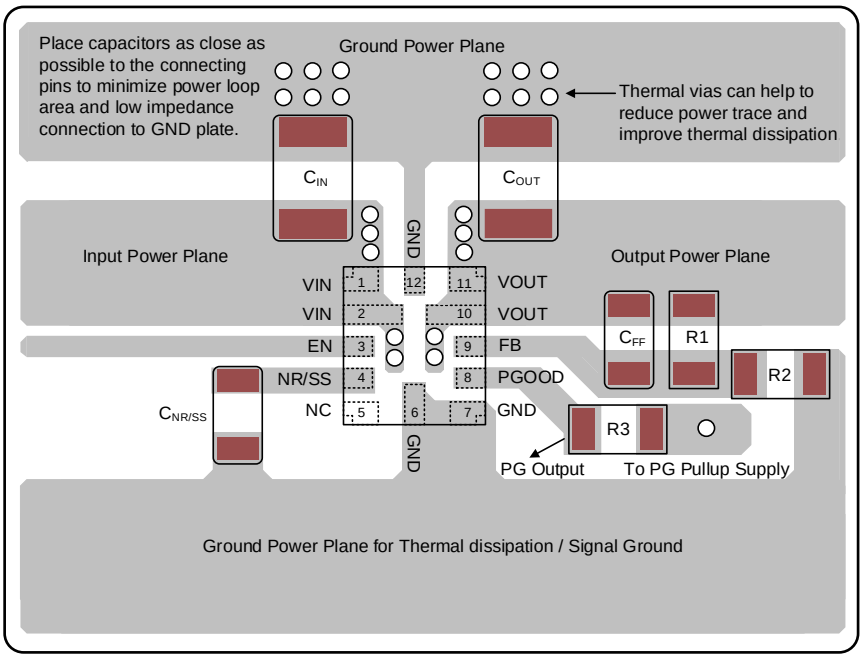


Figure 9. PCB Layout Guide for WQFN-12L 2.2x2.5 (FC) package

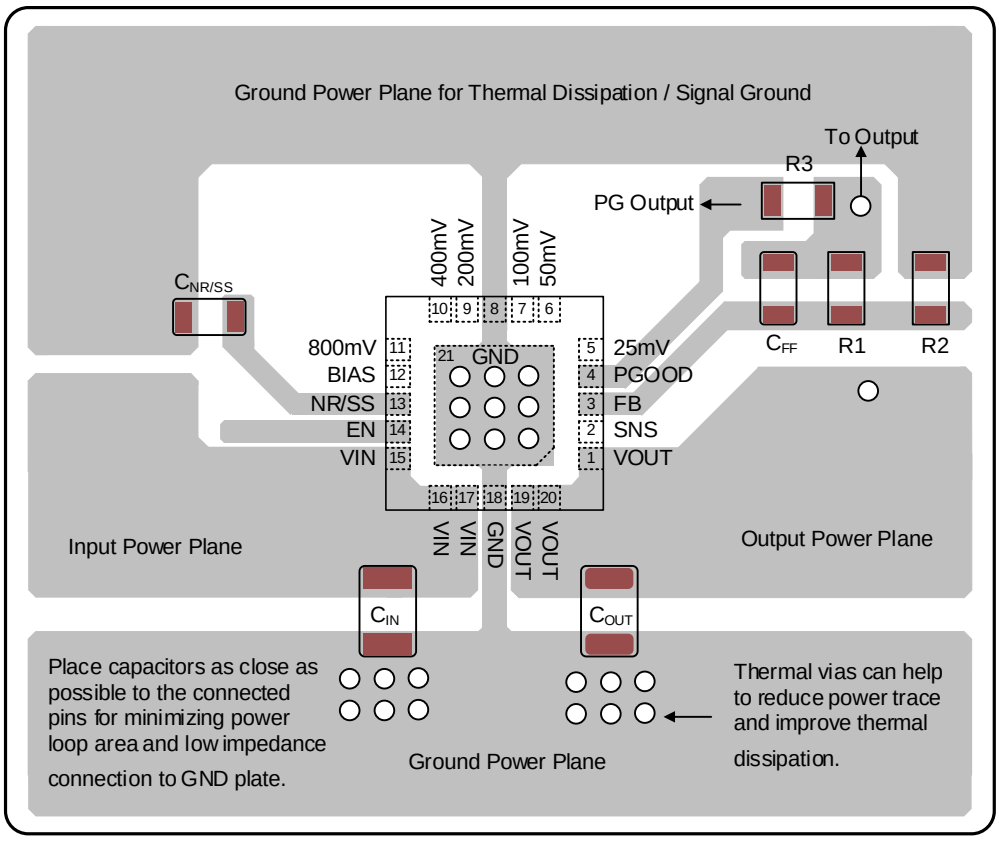
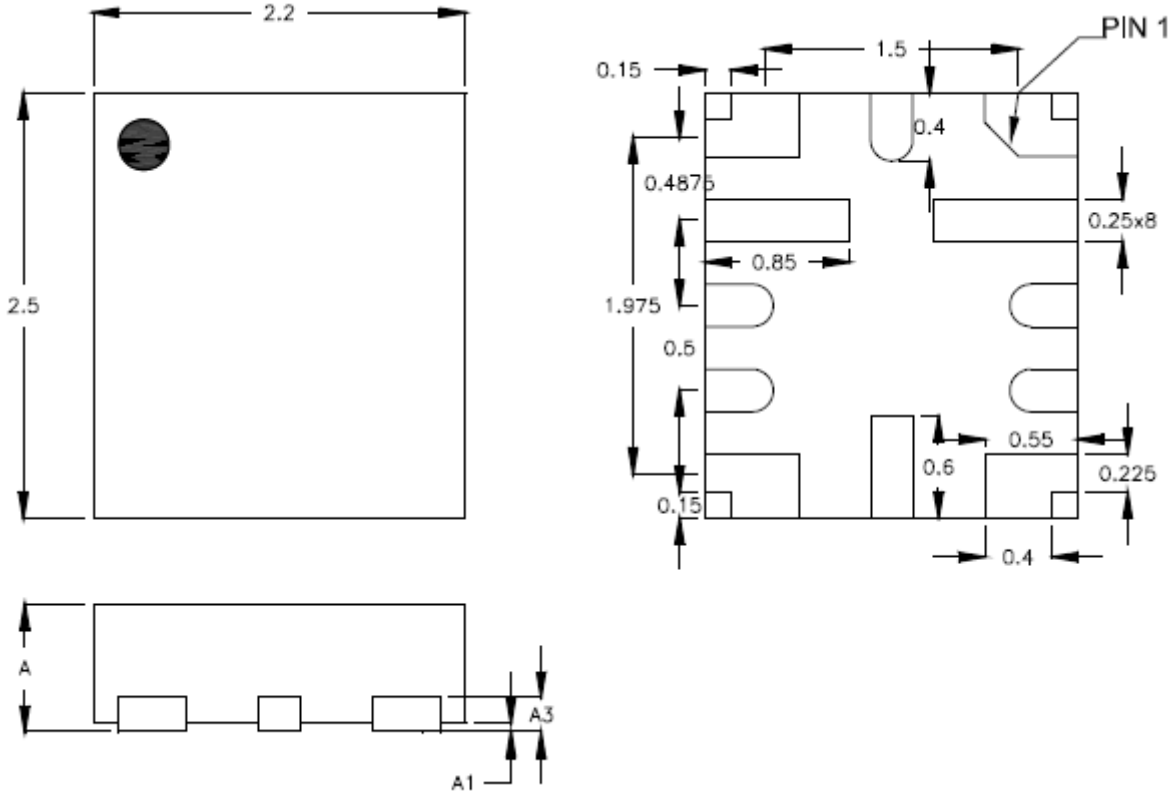


Figure 10. PCB Layout Guide for VQFN-20L 3.5x3.5 package

19 Outline Dimension

19.1 WQFN-12L 2.2x2.5 (FC)

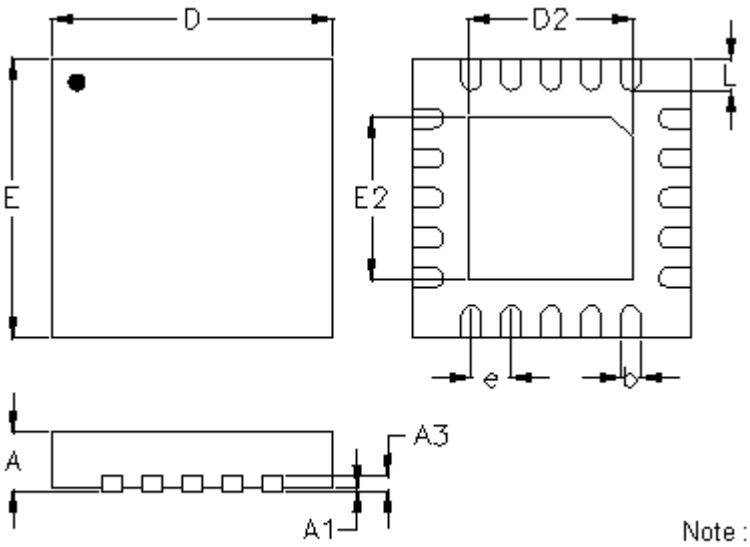


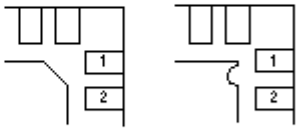
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010

Tolerance
±0.050

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

VQFN-20L 3.5x3.5





DETAIL A

Pin #1 ID and Tie Bar Mark Options

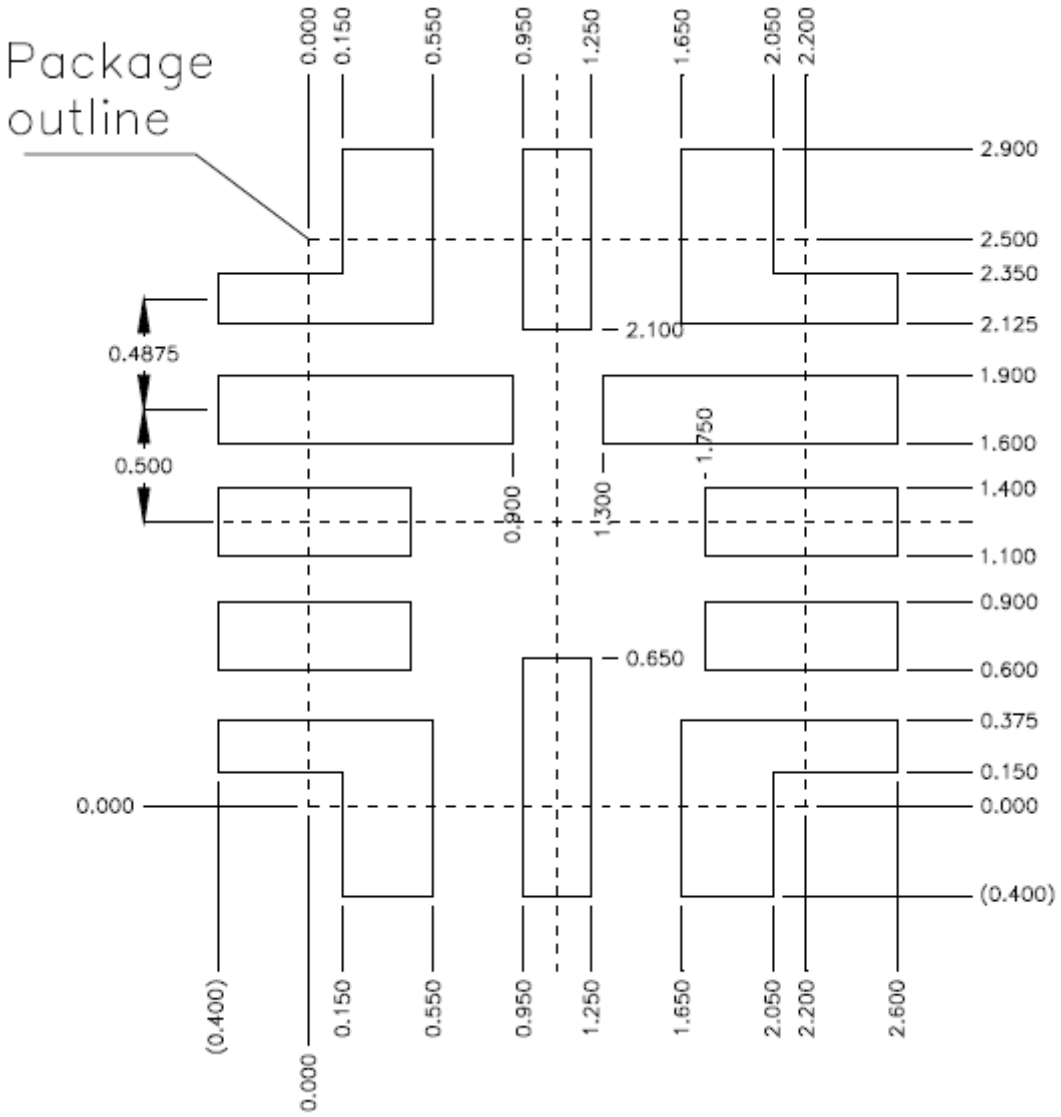
Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.800	1.000	0.031	0.039
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010
b	0.200	0.300	0.008	0.012
D	3.400	3.600	0.134	0.142
D2	2.000	2.100	0.079	0.083
E	3.400	3.600	0.134	0.142
E2	2.000	2.100	0.079	0.083
e	0.500		0.020	
L	0.350	0.450	0.014	0.018

V-Type 20L QFN 3.5x3.5 Package

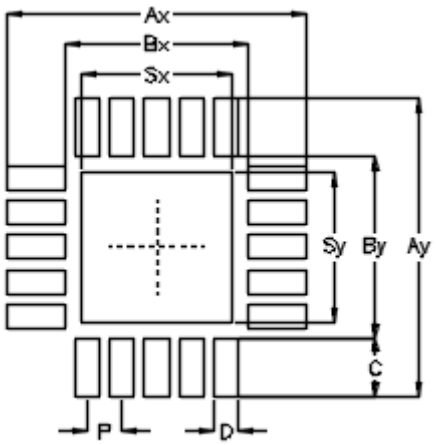
20 Footprint Information

20.1 WQFN-12L 2.2x2.5 (FC)



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

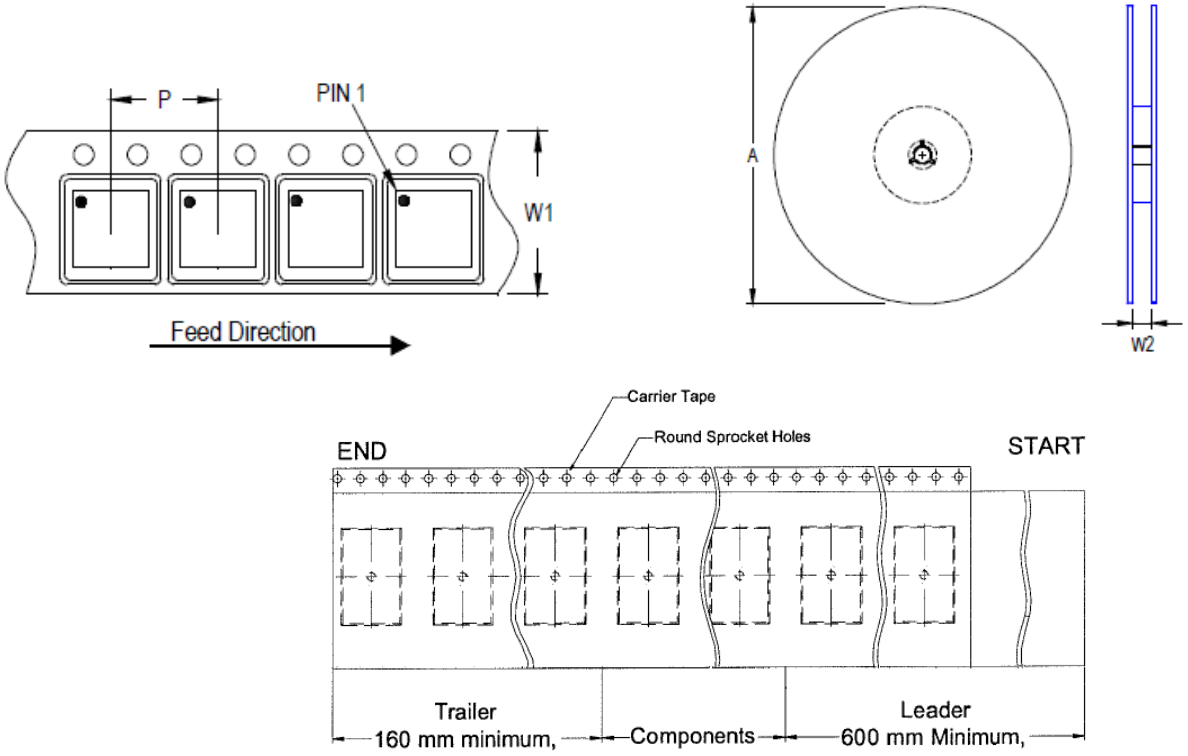
20.2 VQFN-20L 3.5x3.5



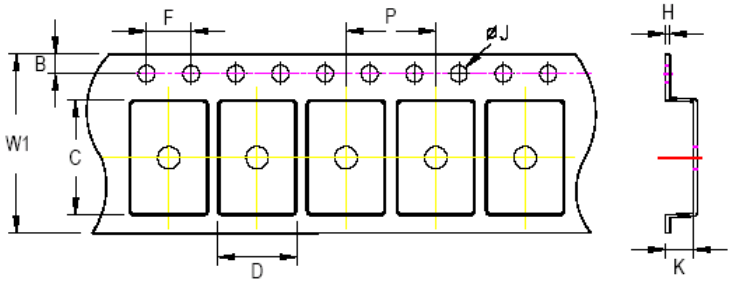
Package	Number of Pin	Footprint Dimension (mm)									Tolerance
		P	Ax	Ay	Bx	By	C	D	Sx	Sy	
V/W/U/XQFN3.5*3.5-20	20	0.50	4.30	4.30	2.60	2.60	0.85	0.35	2.15	2.15	±0.05

21 Packing Information

21.1 WQFN-12L 2.2x2.5 (FC) 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

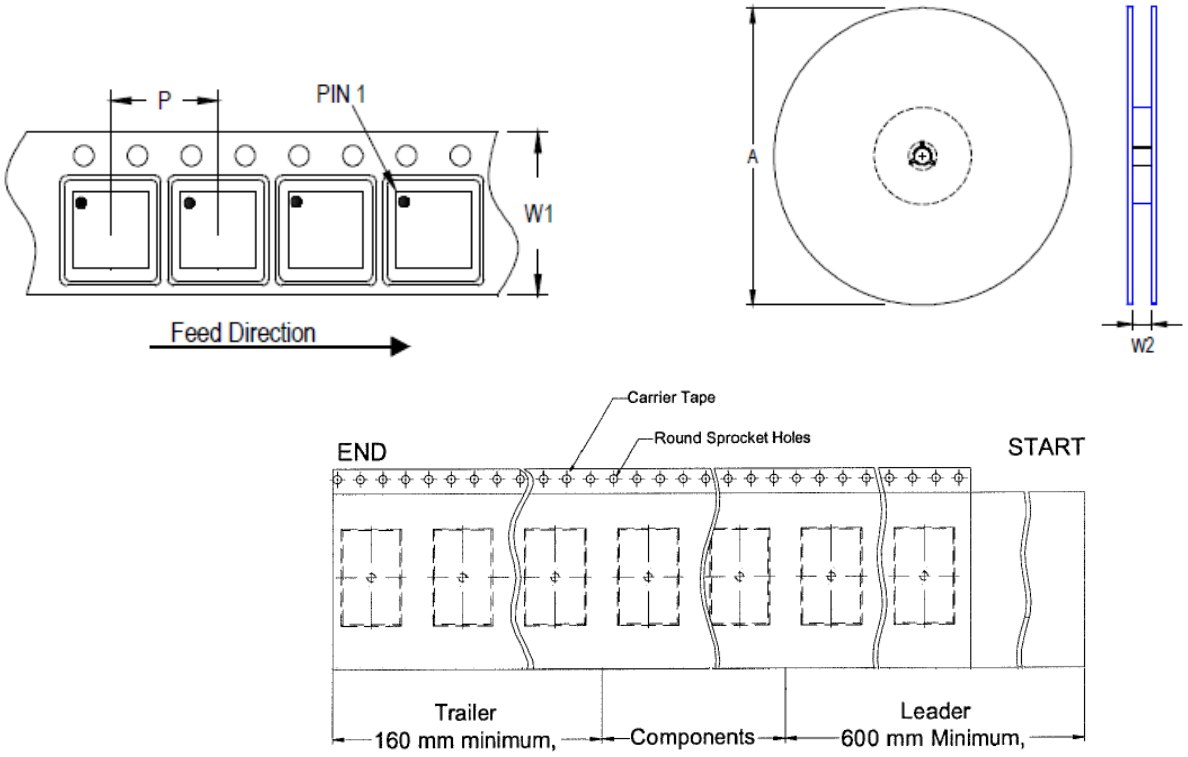


C, D and K are determined by component size. The clearance between the components and the cavity is as follows:

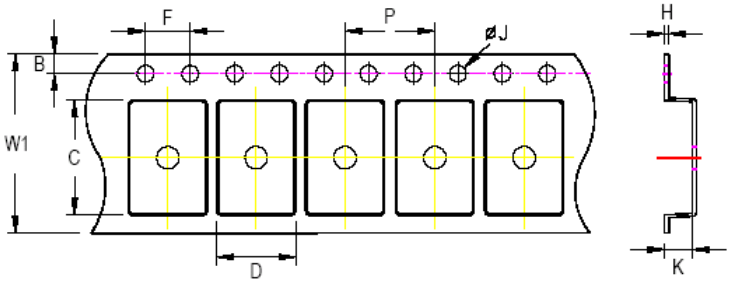
- For 12mm carrier tape: 0.5mm max.

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 VQFN-20L 3.5x3.5 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 3.5x3.5	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

21.3 WQFN-12L 2.2x2.5 (FC) Tape and Reel Packing

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

Container / Package	Reel		Box			Carton		
	Size	Units	Item	Reels	Units	Item	Boxes	Unit
QFN/DFN 2.2x2.5	7”	1,500	Box A	3	4,500	Carton A	12	54,000
			Box E	1	1,500	For Combined or Partial Reel.		

21.4 VQFN-20L 3.5x3.5 Tape and Reel Packing

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

Container / Package	Reel		Box			Carton		
	Size	Units	Item	Reels	Units	Item	Boxes	Unit
QFN/DFN 3.5x3.5	7”	1,500	Box A	3	4,500	Carton A	12	54,000
			Box E	1	1,500	For Combined or Partial Reel.		

21.5 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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22 Datasheet Revision History

Version	Date	Description	Item
00	2023/6/27	Final	Ordering Information
01	2023/9/15	Modify	General Description on P1 Features on P1 Electrical Characteristics on P6 Application Information on P16
02	2023/9/28	Modify	General Description on P1 Features on P1 Functional Block Diagram on P4 Electrical Characteristics on P6 Typical Operating Characteristics on P13
03	2024/1/22	Modify	Functional Pin Description on P3 Application Information on P20
04	2024/4/11	Modify	General Description on P1 Features on P1 Pin Configuration on P3 Functional Pin Description on P4 Functional Block Diagram on P6 Electrical Characteristics on P8, 9 Typical Application Circuit on P10 Operation on P16, 17 Application Information on P18, 19, 20, 21, 22, 25 Packing Information on P33, 34