

# 10V to 80V Hotswap Controller with Accurate Monitoring, PMBus Interface and Dynamic Transient Load Support

## 1 General Description

The RTQ1954 provides enterprise-level protection and high-performance monitoring for 10V to 80V systems such as 48V/54V datacenter network equipment. Sub- $\mu$ s response to short-circuit faults, multiple adjustable high-resolution overcurrent thresholds and remote temperature sensing with adjustable thresholds allow the RTQ1954 to protect and monitor critical systems – including those with wide dynamic range transient loads. Optional programmable MOSFET SOA protection accurately controls maximum MOSFET power dissipation while MOSFET health algorithms monitor the MOSFET even when fully enhanced. An adjustable overcurrent fault timer avoids false trips during dynamic transient overload events while maintaining robust protection from real overload conditions.

For monitoring, the RTQ1954 measures real-time power, voltage, current, temperature and fault data, and transmits this information via an I<sup>2</sup>C/SMBus interface with PMBus compliant command structure. Precision telemetry enables intelligent power management functions, power optimization and early fault detection. The RTQ1954 also improves system diagnostics with adjustable telemetry averaging and peak power measurement.

The RTQ1954 is available in the TSSOP-28 (Exposed Pad) package. The recommended junction temperature range is  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

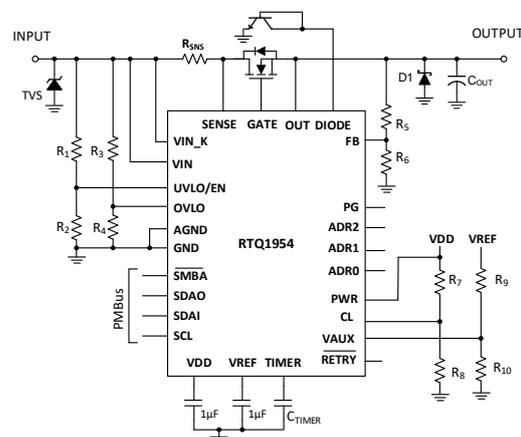
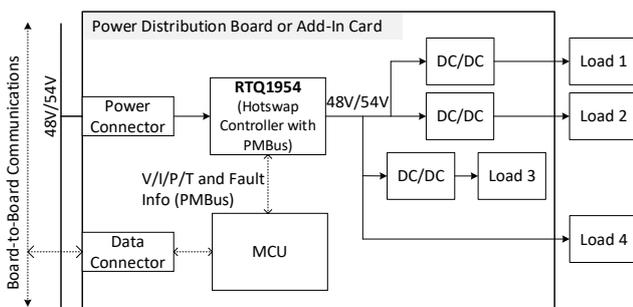
## 3 Features

- **VIN: 10V to 80V (100V AMR)**
- **VIN to VIN\_K:  $\pm 60\text{V}$  AMR**
- **OUT:  $-5\text{V}$  to  $100\text{V}$  AMR**
- **12-bit 1 kHz ADC Telemetry ( $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ )**
  - $\pm 0.8\%$  Voltage
  - $\pm 1\%$  Current
  - $\pm 1.8\%$  Power (Energy Monitoring Supported)
- **Four levels of Overcurrent Protection**
- **10 to 55mV Overcurrent Sense Voltage in 1mV Increments ( $\pm 1\text{mV}$  Accuracy)**
- **Programmable MOSFET SOA Protection**
- **Fast 500ns Response to Short-Circuit**
- **MOSFET Health Warning/Detection**
- **Remote Temperature Sensing with Adjustable Warning/Shutdown Thresholds**
- **PROCHOT Output (VAUX)**
- **Programable UV, OV Thresholds**
- **PMBus™ Compliant Command Structure**
- **$-40^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$  Operation**
- **Available in TSSOP-28 (Exposed Pad)**

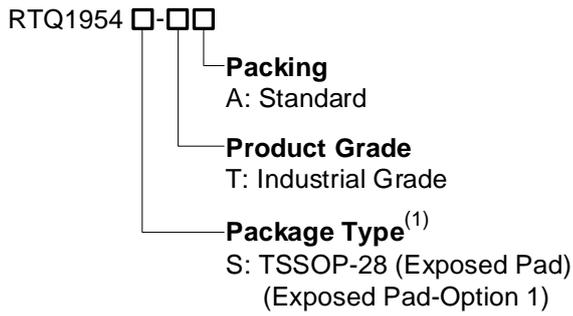
## 4 Applications

- 48V/54V Servers and Network Equipment
- Datacenter Rack Power Distribution
- Base Station Power Distribution
- PLC Power Management
- Industrial Systems

## 2 Simplified Application Circuit



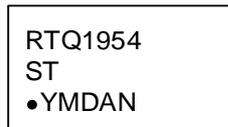
## 5 Ordering Information



### Note 1.

Richtek products are Richtek Green Policy compliant and marked with <sup>(1)</sup> indicates compatible with the current requirements of IPC/JEDEC J-STD-020.

## 6 Marking Information

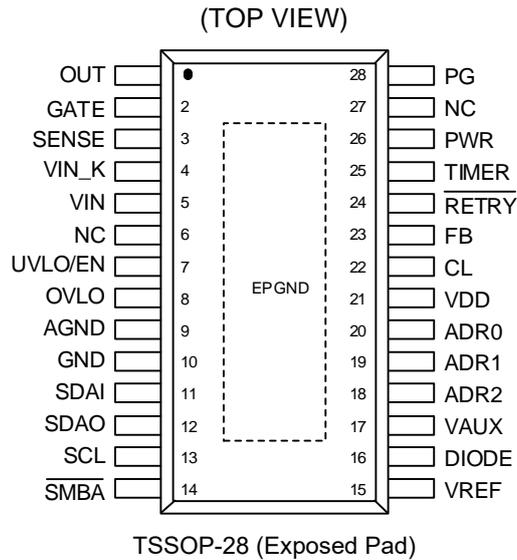


RTQ1954ST: Product Code  
YMDAN: Date Code

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7 Pin Configuration

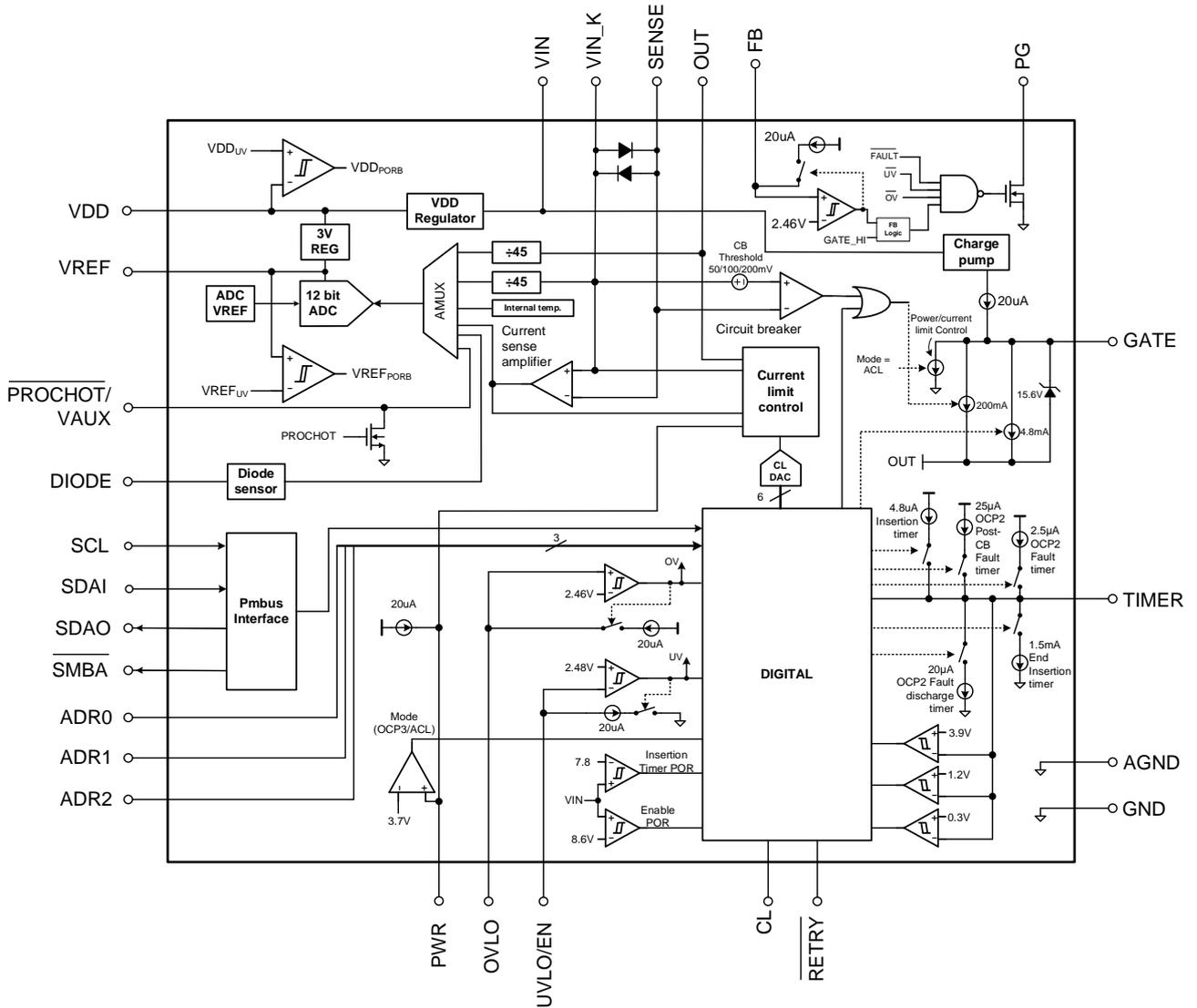


8 Functional Pin Description

Pin No.	Pin Name	Pin Function
1	OUT	Output pin. Connect to the power output node. This pin monitors the output voltage and senses the MOSFET VDS voltage for power limiting.
2	GATE	Gate drive output pin. Connect to the external MOSFET gate.
3	SENSE	Current sense input pin. In conjunction with VIN_K, this pin measures the voltage across the current sense resistor (RSNS). If the voltage across RSNS exceeds the overcurrent threshold, the load current is limited, and the fault timer activates.
4	VIN_K	Positive supply Kelvin pin. This pin senses the input voltage as well as the current sense voltage (in conjunction with SENSE).
5	VIN	Input power supply. This pin supplies power for the device including the internal VDD regulator. An R-C filter can help reduce noise on this pin (see section <a href="#">Input Voltage and Filtering</a> ).
6, 27	NC	No connection.
7	UVLO/EN	Undervoltage-lockout/enable pin. A resistor divider from VIN can set a precision undervoltage-lockout threshold. The pin enable threshold voltage is 2.48V. An internal 20µA current source provides UVLO hysteresis. This pin can also be used for remote shutdown control.
8	OVLO	Overvoltage lockout pin. A resistor divider from VIN can set a precision overvoltage lockout threshold. The pin disable threshold voltage is 2.46V. An internal 20µA current source provides OVLO hysteresis.
9	AGND	Analog device ground. Connect to GND at the pin.
10	GND	Device ground.
11	SDAI	SMBus Data Input pin. Connect to SDAO if the application does not need unidirectional isolation.
12	SDAO	SMBus Data Output pin. Connect to SDAI if the application does not need unidirectional isolation.
13	SCL	SMBus Clock pin.
14	SMBA/FLT	SMBus alert pin. Active low or FLT# open-drain output.

Pin No.	Pin Name	Pin Function
15	VREF	Internal sub-regulator output pin. This internally sub-regulated 3V bias supply requires an external 1 $\mu$ F capacitor to ground for bypassing. Do not connect to GND during start-up.
16	DIODE	External temperature diode pin. Connect this pin to a diode-configured MMBT3904 NPN transistor for temperature monitoring.
17	VAUX	Auxiliary voltage input pin. The internal telemetry system can measure the voltage on this pin from an external source with a full-scale input of 3V. This pin can be set as $\overline{\text{PROCHOT}}$ using PMBus. Alternatively, this pin can be used to set overcurrent protection (OCP2) threshold.
18	ADR2	SMBUS address line 2. Tri-state address line. Should be connected to GND, VDD, or left floating.
19	ADR1	SMBUS address line 1. Tri-state address line. Should be connected to GND, VDD, or left floating.
20	ADR0	SMBUS address line 0. Tri-state address line. Should be connected to GND, VDD, or left floating.
21	VDD	Internal sub-regulator output pin. This internally sub-regulated 4.9V bias supply requires an external 1 $\mu$ F capacitor to ground for bypassing.
22	CL	Overcurrent protection pin. Connect this pin to GND or leave floating to set the nominal overcurrent threshold OCP2 at 50 mV. Connecting CL to VDD sets the overcurrent threshold OCP2 at 26mV. Connect CL to a voltage between 2V and 3.9V to set the OCP2 threshold according to the VAUX pin voltage. The threshold can also be adjusted digitally.
23	FB	Power Good feedback pin. An external resistor divider from the output sets the PG output voltage level. The pin threshold is nominally 2.46 V. An internal 20- $\mu$ A current source provides hysteresis.
24	$\overline{\text{RETRY}}$	Fault retry input pin. When this pin is connected to GND or left floating, the device will continually try to restore power after a fault. If the pin is connected to VDD, the device will latch off after a fault event. Connecting this pin to VREF will retry 8 times and then latch off.
25	TIMER	Timer capacitor pin. An external capacitor connected to this pin sets the insertion time delay (power-on delay), OCP2 fault timeout period, and restart timing.
26	PWR	Mode selection pin. An external resistor (RPWR) connected from this pin to GND sets the mode as Active Current/Power Limit (ACL) mode. The RPWR in conjunction with RSNS sets the maximum power dissipation allowed in the external MOSFET. Pulling up the PWR pin to VDD sets the mode to overcurrent protection, OCP3.
28	PG	Power Good open-drain output pin. This output assumes a high-impedance state when the FB pin voltage exceeds the FB threshold (nominally 2.46 V) and the input voltage is within its undervoltage and overvoltage thresholds and GATE-OUT > 9V.
EPGND	Exposed Pad	Exposed pad of the package. Must be soldered to a large ground plane for best thermal performance.

9 Functional Block Diagram



**10 Absolute Maximum Ratings**

[\(Note 2\)](#)

- VIN, VIN\_K, GATE, UVLO/EN, SENSE, PG to GND ----- -0.3V to 100V
- VIN to VIN\_K ----- -60V to 60V
- VIN\_K to SENSE ----- -1V to 1V
- AGND to GND ----- -0.3V to 0.3V
- OVLO, FB, TIMER, PWR to GND ----- -0.3V to 7V
- OUT to GND ----- -5V to 100V
- SCL, SDAI, SDAO, CL, ADR0, ADR1, ADR2, VDD, VAUX, DIODE, RETRY to GND ----- -0.3V to 5.5V
- Junction Temperature, T<sub>J</sub> ----- 150°C
- Storage Temperature Range, T<sub>STG</sub> ----- -65°C to 150°C

**Note 2.** 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. The GATE pin voltage is typically 13.6V above VIN when the RTQ1954 is enabled. Therefore, the Absolute Maximum Rating for VIN applies only when the RTQ1954 is disabled, or for a momentary surge to that voltage because the Absolute Maximum Rating for the GATE pin is also 100V.

**11 ESD Ratings**

[\(Note 3\)](#)

- ESD Susceptibility
  - HBM (Human Body Model) ----- ±2KV
  - CDM (Charged Device Model) ----- ±500V

**Note 3.** Devices are ESD sensitive. Handling precautions are recommended.

**12 Recommended Operating Conditions**

[\(Note 4\)](#)

- Supply Input Voltage, V<sub>IN</sub> ----- 10V to 80V
- Junction Temperature Range, T<sub>J</sub> ----- -40°C to 125°C

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

### 13 Thermal Characteristics

(Note 5 and Note 6)

Thermal Parameter		TSSOP-28 (Exposed Pad)	Unit
$\theta_{JA}$	Junction-to-ambient thermal resistance	31.6	°C/W
$\theta_{JC(Top)}$	Junction-to-case (top) thermal resistance	18	°C/W
$\theta_{JC(Bottom)}$	Junction-to-case (bottom) thermal resistance	2.2	°C/W
$\theta_{JB}$	Junction-to-board thermal resistance	13.3	°C/W
$\Psi_{JC(Top)}$	Junction-to-case (top) characterization parameter	0.3	°C/W
$\Psi_{JC(Bottom)}$	Junction-to-case (bottom) characterization parameter	1.7	°C/W
$\Psi_{JB}$	Junction-to-board characterization parameter	12.4	°C/W

**Note 5.** For more information about the thermal parameters, see the Application and Definition of Thermal Resistances report, AN061.

**Note 6.**  $\theta_{JA}$ ,  $\Psi_{JC}$ , and  $\Psi_{JB}$  are simulated based on JEDEC 51-7 on a high effective-thermal-conductivity four-layer (2s2p) test board at 25°C and still air; 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

(Unless otherwise stated, the following conditions apply:  $V_{IN} = 48\text{ V}$ ,  $-40^\circ\text{C} < T_J < 125^\circ\text{C}$ ,  $V_{UVLO} = 3\text{ V}$ ,  $V_{OVLO} = 0\text{ V}$ ,  $R_{PWR} = 20\text{ k}\Omega$ . (Note 7))

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
<b>Input Supply (VIN)</b>						
VIN POR Threshold to Trigger Insertion Timer	VINPOR_IT	VIN Increasing	--	7.8	9	V
VIN POR Threshold to Enable All Functions	VINPOR_EN	VIN Increasing	--	8.6	9.9	V
VIN POR Enable Hysteresis	VINPOR_EN_HYS	VIN Decreasing	--	100	--	mV
Input Current, Enabled	IIN_EN	$V_{UVLO} = 3\text{ V}$ , $V_{OVLO} = 2\text{ V}$ (active)	3	5	7	mA
<b>VIN_K</b>						
VIN_K Bias Current	IIN_K		--	330	600	μA
<b>VDD Regulator (VDD Pin)</b>						
VDD Voltage	VDD	$I_{VDD} = 0\text{ mA}$	4.6	4.9	5.15	V
		$I_{VDD} = 10\text{ mA}$	4.6	4.9	5.15	V
VDD Current Limit	VDD_ILIM		-50	-30	-15	mA
VDD Voltage Reset Threshold	VDD_POR	VDD Rising	--	4.1	--	V
<b>UVLO/EN and OVLO (Pins)</b>						
UVLO Threshold	VUVLO_L	Falling (low) threshold	2.41	2.48	2.55	V
UVLO Hysteresis Current	IUVLO_HYS	$V_{UVLO} = 1\text{ V}$	16	20	24	μA
UVLO Bias Current	IUVLO_BIAS	$V_{UVLO} = 3\text{ V}$	--	0	1	μA

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
OVLO Threshold	VOVLO-H	Rising (high) threshold	2.39	2.46	2.53	V
OVLO Hysteresis Current	IOVLO_HYS	VOVLO = 3V	-24	-20	-16	μA
OVLO Bias Current	IOVLO_BIAS	VOVLO = 1V	--	0	1	μA
<b>Power Good (PG)</b>						
Output Low Voltage	VPG_L	ISINK = 2mA	--	200	400	mV
Off Leakage Current	VPG_ILK	VPG = 80V	--	0	1	μA
<b>FB</b>						
FB Threshold	VFB		2.41	2.46	2.52	V
FB Hysteresis Current	VFB_HYS	High threshold	-25	-20	-15	μA
Off Leakage Current	VFB_ILK	VFB = 2.3V	--	0	1	μA
<b>GATE Control</b>						
Source Current	IGATE	Normal Operation	-25	-20	-15	μA
Fault Sink Current		VUVLO = 2V	4	4.8	5.5	mA
POR Circuit Breaker Sink Current		VVIN_K - VSSENSE = 60mV or VIN < VINPOR_IT, VGATE = 5V, OUT = 0V, CB/CL ratio bit = 0, CL = VDD	90	200	350	mA
Active CL Sink Current		VVIN_K - VSSENSE = VCL+25mV, VGATE = 5V, OUT = 0V (Mode = ACL)	0.1	0.4	0.7	mA
Reverse-Bias Voltage of GATE to OUT	VGATEZ	VGATE - VOUT, IZ = -100μA	12	15.6	18	V
Peak charge pump voltage in normal operation (VIN = VOUT)	VGATECP	VGATE - VOUT	11	13	15	V
<b>OUT</b>						
OUT Bias Current, Enabled	IOUT-EN	VIN = VOUT, Normal Operation	55	80	100	μA
OUT Bias Current, Disabled	IOUT-DIS	VOUT = 0V, VVIN_K = VSSENSE, VEN/UVLO = 2V	-2.5	0	2.5	μA
<b>Overcurrent Protection (OCP) and Active Current Limit (ACL)</b>						
Overcurrent Protection Threshold Voltage, OCP1, VVIN_K - VSSENSE	VOCP1	During start-up, disabled after PG goes high	1.5	2	2.5	mV
Overcurrent Protection Threshold Voltage, OCP2, VVIN_K - VSSENSE	VOCP2	CL = VDD	24.7	26	27.3	mV
		CL = GND	47.5	50	52.5	
		CL = 3V, VAUX = 0.057V	35.2	37	38.9	
		CL = 3V, VAUX = 2.74V	46.6	49	51.5	
CL Upper Threshold	VCL-H	OCP2 set based on VAUX	--	3.9	--	V
CL Lower Threshold	VCL-L	OCP2 set based on VAUX	--	2	--	V
VAUX Step Resolution		2V ≤ CL ≤ 3.9V	--	±114	--	mV

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
PMBus Overcurrent Protection, OCP2, Threshold	VOCP2	Min Threshold	9.5	10	10.5	mV
		Max Threshold	52.25	55	57.75	mV
		DAC step resolution	--	1	--	mV
Overcurrent Protection Threshold Voltage, OCP3, VVIN_K – VSENSE	VOCP3	PWR=VDD (Mode = OCP3), CL = VDD	37.5	41	46	mV
		PWR=VDD (Mode = OCP3), CL = GND	63.1	66	71.7	
Overcurrent Protection Level - Active Current Limit (ACL), VVIN_K – VSENSE	VACL	PWR = 2KΩ to GND (Mode = ACL), CL = VDD	37.8	41	45.6	mV
		PWR = 2KΩ to GND (Mode = ACL), CL = GND	63.1	66	71.7	
PWR Comparator Voltage Threshold	VPWR_CMP	To Switch between OCP3 and ACL modes	3.5	3.7	4.1	V
SENSE Input Current	ISENSE	Enabled, SENSE = OUT	--	0	1	μA
		Disabled, OUT = 0V	--	0	1	
		Enabled, OUT = 0V	--	0	1	
CL Pin Input Leakage Current		CL = VDD	--	5	--	μA
<b>Protection Mode: Active Current/Power Limit (ACL)</b>						
Power Limit Sense Voltage, VVIN_K – VSENSE	VPL	VIN = 48V, VOUT = 0V, RPWR = 60K	21.8	26.1	30.3	mV
		VIN = 48V, VOUT = 0V, RPWR = 20K	15.2	18.9	22.7	
		VIN = 48V, VOUT = 24V, RPWR = 60K	32.3	38	43.7	
		VIN = 48V, VOUT = 24V, RPWR = 20K	19.5	23.6	27.7	
		VIN = 48V, VOUT = 0V, RPWR = 100K	28.6	33.5	38.4	
PWR Pin Current	IPWR	VPWR = 2.5V	--	-20	--	μA
		VPWR = VDD	--	3	--	μA
Maximum RPWR	RPWR_MAX		--	--	100	KΩ
<b>Circuit Breaker</b>						
Circuit Breaker Threshold Voltage, VVIN_K – VSENSE	VCB	CB/CL ratio bit = 0, VOCP2 ≥ 33mV	81	100	111	mV
		CB/CL ratio bit = 1, VOCP2 ≥ 33mV	160	200	230	mV
		CB/CL ratio bit = 0, VOCP2 ≤ 32mV	38	50	58	mV
		CB/CL ratio bit = 1, VOCP2 ≤ 32mV	80	100	112	mV

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
<b>TIMER (Pin)</b>						
Upper Threshold	VTMRH		3.74	3.9	4.07	V
Lower Threshold	VTMRL	Restart cycles	1	1.2	1.4	V
		End of eight cycle re-enabled threshold	--	0.3	--	
Insertion Time Current	ITIMER	VTIMER = 2V	-5.9	-4.8	-3.3	μA
Sink Current, End of Insertion Time			0.9	1.5	2.1	mA
Fault Detection Current			-3.2	-2.5	-1.7	μA
Fault Sink Current after CB			-32	-25	-17	μA
Fault Sink Current			14	20	26	μA
Fault Restart Duty Cycle	DCFAULT		--	15	--	%
<b>Internal Reference</b>						
Reference Voltage	VREF		2.91	3	3.09	V
<b>ADC and MUX</b>						
Resolution			--	12	--	Bits
Integral Non-Linearity	INL	ADC only	--	±0.5	--	LSB
Oscillator Accuracy	fOSC		--	±5	--	%
Acquisition + Conversion Time	tACQUIRE	Any channel	--	129	--	μs
Acquisition Round Robin Time <a href="#">(Note 8)</a>	tRR	Cycle all channels	--	1.048	--	ms
<b>Telemetry</b>						
Current Input Full-Scale Range	IINFSR	V <sub>OCP2</sub> ≥ 33mV	58.5	60	61.5	mV
		V <sub>OCP2</sub> ≤ 32mV	26	27	29	mV
Current Input LSB	IINLSB	V <sub>OCP2</sub> ≥ 33mV	--	14.7	--	μV
		V <sub>OCP2</sub> ≤ 32mV	--	6.6	--	μV
VAUX Input Full Scale Range	VAUXFSR		2.93	2.97	3.01	V
VAUX Input LSB	VAUXLSB		--	7.139	--	mV
Input Voltage Full Scale Range	VINFSR		86	88.9	91	V
Input Voltage LSB	VINLSB		--	21.7	--	mV
Output Voltage Full-Scale Range	VOUTFSR		86	88.9	91	V
Output Voltage LSB	VOUTLSB		--	21.7	--	mV

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
VIN, VOUT Absolute Accuracy	V <sub>ACC</sub>	V <sub>IN</sub> , V <sub>OUT</sub> = 80V	-0.8	--	0.8	%
		V <sub>IN</sub> , V <sub>OUT</sub> = 48V	-0.8	--	0.8	
		V <sub>IN</sub> , V <sub>OUT</sub> = 10V	-2.5	--	2.5	
VAUX Absolute Accuracy		VAUX = 2.8V	-0.8	--	0.8	%
		VAUX = 1.5V	-0.8	--	0.8	
		VAUX = 0.75V	-0.8	--	0.8	
Input Current Absolute Accuracy	I <sub>INACC</sub>	V <sub>VIN_K</sub> - V <sub>SENSE</sub> = 22mV (81% I <sub>INFSR</sub> ), CL = VDD	-1	--	1	%
		V <sub>VIN_K</sub> - V <sub>SENSE</sub> = 22mV (81% I <sub>INFSR</sub> ), CL = VDD -40°C < T <sub>J</sub> < 85°C	-0.8	--	0.8	
		V <sub>VIN_K</sub> - V <sub>SENSE</sub> = 5mV (19% I <sub>INFSR</sub> ), CL = VDD	-5	--	5	
		V <sub>VIN_K</sub> - V <sub>SENSE</sub> = 44mV (73% I <sub>INFSR</sub> ), CL = GND	-1	--	1	
		V <sub>VIN_K</sub> - V <sub>SENSE</sub> = 44mV (73% I <sub>INFSR</sub> ), CL = GND -40°C < T <sub>J</sub> < 85°C	-0.8	--	0.8	
		V <sub>VIN_K</sub> - V <sub>SENSE</sub> = 25mV (42% I <sub>INFSR</sub> ), CL = GND	-1	--	1	
		V <sub>VIN_K</sub> - V <sub>SENSE</sub> = 9.5mV (16% I <sub>INFSR</sub> ), CL = GND	-5	--	5	
Input Power Accuracy	P <sub>INACC</sub>	V <sub>VIN_K</sub> - V <sub>SENSE</sub> = 22mV (81% I <sub>INFSR</sub> ), CL = VDD	-1.8	--	1.8	%
		V <sub>VIN_K</sub> - V <sub>SENSE</sub> = 22mV (81% I <sub>INFSR</sub> ), CL = VDD -40°C < T <sub>J</sub> < 85°C	-1.5	--	1.5	
		V <sub>VIN_K</sub> - V <sub>SENSE</sub> = 5mV (19% I <sub>INFSR</sub> ), CL = VDD	-5	--	5	
		V <sub>VIN_K</sub> - V <sub>SENSE</sub> = 44mV (73% I <sub>INFSR</sub> ), CL = GND	-1.8	--	1.8	
		V <sub>VIN_K</sub> - V <sub>SENSE</sub> = 44mV (73% I <sub>INFSR</sub> ), CL = GND -40°C < T <sub>J</sub> < 85°C	-1.5	--	1.5	
		V <sub>VIN_K</sub> - V <sub>SENSE</sub> = 25mV (42% I <sub>INFSR</sub> ), CL = GND	-1.8	--	1.8	
		V <sub>VIN_K</sub> - V <sub>SENSE</sub> = 9.5mV (16% I <sub>INFSR</sub> ), CL = GND	-5	--	5	
<b>Temperature Sense</b>						
On Chip Temperature Accuracy	T <sub>JACC</sub>	T <sub>J</sub> = -40°C to 125°C	-8	--	8	°C
On Chip Temperature Resolution			--	12	--	bits
Temperature Accuracy Using Remote Diode	T <sub>ACC</sub>	T <sub>A</sub> = 25°C to 85°C	-8	--	8	°C
Remote Diode Resolution			--	12	--	bits

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Remote Diode Current Source	IDIODE	High Level	-200	-160	--	μA
		Mid Level	--	-60	--	
		Low Level	--	-10	--	
Remote Diode Current Ratio	IDIODE_CR	High level to low level ratio	13.6	16	17.6	μA/μA
		High level to mid level ratio	2.14	2.67	3.2	
Max Series Resistance with Remote Diode			--	--	300	Ω
<b>PMBus Pin Thresholds (SCL, SDA, <math>\overline{\text{SMBA}}</math>)</b>						
Data, Clock Input Low Voltage	V <sub>IL</sub>	SCL, SDAI	--	--	0.8	V
Data, Clock Input High Voltage	V <sub>IH</sub>	SCL, SDAI	1.35	--	5.5	V
Data Output Low Voltage	V <sub>OL</sub>	SDAO, I <sub>SINK</sub> = 3mA	0	--	0.4	V
Input Leakage Current	I <sub>LEAK</sub>	SDAI, $\overline{\text{SMBA}}$ , SCL = 5V	--	0	1	μA
<b>PROCHOT Output (If VAUX is not used to set OCP2)</b>						
Output Low Voltage	V <sub>PROCHOT_LV</sub>	I <sub>SINK</sub> = 2mA	--	100	400	mV
Off Leakage Current	I <sub>PROCHOT_LK</sub>		--	0	1	μA
<b>Configuration Pin Thresholds (RETRY)</b>						
High Threshold Voltage	V <sub>IH</sub>		3.6	3.9	4.1	V
Low Threshold Voltage	V <sub>IL</sub>		1.7	2	2.2	V
Input Leakage Current	I <sub>LEAK</sub>	$\overline{\text{RETRY}} = 5V$	--	5	--	μA

**Note 7.** Guaranteed by design.

**Note 8.** The sampling time increment is  $t_{\text{ACQUIRE}} \times N$ , where N is the number of active telemetry features (V<sub>IN</sub>, V<sub>OUT</sub>, I<sub>IN</sub>, TEMP\_INTERNAL). If the TEMP\_EXTERNAL telemetry is active, the sampling time increment is 1.048ms.

## 14.1 SMBus Communications Timing Requirements and Definitions

Parameter	Symbol	Min	Typ	Max	Unit
SMBus Operating Frequency	f <sub>SMB</sub>	10	--	1000	kHz
Bus Free Time Between Stop and Start Condition	t <sub>BUF</sub>	0.5	--	--	μs
Hold Time After (repeated) Start Condition. After this period, the first clock is generated.	t <sub>HD:STA</sub>	0.26	--	--	μs
Repeated Start Condition Setup Time	t <sub>SU:STA</sub>	0.26	--	--	μs
Stop Condition Setup Time	t <sub>SU:STO</sub>	0.26	--	--	μs
Data Hold Time (Note 9)	t <sub>HD:DAT</sub>	85	--	--	ns
Data Setup Time	t <sub>SU:DAT</sub>	50	--	--	ns
Detect Clock Low Timeout (Note 10)	t <sub>TIMEOUT</sub>	25	--	35	ms
Clock Low Period	t <sub>LOW</sub>	0.5	--	--	μs
Clock High Period (Note 11)	t <sub>HIGH</sub>	0.26	--	--	μs
Cumulative Clock Low Extended Time (Slave Device) (Note 12)	t <sub>LOW:SEXT</sub>	--	--	25	ms
Cumulative Low Extend Time (Master Device) (Note 13)	t <sub>LOW:MEXT</sub>	--	--	10	ms
Clock/Data Fall Time (Note 14)	t <sub>R</sub>	20	--	120	ns
Clock/Data Rise Time	t <sub>F</sub>	20	--	120	ns

**Note 9.** The device must internally provide sufficient hold time for the SDA signal (with respect to the V<sub>IH,MIN</sub> of the SCL signal) to bridge the undefined region of the falling edge of SCL.

**Note 10.** Devices participating in a transfer can abort the transfer in progress and release the bus when any single clock low interval exceeds the value of t<sub>TIMEOUT,MIN</sub> of 25ms. Devices that have detected this condition must reset their communication and be able to receive a new START condition no later than t<sub>TIMEOUT,MAX</sub> of 35ms.

**Note 11.** t<sub>HIGH,MAX</sub> provides a simple guaranteed method for masters to detect bus idle conditions.

**Note 12.** t<sub>LOW:SEXT</sub> is the cumulative time a slave device is allowed to extend the clock cycles in one message from the initial START to the STOP.

**Note 13.** t<sub>LOW:MEXT</sub> is the cumulative time a master device is allowed to extend its clock cycles within each byte of a message as defined from START-to-ACK, ACK-to-ACK, or ACK-to-STOP.

**Note 14.** Rise and fall times are defined as follows:

$$t_R = (V_{IL,MAX} - 0.15V) \text{ to } (V_{IH,MIN} + 0.15V), t_F = (V_{IH,MIN} + 0.15V) \text{ to } (V_{IL,MAX} - 0.15V)$$

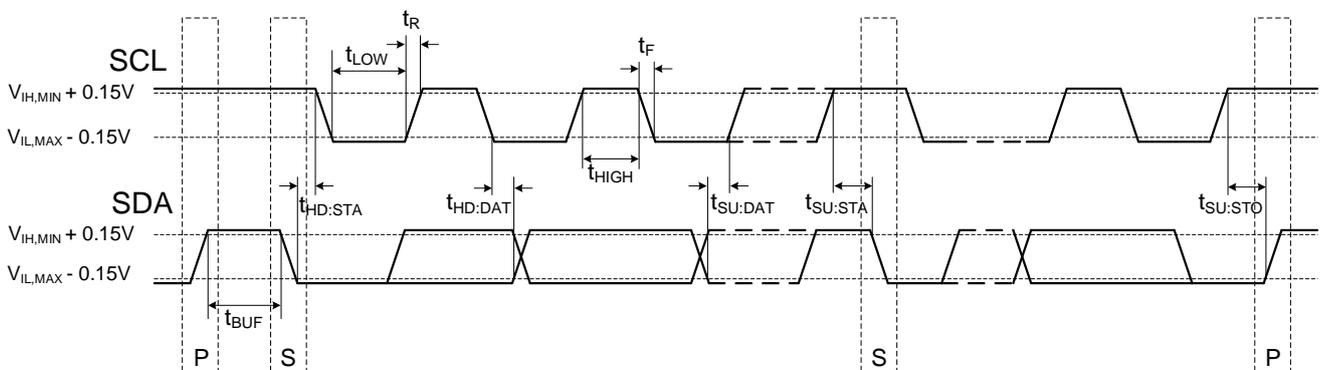


Figure 1. SMBus Timing Diagram

**14.2 Switching Characteristics**

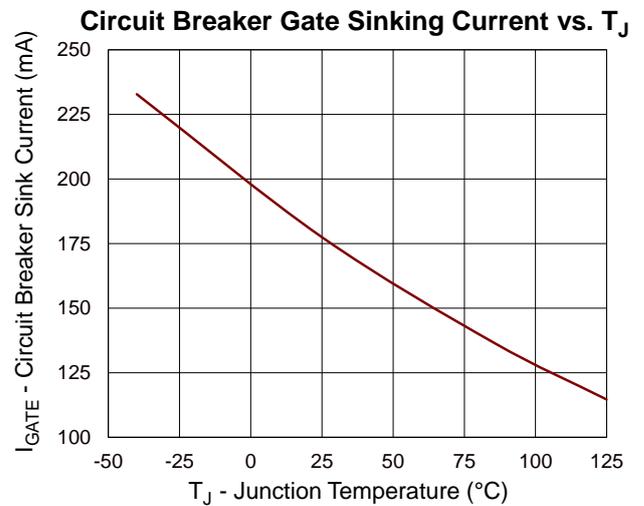
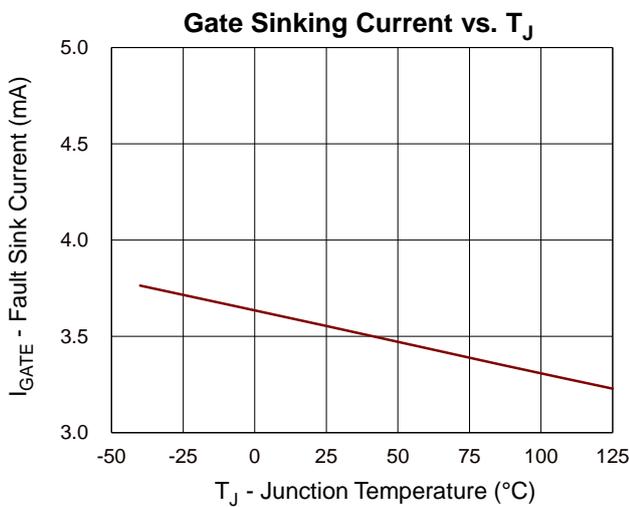
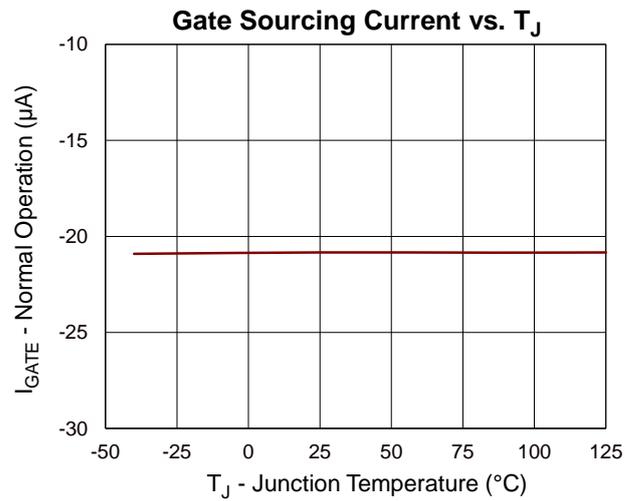
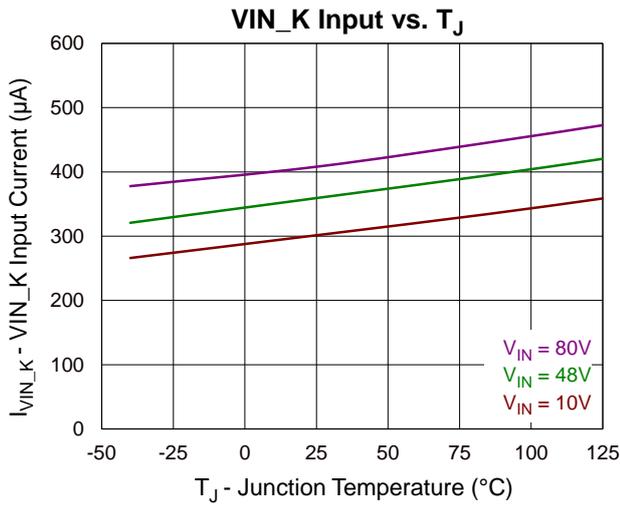
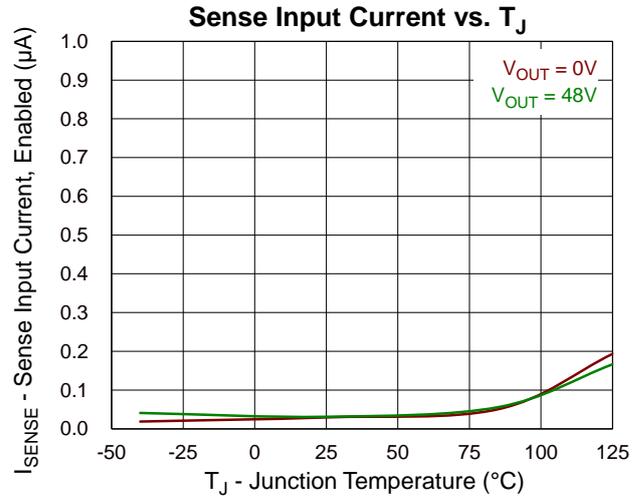
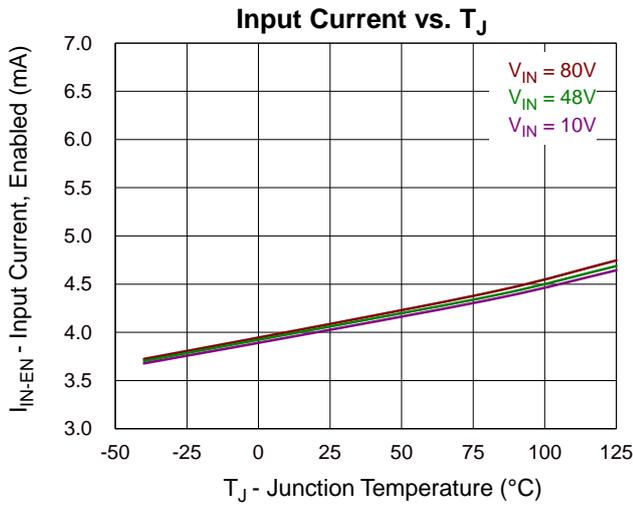
(Unless otherwise stated, the following conditions apply:  $V_{IN} = 48V$ ,  $-40^{\circ}C < T_J < 125^{\circ}C$ ,  $V_{UVLO} = 3 V$ ,  $V_{OVLO} = 0 V$ ,  $R_{PWR} = 20k\Omega$ .)

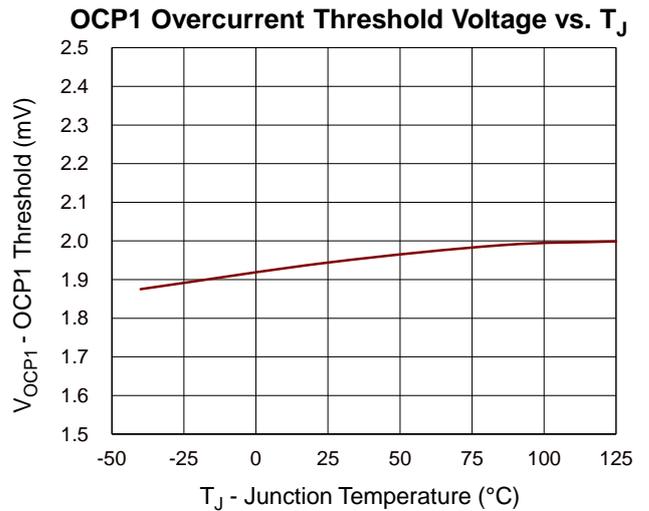
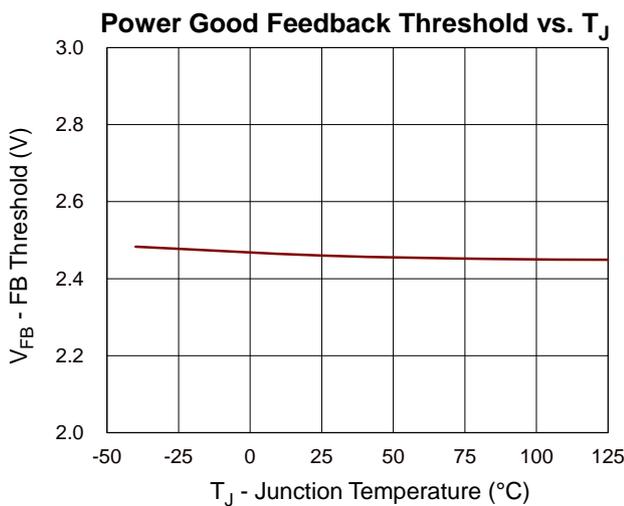
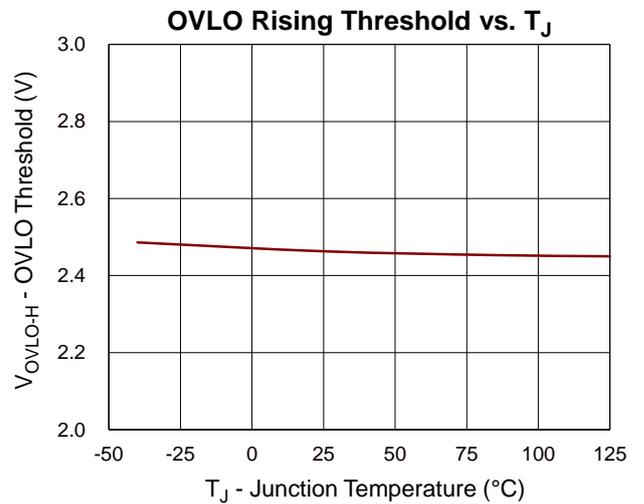
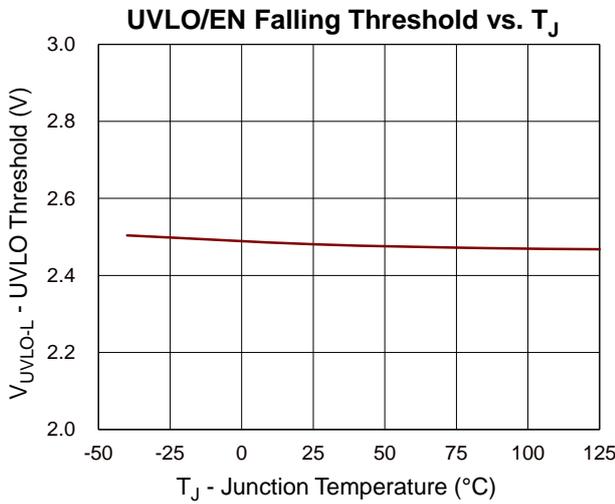
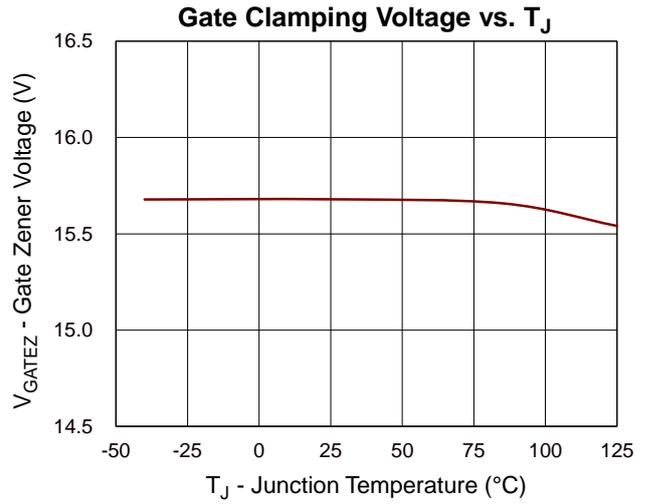
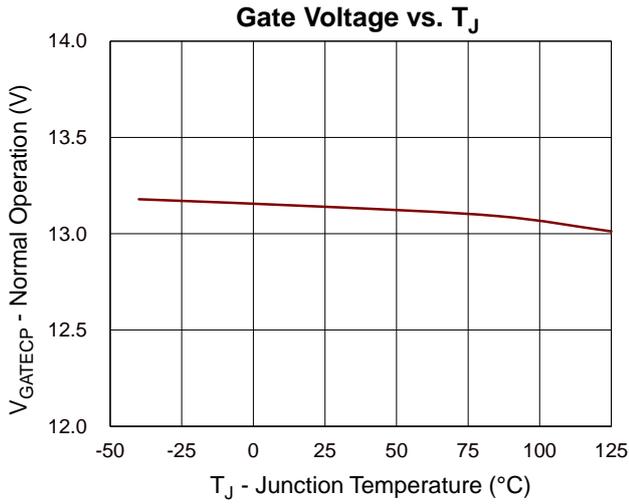
Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
UVLO Delay	t <sub>UVLO_DEL</sub>	Delay to GATE high	7	10.7	12.7	μs
		Delay to GATE low	5.5	9	11.5	
OVLO Delay	t <sub>OVLO_DEL</sub>	Delay to GATE high	7	10.7	12.7	μs
		Delay to GATE low	5.5	9.3	11.5	
FB Delay	t <sub>FB_DEL</sub>	Delay to PG high (FB and GATE_HI TRUE)	70	110	160	μs
		Delay to PG low	7	11.5	13.5	
Circuit Breaker Response Time	t <sub>CB</sub>	V <sub>IN_K-SENSE</sub> stepped from 0 to 150mV, time to GATE-OUT<2V, no load, CB threshold=50mV	--	0.35	0.5	μs
Fault to GATE Low Delay	t <sub>FAULT_DEL</sub>	TIMER pin reaches the upper threshold	--	2	4	μs
OCP1 Response Time	t <sub>OCP1</sub>	Time from V <sub>IN_K-SENSE</sub> = 2mV to GATE starts to pull down, start-up or restart only	--	10	--	μs
OCP3/ACL Blanking Time	t <sub>BLANK</sub>	Mode = OCP3 or ACL	300	500	700	μs
ACL Max Regulation Time	t <sub>ACL</sub>	Mode = ACL	480	530	576	μs

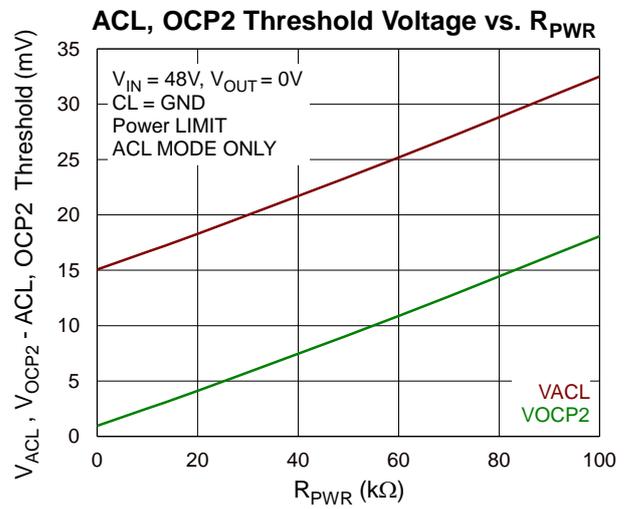
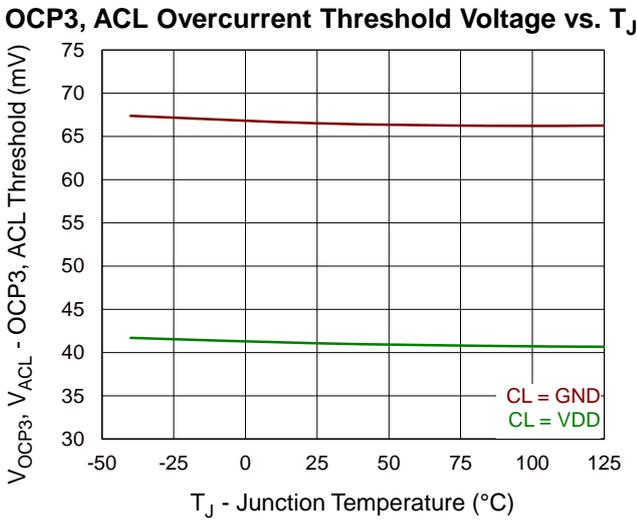
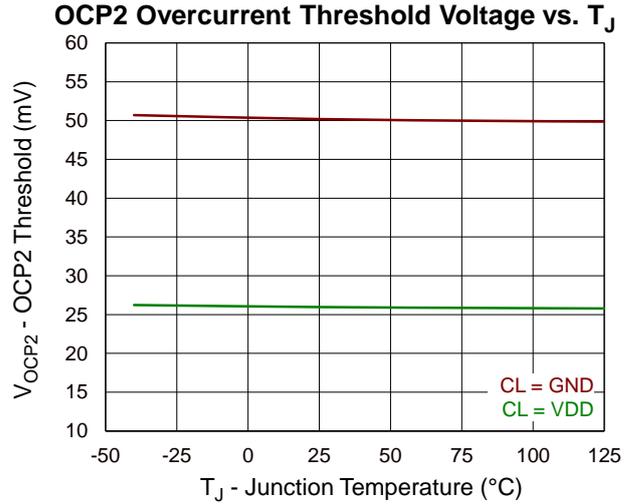
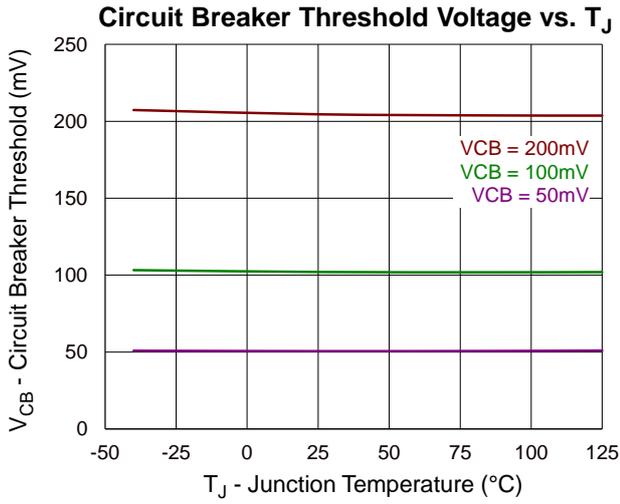


## 16 Typical Characteristics Curves

Unless otherwise stated, the following conditions apply:  $V_{IN} = 48V$ ,  $T_J = 25^\circ C$ .







## 17 Application Information

([Note 15](#))

### 17.1 Overview

The RTQ1954 inline power protection controls inrush current when inserting an add-in-card or circuit card into a live (so called “hot”) backplane power source. The controlled inrush current prevents voltage sagging on the backplane supply voltage and high dV/dt surge on the load. The RTQ1954 provides multi-level Over-Current Protection (OCP) features. During start-up, the RTQ1954 quickly detects overcurrent (OCP1, 2mV sense voltage typical) and disconnects the power flow. Similarly, when removing an add-in-card from a source, a controlled shutdown is implemented to prevent flash arc and possible damage.

In addition to a controlled hot swapping in/out of a power source and a dedicated start-up over-current protection level, the RTQ1954 provides three additional levels of fast and accurate protection to a variety of overload transients during operation. A high-resolution overcurrent protection (OCP2) with sense voltage programmability of 10mV to 55mV provides first-level fault/overcurrent protection along with a hardware adjustable fault timer. The timer is designed to avoid “fault accumulation” and false trips common with dynamic transient, but normal, overload events. The next level of protection, OCP3 (15mV higher sense voltage than OCP2, typical) has a fixed 0.5ms blanking timer to ensure fast unpredictable, but normal, overloads pass through without tripping a fault.

Some systems may benefit from an active current limit (ACL) in addition to overcurrent protection (OCP). ACL differs from OCP functionality by servoing the GATE pin in an attempt to control the system current using feedback. For example, if several hot swap power domains share a common power supply, active current limit can be used to ensure that no single domain consumes more than its share of current. For these systems, the RTQ1954 provides optional hardware adjustable active current/power limit (ACL). Using the same sense voltage as OCP3 (15mV higher than OCP2) and fixed 0.5ms blanking with an additional fixed 0.5ms timer, ACL mode actively monitors and controls current and maximum power dissipation in the MOSFET.

Finally, both OCP and ACL modes implement the same circuit-breaker response in the case of severe overcurrent events. The RTQ1954 has a sub- $\mu$ s response time to short circuit faults that exceed an adjustable circuit-breaker sense voltage threshold to ensure the external series-pass MOSFET will not get damaged.

If the RTQ1954 shuts down the series-pass MOSFET due to a fault, the state of the RETRY pin determines whether the system attempts to restart, and if so, the number of retries.

System software can initiate a system shutdown and restart using the PMBus smart reboot command with a programmable VOUT discharge voltage and reboot time of up to 65s.

Along with protection, the RTQ1954 provides accurate and precise real-time monitoring of power, voltage, current, temperature, and fault data which is transmitted via an I<sup>2</sup>C/SMBus interface with PMBus compliant command structure. Precision telemetry enables intelligent power management functions (e.g. Intel PROCHOT output), power optimization and early fault detection. The RTQ1954 also improves system diagnostics with adjustable telemetry averaging and peak power measurement. Remote temperature sensing with adjustable warning/shutdown thresholds provides additional protection and monitoring for the most critical systems.

Additional features include MOSFET health warning and detection algorithms which monitor the MOSFET even when fully enhanced. Programmable undervoltage lockout (UVLO) and overvoltage lockout (OVLO) shuts down the RTQ1954 when the input voltage is outside the normal operating region.

### 17.2 Input Voltage and Filtering

The RTQ1954 draws power from VIN, and this pin can be filtered from the primary input supply using an R-C network as shown in [Typical Application Circuit](#). A time constant of several tens of microseconds should be

sufficient. While the Absolute Maximum Rating (AMR) of the difference between VIN and VIN\_K is  $\pm 60V$ , the differential voltage should be temporary. This is the case when first applying power to VIN\_K and VIN through the R-C filter or when a fault occurs resulting in an inductive spike on VIN\_K while VIN remains filtered. However, the internal RTQ1954 charge pump is connected to VIN, so VGS of the external MOSFET will be reduced by (VIN\_K – VIN). Therefore, it is important that the differences between VIN and VIN\_K are transient and kept under  $\pm 1V$  during normal operation.

**17.3 Current Sense Inputs**

The RTQ1954 measures the load current by sensing the voltage across the external current sense resistor RSNS (VIN\_K - VSENSE). To avoid instability in current loop control, it is recommended that the RSNS value be no higher than 200mΩ. For designs that require multiple sense resistors in parallel, care must be taken on the layout and connection of these resistors to minimize the effect of imbalance.

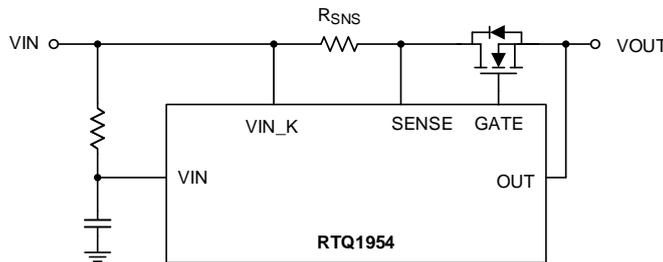


Figure 3. Connection of Sense Resistor to Hot Swap Controller

**17.4 Overcurrent Protection**

The RTQ1954 provides four levels of fast and accurate protection against a variety of overcurrent loads as follows:

- **Start-up protection, OCP1:** protects against unexpected and excessive inrush currents with V<sub>OCP1</sub> (2mV typical) sense voltage threshold.
- **Normal operation, OCP2:** hardware and PMBus adjustable sense voltage, V<sub>OCP2</sub>, of 10mV to 55mV with hardware adjustable non-accumulative fault TIMER. OCP2 is intended to be set above the highest expected steady-state load. OCP2 protects against soft shorts or unexpected overloads resulting in over-current for longer than *expected* transient overload conditions.
- **Normal operation, OCP3:** V<sub>OCP3</sub> sense voltage is fixed 15mV (typical) above V<sub>OCP2</sub> with a 0.5ms blanking timer. OCP3 allows even higher *expected* but unpredictable short overload pulses, while still protecting the system if the overload condition exceeds t<sub>BLANK</sub> (typically 0.5ms).
  - Optional hardware selectable active current/power limit (ACL) mode limits the current/power in the external MOSFET if the sense voltage exceeds V<sub>ACL</sub> (V<sub>OCP2</sub> + 15mV typical).
- **Circuit breaker, CB:** with sub-μs response to extreme overcurrent events (sense voltage exceeding adjustable V<sub>CB</sub>), circuit breaker is the RTQ1954’s ultimate protection against severe fault conditions.

**17.4.1 Start-up Protection, OCP1:**

During the start-up if the voltage across the RSNS resistor (V<sub>VIN\_K</sub> - V<sub>SENSE</sub>) exceeds V<sub>OCP1</sub> (2mV typical), the RTQ1954 turns off the external MOSFET within 10μs (t<sub>OCP1</sub>) using a 4.8mA GATE pulldown current, and the part enters into RETRY mode. In addition, the IIN\_OC\_Fault bit in the STATUS\_INPUT (7Ch) register and the INPUT\_STATUS bit in the STATUS\_WORD (79h) register are toggled high and the SMBA pin is asserted, unless this feature is disabled using the ALERT\_MASK (D8h) register. OCP1 is active following initial power up or

following any RETRY event. These scenarios can be identified by observing PG is low. OCP1 deactivates following a successful start-up as indicated by PG transitioning high. All system loads should be gated by PG, and start-up inrush current should be set to less than the I<sub>OCP1</sub> threshold to avoid tripping OCP1 during a normal start-up.

$$I_{INRUSH} < I_{OCP1} = \frac{2mV}{R_{SNS}}$$

$$I_{INRUSH} = C_{OUT} \times \frac{dV_{OUT}}{dt}$$

where dV<sub>OUT</sub>/dt is determined by C<sub>GATE</sub> (See [Typical Application Circuit](#)) and the RTQ1954 GATE pin source current (20uA typical). It is important to consider variations in C<sub>OUT</sub>, C<sub>GATE</sub> and the GATE pin source current when calculating the worst-case inrush current.

### 17.4.2 Steady State Protection, OCP2:

After power-up, the RTQ1954 actively measures the load current by monitoring the voltage across R<sub>SNS</sub>. If the voltage across R<sub>SNS</sub> exceeds the OCP2 threshold (V<sub>OCP2</sub>), the fault timer is activated and charges C<sub>TIMER</sub> with 2.5uA as described in the Fault Timer section. If the current drops below the I<sub>OCP2</sub> threshold before the fault timer reaches the fault timeout period, t<sub>OCP2</sub>, set by C<sub>TIMER</sub> (TIMER pin reaches 3.9V), the RTQ1954 resumes normal operation and C<sub>TIMER</sub> is discharged using 20uA. Otherwise, the RTQ1954 turns off the external MOSFET with a 4.8mA GATE pulldown and discharges C<sub>TIMER</sub> using 20uA. The IIN\_OC\_Fault bit in the STATUS\_INPUT (7Ch) register and the INPUT\_STATUS bit in the STATUS\_WORD (79h) register are toggled high, PGD will deassert and SMBA pin will be asserted, and RTQ1954 moves to the RETRY phase. SMBA alert can be disabled using the ALERT\_MASK (D8h) register. The t<sub>OCP2</sub> fault timer is set according to the following equation:

$$t_{OCP2} = C_{TIMER} \times \frac{3.9V}{2.5\mu A}$$

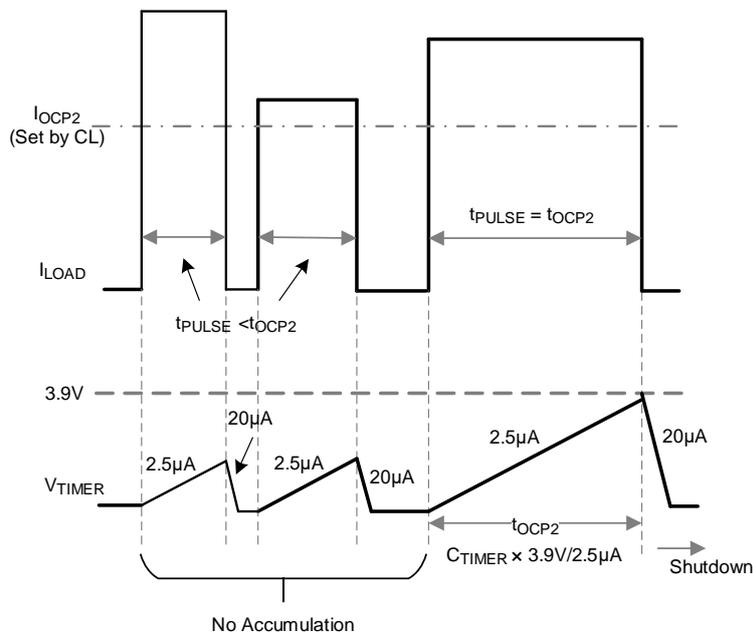


Figure 4. OCP2 Protection Behavior

The RTQ1954's 2.5µA/20µA charge/discharge current ratio (1:8) of the TIMER pin allows for a variety of wide and unpredictable overcurrent scenarios without V<sub>TIMER</sub> accumulation causing false fault tripping.

The RTQ1954 provides flexibility to set the OCP2 threshold voltage using both hardware setting and PMBus. The V<sub>OCP2</sub> can be set by the CL pin (26mV if CL=VDD, 50mV if CL=GND, and based on the VAUX pin voltage if 2 ≤ CL ≤ 3.9) or overridden by setting relevant bits in the DEVICE\_SETUP (D9h) and MFR\_CL\_THRESHOLD (F0h) registers (10 to 55mV with 1mV increments).

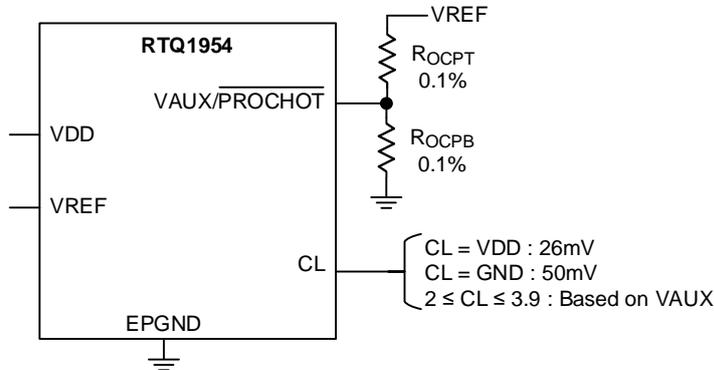


Figure 5. Connection of CL and VAUX Pins to set OCP2 Threshold

ROCPT (kΩ)	ROCPB (kΩ)	VAUX Voltage (V) (±114mV)	OCP2 Threshold (mV)
9.42	100	2.74	49
19.3	100	2.513	48
31.2	100	2.2845	47
45.9	100	2.056	46
64.2	100	1.8275	45
87.6	100	1.599	44
118	100	1.3705	43
162	100	1.1425	42
229	100	0.914	41
336	100	0.6855	40
556	100	0.457	39
1210	100	0.2285	38
5170	100	0.057 (GND)	37

**17.4.3 Steady State Protection, OCP3:**

The RTQ1954 provides another level of protection above OCP2 designed to pass through short high-current pulses avoiding undesired fault tripping. The I<sub>OCP3</sub> threshold is set as

$$I_{OCP3} = I_{OCP2} + \frac{15mV}{R_{SNS}}$$

If the voltage across R<sub>SNS</sub> exceeds the OCP3 threshold (internally fixed at 15mV+V<sub>OCP2</sub>), the RTQ1954 activates the blanking timer of 0.5ms (t<sub>BLANK</sub>). If the current in the MOSFET drops below I<sub>OCP3</sub> before the blanking timer expires, the RTQ1954 resumes normal operation ensuring unpredictable short pulses pass through without tripping a fault. Otherwise, the RTQ1954 turns off the external MOSFET using a 4.8mA GATE pulldown current, and the IIN\_OC\_Fault bit in the STATUS\_INPUT (7Ch) register and the INPUT\_STATUS bit in the STATUS\_WORD (79h) register are toggled high, PG will be deasserted, the SMBA pin will be asserted and the

RTQ1954 moves to the RETRY phase.  $\overline{\text{SMBA}}$  alert can be disabled using the ALERT\_MASK (D8h) register. This mode is activated by pulling up the PWR pin to VDD.

In scenarios where excessive load current can cause voltage sagging at the input bus and/or excessive power dissipation in the load that may violate the external MOSFET SOA limits, the RTQ1954 provides a hardware selectable option to select Active Current/Power (ACL) mode as described in the next section.

#### 17.4.4 Steady State Protection, Active Current/Power Limit (ACL) Mode:

If the PWR pin is connected to GND through R<sub>PWR</sub> resistor, the RTQ1954 sets the protection mode as Active Current/Power (ACL) mode. In this mode, when the voltage across R<sub>SNS</sub> exceeds the V<sub>ACL</sub> threshold (15mV + V<sub>OCP2</sub>), the RTQ1954 activates the blanking timer of 0.5ms (t<sub>BLANK</sub>). If the current in the MOSFET drops below I<sub>ACL</sub> before the blanking timer expires, the RTQ1954 resumes normal operation. Otherwise, the RTQ1954 enters the ACL mode by actively regulating the external current or the power dissipation in the external MOSFET to the set values by adjusting the GATE pin voltage. The I<sub>ACL</sub> current threshold is set as follows:

$$I_{ACL} = I_{OCP2} + \frac{15\text{mV}}{R_{SNS}}$$

The ACL regulation can last up to 0.53ms typical (t<sub>ACL</sub>). If the current/power limit exists longer than t<sub>ACL</sub>, the RTQ1954 turns off the external MOSFET using a 4.8mA pulldown current, and IIN\_OC\_Fault bit in the STATUS\_INPUT (7Ch) register, the INPUT\_STATUS bit in the STATUS\_WORD (79h) register, and the IIN\_OC/PFET\_OP\_FAULT bit in the READ\_DIAGNOSTIC\_WORD (E1h) register is toggled high and the  $\overline{\text{SMBA}}$  pin is asserted, unless this feature is disabled using the ALERT\_MASK (D8h) register.

In the ACL mode, the RTQ1954 either regulates the current or the power dissipation in the external MOSFET depending on which threshold is reached first. During current limiting, the RTQ1954 controls the GATE voltage to quickly limit the output current to I<sub>ACL</sub>=V<sub>ACL</sub>/R<sub>SNS</sub>. In fault conditions where V<sub>ds</sub> is high, such as short circuit, current-limit protection may not be enough and can violate the external MOSFET SOA due to excessive power dissipation. A MOSFET with a higher SOA curve can be chosen to alleviate this issue with the downside of overdesigning the system. The MOSFET SOA curve indicates the amount of power it can dissipate for a given amount of time before the junction temperature reaches its maximum value. The RTQ1954 implements a better solution which is a power limit feature that accurately limits the maximum power dissipation in the external MOSFET. The power dissipation is calculated by multiplying the current in R<sub>SNS</sub> and the voltage across the MOSFET (V<sub>SENSE</sub> - V<sub>OUT</sub>), and comparing with the programmed power limit threshold P<sub>LIM</sub> set by the PWR pin resistor (R<sub>PWR</sub>).

$$P_{LIM} = \frac{(R_{PWR} \times 7 \times 10^{-6} + 0.015 \times V_{DS} + 0.043)}{R_{SNS}}$$

When the dissipated power reaches the power limit threshold, the RTQ1954 regulates the GATE voltage to limit the current (and hence the power dissipation) in the MOSFET to the set values.

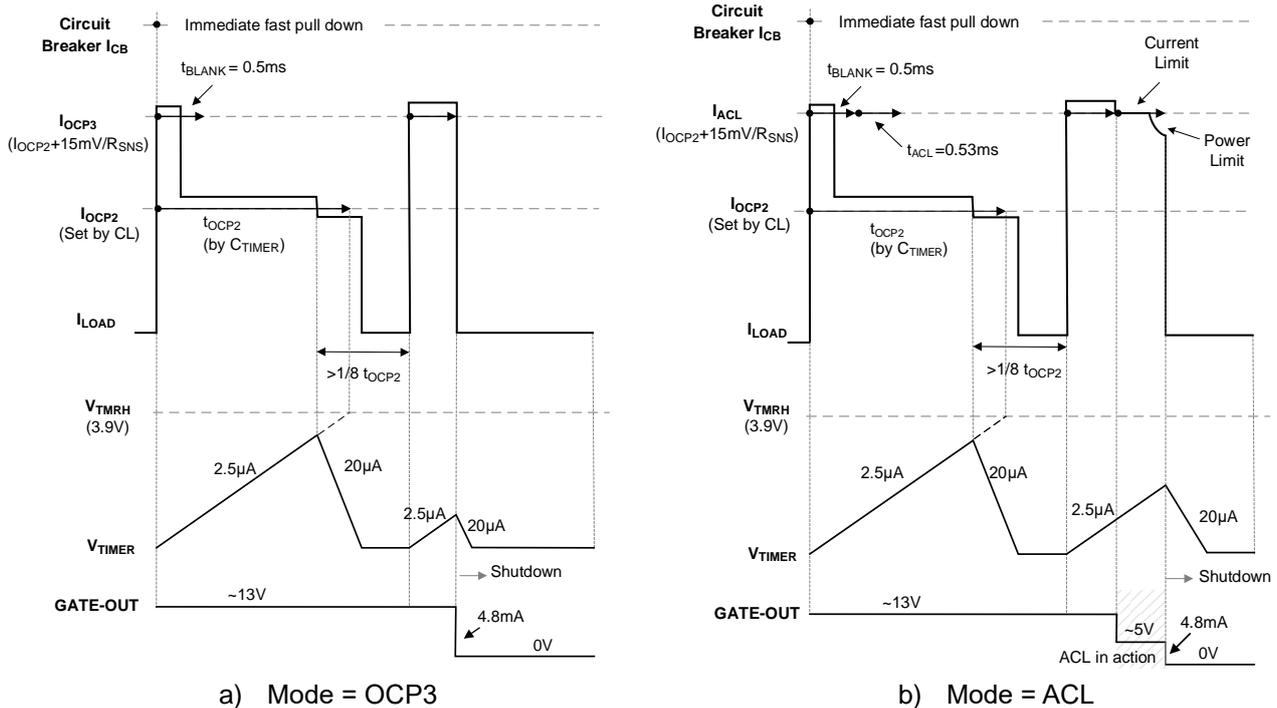


Figure 6. RTQ1954 OCP3 and ACL Protection Mode Behavior

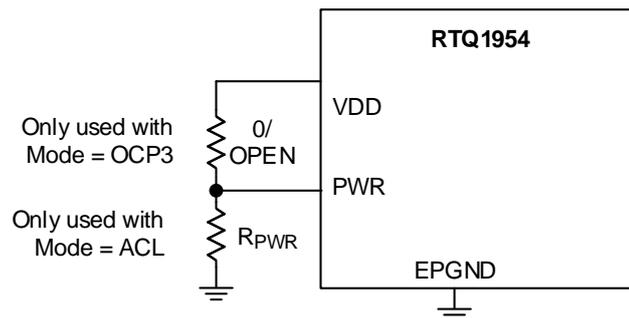


Figure 7. Connection of PWR Pin to Set Mode as OCP3 or ACL

17.4.5 Circuit Breaker

In a scenario such as output short circuit when the current in  $R_{SNS}$  exceeds the  $I_{OCP2}$  and  $I_{OCP3}/I_{ACL}$  thresholds faster than they trip a fault, the RTQ1954 protects the system using a circuit breaker (CB) mechanism. The circuit breaker mechanism is activated when the voltage across  $R_{SNS}$  exceeds the threshold set by  $V_{CB}$ . The circuit breaker current is determined by the following equation:

$$I_{CB} = \frac{V_{CB}}{R_{SNS}}$$

In this event the RTQ1954 switches off the MOSFET using a 200mA GATE pull down current. When the voltage across  $R_{SNS}$  falls below the  $V_{CB}$  threshold, the 200mA current switches off and the GATE voltage starts ramping up to power on the MOSFET. If the fault still exists, the RTQ1954 will turn off the external MOSFET as either of OCP2 or OCP3/ACL triggers the fault. The OCP2 timer pin current is increased to 25µA after a circuit breaker event to quickly turn off the MOSFET and keep it within its SOA. After the timer pin reaches the fault threshold, GATE is shut off. The timer pin pull-up current reverts to 2.5µA in the subsequent cool-down period when auto-

retry is enabled. A circuit breaker event will deassert PG and causes the CB\_FAULT bit to be toggled high in STATUS\_WORD (79h), STATUS\_OTHER (7Fh), STATUS\_MFR\_SPECIFIC (80h) and READ\_DIAGNOSTIC\_WORD (E1h).  $\overline{\text{SMBA}}$  pin is pulled low and the RTQ1954 moves to the RETRY phase.  $\overline{\text{SMBA}}$  alert can be disabled using the ALERT\_MASK (D8h) register. The circuit breaker threshold can be set by relevant bits in DEVICE\_SETUP (D9h) register.

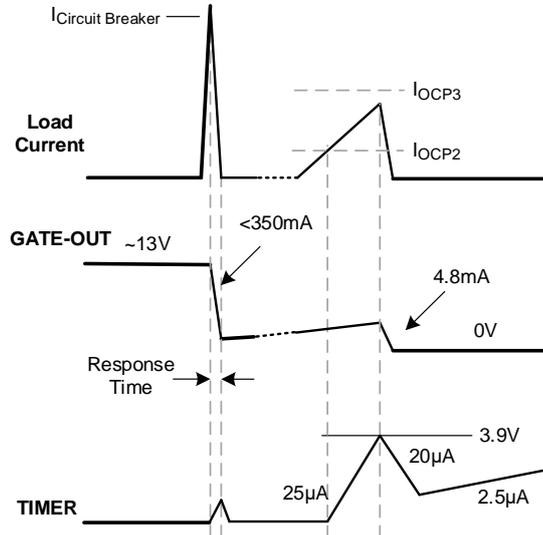


Figure 8. Circuit breaker Mechanism during Normal Operation Short Circuit (Auto-Retry enabled)

### 17.5 Undervoltage-Lockout (UVLO)

The RTQ1954 enables the external MOSFET when the input voltage (VIN) is within the operating range set by the UVLO and OVLO thresholds. When the voltage at the UVLO pin is less than the UVLO low threshold (VUVLO-L) of 2.48V, the external MOSFET is held off by a 4.8mA pulldown current at the GATE. At this condition, the 20µA current sink at the UVLO pin is enabled to provide hysteresis. As the voltage at the UVLO pin increases beyond the UVLO threshold of 2.48V plus the hysteresis voltage (determined by the 20µA sink and external resistor), the 20µA current sink is disabled and the external MOSFET is turned on using a 20µA charge pump at the GATE, provided that the insertion time has passed.

After power-up, a UVLO condition causes the INPUT\_STATUS bit in the STATUS\_WORD (79h) register, the VIN\_UV\_FAULT bit in the STATUS\_BYTE (78h), STATUS\_INPUT (7Ch) and READ\_DIAGNOSTIC\_WORD (E1h) registers to be toggled high and the  $\overline{\text{SMBA}}$  pin is pulled low, unless this feature is disabled using the ALERT\_MASK (D8h) register.

### 17.6 Overvoltage-Lockout (OVLO)

When the voltage at the OVLO pin is higher than the OVLO high threshold (VOVLO-H) of 2.46V, the external MOSFET is held off by a 4.8mA GATE pulldown current. At this condition, the 20µA current source at the OVLO pin is enabled to provide hysteresis. As the voltage at the OVLO pin drops below the OVLO threshold of 2.46V minus hysteresis (determined by the 20µA current source and external resistor), the external MOSFET is enabled. An OVLO condition toggles the VIN\_OV\_FAULT bit in the STATUS\_INPUT (7Ch) and READ\_DIAGNOSTIC\_WORD (E1h) registers, and the INPUT\_STATUS bit in the STATUS\_WORD (79h) register. The  $\overline{\text{SMBA}}$  pin is pulled low unless this feature is disabled using the ALERT\_MASK (D8h) register.

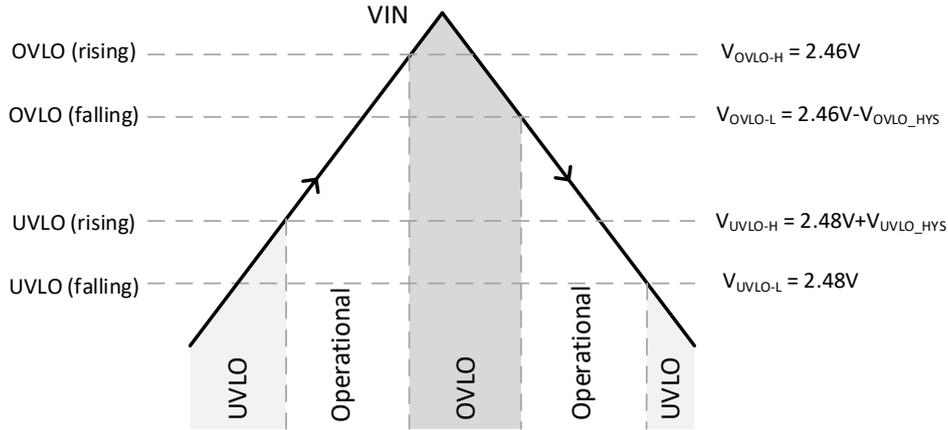


Figure 9. VIN UVLO and OVLO Conditions

Different configurations can be used to set the UVLO and OVLO thresholds using resistive dividers. To accurately set all the VIN OVLO (high and low) and UVLO (high and low) thresholds, it is recommended to use dedicated resistive dividers on UVLO and OVLO pins. However, to reduce the external BOM, the VIN UVLO (high and low) and OVLO (high only) can be set using three-resistor dividers as shown below. In this configuration, the VIN OVLO-L (low) is not set in advance.

$$R_1 = \frac{VIN_{UVLO-H} - VIN_{UVLO-L}}{20\mu A}$$

$$R_3 = \frac{R_1 \times VIN_{UVLO-L} \times 2.46V}{VIN_{OVLO-H} \times (VIN_{UVLO-L} - 2.48V)}$$

$$R_2 = \frac{2.48V \times R_1}{VIN_{UVLO-L} - 2.48V} - R_3$$

$$VIN_{OVLO-L} = \left( \frac{2.46V}{R_3} - 20\mu A \right) \times (R_1 + R_2) + 2.46V$$

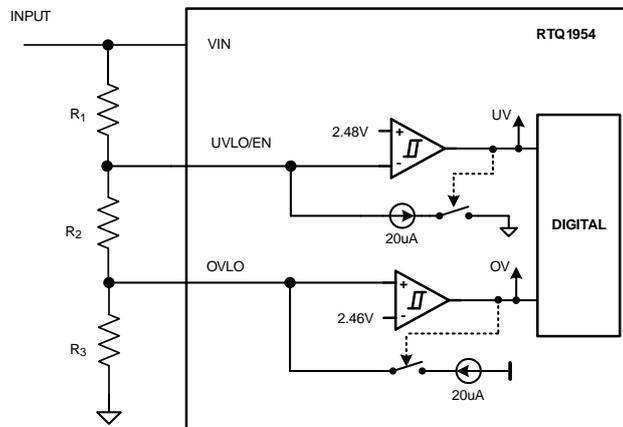


Figure 10. VIN UVLO and OVLO Setting Configuration

17.7 Power Good Pin

Power Good (PG) is an open-drain output indicating the status of the output with the addition of an external pull-up resistor. The internal PG circuitry monitors faults, VIN, FB and GATE-OUT voltage to determine the PG pin voltage status. If the FB pin voltage is below the threshold of 2.46V, the PG pin is pulled low. When the voltage at the FB pin increases beyond the threshold (2.46V) and GATE-OUT voltage is above the 9V threshold (GATE\_HI signal), the PG open-drain output is turned off after 100µs (provided VIN is within the operating range of UVLO and OVLO and no fault exists). Power good is then signaled by the external resistor pulling up on PG. An internal 20µA current source at the FB pin is enabled to create voltage hysteresis (with external resistors). Typically, VOUT is connected to FB pin via a resistor divider although any voltage can be monitored as long as it is within the maximum rating of the FB pin. When VIN goes outside of the operating range set by UVLO and OVLO and/or fault is declared and/or the FB pin drops below its threshold, the PG is pulled low after 10µs. The status of the PG pin can be read through the PMBus interface in either the STATUS\_WORD (79h) or READ\_DIAGNOSTIC\_WORD (E1h) registers.

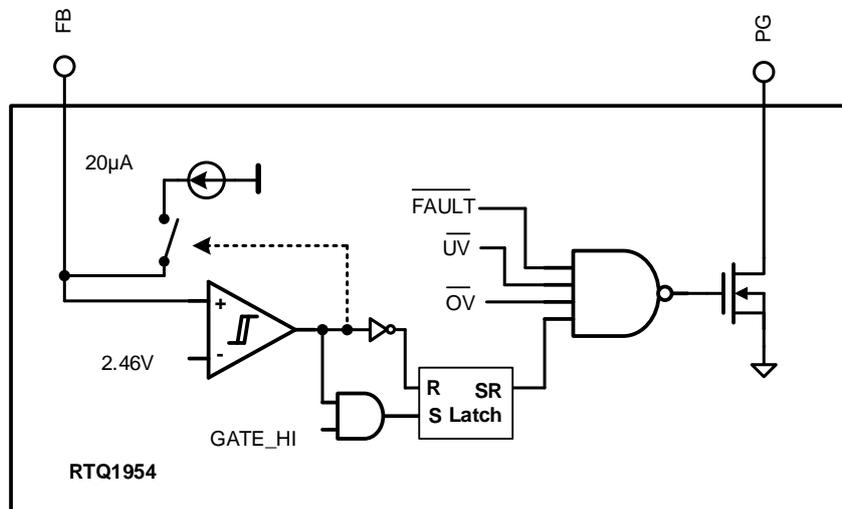


Figure 11. Power Good Logic Block Diagram

VIN UV	VIN OV	FAULT	FB. GATE_HI	PG	Description
L	L	L	H	H	Normal operation
H/L	H/L	H/L	L	L	The FB pin voltage drops below its threshold
H	L	H/L	H/L	L	Input voltage drops below the UVLO threshold
L	H	H/L	H/L	L	Input voltage goes above the OVLO threshold
H/L	H/L	H	H/L	L	Fault is declared

17.8 VDD and VREF Sub-Regulators

The RTQ1954 includes internal sub-regulators to convert the input voltage VIN to 4.9V VDD that is used for internal low-voltage circuits and is used as a pull-up supply for external pins such as CL,  $\overline{\text{RETRY}}$ , and ADR2-0, if they are tied high. It can also be used as a pull-up supply for SMBus and PG pins. There is a second sub-regulator LDO to convert VDD to VREF of 3V which is used to power internal circuitry. CL and  $\overline{\text{RETRY}}$  can be connected to VREF for additional configurations. The VDD and VREF pins are current limited to protect in the event of short circuit.

The VDD and VREF pins should not be loaded by other external circuits due to the limited drive current of the sub-regulators. Place a 1μF 0603 ceramic capacitor close to the VDD and VREF pins to GND. VREF can be externally pulled low to re-latch the PMBus address and reset PMBus registers.

**17.9 Remote Temperature Sensing**

The temperature of an external element, such as the series-pass MOSFET can be measured using either an NPN or PNP transistor connected as a diode (base and collector connected together). If using an NPN transistor, the collector and base need to be shorted together and connected to the DIODE pin of the RTQ1954 and the emitter to the RTQ1954 GND (it is recommended to use a Kelvin connection for the device GND for accurate measurement). Transistors such as MMBT3904 or similar are suitable to use. If using a PNP (MMBT3906 or similar), the collector and base need to be connected to the device GND and the emitter to the DIODE pin.

To measure the series-pass MOSFET temperature, the transistor should be placed as close to the MOSFET as layout allows. To reduce the effect of noise on the measurement, a 1nF 0603 ceramic capacitor needs to be placed in parallel to the DIODE pin and the device GND.

To further reduce the noise, the RTQ1954 has a resistance cancellation feature, making it beneficial to use in noisy environments. It allows a low pass filter to be placed between the RTQ1954 and the remote transistor using two 150Ω resistors and a 1nF capacitor, as shown in the figure below. The series resistance cancellation removes the effect of any resistance in series with the remote transistor. This low pass filter reduces both common and differential modes noises.

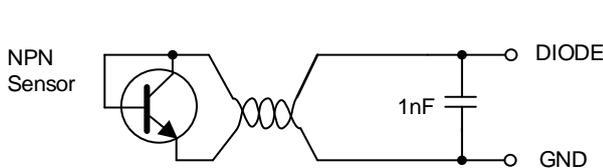


Figure 12. Connection of NPN sensor to device

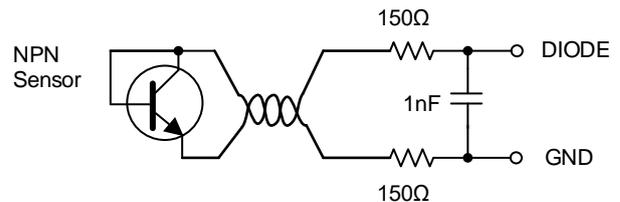


Figure 13. Connection of NPN sensor through low-pass filter

The RTQ1954 periodically sources 10μA, 60μA and 160μA current pulses out of the DIODE pin and measures the temperature by measuring the voltage at the DIODE pin. For accurate temperature measurements, it is required the VIN be in the recommended operating range of 10V to 80V. The temperature can be read using the READ\_TEMPERATURE\_1 (8Dh) PMBus command. By default, the temperature fault and warning thresholds of the RTQ1954 are set to 256°C and are effectively disabled. These thresholds can be reprogrammed through the PMBus interface using the OT\_WARN\_LIMIT (51h) and OT\_FAULT\_LIMIT (4Fh) commands. After the OT fault, the GATE is latched off and requires manual restart. The status of the OT fault and warning can be checked using STATUS\_WORD (79h), STATUS\_TEMPERATURE (7Dh), and READ\_DIAGNOSTIC\_WORD (E1h). If the temperature measurement and protection capability of the RTQ1954 are not used, the DIODE pin should be grounded.

**17.10 MOSFET Health Monitoring**

The RTQ1954 monitors the health condition of an external series-pass MOSFET for two different scenarios, FET SHORT and FET BAD. For the FET SHORT scenario, the RTQ1954 checks for a shorted MOSFET condition at the end of the insertion time (PORIT) while the GATE pin is low. If the voltage across RSNS is greater than 2mV or if the MOSFET VDS < 6V FET SHORT is declared. In this condition, the EXT\_MOSFET\_SHORT bit in the STATUS\_MFR\_SPECIFIC (80h) and READ\_DIAGNOSTIC\_WORD (E1h) registers are toggled high and the SMBA pin is asserted, unless this feature is disabled using the ALERT\_MASK register (D8h).

For the FET BAD scenario, the RTQ1954 checks FET BAD during normal operation after PG is asserted high. FET BAD is detected if the MOSFET gate current exceeds the I<sub>GATE</sub> source current (typically 20μA) or if V<sub>DS</sub> > 4.2V. If the FET BAD scenario remains for 100ms, PG is pulled low, and the FET\_FAULT bit in the STATUS\_MFR\_SPECIFIC (80h) register is toggled high, and the  $\overline{\text{SMBA}}$  pin is asserted, unless this feature is disabled using the ALERT\_MASK register (D8h). On a FET BAD fault, the GATE is latched off and requires manual restart. FET BAD is disabled while the RTQ1954 is in the active current/power regulation (mode = ACL).

### 17.11 Slew Rate Limited Power-Up Sequence

During start-up, as the input Voltage V<sub>IN</sub> increases, the RTQ1954 initially holds GATE off using a 200mA pulldown current. Once V<sub>IN</sub> reaches the POR\_IT threshold of 7.8V, the insertion timer starts by charging C<sub>TIMER</sub> with 4.8μA. At the end of the insertion timer (when the TIMER voltage reaches 3.9V), the RTQ1954 checks for V<sub>IN</sub> to be within the UVLO and OVLO operating threshold and FET SHORT fault. If there is no fault, the external MOSFET is enabled and C<sub>TIMER</sub> is quickly discharged with a 1.5mA internal current sink.

The external MOSFET is turned on with a 20μA current source to charge the GATE capacitance. A capacitor from GATE to GND can be used to limit the V<sub>OUT</sub> slew rate and keep the inrush current (I<sub>INRUSH</sub>) low.

$$C_{\text{GATE}} = \frac{I_{\text{GATE}}}{I_{\text{INRUSH}}} \times C_{\text{OUT}}$$

where C<sub>GATE</sub> is the total GATE capacitance including parasitic capacitances, and I<sub>GATE</sub> is the GATE pull-up source current of 20μA. A limited slew rate can reduce the stress on the MOSFET by extending the startup time and spreading the power dissipation in the MOSFET for a longer period while the timer is off.

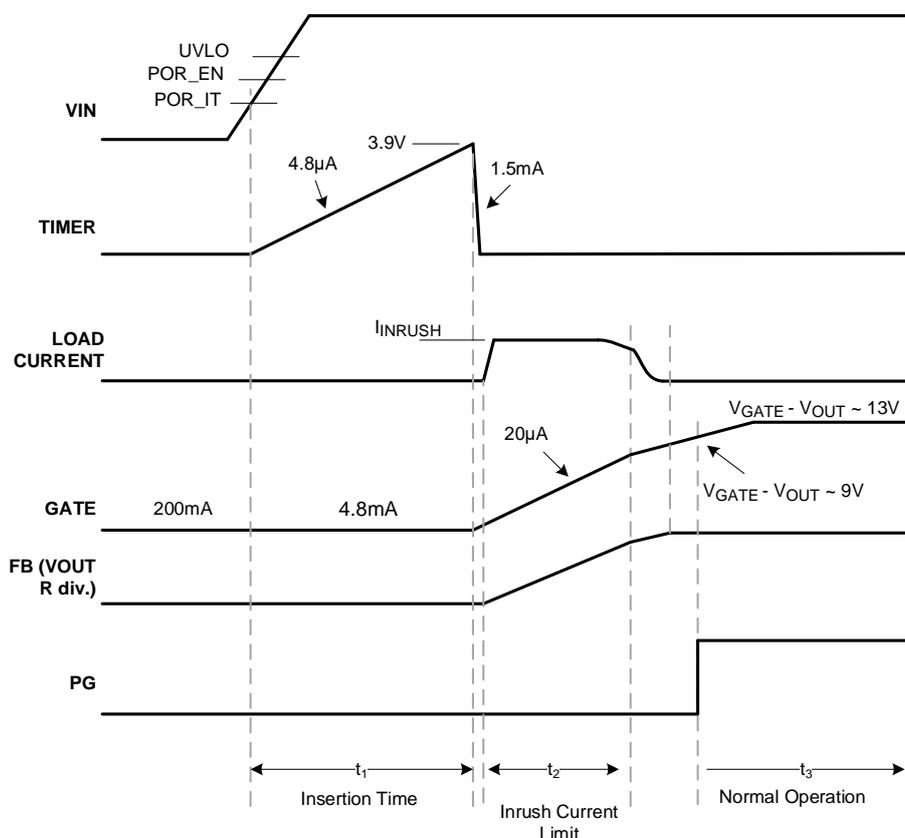


Figure 14. Startup Into Fixed dV/dt Mode (No-Load)

During start-up after VIN has passed POR\_EN of 8.6V, the RTQ1954 asserts the DEFAULTS\_LOADED bit in STATUS\_MFR\_SPECIFIC (80h) to indicate that the volatile memory and device settings are in the default state. The CONFIG\_PRESET bit within the READ\_DIAGNOSTIC\_WORD register (E1h) indicates the default configuration of warning thresholds and device operation and remains high until a CLEAR\_FAULTS (03h) command is received.

**17.12 Gate Control**

To charge the external MOSFET gate capacitance, the RTQ1954 sources 20µA current out of the GATE pin with an internal charge pump. The peak voltage of the charge pump is 15V, and in normal operation, the MOSFET’s gate-source voltage is held sufficiently above 10V for the lowest R<sub>DS(on)</sub>. The GATE-OUT is internally limited to 15.6V to protect the external MOSFET’s gate-source oxide from exceeding 20V in transient conditions. In some scenarios, the RTQ1954 needs to discharge the gate charge and modulate or turn off the MOSFET. During start-up, before VIN reaches POR\_IT, the GATE is held low using a 200mA current sink, and during insertion time, the GATE is held low using a 4.8mA current sink. After OCP1, OCP2 and OCP3 faults, the GATE is pulled down with 4.8mA, and during ACL mode (if activated), the GATE is modulated to keep the current/power within the limits.

**17.13 Fault Timer**

When the current goes above the I<sub>OCP2</sub> threshold, the C<sub>TIMER</sub> is charged using a 2.5µA current source, and t<sub>OCP2</sub> fault timeout period begins. If the current drops below I<sub>OCP2</sub> before the TIMER pin reaches 3.9V, the C<sub>TIMER</sub> is discharged by a 20µA current sink and the RTQ1954 resumes operation. Otherwise, a fault is declared, the GATE pin pulls low using a 4.8mA current sink and C<sub>TIMER</sub> gets discharged using a 20µA current sink. The GATE will be held low until subsequent restart is performed depending on RETRY settings. The RTQ1954’s 2.5µA/20µA charge/discharge current ratio (1:8) on the TIMER pin allows for a variety of wide and unpredictable overcurrent scenarios without V<sub>TIMER</sub> accumulating causing false tripping.

**17.14 PROCHOT Output**

The RTQ1954 has an early warning feature that lets the system management know that the current and/or power is too high so that the system takes proper action, such as reducing the load current. The warning is provided using the VAUX pin which can be set as PROCHOT using the relevant bit in the MFR\_ADV\_CFG\_STATUS (F1h) register. The PROCHOT asserts (goes low) 100µs after the current goes above I<sub>OCP2</sub> during normal operation, and deasserts immediately after the current drops below I<sub>OCP2</sub>. If the VAUX pin is used to set the OCP2 threshold, the PROCHOT output feature will not be available. The PROCHOT is kept deasserted (pulled high) during insertion time.

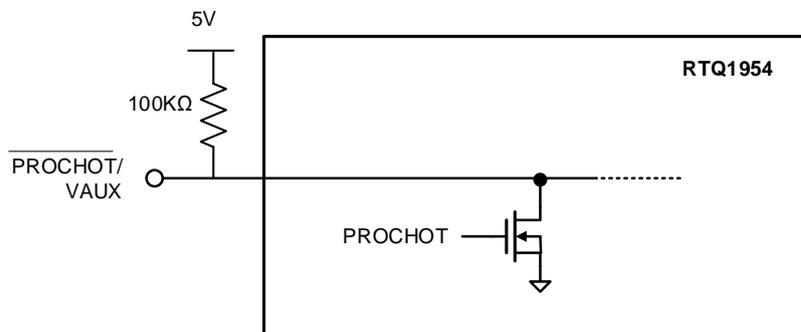


Figure 15. PROCHOT Pin can be Assigned on VAUX Pin using PMBus

## 17.15 Restart and Cooldown Time

If  $\overline{\text{RETRY}} = \text{VDD}$ , no restart will be attempted, and the GATE is pulled low using a 4.8mA current until the RTQ1954 is externally restarted by either power cycling VIN or momentarily pulling UVLO/EN low. The TIMER\_LATCHED\_OFF bit in the READ\_DIAGNOSTIC\_WORD (E1h) register remains high while the latched off condition persists.

If  $\overline{\text{RETRY}} = \text{VREF}$ , the RTQ1954 will restart 8 times, and if  $\overline{\text{RETRY}} = \text{GND/float}$ , the RTQ1954 will restart continuously. Finer restart attempt counts can be selected by setting the appropriate bits in the DEVICE\_SETUP (D9h) register. Each restart attempt consists of 8 cycles of the TIMER pin voltage cycling between 3.9V and 1.2V, and the period of each cycle depends on CTIMER. During the restart attempt, the GATE is held low using a 4.8mA sink current.

Before each restart attempt, the TIMER pin voltage must fall below 0.3V before the next restart is attempted.

After the 8<sup>th</sup> cycle, and when the TIMER voltage drops <0.3V, the GATE is charged using a 20µA current source, and the external MOSFET is turned on. If a fault still exists, the same sequence repeats.

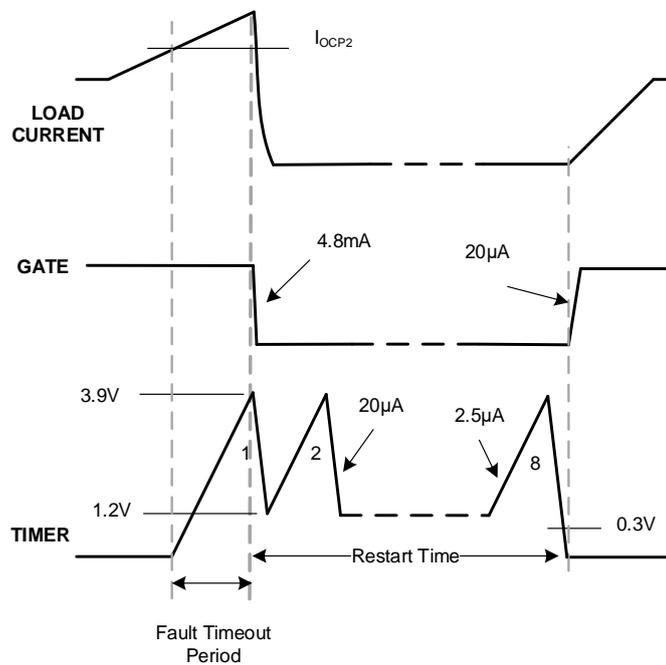


Figure 16. Single restart attempt, DEVICE\_SETUP (D9h [7:5]) = [010]

In some high-power scenarios where the device and external MOSFET temperatures are high and/or large capacitance exists on the output, it may be beneficial to wait, after the 8<sup>th</sup> restart attempt, to allow the external MOSFET to cool down, and/or the output voltage to drop below a certain threshold before enabling the MOSFET again. The cooldown time after the last restart attempt can be set through MFR\_ADV\_COOLDOWN\_TIME (F5h) register. The output voltage threshold where the part will not restart until the VOUT drops below it can be set using VOUT\_UV\_RETRY\_THRESHOLD (EFh).

## 17.16 Power Cycle

When operating in any state, the RTQ1954 power cycle feature turns off the power flow through the external MOSFET and allows it to turn back on after a certain period. When a power cycle command is issued through the PMBus POWER\_CYCLE (FBh) register, the RTQ1954 pulls down the GATE using a 4.8mA current and the TIMER

pin using a 20 $\mu$ A current. If the PG is asserted, it will deassert after 10 $\mu$ s. The device then waits for a power cycle time between 0s to 65s defined by MFR\_ADV\_PWRCYCLE\_TIME (F2H) register. When the timer ends, the RTQ1954 will attempt to restart. An extra condition can be applied before starting the power cycle timer by monitoring the V<sub>OUT</sub> voltage and checking if it is less than a value defined by V<sub>OUT\_UV\_RETRY\_THRESHOLD</sub> (EFh). This extra condition can be enabled by setting the relevant bit in the MFR\_ADV\_CFG\_STATUS (F1h) register.

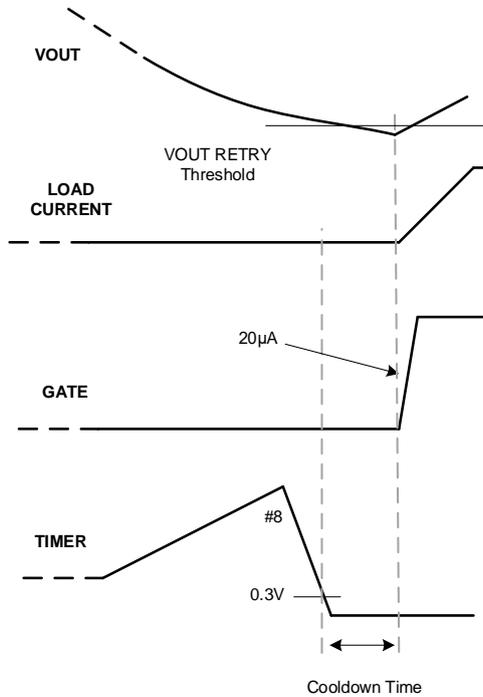


Figure 17. Cooldown Time and V<sub>OUT</sub> UV RETRY Threshold

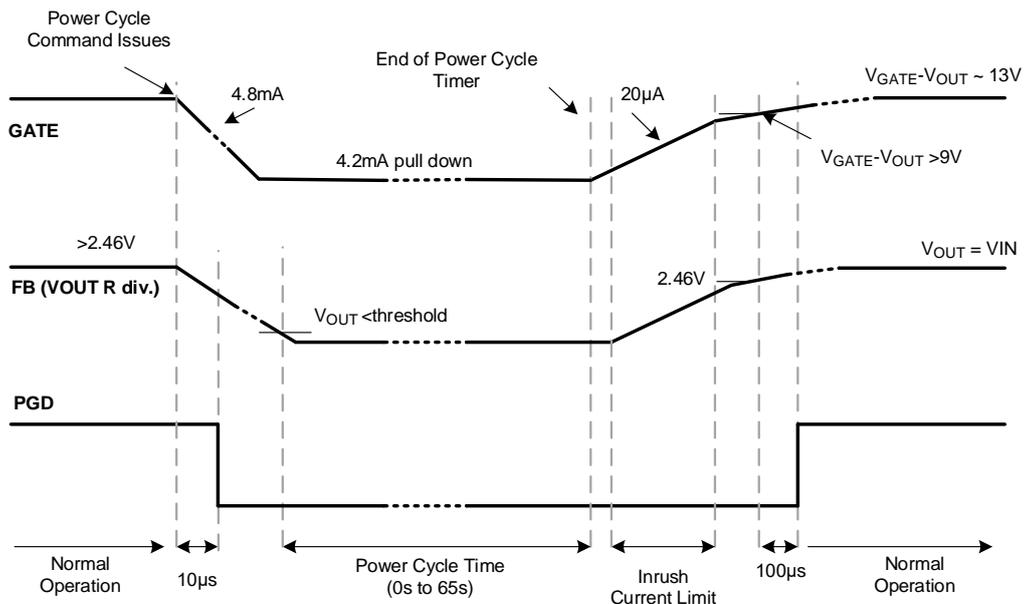


Figure 18. Power Cycle Timing Diagram Example, Restarting Into dV/dt Mode, Time not to Scale

### 17.17 Enable/Disable, Shutdown and Reset Control

During normal operation, the output can be disabled by pulling the UVLO/EN pin or the OVLO pin below or above their thresholds, respectively. To remotely shutdown the load current, the UVLO/EN pin can be pulled low with an open-drain or open-collector device connected to the pin. When UVLO/EN is released, the RTQ1954 enables the GATE. When in a latched-off state after a fault, there are a few ways to manually restart the device, such as toggling UVLO/EN from low to high, power cycling VIN below/above the POR\_EN threshold, changing the PMBus OPERATION (01h) register from OFF to ON, or power cycling through the POWER\_CYCLE (FBh) register. The user-stored register settings data are preserved even after the output is disabled. The output may also be enabled or disabled by using the OPERATION (01h) register.

**Note 15.** The information provided in this section is for reference only. The customer is solely responsible for the designing, validating, and testing your product incorporating Richtek's product and ensure such product meets applicable standards and any safety, security, or other requirements.

## 18 Functional Register Description

### 18.1 PMBus Commands Overview

Code	Command Name	Description	R/W	Bytes	Default
01h	OPERATION	Hot swap operation enable/disable	RW	1	80h
03h	CLEAR_FAULTS	Clears fault (non-active) and warning bits in all registers	W	0	-
19h	CAPABILITY	Retrieves the device capability	R	1	D0h
43h	VOUT_UV_WARN_LIMIT	Retrieves or stores output undervoltage warning threshold for the VOUT pin measurement	RW	2	0000h
4Fh	OT_FAULT_LIMIT	Retrieves or stores overtemperature fault threshold	RW	2	0FFFh
51h	OT_WARN_LIMIT	Retrieves or stores overtemperature warning threshold	RW	2	0FFFh
57h	VIN_OV_WARN_LIMIT	Retrieves or stores input overvoltage warning threshold	RW	2	0FFFh
58h	VIN_UV_WARN_LIMIT	Retrieves or stores input undervoltage warning threshold	RW	2	0000h
5Dh	IIN_OC_WARN_LIMIT	Retrieves or stores input overcurrent warning (mirror of command D3h)	RW	2	0FFFh
78h	STATUS_BYTE	Retrieves information about device operating status	R	1	00h
79h	STATUS_WORD	Retrieves information about device operating status	R	2	0000h
7Ah	STATUS_VOUT	Retrieves information about device output voltage status	R	1	00h
7Ch	STATUS_INPUT	Retrieves information about device input status	R	1	00h
7Dh	STATUS_TEMPERATURE	Retrieves information about temperature status	R	1	00h
7Eh	STATUS_CML	Retrieves information about communication status	R	1	00h
7Fh	STATUS_OTHER	Retrieves other status information	R	1	00h
80h	STATUS_MFR_SPECIFIC	Retrieves information about external MOSFET fault and device circuit breaker and internal die temperature	R	1	10h
86h	READ_EIN	Retrieves energy monitoring measurement	R	6	00h 00h 00h 00h 00h 00h
88h	READ_VIN	Retrieves input voltage measurement	R	2	0000h
89h	READ_IIN	Retrieves input current measurement (mirror of command D1h)	R	2	0000h
8Bh	READ_VOUT	Retrieves output voltage measurement	R	2	0000h
8Dh	READ_TEMPERATURE_1	Retrieves temperature measurement from DIODE pin	R	2	0000h
8Eh	READ_TEMPERATURE_2	Retrieves internal die temperature measurement	R	2	00h
97h	READ_PIN	Retrieves average input power measurement (mirror of command D2h and DFh)	R	2	00h
98h	PMBUS_REVISION	Retrieves PMBus revision	R	1	22h
99h	MFR_ID	Retrieves manufacturer ID	R	3	"RTK"
9Ah	MFR_MODEL	Retrieves part number	R	8	"RTQ195410"
9Bh	MFR_REVISION	Retrieves part revision	R	2	"12"
D0h	READ_VAUX	Retrieves AUX pin voltage measurement	R	2	0000h
D1h	READ_IIN	Mirror of 89h	R	2	0000h
D2h	READ_PIN	Mirror of 97h and DFh	R	2	0000h

Code	Command Name	Description	R/W	Bytes	Default
D3h	MFR_IIN_OC_WARN_LIMIT	Retrieves or stores input current warning threshold (mirror of command 5Dh)	RW	2	0FFFh
D4h	PIN_OP_WARN_LIMIT	Retrieves or stores input power limit warning threshold	RW	2	0FFFh
D5h	READ_PIN_PEAK	Retrieves peak input power measurement	R	2	0000h
D6h	CLEAR_PIN_PEAK	Clears the peak power measurement register	W	0	-
D7h	GATE_MASK	Allows to disable MOSFET shutdown for different faults	RW	1	00h
D8h	ALERT_MASK	Retrieves or stores user SMBA fault mask	RW	2	FD20h
D9h	DEVICE_SETUP	Retrieves or stores device settings about RETRY attempts, CL settings and CB ratio	RW	1	00h
DAh	BLOCK_READ	Retrieves most recent telemetry and diagnostic information	R	12	0880h 0000h 0000h 0000h 0000h 0000h
DBh	SAMPLES_FOR_AVG	Number of samples to be averaged (AVG=2^SAMPLES_FOR_AVERAGE). Also the average register update period (ms). Range from 00h to 0Ch.	RW	1	08h
DCh	READ_AVG_VIN	Retrieves average input voltage measurement	R	2	0000h
DDh	READ_AVG_VOUT	Retrieves average output voltage measurement	R	2	0000h
DEh	READ_AVG_IIN	Retrieves average input current measurement	R	2	0000h
DFh	READ_AVG_PIN	Retrieves average input power measurement (mirror of command 97h and D2h)	R	2	0000h
E0h	BLACK_BOX_READ	Retrieves telemetry and diagnostic data latched on the first assertion of SMBA	R	12	0000h 0000h 0000h 0000h 0000h 0000h
E1h	READ_DIAGNOSTIC_WORD	MFR specific parallel of the STATUS_WORD to convey all FAULT/WARN data in a single transaction	R	2	0880h
E2h	AVG_BLOCK_READ	Retrieves most recent average telemetry and diagnostic information in a single transaction	R	12	0880h 0000h 0000h 0000h 0000h 0000h
EDh	READ_IIN_PEAK	Records or retrieves the peak value of READ_IIN	RW	2	0000h
EEh	READ_IIN_MIN	Records or retrieves the minimal value of READ_IIN	RW	2	0FFFh
EFh	VOUT_UV_RETRY_THRESHOLD	Retrieves or stores the voltage value that VOUT has to drop below it before retry can be attempted.	RW	2	0FFFh
F0h	MFR_CL_THRESHOLD	Retrieves or stores the CL threshold in mV	RW	1	00h
F1h	MFR_ADV_CFG_STATUS	Allows for configuring the device settings.	RW	2	00h
F2h	MFR_ADV_PWRCYCLE_TIME	Retrieves or stores the duration of power cycle timer	RW	2	2710h
F3h	MFR_ADV_RETRY_TIME_OUT	Retrieves or stores the time limit duration of fault retry	RW	2	0000h
F5h	MFR_ADV_COOLDOWN_TIME	Retrieves or stores the cooldown time in ms before each subsequent retry attempt	RW	2	0000h

Code	Command Name	Description	R/W	Bytes	Default
F6h	MFR_TELEM_CFG	Configures the device telemetry settings	RW	2	005Fh
F9h	MFR_HOTSWAP_STATU S	Retrieves the current status of hotswap	RW	3	00000Fh
FBh	POWER_CYCLE	Causes the hot swap to shutdown and remain off for the period defined by F2h	WO	0	-

## 18.2 Data Format for Reading and Writing Telemetry and Fault/Warning Thresholds

The RTQ1954 uses the DIRECT format to read and write telemetry data and warning/fault thresholds as described in section 7.4.1 of PMBus Power System Management Protocol Specification 1.4 (Part II). Conversion of current, temperature, voltage and power from DIRECT format to real-world units is performed by the host system using the appropriate coefficients listed in the table below and using the following equation:

$$X = \frac{1}{m} (Y \times 10^{-R-b})$$

where

- X, is the calculated, real-world value in the appropriate units (A, V, °C, W)
- m, the slope coefficient, is a two byte, two's complement integer
- Y, is a two byte two's complement integer received from the PMBus device
- b, the offset, is a two byte, two's complement integer
- R, the exponent, is a one byte, two's complement integer

Commands	Condition	Format	Bytes	m	b	R	Unit
VIN_OV_WARN_LIMIT VIN_UV_WARN_LIMIT READ_VIN READ_AVG_VIN		DIRECT	2	4617	-140	-2	V
READ_VOUT READ_AVG_VOUT VOUT_UV_WARN_LIMIT VOUT_UV_RETRY_THRESHOLD		DIRECT	2	4602	500	-2	V
READ_VAUX		DIRECT	2	1401	11999	-1	V
READ_IIN READ_AVG_IIN READ_IIN_PEAK READ_IIN_MIN IIN_OC_WARN_LIMIT	CL<33mV	DIRECT	2	15076	-503.9	-2	A <sup>(1)</sup>
READ_IIN READ_AVG_IIN READ_IIN_PEAK READ_IIN_MIN IIN_OC_WARN_LIMIT	CL≥33mV	DIRECT	2	6825	0	-2	A <sup>(1)</sup>
READ_PIN READ_AVG_PIN PIN_OP_WARN_LIMIT READ_PIN_PEAK	CL<33mV	DIRECT	2	1701	-4000	-3	W <sup>(1)</sup>
READ_PIN READ_AVG_PIN PIN_OP_WARN_LIMIT READ_PIN_PEAK	CL≥33mV	DIRECT	2	7677	0	-4	W <sup>(1)</sup>
OT_FAULT_LIMIT OT_WARN_LIMIT READ_TEMPERATURE_1 READ_TEMPERATURE_2		DIRECT	2	16000	0	-3	°C

(1) The coefficients listed for power/current measurements are normalized based on an R<sub>SNS</sub> of 1mΩ.

For registers that accept writing data, the same coefficients can be used to determine the Y value from read-world data as follows:

$$Y = (mX+b) \times 10^R$$

where

- X, is the calculated, real-world value in the appropriate units (A, V, °C, W)
- m, the slope coefficient, is a two-byte, two's complement integer
- Y, is a two-byte two's complement integer received from the PMBus device
- b, the offset, is a two-byte, two's complement integer
- R, the exponent, is a one-byte, two's complement integer

**18.3 PMBus Address Lines (ADR0, ADR1, ADR2)**

The tri-state address lines of ADR0, ADR1, and ADR2 can be set to high (VDD), low (connect to GND) or left floating (high impedance Z) to select one of the 27 addresses for communicating with the RTQ1954 as shown in the table below. Each address is 7-bits (bits 0 to 6) with the eighth bit being the read/write bit. If the OCP3 mode is set (ACL is not active), it is not recommended to connect VREF to GND after power-up to change the PMBus address.

ADR2	ADR1	ADR0	Decoded Address
Z	Z	Z	40h
Z	Z	GND	41h
Z	Z	VDD	42h
Z	GND	Z	43h
Z	GND	GND	44h
Z	GND	VDD	45h
Z	VDD	Z	46h
Z	VDD	GND	47h
Z	VDD	VDD	10h
GND	Z	Z	11h
GND	Z	GND	12h
GND	Z	VDD	13h
GND	GND	Z	14h
GND	GND	GND	15h
GND	GND	VDD	16h
GND	VDD	Z	17h
GND	VDD	GND	50h
GND	VDD	VDD	51h
VDD	Z	Z	52h
VDD	Z	GND	53h
VDD	Z	VDD	54h
VDD	GND	Z	55h
VDD	GND	GND	56h
VDD	GND	VDD	57h
VDD	VDD	Z	58h
VDD	VDD	GND	59h
VDD	VDD	VDD	5Ah

## 18.4 PMBus Command Descriptions

### 18.4.1 Standard PMBus Commands

#### Operation (01h)

Command Code: 01h								
Description: It is a standard PMBus command that switches the MOSFET on and off under host control. It is also used to re-enable the MOSFET after a fault triggered shutdown. Writing an OFF command, followed by an ON command, clears all faults and reenables the device. Writing only an ON after a fault-triggered shutdown does not clear the fault registers or reenables the device.								
Name	OPERATION							
Format	Read/Write Byte							
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	RW	R	R	R	R	R	R	R
Default Value	0x1	0x00						
Bits	Name		Description					
[7]	ON		Hot Swap Enable 0 Hot swap output disabled 1 Hot swap output enabled					
[6:0]	Reserved		Always reads 0					

#### CLEAR\_FAULTS (03h)

Command Code: 03h								
Description: It is a standard PMBus command that resets all stored warning and fault flags and the SMBA signal. If a fault or warning condition still exists when the CLEAR_FAULTS command is issued, the SMBA signal may not clear or re-asserts almost immediately. Issuing a CLEAR_FAULTS command does not cause the MOSFET to switch back on in the event of a fault turnoff; that must be done by issuing an OPERATION command after the fault condition is cleared.								
Name	CLEAR_FAULTS							
Format	Send Byte							
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	W	W	W	W	W	W	W	W
Default Value								
Bits	Name		Description					
NA	CLEAR_FAULTS		Clears fault and warning bits in all the status registers. Any faults that are still active and not cleared will remain set.					

#### CAPABILITY (19h)

Command Code: 19h								
Description: It is a standard PMBus command that provides some of key capabilities of RTQ1954 device.								
Name	CAPABILITY							
Format	Read Byte							
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R
Default Value	0x1	0x2		0x1	0x0			
Bits	Name		Description					
[7]	PEC_SUPPORT		Packet error correction (PEC) support					
[6:5]	MAX_BUS_SPEED		Maximum bus interface speed. Always reads 2. Maximum bus speed is 1MHz.					

[4]	SMBALERT_SUPPORT	Always reads 1. Device supports SMBAlert and ARA
[3:0]	RESERVED	

**VOUT\_UV\_WARN\_LIMIT (43h)**

Command Code: 43h																
Description: It is a standard PMBus command that allows to set and read the VOUT undervoltage warning threshold.																
Name	VOUT_UV_WARN_LIMIT															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
Default Value	0				0x000											
Bits	Name				Description											
[15:12]	Reserved				Reserved											
[11:0]	VOUT_UV_WARN_LIMI T				Undervoltage warning threshold for the VOUT pin measurement, expressed in direct format. A value of 0 is disabled.											

**OT\_FAULT\_LIMIT (4Fh)**

Command Code: 4Fh																
Description: It is a standard PMBus command that sets and reads the overtemperature fault detection threshold.																
Name	OT_FAULT_LIMIT															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
Default Value	0				0xFFFF											
Bits	Name				Description											
[15:12]	Reserved				Reserved											
[11:0]	OT_FAULT_LIMIT				Overtemperature fault threshold for the DIODE pin measurement, expressed in direct format.											

**OT\_WARN\_LIMIT (51h)**

Command Code: 51h																
Description: It is a standard PMBus command that sets and reads the overtemperature warning detection threshold.																
Name	OT_WARN_LIMIT															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
Default Value	0				0xFFFF											
Bits	Name				Description											
[15:12]	Reserved				Reserved											
[11:0]	OT_WARN_LIMIT				Overtemperature warning threshold for the DIODE pin measurement, expressed in direct format.											

**VIN\_OV\_WARN\_LIMIT (57h)**

Command Code: 57h																
Description: It is a standard PMBus command that sets and reads the VIN overvoltage warning threshold.																
Name	VIN_OV_WARN_LIMIT															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
Default Value	0				0xFF											
Bits	Name				Description											
[15:12]	Reserved				Reserved											
[11:0]	VIN_OV_WARN_LIMIT				Overvoltage warning threshold for the OVLO pin measurement, expressed in direct format. 0xFF is disabled											

**VIN\_UV\_WARN\_LIMIT (58h)**

Command Code: 58h																
Description: It is a standard PMBus command that sets and reads the VIN undervoltage warning threshold.																
Name	VIN_UV_WARN_LIMIT															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
Default Value	0				0x00											
Bits	Name				Description											
[15:12]	Reserved				Reserved											
[11:0]	VIN_UV_WARN_LIMIT				Undervoltage warning threshold for the EN/UVLO pin measurement, expressed in direct format. 0x00 is disabled											

**IIN\_OC\_WARN\_LIMIT (5Dh)**

Command Code: 5Dh																
Description: It is a standard PMBus command that sets and reads the input overcurrent warning threshold.																
Name	IIN_OC_WARN_LIMIT															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
Default Value	0				0xFF											
Bits	Name				Description											
[15:12]	Reserved				Reserved											
[11:0]	IIN_OC_WARN_LIMIT				I <sub>RSNS</sub> overcurrent warning, expressed in direct format. A value of 0xFF disables. This is a mirror of command D3h											

**STATUS\_BYTE (78h)**

Command Code: 78h								
Description: The STATUS_BYTE command returns one byte of information with a summary of the most critical faults.								
Name	STATUS_BYTE							
Format	Read Byte							
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R
Default Value	0x0	0x0	0x0		0x0	0x0	0x0	0x0
Bits	Name		Description					
[7]	RESERVED							
[6]	HOTSWAP_OFF		Hot swap gate is off. This bit is live. 0 – The hot swap gate drive output is enabled. 1 – The hot swap gate drive output is disabled, and the GATE pin is pulled down. This can be due to, for example, an overcurrent fault that causes the device to latch off, and undervoltage condition on the UV pin, or the use of the OPERATION command to turn the output off.					
[5:4]	RESERVED							
[3]	VIN_UV_FAULT		A VIN UV fault has occurred					
[2]	TEMP_FAULT		A temperature fault or warning has occurred					
[1]	CML_FAULT		A communication fault has occurred					
[0]	NONEABOVE_STATUS		A fault or warning not listed in bits [7:1] has occurred					

**STATUS\_WORD (79h)**

Command Code: 79h																
Description: returns two bytes of information with a summary of the unit’s fault condition. Based on the information in these bytes, the controller can get more information by reading the appropriate status registers.																
Name	STATUS_WORD															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Default Value	0	0	0	0	0	0	0	0x0	0	0x0	0	0	0	0	0	
Bits	Name		Description													
[15]	VOUT_STATUS		An output voltage fault or warning has occurred													
[14]	Reserved															
[13]	INPUT_STATUS		An input voltage or current fault has occurred													
[12]	MFR_SPECIFIC		A STATUS_MFR_SPECIFIC fault has occurred other than CB_FAULT													
[11]	POWER_GOOD		The Power Good signal has been negated													
[10]	Reserved															
[9]	CB_Fault		Circuit breaker fault triggered													
[8:7]	Reserved															
[6]	HOTSWAP_OFF		Hot swap gate is off. This bit is live. 0 – The hot swap gate drive output is enabled. 1 – The hot swap gate drive output is disabled, and the GATE													

		pin is pulled down. This can be due to, for example, an overcurrent fault that causes the device to latch off, and undervoltage condition on the UV pin, or the use of the OPERATION command to turn the output off.
[5:4]	Reserved	
[3]	VIN_UV_FAULT	A VIN UV fault has occurred
[2]	TEMP_FAULT	A temperature fault or warning has occurred
[1]	CML_FAULT	A communication fault has occurred
[0]	NONEABOVE_STATUS	A fault or warning not listed in bits [7:1] has occurred

**STATUS\_VOUT (7Ah)**

Command Code: 7Ah								
Description: returns one data byte with contents as follows.								
Name	STATUS_VOUT							
Format	Read Byte							
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R
Default Value	0x0		0x0	0x0				
Bits	Name		Description					
[7:6]	RESERVED							
[5]	VOUT_UV_WARN							
[4:0]	RESERVED							

**STATUS\_INPUT (7Ch)**

Command Code: 7Ch								
Description: returns one data byte with contents as follows.								
Name	STATUS_INPUT							
Format	Read Byte							
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R
Default Value	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
Bits	Name		Description					
[7]	VIN_OV_FAULT		A VIN OV fault has occurred					
[6]	VIN_OV_WARN		A VIN OV warning has occurred					
[5]	VIN_UV_WARN		A VIN UV warning has occurred. This flag defaults to 1 on startup, but is cleared to 0 after the first time the input voltage increases above the UVLO pin threshold.					
[4]	VIN_UV_FAULT		A VIN UV fault has occurred					
[3]	RESERVED							
[2]	IIN_OC_FAULT		An IIN OC fault has occurred					
[1]	IIN_OC_WARN		An IIN OC warning has occurred					
[0]	PIN_OP_WARN		A PIN OP warning has occurred					

**STATUS\_TEMPERATURE (7Dh)**

Command Code: 7Dh								
Description: returns one data byte with contents as follows.								
Name	STATUS_TEMPERATURE							
Format	Read Byte							
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R
Default Value	0x0	0x0	0x0					
Bits	Name		Description					
[7]	OT_FAULT		An OT fault has occurred. If STATUS_MFR_SPECIFIC.INT_OT_TEMP_FAULT is also set, then this OT_FAULT was an internal die temp fault. Otherwise, an external OT_TEMP_FAULT was observed.					
[6]	OT_WARN		An OT warning has occurred					
[5:0]	RESERVED							

**STATUS\_CML (7Eh)**

Command Code: 7Eh								
Description: returns one data byte with contents as follows.								
Name	STATUS_CML							
Format	Read Byte							
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R
Default Value	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
Bits	Name		Description					
[7]	INVALID_CMD		An invalid or unsupported command was received					
[6]	INVALID_DATA		Invalid or unsupported data was received					
[5]	PEC_ERROR		Packet error check failed					
[4:2]	RESERVED							
[1]	MISC_COM_FAULT		A miscellaneous communication fault has occurred					
[0]	MEM_ERROR		A OTP eFuse uncorrectable ECC error has occurred					

**STATUS\_OTHER (7Fh)**

Command Code: 7Fh								
Description: returns one data byte with contents as follows.								
Name	STATUS_OTHER							
Format	Read Byte							
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R
Default Value	0x0		0x0	0x0				
Bits	Name		Description					
[7:6]	RESERVED							
[5]	CB_FAULT		A circuit breaker fault has occurred					
[4:0]	RESERVED							

## STATUS\_MFR\_SPECIFIC (80h)

Command Code: 80h								
Description: returns one data byte with contents as follows.								
Name	STATUS_MFR_SPECIFIC							
Format	Read Byte							
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R
Default Value	0x0	0x0	0x0	0x1	0x0	0x0	0x0	
Bits	Name		Description					
[7]	CB_FAULT		A circuit breaker fault has occurred					
[6]	EXT_MOSFET_SHORT		External MOSFET shorted fault					
[5]	FET_FAULT		Vds or Vgs FET BAD fault					
[4]	DEFAULTS_LOADED		The default configuration has been loaded. Set on power up or if VREF is pulled to ground.					
[3]	PROCHOT		Sets if PROCHOT is asserted. Cannot assert SMBAlert#					
[2]	INT_OT_TEMP_FAULT		Set if internal die temp exceeds 150C.					
[1:0]	RESERVED							

## READ\_EIN (86h)

Command Code: 86h						
Description: returns 6 bytes of information that can be used to calculate the input power on the device.						
Name	READ_EIN					
Format	Block Read					
Bits	Byte5	Byte4	Byte3	Byte2	Byte1	Byte0
Read/Write	R	R	R	R	R	R
Default Value	0x0	0x0	0x0	0x0	0x0	0x0
Bits	Name		Description			
[47:24]	SAMPLE_COUNT		24-bit unsigned integer that counts the number of samples of the instantaneous input power.			
[23:16]	ROLLOVER_COUNT		Unsigned integer byte that indicates the number of times the accumulator has rolled over from its maximum positive unsigned integer (7FFFh) to 0.			
[15:0]	ENERGY_COUNT		Accumulator output that continuously sums samples of the instantaneous input power.			

## READ\_VIN (88h)

Command Code: 88h																
Description: returns the measured value of the input voltage.																
Name	READ_VIN															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Default Value	0								0							
Bits	Name					Description										
[15:12]	RESERVED															
[11:0]	READ_VIN					12-bit unsigned number, expressed in direct format										

**READ\_IIN (89h)**

Command Code: 89h																
Description: returns the measured value of the input current.																
Name	READ_IIN															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Default Value	0								0							
Bits	Name				Description											
[15:12]	RESERVED															
[11:0]	READ_IIN				12-bit unsigned number, expressed in direct format											

**READ\_VOUT (8Bh)**

Command Code: 8Bh																
Description: returns the measured value of the output voltage.																
Name	READ_VOUT															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Default Value	0								0							
Bits	Name				Description											
[15:12]	RESERVED															
[11:0]	READ_VOUT				12-bit unsigned number, expressed in direct format.											

**READ\_TEMPERATURE\_1 (8Dh)**

Command Code: 8Dh																
Description: returns the signed value of the temperature measured by the external temperature sense diode.																
Name	READ_TEMPERATURE_1															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Default Value	0															
Bits	Name				Description											
[15:0]	READ_TEMPERATURE_1				16-bit signed number, expressed in direct format, limited to 0xF000 to 0x0FFF											

**READ\_TEMPERATURE\_2 (8Eh)**

Command Code: 8Eh																
Description: returns the signed value of the measured internal die temperature.																
Name	READ_TEMPERATURE_2															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Default Value	0															
Bits	Name					Description										
[15:0]	READ_TEMPERATURE_2					Internal die temp 16-bit signed number, expressed in direct format, limited to 0xF000 to 0x0FFF										

**READ\_PIN (97h)**

Command Code: 97h																
Description: returns the measured value of the input power.																
Name	READ_PIN															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Default Value	0					0										
Bits	Name					Description										
[15:12]	RESERVED															
[11:0]	READ_PIN					12-bit unsigned number, expressed in direct format.										

**PMBUS\_REVISION (98h)**

Command Code: 98h								
Description: returns the revision of the PMBus to which the device is compliant.								
Name	PMBUS_REVISION							
Format	Read Byte							
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R
Default Value	0x2				0x2			
Bits	Name				Description			
[7:4]	PART_I_REVISION				Compliant to PMBus Part I revision 1.2			
[3:0]	PART_II_REVISION				Compliant to PMBus Part II revision 1.2			

**MFR\_ID (99h)**

Command Code: 99h			
Description: returns the identification of the manufacturer.			
Name	MFR_ID		
Format	Block Read		
Bits	Byte2	Byte1	Byte0
Read/Write	R	R	R
Default Value	"RTK"		
Bits	Name	Description	
[23:0]	MFR_ID	ASCII string identifying manufacturer as Richtek (RTK).	

**MFR\_MODEL (9Ah)**

Command Code: 9Ah								
Description: returns the manufacturer's model number.								
Name	MFR_MODEL							
Format	Block Read							
Bits	Byte7	Byte6	Byte5	Byte4	Byte3	Byte2	Byte1	Byte0
Read/Write	R	R	R	R	R	R	R	R
Default Value	"RTQ1954\0"							
Bits	Name	Description						
[63:0]	MFR_MODEL	ASCII string identifying model as the RTQ1954.						

**MFR\_REVISION (9Bh)**

Command Code: 9Bh		
Description: Returns the manufacturer's revision number.		
<b>Name</b>	MFR_REVISION	
<b>Format</b>	Block Read	
<b>Bits</b>	Byte 1	Byte 0
<b>Read/Write</b>	R	R
<b>Default Value</b>	32h, "2"	31h, "1"
<b>Bits</b>	<b>Name</b>	<b>Description</b>
[15:0]	MFR_REVISION	ASCII string identifying hardware revision.

## 18.4.2 MFR Specific PMBus Commands

### READ\_VAUX (D0h)

Command Code: D0h																
Description: returns the measured value of VAUX.																
Name	READ_VAUX															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Default Value	0				0											
Bits	Name				Description											
[15:12]	RESERVED															
[11:0]	READ_VAUX				12-bit unsigned number, expressed in direct format.											

### READ\_IIN (D1h)

Command Code: D1h																
Description: returns the measured value of the input current.																
Name	READ_IIN															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Default Value	0				0											
Bits	Name				Description											
[15:12]	RESERVED															
[11:0]	READ_IIN				Mirror of 89h											

### READ\_PIN (D2h)

Command Code: D2h																
Description: returns the measured value of the input power.																
Name	READ_PIN															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Default Value	0				0											
Bits	Name				Description											
[15:12]	RESERVED															
[11:0]	READ_PIN				Mirror of 97h											

**MFR\_IIN\_OC\_WARN\_LIMIT (D3h)**

Command Code: D3h																
Description: sets and reads the input overcurrent warning threshold.																
Name	MFR_IIN_OC_WARN_LIMIT															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R					RW										
Default Value	0					0xFFFF										
Bits	Name					Description										
[15:12]	RESERVED															
[11:0]	MFR_IIN_OC_WARN_LI MIT					IRSNS overcurrent warning, expressed in direct format. A value of 0xFFFF disables. Mirror of 5Dh										

**PIN\_OP\_WARN\_LIMIT (D4h)**

Command Code: D4h																
Description: sets the value of the input power, in watts, that causes a warning that the input power is high																
Name	PIN_OP_WARN_LIMIT															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R					RW										
Default Value	0					0xFFFF										
Bits	Name					Description										
[15:12]	RESERVED															
[11:0]	PIN_OP_WARN_LIMIT					Overpower warning threshold for the VIN × IIN power calculation, expressed in direct format.										

**READ\_PIN\_PEAK (D5h)**

Command Code: D5h																
Description: returns the maximum value of input power.																
Name	READ_PIN_PEAK															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R					R										
Default Value	0					0xFFFF										
Bits	Name					Description										
[15:12]	RESERVED															
[11:0]	READ_PIN_PEAK					Maximum value for IIN × VIN since reset or last clear, expressed in direct format.										

### CLEAR\_PIN\_PEAK (D6h)

Command Code: D6h	
Description: Clears READ_PIN_PEAK	
Name	CLEAR_PIN_PEAK
Format	Send Byte

### GATE\_MASK (D7h)

Command Code: D7h								
Description: This register prevents specific fault conditions to turn off the MOSFET gate.								
Name	GATE_MASK							
Format	Read/Write Byte							
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	RW	RW	RW	RW	RW	RW	R	RW
Default Value	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
Bits	Name		Description					
[7]	GATE_MASK_FETFAULT							
[6]	GATE_MASK_FETSHORT							
[5]	GATE_MASK_VIN_UV_FAULT							
[4]	GATE_MASK_VIN_OV_FAULT							
[3]	GATE_MASK_IIN_PFET_FAULT							
[2]	GATE_MASK_OT_FAULT							
[1]	RESERVED							
[0]	GATE_MASK_CB_FAULT							

### ALERT\_MASK (D8h)

Command Code: D8h																
Description: This command allows to configure masking SMBA for specific fault or warning.																
Name	ALERT_MASK															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	RW	RW	RW	RW	RW	RW	R	RW								
Default Value	1	1	1	1	1	1	0	1	0	0	1	0	0	0	0	0
Bits	Name		Description													
[15]	ALERT_MASK_VOUT_UV_WARN															
[14]	ALERT_MASK_IIN_LIM_WARN															
[13]	ALERT_MASK_VIN_UV_WARN															
[12]	ALERT_MASK_VIN_OV_WARN															
[11]	ALERT_MASK_POWER_NOT_GOOD															
[10]	ALERT_MASK_OT_WARN															
[9]	RESERVED															
[8]	ALERT_MASK_OP_LIM_WARN															
[7]	ALERT_MASK_FET_FAULT															
[6]	ALERT_MASK_EXT_FET_SHORT															
[5]	ALERT_MASK_VIN_UV_FAULT															
[4]	ALERT_MASK_VIN_OV_FAULT															

[3]	ALERT_MASK_IIN_PFET_FAULT	
[2]	ALERT_MASK_OT_FAULT	Masks OT_FAULT and INT_OT_FAULT
[1]	ALERT_MASK_CML_FAULT	
[0]	ALERT_MASK_CB_FAULT	

**DEVICE\_SETUP (D9h)**

Command Code: D9h								
Description: This command can be used to override pin settings to define the RTQ1954 operation.								
Name		DEVICE_SETUP						
Format		Read/Write Byte						
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	RW		RW	RW	RW	RW	RW	RW
Default Value	0x0		0x0	0x0	0x0	0x0	0x0	0x0
Bits	Name		Description					
[7:5]	RETRY_SETTING		111 = Unlimited Retries 110 = Retry 16 times 101 = Retry 8 times 100 = Retry 4 times 011 = Retry 2 times 010 = Retry 1 times 001 = No Retries 000 = Pin configured retries					
[4]	CL_SETTING		0 = High setting (50mV) 1 = Low setting (26mV)					
[3]	CBCL_RATIO		0 = Low settings (VCB=50mV for VOCP2≤ 32mV, and VCB=100mV for VOCP2≥ 33mV) 1 = High setting (VCB=100mV for VOCP2≤ 32mV, and VCB=200mV for VOCP2≥ 33mV)					
[2]	CL_CONFIG		0 = Use pin settings 1 = Use SMBus settings					
[1]	USE_MFR_CL_THRESHOLD		If CL_CONFIG is set to 1 and if this bit is set, the MFR_CL_THRESHOLD command sets the CL_THRESHOLD. If CL_CONFIG is set to 1 and this bit is 0, then CL_SETTING determines the CL_THRESHOLD.					
[0]	RESEVED							

**BLOCK\_READ (DAh)**

Command Code: DAh												
Description: Concatenates the DIAGNOSIS_WORD with all the input and output telemetry data and temperature.												
Name		BLOCK_READ										
Format		Block Read										
Bits	Byte 11	Byte 10	Byte 9	Byte 8	Byte 7	Byte 6	Byte 5	Byte 4	Byte 3	Byte 2	Byte 1	Byte 0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R
Default Value	0x00		0x00		0x00		0x00		0x00		0x0880	
Bits	Name				Description							
[95:80]	TEMP_BLOCK											

[79:64]	PIN_BLOCK	
[63:48]	VIN_BLOCK	
[47:32]	VOUT_BLOCK	
[31:16]	IIN_BLOCK	
[15:0]	DIAGNOSTIC_WORD	

**SAMPLES\_FOR\_AVG (DBh)**

Command Code: DBh								
Description: This command configures the number of samples used in computing the average of VIN, VOUT, IIN and PIN. It also sets average register update period.								
Name	SAMPLES_FOR_AVG							
Format	Read/Write Byte							
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R				RW			
Default Value	0x0				0x8			
Bits	Name		Description					
[7:4]	RESERVED							
[3:0]	SAMPLES_FOR_AVG		<p>Number of samples used to compute average. Also average register update period.</p> <p><math>Avg = 2^{SAMPLES\_PER\_AVG}</math></p> <p>0000b = <math>2^0 = 1</math> sample per average calculation, 1ms average update period</p> <p>...</p> <p>1100b = <math>2^{12} = 4096</math> samples per average calculation, 4096 ms average update period</p> <p>Values 13, 14, and 15 are reserved and will generate a CML Data error</p>					

**READ\_AVG\_VIN (DCh)**

Command Code: DCh																
Description: Returns the 12-bit average input voltage.																
Name	READ_AVG_VIN															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R				R											
Default Value	0				0x00											
Bits	Name		Description													
[15:12]	RESERVED															
[11:0]	READ_AVG_VIN		12-bit unsigned number, expressed in direct format.													

**READ\_AVG\_VOUT (DDh)**

Command Code: DDh																
Description: Returns the 12-bit average output voltage.																
Name	READ_AVG_VOUT															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R						R									
Default Value	0						0x00									
Bits	Name						Description									
[15:12]	RESERVED															
[11:0]	READ_AVG_VOUT						12-bit unsigned number, expressed in direct format.									

**READ\_AVG\_IIN (DEh)**

Command Code: DEh																
Description: Returns the 12-bit input average current.																
Name	READ_AVG_IIN															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R						R									
Default Value	0						0x00									
Bits	Name						Description									
[15:12]	RESERVED															
[11:0]	READ_AVG_IIN						12-bit unsigned number, expressed in direct format.									

**READ\_AVG\_PIN (DFh)**

Command Code: DFh																
Description: Returns the 12-bit input average power.																
Name	READ_AVG_PIN															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R						R									
Default Value	0						0x00									
Bits	Name						Description									
[15:12]	RESERVED															
[11:0]	READ_AVG_PIN															

## BLACK\_BOX\_READ (E0h)

Command Code: E0h												
Description: The command retrieves BLOCK_READ data latched on the first assertion of $\overline{\text{SMBA}}$												
Name	BLACK_BOX_READ											
Format	Block Read											
Bits	Byte 11	Byte 10	Byte 9	Byte 8	Byte 7	Byte 6	Byte 5	Byte 4	Byte 3	Byte 2	Byte 1	Byte 0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R
Default Value	0x00		0x00		0x00		0x00		0x00		0x00	
Bits	Name				Description							
[95:80]	TEMP_BLOCK											
[79:64]	PIN_BLOCK											
[63:48]	VIN_BLOCK											
[47:32]	VOUT_BLOCK											
[31:16]	IIN_BLOCK											
[15:0]	DIAGNOSTIC_WORD											

## READ\_DIAGNOSTIC\_WORD (E1h)

Command Code: E1h																
Description: Returns all of the RTQ1954 faults and warnings in a single transaction.																
Name	READ_DIAGNOSTIC_WORD															
Format	Read Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Default Value	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
Bits	Name						Description									
[15]	VOUT_UV_WARN															
[14]	IIN_OP_WARN															
[13]	VIN_UV_WARN															
[12]	VIN_OV_WARN															
[11]	$\overline{\text{POWER\_GOOD}}$															
[10]	OT_WARN															
[9]	TIMER_LATCHED_OFF															
[8]	EXT_FET_SHORT															
[7]	CONFIG_PRESET															
[6]	DEVICE_OFF															
[5]	VIN_UV_FAULT															
[4]	VIN_OV_FAULT															
[3]	IIN_OC/PFET_OP_FAULT															
[2]	OT_FAULT															
[1]	CML_FAULT															
[0]	CB_FAULT															

**AVG\_BLOCK\_READ (E2h)**

Command Code: E2h												
Description: Concatenates the DIAGNOSIS_WORD with all the input and output average telemetry data and temperature.												
Name	AVG_BLOCK_READ											
Format	Block Read											
Bits	Byte 11	Byte 10	Byte 9	Byte 8	Byte 7	Byte 6	Byte 5	Byte 4	Byte 3	Byte 2	Byte 1	Byte 0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R
Default Value	0x00		0x00		0x00		0x00		0x00		0x0880	
<b>Bits</b>	<b>Name</b>				<b>Description</b>							
[95:80]	TEMP1											
[79:64]	AVG_PIN											
[63:48]	AVG_VIN											
[47:32]	AVG_VOUT											
[31:16]	AVG_IIN											
[15:0]	DIAGNOSTIC_WORD											

**READ\_IIN\_PEAK (EDh)**

Command Code: EDh																
Description: This command records the maximum value of input current.																
Name	READ_IIN_PEAK															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R								RW							
Default Value	0								0x000							
Bits	Name				Description											
[15:12]	RESERVED															
[11:0]	READ_IIN_PEAK				Records the peak value of READ_IIN seen since last reset. Write 0 to clear. Expressed in direct format.											

**READ\_IIN\_MIN (EEh)**

Command Code: EEh																
Description: This command records the minimum value of input current.																
Name	READ_IIN_MIN															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R								RW							
Default Value	0								0xFFFF							
Bits	Name				Description											
[15:12]	RESERVED															
[11:0]	READ_IIN_MIN				Records the minimal value of READ_IIN seen since last reset. Write 0 to reset. Expressed in direct format.											

**VOUT\_UV\_RETRY\_THRESHOLD (EFh)**

Command Code: EFh																
Description: This command sets the voltage threshold that the RTQ1954 will not restart until VOUT drops below this threshold.																
Name	VOUT_UV_RETRY_THRESHOLD															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R				RW											
Default Value	0				0xFFF											
Bits	Name				Description											
[15:12]	RESERVED															
[11:0]	VOUT_UV_RETRY_THRESHOLD				The Hotswap retry will not start until the VOUT falls below this threshold. Same units as READ_VOUT. Expressed in direct format.											

**MFR\_CL\_THRESHOLD (F0h)**

Command Code: F0h								
Description: This command sets the OCP2 threshold in mV as measured across VIN_K-SENSE.								
Name	MFR_CL_THRESHOLD							
Format	Read/Write Byte							
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	R	RW	RW	RW	RW	RW	RW
Default Value	0x0				0x0			
Bits	Name			Description				
[7:6]	RESERVED							
[5:0]	CL_THRESHOLD			Threshold = (MFR_CL_THRESHOLD + 10mV). In mV units. Maximum value of this field is 45 (threshold of 55mV). A write with a value over 45 will result in STATUS_CML.INVALID_DATA setting.				

**MFR\_ADV\_CFG\_STATUS (F1h)**

Command Code: F1h																
Description: Allows for configuring settings of the RTQ1954 device.																
Name	MFR_ADV_CFG_STATUS															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R				RW			RW			RW	RW	RW	RW	RW	
Default Value	0				0			0			0	0	0	0	0	
Bits	Name				Description											
[15:12]	RESERVED															
[11:9]	retryCntResetPeriod				Allows the retry counter to reset after a period of time without faults. 0 = reset retryCnt after 1.3s 1 = reset retryCnt after 2.6s 2 = reset retryCnt after 5.2s 3 = reset retryCnt after 10.4s											

		≥ 4 is disabled: retryCnt will not reset
[8:5]	RESERVED	
[4]	PROCHOT_EN	If set, the PROCHOT output and STATUS_MFR_SPECIFIC are enabled.
[3]	vout_uv_thresh_pwrcycle_en	If set, the design will wait for VOUT to fall below VOUT_UV_RETRY_THRESHOLD before restarting after a POWER_CYCLE
[2]	vout_uv_thresh_operation_en	If set, the design will wait for VOUT to fall below VOUT_UV_RETRY_THRESHOLD before restarting after an OPERATION Off to On
[1]	vout_uv_thresh_uvlo_en	If set, the design will wait for VOUT to fall below VOUT_UV_RETRY_THRESHOLD before restarting after an UVLO Off to On or after OVLO event
[0]	vout_uv_thresh_fault_en	If set, the design will wait for VOUT to fall below VOUT_UV_RETRY_THRESHOLD before restarting after a fault off to on

**MFR\_ADV\_PWRCYCLE\_TIME (F2h)**

Command Code: F2h																
Description: Sets the power cycle timer duration in ms. If the vout_uv_thresh_pwrcycle_en bit in register F1h is set, the RTQ1954 wait for the VOUT to drop below VOUT_UV_RETRY_THRESHOLD before starting the timer.																
Name	MFR_ADV_PWRCYCLE_TIME															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	RW															
Default Value	0x2710															
Bits	Name					Description										
[15:0]	PWRCYCLE_TIME					This sets the duration of the power cycle timer, in milliseconds. Default is 10 seconds. Set to 0 to disable										

**MFR\_ADV\_RETRY\_TIMEOUT (F3h)**

Command Code: F3h																
Description: Sets the duration of RETRY in ms.																
Name	MFR_ADV_RETRY_TIMEOUT															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	RW															
Default Value	0x0															
Bits	Name					Description										
[15:0]	RETRY_TIMEOUT					This limits the duration of the fault retry, in milliseconds. Set to 0 to disable										

## MFR\_ADV\_COOLDOWN\_TIME (F5h)

Command Code: F5h																
Description: sets the cool down timer in ms that the RTQ1954 waits after the last RETRY attempt before starting up.																
Name	MFR_ADV_COOLDOWN_TIME															
Format	Read/Write Word															
Bits	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	RW															
Default Value	0x0															
Bits	Name					Description										
[15:0]	COOLDOWN_TIME					Cooldown Time in milliseconds. Set to 0 to disable										

## MFR\_TELEM\_CGF (F6h)

Command Code: F6h									
Description: This command is used to configure the telemetry settings for the RTQ1954.									
Name	MFR_TELEM_CGF								
Format	Read/Write Word								
Bits	Byte 1	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	R	RW	RW	RW	RW	RW	RW	RW	RW
Default Value	0x00	0	1	0	1	1	1	1	1
Bits	Name			Description					
[15:8]	RESERVED								
7	TEMP_COMP_RST			Write 1 to reset the temperature compensation factor. Always reads back 0.					
6	TEMP_COMP_EN			If set and INT_TEMP_TELEM_EN is set, then adc measurements will be temperature compensated					
5	TELEM_OVER_SAMPLE			If this bit is set, then EXT_TEMP will be generated every 16ms by averaging 4 samples together. All other telemetry will be averaged with 2 samples and generated every 1ms. The generated telemetry is stored and averaged.					
4	VAUX_TELEM_EN			Enables VAUX telemetry measurement					
3	VOUT_TELEM_EN			Enables VOUT telemetry measurement					
2	VIN_TELEM_EN			Enables VIN telemetry measurement. Enabling this bit plus VIN_TELEM_EN will generate a PIN measurement.					
1	IIN_TELEM_EN			Enables input current measurement. Enabling this bit plus IIN_TELEM_EN will generate a PIN measurement					
0	EXT_TEMP_TELEM_EN			Enables external temperature measurement					

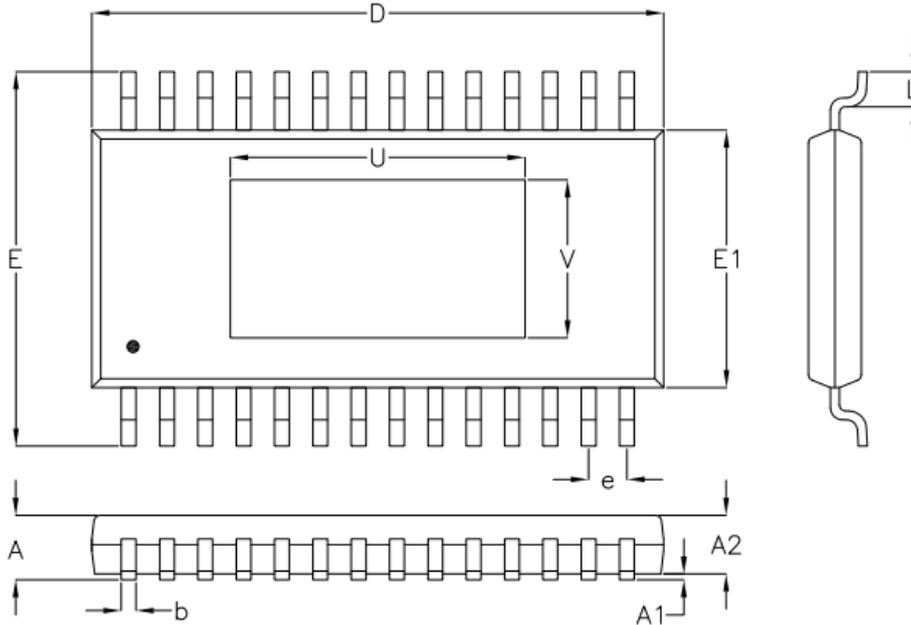
**MFR\_HOTSWAP\_STATUS (F9h)**

Command Code: F9h			
Description: Records the state of the RTQ1954 device.			
Name	MFR_HOTSWAP_STATUS		
Format	Read/Write Block		
Bits	Bit [23:17]	Bit [16:4]	Bit [3:0]
Read/Write	R	R	RW
Default Value	0	0	15
Bits	Name	Description	
[23:17]	RESERVED		
[16:4]	HOTSWAP_STATE	<p>This field records the current state of the hot swap. It is always valid. Each bit indicates if the event is active and preventing the hot swap from turning on. If this field is 0, the gate is on</p> <ul style="list-style-type: none"> <li>0 = INSERTION</li> <li>1 = FETSHORT</li> <li>2 = VIN &lt; POREN</li> <li>3 = UVLO</li> <li>4 = OVLO</li> <li>5 = OT_FAULT</li> <li>6 = FETFAULT</li> <li>7 = Overcurrent</li> <li>8 = Over power</li> <li>9 = Circuit Breaker</li> <li>10 = Pmbus Operation Commanded Off</li> <li>11 = Pmbus Power Cycle</li> <li>12 = OTP Uncorrectable Error</li> </ul>	
[3:0]	HOTSWAP_OFF_REASON	<p>Records the first reason why the hot swap turned off. Write any value to this command to reset this to the value 15/Armed.</p> <ul style="list-style-type: none"> <li>0 = INSERTION</li> <li>1 = FETSHORT</li> <li>2 = VIN&lt; POREN</li> <li>3 = UVLO</li> <li>4 = OVLO</li> <li>5 = OT_FAULT</li> <li>6 = FETFAULT</li> <li>7 = Overcurrent</li> <li>8 = Over power</li> <li>9 = Circuit Breaker</li> <li>10 = Pmbus Operation Commanded Off</li> <li>11 = Pmbus Power Cycle</li> <li>12 = OTP Uncorrectable Error</li> <li>13,14 = Reserved</li> <li>15 = Armed</li> </ul>	

## POWER\_CYCLE (FBh)

Command Code: FBh								
Description: Causes the RTQ1954 shutdown from any state and remain off for the time defined by MFR_ADV_PWRCYCLE_TIME.								
Name	POWER_CYCLE							
Format	Send Byte							
Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Read/Write	W	W	W	W	W	W	W	W
Default Value								
Bits	Name		Description					
NA	POWER_CYCLE		Causes the hot swap to shut down and remain off for the period of time defined by MFR_ADV_PWRCYCLE_TIME.					

**19 Outline Dimension**

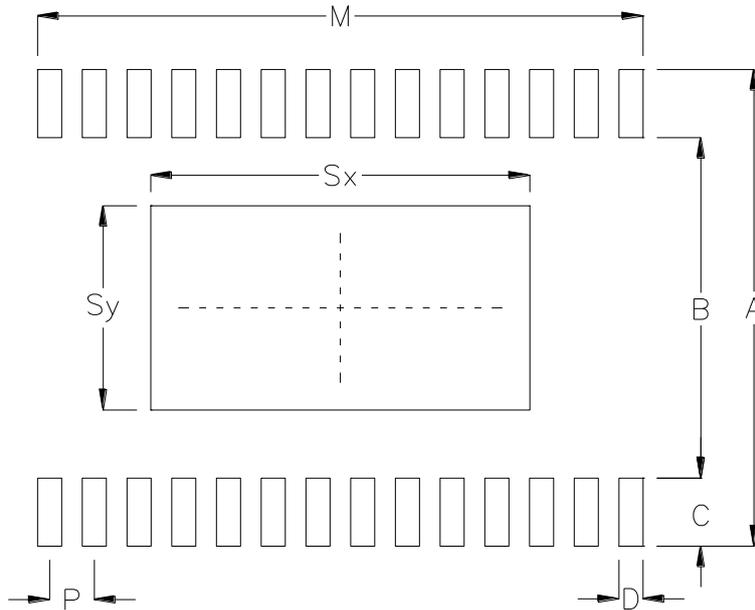


Symbol	Dimensions In Millimeters		Dimensions In Inches		
	Min	Max	Min	Max	
A	1.000	1.200	0.039	0.047	
A1	0.000	0.150	0.000	0.006	
A2	0.800	1.050	0.031	0.041	
b	0.190	0.300	0.007	0.012	
D	9.600	9.800	0.378	0.386	
e	0.650		0.026		
E	6.300	6.500	0.248	0.256	
E1	4.300	4.500	0.169	0.177	
L	0.450	0.750	0.018	0.030	
Option 1	U	4.410	5.510	0.174	0.217
	V	2.400	3.000	0.094	0.118
Option 2	U	5.500	6.170	0.217	0.243
	V	1.600	2.210	0.063	0.087
Option 3	U	5.800	6.200	0.228	0.244
	V	2.600	3.000	0.102	0.118

**28-Lead TSSOP (Exposed Pad) Plastic Package**

**Note 16.** The package of the RTQ1954 uses Option 1.

## 20 Footprint Information

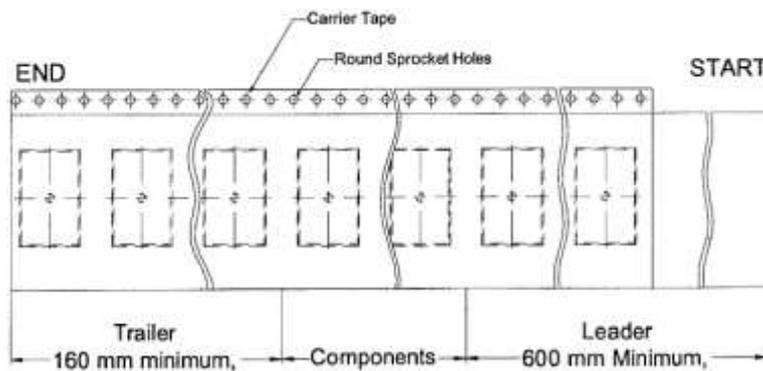
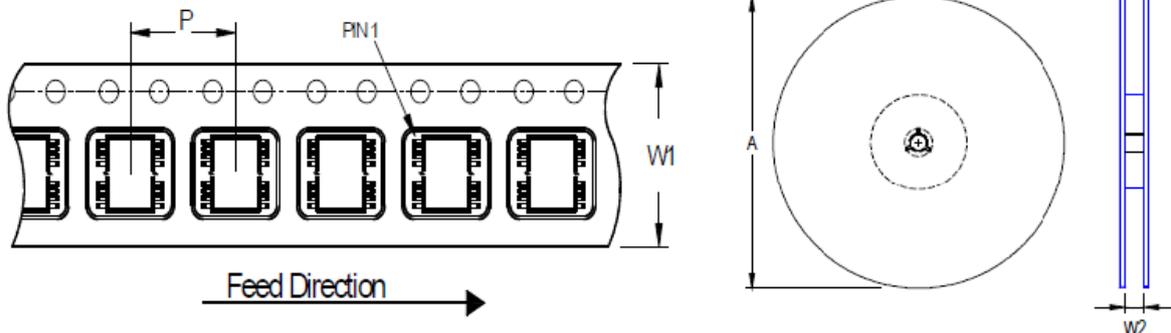


Package		Number of Pins	Footprint Dimension (mm)							Tolerance	
			P	A	B	C	D	Sx	Sy		M
TSSOP-28(PP)	Option1	28	0.65	7.00	5.00	1.00	0.35	5.51	3.00	8.80	±0.10
	Option2							6.17	2.21		
	Option3							6.20	3.00		

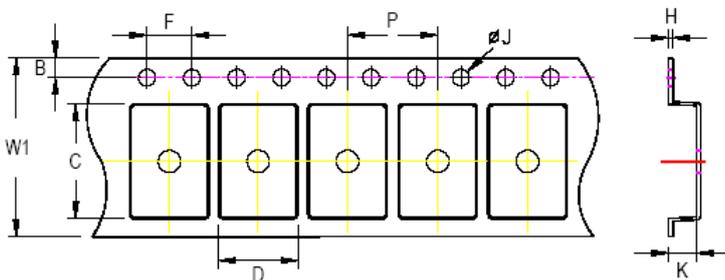
**Note 17.** The package of the RTQ1954 uses Option 1.

**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)				
TSSOP-28	16	8	330	13	2,500	160	600	16.4/18.4



**C, D, and K are determined by component size.**  
**The clearance between the components and the cavity is as follows:**  
**- For 16mm carrier tape: 0.5mm max.**

Tape Size	W1		P		B		F		ØJ		K		H
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Max.	
16mm	16.3mm	7.9mm	8.1mm	1.65mm	1.85mm	3.9mm	4.1mm	1.5mm	1.6mm	1.5mm	1.7mm	0.6mm	

## 21.2 Tape and Reel Packing

Step	Photo/Description	Step	Photo/Description
1	 <p>Reel 13"</p>	4	 <p>1 reel per inner box <b>Box G</b></p>
2	 <p>HIC &amp; Desiccant (2 Unit) inside</p>	5	 <p>6 inner boxes per outer box</p>
3	 <p>Caution label is on backside of AI bag</p>	6	 <p>Outer box <b>Carton A</b></p>

Package	Container		Reel			Box			Carton		
	Size	Units	Item	Reels	Units	Item	Boxes	Units			
TSSOP-28	13"	2,500	Box G	1	2,500	Carton A	6	15,000			

**21.3 Packing Material Anti-ESD Property**

Surface Resistance	Aluminum Bag	Reel	Cover tape	Carrier tape	Tube	Protection Band
$\Omega/\text{cm}^2$	$10^4$ to $10^{11}$					

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## 22 Datasheet Revision History

Version	Date	Description
00	2025/9/25	First Edition