

MAX20459

Automotive High-Current Step-Down Converter with USB-C Dedicated Charging Port

General Description

The MAX20459 combines a 3A high-efficiency, automotive-grade, step-down converter, a USB Type-C DFP controller, and automatic BC1.2 DCP, Apple®, and Samsung® dedicated charger-detection circuitry. The device also includes a USB load current-sense amplifier and configurable feedback-adjustment circuit designed to provide automatic USB voltage compensation. The device limits the USB load current using both a fixed internal peak-current threshold and a user-configurable external current-sense USB load threshold.

The MAX20459 is optimized for high-frequency operation and includes programmable frequency selection from 310kHz to 2.2MHz, allowing optimization of efficiency, noise, and board space based on application requirements. The fully synchronous DC-DC converter integrates high-side and low-side MOSFETs along with an external SYNC input/output, and can be configured for spread-spectrum operation. Additionally, thermal foldback is implemented to avoid excessive heating of the module while charging at high ambient temperature.

The MAX20459 allows flexible configuration and advanced diagnostic options for both standalone and supervised applications. The device can operate as a true one-chip solution that offers advanced fault autorecovery and can be programmed using external programming resistors and/or internal I²C registers.

The MAX20459 is available in a small 5mm x 5mm 32-pin TQFN package and is designed to minimize required external components and layout area.

Applications

- Dedicated USB Charging Port (DCP)
 - Host and Hub Module Dedicated Charging Ports
 - Dedicated Charging Modules

Benefits and Features

- One-Chip Type-C Solution Directly from Car Battery to Portable Device
 - USB Type-C-Compliant DFP Controller
 - Integrated iPhone®/iPad®, Samsung® and BC1.2 DCP Charger Detection
 - 4.5V to 28V Input (40V Load Dump), Synchronous Buck Converter
 - 5V to 7V, 3A Output Capability
 - Standalone Device or I²C Configuration Options and Fault Autorecovery
- Optimal USB Charging and Communication for Portable Devices
 - User-Programmable Voltage Gain Adjusts Output for up to 500mΩ Cable Resistance
 - User-Programmable USB Current Limit
- Low-Noise Features Prevent Interference with AM Band and Portable Devices
 - Fixed-Frequency 310kHz to 2.2MHz Operation
 - Fixed-PWM Option at No Load
 - Spread Spectrum for EMI Reduction
 - SYNC Input/Output for Frequency Parking
- Robust Design Keeps Vehicle System and Portable Device Safe in an Automotive Environment
 - Short-to-Battery Protection on V_{BUS}, HVD± Pins
 - ±15kV Air/±8kV Contact (330pF, 330Ω)
 - ±15kV Air/±8kV Contact ISO 10605 (330pF, 2kΩ)
 - ±15kV Air/±8kV Contact IEC 61000-4-2 (150pF, 330Ω)
 - Overtemperature Protection, Warning, and Intelligent Current Foldback
 - AEC-Q100 Qualified
 - -40°C to +125°C Operating Temperature Range

**Tested in Typical Application Circuit as used on the MAX20459 Evaluation Kit*

Ordering Information appears at end of datasheet.

Apple is a registered trademark of Apple Inc.

Samsung is a registered trademark of Samsung Electronics Co., Ltd.

Simplified Block Diagram

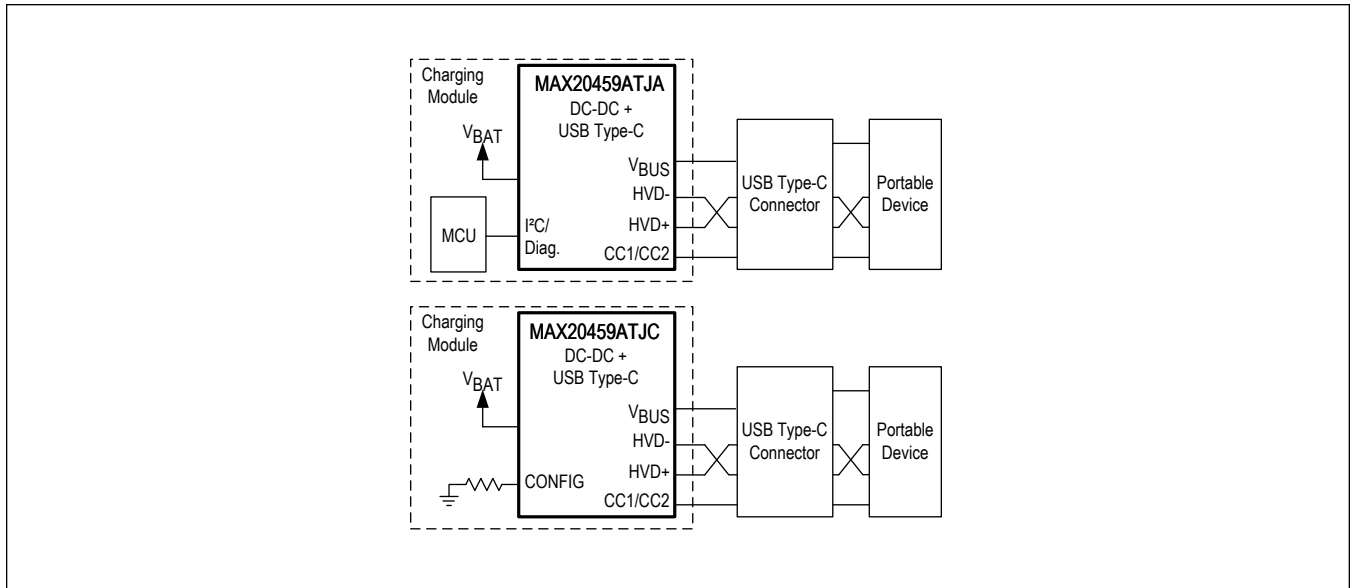


TABLE OF CONTENTS

General Description	1
Applications	1
Benefits and Features	1
Simplified Block Diagram	2
Absolute Maximum Ratings	8
Package Information	8
32 Pin TQFN 5x5x0.75mm	8
Electrical Characteristics	8
Typical Operating Characteristics	14
Pin Configuration	17
MAX20459	17
Pin Description	17
Functional Diagrams	19
ENBUCK Reset Behavior and Timing Diagram	19
ADC Timing Diagram	20
ATTACH Logic Diagram	21
CC Attachment and V_{BUS} Discharge	21
Detailed Block Diagram	22
Detailed Description	23
USB Type-C	23
V_{BUS}	24
External FET Gate Drive (G_DMOS Pin)	24
Legacy Devices	25
USB Type-A-Only Operation	25
Power-Up and Enabling	25
System Enable (HVEN)	25
DC-DC Enable (ENBUCK)	25
Linear Regulator Output (BIAS)	25
Power-On Sequencing	25
Step-Down DC-DC Regulator	26
Step-Down Regulator	26
Wide Input Voltage Range	26
Maximum Duty-Cycle Operation	26
Output Voltage (SENSP)	26
Soft-Start	26
Reset Behavior	26
Reset Criteria	27
Switching Frequency Configuration	27

TABLE OF CONTENTS (CONTINUED)

Switching Frequency Synchronization (SYNC Pin)	27
Forced-PWM Operation	27
Spread-Spectrum Option	27
Current Limit	27
Output Short-Circuit Protection	28
Thermal Overload Protection	28
Automatic Thermal Foldback	28
USB Current-Limit and Output-Voltage Adjustment	28
Current-Sense Amplifier (SENSP, SENSN)	28
USB DC Current Limit Configuration	28
Voltage Feedback Adjustment Configuration	28
Remote-Sense Feedback Adjustment (SHIELD Pin)	29
Automatic Charge Detection with ESD and Short-Circuit Protection	29
I ² C, Control, and Diagnostics	31
I ² C Configuration (CONFIG1 and I ² C)	31
Standalone Configuration (CONFIG1–CONFIG3)	31
I ² C Diagnostics and Event Handling	32
Interrupt and Attach Output (INT(ATTACH))	32
I ² C Output Voltage and Current Measurement	33
I ² C Interface	33
Bit Transfer	34
STOP and START Conditions	34
Early STOP Condition	34
Clock Stretching	34
I ² C General Call Address	34
I ² C Slave Addressing	35
Acknowledge	35
Write Data Format	36
Read Data Format	36
Fault Detection and Diagnostics	36
Fault Detection	36
Fault Output Pin (FAULT)	37
Register Map	39
Summary Table	39
Register Details	39
Applications Information	50
DC-DC Switching Frequency Selection	50
DC-DC Input Capacitor Selection	50

TABLE OF CONTENTS (CONTINUED)

DC-DC Output Capacitor Selection	50
DC-DC Output Inductor Selection	51
Layout Considerations	51
Determining USB System Requirements	51
USB Loads	51
USB Output Current Limit	52
USB Voltage Adjustment	52
Selecting a Current-Sense Resistor	53
Example CONFIG Resistor Selection	53
ESD Protection	53
ESD Test Conditions	54
Human Body Model	54
IEC 61000-4-2	54
Typical Application Circuits	56
Ordering Information	56
Revision History	57

LIST OF FIGURES

Figure 1. USB Type-C Block Diagram	24
Figure 2. Charge Detection Block Diagram	30
Figure 3. I ² C Timing Diagram	34
Figure 4. START, STOP and REPEATED START Conditions	34
Figure 5. Acknowledge Condition	35
Figure 6. Data Format of I ² C Interface	36
Figure 7. DC Voltage Adjustment Model	52
Figure 8. Increase in SENSP vs. USB Current	53
Figure 9. Human Body ESD Test Model	54
Figure 10. IEC 61000-4-2 ESD Test Model	55
Figure 11. Human Body Current Waveform	55
Figure 12. IEC 61000-4-2 Current Waveform	55

LIST OF TABLES

Table 1. Charge Detection Precedence	23
Table 2. Charge-Detection Mode Truth Table (I ² C Variant)	29
Table 3. Charge-Detection Mode Truth Table (Standalone Variant)	29
Table 4. CONFIG1 Pin Table (I ² C Version)	31
Table 5. CONFIG1 Pin Table (Standalone Variant)	31
Table 6. CONFIG2 and CONFIG3 Pin Table (Standalone Variant)	32
Table 7. I ² C Slave Addresses	35
Table 8. Fault Conditions	37
Table 9. Recommended Output Filters	51

Absolute Maximum Ratings

V _{SUPSW} to PGND	-0.3V to +40V
LX, HVEN to PGND (Note 1)	-0.3V to V _{SUPSW} + 0.3V
V _{BIAS} to AGND	-0.3V to +6V
SYNC to AGND	-0.3V to BIAS + 0.3V
SENSN, SENSP, VBMON to AGND	-0.3V to V _{SUPSW} + 0.3V
AGND to PGND	-0.3V to +0.3V
BST to PGND	-0.3V to +46V
BST to LX	-0.3V to +6V
IN, CONFIG1, ENBUCK, SDA (CONFIG2), SCL (CONFIG3), BIAS, DCP_MODE, FAULT, INT(ATTACH), SHIELD, CC1, CC2 to AGND	-0.3V to +6V
HVDP, HVDM to AGND (Note 1)	-0.3V to +18V
G_DMOS to AGND	-0.3V to +16V

LX Continuous RMS Current	3.5A
Output Short-Circuit Duration	Continuous
Thermal Characteristics	
Continuous Power Dissipation, Single-Layer Board (T _A = +70°C, 32-TQFN (derate 21.3mW/°C above +70°C))	1702.10mW
Continuous Power Dissipation, Multilayer Board (T _A = +70°C, 32-TQFN (derate 34.5mW/°C above +70°C))	2758.6 mW
Operating Temperature Range	-40°C to 125°C
Junction Temperature	+150°C
Storage Temperature Range	-40°C to +150°C
Lead Temperature (soldering, 10s)	300°C
Soldering Temperature (reflow)	+260°C

Note 1: Self-protected from transient voltages exceeding these limits in circuit under normal operation.

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 for extended periods may affect device reliability.

Package Information

32 Pin TQFN 5x5x0.75mm

Package Code	T3255+4C
Outline Number	21-0140
Land Pattern Number	90-0012
Thermal Resistance, Single-Layer Board:	
Junction to Ambient (θ _{JA})	47
Junction to Case (θ _{JC})	1.70
Thermal Resistance, Four-Layer Board:	
Junction to Ambient (θ _{JA})	29
Junction to Case (θ _{JC})	1.70

For the latest package outline information and land patterns (footprints), go to www.maximintegrated.com/packages. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to www.maximintegrated.com/thermal-tutorial.

Electrical Characteristics

(V_{SUPSW} = 14V, V_{IN} = 3.3V, V_{ENBUCK} = 3.3V, Temperature = T_A = T_J = -40°C to +125°C, unless otherwise noted, actual typical values may vary and are not guaranteed.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Power Supply and Enable						
Supply Voltage Range	V _{SUPSW}	(Note 2)	4.5		28	V
Load Dump Event Supply Voltage Range	V _{SUPSW_LD}	< 1s			40	V
Supply Current - Off State	I _{SUPSW}	V _{SUPSW} = 18V; V _{HVEN} = 0V; V _{IN} = 0V; OFF state		10	20	μA
Supply Current - Buck Off	I _{SUPSW}	Powered; enabled; buck off		1.1		mA

Electrical Characteristics (continued)

($V_{SUSPSW} = 14V$, $V_{IN} = 3.3V$, $V_{ENBUCK} = 3.3V$, Temperature = $T_A = T_J = -40^{\circ}C$ to $+125^{\circ}C$, unless otherwise noted, actual typical values may vary and are not guaranteed.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Current - Skip Mode	I_{SUSPSW}	Powered; enabled; no load; skip mode		1.8		mA
Supply Current - FPWM	I_{SUSPSW}	Powered; enabled; FPWM mode		28		mA
BIAS Voltage	V_{BIAS}	$5.75V \leq V_{SUSPSW} \leq 28V$	4.5	4.7	5.25	V
BIAS Current Limit			50	150		mA
BIAS Undervoltage Lockout	V_{UV_BIAS}	V_{BIAS} rising	3.0	3.3	3.6	V
BIAS Undervoltage Lockout Hysteresis				0.2		V
SUSPSW Undervoltage Lockout		V_{SUSPSW} rising	3.9		4.42	V
SUSPSW Undervoltage Lockout Hysteresis				0.2		V
IN Voltage Range	V_{IN}		3		3.6	V
IN Overvoltage Lockout	V_{IN_OVLO}	V_{IN} rising	3.8	4	4.3	V
IN Input Current	I_{IN}				10	μA
HVEN Rising Threshold	V_{HVEN_R}		0.6	1.5	2.4	V
HVEN Falling Threshold	V_{HVEN_F}				0.4	V
HVEN Hysteresis	V_{HVEN}			0.2		V
HVEN Delay Rising	t_{HVEN_R}		2.5		15	μs
HVEN Delay Falling	t_{HVEN_F}		5	12	25	μs
HVEN Input Leakage		$V_{HVEN} = V_{SUSPSW} = 18V$, $V_{HVEN} = 0V$			10	μA
G_DMOS Pin						
G_DMOS Unloaded Output Voltage	$G_DMOS_VO_CHP$	Referenced to BIAS, internal discharge path $2M\Omega$ to GND	7	10	13.0	V
G_DMOS Output Impedance	$G_DMOS_RO_CHP$			100	250	k Ω
G_DMOS DC Output Current	$G_DMOS_IO_CHP$	$G_DMOS - V_{BIAS}$		20		μA
USB Type C / Current Level Characteristics						
CC DFP Default Current Source	$I_{DFP0.5_CC}$	$4.0V < V_{BIAS} < 5.5V$, $\pm 20\%$	64	80	96	μA
CC DFP 1.5A Current Source	$I_{DFP1.5_CC}$	$4.0V < V_{BIAS} < 5.5V$, $\pm 8\%$	166	180	194	μA
CC DFP 3.0A Current Source	$I_{DFP3.0_CC}$	$4.0V < V_{BIAS} < 5.5V$, $\pm 8\%$	304	330	356	μA
HVD+, HVD- Pins						
Protection Trip Threshold	V_{OV_D}		3.65	3.85	4.1	V
On-Resistance of HVD+/HVD- short	R_{SHORT}	$V_{HVDP} = 1V$, $I_{HVDM} = 500\mu A$		90	180	Ω

Electrical Characteristics (continued)

($V_{SUSPW} = 14V$, $V_{IN} = 3.3V$, $V_{ENBUCK} = 3.3V$, Temperature = $T_A = T_J = -40^{\circ}C$ to $+125^{\circ}C$, unless otherwise noted, actual typical values may vary and are not guaranteed.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
HVD+/HVD- On-Leakage Current	I_{HVD_ON}	$V_{HVD\pm} = 3.6V$ or $0V$	-7		7	μA
HVD+/HVD- Off-Leakage Current	I_{HVD_OFF}	$V_{HVD+} = 18V$ or $V_{HVD-} = 18V$, $V_{D\pm} = 0V$			150	μA
Current-Sense Amplifier (SENSP, SENSN) and Analog Inputs (VBMON)						
Gain		$10mV < V_{SENSP} - V_{SENSN} < 110mV$, GAIN[4:0] = b11111		19.4		V/V
Overcurrent Threshold		ILIM[2:0] = 111	3.04	3.14	3.30	A
		ILIM[2:0] = 110	2.6	2.75	2.9	
		ILIM[2:0] = 101	2.1	2.25	2.4	
		ILIM[2:0] = 100	1.62	1.7	1.78	
		ILIM[2:0] = 011	1.05	1.13	1.21	
		ILIM[2:0] = 010	0.8	0.86	0.92	
		ILIM[2:0] = 001	0.55	0.6	0.65	
ILIM[2:0] = 000	0.3	0.33	0.36			
SENSN / VBMON Discharge Current	I_{SENSN_DIS}		11	18	32	mA
SENSN / VBMON Minimum Discharge Time	$t_{SENSN_DIS_MIN}$			10		ms
SENSN / VBMON Maximum Discharge Time	$t_{SENSN_DIS_MAX}$			1		s
Forced Buck Off-Time	$t_{BUCKOFF_DIS_CD}$	Startup, ENBUCK toggle; see reset criteria		2		s
Attach Comparator Load Current Rising Threshold		Common mode input = 5.15V	5	16	28	mA
Attach Comparator Hysteresis		Common mode input = 5.15V		2.5		mA
SENSN Undervoltage Threshold (Falling)	V_{UV_SENSN}		4	4.375	4.75	V
SENSN Overvoltage Threshold (Rising)	V_{OV_SENSN}		7	7.46	7.9	V
SENSN Short-Circuit Threshold (Falling)			1.75	2	2.25	V
SENSN Undervoltage Fault Blanking Time				16		ms
SENSN Overvoltage Fault Blanking Time	t_{B,OV_SENSN}	From overvoltage condition to \overline{FAULT} asserted		3	6	μs
SENSN Discharge Threshold Falling		V_{SENSN} Falling	0.47	0.51	0.57	V

Electrical Characteristics (continued)

($V_{SUSPSW} = 14V$, $V_{IN} = 3.3V$, $V_{ENBUCK} = 3.3V$, Temperature = $T_A = T_J = -40^{\circ}C$ to $+125^{\circ}C$, unless otherwise noted, actual typical values may vary and are not guaranteed.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Remote Feedback Adjustment						
SHIELD Input Voltage Range			0.1		0.75	V
Gain			1.935	2	2.065	V/V
Input-Referred Offset Voltage				±2.0		mV
Digital Inputs (SDA, SCL, ENBUCK, DCP_MODE)						
Input Leakage Current		$V_{PIN} = 5.5V, 0V$	-5		+5	μA
Logic-High	V_{IH}		1.6			V
Logic-Low	V_{IL}				0.5	V
Synchronous Step-Down DC-DC Converter						
PWM Output Voltage	V_{SENSP}	$7V \leq V_{SUSPSW} \leq 28V$, no load		5.15		V
Skip Mode Output Voltage	V_{SENSP_SKIP}	$7V \leq V_{SUSPSW} \leq 18V$, no load (<i>Note 2</i>)		5.25		V
Load Regulation		$7V \leq V_{SUSPSW} \leq 18V$, for 5V nominal output setting		51		mΩ
Output Voltage Accuracy		$8V \leq V_{SUSPSW} \leq 18V$, 2.4A, $V_{SENSP} - V_{SENSN} = 79.2mV$, GAIN[4:0] = 11111 cable compensation.	6.33		6.68	V
Spread-Spectrum Range		SS Enabled		±3		%
SYNC Switching Threshold High	V_{SYNC_HI}	Rising	1.4			V
SYNC Switching Threshold Low	V_{SYNC_LO}	Falling			0.4	V
SYNC Internal Pulldown				200		kΩ
SYNC Input Clock Acquisition time	t_{SYNC}	(<i>Note 3</i>)		1		Cycles
High-Side Switch On-Resistance	R_{ONH}	$I_{LX} = 1A$		54	95	mΩ
Low-Side Switch On-Resistance	R_{ONL}	$I_{LX} = 1A$		72	135	mΩ
BST Input Current	I_{BST}	$V_{BST} - V_{LX} = 5V$, high-side on		2.2		mA
LX Current-Limit Threshold				5		A
Skip Mode Peak-Current Threshold	I_{SKIP_TH}			1		A
Negative Current Limit				1.2		A
Soft-Start Ramp Time	t_{SS}			8		ms
LX Rise Time		(<i>Note 3</i>)		3		ns
LX Fall Time		(<i>Note 3</i>)		4		ns

Electrical Characteristics (continued)

($V_{SUPSW} = 14V$, $V_{IN} = 3.3V$, $V_{ENBUCK} = 3.3V$, Temperature = $T_A = T_J = -40^{\circ}C$ to $+125^{\circ}C$, unless otherwise noted, actual typical values may vary and are not guaranteed.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
BST Refresh Algorithm Low-Side Minimum On-Time				60		ns
FAULT, INT (ATTACH), SYNC Outputs						
Output-High Leakage Current		\overline{FAULT} , $\overline{INT(ATTACH)} = 5.5V$	-10		+10	μA
Output Low Level		Sinking 1mA			0.4	V
SYNC Output High Level		Sourcing 1mA, SYNC configured as output	V_{BIAS} -0.4			V
Configuration Resistors Converter						
CONFIG1-3 Current Leakage		$V_{CONFIG} = 0V$ to $4V$			± 5	μA
Minimum Window Amplitude			-4		4	%
ADC						
Resolution				8		Bits
ADC Gain Error				± 2		LSBs
Offset Error	Offset_ADC			± 1		LSB
Oscillators						
Internal High Frequency Oscillator	HFOSC		7	8	9	MHz
Buck Oscillator Frequency	f_{SW}	FSW[2:0] = 000	1.95	2.2	2.45	MHz
Buck Oscillator Frequency	f_{SW}	FSW[2:0] = 101	340	410	480	KHz
Thermal Overload						
Thermal Warning Temperature				130		$^{\circ}C$
Thermal Warning Hysteresis				10		$^{\circ}C$
Thermal Shutdown Temperature				165		$^{\circ}C$
Thermal Shutdown Hysteresis				10		$^{\circ}C$
I²C						
Serial-Clock Frequency	f_{SCL}				400	kHz
Bus Free Time Between STOP and START Condition	t_{BUF}		1.3			μs
START Condition Setup Time	$t_{SU:STA}$		0.6			μs

Electrical Characteristics (continued)

($V_{SUPSW} = 14V$, $V_{IN} = 3.3V$, $V_{ENBUCK} = 3.3V$, Temperature = $T_A = T_J = -40^{\circ}C$ to $+125^{\circ}C$, unless otherwise noted, actual typical values may vary and are not guaranteed.)

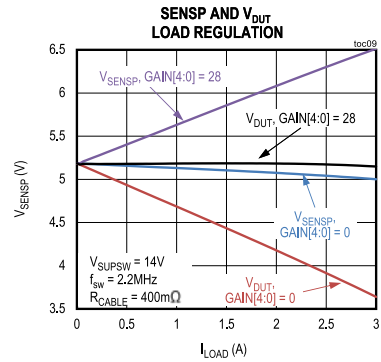
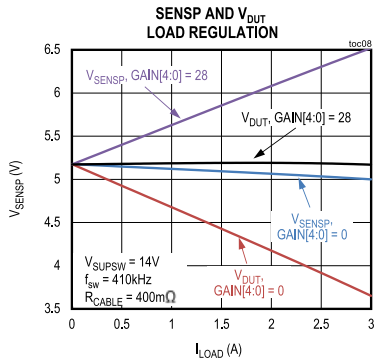
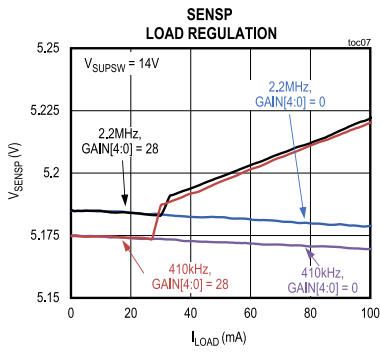
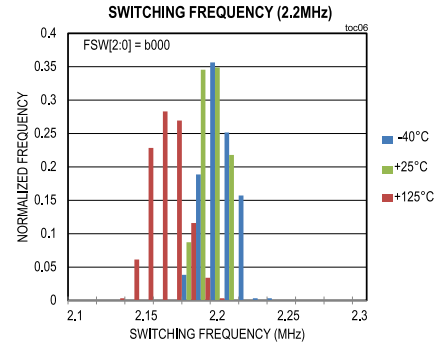
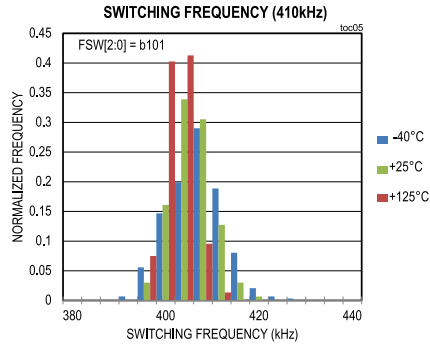
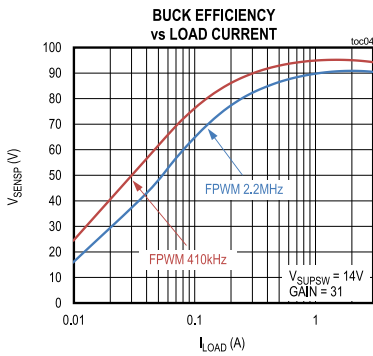
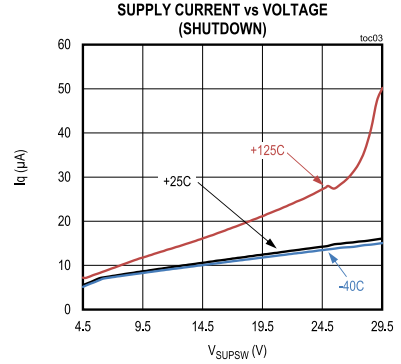
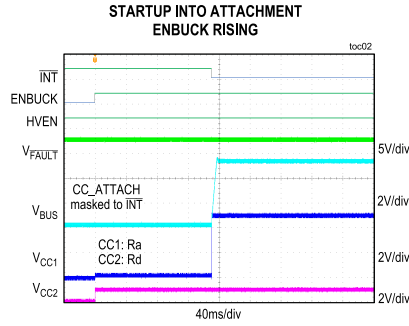
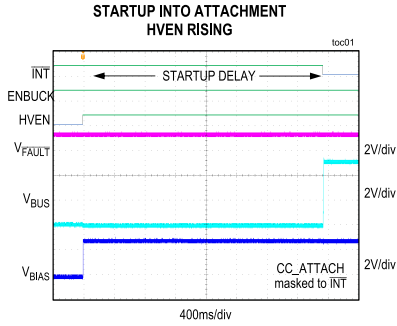
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
START Condition Hold Time	$t_{HD:STA}$		0.6			μs
STOP Condition Hold Time	$t_{SU:STO}$		0.6			μs
Clock-Low Period	t_{LOW}		1.3			μs
Clock-High Period	t_{HIGH}		0.6			μs
Data-Setup Time	$t_{SU:DAT}$		100			ns
Data-Hold Time	$t_{HD:DAT}$	From 50% SCL falling to SDA change	0.3		0.6	μs
Pulse Width of Spike Suppressed	t_{SP}			50		ns
ESD Protection (All Pins)						
ESD Protection Level	V_{ESD}	Human Body Model		± 2		kV
ESD Protection (HVDP, HVDM, CC1, CC2)						
ESD Protection Level	V_{ESD}	ISO 10605 Air Gap (330pF, 330 Ω)		± 15		kV
		ISO 10605 Air Gap (330pF, 2k Ω)		± 15		
		ISO 10605 Contact (330pF, 330 Ω)		± 8		
		ISO 10605 Contact (330pF, 2k Ω)		± 8		
		IEC 61000-4-2 Air Gap (150pF, 330 Ω)		± 15		
		IEC 61000-4-2 Contact (150pF, 330 Ω)		± 8		

Note 2: Device is designed for use in applications with continuous operation of 14V. Device meets electrical table up to maximum supply voltage.

Note 3: Guaranteed by design and bench characterization; not production tested.

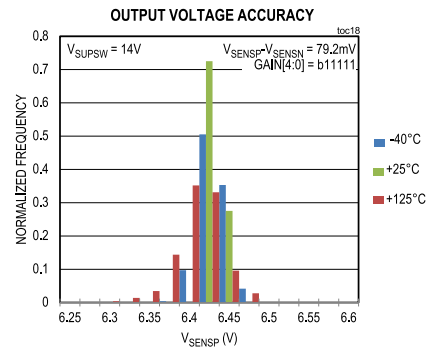
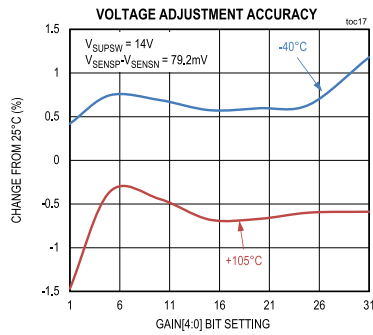
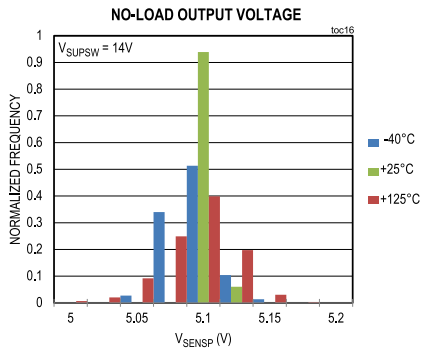
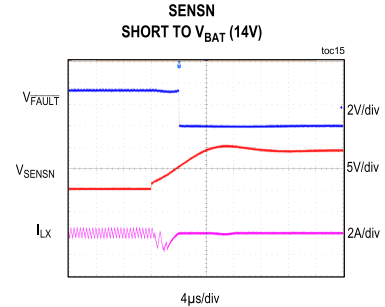
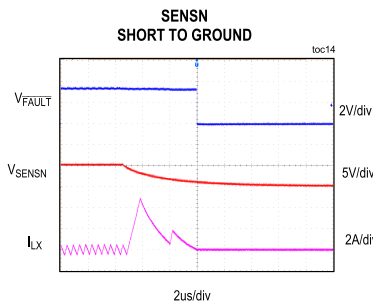
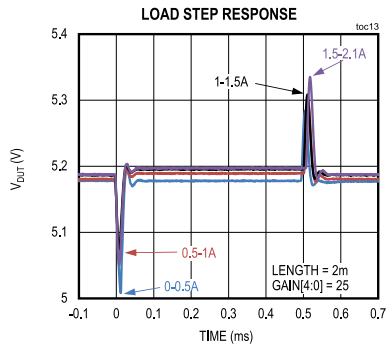
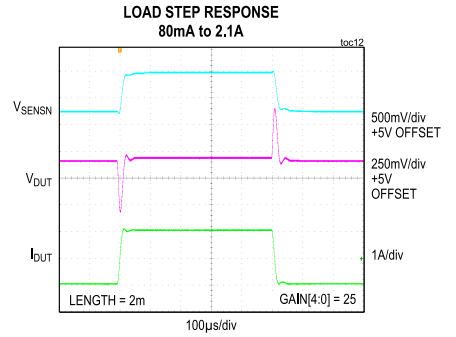
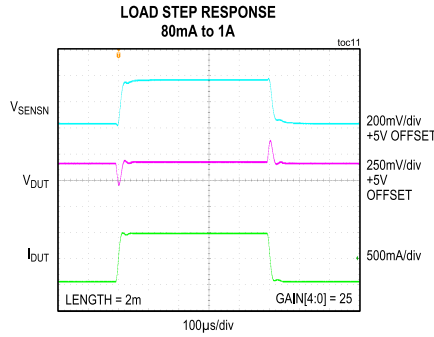
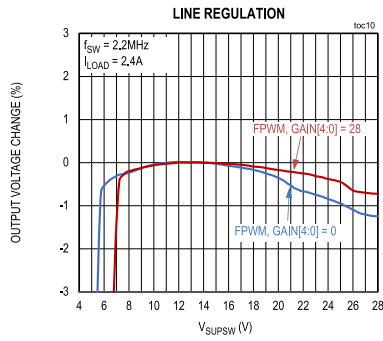
Typical Operating Characteristics

(TA = +25°C, unless otherwise noted.)



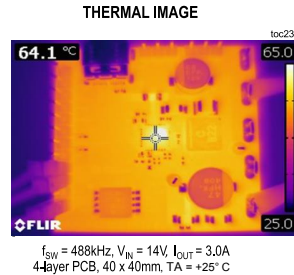
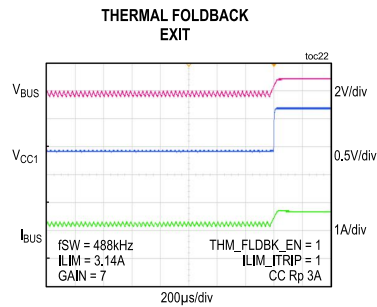
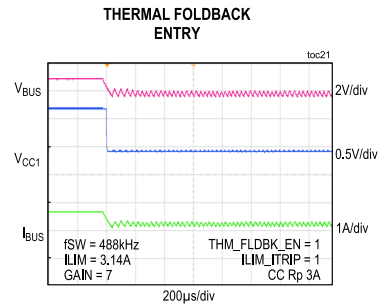
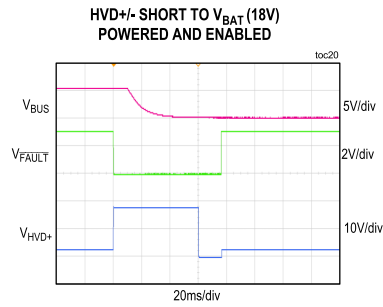
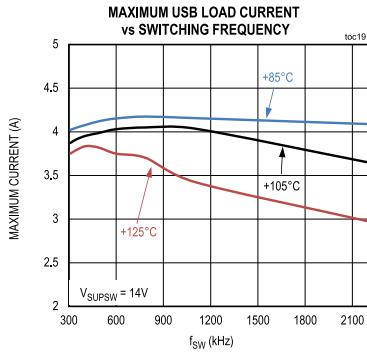
Typical Operating Characteristics (continued)

(TA = +25°C, unless otherwise noted.)



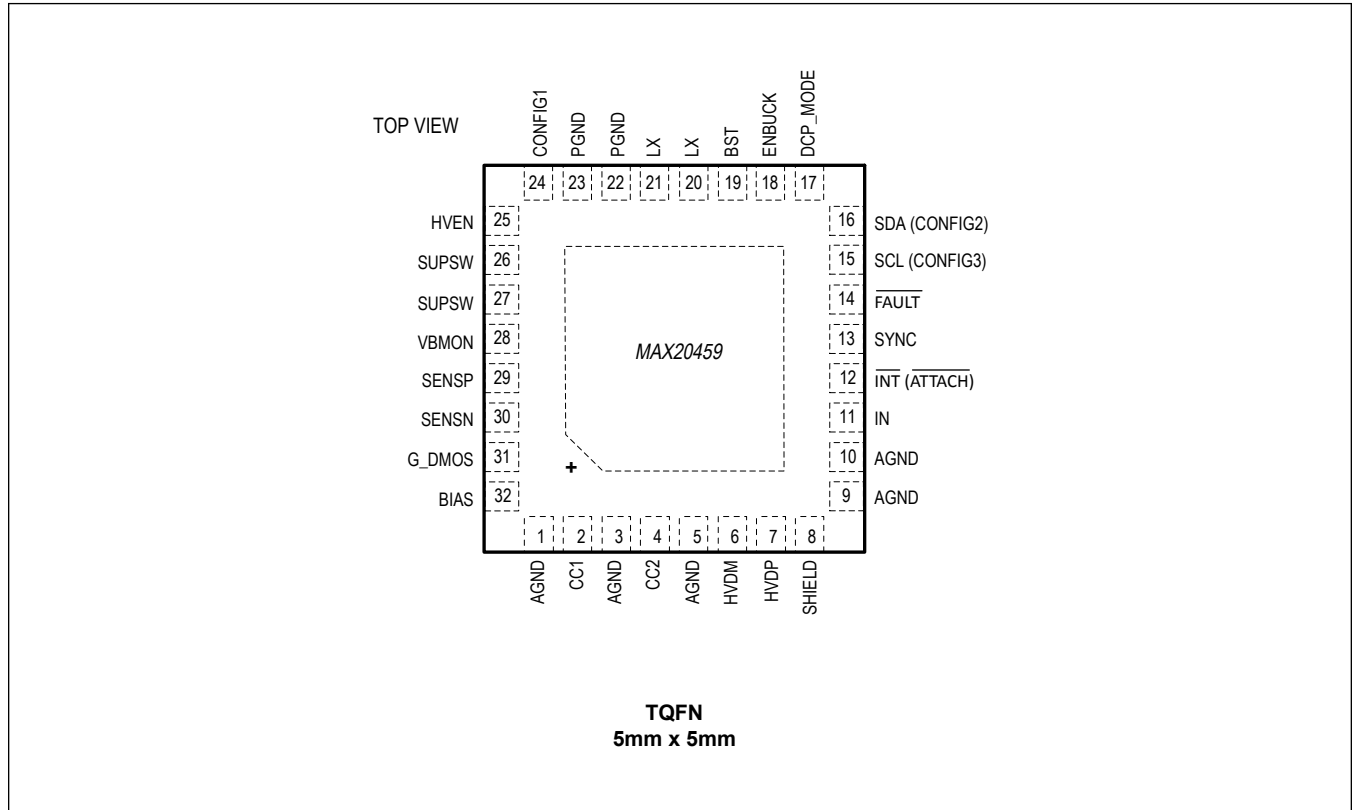
Typical Operating Characteristics (continued)

(TA = +25°C, unless otherwise noted.)



Pin Configuration

MAX20459



Pin Description

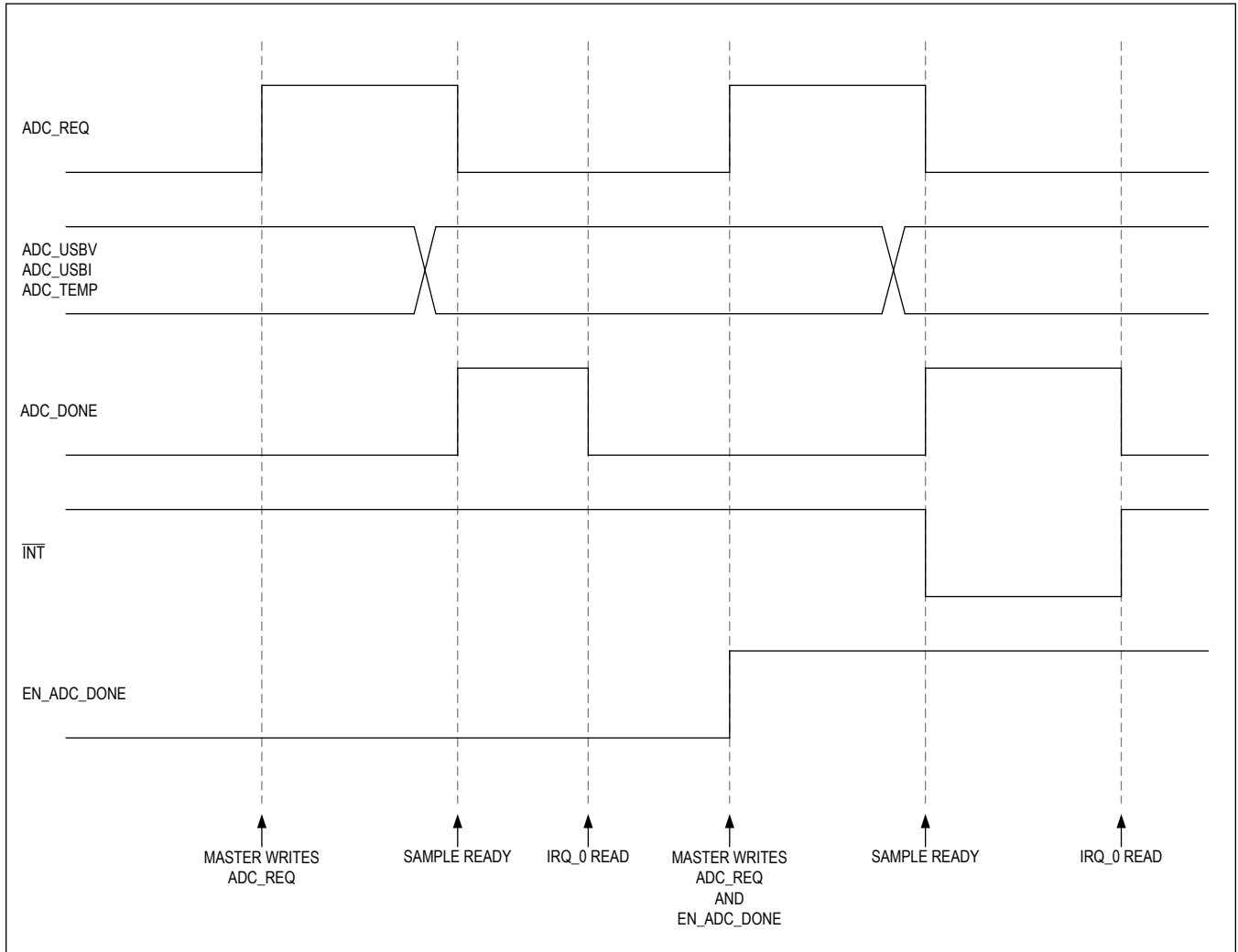
PIN	NAME	FUNCTION
1, 3, 5, 9, 10	AGND	Analog Ground.
2	CC1	Type-C Configuration Channel (CC).
4	CC2	Type-C Configuration Channel (CC).
6	HVDM	High-Voltage-Protected USB D- Interface. Connect HVD- to the downstream USB connector D- pin for charge detection.
7	HVDP	High-Voltage-Protected USB D+ Interface. Connect HVD+ to the downstream USB connector D+ pin for charge detection.
8	SHIELD	Optional Remote-Feedback Input. Tie to AGND if not used.
11	IN	Logic Enable Input. Connect to 3.3V. If no 3.3V rail is available in the system, use a 1kΩ/2kΩ resistor-divider from BIAS to generate 3.3V on IN. See Typical Application Circuits . IN is also used for clamping during overvoltage events on HVD+ or HVD-. Connect a 1μF ceramic capacitor from IN to GND.

Pin Description (continued)

PIN	NAME	FUNCTION
12	$\overline{\text{INT(ATTACH)}}$	Interrupt/Attach. On the I ² C variant, functions as an active-low interrupt pin. On the standalone variant, functions as an active-low attach indicator. Connect a 100k Ω pullup resistor to IN. Tie to AGND if not used.
13	SYNC	Switching Frequency Input/Output for Synchronization with Other Supplies. Configure Sync as an input and tie to AGND if not used. See Applications Information section.
14	$\overline{\text{FAULT}}$	Active-Low, Open-Drain, Fault Indicator Output. Connect a 100k Ω pullup resistor to IN. Tie to AGND if not used.
15	SCL(CONFIG 3)	SCL/Configuration 3. For the I ² C variant, this serves as the SCL pin. For the standalone variant, this serves as CONFIG3 pin. Connect a resistor to AGND to configure thermal foldback, gain, current limit, and CC source current.
16	SDA(CONFIG 2)	SDA/Configuration 2. For the I ² C variant, this serves as the SDA pin. For the standalone variant, this serves as the CONFIG2 pin. Connect a resistor to AGND to configure cable compensation.
17	DCP_MODE	DCP Mode Select. Tie low for Apple 2.4A mode, tie high for Apple 1A mode.
18	ENBUCK	DC-DC Enable Input. Drive high/low to enable/disable the buck converter. Connect to BIAS for always-on operation.
19	BST	High-Side Driver Supply. Connect a 0.1 μ F capacitor from BST to LX.
20, 21	LX	Inductor Connection Pin. Connect an inductor from LX to the DC-DC converter output (SENSP).
22, 23	PGND	Power Ground.
24	CONFIG1	Configuration 1. Connect a resistor to AGND to configure spread spectrum, sync direction, and switching frequency (standalone) or I ² C address.
25	HVEN	Active-High System Enable Pin. HVEN is battery-voltage tolerant. Connect to SUPSW for always-on operation.
26, 27	SUPSW	Internal High-Side Switch Supply Input. SUPSW provides power to the internal buck converter and LDO. Connect a 100nF and 10 μ F ceramic capacitor in parallel with a 47 μ F electrolytic capacitor from SUPSW to PGND. See DC-DC Input Capacitor Selection .
28	VBMON	USB V _{BUS} Monitor Pin
29	SENSP	DC-DC Converter Feedback Input and Current-Sense Amplifier Positive Input. Place the DC-DC bulk capacitance on this net. Connect to the positive terminal of the current-sense resistor and the main output of the converter. Used for internal voltage regulation loop.
30	SENSN	Current-Sense Amplifier Negative Input. Connect to the negative terminal of the current-sense resistor.
31	G_DMOS	Gate-Drive Output. Optionally connect to the gate of an external n-channel FET. Otherwise, terminate with a 2.7M Ω resistor or a 10pF capacitor to AGND.
32	BIAS	5V Linear-Regulator Output. Connect a 2.2 μ F ceramic capacitor from BIAS to GND. BIAS powers the internal circuitry.

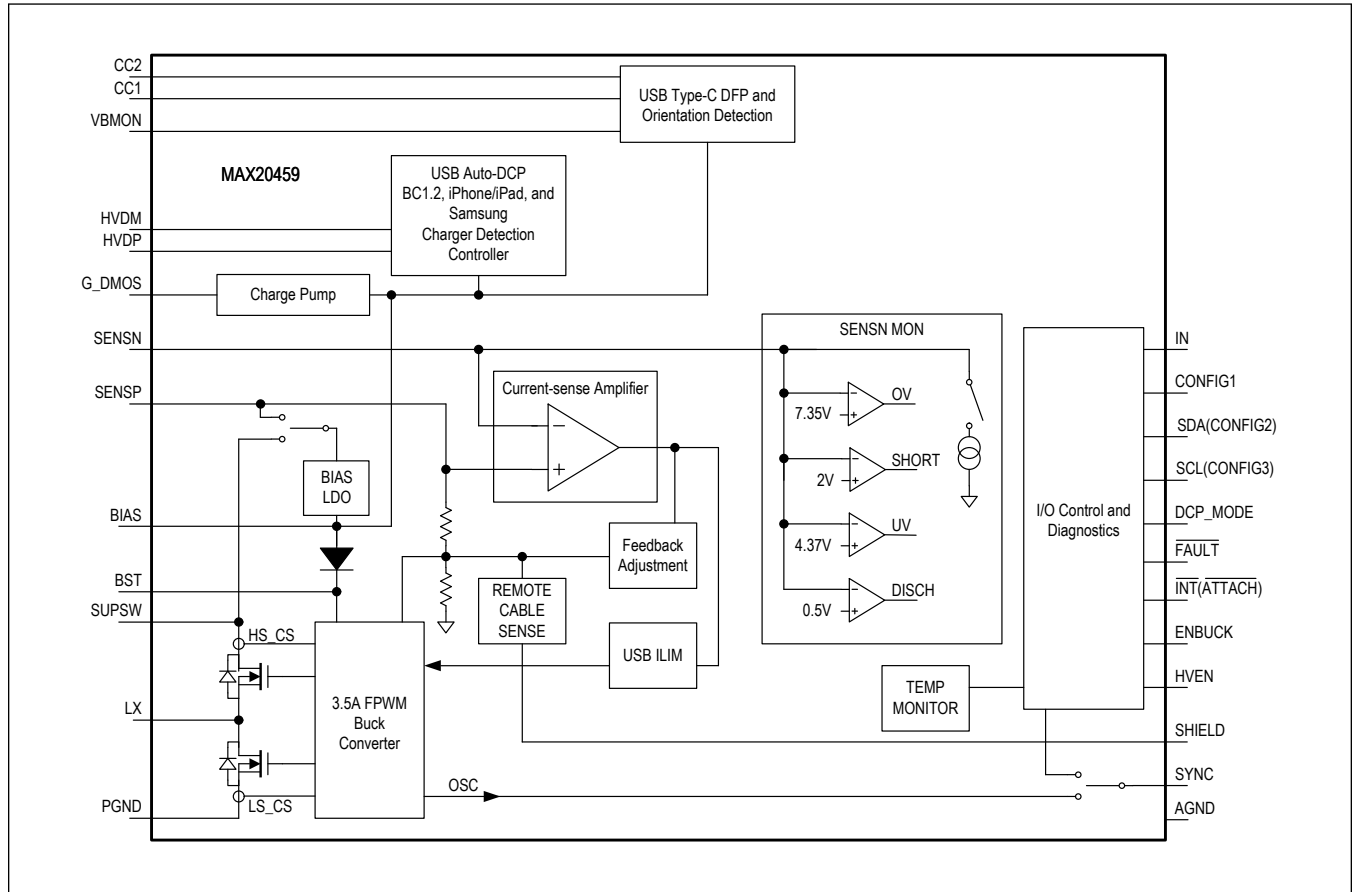
Functional Diagrams (continued)

ADC Timing Diagram



Functional Diagrams (continued)

Detailed Block Diagram



Detailed Description

The MAX20459 combines a 5V/3A automotive-grade step-down converter and a USB Type-C host charger adapter emulator. The MAX20459ATJA variant is configured through I²C, while the MAX20459ATJC variant is configured using resistors connected to the CONFIG1, CONFIG2, and CONFIG3 pins. This device family is designed for high-power USB ports in automotive dedicated charging applications.

The MAX20459 HVD+ and HVD- pins are protected from shorts up to 18V, and include internal ESD protection circuitry. The internal host-charger port-detection circuitry offers automatic sensing and conformance to multiple standards, including USB Type-C 3.0A/1.5A/0.5A, USB-IF BC1.2 DCP mode, Apple 1A and 2.4A DCP modes, Samsung DCP, and China YD/T1591-2009.

The high-efficiency step-down DC-DC converter operates with an input voltage up to 28V and is protected from load-dump transients up to 40V. The DC-DC converter can be programmed for or synced to switching frequencies from 310kHz to 2.2MHz. The converter can deliver 3A of continuous current at an ambient temperature of 105°C.

The MAX20459 features a high-side current-sense amplifier and a programmable feedback-adjustment circuit designed to provide automatic USB voltage adjustment to compensate for voltage drops. The precision current-sense internal circuitry allows for an accurate DC output current limit, which minimizes the solution component size and cost.

USB Type-C

USB Type-C introduces a new connector, cable, and detection mechanism while maintaining backwards-compatibility with the existing USB ecosystem. The Type-C connector has a small form factor, is reversible, and bi-directional (eliminates the Type A/Type B distinction). To maintain the USB host/device relationship, Type-C requires a configuration channel (CC). The CC pins are used to advertise and detect current capabilities, but also device attachment.

A Type-C implementation supports, but does not require, BC1.2. It is also desirable to implement BC1.2 detection on HVDP/HVDM in addition to CC detection. This ensures the highest possible charge current when a legacy adapter is used. [Table 1](#) shows the USB-IF mandated precedence of power negotiation, see USB Type-C 1.3 for details.

MAX20459 provides an integrated Type-C 5V solution tailored to the automotive market. The device integrates all control and power circuitry necessary to provide a 5V/3A Downstream Facing Port (DFP) with high conversion efficiency and low thermal footprint, additionally providing BC1.2 charge detection to maintain compatibility and enable fast charging.

Table 1. Charge Detection Precedence

PRECEDENCE	MODE OF OPERATION	NOMINAL VOLTAGE	MAXIMUM CURRENT
Highest	USB Type-C @ 3A Advertisement	5V	3A
	USB Type-C @ 1.5A Advertisement	5V	1.5A
	USB BC1.2	5V	≤1.5A
Lowest	Default USB Power	USB 3.1	900 mA
		USB 2.0	500 mA

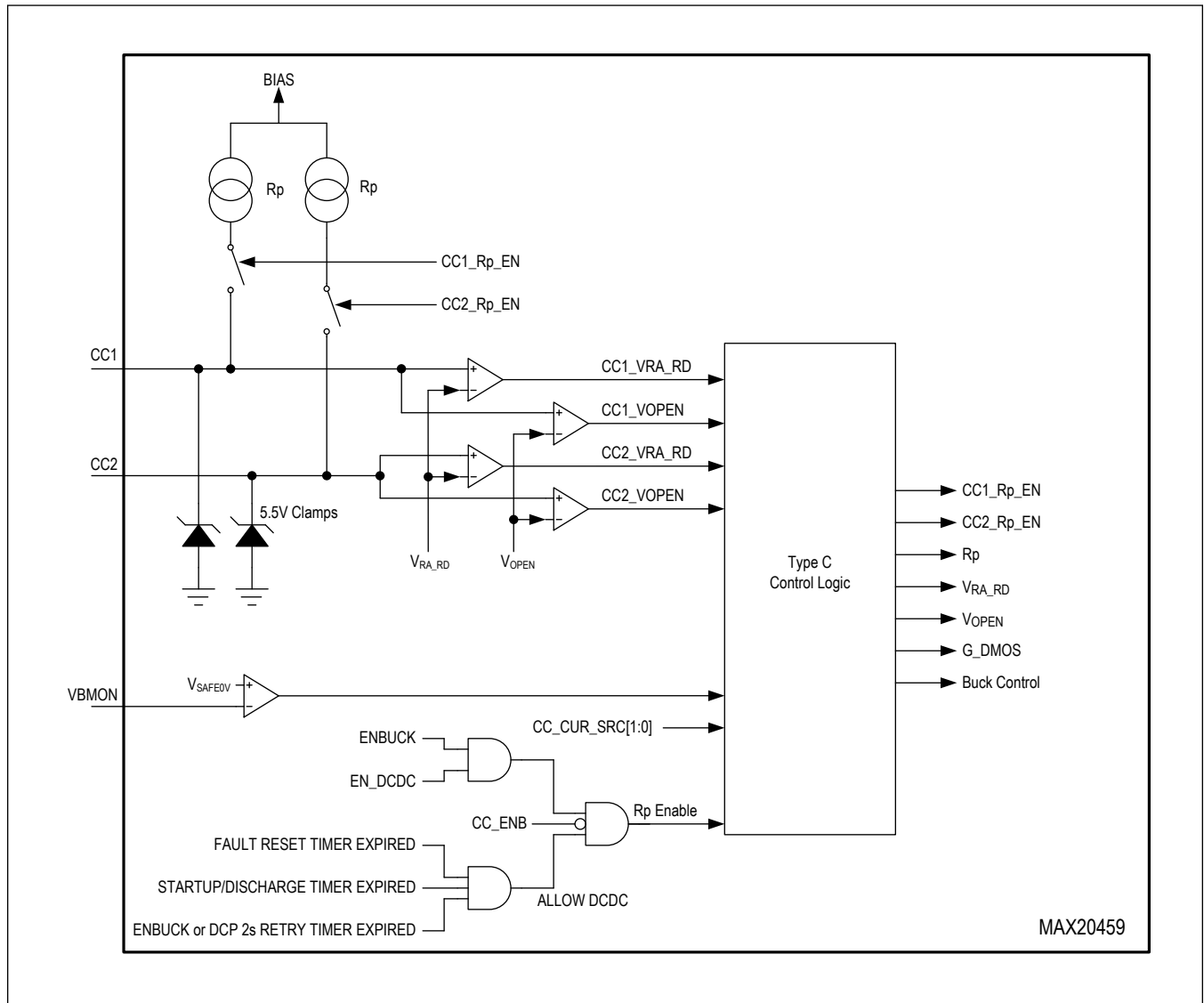


Figure 1. USB Type-C Block Diagram

V_{BUS}

Type-C includes new requirements for V_{BUS}, even when operating exclusively in 5V mode. When no device is attached to the CC pins, the host must turn the V_{BUS} source off so that a near-zero voltage is present at the receptacle pin. To achieve this, MAX20459 disables the external FET gate drive and turns off the buck converter when in a detached state, reducing quiescent current. The MAX20459 integrates control and discharge circuits to ensure all Type-C timing requirements are met.

External FET Gate Drive (G_{DMOS} Pin)

MAX20459 includes a gate drive for an optional external FET that can be used to isolate the bulk capacitance when V_{BUS} is not being sourced. A 2017 ECN from USB-IF increased the capacitance for source-only ports between V_{BUS} and GND when V_{BUS} is not being sourced from 10µF to 3000µF, effectively removing the need for an isolation FET. Therefore, the

external FET on MAX20459 is optional.

If not used, terminate G_DMOS with a 2.7M Ω resistor to ground or a 10pF capacitor to ground. If used, connect the G_DMOS pin to the gate of the external FET. If V_BUS short-to-battery is required with the external FET, the FET should be appropriately rated. The external DMOS device must be a 20V V_GS type. The charge pump generates at least 7V.

Legacy Devices

The Type-C specification ensures inter-operability with Type-A/Type-B devices by defining requirements for legacy adapters. As a DFP, relevant adapters will connect from the Type-C receptacle to either a Type-B plug or to a Type-A receptacle, which can then be used with any legacy Type-A cable. A compliant legacy adapter of this type must include an Rd termination inside the adapter. In this case, MAX20459 will detect a Type-C attachment whenever the adapter is connected, regardless of whether a portable device is connected. The portable device will see the DFP as a BC1.2 port (when configured as such).

USB Type-A-Only Operation

The following configurations allow using MAX20459 as a Type-A charger:

- On the I²C variant, CC_ENB can be set to 1 to bypass the Type-C state machine and allow only Type-A operation.
- On the MAX20459 standalone variant, connect one of the CC pins to a 5.1k Ω resistor to ground and the other to a 100k Ω resistor to ground.

Power-Up and Enabling

System Enable (HVEN)

HVEN is used as the main enable to the device and initiates system start-up and configuration. If HVEN is at a logic-low level, SUPSW power consumption is reduced and the device enters a standby, low-quiescent-current level. HVEN is compatible with inputs from 3.3V logic up to automotive battery. After a system reset (e.g., HVEN toggle, BIAS UV), the I²C variant asserts the INT pin to indicate that the IC has not been configured. The buck converter is forced off until the CONFIGURED bit of SETUP_4 is written to a 1 and a device attachment has occurred. This ensures that a portable device cannot attach before the IC registers are correctly set for the application.

DC-DC Enable (ENBUCK)

The buck regulator on MAX20459 is controlled by the ENBUCK pin. The DC-DC converter is activated by driving ENBUCK high, and disabled by driving ENBUCK low. On the MAX20459ATJA variant, setting ENBUCK low overrides an I²C EN_DCDC enable command. ENBUCK can be directly connected to the BIAS or IN pin for applications that do not require GPIO control of the DC-DC converter enable.

Linear Regulator Output (BIAS)

BIAS is the output of a 5V linear regulator that powers the internal logic, control circuitry, and DC-DC drivers. BIAS is internally powered from SUPSW or SENSP and automatically powers up when HVEN is high and SUPSW voltage exceeds V_UV_SUPSW. The BIAS output contains an undervoltage lockout that keeps the internal circuitry disabled when BIAS is below V_UV_BIAS. The linear regulator automatically powers down when HVEN is low, and the device enters low-shutdown-current mode. Bypass BIAS to GND with a 2.2 μ F ceramic capacitor as close to the pin as possible.

Power-On Sequencing

ENBUCK acts as the master disable for the DC-DC converter. If ENBUCK is low when HVEN is set high, all variants keep the buck converter in the disabled state until ENBUCK is set high.

Step-Down DC-DC Regulator

Step-Down Regulator

The MAX20459 features a current-mode, step-down converter with integrated high-side and low-side MOSFETs. The low-side MOSFET enables fixed-frequency, forced-PWM operation under light loads. The DC-DC features a cycle-by-cycle current limit, and intelligent transition from skip mode to forced-PWM mode which makes the devices ideal for automotive applications.

Wide Input Voltage Range

The device is specified for a wide 4.5V to 28V input voltage range. SUPSW provides power to the internal BIAS linear regulator and internal power switch. Certain conditions such as cold crank can cause the voltage at the output to drop below the programmed output voltage. Under such conditions, the device operates in a high duty-cycle mode to facilitate minimum dropout from input to output.

Maximum Duty-Cycle Operation

The MAX20459 has a maximum duty cycle of 98% (typ). The IC monitors the on-time (time for which the high-side FET is on) in both PWM and skip modes for every switching cycle. Once the on-time is detected continuously for 12 μ s, the low-side FET is forced on for 60ns (typ) every 12 μ s. The input voltage at which the device enters dropout changes depending on the input voltage, output voltage, switching frequency, load current, and the efficiency of the design. The input voltage

at which the device enters dropout can be approximated as:
$$V_{SUPSW} = \frac{V_{OUT} + (I_{OUT} \times R_{ONH})}{0.98}$$

Note: The equation above does not take into account the efficiency and switching frequency but will provide a good first-order approximation. Use the R_{ONH} number from the max column in the Electrical Characteristics table.

Output Voltage (SENSP)

The device features a precision internal feedback network connected to SENSP that is used to set the output voltage of the DC-DC converter. The network nominally sets the no-load DC-DC converter output voltage to 5.15V.

Soft-Start

When the DC-DC converter is enabled, the regulator initiates soft-start by gradually ramping up the output voltage from 0V to 5.15V in approximately 8ms. This soft-start feature reduces inrush current during startup and is guaranteed into compliant USB loads. See [USB Loads](#).

Reset Behavior

The MAX20459 implements a discharge function on SENSN any time the DC-DC is disabled for any reason. When the discharge function is activated, a reset timer is also started. The timer prevents the DC-DC from starting up again until after the timer has expired. This allows for easy compatibility with USB specifications, and removes the need for long discharge algorithms to be implemented in system software. While these timers are keeping the DC-DC off, the Type-C control circuitry is in the disabled state (Rp is off). See the relevant Functional Diagrams and [Figure 1](#) for reset timer details.

For the SENSN overvoltage case, the DC-DC is disabled, but instead of forcing a minimum off-time, the discharge function is disabled after $t_{SENSN_DIS_TIMEOUT}$ and the buck converter will turn on as soon as the V_{UV_SENSN} threshold is crossed.

Reset Criteria

The MAX20459 DC-DC converter will automatically reset for all undervoltage, overvoltage, and overtemperature fault conditions. See [Table 8](#) for details. The fault retry timer is activated after a fault condition is removed, and will prevent the buck converter from turning on until the timer has expired.

Another internal retry timer is enabled after ENBUCK is set low. This will start an internal 2s timer that prevents the buck from turning on until the timer expires.

Switching Frequency Configuration

The DC-DC switching frequency can be referenced to an internal oscillator or from an external clock signal on the SYNC pin. The internal oscillator frequency is set by the FSW[2:0] bits of the SETUP_1 register, which has a POR value corresponding to 2.2MHz. For the standalone variant, the FSW configuration value is loaded from the CONFIG1 pin at startup. The internal oscillator can be programmed to eight discrete values from 310kHz to 2.2MHz.

Switching Frequency Synchronization (SYNC Pin)

When the SYNC pin is configured to operate as an output, skip-mode operation is always disabled, and the internal oscillator frequency is driven out of the SYNC pin with a 180-degree phase shift. This allows other devices to synchronize with the MAX20459.

When SYNC is configured as an input, the SYNC pin becomes a logic-level input which can be used for both operating-mode selection and frequency control. Connecting SYNC to a logic-high signal or an external clock enables fixed-frequency, forced-PWM mode. Connecting SYNC to GND allows intelligent skip-mode operation (Type-A only). The device can be externally synchronized to frequencies within $\pm 20\%$ of the programmed internal oscillator frequency.

Forced-PWM Operation

In forced-PWM mode, the device maintains fixed-frequency PWM operation over all load conditions, including no-load conditions.

Spread-Spectrum Option

Spread-spectrum operation is offered to improve the EMI performance of the MAX20459. Spread-spectrum operation is enabled by the SS_EN bit of the SETUP_0 register, which is pre-loaded on startup from the CONFIG1 pin for both standalone and I²C variants. The internal operating frequency modulates the switching frequency by up to $\pm 3\%$ relative to the internally generated operating frequency. This results in a total spread-spectrum range of 6%. Spread-spectrum mode is only active when operating from the internal oscillator. Spread-spectrum clock dithering is not possible when operating from an external clock.

Current Limit

The MAX20459 limits the USB load current using both a fixed internal peak current threshold of the DC-DC converter, as well as a user-programmable external DC load current-sense amplifier threshold. This allows the current limit to be adjusted between 300mA and 3A, depending on the application requirements, and protects the system in the event of a fault. Upon exceeding either the LX peak or user-programmable current thresholds, the high-side FET is immediately turned off and current-limit algorithms are initiated. If required, a current limit higher than 3A can be achieved by reducing the current-sense resistor value. See [Selecting a Current-Sense Resistor](#).

On the I²C variant, the ILIM_ITRIP bit of the SETUP_2 register determines the output voltage droop required to initiate a DC-DC converter reset during VBUS_ILIM. If the USB current limit is detected for 16ms, and the output voltage falls below the reset threshold (4.38V typ.) but stays above the 2.0V threshold, the $\overline{\text{FAULT}}$ pin asserts, the VBUS_ILIM bit of the IRQ_1 register is set, and the DC-DC converter resets (if ILIM_ITRIP = 0). Conversely, if ILIM_ITRIP = 1, the DC-DC converter will not reset, and it will keep acting as a current source.

On the standalone variant, if the USB current limit is detected for 16ms, and the output voltage falls below the reset threshold (4.38V typ.) but stays above the 2.0V threshold, the $\overline{\text{FAULT}}$ pin asserts, the DC-DC converter will not reset and will keep acting as a current source.

On all variants, the DC-DC converter immediately resets if the output voltage droops to less than 2.0V and either the external current threshold is exceeded, or the internal LX peak-current threshold is exceeded for four consecutive switching cycles.

Output Short-Circuit Protection

The DC-DC converter output (SENSP, SENSN) is protected against both short-to-ground and short-to-battery conditions. If a short-to-ground or undervoltage condition is encountered, the DC-DC converter immediately resets, asserts the FAULT pin, flags the fault in the IRQ_1 register, and then reattempts soft-start after the reset delay. This pattern repeats until the short circuit has been removed.

If a short-to-battery is encountered ($V_{\text{SENSN}} > V_{\text{OV_SENSN}}$), the device stops switching, G_DMOS is disabled, the FAULT pin is asserted, and the fault is flagged in the IRQ_1 register. This behavior persists as long as the OV condition exists on SENSN.

Thermal Overload Protection

Thermal-overload protection limits the total power dissipated by the device. A thermal-protection circuit monitors the die temperature. If the die temperature exceeds +165°C, the device will shut down, allowing it to cool. Once the device has cooled by 10°C, the device is enabled again. This results in a pulsed output during continuous thermal-overload conditions, protecting the device during fault conditions. For continuous operation, do not exceed the absolute maximum junction temperature of +150°C. See [Layout Considerations](#) for more information.

Automatic Thermal Foldback

The MAX20459 implements a thermal foldback feature that, when enabled, reduces the Type-C current limit and advertisement. On the standalone variant, when a thermal warning occurs, the output current limit and the Rp current advertisement are reduced to the setting immediately below what was set by the CONFIG3 resistor (ie. Type-C Rp from 3.0A to 1.5A and ILIM from 3.04A to 2.55A). When the die temperature drops below the thermal-warning threshold, the Rp advertisement and current-limit threshold will return to their original settings based on the value of the CONFIG3 resistor. Note that the CONFIG resistor value is only read at POR.

On the I²C variant, when a thermal warning occurs, the Rp current advertisement is reduced to the setting immediately below what was set by the CC_SRC_CUR[1:0] register (ie. Type-C Rp from 3.0A to 1.5A) and the current limit changes to 1.62A (min). When the die temperature drops below the thermal-warning threshold, the Rp advertisement and current-limit threshold will return to their original settings based on the value of the CC_SRC_CUR[1:0] and ILIM[2:0] register, respectively.

Note that Type-C allows for dynamic Rp changes in the Attached.SRC state without re-initializing detection. MAX20459 thermal foldback does not force BUS to reset or change the BC1.2 mode. Alternative thermal-foldback algorithms are available and can be done in system software. Contact Maxim Applications for support.

USB Current-Limit and Output-Voltage Adjustment

Current-Sense Amplifier (SENSP, SENSN)

MAX20459 features an internal USB load current-sense amplifier to monitor the DC load current delivered to the USB port. The VSENSE voltage ($V_{\text{SENSP}} - V_{\text{SENSN}}$) is used internally to provide precision DC current-limit and voltage-compensation functionality. A 33mΩ sense resistor should be placed between SENSP and SENSN.

USB DC Current Limit Configuration

The MAX20459 allows configuration of the precision DC current limit by the ILIM[2:0] bits of the SETUP_2 register. I²C configuration enables selection of eight discrete DC current-limit values. See SETUP_2 for current-limit configuration values. The standalone variant of the device allow selection of a subset of the eight available current-limit options by reading the CONFIG3 resistor. See [Table 6](#) and the Applications Information section for more information.

Voltage Feedback Adjustment Configuration

The MAX20459 compensates voltage drop for up to 500mΩ of total series resistance on the V_{BUS} and GND path.

Voltage gain is configured by selecting suitable resistors connected to CONFIG2 and CONFIG3 on the standalone variant, or by changing the GAIN[4:0] register on the I²C variant.

Remote-Sense Feedback Adjustment (SHIELD Pin)

The remote-sense feature (available by custom order only) gives another option to adjust the output voltage by sensing the ground node on the USB port at the far end of the captive cable, either with the cable shield or with an additional sensing wire. This feature automatically senses the cable resistance and adjusts the voltage compensation without changing the GAIN[4:0] setting.

The user must compensate for the voltage drop due to the sense resistor, the load-line behavior of the buck, and any difference between the V_{BUS} and GND conductors. Contact Maxim Applications for support and ordering instructions.

Automatic Charge Detection with ESD and Short-Circuit Protection

To maintain compatibility with non-Type-C devices, MAX20459 includes automatic dedicated charger-detection circuitry on the USB 2.0 data D+/D- lines. The device is compatible with Apple iPhone (1A), iPad (2.4A), BC1.2 DCP, and legacy Samsung charge-detection methods. See [Table 2](#) for the I²C variant and [Table 3](#) for the standalone variant.

The MAX20459 does not require an external ESD array, and protects the HVD+ and HVD- pins up to ±15kV Air Gap/±8kV Contact Discharge with the 150pF/330Ω IEC 61000-4-2 model, as well as protecting up to ±15kV Air Gap/±8kV Contact Discharge with the 330pF/2kΩ or 330pF/330Ω ISO 10605 model. See [ESD Protection](#) for additional information. Additionally, the HVD+ and HVD- short-circuit protection features include protection for short to +5V BUS and protection for short to +18V car battery.

Table 2. Charge-Detection Mode Truth Table (I²C Variant)

DEVICE SUFFIX	DEVICE INPUTS			SB SWITCHES	CHARGE-DETECTION MODE
	HVEN	CD[1]	CD[0]		
X	0	X	X	Off	Off
ATJA	1	1	0	On	Auto-DCP/Apple 2.4A (DCP) DCP_MODE pin = 0 (DCP_MODE = 1 will override I ² C register, making Apple 2.4A mode impossible)
ATJA	1	1	1	On	Auto-DCP/Apple 1A (DCP)

Table 3. Charge-Detection Mode Truth Table (Standalone Variant)

DEVICE SUFFIX	DEVICE INPUTS		SB SWITCHES	CHARGE-DETECTION MODE
	HVEN	DCP_MODE PIN		
X	0	X	Off	Off
ATJC	1	0	On	Auto-DCP/Apple 2.4A (DCP)
ATJC	1	1	On	Auto-DCP/Apple 1A (DCP)

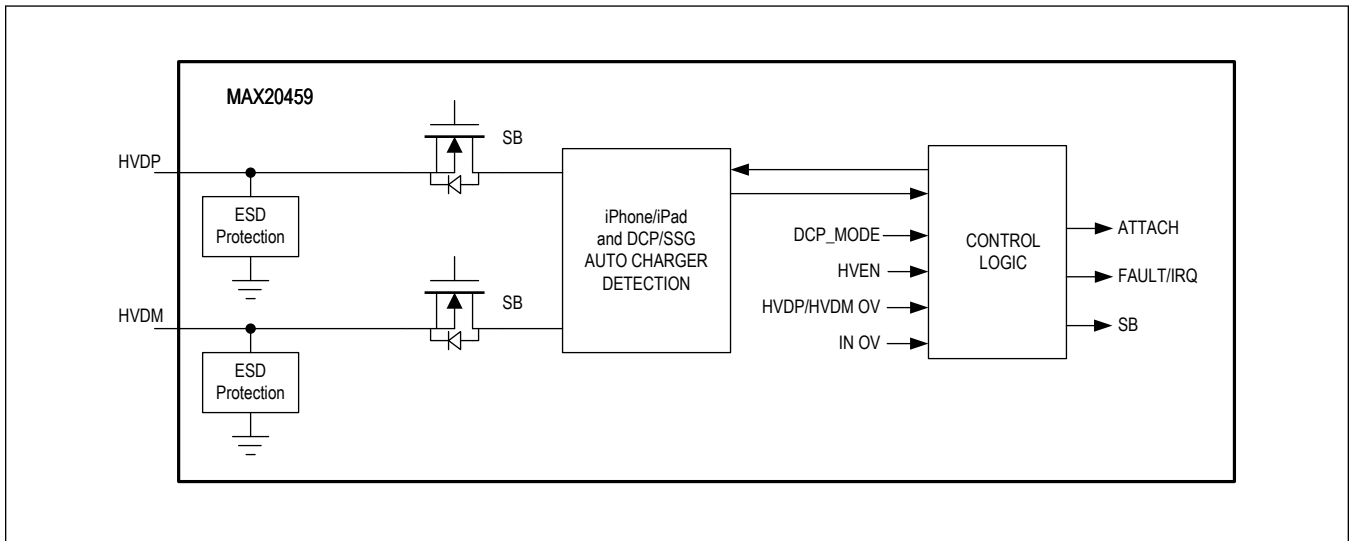


Figure 2. Charge Detection Block Diagram

I²C, Control, and Diagnostics

I²C Configuration (CONFIG1 and I²C)

The MAX20459 I²C variant allows basic device configuration through a resistor placed between the CONFIG1 pin and GND. The configuration parameters correlating to the chosen resistor are pre-loaded into their respective I²C registers on startup when HVEN is toggled high. After startup, the user is free to change the affected I²C registers as desired.

For the I²C variant, CONFIG1 sets the startup value of the DC-DC spread spectrum enable bit SS_EN and the SYNC direction-control bit SYNC_DIR. CONFIG1 also sets the two LSBs of the I²C slave address. The configuration table for the I²C variant CONFIG table is shown in [Table 4](#).

Table 4. CONFIG1 Pin Table (I²C Version)

RESISTANCE (Typ, Ω)	STEP	SS_EN	SYNC_DIR	I ² C_ADDR LSBs
Short to GND	0	1 (ON)	1 (IN)	00
619	1	1 (ON)	1 (IN)	01
976	2	1 (ON)	1 (IN)	10
1370	3	1 (ON)	1 (IN)	11
1820	4	1 (ON)	0 (OUT)	00
2370	5	1 (ON)	0 (OUT)	01
3090	6	1 (ON)	0 (OUT)	10
3920	7	1 (ON)	0 (OUT)	11
4990	8	0 (OFF)	1 (IN)	00
6340	9	0 (OFF)	1 (IN)	01
8250	10	0 (OFF)	1 (IN)	10
11000	11	0 (OFF)	1 (IN)	11
15400	12	0 (OFF)	0 (OUT)	00
23700	13	0 (OFF)	0 (OUT)	01
44200	14	0 (OFF)	0 (OUT)	10
Short to BIAS (or R > 71.5kΩ)	15	0 (OFF)	0 (OUT)	11

Standalone Configuration (CONFIG1–CONFIG3)

The MAX20459 standalone variant allows full device configuration from three resistors placed among the three CONFIG pins and AGND. CONFIG1 sets the internal oscillator switching frequency, the SYNC pin direction, and enables the DC-DC spread-spectrum mode. CONFIG2 sets the 4 LSBs of the voltage adjustment gain (GAIN[3:0]). CONFIG3 sets the USB DC current limit and sets the MSB of voltage-adjustment gain (GAIN[4]). See [Table 5](#) and [Table 6](#) for CONFIG options. See the GAIN[4:0] register description for lookup values. See the [Applications Information](#) section for setting selection and [Ordering Information](#) for variant part number information.

Table 5. CONFIG1 Pin Table (Standalone Variant)

RESISTANCE (typ, Ω)	STEP	SS_EN	SYNC_DIR	FSW (kHz)
Short to GND	0	ON	IN	2200
619	1	ON	IN	488
976	2	ON	IN	350
1370	3	ON	IN	310
1820	4	ON	OUT	2200
2370	5	ON	OUT	488

Table 5. CONFIG1 Pin Table (Standalone Variant) (continued)

RESISTANCE (typ, Ω)	STEP	SS_EN	SYNC_DIR	FSW (kHz)
3090	6	ON	OUT	350
3920	7	ON	OUT	310
4990	8	OFF	IN	2200
6340	9	OFF	IN	488
8250	10	OFF	IN	350
11000	11	OFF	IN	310
15400	12	OFF	OUT	2200
23700	13	OFF	OUT	488
44200	14	OFF	OUT	350
Short to BIAS (or R > 71.5k Ω)	15	OFF	OUT	310

Table 6. CONFIG2 and CONFIG3 Pin Table (Standalone Variant)

RESISTANCE (typ, Ω)	STEP	CONFIG2		CONFIG3		
		GAIN[3:0]	THM_FLDBK_EN	GAIN[4]	CURRENT LIMIT (A, min)	TYPE-C MODE (A)
Short to GND	0	0000	1 (ON)	0	0.55	0.5
619	1	0001	1 (ON)	0	1.55	1.5
976	2	0010	1 (ON)	0	2.55	1.5
1370	3	0011	1 (ON)	0	3.04	3.0
1820	4	0100	1 (ON)	1	0.55	0.5
2370	5	0101	1 (ON)	1	1.55	1.5
3090	6	0110	1 (ON)	1	2.55	1.5
3920	7	0111	1 (ON)	1	3.04	3.0
4990	8	1000	0 (OFF)	0	0.55	0.5
6340	9	1001	0 (OFF)	0	1.55	1.5
8250	10	1010	0 (OFF)	0	2.55	1.5
11000	11	1011	0 (OFF)	0	3.04	3.0
15400	12	1100	0 (OFF)	1	0.55	0.5
23700	13	1101	0 (OFF)	1	1.55	1.5
44200	14	1110	0 (OFF)	1	2.55	1.5
Short to BIAS (or R > 71.5k Ω)	15	1111	0 (OFF)	1	3.04	3.0

I²C Diagnostics and Event Handling

The I²C-based diagnostic functionality is independent of the $\overline{\text{FAULT}}$ pin. Setting the IRQMASK bit for a specific fault condition will not mask the $\overline{\text{FAULT}}$ pin for the respective fault. IRQMASK register functionality affects only the behavior of the $\overline{\text{INT}}$ pin. This allows the $\overline{\text{FAULT}}$ pin to be tied to overcurrent fault input of a hub controller or SoC, while the I²C interface is simultaneously used by the system software for advanced diagnostic functionality.

Interrupt and Attach Output ($\overline{\text{INT}}(\text{ATTACH})$)

The MAX20459 $\overline{\text{INT}}(\text{ATTACH})$ pin functions as an interrupt ($\overline{\text{INT}}$) for the I²C variant. The $\overline{\text{INT}}$ pin will assert an interrupt based on the configuration of the IRQ_MASK_0, IRQ_MASK_1, and IRQ_MASK_2 registers. Interrupt configuration

allows the $\overline{\text{INT}}$ pin to assert any of the featured fault detection, as well as on device attach/detach, and for USB voltage/current ADC conversion completion. The $\overline{\text{INT}}$ pin will only assert while a masked IRQ bit is asserted, which means that its behavior is also dependent on the IRQ_AUTOCLR bit.

The standalone variant of MAX20459 feature an open-drain, active-low, $\overline{\text{ATTACH}}$ output that serves as the attach-detection pin for standalone variants. The $\overline{\text{ATTACH}}$ pin can be used for GPIO input to a microprocessor, or to drive an LED for attach/charge indication.

The $\overline{\text{INT}}(\overline{\text{ATTACH}})$ assertion logic is shown in [ATTACH Logic Diagram](#).

I²C Output Voltage and Current Measurement

The MAX20459 I²C variant allows measurement of the instantaneous SENSE voltage and DC output current using an integrated ADC. To initiate a measurement, set the ADC_REQ bit of the ADC_REQUEST register. The ADC_REQ bit will be cleared by the IC once the measurement is complete and the ADC samples are available. Additionally, the ADC_DONE bit of the IRQ_0 register will be set when the sample is available. ADC_DONE can be masked to assert an interrupt when the sample is ready.

The sampled measurements can be read from the ADC_USBV, ADC_USBI, and ADC_TEMP registers. The new sample will persist in the register until another sample request is initiated by setting the ADC_REQ bit.

All measurements provide 8 bits of resolution. The measured SENSE voltage has a range of 0V to 19.8V. Convert the sample to a voltage by $V_{\text{SENSE}} = \frac{19.8\text{V}}{256} \cdot \text{ADC_USBV}$ (Volts).

The measured SENSE voltage has a range of 0 to 116mV. Convert the sample to a current by $I_{\text{LOAD}} = \frac{116\text{mV}}{256} \cdot R_{\text{SENSE}} \cdot \text{ADC_USBI}$ (Amps).

The measured die temp has a range from -40°C to 170°C and a temperature resolution of 3.5°C. Convert the sample to a die temperature by $T_J = 3.5^\circ\text{C} \cdot \text{ADC_TEMP} - 270$ (°C).

I²C Interface

The MAX20459 features an I²C, 2-wire serial interface consisting of a serial-data line (SDA) and a serial-clock line (SCL). SDA and SCL facilitate communication between the MAX20459 and the master at clock rates up to 400kHz. The master, typically a microcontroller, generates SCL and initiates data transfer on the bus. [Figure 3](#) shows the 2-wire interface timing diagram.

A master device communicates to the MAX20459 by transmitting the proper address followed by the data word. Each transmit sequence is framed by a START (S) or REPEATED START (Sr) condition and a STOP (P) condition. Each word transmitted over the bus is 8 bits long and is always followed by an acknowledge clock pulse.

The MAX20459 SDA line operates as both an input and an open-drain output. A pullup resistor greater than 500Ω is required on the SDA bus. The MAX20459 SCL line operates as an input only. A pullup resistor greater than 500Ω is required on SCL if there are multiple masters on the bus, or if the master in a single-master system has an open-drain SCL output. Series resistors in line with SDA and SCL are optional. The SCL and SDA inputs suppress noise spikes to assure proper device operation even on a noisy bus.

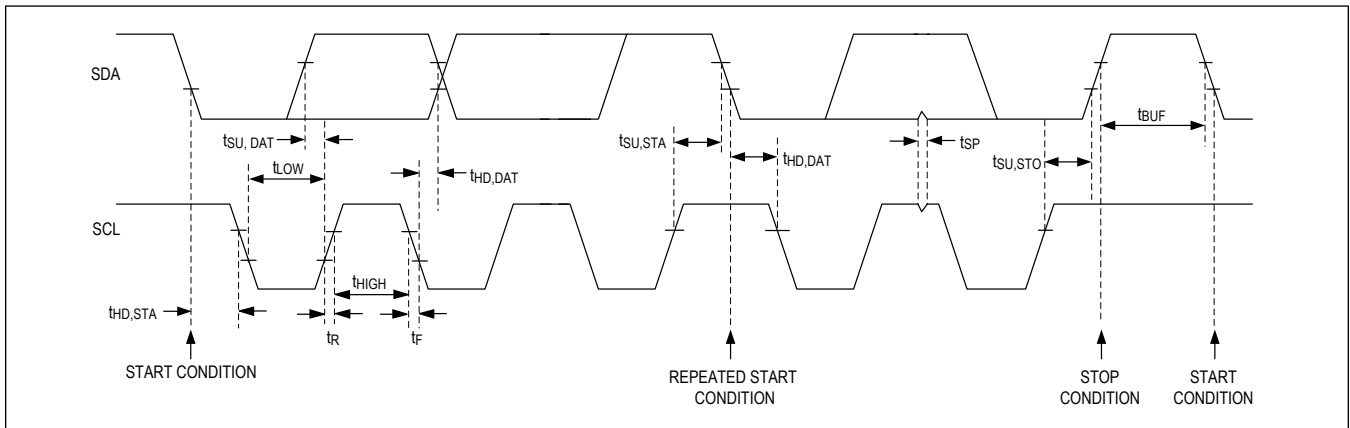


Figure 3. I²C Timing Diagram

Bit Transfer

One data bit is transferred during each SCL cycle. The data on SDA must remain stable during the high period of the SCL pulse. Changes in SDA while SCL is high are control signals (see [STOP and START Conditions](#)). SDA and SCL idle high when the I²C bus is not busy.

STOP and START Conditions

A master device initiates communication by issuing a START condition. A START condition is a high-to-low transition on SDA with SCL high. A STOP condition is a low-to-high transition on SDA while SCL is high (Figure 4). A START (S) condition from the master signals the beginning of a transmission to the MAX20459. The master terminates transmission, and frees the bus, by issuing a STOP (P) condition. The bus remains active if a REPEATED START (Sr) condition is generated instead of a STOP condition.

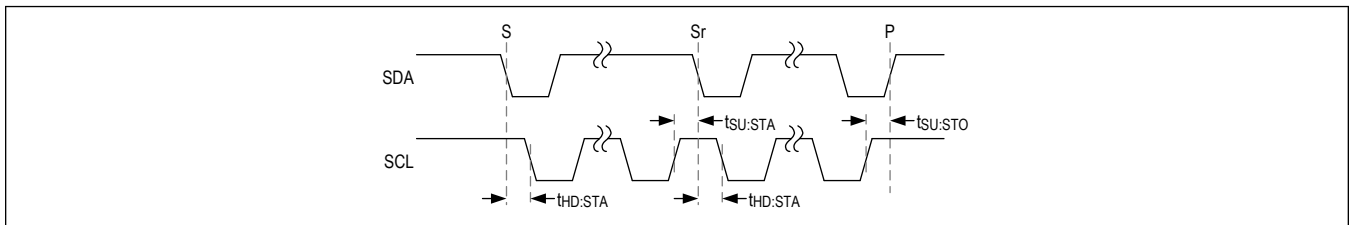


Figure 4. START, STOP and REPEATED START Conditions

Early STOP Condition

The MAX20459 recognizes a STOP condition at any point during data transmission except if the STOP condition occurs in the same high pulse as a START condition.

Clock Stretching

In general, the clock signal generation for the I²C bus is the responsibility of the master device. The I²C specification allows slow slave devices to alter the clock signal by holding down the clock line. The process in which a slave device holds down the clock line is typically called clock stretching. The MAX20459 does not use any form of clock stretching to hold down the clock line.

I²C General Call Address

The MAX20459 does not implement the I²C specification general call address. If the MAX20459 sees the general call

address (0b0000_0000), it will not issue an acknowledge.

I²C Slave Addressing

Once the device is enabled, the I²C slave address is set by the CONFIG1 pin.

The address is defined as the 7 most significant bits (MSBs) followed by the R/W bit. Set the R/W bit to 1 to configure the devices to read mode. Set the R/W bit to 0 to configure the device to write mode. The address is the first byte of information sent to the devices after the START condition.

Table 7. I²C Slave Addresses

CONFIG1 CODE	A6	A5	A4	A3	A2	A1	A0	7-BIT ADDRESS	WRITE	READ
00	0	1	1	0	0	0	0	0x30	0x60	0x61
01	0	1	1	0	0	0	1	0x31	0x62	0x63
10	0	1	1	0	0	1	0	0x32	0x64	0x65
11	0	1	1	0	0	1	1	0x33	0x66	0x67

Acknowledge

The acknowledge bit (ACK) is a clocked ninth bit that the device uses to handshake receipt of each data byte (Figure 5). The device pulls down SDA during the master-generated ninth clock pulse. The SDA line must remain stable and low during the high period of the acknowledge clock pulse. Monitoring ACK allows for detection of unsuccessful data transfers. An unsuccessful data transfer occurs if a receiving device is busy or if a system fault has occurred. In the event of an unsuccessful data transfer, the bus master can reattempt communication.

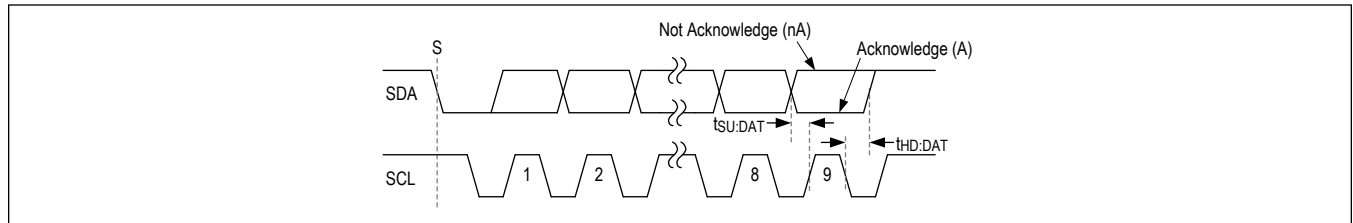


Figure 5. Acknowledge Condition

Write Data Format

A write to the device includes transmission of the following:

- START condition
- Slave address with the write bit set to 0,
- 1 byte of data to register address
- 1 byte of data to the command register
- STOP condition.

Figure 6 illustrates the proper format for one frame.

Read Data Format

A read from the device includes transmission of the following:

- START condition
- Slave address with the write bit set to 0
- 1 byte of data to register address
- Restart condition
- Slave address with read bit set to 1
- 1 byte of data to the command register
- STOP condition

Figure 6 illustrates the proper format for one frame.

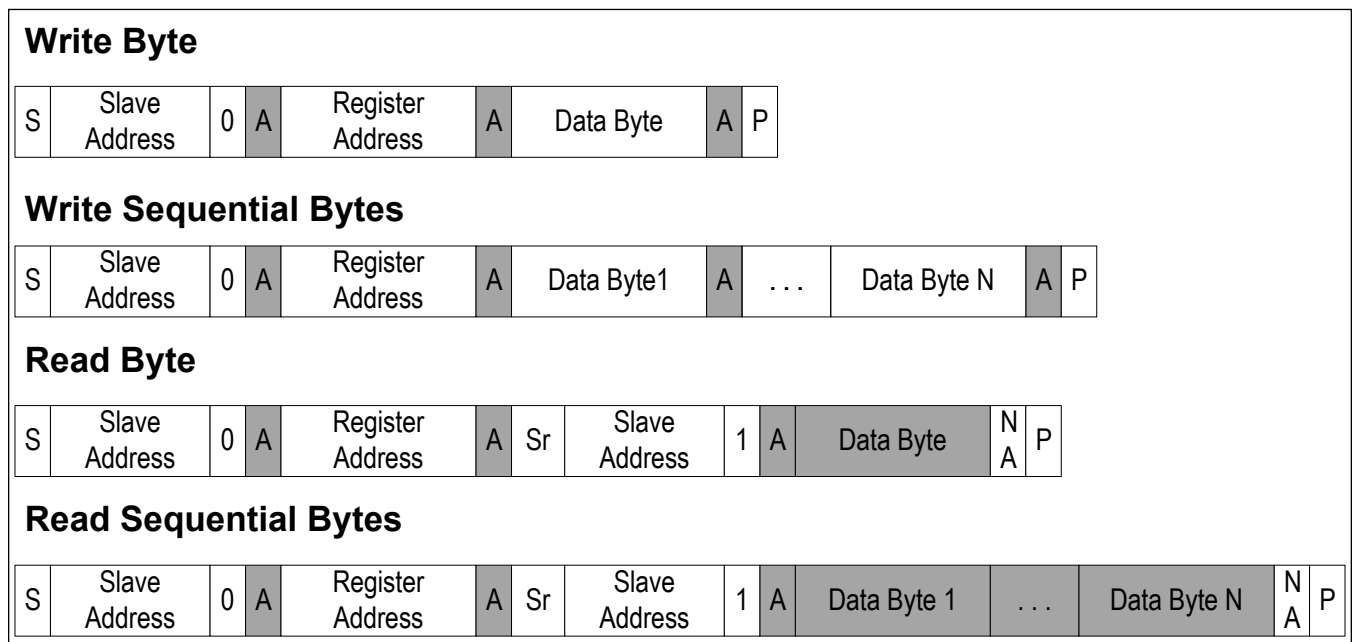


Figure 6. Data Format of I²C Interface

Fault Detection and Diagnostics

Fault Detection

The MAX20459 features advanced device-protection features with automatic fault handling and recovery. Table 8 summarizes the conditions that generate a fault, and the actions taken by the device. For all variants, the FAULT output

remains asserted as long as a fault condition persists.

Fault Output Pin ($\overline{\text{FAULT}}$)

The MAX20459 features an open-drain, active-low $\overline{\text{FAULT}}$ output. The MAX20459 is designed to eliminate false $\overline{\text{FAULT}}$ reporting by using an internal deglitch and fault-blanking timer. This ensures that $\overline{\text{FAULT}}$ is not falsely asserted during normal operation such as starting into heavy capacitive loads. The $\overline{\text{FAULT}}$ pin is designed such that it can be tied directly to the fault input of a microcontroller or used to enable an LED.

Table 8. Fault Conditions

EVENT	IRQ REGISTER BITS (I ² C ONLY)	DEBOUNCE PRIOR TO ACTION	ACTION TAKEN
Thermal Shutdown	THM_SHD	Immediate	Assert $\overline{\text{FAULT}}$ pin, shut down DC-DC converter, disconnect charge-detection circuitry, and disable Rp. When fault resolves and RETRY_TMR expires, release $\overline{\text{FAULT}}$ pin, enable Rp and DC-DC converter.
Thermal Warning/ Foldback	THM_WARN	20 ms	If enabled, initiate thermal-foldback algorithm by reducing the advertised current and current limit. When fault resolves and RETRY_TMR expires, return to original current-advertisement and current-limit settings.
IN Overvoltage	IN_OV	Immediate	Assert $\overline{\text{FAULT}}$ pin and associated IRQ bit, shut down DC-DC converter, disconnect charge-detection circuitry, disable Rp, and reset BC1.2. When fault resolves and RETRY_TMR expires, release $\overline{\text{FAULT}}$ pin, reconnect charge detection circuitry, enable Rp and DC-DC converter.
HVDP/ HVDM Overvoltage	DATA_OV	Immediate	Assert $\overline{\text{FAULT}}$ pin, shut down DC-DC converter, disconnect charge-detection circuitry, disable Rp, and reset BC1.2. When fault resolves and RETRY_TMR expires, release $\overline{\text{FAULT}}$ pin, reconnect charge detection circuitry, enable Rp and DC-DC converter.
USB DC Overcurrent	VBUS_ILIM	16 ms	Assert $\overline{\text{FAULT}}$ pin after overcurrent condition persists for 16ms. When fault resolves and RETRY_TMR expires, release $\overline{\text{FAULT}}$ pin.
USB DC Overcurrent and SENSN < 4.38V	VBUS_ILIM_UV	16 ms	Standalone variant or I ² C variant with ILIM_ITRIP = 1: Assert $\overline{\text{FAULT}}$ pin after overcurrent and undervoltage condition persists for 16ms. When fault resolves and RETRY_TMR expires, release $\overline{\text{FAULT}}$ pin. I ² C variant and ILIM_ITRIP = 0: Assert $\overline{\text{FAULT}}$ pin, shut down DC-DC converter, and disable Rp after overcurrent and undervoltage condition persists for 16ms. When RETRY_TMR expires after shutdown, release $\overline{\text{FAULT}}$ pin, enable Rp and DC-DC converter.
SENSN < 4.38V	VBUS_UV	16 ms	Assert $\overline{\text{FAULT}}$ pin after undervoltage condition persists for 16ms. When fault resolves and RETRY_TMR expires, release $\overline{\text{FAULT}}$ pin.
USB DC Overcurrent and SENSN < 2V	VBUS_SHT_GND	Immediate	Assert $\overline{\text{FAULT}}$ pin, shut down DC-DC converter, disconnect charge-detection circuitry, and disable Rp. When RETRY_TMR expires after shutdown, release $\overline{\text{FAULT}}$ pin, enable Rp and DC-DC converter.
LX Overcurrent for Four Consecutive Cycles and SENSN < 2V	VBUS_SHT_GND	Immediate	Assert $\overline{\text{FAULT}}$ pin, shut down DC-DC converter, disconnect charge detection circuitry, and disable Rp. When RETRY_TMR expires after shutdown, release $\overline{\text{FAULT}}$ pin, enable Rp and DC-DC converter.
SENSN Overvoltage	VBUS_OV	Immediate	Assert $\overline{\text{FAULT}}$ pin, tri-state DC-DC converter, disconnect charge-detection circuitry, and disable Rp. When fault resolves and RETRY_TMR expires, release $\overline{\text{FAULT}}$ pin, enable charge detection circuitry, Rp, and the DC-DC converter.

Table 8. Fault Conditions (continued)

EVENT	IRQ REGISTER BITS (I ² C ONLY)	DEBOUNCE PRIOR TO ACTION	ACTION TAKEN
V _{BUS} Pre-Overvoltage	VBUS_PRE_OV	16 ms	Assert $\overline{\text{FAULT}}$ pin after overvoltage condition persists for 16ms. When fault resolves and RETRY_TMR expires, release $\overline{\text{FAULT}}$ pin.

Register Map

Summary Table

ADDRESS	NAME	MSB							LSB
USER_CMDS									
0x00	SETUP_0[7:0]	-	THM_FL DBK_EN	EN_DCD C	VOUT[2:0]			SYNC_D IR	SS_EN
0x01	SETUP_1[7:0]	FSW[2:0]			GAIN[4:0]				
0x02	SETUP_2[7:0]	-	-	-	ILIM_ITR IP	-	ILIM[2:0]		
0x03	SETUP_3[7:0]	RETRY_TMR[1:0]		CD[1:0]		CC_ENB	-	CC_SRC_CUR[1:0]	
0x04	SETUP_4[7:0]	-	-	-	-	-	-	-	CONFIG URED
0x05	ADC_REQUEST[7:0]	-	-	-	-	-	-	-	ADC_RE Q
0x06	CC_REQUEST[7:0]	-	-	-	-	-	-	CC_FOR CE_ERR	CC_SRC _RST
0x07	IRQ_MASK_0[7:0]	IRQ_AU TOCLR	-	EN_CC_ STATE_ EV	EN_CC_ ATTACH_ IRQ	EN_BC_ ATTACH_ IRQ	EN_CC_ ATTACH_ EV	EN_BC_ ATTACH_ EV	EN_ADC_ DONE
0x08	IRQ_MASK_1[7:0]	-	EN_VBU S_PRE_ OV	EN_VBU S_ILIM_ UV	EN_VBU S_ILIM	EN_VBU S_OV	EN_VBU S_UV	EN_VBU S_SHT_ GND	EN_THM_ SHD
0x09	IRQ_MASK_2[7:0]	-	-	EN_VBU S_PREB IAS	-	EN_THM_ WARN	EN_IN_ OV	EN_DAT A_OV	-
0x0A	IRQ_0[7:0]	UNCON FIGURE D	-	CC_STA TE_EV	CC_ATT ACH_IR Q	BC_ATT ACH_IR Q	CC_ATT ACH_EV	BC_ATT ACH_EV	ADC_DO NE
0x0B	IRQ_1[7:0]	-	VBUS_P RE_OV	VBUS_IL IM_UV	VBUS_IL IM	VBUS_O V	VBUS_U V	VBUS_S HT_GND	THM_SH D
0x0C	IRQ_2[7:0]	-	-	VBUS_P REBIAS	-	THM_W ARN	IN_OV	DATA_O V	-
0x0D	STATUS_0[7:0]	-	-	-	CC_ATT ACH	BC_ATT ACH	VBMON _SAFE	-	VBUS_S TAT
0x0E	STATUS_1[7:0]	-	-	CC_PIN_STATE[1:0]		CC_STATE[3:0]			
0x10	ADC_0[7:0]	ADC_USBI[7:0]							
0x11	ADC_1[7:0]	ADC_USBV[7:0]							
0x12	ADC_2[7:0]	ADC_TEMP[7:0]							

Register Details

[SETUP_0 \(0x0\)](#)

BIT	7	6	5	4	3	2	1	0
Field	–	THM_FLDBK K_EN	EN_DCDC	VOUT[2:0]			SYNC_DIR	SS_EN
Reset	–	0b0	0b1	0b000				
Access Type	–	Write, Read	Write, Read	Write, Read			Write, Read	Write, Read

BITFIELD	BITS	DESCRIPTION	DECODE
THM_FLDBK _EN	6	Lowest the advertised current capability and the output current limit when Thermal Warning is tripped.	0 = Disable Thermal Foldback 1 = Enable Thermal Foldback
EN_DCDC	5	DC/DC Converter Enable. Internally AND'ed with the ENBUCK pin	0 = Disable V _{BUS} Buck Converter 1 = Enable V _{BUS} Buck Converter
VOUT	4:2	V _{BUS} Output Level Selection	000 = 5V 001 = 9V 010 = 12V 011 = 15V 100 = 18V (protected battery pass-through) 101 = 5V 110 = 5V 111 = 5V
SYNC_DIR	1	SYNC Pin Direction Selection. Initial value set by CONFIG1 resistor.	0 = Output 1 = Input
SS_EN	0	Spread Spectrum Enable. Initial value set by CONFIG1 resistor.	0 = Disable spread-spectrum function 1 = Enable spread-spectrum function

SETUP_1 (0x1)

BIT	7	6	5	4	3	2	1	0
Field	FSW[2:0]			GAIN[4:0]				
Reset	0b000			0b00000				
Access Type	Write, Read			Write, Read				

BITFIELD	BITS	DESCRIPTION	DECODE
FSW	7:5	DC/DC Converter Switching-Frequency Selection. Initial value set by CONFIG1 resistor.	000 = 2200 kHz 001 = 1200 kHz 010 = 790 kHz 011 = 600 kHz 100 = 488 kHz 101 = 410 kHz 110 = 350 kHz 111 = 310 kHz

BITFIELD	BITS	DESCRIPTION	DECODE
GAIN	4:0	The gain of the voltage correction applied to the buck converter output (based on DC load sensed by current-sense amp).	0: 0 1: 18 2: 36 3: 54 4: 72 5: 90 6: 108 7: 126 8: 144 9: 162 10: 180 11: 198 12: 216 13: 234 14: 252 15: 270 16: 288 17: 306 18: 324 19: 342 20: 360 21: 378 22: 396 23: 414 24: 432 25: 450 26: 468 27: 486 28: 504 29: 522 30: 540 31: 558

SETUP_2 (0x2)

BIT	7	6	5	4	3	2	1	0
Field	–	–	–	ILIM_ITRIP	–	ILIM[2:0]		
Reset	–	–	–	0b1	–	0b111		
Access Type	–	–	–	Write, Read	–	Write, Read		

BITFIELD	BITS	DESCRIPTION	DECODE
ILIM_ITRIP	4	Determines the buck's retry behavior under USB DC current-limit conditions	0 = VBUS_ILIM_UV fault enabled, VBUS_ILIM fault disabled 1 = VBUS_ILIM_UV fault disabled, VBUS_ILIM fault enabled

BITFIELD	BITS	DESCRIPTION	DECODE
ILIM	2:0	USB DC current-limit threshold	USB DC Current-Limit Threshold (min in Amps) 000 = 0.3 001 = 0.55 010 = 0.8 011 = 1.05 100 = 1.62 101 = 2.1 110 = 2.6 111 = 3.04

SETUP_3 (0x3)

BIT	7	6	5	4	3	2	1	0
Field	RETRY_TMR[1:0]		CD[1:0]		CC_ENB	–	CC_SRC_CUR[1:0]	
Reset	0b11		00		0b0	–	0b01	
Access Type	Write, Read		Write, Read		Write, Read	–	Write, Read	

BITFIELD	BITS	DESCRIPTION	DECODE
RETRY_TMR	7:6	Determines the length of the RETRY timer after a fault condition	00 = 2.0 s 01 = 1.0 s 10 = 0.5 s 11 = 16 ms
CD	5:4	BC1.2 Charge-Detection Configuration Selection. This register is preloaded at startup with 0x10 when DCP_MODE = 0 and with 0x11 when DCP_MODE = 1.	00 = Reserved 01 = Reserved 10 = Auto-DCP/Apple 2.4A 11 = Auto-DCP/Apple 1.0A
CC_ENB	3	Disable Type-C Detection	0 = Type-C Enabled 1 = Type-C Disabled (for Type-A operation only)
CC_SRC_CUR	1:0	Type-C DFP Source Pullup Current Advertisement (Rp)	00 = 0.5A 01 = 1.5A 10 = 3.0A 11 = 0.5A

SETUP_4 (0x4)

BIT	7	6	5	4	3	2	1	0
Field	–	–	–	–	–	–	–	CONFIGURED
Reset	–	–	–	–	–	–	–	0b0
Access Type	–	–	–	–	–	–	–	Write, Read

BITFIELD	BITS	DESCRIPTION	DECODE
CONFIGURED	0	I ² C Configuration Complete Indicator. Upon power-up, the buck converter is prevented from turning on until this bit is written to a one, indicating the part is fully configured for its intended mode of operation.	0 = I ² C configuration pending 1 = I ² C configuration complete

ADC_REQUEST (0x5)

BIT	7	6	5	4	3	2	1	0
Field	–	–	–	–	–	–	–	ADC_REQ
Reset	–	–	–	–	–	–	–	0b0
Access Type	–	–	–	–	–	–	–	Write, Read

BITFIELD	BITS	DESCRIPTION	DECODE
ADC_REQ	0	ADC V/I Sample Request. When a 1 is written, ADC V/I sampling is initiated. This bit is cleared once the requested sampling is complete and the ADC results are updated. The status of the ADC conversion (data ready) can be monitored in the IRQ1 register.	0 = No ADC sample requested 1 = ADC sample requested

CC_REQUEST (0x6)

BIT	7	6	5	4	3	2	1	0
Field	–	–	–	–	–	–	CC_FORCE_ERR	CC_SRC_RST
Reset	–	–	–	–	–	–	0b0	0b0
Access Type	–	–	–	–	–	–	Write, Read	Write, Read

BITFIELD	BITS	DESCRIPTION	DECODE
CC_FORCE_ERR	1	Type-C Force Error Request. This is a request bit (write-only). Forces the Type-C state machine to go through error recovery. This bit will always read back zero.	0 = No change to current operating state 1 = Force transition to Error Recovery state
CC_SRC_RST	0	Type-C Force Source Reset Request. This is a request bit (write-only). The Type-C state machine will be forced back to the UnAttached.SRC state, restarting Type-C detection. This bit will always read back 0.	0 = No change to current operating state 1 = Force transition to UnAttached.SRC state

IRQ_MASK_0 (0x7)

A read-write register that configures which of the conditions in the IRQ_0 register will assert an Interrupt. See the IRQ_0 register for condition descriptions.

BIT	7	6	5	4	3	2	1	0
Field	IRQ_AUTOCLR	–	EN_CC_STATE_EV	EN_CC_AT TACH_IRQ	EN_BC_AT TACH_IRQ	EN_CC_AT TACH_EV	EN_BC_AT TACH_EV	EN_ADC_DONE
Reset	0b0	–	0b0	0b0	0b0	0b0	0b0	0b0
Access Type	Write, Read	–	Write, Read	Write, Read	Write, Read	Write, Read	Write, Read	Write, Read

BITFIELD	BITS	DESCRIPTION	DECODE
IRQ_AUTOCLR	7	IRQ Autoclear	0 = IRQ register flags are latched on until read 1 = IRQ register flags are automatically cleared when the error condition is removed
EN_CC_STATE_EV	5	CC_STATE Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt

BITFIELD	BITS	DESCRIPTION	DECODE
EN_CC_ATT ACH_IRQ	4	Type-C ATTACH STATUS Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt
EN_BC_ATT ACH_IRQ	3	BC1.2 ATTACH STATUS Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt
EN_CC_ATT ACH_EV	2	Type-C ATTACH EVENT Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt
EN_BC_ATT ACH_EV	1	BC1.2 ATTACH EVENT Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt
EN_ADC_D ONE	0	ADC_DONE Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt

IRQ_MASK_1 (0x8)

A read-write register that configures which of the conditions in the IRQ_1 register will assert an Interrupt. See the IRQ_1 register for condition descriptions.

BIT	7	6	5	4	3	2	1	0
Field	–	EN_VBUS_ PRE_OV	EN_VBUS_I LIM_UV	EN_VBUS_I LIM	EN_VBUS_ OV	EN_VBUS_ UV	EN_VBUS_ SHT_GND	EN_THM_S HD
Reset	–	0x0	0b0	0b0	0b0	0b0	0b0	0b0
Access Type	–	Write, Read	Write, Read	Write, Read	Write, Read	Write, Read	Write, Read	Write, Read

BITFIELD	BITS	DESCRIPTION	DECODE
EN_VBUS_P RE_OV	6	VBUS_PRE_OV Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt
EN_VBUS_IL IM_UV	5	VBUS_ILIM_UV Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt
EN_VBUS_IL IM	4	VBUS_ILIM Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt
EN_VBUS_O V	3	VBUS_OV Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt
EN_VBUS_U V	2	VBUS_UV Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt
EN_VBUS_S HT_GND	1	VBUS_SHT_GND Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt
EN_THM_SH D	0	THM_SHD Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt

IRQ_MASK_2 (0x9)

A read-write register that configures which of the conditions in the IRQ_2 register will assert an Interrupt. See the IRQ_2 register for condition descriptions.

BIT	7	6	5	4	3	2	1	0
Field	–	–	EN_VBUS_ PREBIAS	–	EN_THM_ WARN	EN_IN_OV	EN_DATA_ OV	–
Reset	–	–	0x0	–	0b0	0b0	0b0	–
Access Type	–	–	Write, Read	–	Write, Read	Write, Read	Write, Read	–

BITFIELD	BITS	DESCRIPTION	DECODE
EN_VBUS_P REBIAS	5	VBUS_PREBIAS Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt
EN_THM_W ARN	3	THM_WARN Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt
EN_IN_OV	2	IN_OV Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt
EN_DATA_O V	1	DATA_OV Interrupt Enable	0 = Not included in Interrupt 1 = Included in Interrupt

IRQ_0 (0xA)

A read-only register that includes flags which indicate a number of operating conditions. These flags can assert an interrupt by setting the corresponding bit in the MASK register.

IRQ_0 holds notifications of expected operations rather than error/fault conditions.

BIT	7	6	5	4	3	2	1	0
Field	UNCONFIG URED	–	CC_STATE _EV	CC_ATTAC H_IRQ	BC_ATTAC H_IRQ	CC_ATTAC H_EV	BC_ATTAC H_EV	ADC_DON E
Reset	0b0	–	0b0	0b0	0b0	0b0	0b0	0b0
Access Type	Read Only	–	Read Clears All	Read Clears All	Read Clears All	Read Clears All	Read Clears All	Read Clears All

BITFIELD	BITS	DESCRIPTION	DECODE
UNCONFIGU RED	7	I ² C Unconfigured Indicator Bit	0 = Device is fully configured (CONFIGURED written to 1) 1 = Device is not fully configured (CONFIGURED has not been written to 1)
CC_STATE_ EV	5	Type-C State Change Indicator. Clear on read. Not affected by IRQ_AUTOCLR.	0 = No change in Type-C state since last read 1 = Type-C state has changed since last read
CC_ATTACH _IRQ	4	Type-C ATTACH Indicator. This bit indicates a Type-C device attachment is observed on the CC pins. Applies to Attached.SRC states. Further attachment details can be read in the STATUS registers.	0 = No Type-C device attached 1 = Type-C device attached
BC_ATTACH _IRQ	3	BC1.2 ATTACH Indicator. This bit indicates a BC1.2 PD attachment is observed on the HVDP/HVDM pins.	0 = No portable device attached 1 = Portable device attached
CC_ATTACH _EV	2	Type-C ATTACH Event Detected. This bit indicates a Type-C device attachment was initiated and/or terminated as observed on the CC pins. This bit differs from CC_ATTACH (which indicates the current Type-C attach status in real time) in that it is issued only when the status changes from unattached to attached or vice-versa. Clear on read. Not affected by IRQ_AUTOCLR.	0 = No attach or detach event detected since last read 1 = New attach and/or detach event detected

BITFIELD	BITS	DESCRIPTION	DECODE
BC_ATTACH_EV	1	BC1.2 ATTACH Event Detected. This bit indicates a BC1.2 PD attachment was initiated and/or terminated as observed on the HVDP/HVDM pins. This bit differs from BC_ATTACH (which indicates the current BC1.2 attach status in real time) in that it is issued only when the status changes from unattached to attached or vice-versa. Clear on read. Not affected by IRQ_AUTOCLR.	0 = No attach or detach event detected since last read 1 = New attach and/or detach event detected
ADC_DONE	0	ADC Measurement Complete Indicator. Clear on read.	0 = No new data available since last read 1 = New data available

IRQ_1 (0xB)

A read-only register that includes flags which indicate a number of error conditions. These flags can assert an interrupt by setting the corresponding bit in the MASK register.

BIT	7	6	5	4	3	2	1	0
Field	–	VBUS_PRE_OV	VBUS_ILIM_UV	VBUS_ILIM	VBUS_OV	VBUS_UV	VBUS_SHT_GND	THM_SHD
Reset	–	0b0	0b0	0b0	0b0	0b0	0b0	0b0
Access Type	–	Read Clears All	Read Clears All	Read Clears All	Read Clears All	Read Clears All	Read Clears All	Read Clears All

BITFIELD	BITS	DESCRIPTION	DECODE
VBUS_PRE_OV	6	VBUS Pre-Overvoltage Fault Detected. Asserts if overvoltage exists on VBMON when Type-C is enabled and no Type-C device is attached. Clear on read if condition is resolved.	0 = No event 1 = Event detected
VBUS_ILIM_UV	5	VBUS Current Limit and SENSN UV Fault Detected. Disabled when ILIM_ITRIP = 1. Clear on read if condition is resolved.	0 = No event 1 = Event detected
VBUS_ILIM	4	VBUS Current-Limit Condition Detected. Disabled when ILIM_ITRIP = 0. Clear on read if condition is resolved.	0 = No event 1 = Event detected
VBUS_OV	3	VBUS Overvoltage Fault Detected. Detected on SENSN pin. Clear on read if condition is resolved.	0 = No event 1 = Event detected
VBUS_UV	2	VBUS Under Voltage Fault Detected. Detected on SENSN pin. Clear on read if condition is resolved.	0 = No event 1 = Event detected
VBUS_SHT_GND	1	VBUS Short to Ground Fault Detected. Detected on SENSN pin. Clear on read if condition is resolved.	0 = No event 1 = Event detected
THM_SHD	0	Overtemperature Fault Detected. Asserts when the die temperature exceeds 165°C (typ). Clear on read if condition is resolved.	0 = No event 1 = Event detected

IRQ_2 (0xC)

A read-only register that includes flags which indicate a number of error conditions. These flags can assert an interrupt by setting the corresponding bit in the MASK register.

BIT	7	6	5	4	3	2	1	0
Field	–	–	VBUS_PREBIAS	–	THM_WARN	IN_OV	DATA_OV	–
Reset	–	–	0b0	–	0b0	0b0	0b0	–
Access Type	–	–	Read Clears All	–	Read Clears All	Read Clears All	Read Clears All	–

BITFIELD	BITS	DESCRIPTION	DECODE
VBUS_PREBIAS	5	VBUS Pre-Bias. Asserts if Type-C is enabled and VBMON > VSAFE0V when no Type-C device is attached.	0 = No event 1 = Event detected
THM_WARN	3	Thermal Warning Condition Detected. Asserts when the temperature has reached 130°C (typ). If thermal foldback is enabled, the current advertisement and current limit will be lowered while this bit is asserted. Clear on read if condition is resolved.	0 = No event 1 = Event detected
IN_OV	2	IN Pin Overvoltage Fault Detected. Clear on read if condition is resolved.	0 = No event 1 = Event detected
DATA_OV	1	DATA Pin Overvoltage Fault Detected. Clear on read if condition is resolved.	0 = No event 1 = Event detected

STATUS_0 (0xD)

A read-only register that includes information on the current status of the IC.

BIT	7	6	5	4	3	2	1	0
Field	–	–	–	CC_ATTACH	BC_ATTACH	VBMON_SAFE	–	VBUS_STATUS
Reset	–	–	–	0b0	0b0	0b0	–	0b0
Access Type	–	–	–	Read Only	Read Only	Read Only	–	Read Only

BITFIELD	BITS	DESCRIPTION	DECODE
CC_ATTACH	4	Type-C ATTACH Status Indicator. This bit indicates the current Type-C attachment status on the CC pins. More details can be read in the STATUS_1 register.	0 = No Type-C device currently attached 1 = Type-C device currently attached
BC_ATTACH	3	BC1.2 ATTACH Status Indicator. This bit indicates the current device attachment status on the HVDP/HVDM pins. More details can be read in the STATUS_1 register.	0 = No PD currently attached 1 = PD currently attached
VBMON_SAFE	2	VBMON (VBUS) Safe Status Indicator. Determines if the DC-DC converter can be turned on after a Type-C attachment. Only applicable with Type-C enabled.	0 = $V_{BUS} > V_{SAFE0V}$ 1 = $V_{BUS} < V_{SAFE0V}$

BITFIELD	BITS	DESCRIPTION	DECODE
VBUS_STAT	0	Type-C V _{BUS} Status Indicator	0 – V _{BUS} not applied to receptacle 1 – V _{BUS} applied to receptacle (Attached.SRC)

STATUS_1 (0xE)

A read-only register that includes information on the current status of the IC.

BIT	7	6	5	4	3	2	1	0
Field	–	–	CC_PIN_STATE[1:0]		CC_STATE[3:0]			
Reset	–	–	0b00					
Access Type	–	–	Read Only		Read Only			

BITFIELD	BITS	DESCRIPTION	DECODE
CC_PIN_STATE	5:4	Type-C Active CC Pin/Orientation Indicator	00 = No Attachment 01 = Rd detected on CC1 10 = Rd detected on CC2 11 = Not used
CC_STATE	3:0	Type-C Functional Status/State Indicator	0000 = Disabled 0010 = Error Recovery 0011 = Unattached.SRC 0110 = AttachWait.SRC 1000 = Attached.SRC (CC2) 1100 = Attached.SRC (CC1)

ADC_0 (0x10)

BIT	7	6	5	4	3	2	1	0
Field	ADC_USBI[7:0]							
Reset	0x00							
Access Type	Read Only							

BITFIELD	BITS	DESCRIPTION	DECODE
ADC_USBI	7:0	USB Output Current ADC Measurement Result	Output Current = ((116mV/256) x ADC_USBI)/R _{SENSE} (amperes)

ADC_1 (0x11)

BIT	7	6	5	4	3	2	1	0
Field	ADC_USBV[7:0]							
Reset	0x00							
Access Type	Read Only							

BITFIELD	BITS	DESCRIPTION	DECODE
ADC_USBV	7:0	USB Voltage ADC Measurement Result	V _{SENSP} = (19.8V/256) x ADC_USBV (volts), when VOUT[2:0] = b000

ADC_2 (0x12)

BIT	7	6	5	4	3	2	1	0
Field	ADC_TEMP[7:0]							
Reset	0x00							
Access Type	Read Only							

BITFIELD	BITS	DESCRIPTION	DECODE
ADC_TEMP	7:0	Die Temp ADC Measurement Result	Die Temp = $3.5^{\circ}\text{C} \times \text{ADC_TEMP} - 270 (^{\circ}\text{C})$

Applications Information

DC-DC Switching Frequency Selection

The switching frequency (f_{SW}) for MAX20459 is programmable through the CONFIG1 resistor.

Higher switching frequencies allow for smaller PCB area designs with lower inductor values and less output capacitance. Consequently, peak currents and I^2R losses are lower at higher switching frequencies, but core losses, gate-charge currents, and switching losses increase.

To avoid AM-band interference, operation between 500kHz and 1.8MHz is not recommended.

DC-DC Input Capacitor Selection

The input capacitor supplies the instantaneous current needs of the buck converter and reduces the peak currents drawn from the upstream power source. The input-bypass capacitor is a determining factor in the input-voltage ripple.

The input capacitor RMS current rating requirement (I_{RMS}) is defined by the following equation:

$$I_{RMS} = I_{LOAD(MAX)} \frac{\sqrt{V_{SENSP}(V_{SUPSW} - V_{SENSP})}}{V_{SUPSW}}$$

I_{RMS} has a maximum value when the input voltage equals twice the output voltage ($V_{SUPSW} = 2 \cdot V_{SENSP}$), so $I_{RMS(MAX)} = 1/2 \times I_{LOAD(MAX)}$.

Choose an input capacitor that exhibits less than 10°C self-heating temperature rise at the RMS input current for optimal long-term reliability.

The input-voltage ripple is composed of V_Q (caused by the capacitor discharge) and V_{ESR} (caused by the ESR of the capacitor). Use low-ESR ceramic capacitors with high ripple-current capability at the input. Assume the contribution from the ESR and capacitor discharge is equal to 50%. Calculate the input capacitance and ESR required for a specified input-voltage ripple using the following equations:

$$ESR_{IN} = \frac{\Delta V_{ESR}}{I_{OUT} + \frac{\Delta I_L}{2}}$$

where:

$$\Delta I_L = \frac{(V_{SUPSW} - V_{SENSP}) \times V_{SENSP}}{V_{SUPSW} \times f_{SW} \times L}$$

and:

$$C_{IN} = \frac{I_{OUT} \times D(1-D)}{\Delta V_Q \times f_{SW}} \text{ where } D = \frac{V_{SENSP}}{V_{SUPSW}}$$

Where I_{OUT} is the maximum output current and D is the duty cycle.

Bypass SUPSW with 0.1µF parallel to 10µF of ceramic capacitance close to the SUPSW and PGND pins. The ceramic input capacitor of a buck converter has a high $\frac{di}{dt}$; minimize the PCB current-loop area to reduce EMI. Bypass SUPSW with an additional 47µF of bulk electrolytic capacitance to dampen line transients.

DC-DC Output Capacitor Selection

To ensure stability and compliance with the USB and Apple specifications, follow the recommended output filters listed in [Table 9](#). For proper functionality, a minimum amount of ceramic capacitance must be used, regardless of f_{SW} . Additional capacitance for lower switching frequencies can be low-ESR electrolytic types (< 0.25Ω).

DC-DC Output Inductor Selection

Three key inductor parameters must be considered when selecting an inductor: inductance value (L), inductor saturation current (I_{SAT}), and DC resistance (R_{DCR}). To select the proper inductance value, the ratio of inductor peak-to-peak AC current to DC average current (LIR) must be selected. A small LIR will reduce the RMS current in the output capacitor and results in small output-ripple voltage, but this requires a larger inductor. A good compromise between size and loss is a 35% LIR. Determine the inductor value using the equation below.

$$L = \frac{V_{SENSP} \times (V_{SUPSW} - V_{SENSP})}{V_{SUPSW} \times f_{SW} \times I_{OUT} \times LIR}$$

where V_{SUPSW} , V_{SENSP} , and I_{OUT} are typical values (such that efficiency is optimum for nominal operating conditions). Ensure that the inductor I_{SAT} is above the buck converter's cycle-by-cycle peak current limit.

Table 9. Recommended Output Filters

f_{SW} (kHz)	L_{OUT} (μ H)	RECOMMENDED COUT
2200	1.5	22 μ F ceramic OR 10 μ F ceramic + low-ESR 22 μ F electrolytic (< 0.8 Ω)
488	8.2	3 x 22 μ F ceramic OR 22 μ F ceramic + low-ESR 68 μ F electrolytic (< 0.25 Ω)
310	12	22 μ F ceramic + low-ESR 68 μ F electrolytic (< 0.25 Ω)

Layout Considerations

Proper PCB layout is critical for robust system performance. See the MAX20459 EV kit datasheet for a recommended layout. Minimize the current-loop area and the parasitics of the DC-DC conversion circuitry to reduce EMI. The input capacitor placement should be prioritized because in a buck converter, the ceramic input capacitor has high $\frac{di}{dt}$. Place the input capacitor as close as possible to the IC SUPSW and PGND pins. Shorter traces should be prioritized over wider traces.

A low-impedance ground connection between the input and output capacitor is required (route through the ground pour on the exposed pad). Connect the exposed pad to ground. Place multiple vias in the pad to connect to all other ground layers for proper heat dissipation (failure to do so may result in the IC repeatedly reaching thermal shutdown). Do not use separate power and analog ground planes; use a single common ground and manage currents through component placement. High-frequency return current flows through the path of least impedance (through the ground pour directly underneath the corresponding traces).

Determining USB System Requirements

In a Dedicated USB Charging Port (DCP) application, the user port is generally located in a front-facing configuration on the DCP or HUB module. To avoid V_{BUS} voltage drop at the user port when current increases due to trace, connector, and output ferrite resistance, MAX20459 implement voltage-adjustment circuitry that increases the buck's output-voltage regulation point linearly with the output current. The voltage-adjustment gain can be set using either external resistors or I²C depending on the variant. The gain setting must be calculated to take into account all series element and voltage drops in the charging path, including ground return. See the USB Voltage Adjustment section for calculating the optimum gain setting for your application. User cable can be of different length and type, and therefore should not be included in the calculations.

USB Loads

MAX20459 is compatible with both USB-compliant and non-compliant loads. A compliant USB device is not allowed to sink more than 30mA and must not present more than 10 μ F of capacitance when initially attached to the port. The device then begins its HVD+/HVD- connection and enumeration process. After completion of the connect process, the device can pull 100mA/150mA and must not present a capacitance greater than 10 μ F. This is considered the hot-inserted, USB-compliant load of 44 Ω in parallel with 10 μ F.

For non-compliant USB loads, the ICs can also support both a hot insertion and soft-start into a USB load of 2Ω in parallel with 330μF.

USB Output Current Limit

The USB load current is monitored by an internal current-sense amplifier through the voltage created across R_{SENSE} . MAX20459 offers an adjustable USB current-limit threshold. See SETUP_2 or [Table 6](#) to select an appropriate register or resistor value for the desired current limit.

USB Voltage Adjustment

[Figure 7](#) shows a DC model of the voltage-correction function of MAX20459. Without voltage adjustment ($V_{ADJ} = 0$, $GAIN[4:0] = 0$), the voltage seen by the device at the end of the cable will decrease linearly as load current increases. To compensate for this, the output voltage of the buck converter should increase linearly with load current. The slope of $SENSP$ is called R_{COMP} such that $V_{ADJ} = R_{COMP} \cdot I_{LOAD}$ and $R_{COMP} = G \cdot R_{SENSE}$ (see [Figure 8](#)). The R_{COMP} adjustment values available on MAX20459 are listed in the $GAIN[4:0]$ register description and are based on a 33mΩ sense resistor.

For $V_{DUT} = V_{NO_LOAD}$; $0 \leq I_{LOAD} \leq 3A$, R_{COMP} must equal the sum of the system resistances. Calculate the minimum R_{COMP} for the system so that V_{DUT} stays constant:

$$R_{COMP_SYS} = R_{LR} + R_{SENSE} + R_{PCB} + R_{CABLE}$$

Where R_{CABLE} is the round-trip resistance of the USB cable (including the effect from the cable shield, if it conducts current), R_{LR} is the buck converter's load regulation expressed in mΩ (51mΩ typ.), and R_{PCB} is the resistance of any additional V_{BUS} parasitics (the V_{BUS} FET, PCB trace, ferrites, and the USB connectors). Find the setting for $GAIN[4:0]$ using the minimum R_{COMP} .

$$GAIN[4 : 0] = \text{ceiling}\left(\frac{R_{COMP_SYS}}{18m\Omega}\right)$$

The nominal DUT voltage can then be estimated at any load current by:

$$V_{DUT} = V_{NO_LOAD} + 18m\Omega \cdot GAIN[4 : 0] \cdot I_{LOAD} - R_{COMP_SYS} \cdot I_{LOAD}$$

These equations presume a 33mΩ sense resistor, which is recommended.

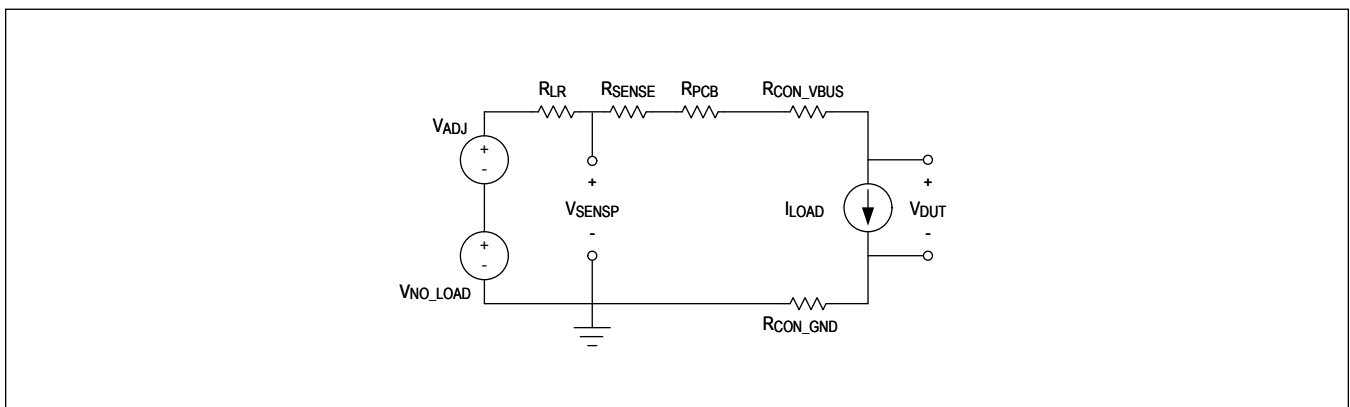


Figure 7. DC Voltage Adjustment Model

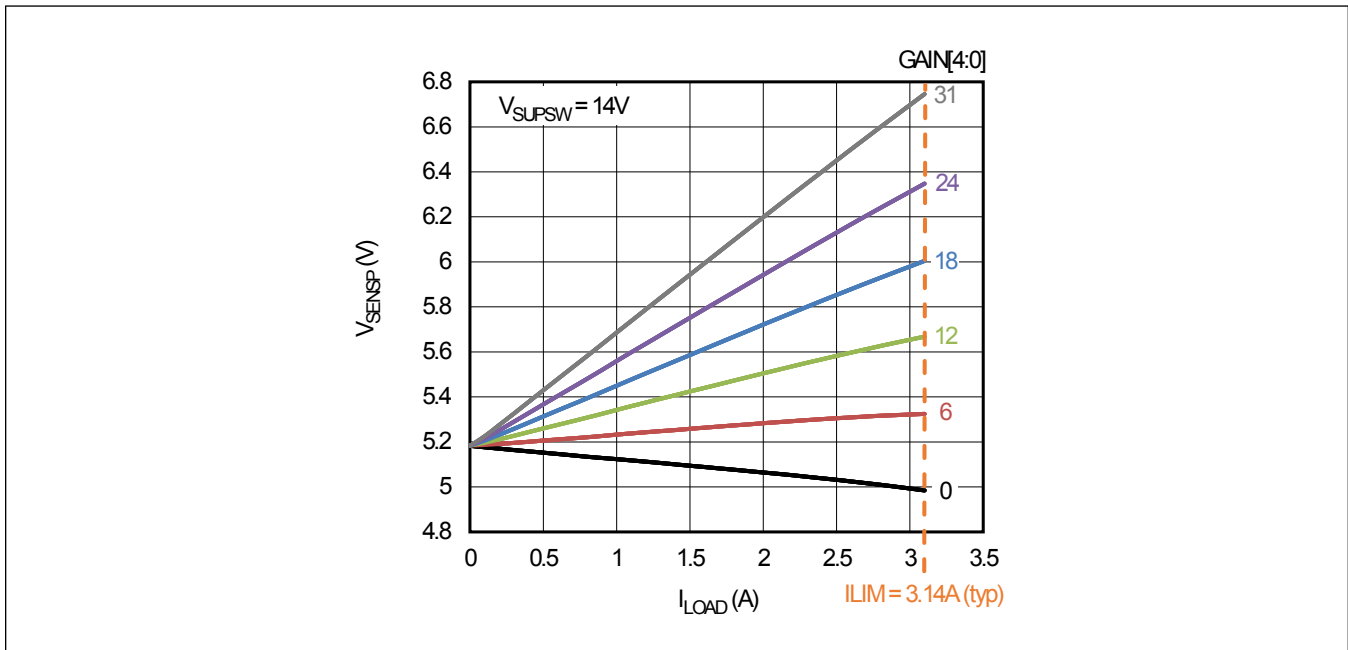


Figure 8. Increase in SENSE vs. USB Current

Selecting a Current-Sense Resistor

The external current-sense resistor (R_{SENSE}) is critical for accurate current-limit, voltage-adjustment, attach-detection, and ADC measurement. Select a resistor with high precision and low temperature variation (ppm). It is highly recommended that designs use a resistor with an exact value of 33mΩ. Since the current limit and voltage adjustment are selected digitally (there are a discrete number of levels), changing this value also changes the possible current-limit thresholds, the voltage-adjustment compensation, and the attach threshold. The specifications in the register and resistor tables will need to be scaled accordingly.

Use $R_{COMP} = G \cdot R_{SENSE}$ to scale for other resistance values.

Example CONFIG Resistor Selection

With $R_{PCB} = 20m\Omega$, $R_{SENSE} = 33m\Omega$, and $R_{LR} = 51m\Omega$, the total system resistance is $R_{COMP_SYS} = 20 + 33 + 51 = 104m\Omega$. The desired $GAIN[4:0]$ register setting is then $\text{ceiling}(104/18) = 6 = b00110$, which sets the adjustment level to 108mΩ. To set $GAIN[4:0]$ using the CONFIG resistors, the appropriate step must be selected for both CONFIG2 and CONFIG3. The MSb of the GAIN register ($GAIN[4]$) is selected by CONFIG3. In this example, $GAIN[4] = b0$. If it is a 3A application with automatic thermal foldback, then CONFIG3 should be set to Step 3, which is set with a 1370Ω resistor on the CONFIG3 pin.

From the previous calculation, $GAIN[3:0] = b0110$. This corresponds to Step 6 and a CONFIG2 resistor of 3090Ω. CONFIG1 sets the remaining parameters. For example, to run the buck using the internal clock switching at 488kHz with spread spectrum enabled, CONFIG1 should be set to Step 1 (619Ω).

ESD Protection

The high-voltage MAX20459 requires no external ESD protection. All Maxim devices incorporate ESD protection structures to protect against electrostatic discharges encountered during handling and assembly. While competing solutions can latch-up and require the power to be cycled after an ESD event, the MAX20459 continues to work without latch-up. When used with the configuration shown in the Typical Application Circuit, the MAX20459 is characterized for

protection to the following limits:

- $\pm 15\text{kV}$ ISO 10605 (330pF, 330 Ω) Air Gap
- $\pm 15\text{kV}$ ISO 10605 (330pF, 2k Ω) Air Gap
- $\pm 8\text{kV}$ ISO 10605 (330pF, 330 Ω) Contact
- $\pm 8\text{kV}$ ISO 10605 (330pF, 2k Ω) Contact
- $\pm 15\text{kV}$ IEC 61000-4-2 (150pF, 330 Ω) Air Gap
- $\pm 8\text{kV}$ IEC 61000-4-2 (150pF, 330 Ω) Contact

Note: All application-level ESD testing is performed on the standard evaluation kit.

ESD Test Conditions

ESD performance depends on a variety of conditions. Contact Maxim for test setup, test methodology, and test results.

Human Body Model

[Figure 9](#) shows the Human Body Model, and [Figure 11](#) shows the current waveform it generates when discharged into a low impedance. This model consists of a 100pF capacitor charged to the ESD voltage of interest, which is then discharged into the device through a 1.5k Ω resistor.

IEC 61000-4-2

The IEC 61000-4-2 standard covers ESD testing and performance of finished equipment. MAX20459 helps users design equipment that meets Level 4 of IEC 61000-4-2. The main difference between tests done using the Human Body Model and IEC 61000-4-2 is a higher peak current in IEC 61000-4-2. Because the series resistance is lower in the IEC 61000-4-2 ESD test model [Figure 10](#), the ESD withstand-voltage measured to this standard is generally lower than that measured using the Human Body Model. [Figure 12](#) shows the current waveform for the 8kV, IEC 61000-4-2 Level 4 ESD Contact Discharge test. The Air Gap Discharge test involves approaching the device with a charged probe. The Contact Discharge method connects the probe to the device before the probe is energized.

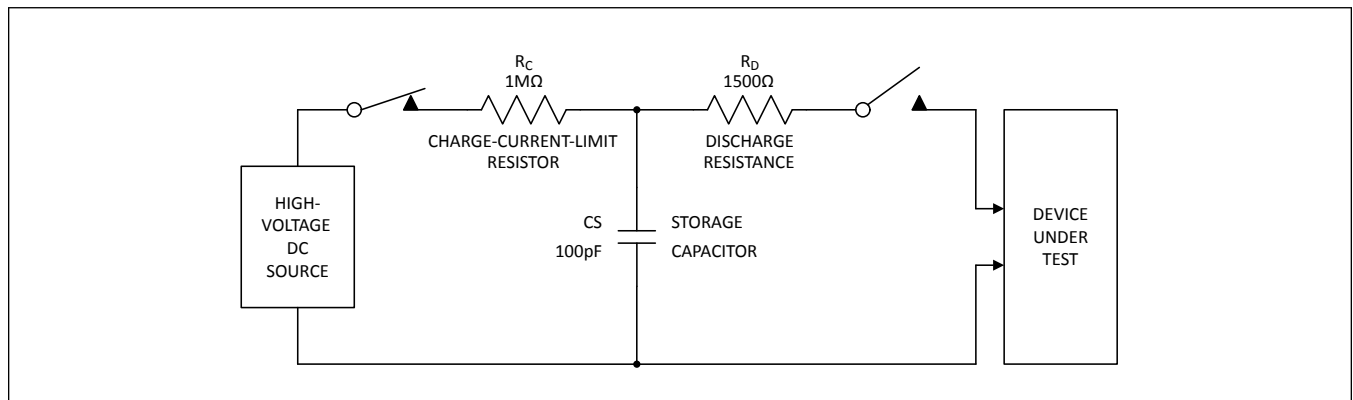


Figure 9. Human Body ESD Test Model

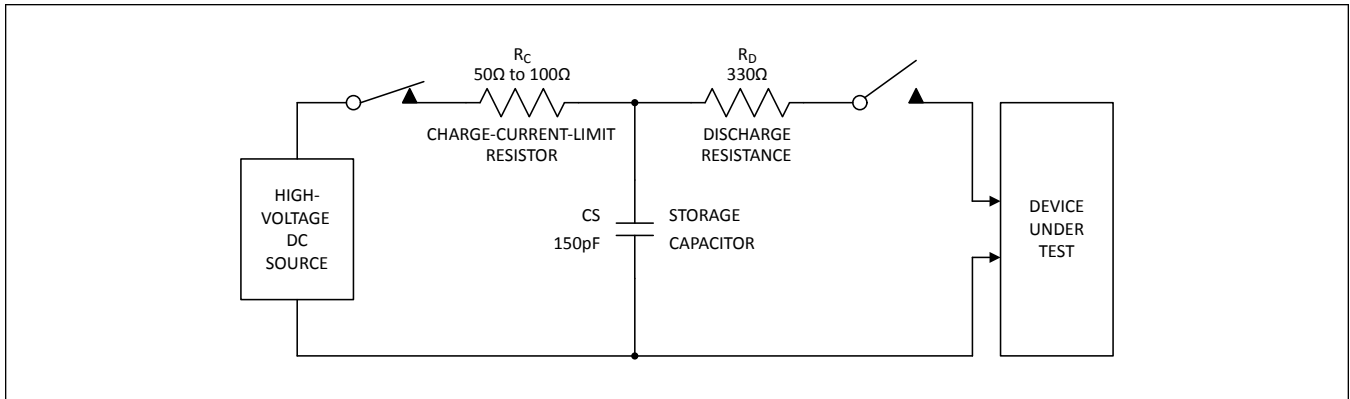


Figure 10. IEC 61000-4-2 ESD Test Model

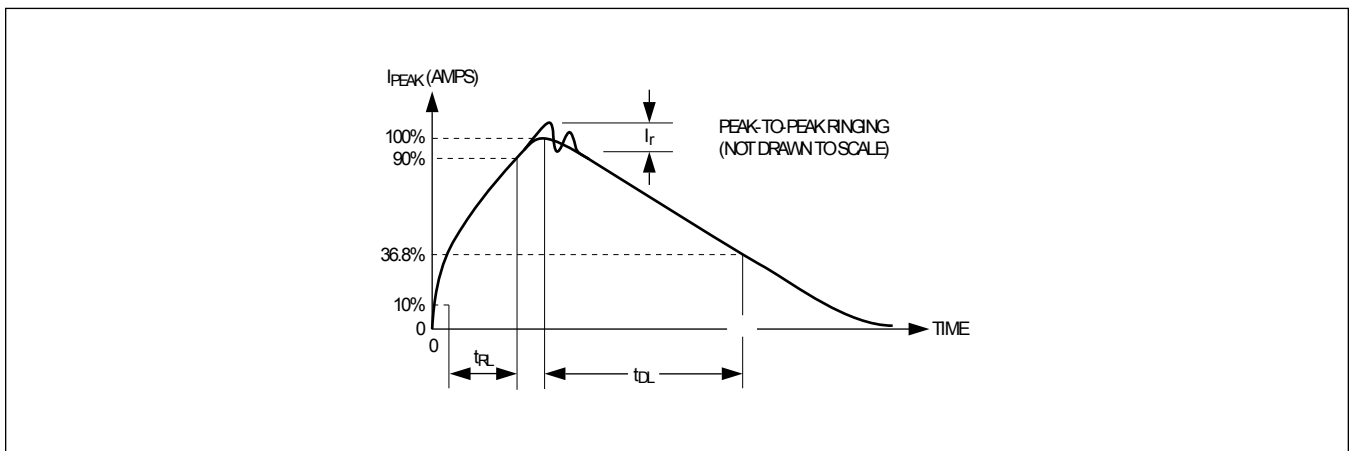


Figure 11. Human Body Current Waveform

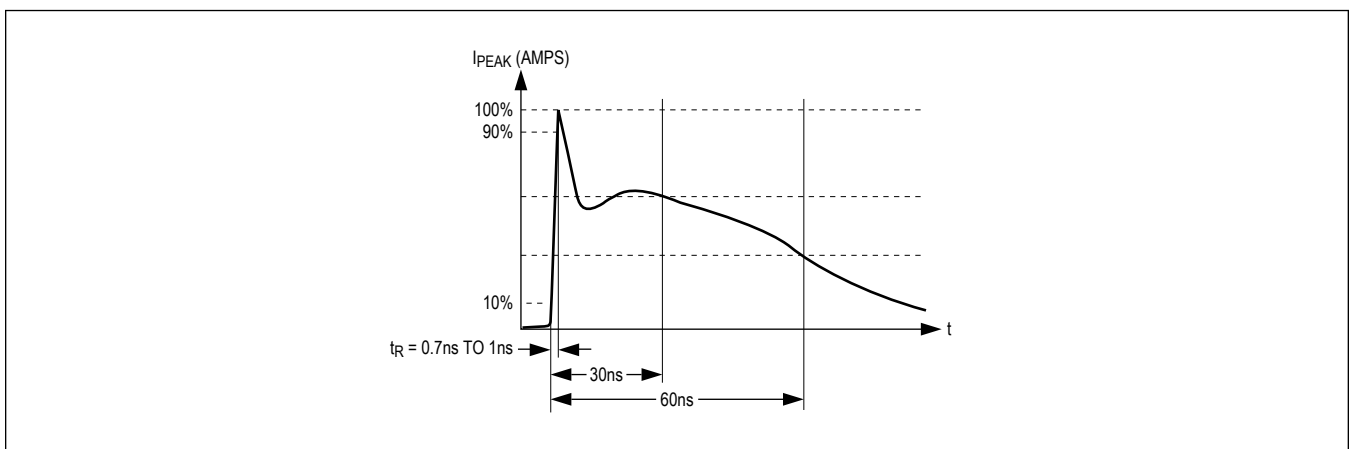
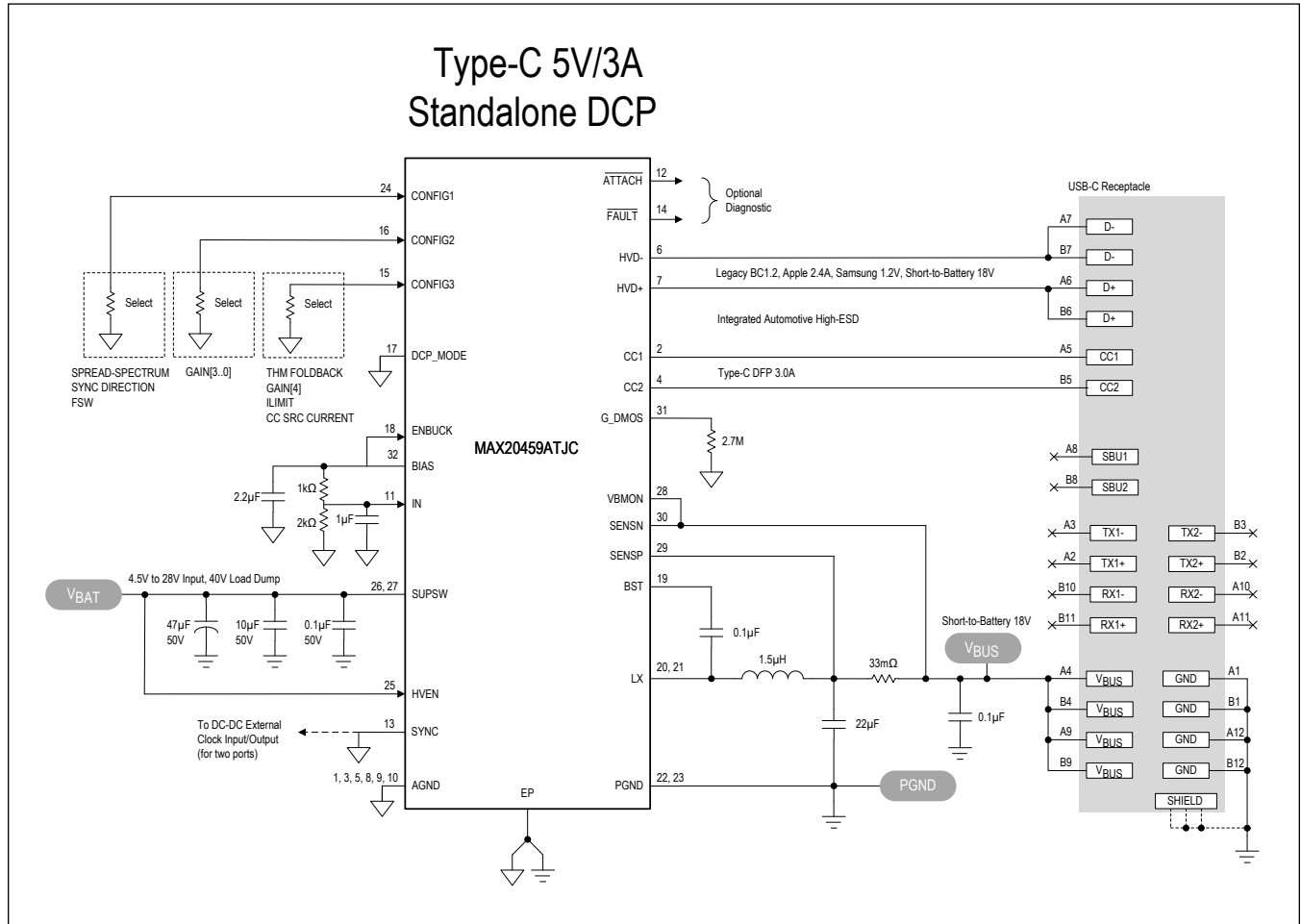


Figure 12. IEC 61000-4-2 Current Waveform

Typical Application Circuits



Ordering Information

PART NUMBER	TEMP RANGE	PIN-PACKAGE	I ² C
MAX20459ATJA/V+	-40°C to +125°C	32 TQFN-EP*	Yes
MAX20459ATJC/V+	-40°C to +125°C	32 TQFN-EP*	No

V Denotes Automotive Qualified Parts

+ Denotes a lead(Pb)-free/RoHS-compliant package.

*EP = Exposed pad.

MAX20459

Automotive High-Current Step-Down Converter with USB-C Dedicated Charging Port

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	11/19	Initial release	—

For pricing, delivery, and ordering information, please visit Maxim Integrated's online storefront at <https://www.maximintegrated.com/en/storefront/storefront.html>.

Maxim Integrated cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim Integrated product. No circuit patent licenses are implied. Maxim Integrated reserves the right to change the circuitry and specifications without notice at any time. The parametric values (min and max limits) shown in the Electrical Characteristics table are guaranteed. Other parametric values quoted in this data sheet are provided for guidance.