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MAX20335

Wearable Charge-Management Solution

General Description

The MAX20335 is a battery-charge-management solution ideal for low-power wearable applications. The device includes a linear battery charger with a smart power selector and several power-optimized peripherals. The MAX20335 features two ultra-low quiescent current buck regulators and three ultra-low quiescent current low-dropout (LDO) linear regulators, providing up to five regulated voltages, each with an ultra-low quiescent current, allows designers to minimize power consumption and extend battery life in 24/7 operation devices, such as those in the wearable market.

The battery charger features a smart power selector that allows operation on a dead battery when connected to a power source. To avoid overloading a power adapter, the input current to the smart power selector is limited based on an I^2C register setting. If the charger power source is unable to supply the entire system load, the smart power control circuit supplements the system load with current from the battery. The charger also supports temperature dependent charge currents.

The two synchronous, high-efficiency step-down buck regulators feature a variable frequency mode for increased efficiency during light-load operation. The output voltage of these regulators can be programmed through I^2C with the default preconfigured. The buck regulators can support dynamic voltage scaling to further improve system power consumption.

The three configurable LDOs each have a dedicated input pin. Each LDO regulator output voltage can be programmed through I^2C with the default preconfigured. The linear regulators can also be configured to operate as power switches that may be used to disconnect the quiescent load of the system peripherals.

The MAX20335 features a programmable power controller that allows the device to be configured for applications that require the device be in a true-off, or always-on, state. The controller also provides a delayed reset signal and voltage sequencing.

The MAX20335 is available in a 36-bump, 0.4mm pitch, 2.72mm x 2.47mm wafer-level package (WLP).

Benefits and Features

- Extend System Use Time Between Battery Charging
  - Dual Ultra-Low-I_Q 200mA Buck Regulators
    - Output Programmable from 0.7V to 2.275V and 0.7V to 3.85V
    - 0.9µA (typ) Quiescent Current (Buck 1)
    - Optional Fixed Peak-Current Mode to Optimize Ripple Frequency in Noise-Sensitive Applications
  - Three Ultra-Low-I_Q 100mA LDOs
  - LDO1
    - Output Programmable from 0.8V to 3.6V
    - 0.6µA (typ) Quiescent Current
    - 2.7V to 5.5V Input with Dedicated Pin
  - LDO2/3
    - Output Programmable from 0.9V to 4V
    - 1µA (typ) Quiescent Current
    - 1.71V to 5.5V Input with Dedicated Pin
- Easy-to-Implement Li+ Battery Charging
  - Smart Power Selector
  - 28V/-5.5V Tolerant Input
  - Thermistor Monitor
- Minimize Solution Footprint Through High Integration
  - Provides Five Regulated Voltage Rails
  - Switch Mode Option on Each LDO
- Optimize System Control
  - Monitors Pushbutton for Ultra-Low Power Mode
  - Power-On Reset Delay and Voltage Sequencing
  - On-Chip Voltage Monitor Multiplexer

Applications

- Wearable Electronics
- Fitness Monitors
- Rechargeable IoT devices

***Ordering Information* appears at end of data sheet.**

19-100288; Rev 0; 3/18

maxim integrated™

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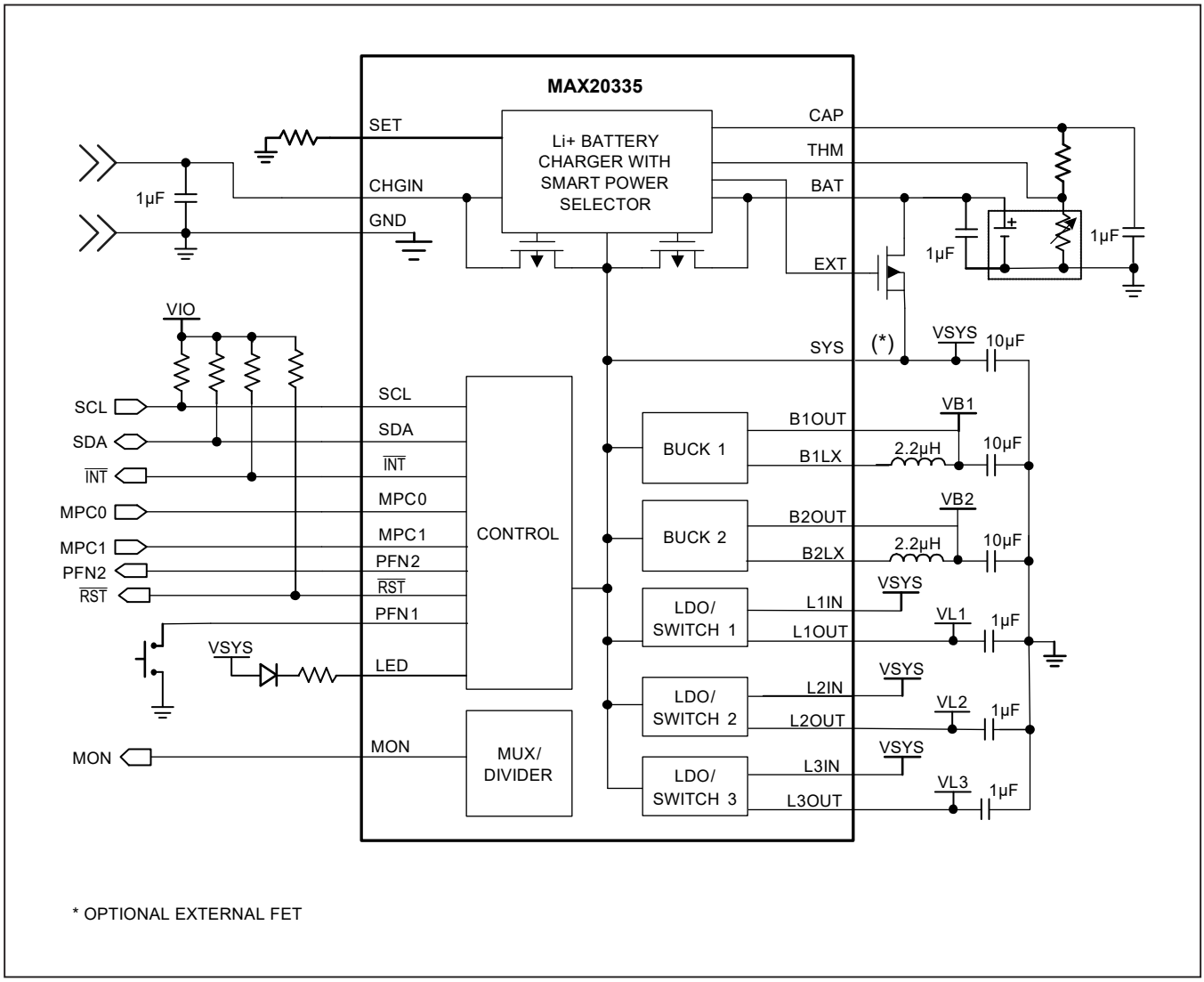
Typical Application Circuit



Absolute Maximum Ratings

(Voltages referenced to GND.)
SDA, SCL, THM, $\overline{RST}$, SYS, PFN1, PFN2, MPC0, MPC1, $\overline{INT}$, MON, BAT, LED, L1IN, L2IN, L3IN ..... -0.3V to +6.0V
B1LX, B2LX, B1OUT, B2OUT, EXT ..... -0.3V to (V_{SYS} + 0.3V)
L1OUT ..... -0.3V to (V_{L1IN} + 0.3V)
L2OUT ..... -0.3V to (V_{L2IN} + 0.3V)
L3OUT ..... -0.3V to (V_{L3IN} + 0.3V)
CHGIN ..... -6V to +30V
CAP ..... -0.3V to min ($|V_{CHGIN}|$ + 0.3V, +6V)
SET ..... -0.3V to V_{BAT} + 0.3V
Continuous Current into CHGIN, BAT, SYS .....±1000mA
Continuous Current into any other terminal .....±100mA
Continuous Power Dissipation (multilayer board at +70°C):
6 x 6 Array 36-Bump 2.72mm x 2.47mm
0.4mm Pitch WLP (derate 21.70mW/°C).....1.74W
Operating Temperature Range..... -40°C to +85°C
Junction Temperature.....+150°C
Storage Temperature Range..... -65°C to +150°C
Soldering Temperature (reflow).....+260°C

Package Information

PACKAGE TYPE: 36 WLP	
Package Code	W362D2+1
Outline Number	**21-0897**
Land Pattern Number	Refer to **Application Note 1891**
THERMAL RESISTANCE, FOUR-LAYER BOARD	
Junction to Ambient (θ_{JA})	46°C/W

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_{CHGIN} = 5.0V, V_{BAT} = 3.7V, T_A = -40°C to +85°C, all registers in their default state, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
GLOBAL SUPPLY CURRENT (L_IN Connected to SYS)						
Charger Input Current	I_{CHG}	All functions disabled		0.26		mA
		Power on, V_{CHGIN} = 5V SYS switch closed, buck regulators enabled, LDO1 enabled, I_{SYS} = 0A, I_{B_OUT} = 0A, I_{L_OUT} = 0A			1.5	
BAT Input Current	I_{BAT}	Power off, V_{CHGIN} = 0V, SYS switch open		0.96	1.7	µA
		Power on, V_{CHGIN} = 0V SYS switch closed, 2x buck regulators enabled, LDOs disabled. I_{SYS} = 0A, I_{B_OUT} = 0A		2.8	4.3	
		Power on, V_{CHGIN} = 0V SYS switch closed, 2x buck regulators enabled, LDO1 enabled, I_{SYS} = 0A, I_{B_OUT} = 0A, I_{L_OUT} = 0A		3.5	7	
		Power on, V_{CHGIN} = 0V SYS switch closed, 2x buck regulators enabled, 3x LDOs enabled, I_{SYS} = 0A, I_{B_OUT} = 0A, I_{L_OUT} = 0A		5.2		
BUCK REGULATOR 1 (V_{SYS} = +3.7V, L = 2.2µH, C = 2.2µF, V_{B1OUT} = 1.2V)						
Input Voltage	V_{IN_BUCK1}	Input voltage = V_{SYS}	2.7		5.5	V
Output Voltage	V_{OUT_BUCK1}	25mV step resolution	0.7		2.275	V
Output UVLO Voltage	V_{UVLO_BUCK1}	**Note:** For V_{OUT} < UVLO ZC is imposed. Falling edge (75mV typ hysteresis)		0.35	0.55	V
Quiescent Supply Current	I_{Q_BUCK1}	Buck enabled, I_{B1OUT} = 0mA, V_{SYS} = 3.7V, V_{B1OUT} = 1.2V (Note 2)		0.9	1.3	µA
Dropout Quiescent Supply Current	I_{QDO_BUCK1}	I_{B1OUT} = 0mA, (V_{SYS} – V_{OUT}) ≤ 0.1V		1.1		mA
Shutdown Supply Current with Active Discharge Enabled	I_{SD_BUCK1}	Buck1 disabled. Falling edge (75mV typ hysterisis)		60		µA
Output Accuracy	ACC_{BUCK1}	I_{B1OUT} = 1mA	-2.5		+2.5	%
Peak-to-Peak Ripple	$V_{PPRIPPLE1}$	Buck1ISet = 100mA, C_{OUT} = 2.2µF, I_{B1OUT} = 1mA		10		mV
I_{PEAK} Set Range	I_{PEAK_BUCK1}	25mA step resolution set by Buck1ISet[3:0].	50		375	mA

Electrical Characteristics (continued)

(V_{CHGIN} = 5.0V, V_{BAT} = 3.7V, T_A = -40°C to +85°C, all registers in their default state, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Load Regulation Error	V_{LOADR_BUCK1}	Buck1ISet = 150mA, Buck1IAdptEnb = 0, I_{B1OUT} = 300mA		-3		%
Line Regulation Error	V_{LINER_BUCK1}	V_{B1OUT} = 1.2V; V_{SYS} from 2.7V to 5.5V		3		mV
Maximum Operating Output Current	I_{OUT_BUCK1}	V_{SYS} = 3.7V, Buck1VSet = 1.2V, Buck1ISet = 200mA, Buck1IAdptEnb = 0, load regulation error = -5%	200	500		mA
B1OUT Pulldown Current	I_{LEAK_B1OUT}	Buck1 enabled		110		nA
B1OUT Pulldown Resistance	R_{PD_B1OUT}	Buck1 disabled, V_{B1OUT} = 1.2V		12		MΩ
pMOS On-Resistance	R_{ONP_BUCK1}	Buck1FFET = 0		0.27	0.5	Ω
		Buck1FFET = 1		0.55	1	Ω
nMOS On-Resistance	R_{ONN_BUCK1}	Buck1FFET = 0		0.24	0.45	Ω
		Buck1FFET = 1		0.43	0.9	Ω
Freewheeling On-Resistance	R_{ONFW_BUCK1}	V_{SYS} = 3.7V, V_{B1OUT} = 1.2V		7.3	13	Ω
Minimum T_{ON}	T_{ON_MIN}			40	80	ns
Maximum Duty Cycle	D_{MAX_BUCK1}	Buck1IAdptEnb = 0		98		%
Switching Frequency	f_{SW_BUCK1}	Load regulation error = -3%		3		MHz
Average Current During Short-Circuit to GND	I_{SHRT_BUCK1}	Buck1ISet = 150mA, Buck1IAdptEnb = 0, V_{B1OUT} = 0V		100		mA
BLX Leakage Current	I_{BLX_BUCK1}			0.005	1	µA
Active Discharge Current	I_{PD_BUCK1}	V_{B1OUT} = 1.2V		17		mA
Passive Discharge Resistance	R_{PD_BUCK1}	V_{B1OUT} = 1.2V		9		kΩ
Full Turn-On Time	t_{ON_BUCK1}	Time from enable to full current capability, Buck1Fst = 0		58		ms
Efficiency	Eff_{BUCK1}	I_{LOAD} = 10mA, Buck1ISet = 150mA, Inductor = BOURNS SRP2010-2R2M, V_{B1OUT} = 1.2V		87		%
BLX Rising/Falling Slew Rate	SR_{BLX_BUCK1}	Buck1LowEMI = 0		2		V/ns
		Buck1LowEMI = 1		0.5		
Thermal-Shutdown Temperature	T_{SHDN_BUCK1}			140		°C
Thermal-Shutdown Temperature Hysteresis	$T_{SHDN\_HYST\_BUCK1}$			10		°C

Electrical Characteristics (continued)

(V_{CHGIN} = 5.0V, V_{BAT} = 3.7V, T_A = -40°C to +85°C, all registers in their default state, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
BUCK REGULATOR 2 (V_{SYS} = +3.7V, L = 2.2µH, C = 2.2µF, V_{B2OUT} = 1.2V)						
Input Voltage	V_{IN_BUCK2}	Input voltage = V_{SYS}	2.7		5.5	V
Output Voltage	V_{OUT_BUCK2}	50mV step resolution	0.7		3.85	V
Output UVLO Voltage	V_{UVLO_BUCK2}	**Note:** For V_{OUT} < UVLO ZC is imposed. Falling edge (75mV typ hysteresis)		0.35	0.55	V
Quiescent Supply Current	I_{Q_BUCK2}	Buck enabled, I_{B2OUT} = 0mA, V_{SYS} = 3.7V, V_{B2OUT} = 1.2V (Note 2)		1	1.4	µA
Dropout Quiescent Supply Current	I_{QDO_BUCK2}	I_{B2OUT} = 0mA, $V_{SYS} - V_{B2OUT} \le 0.1V$		1.1		mA
Shutdown Supply Current with Active Discharge Enabled	I_{SD_BUCK2}	Buck1 disabled, Buck2ActDSC = 1.		60		µA
Output Accuracy	ACC_{BUCK2}	I_{B2OUT} = 1mA, V_{B2OUT} < 3.4V	-2.5		+2.5	%
Peak-to-Peak Ripple	$V_{PPRIPPLE2}$	Buck2ISet = 100mA, C_{OUT} = 2.2µF, I_{B2OUT} = 1mA		10		mV
I_{PEAK} Set Range	I_{PEAK_BUCK2}	25mA step resolution set by Buck2ISet[3:0].	50		375	mA
Load Regulation Error	V_{LOADR_BUCK2}	Buck2ISet = 150mA, Buck2IAdptEnb = 0, I_{B2OUT} = 300mA		-3		%
Line Regulation Error	V_{LINER_BUCK2}	V_{B2OUT} = 1.2V; V_{SYS} from 2.7V to 5.5V		3		mV
Maximum Operating Output Current	I_{OUT_BUCK2}	V_{SYS} = 3.7V, Buck2VSet = 1.2V, Buck2ISet = 200mA, Buck2IAdptEnb = 0, load regulation = -5%	200	500		mA
B2OUT Pulldown Current	I_{LEAK_B2OUT}	Buck2 enabled		220		nA
B2OUT Pulldown Resistance	R_{PD_B2OUT}	Buck2 disabled, V_{B2OUT} = 1.2V		6		MΩ
pMOS On-Resistance	R_{ONP_BUCK2}	Buck2FFET = 0		0.27	0.5	Ω
		Buck2FFET = 1		0.55	1	Ω
nMOS On-Resistance	R_{ONN_BUCK2}	Buck2FFET = 0		0.24	0.45	Ω
		Buck2FFET = 1		0.43	0.9	Ω
Freewheeling On-Resistance	R_{ONFW_BUCK2}	V_{SYS} = 3.7V, V_{B2OUT} = 1.2V		7.3	13	Ω

Electrical Characteristics (continued)

(V_{CHGIN} = 5.0V, V_{BAT} = 3.7V, T_A = -40°C to +85°C, all registers in their default state, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Minimum T_{ON}	T_{ON_MIN}			40	80	ns
Maximum Duty Cycle	D_{MAX_BUCK2}	Buck2IAdptEnb = 0		98		%
Switching Frequency	f_{SW_BUCK2}	Load regulation error = -3%		3		MHz
Average Current During Short-Circuit to GND	I_{SHRT_BUCK2}	Buck2ISet = 150mA, Buck2IAdptEnb = 0, V_{B2OUT} = 0V		100		mA
BLX Leakage Current	I_{BLX_BUCK2}			0.005	1	µA
Active Discharge Current	I_{PD_BUCK2}	V_{B2OUT} = 1.2V		17		mA
Passive Discharge Resistance	R_{PD_BUCK2}	V_{B2OUT} = 1.2V		9		kΩ
Full Turn-On Time	T_{ON_BUCK2}	Time from enable to full current capability, Buck2Fst = 0		58		ms
Efficiency	Eff_{BUCK2}	I_{LOAD} = 10mA, Buck2ISet = 150mA, Inductor = BOURNS SRP2010-2R2M, V_{B2OUT} = 1.2V		87		%
BLX Rising/Falling Slew Rate	SR_{BLX_BUCK2}	Buck2LowEMI = 0		2		V/ns
		Buck2LowEMI = 1		0.5		
Thermal-Shutdown Temperature	T_{SHDN_BUCK2}			140		°C
Thermal-Shutdown Temperature Hysteresis	$T_{SHDN\_HYST\_BUCK2}$			10		°C
LDO1 (C = 1µF, unless otherwise noted. Typical values are at V_{L1IN} = 3.7V, with I_{L1OUT} = 10mA, V_{L1OUT} = 3V.)						
Input Voltage	V_{INLDO1}	LDO mode	2.7		5.5	V
		Switch mode	1.2		5.5	V
Quiescent Supply Current	I_{Q_LDO1}	LDO enabled, I_{L1OUT} = 0µA		0.55	4	µA
		LDO enabled, I_{L1OUT} = 0µA, Switch mode		0.45		
Shutdown Supply Current with Active Discharge Enabled	I_{SD_LDO1}	LDO1 disabled. LDO1ActDSC=1.		55		µA
Maximum Output Current	I_{L1OUT_MAX}		100			mA
Output Voltage	V_{L1OUT}		0.8		3.6	V
Output Accuracy	ACC_{LDO1}	V_{L1IN} = (V_{L1OUT} + 0.5V) or higher, I_{L1OUT} = 100µA	-2.7		+2.7	%

Electrical Characteristics (continued)

(V_{CHGIN} = 5.0V, V_{BAT} = 3.7V, T_A = -40°C to +85°C, all registers in their default state, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Dropout Voltage	V_{DROP_LDO1}	V_{L1IN} = 3V, $I_{L1OUT\_}$ = 100mA, LDO1VSet = 3V			102	mV
Line Regulation Error	$V_{LINEREG\_LDO1}$	V_{L1IN} = (V_{L1OUT} + 0.5V) to 5.5V	-0.12	0.022	+0.12	%/V
Load Regulation Error	$V_{LOADREG\_LDO1}$	I_{L1OUT} = 100µA to 100mA		0.002	0.005	%/mA
Line Transient	$V_{LINETRAN\_LDO1}$	V_{L1IN} = 4V to 5V, 200ns rise time		±36		mV
		V_{L1IN} = 4V to 5V, 1µs rise time		±28		mV
Load Transient	$V_{LOADTRAN\_LDO1}$	I_{L1OUT} = 0mA to 10mA, 200ns rise time		145		mV
		I_{L1OUT} = 0mA to 100mA, 200ns rise time		290		mV
Passive Discharge Resistance	R_{PD_LDO1}		5	10	16	KΩ
Active Discharge Current	I_{ADL_LDO1}	V_{L1IN} = 3.7V	7	20	37	mA
Switch Mode Resistance	R_{ON_LDO1}	V_{L1IN} = 2.7V, I_{L1OUT} = 100mA		0.5	0.85	Ω
		V_{L1IN} = 1.8V, I_{L1OUT} = 100mA		0.76	1.3	
		V_{L1IN} = 1.2V, I_{L1OUT} = 5mA		1.7	2.8	
Turn-On Time	t_{ON_LDO1}	I_{L1OUT} = 0mA, time from 10% to 90% of final value		1.6	3.7	ms
		I_{L1OUT} = 0mA, time from 10% to 90% of final value, Switch mode		0.25	0.65	
Short-Circuit Current Limit	I_{SHRT_LDO1}	V_{L1IN} = 2.7V, V_{L1OUT} = GND	150	345	550	mA
		V_{L1IN} = 2.7V , V_{L1OUT} = GND, Switch mode	150	335	550	mA
Thermal-Shutdown Temperature	T_{SHDN_LDO1}			150		°C
Thermal-Shutdown Temperature Hysteresis	$T_{SHDN\_HYST\_LDO1}$			16		°C
Output Noise	OUT_{NOISE}	10Hz to 100kHz, V_{L1IN} = 5V, V_{L1OUT} = 3.3V		110		µVrms
		10Hz to 100kHz, V_{L1IN} = 5V, V_{L1OUT} = 2.5V		95		
		10Hz to 100kHz, V_{L1IN} = 5V, V_{L1OUT} = 1.2V		60		
		10Hz to 100kHz, V_{L1IN} = 5V, V_{L1OUT} = 0.8V		60		

Electrical Characteristics (continued)

(V_{CHGIN} = 5.0V, V_{BAT} = 3.7V, T_A = -40°C to +85°C, all registers in their default state, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
LDO2 (C = 1µF, unless otherwise noted. Typical values are at V_{L2IN} = 3.7V, with I_{L2OUT} = 10mA, V_{L2OUT} = 3V.)						
Input Voltage	V_{INLDO2}	LDO mode	1.71		5.5	V
		Switch mode	1.2		5.5	V
Quiescent Supply Current	I_{Q_LDO2}	I_{L2OUT} = 0µA		1	5.1	µA
		I_{L2OUT} = 0µA, Switch mode		0.5		
Quiescent Supply Current in Dropout	I_{QDO_LDO2}	I_{L2OUT} = 0µA, V_{L2IN} = 2.9V, LDO2VSet = 3V.		1.8		µA
Shutdown Supply Current with Active Discharge Enabled	I_{SD_LDO2}	LDO2 disabled. LDO2ActDSC=1.		54		µA
Maximum Output Current	I_{L2OUT_MAX}	V_{L2IN} ≥ 2.7V	100			mA
		V_{L2IN} = 1.8V or lower	50			mA
Output Voltage	V_{L2OUT}		0.9		4	V
Output Accuracy	ACC_{LDO2}	V_{L2IN} = (V_{L2OUT} + 0.5V) or higher, I_{L2OUT} = 100µA	-2.7		+2.7	%
Dropout Voltage	V_{DROP_LDO2}	V_{L2IN} = 3V, $I_{L2OUT\_}$ = 100mA, LDO2VSet = 3V			100	mV
Line Regulation Error	$V_{LINEREG\_LDO2}$	V_{L2IN} = (V_{L2OUT} + 0.5V) to 5.5V	-0.4	+0.05	+0.4	%/V
Load Regulation Error	$V_{LOADREG\_LDO2}$	I_{L2OUT} = 100µA to 100mA		0.001	0.005	%/mA
Line Transient	$V_{LINETRAN\_LDO2}$	V_{L2IN} = 4V to 5V, 200ns rise time		±35		mV
		V_{L2IN} = 4V to 5V, 1µs rise time		±25		mV
Load Transient	$V_{LOADTRAN\_LDO2}$	I_{L2OUT} = 0mA to 10mA, 200ns rise time		100		mV
		I_{L2OUT} = 0mA to 100mA, 200ns rise time		200		mV
Passive Discharge Resistance	R_{PD_LDO2}		5	10	16	KΩ
Active Discharge Current	I_{ADL_LDO2}	V_{L2IN} = 3.7V	7	20	37	mA
Switch Mode Resistance	R_{ON_LDO2}	V_{L2IN} = 2.7V, I_{L2OUT} = 100mA		0.46	0.76	Ω
		V_{L2IN} = 1.8V, I_{L2OUT} = 50mA		0.7	1.15	
		V_{L2IN} = 1.2V, I_{L2OUT} = 5mA		1.7	2.6	
Turn-On Time	t_{ON_LDO2}	I_{L2OUT} = 0mA, time from 10% to 90% of final value		1.5	3.7	ms
		I_{L2OUT} = 0mA, time from 10% to 90% of final value, Switch mode		0.25	0.65	

Electrical Characteristics (continued)

(V_{CHGIN} = 5.0V, V_{BAT} = 3.7V, T_A = -40°C to +85°C, all registers in their default state, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Short-Circuit Current Limit	I_{SHRT_LDO2}	V_{L2IN} = 2.7V, V_{L2OUT} = GND	140	340	600	mA
		V_{L2IN} = 2.7V , V_{L2OUT} = GND, Switch mode	140	330	600	mA
Thermal-Shutdown Temperature	T_{SHDN_LDO2}			150		°C
Thermal-Shutdown Temperature Hysteresis	$T_{SHDN\_HYST\_LDO2}$			21		°C
Output Noise	OUT_{NOISE}	10Hz to 100kHz, V_{L2IN} = 5V, V_{L2OUT} = 3.3V		150		µVrms
		10Hz to 100kHz, V_{L2IN} = 5V, V_{L2OUT} = 2.5V		125		
		10Hz to 100kHz, V_{L2IN} = 5V, V_{L2OUT} = 1.2V		90		
		10Hz to 100kHz, V_{L2IN} = 5V, V_{L2OUT} = 0.9V		80		
L2IN UVLO	V_{UVLO_LDO2}	V_{L2IN} Falling	1.14	1.38		V
		V_{L2IN} Rising		1.4	1.64	
LDO3 (C = 1µF, unless otherwise noted. Typical values are at V_{L3IN} = 3.7V, with I_{L3OUT} = 10mA, V_{L3OUT} = 3V.)						
Input Voltage	V_{INLDO3}	LDO mode	1.71		5.5	V
		Switch mode	1.2		5.5	V
Quiescent Supply Current	I_{Q_LDO3}	I_{L3OUT} = 0µA		1	5.1	µA
		I_{L3OUT} = 0µA, Switch mode		0.5		
Quiescent Supply Current in Dropout	I_{QDO_LDO3}	I_{L3OUT} = 0µA, V_{L3IN} = 2.9V, LDO3VSet = 3V.		1.8		µA
Shutdown Supply Current with Active Discharge Enabled	I_{SD_LDO3}	LDO3 disabled. LDO3ActDSC=1.		54		µA
Maximum Output Current	I_{L3OUT_MAX}	V_{L3IN} ≥ 2.7V	100			mA
		V_{L3IN} = 1.8V or lower	50			mA
Output Voltage	V_{L3OUT}		0.9		4	V
Output Accuracy	ACC_{LDO3}	V_{L3IN} = (V_{L3OUT} + 0.5V) or higher, I_{L3OUT} = 100µA	-2.7		+2.7	%
Dropout Voltage	V_{DROP_LDO3}	V_{L3IN} = 3V, $I_{L3OUT\_}$ = 100mA, LDO3VSet = 3V			100	mV

Electrical Characteristics (continued)

(V_{CHGIN} = 5.0V, V_{BAT} = 3.7V, T_A = -40°C to +85°C, all registers in their default state, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Line Regulation Error	$V_{LINEREG\_LDO3}$	V_{L3IN} = (V_{L3OUT} + 0.5V) to 5.5V	-0.4	+0.05	+0.4	%/V
Load Regulation Error	$V_{LOADREG\_LDO3}$	I_{L3OUT} = 100µA to 100mA		0.001	0.005	%/mA
Line Transient	$V_{LINETRAN\_LDO3}$	V_{L3IN} = 4V to 5V, 200ns rise time		±35		mV
		V_{L3IN} = 4V to 5V, 1µs rise time		±25		mV
Load Transient	$V_{LOADTRAN\_LDO3}$	I_{L3OUT} = 0mA to 10mA, 200ns rise time		100		mV
		I_{L3OUT} = 0mA to 100mA, 200ns rise time		200		mV
Passive Discharge Resistance	R_{PD_LDO3}		5	10	16	KΩ
Active Discharge Current	I_{ADL_LDO3}	V_{L3IN} = 3.7V	7	20	37	mA
Switch Mode Resistance	R_{ON_LDO3}	V_{L3IN} = 2.7V, I_{L3OUT} = 100mA		0.46	0.76	Ω
		V_{L3IN} = 1.8V, I_{L3OUT} = 100mA		0.7	1.15	
		V_{L3IN} = 1.2V, I_{L3OUT} = 5mA		1.7	2.6	
Turn-On Time	t_{ON_LDO3}	I_{L3OUT} = 0mA, time from 10% to 90% of final value		1.5	3.7	ms
		I_{L3OUT} = 0mA, time from 10% to 90% of final value, Switch mode		0.25	0.65	
Short-Circuit Current Limit	I_{SHRT_LDO3}	V_{L3IN} = 2.7V, V_{L3OUT} = GND	140	340	600	mA
		V_{L3IN} = 2.7V , V_{L3OUT} = GND, Switch mode	140	330	600	mA
Thermal-Shutdown Temperature	T_{SHDN_LDO3}			150		°C
Thermal-Shutdown Temperature Hysteresis	$T_{SHDN\_HYST\_LDO3}$			21		°C
Output Noise	OUT_{NOISE}	10Hz to 100kHz, V_{L3IN} = 5V, V_{L3OUT} = 3.3V		150		µVrms
		10Hz to 100kHz, V_{L3IN} = 5V, V_{L3OUT} = 2.5V		125		
		10Hz to 100kHz, V_{L3IN} = 5V, V_{L3OUT} = 1.2V		80		
		10Hz to 100kHz, V_{L3IN} = 5V, V_{L3OUT} = 0.9V		60		
L3IN UVLO	V_{UVLO_LDO3}	V_{L3IN} Falling	1.14	1.38		V
		V_{L3IN} Rising		1.4	1.64	

Electrical Characteristics (continued)

(V_{CHGIN} = 5.0V, V_{BAT} = 3.7V, T_A = -40°C to +85°C, all registers in their default state, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
CHGIN TO SYS PATH (V_{CHGIN} = 5.0V, V_{SYS} = V_{SYS_REG})						
Allowed CHGIN Input Voltage Range	V_{CHGIN_RNG}		-5.5		28	V
V_{CHGIN} Detect Threshold	V_{CHGIN_DET}	Rising	3.8	3.9	4.1	V
		Falling	3.0	3.1	3.2	
V_{CHGIN} Overvoltage Threshold	V_{CHGIN_OV}	Rising	7.2	7.5	7.8	V
V_{CHGIN} Overvoltage Threshold Hysteresis	$V_{CHGIN\_OV\_HYS}$			200		mV
V_{CHGIN} Valid Trip Point	$V_{CHGIN-SYS\_TP}$	V_{CHGIN} – V_{SYS}, Rising, V_{BAT} = 4V	+30	+145	+290	mV
V_{CHGIN} Valid Trip Point Hysteresis	$V_{CHGIN-SYS\_TP\_HYS}$			275		mV
Input Limiter Current	I_{LIM}	ILimCntl[1:0] = 00		0		mA
		ILimCntl[1:0] = 01		90	100	
		ILimCntl[1:0] = 10		450	550	
		ILimCntl[1:0] = 11		1000		
Internal CAP Regulator	V_{CAP}	V_{CHGIN} = 5V	3.9	4.2	4.7	V
CHGIN-SYS Regulation Voltage	$V_{CHGIN-SYS}$	V_{CHGIN} = 4V, I_{SYS} = 1mA		40		mV
CHGIN to SYS On-Resistance	$R_{CHGIN-SYS}$	V_{CHGIN} = 4.4V, I_{SYS} = 500mA		370	660	mΩ
Thermal-Shutdown Temperature	T_{CHGIN_SHDN}	(Note 3)		+150		°C
Thermal-Shutdown Temperature Hysteresis	$T_{CHGIN\_SHDN\_HYS}$			30		°C
Input Current Soft-Start Time	t_{SFST_LIM}			1		ms
Internal Supply Switchover Threshold	V_{CCINT_TH}	V_{CHGIN} = V_{CAP} rising, V_{BAT} = 4.2V	2.5	2.8	3.0	V

Electrical Characteristics (continued)

(V_{CHGIN} = 5.0V, V_{BAT} = 3.7V, T_A = -40°C to +85°C, all registers in their default state, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
SYS, BATTERY, AND VCCINT UVLOs						
SYS UVLO Threshold	$V_{SYSUVLO\_R}$	Rising		2.64	2.69	V
	$V_{SYSUVLO\_F}$	Falling	2.57	2.62	2.67	V
SYS UVLO Threshold Hysteresis	$V_{SYSUVLO\_HYS}$	Hysteresis		26		mV
SYS UVLO Falling Debounce Time	$t_{SYSUVLO\_FDEB}$	SYS Falling		20		µs
V_{CCINT} UVLO Threshold (POR)	V_{UVLO}	V_{CCINT} Rising	0.8	1.82	2.6	V
V_{CCINT} UVLO Threshold Hysteresis	V_{UVLO_HYS}			140		mV
BAT UVLO Threshold	V_{BAT_UVLO}	Rising (Valid only when CHGIN is present. When $V_{BAT} < V_{BAT\_UVLO}$, the BAT-SYS switch opens and BAT is connected to SYS through a diode.)	1.9	2.05	2.2	V
BAT UVLO Threshold Hysteresis	$V_{BAT\_UVLO\_HYS}$	Hysteresis		50		mV
BATTERY CHARGER (See Figure 5a and Figure 5b) (V_{BAT} = 4.2V. Typical values are at V_{CHGIN} = 5.0V, V_{SYS} = V_{SYS_REG})						
Allowed BAT Voltage Range	V_{BAT_RNG}		0		5.5	V
BAT to SYS On-Resistance	$R_{BAT-SYS}$	V_{BAT} = 4.2V, I_{BAT} = 300mA		80	140	mΩ
Current Reduce Thermal Threshold Temperature	T_{CHG_LIM}	(Note 4)		120		°C
BAT-to-SYS Switch-On Threshold	$V_{BAT-SYS-ON}$	SYS falling	10	22	35	mV
BAT-to-SYS Switch-Off Threshold	$V_{BAT-SYS-OFF}$	SYS rising	-3	-1.5	0	mV
SYS-BAT Regulation Voltage	V_{SYS_REG}	V_{CHGIN} = 5V, I_{SYS} = 1mA	V_{BatReg} + 140mV	V_{BatReg} + 200mV	V_{BatReg} + 260mV	V

Electrical Characteristics (continued)

(V_{CHGIN} = 5.0V, V_{BAT} = 3.7V, T_A = -40°C to +85°C, all registers in their default state, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
SYS Threshold Voltage Charger Limiting Current (Note 5)	V_{SYS_LIM}	SysMin = 000, V_{BAT} > 3.6V		V_{BAT}+ 0.1		V
		SysMin = 000, V_{BAT} < 3.4V		3.6		
		SysMin = 001, V_{BAT} < 3.4V		3.7		
		SysMin = 010, V_{BAT} < 3.4V		3.8		
		SysMin = 011, V_{BAT} < 3.4V		3.9		
		SysMin = 100, V_{BAT} < 3.4V	3.86	4	4.14	
		SysMin = 101, V_{BAT} < 3.4V		4.1		
		SysMin = 110, V_{BAT} < 3.4V		4.2		
		SysMin = 111, V_{BAT} < 3.4V		4.3		
Charger Current Soft-Start Time	t_{CHG_SOFT}			1		ms
PRECHARGE						
Precharge Current	I_{PCHG}	IPChg = 00		5		%I_{FChg}
		IPChg = 01	9	10	11	
		IPChg = 10		20		
		IPChg = 11		30		
Prequalification Threshold	V_{BAT_PChg}	VPChg = 000		2.1		V
		VPChg = 001	2.15	2.25	2.35	
		VPChg = 010		2.40		
		VPChg = 011		2.55		
		VPChg = 100		2.7		
		VPChg = 101		2.85		
		VPChg = 110		3.0		
		VPChg = 111		3.15		
Prequalification Threshold Hysteresis	$V_{BAT\_PChg\_HYS}$			90		mV

Electrical Characteristics (continued)

(V_{CHGIN} = 5.0V, V_{BAT} = 3.7V, T_A = -40°C to +85°C, all registers in their default state, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
FAST CHARGE						
SET Current Gain Factor	K_{SET}			2000		A/A
SET Regulation Voltage	V_{SET}			1		V
Fast-Charge Current	I_{FChg}	R_{SET} = 400kΩ		5		mA
		R_{SET} = 40kΩ	45	50	55	
		R_{SET} = 4kΩ	450	500	550	
Fast-Charge Current Accuracy (Note 6)	I_{FChg_ACC}	R_{SET} Range = 4kΩ to 40kΩ	-10		+10	%
MAINTAIN CHARGE						
Charge Done Qualification	I_{Chg_DONE}	ChgDone = 00		5		%I_{FChg}
		ChgDone = 01	8.5	10	11.5	
		ChgDone = 10		20		
		ChgDone = 11		30		
BAT Regulation Voltage (Note 7)	V_{BatReg}	BatReg = 0000		4.05		V
		BatReg = 0001		4.10		
		BatReg = 0010		4.15		
		BatReg = 0011, T_A = +25°C	4.179	4.2	4.221	
		BatReg = 0011, T_A = 0 to +45C	4.168	4.2	4.232	
		BatReg = 0100		4.25		
		BatReg = 0101		4.3		
		BatReg = 0110		4.35		
		BatReg = 0111		4.4		
		BatReg = 1000		4.45		
		BatReg = 1001		4.5		
		BatReg = 1010		4.55		
		BatReg = 1011		4.6		
BAT Recharge Threshold	$V_{BatReChg}$	BatReChg = 00		V_{BatReg} - 70		mV
		BatReChg = 01		V_{BatReg} - 120		
		BatReChg = 10		V_{BatReg} -170		
		BatReChg = 11		V_{BatReg} -220		

Electrical Characteristics (continued)

(V_{CHGIN} = 5.0V, V_{BAT} = 3.7V, T_A = -40°C to +85°C, all registers in their default state, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
CHARGER TIMER						
Maximum Prequalification Time	t_{PChg}	PChgTmr = 00		30		min
		PChgTmr = 01		60		
		PChgTmr = 10		120		
		PChgTmr = 11		240		
Maximum Fast-Charge Time	t_{FChg}	FChgTmr = 00		75		min
		FChgTmr = 01		150		
		FChgTmr = 10		300		
		FChgTmr = 11		600		
Maintain-Charge Time	t_{TOChg}	TOChgTmr = 00		0		min
		TOChgTmr = 01		15		
		TOChgTmr = 10		30		
		TOChgTmr = 11		60		
Timer Accuracy	t_{CHG_ACC}		-10		+10	%
Timer Extend Threshold	TIM_{EXD_THRES}	If charge current is reduced due to ILIM or TDIE this is the percentage of charge current below which timer clock operates at half speed		50		$\%I_{FChg}$
Timer Suspend Threshold	TIM_{SUS_THRES}	If charge current is reduced due to ILIM or TDIE this is the percentage of charge current below which timer clock pauses		20		$\%I_{FChg}$
THERMISTOR MONITOR AND NTC DETECTION						
THM Hot Threshold	T_4	V_{THM} falling	30.9	32.9	34.9	%CAP
		V_{THM} falling	21.3	23.3	25.3	
THM Warm Threshold	T_3	V_{THM} falling	48	50	52	
		V_{THM} falling	30.9	32.9	34.9	
THM Cool Threshold	T_2	V_{THM} rising	62.5	64.5	66.5	
THM Cold Threshold	T_1	V_{THM} rising	71.9	73.9	75.9	
THM Disable Threshold	THM_{DIS}	V_{THM} rising	91	93	95	
THM Threshold Hysteresis	THM_{HYS}			60		mV
THM Input Leakage	I_{LKG_THM}		-1		1	µA

Electrical Characteristics (continued)

(V_{CHGIN} = 5.0V, V_{BAT} = 3.7V, T_A = -40°C to +85°C, all registers in their default state, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
START UP TIMING (See Figure 2)						
Boot Delay	t_{RST}	BootDly = 00		80		ms
		BootDly = 01		120		
		BootDly = 10		220		
		BootDly = 11		420		
Boot Delay Timer Accuracy	t_{RST_ACC}		-10		10	%
DIGITAL SIGNALS						
Input Logic-High (SDA, SCL, MPC0, MPC1, PFN1, PFN2)	V_{IH}		1.4			V
Input Logic-Low (SDA, SCL, MPC0, MPC1, PFN1, PFN2)	V_{IL}				0.5	V
Output Logic-Low (SDA, $\overline{RST}$, $\overline{INT}$, LED, PFN2)	V_{OL}	I_{OL} = 4mA			0.4	V
High Level Leakage Current (SDA, $\overline{RST}$, $\overline{INT}$, LED, PFN2)	I_{LK}				1	µA
SCL Clock Frequency	f_{SCL}				400	kHz
Bus Free Time Between a STOP and START Condition	t_{BUF}		1.3			µs
START Condition (Repeated) Hold Time	$t_{HD:STA}$	(Note 8)	0.6			µs
Low Period of SCL Clock	t_{LOW}		1.3			µs
High Period of SCL Clock	t_{HIGH}		0.6			µs
Setup Time for a Repeated START Condition	$t_{SU:STA}$		0.6			µs
Data Hold Time	$t_{HD:DAT}$	(Note 9)	0		0.9	µs
Data Setup Time	$t_{SU:DAT}$	(Note 9)	100			ns
Setup Time for STOP Condition	$t_{SU:STO}$		0.6			µs
Spike Pulse Widths Suppressed by Input Filter	t_{SP}	(Note 10)		50		ns

Electrical Characteristics (continued)

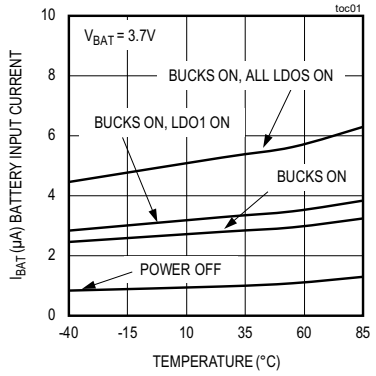
(V_{CHGIN} = 5.0V, V_{BAT} = 3.7V, T_A = -40°C to +85°C, all registers in their default state, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

Note 1: All devices are 100% production tested at T_A = +25°C. Limits over the operating temperature range guaranteed by design.
Note 2: This value is included in the I_{BAT} quiescent current values for the ON states.
Note 3: When the die temperature exceeds T_{CHGIN_SHDN}, the CHGIN to SYS path opens, and the charger is turned off.
Note 4: When the die temperature exceeds T_{CHG_LIM}, the charger current starts to decrease.
Note 5: This is the threshold at which the charger starts to limit the current due to SYS dropping; if VSYS drops below this value the charger will not move to maintain charge.
Note 6: Fast charge current accuracy tested only at 50mA and 500mA, all other values guaranteed by design.
Note 7: Values over temperature are not production tested and guaranteed by characterization.
Note 8: f_{SCL} must meet the minimum clock low time plus the rise/fall times.
Note 9: The maximum $t_{HD:DAT}$ has to be met only if the device does not stretch the low period (t_{LOW}) of the SCL signal.
Note 10: Filters on SDA and SCL suppress noise spikes at the input buffers and delay the sampling instant.

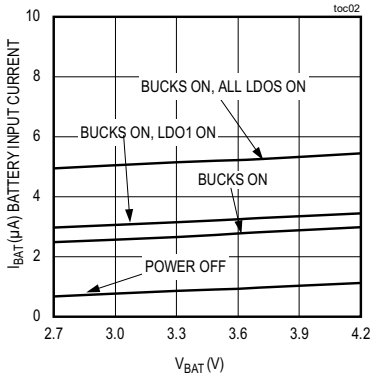
Typical Operating Characteristics

(V_{BAT} = 3.7V, V_{CHGIN} = 0V, registers in their default state, T_A = +25°C, unless otherwise noted.)

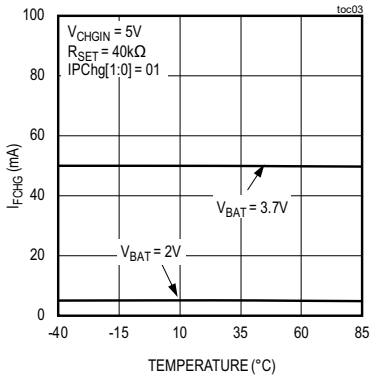
I_{BAT} vs. TEMPERATURE



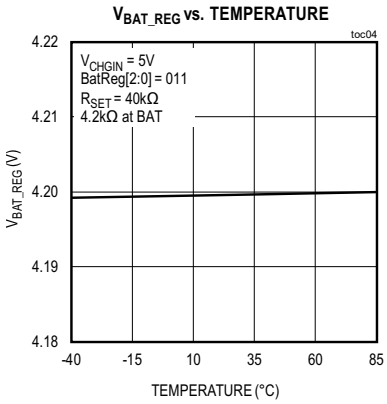
I_{BAT} vs. V_{BAT}



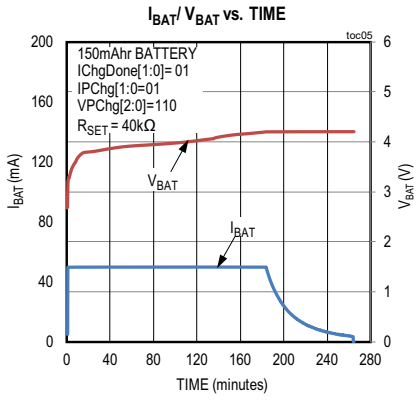
I_{FCHG} vs. TEMPERATURE



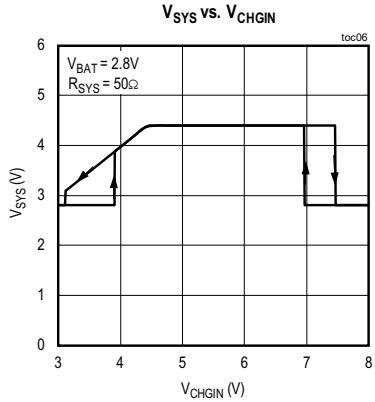
V_{BAT_REG} vs. TEMPERATURE



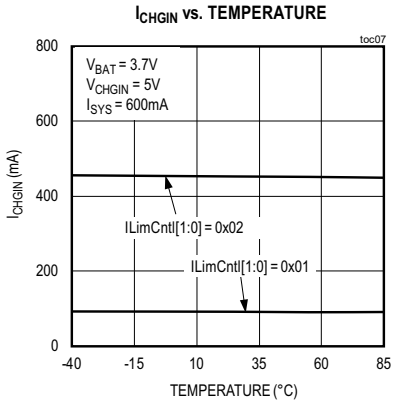
I_{BAT}/ V_{BAT} vs. TIME



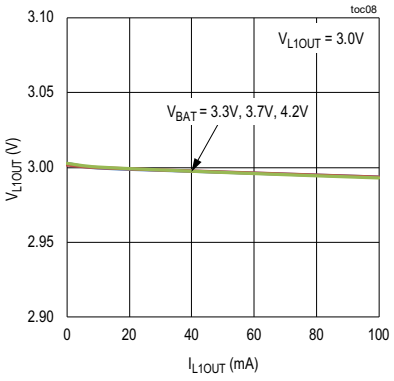
V_{SYS} vs. V_{CHGIN}



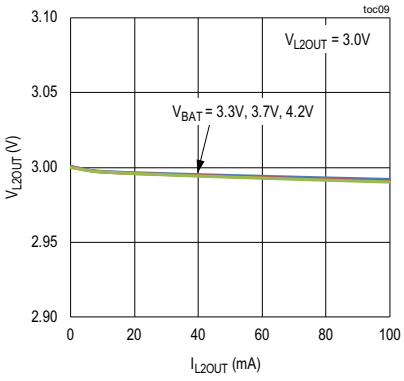
I_{CHGIN} vs. TEMPERATURE



V_{L1OUT} vs. LOAD



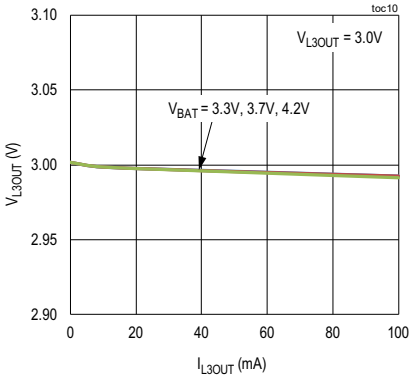
V_{L2OUT} vs. LOAD



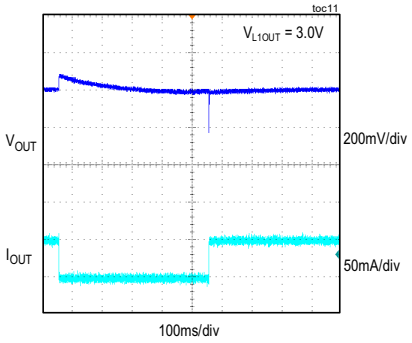
Typical Operating Characteristics (continued)

(V_{BAT} = 3.7V, V_{CHGIN} = 0V, registers in their default state, T_A = +25°C, unless otherwise noted.)

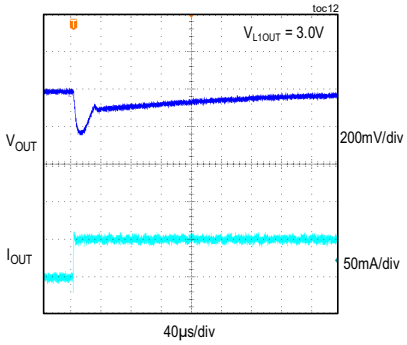
V_{L3OUT} vs. LOAD



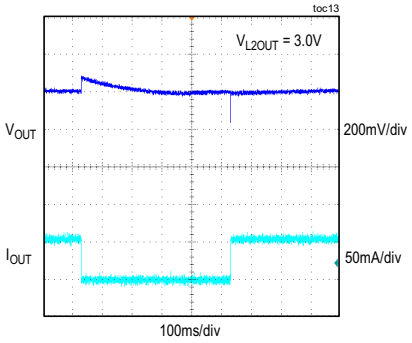
LDO1 TRANSIENT RESPONSE



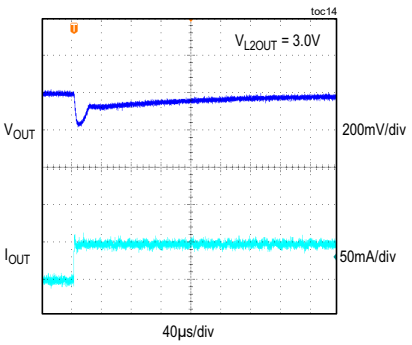
LDO1 TRANSIENT RESPONSE



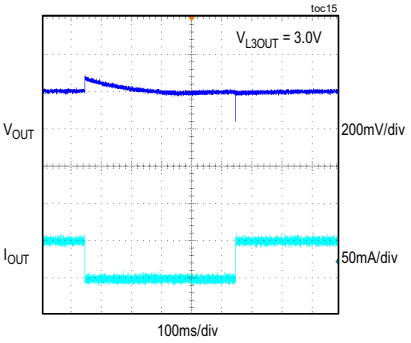
LDO2 TRANSIENT RESPONSE



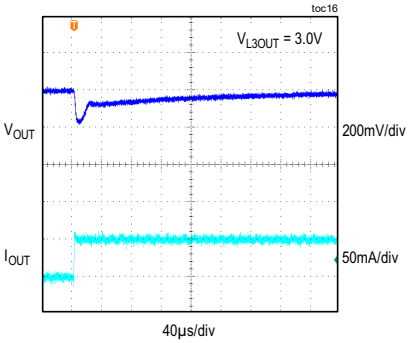
LDO2 TRANSIENT RESPONSE



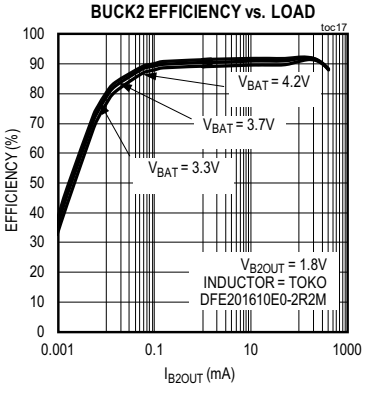
LDO3 TRANSIENT RESPONSE



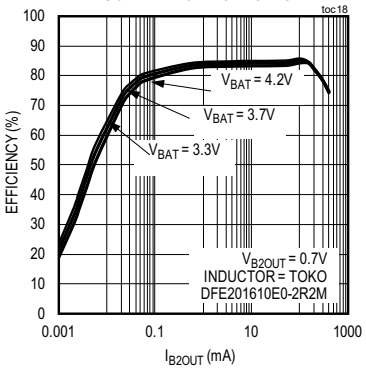
LDO3 TRANSIENT RESPONSE



BUCK2 EFFICIENCY vs. LOAD

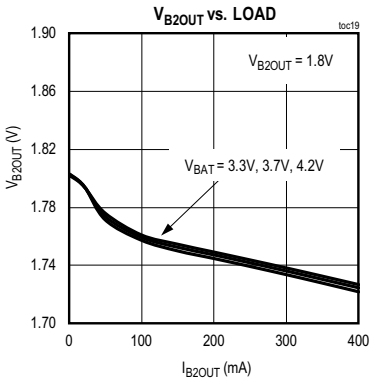


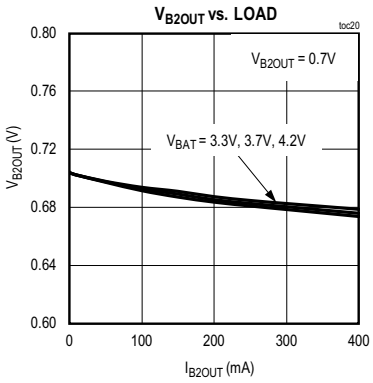
BUCK2 EFFICIENCY vs. LOAD

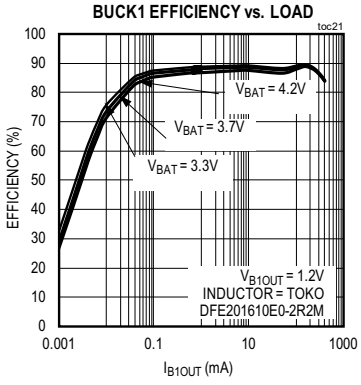


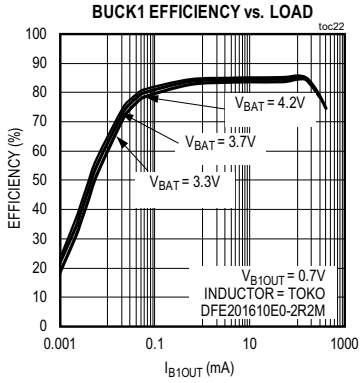
Typical Operating Characteristics (continued)

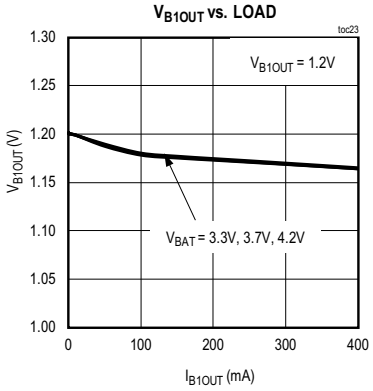
(V_{BAT} = 3.7V, V_{CHGIN} = 0V, registers in their default state, T_A = +25°C, unless otherwise noted.)

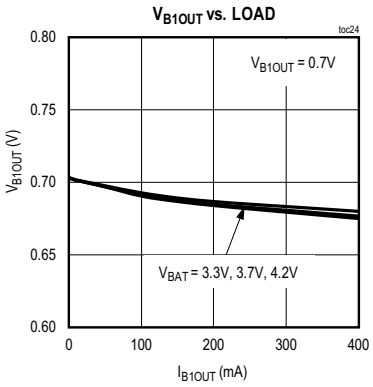


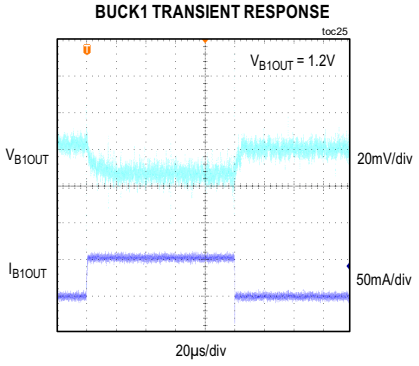


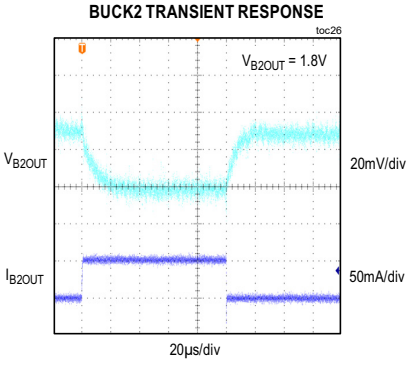




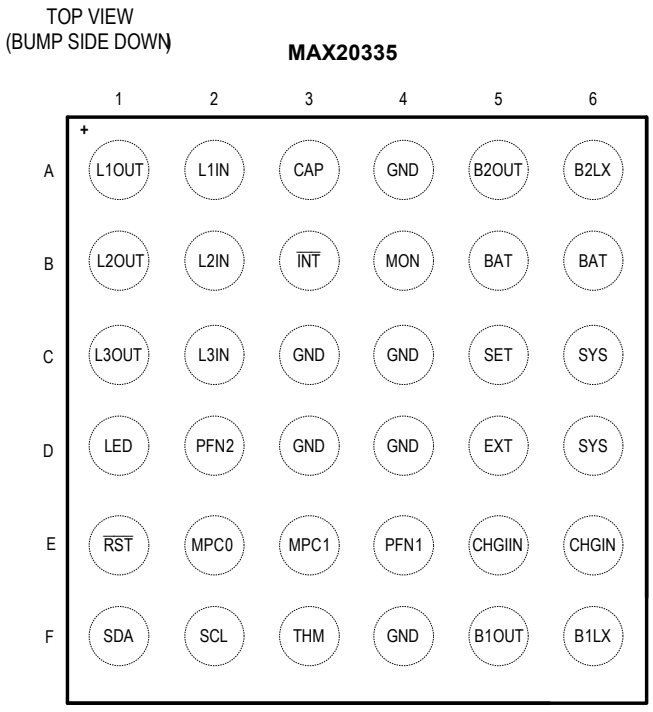








Bump Configuration



WLP
(2.72mm x 2.47mm)

Bump Description

BUMP	NAME	FUNCTION
A1	L1OUT	LDO1 Output. Bypass with a minimum 1µF capacitor to GND.
A2	L1IN	LDO1 Input
A3	CAP	Bypass for Internal LDO. Bypass with a 1µF capacitor to GND.
A4, C3, C4 D3, D4, F4	GND	Ground
A5	B2OUT	0.7V to 3.85V Buck Regulator Output Feedback. Bypass with a 10µF capacitor to GND.
A6	B2LX	0.7V to 3.85V Buck Regulator Switch. Connect 2.2µH inductor to B2OUT.
B1	L2OUT	LDO2 Output. Bypass with a minimum 1µF capacitor to GND.
B2	L2IN	LDO2 Input
B3	$\overline{INT}$	Open-Drain, Active-Low Interrupt Output.
B4	MON	Voltage Monitor Pin
B5,B6	BAT	Battery Connection. Connect BAT to a positive battery terminal, bypass BAT with a minimum 1µF capacitor to GND.