MAX8895V/MAX8895W/ MAX8895X/MAX8895Y

Li-Ion Chargers with Smart Power Selector, Adapter Type Detection, and USB Enumeration

General Description

The MAX8895_ USB-compliant linear battery chargers operate from either a USB port or dedicated charger with automatic detection of adapter type and USB enumeration capability. The MAX8895_ integrate the battery disconnect switch, current-sense circuit, MOSFET pass elements, and thermal regulation circuitry, and eliminate the external reverse-blocking Schottky diode to create the simplest and smallest stand-alone charging solutions.

The MAX8895_ includes an automated detection of charge adapter type, making it possible to distinguish between USB 2.0 device, USB charger, and dedicated charger devices. Furthermore, the MAX8895_ include a USB enumeration function that automatically negotiates with a USB host, making it possible to achieve the highest current available from a USB 2.0 device or USB charger without processor intervention. The adapter type detection is compliant with USB 2.0 specification as well as USB charging Revision 1.1.

The MAX8895_ controls the charging sequence for single-cell Li+ batteries from initial power-OK indication, through prequalification, fast-charge, top-off, and finally charge termination. Charging is controlled using constant current, constant voltage, and constant die-temperature (CCCVCTj) regulation for safe operation under all conditions. The maximum charging current is adaptively controlled by subtracting the system current from the input current limit, ensuring that the charging current is always maximized for any given operating condition.

The MAX8895_ features optimized smart power control to make the best use of limited USB or adapter power. Battery charge current is set independently of the SYS_ input current limit. Power not used by the system charges the battery. Automatic input selection switches the system from battery to external power. This allows the application to operate without a battery, discharged battery, or dead battery.

Other features include undervoltage lockout (UVLO), overvoltage protection (OVP), charge status flag, charge fault flag, power-OK monitor, battery thermistor monitor, charge timer, and a 3.3V output.

The MAX8895_ operates from a +4.0V to +6.6V supply and include overvoltage protection up to +16V. The MAX8895_ is specified over the extended temperature range (-40°C to +85°C) and are available in a compact 2.36mm x 2.36mm, 25-bump WLP package (0.4mm pitch).

Features

♦ **Enables Charging from a USB Port***

♦ **Automatic Detection of Adapter Type**

♦ **Enumeration Capability Without Processor Intervention**

♦ **USB Low-Speed Operation Without External Crystal (MAX8895V/MAX8895W/MAX8895X)**

♦ **USB Full-Speed Operation Using an External Crystal (MAX8895Y)**

♦ **Compliant with USB 2.0 Specification**

♦ **Compliant with USB Charging Specification (Revision 1.1)**

♦ **Adaptive Input Current Limit for Dedicated Charger**

♦ **Input Overvoltage Protection to 16V**

♦ **Automatic Current Sharing Between Battery Charging and System**

♦ **Smart Power Selector™ Allows Operation with Discharged or No Battery**

♦ **NTC Monitoring of Battery Temperature**

♦ **No External MOSFETs Required**

♦ **Thermal Regulation Prevents Overheating**

♦ **2µA Shutdown Current**

♦ **Tiny 2.36mm x 2.36mm, 25-Bump, 0.4mm Pitch WLP Package**

Applications

Bluetooth® Headsets

Charging Cradles

Portable Devices

Ordering Information and *Typical Operating Circuit* **appear at end of data sheet.**

Bluetooth is a registered trademark of Bluetooth SIG.

Smart Power Selector is a trademark of Maxim Integrated Products, Inc.
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For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim's website at www.maximintegrated.com.

MAX8895V/MAX8895W/MAX8895X/MAX8895Y

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ABSOLUTE MAXIMUM RATINGS

BUS_ to AGND ....-0.3V to +16.0V
XIN, XOUT, INT_3V3 to AGND ....-0.3V to +4.0V
$\overline{\text{ENU\_EN}}$, SUS_EN, RWU, D+, D-, $\overline{\text{PREQ}}$, $\overline{\text{CHG}}$, $\overline{\text{UOK}}$,
    $\overline{\text{FLT}}$, BAT_, SYS_, $\overline{\text{CEN}}$, STDBY, $\overline{\text{DET\_DONE}}$,
    IBUS_DEF, CHG_TYPE to AGND ....-0.3V to +6.0V
KB_TM, ISET, THM, IDN,
    CT to AGND ....-0.3V to (V$_{INT\_3V3}$ + 0.3V)
DGND to AGND ....-0.3V to + 0.3V

I$_{BUS\_}$, I$_{BAT\_}$, and I$_{SYS\_}$ Continuous Current .... 1800mA$_{RMS}$
Continuous Power Dissipation (T$_A$ = +70°C)
    25-Bump, 2.36mm x 2.36mm WLP
    (derate 19.34mW/°C above +70°C) 1560mW
Operating Temperature .... -40°C to +85°C
Junction Temperature ....+150°C
Storage Temperature Range .... -65°C to +150°C
Soldering Temperature (reflow) ....+260°C

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.

ELECTRICAL CHARACTERISTICS

(THM = $\overline{\text{CEN}}$ = SUS_EN = AGND, V$_{BAT\_}$ = 4.2V, V$_{BUS\_}$, CT, $\overline{\text{PREQ}}$, $\overline{\text{CHG}}$, $\overline{\text{UOK}}$, $\overline{\text{FLT}}$, $\overline{\text{DET\_DONE}}$ are unconnected, T$_A$ = -40°C to +85°C, unless otherwise noted. Typical values are at T$_A$ = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
USB-TO-SYS PREREGULATOR							
USB Operating Range		Initial V$_{BUS\_}$ voltage before enabling charger		4.0		6.6	V
USB Standoff Voltage		V$_{BAT\_}$ = V$_{SYS\_}$ = 0V, I$_{BUS\_}$ < 650µA (max)				14	V
BUS_OK Debounce Timer	t$_{USB\_DB}$	Time from BUS_ within valid range until $\overline{\text{UOK}}$ logic-low			500	650	ms
USB Undervoltage Lockout Threshold		$\overline{\text{UOK}}$ logic-low, V$_{BUS\_}$ rising, 100mV hysteresis	Before initial detection of external device	3.85	4.0	4.15	V
		$\overline{\text{UOK}}$ logic-low, V$_{BUS\_}$ falling	USB 2.0 low-power device	3.75	3.9	4.05	
		$\overline{\text{UOK}}$ logic-low, V$_{BUS\_}$ falling	USB 2.0 high-power device	3.95	4.1	4.25	
		$\overline{\text{UOK}}$ logic-low, V$_{BUS\_}$ falling	Dedicated charger or USB charger	V$_{SYS\_}$ -100mV	V$_{SYS\_}$ + 50mV	V$_{SYS\_}$ + 200mV	
USB Overvoltage Protection Threshold		$\overline{\text{UOK}}$ logic-low, V$_{BUS\_}$ rising, 100mV hysteresis		6.8	6.95	7.1	V
USB Input Supply Current (Note 2)	I$_{DETECT}$	Charge type detection, I$_{SYS\_}$ = I$_{BAT\_}$ = 0mA, V$_{\overline{CEN}}$ = 0V	MAX8895V/ MAX8895W/ MAX8895X			0.5	mA
			MAX8895Y			2.5	
	I$_{ENUMERATE}$	USB 2.0 enumeration in progress, I$_{SYS\_}$ = I$_{BAT\_}$ = 0mA, V$_{\overline{CEN}}$ = 0V				100	
	I$_{SUSPEND}$	Suspend mode, I$_{SYS\_}$ = I$_{BAT\_}$ = 0mA, V$_{STDBY}$ = 3.3V	MAX8895V/ MAX8895W/ MAX8895X			0.5	
			MAX8895Y			2.5	
	I$_{USB\_100mA}$	USB 2.0 low-power device detected	T$_A$ = 0°C to +85°C			100	
			T$_A$ = -40°C to +85°C			102.5	
	I$_{USB\_500mA}$	USB 2.0 high-power device detected				500	
USB Input Current Limit	I$_{SUS}$	During suspend			0		mA
	I$_{ENU}$	During USB enumeration		40	45	55	
	I$_{USB\_LP}$	USB 2.0 low-power device detected		80	90	98	
	I$_{USB\_HP}$	USB 2.0 high-power device detected		460	475	490	

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ELECTRICAL CHARACTERISTICS (continued)

(THM = $\overline{CEN}$ = SUS_EN = AGND, $V_{BAT\_}$ = 4.2V, $V_{BUS\_}$, CT, $\overline{PREQ}$, $\overline{CHG}$, $\overline{UOK}$, $\overline{FLT}$, $\overline{DET\_DONE}$ are unconnected, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
$V_{BUS\_}$-to-$V_{SYS\_}$ On-Resistance		$V_{BUS\_}$ = $V_{\overline{CEN}}$ = 5V, $I_{SYS\_}$ = 400mA		200	320	mΩ
$V_{SYS\_}$-to-$V_{BAT\_}$ Reverse Regulation		When SYS is in regulation and charging stops, $V_{SYS\_}$ falling, 50mV hysteresis	$V_{BAT\_}$ - 80mV	$V_{BAT\_}$ - 50mV	$V_{BAT\_}$ - 20mV	V
Input Limiter Soft-Start Time		Input current ramp time		50	100	µs
Thermal-Limit Start Temperature	T_{DIE_LIM}			+110		°C
Thermal-Limit Start Temperature Hysteresis				10		°C
Thermal-Limit Gain		$I_{SYS\_}$ reduction/die temperature (above +110°C)		5		%/°C
$V_{BUS\_}$ Adaptive Current Regulation Threshold		$V_{BUS\_}$ regulation threshold where input current limit is regulated for dedicated charger or USB charger		$V_{SYS\_}$ + 440mV	$V_{SYS\_}$ + 550mV	V
SYS_ Regulation Voltage		$V_{BAT\_}$ > 3.45V, $I_{SYS\_}$ = 1mA to 1.6A, $V_{BUS\_}$ = $V_{\overline{CEN}}$ = 5V		$V_{BAT\_}$ + 140mV	$V_{BAT\_}$ + 210mV	V
Minimum SYS Regulation Voltage		$V_{BUS\_}$ = 6V, $I_{SYS\_}$ = 1mA to 1.6A, $V_{\overline{CEN}}$ = 5V	3.3	3.4	3.55	V
CHARGER						
BAT_-to-SYS_ On-Resistance		$I_{SYS\_}$ = 200mA		55	80	mΩ
BAT_ Undervoltage Lockout	$V_{BAT\_UVLO\_F}$	$V_{BAT\_}$ falling	2.60	2.85	3.1	V
	$V_{BAT\_UVLO\_R}$	$V_{BAT\_}$ rising	2.75	3.00	3.25	
Charger Soft-Start Time		Charge-current ramp time		1		ms
BAT_ Leakage Current		$V_{BUS\_}$ not connected		2	6	µA
		$V_{BUS\_}$ connected, $V_{\overline{CEN}}$ = 5V		2	6	
PRECHARGE MODE						
BAT_ Precharge-Current Set Range	I_{PCHG}	R_{ISET} = 30kΩ to 1.875kΩ, $V_{BAT\_}$ >1.4V (Note 3)		I_{FCHG}/10		A
BAT_ Prequalification Threshold	$V_{BAT\_PCHG\_R}$	$V_{BAT\_}$ rising	2.7	2.8	2.9	V
	$V_{BAT\_PCHG\_F}$	$V_{BAT\_}$ falling	2.6	2.7	2.8	
FAST-CHARGE MODE						
BAT_ Charge-Current Set Range	I_{FCHG}	R_{ISET} = 30kΩ to 1.875kΩ, $V_{BAT\_}$ >1.4V (Note 3)	0.1		1.85	A
		ISET = INT_3V3 (Note 3)		600		mA
BAT_ Charge-Current Accuracy, Charger Loop in Control		$V_{BUS\_}$ = 5.5V (Note 3)	R_{ISET} = 1.875kΩ		1850		mA
			R_{ISET} = 5kΩ	540	600	660	
			R_{ISET} = 30kΩ	90	100	110	
BAT_ Fast-Charge Threshold	$V_{BAT\_FCHG\_R}$	$V_{BAT\_}$ rising threshold, where charging current I_{FCHG} is reduced to I_{TCHG}	3.9	4.0	4.1	V
	$V_{BAT\_FCHG\_F}$	$V_{BAT\_}$ falling threshold, where charging current is increased to I_{FCHG}	3.7	3.8	3.9	

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ELECTRICAL CHARACTERISTICS (continued)

(THM = $\overline{CEN}$ = SUS_EN = AGND, $V_{BAT\_}$ = 4.2V, $V_{BUS\_}$, CT, $\overline{PREQ}$, $\overline{CHG}$, $\overline{UOK}$, $\overline{FLT}$, $\overline{DET\_DONE}$ are unconnected, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
TOP-OFF CHARGE MODE							
Top-Off Charge Current	I_{TCHG}	R_{ISET} = 30kΩ to 1.875kΩ (Note 3)			0.6 x I_{FCHG}		A
BAT_ Charge Termination Current Range	I_{CHG_DONE}	R_{IDN} = 240kΩ to 15kΩ		10		160	mA
		IDN = INT_3V3			80		
BAT_ Regulation Voltage	V_{BAT_REG}	$I_{BAT\_}$ = 0mA	T_A = +25°C	4.179	4.200	4.221	V
			T_A = 0°C to +85°C	4.158	4.200	4.242	
BAT_ Recharge Threshold	V_{BAT_RECHG}	Recharge threshold in relation to $V_{BAT\_}$ in DONE state going into top-off mode (Figure 20)		-100	-200	-300	mV
CHARGE TIMER							
Maximum Prequalification Time	t_{PCHG}	From $V_{\overline{CEN}}$ falling to end of prequalification charge mode, $V_{BAT\_}$ = 2.5V	C_T = 0.068µF		16		Min
			C_T = AGND		20		
Maximum Fast-Charge Time	t_{FCHG}	From $V_{\overline{CEN}}$ falling to $V_{\overline{FLT}}$ falling	C_T = 0.068µF		100		Min
			C_T = AGND		120		
Maintain-Charge Time	t_{MTCHG}		C_T = 0.068µF		4		Min
			C_T = AGND		5		
Timer Accuracy		C_T = 0.068µF		-30		+30	%
		C_T connected to AGND		-30		+30	
Timer Extend Threshold		Percentage of charge current below which timer clock operates at half speed			50		%
Timer Suspend Threshold		Percentage of charge current below which timer clock pauses			20		%
ADAPTER TYPE DETECTION							
D- Current Sink	I_{DM_SINK}	MAX8895V/MAX8895X/MAX8895Y		50	86	150	µA
		MAX8895W		64	86	102	
D+ Source Voltage	V_{DP_SRC}	I_{DP_SRC} = 0 to 200µA		0.5	0.6	0.7	V
D+ Detection Threshold	V_{DAT_REF}			0.25	0.32	0.40	V
D+ Source On-Time	$t_{DP\_SRC\_ON}$			100			ms
D+ Source to High Current Time	$t_{DP\_SRC\_HC}$			40			ms
D- Pullup Resistor	R_{DM_PU}	MAX8895V/MAX8895W/MAX8895X only, external series resistor = 33Ω		1.425	1.500	1.575	kΩ
D+ Pullup Resistor	R_{DP_PU}	MAX8895Y only, external series resistor = 33Ω		1.425	1.500	1.575	kΩ
D+ Charger Detection Pullup Resistor	$R_{DP\_CD\_PU}$	$R_{DP\_CD\_PU}$ connect to INT_3V3		200	330	600	kΩ
D- Weak Current Sink	$I_{DM\_CD\_PD}$					0.1	µA
D- Logic-High Threshold	V_{DM_IH}			0.8		2.0	V

ELECTRICAL CHARACTERISTICS (continued)

(THM = $\overline{CEN}$ = SUS_EN = AGND, $V_{BAT\_}$ = 4.2V, $V_{BUS\_}$, CT, $\overline{PREQ}$, $\overline{CHG}$, $\overline{UOK}$, $\overline{FLT}$, $\overline{DET\_DONE}$ are unconnected, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Enumeration Time Limit	t_{ENUM}	Time from start of enumeration process until enumeration must be completed; if not completed, the MAX8895_ retries to enumerate			10		s
Reconnect Timer	t_{FAULT}	Time from failed enumeration to adapter type detection reenabled			3		s
Enumeration Fail to Reconnect Timer	t_{ENU_FAULT}	Time from enumeration fail at 500mA until enumeration is retried at 100mA or time from enumeration fail at 100mA until reconnect timer is started			87		ms
Reenumeration Timer	t_{RE_ENUM}	Time from when the MAX8895_ has entered suspend mode until it reenumerates, RWU = AGND			100		ms
Oscillator Frequency Accuracy		MAX8895V/MAX8895X only (internal oscillator), T_A = +25°C		5.91	6.00	6.09	MHz
XIN Input Current		MAX8895Y only, V_{XIN} = V_{STDBY} = 3.3V				10	µA
XIN Logic-High Input Voltage		MAX8895Y only		2/3x V_{INT_3V3}		V_{INT_3V3}	V
XIN Logic-Low Input Voltage		MAX8895Y only				0.4	V
THM							
THM Cold Threshold	T_{AMB_COLD}	When charging is suspended, rising threshold, 2% hysteresis		72	74	76	% of V_{INT_3V3}
THM Hot Threshold	T_{AMB_HOT}	When charging is suspended, falling threshold, 2% hysteresis		26	28	30	% of V_{INT_3V3}
THM Threshold, Disabled		When THM function is disabled, falling threshold, 2% hysteresis			3		% of V_{INT_3V3}
THM Input Leakage		THM = AGND or INT_3V3	T_A = +25°C	-0.1	0.001	+0.2	µA
			T_A = +85°C		0.01		
LOGIC I/O: $\overline{CHG}$, $\overline{FLT}$, $\overline{UOK}$, $\overline{CEN}$, $\overline{PREQ}$, KB_TM, RWU, STDBY, SUS_EN, $\overline{ENU\_EN}$, $\overline{DET\_DONE}$, CHG_TYPE, IBUS_DEF							
Logic-Input Threshold		High level		1.3			V
		Low level				0.4	
		Hysteresis			50		mV
Logic-Input Leakage Current		$V_{BUS\_}$ = 0 to 5.5V	T_A = +25°C		0.001	1	µA
			T_A = +85°C		0.01		
Logic-Low Output Voltage ($\overline{CHG}$, $\overline{FLT}$, $\overline{UOK}$, $\overline{PREQ}$, $\overline{DET\_DONE}$, CHG_TYPE Only)		Sinking 10mA			35	100	mV
Logic-High Output-Leakage Current ($\overline{CHG}$, $\overline{FLT}$, $\overline{UOK}$, $\overline{PREQ}$, $\overline{DET\_DONE}$, CHG_TYPE Only)		$V_{SYS\_}$ = 5.5V	T_A = +25°C		0.001	1	µA
			T_A = +85°C		0.01		

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ELECTRICAL CHARACTERISTICS (continued)

(THM = $\overline{CEN}$ = SUS_EN = AGND, $V_{BAT\_}$ = 4.2V, $V_{BUS\_}$, CT, $\overline{PREQ}$, $\overline{CHG}$, $\overline{UOK}$, $\overline{FLT}$, $\overline{DET\_DONE}$ are unconnected, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
USB DATA INTERFACE						
Differential-Receiver Input Sensitivity		$|V_{D+} - V_{D-}|$	0.2			V
Differential-Receiver Common-Mode Voltage			0.8		2.5	V
D+, D- Input Impedance			300			kΩ
D+, D- Output Low Voltage	V_{OL}	R_{LOAD} = 1.5kΩ from V_{D-} to 3.6V			0.3	V
D+, D- Output High Voltage	V_{OH}	R_{LOAD} = 15kΩ from D+ and D- to AGND	2.8		3.6	V
Driver Output Impedance		Excludes external resistor	2	7	11	Ω
BUS_ Idle Time	t_{IDLE}	Only valid when an adapter type is detected as a USB 2.0 device; time BUS_ is inactive until charging current is reduced to $I_{SUSPEND}$		3		ms
USB Host Remote Wake-Up Timer	t_{RWU}	Time delay from when the MAX8895_ is put into suspend mode until they request the host for a remote wake-up		100		ms
D+, D- Rise Time (Note 5)	t_{RISE}	MAX8895V/MAX8895W/MAX8895X only, C_L = 50pF to 600pF, (Figures 5 and 6)	75		250	ns
		MAX8895Y only, C_L = 50pF (Figures 5 and 6)	4		20	
D+, D- Fall Time (Note 5)	t_{FALL}	MAX8895V/MAX8895W/MAX8895X only, C_L = 50pF to 600pF (Figures 5 and 6)	75		250	ns
		MAX8895Y only, C_L = 50pF (Figures 5 and 6)	4		20	
Rise-/Fall-Time Matching (Note 5)		MAX8895V/MAX8895W/MAX8895X only, C_L = 50pF to 600pF (Figures 5 and 6)	80		120	%
		MAX8895Y only, C_L = 50pF (Figures 5 and 6)	90		110	
Output-Signal Crossover Voltage (Note 5)		MAX8895V/MAX8895W/MAX8895X only, C_L = 50pF to 600pF (Figures 5 and 6)	1.3		2.0	V
		MAX8895Y only, C_L = 50pF (Figures 5 and 6)	1.3		2.0	
INT_3V3 REGULATOR						
INT_3V3 Voltage		$V_{BUS\_}$ = 5V, I_{INT_3V3} = 0 to 10mA	3.0	3.3	3.6	V
ESD PROTECTION (D+, D-, $V_{BUS\_}$)						
Human Body Model		$V_{BUS\_}$ bypassed with 1µF to AGND		±8		kV

Note 1: Specifications are 100% production tested at T_A = +25°C. Limits over the operating temperature range are guaranteed by design and characterization.
Note 2: Sum of input current limit and current used for INT_3V3.
Note 3: Maximum charging current is adaptively regulated to I_{IN_LIM} - $I_{SYS\_}$ with a maximum value of $\overline{I_{CHG}}$.
Note 4: All devices are 100% production tested at T_A = +25°C. Limits over the operating temperature range are guaranteed by design.
Note 5: Guaranteed by design, not production tested.

Typical Operating Characteristics

($V_{BAT\_}$ = 4.2V, $V_{BUS\_}$ = 5V, ISET = IDN = CT = SUS_EN = INT_3V3, STDBY = $\overline{ENU\_EN}$ = RWU = $\overline{CEN}$ = KB_TM = AGND, circuits of Figures 4 and 5 (MAX8895V/MAX8895X and MAX8895Y, respectively), T_A = +25°C, unless otherwise noted.)


MAX8895V/W/X $V_{BUS\_}$ INPUT SUPPLY CURRENT vs. $V_{BUS\_}$ (SUSPEND MODE)
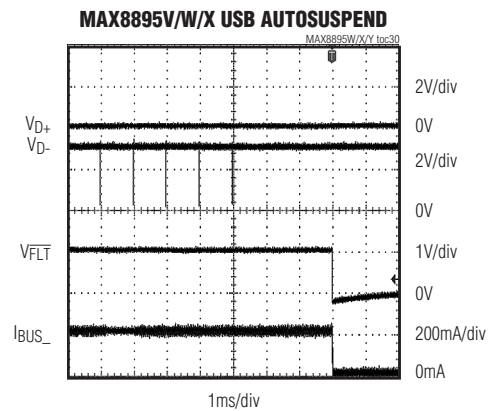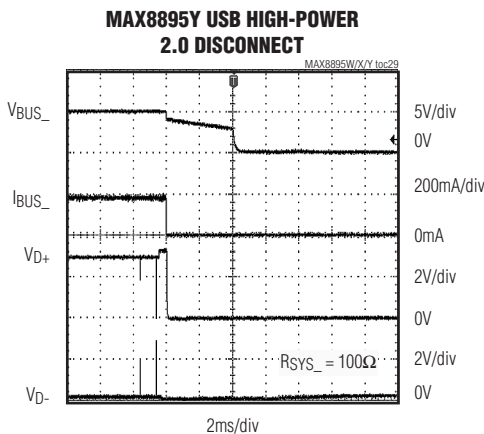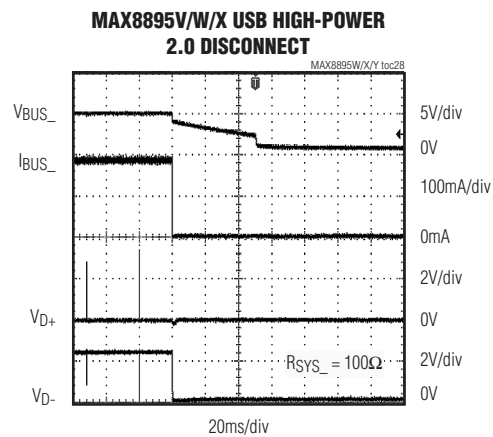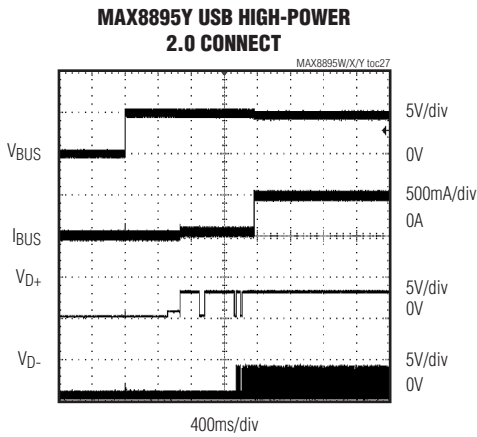

MAX8895V/W/X $V_{BUS\_}$ INPUT SUPPLY CURRENT vs. $V_{BUS\_}$ (CHARGER ENABLED)

MAX8895V/W/X $V_{BUS\_}$ INPUT SUPPLY CURRENT vs. $V_{BUS\_}$ (CHARGER DISABLED)

MAX8895Y $V_{BUS\_}$ INPUT SUPPLY CURRENT vs. $V_{BUS\_}$ (SUSPEND MODE)

MAX8895Y $V_{BUS\_}$ INPUT SUPPLY CURRENT vs. $V_{BUS\_}$ (CHARGER ENABLED)

MAX8895Y $V_{BUS\_}$ INPUT SUPPLY CURRENT vs. $V_{BUS\_}$ (CHARGER DISABLED)

BATTERY LEAKAGE CURRENT vs. BATTERY VOLTAGE

BATTERY LEAKAGE CURRENT vs. TEMPERATURE

CHARGE CURRENT vs. BATTERY VOLTAGE (DEDICATED CHARTER)
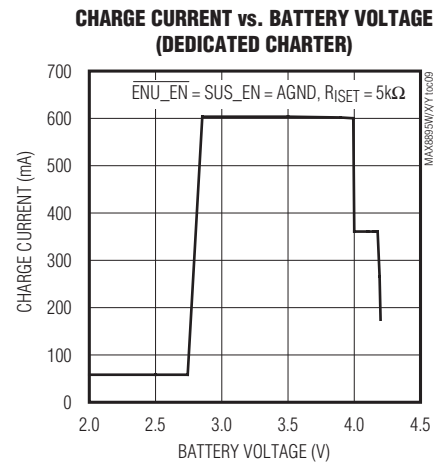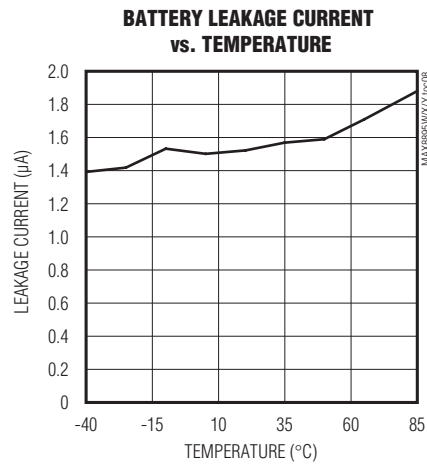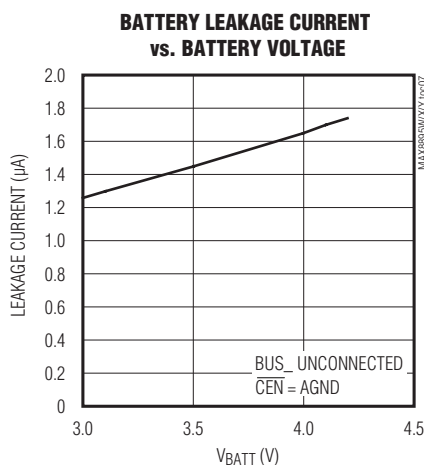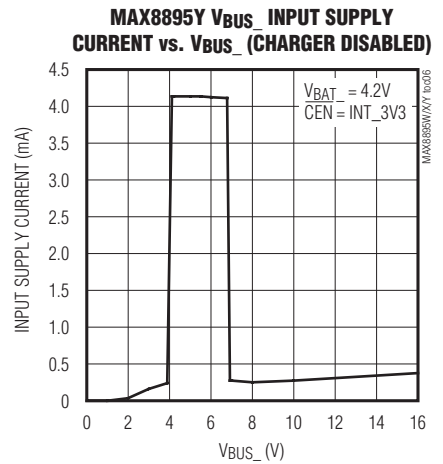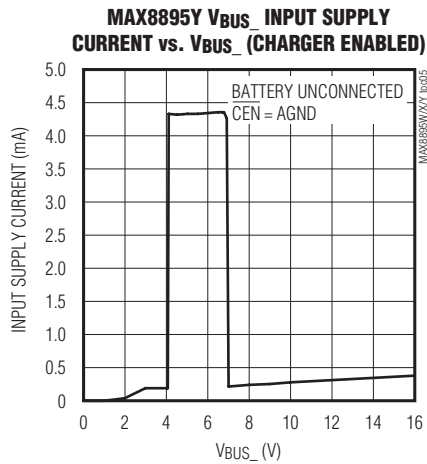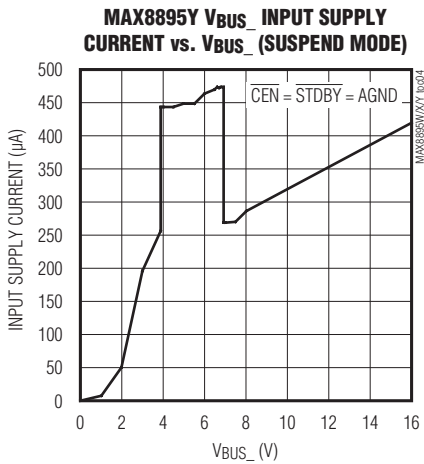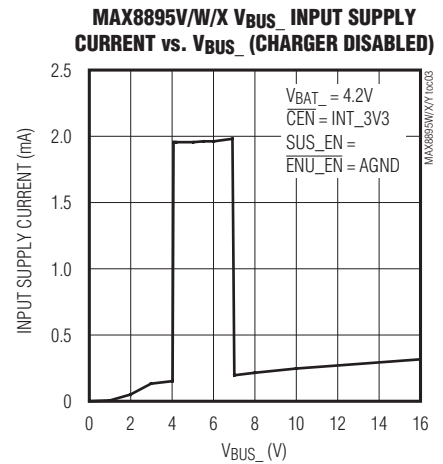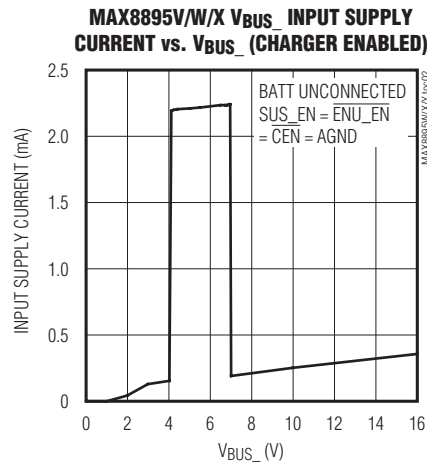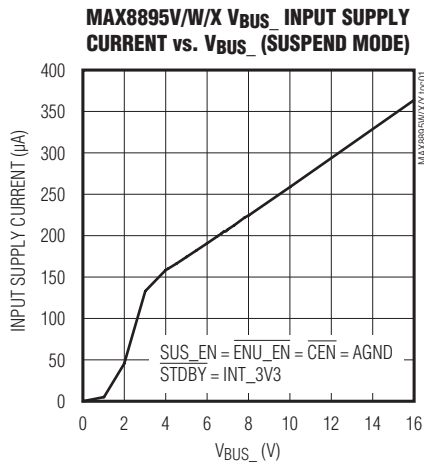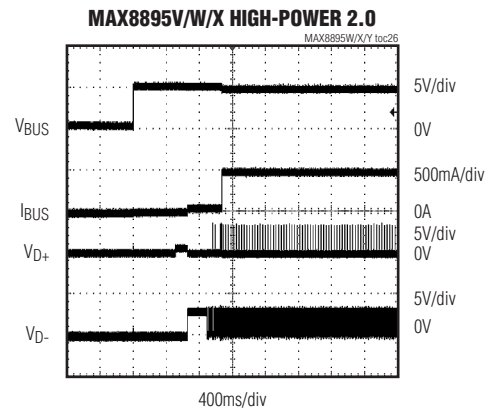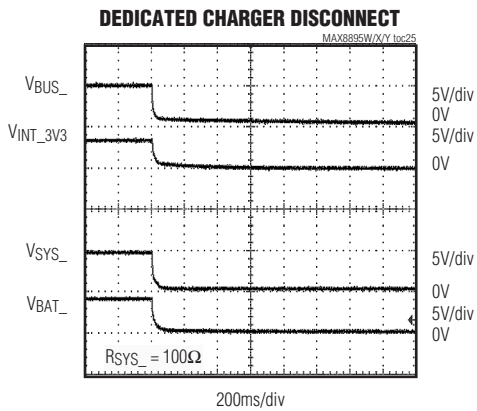
Li-Ion Chargers with Smart Power Selector, Adapter Type Detection, and USB Enumeration

Typical Operating Characteristics (continued)

($V_{BAT\_}$ = 4.2V, $V_{BUS\_}$ = 5V, ISET = IDN = CT = SUS_EN = INT_3V3, STDBY = $\overline{ENU\_EN}$ = RWU = $\overline{CEN}$ = KB_TM = AGND, circuits of Figures 4 and 5 (MAX8895V/MAX8895X and MAX8895Y, respectively), T_A = +25°C, unless otherwise noted.)
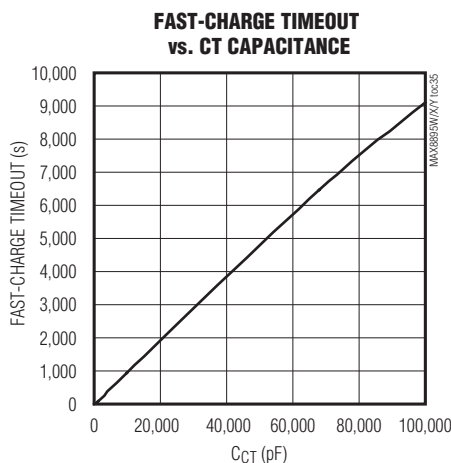

CHARGE CURRENT vs. BATTERY VOLTAGE (LOW-POWER USB)
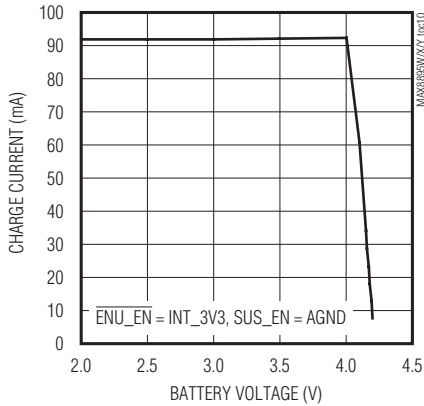
CHARGE CURRENT vs. BATTERY VOLTAGE (HIGH-POWER USB)
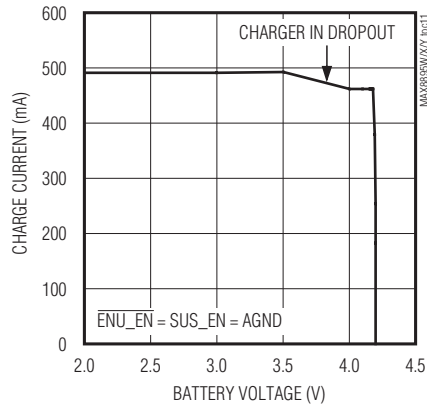
CHARGE CURRENT (DEDICATED CHARGER) vs. AMBIENT TEMPERATURE
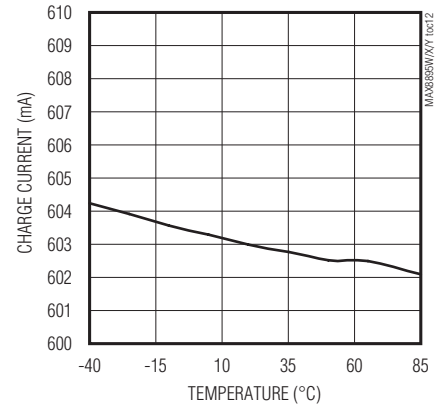
BATTERY REGULATION VOLTAGE vs. AMBIENT TEMPERATURE
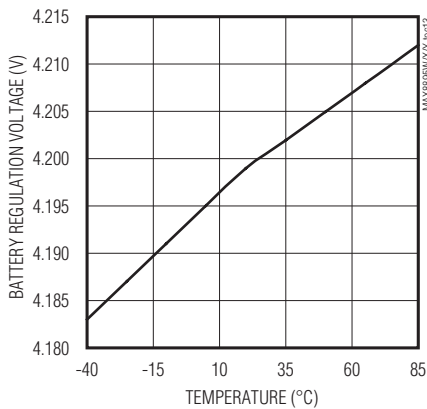
SYS_ OUTPUT VOLTAGE vs. $V_{BUS\_}$
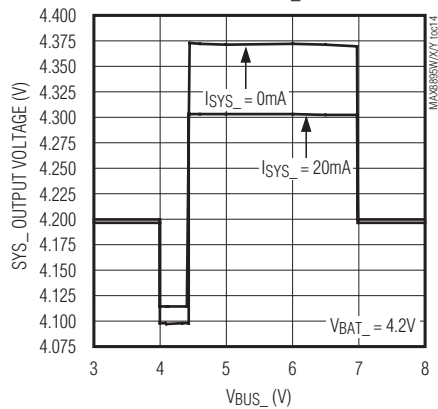
SYS_ OUTPUT VOLTAGE vs. BATTERY VOLTAGE
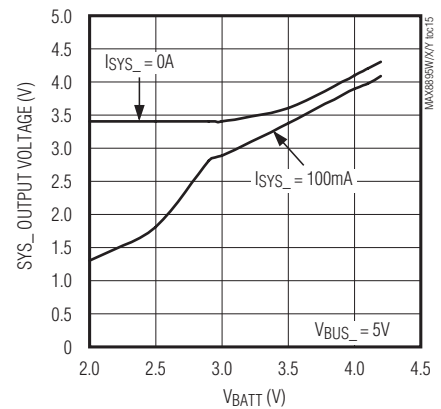
SYS_ DROPOUT VOLTAGE vs. LOAD CURRENT
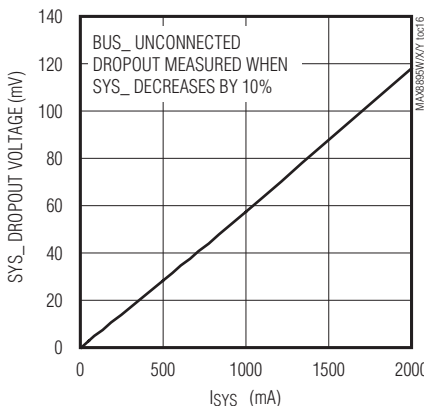
SYS_ OUTPUT VOLTAGE vs. LOAD CURRENT (HIGH-POWER USB MODE)
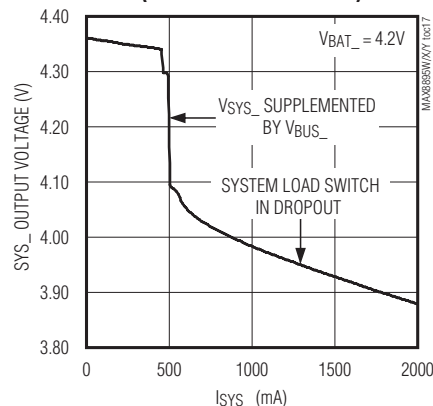
SYS_ OUTPUT VOLTAGE vs. LOAD CURRENT (DEDICATED CHARGER)

_____Typical Operating Characteristics (continued)

($V_{BAT\_}$ = 4.2V, $V_{BUS\_}$ = 5V, ISET = IDN = CT = SUS_EN = INT_3V3, STDBY = $\overline{ENU\_EN}$ = RWU = $\overline{CEN}$ = KB_TM = AGND, circuits of Figures 4 and 5 (MAX8895V/MAX8895X and MAX8895Y, respectively), T_A = +25°C, unless otherwise noted.)
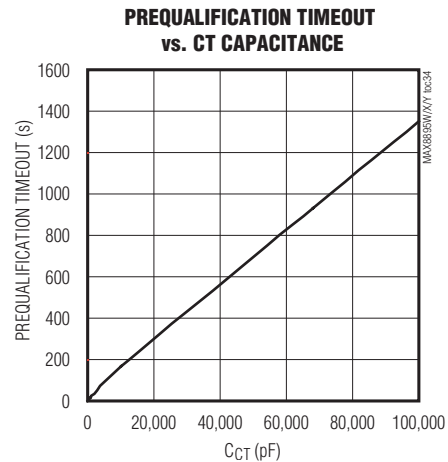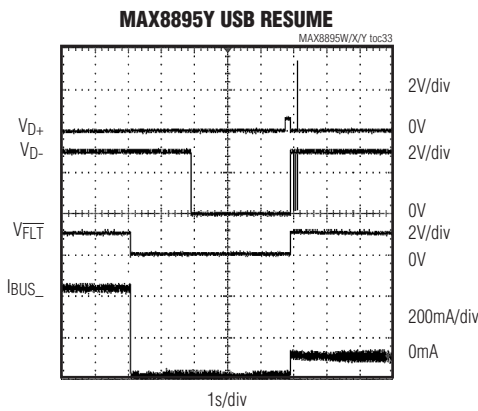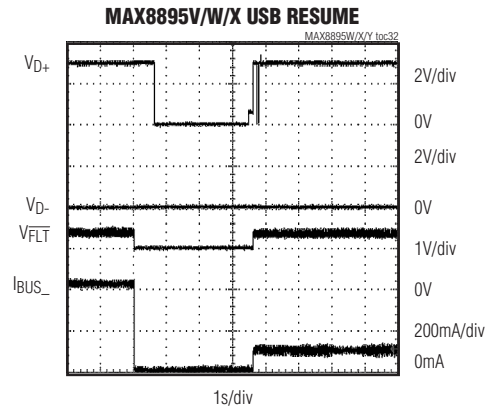
INT_3V3 VOLTAGE vs. BUS_ VOLTAGE

CHARGE PROFILE (NOKIA AC-10 CHARGER)

CHARGE PROFILE (USB 2.0 CHARGER)

MAX8895V/W/X EYE DIAGRAM

MAX8895Y EYE DIAGRAM

DEDICATED CHARGER CONNECT

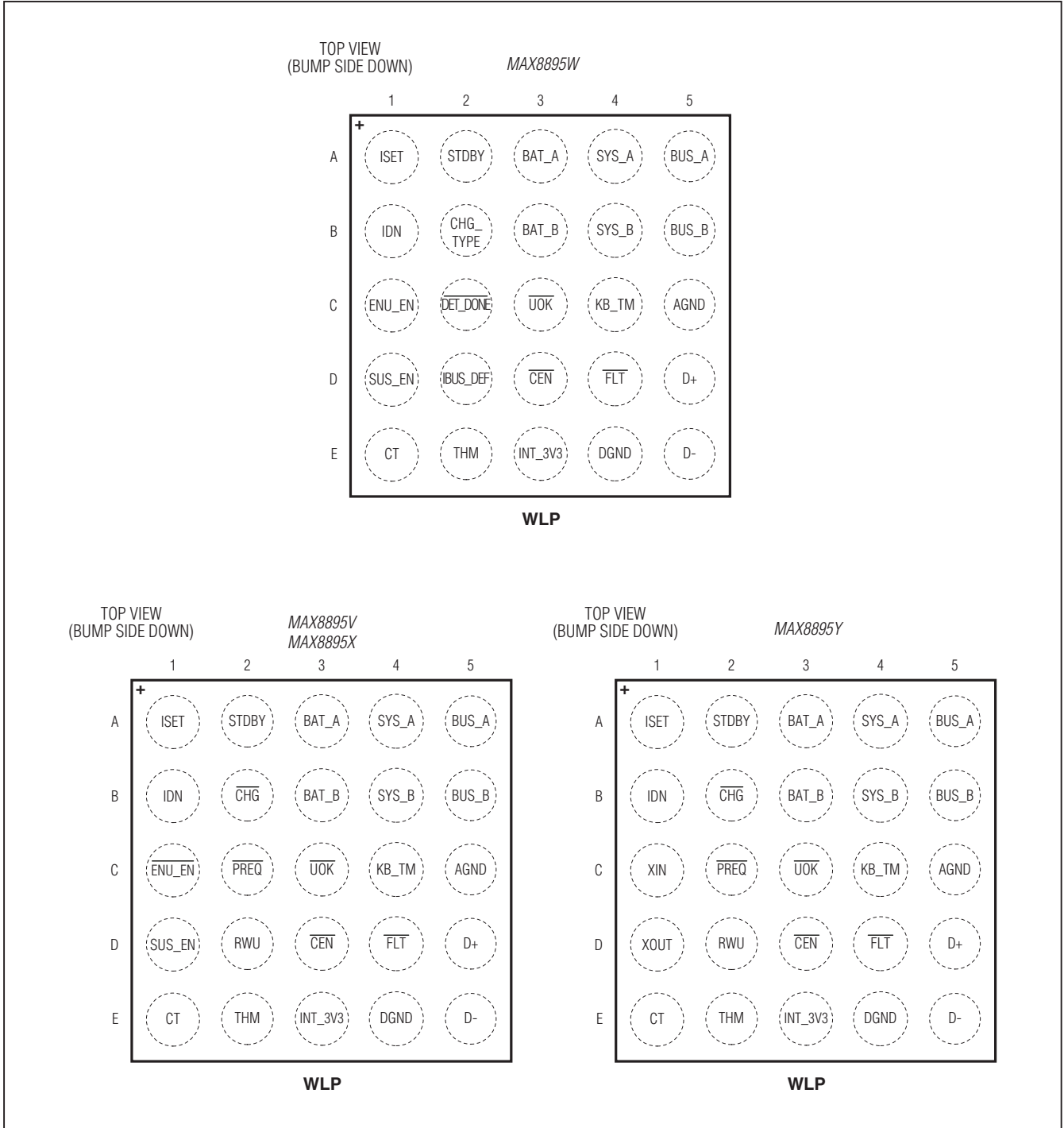### Typical Operating Characteristics (continued)

($V_{BAT\_}$ = 4.2V, $V_{BUS\_}$ = 5V, ISET = IDN = CT = SUS_EN = INT_3V3, STDBY = $\overline{ENU\_EN}$ = RWU = $\overline{CEN}$ = KB_TM = AGND, circuits of Figures 4 and 5 (MAX8895V/MAX8895X and MAX8895Y, respectively), T_A = +25°C, unless otherwise noted.)

DEDICATED CHARGER DISCONNECT

MAX8895W/X/Y toc25

MAX8895V/W/X HIGH-POWER 2.0

MAX8895W/X/Y toc26

MAX8895Y USB HIGH-POWER 2.0 CONNECT

MAX8895W/X/Y toc27

MAX8895V/W/X USB HIGH-POWER 2.0 DISCONNECT

MAX8895W/X/Y toc28

MAX8895Y USB HIGH-POWER 2.0 DISCONNECT

MAX8895W/X/Y toc29

MAX8895V/W/X USB AUTOSUSPEND

MAX8895W/X/Y toc30

Li-Ion Chargers with Smart Power Selector, Adapter Type Detection, and USB Enumeration

Typical Operating Characteristics (continued)

($V_{BAT\_}$ = 4.2V, $V_{BUS\_}$ = 5V, ISET = IDN = CT = SUS_EN = INT_3V3, STDBY = $\overline{ENU\_EN}$ = RWU = $\overline{CEN}$ = KB_TM = AGND, circuits of Figures 4 and 5 (MAX8895V/MAX8895X and MAX8895Y, respectively), T_A = +25°C, unless otherwise noted.)

MAX8895Y USB AUTOSUSPEND

MAX8895V/W/X USB RESUME

MAX8895Y USB RESUME

PREQUALIFICATION TIMEOUT vs. CT CAPACITANCE

FAST-CHARGE TIMEOUT vs. CT CAPACITANCE

Pin Configurations

TOP VIEW
(BUMP SIDE DOWN)   MAX8895W

	1	2	3	4	5
A	ISET	STDBY	BAT_A	SYS_A	BUS_A
B	IDN	CHG_TYPE	BAT_B	SYS_B	BUS_B
C	ENU_EN	DET_DONE	$\overline{UOK}$	KB_TM	AGND
D	SUS_EN	IBUS_DEF	$\overline{CEN}$	$\overline{FLT}$	D+
E	CT	THM	INT_3V3	DGND	D-

WLP

TOP VIEW
(BUMP SIDE DOWN)   MAX8895V
                          MAX8895X

	1	2	3	4	5
A	ISET	STDBY	BAT_A	SYS_A	BUS_A
B	IDN	$\overline{CHG}$	BAT_B	SYS_B	BUS_B
C	ENU_EN	$\overline{PREQ}$	$\overline{UOK}$	KB_TM	AGND
D	SUS_EN	RWU	$\overline{CEN}$	$\overline{FLT}$	D+
E	CT	THM	INT_3V3	DGND	D-

WLP

TOP VIEW
(BUMP SIDE DOWN)   MAX8895Y

	1	2	3	4	5
A	ISET	STDBY	BAT_A	SYS_A	BUS_A
B	IDN	$\overline{CHG}$	BAT_B	SYS_B	BUS_B
C	XIN	$\overline{PREQ}$	$\overline{UOK}$	KB_TM	AGND
D	XOUT	RWU	$\overline{CEN}$	$\overline{FLT}$	D+
E	CT	THM	INT_3V3	DGND	D-

WLP

_____**Pin Description**

PIN	NAME			FUNCTION
	MAX8895W	**MAX8895V/ MAX8895X**	**MAX8895Y**	
A1	ISET	ISET	ISET	Maximum Fast-Charge Current Selection. Connect a resistor from ISET to AGND to set the fast-charge current from 0.1A to 1.85A. $I_{FCHG} = 3000/R_{ISET}$ If ISET is connected to INT_3V3 the default I_{FCHG} is set as maximum charge current. ISET can also be used to monitor the actual current charging the battery. See the _Monitoring Charge Current_ section for details.
A2	STDBY	STDBY	STDBY	Standby Mode Enable. Connect STDBY to AGND to enter automatic detect mode. In automatic detect mode, the MAX8895V/MAX8895W/MAX8895X determine when to enter suspend mode depending on the status of the SUS_EN logic input. When using the MAX8895Y, the IC always starts in automatic suspend mode. Connect STDBY to INT_3V3 or drive logic-high to force the MAX8895_ into suspend mode regardless of external conditions.
A3	BAT_A	BAT_A	BAT_A	Li+ Battery Connection ($V_{BAT\_}$). Connect a single-cell Li+ battery from $V_{BAT\_}$ to DGND. The battery charges from $V_{SYS\_}$ when a valid source is present at $V_{BUS\_}$. $V_{BAT\_}$ powers $V_{SYS\_}$ when $V_{BUS\_}$ power is not present, or when the $V_{SYS\_}$ load exceeds the input current limit. Bypass $V_{BAT\_}$ to DGND with a 10µF X5R or X7R ceramic capacitor. Both BAT_A and BAT_B must be connected together externally.
B3	BAT_B	BAT_B	BAT_B	
A4	SYS_A	SYS_A	SYS_A	System Supply Output ($V_{SYS\_}$). $V_{SYS\_}$ is connected to $V_{BAT\_}$ through an internal 55mΩ system load switch when $V_{BUS\_}$ is invalid, or when the $V_{SYS\_}$ load is greater than the input current limit. When a valid voltage is present at $V_{BUS\_}$, $V_{SYS\_}$ is limited to 4.35V when using the MAX8895V/MAX8895X/ MAX8895Y, and 4.53V when using the MAX8895W. When the system load current ($I_{SYS\_}$) exceeds the $V_{BUS\_}$ current limit $V_{BAT\_}$ also powers $V_{SYS\_}$ to maintain the load current. Bypass $V_{SYS\_}$ to DGND with a 10µF X5R or X7R ceramic capacitor. Both SYS_A and SYS_B must be connected together externally.
B4	SYS_B	SYS_B	SYS_B	
A5	BUS_A	BUS_A	BUS_A	USB Power Input ($V_{BUS\_}$). During initial connection of an external device, the MAX8895_ identifies the type of connection established and set the input current limit accordingly. Bypass $V_{BUS\_}$ to DGND with a 10µF X5R or X7R ceramic capacitor. Both BUS_A and BUS_B must be connected together externally.
B5	BUS_B	BUS_B	BUS_B	
B1	IDN	IDN	IDN	Charge Termination Current Threshold. Connect a resistor from IDN to AGND to set the termination current threshold from 10mA to 160mA. $I_{TERM} = 2400/R_{IDN}$ If IDN is connected to INT_3V3, the termination current is set to the default I_{CHG_DONE} threshold.

Pin Description (continued)

PIN	NAME			FUNCTION
	MAX8895W	MAX8895V/MAX8895X	MAX8895Y	
B2	—	$\overline{CHG}$	$\overline{CHG}$	Active-Low, Charging Indicator. $\overline{CHG}$ is an open-drain output that is pulled low when the battery is in prequalification mode, fast-charge mode, or top-off states. Otherwise, $\overline{CHG}$ is high impedance.
	CHG_TYPE	—	—	CHG_TYPE is used to indicate capacity of input current. IF CHG_TYPE is high, the input current can be greater than or equal to 500mA. If CHG_TYPE is low, the input current is 100mA from the USB 2.0 host.
C1	—	—	XIN	Crystal Oscillator Input. Connect XIN to one side of a parallel resonant 12MHz ±0.25% crystal and a capacitor to AGND. XIN can also be driven by an external clock referenced to INT_3V3.
	—	$\overline{ENU\_EN}$	—	Automatic Enumeration Enable. Connect $\overline{ENU\_EN}$ to AGND to allow the MAX8895V/MAX8895X to automatically perform enumeration. Connect to INT_3V3 or drive logic-high to force the input current limit to 100mA without performing an adapter type detection.
	$\overline{ENU\_EN}$	—	—	Automatic Enumeration Enable. Connect $\overline{ENU\_EN}$ to AGND to allow the MAX8895W to automatically perform enumeration. By connecting $\overline{ENU\_EN}$ to INT_3V3 or drive logic-high, disables automatic enumeration and sets the input current limit to level determined by the IBUS_DEF if a USB 2.0 device is detected.
C2	—	$\overline{PREQ}$	$\overline{PREQ}$	Active-Low, Prequalification Charging Output. $\overline{PREQ}$ is an open-drain output that is pulled low when the charger enters the prequalification state.
	$\overline{DET\_DONE}$	—	—	Active-Low Adapter-Type Detection Done Output. $\overline{DET\_DONE}$ is an open-drain output that is pulled low when adapter detection is completed. $\overline{DET\_DONE}$ is high impedance in suspend mode.
C3	$\overline{UOK}$	$\overline{UOK}$	$\overline{UOK}$	Active-Low, $V_{BUS\_}$ Power-OK Output. $\overline{UOK}$ is an open-drain output that is pulled low when a valid input is detected at $V_{BUS\_}$.
C4	KB_TM	KB_TM	KB_TM	Keyboard Test Mode. In normal operation, connect KB_TM to AGND. This input is only used during USB certification.
C5	AGND	AGND	AGND	Analog Ground. Both AGND and DGND should be connected together at the negative terminal of the battery.
D1	—	—	XOUT	Crystal Oscillator Output. Connect XOUT to one side of a parallel resonant 12MHz ±0.25% crystal and a capacitor to AGND. Leave XOUT unconnected if XIN is driven by an external clock.
	SUS_EN	SUS_EN	—	Automatic Suspend Mode Detection Enable. Connect SUS_EN to AGND to disable the automatic suspend mode detection. Connect SUS_EN to INT_3V3 or drive logic-high to enable the automatic detection of suspend mode.
D2	—	RWU	RWU	Remote Wake-up. Connect RWU to AGND or logic-low for remote wake-ups whenever the device is put into suspend mode and the supervisor determines that more current is needed.
	IBUS_DEF	—	—	Sets USB Input Current if Adapter is Detected as a USB 2.0 Device and $\overline{ENU\_EN}$ is Logic-High. If IBUS_DEF is connected high, the input current limit is set to 500mA. If IBUS_DEF is connected low or to ground, the input current limit is set to 100mA.

_____**Pin Description (continued)**

PIN	NAME			FUNCTION
	MAX8895W	**MAX8895V/ MAX8895X**	**MAX8895Y**	
D3	$\overline{\text{CEN}}$	$\overline{\text{CEN}}$	$\overline{\text{CEN}}$	Charger Enable Input. Connect $\overline{\text{CEN}}$ to AGND to enable battery charging when a valid source is connected at $V_{BUS\_}$. Connect $\overline{\text{CEN}}$ to INT_3V3 or drive logic-high to disable battery charging. In this condition the USB state machine is still active, and $V_{SYS\_}$ is powered from $V_{BUS\_}$ under normal conditions and supplemented from $V_{BAT\_}$ if sufficient current is not available from $V_{BUS\_}$ input.
D4	$\overline{\text{FLT}}$	$\overline{\text{FLT}}$	$\overline{\text{FLT}}$	Active-Low Fault Output. $\overline{\text{FLT}}$ is an open-drain output that is pulled low when the battery charger timer expires before prequalification or fast-charge completes. $\overline{\text{FLT}}$ is also pulled low during adapter type detection or if USB enumeration fails.
D5	D+	D+	D+	USB D+ signal. Connect D+ to a USB "B" connector through a 33Ω series resistor. The 1.5kΩ D+ pullup resistor is internal to the device (for MAX8895Y only).
E1	CT	CT	CT	Timer Set Capacitor. Connect a capacitor from CT to AGND to set the fault timers for prequalification and fast-charge. $t_{PREQUAL}$ = 16min x (C_{CT}/0.068µF) t_{FCHG} = 100min x (C_{CT}/0.068µF) t_{MTCHG} = 4min x (C_{CT}/0.068µF) If CT is connected directly to AGND, the default timers are used.
E2	THM	THM	THM	Thermistor Input. Connect a negative temperature coefficient (NTC) thermistor that has good thermal contact with the battery from THM to AGND. Connect a resistor equal to the thermistor at T_A = +25°C resistance from THM to INT_3V3. Charging is suspended when the thermistor is outside the hot and cold limits. Connect THM to AGND to disable the thermistor temperature sensor.
E3	INT_3V3	INT_3V3	INT_3V3	LDO Output. INT_3V3 is the output of an LDO that powers the internal circuitry. INT_3V3 is powered from the $V_{BUS\_}$ input. Connect a 0.1µF capacitor from INT_3V3 to AGND.
E4	DGND	DGND	DGND	Digital Ground. Both AGND and DGND should be connected together at the negative terminal of the battery.
E5	D-	D-	D-	USB D- Signal. Connect D- to a USB "B" connector through a 33Ω series resistor. The 1.5kΩ D- pullup resistor is internal to the device (for MAX8895V/ MAX8895W/MAX8895X only).

Li-Ion Chargers with Smart Power Selector, Adapter Type Detection, and USB Enumeration
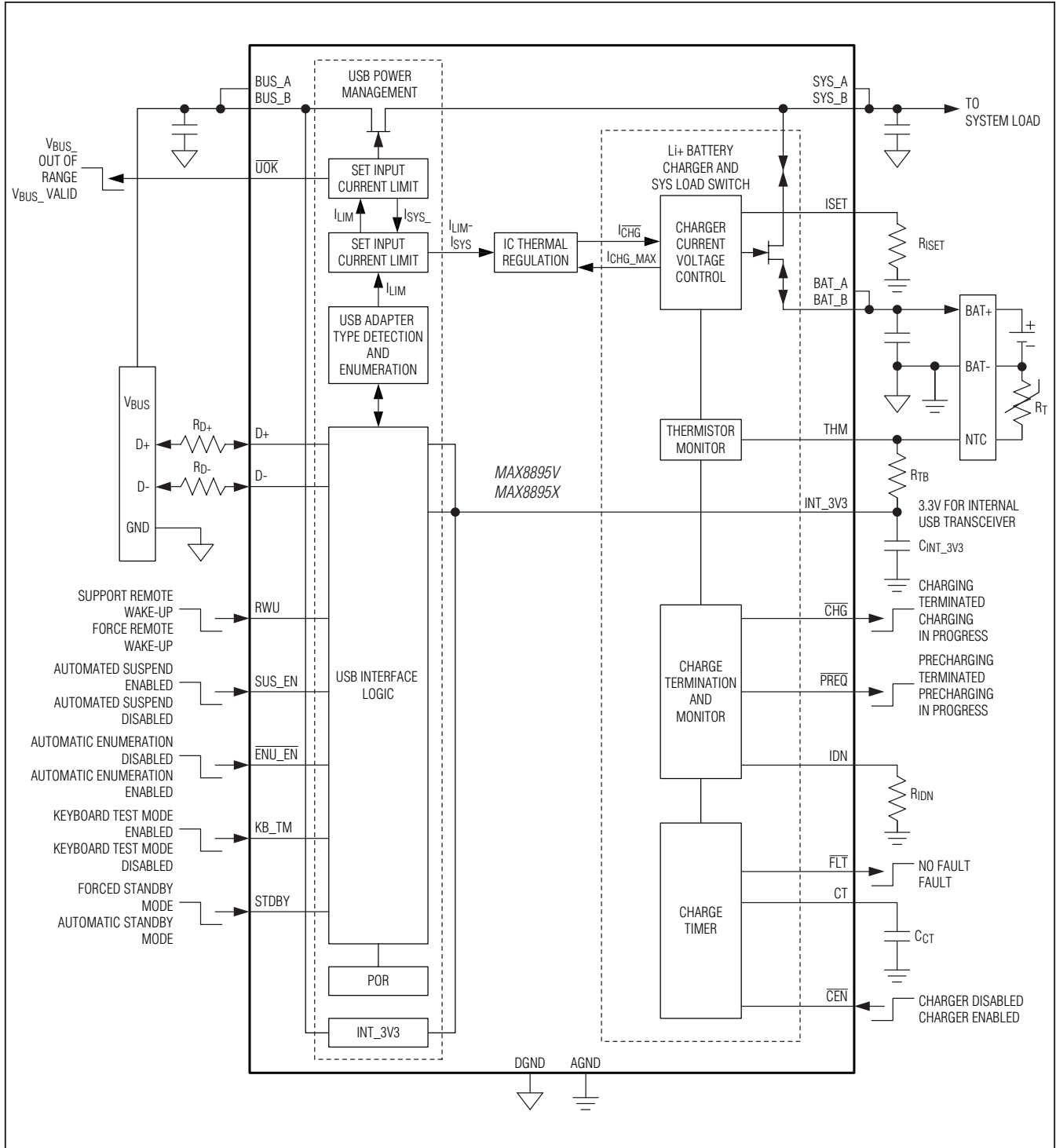
Figure 1. MAX8895V/MAX8895X Block Diagram
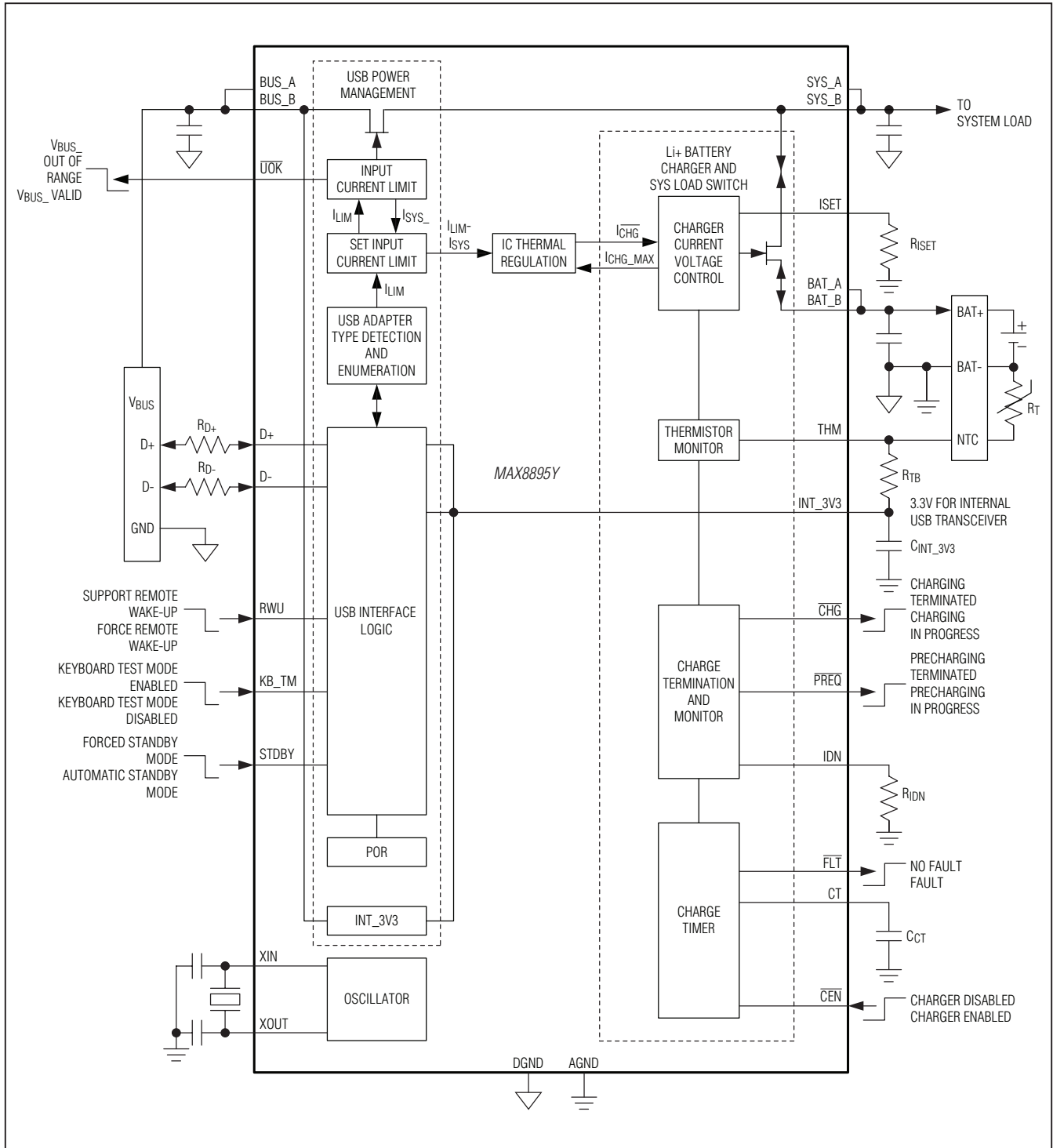
Figure 2. Differential Input Configuration
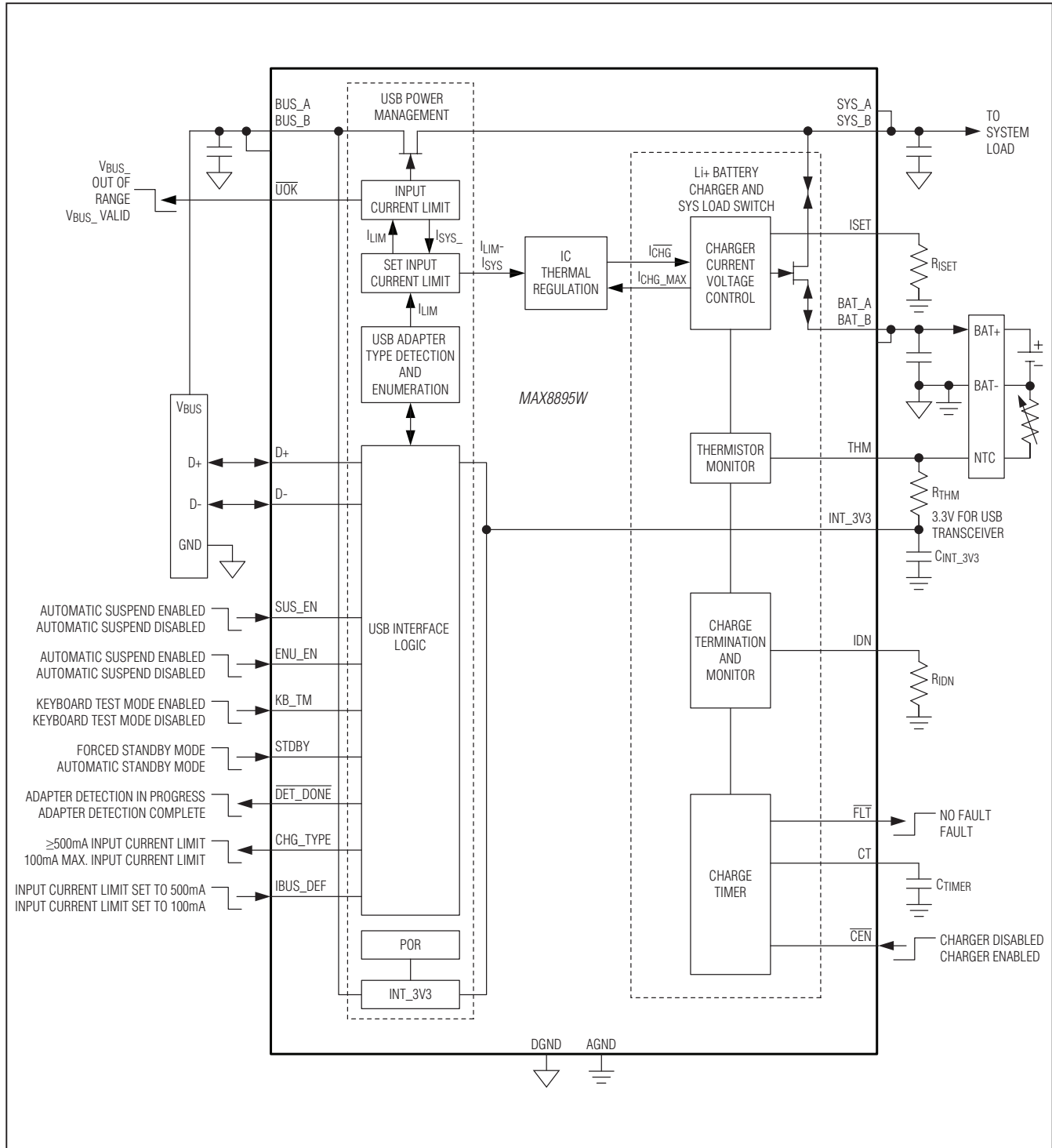
Figure 3. MAX8895W Block Diagram
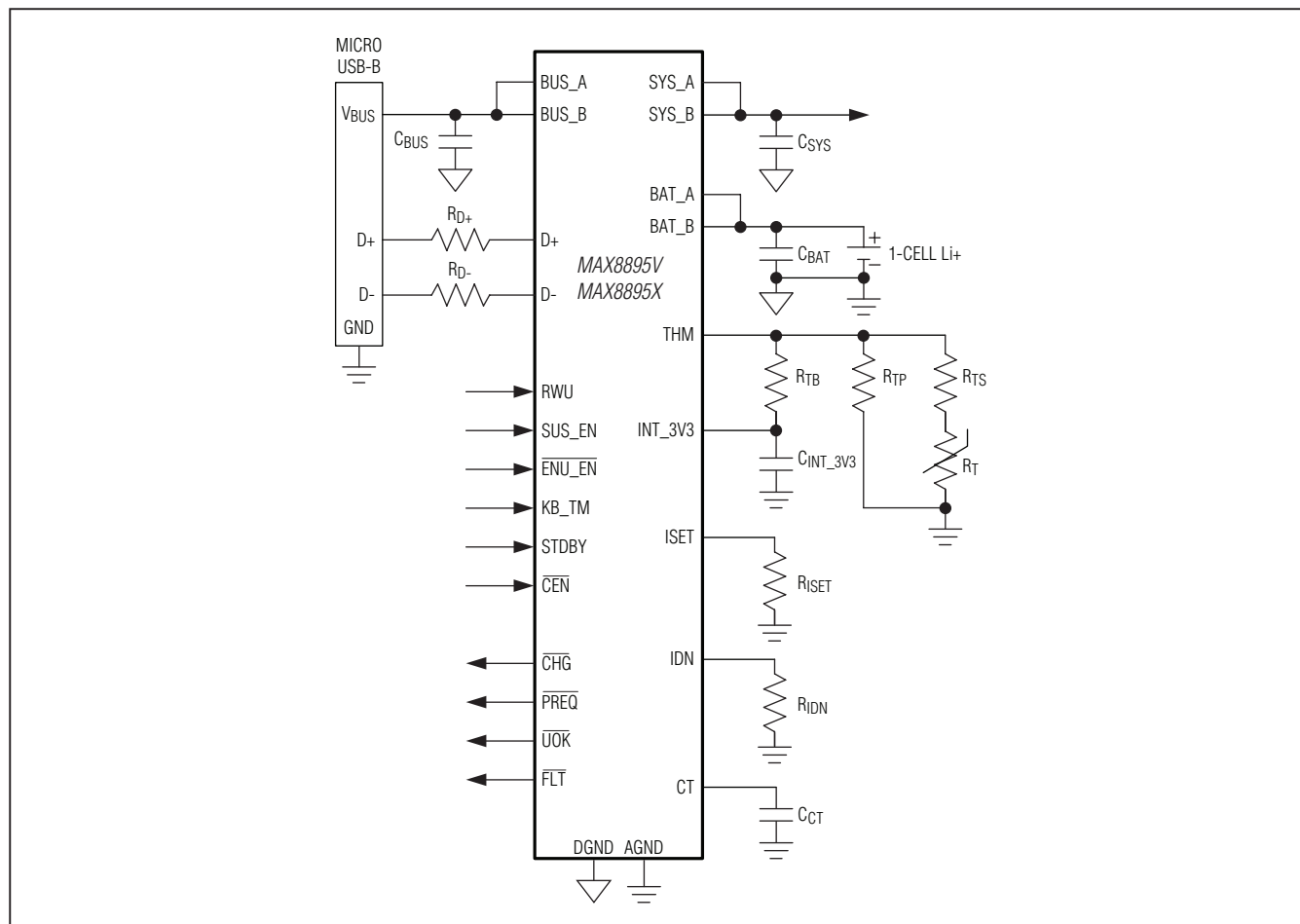
Figure 4. MAX8895V/MAX8895X Typical Application Circuit

NAME	VALUE	FUNCTION
C_{BUS}	10µF, 16V	Decoupling of input supply.
C_{SYS}	10µF, 6.3V	Decoupling of system rail.
C_{BAT}	10µF, 6.3V	Decoupling of battery rail.
R_T	User dependent	Thermistor for thermal sensing. See the *Thermistor Input (THM)* section for details.
R_{TB}, R_{TP}, R_{TS}	User dependent	Bias resistors for thermal sensing. See the *Thermistor Input (THM)* section for details.
C_{INT_3V3}	0.1µF, 6.3V	Decoupling of internal 3.3V rail.
C_{CT}	1000pF to 0.2µF	Capacitor to set charge timer, optional. See the *Fault Output ($\overline{FLT}$) and Charge Timer (CT)* section for details.
R_{ISET}	1.875kΩ to 30kΩ	Resistor to set maximum charging current, optional.
R_{IDN}	15kΩ to 240kΩ	Resistor to set termination current for charger, optional.
R_{D+}, R_{D-}	33Ω	D+/D- serial impedance.

Figure 5. MAX8895Y Typical Application Circuit

NAME	VALUE	FUNCTION
C_{BUS}	10µF, 16V	Decoupling of input supply.
C_{SYS}	10µF, 6.3V	Decoupling of system rail.
C_{BAT}	10µF, 6.3V	Decoupling of battery rail.
R_T	User dependent	Thermistor for thermal sensing. See the *Thermistor Input (THM)* section for details.
R_{TB}, R_{TP}, R_{TS}	User dependent	Bias resistors for thermal sensing. See the *Thermistor Input (THM)* section for details.
C_{INT_3V3}	0.1µF, 6.3V	Decoupling of internal 3.3V rail.
XTAL	12MHz 2500ppm	MAX8895Y only, clock source for full-speed mode, requires a 2500ppm or better accuracy.
C_{XTAL_IN}	User dependent	MAX8895Y only, crystal load capacitor, only required for full-speed operation. See the *External Crystal/Ceramic Resonator* section for details.
C_{XTAL_OUT}	User dependent	MAX8895Y only, crystal load capacitor, only required for full-speed operation.
C_{CT}	1000pF to 0.2µF	Capacitor to set charge timer, optional. See the *Fault Output ($\overline{FLT}$) and Charge Timer (CT)* section for details.
R_{ISET}	1.875kΩ to 30kΩ	Resistor to set maximum charging current, optional.
R_{IDN}	15kΩ to 240kΩ	Resistor to set termination current for charger, optional.
R_{D+}, R_{D-}	33Ω	D+/D- serial impedance.

Figure 6. MAX8895W Typical Application Circuit

NAME	VALUE	FUNCTION
C_{BUS}	10µF, 16V	Decoupling of input supply.
C_{SYS}	10µF, 6.3V	Decoupling of system rail.
C_{BAT}	10µF, 6.3V	Decoupling of battery rail.
R_{THM}	User dependent	Thermistor for thermal sensing. See the *Thermistor Input (THM)* section for details.
R_{TB}, R_{TP}, R_{TS}	User dependent	Bias resistors for thermal sensing. See the *Thermistor Input (THM)* section for details.
C_{INT_3V3}	0.1µF, 6.3V	Decoupling of internal 3.3V rail.
C_{CT}	1000pF to 0.2µF	Capacitor to set charge timer, optional. See the *Fault Output ($\overline{FLT}$) and Charge Timer (CT)* section for details.
R_{ISET}	1.875kΩ to 30kΩ	Resistor to set maximum charging current, optional.
R_{IDN}	15kΩ to 240kΩ	Resistor to set termination current for charger, optional.
R_{D+}, R_{D-}	33Ω	D+/D- serial impedance.

Li-Ion Chargers with Smart Power Selector, Adapter Type Detection, and USB Enumeration

Detailed Description

The MAX8895_ is an integrated 1-cell Li+ charger with USB enumeration capability. All power switches for charging and switching the load between battery and external power are internal. No external MOSFETS are required.

The MAX8895_ makes it possible to negotiate more than 100mA of charging current from a USB host or hub without processor intervention. The MAX8895_ also automatically detects a dedicated charger or USB charger and set the input current limit accordingly. The battery charge current can be set up to 1.85A. Input power not used by the system charges the battery.

USB Interface

An integrated USB peripheral controller provides auto-enumeration for full-speed (MAX8895Y) and low-speed (MAX8895V/MAX8895W/MAX8895X) modes.

The USB controller executes the adapter detection sequence, which consists of detecting the type of adapter that is externally connected and setting the input current limit accordingly.

If attached to a USB charger (host or hub) or a USB 2.0 (host or hub), it enumerates as an HID device and negotiates the maximum charging current level (from $V_{BUS\_}$).

The MAX8895V/MAX8895W/MAX8895X operate in low-speed mode, using an internal 6MHz oscillator, and does not require an external crystal to be USB compliant. The MAX8895Y operates in full-speed mode and requires an external 12MHz crystal.

According to the USB 2.0 specification, a low-speed device is not allowed to use a standard USB "B" connector. This is why MAX8895_ is available in both a low- and full-speed version. This makes it possible to use a custom or captive cable for low-speed mode using the MAX8895V/MAX8895W/MAX8895X and still be USB compliant. Operating in full-speed mode, using the MAX8895Y allows use of a standard USB "B" connector.

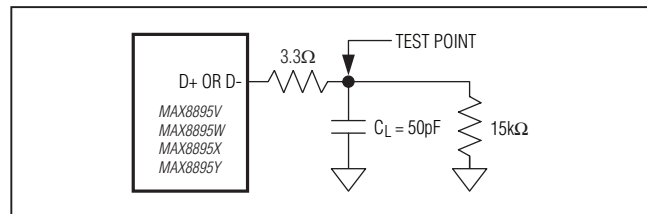### USB Timing

Figure 7. USB Rise and Fall Timing

Figure 8. Load for D+/D- AC Measurements

D+ and D-

The internal USB full speed (MAX8895Y)/low-speed (MAX8895V/MAX8895W/MAX8895X) transceiver is brought out to the bidirectional data pins D+ and D-. These pins are ESD protected up to ±8kV (HBM). Connect these pins to a USB "B" custom connector through external 33Ω series resistors. The MAX8895V/MAX8895X provide an automatic switchable 1.5kΩ pull-up resistor for D-, while the MAX8895Y provides an automatic switchable 1.5kΩ pullup resistor for D+.

Adapter Detection

When an adapter is present on $V_{BUS\_}$, the MAX8895_ examines the external device to identify the type of adapter connected.

The possible adapter types are:

• Dedicated charger
• USB charger (host or hub)
• USB 2.0 (host or hub) low power
• USB 2.0 (host or hub) high power

Each of these different devices has different current capability as shown in Table 1.

Table 1. Adapter Types

ADAPTER TYPE	OUTPUT VOLTAGE	OUTPUT CURRENT
Dedicated charger	4.75V to 5.25V at I_{LOAD} < 500mA 2.0V to 5.25V for I_{LOAD} ≥500mA	500mA to 1.85A
USB charger	4.75V to 5.25V at I_{LOAD} < 500mA 0 to 5.25V for I_{LOAD} ≥ 500mA	500mA to 900mA for low speed, full speed 500mA to 1.5A for low speed and full speed
USB 2.0 low power	4.25V to 5.25V	100mA (max)
USB 2.0 high power	4.75V to 5.25V	500mA (max)

Li-Ion Chargers with Smart Power Selector, Adapter Type Detection, and USB Enumeration

When an adapter is connected to the MAX8895_, a series of tests is performed to identify the type of device connected. The sequence is done according to the flow charts in Figures 7 and 8. Figures 9, 10, and 11 show the adapter-type detection timing.
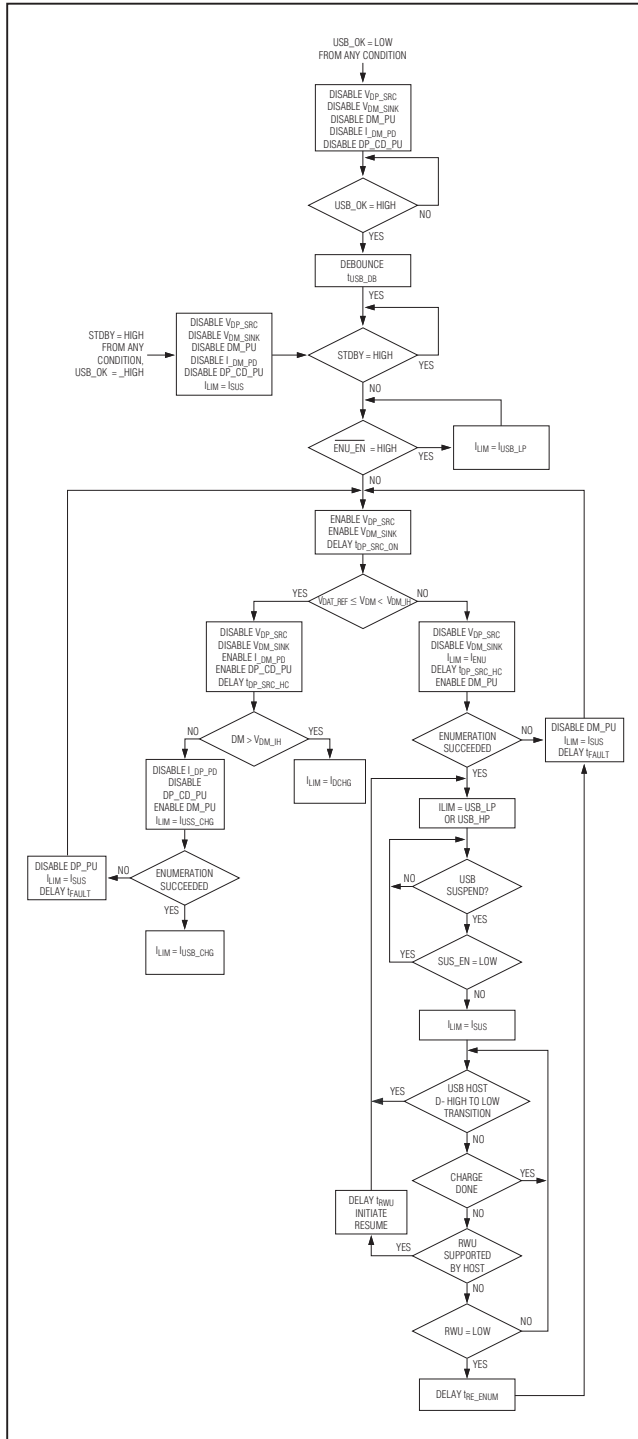

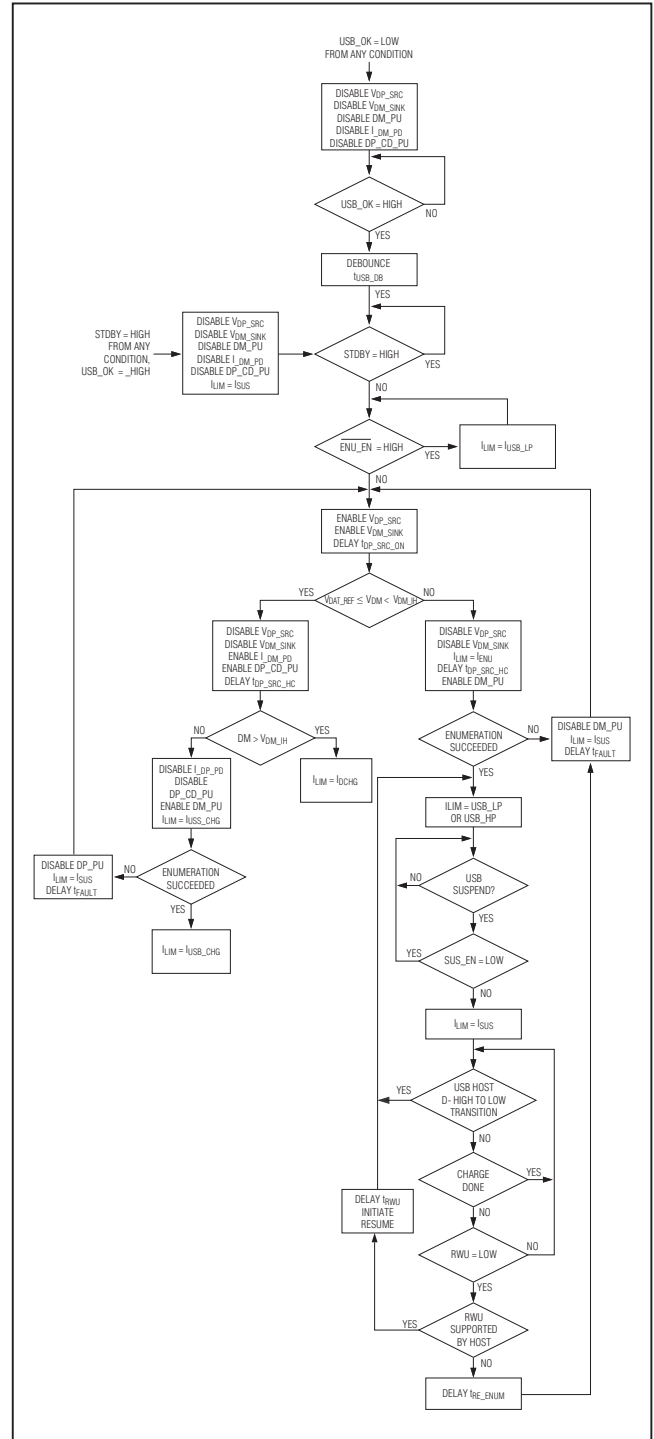Figure 9. MAX8895X Flow Chart for Adapter Type Detection

Figure 10. MAX8895V Flow Chart for Adapter Type Detection
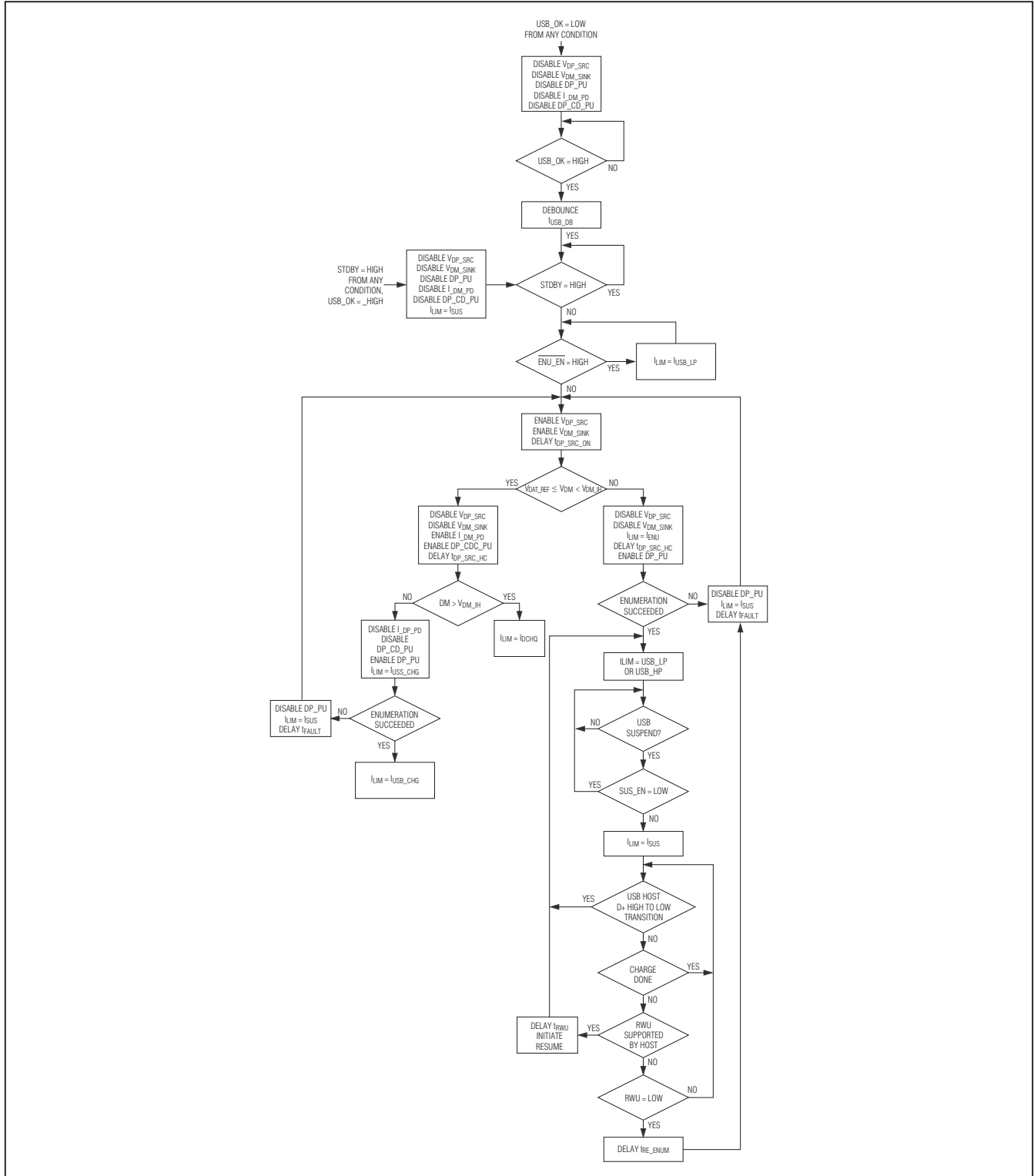
Figure 11. MAX8895Y Flow Chart for Adapter Type Detection
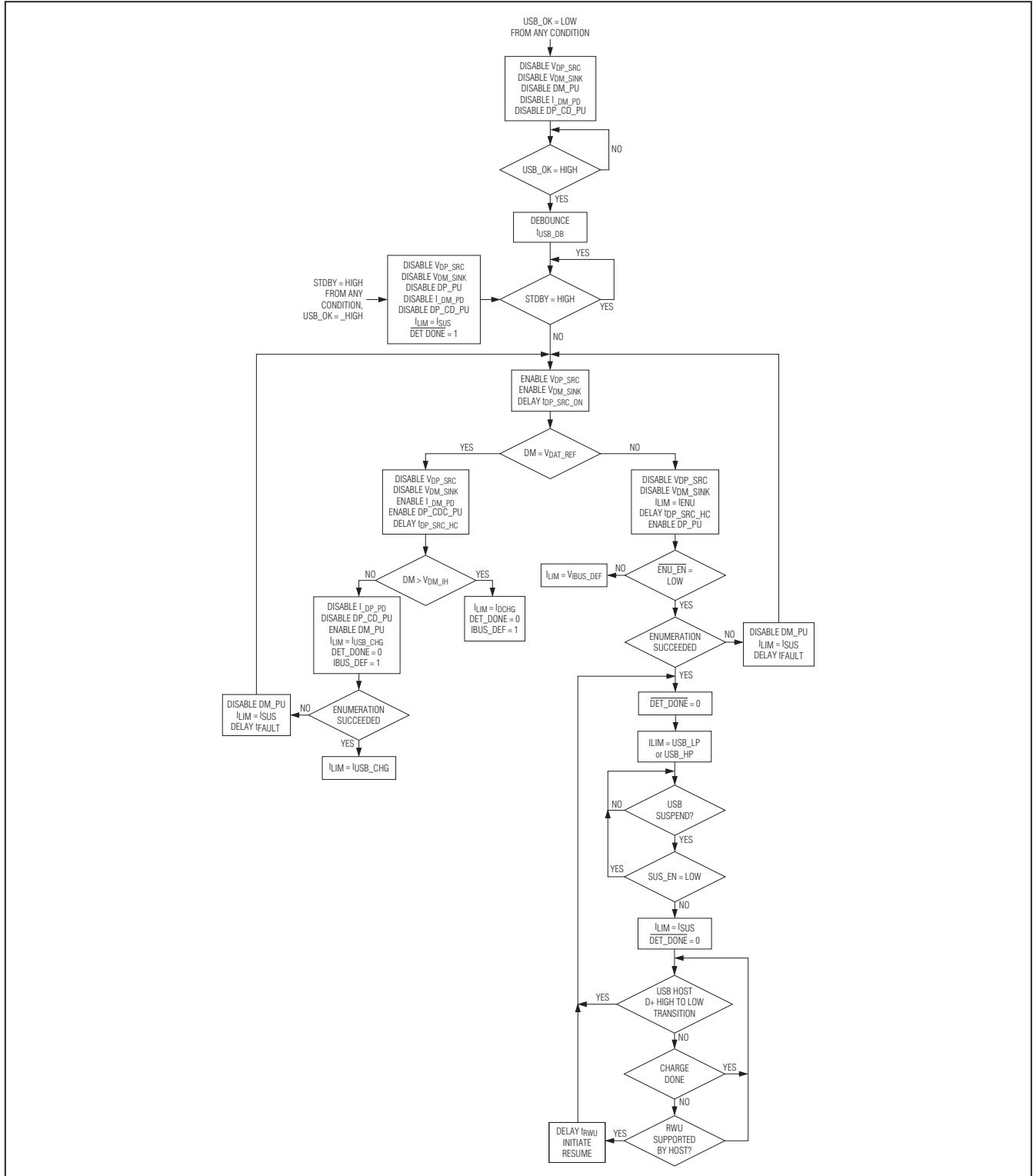
Figure 12. MAX8895W Flow Chart for Adapter Type Detection

Li-Ion Chargers with Smart Power Selector, Adapter Type Detection, and USB Enumeration
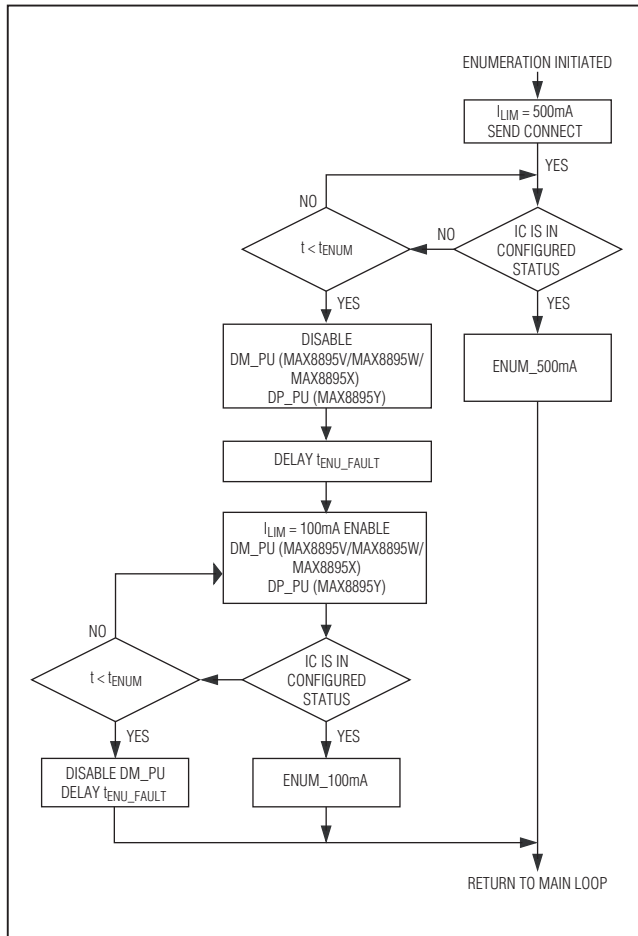
Figure 13. Flow Chart for Enumeration Process

Once the type of adapter is determined, the MAX8895_ determines the maximum input current limit, if the external adapter is recognized as a USB charger or USB 2.0 device. The MAX8895_ then initiates enumeration and determine the maximum input current limit according to Figure 13.

Low-Power Mode

Driving STDBY high disables the charger as well as $V_{SYS\_}$, to reduce the input current drawn from $V_{BUS\_}$. The current drawn in this mode is less than 500µA for the MAX8895V/MAX8895W/MAX8895X and 2.5mA for the MAX8895Y. In this mode, the D+ and D- lines become high impedance. When STDBY is high, $V_{SYS\_}$ is regulated to 50mV (typ) below $V_{BAT\_}$.

USB Suspend

According to the USB rev 2.0 specification, when a USB host stops sending traffic for at least 10ms to a peripheral (MAX8895_), the peripheral must enter a power-down state called SUSPEND. Once suspended, the peripheral must have enough of its internal logic active to recognize when the host resumes signaling, or if enabled, for generating remote wake-up.

The MAX8895_ enters SUSPEND state in two ways:

- **MAX8895V/MAX8895W/MAX8895X:** When no activity is present on D+/D- for 10ms (max), the MAX8895V/MAX8895W/MAX8895X automatically enters suspend mode to be compliant with USB specification. The MAX8895V/MAX8895W/MAX8895X only enters suspend mode if SUS_EN is pulled high. When entering suspend mode the MAX8895V/MAX8895W/MAX8895X disables the charger as well as $V_{SYS\_}$ to reduce the input current drawn from $V_{BUS\_}$. The current drawn in this mode is less than 500µA for the MAX8895V/MAX8895W/MAX8895X, ensuring that the device is compliant with USB specification. In suspend state the bus is IDLE: D+ is low and D- is kept high by the MAX8895V/MAX8895W/MAX8895X pullup resistor. When in suspend mode, $V_{SYS\_}$ is powered from $\overline{V_{BAT\_}}$. When entering automatic suspend mode, the $\overline{FLT}$ output is pulled low as an indication that the charger is disabled.

- **MAX8895Y:** When no activity is present on D+/D- for 10ms (max), the MAX8895Y automatically enters suspend mode to be compliant with USB specification. When entering suspend mode, the MAX8895Y disables the charger as well as $V_{SYS\_}$ to reduce the input current drawn from $V_{BUS\_}$. The current drawn in this mode is less than 2.5mA, ensuring that the device is compliant with the USB specification.

In suspend state, the bus is IDLE: D- is low and D+ is kept high by the MAX8895Y pullup resistor. When in suspend mode, $V_{SYS\_}$ is powered from $\overline{V_{BAT\_}}$. When entering automatic suspend mode, the $\overline{FLT}$ output is pulled low as an indication that the charger is disabled.
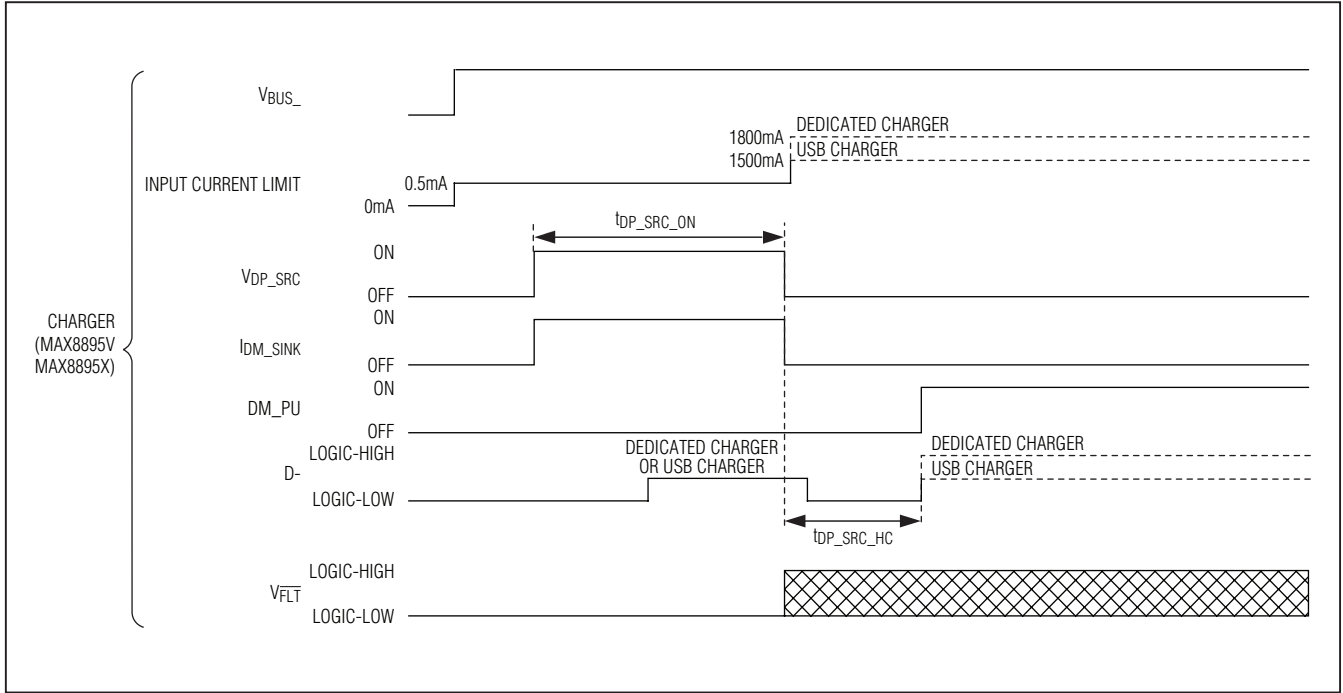
Figure 14a. Charger Detection Timing Diagram (MAX8895V/MAX8895X)
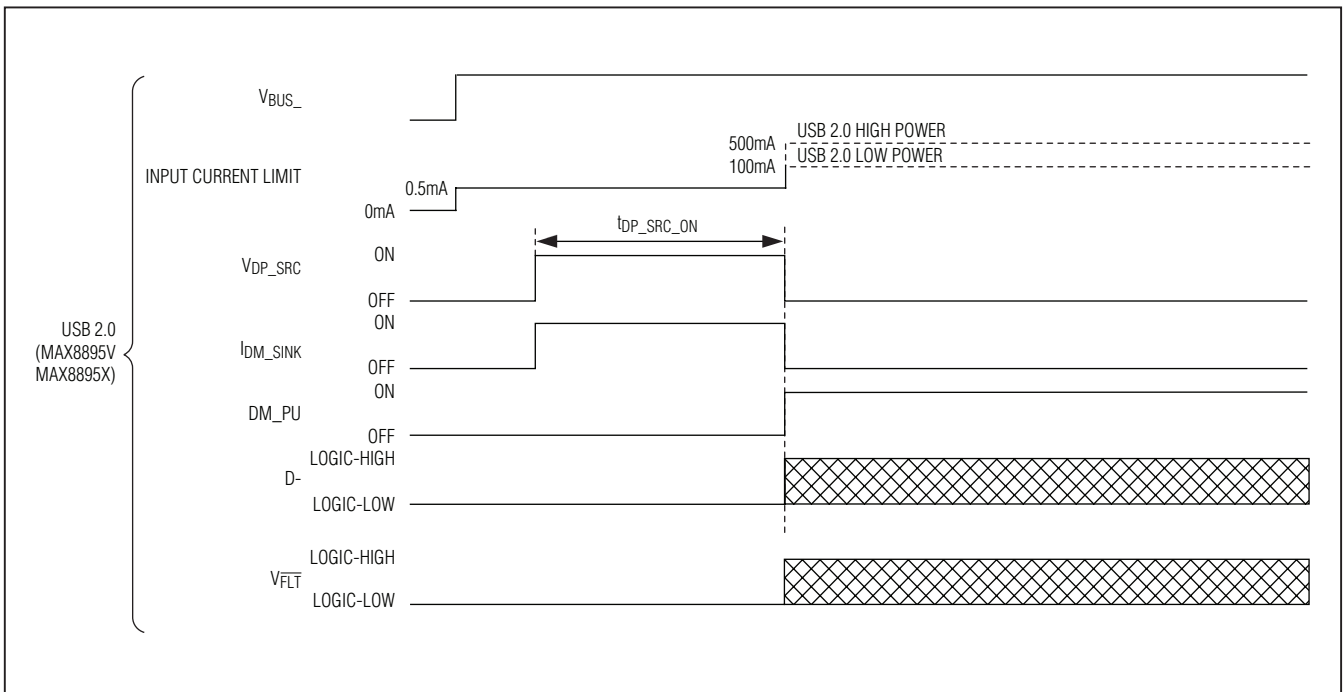
Figure 14b. USB Detection Timing Diagram (MAX8895V/MAX8895X)
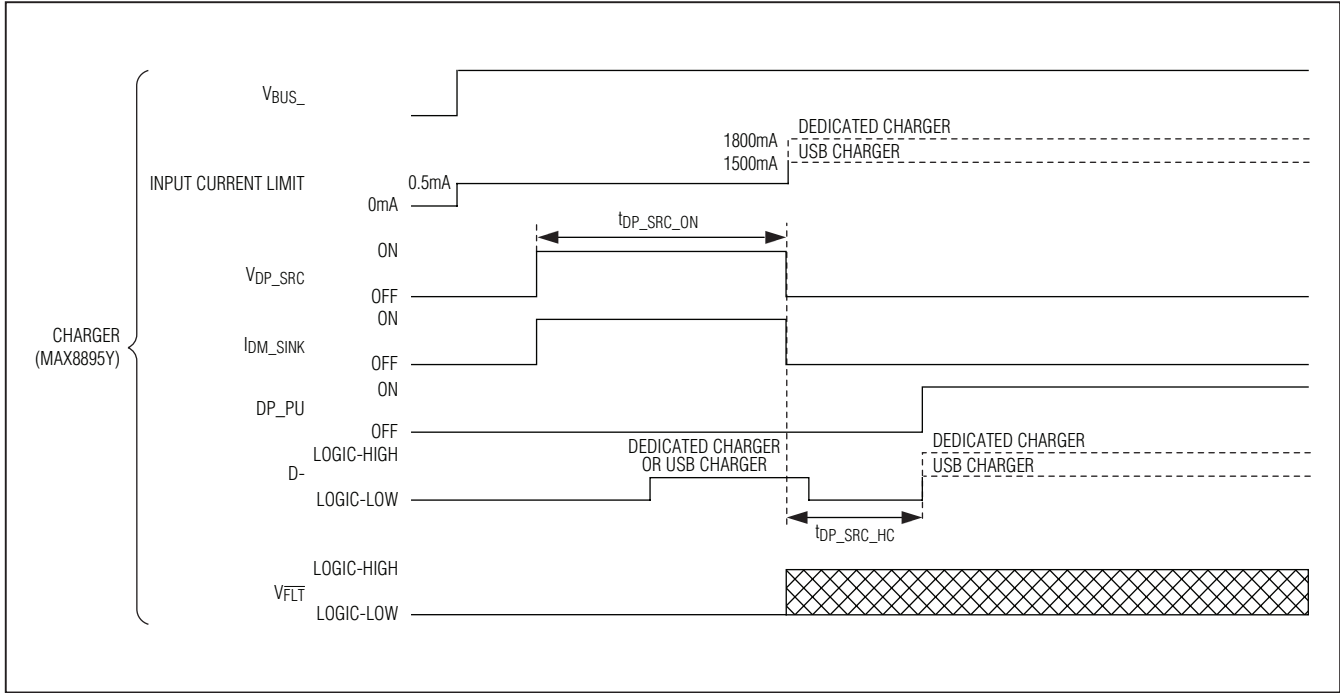
Figure 15a. Charger Detection Timing Diagram (MAX8895Y)
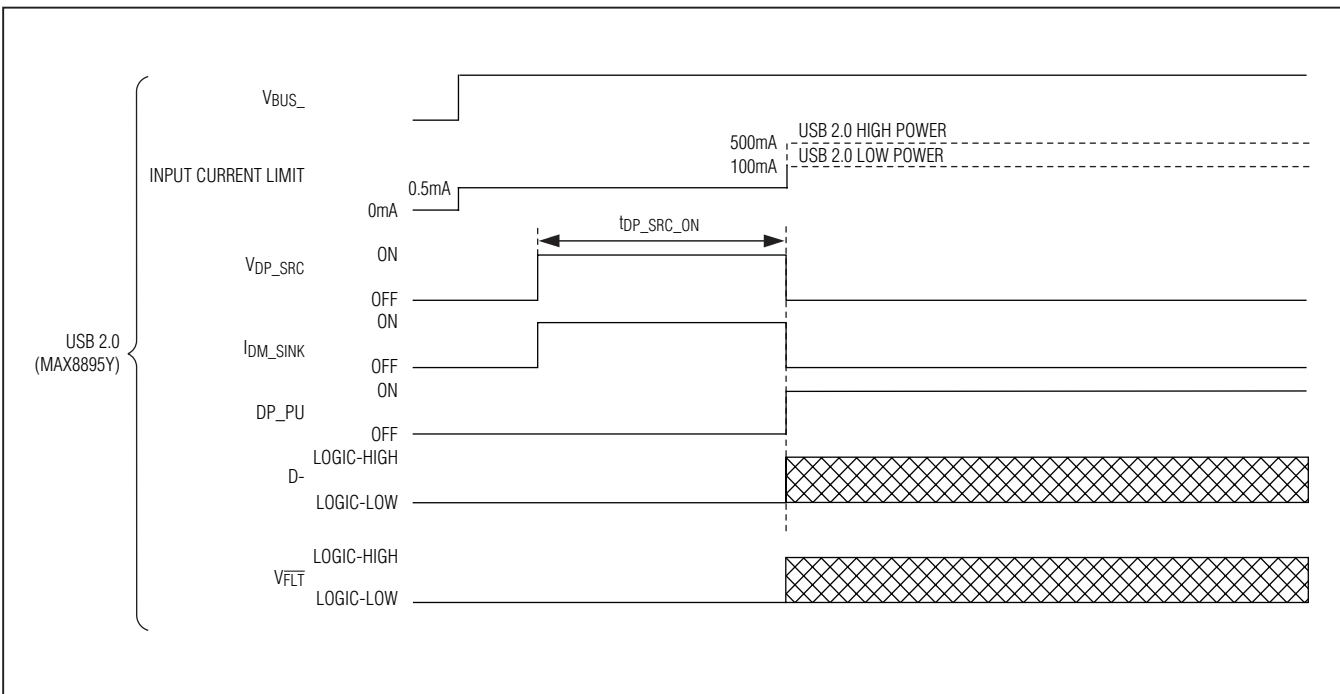
Figure 15b. USB Detection Timing Diagram (MAX8895Y)

Figure 16a. Charger Detection Timing Diagram (MAX8895W)

Figure 16b. USB Detection Timing Diagram (MAX8895W)

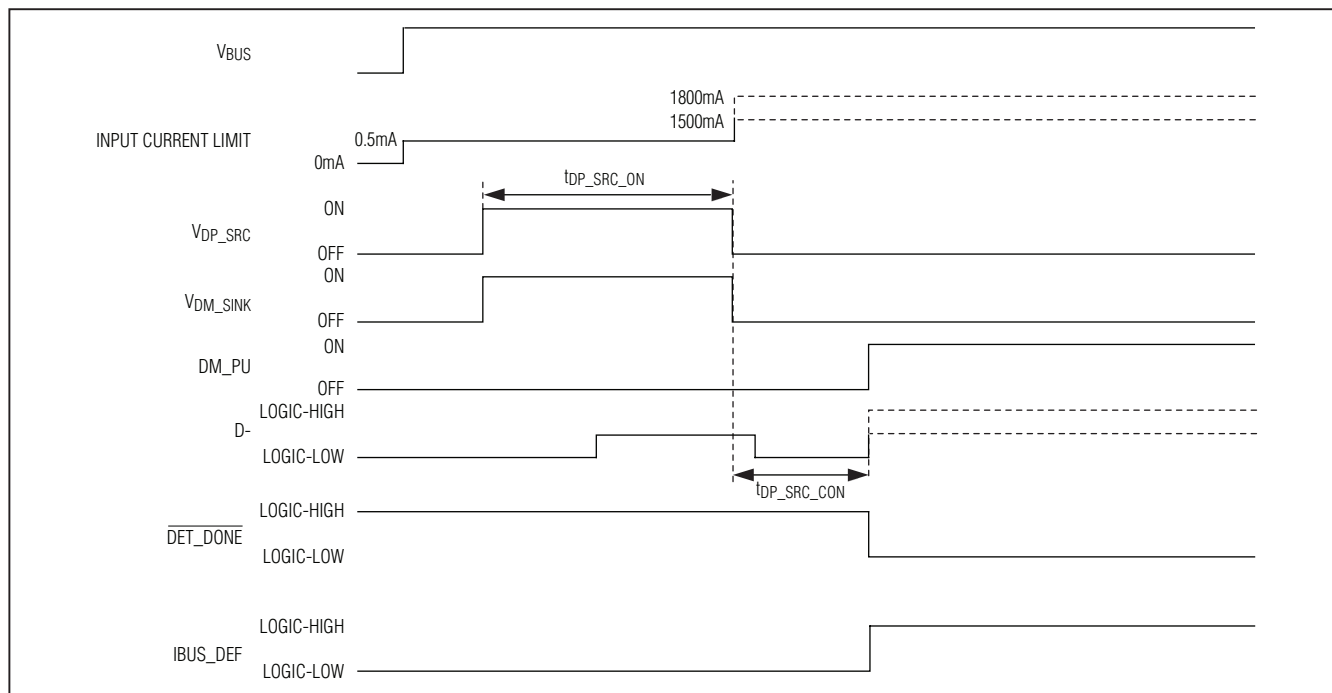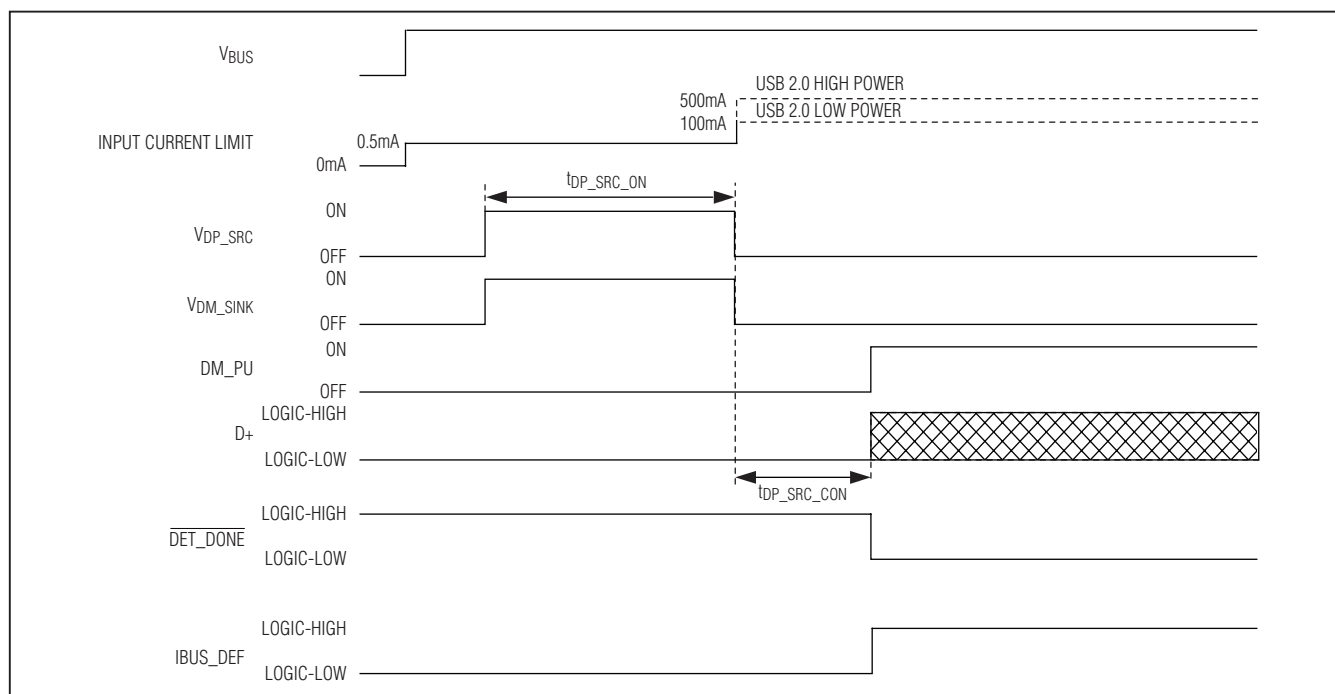# Li-Ion Chargers with Smart Power Selector, Adapter Type Detection, and USB Enumeration

Wake-Up and USB Resume

The MAX8895_ can wake up four ways while in suspend mode:

- Logic-high to logic-low transition of STDBY initiating enumeration.

- **MAX8895V/MAX8895W/MAX8895X:** If STDBY is logic-low and SUS_EN is logic-high, the MAX8895V/MAX8895W/MAX8895X monitor the bus activity on the D- line. If the host resumes bus activity, the MAX8895V/MAX8895W/MAX8895X detects this as a 1 to 0 transition **on D-**. Once this occurs, the device restarts the oscillator and waits for it to stabilize.

- **MAX8895Y:** If STDBY is logic-low, the MAX8895Y monitors the bus activity on the D+ line. If the host resumes bus activity, the MAX8895Y detects this as a 1 to 0 transition **on D+**. Once this occurs, the device restarts the oscillator and waits for it to stabilize.

- Remote wake-up is supported by the MAX8895V/MAX8895X/MAX8895Y, but the remote wake-up feature must be enabled by the host during the enumeration process. Once suspended, the MAX8895V/MAX8895X/MAX8895Y look at the state of the battery charger. If the charger is not in the done state, the MAX8895V/MAX8895X/MAX8895Y initiate a remote wake-up signal. If the charger is in the done state, a remote wake-up is not initiated before the charger is restarted due to a drop in battery voltage.

- When the MAX8895V/MAX8895X/MAX8895Y initiate a remote wake-up, they first restart the oscillator and wait for the oscillator to stabilize, and then send the remote wake-up event to signal to the host that it needs to be driven out of the suspend status.

- If RWU is connected to ground and the remote wake-up feature has not been set by the host during enumeration, the IC waits t_{RE_ENUM} after entering suspend mode, then disconnects the pullup resistor and reinitiates the charger type detection.

Enumeration

USB bus enumeration is an activity that identifies and assigns unique addresses to devices attached to the bus. Once the MAX8895_ detects $V_{BUS\_}$ is valid for T_{USB_DB}, the MAX8895_ initiates the detection process to determine the type of device that it is connected to. If the device type is a USB 2.0 host/hub or USB charger, a 1.5kΩ pullup resistor is connected between D- (MAX8895V/MAX8895W/MAX8895X) or D+ (MAX8895Y) to INT_3V3.

Enumeration is started on the MAX8895V/MAX8895W/MAX8895X only if $\overline{ENU\_EN}$ is logic-low. If $\overline{ENU\_EN}$ is logic-high, the MAX8895V/MAX8895W/MAX8895X does not connect a pullup resistor between D- and INT_3V3, and the current limit is set to 100mA regardless of the input type.

When the USB 2.0 host/hub or USB charger detects a plugged-in peripheral (MAX8895_), it interrogates the peripheral to learn about its capabilities and requirements; and if all is well, configures it to bring it on line. This process is known as enumeration.

During enumeration the host sends multiple requests to the device (MAX8895_) asking for descriptors (see Table 2) that define the device operation.

All the enumeration tasks are self-managed by the MAX8895_ serial interface engine (SIE) without any processor intervention.

The SIE supports the following features:

- USB 2.0 low-speed (1.5Mbps): the MAX8895V/MAX8895W/MAX8895X pulls D- high to indicate to the host that it is a low-speed device

- Full-speed (12Mbps) operation: the MAX8895Y pulls D+ high to indicate to the host that it is a full-speed device

- Human interface device (HID) in the consumer page (MAX8895_ does not require any custom drivers)

- 8 bytes end-point zero (control end point)

- 1 byte end-point one (INT-IN end point)

- USB suspend/resume support

- Remote wake-up capability

At the end of enumeration (if successful), the device is ready to transfer data (if needed) and enabled to sink the negotiated current from $V_{BUS\_}$.

Figure 17 shows USB bus traffic as captured by a CATC USB bus analyzer. The traces show a PC (host) enumerating the peripheral (MAX8895V/MAX8895W/MAX8895X). Notice that the LS field indicates the low-speed (1.5Mbps) operation of the MAX8895V/MAX8895W/MAX8895X.

1) The host uses the default CONTROL end-point EP0 (shown in the "ENDP" boxes) to send a request to the device. The host initially sends requests to address 0 (shown in the ADDR boxes) to communicate with a device to which it has not yet assigned a unique address.
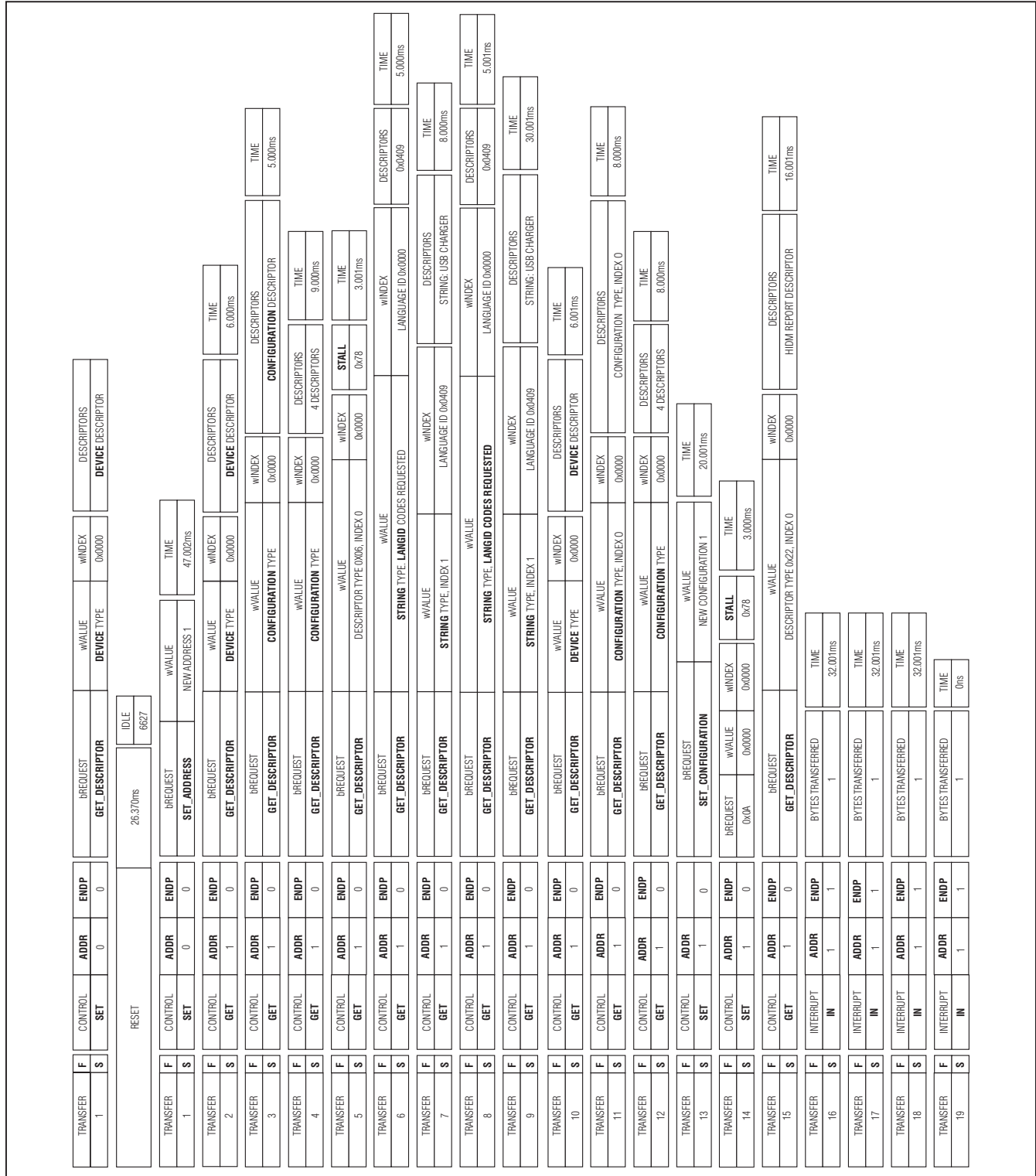
Figure 17. USB Bus Traffic: MAX8895V/MAX8895W/MAX8895X Enumeration

Figure 18. USB Bus Traffic: MAX8895Y Enumeration

Li-Ion Chargers with Smart Power Selector, Adapter Type Detection, and USB Enumeration

2) The host begins by sending a Get_Descriptor_Device request (Transfer 0 in Figure 16). It does this to determine the maxPacketSize of the device's EP0 buffer (for the MAX8895V/MAX8895X, it is 8 bytes). The host then resets the device by issuing a bus reset (packet 69).

3) In transfer 1, the host assigns a unique address to the peripheral by using the Set_Address request. The assigned address depends on how many other USB devices are currently attached to the host. In this case, the address assigned to our peripheral device (MAX8895V/MAX8895X) is 3. Thereafter, the MAX8895V/MAX8895X respond only to requests directed to address 3. This address remains in force until the host does a bus reset or the device is disconnected. Notice that the peripheral address field (ADDR) in the bus trace changes from 0 to 3 after transfer 1.

4) In transfers 2 to 11, the host asks for various descriptors. The device FSM needs to determine from the eight setup bytes which descriptor to send, use this information to access one of several character arrays (ROMs) representing the descriptor arrays.

5) In transfer 12, the host requests the device to use the specified configuration (1) and the device enters the configured state.

According to the USB 2.0 specification, a bus powered device can be either low power (it may draw no more than 100mA) or high power (it may draw no more than 500mA).

All devices must default to low power. The transition to high power is under software control (running on the host side). It is the responsibility of software to ensure adequate power is available before allowing devices to consume high-power.

The MAX8895_ initiates enumeration by asking for 500mA of current. If the MAX8895_ does not enter configured status before the t_{ENUM} (10s, typ), it interprets this as an indication that the host is not able to support the requested current. The MAX8895_ disconnects the pullup resistor on D- (MAX8895V/MAX8895X)/D+ (MAX8895Y), wait for t_{ENU_FAULT}, and then retry to enumerate, but now as a low current device (100mA). If the MAX8895_ has still not reached the configured status after t_{ENUM}, the MAX8895_ assumes that either the host is nonresponsive or a wrong adapter type is detected. In this case, the MAX8895_ disconnects the pullup resistor on D- (MAX8895V/MAX8895W/MAX8895X)/D+ (MAX8895Y) and wait for $t_{ENU\_FAULT} + t_{FAULT}$ before starting the adapter detection process again.

Figure 18 shows the USB traffic captured during the MAX8895Y enumeration. Notice the field FS indicates the full-speed (12Mbps) operation of the MAX8895Y.

Table 2. Device Descriptor

FIELD	LENGTH (bits)	OFFSET (bits)	DECODED	HEXVALUE	DESCRIPTION
bLength	8	0	0x12	0x12	Descriptor size is 18 bytes
bDescriptorType	8	8	0x01	0x01	Device descriptor type
bcdUSB	16	16	0x0200	0x0200	Device compliant to the USB specification version 2.0
bDeviceClass	8	32	0x00	0x00	Each interface specifies its own class information
bDeviceSubClass	8	40	0x00	0x00	Each interface specifies its own subclass information
bDeviceProtocol	8	48	0x00	0x00	No protocols the device basis
bMaxPacketSize0	8	56	0x08	0x08	Maximum packet size for end-point zero is 8
idVendor*	16	64	—	—	Vendor ID is 2922: Maxim Integrated Products
idProduct*	16	80	0x5346	0x5346	Product ID is 21318
bcdDevice	16	96	0x1234	0x1234	The device release number is 1.00
iManufacturer	8	112	0x00	0x00	The device does not have the string descriptor describing the manufacturer
iProduct	8	120	0x01	0x01	The product stringed descriptor index is 1
iSerialNumber	8	128	0x00	0x00	The device does not have the string descriptor describing the serial number
bNumConfigurations	8	136	0x01	0x01	The device has 1 possible configuration

Li-Ion Chargers with Smart Power Selector, Adapter Type Detection, and USB Enumeration

Smart Power Selector

The Smart Power Selector seamlessly distributes power between the external $V_{BUS\_}$ input, the battery ($V_{BAT\_}$), and the system load ($V_{SYS\_}$). See Figure 19. The Smart Power Selector basic functions are:

- With both an external adapter and battery connected:

  a. When the system load requirements are less than the input current limit, the battery is charged with residual power from the input.

  b. When the system load requirements exceed the input current limit, the battery supplies supplemental current to the load.

- When the battery is connected and there is no external power input, the system is powered from the battery.

- When an external power input is connected and there is no battery, the system is powered from $V_{BUS\_}$.

If the junction temperature starts to get too hot (+110°C typ), the charging rate is reduced. If this is not sufficient to cool down the MAX8895_, the input current limit is then reduced.

System Load Switch

An internal 55mΩ (typ) MOSFET connects $V_{SYS\_}$ to $V_{BAT\_}$ (Q2, Figure 19) when no voltage source is available at $V_{BUS\_}$ and $V_{BAT\_}$ is above the battery UVLO threshold. When an external source is detected at $V_{BUS\_}$, this switch controls the charging of $V_{BAT\_}$ and $V_{SYS\_}$ is powered from the valid input source through the input current limiter.

The $V_{SYS\_}$ - $V_{BAT\_}$ switch also prevents $V_{SYS\_}$ from falling below $V_{BAT\_}$ when the system load exceeds the input current limit. If that should happen, $V_{SYS\_}$ is allowed to drop to $V_{BAT\_}$. At this point, the $V_{SYS\_}$ - $V_{BAT\_}$ switch turns on so that the battery supplies additional $I_{SYS\_}$ load current. If the system load continuously exceeds the input current limit, then the battery does not charge, even though external power is connected. This is not expected to occur in most cases, since high loads usually occur only in short peaks. During these peaks, battery energy is used, but at all other times the battery charges.

Input Limiter

The input limiter distributes power from the external adapter to the system load and battery charger. In addition to the input limiter's primary function of passing power to the system and charger, it performs several additional functions to optimize use of available power.

- **Input Voltage Limiting:** If the $V_{BUS\_}$ input voltage is above the overvoltage threshold (V_{BUS_OVP}), the MAX8895_ enters overvoltage lockout (OVL). OVL protects the MAX8895_ and downstream circuitry from high-voltage stress up to 16V at $V_{BUS\_}$. In OVL, V_{INT_3V3} remains on, the input switch that sees overvoltage (Q1, Figure 19) opens, $\overline{FLT}$ is pulled low, and $\overline{UOK}$, $\overline{CHG}$, $\overline{DET\_DONE}$, and $\overline{PREQ}$ become high-impedance. In OVL, the charger turns off. The $V_{BAT\_}$ - $V_{SYS\_}$ switch (Q2, Figure 19) closes, allowing the battery to power $V_{SYS\_}$. $V_{BUS\_}$ is also invalid if it is less than $V_{BAT\_}$, or less than the USB undervoltage threshold ($V_{BUS\_UVLO\_F}$). With an invalid input voltage, $V_{SYS\_}$ connects to BAT_ through a 55mΩ (typ) switch (Q2, Figure 19).

- **Input Overcurrent Protection:** The current at $V_{BUS\_}$ is limited to prevent input overload. This current limit is automatically selected to match the capabilities of the adapter source, whether it is a 100mA or 500mA USB 2.0 source, or 500mA to 1.8A for a dedicated adaptor or USB charger. When the load exceeds the input current limit, $V_{SYS\_}$ drops to 50mV (typ) below $V_{BAT\_}$ and the battery supplies supplemental load current.
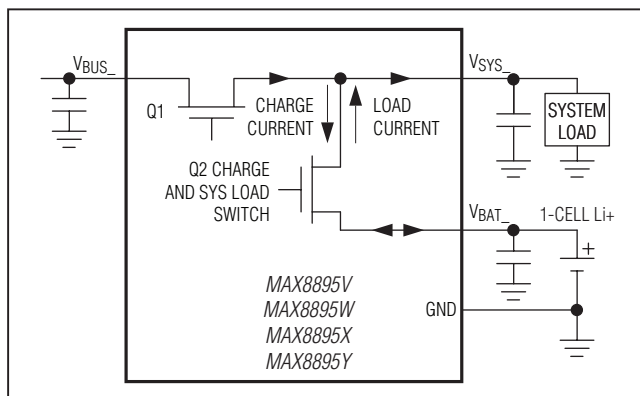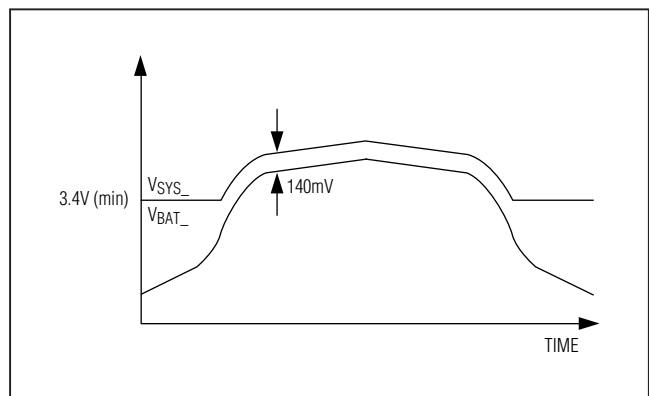

Figure 19. Smart Power Selector Block Diagram

Figure 20. $V_{SYS\_}$ Regulation

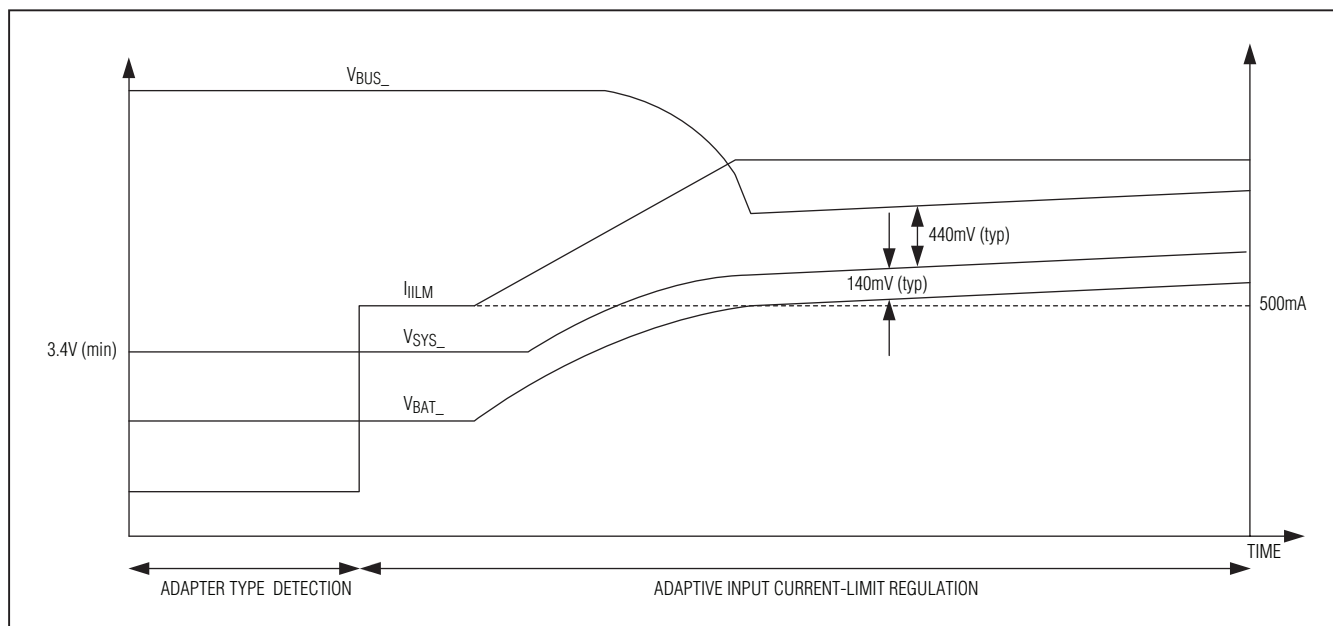*Contact factory for specific vendor ID and product ID.

Figure 21. Adaptive Input Current-Limit Regulation Loop

- **Thermal Limiting:** The MAX8895V/MAX8895X/MAX8895Y reduce input current by 5%/°C when its die temperature exceeds T_{DIE_LIM} (+110°C typ). The system load ($V_{SYS\_}$) has priority over charger current, so the input current is first reduced by lowering the charge current. If the junction temperature still reaches T_{DIE_LIM} +20°C in spite of charge current reduction, no input $V_{BUS\_}$ current is drawn, the battery supplies the entire system load, and V_{SYS} is regulated at 50mV (typ) below $V_{BAT\_}$.

  Note: The on-chip thermal limiting circuitry is not related to, and operates independently from, the thermistor input.

- **Adaptive Battery Charging:** While the system is powered from $V_{BUS\_}$, the charger draws power from $V_{SYS\_}$ to charge the battery. If the combined load between the charger and system exceeds the input current limit, an adaptive charger control loop reduces charge current to prevent the $V_{SYS\_}$ voltage from collapsing.

Regulation Threshold

The MAX8895_ always regulates $V_{SYS\_}$ to 140mV (typ) above $V_{BAT\_}$ with a minimum voltage of 3.4V regardless of what device is connected. The 3.4V minimum voltage regulation reduces the ripple on $V_{SYS\_}$ during peak load conditions where the input current limit is tripped.

Input Current Limit

If the connected adapter is a USB 2.0 device the input current limit is set by default to 100mA.

If $\overline{ENU\_EN}$ is connected to INT_3V3 or driven logic-high for the MAX8895V/MAX8895X/MAX8895Y, the charger input current limit remains at 100mA. If $\overline{ENU\_EN}$ is set to logic-high for the MAX8895W the charger's input current limit is determined by the logic state of IBUS_DEF.

When $\overline{ENU\_EN}$ is connected to AGND, automatic enumeration is initiated. The MAX8895_ proceeds to determine if the external USB device is a low- or high-power device and set the input current limit to 100mA or 500mA, respectively. For a dedicated charger or USB charger, the current limit is determined by loading the adapter. When the adapter's output voltage starts to collapse, it is an indication that the current limit of the device is reached.

The MAX8895_ set the input current limit to regulate V_{BUS} to V_{SYS} +440mV (typ). This ensures that the power dissipation in the MAX8895_ is kept to a minimum, and at the same time, ensuring that the adapter's current capability is fully utilized. When a dedicated charger is detected, the input current limited is limited by the adaptive input current limit. In this mode, it is up to the adapter to limit the maximum current, which is 1.85A for a dedicated charger and 1.5A for a USB charger, according to the USB charging specification.

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If the adapter output (V_{BUS}) starts to drop below V_{SYS} - 440mV (typ), the input current limit function adaptively decreases the input current limit to ensure that the adapter is not overloaded. When the input current limit is reached, the first action taken by the MAX8895_ is to reduce battery charge current. If, after the charge current is reduced to 0mA, the load at I_{SYS} still exceeds the input current limit, V_{SYS} begins to fall. When V_{SYS} drops to 50mV below V_{BAT}, the V_{SYS} - V_{BAT} switch turns on, using battery power to support the system load during the load peak. See Figure 21 for more information.

Power Monitor Output ($\overline{UOK}$)

$\overline{UOK}$ is an open-drain output that pulls low when the $V_{BUS\_}$ input has valid power.

The $\overline{UOK}$ monitor has several different thresholds, depending on what type of adapter detected. The different thresholds are as follows:

- The initial detection threshold allows all types of adapters to be detected on $V_{BUS\_}$. Once the type of adapter is determined, the UVLO threshold is changed.

- For any USB 2.0 device the UVLO thresholds are set to be compliant with USB specifications.

- For a dedicated charger, the UVLO (falling) threshold is lowered to $V_{SYS\_}$ + 50mV (typ) to allow for supporting collapsing charger types, allowing the MAX8895_ to operate with lower power dissipation.

Note that since the $V_{BUS\_}$ UVLO threshold is changed after initial detection of the device type, there are conditions where the MAX8895_ can toggle between $V_{BUS\_}$ valid and not valid. This is an indication that the adapter is not within the specified limits.

See Table 3 for more information.

Table 3. $\overline{UOK}$ Monitor Thresholds

THRESHOLDS	UVLO	OVLO (V)
Initial $V_{BUS\_}$ detection	4.0V (typ), rising	
For USB 2.0 low power	3.9V (typ), falling	6.9
For USB 2.0 high power	4.1V (typ), falling	
For dedicated charger to USB charger	$V_{SYS\_}$ + 50mV (typ), falling	
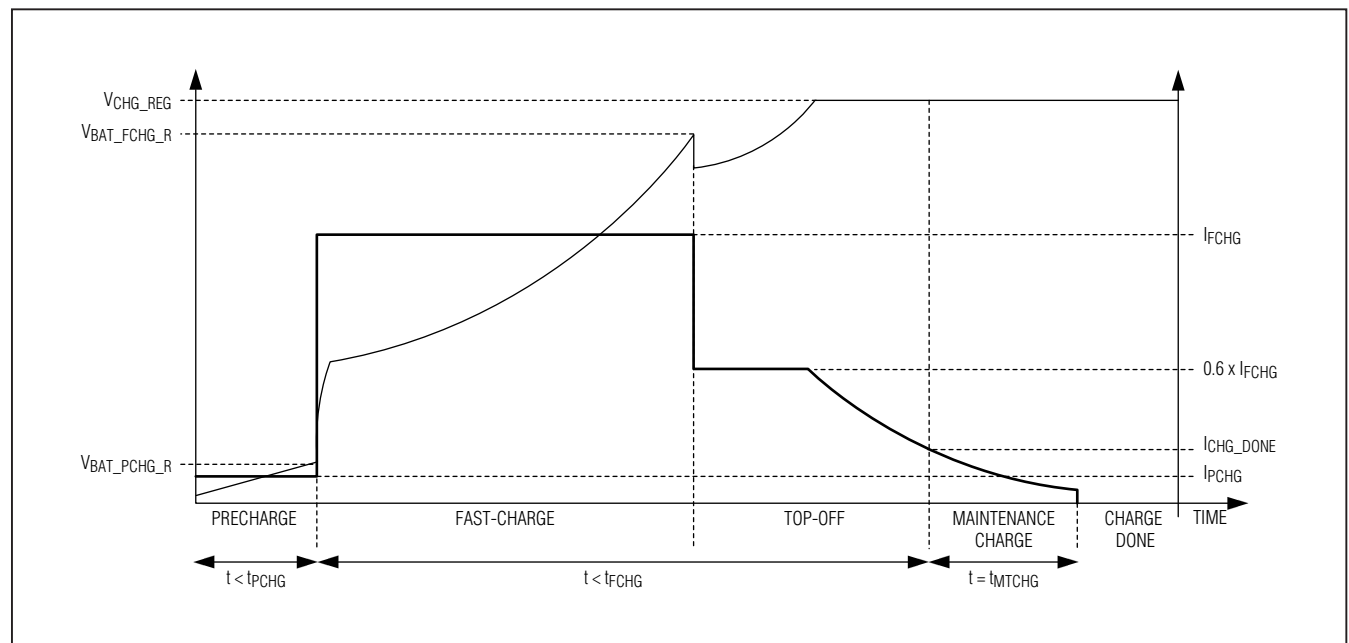
Figure 22. Charging States

Soft-Start

To prevent input transients that can cause instability in the USB power source, the rate of change of input current and charge current is limited. When a valid USB 2.0 input is connected, the input current limit is ramped from 0 to 100mA in 50μs. Once enumeration is ended, the current can be ramped to 500mA or to the new input current limit value in 50μs.

When the charger is enabled, the charge current ramps from zero to the final value in 1.5ms (typ). Charge current also ramps when transitioning to fast-charge from prequalification and when changing the USB charge current from 100mA to 500mA.

Note: There is no di/dt limiting if I_{ISET} is changed suddenly using a switch at R_{ISET}.

Battery Charger

The battery charger has five different states of operation (see Figures 22 and 23):

- **Precharge:** When the battery voltage is below $V_{BAT\_PCHG\_R}$. In this state, the battery is charged at maximum I_{PCHG}. If the $I_{PCHG} > I_{LIM}$, then the precharging current is determined by the I_{LIM} (input current limit). Charging a Li+ battery at high charging current when it is fully discharged can cause the battery to become unstable and potentially dangerous. Charging at high charging rates on a fully discharged battery can also reduce life cycles of the Li+ battery.

- **Fast-charge:** In fast-charge mode, the charging current is set to maximum I_{FCHG}. The actual charging current is determined by $I_{LIM} - I_{SYS\_}$.

- **Top-off charge:** In top-off mode, the battery voltage has almost reached the set point ($V_{BAT\_FCHG\_R}$). The charging current is reduced in this mode to prevent overcharging the battery, and also to minimize the power dissipation in the battery.

- **Maintenance charge:** The charger enters this mode when the charging current has dropped below the I_{CHG_DONE} threshold. The charger continues to charge for t_{MTCHG} time to ensure the battery is fully charged before the charger is disabled.

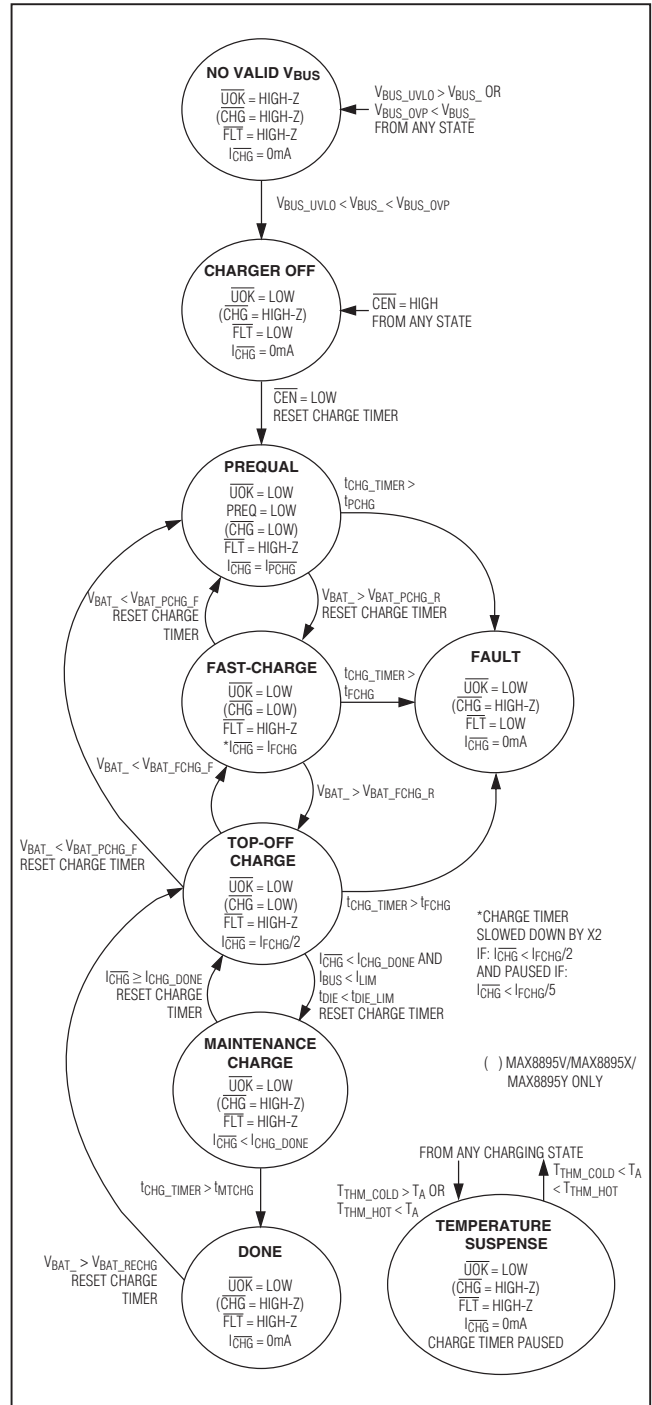- **Charge done:** Charger is disabled and only engages again if the battery voltage drops below the V_{BAT_RECHG} threshold.

Figure 23. Charger Flow Chart

Charge Enable ($\overline{CEN}$)

When $\overline{CEN}$ is logic-low, the battery charger is enabled. When $\overline{CEN}$ is logic-high, the battery charger is disabled. $\overline{CEN}$ does not affect $V_{SYS\_}$. In many systems, there is no need for the system controller (typically a microprocessor) to disable the battery charger because the MAX8895_ Smart Power Selector circuitry independently manages charging and USB-battery power handover. In these situations, $\overline{CEN}$ may be connected to ground.

Setting Charge Current (ISET)

ISET adjusts the charge current to match the capacity of the battery. The maximum charging current can be fixed by connecting ISET to INT_3V3 or can be adjusted by connecting ISET to ground through a resistor. When ISET is connected to ground through a resistor the maximum charging current is determined using the following formula:

$$I_{FCHG} = \frac{3000}{R_{ISET}}$$

where R_{ISET} is a resistor from ISET to ground.

Determine the I_{FCHG} value by considering the characteristics of the battery. It is not necessary to limit charge current based on the capabilities of the expected adapter input, the system load, or thermal limitations of the PCB. The MAX8895_ automatically adjusts the charging algorithm to accommodate these factors.
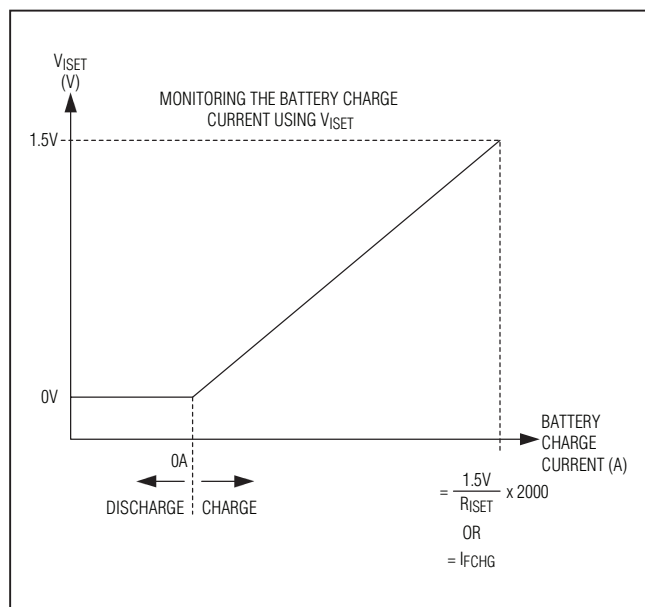

Figure 24. Monitoring Charge Current with the ISET Voltage

Monitoring Charge Current (ISET)

In addition to setting charge current, ISET can also be used to monitor the actual current charging the battery. The ISET output voltage is:

$$I_{\overline{CHG}} = \left(\frac{V_{ISET}}{R_{ISET}} \right) \times 2000$$

where:

$I_{\overline{CHG}}$ is the actual battery charge current, R_{ISET} is a resistor from ISET to ground.

A 1.5V output indicates the battery is being charged at the maximum fast-charge current (I_{FCHG}). 0V indicates no charging. The ISET voltage is also used by the charger control circuitry to set and monitor the battery current. Avoid adding more than 10pF of capacitance directly to the ISET pin. If filtering of the charge current monitor is necessary, add a resistor of 100kΩ or more between ISET and the filter capacitor to preserve charger stability.

If the maximum charge current (I_{FCHG}), is set to the default value, the current monitor function is not available.

Charge Termination (IDN)

When the charge current falls to the termination threshold and the charger is in voltage mode, charging is complete. Charging continues for a time period defined by the t_{CHG_DONE} and then enters the DONE state where charging stops.

The IDN input adjusts the charge current termination threshold. The termination threshold can be fixed by connecting IDN to INT_3V3 or can be adjusted by connecting IDN to ground through a resistor. When IDN is connected to ground through a resistor, the charge done threshold is determined using the following formula:

$$I_{TERM} = \frac{2400}{R_{IDN}}$$

where R_{IDN} is a resistor from IDN to ground.

Note that if charge current falls to I_{TERM} as a result of the input or thermal limiter, the charger does not enter the DONE state. For the charger to enter DONE, charge current must be less than I_{TERM}, the charger must be in voltage mode, and the input or thermal limiter must not be reducing charge current. The charger exits the DONE state and fast-charge resumes if the battery voltage subsequently drops below V_{BAT_RECHG} or if $\overline{CEN}$ is cycled. Connecting IDN to INT_3V3 selects the default termination current threshold.

Charge Status Outputs
Charge Output ($\overline{CHG}$) (MAX8895V/MAX8895X/ MAX8895Y Only)

$\overline{CHG}$ is an active-low, open-drain output that is driven low during charging. $\overline{CHG}$ is logic-low when the battery charger is in fast-charge and top-off states. When charge current falls to the charge termination threshold and the charger is in voltage mode $\overline{CHG}$ goes high impedance. $\overline{CHG}$ holds its current state if the thermistor causes the charger to enter temperature suspend mode. When the MAX8895V/MAX8895X/MAX8895Y are used with a microprocessor, connect a pullup resistor between $\overline{CHG}$ and the logic I/O voltage to indicate charge status to the microprocessor. Alternatively, $\overline{CHG}$ can sink up to 20mA for an LED indicator.

Prequalification Output ($\overline{PREQ}$) (MAX8895V/MAX8895X/MAX8895Y Only)

$\overline{PREQ}$ is an active-low, open-drain output that is driven low when the charger is in prequalification state. When the MAX8895V/MAX8895X/MAX8895Y are used in conjunction with a microprocessor, connect a pullup resistor between $\overline{PREQ}$ and the logic I/O voltage to indicate charge status to the microprocessor. Alternatively, $\overline{PREQ}$ can sink up to 20mA for an LED indicator.

Fault Output ($\overline{FLT}$) and Charge Timer (CT)

$\overline{FLT}$ is an active-low, open-drain output that is driven low during a battery fault. The fault state occurs when either the prequalification or fast-charge timer expires. The prequalification and fast-charge fault timers are set by C_{CT}:

$$t_{PREQUAL} = 16min \times \frac{C_{CT}}{0.068\mu F}$$

$$t_{FCHG} = 100min \times \frac{C_{CT}}{0.068\mu F}$$

While in fast-charge mode, a large system load or device self-heating may cause the MAX8895_ to reduce charge current. Under these circumstances, the fast-charge timer adjusts to ensure that adequate charge time is still allowed. Consequently, the fast-charge timer is slowed by 2x if charge current is reduced below 50% of the programmed fast charge level. If charge current is reduced to below 20% of the programmed level, the fast-charge timer is paused. The fast-charge timer is not adjusted if the charger is in voltage mode where charge current reduces due to current tapering under normal charging.

To exit a fault state, toggle $\overline{CEN}$ or remove and reconnect the $V_{BUS\_}$ input source. **Note:** A thermistor out-of-

range or on-chip thermal limit conditions are not considered faults. When the MAX8895V/MAX8895X/MAX8895Y are used in conjunction with a microprocessor, connect a pullup resistor between $\overline{FLT}$ and the logic I/O voltage to indicate fault status to the microprocessor. Alternatively, $\overline{FLT}$ can sink up to 20mA for an LED indicator.

CHG_TYPE Output (MAX8895W Only)

The output CHG_TYPE is used to indicate the type of interface detected. If CHG_TYPE output is logic level low the input current limit is set to 100mA or less. If CHG_TYPE output is logic level high the input current limit is set to 500mA or greater.

$\overline{DET\_DONE}$ Output (MAX8895W Only)

$\overline{DET\_DONE}$ is an active low, open-drain output that is driven low once adapter detection is complete. $\overline{DET\_DONE}$ is high impedance in suspend mode.

IBUS_DEF Output (MAX8895W Only)

The IBUS_DEF input is only valid when $\overline{ENU\_EN}$ is set to logic-high activating the adapter type detection. If the adapter type is detected as a USB 2.0 device, the input current limit is set to the programmed value and the MAX8895W does not initiate USB enumeration. If IBUS_DEF is connected to ground or logic level low, the input current limit is set to 100mA. If IBUS_DEF is connected to INT_3V3 or logic level high, the input current limit is set to 500mA.

Thermistor Input (THM)

The THM input connects to an external negative temperature coefficient (NTC) thermistor to monitor battery or system temperature. Charging is suspended when the thermistor temperature is out of range. The charge timers are suspended and hold their state, but no fault is indicated. When the thermistor comes back into range, charging resumes and the charge timer continues from where it was at previously. Connecting THM to AGND disables the thermistor monitoring function.

Since the thermistor monitoring circuit employs an external bias resistor from THM to V_{INT_3V3} (R_{TB}, Figure 25), the thermistor is not limited only to 10kΩ (at T_A = +25°C). Any resistance thermistor can be used as long as the value of R_{TB} is equivalent to the thermistor's T_A = +25°C resistance. For example, with a 10kΩ at T_A = +25°C thermistor, use 10kΩ at R_{TB}, and with a 100kΩ at T_A = +25°C thermistor, use 100kΩ.

For a typical 10kΩ at T_A = +25°C thermistor and a 10kΩ R_{TB} resistor, the charger enters a temperature suspend state when the thermistor resistance falls below 3.97kΩ (too hot) or rises above 28.7kΩ (too cold). These limits

correspond to a 0°C to +50°C range when using a 10kΩ NTC thermistor with a beta of 3500. The general relation of thermistor resistance to temperature is defined by the following equation:

$$R_T = R_{25} \times e^{\left\{ \beta\left(\frac{1}{T+273} - \frac{1}{298}\right)\right\}}$$

where:

R_T = The resistance (Ω) of the thermistor at temperature T in °C.

R_{25} = The resistance (Ω) of the thermistor at T_A = +25°C.

ß = The material constant of the thermistor which typically ranges from 3000K to 5000K.

T = The temperature of the thermistor in °C.

Table 4 shows the MAX8895_ THM temperature limits for different thermistor material constants.

Table 4. Fault Temperatures for Different Thermistors

THERMISTOR β (K)	3000	3250	3500	3750	4250
R_{TB} (kΩ) (Figure 22)	10	10	10	10	10
Resistance at +25°C (kΩ)	10	10	10	10	10
Resistance at +50°C (kΩ)	4.59	4.30	4.03	3.78	3316
Resistance at 0°C (kΩ)	25.14	27.15	29.32	31.66	36.91
Nominal hot trip temperature (°C)	55	53	50	49	46
Nominal cold trip temperature (°C)	-3	-1	0	2	4.5
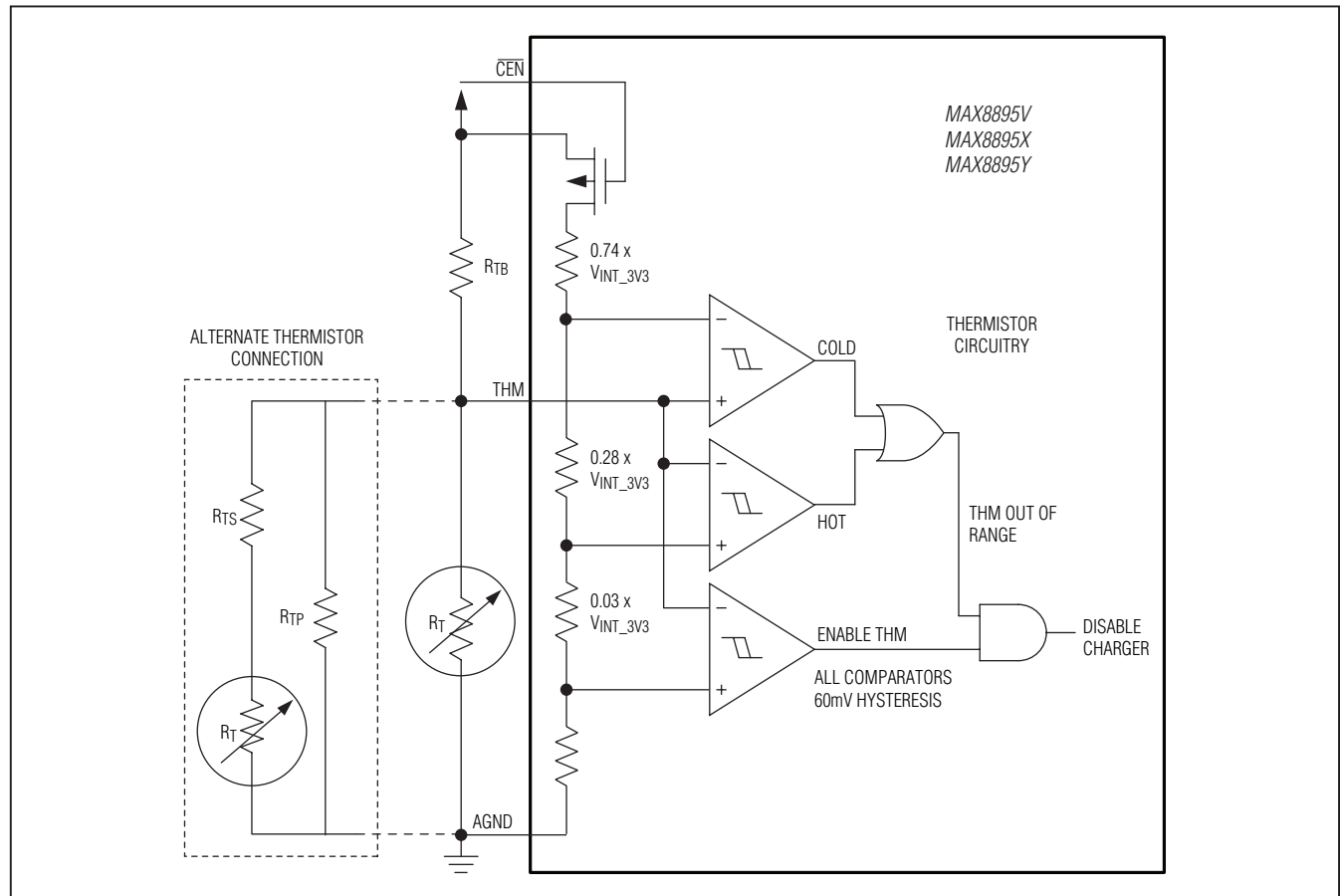
Figure 25. Thermistor Monitor Circuitry

Some designs may require other thermistor temperature limits. The threshold adjustment can be accommodated by changing R_{TB}, connecting a resistor in series and/or in parallel with the thermistor, or using a thermistor with different ß. For example, a T_A = +45°C hot threshold and T_A = 0°C cold threshold can be realized by using a thermistor with a ß of 4250 and connecting a 120kΩ resistor in parallel. Since the thermistor resistance near T_A = 0°C is much higher than it is near T_A = +50°C, a large parallel resistance lowers the cold threshold, while only slightly lowering the hot threshold. Conversely, a small-series resistance raises the cold threshold, while only slightly raising the hot threshold. Raising R_{TB} lowers both the hot and cold thresholds, while lowering R_{TB} raises both thresholds.

Thermal Shutdown

Thermal shutdown limits total power dissipation in the MAX8895_. When the junction temperature exceeds +160°C (typ), the device turns off, allowing the MAX8895_ to cool. The MAX8895_ turn on and begin soft-start after the junction temperature cools by 20°C (typ). This results in a pulsed charge current during continuous thermal-overload conditions.

External Clock (MAX8895Y)

The MAX8895Y includes full-speed USB 2.0 compatibility. USB 2.0 full speed requires that the system clock of the transceiver is within ±2500ppm, over temperature, aging, etc. Therefore, the MAX8895Y requires an external resonator or clock source to stay within this limit.

The MAX8895Y local oscillator and internal digital clocks are derived from the reference clock at the XIN input.

External Crystal/Ceramic Resonator (MAX8895Y)

XIN and XOUT are used to interface to an external 12MHz crystal or ceramic resonator. Connect a 33pF load capacitor from both XIN/XOUT to ground.

Requirements for the external resonator/crystal for MAX8895Y:

Frequency: 12MHz ±0.25%

C_{LOAD}: 33pF ±20%

Drive level: 200μW

Series resonance resistance: 60Ω (maximum), 30Ω (typical)

Note: Series resonance resistance is the resistance observed when the resonator is in the series resonant condition. This is a parameter often stated by quartz crystal vendors and is called R1. When a resonator is used in the parallel resonant mode with an external load capacitance, as is the case with the MAX8895Y oscillator circuit, the effective resistance is sometimes stated. The effective resistance at the loaded frequency of oscillation is:

$$R_{EFF} = R1 \times \left[1 + \left(\frac{C_O}{C_{LOAD}} \right) \right]^2$$

where:

R1 = Series resonance resistance

C_O = Crystal capacitor

C_{LOAD} = External load capacitance

For typical C_O and C_{LOAD} values, the effective resistance can be greater than R1 by a factor of 2.

External Clock (MAX8895Y)

The MAX8895Y can also be driven from an external clock. The MAX8895Y accepts an external clock input at XIN. The external clock can either be a digital level square wave or sinusoidal and this may be directly coupled to XIN without the need for additional components. If the peaks of the reference clock are above V_{INT_3V3} or below ground, the clock signal must be driven through a DC-blocking capacitor (approximately 33pF) connected to XIN.

The external clock source can either be enabled using the $\overline{UOK}$ or INT_3V3 signals depending on if the clock source is active-low or active-high enabled.

If the INT_3V3 rail is used, ensure that no significant load is taken from this output since this affects the performance of the MAX8895Y.

Clock Timing Accuracy (MAX8895Y)

USB 2.0 specification requires the system clock to be within ±2500ppm over temperature, aging, etc. It is recommended to use a clock source with tighter initial accuracy to ensure that over time the accuracy of ±2500ppm is still valid.

ESD Protection

D+, D-, and $V_{BUS\_}$ possess extra protection against static electricity to protect the devices up to ±8kV (HBM). The ESD structures withstand high ESD in all operating modes: normal operation, suspend mode, and powered down. $V_{BUS\_}$ requires 1μF ceramic capacitors connected to ground as close as possible to the pins.

Li-Ion Chargers with Smart Power Selector, Adapter Type Detection, and USB Enumeration

ESD Test Conditions

ESD performance depends on a variety of conditions. Contact Maxim for a reliability report that documents test setup, test methodology, and test results. Figure 26 shows the Human Body Model, and Figure 27 shows the current waveform generated when discharged into a low impedance. This model consists of a 100pF capacitor charged to the ESD voltage of interest, which then discharges into the test device through a 1.5kΩ resistor.

Applications Information

Capacitor Selection

Ceramic X5R or X7R dielectric capacitors are recommended for best operation. When selecting ceramic capacitors in the smallest available case size for a given value, ensure that the capacitance does not degrade significantly with DC bias. Generally, ceramic capacitors with high values and very small case size have poor DC bias characteristics. Evaluate capacitors carefully before using.

Ground Connections

Minimize trace lengths between the bypass capacitors and ground. Use separate digital/power ground (DGND) and analog ground (AGND) copper areas, and connect them together at the negative terminal of the battery. The pins and/or external components for KB_TM, crystal load capacitors, ISET, IDN, CT, thermistor, and INT_3V3 should connect to a quiet analog ground. All other ground connections should connect to DGND.

Recommended PCB Layout and Routing

Place all bypass capacitors for INT_3V3, $V_{BUS\_}$, $V_{BAT\_}$, and $V_{SYS\_}$ as close as possible to the device. Connect the battery to BAT_A and BAT_B as close as possible to the device to provide accurate battery voltage sensing. Make all high-current traces short and wide to minimize voltage drops.

When using the MAX8895Y, place the external crystal and load capacitors as close as possible to the MAX8895Y. The crystal and load capacitors should be kept as far away as possible from the D+/D- traces.

Refer to the MAX8895 Evaluation Kit for an example layout. The MAX8895 Evaluation Kit supports the MAX8895V/MAX8895X and MAX8895Y.
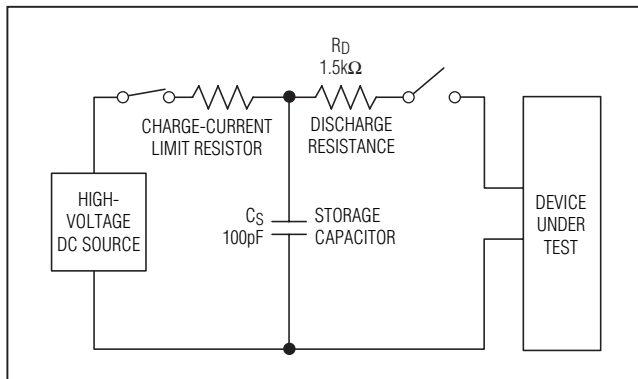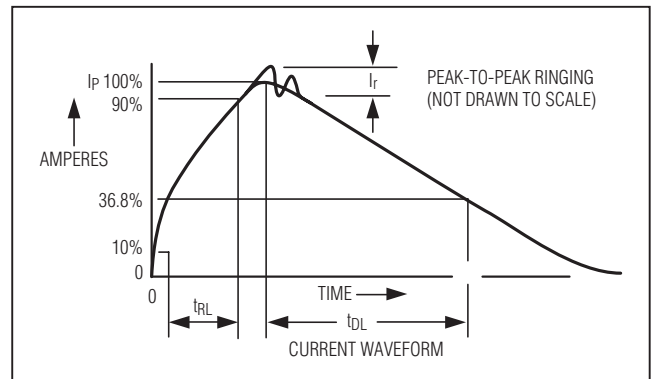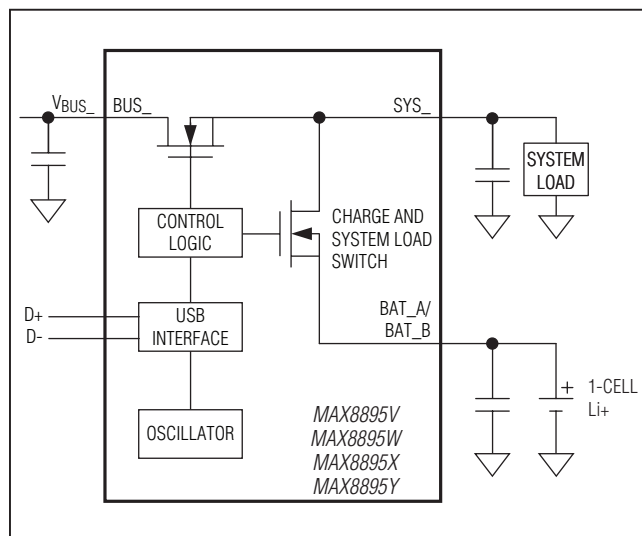

Figure 26. Human Body Test Model

Figure 27. Human Body Model Current Waveform

Li-Ion Chargers with Smart Power Selector, Adapter Type Detection, and USB Enumeration

Typical Operating Circuit

Chip Information

PROCESS: BiCMOS

Ordering Information

PART	USB INTERFACE TYPE	PIN-PACKAGE
MAX8895VEWA+T	Low speed	25 WLP 2.36mm x 2.36mm
MAX8895WEWA+T**	Low speed	25 WLP 2.36mm x 2.36mm
MAX8895XEWA+T	Low speed	25 WLP 2.36mm x 2.36mm
MAX8895YEWA+T	Full speed	25 WLP 2.36mm x 2.36mm

Note: All devices are specified over the -40°C to +85°C operating temperature range.
+Denotes a lead(Pb)-free/RoHS-compliant package.
T = Tape and reel.
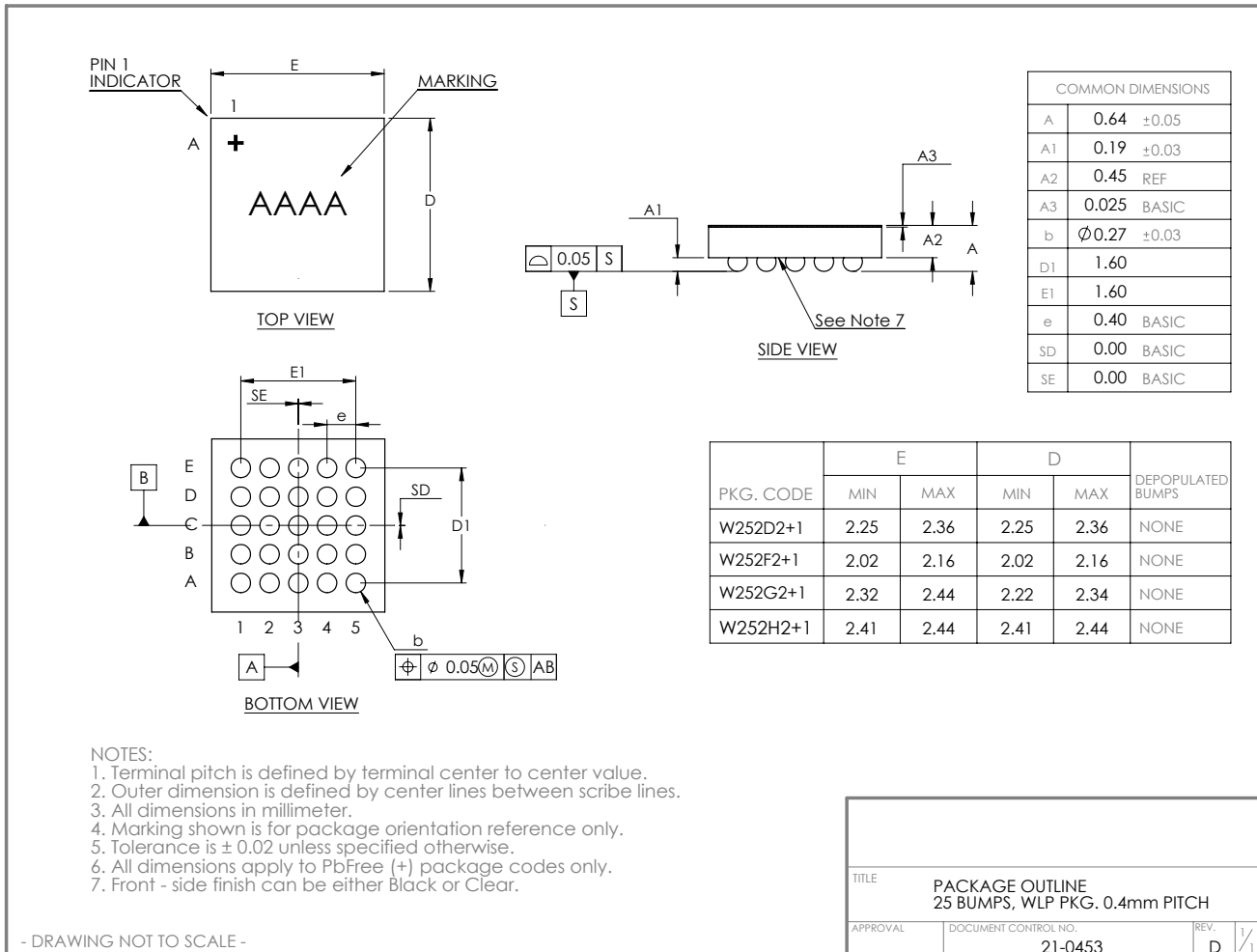**Contact factory for availability.

Li-Ion Chargers with Smart Power Selector, Adapter Type Detection, and USB Enumeration

Package Information

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 TYPE	PACKAGE CODE	OUTLINE NO.	LAND PATTERN NO.
25 WLP	W252D2+1	**21-0453**	Refer to **Applications Note 1891**

COMMON DIMENSIONS

A	0.64	±0.05
A1	0.19	±0.03
A2	0.45	REF
A3	0.025	BASIC
b	⌀0.27	±0.03
D1	1.60	
E1	1.60	
e	0.40	BASIC
SD	0.00	BASIC
SE	0.00	BASIC

	E		D		DEPOPULATED BUMPS
PKG. CODE	MIN	MAX	MIN	MAX	
W252D2+1	2.25	2.36	2.25	2.36	NONE
W252F2+1	2.02	2.16	2.02	2.16	NONE
W252G2+1	2.32	2.44	2.22	2.34	NONE
W252H2+1	2.41	2.44	2.41	2.44	NONE

NOTES:
1. Terminal pitch is defined by terminal center to center value.
2. Outer dimension is defined by center lines between scribe lines.
3. All dimensions in millimeter.
4. Marking shown is for package orientation reference only.
5. Tolerance is ± 0.02 unless specified otherwise.
6. All dimensions apply to PbFree (+) package codes only.
7. Front - side finish can be either Black or Clear.

- DRAWING NOT TO SCALE -

TITLE	PACKAGE OUTLINE 25 BUMPS, WLP PKG. 0.4mm PITCH		
APPROVAL	DOCUMENT CONTROL NO. 21-0453	REV. D	1/1

Li-Ion Chargers with Smart Power Selector, Adapter Type Detection, and USB Enumeration

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	7/10	Initial release	—
1	10/10	Added MAX8895W to data sheet	1–38
2	2/11	Added patent information	1
3	4/11	Added contact factory note for MAX8895W	1
4	9/12	Added MAX8895V to data sheet	1–42

Maxim Integrated 160 Rio Robles, San Jose, CA 95134 USA 1-408-601-1000