19-1796; Rev 0; 12/00

EVALUATION KIT AVAILABLE

Power Source Selector for Dual-Battery Systems

MAX1773

General Description

The MAX1773 highly integrated IC serves as the control logic for a system with multiple power sources. It directly drives external P-channel MOSFETs to select from an AC adapter and dual battery sources for charge and discharge. The selection is made based on the presence of the power sources and the state of the batteries. The MAX1773 detects low battery conditions using integrated analog comparators and checks for the presence of a battery by using battery thermistor outputs.

The MAX1773 is designed for use with a buck topology charger. It provides a simple and easily controlled solution to a difficult analog power control problem. The MAX1773 provides most of the power source monitoring and selection, freeing the system power management microprocessor (µP) for other tasks. This not only simplifies development of the power management firmware for the µP but also allows the µP to enter standby, thereby reducing system power consumption.

Applications

Notebook and Subnotebook Computers

PDAs and Handy-Terminals

Internet Tablets

Dual-Battery Portable Equipment

Features

- **Patented† 7-MOSFET Topology Offers Low-Cost Solution**
- **Automatically Detects and Responds to:**
  - **Low Battery Voltage Condition**
  - **Battery Insertion and Removal**
  - **AC Adapter Presence**
- **Direct Drive of P-Channel MOSFETs**
- **Simplifies Power Management µP Firmware**
- **Extends Battery Life by Allowing Power Management µP to Enter Standby**
- **4.75V to 28V AC Adapter Input Voltage Range**
- **Integrated LDO with 1mA Drive Capability**
- **Small Footprint 20-Pin TSSOP Package**

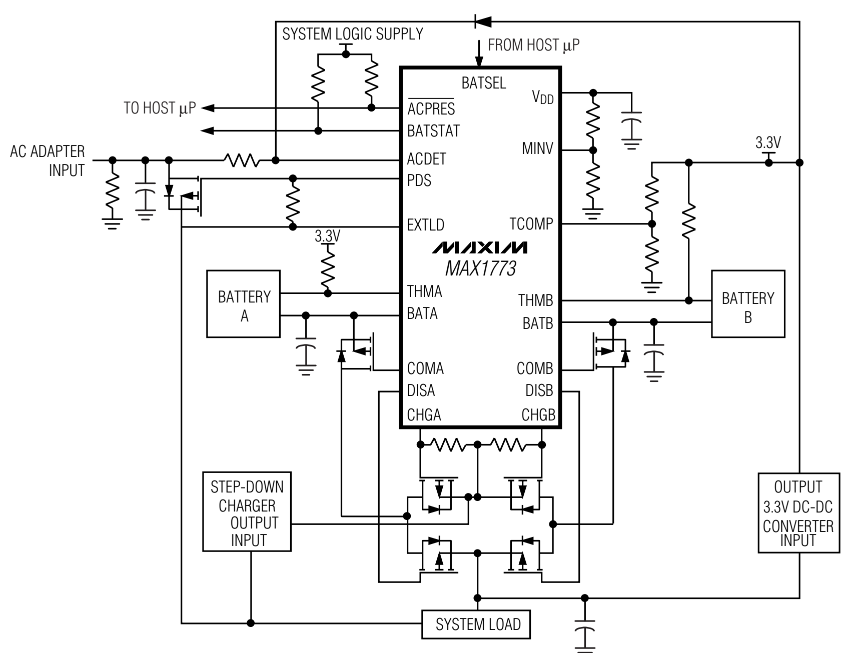
Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX1773EUP	-40°C to +85°C	20 TSSOP

Pin Configuration appears at end of data sheet.

†*Covered by U.S. Patent number 5,764,032.*

Typical Operating Circuit



ABSOLUTE MAXIMUM RATINGS

V_{BATA}, V_{BATB} to GND ....-0.3V to +20V
V_{COMA} to GND.......................................-0.3V to (V_{BATA} + 0.3V)
V_{COMB} to GND.......................................-0.3V to (V_{BATB} + 0.3V)
V_{CHGA}, V_{CHGB}, V_{EXTLD}, V_{ACDET} to GND ....-0.3V to +30V
V_{PDS}, V_{DISA}, V_{DISB} to GND..................-0.3V to (V_{EXTLD} + 0.3V)
V_{DD}, V_{BATSEL}, $V_{\overline{ACPRES}}$, $V_{BATSTAT}$, V_{TCOMP},
V_{MINV} to GND...-0.3V to +6V
V_{THMA}, V_{THMB} (Note 1)... -0.3V to +6V

Continuous Current out of THMA, THMB...........................20mA
$I_{\overline{ACPRES}}$, $I_{BATSTAT}$ Sink Current...30mA
Continuous Power Dissipation (T_A = +70°C)
20-Pin TSSOP (derate 7.0mW/°C above +70°C) 560mW
Operating Temperature ....-40°C to +85°C
Storage Temperature ....-65°C to +150°C
Lead Temperature (soldering, 10s) ....+300°C

Note 1: Signals on THMA and THMB below -0.3V are clamped by internal diodes limit forward diode current to maximum continuous current. When voltage on these pins is below -0.3V.

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

(V_{BATA} = V_{BATB} = 16.8V, C_{VDD} = 3.3µF, V_{MINV} = 0.93V, V_{EXTLD} = V_{ACDET} = 28V, V_{TCOMP} = 3V, V_{THMA} = V_{THMB} = 1.65V, V_{BATSEL} = 0, C_{COMA} = C_{COMB} = C_{DISA} = C_{DISB} = C_{CHGA} = C_{CHGB} = C_{PDS} = 5nF, **T_A = 0°C to +85°C,** unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
EXTLD Supply Voltage Range	V_{EXTLD} > V_{BATA} and V_{BATB}		4.75		28	V
BATA, BATB Supply Voltage Range			4.75		19	V
BATA, BATB Quiescent Current (Current from the higher voltage supply)	V_{BATA} = 4.75V to 19V, V_{BATB} = 4.75V to 19V, I_{VDD} = 0	V_{ACDET} = 28V		5	8	µA
		V_{ACDET} = 2.2V to V_{BATA} and V_{BATB}		40	70	
BATA, BATB Quiescent Current (Current from the lower voltage supply)	V_{BATA} = 4.75V to 19V, V_{BATB} = 4.75V to 19V, I_{VDD} = 0	V_{ACDET} = 28V		5	8	µA
		V_{ACDET} = 2.2V to V_{BATA} and V_{BATB}		8	13	
EXTLD Quiescent Current	V_{ACDET} = 28V, V_{EXTLD} = 28V			35	55	µA
	V_{ACDET}= 2.2V to V_{BATA} and V_{BATB}, V_{EXTLD} = 16V			5	8	
LINEAR REGULATOR						
V_{DD} Output Voltage	I_{VDD} = 0 to 100µA		3.234	3.3	3.367	V
	I_{VDD} = 100µA to 1mA		3.168	3.3	3.432	
V_{DD} Power-Supply Rejection Ratio	V_{BATA} or V_{BATB} = 5V to 19V, V_{EXTLD} = 5V				1.0	mV/V
	V_{BATA} = V_{BATB} = 5V, V_{EXTLD} = 5V to 28V				1.0	
	V_{BATA}, V_{BATB}, or V_{EXTLD} = 5V to 19V, sawtooth at 10V/µs, other supplies = 12V			1		
V_{DD} Undervoltage Lockout	Hysteresis is typically 50mV		2.0	2.5	3.0	V
COMPARATORS						
TCOMP Undervoltage Lockout (Note 2)			0		1.1	V
THM_ Input Voltage Range			0		5.5	V
THM_ Input Leakage Current	$V_{THM\_}$ = 5.5V			0.1	100	nA
TCOMP Input Voltage Range	V_{THMA} = V_{THMB} = 0 to 5.5V		0		5.5	V
	V_{THMA} = V_{THMB} = 0 to 5.5V, V_{BATA} = V_{BATB} = V_{EXTLD} = 4.75V		0		4.3	

ELECTRICAL CHARACTERISTICS (continued)

(V_{BATA} = V_{BATB} = 16.8V, C_{VDD} = 3.3µF, V_{MINV} = 0.93V, V_{EXTLD} = V_{ACDET} = 28V, V_{TCOMP} = 3V, V_{THMA} = V_{THMB} = 1.65V, V_{BATSEL} = 0, C_{COMA} = C_{COMB} = C_{DISA} = C_{DISB} = C_{CHGA} = C_{CHGB} = C_{PDS} = 5nF, **T_A = 0°C to +85°C,** unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
TCOMP Input Leakage Current	V_{TCOMP} = 5.5V			0.1	100	nA
THM_ to TCOMP Trip Threshold	THM_ falling with respect to TCOMP		-30		30	mV
THM_ to TCOMP Hysteresis			15	50		mV
ACDET Operating Voltage Range (Note 3)			2.2		28	V
ACDET Logic Threshold High			2.2			V
ACDET Input Bias Current	V_{ACDET} = 3V, V_{ACDET} < V_{BATA} and V_{BATB}			4	8	µA
	V_{ACDET} = 3V, V_{ACDET} < V_{BATB}, V_{BATA} = 0			5	9	
	V_{ACDET} = 28V, V_{ACDET} > V_{BATA} and V_{BATB}			6	11	
ACDET to BATA Trip Threshold	V_{ACDET} falling with respect to V_{BATA}		0	50	100	mV
ACDET to BATA Hysteresis			100	150	200	mV
ACDET to BATB Trip Threshold	V_{ACDET} falling with respect to V_{BATB}		0	50	100	mV
ACDET to BATB Hysteresis			100	150	200	mV
MINV Operating Voltage Range	V_{BATA} = V_{BATB} = 5 × V_{MINV}		0.93		2.6	V
MINV Input Bias Current	V_{MINV} = 0.93V to 2.6V		-100		100	nA
BAT_ Minimum Voltage Trip Threshold	$V_{BAT\_}$ falling	V_{MINV} = 0.93V	4.55	4.65	4.75	V
		V_{MINV} = 2.6V	12.7	13	13.3	
BATSEL Input Low Voltage	Typical hysteresis is 100mV				0.8	V
BATSEL Input High Voltage			2.0			V
BATSEL Input Leakage Current	V_{BATSEL} = 5.5V				1	µA
BATSEL Action Delay			20		100	µs
GATE DRIVERS						
COM_ Initial Source Current	$V_{BAT\_}$ = 16.8V, $V_{COM\_}$ = 14.8V		5			mA
COM_ Final Source Current	$V_{BAT\_}$ = 16.8V, $V_{COM\_}$ = 16.4V		10			µA
	$V_{BAT\_}$ = 16.8V, $V_{COM\_}$ = 14.8V		50	100	150	
COM_ Sink Current (PMOS Turn-On) (Note 4)	$V_{COM\_}$ = 11.8V, $V_{BAT\_}$ = 16.8V		4			mA
COM_ Turn-On Clamp Voltage ($V_{COM\_}$ to $V_{BAT\_}$)	$V_{BAT\_}$ = 8V to 19V		-11.5	-9.5	-7.5	V
	$V_{BAT\_}$ = 4.75V to 8V		-8.00		-4.25	
PDS Source Current (PMOS Turn-Off)	V_{PDS} = 10V, V_{EXTLD} = 12V		5			mA
PDS Sink Current (PMOS Turn-On)	V_{PDS} = 2V to 28V		0.8	1.0	1.2	mA
PDS Leakage Current (PMOS Off)	V_{PDS} = 28V			0.1	2	µA
CHG_ Sink Current (PMOS Turn-On)	$V_{CHG\_}$ = 2V to 22V		0.7	1.0	1.3	mA
CHG_ Leakage Current (PMOS Off)	$V_{CHG\_}$ = 28V			0.1	2	µA
DIS_ Initial Source Current	V_{EXTLD} = 15V, $V_{DIS\_}$ = 13V		5			mA
DIS_ Final Source Current	V_{EXTLD} = 15V, $V_{DIS\_}$ = 14.6V		10			µA
	V_{EXTLD} = 15V, $V_{DIS\_}$ = 13V		50	100	150	
DIS_ Sink Current (PMOS Turn-On) (Note 5)	V_{EXTLD} = 16.8V, $V_{DIS\_}$ = 11.8V		4			mA

ELECTRICAL CHARACTERISTICS (continued)

(V_{BATA} = V_{BATB} = 16.8V, C_{VDD} = 3.3µF, V_{MINV} = 0.93V, V_{EXTLD} = V_{ACDET} = 28V, V_{TCOMP} = 3V, V_{THMA} = V_{THMB} = 1.65V, V_{BATSEL} = 0, C_{COMA} = C_{COMB} = C_{DISA} = C_{DISB} = C_{CHGA} = C_{CHGB} = C_{PDS} = 5nF, **T_A = 0°C to +85°C,** unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
DIS_ Turn-On Clamp Voltage ($V_{DIS\_}$ to V_{EXTLD})	V_{EXTLD} = 8V to 28V	-11.5	-9.5	-7.5	V
	V_{EXTLD} = 4.75V to 8V	-8.00		-4.25	
STATUS OUTPUTS					
$\overline{ACPRES}$ Sink Current	$V_{\overline{ACPRES}}$ = 0.4V	1			mA
	$V_{\overline{ACPRES}}$ = 5.5V			30	
BATSTAT Sink Current	$V_{BATSTAT}$ = 0.4V	1			mA
	$V_{BATSTAT}$ = 5.5V				
$\overline{ACPRES}$ Leakage Current	$V_{\overline{ACPRES}}$ = 5.5V		0.1	1	µA
BATSTAT Leakage Current	$V_{BATSTAT}$ = 5.5V		0.1	1	µA
TRANSITION TIMES					
Battery Switchover Delay (Note 6)	V_{ACDET} = 2.2V, V_{MINV} = 0.93V			5	µs
Battery Action Delay (Note 7)	V_{ACDET} = 2.2V, V_{MINV} = 0.93V			260	µs
Thermistor Action Delay (Note 8)	V_{ACDET} = 2.2V, V_{MINV} = 0.93V			12	µs
AC to Battery Switchover Delay (Note 9)	V_{ACDET} = 2.2V, V_{MINV} = 0.93V			10	µs
Battery to AC Switchover Delay (Note 10)	V_{ACDET} = 2.2V, V_{MINV} = 0.93V			260	µs
CHG_ Turn-On Delay (Note 11)		130	300	530	µs

ELECTRICAL CHARACTERISTICS

(V_{BATA} = V_{BATB} = 16.8V, C_{VDD} = 3.3µF, V_{MINV} = 0.93V, V_{EXTLD} = V_{ACDET} = 28V, V_{TCOMP} = 3V, V_{THMA} = V_{THMB} = 1.65V, V_{BATSEL} = 0, C_{COMA} = C_{COMB} = C_{DISA} = C_{DISB} = C_{CHGA} = C_{CHGB} = C_{PDS} = 5nF, **T_A = -40°C to +85°C,** unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
EXTLD Supply Voltage Range	V_{EXTLD} > V_{BATA} and V_{BATB}		4.75		28	V
BATA, BATB Supply Voltage Range			4.75		19	V
BATA, BATB Quiescent Current (Current from the higher voltage supply)	V_{BATA} = 4.75V to 19V, V_{BATB} = 4.75V to 19V, I_{VDD} = 0	V_{ACDET} = 28V			8	µA
		V_{ACDET} = 2.2V to V_{BATA} and V_{BATB}			70	
BATA, BATB Quiescent Current (Current from the lower voltage supply)	V_{BATA} = 4.75V to 19V, V_{BATB} = 4.75V to 19V, I_{VDD} = 0	V_{ACDET} = 28V			8	µA
		V_{ACDET} = 2.2V to V_{BATA} and V_{BATB}			13	
EXTLD Quiescent Current	V_{ACDET} = 28V, V_{EXTLD} = 28V				55	µA
	V_{ACDET} = 2.2V to V_{BATA} and V_{BATB}, V_{EXTLD} = 16V				8	
LINEAR REGULATOR						
V_{DD} Output Voltage	I_{VDD} = 0 to 100µA		3.234		3.367	V
	I_{VDD} = 100µA to 1mA		3.168		3.432	
V_{DD} Power-Supply Rejection Ratio	V_{BATA} or V_{BATB} = 5V to 19V, V_{EXTLD} = 5V				1.0	mV/V
	V_{BATA} = V_{BATB} = 5V, V_{EXTLD} = 5V to 28V				1.0	
V_{DD} Undervoltage Lockout	Hysteresis is typically 50mV		2.0		3.0	V
COMPARATORS						
TCOMP Undervoltage Lockout (Note 2)			0		1.1	V

ELECTRICAL CHARACTERISTICS (continued)

(V_{BATA} = V_{BATB} = 16.8V, C_{VDD} = 3.3µF, V_{MINV} = 0.93V, V_{EXTLD} = V_{ACDET} = 28V, V_{TCOMP} = 3V, V_{THMA} = V_{THMB} = 1.65V, V_{BATSEL} = 0, C_{COMA} = C_{COMB} = C_{DISA} = C_{DISB} = C_{CHGA} = C_{CHGB} = C_{PDS} = 5nF, **T_A = -40°C to +85°C,** unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
THM_Input Voltage Range		0		5.5	V
THM_Input Leakage Current	$V_{THM\_}$ = 5.5V			100	NA
TCOMP Input Voltage Range	V_{THMA} = V_{THMB} = 0 to 5.5V	0		5.5	V
TCOMP Input Voltage Range	V_{THMA} = V_{THMB} = 0 to 5.5V, V_{BATA} = V_{BATB} = V_{EXTLD} = 4.75V	0		4.3	V
TCOMP Input Leakage Current					
THM_ to TCOMP Trip Threshold					
THM_ to TCOMP Hysteresis					
ACDET Operating Voltage Range (Note 3)		2.2		28	V
ACDET Logic Threshold High		2.2			V
ACDET Input Bias Current	V_{ACDET} = 3V, V_{ACDET} < V_{BATA} and V_{BATB}			8	µA
ACDET Input Bias Current	V_{ACDET} = 3V, V_{ACDET} < V_{BATB}, V_{BATA} = 0			9	µA
ACDET Input Bias Current	V_{ACDET} = 28V, V_{ACDET} > V_{BATA} and V_{BATB}			11	µA
ACDET to BATA Trip Threshold	V_{ACDET} falling with respect to V_{BATA}	-35		125	mV
ACDET to BATA Hysteresis		100		200	mV
ACDET to BATB Trip Threshold	V_{ACDET} falling with respect to V_{BATB}	-35		125	mV
ACDET to BATB Hysteresis		100		200	mV
MINV Operating Voltage Range	V_{BATA} = V_{BATB} = 5 × V_{MINV}	0.93		2.6	V
MINV Input Bias Current	V_{MINV} = 0.93V to 2.6V	-100		100	nA
BAT_ Minimum Voltage Trip Threshold	$V_{BAT\_}$ falling, V_{MINV} = 0.93V	4.55		4.75	V
BAT_ Minimum Voltage Trip Threshold	$V_{BAT\_}$ falling, V_{MINV} = 2.6V	12.7		13.3	V
BATSEL Input Low Voltage	Typical hysteresis is 100mV			0.8	V
BATSEL Input High Voltage		2.0			V
BATSEL Input Leakage Current	V_{BATSEL} = 5.5V			1	µA
BATSEL Action Delay		20		100	µs
GATE DRIVERS					
COM_ Initial Source Current	$V_{BAT\_}$ = 16.8V, $V_{COM\_}$ = 14.8V	4			mA
COM_ Final Source Current	$V_{BAT\_}$ = 16.8V, $V_{COM\_}$ = 16.4V	10			µA
COM_ Final Source Current	$V_{BAT\_}$ = 16.8V, $V_{COM\_}$ = 14.8V	50		150	µA
COM_ Sink Current (PMOS Turn-On) (Note 4)	$V_{COM\_}$ = 11.8V, $V_{BAT\_}$ = 16.8V	2			mA
COM_ Turn-On Clamp Voltage ($V_{COM\_}$ to $V_{BAT\_}$)	$V_{BAT\_}$ = 8V to 19V	-11.5		-7.25	V
COM_ Turn-On Clamp Voltage ($V_{COM\_}$ to $V_{BAT\_}$)	$V_{BAT\_}$ = 4.75V to 8V	-8.00		-4.25	V
PDS Source Current (PMOS Turn-Off)	V_{PDS} = 10V, V_{EXTLD} = 12V	4			mA
PDS Sink Current (PMOS Turn-On)	V_{PDS} = 2V to 28V	0.7		1.3	mA
PDS Leakage Current (PMOS Off)	V_{PDS} = 28V			2	µA
CHG_ Sink Current (PMOS Turn-On)	$V_{CHG\_}$ = 2V to 22V	0.6		1.4	mA

Power Source Selector for Dual-Battery Systems

ELECTRICAL CHARACTERISTICS (continued)

(V_{BATA} = V_{BATB} = 16.8V, C_{VDD} = 3.3µF, V_{MINV} = 0.93V, V_{EXTLD} = V_{ACDET} = 28V, V_{TCOMP} = 3V, V_{THMA} = V_{THMB} = 1.65V, V_{BATSEL} = 0, C_{COMA} = C_{COMB} = C_{DISA} = C_{DISB} = C_{CHGA} = C_{CHGB} = C_{PDS} = 5nF, **T_A = -40°C to +85°C,** unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
CHG_ Leakage Current (PMOS Off)	$V_{CHG\_}$ = 28V			2	µA
DIS_ Initial Source Current	V_{EXTLD} = 15V, $V_{DIS\_}$ = 13V	4			
DIS_ Final Source Current	V_{EXTLD} = 15V, $V_{DIS\_}$ = 14.6V	10			µA
	V_{EXTLD} = 15V, $V_{DIS\_}$ = 13V	50		150	
DIS_ Sink Current (PMOS Turn-On) (Note 5)	V_{EXTLD} = 16.8V, $V_{DIS\_}$ = 11.8V	2			mA
DIS_ Turn-On Clamp Voltage ($V_{DIS\_}$ to V_{EXTLD})	V_{EXTLD} = 8V to 28V	-11.5		-7.25	V
	V_{EXTLD} = 4.75V to 8V	-8.00		-4.25	
STATUS OUTPUTS					
$\overline{ACPRES}$ Sink Current	$V_{\overline{ACPRES}}$ = 0.4V	1			mA
	$V_{\overline{ACPRES}}$ = 5.5V			30	
BATSTAT Sink Current	$V_{BATSTAT}$ = 0.4V	1			mA
	$V_{BATSTAT}$ = 5.5V			30	
$\overline{ACPRES}$ Leakage Current	$V_{\overline{ACPRES}}$ = 5.5V			1	µA
BATSTAT Leakage Current	$V_{BATSTAT}$ = 5.5V			1	µA
TRANSITION TIMES					
Battery Switchover Delay (Note 6)	V_{ACDET} = 2.2V, V_{MINV} = 0.93V			5	µs
Battery Action Delay (Note 7)	V_{ACDET} = 2.2V, V_{MINV} = 0.93V			260	µs
Thermistor Action Delay (Note 8)	V_{ACDET} = 2.2V, V_{MINV} = 0.93V			12	µs
AC to Battery Switchover Delay (Note 9)	V_{ACDET} = 2.2V, V_{MINV} = 0.93V			10	µs
Battery to AC Switchover Delay (Note 10)	V_{ACDET} = 2.2V, V_{MINV} = 0.93V			260	µs
CHG_ Turn-On Delay (Note 11)		130		530	µs

Note 2: TCOMP undervoltage lockout sets the MAX1773's internal status bits for the batteries to be designated as "absent" ($V_{THM\_}$ > V_{TCOMP}).

Note 3: V_{ACDET} must remain above 2.2V, except in power-up.

Note 4: COMA cannot sink current until V_{COMB} > V_{BATB} - 2V. Likewise, COMB cannot sink current until V_{COMA} > V_{BATA} - 2V.

Note 5: DISA cannot sink current until V_{DISB} > V_{EXTLD} - 2V. Likewise, DISB cannot sink current until V_{DISA} > V_{EXTLD} - 2V.

Note 6: Battery Switchover Delay starts when either $V_{COM\_}$ or $V_{DIS\_}$ of the connected battery begins to rise and ends when both $V_{COM\_}$ and $V_{DIS\_}$ of the other battery have fallen 3V below their sources (Figures 1 and 2).

Note 7: Battery Action Delay starts when the connected battery's voltage falls below 5 × V_{MINV} and ends when both $V_{COM\_}$ and $V_{DIS\_}$ of the other battery have fallen 3V below their sources (Figures 1 and 2).

Note 8: Thermistor Action Delay begins when $V_{THM\_}$ of the connected battery rises above V_{TCOMP} and ends when both $V_{COM\_}$ and $V_{DIS\_}$ of the other battery have fallen 3V below their sources (Figures 3 and 4).

Note 9: AC to Battery Switchover Delay begins when V_{ACDET} falls below its threshold and ends when both $V_{COM\_}$ and $V_{DIS\_}$ of the battery being switched to have fallen 3V below their sources (Figure 5).

Note 10: Battery to AC Switchover Delay begins when V_{ACDET} rises above its threshold and ends when $V_{DIS\_}$ of the battery being switched from has begun to rise (Figure 6).

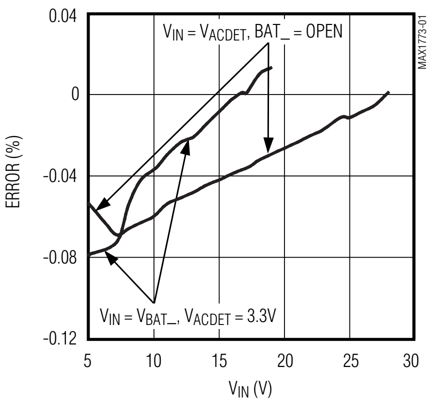
Note 11: CHG_ Turn-on Delay begins when $V_{CHG\_}$ of the battery being switched from begins to rise and ends when $V_{CHG\_}$ of the battery being switched to begins to fall (Figures 7 and 8).

Power Source Selector for Dual-Battery Systems

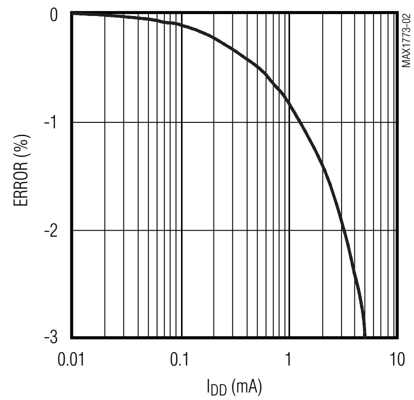
Typical Operating Characteristics

(T_A = +25°C, unless otherwise noted.)

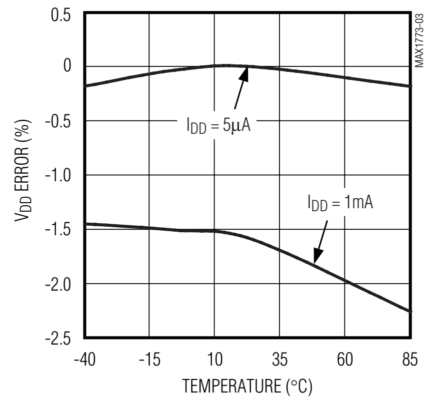
V_{DD} ERROR vs. INPUT VOLTAGE



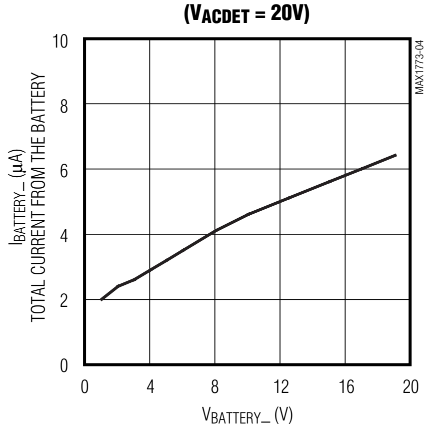
V_{DD} ERROR vs. I_{DD}



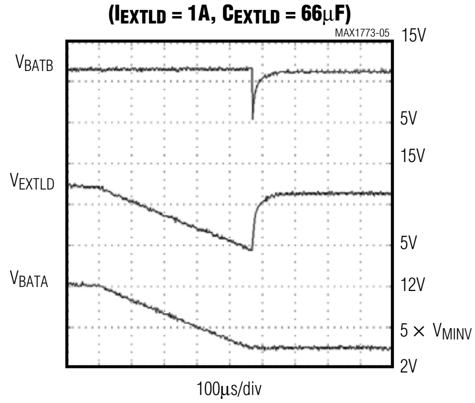
V_{DD} ERROR vs. TEMPERATURE



BATTERY CURRENT vs. BATTERY VOLTAGE (V_{ACDET} = 20V)

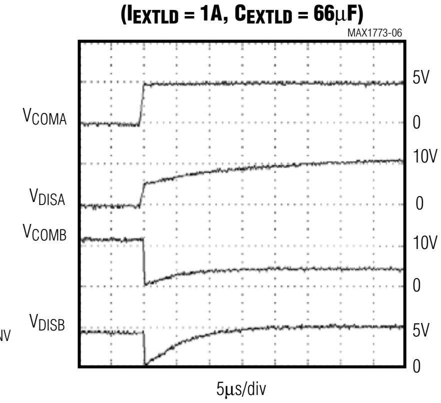


TRANSITION FROM BATTERY A TO BATTERY B (MINV) (I_{EXTLD} = 1A, C_{EXTLD} = 66µF)



V_{BATA} = 12V, BATTERY A REMOVED AT 100µsec
V_{BATB} = 10.75V
V_{MINV} = 1.4V

TRANSITION FROM BATTERY A TO BATTERY B (MINV) (I_{EXTLD} = 1A, C_{EXTLD} = 66µF)



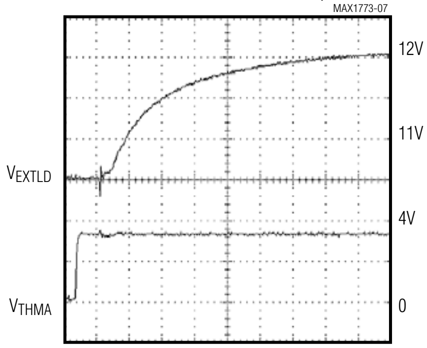
V_{BATA} = 12V
V_{BATB} = 10.75V

Typical Operating Characteristics (continued)

(T_A = +25°C, unless otherwise noted.)

TRANSITION FROM BATTERY A TO BATTERY B (TCOMP) (I_{EXTLD} = 4A, C_{EXTLD} = 66µF)

MAX1773-07

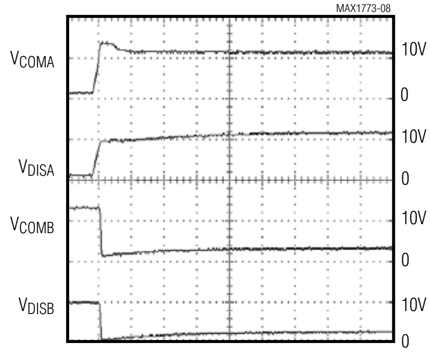


10µs/div

V_{BATA} = 10.5V AT 4A
V_{BATB} = 12V AT 4A

TRANSITION FROM BATTERY A TO BATTERY B (T_{COMP}) (I_{EXTLD} = 4A, C_{EXTLD} = 66µF)

MAX1773-08

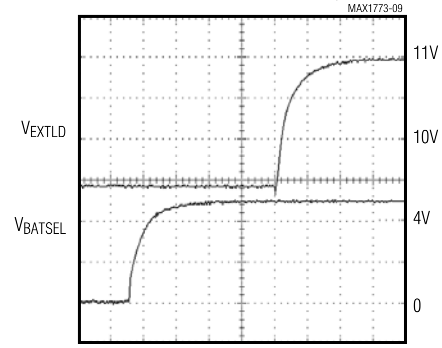


5µs/div

V_{BATA} = 10.5V AT 4A
V_{BATB} = 12V AT 4A

TRANSITION FROM BATTERY A TO BATTERY B (BATSEL) (I_{EXTLD} = 4A, C_{EXTLD} = 66µF)

MAX1773-09

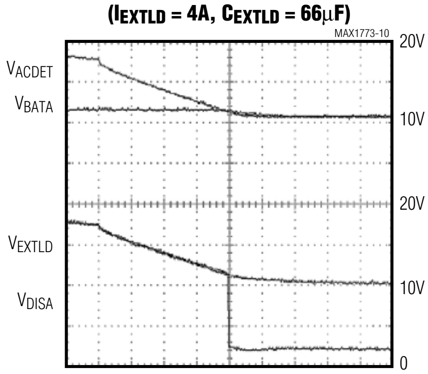


50µs/div

V_{BATA} = 9.4V AT 4A
V_{BATB} = 10.8V AT 4A

TRANSITION FROM AC ADAPTER TO BATTERY A (I_{EXTLD} = 4A, C_{EXTLD} = 66µF)

MAX1773-10

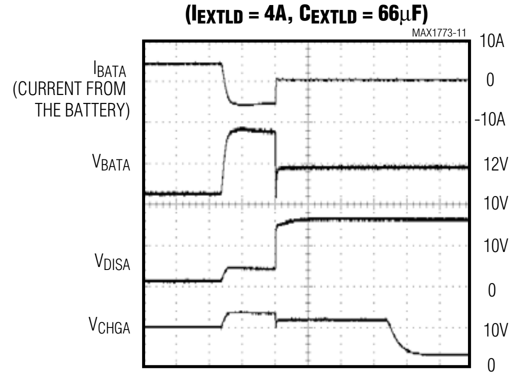


20µs/div

V_{BATA} = 10.8V AT 4A
$V_{ACADAPTER}$ = 17.5V AT 4A

TRANSITION FROM TRANSITION FROM BATTERY A TO AC ADAPTER (I_{EXTLD} = 4A, C_{EXTLD} = 66µF)

MAX1773-11



100µs/div

$V_{ACADAPTER}$ = 17.5A AT 4A
V_{BATA} = 10.5V AT 4A
$V_{ACADAPTER}$ APPLIED AT 240µs
CHARGER INPUT OPEN

Pin Description

PIN	NAME	FUNCTION
1	BATA	Battery A Connection
2	THMA	Thermistor A Input
3	CHGA	Open-Drain Gate Driver for Charge Path MOSFET to Battery A
4	DISA	Gate Driver for Discharge Path MOSFET to Battery A. Switches from V_{EXTLD} to (V_{EXTLD} - 9.5V).
5	COMA	Gate Driver for Common Path MOSFET to Battery A. Switches from V_{BATA} to (V_{BATA} - 9.5V).
6	GND	Ground
7	MINV	Minimum Operating Voltage Set Point. The battery voltage switchover set point is 5 × V_{MINV}.
8	EXTLD	External Load Connection. Source connection for the PDS, DISA, and DISB MOSFETs.
9	PDS	Gate Driver for the AC Adapter MOSFET
10	ACDET	AC Adapter Detection Input
11	BATSTAT	Open-Drain Battery Status Output. Use a pullup resistor to the system logic supply.
12	$\overline{ACPRES}$	Open-Drain AC Presence Output. Use a pullup resistor to the system logic supply.
13	BATSEL	Battery Select Digital Input. Selects which battery to charge or discharge.
14	TCOMP	Externally Set Thermistor Trip Point. Sets the thermistor voltage level for detecting the battery's presence.
15	V_{DD}	Linear Regulator Output
16	COMB	Gate Driver for Common Path MOSFET to Battery B. Switches from V_{BATB} to (V_{BATB} - 9.5V).
17	DISB	Gate Driver for Discharge Path MOSFET to Battery B. Switches from V_{EXTLD} to (V_{EXTLD} - 9.5V).
18	CHGB	Open-Drain Gate Driver for Charge Path MOSFET to Battery B
19	THMB	Thermistor B Input
20	BATB	Battery B Connection

Power Source Selector for Dual-Battery Systems

Transition Time Diagrams

(V_{COM_GS} = COM_ turn-on clamp voltage, V_{DIS_GS} = DIS_ turn-on clamp voltage, $V_{CHARGER}$ = system step-down charger output.)

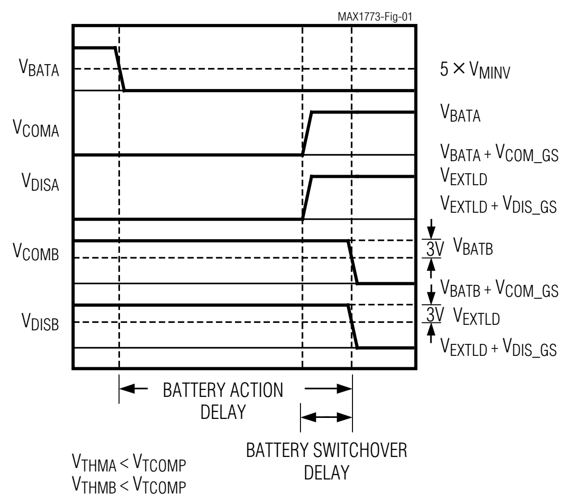


Figure 1. Battery Delay (Battery A to Battery B)

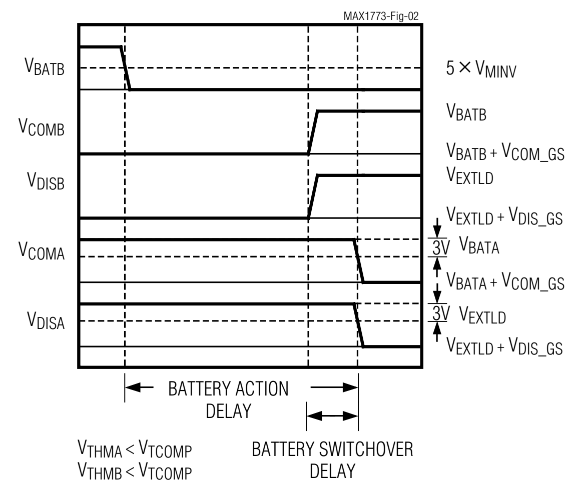


Figure 2. Battery Delay (Battery B to Battery A)

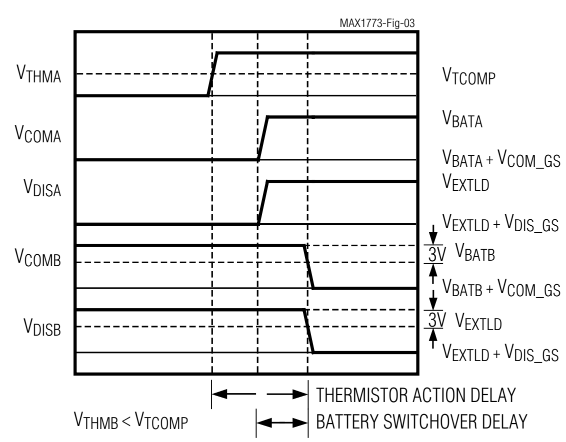


Figure 3. Thermistor Switchover Delay (Battery A to Battery B)

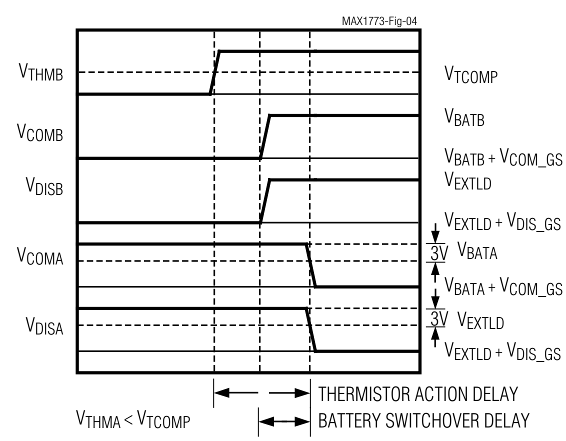


Figure 4. Thermistor Switchover Delay (Battery B to Battery A)

Transition Time Diagrams (continued)

(V_{COM_GS} = COM_ turn-on clamp voltage, V_{DIS_GS} = DIS_ turn-on clamp voltage, $V_{CHARGER}$ = system step-down charger output.)

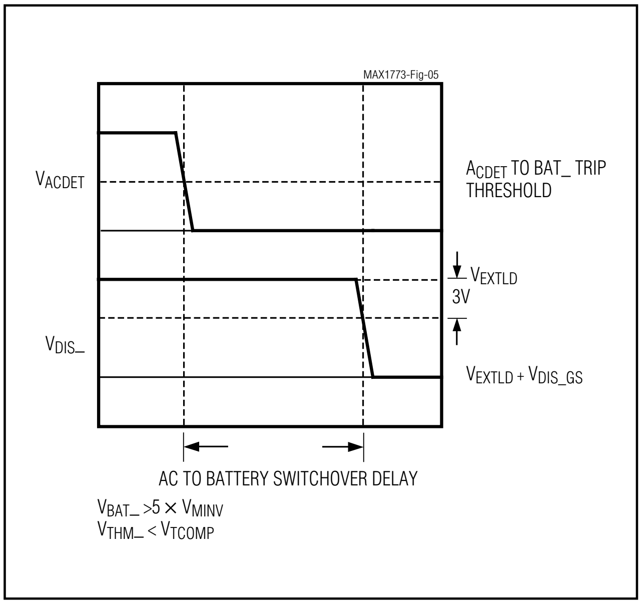


Figure 5. AC to Battery Switchover Delay

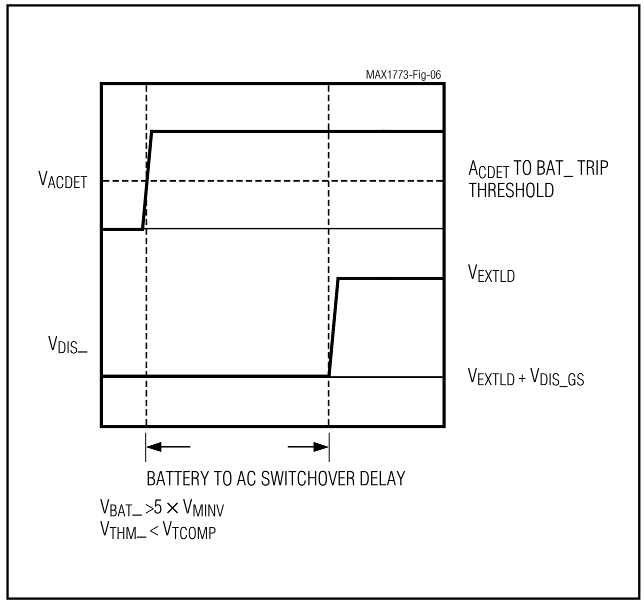


Figure 6. Battery to AC Switchover Delay

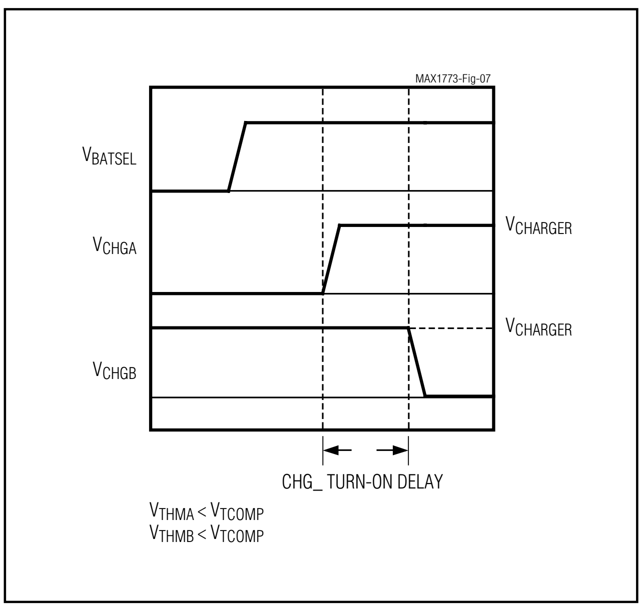


Figure 7. Charge Turn-On Delay (Battery A to Battery B)

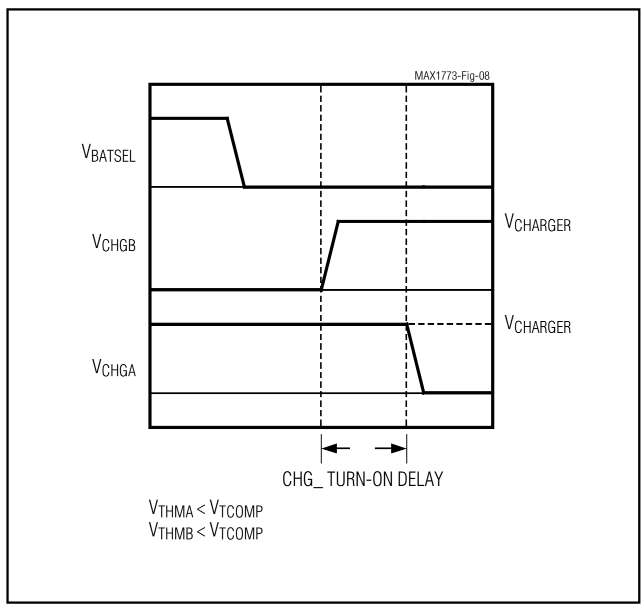


Figure 8. Charge Turn-On Delay (Battery B to Battery A)

Power Source Selector for Dual-Battery Systems

Table 1. AC Adapter States

BATSEL	BATTERY A	BATTERY B	BATSTAT	CONNECTION STATE
0	Present	X	0	AC adapter is connected to load. Battery A's charge path connected.
0	Absent	X	1	AC adapter is connected to load.
1	X	Present	1	AC adapter is connected to load. Battery B's charge path connected.
1	X	Absent	0	AC adapter is connected to load.

X = Don't care, Present: $V_{THM\_} < V_{TCOMP}$, Absent: $V_{THM\_} > V_{TCOMP}$, $\overline{ACPRES} = 0$

Table 2. Simplified Standard Battery States (without latches)

BATSEL	BATTERY A	VBATA	BATTERY B	VBATB	BATSTAT	CONNECTION STATE
0	Present	$>5 \times V_{MINV}$	X	X	0	Battery A is connected to the load.
X	Present	$>5 \times V_{MINV}$	Absent	X	0	Battery A is connected to the load.
X	Present	$>5 \times V_{MINV}$	X	$< 5 \times V_{MINV}$	0	Battery A is connected to the load.
X	X	$<5 \times V_{MINV}$	Present	$> 5 \times V_{MINV}$	1	Battery B is connected to the load.
X	Absent	X	Present	$> 5 \times V_{MINV}$	1	Battery B is connected to the load.
1	X	X	Present	$> 5 \times V_{MINV}$	1	Battery B is connected to the load.

X = Don't care, Present: $V_{THM\_} < V_{TCOMP}$, Absent: $V_{THM\_} > V_{TCOMP}$

Detailed Description

The MAX1773 provides the functions necessary to allow an external controller to manage the power connections needed for two battery packs, an AC adapter input, a battery charger, and the system load. The MAX1773 uses seven PMOS FETs to provide all the switching necessary in systems using a step-down charger powered by the AC adapter (Figures 9 and 10). The MAX1773 automatically adapts to many transient conditions—such as AC plug-in, battery hot swapping, and battery switchover—to provide constant power to the system without requiring real-time support from an external controller. The MAX1773 draws its power from the highest voltage supply present (Figure 11).

Battery Detection

The MAX1773 monitors the battery's thermistor voltage to determine the presence of the battery. The device compares the battery's thermistor voltage ($V_{THM\_}$) to the thermistor trip point (V_{TCOMP}). If $V_{THM\_} < V_{TCOMP}$, then the MAX1773 assumes that the battery is present. However, if $V_{THM\_} > V_{TCOMP}$, the MAX1773 assumes that the battery is absent and does not charge or discharge the battery.

Modes of Operation

The MAX1773 provides three modes of operation. Start-up States mode provides functionality when the MAX1773 is initially powered by a battery when no AC adapter is present. AC adapter States mode provides functionality when an AC Adapter is present. Standard Battery States mode provides functionality when one or both batteries are present, the AC adapter is not present, and EXTLD is above 2.2V. The Standard Battery States mode requires an external supply with an output voltage between 2.2V and 4.5V for ACDET, as shown in Figure 10. The external power supply must be powered from EXTLD.

AC Adapter States

The MAX1773 checks for the presence of an AC adapter by sensing the voltage at ACDET. When V_{ACDET} exceeds the batteries' voltage and 4.75V, then the MAX1773 uses the AC adapter to power the load. In addition, if the selected battery is present, the MAX1773 connects the selected battery's charge path. See Table 1 for a detailed listing of the MAX1773 states for operation with an AC adapter detected.

Standard Battery States

When the AC adapter power supply is not present, the MAX1773 uses the batteries to supply the load. BATSEL allows an external controller to select a battery. Table 2 shows the simplified standard battery states that normally control operation. However, the Battery Switchover Latch, the Low-Battery Latch, and the Discharged Battery Latch are able to suspend the state table and provide additional functionality.

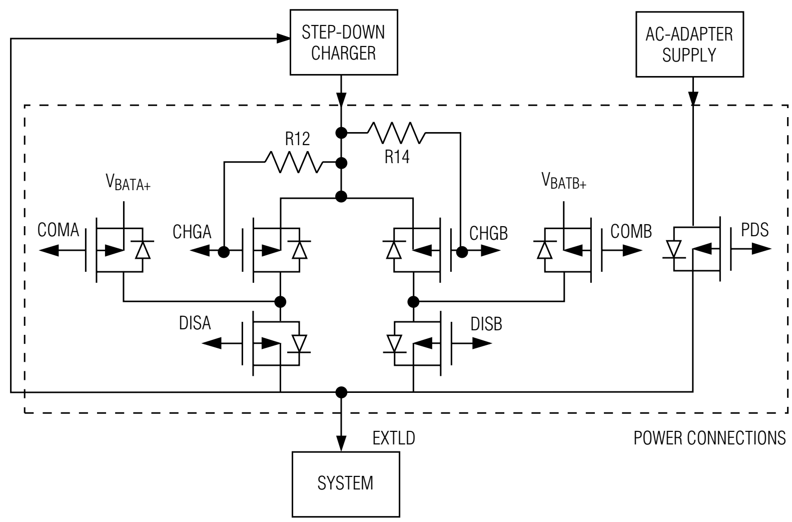


Figure 9. 7-MOSFET Topology

Table 3. Startup States

V_{BATA}	V_{BATB}	BATTERY A	BATTERY B	CONNECTION STATE
$>5 \times V_{MINV}$	X	Present	X	Battery A is connected to the load.
$<5 \times V_{MINV}$	$>5 \times V_{MINV}$	Present	Present	Battery B is connected to the load.
X	$>5 \times V_{MINV}$	Absent	Present	Battery B is connected to the load.
X	X	Absent	Absent	No connections.
$<5 \times V_{MINV}$	$<5 \times V_{MINV}$	X	X	No connections.
$<5 \times V_{MINV}$	X	X	Absent	No connections.
X	$<5 \times V_{MINV}$	Absent	X	No connections.

X = Don't care, Present: $V_{THM\_} < V_{TCOMP}$, Absent: $V_{THM\_} > V_{TCOMP}$

The Battery Switchover Latch stops the MAX1773 from oscillating when the device switches from the selected battery and then the selected battery's voltage recovers. According to the state table, the MAX1773 would switch back to the selected battery as soon as the battery's voltage recovered. The Battery Switchover Latch suspends the state table as soon as the MAX1773 switches over to the nonselected battery. This causes the MAX1773 to continue to power from the nonselected battery unless the latch is cleared. The Battery Switchover Latch is cleared when BATSEL is toggled (to select the other battery), when in the Startup States mode, in the AC Adapter States mode, and when the selected battery is removed ($V_{THM\_} > V_{TCOMP}$).

To prevent the MAX1773 from switching to a discharged battery, the Low-Battery Latch suspends the state table when the unconnected battery's voltage is below $5 \times V_{MINV}$ and the discharging battery's voltage drops below $5 \times V_{MINV}$. Instead of switching to the unconnected battery, the MAX1773 continues to power from the discharging battery. This latch is cleared when the unconnected battery is removed ($V_{THM\_} > V_{TCOMP}$), when in the Startup States mode, when in the AC Adapter States mode, and if the unconnected battery's voltage rises above $5 \times V_{MINV}$.

The Discharged Battery Latch sets whenever the MAX1773 is in the Standard Battery States mode, both batteries are present ($V_{THM\_} < V_{TCOMP}$), one of the batteries is low ($V_{BAT\_} < 5 \times V_{MINV}$), and the other battery's voltage is below V_{ACDET}. While the Discharged Battery Latch is set, the state table is suspended, the MAX1773 is not allowed to switch batteries, and the

Power Source Selector for Dual-Battery Systems

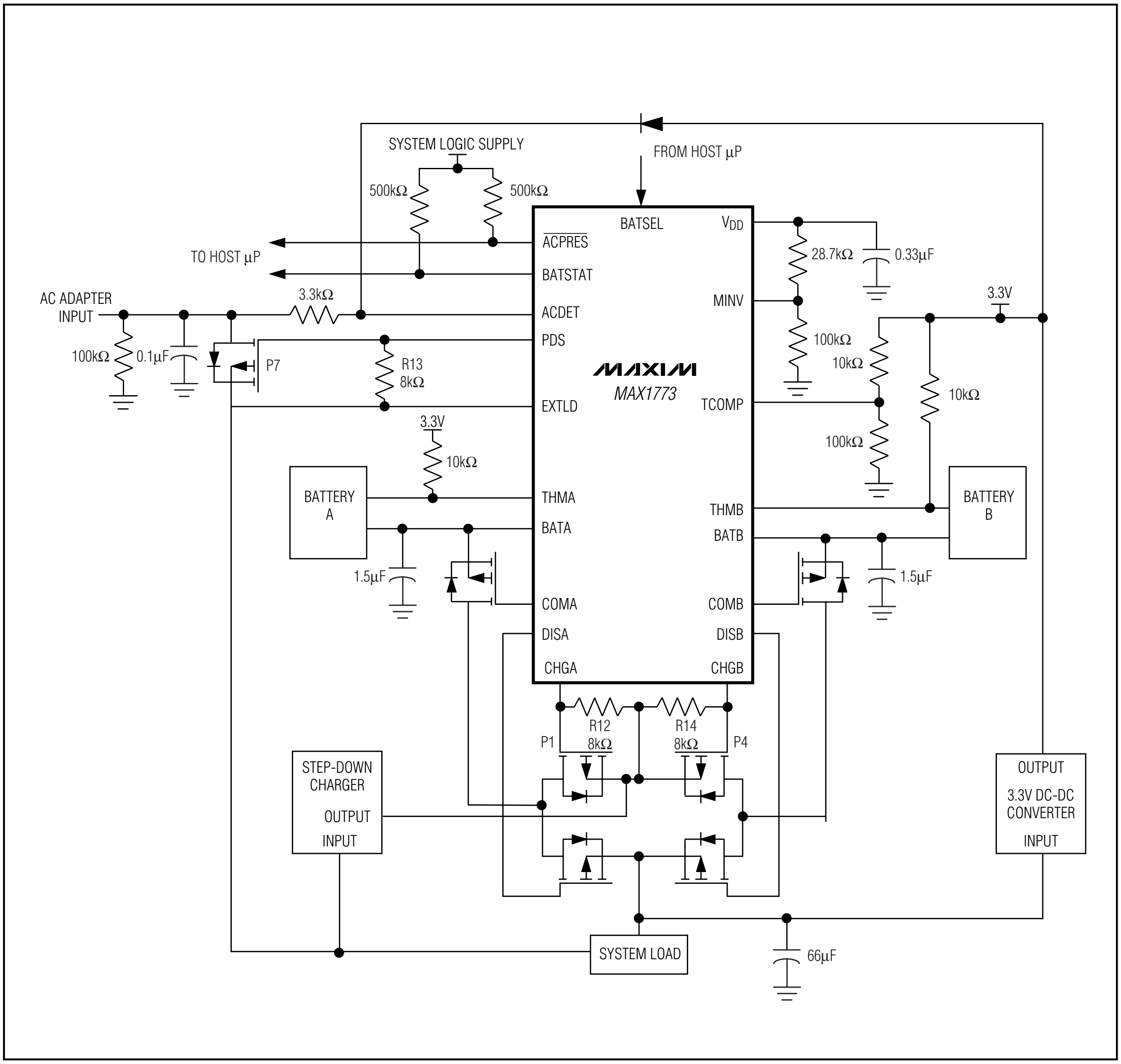


Figure 10. Standard Application Circuit

Low Battery Latch is cleared. The Discharged Battery Latch is cleared when both batteries are above V_{ACDET}, in the AC Adapter States mode, and in the Startup States mode.

Startup States

When V_{ACDET} rises at startup, the MAX1773 uses Startup States. See Table 3 for a detailed listing of the MAX1773 states in this mode. Note that once ACDET rises above 2.2V, the MAX1773 is no longer in the Startup States mode and enters either the Standard Battery States mode or the AC Adapter States mode.

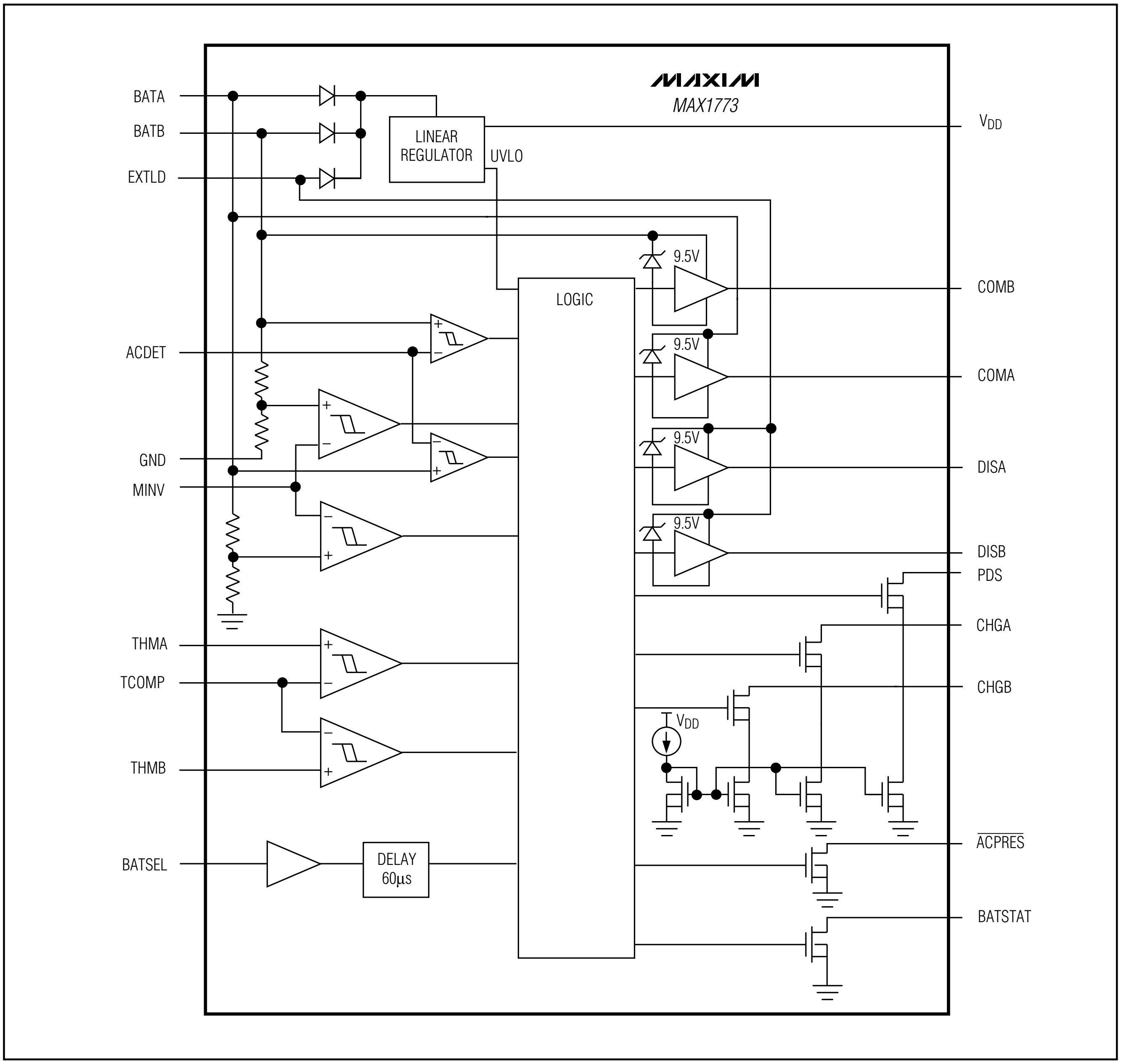


Figure 11. Functional Diagram

Status and Configuration

BATSTAT and $\overline{ACPRES}$ provide information to an external controller. Table 4 shows the different states of BATSTAT and $\overline{ACPRES}$.

In the AC Adapter States mode, the BATSEL Action Delay (see *Electrical Characteristics*) allows the external controller to tell if both batteries are absent. When both batteries are absent in the AC Adapter States mode and BATSEL changes states, BATSTAT is immediately updated. However, changes to the connection states are delayed (see Table 1 for connection states). If BATSEL is returned to its original state within the BATSEL Action Delay, then changes to the connection states are never made. Note that in the Standard

Table 4. Status Bits

MODE	STATUS	BATSTAT	$\overline{ACPRES}$
All	V_{DD} Undervoltage Lockout	1	1
Startup States		1	1
Standard Battery States	Selected Battery Discharge Path Connected	BATSEL	1
Standard Battery States	Other Battery Discharge Path Connected	$\overline{BATSEL}$	1
AC Adapter States	Selected Battery Charge Path Connected	BATSEL	0
AC Adapter States	Selected Battery Absent	$\overline{BATSEL}$	0

Battery States mode and in the AC Adapter States mode when one or both batteries are present, both BATSTAT and the connection states are delayed during the BATSEL Update Delay.

MOSFET Drivers

To minimize the time when no supply is connected to the external load during switchover transients, the MAX1773 uses active pullup drivers for the discharge paths (DIS_) and the common paths (COM_). When the MAX1773 initially begins to pull up one of these pins, it uses a large current (Initial COM_ Source Current and Initial DIS_ Source Current; see *Electrical Characteristics*). Once the COM_ voltage rises to within 2V of $V_{BAT\_}$ or the DIS_ voltage rises to within 2V of V_{EXTLD}, then a weaker driver is used to hold up the voltage (Final COM_ Source Current and Final DIS_ Source Current; see *Electrical Characteristics*).

The MAX1773 is designed to prevent shoot-through from one battery to the other when transitioning from discharging one battery to discharging the other battery. To accomplish this, the MAX1773 does not connect the second battery to EXTLD until it senses that the first battery is disconnected from EXTLD. See Notes 4 and 5 of *Electrical Characteristics*.

To allow flexibility when choosing the higher voltage PDS PMOS FET (P7, Figure 10), the MAX1773 does not limit the gate-to-source voltage applied to the PDS PMOSFET. The minimum V_{GS} is set by the MAX1773 PDS sink current (see *Electrical Characteristics*) and the external resistor from PDS to EXTLD (R13):

$$V_{GS(MIN)} = -I_{PDS(SINK)} \times R_{PDS}$$

where $V_{GS(MIN)}$ is the minimum P7 gate-to-source voltage, $I_{PDS(SINK)}$ is the PDS sink current, and R_{PDS} is R13.

The MAX1773 uses open-collector drivers to open the charge paths. Minimize the value of the pullup resistors on the charge paths (R12 and R14) to allow the MAX1773 to quickly turn on the PMOS FETs; however, keep the value large enough to prevent a lower V_{GS} than specified by the PMOS FET. The minimum V_{GS} is:

$$V_{GS(MIN)} = -I_{CHG\_(SINK)} \times R_{CHG\_}$$

where $V_{GS(MIN)}$ is the minimum P1 or P4 gate-to-source voltage, $I_{CHG\_(SINK)}$ is the CHG_ sink current (see *Electrical Characteristics*), and $R_{CHG\_}$ is R12 or R14.

V_{DD} Regulator

The MAX1773 features an internal linear regulator to provide power for itself and external circuitry. The linear regulator's output is available at V_{DD} and is nominally 3.3V. When the linear regulator is not used to power external circuitry, bypass it with a 0.33µF ceramic capacitor. To supply external loads up to 1mA, bypass the linear regulator with a 3.3µF tantalum capacitor.

Applications Information

Load Switchover Transients

When power switches from one power source to another, a transient is created on the load. This transient (ΔV_{EXTLD}) is minimized by the capacitance on the load (C_{EXTLD}). The voltage transient can be approximated as:

$$\Delta V_{EXTLD} = \frac{i_{EXLTLD} \times t_{SWITCHOVER}}{C_{EXTLD}}$$

where $t_{SWITCHOVER}$ is the time where no supply is connected to the EXTLD.

In applications where the battery voltage always falls away slowly, $t_{SWITCHOVER}$ is primarily composed of the Battery Switchover Delay. However, in applications where the battery voltage can suddenly fall away, $t_{SWITCHOVER}$ is substantially increased because it is primarily composed of the Battery Action Delay (Figures 1 and 2).

Ideally, when a battery is removed from the system, the thermistor connection is broken before the battery's power path is broken. In this case, $t_{SWITCHOVER}$ is typi-

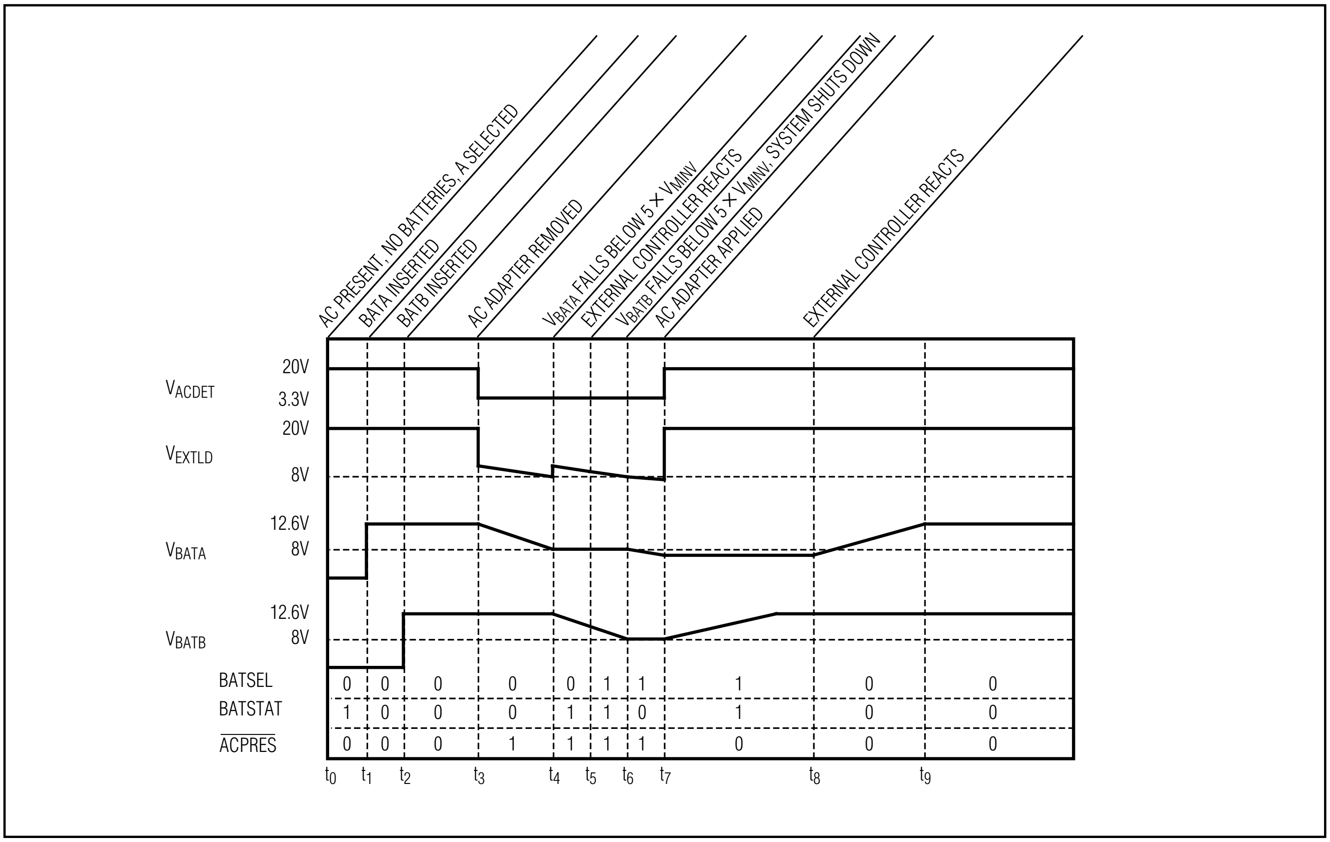


Figure 12. Charge/Discharge Example

cally bound by the Thermistor Action Delay (Figures 3 and 4). However, if the battery's power path is broken first, then $t_{SWITCHOVER}$ primarily consists of the shorter of the following times: time until the thermistor connection is broken plus the Thermistor Action Delay, or the Battery Action Delay.

Source Switchover Transients

When the MAX1773 suddenly switches a power supply to the load, it creates a current transient from the source to charge up the capacitance on the load. The peak current drawn is approximated by:

$$I_{PK} = \frac{\Delta V_{EXTLOAD}}{R_{SOURCE} + R_{SWITCH} + R_{ESR}}$$

where $\Delta V_{EXTLOAD}$ is the voltage difference between the supply switched off and the supply switched on, R_{SOURCE} is the source resistance of the power supply switched on, R_{SWITCH} is the $R_{DS(ON)}$ of the PMOS FETs in the path, and R_{ESR} is the equivalent series resistance of the output capacitance.

The duration of the current transient is determined by R_{SOURCE}, R_{SWITCH}, R_{ESR}, and the output capacitance. Smaller resistances and less output capacitance reduce the transient duration.

Typical Operation

Figure 12 shows a typical discharge and charge cycle for a system utilizing the MAX1773, two 3-cell lithium-ion (Li+) batteries, and a 20V AC adapter power supply. The diagram starts with the AC adapter applied, no batteries present, and battery A selected (see *AC Adapter States*). BATSTAT = $\overline{BATSEL}$ = 1 indicates that battery A is not present and battery A's charge path is not connected. If the external controller polled the MAX1773 as described in *Status and Configuration*, then BATSTAT would return $\overline{BATSEL}$ (0) to indicate that battery B is not present.

At t_1, battery A is inserted and the MAX1773 connects battery A's charge path. Note that BATSTAT changes to BATSEL (0) to indicate that battery A is present.

At t_2, battery B is inserted. BATSTAT does not change and still indicates that battery A is present.

Power Source Selector for Dual-Battery Systems

Table 5. Recommended Manufacturers

SUPPLIER	PHONE	FAX
Fairchild	408-822-2000	408-822-2102
IR	310-322-3331	310-322-3332
Siliconix	408-988-8000	408-970-3950

At t_3, the AC adapter is removed and the MAX1773 automatically disconnects battery A's charge path and connects battery A's discharge path (see *Standard Battery States*). $\overline{\text{ACPRES}}$ changes to 1 to indicate that the AC adapter source is no longer present. BATSTAT = BATSEL (0) to indicate that battery A is present and supplying the load. Between t_3 and t_4, battery A discharges as it supplies the load.

At t_4, battery A's voltage falls below 5 × V_{MIN}, and the MAX1773 automatically disconnects battery A's discharge path and connects battery B's discharge path. BATSTAT goes to $\overline{\text{BATSEL}}$ (1) to indicate that battery A is no longer supplying the load.

Shortly after BATSTAT goes high, the external controller should catch up to the MAX1773 and change BATSEL. This is shown at t_5. BATSTAT remains at 1, indicating that battery B is present and supplying the load.

At t_6, battery B falls below 5 × V_{MIN}, and the MAX1773 automatically disconnects battery B's discharge path and connects battery A's discharge path. BATSTAT changes to $\overline{\text{BATSEL}}$ (0) to indicate that battery B is no longer supplying the load. At this point, the external controller orders a controlled shutdown of the system and drastically reduces the supply current.

At t_7, the AC adapter supply is reconnected to the system. The MAX1773 automatically disconnects battery A's discharge path, connects the AC adapter's load path (PDS switch), and connects battery B's charge path. BATSTAT goes to BATSEL (1) to indicate that battery B is present. $\overline{\text{ACPRES}}$ goes to 0 to indicate that the AC adapter source is present.

At t_8, the external controller recognizes that battery B is charged and changes BATSEL to battery A. BATSTAT goes to BATSEL (0) to indicate that battery A is present.

After t_9, the batteries are fully charged and the system is ready for another cycle.

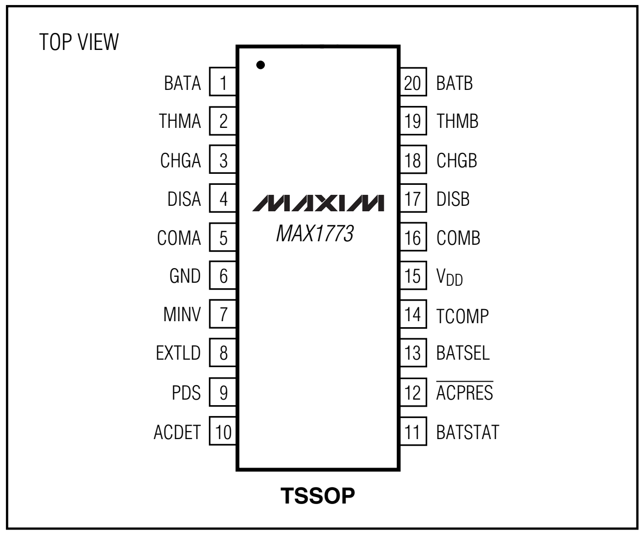
Power MOSFET Selection

The MAX1773 does not place stringent requirements on the external PMOS FETs. Use PMOS FETs with low V_{GS} thresholds (logic level FETs). Low $R_{DS(ON)}$ PMOS FETs are desirable since the PMOS FET's resistance directly contributes to power losses. Also, ensure that the PMOS FET's V_{DS} and V_{GS} ratings exceed the specific circuit requirements. See Table 5 for a list of recommended manufacturers.

Layout Guidelines

The MAX1773 does not use fast switching times or high frequencies. Therefore, the layout requirements are minimal. Keep the gate connections to the external PMOS FETs short to minimize capacitive coupling, reduce parasitic inductance, and ensure stability. In addition, minimize the power path length when possible to reduce the path's resistance. See the MAX1773 evaluation kit for a layout example.

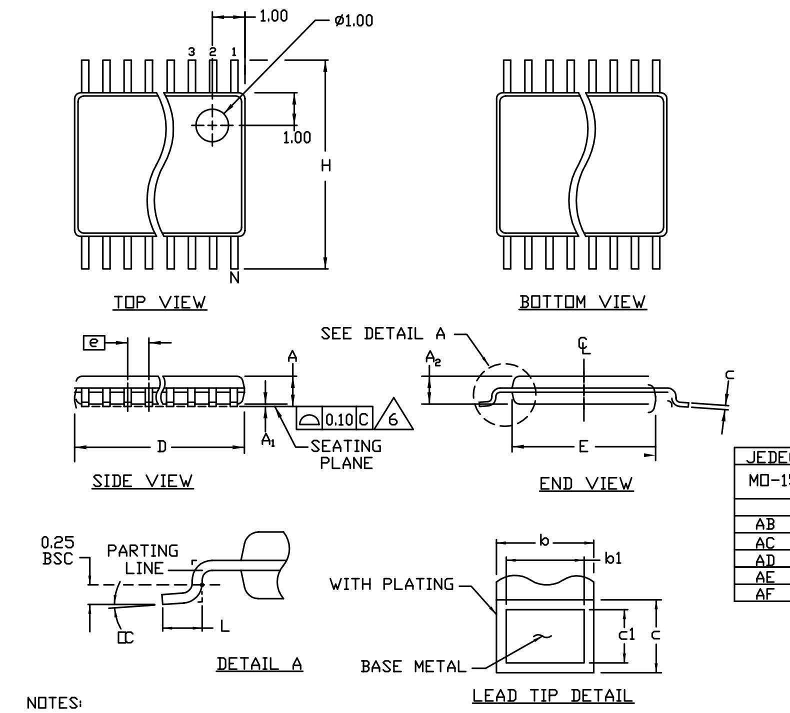
Pin Configuration



Chip Information

TRANSISTOR COUNT: 5245

PROCESS: BiCMOS



SYMBOL	COMMON DIMENSIONS			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	—	1.10		.043
A_1	0.05	0.15	.002	.006
A_2	0.85	0.95	.033	.037
b	0.19	0.30	.007	.012
b1	0.19	0.25	.007	.010
c	0.090	0.20	.0035	.008
c1	0.090	0.135	.0035	.0053
D	SEE VARIATIONS		SEE VARIATIONS	
E	4.30	4.50	.169	.177
e	0.65 BSC		.026 BSC	
H	6.25	6.50	.246	.256
L	0.50	0.70	.020	.028
N	SEE VARIATIONS		SEE VARIATIONS	
α	0°	8°	0°	8°

JEDEC			VARIATIONS			
MO-153	N		MILLIMETERS		INCHES	
			MIN.	MAX.	MIN.	MAX.
AB	14	D	4.90	5.10	.193	.201
AC	16	D	4.90	5.10	.193	.201
AD	20	D	6.40	6.60	.252	.260
AE	24	D	7.70	7.90	.303	.311
AF	28	D	9.60	9.80	.378	.386

NOTES:

1. DIMENSIONS D AND E DO NOT INCLUDE FLASH
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED 0.15mm PER SIDE
3. CONTROLLING DIMENSION: MILLIMETER
4. MEETS JEDEC OUTLINE MO-153 VARIATIONS- AB, AC, AD, AE, AF
5. "N" REFERS TO NUMBER OF LEADS
6. THE LEAD TIPS MUST LIE WITHIN A SPECIFIED ZONE. THIS TOLERANCE ZONE IS DEFINED BY TWO PARALLEL PLANES. ONE PLANE IS THE SEATING PLANE, DATUM [-C-]; THE OTHER PLANE IS AT THE SPECIFIED DISTANCE FROM [-C-] IN THE DIRECTION INDICATED.

MAXIM

PROPRIETARY INFORMATION

TITLE: PACKAGE OUTLINE, TSSOP, 4.40 MM BODY

APPROVAL | DOCUMENT CONTROL NO. 21-0066 | REV D | 1/1

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