19-4785; Rev 0; 11/98

EVALUATION KIT MANUAL FOLLOWS DATA SHEET

Bridge-Battery Backup Controllers for Notebooks

General Description

The MAX1612/MAX1613 manage the bridge battery (sometimes called a hot-swap or auxiliary battery) in portable systems such as notebook computers. They feature a step-up DC-DC converter that boosts 2-cell or 3-cell bridge-battery voltages up to the same level as the main battery. This voltage boosting technique reduces the number of cells otherwise required for a 6-cell plus diode-OR bridging scheme, reducing overall size and cost. Another key feature is a trickle-charge timer that minimizes battery damage caused by constant charging and eliminates trickle-charge current drain on the main battery once the bridge battery is topped off.

These devices contain a highly flexible collection of independent circuit blocks that can be wired together in an autonomous stand-alone configuration or used in conjunction with a microcontroller. In addition to the boost converter and charge timer, there is a micropower linear regulator (useful for RTC/CMOS backup as well as for powering a microcontroller) and a high-precision low-battery detection comparator.

The two devices differ only in the preset linear-regulator output voltage: +5.0V for the MAX1612 and +3.3V for the MAX1613. Both devices come in a space-saving 16-pin QSOP package.

Applications

- Notebook Computers
- Portable Equipment
- Backup Battery Applications

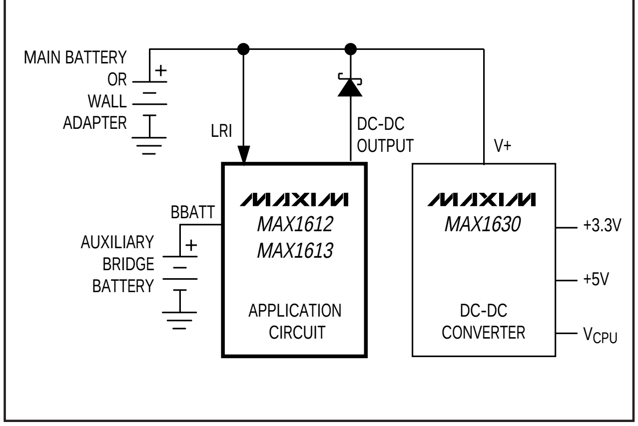
Features

- **Reduce Battery Size and Cost**
- **Four Key Circuit Blocks**
  - **Adjustable Boost DC-DC Converter**
  - **NiCd/NiMH Trickle Charger**
  - **Always-On Linear Regulator (+28V Input)**
  - **Low-Battery Detector**
- **Low 18µA Quiescent Current**
- **Selectable Charging/Discharging Rates**
- **Preset Linear-Regulator Voltage**
  - **5V (MAX1612)**
  - **3.3V (MAX1613)**
- **4V to 28V Main Input Voltage Range**
- **Internal Switch Boost Converter**
- **Small 16-Pin QSOP Package**

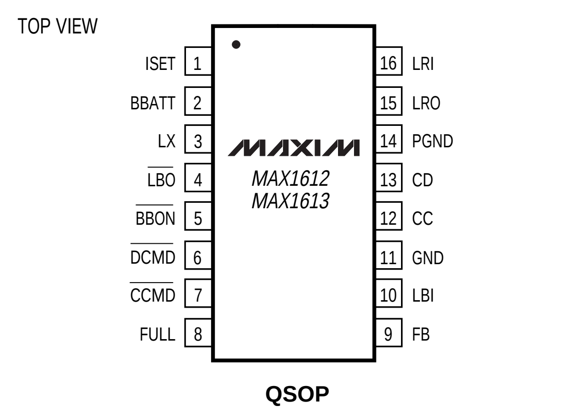
Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX1612EEE	-40°C to +85°C	16 QSOP
MAX1613EEE	-40°C to +85°C	16 QSOP

Typical Operating Circuit



Pin Configuration



Bridge-Battery Backup Controllers for Notebooks

ABSOLUTE MAXIMUM RATINGS

LRI, ISET to GND..-0.3V to +30V
LX to GND ....-0.3V to +14V
PGND to GND...-0.3V to +0.3V
BBATT, LRO, $\overline{CCMD}$, $\overline{DCMD}$, FULL, $\overline{BBON}$,
$\overline{LBO}$ to GND ....-0.3V to +6V
CC, CD, LBI, FB to GND...........................-0.3V to (V_{LRO} + 0.3V)
FB, LBI, ISET, and BBATT Current.....................................50mA
LRO Output Current 50mA

Continuous Power Dissipation (T_A = +70°C)
QSOP (derate 8.30mW/°C above +70°C).................... 667mW
Operating Temperature Range
MAX1612/MAX1613EEE ....-40°C to +85°C
Storage Temperature Range ....-65°C to +160°C
Lead Temperature (soldering, 10sec) .... +300°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

(V_{LRI} = V_{ISET} = 20V, $\overline{CCMD}$ = $\overline{DCMD}$ = $\overline{BBON}$ = LRO, V_{BBATT} = 3V, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
Linear-Regulator Input Voltage Range	V_{LRI}	MAX1612	5.7		28	V
		MAX1613	4		28	
Linear-Regulator Quiescent Current	I_{LRI}	$V_{\overline{BBON}}$ ≥ 2V		18	28	µA
		$V_{\overline{DCMD}}$ = 0, $R_{\overline{BBON}}$ = 1MΩ to GND (boost converter on)		42	58	
Linear-Regulator Output Voltage	V_{LRO}	0 ≤ I_{LRO} ≤ 10mA, 5.7V ≤ V_{LRI} ≤ 28V (MAX1612)	4.7	5.0	5.3	V
		0 ≤ I_{LRO} ≤ 10mA, 4V ≤ V_{LRI} ≤ 28V (MAX1613)	3.1	3.3	3.5	
Linear-Regulator Output Undervoltage Lockout Threshold	V_{UVLO}	LRO rising hysteresis = 200mV	2.65		2.97	V
BATTERY CHARGER						
ISET Leakage Current	$I_{ISET(LEAK)}$	V_{ISET} = 28V, V_{BBATT} = 0		0.3	5	µA
BBATT Leakage Current	$I_{BBATT(LEAK)}$	V_{ISET} = 0 or 28V, V_{BBATT} = 6V	-5		5	µA
Charge-Switch On Voltage		I_{ISET} = 10mA, $V_{\overline{CCMD}}$ = 0, V_{BBATT} = 2V	0.5	1	1.3	V
Charge-Switch Loss Current		$\overline{CCMD}$ = GND, I_{ISET} = 10mA, V_{BBATT} = 2V, %loss = [(I_{ISET} - I_{BBATT}) / I_{ISET}) · 100%		0.1	5	%
LOW-BATTERY COMPARATOR						
LBI Falling Trip Voltage	V_{LBTL}		1.76	1.8	1.84	V
LBI Rising Trip Voltage	V_{LBTH}		1.955	2	2.045	V
LBI Input Current	I_{LBI}	V_{LBI} = 1.9V		0.2	10	nA
$\overline{LBO}$, FULL Output Leakage Current	$I_{\overline{LBO}}$, I_{FULL}	$V_{\overline{LBO}}$ = V_{FULL} = 5.5V			1	µA
$\overline{LBO}$, FULL Output Voltage Low		I_{SINK} = 1mA			0.4	V
LBI Comparator Response Time	t_{PD}	Overdrive = 100mV		20		µs

ELECTRICAL CHARACTERISTICS (continued)

(V_{LRI} = V_{ISET} = 20V, $\overline{CCMD}$ = $\overline{DCMD}$ = $\overline{BBON}$ = LRO, V_{BBATT} = 3V, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

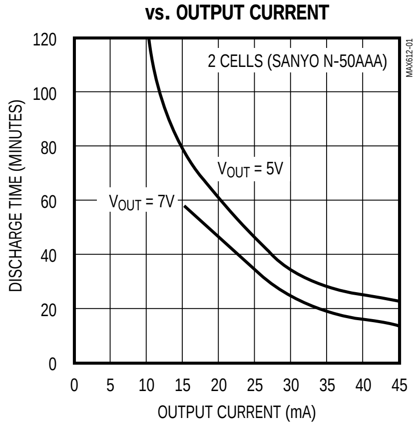
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
DC-DC CONVERTER						
FB Trip Point	V_{FB}		1.95		2.05	V
FB Input Current	I_{FB}	V_{FB} = 2.1V		0.15	10	nA
LX Switch Current Limit	I_{PEAK}	$R_{\overline{BBON}}$ = 100kΩ to GND	0.580	0.835	1.100	A
LX Off-Leakage		V_{LX} = 12V		0.01	10	µA
LX On-Resistance	R_{DSON}	I_{LX} = 200mA		0.5	1.5	Ω
LX Zero Crossing Trip Threshold		Voltage that allows a new cycle, defined as (V_{BBATT} - V_{LX}) (see *DC-DC Converter* section)	-0.2	-0.1	0.2	V
$\overline{BBON}$ Logic Input Low Voltage					2.1	V
TIMER BLOCK						
CC Output Current		$V_{\overline{CCMD}}$ = 0, CC = GND	4.35	5.00	5.65	µA
CD Oscillator Frequency	CD_{OSC}	C_{CD} = 3.3nF	600	758	950	Hz
CC Oscillator Frequency	CC_{OSC}	C_{CC} = 33nF	60	75.8	95	Hz
ISET Logic Input Low Voltage		Resets the counter	0.4			V
CD to CC Current Matching		$V_{\overline{DCMD}}$ = 0, CD = GND	-1		1	%
Logic Input Low Level	V_{IL}	$\overline{CCMD}$, $\overline{DCMD}$			0.8	V
Logic Input High Level	V_{IH}	$\overline{CCMD}$, $\overline{DCMD}$	2.2			V
Logic Input Leakage Current	$I_{(\overline{CCMD})}$, $I_{(\overline{DCMD})}$	$V_{\overline{CCMD}}$, $V_{\overline{DCMD}}$ = 0 to V_{LRO}			1	µA

Note 1: Specifications from 0°C to -40°C are guaranteed by design, not production tested.

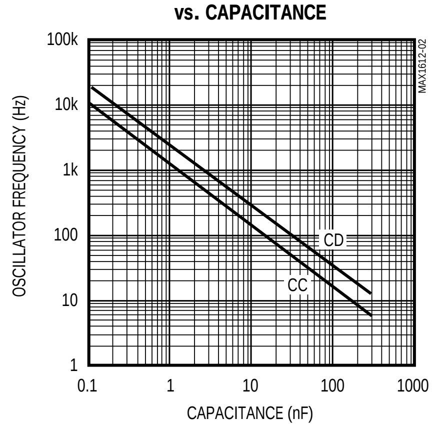
Typical Operating Characteristics

(Circuit of Figure 3, T_A = +25°C, unless otherwise noted.)

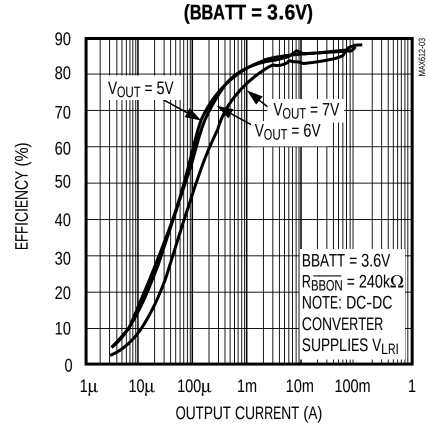
DISCHARGE TIME vs. OUTPUT CURRENT



OSCILLATOR FREQUENCY vs. CAPACITANCE



EFFICIENCY vs. OUTPUT CURRENT (BBATT = 3.6V)

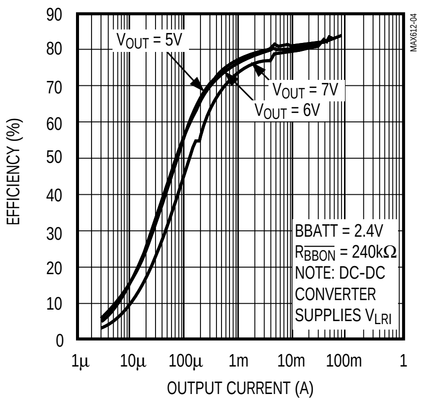


Bridge-Battery Backup Controllers for Notebooks

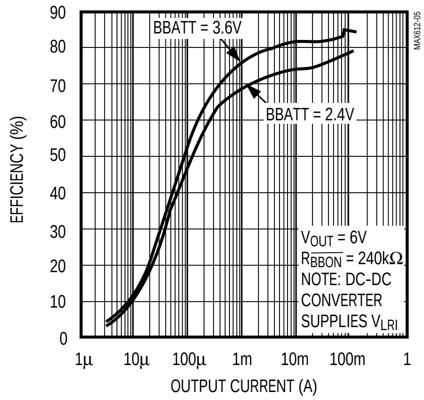
Typical Operating Characteristics (continued)

(Circuit of Figure 3, T_A = +25°C, unless otherwise noted.)

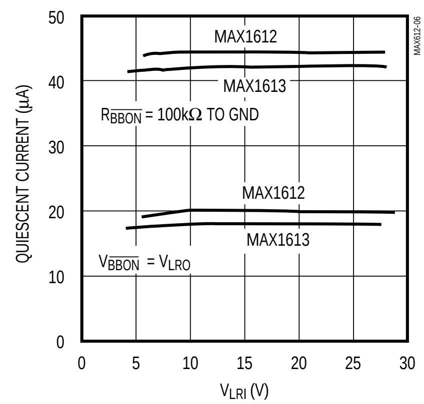
EFFICIENCY vs. OUTPUT CURRENT (BBATT = 2.4V)



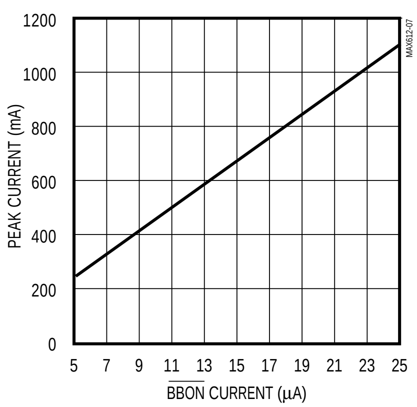
EFFICIENCY vs. OUTPUT CURRENT (BBATT = 6V)



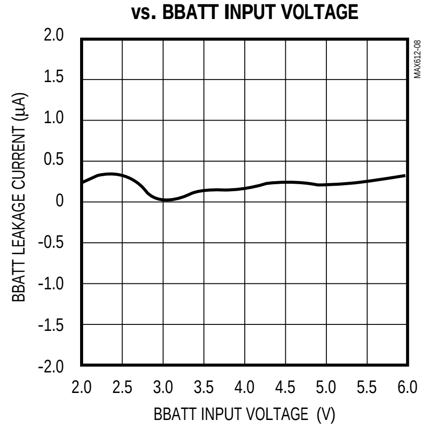
QUIESCENT CURRENT vs. LRI VOLTAGE



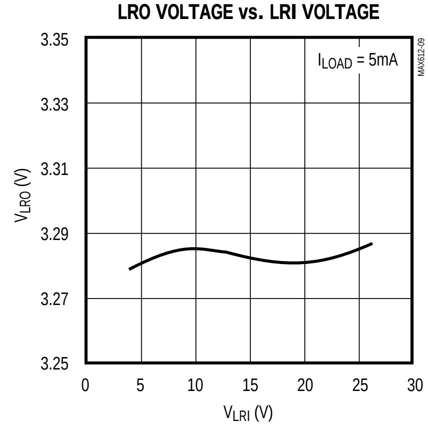
PEAK CURRENT vs. BBON CURRENT



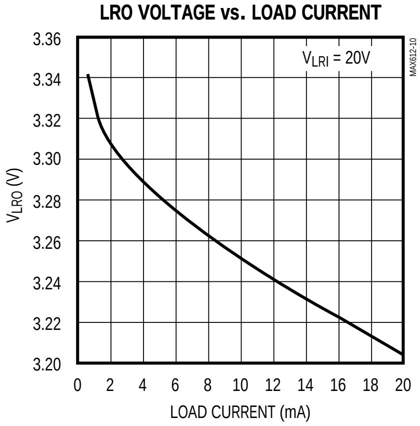
BBATT LEAKAGE CURRENT vs. BBATT INPUT VOLTAGE



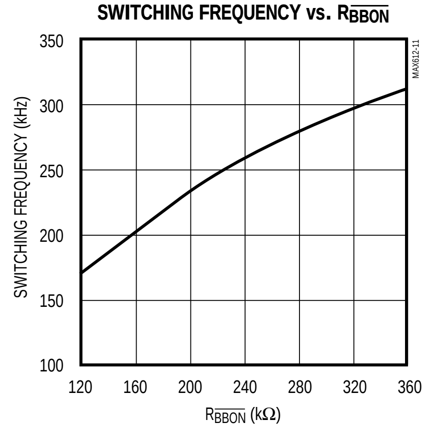
MAX1613 LRO VOLTAGE vs. LRI VOLTAGE



MAX1613 LRO VOLTAGE vs. LOAD CURRENT



SWITCHING FREQUENCY vs. $R_{\overline{BBON}}$



Pin Description

PIN	NAME	FUNCTION
1	ISET	Bridge-Battery Charge-Current Input. Connect a current-setting resistor from this input to a voltage higher than the bridge battery. Maximum current rating is 10mA. Pulling ISET below 0.4V resets the internal counter.
2	BBATT	Bridge-Battery Connection. Bridge-battery charger output.
3	LX	Step-Up DC-DC Converter N-Channel MOSFET Drain. The maximum operating range is 12V.
4	$\overline{\text{LBO}}$	Open-Drain Low-Battery Detector Output. When V_{LBI} falls below 1.8V, $\overline{\text{LBO}}$ sinks current. When V_{LBI} rises above 2.0V, $\overline{\text{LBO}}$ becomes high impedance.
5	$\overline{\text{BBON}}$	Bridge-Battery On Input. When high, the DC-DC converter turns off. When pulled low through an external resistor, the resistor sets the peak inductor current. The inductor current is approximately 42,000 times the current in the external resistor ($R_{\overline{BBON}}$).
6	$\overline{\text{DCMD}}$	Discharge Command Input. When low with $\overline{\text{CCMD}}$ high, the internal timer counts down at a frequency set by the CD capacitor. When both $\overline{\text{DCMD}}$ and $\overline{\text{CCMD}}$ are low, discharge takes precedence.
7	$\overline{\text{CCMD}}$	Charge Command Input. When low with $\overline{\text{DCMD}}$ high, the internal switch from ISET to BBATT is closed, charging the bridge battery. $\overline{\text{CCMD}}$ is inhibited if $\overline{\text{DCMD}}$ is low. The internal timer counts up at a frequency set by the CC capacitor.
8	FULL	Open-Drain Bridge-Battery Full Indicator Output. When the internal timer reaches all 1sec, FULL goes high impedance.
9	FB	Feedback Input of Step-Up DC-DC Converter. Regulates to 2V. Connect feedback resistors to set output voltage (Figure 2).
10	LBI	Low-Battery-Detector Input. When LBI falls below 1.8V, $\overline{\text{LBO}}$ goes low and sinks current. When LBI goes above 2.0V, $\overline{\text{LBO}}$ goes high impedance. Hysteresis is typically 200mV.
11	GND	Ground
12	CC	Charge Oscillator Capacitor Input. This capacitor programs the charging oscillator frequency, which sets the time for the internal counter to reach all 1s. Determine the capacitor value by: CC (in nF) = 4.3 · charge time (in hours).
13	CD	Discharge Oscillator Capacitor Input. This capacitor sets the discharging oscillator frequency, which determines the maximum time to decrement the counter from all 1s to all 0s. Calculate the capacitor value as follows: CD (in nF) = 4.3 · discharge time (in hours).
14	PGND	Power Ground and Step-Up DC-DC Converter N-Channel MOSFET Source
15	LRO	5V (MAX1612) or 3.3V (MAX1613) Linear-Regulator Output. Bypass to GND with a 1µF capacitor. Maximum external load current is 10mA.
16	LRI	Linear-Regulator Supply Input

Bridge-Battery Backup Controllers for Notebooks

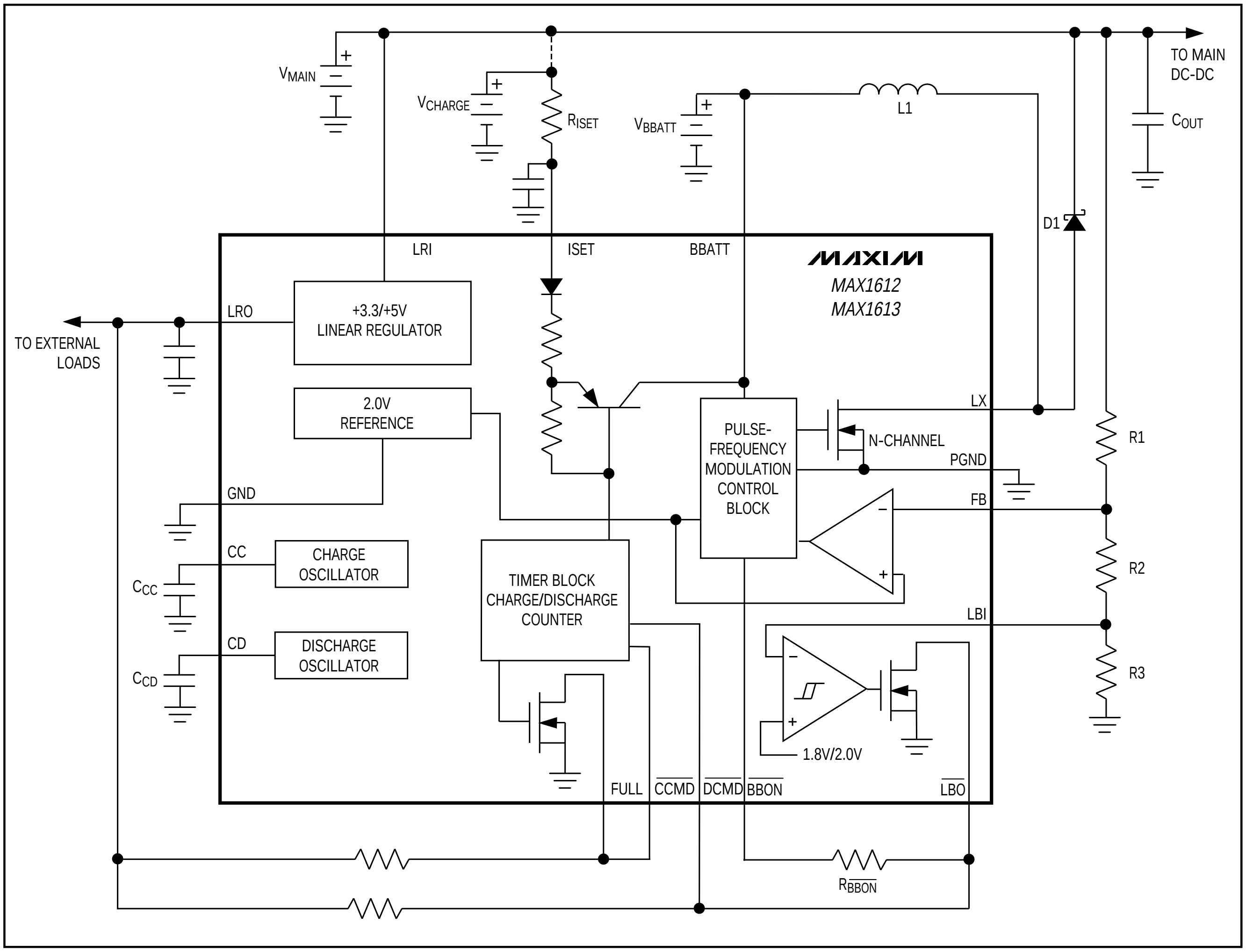


Figure 1. Functional Diagram

Detailed Description

The MAX1612/MAX1613 manage the bridge battery (auxiliary battery) in portable systems. These devices consist of a timer block that monitors the charging process, a linear regulator for supplying IC power and external circuitry to the MAX1612/MAX1613, and a DC-DC step-up converter that powers the system when the main battery is removed (Figure 1). The boost DC-DC converter reduces the number of bridge-battery cells required to supply the system's DC-DC converter. When the main supply is present, the DC-DC converter is inactive, reducing the drain on the main battery to only 18µA. However, if the main battery voltage falls (as detected by the low-battery comparator), the bridge battery becomes the input source.

The MAX1612/MAX1613 have an internal linear regulator set at +5V (MAX1612) or +3.3V (MAX1613). The linear regulator can deliver a load up to 10mA, making it capable of powering external components such as a microcontroller (Figure 4). An undervoltage lockout feature disables the device when the input voltage falls below the operating range, preventing the DC-DC converter from inadvertently powering up.

The MAX1612/MAX1613 feature an internal counter intended to track the charging and discharging process. The counter tracks the charge on the bridge battery, allowing trickle charge to terminate when the maximum charge is achieved. The charging rate is determined by current through the ISET switch, and limited by the switch's maximum current specification as well as by the bridge cell's charging capability. As

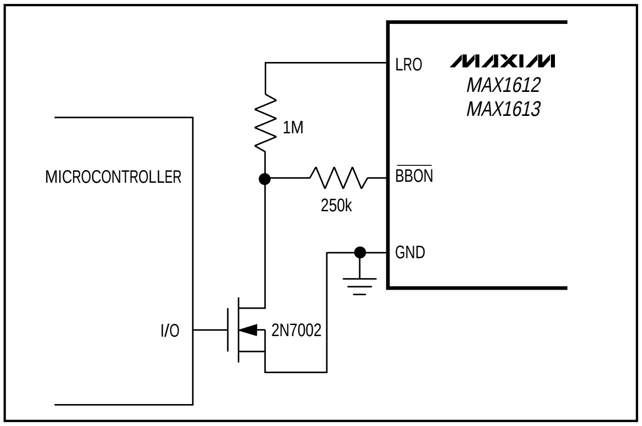


Figure 2. Reducing $\overline{BBON}$ Noise Sensitivity

specifications vary, the counter frequency can be adjusted to accommodate these variances by adjusting C_{CC}. Similarly, the discharging oscillator frequency can be adjusted with the C_{CD} capacitor. However, the rate of bridge battery discharge depends on the DC-DC converter's load. Decrementing the charge/discharge counter is used only to estimate the remaining charge on the bridge battery. The counter increments (or decrements) based on $\overline{CCMD}$ and $\overline{DCMD}$ logic states. Note that the net charge must exceed the net discharge to compensate for charging efficiency losses.

Figure 3 shows a typical stand-alone application (see *Design Procedure* for details). It reduces the need for an external microcontroller to manage these functions. However, if the design requires greater flexibility, a microcontroller can be used as shown in Figure 4.

DC-DC Converter

The DC-DC step-up converter is a pulse-frequency modulated (PFM) type. The on-time is determined by the time it takes for the inductor current to ramp up to the peak current limit (set via $R_{\overline{BBON}}$), which in turn is determined by the bridge battery voltage and the inductor value. With light load or no load, the converter is forced to operate in discontinuous-conduction mode (where the inductor current decays to zero with each cycle) by a comparator that monitors the LX voltage waveform. The converter will not start a new cycle until the voltage at LX goes below the battery voltage. At full load, the converter operates at the crossover point between continuous and discontinuous mode. This "edge of continuous" algorithm results in the minimum possible physical size for the inductor. At light loads, the devices pulse infrequently to maintain output regulation ($V_{FB} \geq 2V$). Note that the LX comparator requires the DC-DC output voltage to be set at least 0.6V above the maximum bridge battery voltage.

Timer Block

The MAX1612/MAX1613 have an internal charge/discharge counter that keeps track of the bridge-battery charging/discharging process. When $\overline{CCMD}$ is low and $\overline{DCMD}$ is high, the internal counter increments until the FULL pin goes high, indicating that the counter has reached all 1s. The maximum counter value is 2^{21}. Additional pulses from the CC oscillator will not cause the counter to wrap around. In the stand-alone application (Figure 3), terminate the charging process automatically by connecting FULL to $\overline{CCMD}$. In a microcontroller application, pull $\overline{CCMD}$ high. The counter only specifies the maximum time for full charging; it does not control the actual rate of charging. $\overline{CCMD}$ controls the charging switch, and the resistor at ISET sets the charging rate.

During the discharging process, drive $\overline{DCMD}$ low in order to begin decrementing the counter. When the counter is full, FULL is high. As soon as the counter decrements just two counts, the FULL pin sinks current, indicating that the battery is no longer full. The counter only indicates the relative portion of the charge remaining. The incrementing and decrementing rate depends on the maximum charge and discharge times set forth by charging and discharging rates (see the following equations for CC and CD). Note that the actual discharging is caused by the input current of the step-up DC-DC converter loading down the bridge battery, which is controlled via $\overline{BBON}$ rather than by $\overline{DCMD}$.

The CC and CD capacitor values determine the upcount and downcount rates by controlling the discharging oscillator frequency. Determine the maximum charge and discharge times as follows:

$$C_{CC} (nF) = 4.3 \cdot t_{HRS}$$

$$C_{CD} (nF) = 4.3 \cdot t_{HRS}$$

where C_{CC} is the charging capacitor, C_{CD} is the discharging capacitor and t_{HRS} is the maximum time in hours for the process. Choose values that allow for losses in the battery charging and discharging process, such as battery charging inefficiencies, errors in charging current value caused by variable main battery voltages, leakage currents, and losses in the device's internal switch. For charging, use the standard charge rate recommended by the battery manufacturer. **The maximum charging current is restricted to the battery specifications. Consult the battery manufacturer's specifications. Do not set the charging current above 10mA.**

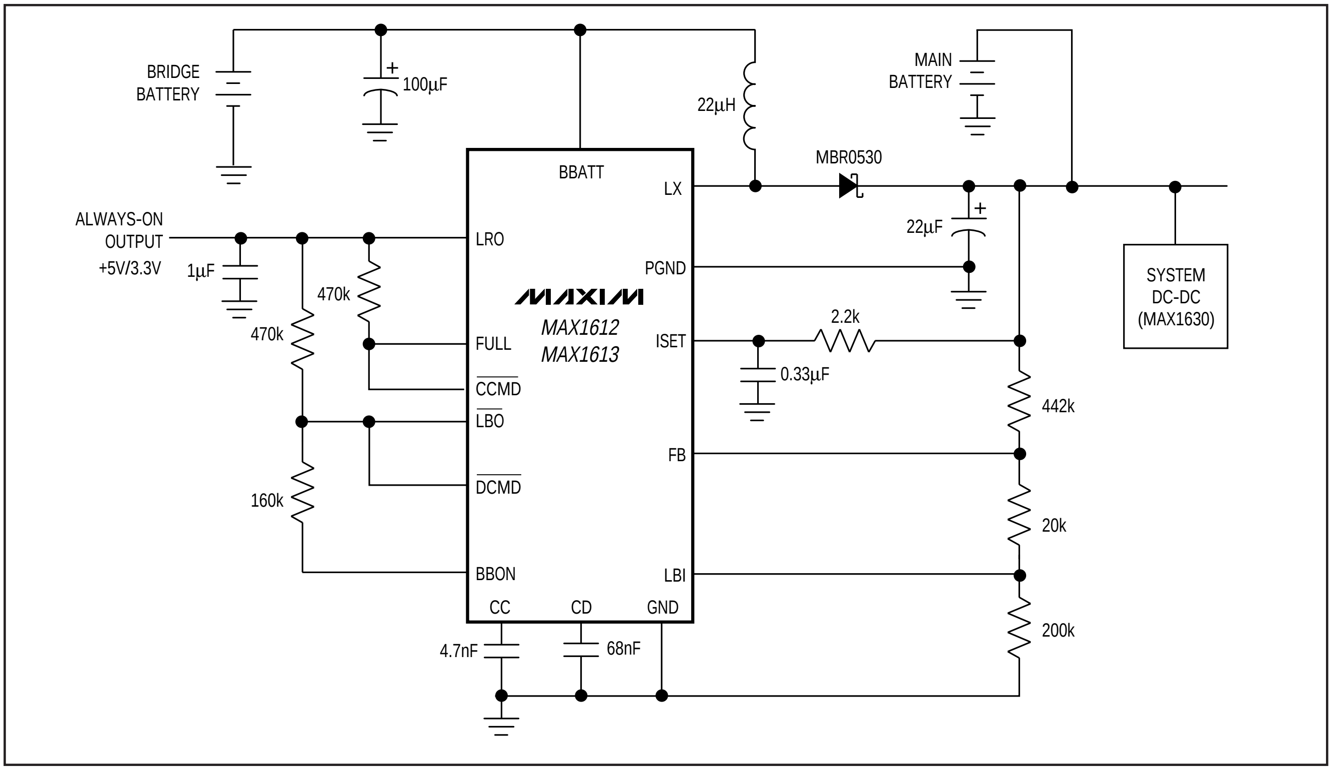


Figure 3. Stand-Alone Application

The counter block can be used to estimate the charge remaining in the battery. For example, if the maximum expected charge time is 14 hours (C_{CC} = 60nF) and the maximum expected discharge time is about 2 hours (C_{CD} = 8.6nF), the battery reaches full charge in 14 hours with the FULL pin going high. If the bridge battery must supply the load for 1 hour, the counter will decrement down to about half full. Recharging the battery will now require only 7 hours to reach all 1s in the counter, signaling with FULL going high.

If both $\overline{DCMD}$ and $\overline{CCMD}$ are pulled low simultaneously, the counter defaults to the discharge mode. When the bridge battery is supplying the circuit, it is considered to be in discharge mode (Table 1).

Charge Current Selection (ISET)

A resistor between ISET and a voltage higher than the bridge battery sets the charging rate. The switch is open when $\overline{CCMD}$ is high and is turned on when $\overline{CCMD}$ is pulled low (assuming $\overline{DCMD}$ is high). If the voltage at ISET falls below 0.4V, the internal counter resets to all 0s. The internal high-voltage switch has a typical on-state voltage drop of 1V (Figure 1). Therefore, the charge current equals:

$$I_{ISET} = [\ (V_{CHARGE} - V_{BBATT}\ ) - 1V] \ /\ R_{ISET}$$

Linear-Regulator Output (LRO)

The linear-regulator output, LRO, is set at +5.0V for the MAX1612 and at +3.3V for the MAX1613, with a tolerance of ±6%. For powering external circuitry such as the microcontroller shown in Figure 4, LRO is guaranteed to deliver up to 10mA while maintaining regulation. If the voltage at the linear-regulator input falls below the operating range, an undervoltage-lockout feature shuts down the entire device.

Table 1. $\overline{CCMD}$, $\overline{DCMD}$ Truth Table

$\overline{DCMD}$	$\overline{CCMD}$	COUNTER	ISET SWITCH
0	0	Count Down	Off
0	1	Count Down	Off
1	0	Count Up	On
1	1	No Count	Off

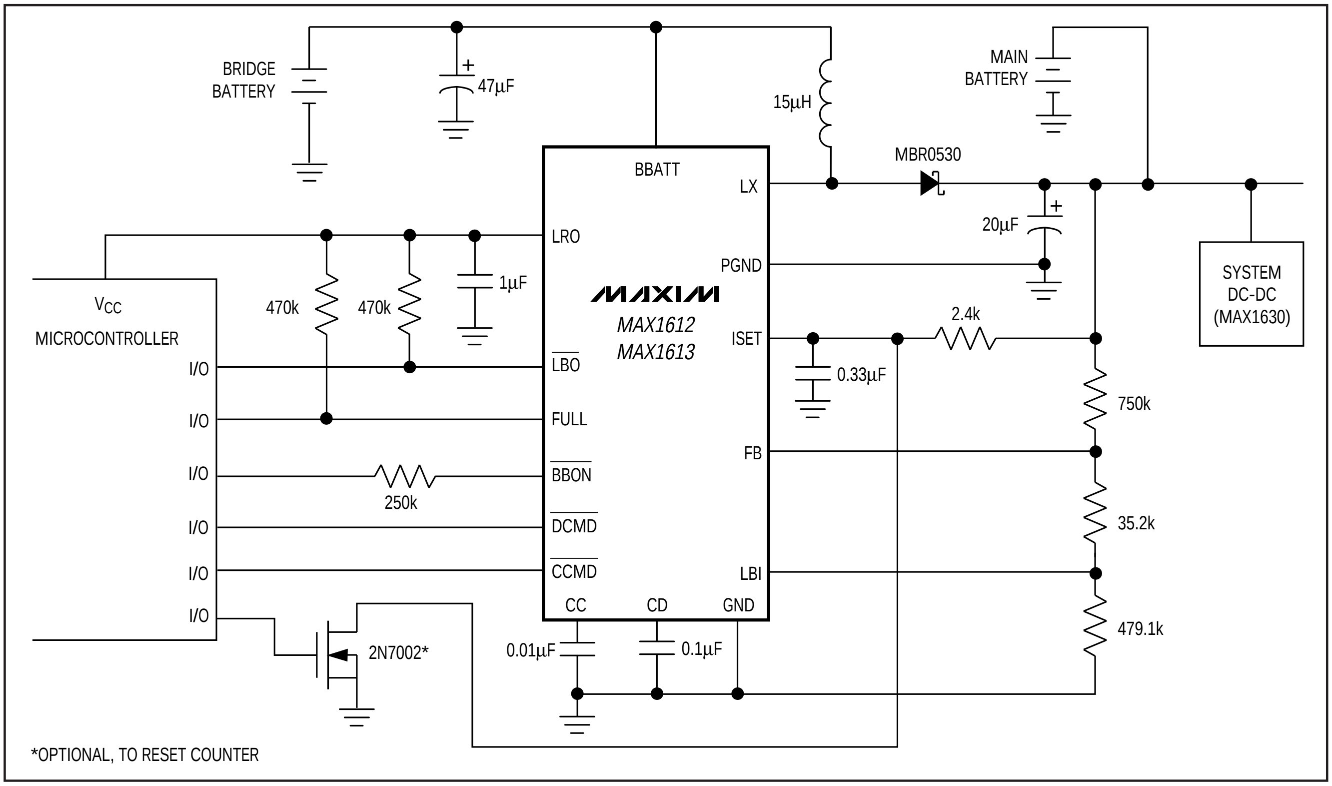


Figure 4. Microcontroller-Based Application

Low-Battery Comparator (LBI, $\overline{\textbf{LBO}}$)

The MAX1612/MAX1613 feature a low-battery comparator with a factory-preset 1.8V threshold. This comparator is intended to monitor the main high-voltage battery. As the voltage falls below 1.8V, the open-drain $\overline{\text{LBO}}$ output sinks current. With 200mV of hysteresis, the output will not go high until V_{LBI} exceeds 2.0V. $\overline{\text{LBO}}$ can easily be connected to $\overline{\text{BBON}}$ to start the DC-DC converter when V_{LBI} < 1.8V (stand-alone application, Figure 3). Figure 4 shows an application using a microcontroller, where $\overline{\text{LBO}}$ alerts the microcontroller to the falling voltage and pulls $\overline{\text{BBON}}$ low through an external resistor to start the DC-DC converter while also pulling $\overline{\text{DCMD}}$ low to start the counter.

$\overline{\textbf{BBON}}$ Control Input

The $\overline{\text{BBON}}$ input serves two functions: setting the peak LX switch current, and enabling the DC-DC converter. The control signal is normally applied to $R_{\overline{BBON}}$ rather than at the pin itself. The peak LX switch current is directly proportional to and 42,000 times greater than the current through $R_{\overline{BBON}}$ (see *Typical Operating Characteristics*). The $\overline{\text{BBON}}$ pin is internally regulated to 2V, so that when the control input is forced low, the voltage across $R_{\overline{BBON}}$ is 2V.

When driving $\overline{\text{BBON}}$ from external logic, ensure the low state has minimal noise. Otherwise, drive $R_{\overline{BBON}}$ with an N-channel FET whose source is returned directly to GND (Figure 2).

Applications Information

Design Procedure

The following section refers to the Functional Diagram of Figure 1.

Step 1: Select the output voltage and maximum output current for the boost DC-DC converter. Generally, choose an output voltage high enough to run the main system's buck DC-DC converters. Assuming the maximum battery capacity is 50mAh (Sanyo 1.2V N-50AAA), the following equations can help the design process:

$$I_{PEAK} = 2 \cdot I_{OUT} \cdot (V_{OUT} + V_D) / (V_{BBATT} - V_{RDSON})$$

$$I_{IN} = 0.5 \cdot I_{PEAK}$$

where I_{PEAK} is the peak current, I_{OUT} is the load current, V_{BBATT} is the bridge-battery voltage, V_D is the forward drop across D1, V_{OUT} is the output voltage, I_{IN} is average current provided by the bridge battery, and $V_{RDS(ON)}$ is the voltage drop across the internal N-channel power transistor at LX (typically 0.5V). A larger number of cells reduces the I_{PEAK} and, in effect, reduces the discharge current, thereby extending the discharge time. The same is true for decreasing the output voltage or output current. For example, choose the following values: I_{OUT} = 100mA, V_{OUT} = 5V, and V_{BBATT} = 2V (two cells). Using the minimum voltage of 1V for each cell, Table 2 summarizes some common values.

Step 2: To avoid saturation, choose an inductor (L) with a peak current rating above the I_{PEAK} calculated in Step 1. Use low series resistance (≤ 200mΩ), to optimize efficiency. In this example, a 15µH inductor is used. See Table 4 for a list of component suppliers.

The "edge-of-continuous" DC-DC algorithm causes the inductor value to fall out of the peak current equation. Therefore, the exact inductor value chosen is not critical to the design. However, the switching frequency is inversely proportional to inductance, so trade-offs of switching losses versus physical inductor size can be made by adjusting the inductor value.

$$f = \frac{1}{L(I_{PEAK})}\left[\frac{(V_{BBATT} - V_{RDSON})\,(V_{OUT} - V_{BBATT} - V_D)}{(V_{OUT} - V_{RDSON} - V_D)}\right]$$

where f is the switching frequency, V_{OUT} is the output voltage, V_{RDSON} is the voltage across the internal MOSFET switch, V_D is the forward voltage of D1, I_{PEAK} is the peak current, and V_{BBATT} is the bridge battery voltage. The maximum practical switching frequency is 400kHz.

Step 3: Choose the charging (C_{CC}) and discharging (C_{CD}) timing capacitors. These capacitors set the frequency that the counter increments/decrements.

$$C_{CC}\ (nF) = 4.3 \cdot \text{expected charge time (in hours)}$$
$$C_{CD}\ (nF) = 4.3 \cdot \text{expected discharge time (in hours)}$$

For instance, using a charge time of 16 hours and a discharge time of one hour, C_{CC} = 68nF and C_{CD} = 4.3nF. (Consult battery manufacturers' specifications for standard charging information, which generally compensates for battery inefficiencies.)

Step 4: Using the peak current calculated in Step 1, calculate the series resistor ($R_{\overline{BBON}}$) as follows:

$$R_{\overline{BBON}} = (V_{\overline{BBON}} \cdot 42{,}000) / I_{PEAK}$$

where $V_{\overline{BBON}}$ = 2V (internally regulated).

Table 2. Summary of Common Values for Designing with the MAX1612/MAX1613

V_{OUT} (V)	V_{BBATT} (V)	AVERAGE I_{PEAK} (mA)	I_{IN} (mA)	MINIMUM DISCHARGE TIME (MINUTES)
6	2	600	300	10
5	2	500	250	12
4.5	2	450	225	13.2
6	3	400	200	15
5	3	333	167	18
4.5	3	300	150	20
6	4	300	150	20
5	4	250	125	24

Note: *In this table, I_{OUT} = 100mA and battery capacity = 50mAh.*

Table 3. Component List

INDUCTORS	CAPACITORS	RECTIFIERS	BATTERY
Sumida CD43 or CD54 series	Sprague 595D series, AVX TPS series	Motorola MBR0530, NIEC EC10QS03L	Sanyo N-50AAA

Table 4. Component Suppliers

SUPPLIER	PHONE	FAX
AVX	USA: 207-287-5111	USA: 207-283-1941
Motorola	USA: 408-749-0510 800-521-6274	—
NIEC	USA: 805-867-2555 Japan: 81-3-3494-7411	USA: 805-867-2556 Japan: 81-3-3494-7414
Sanyo	USA: 619-661-6835 Japan: 81-7-2070-6306	USA: 619-661-1055 Japan: 81-7-2070-1174
Sumida	USA: 708-956-0666 Japan: 81-3-3607-5111	USA: 708-956-0702 Japan: 81-3-3607-5144

Step 5: Resistors R1, R2, and R3 set the DC-DC converter's output voltage and the low-battery comparator trip value. The sum of R1, R2, and R3 must be less than 2MΩ, to minimize leakage errors. Choose resistor R1 = 750kΩ for the example. Calculate R2 and R3 as follows:

$$R2 = [\, V_{OUT}\,(R3) - 2\,(R1) - 2\,(R3)\,] / (2 - V_{OUT})$$
$$R3 = (R1 + R2) / [\,(V_{TRIP} / 1.8) - 1]$$

Table 5. Surface-Mount Inductor Information

MANUFACTURER AND PART	INDUCTANCE (µH)	RESISTANCE (Ω)	RATED CURRENT (A)	HEIGHT (mm)
Sumida CD43-8R2	8.2	0.132	1.26	3.2
Sumida CD43-150	15	0.235	0.92	3.2
Sumida CD54-100	10	0.100	1.44	4.5
Sumida CD54-150	15	0.140	1.30	4.5
Sumida CD54-220	22	0.180	1.11	4.5

where V_{OUT} is the DC-DC converter's output voltage and V_{TRIP} is the voltage level the main battery must fall below to trip the low-battery comparator. For example, for a +5V boost DC-DC output, a 4.75V main battery trip level is feasible. For this case, R1 = 750kΩ, R2 = 26kΩ, and R3 = 474kΩ.

Step 6: Select a resistor value to set the charging current. The resistor value at ISET limits the current through the switch for bridge-battery charging. There is a voltage drop across the high-voltage switch (see *Electrical Characteristics*) with a typical value of 1V. The maximum charge current through the internal high-voltage switch is 10mA.

$$R_{ISET} = (V_{CHARGE} - V_{SWITCH} - V_{BBATT}) / I_{CHARGE}$$

where V_{CHARGE} is the charging supply voltage, V_{SWITCH} is the drop across the high-voltage internal switch, V_{BBATT} is the bridge battery voltage, and I_{CHARGE} is the charge current (in amperes).

Stand-Alone Application

To reduce cost and save space, the MAX1612/MAX1613 can be operated in a stand-alone configuration, which eliminates the need for a microcontroller. A stand-alone configuration could also reduce the workload of an existing microcontroller in the system, thus allowing these unused I/Os to be used for other applications.

Figure 3 shows the MAX1612/MAX1613 operating without the microcontroller by using the low-battery detector to monitor the main battery. If the main battery is too low, $\overline{LBO}$ pulls $\overline{BBON}$ and $\overline{DCMD}$ low to start the DC-DC step-up converter and allow the bridge battery to discharge. If the bridge battery requires charging, FULL pulls $\overline{CCMD}$ low to start the battery charging process. If both $\overline{CCMD}$ and $\overline{DCMD}$ are low, discharging takes precedence and the bridge battery keeps the boost DC-DC converter active.

Microcontroller-Based Application

The MAX1612/MAX1613 are also suited to operate in a microcontroller-based system. A microcontroller-based application provides more flexibility by allowing for separate, independent control of the charging process, the DC-DC converter, and the counter. Independent control can be beneficial in situations where other subsystems are operating, so that automatic switchover of power might create some timing issues. If necessary, a microcontroller can be used to reset the counter by taking ISET low. Another advantage of a microcontroller-based system is the ability to stop charging the bridge battery during a fault condition.

Figure 4 shows an example of how the MAX1612/MAX1613 can be interfaced to a MAX1630 to deliver the input voltage to the main DC-DC converter. In this example, the microcontroller monitors the main battery's status and switches over to the bridge battery when V_{MAIN} falls below a specified trip level (see *Design Procedure*). When V_{MAIN} falls below the LBI threshold, $\overline{LBO}$ goes low. This signals the microcontroller, via an I/O, to switch over to the bridge battery as the input source to the system main DC-DC converter.

In this application, the microcontroller also initiates the bridge-battery charging process. When $\overline{CCMD}$ goes low with $\overline{DCMD}$ high, the battery is charged through the internal switch. The counter increments until it overflows and FULL goes high, indicating a full charge. The microcontroller I/O can read and write the appropriate states to control the execution and timing of the entire process.

If the main DC-DC is supplied by the main source, the MAX1612/MAX1613's step-up converter turns off, minimizing power consumption. The device typically draws only 18µA of quiescent current under this condition.

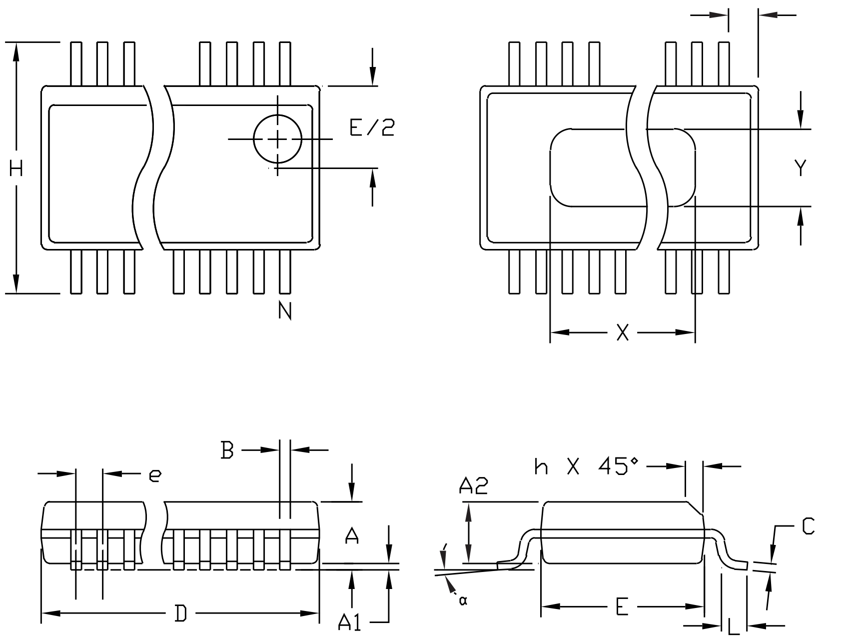
Bridge-Battery Backup Controllers for Notebooks

Chip Information

TRANSISTOR COUNT: 3543

Package Information

QSOP.EPS



DIM	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX
A	.061	.068	1.55	1.73
A1	.004	.0098	0.102	0.249
A2	.055	.061	1.40	1.55
B	.008	.012	0.20	0.31
C	.0075	.0098	0.191	0.249
D	SEE VARIATIONS			
E	.150	.157	3.81	3.99
e	.025 BSC		0.635 BSC	
H	.230	.244	5.84	6.20
h	.010	.016	0.25	0.41
L	.016	.035	0.41	0.89
N	SEE VARIATIONS			
X	SEE VARIATIONS			
Y	.071	.087	1.803	2.209
α	0°	8°	0°	8°

VARIATIONS:

	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	N	
D	.189	.196	4.80	4.98	16	AA
S	.0020	.0070	0.05	0.18		
X	.107	.123	2.72	3.12		
D	.337	.344	8.56	8.74	20	AB
S	.0500	.0550	1.270	1.397		
D	.337	.344	8.56	8.74	24	AC
S	.0250	.0300	0.635	0.762		
D	.386	.393	9.80	9.98	28	AD
S	.0250	.0300	0.635	0.762		
X	.271	.287	6.88	7.29		

NOTES:

1. D & E DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .006" PER SIDE.
3. HEAT SLUG DIMENSIONS X AND Y APPLY ONLY TO 16 AND 28 LEAD POWER-QSOP PACKAGES.
4. CONTROLLING DIMENSIONS: INCHES.

MAXIM

PROPRIETARY INFORMATION

TITLE:

PACKAGE OUTLINE, QSOP, .150", .025" LEAD PITCH

APPROVAL	DOCUMENT CONTROL NO.	REV	
	21-0055	B	1/1