OBSOLETE

Texas Instruments

Application Report

SNOA090B–March 2000–Revised April 2013

AN-1165 Configuration Guide for LM3647 Reference Design

ABSTRACT

The LM3647 demo board allows you to create a battery charging solution with little effort.

Contents

List of Figures

List of Tables

1 Introduction

The LM3647 provides a single-chip charge management solution for Nickel Cadmium, Nickel Metal Hydride and Lithium-Ion cells. The device handles the entire charging process from rejuvenating deeply discharged cells to providing a number of charge termination and maintenance options.

1.1 Standard Cells

The charge and discharge parameters of cells are often identical within families of size and capacity when normalized to a standard cell rating. The standard cell rating (C) is defined as the capacity of a new cell under constant-current discharge at room temperature. Since discharge and charge are inversely related, the standard cell rating is also used in reference to charge rates. Therefore, a charge rate of 0.1C means that a completely discharged cell, at perfect charge efficiency, will attain full charge in 10 hours.

1.2 Jumper Locations and Pin Numbering

Jumpers on the LM3647 reference design are shown in Figure 1. The dots indicate the position of pin 1.

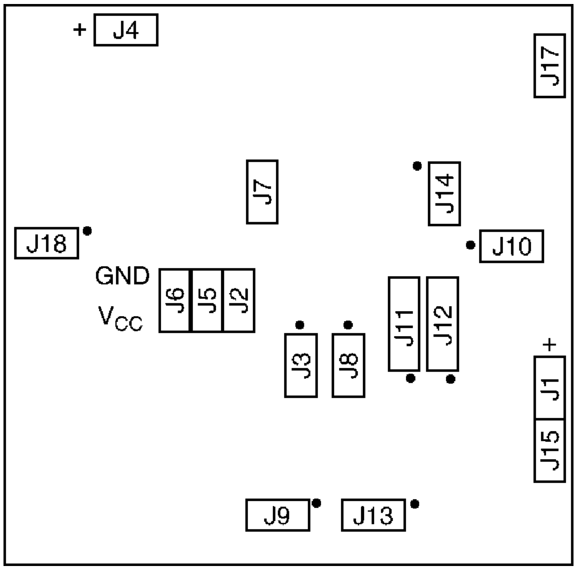

Figure 1. Jumper Location

1.3 Nickel-Cadmium Battery Configuration

Ni-Cd cells have a nominal voltage of 1.2V and can reach a peak of 1.85V during charging. The rated cell capacities of Ni-Cd cells are based on minimum values. When cells are partially discharged and repeatedly charged, they become prone to an effect known as "memory". To improve Ni-Cd battery service life, the Discharge Before Charge feature (which also enables Maintenance mode) should be enabled.

Table 1. Ni-Cd Jumper Settings

Battery Chemistry Type	Number of Cells	Voltage Range		PWM Feedback	Current Control	Battery Type	Discharge Maintenance
		J11	J12	J14	J6	J5	J2
Ni-Cd	4	13–14	13–14	5–6	Table 3	GND	Table 5
Ni-Cd	5	3–4	3–4	7–8	Table 3	GND	Table 5
Ni-Cd	6	9–10	9–10	7–8	Table 3	GND	Table 5
Ni-Cd	8	11–12	11–12	9–10	Table 3	GND	Table 5
Ni-Cd	10	7–8	7–8	9–10	Table 3	GND	Table 5

1.4 Nickel-Metal Hydride Configuration

Ni-MH cells also have a nominal voltage of 1.2V and can reach a peak of 1.85V during charging. The rated cell capacities of Ni-MH cells are based on average values. For Ni-MH cells, the rated capacity is determined at a discharge rate that fully depletes the cell in five hours. The Ni-MH cell provides 30% greater capacity over a standard Ni-Cd and is less affected by memory than the Ni-Cd cell. The Discharge Before Charge feature is not as important for Ni-MH, but can still be helpful in extending battery life.

Table 2. Ni-MH Jumper Settings

Battery Chemistry Type	Number of Cells	Voltage Range		PWM Feedback	Current Control	Battery Type	Discharge Maintenance
		J11	J12	J14	J6	J5	J2
Ni-MH	4	13–14	13–14	5–6	Table 3	V_{CC}	Table 5
Ni-MH	5	3–4	3–4	7–8	Table 3	V_{CC}	Table 5
Ni-MH	6	9–10	9–10	7–8	Table 3	V_{CC}	Table 5
Ni-MH	8	11–12	11–12	9–10	Table 3	V_{CC}	Table 5
Ni-MH	10	7–8	7–8	9–10	Table 3	V_{CC}	Table 5

1.5 Ni-Cd and Ni-MH Configuration Options

It is possible to charge Ni-Cd and Ni-MH cells either with Fast PWM or Slow PWM modes. The Fast PWM mode provides a higher quality charge than the Slow PWM mode. Cost-sensitive applications can implement the Slow PWM mode, which reduces the number of required components.

Table 3. Ni-Cd/Ni-MH Charge Regulation

Charge Regulation	J7	Note
Fast PWM Mode	V_{CC}	*Note: Set Feedback Current Range*
Slow PWM	GND	*Note: J10 Must Not Be Open*

NOTE: During the charge cycle of Ni-based batteries, should J6 (SEL3) come loose, the LM3647 charge control will switch from Fast PWM Mode to the Slow PWM (ON/OFF) Mode. Since the regulation signal is inverted, the battery will be exposed to maximum voltage and current. When using the LM3647 to charge both Ni-based and Li-Ion batteries, hardwire SEL3 directly to V_{CC}. (The voltage feedback resistor values, normally selected via J11 & J12, will need to be modified slightly when charging 4.1V/cell Li-Ion battery-packs.) For production-intent Ni-Cd/Ni-MH and Li-Ion designs, Pin 1 should be connected directly to V_{CC} to prevent potential overstress to the battery pack.

Table 4. Ni-Cd/Ni-MH Charge Control

Current Control	J6	Note
LM3647 Current Feedback	V_{CC}	*Note: Set Feedback Current Range*
External Current Control	GND	

In order to ensure a fully charged battery, a Maintenance Charge is applied to counter the effects of self-discharge. Another method to ensure a fully charged battery is to minimize the effects of memory. Ni-Cd cells are prone, and to a lesser extent Ni-MH cells, to a voltage depression effect known as "memory". This effect occurs when cells are routinely partially discharged. To minimize this effect, the LM3647 can discharge Nickel-based cells before starting the normal charge sequence. Enabling this feature requires that a suitable discharge resistor is installed at J15. A typical discharge rate for this purpose is 0.2C.

Table 5. Ni-Cd/Ni-MH Discharge Setting

Discharge Maintenance	J2	Note
No Discharge before Charge	V_{CC}	
Discharge before Charge	N.C.	*Note: Install Discharge Resistor*
Maintenance Charge Only	GND	

1.6 Lithium-Ion Configuration

Li-Ion cells have a nominal voltage of either 3.6V or 3.7V and during charging can reach a peak of 4.1V or 4.2V, respectively. Cells are first charged with a constant-current until it reaches its maximum voltage and then charged with a constant-voltage until current drops to a preset threshold. Charging Li-Ion cells requires finer charge control than Ni-cells, which omits the possibility of using Slow PWM mode; settings for Fast PWM will need to be used.

Table 6. Li-Ion Jumper Settings

Battery Chemistry Type	Number Of Cells	Voltage Range		PWM Feedback	Cell Voltage	Battery Type	Maintenance Charge
		J11	J12	J14	J6	J5	J2
Li-Ion	1	1–2	3–4	3–4	Table 7	N.C.	Table 8
Li-Ion	2	3–4	3–4	5–6	Table 7	N.C.	Table 8
Li-Ion	3	5–6	5–6	7–8	Table 7	N.C.	Table 8
Li-Ion	4	7–8	7–8	9–10	Table 7	N.C.	Table 8

1.6.1 Li-Ion Configuration Options

The maximum cell voltage for Li-Ion varies per manufacturer. The LM3647 can accommodate two different voltages, without changing the scaling networks. Caution: When using the LM3647 to charge both Ni-based and Li-Ion batteries, hardwire J6 (SEL3) directly to V_{CC}.

Table 7. Li-Ion Cell Voltage

Maximum Cell Voltage	J6
4.2V / cell	V_{CC}
4.1V / cell	GND

A number of Li-Ion post-charge options are available to counter the effects of self-discharge. A choice of a low-rate maintenance charge and an automatic restart of the charge process are available.

Table 8. Li-Ion Maintenance Settings

Maintenance Charge	J2
Maintenance until Removal	V_{CC}
Maintenance w/Auto-Restart	N.C.
No Maintenance w/Auto-Restart	GND

1.7 Feedback Current Range

The appropriate current range must be selected when charging Nickel-based batteries with current feedback enabled or when charging Li-Ion batteries.

A Topping charge, or Top-Up Charge, is performed on Nickel-based cells to ensure a full charge.

Table 9. Li-Ion/Ni-MH/Ni-Cd Current Range When Feedback is Enabled

Range	J10	J9	J13
390 mA	1–2	3–4	3–4
470 mA	1–2	5–6	5–6
560 mA	1–2	7–8	7–8
750 mA	1–2	9–10	9–10
830 mA	2–3	3–4	3–4
1000 mA	2–3	5–6	5–6
1200 mA	2–3	7–8	7–8
1600 mA	2–3	9–10	9–10

A Topping charge, or Top-Up Charge, is performed on Nickel-based cells to ensure a full charge, see Table 10.

Table 10. Topping Charge and Maximum Charge

Scaled Topping Charge	J18
2.4C	3–4
1.2C	5–6
0.7C	7–8
0.5C	9–10

A thermistor at the charging cell can be used with the LM3647 to provide an enhanced charging solution. A thermistor to measure the temperature of the battery pack is optional, see Table 11.

Table 11. Optional Temperature Sensor

Temperature Sense	J8	J3
Not Used	1–2	x
Used	N.C.	*Note: Connect NTC thermistor*

Example 1. Charging a Nickel-Cadmium Battery Pack

Battery Pack: 4.8V pack: 4 cells @ 1.2V, 650 mAh

Charger Requirement: Low-cost, Discharge Before Charge

The minimum input voltage required at full load is:

minimum V_{supply} = N (V_{pk}) + V_{reg} → minimum V_{supply} = 4(1.85V) + 1.25V = 8.65V

Charging at a rate faster than 1.0C is not normally recommended. Thus, a charge current of 650 mA will charge the battery in approximately one hour. The value of the regulator resistor is obtained via:

R_{reg} = (1.25V - 0.7V) / 650 mA = 0.85Ω ≈ 1.0Ω

The power dissipated by the regulator resistor is approximately 0.42 watt. Thus, a 1.0Ω resistor with a power rating greater than 0.5 watt (i.e., 2 watts - 5 watts) should be connected to J17.

A discharge rate of 0.2C is typical for most discharge before charge applications. The value of the discharge resistor is obtained via:

C = 650 mAh → 0.2C = 130 mAh

In order to discharge within 30 minutes, a current of 260 mA will be required — resulting in a discharge resistor value:

R_{dischg} = 4(0.9v) / 200 mA = 13.8Ω ≈ 14Ω

The power dissipated by the discharge resistor is approximately 0.9 watts.

NOTE: V_{reg} is the minimum input to output voltage drop across LM317

Table 12. Charger Settings for 4.8V Nickel-Cadmium Pack

Jumper	Connection	Comment	Jumper	Connection	Comment
J1	Battery Pack	4 Ni-Cd cells	J10	X	Only for Fast PWM
J2	N.C.	Disch. before charge	J11	13-14	Ni 4-cells Range
J3	N.C.	No NTC used	J12	13-14	Ni 4-cells Range
J4	Power Supply	minimum V_{supply} = 8.65v	J13	X	Only for Fast PWM
J5	GND	Ni-Cd Battery	J14	X	Only for Fast PWM
J6	GND	Ext. Current Control	J15	R_{dischg}	14Ω / 5W Resistor
J7	Slow	Slow for Ext. Control	J16	N.C.	No J16 on Ref. Board
J8	1-2	Shorted	J17	R_{reg}	1.0Ω / 5W Resistor
J9	X	Only for Fast PWM	J18	9-10	0.5C Topping

Example 2. Charging a Nickel Metal Hydride Battery Pack

Battery Pack: 4.8V pack: 4 cells @1.2V, 1200 mAh

Charger Requirement: High-Quality Charge, Long Cell Life

The minimum input voltage required at full load is:

minimum $V_{supply} = N\ (V_{pk}) + V_{reg} \rightarrow$ minimum $V_{supply} = 4(1.85V) + 1.25V = 8.65V$

Fast PWM is recommended for a high quality charge.

The value of the discharge resistor for 0.2C is obtained via:

$C = 1200\ mAh \rightarrow 0.2C = 240\ mAh$

In order to discharge within 30 minutes, a current of 480 mA will be required — resulting in a resistor value:

$R_{dischg} = 4(0.9V) / 480\ mA = 7.5\Omega$

The power dissipated by the discharge resistor is approximately 1.7 watts.

NOTE: V_{reg} is the minimum input to output voltage drop across LM317.

Table 13. Charger Settings for 4.8V Nickel Metal Hydride Pack

Jumper	Connection	Comment	Jumper	Connection	Comment
J1	Battery Pack	4 Ni-MH cells	J10	2-3	1200 mA Range
J2	N.C.	Disch. before charge	J11	13-14	Ni 4-cells Range
J3	NTC	Batt Pack Themistor	J12	13-14	Ni 4-cells Range
J4	Power Supply	minimum V_{supply} = 8.65v	J13	7-8	1200 mA Range
J5	VCC	Ni-MH Battery	J14	5-6	Ni 4-cells Range
J6	VCC	Fast PWM Mode	J15	R_{dischg}	10Ω / 10W Resistor
J7	Fast	Fast PWM Model	J16	N.C.	No J16 on Ref. Board
J8	Open	Attach NTC at J3	J17	N.C.	Only used in Slow
J9	7-8	1200 mA Range	J18	9-10	0.5C Topping

Example 3. Charging a Lithium-Ion Battery Pack

Battery Pack: 10.8V pack: 3 cells @ 3.6V, 1200 mAh

Charger Requirement: High-Quality Charge, Long Cell Life

A 3.6V cell develops a peak voltage of 4.1V when charging. The minimum input voltage required at full load is:

minimum V_{supply} = N (V_{pk}) + V_{reg} → minimum V_{supply} = 3(4.1V) + 1.25V = 13.55V

NOTE: V_{reg} is the minimum input to output voltage drop across LM317. For multi-chemistry charging solutions, it is recommended that J6 be hardwired to V_{CC}. Scaling resistors will have to be changed to accommodate 4.1V cells.

Table 14. Charger Settings for 10.8V Lithium-Ion Pack

Jumper	Connection	Comment	Jumper	Connection	Comment
J1	Battery Pack	3 Li-Ion cells	J10	2-3	1200 mA Range
J2	N.C.	Maint. with auto-restart	J11	5-6	3 Li-Ion cells
J3	NTC	Battery Pack Thermistor	J12	5-6	3 Li-Ion cells
J4	Power Supply	minimum V_{supply} = 13.55v	J13	7-8	1200 mA Range
J5	N.C.	Li-Ion Battery	J14	7-8	3 Li-Ion cells
J6	GND	4.1V /cell	J15	N.C.	Only Used for Ni-cells
J7	Fast	Fast PWM Mode	J16	N.C.	No J16 on Ref. Board
J8	Open	Attach NTC at J3	J17	N.C.	Only used in Slow
J9	7-8	1200 mA Range	J18	X	0.5C Topping

1.8 References

- *AN-1164 LM3647 Reference Design Demonstration Board User' Guide* (SNVA023)
- *LM3647 Universal Battery Charger for Li-Ion, Ni-MH and Ni-Cd Batteries Data Sheet* (SNOS517)
- *Fairchild Semiconductor 1N5401 Data Sheet* (http://www.fairchildsemi.com/ds/1N/1N5401.pdf)

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265