

# **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

1	Introduction .....	2
	1.1 Standard Cells .....	2
	1.2 Jumper Locations and Pin Numbering .....	2
	1.3 Nickel-Cadmium Battery Configuration .....	2
	1.4 Nickel-Metal Hydride Configuration .....	3
	1.5 Ni-Cd and Ni-MH Configuration Options .....	3
	1.6 Lithium-Ion Configuration .....	4
	1.7 Feedback Current Range .....	5
	1.8 References .....	8

### List of Figures

1	Jumper Location .....	2
---	-----------------------	---

### List of Tables

1	Ni-Cd Jumper Settings .....	2
2	Ni-MH Jumper Settings .....	3
3	Ni-Cd/Ni-MH Charge Regulation .....	3
4	Ni-Cd/Ni-MH Charge Control .....	3
5	Ni-Cd/Ni-MH Discharge Setting .....	4
6	Li-Ion Jumper Settings .....	4
7	Li-Ion Cell Voltage .....	4
8	Li-Ion Maintenance Settings .....	4
9	Li-Ion/Ni-MH/Ni-Cd Current Range When Feedback is Enabled .....	5
10	Topping Charge and Maximum Charge.....	5
11	Optional Temperature Sensor .....	5
12	Charger Settings for 4.8V Nickel-Cadmium Pack .....	6
13	Charger Settings for 4.8V Nickel Metal Hydride Pack .....	7
14	Charger Settings for 10.8V Lithium-Ion Pack .....	8

## 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.

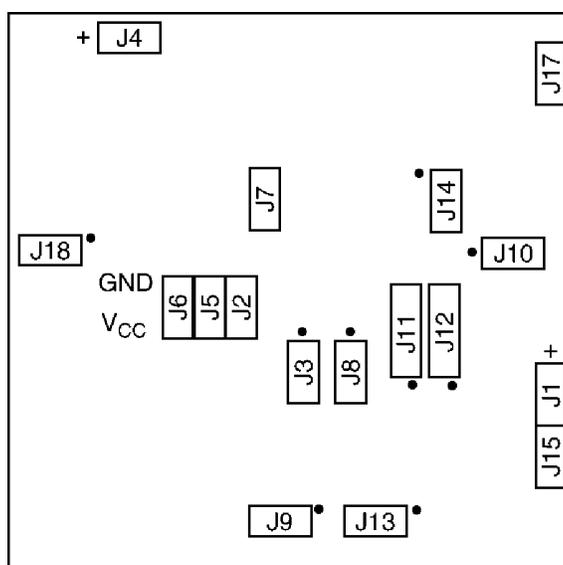


Figure 1. Jumper Location

### 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	<a href="#">Table 3</a>	GND	<a href="#">Table 5</a>
Ni-Cd	5	3–4	3–4	7–8	<a href="#">Table 3</a>	GND	<a href="#">Table 5</a>
Ni-Cd	6	9–10	9–10	7–8	<a href="#">Table 3</a>	GND	<a href="#">Table 5</a>
Ni-Cd	8	11–12	11–12	9–10	<a href="#">Table 3</a>	GND	<a href="#">Table 5</a>
Ni-Cd	10	7–8	7–8	9–10	<a href="#">Table 3</a>	GND	<a href="#">Table 5</a>

## 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	<a href="#">Table 3</a>	V <sub>CC</sub>	<a href="#">Table 5</a>
Ni-MH	5	3–4	3–4	7–8	<a href="#">Table 3</a>	V <sub>CC</sub>	<a href="#">Table 5</a>
Ni-MH	6	9–10	9–10	7–8	<a href="#">Table 3</a>	V <sub>CC</sub>	<a href="#">Table 5</a>
Ni-MH	8	11–12	11–12	9–10	<a href="#">Table 3</a>	V <sub>CC</sub>	<a href="#">Table 5</a>
Ni-MH	10	7–8	7–8	9–10	<a href="#">Table 3</a>	V <sub>CC</sub>	<a href="#">Table 5</a>

## 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 <sub>CC</sub>	<i>Note: Set Feedback Current Range</i>
Slow PWM	GND	<i>Note: J10 Must Not Be Open</i>

---

**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<sub>CC</sub>. (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<sub>CC</sub> to prevent potential overstress to the battery pack.

---

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

Current Control	J6	Note
LM3647 Current Feedback	V <sub>CC</sub>	<i>Note: Set Feedback Current Range</i>
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.	<i>Note: Install Discharge Resistor</i>
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	<a href="#">Table 7</a>	N.C.	<a href="#">Table 8</a>
Li-Ion	2	3–4	3–4	5–6	<a href="#">Table 7</a>	N.C.	<a href="#">Table 8</a>
Li-Ion	3	5–6	5–6	7–8	<a href="#">Table 7</a>	N.C.	<a href="#">Table 8</a>
Li-Ion	4	7–8	7–8	9–10	<a href="#">Table 7</a>	N.C.	<a href="#">Table 8</a>

### 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.	<i>Note: Connect NTC thermistor</i>

### 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:

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

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:

$$R_{\text{reg}} = (1.25\text{V} - 0.7\text{V}) / 650 \text{ mA} = 0.85\Omega \approx 1.0\Omega$$

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:

$$C = 650 \text{ mAh} \rightarrow 0.2C = 130 \text{ mAh}$$

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

$$R_{\text{dischg}} = 4(0.9\text{v}) / 200 \text{ mA} = 13.8\Omega \approx 14\Omega$$

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

---

**NOTE:**  $V_{\text{reg}}$  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 $V_{\text{supply}} = 8.65\text{v}$	J13	X	Only for Fast PWM
J5	GND	Ni-Cd Battery	J14	X	Only for Fast PWM
J6	GND	Ext. Current Control	J15	$R_{\text{dischg}}$	14Ω / 5W Resistor
J7	Slow	Slow for Ext. Control	J16	N.C.	No J16 on Ref. Board
J8	1-2	Shorted	J17	$R_{\text{reg}}$	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:

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

Fast PWM is recommended for a high quality charge.

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

$$C = 1200 \text{ mAh} \rightarrow 0.2C = 240 \text{ mA}$$

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

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

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

---

**NOTE:**  $V_{\text{reg}}$  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 $V_{\text{supply}} = 8.65\text{v}$	J13	7-8	1200 mA Range
J5	VCC	Ni-MH Battery	J14	5-6	Ni 4-cells Range
J6	VCC	Fast PWM Mode	J15	$R_{\text{dischg}}$	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  $V_{\text{supply}} = N (V_{\text{pk}}) + V_{\text{reg}} \rightarrow \text{minimum } V_{\text{supply}} = 3(4.1\text{V}) + 1.25\text{V} = 13.55\text{V}$

**NOTE:**  $V_{\text{reg}}$  is the minimum input to output voltage drop across LM317. For multi-chemistry charging solutions, it is recommended that J6 be hardwired to  $V_{\text{CC}}$ . 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 $V_{\text{supply}} = 13.55\text{v}$	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>)

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

### Products

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Applications Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

### Applications

Automotive and Transportation	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Space, Avionics and Defense	<a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a>
Video and Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>

### TI E2E Community

[e2e.ti.com](http://e2e.ti.com)