Model NDX40 Series
Automatic Battery Chargers

Application Notes

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For Sales, Support and Service
phone: 407-331-4793
fax: 407-331-4708

website: www.xenotronix.com
email: information@xenotronix.com

Xenotronix/TLI, Inc.
2541 Tracy Road
Toledo, Ohio 43619
Phone: 419-666-6982
Fax: 419-666-6534

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INTRODUCTION

The Model NDX40 is designed with the best interests of your battery in mind. It is a high reliability battery charger designed for recharging Nickel-Cadmium (NiCd) and Nickel-Metal-Hydride (NiMH) batteries. It can charge from 1 to 10 cells at currents from 500 mA to 2500 mA. Accurate detection of fully charged batteries is accomplished using Negative Delta V ($-\Delta V$) sensing with 12.5-bit resolution, digital filtering, current-less voltage sensing, and a nominal -0.5% (with respect to top level) $-\Delta V$ detection level. To prevent the false detection of $-\Delta V$, the sensing circuit is inhibited at the beginning of the charge cycle. The back-up timer is matched to four charging rates: 2C (45 min), 1C (1.5 hr), 0.5C (3 hr), and 0.25C (6 hr). An optional temperature sensor can be used to detect when the battery temperature falls out of the safe range of 0 ºC to 50 ºC. Outside the set temperature range, float charge takes place and the back-up timer is paused. A built-in hysteresis (offset) prevents rapid on/off cycling. When the battery temperature returns to a safe range, the charger resumes where it left off. This option is recommended for the quicker 2C and 1C charge rates to minimize the effects of overcharging. When charging is complete, the charger will enter a float charge mode where a lower current is pulsed to avoid cell degradation due to dendritic (crystalline) growths. The unit incorporates protection against open circuit batteries, during which time outputs are switched off and timing reset. The unit has a single yellow LED that comes on during charge and flashes when the battery is charged and ready for use.

Equipped with a thick aluminum heat-sinking chassis to ensure field reliability and performance, the NDX40 is designed to withstand rugged applications. An IEC-320 input module and switchable input power are included to provide the maximum flexibility. The standard output cable is three feet long and has a barrel plug connector. An optional four-conductor cable with a thermistor is offered for wiring to a custom connector – the included temperature sensor must be built into the battery pack. We also offer an optional temperature probe on a secondary cable that can be added to monitor the external battery pack temperature.

FEATURES

Quick Charge

Constant current charging is recommended for NiCd and NiMH cells and is required with negative-delta-V (–ΔV) charge termination. If fluctuations in the charge current occur, the charge voltage will change causing faulty operation of the charger (stopping of charge before completion / false –ΔV detection). Charge currents are available between 500 mA and 2500 mA in 10 mA increments. Four charge rates are available: 2C, 1C, 0.5C, and 0.25C. The very fast charge rate of 2C is only suitable for special NiCd batteries. The quick charge rates of 1C and 0.5C are suitable for both NiCd and NiMH batteries, depending on manufacturer and model. The 0.25C charge rate is an option for charging large batteries. When charging at this low rate (0.25C), the voltage drop may be too small for the –ΔV cutoff circuit to detect. However, this is not a problem as battery manufactures recommend timer-controlled charge systems at this low charge rate and the NDX40 already has a timer charge termination function as a backup.

Pulsing Trickle Charge

At the end of the normal quick charge, the charger enters the trickle charge mode where a current is pulsed to avoid cell degradation due to dendritic growths. The active materials of a NiCd battery are present in finely divided crystals. In a good cell, these crystals remain small, obtaining maximum surface area. Over time, if the cells are not exercised, the crystals grow and drastically reduce the surface area. The result is a voltage depression that leads to a loss of performance. The pulsed trickle charge helps to limit the growth of these crystals. NiMH batteries are also affected to a lesser degree.

Negative-Delta-V (–ΔV) Charge Termination

This is the most recommended full-charge detection method for quick charging NiCd batteries between 2C and 0.5C charge rates. It is also suitable for NiMH batteries being quick charged between 1C and 0.5C charge rates. As batteries are charged with a constant current their voltage increases as charge progresses; peaks when charge is completed; and then subsequently decreases. The –ΔV circuit controls charge by detecting the voltage drop following the peak. Because the switching of the switch mode power supply can cause interference on the battery voltage reads, the charge is stopped for a short time at the end of which the voltage sampling is done (current-less). The voltage reading is digitally filtered and digitally stored in a sample-and-hold circuit. This approach ensures accurate detection of the battery full-charge condition with a –ΔV sensitivity of 0.5%. In order to obtain a sufficient voltage drop for a reliable measurement, the charge rate should be 0.5C or higher. In addition, all cells in a pack must be well matched. Failing to achieve a sufficient negative slope would allow the quick charge to continue, causing excessive heat due to overcharge. Chargers using the –ΔV charge termination should include other charge termination methods to provide save charging under all conditions, and the NDX40 includes a timer backup and optional temperature protection.

Negative-Delta-V Initial Delay (Inhibit)

When batteries are left unused for a long time or excessively discharged, the charge voltage may show signs of swinging at the beginning of charge (pseudo –ΔV). To prevent the charger from prematurely shutting off due to this false –ΔV phenomenon, the –ΔV detection circuit is initially delayed as the quick charge is begun.

Backup Timer Charge Termination
Overcharging batteries causes degradation in the characteristics of the battery. A backup timer is provided as a double-safety control. If for any reason the –ΔV circuit fails to detect a fully charged battery, the back-up timer will terminate the quick charge, preventing overcharge. The backup timer is longer than the time expected for the –ΔV circuit to detect a fully charged battery.

Optional Temperature Protection
As NiCd batteries are charged, their temperature decreases. If they become too cold, the efficiency of the oxygen recombination cycle is greatly reduced and pressure build occurs. As NiMH batteries are charged, their temperature increases. As both NiCd and NiMH batteries are overcharged, their temperatures increase causing degradation in the characteristics of the battery. To reduce the risk of cell degradation, an optional temperature sensor can be used to detect when the cell temperature falls out of the safe range of 0 to 50 ºC. Outside the set temperature range, trickle charging takes place and the backup timer is paused. A built-in hysteresis (offset) prevents rapid on/off cycling. When the battery temperature returns to a safe range, the charger resumes where it left off during the charge cycle. Two options are available. One is to use a temperature sensor built into the battery pack. The charger is supplied with a four-wire output cable and a loose temperature sensor and the user must provide the interconnection. This is the most accurate way to monitor the cell temperature. The other option is to use a temperature probe cable. This cable is a separate cable with a temperature sensor at the end. The sensor can be either inserted into the cell pack or pressed against the external. It is not as sensitive as one built into a battery pack, but it gives good results.

Standard Output Cable and Connector
The standard output cable is fixed to the chassis and is made with black zipcord (parallel cord), size 18 AWG, 2-conductor, 3-feet long, and has a molded on barrel plug connector with a molded strain relief. The output connector has a 5.5 mm (0.22”) O.D. and a 2.5 mm (0.10”) I.D. The outer sleeve is negative and the center contact is positive.

Input
The IEC-60320 input module contains an input fuse and a spare. It can accept detachable cordsets for any country in the world. The standard cordset is six feet long and has a NEMA 5-15P grounding plug for use in North America. The input is switch selectable for either 115 or 230 VAC operation at a line frequency between 50-60 Hz.

Indicator
The indicator on the front panel is a single yellow LED. The LED is dark whenever a battery is not attached. With a battery is attached, during quick charge the LED will light continuously. After quick charge is terminated, the LED will begin to flash. The flash rate will be different for different charge rates – this is normal.

SPECIFICATIONS

General Conditions: Ambient Temperature = 25 ºC (77 ºF)

Quick Charge Rate	2C (C/.5)	1C (C/1)	.5C (C/2)	.25C (C/4)
Minimum Charge Current	0.5 A / 500 mA	0.5 A / 500 mA	0.5 A / 500 mA	0.5 A / 500 mA
Maximum Charge Current	2.5 A / 2500 mA	2.5 A / 2500 mA	2.5 A / 2500 mA	2.5 A / 2500 mA
Float Charge Rate (avg.)	0.05C (C/20)	0.025C (C/40)	0.0125C (C/80)	0.01C (C/100)
Peak Float Charge Current	0.27 * I_{chg}	0.27 * I_{chg}	0.27 * I_{chg}	1.7 * I_{chg}
Battery Capacity (mAh)	250 to 1250	500 to 2500	1000 to 5000	5000 to 10000
Normal Recharge Time (approx.)	35 min.	1 hr., 10 min.	2 hr., 30 min.	5 hr., 35 min.
Back-up Timer (approx.)	45 min.	1 hr., 30 min.	3 hr.	6 hr.
–ΔV Inhibit (approx.)	1.5 min.	3 min.	6 min.	12 min.
–ΔV Detection Level	Nominal -0.5% with respect to top level			
Open-Circuit Voltage	About 20 to 22 volts			
Number of Cells	1 to 10 (for 11 & 12 cell applications, please call)			
Battery Chemistry	Rechargeable Nickel-Cadmium (NiCd) and Rechargeable Nickel-Metal-Hydride (NiMH)			
Input Rating	115 or 230 VAC ± 10%, 50 – 60 Hz, 0.70 A (RMS)			
Line / Load Regulation	± 2% maximum			
Ambient Operating Temperature	15 to 35 ºC (59 to 90 ºF)			
Ambient Storage Temperature	-40 to 80 ºC (-40 to 176 ºF)			
Dimensions	W 5.5" (14 cm) x D 3.5" (8.9 cm) x H 2.9" (7.3 cm)			
Weight	About 4 lbs (1.8 kg) with standard output cable			

PART NUMBERING SYSTEM

Model No. NDX40

Voltage Code (three digit number with decimal point one digit from the right)

012	1.2 V
024	2.4 V
036	3.6 V
048	4.8 V
060	6.0 V
072	7.2 V
084	8.4 V
096	9.6 V
108	10.8 V
120	12.0 V
132*	13.2 V
144*	14.4 V

Current Code (three digit number with the decimal point two digits from the right)

Minimum 0.50 A / 500 mA	050
Custom to nearest 0.01 A / 10 mA	nnn
Maximum 2.50 A / 2500 mA	250

Charge Rate / Backup Timer Code

A	2C (C/0.5), 45 min
B	1C (C/1), 1.5 hr
C	0.5C (C/2), 3 hr
D	0.25C (C/4), 6 hr

Option Letter Code

/P	Temperature Probe Cable
/T	4-Wire Output Cable w/ Thermistor

Example: **NDX40-072250B/T**
Is a model NDX40 battery charger for a 7.2 V, 2500 mAh battery, to be charged at the 1C charge rate of 2.50 A (2500 mA). Unit is equipped with the optional 4-wire output cable and thermistor for wiring to a custom battery pack connector.

Notes:

1. Chargers for 13.2 V and 14.4 V battery packs require special transformers and have reduced maximum charge currents of 2.25 A and 2.10 A respectively.
2. For chargers with quick charge currents less than 0.5 A, please call.
3. For operation at quick charge currents greater than 2.0 A, the input voltage must be maintained at a minimum of 108/216 VAC.

SELECTING THE CORRECT CHARGER

Determine Battery Requirements

To select the correct charger for your battery, you must first determine your battery's charging requirements. Battery manufacturers normally list one or more acceptable charge rates (C-rate), charge currents, or charge times for each battery. If an available charge rate, current, or time is not listed that exactly matches your requirements, it is safest to select the charger with the next lower charge rate (longer charge time at a lower current). In any case, the 0.5C rate should be safe for almost every battery except those specifically designed for slow charge rates. For those batteries, we offer the NTX7 and MHTX7 chargers that will charge the battery at the 0.1C rate (see note below or call for more details).

Voltage Code

The voltage code is a three digit number representing the nominal battery voltage with the decimal point understood to be one digit from the right with leading and trailing zeros added as required. For example, a 7.2 volt battery would have a voltage code of **072**. The model number is always **NDX40** and is separated from the voltage code by a dash (**-**). So far, we have **NDX40-072**…

Current and Charger Rate Codes

The tricky part is selecting the correct charge current code and charge rate code. The charge current code is a three digit number representing amperes with the decimal point understood to be two digits from the right with leading and trailing zeros added as required. For example, a charge current of 2.50 A would have a charge current code of **250**. The charge rate codes are: **A** = 2C (C/0.5); **B** = 1C (C/1); **C** = 0.5C (C/2); **D** = 0.25C (C/4). If you have a 650 mAh capacity battery, and the manufacturer recommends a 2C (C/0.5) charge rate, you would multiply the capacity rating by 2 (or divide by 0.5) giving 1300. This is the charge current in mA. To convert to amps, divide by 1000 (or multiply by 0.001) giving 1.30 A. The charge current code for 1.30 A is **130**. The charge rate code for 2C (C/0.5) is **A**. These codes are added to the existing model number so that we now have **NDX40-072130A**…

This would be a complete model number unless an option code was added.

Option Codes

In this example, because we are charging at such a fast rate, it is recommended that a temperature sensor be used. There are two options: Use the **/T** option for a four-wire output cable with a thermistor for building into the battery pack. The four wires are for connecting to your own battery connection system (two for the battery and two for the thermistor). This is the most accurate way to monitor the battery temperature. Use the **/P** option for an external temperature probe cable. This is a cable with a thermistor on the end for mounting to the external surface of the battery pack. It is not as sensitive as a thermistor built into the battery pack, but it still gives good results and is easier to implement. If you selected the four-wire cable w/ thermistor, append the **/T** suffix onto the end of the model number. This makes the completed model number for the example:

NDX40-072130A/T. It would be good for a 7.2 V, 650 mAh battery, charged at the 2C rate of 1.3 A. The charger would be supplied with a four-wire output cable and a thermistor.

Notes:
Most NiCd batteries are suited for quick charging at the 1C (C/1) charge rate. Most NiMH batteries are suited for quick charging at the 0.5C (C/2) charge rate. When charging batteries at the 2C (C/0.5) or 1C (C/1) charge rates, it is recommended that a backup charge termination by use of a temperature sensor be implemented. This will minimize the effects of overcharge due to a failure to detect $-\Delta V$.

If only a 0.1C (C/10) charge rate is specified, please look into using our Model NTX7 for nickel-cadmium, or MHTX7 for nickel-metal-hydride, battery chargers. These chargers operate at the 0.1C (C/10) rate and are available with charge currents from 50 mA to 500 mA for 500 mAh to 5000 mAh batteries. The recharge time is 14 hours and then the charger switches to a trickle charge mode. These chargers are wall-plug type and are only available for 120 VAC operation.

CURRENT SELECTION TABLE

This table shows a representative sample of available battery capacities cross-referenced to the charge current required to recharge that capacity battery at the specified charge rate and backup timer. The current code to be used in the model number is in parenthesis.

This table does not represent the only values available. Any battery capacity between 250 mAh and 10,000 mAh can be charged with currents between 500 mA and 2,500 mA, in 10 mA increments, assuming that the battery can be charged at that charge rate.

Battery Capacity (C) In mAh	Charge Current at Specified Charge Rate / Back-Up Timer			
	2C (C/0.5) 45 min.	1C (C/1) 1.5 hr.	0.5C (C/2) 3 hr.	0.25C (C/4) 6 hr.
250	500 (050)			
300	600 (060)			
350	700 (070)			
400	800 (080)			
450	900 (090)			
500	1,000 (100)	500 (050)		
550	1,100 (110)	550 (055)		
600	1,200 (120)	600 (060)		
650	1,300 (130)	650 (065)		
700	1,400 (140)	700 (070)		
750	1,500 (150)	750 (075)		
800	1,600 (160)	800 (080)		
850	1,700 (170)	850 (085)		
900	1,800 (180)	900 (090)		
950	1,900 (190)	950 (095)		
1,000	2,000 (200)	1,000 (100)	500 (050)	
1,100	2,200 (220)	1,100 (110)	550 (055)	
1,200	2,400 (240)	1,200 (120)	600 (060)	
1,300		1,300 (130)	650 (065)	
1,400		1,400 (140)	700 (070)	
1,500		1,500 (150)	750 (075)	
1,600		1,600 (160)	800 (080)	
1,700		1,700 (170)	850 (085)	
1,800		1,800 (180)	900 (090)	
1,900		1,900 (190)	950 (095)	
2,000		2,000 (200)	1,000 (100)	500 (050)
2,100		2,100 (210)	1,050 (105)	525 (053)
2,200		2,200 (220)	1,100 (110)	550 (055)
2,300		2,300 (230)	1,150 (115)	575 (058)
2,400		2,400 (240)	1,200 (120)	600 (060)
2,500		2,500 (250)	1,250 (125)	625 (063)
2,600			1,300 (130)	650 (065)
2,700			1,350 (135)	675 (068)
2,800			1,400 (140)	700 (070)
2,900			1,450 (145)	725 (073)
3,000			1,500 (150)	750 (075)
3,500			1,750 (175)	875 (088)
4,000			2,000 (200)	1,000 (100)
4,500			2,250 (225)	1,125 (113)
5,000			2,500 (250)	1,250 (125)
6,000				1,500 (150)
7,000				1,750 (175)
8,000				2,000 (200)
9,000				2,250 (225)
10,000				2,500 (250)

GETTING THE MOST OUT OF YOUR BATTERY AND OTHER NOTES

Initial Charge and Priming

Many battery manufacturers recommend to slow charge a new NiCd battery for 24 hours before use. This initial charge helps to redistribute the electrolyte to remedy dry spots on the separator that may appear when the electrolyte gravitates to the bottom of the cell during long storage. A slow charge also helps to bring all the individual cells within a battery pack up to an equal charge level because each cell may have self-discharged to different capacity levels during storage. Some battery manufactures do not fully form their NiCd batteries before shipment. These batteries will reach their full potential only after the user has primed them through several charge/discharge cycles. Early performance may be inconsistent but the capacity levels become steady once fully primed.

Exercising

The effects of dendritic growths, or crystalline formation, are most pronounced when a NiCd battery is left on a regular charger for weeks, or is repeatedly recharged without a periodic full discharge. Since most applications do not use up all the energy before recharge, a periodic discharge to one volt per cell is essential for the NiCd to prevent the buildup of dendritic growths on the cell plates. All NiCd batteries in regular use and on standby mode (attached to the charger for operational readiness) should be exercised once per month. Between these monthly exercise cycles, no further attention is needed and the battery can be used with any desired user pattern. NiMH batteries are also affected by dendritic growths, but to a lesser degree – they only need to be exercised once every three months. Because of its shorter cycle life, it is not recommended to over exercise NiMH batteries. It is neither necessary, nor advisable, to discharge a NiCd battery before each charge because excessive cycling puts extra strain on the battery. The pulsed trickle charge implemented by the NDX40 will help alleviate the formation of dendritic growths when left on charge for extended periods.

Reconditioning

When a battery is not exercised for several months, the crystals ingrain themselves, making them more difficult to break up. If this is the case, exercise is no longer effective in restoring a battery and reconditioning is required. Recondition is a slow, deep discharge that removes the remaining battery energy by draining the cells to a voltage to below one volt per cell. Tests performed by the US Army Lab have shown that a NiCd cell needs to be discharged to at least 0.6 volts to effectively break up the more resistant crystalline formation. During reconditioning, the current and voltage must be carefully controlled to prevent cell reversal.

Normal Discharging

For the longest life, shallow rather than deep discharge cycles are preferred. The batteries longevity is directly related to the depth of discharge.

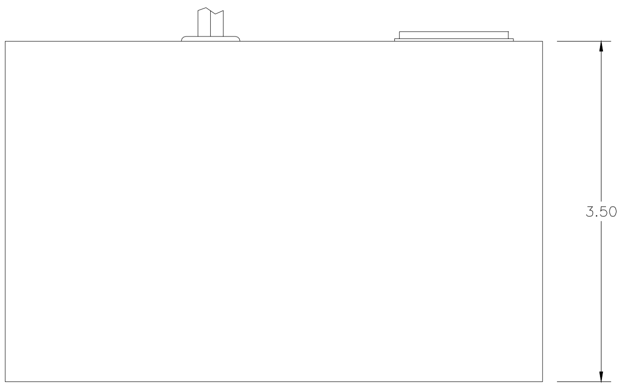
Charging
For the longest life and best charging efficiency, recharge NiCd and NiMH batteries at room temperature and at the recommended charge rate.

Self-Discharge
Both NiCd and NiMH batteries are affected by reasonably high self-discharge. A NiCd battery may lose up to 10% of its capacity within the first 24 hours, after which the self-discharge settles to about 10% per month. The self-discharge of a NiMH battery is typically 50% higher than that of a NiCd. Self-discharge is increased by elevated temperatures.

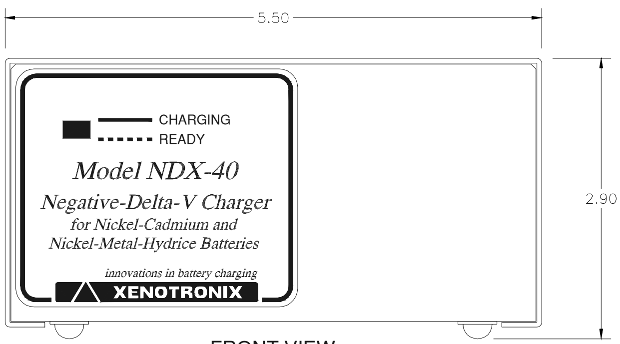
Memory Effect
Memory effect is that characteristic attributed to NiCd cells wherein the cell retains the characteristics of the pervious cycling. That is, after repeated shallow depth discharges the cell will fail to provide a satisfactory full depth discharge. Improvements in battery technology have virtually eliminated this phenomenon. The problem with modern batteries is not so much the cyclic memory but the effects of dendritic growths, or crystalline formation.

Low Voltage Disconnect
When exercising or reconditioning a battery, a low voltage disconnect should be used to prevent over discharging the battery and reversing the cells. Xenotronix/TLI manufactures a line of inexpensive low voltage disconnects that can be used on 5 cell to 20 cell battery packs for exercising and 8 cell to 20 cell battery packs for reconditioning. The minimum cutoff voltage is 4.5 volts. For cutoff voltages less than 4.5 volts please call our sales department. The models available are the LVD10 for load currents up to 10 A, and the LVD20 for load currents up to 20 A.

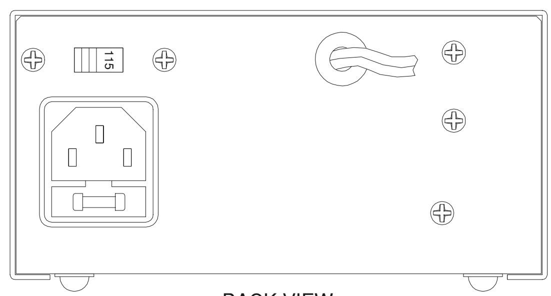
OUTLINE DRAWING & DIMENSIONS



TOP VIEW



FRONT VIEW



BACK VIEW