



BASIC CHARGER
User Manual

Revision 1.0

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1. Introduction

Aim of this document is to create a complete reference for the BASIC CHARGER usage, functioning and structure in order to help new developments starting from this design.

This reference is divided in three main blocks:

- BASIC CHARGER reference
- BASIC CHARGER usage
- Software reference

The basic charger reference is a collection of informations on the charger interfaces, starting from the schematic diagram to the software and PIC firmware functions. In this section you can find all the info for patch, upgrade and modify the system.

The usage is a reference for the on-the-field charger usage, in the case of local control (without PC) or remote control (controlled by PC software).

The software reference is a short description of the PC software furnished with the charger project.



2. Basic charger general description

The BASIC CHARGER is a “general purpose” charger based on a PIC microcontroller. This charger is completely dependent from the PIC firmware for all the functions, and the hardware outside the microcontroller is minimal. The charger blocks are the following:

- RS232 interface, based on a 5 volts RS232 transceiver, that connects directly the charger to a personal computer
- A linear regulator for 5V power supply
- A mosfet based linear charge/discharge circuit
- Two separated feedback for battery current and voltage

The charge/discharge circuit is based on a P-channel mosfet for the battery charge and N-channel mosfet for discharge. The general principle is very simple: The PIC microcontroller controls the Mosfets gate voltage in order to sink or source a fixed current from/to the batteries. The feedback is a powerful current to voltage converter that use the Hall effect for non-invasive current measurement, in order to have no series components in the current flow, extending the range of current measurement and control. The other feedback, the battery voltage, is used for end-of-charge or end-of-discharge detection. The gate voltage is controlled using a PWM signal, filtered and referenced to the ground for N-channels or to the power supply for P-channels. The high-current path has a very few active or passive components: The charge currents flow from the power supply to the battery trough only the P-channel mosfet, and the discharge current flows from the battery positive to the battery negative trough the N-channel mosfets. This solutions has the advantage to reduce the power loss on these circuits and to charge and discharge a very high currents also starting from a very-low (11V minimum) power supply. The disadvantage is that the charger has to be switched on before the battery connection because the cell (via the P-channel body diode) can auto-supply the charger giving a not well defined functioning. The charger has the following capabilities for the charge/discharge management:



Charge process

The charge is performed using a constant current source with a user-defined current intensity. The range for the current can be chosen between 0.1 and 5 amperes. The lower limit is due to the current-to-voltage transducer that is configured for the high discharge currents measurement and has some limitations on the low currents. The upper limit depends on the P-channel MOSFET internal resistance and practically from the actual batteries safe charge current range that is about 1.5 the cell capacity or 5A (3300mA by 1.5). The charge continues until the PIC microcontroller detects a fall in the battery pack voltage of a few millivolts (user defined from 1mV to 255mV) with respect to the maximum voltage reached in the charge process. A timeout for safe operations is defined.

Discharge process

The discharge is performed using a constant current source with a user-defined current intensity. The range for the current can be chosen between 0.1 and 30 amperes. The lower limit is due to the current-to-voltage transducer that is configured for the high discharge currents measurement and has some limitations on the low currents. The upper limit depends on the N-channel power dissipation and in the cooler circuit for these two transistors. Practically a Pentium processor cooler with fan with two N-channel TO-247 transistors can reach about 300W of power dissipation or about 40A from a 7.2V battery pack: I have limited this current to 30A because the cooler is really too hot and dangerous at 40A and all the tests on the batteries that I found on the specialized magazines were performed at 30A (mean battery voltage, run time...). The charge continues until the PIC microcontroller detects a fall in the battery pack voltage of a few millivolts (user defined from 1mV to 255mV) with respect to the maximum voltage reached in the charge process. A timeout for safe operations is defined.

The basic charger can be used with or without a PC connected: with the PC all the charge or discharge parameters can be trimmed and modified, without the PC only two independent charge/discharge profiles can be stored and used. The charge or discharge parameters are entered for fast charge/discharge and slow charge/discharge: in effect for charge or discharge completion is necessary to have a fast charge/discharge followed by a slow charge/discharge and only the completion of the second phase.



Cell number setting

The number of cells to be charged or discharged is completely independent from the hardware setting because the charger works on the delta peak detection and this peak can be user programmed; the discharger works on the pack cut off voltage that is an absolute value user specified. In practice the only real limitation is on the maximum voltage read from the PIC microcontroller that actually is set to 12V, or 6 NiMh/NiCd cells. For example if the delta peak voltage is 15mV per cell and the cut off voltage is 0.7 volts per cell if the user use a standard 6-cells pack the values are 90mV (15*6) for the delta peak and 4.2V (0.7*6) for the cut off, proportionally scaled if the number of cells decrease.

Interface description

The main interfaces of the basic charger are below listed:

Hardware interfaces

Connectors	Name	Description
J11,J12	DC SUPPLY +	Power supply: two connections are provided in order to lower the cable resistance. Connect to a 12V to 16V power supply.
J13,J14	DC SUPPLY -	Power supply return.
J16	BATTERY +	Connection to the positive pole of the battery for the voltage reading. Is separated from J17 in order to have no voltage loss during the battery voltage measurement.
J17	BATTERY +	Connection to the positive pole of the battery. This wire should be at least 2.5sqmm in order to allow the 30A continuous current flow.
J8	BATTERY -	Connection to the negative pole of the battery for the voltage reading reference. Is separated from J15 in order to have no voltage loss during the battery voltage measurement.
J15	BATTERY -	Connection to the negative pole of the battery. This wire should be at least 2.5sqmm in order to allow the 30A continuous current flow.
J4,J2	SERIAL PORT	J4 pin 1 is the RS232 TX wire, and should be connected to the pin 3 of DEM9P connector; J4 pin 2 is the RS232 RX wire, and should be



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		connected to the pin 2 of DEM9P connector. J2 is the ground and should be connected to the DEM9P connector pin 5. This definition is for a very-basic null modem cable for two PC connection with a 2 and 3 pins twisted. (female to female cable)
J3	FAN +	Power supply to the fan cooler (fan red wire)
J18	FAN -	Power supply return from the fan cooler (fan black wire)
J9,J1	SWITCHES	This connector has the switches contacts for operational selection. The switches have a microcontroller internal pull-up and closes to 0V the input signal when activated. (see the table for switches assignment)
J10,J5	START	Closing these two wires the user force the microcontroller to the reset state: when released the PIC reads the switches status and starts the selected operation.
J7	LED +	To be connected to the LED anode.
J6	LED -	To be connected to the LED cathode.

Keys interface

Connectors	Name	Description
J9 pin 1	K3	If the switch is open (logic level high on the PIC pin) the charger is controlled by the PC: if it is closed (logic level low on the PIC pin) is in local management mode
J9 pin 2	K2	If the switch is open (logic level high on the PIC pin) the profile selected in the charger is for NiCd batteries. If the switch is closed (logic level low on the PIC pin) the profile selected in the charger is for NiMh batteries.
J9 pin 3	K1	If the switch is open (logic level high on the PIC pin) the charger starts a discharge cycle, if it is closed (logic level low on the PIC pin) a charge cycle is started.
		Note. The three pins in the table are shorted to 0V or left open for proper operations.

Serial interface



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Connectors	Name	Description
J4 pin 1	TX	RS232 TX signal for transmission. The serial port parameters are 9600 baud, no parity, 1 stop bit.
J4 pin 2	RX	RS232 RX signal for transmission. The serial port parameters are 9600 baud, no parity, 1 stop bit.

Software interface

The software interface is a collection of the commands to be sent to the charger and answers to be received in the PC software. The basic command and answer format is composed by 4 bytes as below described:

Bytes		Name	Remarks
B[7:6]	B[5:0]		
00	C[5 :0]	Command code	These 6 bits encodes the 64 possible commands or answer codes : in fact the CCCCCC code specify what is the packet contents.
01	D[5 :0]	Data LSB	This byte holds the 6 LSB for the data trasmitted or received.
10	D[11 :6]	Data MSB	This byte holds the 6 MSB for the data trasmitted or received.
11	CHK[5 :0]	Checksum	The CHK field is the packet checksum : for a valid packet the relationship between the four values is the following : $C[5:0] + D[5:0] + D[11:6] + CHK[5:0] = 0$ (on 6 bits)

The packet format is checked by the charger and the wrong commands (invalid checksum or not implemented) are rejected. The commands can be sent with



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no time space between the packets. The values from the charger are sent in burst of packets at 10 Hz rate, in accord to the below tables.

The commands are accepted only in REMOTE control (K3 switch open) and are the following:

Code	Data	Description
1	00DD.DDDD.DDDD	Set PWM output for charge control. This signal drives directly (after filtering) the N-channel mosfets. The value can be set between 0 and 1023.
2	00DD.DDDD.DDDD	Set PWM output for discharge control. This signal drives directly (after filtering) the P-channel mosfets. The value can be set between 0 and 1023.
3	0000.0000.000L	Set LED status: L=0 means LED off, L=1 means LED on.
4	0000.0000.000F	Set FAN cooler status: F=0 means FAN off, F=1 means FAN on.
5	XXXX.XXXX.XXXX	Not implemented
6	0000.AAAA.AAAA	Set address for charger EEPROM access. The address is stored for read or write operations.
7	0000.EEEE.EEEE	Writes the E[7:0] data byte in the internal eeprom memory.
8	XXXX.XXXX.XXXX	Reads the eeprom memory byte pointed by the stored internal address.

Notes: X bits means don't care value.



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In remote control (PC in control) the packets coming from the charger are the following:

Code	Data	Description
1	DDDD.DDDD.DDDD	Charge or discharge current value on 12 bits. (0 to 4095)
2	DDDD.DDDD.DDDD	Voltage battery on 12 bits. (0 to 4095)
3	FKKK.EEEE.EEEE	K is the key switches value in the order [K1 K2 K3] starting from MSB. 0 means that the switch is closed, 1 means that the switch is opened. F=0 means that no EEPROM read operation has requested (cyclic sending), F=1 means that the packet has been sent following a EEPROM read function. E[7:0] is the last EEPROM read value.

Notes: X bits means don't care value.

In local control (PC not in control) the packets coming from the charger are the following (used for status monitoring):

Code	Data	Description
1	DDDD.DDDD.DDDD	Charge or discharge current value on 12 bits. (0 to 4095)
2	DDDD.DDDD.DDDD	Voltage battery on 12 bits. (0 to 4095)
3	0000.KKKS.SSSS	Status word. K is the key switches value in the order [K1 K2 K3] starting from MSB. 0 means that the switch is closed, 1 means that the switch is opened. S is the variable that identify the charger/discharger status: 0: Zero current sampling 1: Fast charge or discharge 2: Battery recovery 3: Slow charge or discharge 4: End of charge or discharge

Notes: X bits means don't care value.



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Current and voltage scaling factors

The raw 12 bits digital numbers for current and voltage monitoring, coming from the charger, needs an additional explaining for right understanding. The voltage is read from the PIC with a full-scale value of 4095 and this value correspond to about 11V on the battery giving a conversion factor of 350 count per volts. For the current the conversion factor is 21 count for Ampere in charge and about 18 count for Ampere in discharge. The zero current count is about the mid of the scale or 1024 counts, but depending from the temperature and other factors must be nulled at the start of each measurement session. The charge current gives a negative values with respect to the zero value (1024-K) and the discharge current gives a positive values with respect to the zero value (1024+K). For this reason the parameters entered in the profile for NiMh and NiCd have to be signed.

Internal EEPROM memory map

Address	Name	Remarks
0	FASTCL	LSB for fast current charge (65536-I*21)
1	FASTCH	MSB for fast charge.
2	SLOWCL	LSB for slow current charge (65536-I*21)
3	SLOWCH	MSB for slow charge.
4	DELTA V	Delta V peak for charge finish (65536-V*350)
5	FASTDL	LSB for fast current discharge (65536-I*18)
6	FASTDH	MSB for fast discharge.
7	SLOWDL	LSB for slow current discharge (65536-I*18)
8	SLOWDH	MSB for slow discharge.
9	COFFL	LSB for cutoff voltage (V*350)
10	COFFH	MSB for cutoff voltage
11	TIMF	Timeot in fast charge (multiple of 25.6 sec)
12	TIMS	Timeout in slow charge (multiple of 25.6 sec)
13	INHIB	Peak inhibit at start of charge (multiple of 25.6 sec)
14	-	-
15	-	-

Notes: I in ampere and V in volts.
The locations from 0 to 15 are for NiMh profile
The locations from 16 to 31 are for NiCd profile



3. Basic charger usage in LOCAL control

The "local" control is useful when no PC is connected to the charger and the battery packs are charged and discharged in stand-alone mode. In this mode the user can select the two charge/discharge profiles (named NiMh and NiCd for consistency with default values stored in the charger) for 6 cells. These values are user tunable using the "Set Parameters" software (see below chapter), and the reference name can be modified (on the printed label).

After the parameters programming the user can disconnect the charger and print the new values on a adhesive label (see relevant file) to be put on a charger side, for easy switches positioning.

The Operative sequence for charge or discharge a battery pack is the following:

- Power up the charger with a suitable power supply
- Connect the battery pack
- Select the right charge/discharge and profile via switches
- Press the "start" button.

The charger operational sequence for "charge battery" is the following:

- During the initial calibration the led flash quickly and stay almost of the time turned on for "charge" indication
- During the fast charge the led flash about 2 times per second and the battery is charged using the parameters for "fast" current charge. This period has a variable duration depending on the ratio between the cell capacity and the charge current.
- The end of fast charge is for delta peak reaching or timeout. After this phase is started the battery recovery (about 20 sec) and the led flash 1 time per second.
- Then in slow charge the led flash about 1 times every 2 second and the battery is charged using the parameters for "slow" current charge. This period has a variable duration depending on the ratio between the cell capacity and the charge current.
- The end of slow charge is for delta peak reaching or timeout. After this phase is started the system cooling (about 25 sec) and the led stay always on.
- For start another charge the user has to press the "start" button.

The charger operational sequence for "discharge battery" is the following:

- During the initial calibration the led flash quickly and stay almost of the time turned off for "discharge" indication
- During the fast discharge the led flash about 2 times per second and the battery is discharged using the parameters for "fast"



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- current discharge. This period has a variable duration depending on the ratio between the cell capacity and the discharge current.
- The end of fast discharge is for cut off voltage reaching. After this phase is started the battery recovery (about 20 sec) and the led flash 1 time per second.
 - Then in slow discharge the led flash about 1 times every 2 second and the battery is discharged using the parameters for "slow" current discharge. This period has a variable duration depending on the ratio between the cell capacity and the charge current.
 - The end of slow discharge is for cut off voltage reaching. After this phase is started the system cooling (about 25 sec) and the led stay always on.
 - For start another discharge the user has to press the "start" button.



4. Basic charger usage in REMOTE control

In "remote control" the battery charger is controlled by the PC, using the software illustrated in the following chapters. The actions that the user can perform are the same as in local control mode but all the parameters can be easily configured in graphic form.

Using the basic charger in local mode the user can monitor the charge / discharge process via a separated Windows application.

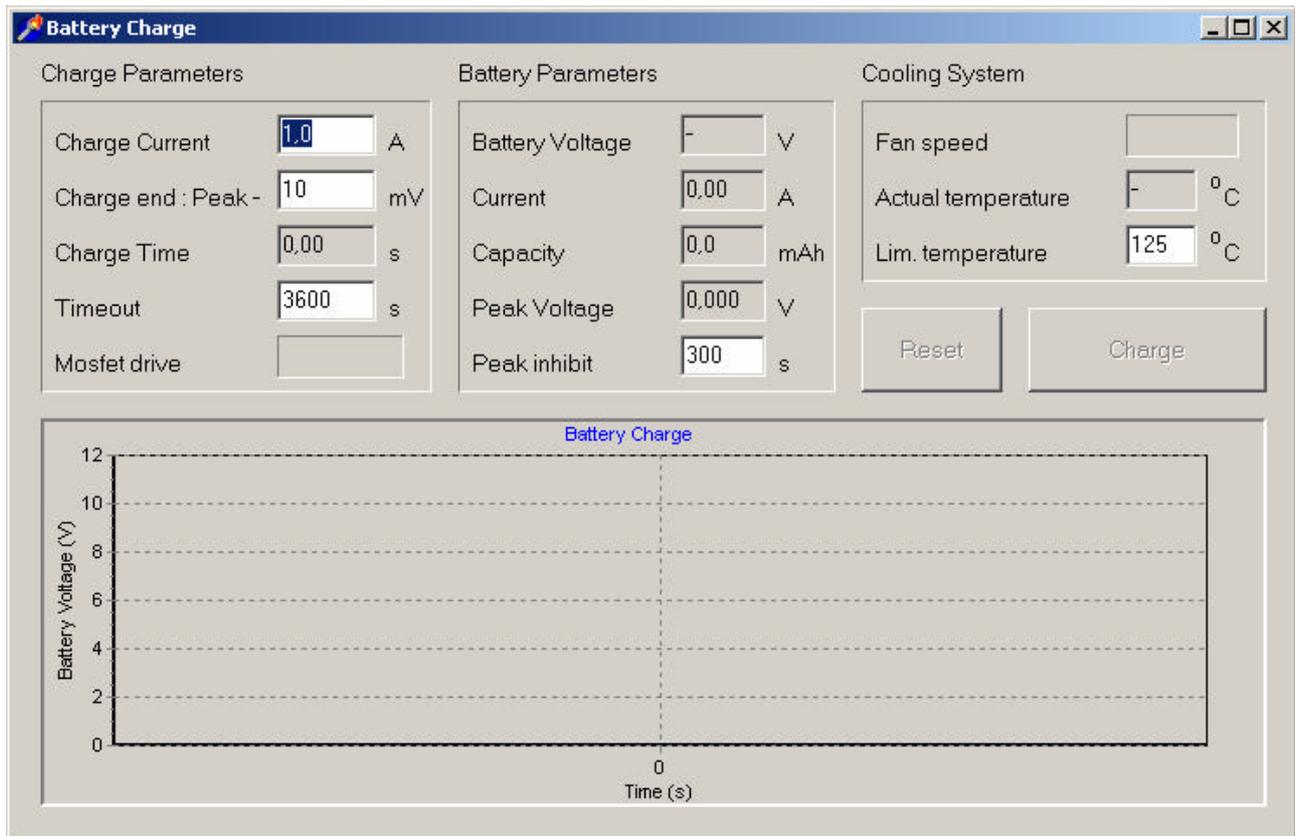
In remote control the user has to switch the appropriate key (K3) and to press the start button in order to wait for any incoming command signal.



5. Battery charge software description

The "battery charge" executable let the user to charge in "graphic mode" the battery packs.

The following figure illustrate the display of this program:



The user can modify the boxes in white, while the boxes in gray are reserved to the program output. The "Start" button is the "Charge" box and for stop the process in any moment the user can press the "Reset" button. When the program starts the Reset and Charge button are disabled and the program initialize the charger calibrating the zero current level. When the user starts the charge the program sample all the user-entered values and until the next start the parameters cannot be changed. The user can modify the following parameters:

- Charge current (0.1A to 5A, do not exceed 2C current)
- Deltav: mV under the peak for charge finish (suitable value 5-15mV per cell, the low value for NiMh, the higher one for NiCd)
- Timeout (in second, depends on the charge current and cell capacity)
- Peak Inhibit (in second, 300s is a good value)



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The program starts to display the cell voltage and the autozoom function follow the track with the voltage on the screen; the user can zoom in or out a particular region of the screen just selecting with the mouse left button a region from the up left to the down right bound; selecting from down right to the up left the "zoom full screen" is performed.

The program displays these other values:

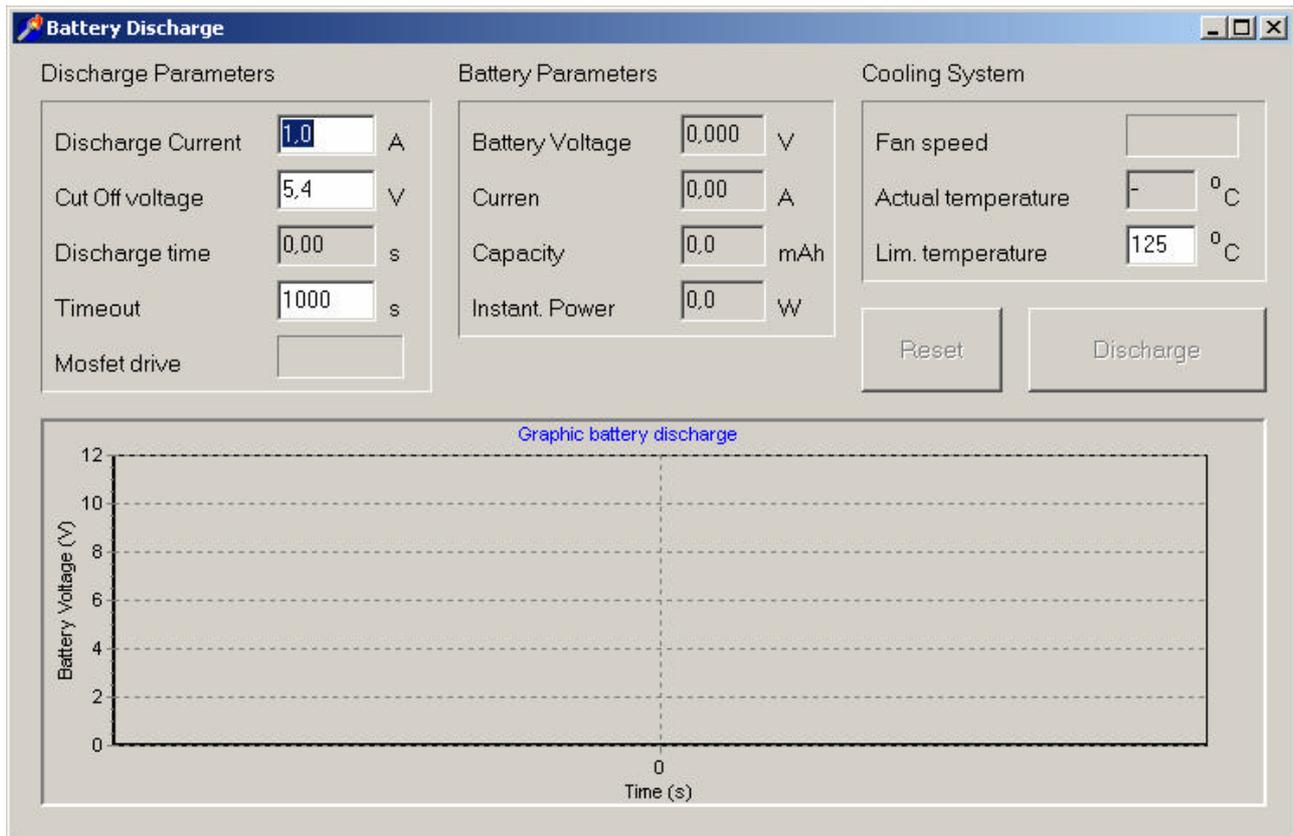
- Charge time in seconds
- Battery effective current, voltage and capacity
- Peak voltage for the pack
- Mosfet drive indicator for closed loop current control



6. Battery discharge software description

The “battery discharge” executable let the user to discharge in “graphic mode” the battery packs.

The following figure illustrate the display of this program:



The user can modify the boxes in white, while the boxes in gray are reserved to the program output. The “Start” button is the “Discharge” box and for stop the process in any moment the user can press the “Reset” button. When the program starts the Reset and Discharge button are disabled and the program initialize the charger calibrating the zero current level. When the user starts the discharge the program sample all the user-entered values and until the next start the parameters cannot be changed. The user can modify the following parameters:

- Discharge current (0.1A to 30A, do not exceed 15C current)
- Cut off voltage: the voltage level for discharge finish (suitable value 0.6-0.8V per cell, the low value for NiCd, the higher one for NiMh)
- Timeout (in second, depends on the discharge current and cell capacity)

The program starts to display the cell voltage and the autozoom function follow the track with the voltage on the screen; the user can zoom in or out a



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particular region of the screen just selecting with the mouse left button a region from the up left to the down right bound; selecting from down right to the up left the “zoom full screen” is performed.

The program displays other values:

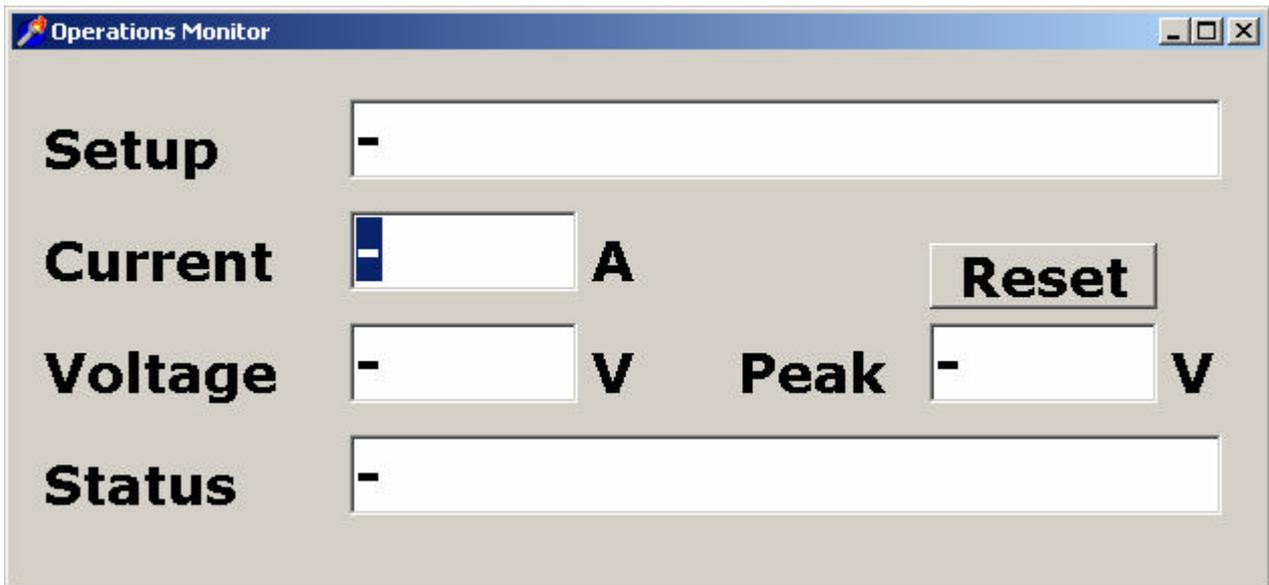
- Discharge time in seconds
- Battery effective current, voltage and capacity
- Instantaneous power dissipation
- Mosfet drive indicator for closed loop current control



7. Monitor software description

This program monitors the operation on the basic charger when the local control mode is enabled.

“Operations monitor” displaying



The program can be started in any moment and can display the actual charger state. The “setup” field reflects the switches status if there is selected the NiMh or NiCd profile and charge or discharge. The “Current and Voltage” are the actual values for the pack under operation. The “Peak” is the maximum voltage reached in charge by the battery pack. The “Status” is the the phase of charging or discharging (fast,slow, recovery...) that is enabled at any moment.



8. Set Parameters software description

The "Set Parameters" program can update the charger parameters and manage a small archive for the user "profiles".

	NiMH	NiCD	
FAST CHARGE	-3,98	-3,98	A
SLOW CHARGE	-0,98	-0,98	A
TIMEOUT FAST CH.	60	60	min
TIMEOUT SLOW CH.	60	60	min
FAST DISCHARGE	20,01	20,01	A
SLOW DISCHARGE	1,99	1,99	A
CUT OFF VOLTAGE	5,40	4,20	V
DELTA V CHARGE	-30	-80	mV

SAVE to DISK **STORE in HW**

RECALL from DISK **READ from HW**

This program has two column (one for NiMh setup and other for NiCd cells) of values and the remarks for single values is the following:

- Fast Charge: value in A for the first (fast) phase of charge process. The value must be negative (current that enter in the battery).
- Slow Charge: value in A for the second (slow) phase of charge process. The value must be negative (current that enter in the battery).
- Timeout for fast and slow charge process in minutes.



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- Fast Discharge: value in A for the first (fast) phase of discharge process. The value must be positive (current that exit from the battery).
- Slow Discharge: value in A for the second (slow) phase of discharge process. The value must be positive (current that exit from the battery).
- Cut off voltage: value in volt for discharge stop.
- DeltaV charge: value in mV for finishing the charge.

The commands for profile management are the following:

- Store in HW: stores the values in the charger
- Read from HW: recall the values now stored in the charger
- Save to disk: save the profile displayed on the screen in the mass memory. The user can modify the name and the extension is ".config".
- Recall from disk: read the profile from the mass memory. The user can modify the name and the extension is ".config".