

Constructing an Inexpensive Smart-Charging Unit for Revision A and Revision K i-Cybie

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Abstract:

Charging instructions listed in the manual that comes with i-Cybie is a direct transformer-to-cell recharging process. This process can permanently damage the NiCd cells that come with the unit. I propose a more complex energy distribution device. This paper will describe and construct an inexpensive scratch-built project which, in 120 minutes, can supply a full charge to a cell without damage.

Introduction

The i-Cybie dog, currently manufactured by Silverlit Electronics,¹ supplies the robot with a 800mAh NiCd 10-cell AA battery pack and charger. Rated at 12V, the robot is operational for about 40 minutes from experiments conducted during the course of research. This means the unit must be recharged a substantial number of times depending on the level of play introduced by the user. Using the accompanying charger, rated at 15V, 300mA, one finds a reduction of battery life by overcharging the batteries or charging them at too high a charge rate. A revised 1400mAh cell is available for purchase from the manufacturer. Still, the problem remains; the standard charging procedure listed in the i-Cybie manual damages the cells². A more advanced smart charging system is required to solve the problem.

Charging Theory: Considering Efficiency

When considering charging a cell, the rate at which the cell is charged is crucial to its life. The charge rate must be optimized to the storage capacity of the cell. Overcharging or charging at too high a charge rate will reduce its life. To calculate the optimum charge rate, divide the battery capacity by 10. For the Revision A and K i-Cybies, a 800mAh battery was used, which yields a 80mAh charge rate. The upgraded 1400mAh NiCd yields a 140mAh charge rate.

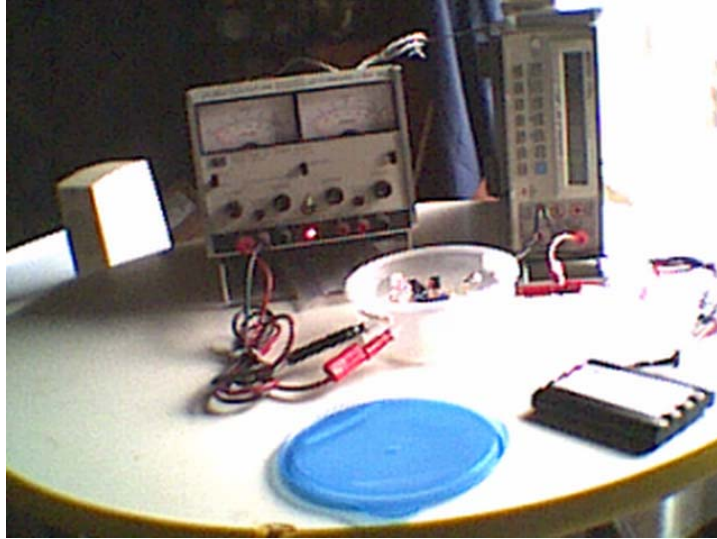


Figure 1: Experimental Setup

Figure 1 shows the experimental setup. For the purposes of this paper, I used a Hewlett-Packard 6227B Dual Power Supply and a 3458A Digital Multimeter to explicitly dispense and measure the current passing through the device.

Theory of Operation

The Cybie charger is designed around the LM3914 chip. It is a monolithic integrated circuit that senses analog voltage levels driving a series of LEDs. In the charger it is employed as a differential device by monitoring input vector-state voltage and dividing it between the source and cell's energy potential. I have thought of this problem in terms of energy (in joules) being transported from source to cell and not simply in the two-dimensional vectored terms of voltage and current. It is the energy quotient that must be calculated and precisely regulated to fully appreciate the benefits of using stored power. This unit has been designed to emit the proper energy quotients, calibrated for either cells' power ratings. Additional features include the ability to provide a clean, ripple free signal with reverse polarity protection.

As energy is transferred, a sequence of LEDs display the storage level. Once the battery is fully charged to its energy quotient, the circuit closes the gate between the source and cell. The battery is now ready for use.

Constructing the Apparatus

The Cybie charger's design is based around the idea of using inexpensive and widely available parts. The charger was constructed on a small piece of solderless breadboard and off-the-shelf components.

Rounding these values up is permissible to allow for available parts as long as no more than a 20% deviation occurs in the output power. It is possible to “piggyback” resistors (connect smaller combinatorial values) as long as the final deviation is noted. Most resistors found off-the-shelf have a 10% tolerance within their values; check the value of the R1 resistor with a multimeter. Take this value and divide it into 1.25 to find I_m .

$$I_m = \frac{1.25}{R1} \quad (1.4)$$

To calculate deviation, take the measured value I_m , subtract the calculated value I_t , and divide it by the calculated value. The bars indicate absolute value; here it will always be positive.

$$Deviation = \left| \frac{I_m - I_t}{I_t} \right| \quad (1.5)$$

For the constructed Cybie charger in this paper:

$$Deviation = \left| \frac{0.083 - 0.080}{0.080} \right| = \left| \frac{0.003}{0.080} \right| = 3.75\% \quad (1.6)$$

The charger has a 3.75% deviation. Since this is less than the tolerance of 20%, the circuit can be considered complete for this application. The power will stay close to the calculated value, the LM317T is a good current limiter and the diode 1N4007 provides reverse polarity protection.

Different colored LEDs were used to indicate the level of energy present in the cell. The low-level indicator diode is D1 and the full-level indicator diode is D10. To portray this relationship, D1 is a white-light diode, D2 – D6 are red, and D7 – D10 are green. When assembling the circuit, use the colors which best suit the application.

Once the circuit is assembled, the board is placed in the plastic container with lid. This application used stand-offs to set the board within the container. Holes are cut to allow for external connections and to set the calibration level at the 10k variable resistor. Figure 3 shows the completed apparatus. The circuit is quite simple and rather easy to construct.

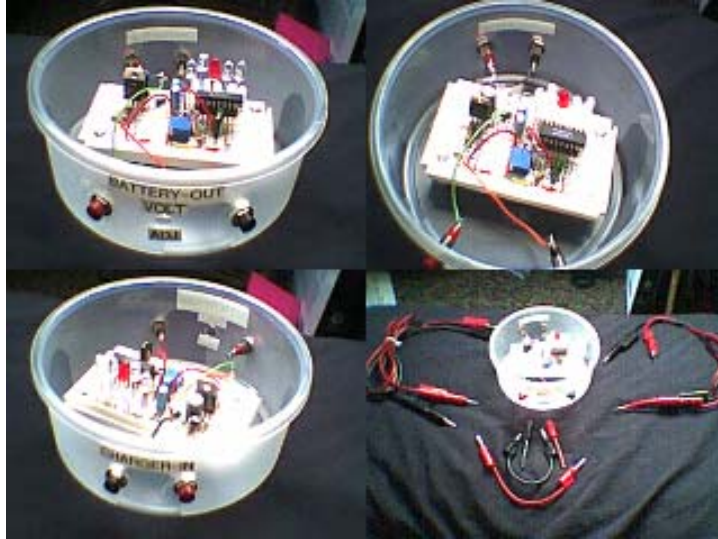


Figure 3: Completed Charger

Calibrating the Device

Connect the source to the charger with a voltmeter as shown in Figure 1 *without* the battery connected. Apply power to the source and set the voltage to a reading of 12.65V. While monitoring the voltage level, adjust the 10k resistor until the full-level indicator LED (D10) lights. Lower the voltage at the source and observe the sequence of LEDs lighting at their respective levels. Verify that the low-level indicator diode (D1) lights at 11.89V. Perform this operation at least twice until comfortable with the electrical characteristics of the device.

Calibration should be performed every 25 charge operations.

Operating the Device

The Cybie charger is a great companion device to the i-Cybie robot; it is the best alternative to buying expensive assembled chargers. Care should be taken in its operation. The device should be used indoors and away from liquids to prevent shorting the apparatus or the cells. It should be operated in an environment of 10° - 70°C, 20% - 80% humidity and be free from shock and vibration.

To operate the Cybie charger, connect the setup shown in Figure 1. Be certain to not apply any power to the circuit unless it is complete. A separate power source can be used in place of the HP6227B; even the original charging unit can be integrated into the device as long as the attached length of wire is not altered. Connect the source to the device. Connect the battery—negative first, positive last. Apply power to the source. The low-level indicator LED (D1) will light and the device will start transferring energy.

During the charge process, the LEDs will light sequentially as the cell stores energy until the full-level indicator LED (D10) glows singly. An exhausted cell will take approximately 120 minutes to fill; the device will then turn off the circuit and go into standby once charging is completed. Turn off the source before disconnecting any wires to the cell. Disconnect the cell—positive first, negative last.

NOTE: Do not connect or disconnect wires with *any* power present. It will reset the circuit. If this happens, turn off power and reconnect according to the *Operating the Device* section of this paper.

Upgrading the Batteries

It is possible to construct a set of batteries to replace the original ones. Currently, AA-tabbed NiMH 2300mAh cells are available from a variety of manufacturers found via the Google (www.google.com) search engine. These batteries can be assembled in packs of ten and fit into the i-Cybie's battery compartment. The Cybie can use larger capacity batteries. However, when recharging with the Cybie charger, be sure to recalculate the charge rate in equation 1.3 and change the value of R1 according to the constraints outlined in this paper.

Conclusion

The i-Cybie robot is a complex, well-engineered machine whose life has not been fully tested. This is due, in part, to the poor quality of the batteries, small energy storage, and an unregulated charging system. The i-Cybie provides many hours of entertainment and exhibits enough complex behaviors to make a study of robotic social systems viable. But unless a better charging apparatus can be designed, these abilities are non-existent. The Cybie charger is a first step. After a few adaptations, the i-Cybie's onboard computer can be upgraded, and better batteries can be used to enhance the experience. As parts for the Cybie become more scarce and replacement chargers are no better than the originals, a cheap alternative such as the device described in this paper is an inviting prospect.

Appendix

Here is a table of parts and the associated costs. For what the device does, this is very reasonable.

CYBIE CHARGER Parts and Costs	ITEM	SUPPLIER	COST
1	LM317T	Radio Shack <i>www.radioshack.com</i>	1.99
2	LM3914N	Jameco Electronics <i>www.jameco.com</i>	2.25
3	Precision Variable Resistor -- 10k	Mouser Electronics <i>www.mouser.com</i>	2.19
4	LED, White	Radio Shack	1.79
5	LED, Red/Green (9)	Radio Shack	7.11
6	Misc. Capacitors and Resistors	Radio Shack	4.25
7	Solderless Breadboard	Radio Shack	4.75
8	Circuit Casing (Cheap Tupperware)	Local Grocery Store	0.35
TOTAL:			24.68

Table 1: Parts and Costs

Any further questions or concerns should be addressed to the author at:

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¹ www.i-cybie.com

² SilverLit Electronics, *i-Cybie Instruction Manual*, pp.7, 9, (2001).