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APPLICATION NOTE 3388

Detecting Primary Cells with the DS2711/12

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Abstract: The DS2711 and DS2712 Loose Cell NiMH Chargers (designed for one or two AA or AAA NiMH "loose" cells) detect an alkaline primary cell and avoid charging it. This application note characterizes a wide variety of used and new cells from a variety of manufacturers and shows how the charger ICs can distinguish between NiMH rechargeable cells and alkaline primary cells.

Introduction

The DS2711 and DS2712 Loose Cell NiMH Chargers provide an ideal solution for charging one or two AA or AAA NiMH "loose" cells. They have the ability to detect an alkaline primary cell and avoid charging it. (The manufacturers of alkaline primary cells do not recommend charging their cells, and thus it is important for chargers to be able to distinguish which cells are safe to charge, and which are not.)

This application note presents data that illustrates the ability of these devices to distinguish between NiMH rechargeable cells and alkaline primary cells. It characterizes a wide variety of used and new cells from a variety of manufacturers.

Preparing the Cells

New and aged NiMH rechargeable cells and alkaline primary cells were collected. Each cell was connected to a DS2711, which identified the battery chemistry and whether to charge the cell.

The selection of NiMH cells included AA and AAA cells from: Maxell, Panasonic, Rayovac, Sanyo, and Sony. The selection of primary cells included: Duracell Ultra, Rayovac Maximum Plus, Energizer Max, Energizer e² Lithium, and Energizer e² Titanium. The aged cells were up to one year old and have gone through numerous charge and discharge cycles.

All of the NiMH cells were charged using the DS2711 and then discharged to the target charge state. The alkaline cells were brand new, taken out of the package, and then discharged to the desired charge state.

The impedance of a cell will vary depending on its remaining capacity, or charge state. For this Application Note, 4 charge states were chosen: Full, Low, Empty, and Depleted.

"Full" indicates that the NiMH cell was fully charged by the DS2711. For the alkaline cells, "Full" indicates that the cell remained in the "out of the package" state. "Low" indicates that the cell was discharged to 1.2V under a 50mA load. "Empty" indicates that the cell was discharged to 0.8V under a 50mA load. "Depleted" indicates that the cell was discharged to 0.0V under a 50mA load.

Impedance Data

Measurements were taken to calculate the impedance of each cell once the cells were discharged to the desired charge state. This was accomplished by first measuring the Open Circuit Voltage (V_{OFF}) of each cell. Then a 500mA charge current was applied to the cell and the voltage (V_{ON}) was measured .5 seconds later. The impedance was then calculated using Ohms Law:

$$\text{Impedance} = \frac{V_{ON} - V_{OFF}}{500\text{mA}}$$

Table 1 shows the calculated impedance for all of the AA Cells in each of the charge states. Table 2 shows the same data for all of the AAA cells.

Table 1. Calculated Impedance of the various AA Cells in each of the charge states

		Charge States Impedance (mΩ)			
Cell Type	**Cell Brand**	**Full**	**Low**	**Empty**	**Depleted**
Alkaline - AA	Duracell Ultra	181	451	910	671
	Rayovac Maximum Plus	248	761	1282	462
	Energizer Max	140	912	1080	524
	Energizer e² Lithium	159	174	272	850
	Energizer e² Titanium	186	436	486	444
New NiMH - AA	Panasonic (1950 mAh)	42	52	60	448
	Rayovac (2000 mAh)	40	48	64	638
	Sanyo (1600mAh)	34	54	206	982
Aged NiMH - AA	Maxell (2000 mAh)	58	285	555	629
	Rayovac (1800 mAh)	45	55	187	391
	Sanyo (2000 mAh)	81	83	131	812
	Sony (2000 mAh)	57	116	551	1420

Table 2. Calculated Impedance of the various AAA Cells in each of the charge states

		Charge States Impedance (mΩ)			
Cell Type	**Cell Brand**	**Full**	**Low**	**Empty**	**Depleted**
Alkaline - AAA	Duracell Ultra	282	602	1035	1640
	Rayovac Maximum Plus	322	883	1114	1892
	Energizer Max	253	367	525	1071
	Energizer e² Lithium	222	253	523	834
	Energizer e² Titanium	192	442	268	455
New NiMH - AAA	Rayovac (800 mAh)	100	106	152	353
	Sanyo (700 mAh)	98	128	128	844
	Panasonic (750 mAh)	100	72	142	147
Aged NiMH - AAA	Rayovac (700 mAh)	54	168	144	357
	Sanyo (700 mAh)	106	154	507	819

	Sony (700 mAh)	62	64	396	712

Charging Results

The Cell Impedance Test Threshold (CTST) is set by the value of the CTST resistor (R_{CTST}). The value of R_{CTST} is based on the desired impedance threshold and the charge current. It was determined from the Impedance Data that a threshold of 160mΩ for both AA and AAA would allow the rechargeable NiMH cells, both new and aged, to pass the Cell Impedance Test, and the alkaline cells would fail the test. R_{CTST} can be determined using the following equation

$$R_{CTST} = \frac{8000}{\text{CTST Threshold } (\Omega) \times \text{Charge Current } (A)}$$

A R_{CTST} of 100kΩ was used for the 500mA charge current and a R_{CTST} of 50kΩ was used for the 1Amp charge current in this Application Note.

Table 3 is the legend for the abbreviations found in the Result Tables. "NC" indicates that the cell was Not Charged because the V_{OC} was greater than 1.75V, which is the limit for the DS2711 to detect the insertion of a battery in its Presence Test. "PC" indicates the V_{OC} was less than 1.0V and the device entered the Pre-Charge state that charges the cell at a reduced rate equivalent to ¼ the fast charge current. If the V_{OC} of the cell has not recovered above 1.0V after 34 minutes, the DS2711 goes to FAULT. "CTST" indicates the cell failed the Cell Impedance Test and caused the DS2711 to go to FAULT. The Cell Impedance Test takes place once every 31 seconds. "OV" indicates that the V_{CH} (cell voltage with the charge current applied) was greater than 1.75V, which caused the DS2711 to go to FAULT. The Over Voltage test occurs once every second during a charge. "Ch" indicates the cell was Charged by the DS2711.

Additional information included in the Result Tables is the time between the start of the charge and the time that the DS2711 went to FAULT. The time is presented in "XXs" (seconds) or "XXm" (minutes) depending on which is appropriate. Also "X RS" indicates the number of times the charge was restarted before a complete charge was possible. For NiMH cells that were deeply discharged, the DS2711 may initially detect the impedance is too high. However, after 1 or 2 attempts, the impedance recovers to a point where it will pass the Cell Impedance Test and charge properly.

Table 3. Legend for Result Tables 4-7

Abbreviation	Meaning
NC	No Charge
PC	Pre-charge
CTST	Fail Impedance Test
OV	Fail Over Voltage Test
Ch	Charged OK
(XXs)	Seconds until FAULT
(XXm)	Minutes until FAULT
(X RS)	Times Charge was restarted

Tables 4 and 5 contain the results of placing each of the AA and AAA cells into a DS2711 Evaluation Board configured in Parallel Charging Mode and using an external charge source set up to supply a

500mA charge current. Tables 6 and 7 contain the same data for a 1 Amp charge current.

Table 4. Results of charging the AA cells with a 500mA Charge Current

		Charge StatesCharge Results for 500mA Current			
Cell Type	**Cell Brand**	**Full**	**Low**	**Empty**	**Depleted**
Alkaline - AA	Duracell Ultra	CTST (31s)	CTST (31s)	CTST (31s)	PC (34m)
	Rayovac Maximum Plus	CTST (31s)	CTST (31s)	CTST (31s)	CTST (31s)
	Energizer Max	OV (155s)	CTST (31s)	CTST (31s)	CTST (31s)
	Energizer e² Lithium	NC	OV (295m)	CTST (25m)	PC (34m)
	Energizer e² Titanium	CTST (31s)	CTST (31s)	CTST (31s)	CTST (31s)
New NiMH - AA	Panasonic (1950 mAh)	Ch	Ch	Ch	Ch
	Rayovac (2000 mAh)	Ch	Ch	Ch	Ch (1 RS)
	Sanyo (1600mAh)	Ch	Ch	Ch	Ch (2 RS)
Aged NiMH - AA	Maxell (2000 mAh)	Ch	Ch	Ch (1 RS)	Ch (2 RS)
	Rayovac (1800 mAh)	Ch	Ch	Ch (1 RS)	Ch (1 RS)
	Sanyo (2000 mAh)	Ch	Ch	Ch	Ch (1 RS)
	Sanyo (2000 mAh)	Ch	Ch	Ch	Ch

Table 5. Results of charging the AAA cells with a 500mA Charge Current

		Charge StatesCharge Results for 500mA Current			
Cell Type	**Cell Brand**	**Full**	**Low**	**Empty**	**Depleted**
Alkaline - AAA	Duracell Ultra	CTST (31s)	CTST (31s)	CTST (31s)	CTST (31s)
	Rayovac Maximum Plus	CTST (31s)	CTST (31s)	CTST (31s)	CTST (31s)
	Energizer Max	CTST (31s)	CTST (31s)	CTST (31s)	CTST (31s)
	Energizer e² Lithium	NC	CTST (20m)	PC (34m)	PC (34m)
	Energizer e² Titanium	CTST (31s)	CTST (31s)	CTST (31s)	CTST (31s)
New NiMH - AAA	Rayovac (800 mAh)	Ch	Ch	Ch	Ch
	Sanyo (700 mAh)	Ch	Ch	Ch	Ch (1 RS)
	Panasonic (750 mAh)	Ch	Ch	Ch	Ch (1 RS)
Aged NiMH - AAA	Rayovac (700 mAh)	Ch	Ch	Ch	Ch
	Sanyo (700 mAh)	Ch	Ch	Ch (1 RS)	Ch (1 RS)
	Sony (700 mAh)	Ch	Ch	Ch (1 RS)	Ch (1 RS)

Table 6. Results of charging the AA cells with a 1A Charge Current

		Charge StatesCharge Results for 1A Current			
Cell Type	**Cell Brand**	**Full**	**Low**	**Empty**	**Depleted**
Alkaline - AA	Duracell Ultra	OV (7s)	OV (7s)	OV (3s)	CTST (31s)
	Rayovac Maximum Plus	OV (3s)	OV (3s)	OV (2s)	OV (22s)
	Energizer Max	OV (11s)	OV (3s)	OV (3s)	OV (3s)
	Energizer e² Lithium	NC	OV (237m)	CTST (400s)	OV (2s)
	Energizer e² Titanium	OV (14s)	CTST (31s)	CTST (31s)	CTST (31s)

New NiMH - AA	Panasonic (1950 mAh)	Ch	Ch	Ch	Ch
	Rayovac (2000 mAh)	Ch	Ch	Ch	Ch
	Sanyo (1600mAh)	Ch	Ch	Ch	Ch
Aged NiMH - AA	Maxell (2000 mAh)	Ch	Ch	Ch	Ch
	Rayovac (1800 mAh)	Ch	Ch	Ch	Ch
	Sanyo (2000 mAh)	Ch	Ch	Ch	Ch
	Sony (2000 mAh)	Ch	Ch	Ch	Ch

Table 7. Results of charging the AAA cells with a 1A Charge Current

		Charge StatesCharge Results for 1A Current			
Cell Type	**Cell Brand**	**Full**	**Low**	**Empty**	**Depleted**
Alkaline - AAA	Duracell Ultra	OV (3s)	OV (3s)	OV (3s)	OV (2s)
	Rayovac Maximum Plus	OV (2s)	OV (3s)	OV (3s)	OV (3s)
	Energizer Max	OV (2s)	OV (21s)	OV (2s)	OV (2s)
	Energizer e² Lithium	NC	CTST (32m)	PC (34m)	PC (34m)
	Energizer e² Titanium	OV (2s)	OV (10s)	CTST (31s)	CTST (31s)
New NiMH - AAA	Rayovac (800 mAh)	Ch	Ch	Ch	Ch
	Sanyo (700 mAh)	Ch	Ch	Ch	Ch
	Panasonic (750 mAh)	Ch	Ch	Ch	Ch
Aged NiMH - AAA	Rayovac (700 mAh)	Ch	Ch	Ch	Ch
	Sanyo (700 mAh)	Ch	Ch	Ch	Ch
	Sony (700 mAh)	Ch	Ch	Ch	Ch

Summary

The Result Tables (Tables 4-7) show that the DS2711 and DS2712 are able to detect the alkaline primary cells and avoid charging them. At the 500mA charge rate, the majority of the alkaline cells were charged for 31 seconds until the charge was stopped because the cell failed the Cell Impedance Test. When charged at the higher charge rate of 1Amp, the majority of the alkaline primary cells failed the Over Voltage Test within the first 10 seconds of charge, which also terminated the charge.

The Energizer e² Lithium cells are the only primary cells that are not immediately detected. They have a very low impedance value for a primary cell, which makes their detection more difficult. New cells have a Open Circuit Voltage (V_{OC}) of approximately 1.8V, so they are easily avoided since they fail the Presence Test. The AA and AAA cells in the Depleted Charge State (as well as the AAA cells in the Empty charge state) have a V_{OC} below 1.0V and so the cells stay in a reduced rate Pre-Charge for the duration of the 34-minute Pre-Charge period and then the charge is terminated without any noticeable effects on the cells.

The Energizer e² Lithium AA and AAA cells in the Low Charge State (as well as the AA cells in the Empty Charge State) are the cells that were charged by the DS2711, but they did not show any signs of leaking or exploding. The only noticeable effect was the cells heated up approximately 10 degrees C above room temperature prior to the charge being terminated. As is the case with all primary cells, the manufacturer does not recommend charging.

After the Energizer e² Lithium cells were charged, they were discharged to their initial charge state, and they reached that state very quickly, indicating that very little of the charge current was converted into

actual capacity of the cell.

Some of the Empty or Depleted Rechargeable NiMH cells required restarting the charge once or twice before the impedance recovered enough to pass the Cell Impedance Test. This restarting occurred with the 500mA charge rate rather than the 1Amp charge rate because the 1Amp charge supplies enough capacity to the cell to reduce the impedance below the Cell Impedance Threshold within the first 31 seconds. When charging at 500mA, it takes twice as long to recover the cell to an acceptable impedance level.

The data presented in this Application Note illustrates the ability of the DS2711 and DS2712 to effectively detect and avoid charging alkaline primary cells, as recommended by the manufacturers of the primary cells, and still be able to properly charge NiMH rechargeable cells.

Related Parts		
DS2711	Loose-Cell NiMH Chargers	Free Samples
DS2712	Loose-Cell NiMH Chargers	Free Samples

More Information
For Technical Support: http://www.maximintegrated.com/support
For Samples: http://www.maximintegrated.com/samples
Other Questions and Comments: http://www.maximintegrated.com/contact

Application Note 3388: http://www.maximintegrated.com/an3388
APPLICATION NOTE 3388, AN3388, AN 3388, APP3388, Appnote3388, Appnote 3388