AA Battery Selection and Storage for Portable Operation

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AA batteries are probably the most common size of replaceable battery. This paper gives a brief comparison of battery types. It also looks at battery capacity versus cost, load current, operation temperature and long term storage. Although it mainly concentrates on tests that have been performed on Alkaline batteries, it also considers other types for comparison where relevant.

Comparison of AA battery types

There are a number of commonly available battery types in the AA format. The following table gives a brief outline of the available types.

Type	Nominal terminal voltage	Notes:
Zinc Carbon	1.5V	The original battery chemistry. Limited capacity and prone to “leak”. Not often seen now.
Zinc Chloride	1.5V	The so called “Heavy Duty” battery. A better alternative to Zinc Carbon. Only really suitable for low drain applications.
Alkaline	1.5V	Possibly the most useful and commonly used type.
Lithium	1.5V	Expensive but very high performance. Very long shelf life.
Nickel Cadmium (NiCd)	1.2V	Until recently the most common rechargeable format. Falling out of favor now due partly to European RoHS* legislation. Capacity is usually a fraction offered by the better single use batteries. Very good performance at high current.
Nickel Metal Hydride (NiMh)	1.2V	Becoming the preferred option for rechargeable cell use. Performance is starting to approach single use batteries.

**RoHS refers to the European "Restriction of Hazardous Substances" for items that can make their way into domestic waste. This legislation bans the use of Lead and Cadmium along with a number of other toxic substances in virtually all products.*

Rechargeable batteries (NiCd and NiMh) are known to provide much better performance for high current demand applications (e.g Power tools) but have a lower terminal voltage which makes them unsuitable for some other applications. These battery types are also prone to self discharge and need to be "topped up" if left for more than about a month at room temperature. There is still some debate about the need to fully discharge these batteries before charging. This aspect is beyond the scope of this paper.

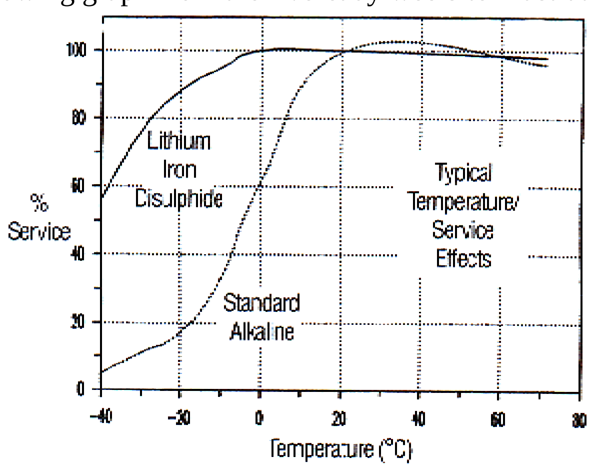
AA Alkaline Battery Capacity

Claimed capacity of single use batteries can vary.

- **Alkaline Industrial: 2.7Ah**
- **Eveready e2 Titanium: 3.1Ah**
- **Lithium Ion Disulphide: 2.9Ah**
- **Is there any point in buying cheaper (especially alkaline) batteries?**

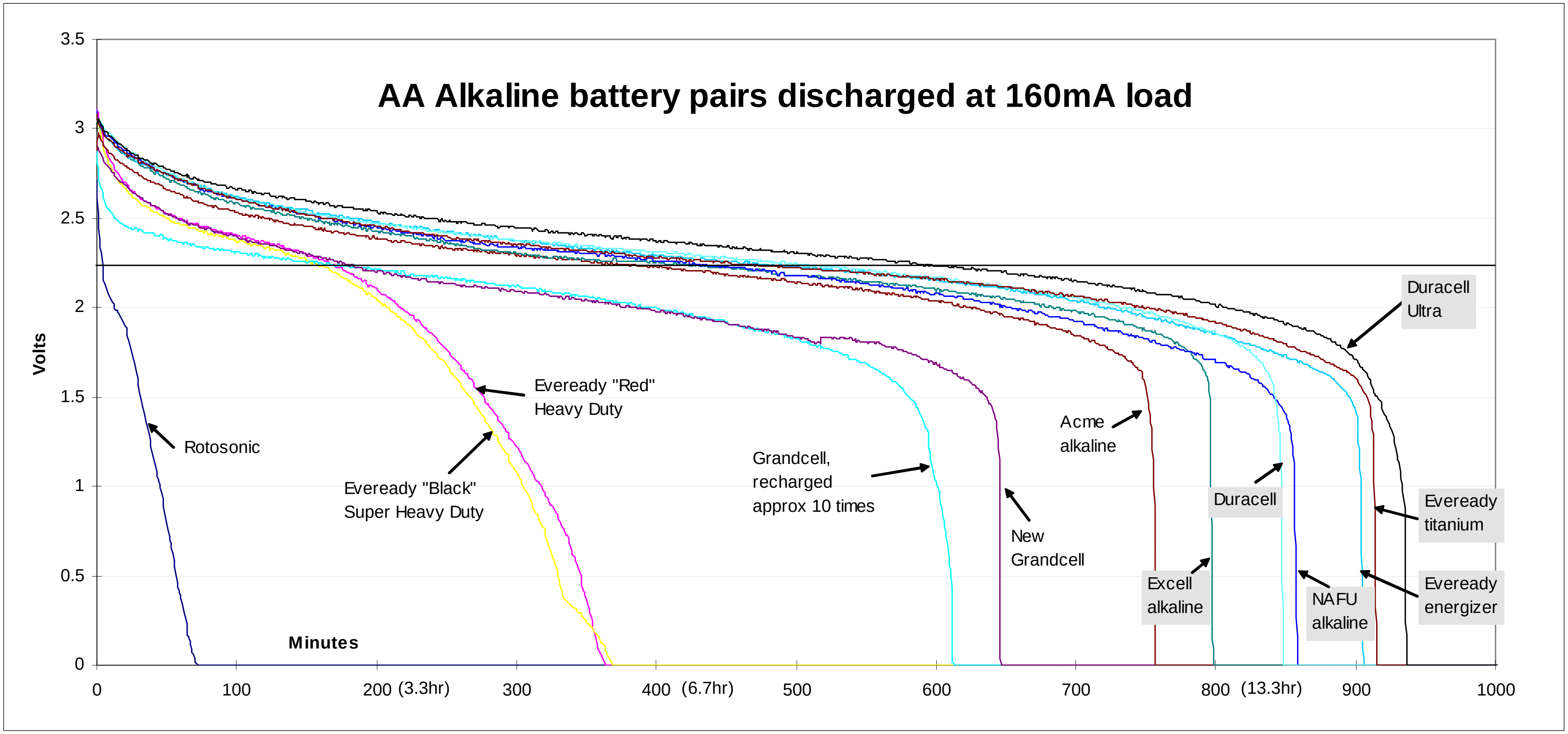
Capacity at low temperatures

Most batteries reduce their apparent capacity at low temperatures. Standard Alkaline batteries lose up to 40% of their room temperature capacity when discharged at 0°C. Lithium on the other hand maintains its capacity to much lower temperatures. The following graph from the Eveready web site illustrates this comparison.



Alkaline capacity Vs Brand

A commonly asked question: "Is there any value in purchasing a cheaper battery?" The following should hopefully provide some answers to this question.

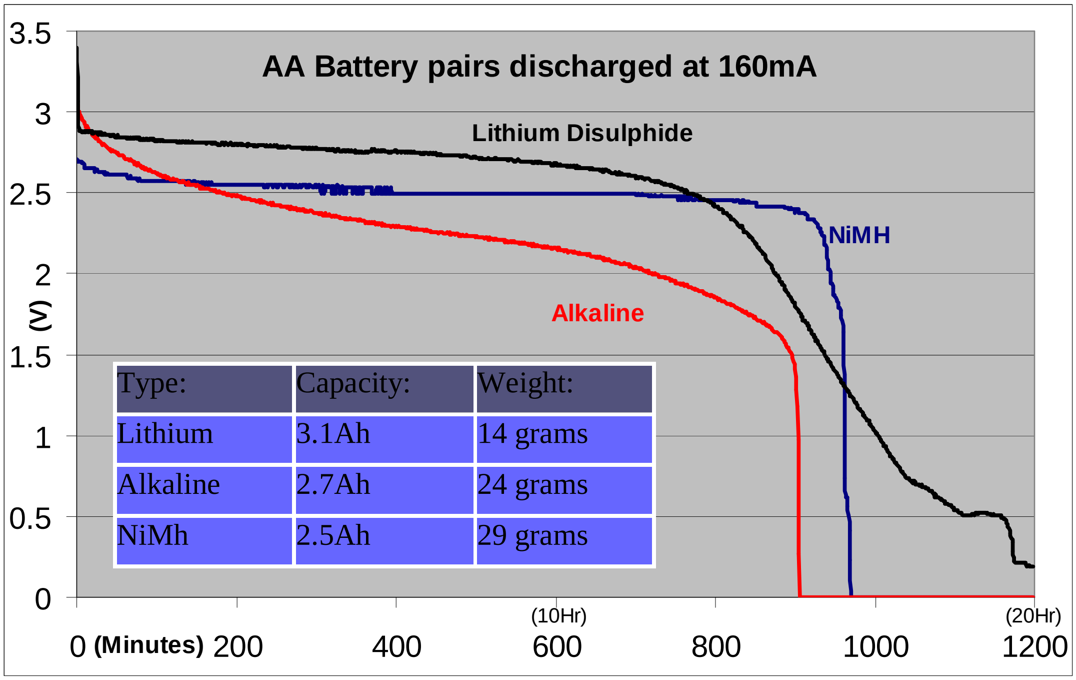

AA Alkaline battery pairs discharged at 160mA load
Volts
Minutes
3.5
3
2.5
2
1.5
1
0.5
0
0
100
200 (3.3hr)
300
400 (6.7hr)
500
600
700
800 (13.3hr)
900
1000
Duracell Ultra
Eveready "Red" Heavy Duty
Rotosonic
Eveready "Black" Super Heavy Duty
Grandcell, recharged approx 10 times
New Grandcell
Acme alkaline
Duracell
Excell alkaline
NAFU alkaline
Eveready titanium
Eveready energizer

The following table shows a comparison of various brands.

Rank	Type	Time (to 2.5V)	Cost	$/Hr
1	Digitor Exxtra	3:03	$1.20*	$0.39*
2	Rocket	2:41	$2.33	$0.87
3	Energizer	2:58	$2.74	$0.92
4	Excell	2:26	$2.50	$1.03
5	Duracell Ultra	3:52	$4.20	$1.09
6	Eveready Blue	0:34	$0.64	$1.13
7	Energizer Lithium	12:44	$14.99	$1.18
8	Eveready Gold	2:15	$2.75	$1.22
9	Reliance	2:01	$2.50	$1.24
10	Duracell	2:51	$3.68	$1.29
11	Acme	1:56	$2.50	$1.29
12	Toshiba	2:17	$3.48	$1.52
13	Eveready Titanium	2:41	$4.25	$1.58
14	Eveready Red	0:57	$1.68	$1.77
15	Eveready Black	0:50	$2.08	$2.50
16	Grandcell (10 cycles)	0:12	$0.54	$2.68
17	Grandcell (new)	0:58	$5.35	$5.53
18	Okkaido	0:05	$0:50	$6.00
19	Black Power	0:04	$0.50	$7.50
20	Keneng	0:01	$0.50	$18.75
21	Rotosonic	0:01	$0.50	$20.00

* The Digitor Exxtra batteries were purchased in a 40 pack where all others were prices as 2-pack. Hence the $/Hr rating is not really a fair comparison in this case. All tests are based on a single test sample and may not accurately reflect the results of all batteries of the same type and brand.

Capacity Vs Type



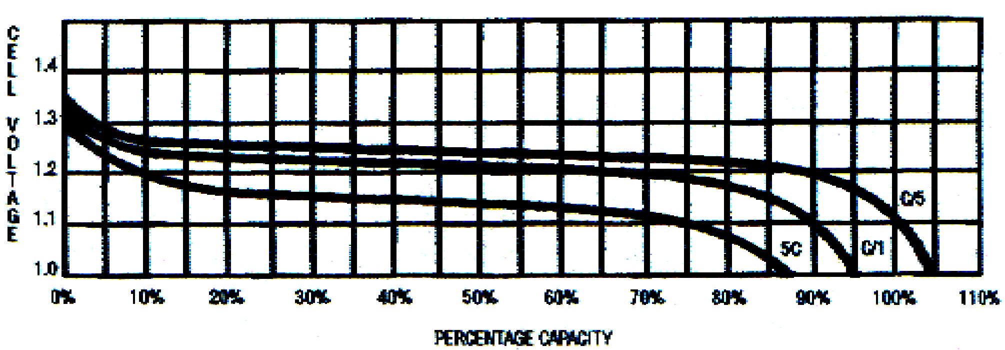
Type:	Capacity:	Weight:
Lithium	3.1Ah	14 grams
Alkaline	2.7Ah	24 grams
NiMh	2.5Ah	29 grams

The above compares the discharge rates of the higher performance options. (Results are based on two batteries in series) It shows that in higher drain applications, the Lithium and 2500mAh NiMh significantly outperform even the best alkaline batteries.

The lower published per cell terminal voltage of NiMh (1.2V) can become irrelevant as time increases since the voltage is essentially constant. The only downside is that the weight of these high capacity rechargeable batteries is around twice that of Lithium.

Discharge rates affect capacity

Discharge rate has a significant effect on capacity, particularly with alkaline and zinc batteries. Lithium, NiCd and NiMh cells perform much better under load.



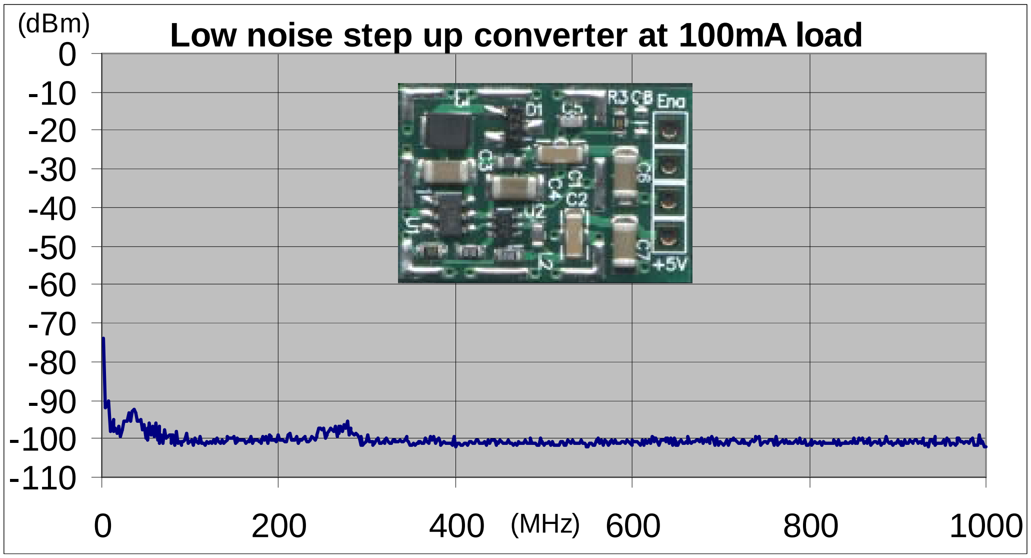
The above graph shows how well NiCd batteries in particular hold their capacity with different loads. (C/5 indicates discharge at 20% of cell capacity, 5C indicates discharge at 5 times cell capacity). NiMh batteries reflect similar results.

While there is no graph shown here to directly illustrate it, Alkaline and especially Zinc (so called “heavy duty”) batteries fall off considerably with increasing load. NiCd, NiMh and Lithium (either single use or rechargeable) batteries are a far better choice for high drain applications.

Use of a boost converter

A switching boost converter can be used to maintain a constant voltage for any type of battery technology where it is required. The main issue is that the current drawn from the supply increases as the battery voltage drops. This results in an increasingly diminishing capacity especially with alkaline batteries. It does however mean that you can effectively “suck the last bit of life” out of a battery when it would otherwise be unusable.

Many people are scared of using switching converters in sensitive receiving systems due to noise. A properly designed converter should not cause such problems. While the design of such a converter is beyond the scope of this paper, the following graph shows the results obtained with such a circuit (producing regulated 5V from a 3V battery) which uses a careful selection of SMD ferrites and feed through capacitors.

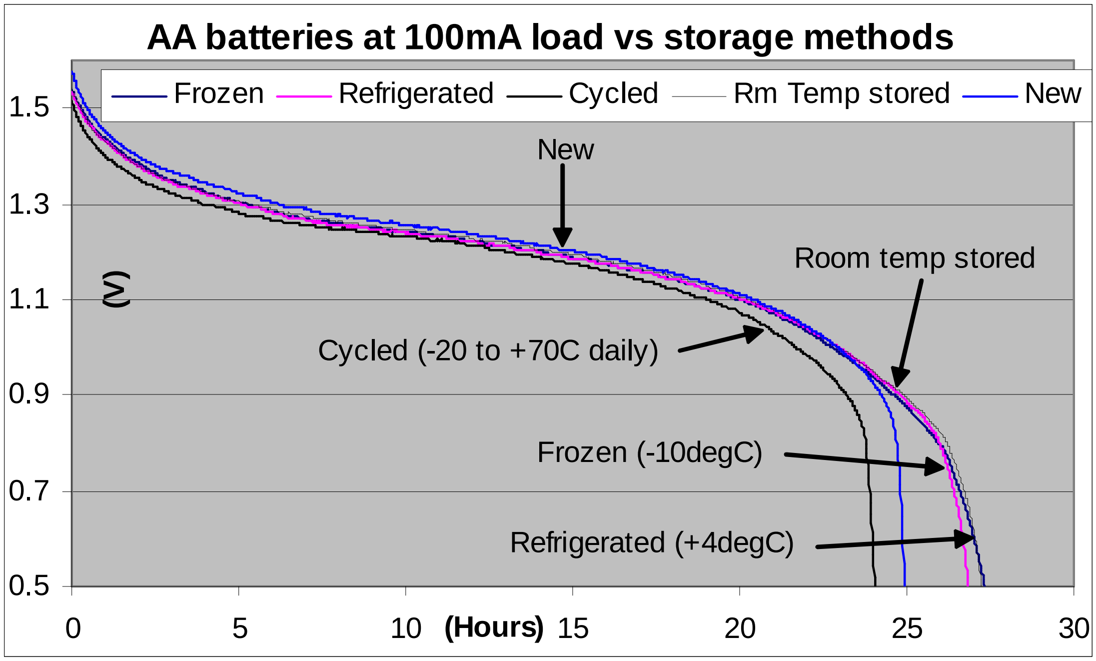


Alkaline battery storage and effects on Capacity

How does storage of alkaline batteries affect their capacity? – This is something that has intrigued the author for some time. I had been told some years ago that batteries should be stored in the fridge rather than on the shelf to help retain their capacity.

The chart below shows a comparison for an alkaline cell:

- Stored at room temperature for 12 months
- Stored at 4°C for 12 months (refrigerated)
- Stored at -10°C for 12 months (Frozen)
- Cycled between -20°C and +70°C twice daily for 12 months
- Newly purchased battery



The results show that there is very little change for storing batteries at any temperature including and below room temperature. The battery cycled from -20°C to +70°C daily was done to simulate the extreme case of storage in an outside shed or motor vehicle and was the only case where capacity was noticeably diminished, but even then the results after 12 months were still quite usable. A newly purchased cell showed a quicker final discharge because its terminal voltage was higher throughout the earlier parts of the discharge curve. Its actual capacity was greater than any of the stored batteries.

The graph shows that apart from storage involving extremely high temperatures, there is no noticeable benefit from storing alkaline batteries at low temperature. In fact it is better to purchase new cells as needed than to store old ones for any significant length of time.

Summary

- Depending on type, capacity varies with load and operation temperature.
- Room temperature storage is adequate - There is no real benefit from cold storage.
- Well designed switching converters can be useful in radio applications to extend effective battery life.
- Rechargeable batteries are challenging single use alternatives.
- You get what you pay for……