DRY CELL RECHARGER

ALAN TONG

Last month's feature article described "Better Use of Dry Cells", this month we show how to use your cells up to twenty times.

In last months article it was established that zinc carbon and alkaline cells are far superior products to nickel cadmium rechargeable cells (NiCad's). It may then come as some surprise that ordinary "primary" zinc carbon and alkaline cells can be recharged.

Recharging Dry Cells

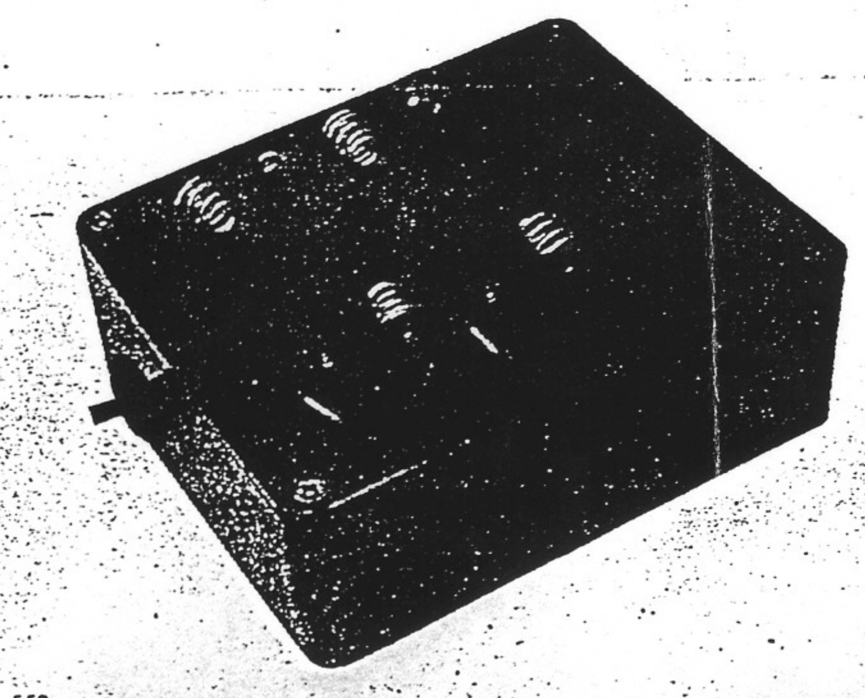
There are several advantages to recharging dry cells as opposed to NiCad's. Firstly the capacity of dry cells (especially alkaline) is much greater than that of NiCad's. This means that in a typical application a recharged dry cell will last five times as long as a NiCad.

NiCad's discharge themselves rapidly on standing, this makes them unsuitable for some applications such as clocks and emergency lighting, while recharged dry cells are suitable. The biggest argument for recharging dry cells however is cost. NiCad's cost several pounds while "used" dry cells are effectively free since they are usually thrown away.

Why then are 20 billion batteries thrown away every year? As already mentioned most people don't realise that they can be reused. Manufacturers will admit (reluctantly) that these cells can be recharged. If there was no possibility of cells being recharged there would be little point in telling you not to recharge them, since nobody would try.

Warnings printed on the cells range from the mild *Do not recharge* to the extreme *Danger of leakage or explosion.* Firstly cells cannot explode (unless thrown on a fire), all cells from reputable manufacturers have either a weak spot or wax plug built in to prevent any serious pressure build up. This can occur if a cell is inserted the wrong way around or if a discharged cell is inserted with fresh ones. The safety "vent" allows the gases to escape in a controlled way. An engineer working for a well known battery manufacturer told me that he had been recharging dry cells for several years.

If a standard dry cell is plugged into a NiCad recharger it will be partially recharged, but there is an increased chance that it will leak. The amount of charge retained will also be a barely useful amount. *I do not recommend even trying this.*



Matter of Chemistry

The chemical process involved in discharging a typical cell is shown in Fig. 1. When in use the anode, often zinc, is oxidised forming zinc oxide. This oxygen has come from the cathode which has been reduced (different processes occur in different types of cell but these are best left to chemists).

To recharge this cell we have to get the zinc oxide back to zinc. This is a process similar to electroplating. If you can remember electroplating experiments from the dreaded chemistry lessons you will recall that it involves an electric current flowing through a solution; copper sulphate is commonly used to demonstrate this.

In this experiment copper is deposited on to one of the electrodes. The problem is that the electrode has not been plated with a coat of shiny copper, instead the copper is in spongy lumps. This is what happens when you recharge an ordinary cell in a NiCad recharger. NiCad rechargers simply

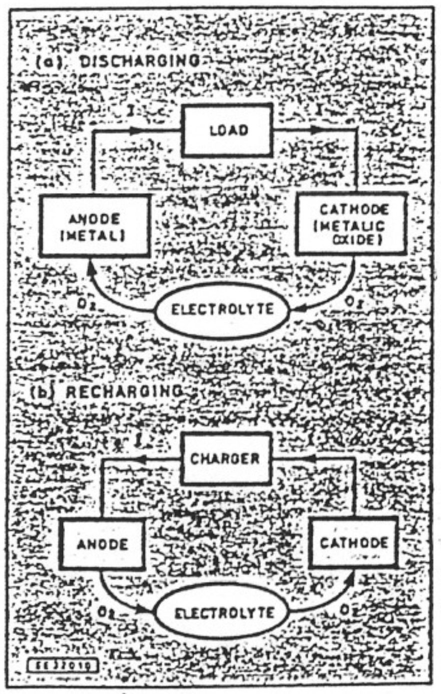


Fig. 1. Chemical process involved in discharge and charge.

force a d.c. current through the cell in the opposite direction to normal (Fig. 1b).

Inside the cell the zinc is plated out into a spongy mess instead of the original hard compact state. This re-plated zinc will take up more volume than it originally did, causing the internal components to distort. This distortion prevents an effective recharge and can lead to leakage.

Periodic Current Reversal

Not surprisingly the electroplating industry has found a way to produce successful results with these metals. The solution is known as periodic current reversal (PCR). PCR as it's name suggests consists of reversing the current flow at regular intervals, this prevents dendrite formation (see Part One) and gives a smooth finish.

When PCR is used to recharge dry cells the internal structure is not distorted and the cell can be successfully recharged without risk of leakage. It should be noted at this point that dry cells can only be recharged about 20 times before the capacity drops off, but when you consider that this is equivalent to recharging NiCad's 100 times and that the cell was "free" in the first place it is not a serious problem.

Safety

It is worth re-examining the question of safety at this point. Cells will not explode unless thrown on a fire, and with a bit of care they will not leak. Then why are warnings printed on cells? One reason may be that *a little bit of knowledge can be a dangerous thing*. If people know that cells can be recharged, but not how to recharge them, then mistakes could be made.

We cannot really expect the battery manufacturers to promote dry cell recharging. The dry cell market is a saturated one and any serious reduction in the number of cells sold might cause companies to fold.

The situation, however is different in other countries. In Japan recharging is officially encouraged and battery companies sell rechargers (mostly d.c.). In these countries there are no warnings on the cells, although export batteries still bear warnings! A well known manufacturer of alkaline cells in the UK prints on its cells

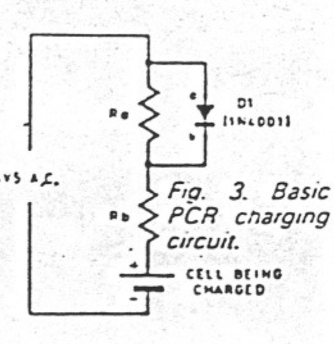


Fig. 3. Basic PCR charging circuit.

TABLE 1

CELL SIZE	AAA	AA	C	D
Ra	1k5(½)	560R(½)	220R(½)	68R(1)
Rb	120R(½)	47R(1)	18R(3)	6R8(5)
T1 RATING	1VA	1VA	2VA	5VA

FIGURES IN BRACKETS SHOW POWER RATINGS FOR RESISTORS

N B FOR STANDARD (1200mAH) D SIZED NI-CAD'S USE VALUES AS FOR C SIZE. FOR INDUSTRIAL (4000mAH) USE D SIZED VALUES.

Table 1. Resistor selection for various batteries.

for the home market "Do not recharge or dispose in fire, may explode or leak" curiously batteries for export simply state "Do not recharge".

Important Guidelines

Some guidelines are necessary for safe and efficient recharging. It would be irresponsible to publish a recharging circuit without them (*a little bit of knowledge . . .*).

1. Recharge using PCR, do not use d.c.
2. Limit the forward and reverse currents. (see Table 1)
3. Limit the recharge time, or in other words do not try to put more energy back into a cell than it originally contained.
4. Recharge soon after discharge as cells left in a discharged state for a long period of time (more than a few weeks) will not accept a recharge.
5. Do not fully discharge cells, some cells especially zinc chloride dry out as they discharge.

If a cell fully dries out the chemical reactions cannot be reversed so the cell cannot be recharged. In practice this means stopping using cells when the radio begins to distort or the torch bulb seriously dims.

6. [illegible] turers, these will be better quality, will last longer and are less prone to leakage.
7. Do not keep cells for long periods of time, cells get more prone to leakage as they get older. Discard cells after one or two years.
8. Only use the following PCR Recharger with zinc carbon, zinc chloride, alkaline and Ni-Cad cells (these are the most common anyway)

In five years of recharging I have never had a cell leak when using PCR, some old cells have leaked when I have used d.c. but since they have only leaked in the charger, not when in use, no damage was done.

Design

To recharge cells, a current of the correct magnitude that will be reversed at regular intervals is required. The frequency at which this reversal occurs is not critical so it makes sense to use mains frequency (50Hz). Obviously applying an ordinary alternating current (a.c.) to a battery will achieve nothing as on positive cycles it will charge the cell, on negative cycles it will discharge the cell (Fig. 2) What is required is a waveform where the forward charge current will be greater than the reverse current. This can be achieved by biassing the a.c. waveform to give it a non zero average.

A simple way of achieving this is to shunt a resistor with a diode; this leads to a very simple circuit shown in Fig. 3. When current is flowing in the forward charge direction it will flow through the diode bypassing R_a and then flow through R_b. This will give a current of $I = (4.5-0.7-1.5)/R_b$. The 1.5V being the voltage from the cell when it is recharged and the 0.7V being the voltage drop across the diode.

When the current flows in the opposite direction it passes through both R_a and R_b (the diode is reverse biassed so no current will flow through it). The reverse current is given by $I = (4.5+1.5)/(R_a+R_b)$. The most efficient ratio of forward to reverse currents is about 5 to 1. To make the charger compatible with NiCad's, standard NiCad charging currents have been used.

As a design example AA size batteries require a forward charge current of 50mA. Rearranging the equation for forward charge current we get $R_b = (4.5-1.5-0.7)/0.05$. This gives a value of 46 ohms, the nearest available resistor is 47 ohms. The reverse current (one fifth of the forward) should be 10mA. Rearranging the reverse current equation we get $R_a + R_b = (4.5+1.5)/0.01$. This gives a value of R_a of 553 ohms, the nearest available value is 560 ohms. The power

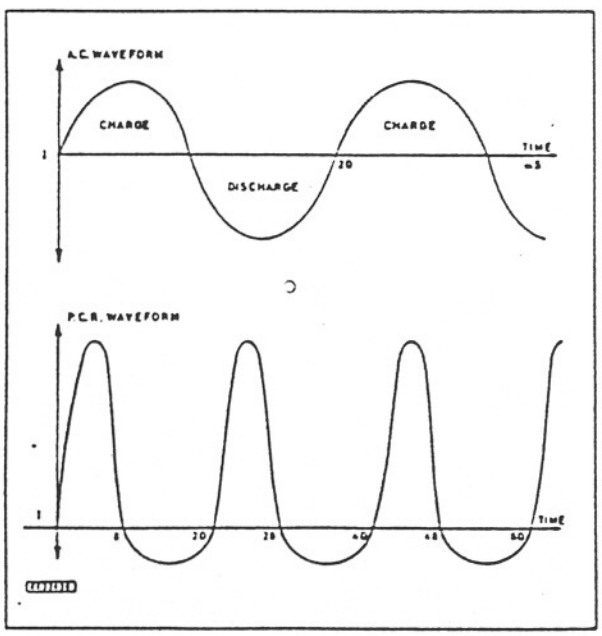


Fig. 2. Standard a.c. and PCR a.c. waveform.

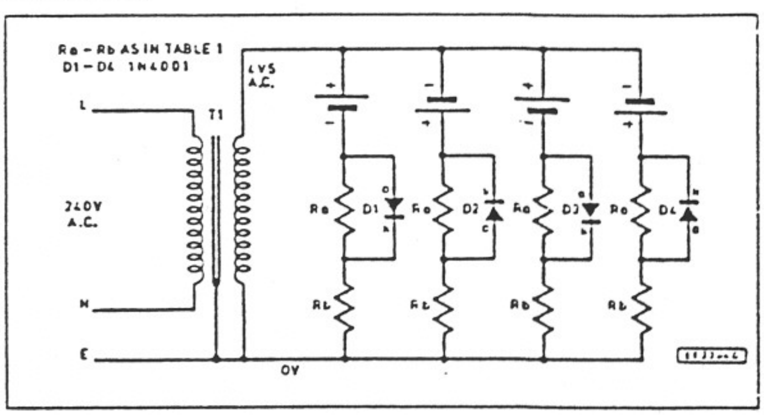


Fig. 4. Complete circuit of the Dry Cell Recharger.

COMPONENTS

Resistors
R_a and R_b see Table 1 (4 off each)

Semiconductors
D1 to D4 1N4001 (4 off)

Miscellaneous
T1 Mains (240V) primary, 4.5V secondary at 1VA to 5VA – see Table 1
Mains lead and fused (1A) plug; stripboard – see text; MB3 plastic box – see text; battery holder for four cells (AAA to D size – see Table 1); earth tag and fixings for T1, battery holder and stripboard; connecting wire; mains lead grommet and cable clamp.

See SHOP TALK Page

Approx cost guidance only **£8.50**

rating for the resistors and transformer must also be calculated. All the necessary values are in Table 1.

The full circuit diagram (Fig. 4) allows for four cells to be charged at once. A higher rated transformer will be required if you wish to recharge more than four cells at once. Note however that an even number of cells should be recharged at one time, this ensures that a balanced load is provided to the transformer. – Note that the diodes and cells are reversed in each section of the circuit.

The circuit as it stands is very simple. This is deliberate as in an article designed to save money it seems pointless to add the usual flashing l.e.d.'s and timing units found in most NiCad chargers.

Construction

Construction (Fig. 5) should cause no problems due to the simplicity of the project. The exact components used will depend on the size of batteries you wish to recharge. The circuit is built on a piece of stripboard. The size used can be chosen to fit in the box used. The minimum sensible size being 12 strips by 21 holes.

Connections to the transformer should be double checked and any terminals connected to the mains should be insulated. Where the mains cable enters the box a grommet and cable clamp should be used to prevent possible damage to the cable. The size of hole drilled for this will depend on the grommet used.

The mains plug used should have a one amp fuse rather than the usual thirteen amp. The transformer should be securely fixed within the box and its frame should be connected to the mains earth lead.

Five holes will need to be drilled in the top of the box to connect to the battery holders. Ensure enough wire is run to the battery holders to allow the lid to be removed. The holders can either be glued or screwed to the top of the box. One practical note about the battery holders: the metal terminals will have to be carefully soldered or the plastic surrounding them will melt.

The case used for this project was a MB3 plastic box measuring 115 × 95 × 43.5mm. If you choose to use a metal box ensure that it is correctly earthed.

Testing

An ammeter can be used to test the circuit. If the meter leads are connected to the terminals on one of the battery holders, and the recharger plugged into the mains, a current slightly less than the forward charging current should be measured.

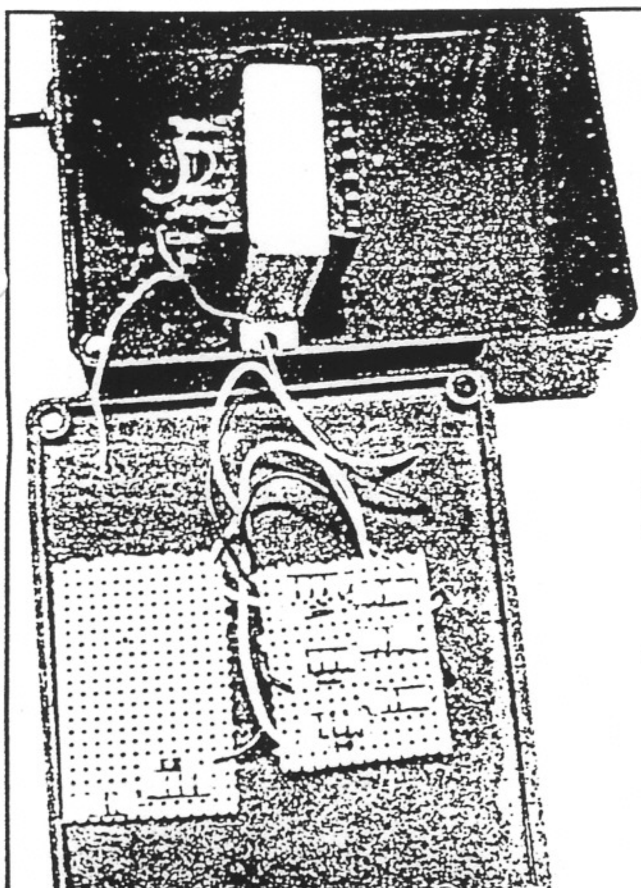
Disconnect the unit from the mains and insert some cells to be recharged. Measure the voltage across one of the cells, then plug the unit into the mains again, a slight rise in voltage should be observed. If this rise is observed then the cell is being recharged.

In Use

Operation is simple, discharged cells are simply inserted into the battery holders and the unit connected to the mains. The only question is how long to charge cells for? This depends on what type of cell is being recharged and how discharged the cell was in the first place.

Zinc carbon and zinc chloride cells usually require 12 to 18 hours to recharge. Alkaline cells, since they have much higher capacities, require 24 to 36 hours. By using a battery tester, the state of charge of a cell can be measured (see part one of this article). Recharging should be halted when a cell gives a slightly lower reading than a new cell. Do not try to put more into a cell than it originally contained as it could leak.

The recharger only has to be used a few times to pay for itself.



Prototype charger was made using scraps of stripboard to hold the components. Mains connections to the transformer should be insulated before testing.

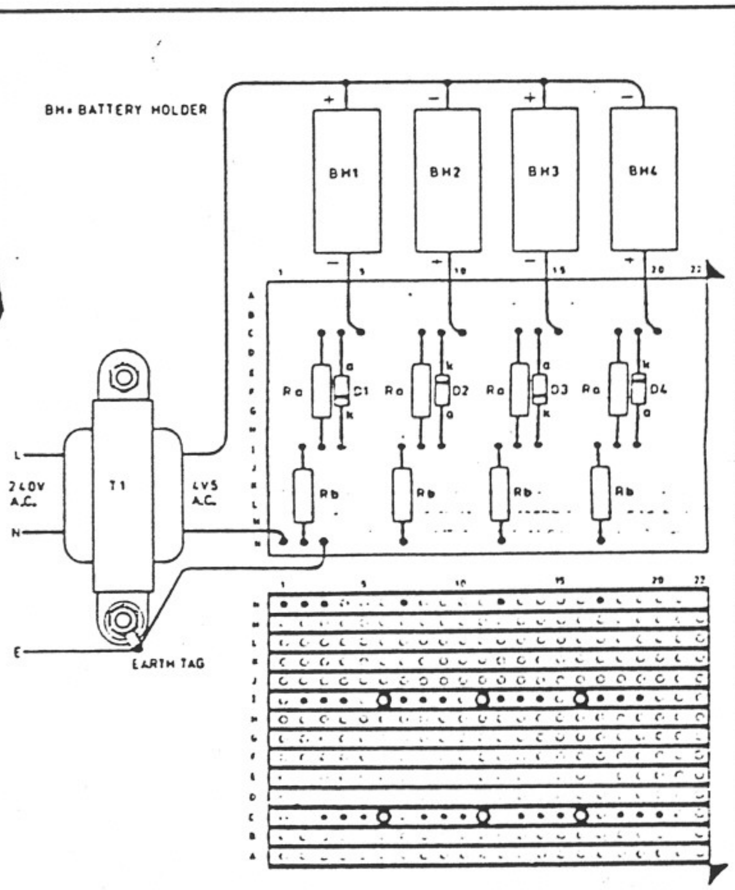
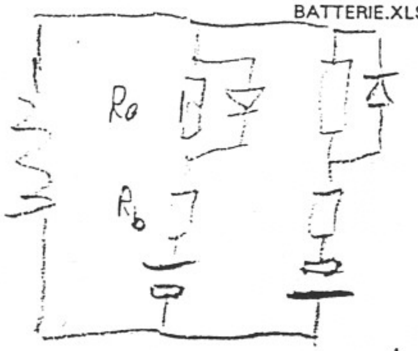


Fig. 5. Construction of the Dry Cell Recharger.



Ueff

Volt	Kapazität	I - Lade	t - Lade	Batt.-Typ	Typ	Trafo	Ra	Rb	V/R I	VA	BattAnz.	PRa	PRb
9,0	560	50	30	E-Block	6LR61	12	2100	46,0	5	1,0	2	0,2011	0,115
1,5	1050	20	30	Micro / AAA	LR03	6	1875	190,0	5	0,4	4	0,0247	0,076
1,5	2300	50	30	Mignon / AA	LR6	6	750	76,0	5	1,0	4	0,0618	0,19
1,5	6300	130	30	Baby / C	LR14	6	288,46	29,2	5	2,6	4	0,1608	0,494
1,5	12000	400	30	Mono / D	LR20 Serie2000	6	93,75	9,5	5	8,1	4	0,4947	1,52
1,2	600	50	14	Mignon / AA	R6 NC 601RS	6	720	82,0	5	1,0	4	0,058	0,205
1,2	1800	180	14	Baby / C	R14 NC RSH1,8	6	200	22,8	5	3,7	4	0,2089	0,738
1,2	4000	400	14	Mono / D	R20 NC RSH4	6	90	10,3	5	8,1	4	0,4642	1,64
6,0	1300	130	14	Pack	NP-22 NC	12	692,31	40,8	5	1,3	1	0,4174	0,689
9,6	1400	140	14	Pack	BA601 NC	12	771,43	12,1	5	2,9	2	0,5862	0,238

Volt	Kapazität	I - Lade	t - Lade	Batt.-Typ	Typ	Trafo	Ra	Rb	V/R I	VA	BattAnz.	PRa	PRb
9,0	560	50	30	E-Block	6LR61	12	2100	46,0	5	1,0	2	0,2011	0,115
1,5	1050	20	30	Micro / AAA	LR03	9	2625	340,0	5	0,6	4	0,0329	0,136
1,5	2300	50	30	Mignon / AA	LR6	9	1050	136,0	5	1,5	4	0,0823	0,34
1,5	6300	130	30	Baby / C	LR14	9	403,85	52,3	5	4,0	4	0,214	0,884
1,5	12000	400	30	Mono / D	LR20 Serie2000	9	131,25	17,0	5	12,2	4	0,6584	2,72
1,2	600	50	14	Mignon / AA	R6 NC 601RS	9	1020	142,0	5	1,5	4	0,0786	0,355
1,2	1800	180	14	Baby / C	R14 NC RSH1,8	9	283,33	39,4	5	5,5	4	0,2829	1,278
1,2	4000	400	14	Mono / D	R20 NC RSH4	9	127,5	17,8	5	12,2	4	0,6288	2,84
6,0	1300	130	14	Pack	NP-22 NC	12	692,31	40,8	5	1,3	1	0,4174	0,689
9,6	1400	140	14	Pack	BA601 NC	12	771,43	12,1	5	2,9	2	0,5862	0,238

Volt	Kapazität	I - Lade	t - Lade	Batt.-Typ	Typ	Trafo	Ra	Rb	V/R I	VA	BattAnz.	PRa	PRb
9,0	560	50	30	E-Block	6LR61	12	2100	46,0	5	1,0	2	0,2011	0,115
1,5	1050	20	30	Micro / AAA	LR03	7,5	2250	265,0	5	0,5	4	0,0288	0,106
1,5	2300	50	30	Mignon / AA	LR6	7,5	900	106,0	5	1,3	4	0,072	0,265
1,5	6300	130	30	Baby / C	LR14	7,5	346,15	40,8	5	3,3	4	0,1873	0,689
1,5	12000	400	30	Mono / D	LR20 Serie2000	7,5	112,5	13,3	5	10,2	4	0,5763	2,12
1,2	600	50	14	Mignon / AA	R6 NC 601RS	7,5	870	112,0	5	1,3	4	0,0683	0,28
1,2	1800	180	14	Baby / C	R14 NC RSH1,8	7,5	241,67	31,1	5	4,6	4	0,2458	1,008
1,2	4000	400	14	Mono / D	R20 NC RSH4	7,5	108,75	14,0	5	10,2	4	0,5463	2,24
6,0	1300	130	14	Pack	NP-22 NC	12	692,31	40,8	5	2,6	2	0,4174	0,689
9,6	1400	140	14	Pack	BA601 NC	12	771,43	12,1	5	2,9	2	0,5862	0,238

Volt	Kapazität	I - Lade	t - Lade	Batt.-Typ	Typ	Trafo	Ra	Rb	V/R I	VA	BattAnz.	PRa	PRb
9,0	560	50	30	E-Block	6LR61	12	2100	46,0	5	1,0	2	0,2011	0,115
1,5	1050	20	30	Micro / AAA	LR03	4,5	1500	115,0	5	0,3	4	0,0207	0,046
1,5	2300	50	30	Mignon / AA	LR6	4,5	600	46,0	5	0,8	4	0,0518	0,115
1,5	6300	130	30	Baby / C	LR14	4,5	230,77	17,7	5	2,0	4	0,1346	0,299
1,5	12000	350	30	Mono / D	LR20 Serie2000	4,5	85,714	6,6	5	5,3	4	0,3623	0,805
1,2	600	50	14	Mignon / AA	R6 NC 601RS	4,5	570	52,0	5	0,8	4	0,0479	0,13
1,2	1800	180	14	Baby / C	R14 NC RSH1,8	4,5	158,33	14,4	5	2,7	4	0,1723	0,468
1,2	4000	400	14	Mono / D	R20 NC RSH4	4,5	71,25	6,5	5	6,1	4	0,3829	1,04
6,0	1300	130	14	Pack	NP-22 NC	12	692,31	40,8	5	1,3	1	0,4174	0,689
9,6	1400	140	14	Pack	BA601 NC	12	771,43	12,1	5	2,9	2	0,5862	0,238

Für Monozellen mit 8V-Versorgung (Märklin-Trafo)

R_A = 100Ω; 1W → Entladestrom 84 mA

R_B = 13Ω; 3W → Ladestrom 446 mA