e3DHW: Power Management System

note: *to use the links, download this file and use a pdf-viewer on your PC..*

Introduction

A problem that is always present in DIY electronic realizations is the choice of the power supply and the energy source: batteries or grid? Or solar panel? Or...

Power Management System is a simple and general project methodology which, within the e3DHW vision, solves many problems related to the power supply of DIY electronic devices flexibly.

e3DHW-PMS (*e3DHW- Power Management System*) has the following objectives::

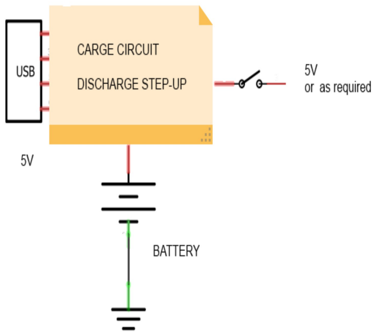
- *Very simple, cheap and substantially similar power supply circuit for all DIY electronic devices.*
- *In mains operations the batteries are used as buffer batteries, therefore UPS units are not required for 7/24 operation.*
- *Operation as a portable device periodically requires a recharge phase.*
- *Possibility to change the energy source in real-time without modifying the circuit: the same device will work with batteries, with the grid, with solar panels, with 12 V car, etc ... without circuit modifications.*

In particular, the key ideas for **e3DHW-PMS** are

1. ***Standardize power supplies to 5 V DC,*** *using USB connectors:*
    - In the consumer sector, this trend has already been in place for some time: for example, I have an 'action cam', basically a camera, which is recharged via USB.
    - Since the TTL era, many integrated circuits require 5 V of power.
    - Linked to the market induced by the diffusion of smartphones, there is a lively development of 5V charging devices: mains power supplies, car power supplies, solar panels, power banks, etc. At increasingly attractive prices.
    - Among the electronic modules available on the market, also due to the aforementioned trend, we find circuits for charging and/or discharging various types of batteries (power-bank) and many step-up and step-down circuits that function as DC-DC transformers, dedicated to the 5 V. They are economical, with high efficiency (even over 95%) and available for various powers (see below)
    - Up to 2.5 W we are in the field of standard USB powers (5V, 0.5A), e.g. PC sockets. From 2.5 to 5 W (5V 1A) we can use smartphone power supplies. Over 5W it is necessary to use more powerful power supplies: QC2.0 (10 W), WC5.0 (15W), etc ..
2. ***Use rechargeable NiMH batteries,*** *in buffer battery mode.*
    - They are cheap and very widespread batteries, with a high charge density, and are suitable for continuous charging (trickle current).
    - Using NiMH batteries as buffer batteries, the required circuit (slow charge) can be very simple.
3. ***Use LiIon rechargeable batteries*** *for portable devices.*
    - They are batteries with high rated voltage (3.7) and high discharge current.
    - They do not tolerate continuous charging, they are suitable only for intermittent use.
    - They are more delicate than NiMH, you must always use one of the many existing modules for charging and discharging, with control of overcharge and overdischarge situations and for correct use as a UPS.

Overview e3DHW-PMS

*This image summarizes some **e3DHW-PMS** possibilities (indicative web prices):*

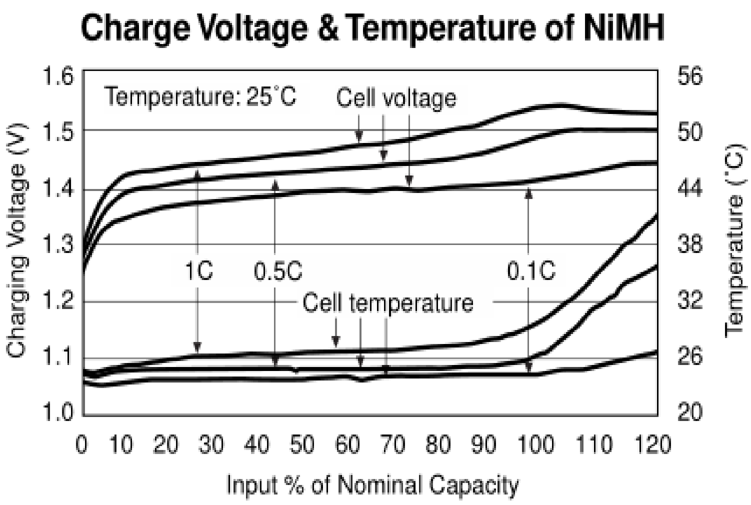
Energy source (<5W)	Connection	
Internal batteries	none	
AC grid 1 A 4 € 	1) cable coming out of the device, with USB A male 	
12V Car 3 € 		
Solar 12 € 	2) micro B USB female socket on the device (like a smartphone) + USB cable 	
Wind 7.50 US$ 		
Power bank 21 € 		
Any source capable of recharging a smartphone	Standard USB plugs/sockets	**Power supply stage** that acts as a power bank

1) energy sources designed for smartphones typically have 5V 1A output
2) Up to 10/15 A can be obtained from a LiIon battery during the discharge phase

Rechargeable batteries

The **slow charge** is defined as the maximum current that can be applied without time limits and without damaging the battery. For NiMH batteries, it is a value between C/40 and C/10 (C is the battery capacity in mAh) (ref. [1]).

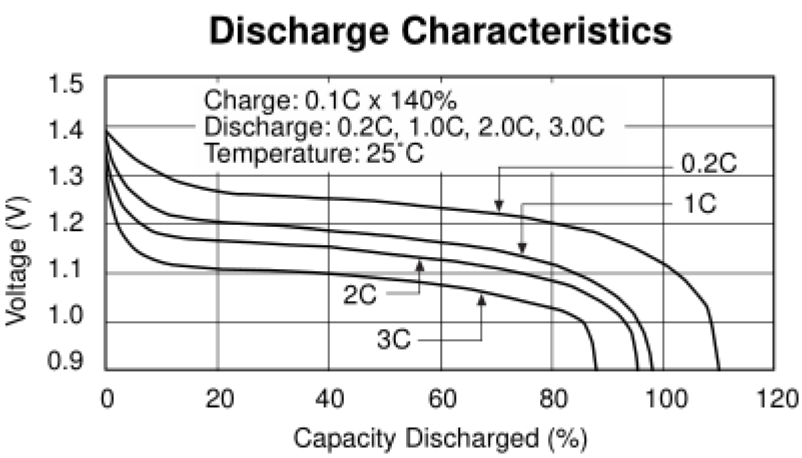
Fast Charge is usually defined as charging in 1h, with a current of 1.2C (ref [1]).



NiMH charge notes:

Max voltage (typical, T < 40°): 1.47V (rif. [5]).
Max current 1.2C (fast charge 1h constant current) (rif [1])

end charge: the voltage reaches a maximum and the temperature increases.
In any case, the battery temperature must not exceed 45 ° -50 ° C (rif. [3]).



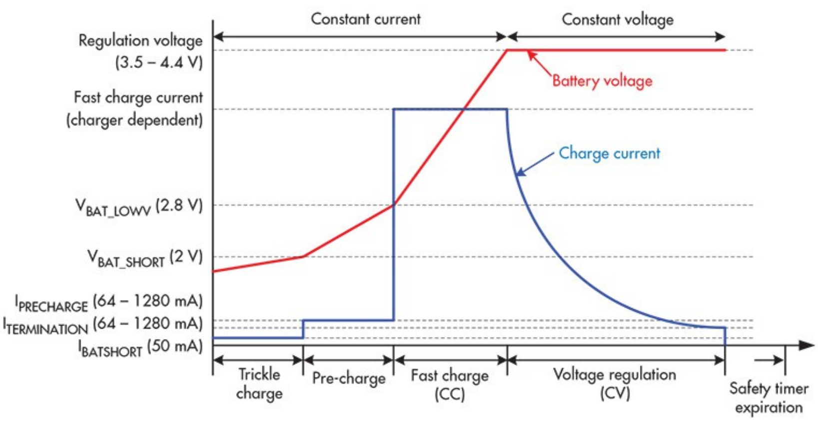
NiMH discharge notes:

Rated voltage (at 50% capacity, discharge at 0.2C): 1.2 V (ref. [2]).

Minimum voltage: = 0.9 V (rif. [2]).

Max current: 3C (but for some models also 10C - ref. [3]).

LiIon charge notes:



Rated voltage 3.7 V

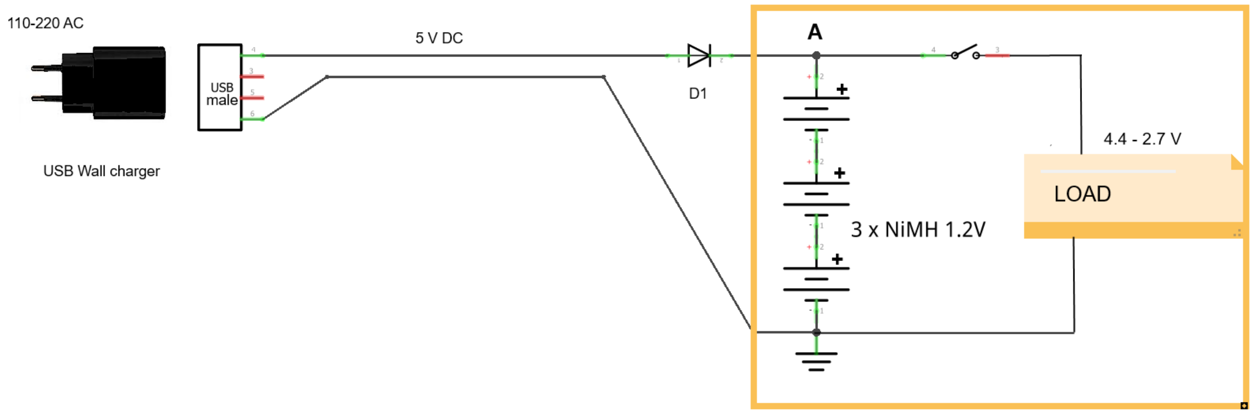
Max voltage (18650): 4.2 ± 0.025 V
Min voltage: 2.5-3V

Charge: constant current (CC) phase @1C
then phase at constant voltage (CV) @4.2 V
end: current <= 0.1C

Basic circuit for NiMH

I am always looking for simple, effective and economical solutions, and for NiMH batteries I studied a circuit that seems interesting to me: using 3 NiMH batteries in series and 5V as a power supply the circuit for slow charging can be very simple by choosing a charge at constant voltage: only a silicon diode.

This method is quite general and applies both to electrical devices (e.g.. Led lights) that tolerate variable voltages, and to electronic devices that require fixed voltages, in this case a step-up/step-down module must be used..



Charge

The diode has a dual purpose: it lowers the power supply voltage by 0.6V and excludes the power supply when it is not powered in AC.
Let's do some calculations

The voltage at node A varies: min: 3*0.9 = 2.7 V max: 5 – 0.6 = 4,4 V = 3 x 1.46 V The battery charging current (constant voltage, 5V) depends on: (power supply voltage - battery voltage) which varies from (4.4-2.7) = 1.7 to 0 V, the sum of the internal resistances of the batteries, the diode, and the power supply. The trend is exponential, the charging current tends to zero with a completed charge (4.4 V).

1) The current supplied by the source at 5V must not exceed the value 1.2C (with discharged batteries).
2) The 5V source should be protected against overload (Some USB wall charger I tested have this protection)
3) The batteries used must be as equal as possible (same brand, same type, same capacity, same initial charge) to ensure a uniform division of charge and voltages.
4) Problems can occur in the event of a battery break or in the case of a very high ambient temperature (> 40 ° C). In the event of a malfunction, the typical symptom is overheating of one of the batteries or too low a voltage, under load, e.g. at 0.1 C
5) A damaged element can quickly lead to the breakage of the other elements.

Obviously, you will have very long charging times, but in principle this is not a problem, being able to keep the batteries always on charge. The minimum charging time can be measured using a 5V source with an internal resistance close to 0 and a current limit of 1C.
Keeping the batteries always powered by the mains is the best solution: the maintenance current is self-adjusting and is less than 1 mA, and the total absorption cannot be measured with my instruments, resulting in less than 1 W. The batteries are always charged and therefore ready for autonomous operation, but they are not very stressed and therefore last a long time,

Different considerations with intermittent sources, such as solar and wind: it is necessary to calculate the average values conservatively, considering the possibility of long periods (days) without sun or calm. It is also possible to charge the batteries from multiple sources simultaneously: for each source, add a diode to the base circuit.

discharge

The maximum discharge current of NiMH batteries is 3C but it can also reach 10C for some special types. Considering the cheaper batteries, from 1000 mAh, it means 10 hours of autonomy at 100 mA (0.1C) up to 20 minutes at 3A (3C).
Knowing the absorption of the apparatus and the type of use that it intends to do (intermittent, continuous, etc.) it is easy to calculate the required capacity of NiMH batteries, these are typically 1000 mAh, but some types can reach up to 2850 mAh (Wikipedia, 18 October 2018).
Also evaluate the use of multiple groups of 3 batteries in parallel.

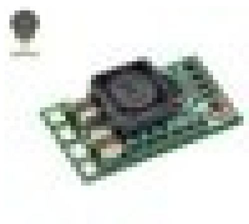
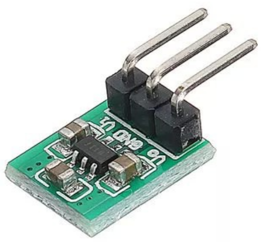
Important warning, absolutely avoid to drain the 3 batteries over 2.7V (overdischarge)..
The life of NiMH batteries is damaged both by overload and overdischarge. It is advisable to provide control circuits with load disconnection or at least a warning for the user.

In the base circuit, in the discharge phase, the required current is supplied by both the batteries and the mains power supply. The balance is obtained when the batteries absorb a negligible current and the mains power supply provides all the current required by the load (2.5-15 W).

n the event of an emergency, the three NiMH batteries can always be replaced by normal alkaline AA batteries.

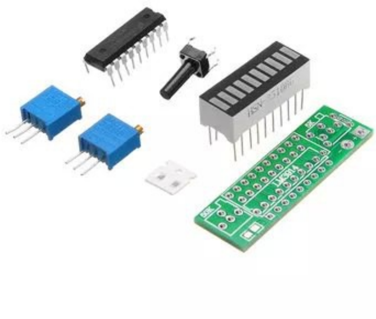
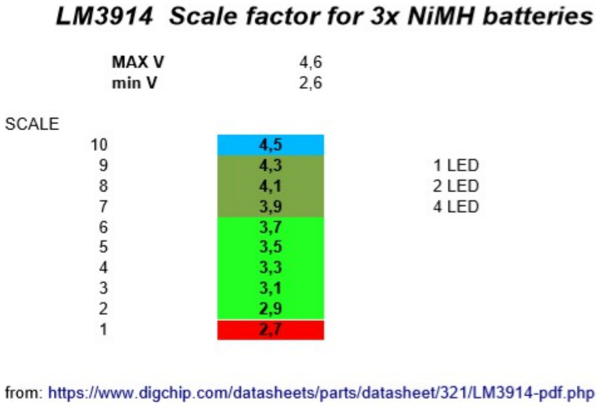
The use of step-up or step-down DC-DC converters allows obtaining, starting from 4.4 V, a wide range of stabilized voltages as required by the electronic circuits.
As an example, I consider the following voltage regulator modules to be interesting for **e3DHW-PMS** projects (the price is only indicative and includes shipping):

	PFM Control DC-DC 0.9V-5V To USB 5V Boost Step Up Power Supply Module IN: 0.9 – 5 V OUT: 5 V, 600 mA efficiency max: 96%	1.30 €

	Mini DC-DC 0.8-5V To DC 5V Step Up Boost Power Module Board For Arduino IN: 0.8 – 5 V OUT: 5 V, 7 - 480 mA efficiency max: 85%	1.84 €
	XL6009 Step Up Boost Voltage Power Supply Module Adjustable Converter Regulator IN: 3.5 – 35 V OUT: 5 – 35 V, 10 W efficiency max: 94%	2.16 €
	WAVGAT Mini DC-DC 12-24V To 5V 3A Step Down Power Supply Module IN: 4.5 – 24 V OUT: 0.8 -17V adjustable 1.8, 2.5, 3,3, 5, 9, 12 fixed 1,5 A (3 A + radiator) efficiency max: 97.5%	0.50 €
	Mini 2 in 1 1.8V-5V to 3.3V DC Step Down Step Up Converter Power For Arduino Wifi Bluetooth ESP8266 HC-05 CE1101 LED Module IN: 1.8 – 5 V OUT: 3.3 V ± 4% 100 mA without load: 0.65 mA	1.62 €
	4Pcs ISDT 1.5V 2000mAh Rechargeable AA Ni-MH Battery	8.53 €

Anche i seguenti moduli possono essere utili:

	10 pcs Micro B USB To Dip Female Socket	10x 2.22 €

	10 pcs USB 2.0 Female A Head Socket To DIP	10x 2,41 €
	LM3914 DIY Kit Display LED Indicator 10 Segment Capacity Power Level Battery standby (5V): 2,4 mA, any led on: 4 – 25 mA  	1.99 €

Circuito base per batterie LiIon

The most common type of secondary LiIon battery is the 18650 (nominal 3.7V) with high capacity and high discharge currents, supplied by many manufacturers:

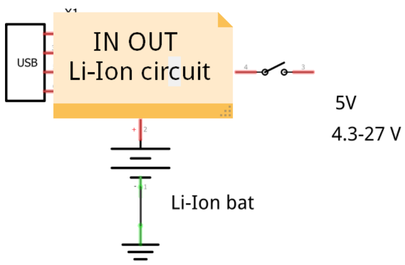
- Panasonic: NCR18650 (2900mAh), NCR18650A (3100mAh), NCR18650B (3400mAh), NCR18650 G, (3600mAh.)

High discharge currents, 10+ A:

- Sanyo-Panasonic NCR18650GA (3500mAh, 10A)
- Samsung 30Q, 25S
- Sony: VTC-5, 5A 6.
- LG: HG/HE 2 (15A)

note: if the battery does not contain protection circuits (PCB) it is necessary to use an external protection circuit (BMS ref [8]).

For the rapid recharging of LiIon batteries, it is necessary to act in two phases: in the first a constant current is supplied (<= 1C) up to reach 4.2 V, then it is completed at constant voltage (4.2 V) until the current decreases (< 0.1 -0.03 C).



There are many suitable circuits (ref [1]), for simplicity we can use one of the many modules available on the market for charging LiIon batteries, some of which include both the charging circuit and a step-up output stage. The output is typically 5V (for 'power bank' like applications) or 12 V, but can also be variable (4.3 - 27 V).

LiIon vs NiMH

The complexity and cost of the two basic solutions are practically equivalent

PRO:

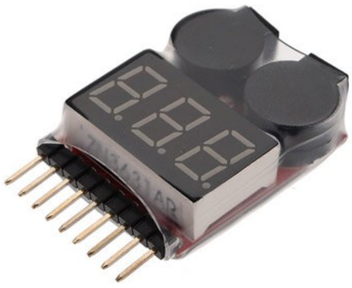
- battery packs with high discharge currents (electric tools).
- fast charge (about 1.5 h) and 'Quick charge'.
- smaller footprint
- longer battery life, more charge/discharge cycles (1000 vs 500)

VERSUS::

- LiIon batteries are damaged by the maintenance current, they cannot be used directly as a buffer battery.
- they are not compatible with alkaline batteries.
- risk of fire and explosion.
- you need a BMS to handle battery packs.

As an example, some specific LiIon battery modules (the price is only indicative and includes shipping):

	2Pcs 5V Lithium Battery Charger Step Up Protection Board Boost Power Module Micro USB Li-Po Li-ion 18650 Power Bank IN: 5V 1A OUT: 5V 1.2A standby: 0.1 mA	2x 3.44 €
	3.7V 9V 5V 2A Adjustable Step Up 18650 Lithium Battery Charging Discharge Integrated Module IN: 4.5 – 8 V 1A OUT: 4.3-27V adjustable, 5V – 1.4A, 12V – 0.6A standby: 0.5 mA	1.84 €
	5V/12V 18650 Lithium Battery Boost Step Up Module Charge Discharge IN: 5V OUT: 5 V 1A or 12V note: UPS function, with battery disconnection	2.50 €

	*1S-8S-Li-po-Battery-Voltage-Tester-Checker-Indicator-Monitor-Buzzer-Alarm* Note: Measures the voltage of the individual elements (max 8) and the total voltage. Perhaps oversized, however, it has a unique function: it beep and turns on an LED when the voltage drops below 2.7V! This can save battery life.	2.21€
	4PCS NCR18650B 3.7V 3400mAh Protected Rechargeable Lithium Battery	35.43 €

Applications DIY

The Ikea BLÅVIK lamp uses 3 NiMH rechargeable AA batteries as power supply, with a 5-hour battery life (with 1000 mAh batteries). Adding the slow charge circuit results in continuous operation.
It can thus be used as a low-power bedside lamp (<0.5 W) with the advantage of working as an emergency lamp in the event of a blackout. For the complete description of the change, see ... ..

The Livarno mod z3199 garden spotlight is marketed by Lidl, and uses 3 AA NiMH 600 mA batteries recharged by a solar panel. It has a motion sensor (PIR) that controls the lighting of the light.
After two years of perfect operation in my garden, the solar cell, exposed to the elements, has become unusable.
By adding a slow charge circuit I can recharge the batteries with a power bank from time to time, or directly from the mains. For the complete description of the change, see ... ..

NiMH AA battery tester.
Automatic operation with microcontroller: insert the NiMH AA battery and check the LEDs.
Safe discharge of charged batteries, a Beep signals the achievement of 0.9 V, avoiding the risk of overdischarge.
Passive circuit, without power supply: uses the remaining battery charge.

References

1) *National Semiconductor,* Battery Chargin: http://www.ti.com/lit/an/snva557/snva557.pdf
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4) *Dr. Gough's*, Experiment: Charging Ni-MH Batteries with Constant Voltage? https://goughlui.com/2019/04/14/experiment-charging-ni-mh-batteries-with-constant-voltage/
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13) Digi-Key's, A Designer's Guide to Lithium (Li-ion) Battery Charging, https://www.digikey.com/en/articles/techzone/2016/sep/a-designer-guide-fast-lithium-ion-battery-charging