Batteries for Effects

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Small effects devices (e.g. distortion boxes of guitars) have always been (and still are) operated using batteries. Does the internal resistance of these batteries influence the sound? Could it be that in particular the zinc-carbon-batteries used back in the day helped generate a different sound compared to the alkaline batteries now seen as standard? Yes, indeed, they may have – and for a very simple reason: the sound of such (analog) effects devices depends on the supply voltage. Without delving into electro-chemistry [1, 2]: chemical mechanisms running in a battery generate an electrical voltage, e.g. 1,5 V in an AA-battery. This is based on decomposition processes: a dissolving metal releases electrons that create an electrical current. Once the metal has completely dissipated, the battery is "empty". However, this does not happen suddenly but the voltage keeps decreasing over time (of use). The speed of this decay depends on the load (the strength of the extracted current) and on the type of battery.

The quantity that lets us estimate the lifetime of a battery is the **capacity**. This term reminds us of the "capacitance" value that is printed on the side of capacitors, and indeed, a battery is a kind of huge capacitor. Still, there are fundamental differences: a capacitor can, for example, be recharged again and again but a (regular, non-rechargeable) battery cannot. The capacitance value of a capacitor has the unit **Farad** (after M. Faraday, 1791-1867), and 1F = 1As/V. A capacitor of a capacitance of 1 F that is charged to 1 V will be able to deliver a current of 1 A for 1 s (o.k. – that's a bit of a simplification but it's not entirely wrong, either). For batteries, we do not find a specification in Farad but a number with the unit Ah (**ampere-hours**). In fact, most non-rechargeable batteries do not even have a specification, but you will have seen one at least on re-chargeable batteries. An AA-battery might have e.g. 0.8Ah, indicating that it can generate a current of 0.8 A for about an hour. Or, it could deliver 0,08 A for 10 hours. Now, however, we need to be a bit more precise: while the battery capacity is calculated by multiplying time and current, this product is not valid for all operating conditions. We will not be able to get 8A for 6 minutes out of that AA-battery, and much less 800A for 3,6 seconds. Also you will not want to operate the battery until it is entirely flat, because long before it is completely depleted, the device supplied with the battery current will not work properly anymore. So, the Ah-specification is just a coarse guide-number for comparing batteries: an alkaline battery of a capacity of 2,1 Ah holds (ideally) three times the charge of a zinc-carbon battery with a specification of 0.7 Ah.

It does not really help to discuss the Ah-specifications extensively, because rarely any manufacturer lists the corresponding value on the batteries, and because (as mentioned above) rarely will any user push a battery into complete discharge. Rather than any technically sensible number, we find fantasy names printed on batteries such as: Longlife, Longlife Extra, Superlife, Special Power ... these would be the bad ones, the (from today's point of view) obsolete zinc-carbon old-timers. And then we have on the other side: High Energy, High Alkaline, Super Alkaline, Ultra Alkaline ... the (more or less) good ones. Looking at the charge-storage capabilities, alkaline batteries clearly are ahead of their zinc-carbon cousins. Professional literature states 1.5 ... 2.1 Ah (alkaline) vs. a mere 0.7 ... 1 Ah (zinc-carbon) for AA-types. Now, however, the guitar player enters the scene and asks: "*well then, these alkalines may be able to store more, but won't my distortion pedal sound worse operating with them compared to if I run them with zinc-carbon? Cause back when they made the only true, good fuzz-boxes, they didn't even have any alkalines – my idols, who set the reference sound-wise, had nothing but zinc-carbon stuff to work with!*"

 Translated by Tilmann Zwicker

This is a justified question. The alkaline-battery did enter the market as early as 1959; nevertheless at least for the 1960's, the zinc-carbon-battery would have been remaining as standard gear. However, in your run-of-the-mill effects, we do not find the AA-battery-type but rather the 9V-block. While the volume of this block is almost 3 times that of a AA-battery, the capacity is still smaller at only 0.3 – 0.4 Ah (for the **zinc-carbon-block**). That is easily explained: the voltage is 6 times higher. Comparing batteries with different voltages, we need to multiply the Ah with the voltage in order to arrive at the (theoretically) stored energy. Examples: car battery = 100Ah x 12V = **1200Wh**; alkaline-AA = 2Ah x 1.5V = **3Wh**; alkaline-block = 0.5Ah x 9V = **4.5Wh**. The unit Wh indicates Watt-hours. The thousand-fold unit – the **kilowatt-hour**, is the unit for the power meter (1kWh = 0.3 €).

It has already been mentioned that the extractable energy depends on the discharge-current. For small currents of a few mA, this is no issue, but at 1 A (for example), the capacity drops to 30 - 60%. We will not look into this issue further since (floor-) effects devices rarely require more than 5 mA (with a few exceptions). The **discharge-curve** merits closer investigation, though: it indicates how the battery voltage under load decreases over time. Again, this depends – strictly speaking – on several factors but the general tendency can be seen in **Fig. 1**. Immediately striking is the fact that the voltage very quickly drops below the nominal 9V! It is no wonder that in the early days the "lifetime" of a battery was specified via the drop to 4.5 V. We can expect that many transistor circuits will not work properly anymore with such low voltages. Or is it here where they actually distort in the right way? In the latter case it would be helpful to install a low-drop control-circuit that suitably stabilizes the supply voltage. What is not necessary is to desperately search for old batteries because only they would create the desired sound: the supply voltage is the one relevant parameter. The internal resistance (including its dynamic component) is so small that it will not influence the sound of the effect. Some supplementary information regarding the right hand part of the figure: it shows the discharge curves of 4 alkaline batteries from the same manufacturer ranging from "Normal" to "Super-Max". In a test report a corresponding comment could be read: "The best of all the tested alkaline-batteries costs 6 (!) times as much as the cheapest ... and features a lifetime of merely 25% more."

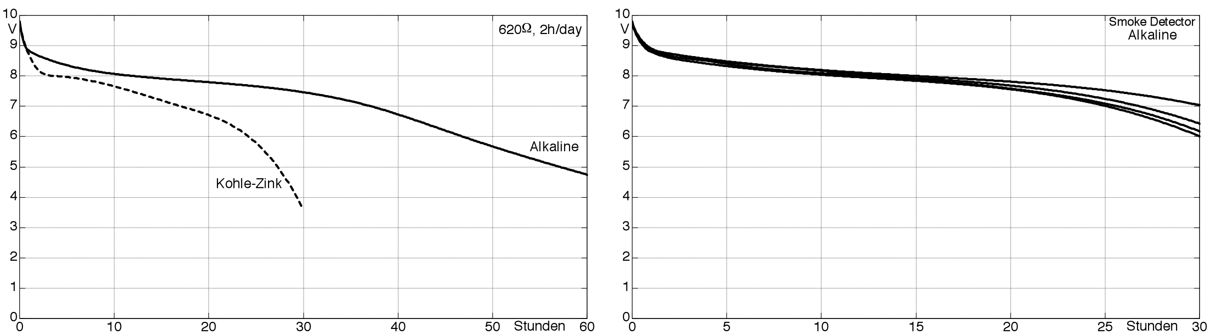

Fig. 1: Discharge-curves, left the comparison zinc-carbon vs. alkaline, on the right four different alkaline batteries. Installed in a smoke detector: 10kΩ load with an additional 620Ω-load in parallel during 1s each hour.

Note: The "capacity" specified for batteries is, physically seen, in fact a "charge":
charge = current x time, with the unit Ah or As (1Ah = 3600As);
capacity = charge / voltage, with the unit Farad = As/V.

Literatur:
[1] Hamann C., Vielstich W.: Elektrochemie, Wiley-VCH, 2005.
[2] Schmickler W.: Grundlagen der Elektrochemie, Vieweg/Teubner, 1996.

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