Morse Code Tutor -
From the ground up.

Part 11: Battery Operation

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A fellow ham wanted to demonstrate his latest project. He took his Morse Code Tutor to a local hamfest, armed with a 9V battery to power it. Unfortunately, the battery died, cutting the demonstration short. Has this ever happened to you?

The story got me thinking about battery power. I always plug mine in. But an AC outlet is not always available. If 9V batteries aren't the answer, what is?

Consider how power is supplied to the Tutor. The circuit is currently designed to run on 5V internally. This 5V is supplied via a DC-DC buck converter, which converts the input voltage (7-15VDC) to 5V. Note that 6V input on the barrel connector will still work, but result in less than 5V at the output of the converter.

I made a series of measurements regarding current draw and battery life. Almost all of these measurements were made at the 5V input point: in other words, between the buck converter and the rest of the circuit.

W8BH Morse Tutor current draw at 5 VDC:

Device	Current (mA) at rest	Current (mA) with WiFi on
Blue Pill with 2.2" display	160	n/a
ESP32 with 2.2" display	160	240
ESP32 with 3.2" display	160	240

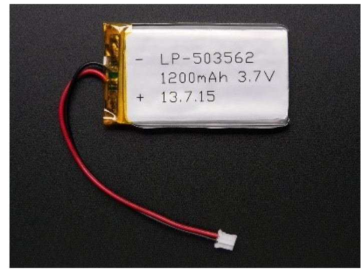
I assumed that the larger display would have a larger current draw. In practice the larger display did not require more power. But the WiFi radio requires significantly more power. Even in receive, about 80 mA of additional power is required. During transmit, power spikes of a few hundred mA are required, but these spikes are very brief - on the order of a few milliseconds - and do not appear on the multimeter. Bottom line: use AC power or a larger battery if you intend to transmit.

The buck module converts higher input voltages down to 5V with relatively good efficiency. The quoted efficiency of these devices is around 90%. In practice, at 9V input the current draw is 110 mA, and the efficiency is power out/power in = (5V * 160 mA) /(9 V* 108 mA) = 80%.

We can avoid power losses in the buck converter if we supply 5V directly to the circuit. But there are no handy 5V cells to choose from (5V battery packs are usually 3.7 V cells with internal boost circuitry).

Any supply greater than 5.25V would likely harm the internal components, and the blue-pill 5V regulator is known to be rather weak. So… how low can you go? In other words, if we can't supply 5.0V and don't have room to go higher, what is the lowest input voltage we can supply and still have a working device? The answer, based on empirical observation of the ESP32 version, is about 3.65V.

Fortunately, we have many battery choices between 5 and 3.7V.   Which is best? I concentrated on two types of battery: non-rechargeable, department-store alkaline cells and rechargeable lithium-polymer cells. The Lipo cells, like the one shown here, have built-in protection circuity and are terminated with JST-PH connectors. You may have other favorites, but the table below should give you a good idea of what to expect with your battery of choice.



I tested several combinations, and list them here from shortest to longest runtime. For these tests I used the ESP32 Tutor with a 3.2" display, and played a text file from the SD card at 20 WPM at medium (just under 50%) volume with the on-board speaker. I recorded the voltage drop over time, and noted when playback stopped. I did not go to the store for the newest, freshest batteries, but instead chose right-from-the-package cells from my battery drawer. I am sorry to report that many batteries were harmed during this experiment. My Lipo cells are 2-6 years old and have each gone through tens of discharge cycles.

Battery	Power Conversion*	Runtime (hours)
9V alkaline	Buck	0.8
2 AA alkaline (3V)	Boost	1.0
350 mAh 3.7V Lipo	None	1.2
350 mAh 3.7V Lipo	Boost	1.3
500 mAh 3.7V Lipo	None	1.5 – 1.7
3 AAA alkaline (4.5V)	None	1.5
4 AAA alkaline (6V)	Buck	3.1
3 AA alkaline (4.5V)	None	6.0
1300 mAh 3.7V Lipo	None	7.2
2800 mAh 5V Lipo	Internal	9.1
4400 mAh 3.7V Lipo	None	16.0

*Power Conversion details:

1. None = direct connection from battery to 5V input
2. Boost = connection of battery to 5V input via Comidox 5V boost module
3. Buck = connection of battery to 5V input via mini360 buck module (set at 5V)
4. Internal = direct connection of Battery w/ internal boost to 5V input

There are a few important things to notice. First, as expected, the 9V battery is a poor choice in terms of runtime.   These batteries are typically rated at 150 mAh.   I was lucky to get one hour out of one, at around 100 mAh.   I don't recommend using them unless that's all you've got.

I was hoping that three (3) AAA alkalines would yield a few hours of runtime, but they did not. Perhaps my batteries were not fresh enough.

Three (3) AA batteries are a very good choice. At 6 hours of continuous runtime they offer a good tradeoff between size, cost, and ease of use.

If you need very long runtimes, consider a Lipo battery. My two-cell (18650) battery pack at 4400 mAh lasted a whopping 16 hours before the Tutor quit. Note that these batteries are only about 60% discharged when their voltage falls below the 3.65V threshold. So, for 3.7V Lipo cells, make sure they are fully charged to 4.2V before using.

You might consider using a battery with a boost circuit. Similar to buck converters, these modules will raise an input voltage of 1.5V-4.5V to 5V. I experimented with a tiny boost converter, but it did not significantly lengthen the runtime of two (2) AA batteries in series, nor help a small 350 mAh Lipo battery. You may have better results.

Is there a better way to battery power? One final consideration would be to use power the circuit from 3.3V instead of 5V. This would require a board re-design, but could save power if long battery operation is a must.

Summary:

1. The Morse Tutor reliably works down to 3.65 volts on its 5V input
2. Batteries that don't work well (less than 2 hours of playback)
    a. 9V batteries
    b. (3) AAA batteries in series
    c. (2) AA/AAA batteries in series with boost module
3. Batteries good enough for a day at the hamfest
    a. 3 AA batteries in series, yielding 6 hours playback.
    b. 1300-4400 mAh Lipo batteries: 7-16 hours
4. The WiFi radio requires significantly more power, even in receive.