btest – Battery test software for HP 50g

Release : 20 September 2007

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Notes:

The measurements time is variable and may take 10s of seconds.

The current (I) values used in the formula are constants measured during program development and are part of the calibration matching the results to a particular HP 50g and set of test equipment. Variations between calculators contribute to lower the accuracy of the results.

Correction / suggestion: asmcode gmail.com

Voltage measurements:

The voltage measurement is taken while the CPU is set to a lower frequency than normal which reduces the rate of voltage change while using a battery power source. Then a number of readings are taken and summed together so:

$$\frac{\sum^{2^5} ADC_{10\text{bit}}}{2^2} \approx ADC_{13\text{bit}}$$

This method produces a more precise voltage value than relying on a single reading at 10 bits where the least significant bit is affected by noise.

The voltage reading is calibrated to agree with the voltage meters used on one particular HP 50g (at 24 C). This is to say the program used on any other calculator will very likely vary. Hopefully not by much.

Assumptions: The voltage change due to gradual battery depletion is insignificant during the interval of measurement while the device is set to 0.85MHz (the current draw is ~6mA).

Resistance measurement:

Any power source that is likely to be connected to the HP 50g will have a source resistance resulting in a voltage drop seen by the ADC with an increase in current draw. A lower source resistance results in a lower voltage drop and therefore a lower usable voltage at maximum load.

The formula used to estimate source resistance is:

$$R_{\text{source}} = \frac{V_{0.85\text{MHz}} - V_{202.8\text{MHz}}}{I_{difference}}$$

The voltage measurement is taken after enough time is given for the current draw of the regulator to match that of the circuits. The regulator takes time to adjust to an increase in current draw during which period the output capacitors make up for the regulator deficiency, briefly masking the true source resistance.

Assumptions made for resistance calculation: The HP 50g uses a linear regulator and therefore has a constant current draw for any input voltage above the low battery warning (running a given algorithm and set to a particular CPU frequency).

Maximum current:

The source resistance determines the lower limit on the usable input voltage. Lower voltages or a greater source resistance will reduce the maximum current that may be drawn by the HP 50g before a low battery condition is detected. The low battery level used by the program (4.72V) was not measured accurately consequently the maximum current reading is not intended to be used as an indication of an actual maximum current draw.

For a voltage reading alone to be used to determine remaining capacity the value must be compared against a discharge curve that corresponds to the battery chemistry. Short of including a tentative sample of curves related to common battery types, the source resistance and maximum current values may be used to estimate remaining capacity with some confidence.

As a rough indication, during start up the HP 50g's peak current draw is under 100 mA. The batteries are still usable provided they can source this current without the voltage dropping below the minimum for the regulator.

Power loss during conversion:

Zero loss would require the source voltage to match the requirements of the HP 50g circuits and have no source resistance.

This not being the case, the following formula is used tentatively to estimate conversion loss, including voltage source resistance as a factor based on the assumption that a more efficient conversion would draw less current so the converter is at least responsible for some of the energy loss to heat overcoming source resistance.

$$\frac{100\times(V_0-3.3\text{V})}{V_0}=\%_{LOSS} \quad \text{where} \quad V_0=V_{0.85\text{MHz}}+I_{0.85\text{MHz}}R_{internal}$$

The average conversion efficiency using four AAA alkaline/Zinc Chloride batteries is under 65%. The energy of at least one cell is wasted. Assuming the linear regulator could operate down to ~3.4V then using three AAA alkaline batteries instead of four would theoretically provide an equal run time (with the low battery warning turned on during most of the usable capacity).

A lower voltage power source (which could maintain it's usable voltage above the minimum required) and of the same mAh rating would provide a similar run time under the same operating conditions. For example rechargeable batteries have a lower starting voltage which results in a lower average loss than alkaline or Zinc Chloride.

Rough estimates using four AAA cells:

Chemistry	Capacity (mAh)	average loss %	Effective (mAh)
Alkaline	1100	~45	605
NiMH	950	~33	635

References:

Atmel Application Note AVR121

Wikipedia articles:
AAA_battery
Rechargeable_alkaline_battery
Nickel_metal_hydride_battery
Nickel-cadmium_battery

License:

Disclaimer:

The software uses the HP 50g in ways that the device may not have been designed for. While our particular device exhibited no worrying signals or suffered damage during development (not even any smoke) no guarantee is made that the use of the program is safe to run on a HP 50g, that it will produce no long term damage or that it will not void the warranty.

There may be a risk involved in running software on your HP 50g that uses the device in any way for which it was not intended.

The software is provided as-is and on condition that the user accepts responsibility for the consequences of its use.