Energizer

TECHNICAL BULLETIN

Battery Internal Resistance Version 1.1.0 December 2005

Battery Internal Resistance

The internal resistance (IR) of a battery is defined as the opposition to the flow of current within the battery. There are two basic components that impact the internal resistance of a battery; they are electronic resistance and ionic resistance. The electronic resistance plus the ionic resistance will be referred to as the **total effective resistance**.

The electronic resistance encompasses the resistivity of the actual materials such as the metal covers and internal components; as well as, how well these materials make contact with each other. The effect of this portion of the total effective resistance occurs very quickly and can be seen within the first few milliseconds after a battery is place under load.

Ionic resistance is the resistance to current flow within the battery due to various electrochemical factors such as, electrolyte conductivity, ion mobility and electrode surface area. These polarization effects occur more slowly than electronic resistance with the contribution to total effective resistance typically starting a few milliseconds or more after a battery is placed under load.

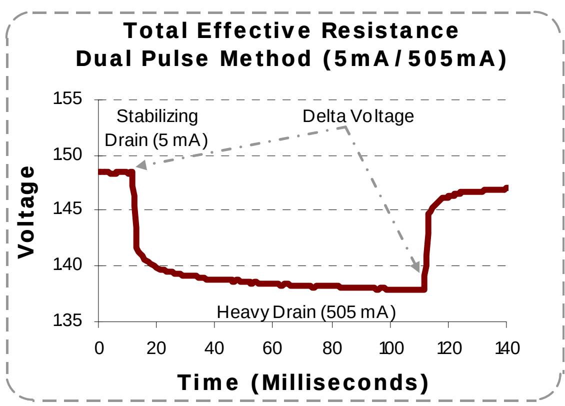
A 1000 Hz impedance test is sometimes used to represent internal resistance. Impedance is defined as resistance to AC current flow. Due to the high speed of a 1000 Hz test, a portion of the ionic resistance factors may not be fully captured.

Typically, the 1000 Hz impedance value will be less than the total effective resistance value for the same battery. An impedance test across a range of frequencies is recommended to accurately portray internal resistance.

The impact of electronic and ionic resistance can be observed using a dual pulse test. This test involves placing a battery on a low background drain allowing it to first stabilize and then pulsing it with a heavier load for approximately 100 milliseconds.

Using "Ohms Law", the total effective resistance is subsequently calculated by dividing the change in voltage by the change in current.

As an example (fig. 1), if a 5 mA stabilization load is used in combination with a 505 mA pulse, the change in current is 500 mA. If the voltage changes from 1.485 to 1.378, the delta voltage would be 0.107 Volts, thus yielding a total effective resistance of 0.107 Volts / 500mA or 0.214 Ohms.



(fig. 1)

The typical effective resistances of fresh Energizer alkaline cylindrical batteries (using a 5 mA stabilization drain followed by a 505 mA 100 millisecond pulse) will be approximately 150 to 300 milliohms, depending on size.

Flash amps can also be used to provide an estimate of internal resistance. Flash amps are defined as the maximum current a battery can deliver for a very short period of time. This test is typically performed by electrically shorting a battery with a 0.01 ohm resistor for approximately 0.2 seconds and capturing the closed circuit voltage. The current flow through the resistor can be calculated using Ohms Law and dividing the closed circuit voltage by 0.01 ohms. The open circuit voltage prior to the test is divided by the flash amps to obtain an estimate of internal resistance. Since Flash Amps can be difficult to accurately measure and OCV is dependent on many factors, this measurement technique should only be used as a general estimate of internal resistance.

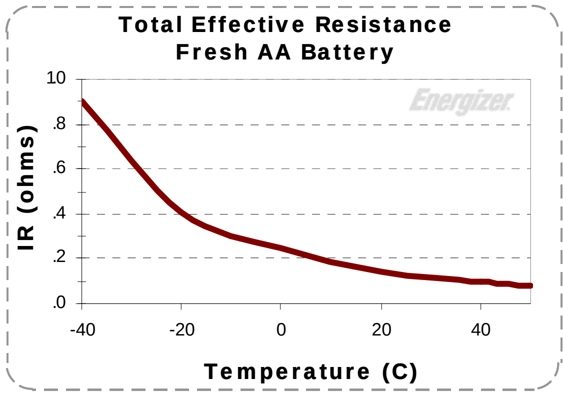
The voltage drop of a battery under load is a function of total effective resistance and current drain rate. An estimate of initial voltage drop under load can be calculated by multiplying the total effective resistance by the current drain placed on the battery.

Example: A 1 Amp drain is placed on a battery with an IR of 0.1 Ohms.
1.0 Amps X 0.1 Ohms = 0.1 Volts
Open circuit voltage = 1.6 Volts
1.6 Volts – 0.1 Volts = 1.5 Volts
(expected closed circuit voltage)

In general, internal resistance will rise during discharge due to the active materials within the battery being used. However, the rate of change during discharge is not consistent. Battery chemistry, depth of discharge, drain rate and the age of the battery can all impact internal resistance during discharge.

Cold temperatures cause the electrochemical reactions that take place within the battery to slow down and will reduce ion mobility in the electrolyte. Subsequently, internal resistance will rise as ambient temperatures drops.

The graph (fig. 2) shows the effect of temperature on the total effective resistance of a fresh Energizer E91 AA alkaline battery.



(fig 2.)

In summary, internal resistance can be calculated based on the voltage drop of the battery under a known load. Results will be affected by technique, settings and environmental conditions. The internal resistance of a battery should be viewed as a general guideline and not as a precise value when applying it to the expected voltage drop in a specific application.