

Simple Circuit Measures Battery Impedance

This application note describes the use of a current-sense amplifier, op amp and variable load to calculate the internal impedance of any battery up to 36V. Battery impedance measurement is an important parameter in determining response to changes in load current, charging currents, short circuits, etc.

The circuit of **Figure 1** lets you calculate battery impedance as the ratio of an ac voltage applied across the battery to the resulting ac current through the battery. Batteries are seldom specified for parameters other than voltage and amp-hour capacity, but this internal impedance is important. A photo flash, for example, recycles twice as fast with nickel-cadmium (NiCd) batteries as with higher impedance alkaline types.

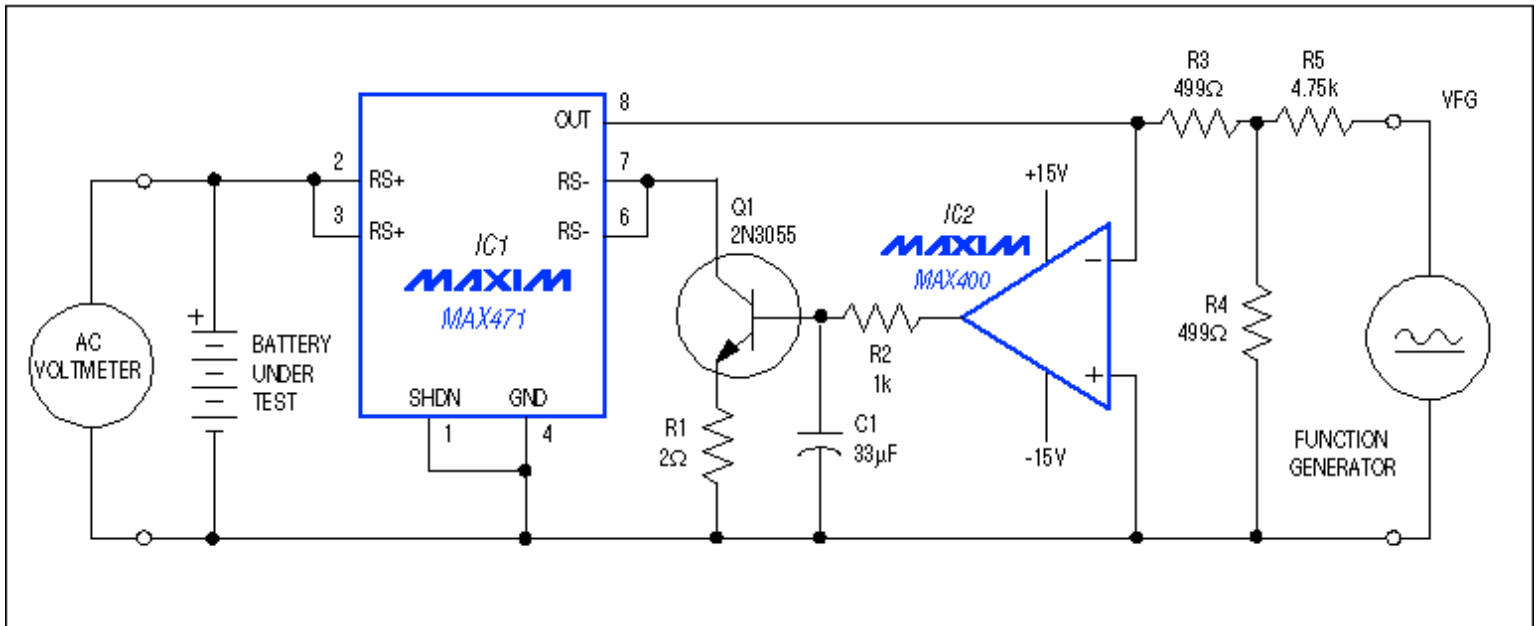


Figure 1. With a bench power supply, function generator, and ac voltmeter, this circuit measures battery impedance under a varying load.

By applying an ac voltage superimposed on a ten-times-larger negative-dc voltage (at VFG), the function generator determines the battery current drawn by Q1. Generator voltage causes the op-amp output to go high and turn Q1 on, which allows battery current to flow through the high-side current-sensing amplifier IC1. IC1's output current (pin 8) equals 1/2000 of this battery current.

C1, IC2, and Q1 thus form a loop in which the op amp forces a virtual ground at the left end of R3. The op amp's extremely low offset voltage (10μV maximum) ensures accuracy. This virtual-ground condition enables the voltage divider (R5 and R3 || R4) and function generator to determine the voltage across R3. The following equation represents the resulting current in R3:

$$i_{R3} = \frac{R3 \parallel R4}{R3 \parallel R4 + R5} \times \frac{V_{FG}}{R3}$$

Substituting resistor values and noting that battery current is 2000 times i_{R3} ,

$$i_{\text{BATTERY}} = -\frac{V_{\text{FG}}}{5}$$

To operate, set the generator's ac voltage to approximately 10% of its dc component. Equation 2 then gives the resulting ac current in the battery (i_B). Using an ac voltmeter, you can measure ac voltage across the battery (v_B) and calculate the average cell impedance as $v_B / (Ni_B)$, where N is the number of cells. The circuit easily accommodates battery voltages of 3V or more.

You can replace the R3/R4/R5 network with its Thevenin equivalent, but the result is a smaller V_{FG} . You can regain the V_{FG} magnitude by substituting a larger value for R3, but the resulting increase in loop gain can cause instability. R2/C1 is a frequency-compensation network for the configuration shown.

The crude voltage-to-current converter (Q1/R1) should not allow Q1 to saturate under the conditions of peak battery current and minimum battery voltage. The V-to-I transconductance (set by R1) combines with IC1's scaling factor (1/2000) and the impedance seen by IC1's signal output (pin 8) to affect the loop gain. For the resistor values shown, the suggested test frequency-about 100Hz-is one for which most ac voltmeters are quite accurate.

Table 1 shows measurements made by this circuit on freshly charged NiCd and alkaline batteries.

Table 1. Measurements Made by MAX471 on Freshly Charged NiCd and Alkaline Batteries

BATTERY TYPE	NUMBER OF CELLS	BATTERY CURRENT		ac BATTERY VOLTAGE (mVp-p)	PER-CELL IMPEDANCE (Ω)
		dc (A)	ac (mA _{p-p})		
NiCd AA	4	0.4	40	19.8 (7mV _{RMS})	0.124
Alkaline AA	4	0.4	40	50.9 (18mV _{RMS})	0.318

NiCd impedance is about one-third that of alkaline, but alkaline capacity is generally double that of NiCd. This circuit applies a known and fixed ac current regardless of the battery's terminal voltage, so a simple data logger enables it to monitor battery impedance over the battery's lifetime. Because the battery current is servo-controlled, the impedance measurement (though quite small) is relatively unaffected by the circuit wiring and connections. The ac battery voltage, however, is a measure of the quality of connections between the cells and from the cells to the battery holder.

More Information

MAX400: [QuickView](#) -- [Full \(PDF\) Data Sheet](#) -- [Free Samples](#)

MAX471: [QuickView](#) -- [Full \(PDF\) Data Sheet](#) -- [Free Samples](#)