

# Simulating Battery Impedance with the Model 2302 and 2306 Battery Simulator/Chargers

## Introduction

The impedance of cells and battery packs varies according to a variety of factors, such as, but not limited to, chemistry, mechanical construction, number of charge/discharge cycles, temperature, and depth of discharge. In applications using batteries with dynamic or pulsed current loads, the voltage across the DUT may vary significantly. If the peak load current is high enough, the voltage drop caused by the impedance of the battery may compromise the performance of the device, including shutdown if the voltage transient is below the operating threshold. This phenomenon is common in TDMA and GSM cellular handsets where the magnitude of the high and low current levels during RF transmission vary by as much as a factor of 20. In the absence of any filtering capacitance between the battery and the RF power amplifier, the handset will shut off if the supply voltage is below the operating threshold for periods as short as several microseconds. The variable impedance output, available exclusively in the Model 2302/2306 battery simulators, enables test and design engineers to simulate the transient voltage response of a battery with pulsed current loads.

## Theory

The battery channel in the Models 2302 and 2306 is designed with a variable impedance output to facilitate evaluation of handset performance with a “real” battery, i.e., having a non-zero, variable impedance during the course of operation. **Figure 1** shows the transient voltage and current performance of a typical GSM handset with the battery channel and output impedance set

to  $0.00\Omega$ . With the exception of the brief transient at the beginning and end of the pulse, the voltage drop at the battery terminals of the handset is nearly zero. The objective is to maintain the programmed voltage across the DUT (or in other words, maintain an effective output impedance of approximately  $0.00\Omega$ ).

In reality, batteries do not have zero impedance and the voltage drop produced by pulsed current loads may have a significant effect on the performance of the device. **Figure 2** shows a simple schematic of a battery, represented by an ideal voltage source ( $V_{cell}$ ), the internal impedance ( $R_i(t)$ ), connected to a DUT with interconnects having a resistance ( $R_{interconnect}$ ).

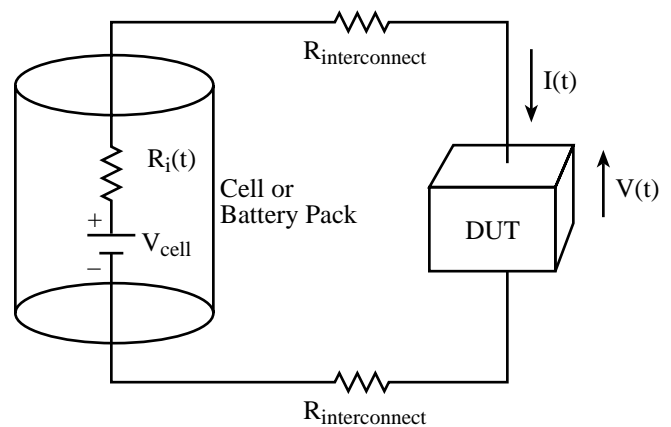


Figure 2. Schematic of a battery represented by an ideal voltage source and a time varying internal impedance connected to a DUT.

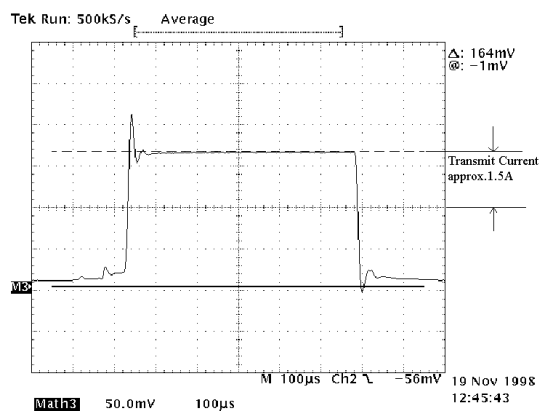
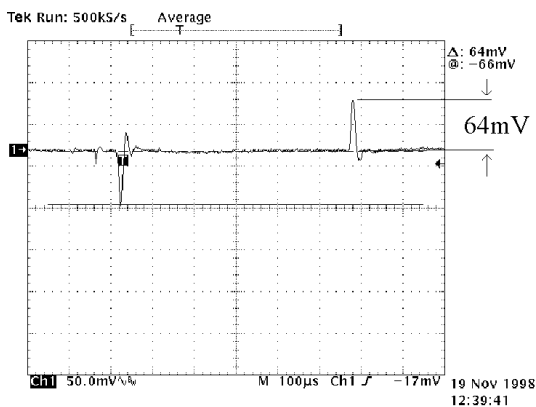


Figure 1. Transient voltage and current performance of a typical GSM handset with the battery channel and output impedance set to  $0.00\Omega$ .

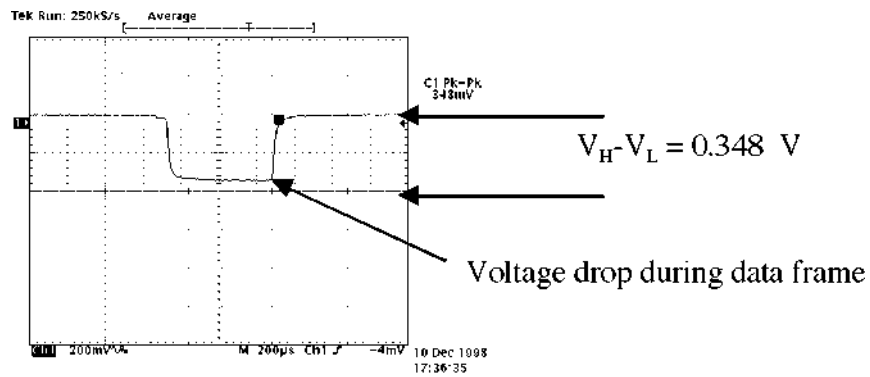


Figure 3. Voltage drop during the data frame of a GSM phone with the supplied Li ion battery.

If  $R_{interconnect}$  is small compared to  $R_i(t)$  and  $R_i(t)$  is assumed to be relatively constant during the length of the pulse,  $R_i(t) \approx R_i$ , then the voltage across the DUT may be expressed as:

$$V(t) = I(t)R_i(t) \approx I(t)R_i$$

where  $I(t)$  is the time varying current through the battery.

Figure 3 shows the voltage at the battery terminals of the same GSM phone as in Figure 1, using the battery supplied with the handset.

Figure 4 shows the actual performance of typical Li-ion, NiMH, and NiCd handset battery packs with a dynamic load simulating a GSM handset during transmission. The pulse minimum voltage is the voltage at the battery terminals during the transmit, or high current, portion of the data frame. The average battery voltage is the voltage across the terminals measured with a 6½-digit DMM at approximately 50 readings per second. In all cases, the pulse minimum voltage reaches the arbitrarily speci-

fied shut-off threshold of 5.7V before the average battery voltage by a significant margin. Also, the difference between the pulse minimum voltage and the average battery voltage varies for different battery packs and ranges between 200 and 500mV. Since voltage levels below the operating threshold of the RF amplifier for periods as short as 5–10µs are sufficient to shut off the handset, the critical voltage necessary to maintain handset operation is the pulse minimum voltage. These measurements show that battery impedance must be considered when evaluating handset talk time and standby performance.

## Application and Performance

Several methods can be used to determine the electronic resistance of a cell or battery pack. The first method uses information provided by the battery manufacturer or direct measurements with a suitable instrument. Here's how to obtain a close estimate

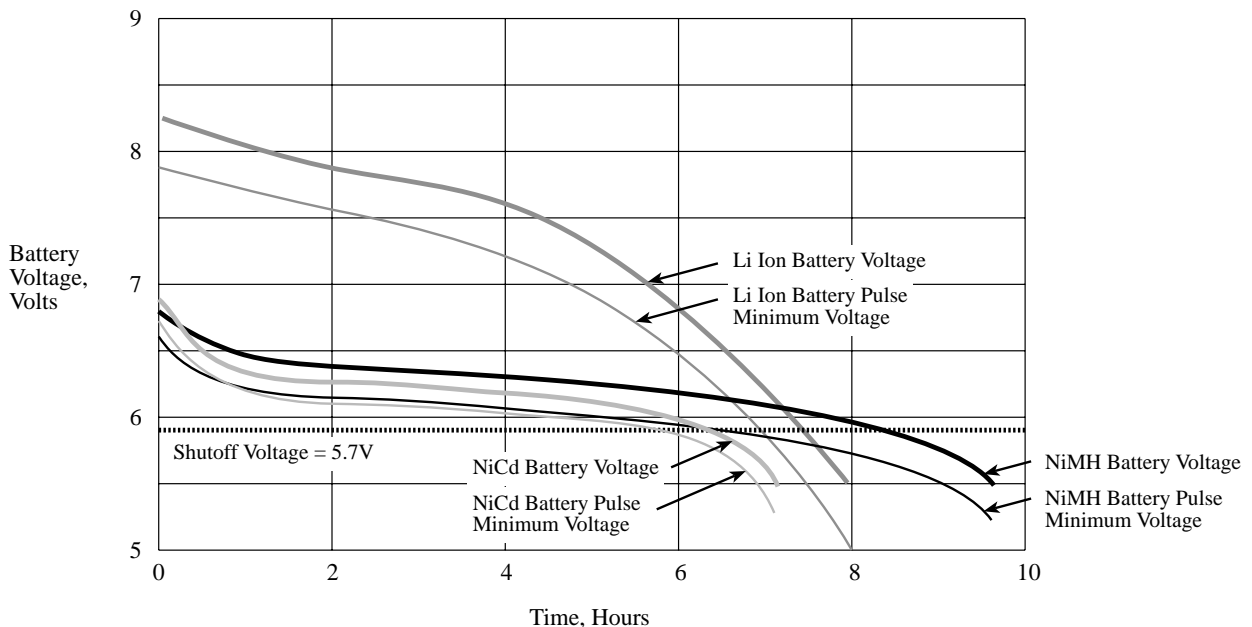


Figure 4. Average and minimum battery pack voltage during a load pulse from a dynamic load simulating a TDMA phone.

of the electronic resistance under actual operating conditions, using a two-channel oscilloscope, a non-inductive power resistor, the battery (pack), and the DUT:

1. Connect the battery pack to the handset with the  $0.1\Omega$  resistor using several inches of heavy gage wire, as shown in **Figure 5**.
2. Connect the channel #1 oscilloscope probe to the battery terminals of the phone to record the voltage waveform. Connect channel #2 across the resistor to display the current waveform at  $1A/100mV$ .
3. Place the handset in the desired operating mode and record the voltage and current values at the low current and high current levels of the pulse.
4. Once these values are obtained, the electronic resistance of the battery can be calculated using:

$$R_i = \frac{V_H - V_L}{I_H - I_L} - R_t$$

where  $R_t$  is the resistance of the  $0.1\Omega$  resistor and the short length of heavy gage wire, and  $V_H, V_L, I_H,$  and  $I_L$  are the voltage and current levels during the high and low levels of the pulse.

In our example,  $V_H - V_L = 0.348V$  from **Figure 3**,  $I_H - I_L = 1.454 A$ , and  $R_t$  was measured to be  $0.115\Omega$ . The value of  $R_i$  may be determined by performing a 4-wire resistance measurement with a high-quality DMM. Inserting these values into the previous equation, we calculate  $R_i$  to be  $0.239\Omega$ . To verify the results the phone is disconnected from the battery and connected to the output of the to Model 2306 battery channel. **Figure 6** shows the voltage waveform of the phone with the output impedance of the Model 2306 set to  $0.24\Omega$ .

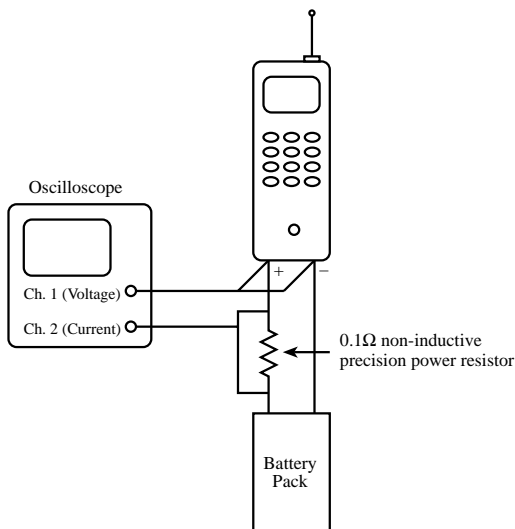


Figure 5. The connections between the battery pack and the phone used to calculate the electronic resistance.

For this value of output impedance, the voltage drop across the output terminals is  $0.360V$ . This value agrees to within 3% with the results obtained using the battery included with the handset.

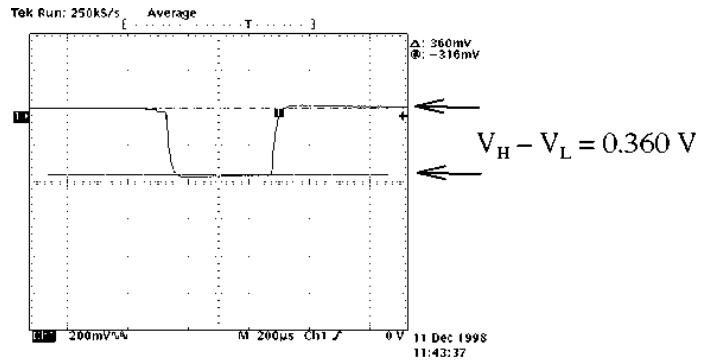


Figure 6. Voltage drop during the transmit portion of the pulse of a GSM phone with the Model 2306 battery channel, output impedance set to  $0.24\Omega$ .

## Example Application

This application illustrates simulating a reference battery pack with the Model 2302/2306 to examine the power consumption characteristics of an RF power amplifier module in a GSM handset. **Figure 7** shows the current consumption of the GSM handset during transmission with a Model 2302/2306 simulating a battery with a nominal output voltage of  $3.60V$ . During transmission, the output impedance of the supply is increased in  $10m\Omega$  increments from  $0.00$  to  $0.51\Omega$  until the phone shuts off. The graph clearly shows the RF amplifier draws increasing amounts of current as it attempts to maintain a constant output power level as the available voltage during the pulse decreases. Since the average current consumption is strongly affected by the increase in the transmit current level, it shows a similar dependence on the output impedance of the simulated battery. Using this technique and additional measurement equipment, effects of the voltage drop during the pulse on other performance parameters of the handset may also be investigated. The Model 2302/2306 provides an accurate and repeatable substitute for a battery when excellent transient performance and the ability to vary the output impedance are required.

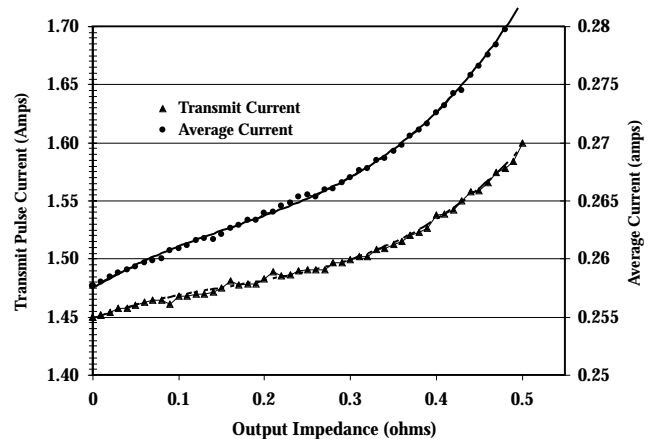


Figure 7. The transmit and average current consumption of a typical GSM handset during transmission with a Model 2302/2306 simulating a battery with a nominal output voltage of  $3.60V$  and output impedance from  $0.00$  to  $0.51\Omega$ .

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