Application Note

Urban Drive Profile Cycle Testing (Arbitrary Waveforms)

Application Note UDPC100

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Standard charge/discharge battery cycling provides essential information about cell efficiency, state of health SOH, state of charge SOC, but does not simulate the real-life environment experienced by cells for example in electric vehicle applications. Standard charge / discharge tests leave a great deal unknown that could lead to major safety, degradation, and reliability issues when energy devices are used in real-life conditions.

As an example, driving an electric vehicle in an urban environment requires frequent adjustments to vehicle speed (acceleration, deceleration, stopping, starting, and idling). This applies unique stresses to the power source, for example the Li-Ion battery pack. Vehicle air-conditioning / heating, plus passenger loading are additionally applied to the battery during typical use.

In electric vehicles, regenerative braking also applies stresses with frequent switching between charge and discharge. Switching from regenerative charge mode during braking to sudden discharge fast acceleration provide major challenges to battery pack durability. Of course, batteries can be tested in actual road usage, but this is both time consuming and expensive, and does not provide methods to reliably compare different battery technologies as each drive will be different. Urban drive profile cycles enable effective and efficient reproduction of real-world conditions in a safe environment.

Standard Urban Drive Profiles (for example IEC 62660)

Use of test equipment able to perform standardized urban drive cycle tests such as **IEC 62660** provides performance and life testing for secondary Li-Ion cells used in battery electric vehicles BEV, hybrid electric vehicles HEV, and Plug-in hybrid electric vehicles PHEV. Standard profiles allow real-world comparison between competing vehicles and battery chemistries.

Dedicated User Specific Profiles

In addition to standard approved urban drive profiles, dedicated unique profiles can easily be developed to test specific battery load conditions obtained from recorded data. These are unique per manufacturer and can be extensive in duration depending on what test conditions are to be reproduced. In response to this requirement, Solartron has developed a unique test capability to replay continuous test sequences, only limited by the size of disk drive that stores the test profile(s).

In addition, these profiles can be reproduced with high definition due to Solartron battery analyzer's 24-bit performance and high system data rates. This capability provides a technological edge in cell development, enabling development of batteries that have superior capabilities that out-perform competitor systems.

Other applications:

Electric vehicle development is a major application that requires simulation of real-life charge/discharge conditions. However, there are many other applications able to make use of this technology. Diverse applications include:

- Air-taxi flight loading (simulating take-off, landing, hovering, high head wind loading etc.)
- Similarly for parcel delivery drones
- Development of energy sources for power tools
- Military applications

The applications are endless.

SI-9300R Unique Test Capabilities

The SI-9300R battery analysis system has unique market-leading capabilities for urban drive cycle testing and simulation, in a wide range of conditions. Due to its patented technology, the SI-9300R is able to apply continuous arbitrary waveform sequences, and at the highest sample rate in the industry.

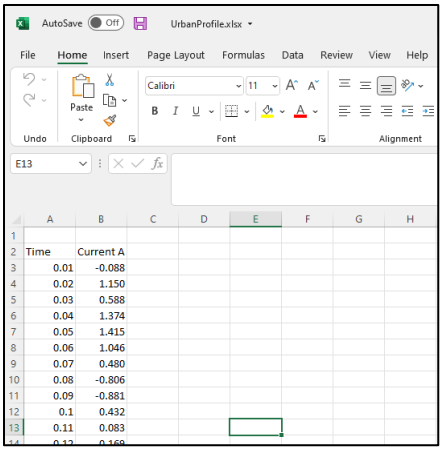
Check out these features:

- Multiple waveforms derived from standards, from calculations, or from measured parameters - voltage, current, power or load sequences, can be configured as CSV text files and stored on a shared centralized disk drive ready for use.
    - Cycler channels directly access stored data allowing unlimited waveform duration with sequences that can run for hours or days as needed
    - Fast time increments (up to 1 msec per point) enables combinations of ramps, pulses, and even sinusoids to be applied to the cell
- Waveforms can be repeated, looped, or sequenced to simulate different conditions.
- Multiple channels can sequence profiles simultaneously – no overall "system limit" on measurement rates. Each channel can collect and store data at a high rate of up to 1000 s/s using patented direct to disk technology (without PC intervention!)
- Fast charge/discharge switching to accurately simulate regenerative braking unlike many cyclers designed using electrical switching.
- Safety limits are available throughout the sequencing to ensure cell safety by monitoring voltage, current, power, load, temperature, and other key parameters.
- Climate chambers can be automatically controlled throughout all sequences.
- Coulometry is available during profile operation to observe overall cell charge / discharge during the sequence.
- Analytical techniques such as EIS can be integrated between urban drive cycle sequences to provide detailed cell degradation analysis.

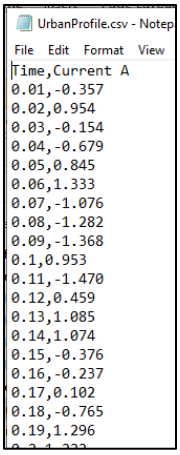
Urban Drive Cycle Test Procedure Setup

Step1: Create CSV text files that contain the waveform data

Data is created in one or more drive cycle text files (CSV comma separated variable files). Excel or mathematical/scientific programs can be used to create the data using algorithms, formulas, or direct data entry. Data is set up in two columns representing time and the applied level (as voltage, current, power or load). The rows in the data represent the time increments which, for this system, can be as fast as 1 millisecond per point. The data is then exported into one or more text (CSV) files and can then be assigned to arbitrary waveform steps in the Test Procedure.

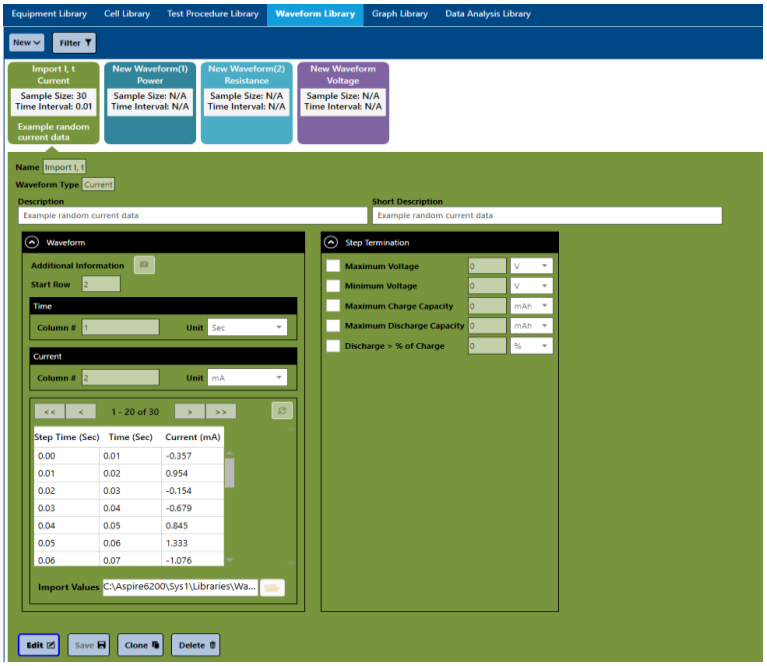


Create simple 2 column file (Time and Current level) in Excel, and Export to CSV file.



Step2: Import to Waveform Library

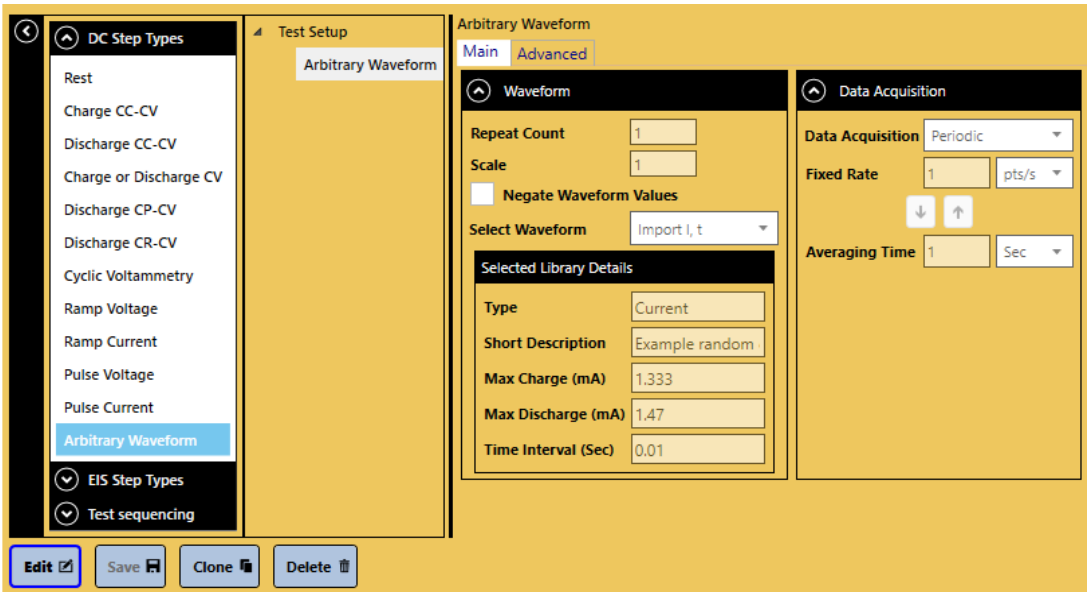
One or more waveform libraries can be created that allow the waveforms to be collected in centralized folder locations – usually on a Network Attached Storage (NAS) disk drive. The waveforms and libraries are available to all users of the system, (no need to copy from one



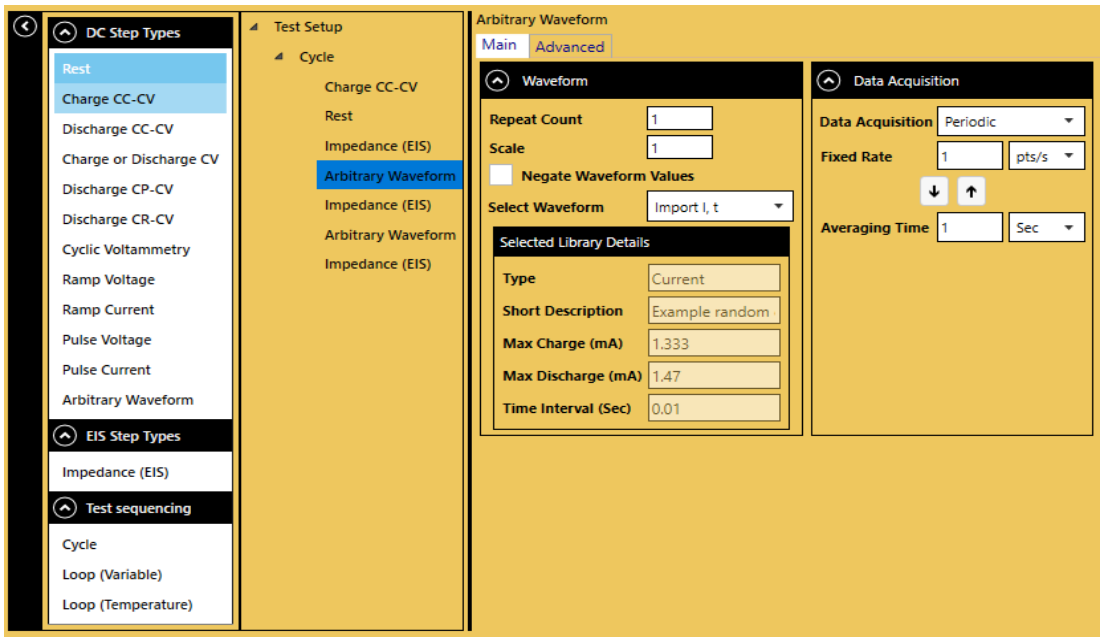
user to another). Each waveform has an individual library entry. Different colors are used to represent current, voltage, power, or load profiles as shown above. Unlimited numbers of waveforms can be stored.

Step3: Create Test Procedures

This can be a simple single step Test Procedure as shown here that runs a single waveform.



Alternatively, comprehensive Test Sequences can be set up that use more than one waveform profile together with standard CC-CV charge steps, rests, and EIS impedance analysis to monitor the effect of the cycled profiles. This example shows cycling of multiple tests in sequence:

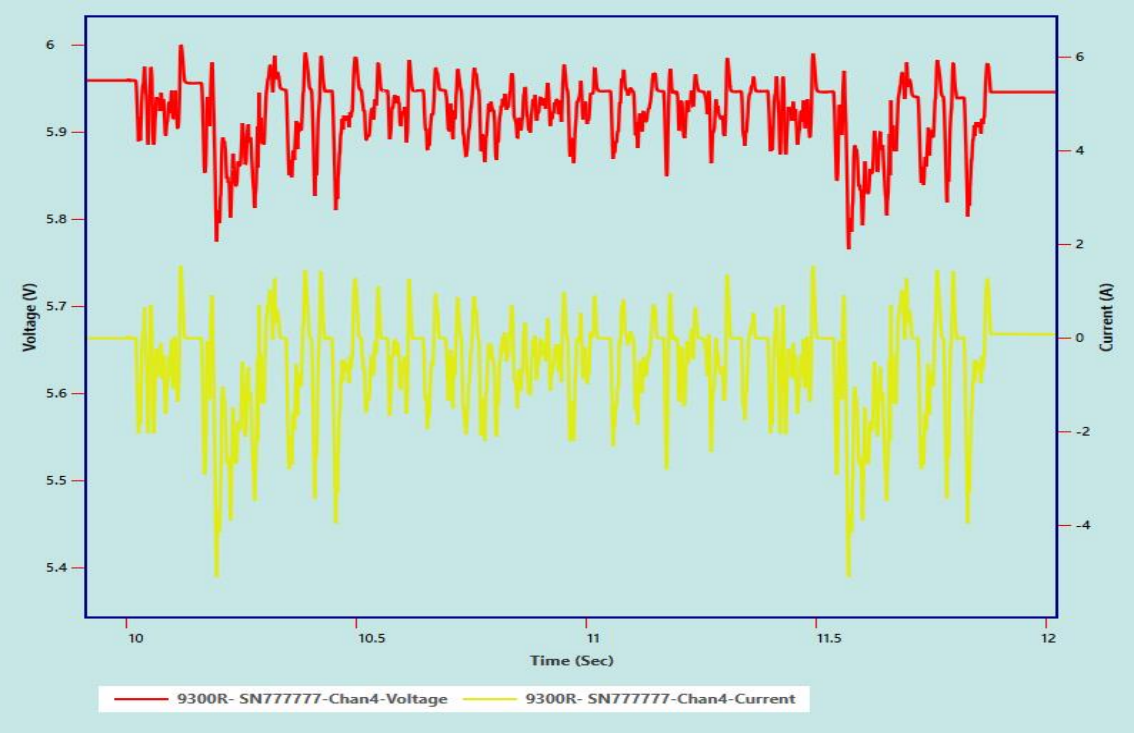


Step4: Data Collection and Analysis

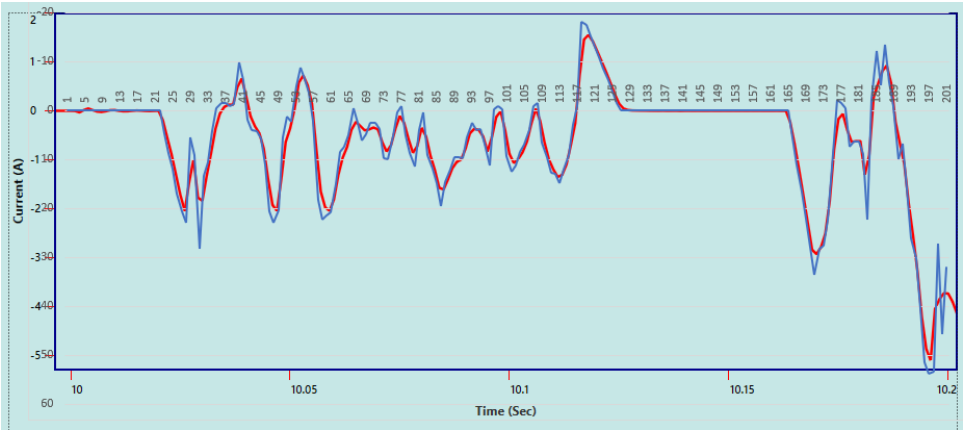
The test sequence can be configured to collect data at up to 1000 s/s simultaneously **on all channels**, independent of the rate of steps in the drive profile. The SI-9300R uses patented Direct to Disk data storage technology that enables fast data collection on all channels without system limits and without PC intervention.

The data is typically stored in a centralized location such as on a network attached storage drive (NAS) and can be viewed for analysis at any point during or after the sequence completes.

Below is an example of data applied to the cell and collected at 1 msec per data point. Note how quickly the system applies the required levels, switching automatically between charge and discharge modes as needed.



Zoomed data showing 1 msec time resolution per point:



Other Key Capabilities of the SI-9300R Battery Analyzer System

Key capabilities of the SI-9300R in addition to its drive cycle functionality:

- Regenerative power (Return to Grid - RTG). Cell discharge power is recycled to other channels or to the grid, reducing power wasted in heat that would otherwise have to be dissipated by large air or water coolers. RTG capability saves operational power consumption along with the overall footprint and volume over conventional systems.
- 24-bit measurement technology allows use of advanced techniques such as High Precision Coulometry (HPC) and voltage/charge derivatives dV/dQ and dQ/dV which allow the user to analyze cell failure mode and cell degradation.
- Simultaneous EIS impedance measurement per channel, increasing overall test throughput and availability of cell diagnostic information
- 200 Amps per channel (300 Amps for pulse waveforms). Up to 1000 Amps connecting channels in parallel
- High data measurement sample rate per channel (plus anode/cathode for 3 terminal cells) with no overall system data rate limitation allows full cell diagnostics
- DC and EIS analysis functions for individually testing Anode / Cathode of specially constructed 3-terminal cells.
- Industry leading Flux Gate Sensor current measurement technology for high accuracy and ultra-low temperature drift.

Please contact us for more information about the SI-9300R battery analyzer product:

www.ameteksi.com

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