

Supercapacitor Testing System



- Charge Discharge Cycling
- ESR Measurement
- Leakage Current Measurement
- Cyclic Voltammetry
- Voltage Clamp
- Fast Rise Time and Low Noise
- Fast Data Collection

Arbin Supercapacitor Testing System, **SCTS**, is designed for R&D and testing of supercapacitor (ultracapacitor) for application in low power memory backup to high power automotive subsystem and everything in between. The system offers unique supercapacitor testing functionalities in a highly reliable, safe, and easy to maintain structure. Each system is custom configured according to customer's requirement.



Features

- High stability and accuracy with linear circuitry and 16-bit ADC/DAC. Linear circuitry offers low noise, fast slew rate, and smooth transition control across zero current.
- Bipolar linear circuitry meets requirements for high power applications (> 40V), as well as for measurement of leakage current.
- Multiple current ranges provide possibility to test leakage current alternately with high-current cycling tests on the same channel.
- Test sequence may be based upon constant current, voltage, load, and power. Other modes include linear ramp, staircase, or other control profiles generated by simulation of time-domain regimes or mathematical formula.
- Multiple channels per system with independent control of each channel.
- Continuous testing with combined steady and pulse modes at fast current rise time.
- ESR, capacitance, power, and energy can be determined in one testing run.
- Power charge/discharge cycling may be performed with fast data acquisition, 60 ~ 150ms/point/channel, depending upon the total number of channels.
- Built-in macro command function to automatically summarize the ESR, EPR, capacitance, power, energy, and statistical data.
- Modular plug-in structure for easy maintenance.
- Multiple safety protections such as voltage clamp and voltage/current/time/temperature limit are integrated in the hardware and software.
- Auxiliary temperature, pressure, voltage, and, digital I/O are available.

Testing Capabilities

Power Charge/Discharge Cycling

Power charge-discharge cycling is a common way to compare relative cycling efficiency among capacitors. Using current/power control mode, an operator could perform a constant current/power discharge down to the lower voltage limit followed by a constant current/power charge up to the upper voltage limit. This charge-discharge cycle can be repeated up to 32,768 times. An indicator of capacitor quality, such as capacitance, can be monitored at any moment during the cycling test. For supercapacitor, the duration of each cycle is much shorter than for batteries, usually requiring a few seconds to minutes. Therefore, fast data acquisition and control are provided for SCTS. Moreover, voltage clamping with < 1ms response time is essential to prevent overcharging.

Online DC-ESR Measurement

In SCTS, equivalent series resistance (ESR) calculation is based upon time-domain impedance analysis using a pulse methodology. Obtained DC-ESR value is averaged over 10 pulses.

ESR measurement functionality is integrated into test procedures, which regimes can contain charge-discharge cycling, capacitance and leakage current measurement, and self-discharge voltage monitoring in one exercise. In ESR monitoring, a key parameter, T_1 – data sampling time, are adjustable to obtain accurate ESR readings for different capacitance ranges and capacitor types. Each DC ESR measurement takes less than 0.4s.

Capacitance, Power, and Energy Calculations

In order to accommodate the data treatment procedures and formats prevalent in most supercapacitor R&D laboratories, Arbin's *MITS Pro* software interfaces with Microsoft® Excel and provides embedded macros to represent data in Excel chart format. An optional macro-command subroutine can automatically convert obtained discharge capacity and energy values to capacitance, power, and energy release.

Injection Equivalent Parallel Resistance and Leakage Current

Following the application of a constant voltage to a capacitor, the current drawn will attain to a small equilibrium ($\Delta I/\Delta t \sim 0$) value, known as injection leakage current. To guarantee the stability and accuracy of this leakage current measurement, Arbin's SCTS employs low-noise DAC and ADC. For a typical low current range setting of $\pm 10 \sim 100 \mu\text{A}$, accuracy is $0.02 \sim 0.2 \mu\text{A}$. Stability of constant V control is guaranteed by separated control loop in low current range.

(Notes: For a capacitor of 0.5~1F, leakage current usually ranges from 1.0 μ A to 10 μ A but current ripple may be slightly greater than 0.2 μ A during constant voltage control. The EPR value must be determined from average current readings, which can be calculated automatically through the macro-command.)

Self-Discharge Voltage Monitoring and Leakage Current

The magnitude of self-discharge, or internal leakage current is an important indicator of the quality of supercapacitors. This measurement is in parallel with injection leakage current. Open-circuit voltage of a charged capacitor is monitored with respect to time. A dynamic leakage current can be deducted from the obtained voltage-time curve. Since the leakage current varies with voltage, a tabular data file of voltage versus time allows user to calculate it at any voltage value. The macro-command subroutine can easily convert the data to self-discharge current (or dynamic leakage current), I_{SD} . Arbin SCTS features high input impedance for voltage and current measurement ($\sim 10G\Omega$ for voltage range < 12V). Therefore, the measurement circuit does not influence the measured current value.

Pulse Function and Voltage Drop

One optional feature, High-Speed Pulse (HSP), is for GSM/CDMA and other high-speed pulse tests. This function requires high resource allocation from the micro-controller (maximum of 8 channels per MC) and from PC (maximum of 32 channels per PC). The rise time of the pulse current ranges from 20 μ s to 2ms (varies according to instrument current and voltage range). The maximum number of stages in one pulse train is 10. Two data points per stage are taken when one pulse is sampled. The first pulse logging delay is 0.10~0.15s for the fast pulse. The fastest repetitive pulse logging interval is 1s.

In telecommunication applications, voltage drop is commonly used for industrial quality control of capacitors. The quantity is defined as the voltage difference between data sampled immediately prior to the pulse and at the last instant of the pulse stage. It may be identified as GSM or CDMA voltage drop, according to the pulse regime that is applied. Because Arbin's ESR determination is based on very fast data sampling during pulse, (within as little as 50 μ s), this measurement is less affected by the value of the pulse current and, hence, more accurate as a diagnostic parameter (this function applies only if the pulse feature is included).

Single Pulse Function

Single pulse functions are included for fast data acquisition, which could be desired during charge/discharge transition of supercapacitor. Interval between 2 data points is down to 0.5ms. However, maximum number of data points in one

continuous fast acquisition is 10, and the total duration for this fast acquisition is up to 500 μ s.

On-line AC Impedance Measurement

AC impedance step can be embedded in testing schedule for on-line measurement. Sine wave current at different frequencies is applied to the cell and the potential response is measured to determine the AC impedance.

Arbin offers two types of ACIM module for measurement of AC impedance. One module with one frequency of 1kHz and another module with 4 frequencies of 200Hz/500Hz/1kHz/2kHz. One ACIM module needs to be installed for each micro-controller unit, which can handle up to 40 main I/V channels.

Safety Features

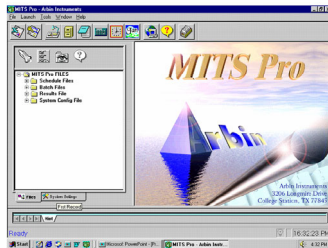
The SCTS hardware and software have many safety provisions to protect it from power failure, circuitry failure, environment failure, or system problems.

- **Current limiting circuitry** prevents current from exceeding maximum current range even when shorted.
- **Watchdog** turns off the system in case of a major hardware failure.
- **Fuses** prevent damage from unexpected shortage or over current.
- **Thermoswitches** prevent over heating from an abnormally large current or breakdown of cooling fans.
- **UPS** (uninterruptible power supplier) prevent data loss or system damage from power failure (optional).
- **Software Safety Limits.** In each schedule, there are safety limits for current, voltage, and temperature for the entire test.
- **Software Step Limits.** For each step, there are limits available for almost every variable or meta variables that can be set for termination of the step or the test.
- **Voltage Clamp:** hardware voltage clamp is available for additional safety protection and to provide smooth current/voltage mode transaction.



MITS Pro Software

MITS Pro, as the operating software, provides the same stable and robust software platform across the entire Arbin product line. Its unique open-ended structure offers full Microsoft compatibility, ease of upgrade, and flexibility. When it applies on SCTS series of testers, it offers unique testing platform for supercapacitor's specific testing needs.



General Specifications

Current range	1 μ A ~ 2000A
Voltage range	0 ~ 56V
Power range per channel	Up to 60kW
Current range per channel	2 or 3
Current rise time	20 μ s ~ 2ms (depending on I/V range)
Accuracy	0.05% FSR standard, 0.02% FSR optional
Maximum number of channel under one PC	20 or 48 channels (depending on I/V range)
Features	Low noise, fast rise time

Sample Test Results

