Shore Western

high performance hydraulic solutions

SC6000 Servo Controller

The SC6000 Controller

Designed and developed to address the needs of modern testing laboratories the SC6000 Servo Controller key attributes include versatility, ease of use and safety while supplying the functionality required in today's complex experiments and simulations. The result is a servo controller that can accept a wide range of transducers and drive popular brands of servo valves while offering a software package that makes setting up a system and running experiments simple.

Depending on the application, the SC6000 Controller is packaged in one of several enclosure configurations ranging from a desktop unit controlling 2 actuators to a roll-around-console controlling up to 16 actuators. Each controller configuration includes one or more servo controller cards, a Windows based computer, basic data acquisition, integrated IO boards, the operating and application software. Servo Suite Software is the basic test software system providing network connectivity, security, setup and operation of the hardware. Application software add-ons provide standard and custom solutions to specific testing and simulation requirements.

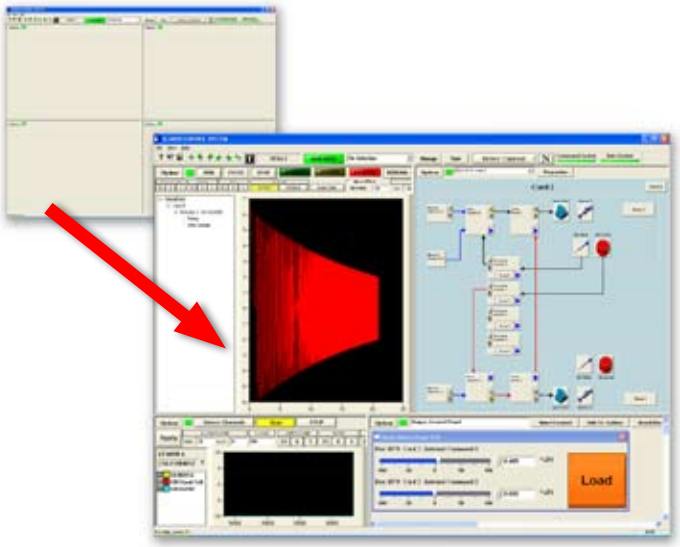
The versatility of the SC6000 based control system comes from its ability to easily make both hardware and software reconfigurations. A distributed computing philosophy permits a large number of control and data acquisition channels to interconnect forming a seamless control and data acquisition system. Each SC6000 card can either act independently for a single test station or be combined with other cards for large multi channel tests.

Servo Suite Software makes defining and redefining different system configurations straightforward. Each configuration can consist of multiple computers with servo and data acquisition cards. Software settable input selectors and a few hardware jumpers permit changing the topography of the servo circuitry. Custom programming is available to solve complex problems and special conditions.

Software Architecture

Default User Interface

The default user interface is a four panel display that is user configurable with a variety of data displays and test control panels.



These panels can be sized, positioned and minimized to form a custom user interface. Controls and indicators can be selected and dragged to their desired positions and the appropriate properties set. Once the display is set up and saved, most display settings can be recalled again. Multiple displays can be created and easily selected.

Shore Western's software philosophy is to eliminate the problems associated with pull down menus and various screens to view channel data. Except for special, hard coded systems, the display settings are available to all SC6000 users on the network.

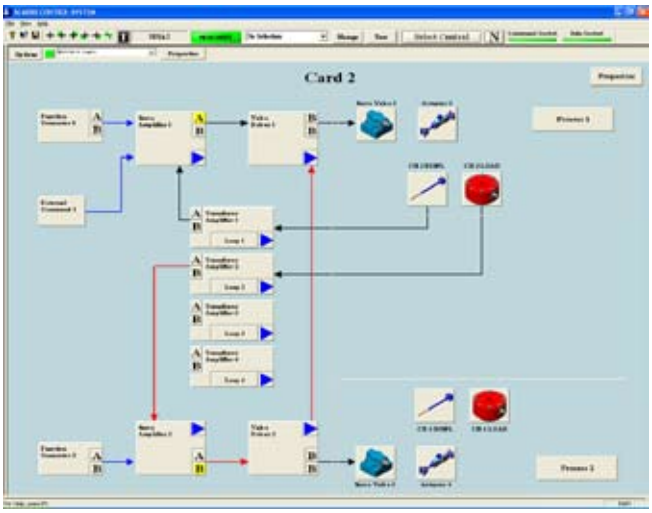
Controller Network Interface

The Networked Multi-User Interface allows any Windows PC on your lab network or on the Internet with SC6000 software to act as a client for the SC6000 test application server. Limited only by network bandwidth and PC processor speeds, additional SC6000 controllers, with up to sixteen control channels each can be interconnected along with other independent data acquisition computers to form a complex control and data acquisition system. For large aerospace and civil engineering tests, multiple SC6000 controller cards may be used to conduct multi-channel tests on one test article, controlled from one or more PC's. Remote access is done by simply logging onto the IP address of the remote controller via the application window with appropriate permissions and password.

Controller Network Interface

Graphical Servo Loop Set-up Software

Each servo card is depicted using block diagrams representing its servo loops including both the PID closed loop control as well as all of the feedback sensors, servo valves and the actuators.



Control Loop Diagram

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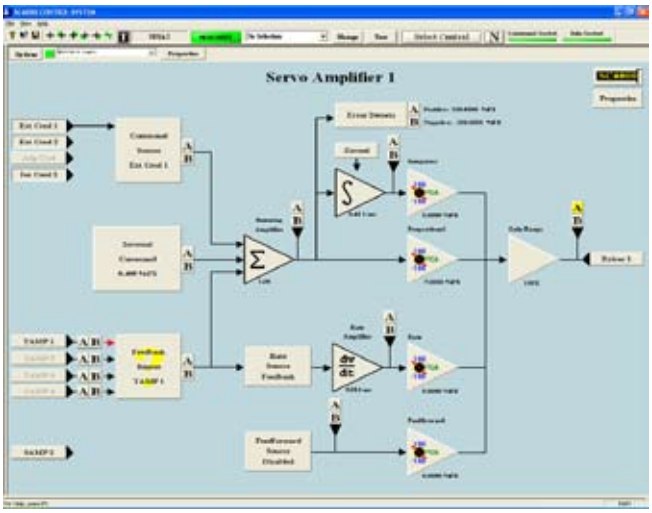
With two mouse clicks the user can, from any control system diagram, interrogate and change any control variable, sensor, or topography setting. For instance, by clicking on the servo amplifier icon the diagrams go to a more detailed view of that portion of the diagram, as shown below. At this level, the user may make changes and tune the system or change the configuration of the board in order to affect a new control strategy.

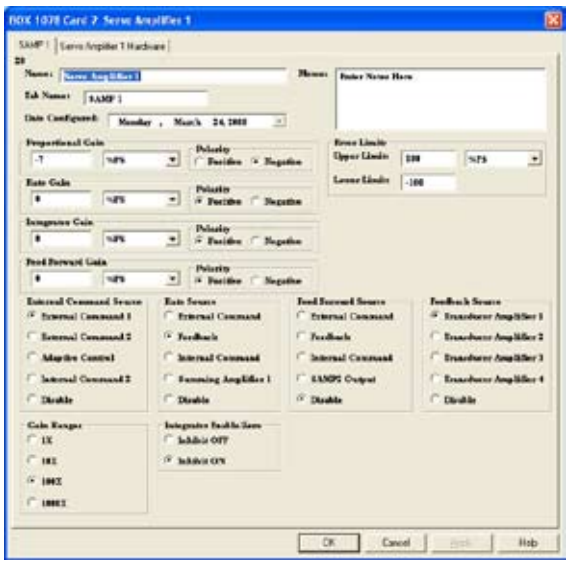
Error limits are available on the transducers amplifiers and can be set to detect out of range conditions. Error detects on the servo amplifier use a monitor point at a selected circuit location, for example, the servo amplifier summing point. The system responds to an error condition by either activating the E-Stop circuit or by pausing a running waveform depending on how the error detect is configured.



Servo Amplifier Diagram (detailed view)

Property Sheet

Another way to look at control card's settings is the card's Property Sheet that defines all the settings for a particular channel of control. All settings are viewed on a tabbed screen as shown below. Settings for a particular loop of control are available to be viewed and changed in the intuitive user interface.

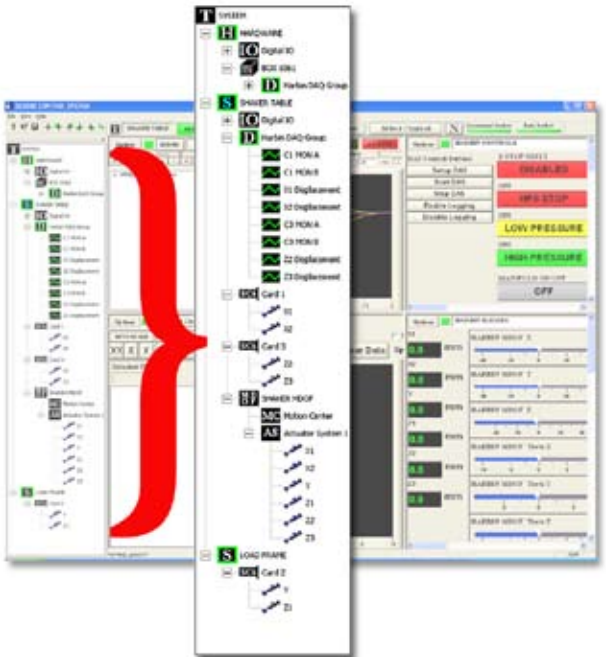


Property Sheet

System Resource Tree

Hardware in the system being controlled is displayed in the System Resource Tree. It displays and manages all hardware and how the current hardware is assigned to one or more subsystems. Hardware is either available for allocation as shown in the section labeled 'HARDWARE' in the example or allocated to subsystems as shown in the 'LOAD FRAME' and 'SHAKER TABLE' sections.

Right clicking an element will bring up a menu where the property dialog can be selected which allows the system specific identity and operating parameters to be set. Other options may be available for specific elements. System elements can be assigned to newly defined subsystems by dragging from the available HARDWARE and dropping on the desired subsystem.



System Resource Tree

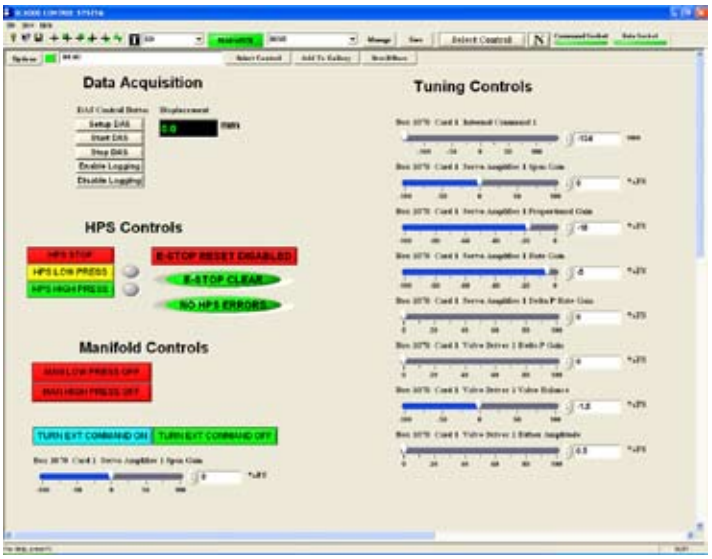
Custom Screen Builder

Without writing any software users can create specialized test interfaces and software display panels utilizing the SC6000 Custom Screen Builder. This functionality is provided in two ways; user interface tools and block programs. User interface tools are preprogrammed screen components which are user assigned and programmable. An extensive user library of interface tools, such as buttons, indicators, lights, sliders, and toggles are readily available. Some pre-configured components are hard coded and not user definable. However, most of the above mentioned tools are user programmable and may be linked to block programs.

Block programming allows the user to do tasks via predefined functions using a high level, iconic programming interface allowing the user to do mode switch, auto balance, digital I/O control, and utility functions like delay. These various block functions may be strung together in a flow diagram sequence with start and stop buttons. This block programming functionality may be directly linked to the programmable buttons and other tools to allow the user to accomplish complex tasks with one button push.

For example, a button called “System Start” could be directly linked to a block program. With the block program, you could start the system in the desired mode of control, auto balance the feedback sensors, turn on the hydraulics (HPS and service manifold) and have the system ready to run a test all with one button and a block program. Programs or strung together function blocks are then saved as a user named function for use with the programmable buttons.

The screen below shows a custom screen that emulates a simple, single axis test controller. All of the visual components - slider bars, buttons and numerical displays, are ready built and can be linked directly to most any function on the SC6000 Controller Card. Servo tuning, data acquisition and a variety of digital I/O functions may be built quickly using the tools provided.



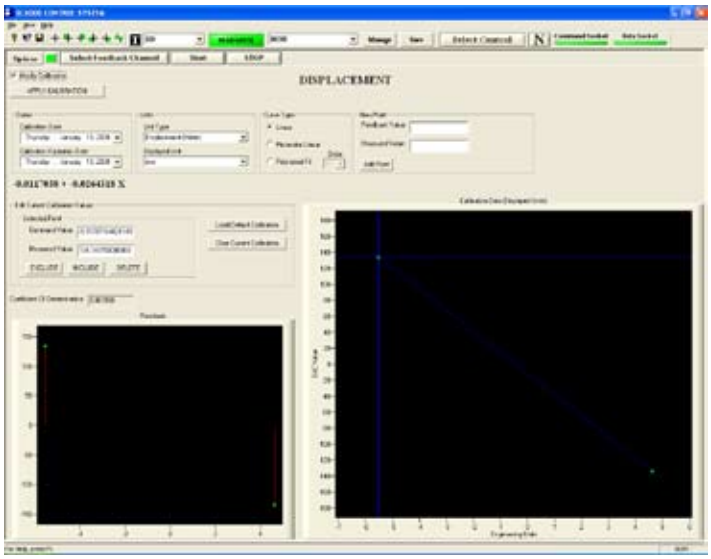
Customer Screen Builder

Calibration

A complete, easy to use, multi-point calibration package is included in the SC6000 system. The user can effortlessly calibrate load, displacement, pressure or any other compatible sensor.

The calibration screen allows linear, piecewise linear and higher order polynomial fit calibrations to be performed. The calibration screen displays basic statistical information on the calibration. It allows the user to calibrate sensors or check existing calibrations easily and quickly. A curve fit displays the estimated calibration error based on the nonlinearity of the sensor and number of points used in the calibration.

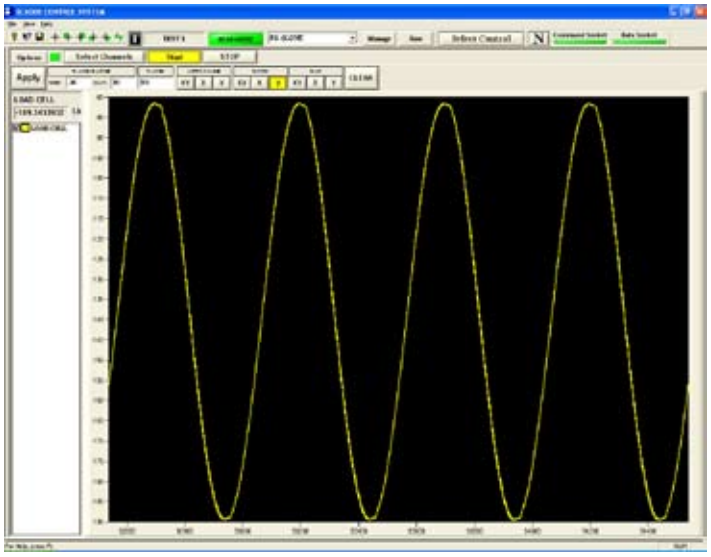
Control loop reconfiguration is simple, with real time scopes available to view test data. They can display multiple channels versus time or channel versus channel.



Callibration Screen

Data Acquisition

The SC6000 Servo Control system has powerful data acquisition functionality. Commercial A/D boards may be added and will plug and play with the SC6000 software and immediately become available to the control system. Many National Instruments M-Series Cards are fully compatible with the system. The user may specify the sample rate, the data viewing rate to screen and the final decimation rate that determines the data rate to disk. The data is typically sampled at a relatively high rate 5000 Hz per channel – higher rates are possible. The data is then down sampled to a rate that is appropriate for the particular test to maximize the available hard drive space yet capture data peaks. The data may be synchronized with the test run button in the control program or it may run continuously depending on set up. The data is saved in ASCII format, to allow the use of common spread sheets to view and analyze the data. The data acquisition resources may be allocated to any test station.

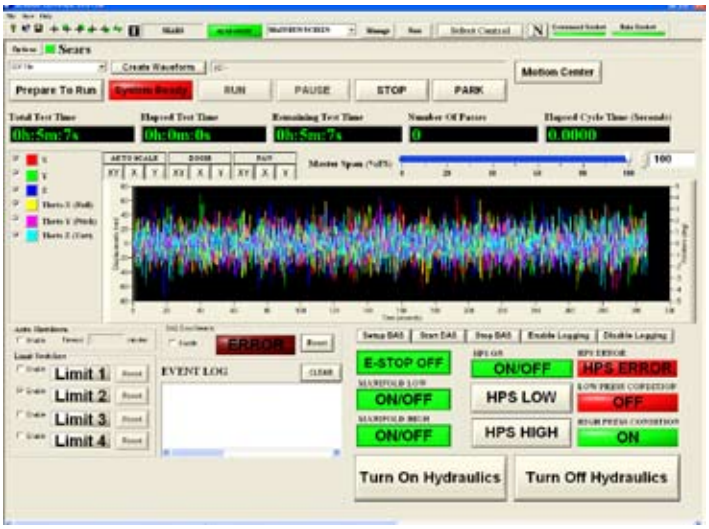


Real Time Scope

MAST Table

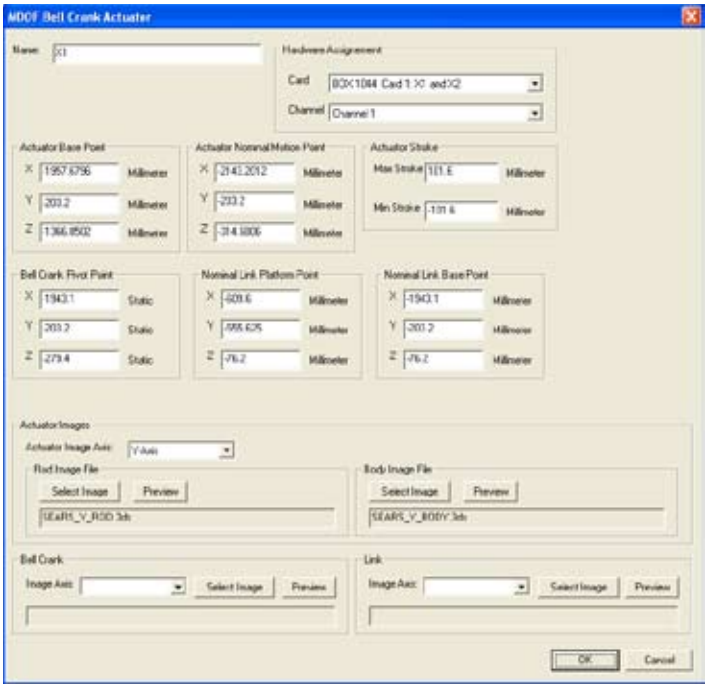
Body Cote mast table

Shore Western has developed a software package specifically for MAST table applications allowing them to be easily managed and operated. The software utilizes a global coordinate system which is defined relative to the top surface and mechanical center of the specimen mounting table. All Motion Center Waveforms are run with respect to the motion center as defined by these global coordinates. The kinematics of the system are modeled such that cross coupling is virtually eliminated allowing pure motions (translation and rotations) with very accurate control.



Sears Seating graphic

The global coordinates' selection control panel allows the position of the motion center to be set. This position is relative to the top center of the table.

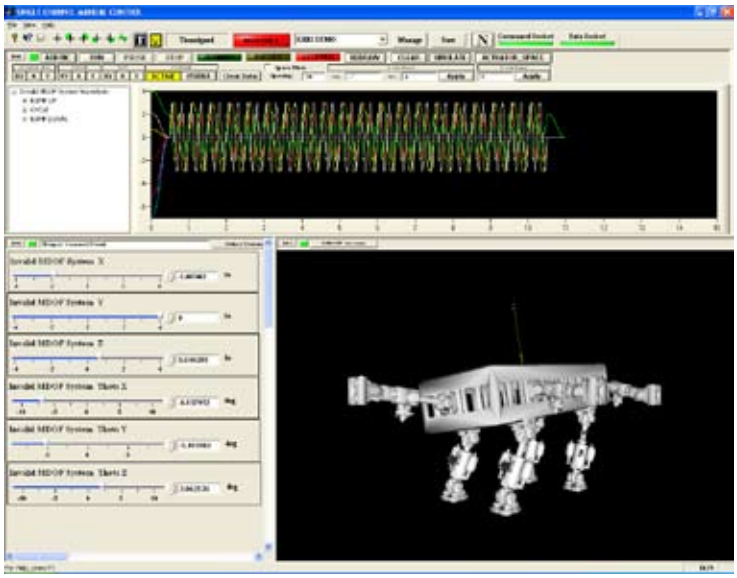


Global Coordinates screen

The maximum and minimum selection control panel allows the maximum and minimum values for each degree of freedom (DOF) to be specified. A given DOF value is specified when the motion center's global coordinates are all set to zero and the table is at zero position. User selected values put limits on what the table can be commanded to do. It should be noted that these values do not reflect the same limits of motion when starting from a motion center with non-zero global coordinates or when the table is not at its nominal position.

Once the coordinates and geometry for a MAST Table are defined, a test can be set up, verified and run. The test set up is managed from the MAST Table Supervisor screen where the user prepares to run the test by selecting the time histories or waveforms to perform the test. A graph of the selected waveforms will show exactly what the test selected looks like. The user can run the entire test from this window turning on hydraulics, enabling the test system and starting the test. This application is designed for 24/7 unattended operation.

An optional screen is available that shows a kinematic 3D model of the MAST system. The high resolution graphics and the integrated MAST kinematic model allow the user to move the table in Cartesian coordinates with a simple slider bar for all six degrees of freedom. Coordinates and roll centers may be changed with simple slider bar operation. Drive files may be run in the kinematic model to allow the user to make sure that the selected data is within the physical limits of the testing system and to give the user a view of the table motions before actually running the test.



Kinematic Model

Real Time Adaptive Control (RTAC)

RTAC is designed to allow the control system to adapt on a point-by-point basis to allow arbitrary or field recorded time histories of acceleration, load, strain or displacement to be simulated in an accurate

manner. The software does both amplitude and phase corrections of the control waveform to compensate for system and specimen nonlinearities in order to achieve an accurate test response. Typically only a few repetitions of the desired waveform is required to achieve accurate data reproduction. The RTAC algorithm has been proven to be very robust, when dealing with external disturbances from other channels or inputs. At this time, RTAC is available in only one degree of freedom, however, multiple, independent channels of RTAC can be configured with one control card per channel.

Hardware Specifications

SC6000 Servo Card specifications

- Dual channel servo boards that can be operated either independently or synchronously.
- Each of the boards represents a test station that will start and stop independently.
- Each board has 2 servo amplifiers, 2 each two-stage valve drivers and 4 transducer amplifiers and 24 channels of digital I/O.
- The four transducer amplifiers can be configured to either DC or AC amplifiers. Transducer amplifiers are all controlled from the computer.
- The DC amplifiers can be configured for load cells, pressure transducers, high-level voltage inputs or standard 4-20 ma inputs.
  - DC amplifier has a gain setting for low or high level inputs (Manually Selected)
  - DC amplifier has gain ranges; .5x, 1x, 2x, & 4x, software programmable
  - DC amplifier has excitation 0-10 V software adjustable
  - DC amplifier has polarity software adjustable
  - DC amplifier has an offset +/- 2.5 V, software adjustable
- The AC amplifiers are used with LVDT and RVDT type transducers, and include independent carrier frequency selection, and demodulator phase adjustment.
  - AC amplifier has four gain ranges; .5x, 1x, 2x, & 4x.
  - AC amplifier excitation frequency is 2.5 or 10 K Hz switchable
  - AC amplifier excitation amplitude 0-20 V peak to peak adjustable
  - AC amplifier polarity is software selectable
  - AC amplifier filter has a 3 pole filter
  - AC amplifier has an offset +/- 2.5 V, software adjustable
- Servo amplifiers are configurable for P, PD PID, or PIDF type with selectable inputs for the command. Differential pressure stabilization is available as part of the control circuit when used with one of the 4 transducer amplifier.
- All control is digitally supervised analog control. Digital outer loop control is optional. This allows for a high bandwidth yet allows the processor to be used for compensation and outer loop calculations.
- Dither frequency is selectable for multiple frequencies between 100 and 1000Hz.
- Valve balance range is 20% of maximum servo valve current level.
- The selectable input for driver amplifier permits bumpless transfer between feedback inputs but requires two servo channels per drive channel.
- The controller can also accept an external input for operation from an external source.
- 2 software controlled monitor points are available per card for monitoring up to 2 specific locations in the analog circuit.
- Error detects on the AC/DC amplifier outputs and monitor points.
- Discrete I/O for all on-off control sequences, including valves, pumps, chambers, and other test related on/off devices.
- I/O may be sequenced as part of a test sequence in a graphical block program.
- Connectors, power sources, and cables are provided as required for:
  - Servo valve
  - LVDT/LDT
  - Load cell/differential pressure sensor
  - HPS, HSM
  - Digital I/O
  - Data Acquisition

Test Application Examples

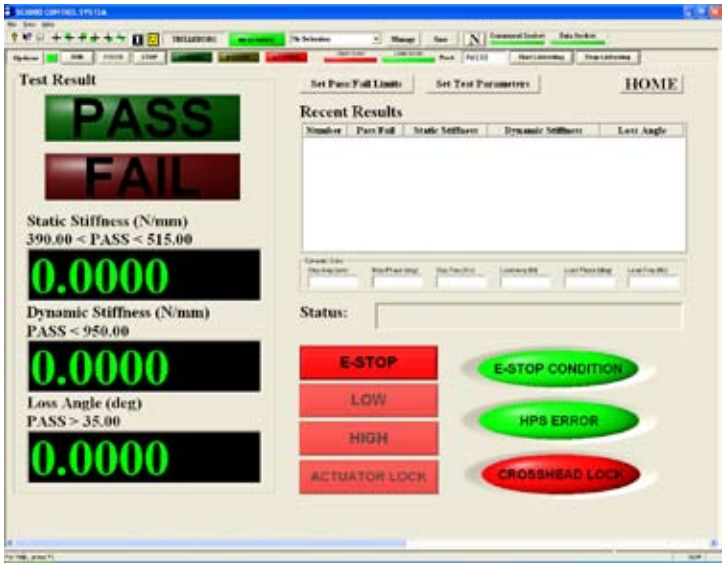
Listed below are some example applications operating on the SC6000 Controller. These examples show the Shore Western SC6000 controller in existing, real world applications on test sytems in Shore Westerns proven market places; Civil Engineering, Automotive, Material Testing, Aerospace and Bio-Medical. In some cases they have been created with specific solutions and custom software, in others they are using off-the-shelf software configured for the specific test. These examples do not cover all possibilities but are representative of what can be done with the SC6000 controller.

Material Testing

Material Testing

Material testing encompasses a wide range of disciplines, from ultimate strength coupon testing with metals to crack propagation in concrete to airframe fatigue testing in aerospace applications. Using the SC6000 standard software packages various tests can be conducted for doing low and high cycle fatigue, as well as multi-axial materials tests done on axial-torsion load frames. Pre-recorded time history data or flight profiles can be used to conduct tests. Virtually any sequence that can be measured or developed in a spread sheet may be played out as a test command profile and data may be recorded for subsequent analysis in other packages.

The SC6000 works with a wide range of extensometers for closed loop strain control. The SC6000 has analog loop closure timing, virtually eliminating the end to end loop timing issues present in many digital controls, making the SC6000 ideal as an inner PID loop slave controller used with custom outer loop material research packages created by 3rd parties for crack growth, thermal mechanical fatigue, and other high end specific tests. Properly configured, the SC6000 will assure waveform fidelity and accurate phase matching on command signals from an analog external command.

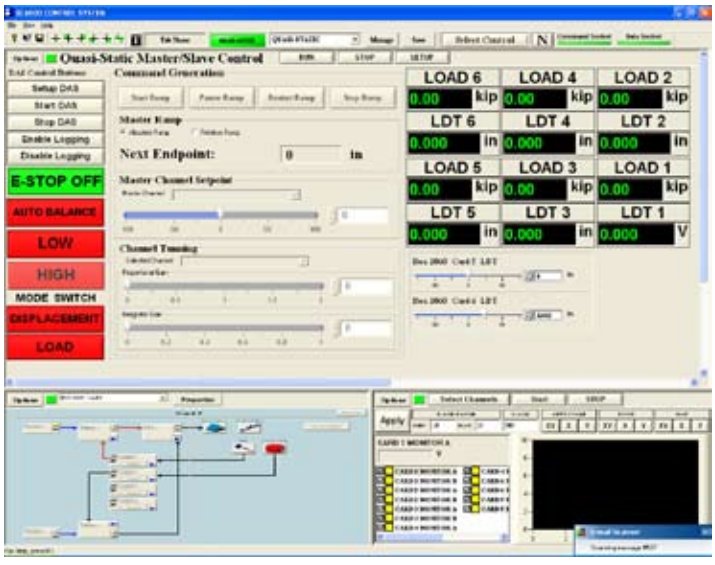


Material Test Screen

Elastomer Testing

Elastomer test applications can be created to allow various customer-specific test protocols. Shown in the example is the control screen of a test created for pass/fail production line testing of rubber bushings. The control panel provides system control buttons, test data display for the current test item and a pass/fail indicator. This particular test is for elastomer property identification for loss angle, static and dynamic stiffness. A full functioned FFT analyzer is available to allow more manual investigations of behavior to occur. Elastomeric testing has two target markets, product manufacture and laboratory testing. The SC6000 software can support both.

Civil Engineering



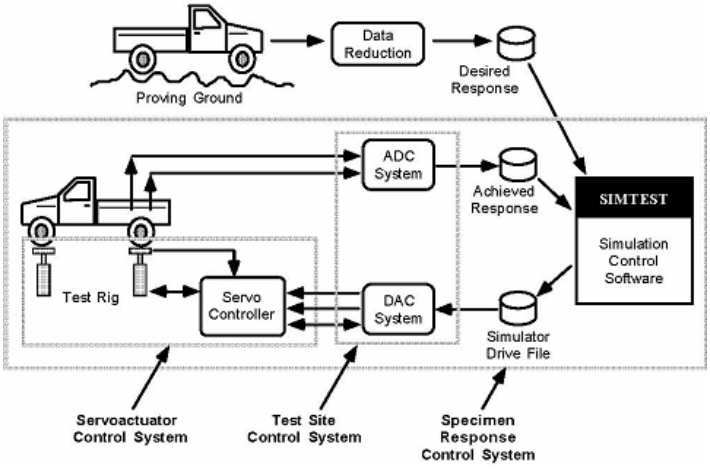
Multi Story Test Application

Applied in a custom Multiple Floor Structural Test application the SC6000 controller applies a multiple floor master-slave control which allows actuators on each floor of a multi story building model to impart loads on their respective floor with a proportionate load based on user defined geometry. The basic operational mode of the system is to use the top floor controlled in displacement control with a specific load limit as the master. The lower floors are then controlled in load and their

respective amplitude is scaled based on their relative position in the building. Special PID tuning and adaptive control are used to maintain stability through specimen failure.

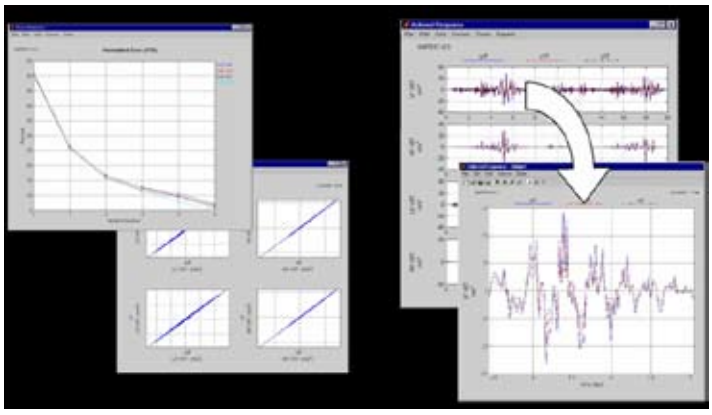
Automotive

Road simulation allows a user to take field data and replicate with a high degree of accuracy that same road data in the laboratory. The process is iterative. First the test system and specimen are subjected to a known input and the response from sensors on the test article is collected. A system model is calculated for either a square matrix (number of inputs = outputs) or non square matrix (number of inputs< outputs). Once the

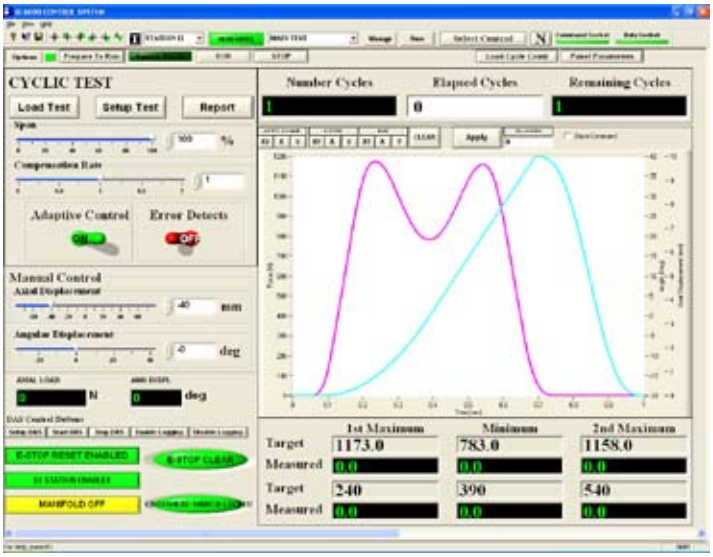


SimTest Control

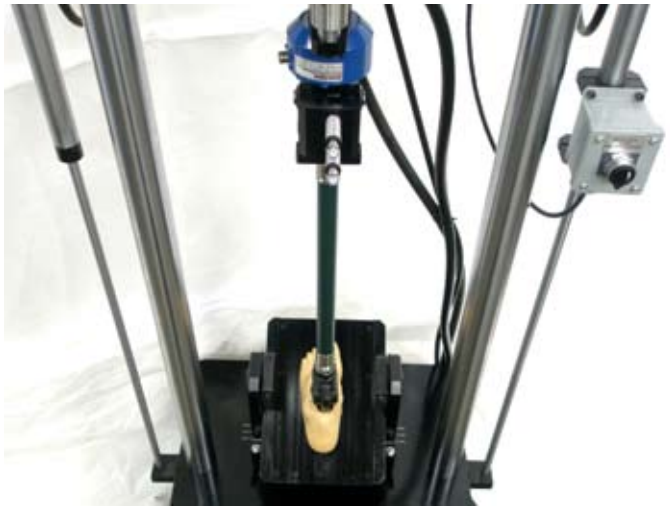
system model is created then the system undergoes an iterative process with each subsequent pass the simulation error is used to correct the drive signal. The process is continued until the system response converges on the desired response with an acceptable RMS error level. This process is very accurate, limited by the repeatability of the remote sensors.



Iteration Results



Foot Prosthesis Screen



Foot Tester

Biomedical

Shown below is a test profile from a multi-axis prosthetic foot test system conforming to ISO 22675. This application, while custom coded, utilizes Shore Western's Real Time Adaptive Control (RTAC) algorithm. Shore Western's proprietary RTAC optimizes the drive signal to reproduce the peaks and valleys in the gait sequence very accurately, in most cases within 5-10 Newtons, after taking only a few passes through the data. RTAC continues to update and respond to changes in sample stiffness, continuing to deliver an accurate load right up until the specimen fails.

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