

SureTorque ST-S3 Automatic Closure Torque Tester / Cap Tightener Theory of Operation

Manufacturer Name and Address

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General Description of the Product

The SureTorque ST-S3 is an instrument designed to measure the torque required to remove or tighten many types of threaded closures in a production or laboratory environment.

The instrument has the ability to re-apply the threaded closures to a preset torque value. Various types of threaded closures can be measured and a wide range of information about the threaded closures can be extracted from the measurements. The information reported includes peak removal torque, torque required to break tamper-evident bands or seals, application torque, stripping torque, child-resistant closure ratchet (non-opening) torque, child resistant closure opening torque, rolled-on cap stripping torque.

It is possible to perform non-destructive testing on most threaded closures, where the closure is re-applied to the container following detection of the peak thread break torque. By re-applying torque before the seal is broken, gas pressure (CO₂ for preservation or N₂ for structural rigidity) can be maintained inside the bottle, allowing the product to be re-introduced to the production line rather than discarded.

The instrument is designed with a streamlined user interface for rapid testing in a production environment. Additional data acquisition software allows the unit to be used to measure, analyze and store threaded closure torque data in a laboratory environment.

Custom tooling is required to secure the containers being tested and to correctly grip and rotate the threaded closures.

Torque sensor description

The ST-S3 instruments use a calibrated strain gage based torque transducer as the basic mechanism of measuring torque. Inside the transducer, at the middle section, strain gauges are attached to a cube with cyanoacrylate. As torque is introduced at the load side of the transducer, the cube and with it, the strain gage foils are deformed, causing electrical resistance to change. This resistance change, usually measured using a Wheatstone bridge, is proportional to the torque applied at the end of the transducer. The result is a calibrated torque sensor with excellent resolution, accuracy, long term stability, ruggedness and repeatability.

A servo drive controlled stepper motor is used to apply rotational force to the closure at a known rotary speed (i.e. 1 RPM). The speed of the torque increase (torque ramp) is also programmable. A data acquisition system based on an instrumentation amplifier (supporting both DC and AC bridge excitation), an 80SPS analog to digital converter and a Programmable Logic Controller (PLC) gathers torque data, controls test parameters, and graphs the resulting torque vs. position charts on the integrated touchscreen HMI. The PLC firmware also provides support for production testing including pass/fail limit testing, report generation and linking to external data repository storage.

Calibration

The system can be calibrated at the factory, and may be calibrated in the field, using a precision pulley of known radius and NIST traceable dead weight(s) used with a calibration fixture and pulley system. Quick torque verification is also possible by running a test cycle with a dynamic magnetic torque standard called “Gold Bottle”.

The precision weights are hung from the pulley to provide a known, traceable torque standard to the instrument.

Given the highly linear nature of strain gage based transducers, a single point calibration method is used both for CW and CCW calibrations.

Calibration values for torque values between calibration points are calculated by linearization between the calibration points.

Verification of calibration is provided by applying the linearization routine and hanging different weights to verify the results are as expected and within tolerance.

Custom Tooling and Accessories

Custom tooling is always required to interface the customer specific containers and threaded closures to the torque sensor and drive unit.

Units of Measurement

The user may select units of measurement for the display including lbf_{in}, oz_{in}, Nm, dNm, Kg_{cm} and others. Different unit system selections can be associated with different test recipes and the UoM is maintained after power-off.

Programmable Testing

Test parameters including test direction, angular speed limit, torque ramp parameters, type of test being performed, pass/fail criteria, data output type and many other settings are available. These may be set by the user and saved as a named test profile in the PLC memory.

Drive Motor

A variable speed and torque stepper motor is used with a 5:1 gear ratio for output torque increase & speed reduction. The motor has a programmable speed, typically from 0.1 RPM to 200 rpm, with up to 88 lbf_{in} of peak torque.

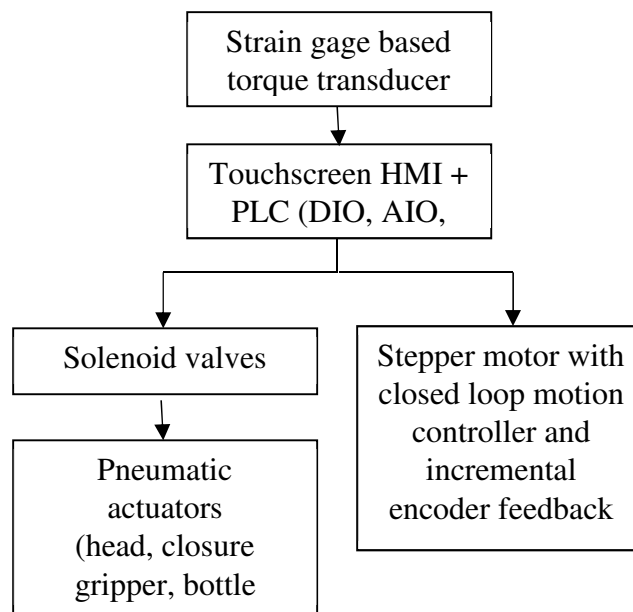
Power Supplies

Power is provided by an agency approved (UL Canada & US, TUV) external wall plug power supply which converts 110/220 VAC 50/60 Hz to 24VDC. The wall plug supply has overcurrent and overvoltage protection. Internal wiring is 24VDC maximum and is power limited to 150W. The servo drive board has a regulator for 5VDC to power optional pressure gages.

On the rear panel, a user replaceable fuse provides additional overcurrent protection to protect the equipment in the event the power supply fails.

No user-replaceable parts exist inside the enclosure(s) of the ST-S3 model.

System Block Diagram



Touchscreen HMI + PLC (DIO, AIO, etc.)

The Unitronics V350-35-T2 PLC offers the following onboard I/Os:

- 12 Digital Inputs, configurable via wiring to include 2 Analog and 3 HSC/Shaft-encoder Inputs
- 12 Transistor Outputs

I/O configurations can be expanded to include up to 512 I/Os via Expansion Modules.

Optionally, Ethernet, additional RS232/RS485, CANbus, Profibus Slave communication modules are available.

PLC Power Supply

Input voltage 24VDC (Permissible range 20.4VDC to 28.8VDC with less than 10% ripple)

Typical current consumption:

- NPN inputs 230mA@24VDC
- PNP inputs 135mA@24VDC

Digital Inputs

Number of inputs: 12 – configurable.

Input type: configurable (digital: NPN or PNP, analog: voltage or current, and other types)

Galvanic isolation: None

Nominal input voltage: 24VDC

Input voltage: PNP (source) 0-5VDC for Logic '0', 17-28.8VDC for Logic '1'

NPN (sink) 17-28.8VDC for Logic '0', 0-5VDC for Logic '1'

Input current: 8mA@24VDC

Input impedance: 3K Ω

Response time: 10ms typical, when used as normal digital inputs

Input cable length: Normal digital input Up to 100 meters

High Speed Input Up to 50 meters, shielded

High speed inputs:

Frequency (max): 20 kHz (10m cable), Duty cycle 40-60%, Resolution 32-bit

Analog Inputs

Number of inputs: 2 - configurable

Input type: configurable 0-20mA, 4-20mA 0-10VDC

Input impedance: 243 Ω >150K Ω

Maximum input rating: 25mA, 6V 15V

Galvanic isolation: None

Conversion method: Successive approximation

Resolution (except 4-20mA): 10-bit (1024 units)

Resolution (at 4-20mA): 204 to 1023 (820 units)

Conversion time: One configured input is updated per scan.

Precision: 0.9%

Status indication: if an analog input deviates above the permissible range, its value will be 1024.

Digital Outputs

Number of outputs: 12 transistor pnp (source)

Output type: P-MOSFET (open drain)

Isolation: None

Output current (resistive load): 0.5A maximum per output, 3A maximum total

Maximum frequency: 50Hz (resistive load), 0.5Hz (inductive load)

PWM maximum frequency: 0.5KHz (resistive load)

Short circuit protection: Yes, indication via software

Operating voltage: 20.4 to 28.8VDC

Nominal voltage: 24VDC

Graphic Display Screen

LCD Type: TFT, LCD display

Illumination backlight: White LED, software-controlled

Display resolution: 320x240 pixels

Viewing area: 3.5"

Colors: 65,536 (16-bit)

Touchscreen: Resistive, analog

Screen brightness control: via software

Virtual Keypad: Displays virtual keyboard when the application requires data entry

Physical keypad: Number of keys: 5 programmable function keys

 Key type: Metal dome, sealed membrane switch

Program

Memory size: Application Logic – 1Mb, Images – 6Mb, Fonts – 512 Kb

Operand type	Quantity	Symbol	Value
Memory Bits	8192	MB	Bit (coil)
Memory Integers	4096	MI	16-bit signed/unsigned
Long Integers	512	ML	32-bit signed/unsigned
Double Word	256	DW	32-bit unsigned
Memory Floats	64	MF	32-bit signed/unsigned
Fast Bits	1023	XB	Fast Bits (coil) – not retained
Fast Integers	512	XI	16 bit signed/unsigned (fast, not retained)
Fast Long Integers	256	XL	32 bit signed/unsigned (fast, not retained)
Fast Double Word	64	XDW	32 bit unsigned (fast, not retained)
Timers	384	T	Res. 10 ms; max 99h, 59 min, 59.99 s
Counters	32	C	32-bit

Data Tables: 120K dynamic data (recipe parameters, datalogs, etc.), 192K fixed data (read-only data, ingredient names, etc). Expandable via SD card.

HMI displays: Up to 1024

Program scan time: 15µS per 1kb of typical application

Removable Memory: Micro SD card Compatible with standard SD and SDHC; up to 32GB store datalogs, Alarms, Trends, Data Tables, backup Ladder, HMI, and OS

Communication Ports

Port 1: 1 channel, RS232/RS485 - configurable

Galvanic isolation: No

Baud rate: 300 to 115200 bps

RS232: Input voltage ±20VDC absolute maximum, Cable length 15m maximum (50')

RS485: Input voltage -7 to +12VDC differential maximum, Cable type Shielded twisted pair, in compliance with EIA 485, Cable length 1200m maximum (4000'), Nodes Up to 32

Miscellaneous

Clock: (RTC) Real-time clock functions (date and time).

Battery back-up: 7 years typical at 25°C, battery back-up for RTC and system data, including variable data. Battery is replaceable, coin-type 3V, lithium battery, CR2450.

I/O Expansion

Additional I/Os may be added. Configurations vary according to module. Supports digital, high-speed, analog, weight and temperature measurement I/Os.

Local: Via I/O Expansion Port. Integrate up to 8 I/O Expansion Modules comprising up to 128 additional I/Os. Adapter required (P.N. EX-A2X).

Remote Via CANbus port. Connect up to 60 adapters to a distance of 1000 meters from controller; and up to 8 I/O expansion modules to each adapter (up to a total of 512 I/Os). Adapter required (P.N. EX-RC1).

Expansion Module Analog Input specifications (torque transducer signal conversion):

Nominal operating voltage: 12 / 24VDC

Operating voltage range: 10.2 to 28.8VDC

Power Consumption: 30mA @ 24VDC

Input voltage ranges: 0 -20mV to +20mV

1 -80mV to +80mV

Excitation: 5V, software selectable: DC or AC

Short circuit protection Yes, up to 1 minute

A/D Converter: Conversion method: Sigma-Delta

Resolution: 24 bits

Conversion period: 12.5msec (80Hz)

Linearity error: 0.01% maximum of full scale

Common-mode rejection: >100dB @ DC, 50Hz, 60Hz

Offset drift: 100nV / °C typ.

Gain drift 3ppm / °C typ.

Environment

Operational temperature: 0 to 50°C (32 to 122°F)

Storage temperature: -20 to 60°C (-4 to 140°F)

Relative Humidity (RH): 10% to 95% (non-condensing)

Mounting method: Panel mounted (IP65/66/NEMA4X)

ST-S3 Materials List:

Aluminum, stainless steel, nickel plated steel, plastic (PE,PC,PVC, Acrylic, HDPE), polyurethane, silicon, tin, iron ferrite, ceramic, brass, gold, glass, liquid crystal, rubber feet.

Applicable CE Directives

CE Marking is required for the ST-S3 model. Please refer to the CE Mark Decision Tree document for the decisions leading to the following list of applicable directives.

- The ST-S3 product complies with 2002/96/EC Waste Electrical and Electronic Equipment.
- The ST-S3 product is RoHS exempt per directive 2002/95/EC (as amended by 2008/35/EC) and 2002/96/EC (as amended by 2003/108/EC and 2008/34/EC) because it falls under Annex 1A Category 9: “Measuring, Weighing or Adjusting appliances for household or as laboratory equipment”.
- The ST-S3 Product complies with 2004/108/EC on Electromagnetic Compatibility.
- The ST-S3 Product complies with 2006/42/EC on Machinery with powered moving parts. This directive includes a recommendation for a risk assessment of the ST-S3 machine, see the separate document ST-S3 Risk Analysis File.
- The ST-S3 Product is exempt from compliance with 2006/95/EC the Low Voltage directive since it operates on 24 VDC internally. This is less than the 75V limit described in the Low Voltage directive.

List of Harmonized Standards Applicable to the Product

No harmonized standards were applied to the design of the ST-S3 product.

List of the solutions adopted to satisfy the essential requirements

The ST-S3 model is intended for industrial or laboratory operating environments and is not intended to be a consumer product. The essential requirements are defined within the applicable CE directives list above.

The main requirements are those for safe and reliable operation of the instrument. Requirements also state the equipment in use must not generate electromagnetic interference for other nearby equipment nor respond inappropriately to outside electromagnetic interference.

Solutions adopted for safe operation include two hand controls, pinch point guard(s), emergency stop switch to turn off electrical and pneumatic power when the switch is pressed. The emergency stop switch must be manually reset to continue. The E-stop operation is positive and separate from the PLC, so emergency stop function is not under software control.

Enclosures and guards covers are positively fixed in place.

Additional safety against electric overcurrent is provided by a manually replaceable fuse which interrupt power to components if their current limit is exceeded.

Solutions adopted for EMI, ESD and RF emissions and acceptance include filtering and shielding to keep the instrument from generating or accepting harmful emissions. Laboratory testing was completed to assure the instrument meets these requirements.

Information about the Manufacturer's Quality Systems

The ST-S3 product is manufactured in a facility certified to the parts of ISO/IEC 17025:2005 standard which apply to the calibration of Torque.

The manufacturer's facility operates with quality policies and procedures based on ISO/IEC 13485:2003 and all associates are trained to a Quality Manual which is maintained in accordance with these two ISO/IEC standards.

Specifications

Testing	
Torque Tests	Cap release test, Final application, Fatigue, Tamper evident break
Torque Range	0-88 lbf•in (0-10N•m)
Torque Transducer	Strain gauge
Accuracy	+/- 0.5% for static loads over full scale
Resolution	Min 0.1 lbf•in
Maximum	Overload 150%
Rotation	0-60 RPM, CW and CCW, Infinite
Modes	Position, Speed or Torque control
Torque Units	d•Nm, N•m, kg•cm, kg•m, oz•in, lbf•in
Calibration	Certi fiable (NIST)
Standards	Meets or exceeds NIST, ASTM, FDA, GMP
Electrical	
Control	PLC-based system
Analog Signal	16bit/12.5ms conversion
Response Time (avg)	<12.5ms
HMI Display	3.5" 256-Color Touch panel
Communication	RS-232/RS-485 (USB, Ethernet optional)
Real-Time Clock	7-year typical battery backup
Utilities	
Air Source	80-125 PSI, 5 SCFM
Power Source	100-240VAC, ~2.5A, 50-60 Hz

Environment	
Temperature Range	32-122°F (0-50°C)
Relative Humidity	10% to 95% (non-condensing)
Mounting	Flat surface or desktop
Container Sizes	
Height Range	2.75" (with base adapter) to 13.75"
Diameter Range	0.25" to 5.00"
Dimensions	
Dimensions	29" x 12" x 20" (HxWxD)
Weight	86 lbs
Materials of Construction	
Exterior	Framework Anodized Aluminum and Stainless Steel
Hardware	Stainless Steel
Tooling	Anodized Aluminum, Nickle Plated Steel, Polyurethane, Acrylic, HDPE, UHMW