SG12

NON-ROTATING TORQUE/FORCE SENSOR MODULE

FEATURES

- Fast and easy strain gauge interface
- Low power consumption (8.5mA)
- 1kSa/s sample rate, 1ms sample period, 500Hz Nyquist
- Serial data interface 230400 baud (N81)
- Analog output (12 bit resolution)
- Selectable digital filters
- Settable gain (x171/x285)
- Temperature sensor (±3C)
- LED indicator for activity/error
- Built-in data emulator for easy testing
- Compatible with Sensitivus SerialPlot Windows software (open source)

APPLICATIONS

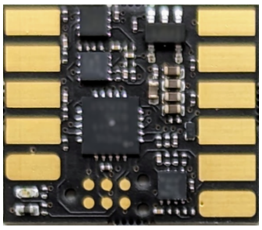
- Industrial applications
- Agriculture
- Medical

DESCRIPTION

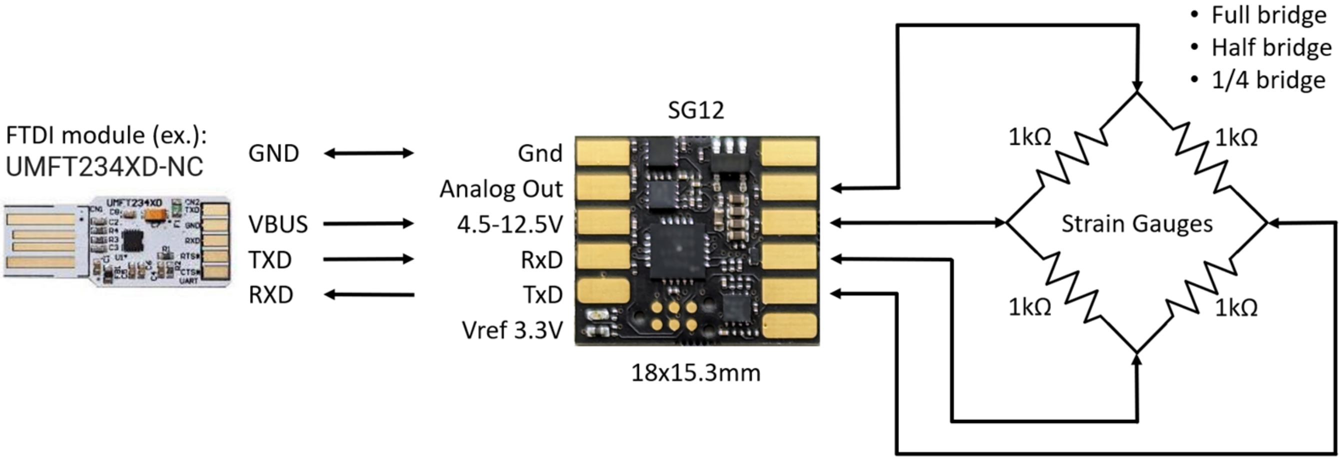
The SG12 non-rotating torque/force sensor provides a fast easy-to-use interface to any ¼, half, or full strain gauge bridge. It includes a lot of the optimizations in the SG3Q technology and offers both a digital serial and an analog interface.

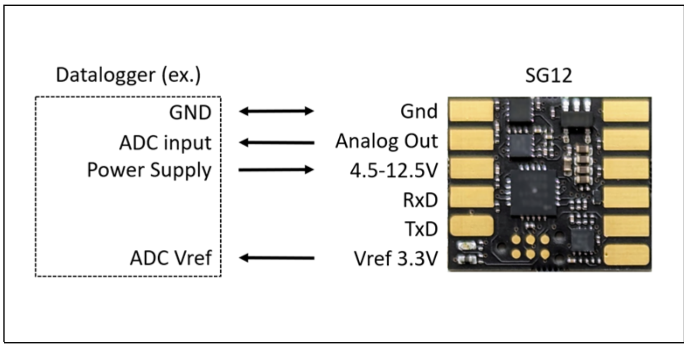
With a 1ms sample rate and adjustable filters, the sensor module is useful for many non-rotating applications.

Torque/force-sensing based on strain gauges is a very well-known and well-understood technology. This is easy to apply to any shape and type of metal.

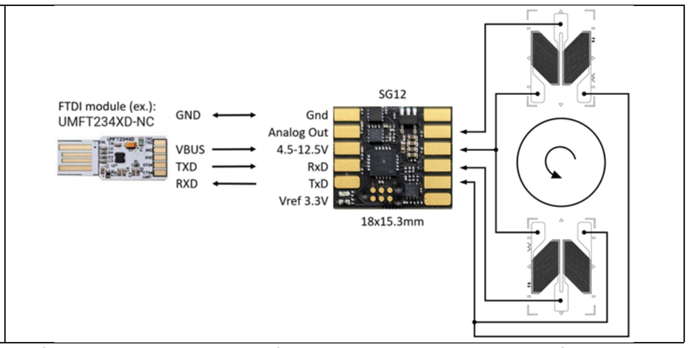


TYPICAL APPLICATIONS





Example connection to an analog data logger



Strain gauge connection for measuring torque on a shaft using 2x shear mode strain gauges in full bridge

TECHNOLOGY DESCRIPTION

The SG12 module combines the superior zero-point stability, resolution, and accuracy of a strain gauge based solution with low power consumption in a compact design that can be directly integrated into many systems.

For deeper integration, Sensitivus is available to help integrate the technology into another circuit.

Strain Gauges

Be careful to select the right type of strain gauge and bonding method. Consult the strain gauge manufacturer for instructions and recommendations.

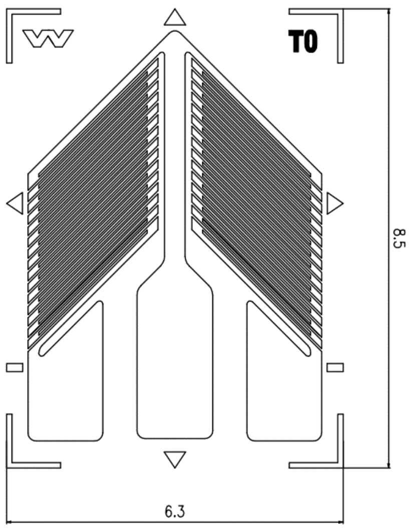


Figure 1 Typical 3-terminal +/-45° shear type strain gauge

Example data

Mounting area: 11.0x8.0mm (base size 8.5x6.3mm)
Enameled wires pre-soldered: 30mm length
Impedance: 2x1000R +/-0.1%
Gauge factor: 2.0 +/-1%

The number of strain gauges used in a given application depends on the actual requirements. Typically, half-bridge or full-bridge configurations are recommended.

Calibration

As with all torque/load cells, two distinct types of calibrations are normally performed.

Slope

Slope calibration is typically performed at the factory on each unit in a setup applying a known load. As the sensor is linear from positive to negative, only one other known point is needed. Typically, this is the zero point, as it is easy to establish.

Performing this calibration removes most effects of tolerances in strain gauge, bonding location, metal, components, etc.

This calibration value typically stays constant over the lifetime of the sensor.

Zero

Zero-calibration is the only other calibration needed. This needs to happen when zero torque is applied. Within a well-defined application, this may be possible to implement with an auto-zero algorithm. The SG12 module has a “zero command” to set the zero level (often called a tare function in a scale application).

Environmental Protection

To protect the strain gauge from humidity and light mechanical impact, a cover glue is recommended as a minimum. Consult the strain gauge supplier or bonding service provider for more information about this.

For best performance, the SG12 module and all exposed strain gauge connections should be covered with conformal coating as changes in humidity may influence measured values. The best way to do this is to “bake” the circuit at 60C for 20 minutes first to remove humidity.

ELECTRICAL INTERFACE

System connections

The system side of the module connects to a serial UART port (0-3.3V signaling) and/or to an analog input of the controlling system.

PIN	NAME	DESCRIPTION
1	Gnd	Module ground
2	Analog Out	Analog output voltage proportional to the strain sensed by the strain gauges. In the range of 0V to 3.3V (Vref)
3	4.5-12.5V	Module power supply.
4	RxD	Serial data input on the module
5	TxD	Serial data output from the module
6	Vref 3.3V	Reference voltage output from the module to be used as reference for the Analog Out signal.

Strain gauge bridge connections

The strain gauge side of the module connects to a full, half, or quarter bridge configuration.

PIN	NAME	DESCRIPTION
1	Bridge N	Bridge excitation voltage output (0-3.3V)
2	Bridge W	Input voltage from the bridge
3	Bridge S	Bridge excitation voltage output (0-3.3V)
4	Bridge E	Input voltage from the bridge
5	Bridge M	Reserved

Each resistor/strain gauge is assumed to be 1kΩ, but the module will work with smaller and larger values as well. Keep the tolerances tight (0.1% recommended) to avoid having the zero-point offset too large. Expect some variation in strain gauge resistance during the bonding process.

Connecting in full-bridge is always preferred, for maximum sensitivity, temperature compensation, and signal to noise ratio.

To use in half-bridge / quarter-bridge mode, replace one or more of the bridge elements with a "dummy resistor", that closely matches the resistance of each strain gauge element (within 0.1%).

In half-bridge mode, place the two active strain gauge elements in the "top" of the bridge, such that the strain gauge elements are connected between Bridge S and Bridge N, and Bridge N and Bridge E respectively, and place the dummy resistors at the two lower bridge sides.

System commands

When using the serial interface, please consult the protocol specification (GD10950) for details. The output data is available in both a simplified comma-separated ASCII format and a CRC-8 protected binary packet format.

Several commands are available to change settings in the sensor module, including:

- Digital low pass filter settings
- Reduced output sample rate
- Zero offset calibration
- Switching between ASCII and binary output
- Polarity of the output
- Self-test with internally generated output waveforms

PC software

The sensor is compatible with the open-source package "Sensitivus SerialPlot" allowing as an easy way to plot the measurements streaming out on the serial port.

This software runs under MS Windows, and can be downloaded for free from this repository:
https://bitbucket.org/sensitivusgauge/sensitivus_serialplot/src/master/

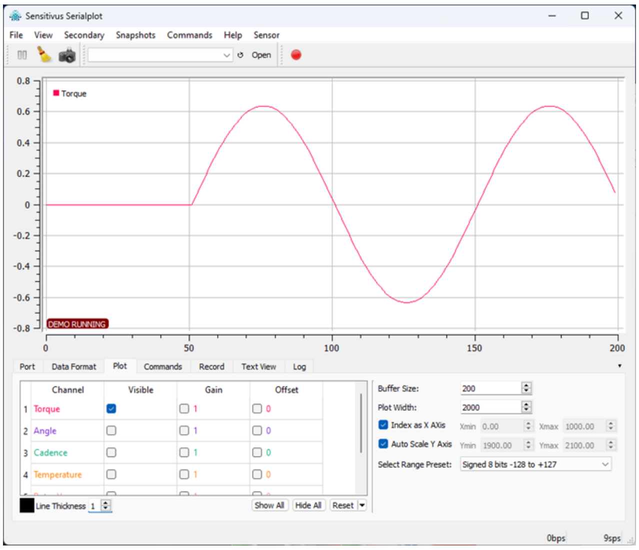


Figure 2 Example screenshot from Sensitivus Serialplot

This software can also be used to update the firmware in the module if that should be needed at a later stage.

LED indications

The following light patterns are shown on the small red LED:

- Constant light: Stuck in the bootloader, need new firmware update
- Slow flashing (2/sec): Normal operation
- Fast flashing (10/sec): Error in strain gauge interface or connections

Later versions of the firmware may define additional displays.

ELECTRICAL PERFORMANCE

Analog output

The analog output performance is measured with 4 different settings of the digital filter options in the module. All measurements are done using a simulated step input at the strain gauge interface.

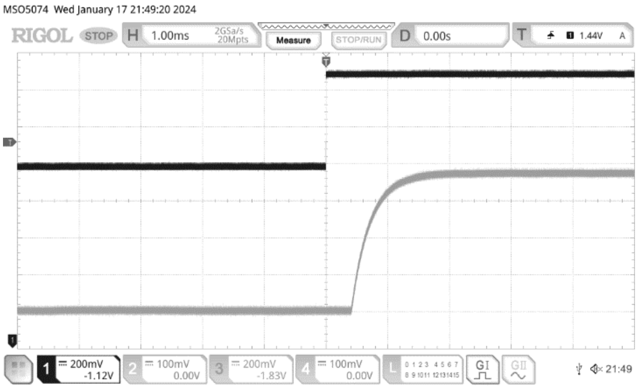


Figure 3 Analog output response - no filter

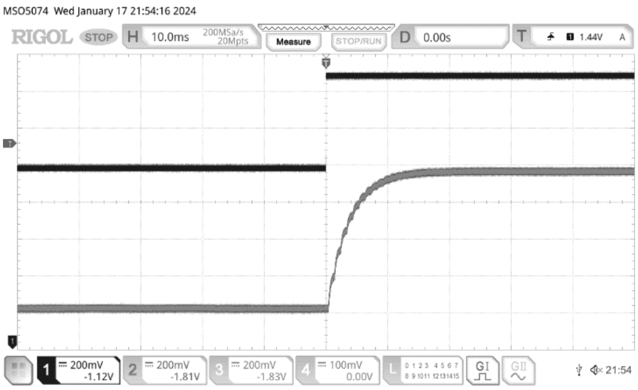


Figure 4 Analog output response - light filter

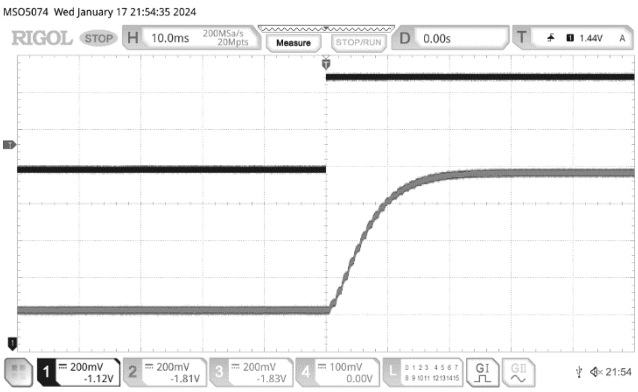


Figure 5 Analog output response - medium filter

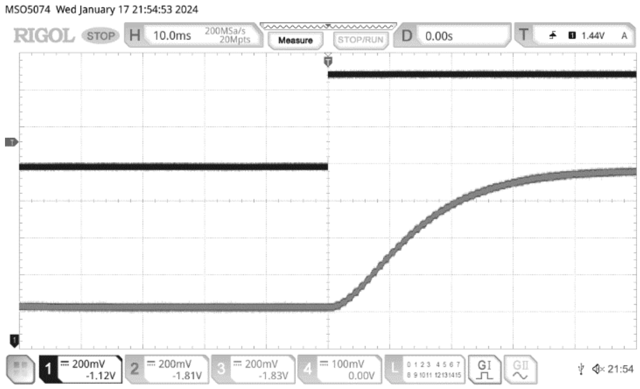


Figure 6 Analog output response - strong filter

Temperature performance

The digital output performance over temperature is measured by moving the sensor between high and low temperature environments to show the worst case (ramping temperature is less difficult).

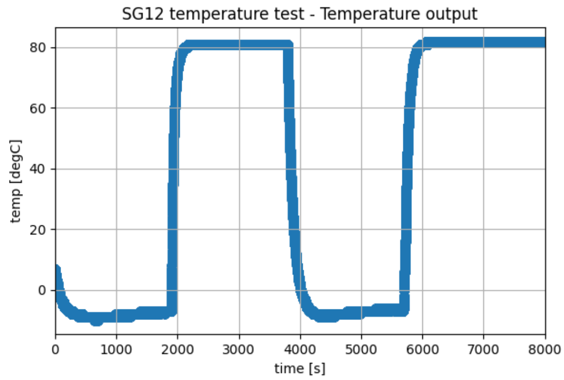


Figure 7 Temperature output from the sensor

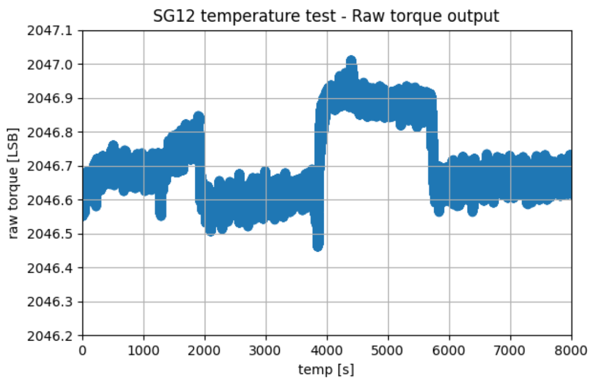


Figure 8 Raw torque/force output measured with a 50ms moving average. The temperature drift is within one LSB.

APPLICATION INFORMATION

Soldering precautions

Take great care not to apply too much heat when soldering to the terminals of the module. The tiny components used in the SG12 module are easily damaged.

Gain and strain

Use proper procedures for designing the metal used for the force/torque sensing. The better the design of the metal, the better the total sensing solution will be.

Suggested steps:

- Determine max load including a safety margin for overload conditions
- Select a suitable metal type with high yield-strain
- Design the metal to yield at the max load including safety margin (don't make it stronger than needed, as that will reduce the signal and result in more noise)
- Consider making the strain gauge area the weakest/highest strain area of the metal part
- Make the strain in the strain gauge area as uniform as possible (avoid strain gradients)
- Minimize strain from any non-related force/torque by the design of the metal

Wheatstone bridge and strain gauges

Strain gauges normally have a gauge factor of 2. That means the output measured in V/V is twice the linear strain measured in m/m. Both are in effect dimensionless. This is achieved with a full bridge configuration.

With the gain settings possible, the following digital output levels are possible (here measured as µV/V, so microvolt output per volt bridge excitation). One LSB is the digital resolution, which is one of the 4096 steps for full scale (FS).

Gain Setting	1 LSB	Full Scale
x171	1.43 µV/V	5848 µV/V
x285	0.86 µV/V	3509 µV/V

Since the zero offset is typically a little off from the center, consider using max 3500 LSB for the useful full-scale output and reserve the rest to account for the non-ideal zero-point. This can be due to tolerances, bonding effects, strain in the metal at zero load, etc.

The full-scale (all 4096 steps) strain ranges measured with linear strain gauges using the gain settings are shown here.

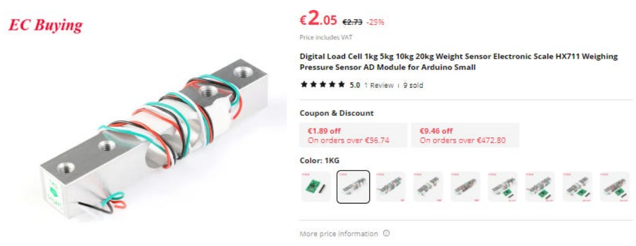
Gain	1/4 Bridge	1/2 Bridge	Full Bridge
x171	±5848 µm/m	±2924 µm/m	±1462 µm/m
x285	±3509 µm/m	±1754 µm/m	±877 µm/m

If using shear-mode strain gauges to measure shear strain – the same values apply. Full scale in the x285 gain setting full-bridge configuration is still ±877 µm/m shear strain.

Connecting a cheap load cell

Many cheap load cells are available. Here is an example found online that was used to set up a quick test. This type of so-called bending beam load cell is useful for measuring linear forces.

Notice how this type of load cell is designed with the strain gauges placed in a very weak area of the metal, whereas the mounting holes are in a much more rigid area. This is typical for good load cell designs.



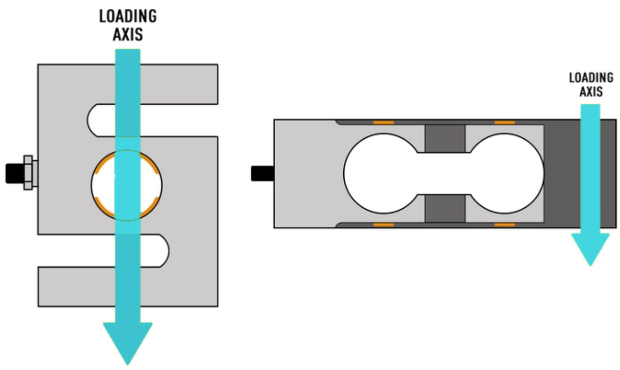
The load cell was connected to the SG12 module like this:

PIN	NAME	CONNECTION
1	Bridge N	Red wire (typical color used)
2	Bridge W	Green wire
3	Bridge S	Black wire (typical color used)
4	Bridge E	White wire
5	Bridge M	Not connected

The strain gauges of this particular load cell are internally connected as a full-bridge.

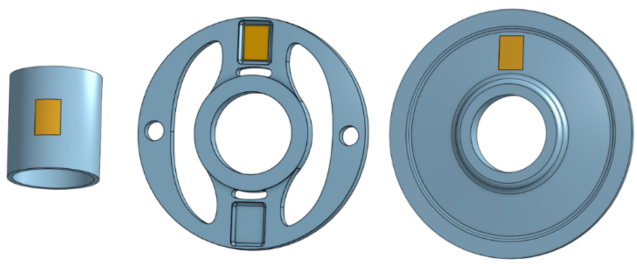
Typical load cell shapes

Two typical load cell shapes are shown for reference below.



Both shapes are optimized for linear forces while reducing the unwanted effects of other forces.

Load cells optimized for measuring torque are typically either tube/rod-shaped or flat discs with/without "spokes" as shown below.



To find the best metal shape for a given application, performing finite element modeling (FEA) is highly recommended. The final sensor performance can typically be predicted to within 1-2% using FEA.

Online workshop in sensing metal design

Sensitivus offers an online workshop for torque/force sensing metal design tailored to customer applications. Inquire for details.

NOTICES AND RESTRICTED USE INFORMATION

DOCUMENT INFORMATION

Prepared	*Checked (Sign)*	*Date*	*Document no*
RO;KL		2024-10-29	DS11429-6

Approved (Sign)	*Date*	*File / reference*
RO	2024-10-29	DS11429-6 SG12 Non-Rotating Torque-Force Sensor Module.docx