Embedded Microstrain Sensing for Robot Arms, Hands, and Drivetrain Components

Give your robots true force and load awareness with STREAL

Why Robots and AMRs Need Local Strain Sensing

Traditional force torque sensors at the wrist or in the load path only see what passes through a specific interface. Many important events occur inside the structure and never show up cleanly at those locations. Examples include:

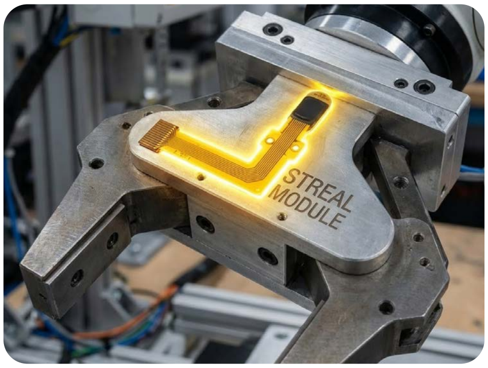
- Micro collisions and unexpected contact along links
- Local bending and overload near a gearbox or bearing
- Slip at a gripper jaw or tool interface
- Structural fatigue and stiffness changes in frames or arms

By placing STREAL sensors inside joints, links, and frames, you can observe these local events directly and detect issues earlier and more reliably.

What is STREAL

STREAL is a semiconductor grade strain sensing platform that lets you measure forces, torques, and structural loads at the exact mechanical point where they occur. Instead of external load cells or foil gauges, STREAL integrates the strain elements, analog front end, ADC, temperature sensor, and digital interface into a single silicon chip. The chip is packaged into thin stainless steel or ceramic modules that mount on robot structures such as links, joints, grippers, spindles, and AMR frames.

Each module measures strain due to tensile/compressive and shear (torsional) loads and converts it into a digital output through SPI. With appropriate calibration, the strain data can be interpreted as torque, force, or structural load that your controls, safety, or quality logic can act on in real time.

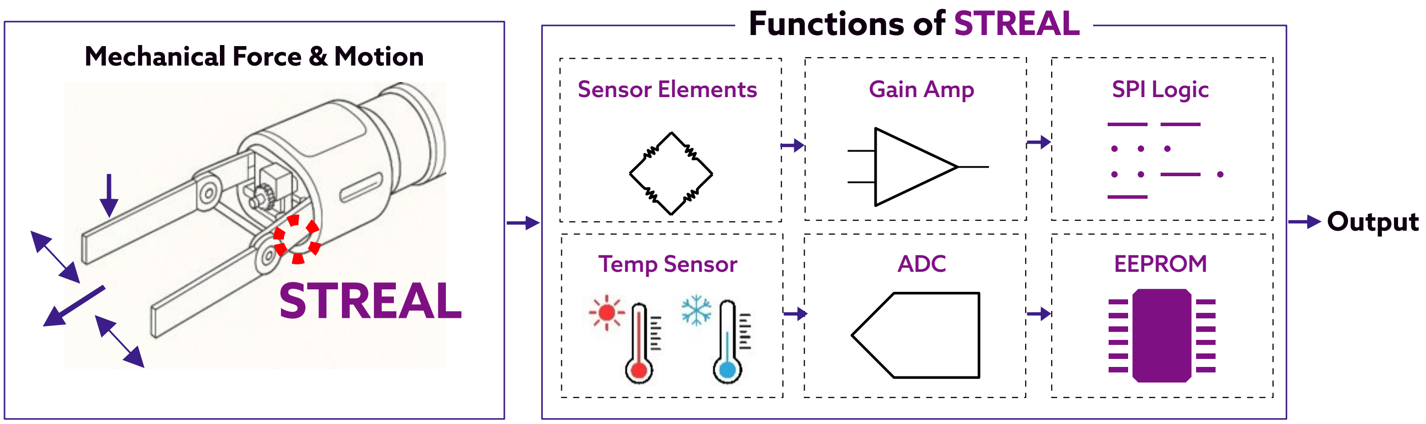


STREAL Platform at a Glance

- Strain resolution: As low as 0.1 με
- Integrated strain elements, amplifier, ADC, temperature sensor
- Digital SPI interface to host controller
- Tension/compression and shear configurations
- STREAL is well suited for metals such as stainless steel and aluminum

Key Benefits for Robot Builders and Integrators

- **Higher Precision Control**
  Local torque and load estimates improve position and velocity control under varying payloads and contact conditions
- **Minimal Design Intrusion**
  Thin modules add little mass and fit on link surfaces, housings, or jaws with minor mechanical changes
- **Simplified Electronics**
  There is no external bridge amplifier box. SPI output simplifies wiring into controllers and edge nodes
- **Improved Safety and Contact Awareness**
  Distributed sensing across multiple links helps detect abnormal contact faster and helps identify where it occurred
- **Predictive Maintenance and Health Monitoring**
  Long term strain signatures and cycle counts reveal loosening joints, bearing degradation, misalignment, and fatigue before failure

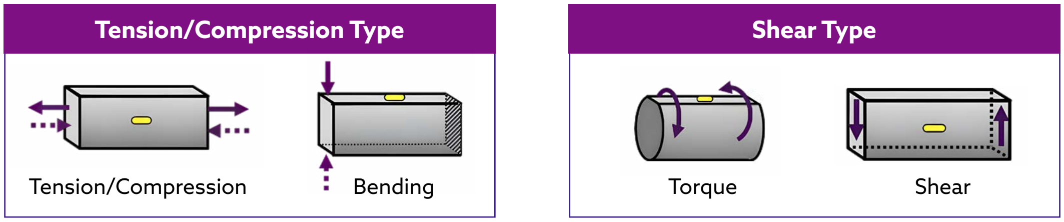


How STREAL Senses Strain, Force, and Torque

STREAL measures microstrain at the surface of a structural member. When your robot link, jaw, or housing is loaded, it deforms elastically by a small amount. This deformation appears as strain that the semiconductor elements inside STREAL can detect. Once installed, STREAL converts strain signals into digital samples. With calibration, you can map this strain to engineering quantities such as joint torque, gripping force, payload at a given reach, or frame load. Typical calibration workflow for a robot component is:

1. Choose the mounting location on a link, jaw, housing, or frame where strain correlates well with the quantity you want to measure
2. Determine component stiffness through finite element analysis (FEA), analytical beam formulas, or experimental testing
3. Apply known loads over the operating range. For example, sweep joint torque, gripping force, or payload
4. Record STREAL output and fit a linear or piecewise linear calibration curve between strain (digital counts) and the target quantity

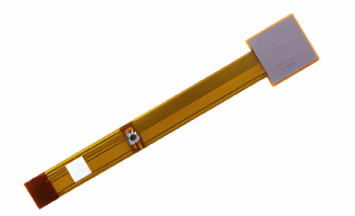
Because the structure operates in the elastic region, strain is proportional to applied load, which makes calibration simple and repeatable.



STREAL supports the main structural strain modes: Tension and compression, Bending, Torque (torsion), Shear

Product Family Overview

Each STREAL chip integrates the full signal chain, which means you do not need external Wheatstone bridge circuits, instrumentation amplifiers, or separate ADCs for the strain channel. You only provide a supply voltage and connect SPI to your microcontroller, motion control card, or industrial PC.

	SR300 Series – Low Power Sensing Slim, stainless steel module for flat surfaces	**SR500 Series – High Resolution Industrial Sensing** Ceramic module shape with excellent insulation performance
		
External dimensions	Total length 66 mm x width 6.5 mm (Terminal)	Total length 65.75 mm x Width 10.5 mm
Resolution	1 με	0.1 με
Power consumption	3 mW at 3.3 V	Higher than SR300 but optimized for precision use on mains powered systems.
Integrated functions	12-bit ADC, temperature sensor, variable gain amplifier (8~1016), offset compensation	16-bit ADC, temperature sensor, high-performance AFE (Analog Front End), OSR (Over Sampling Ratio), offset/sensitivity temperature compensation, self-diagnosis.
Suitable for	Low power IoT nodes, battery powered strain sensing on robot frames and AMR chassis, non-critical torque, and load monitoring	Robot joints, precision links, grippers, spindle housings, gearboxes, and critical structural health monitoring

SR500 is available as a customer specific custom product, not yet qualified as a standard offering, with sample units available and specifications subject to change.

Robotics Applications and Integration

Robot Arm Joints and Links

STREAL modules can be placed on the inner side of the arm is preferable or near transmission outputs to sense bending and torsion. Typical objectives:

- Estimate joint torque independently of motor current
- Detect unexpected contact along the arm
- Monitor strain cycles at critical sections for fatigue analysis and service planning

Robot Hands and Grippers

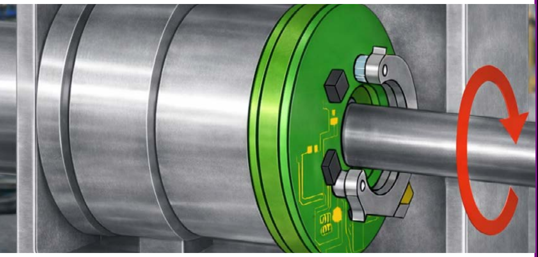
Mount STREAL close to the jaw or finger structure so strain reflects grip force:

- Detect slip, part loss, or incorrect part size from changes in gripping force
- Infer object stiffness from the relationship between displacement and force
- Protect sensitive parts by enforcing force limits directly from structural strain

Motors, Gearboxes, Reducers, and Bearings

Mount STREAL on housings or bearing blocks that see load:

- Observe torsional and bending strain that correlates with overload, misalignment, and bearing wear
- Combine with vibration and temperature to improve diagnostics and predictive maintenance
- Monitor long term stiffness changes as structures loosen or degrade



Rotating Parts with NFC

For rotating shafts or components where direct wiring is difficult, STREAL can be combined with near field communication (NFC) hardware:

- STREAL is mounted on the rotating part and connected to an NFC board
- Power and digitized strain data couple across a small air gap to a stationary reader
- This allows torque and load sensing on rotating shafts without slip rings

Request an Evaluation Kit

Design Support

Macnica Provides:

- Evaluation boards and modules for SR300 and SR500*
- Reference designs and application notes for robot specific placements
- Example firmware for SPI communication, calibration routines, and filtering
- Support for NFC based torque sensing on rotating elements
- Guidance on FEA based placement and mechanical design reviews

*SR500 is available as a customer specific custom product, not yet qualified as a standard offering, with sample units available and specifications subject to change.