



Whitepaper

Gaining the Upper Hand

A Blueprint for Edge Tactile Sensing and
Predictive Robotic Dexterity

October 2026

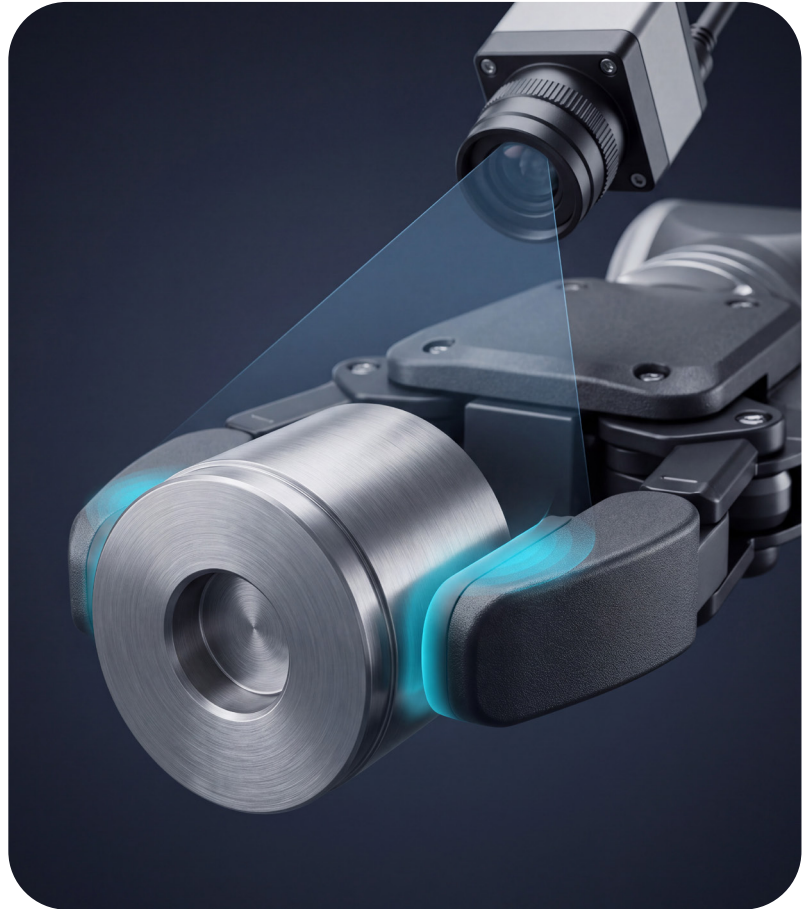


The Physical AI Bottleneck: Why Vision is Not Enough

Robotic systems are increasingly capable of seeing, interpreting, and planning their interactions with the physical world. But manipulating objects remains a difficult engineering problem. For a robotic hand or gripper, for example, identifying an object is only the first step. Once contact occurs, the system needs to know whether the object has been grasped securely, how force is distributed across the contact surface, and whether the grip is beginning to change.

Yes, vision plays a vital role in locating objects and guiding motion, but cameras have limitations at the point of contact. A gripper's own fingers can obscure the area being handled, and visual data alone cannot directly measure grip force or confirm the physical state of the contact. Tactile sensing adds ground-truth information to visual estimates, giving the robot direct feedback about what is happening between the gripper and the object.

Another challenge with robotic hands and grippers is architectural. Tactile sensors generate a continuous stream of data, but sending every raw signal back to the robot's central processor adds communication overhead, wiring complexity, and latency. For grip functions that require a rapid response, developers benefit from placing more sensing intelligence and processing close to the end effector.



This creates a Sense → Decide → Act architecture. Tactile and auxiliary sensors capture what is happening at the point of contact. Localized Edge processing interprets that information and converts raw sensor data into useful grip-state information. The system then uses those insights to support functions, such as contact detection, force estimation, slip detection, and grip-force control, while communicating higher-level information back to the robot's main controller.

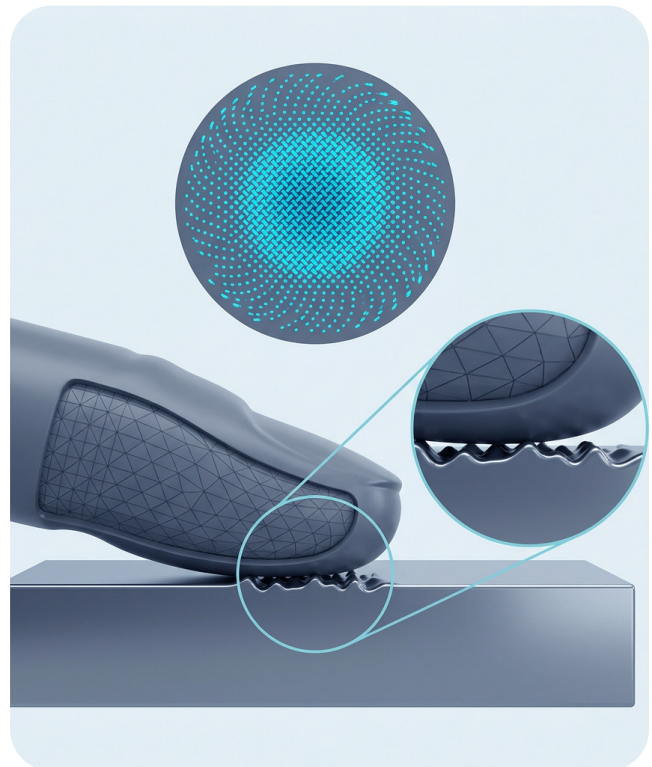
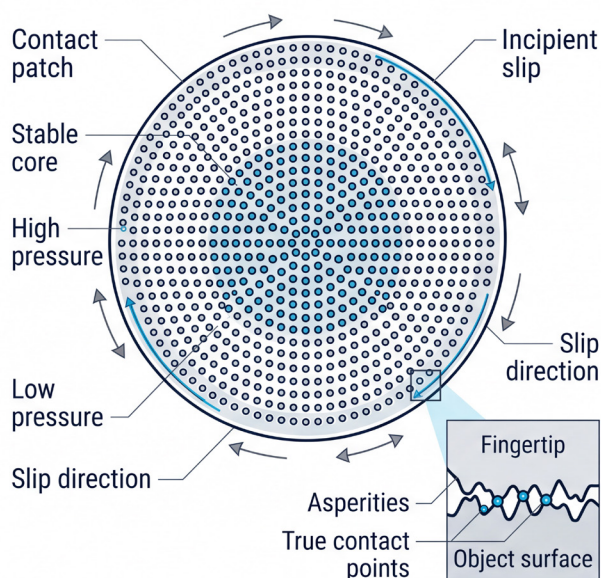
This whitepaper examines how Synaptics and Grinn are bringing these elements together in a developer platform that combines tactile sensing, localized AI processing and motor function near the robotic hand or gripper. Using an industrial robotic gripper prototype equipped with Synaptics capacitive tactile sensor modules and Astra® Edge AI processors as the reference implementation, it explores the building blocks developers can use to create more responsive and capable robotic end effectors.

The Science of the Grip

To build a better robotic hand, we have to understand that slip isn't a binary event. It isn't a simple state of held or dropped. Instead, slip is a spectrum that begins long before the eye sees the object move. To understand this, we have to zoom into the contact patch, the microscopic region where the robot's skin meets the object's surface.

Even the most polished glass surface is a landscape of jagged peaks and valleys known as asperities. True contact only happens at these highest peaks. When a robot presses a fingertip onto a surface, the pressure isn't uniform. It's highest at the center of the contact patch and tapers off toward the edges. As gravity or motion pulls at the object, the asperities at the periphery reach their limit and break free first.

This creates a state called incipient slip. At this stage, the outer ring of the contact patch is sliding, but the core is still locked solid. The object hasn't visibly moved yet, but the grip is no longer stable. This is the ghost in the grip. If a robot detects this early stage of failure, it has a window of opportunity to respond before a secure grasp becomes a dropped item.



Get a Grip

Most robotic grippers and hands on the market do not have tactile sensing. When they do, it's often just a rudimentary shear sensor. But shear sensors fail on soft and irregular items. A more-robust solution involves watching the entropy, or the statistical disorder, of the contact patch. As a grip fails, the order of the contact points collapses into disorder, starting at the edges. By tracking the rate of change in this disorder, a system senses a failing grip on objects it has never encountered before. This moves us away from memorizing specific objects and toward a universal understanding of friction and stability.

The Biological Benchmark: Human Reflexes in Silicon

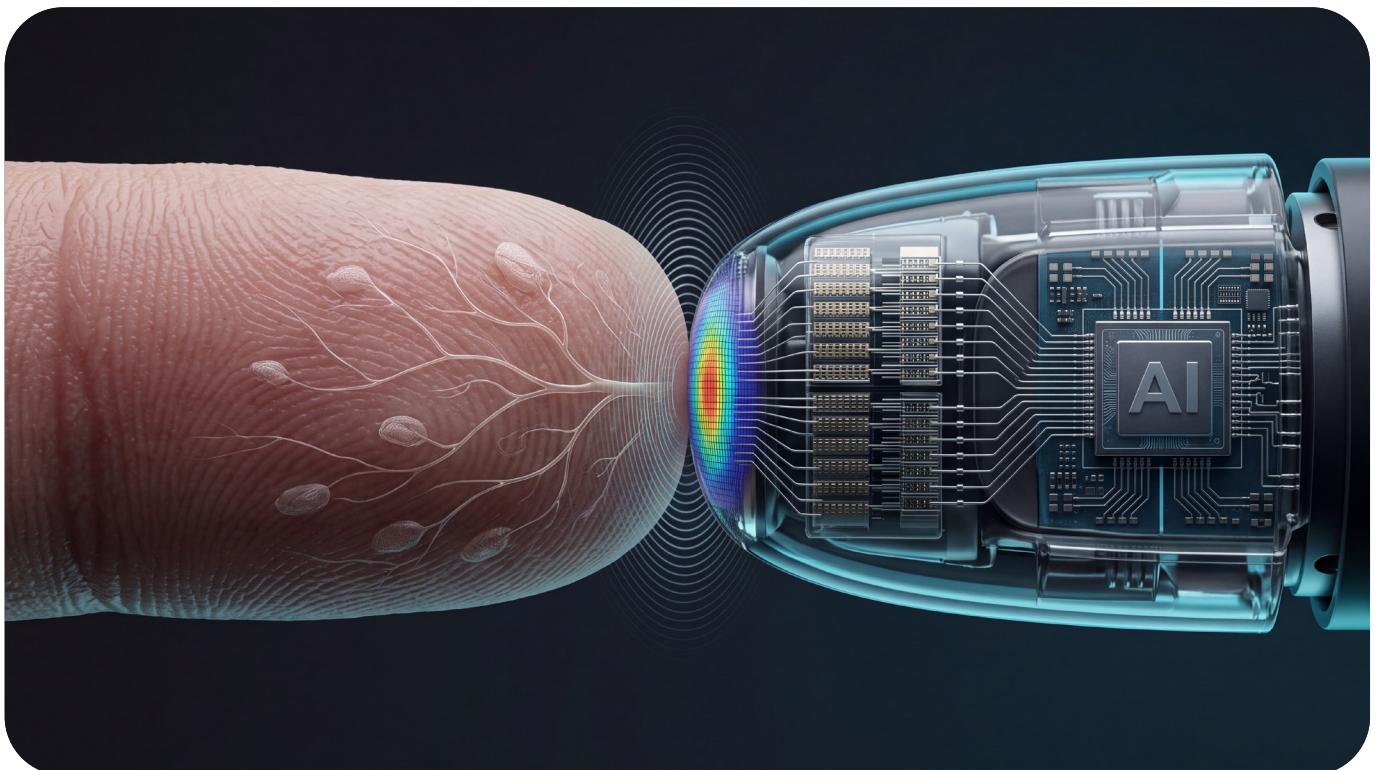
Nature has already provided the perfect blueprint for this problem of grip in the human hand. When you catch a slipping glass of water with your eyes closed, your brain doesn't engage in conscious deliberation. Your fingertips pick up a faint change in vibration and pressure, and your nervous system issues a “smart squeeze” to arrest the slide.

Research into human micro-neurography shows that we correct our grip force roughly 74 milliseconds after a slip begins. This response is an automatic sensorimotor reflex. Crucially, the receptors in our fingertips that fire during these events are fast-adapting nerve endings. They ignore steady pressure and respond only to dynamic, high-frequency vibrations. They act as biological accelerometers, tuned to detect the high-frequency chatter of asperities snapping free at the contact edge.

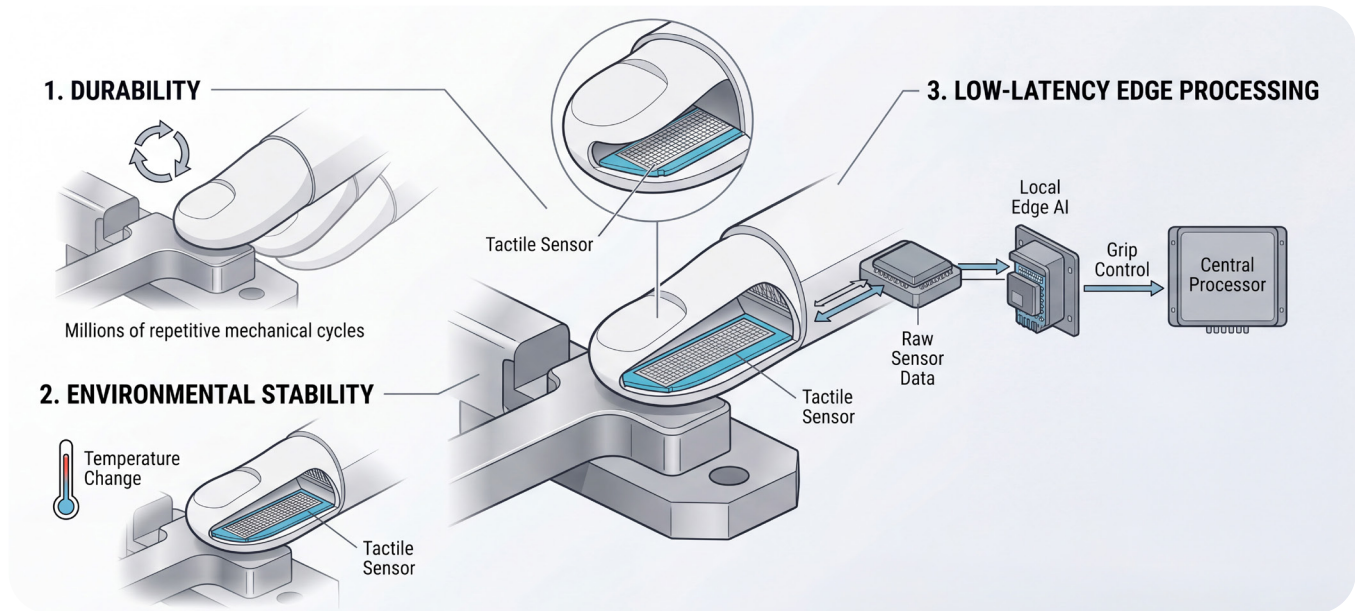
To get as close as possible to this human 74-millisecond response time, a robotic system must possess two distinct capabilities. First, it needs to catch fast vibrations to detect the onset of slip. Second, it needs a dense spatial map of pressure to understand how the load is distributed.

Historically, these two needs were in conflict. You could have a fast sensor or a detailed one, but rarely both at the edge. Synaptics has solved this by implementing a two-rate sensing architecture that mirrors human skin. We use a fast channel sampled in the kilohertz range to capture the “sound” of friction. Simultaneously, we use a spatial channel, powered by dense capacitive tactile sensing modules, to map the shape of the contact.

By fusing these two channels, the robot gets a complete picture of the event. It hears the slip beginning and feels exactly where and how the fingertip is loaded. This allows for a reaction that is both fast enough to matter and precise enough to avoid crushing the object.



Design Considerations for Reliable Tactile Sensing



Before Synaptics could implement this new architecture, we had to address the significant limitations of traditional tactile sensors. Many existing solutions on the market rely on piezoresistive sensing. While these sensors are common, they suffer from rapid material aging. In an industrial environment, customers typically demand sensors that survive millions of cycles. Some even ask for a lifespan of 15 million cycles. Piezoresistive materials sometimes deteriorate before reaching these marks, making them less suitable for long-term deployment in factories and homes.

Environmental sensitivity is another major hurdle. Many competing tactile sensors are highly susceptible to temperature drift. As the ambient temperature changes, the sensor's baseline shifts, leading it to report incorrect grip levels. This is a deal breaker for robots that need to move between climates or work near heat-generating machinery. Some solutions also rely on magnetic sensing, which causes errors with pressure readings.

Piezoresistive and magnetic sensing have their place, of course. For some applications, they even outperform capacitive sensing. But to achieve fast response, Synaptics has moved the decision-making process. Shifting AI to the far Edge means placing the intelligence directly at the point of contact. This eliminates the latency bottleneck and reduces the massive amount of wiring required to ship raw sensor data across a robotic arm. By processing information locally, Synaptics ensures that robots react rapidly, regardless of what the central processor is doing.

Slow and steady doesn't win the race

One challenge with traditional systems is latency. In most current robotic architectures, the brain or central GPU is far removed from the hand. By the time the sensors ship their raw data back to the central processor, the processor identifies the slip, and the command to tighten the grip returns to the hand, the object is already on the floor or hurtling down the conveyor.

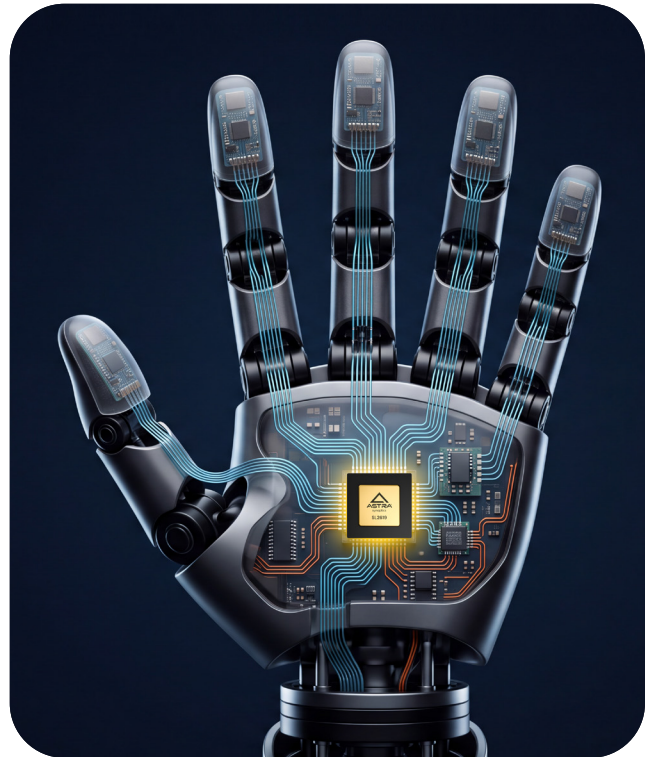
Architecture: Capacitive Tactile Sensing Module & the Synaptics Astra SL2619

The heart of the Synaptics blueprint for Edge tactile sensing and predictive robotic dexterity is the tactile sensor module and the Astra SL2619-based rapid prototyping platform.

Using the Synaptics Coralboard™, powered by the Grinn SL261x Astra SoM, and an Industrial HAT extension designed to handle multimodal sensor fusion, Synaptics has integrated this compute power directly at the end of the robotic arm. This setup allows the robot to think with its hands, creating a distributed sensory system that detects, filters, and responds to physical information close to the sensors and actuators.

The platform's architecture utilizes several key components to achieve Edge tactile sensing and predictive robotic dexterity:

- **The Astra SL2619 Processor:** Handles the localized AI models for slip prediction and force adjustment using the integrated Torq™ NPU, which handles inference workloads ranging from traditional CNNs to transformer architectures.
- **Industrial HAT add-on:** Provides the necessary interfaces, including I2C, SPI, and CAN, to connect a variety of auxiliary sensors.
- **Capacitive Tactile Sensing (CTS) Modules:** These modules fit into the fingers of the gripper, providing a high-density matrix of force sensing points.
- **Integrated Auxiliary Sensors:** The platform aggregates data from microphones, cameras, and temperature sensors to provide environmental context.



This design mirrors the human neural system. As a human, you don't have to constantly think about how you're moving your hand when you touch an object. Your hand makes its own decisions at a local level. By replicating this in silicon, we unload the heavy computational burden from the robot's main processing unit. The main brain stays focused on high-level path planning and task coordination while the Astra platform handles the intricacies of the grip.

This modular approach also makes the system more flexible. Because it's a Linux-based platform and features the open-source, standards-based Torq Edge AI compiler, developers quickly iterate on their designs, integrate new sensors, and deploy complex neural networks without needing a complete system overhaul.

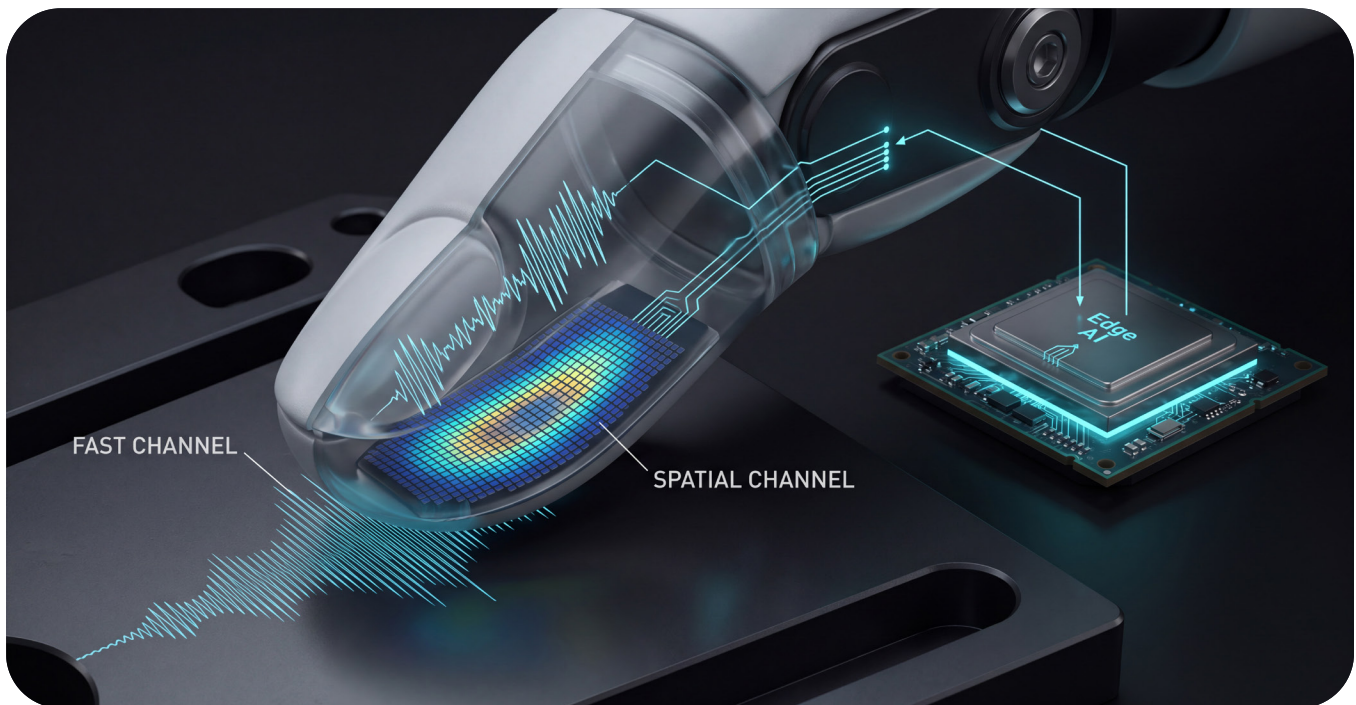
The Two-rate Sensing insight

The effectiveness of the Synaptics architecture relies on the two-rate sensing insight. No single measurement can capture the complexity of a grip. Catching the onset of a failure is a fast, transient phenomenon. Slip vibrations can run to several hundred hertz. According to the Nyquist limit, you have to sample at more than twice the highest frequency you care about, or the signal becomes corrupted. This is why the fast channel is sampled in the kilohertz range. It's tuned specifically to catch the high frequency shudder of a surface beginning to break free.

The spatial channel handles the quasi-static shape of the contact. It answers different questions:

- Where is the load sitting?
- How is the pressure distributed across the fingertip?
- Is the center of pressure migrating toward a failing edge?

While the fast channel “hears” the slip, the spatial channel “feels” the state of the grasp.



The End of Excessive Wiring

One challenge in robotics is the physical complexity of wiring. In some architectures, where raw data reaches a central GPU, the robotic arm requires a bundle of cables. This involves added weight, higher cost, and some added points of failure. By shifting processing to the Edge, Synaptics takes the system's data needs in another direction.

The Astra platform processes raw sensor data locally and only ships actionable metadata back to the central brain. Instead of raw pressure readings, the hand simply reports that it has a secure grip or that it's successfully recovered from a minor slip. This dramatically simplifies the wiring requirements and lowers the overall cost of the solution.

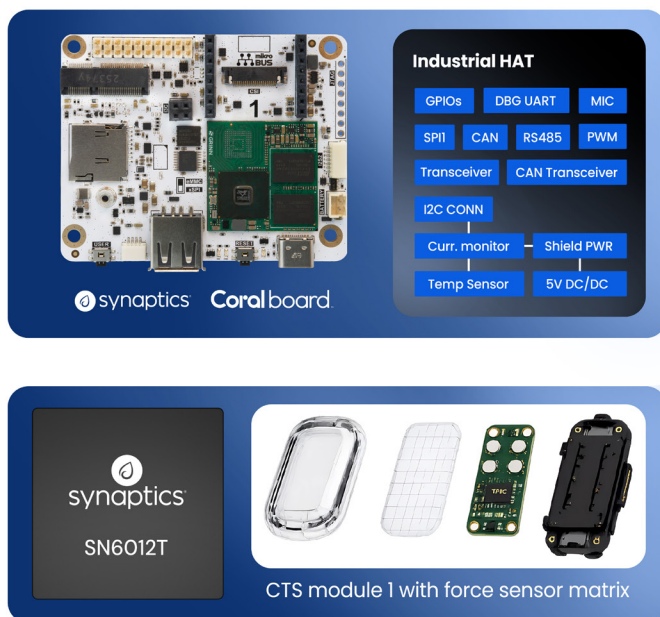
Real-World Application: The Industrial Gripper Platform

To prove the validity of this blueprint, Synaptics has partnered with Grinn to create a demonstrable platform that showcases these technologies in action. The demo features an off-the-shelf industrial robotic arm equipped with Synaptics' integrated tactile sensing and Edge AI compute subsystem. The Edge AI models that run on this platform are from TacnIQ.ai. This platform is a peek at a new direction for tactile-enabled robotics.

The demo highlights several advanced capabilities:

- **Voice-Instructed Dexterity:** Using natural language, an operator can tell the robot to “pick up the cylinder” or “grab the ball.” The system uses its integrated compute to recognize the command and execute the task.
- **Live Heat Map Visualization:** The platform provides a real time visual representation of the force distribution across the tactile sensors. When the system increases its grip, operators see the heat map change colors in response.
- **Autonomous Slip Recovery:** When handling slick or heavy objects, the system detects incipient slip and automatically increases the grip force in real time without human intervention.
- **Shape Awareness:** The gripper handles varied shapes (cubes, spheres, and cylinders) adapting its force and contact points based on the tactile feedback it receives.

Gripper Demo Architecture



Platform Features

- Acquisition and processing of force sensor data (SN6012T)
- Visualization of force sensor readings
- Robotic arm kinematics & control
- Integrated auxiliary sensors
- Optimized AI models for slip, shear, friction, and impact detection

About Grinn

Grinn is a full-cycle technology company specializing in the design and development of advanced IoT and embedded solutions. From initial concept through production, Grinn offers comprehensive services in hardware design, embedded software development, mechanical engineering, and manufacturing support.

TacnIQ.ai

TacnIQ is an AI pioneer that developed the foundation model for touch, enabling robots and machines to feel by gathering massive real-world tactile datasets. The company provides plug-and-play tactile intelligence and development kits across industries such as logistics, healthcare, construction, and e-commerce.

Everything in this demo, from the robotic arm kinematics to the user interface, is powered by the Astra platform. It shows that manufacturers don't need a massive, power-hungry compute platform to achieve sophisticated robotic control. This platform is designed to be developer friendly, providing the building blocks that ODMs and OEMs need to create their own dexterous hands. It proves that the missing sense of touch is ready for real-world deployment, moving beyond simple industrial grippers to complex humanoid hands and collaborative robots that work safely alongside humans.

Feeling Earlier to Move Faster

Robotics development is increasingly focused on dexterity rather than only arm strength or centralized processing capacity. As robotic systems move into less structured environments, including homes, hospitals, and collaborative industrial settings, reliable grasping and manipulation become central engineering requirements. The current limiting factor is often not object recognition or task planning, but the ability to maintain stable, adaptive contact with varied objects.

An Edge tactile sensing architecture addresses this challenge by moving more sensing interpretation and control closer to the point of contact. Local processing can reduce the time between sensing, decision-making, and actuation, supporting faster responses to early indicators of slip. Capacitive tactile sensing may also help address durability and environmental-stability concerns associated with some traditional sensing approaches.

For robotic hand and gripper designers, the practical implication is that earlier detection can be more effective than simply applying greater force. Systems that can interpret tactile feedback at the Edge may operate with lower safety margins, adapt more quickly to changing contact conditions, and reduce the risk of damaging delicate objects.

The Synaptics platform brings together tactile sensing and Edge processing as one approach to implementing this capability in robotic end effectors. In this model, touch becomes part of a distributed control architecture, enabling robotic systems to respond to contact conditions closer to where they occur.

Get started: To discover more about Astra, visit www.synaptics.com/products/embedded-processors. To learn more about Grinn Global and their services, visit grinn-global.com/services. To learn more about TacIQ.ai's TIQ-1 model, contact TacIQ.ai at tacniq.ai/contact.



Copyright

Copyright© 2026 Synaptics Incorporated. All rights reserved.

Trademarks

Synaptics, the Synaptics logo, AI Native Synaptics logo, Astra, and the Astra logo are trademarks or registered trademarks of Synaptics Incorporated in the United States and/or other countries. All other trademarks are the property of their respective owners.

Contact

Visit our website at www.synaptics.com to locate the Synaptics office nearest you.

Notice

Use of the materials may require a license of intellectual property from a third party or from Synaptics. This document conveys no express or implied licenses to any intellectual property rights belonging to Synaptics or any other party. Synaptics may, from time to time and at its sole option, update the information contained in this document without notice.

INFORMATION CONTAINED IN THIS DOCUMENT IS PROVIDED "AS-IS," AND SYNAPTICS HEREBY DISCLAIMS ALL EXPRESS OR IMPLIED WARRANTIES, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, AND ANY WARRANTIES OF NON-INFRINGEMENT OF ANY INTELLECTUAL PROPERTY RIGHTS. IN NO EVENT SHALL SYNAPTICS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, PUNITIVE, OR CONSEQUENTIAL DAMAGES ARISING OUT OF OR IN CONNECTION WITH THE USE OF THE INFORMATION CONTAINED IN THIS DOCUMENT, HOWEVER CAUSED AND BASED ON ANY THEORY OF LIABILITY, WHETHER IN AN ACTION OF CONTRACT, NEGLIGENCE OR OTHER TORTIOUS ACTION, AND EVEN IF SYNAPTICS WAS ADVISED OF THE POSSIBILITY OF SUCH DAMAGE. IF A TRIBUNAL OF COMPETENT JURISDICTION DOES NOT PERMIT THE DISCLAIMER OF DIRECT DAMAGES OR ANY OTHER DAMAGES, SYNAPTICS' TOTAL CUMULATIVE LIABILITY TO ANY PARTY SHALL NOT EXCEED ONE HUNDRED U.S. DOLLARS.