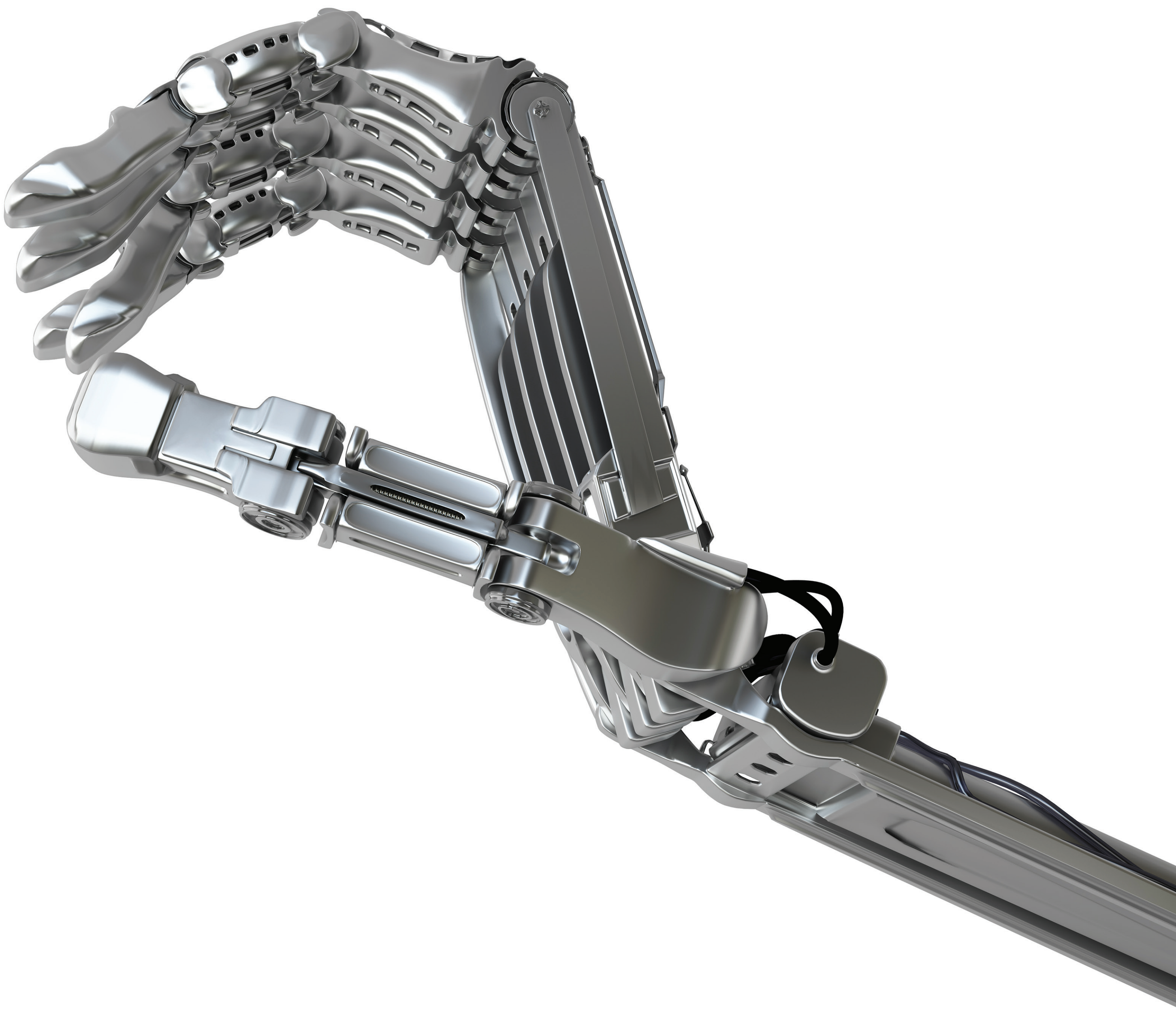
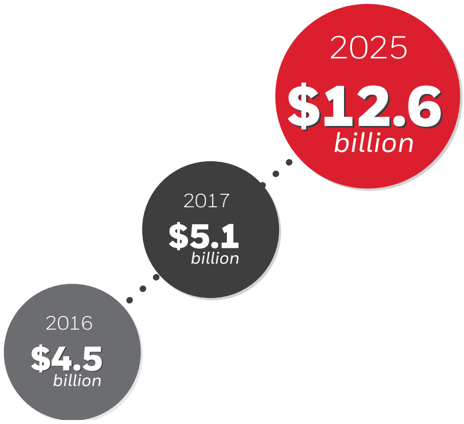
FORCE SENSORS IN ROBOTIC APPLICATIONS

Application Note



As an integral component in robotic applications, force sensors have numerous strengths that can add value to robotic applications. To deliver their full potential, it’s important to understand the roles they can perform and their key attributes.



ROBOT TYPES AND THEIR FUNCTIONALITY

What is a robot? The first picture that comes to mind is a humanoid robot walking and handling objects like a normal human does.

The Oxford English Dictionary defines it as, “A machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer.”

Robots come in different sizes, and purposes. This Application Note will be referring to two specific robot types – surgical robots and industrial robots.

Surgical robots allow doctors to perform complex procedures with precision and is usually minimally invasive.

Industrial robots are capable of performing repetitive tasks and improving productivity and throughput.

APPLICATION OF SENSORS IN ROBOTS

What are the types of components used in robots and where are they used?

Position sensors enable robots to work with humans without the risk of injury to the human and/or damage to the robot.

Optical scan engines enable robots to conduct tasks including selection, inspection, path following and more

Thermistors can be integrated into temperature chambers to ensure temperature is maintained.

Board-Mount Pressure Sensors measure the pressure of the air or fluid in the lines that control, lubricate or provide power to the robot.

Magnetic Position Sensor ICs help maintain a high level of accuracy and precision in factory automation.

MICRO SWITCH Basic Switches are used in operator control assembles, and also for end-of-travel and grid-style guidance to define range.

Force sensors, used in the gripper, identify the force applied on any item to ensure safe grasping or gripping.

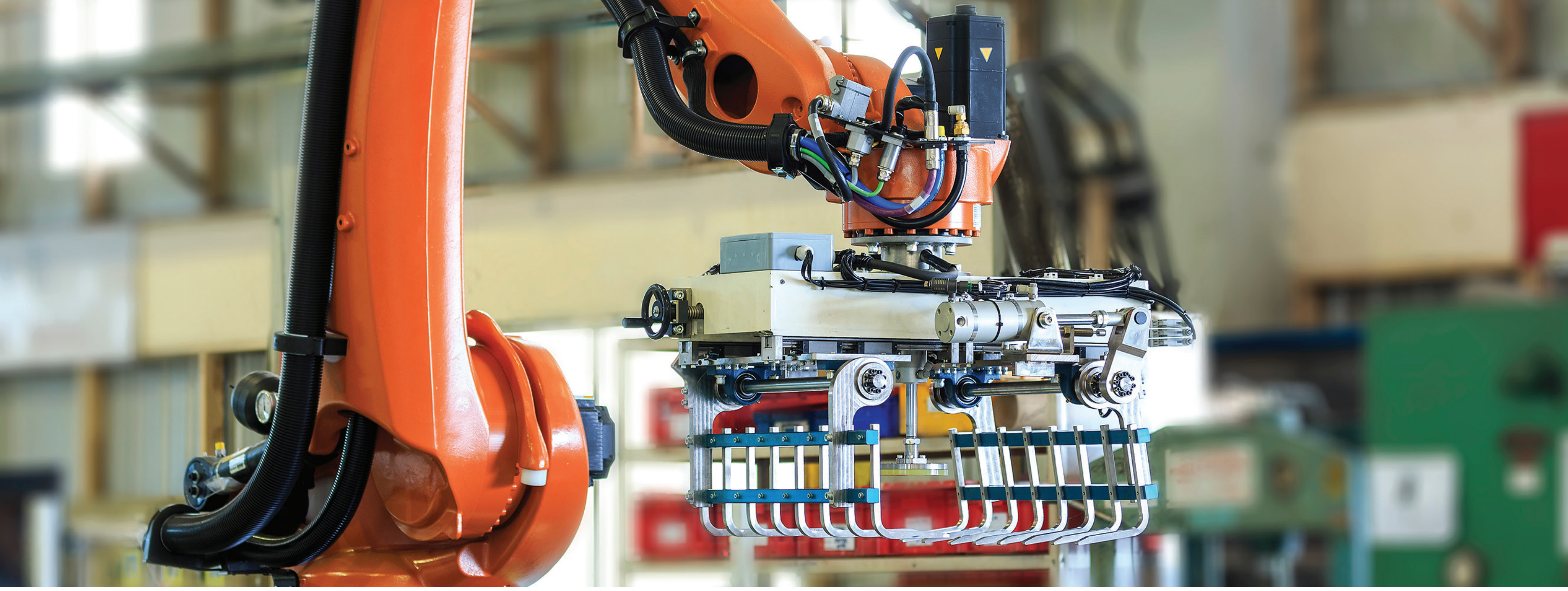
A GROWING GLOBAL MARKET

In December 2020, *BusinessWire* reported, “The (robotics) market is experiencing a significant transformation, with robots growing beyond the workhorses of industrial shop floors and beginning to adopt the roles of personal assistants, surgical assistants, delivery vehicles, autonomous vehicles, exoskeletons, and crewless aerial vehicles, among many other uses.”[1]

This growth is very apparent in the medical industry. It is estimated that over from 2016 to 2025 the market will increase from 4.5 billion to some 12.6 billion U.S. dollars.[2]

[1] https://www.businesswire.com/news/home/20201216005516/en/Global-Robotics-Market-Growth-Trends-and-Forecasts-Report-2020-2025-Advent-Of-Industry-4.0-Driving-Automation-Increasing-Emphasis-On-Safety---Res-earchAndMarkets.com

[1] https://www.statista.com/statistics/877720/surgical-robots-market-value-worldwide/



FORCE SENSOR USE IN SURGICAL ROBOTICS

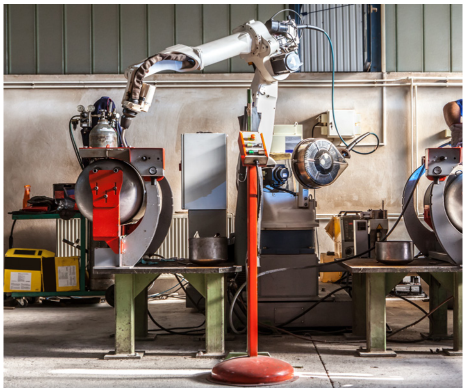
A small, digital sensor mounted on the tip gives fast, accurate feedback even in crucial situations leading to better outcomes for patients:

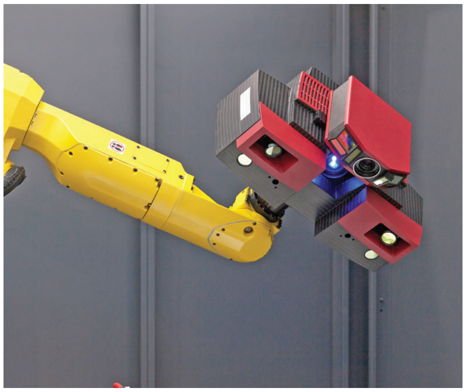
- **Small size:** Space is at a premium.
- **Haptic feedback:** Accuracy and digital output makes quick, reliable feedback a possibility.
- **New functionality:** Digital output enables wireless sensor transmission to controller.
- **Predictability:** Variations in temperature don't impact sensor output – safer surgeries, better outcomes.
- **Flexible design:** Replaceable end effectors with built-in force feedback now are possible.

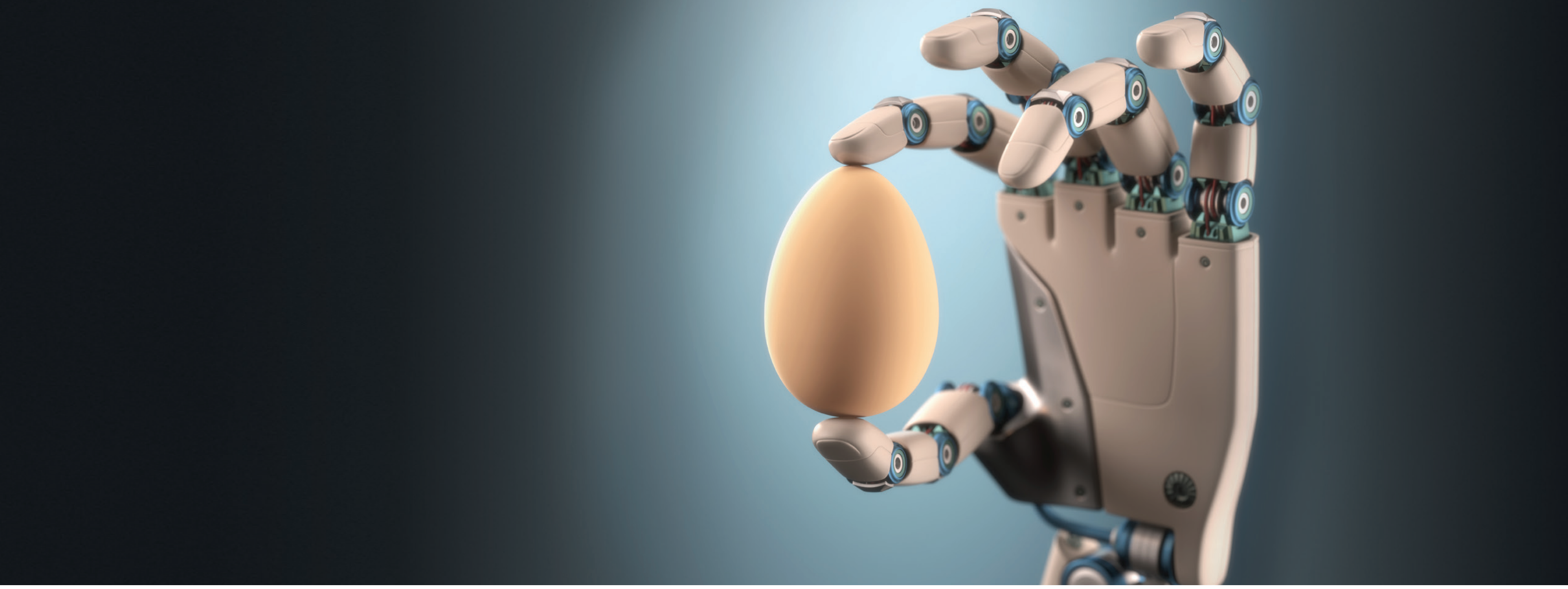
FORCE SENSOR USE IN INDUSTRIAL GRIPPERS

A small, digital force sensor mounted on the gripper pads will help improve productivity and reduce downtime:

- **Long term reliability:** Compared to a spring and Hall-effect sensor or actuator current sensor, fatigue and creep don't impact long term readings – lesser downtime, higher productivity
- **Support many shapes and sizes:** The same gripper can be used for different shapes and sizes and the feedback is based on force on the object and not indirect measurement.
- **Temperature compensation:** The robot continues to be just as productive irrespective of the temperature on the production floor or in the environment.
- **No recalibration/fatigue:** Calibrated, compensated, long cycle life – your robots keep working without downtime.





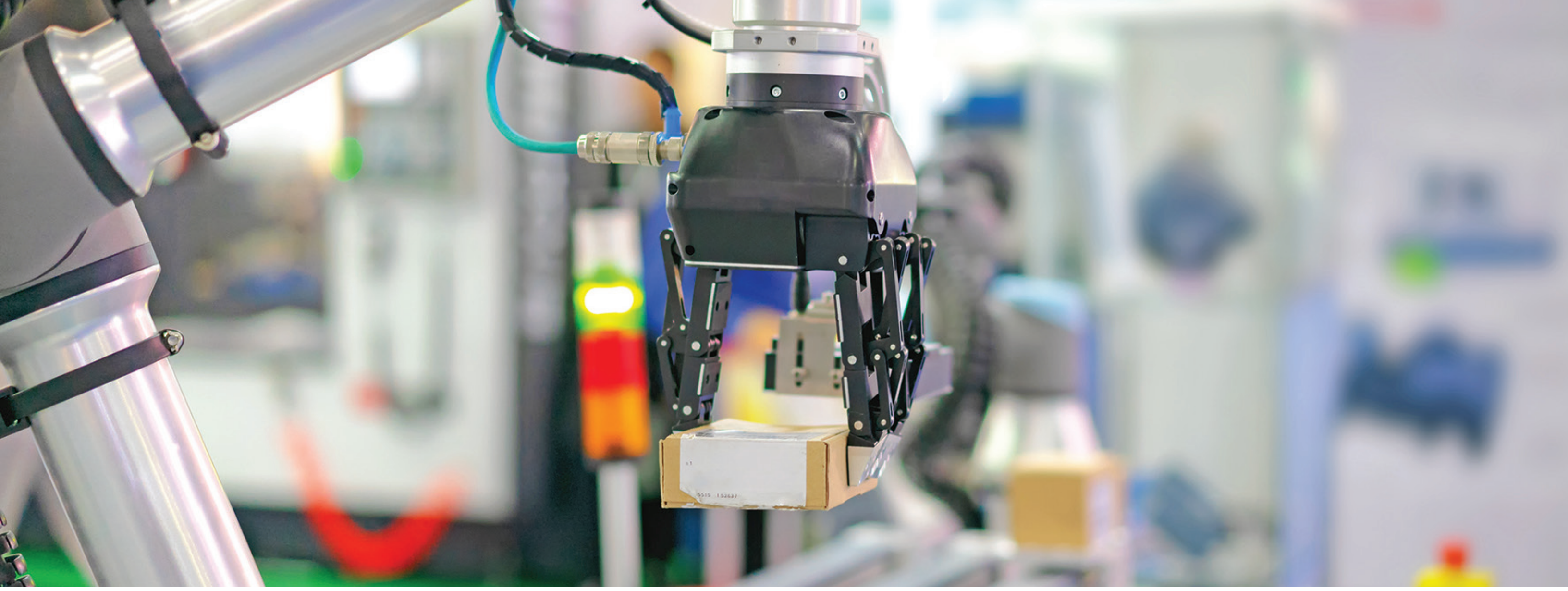


FORCE MEASUREMENT TECHNIQUES

TABLE 1. TRADITIONAL METHODS TO MEASURE THE AMOUNT OF FORCE BEING APPLIED TO AN OBJECT

SENSOR TYPE.	SENSORY TYPE AND ATTRIBUTES	ADVANTAGES	DISADVANTAGES
Piezoresistive array	Array of piezoresistive junctions	• Simple signal conditioning • Simple design • Suitable for mass production	• Temperature sensitive • Frail • Signal drift and hysteresis
Capacitive array	• Array of capacitive junctions • Row and column electrodes separated by elastomeric dielectric	• Good sensitivity • Moderate hysteresis	Complex circuitry
Piezoresistive MEMS array	Silicon micromachined array with doped strain gauge flexure	Suitable for mass production	Frail
Optical	Combined tracking of optical markers with a constitutive model	No interconnects to break	Complex computing required
Load cells	Single strain gauge converts resistance change to a mV output	• Large force ranges • High accuracy	• High cost • Analog output • mV

Some additional ways to measure force are the current draw at the actuator or a force-torque sensor mounted on the "wrist" of the robot. These are useful methods to measure gripper force; however, they can only be used to measure when the gripped object exerts enough torque to get readings.



CHOOSING THE RIGHT FORCE SENSOR

Some factors to be considered while selecting a force measurement method are:

Digital output: Digital output sensor minimizes noise and provides flexibility in obtaining the sensor signals for integration into complex control software. A digital sensor provides greater value compared to analog sensors for more complex applications.

Size: A large sensor provides a larger contact area but minimizes the potential location categories of gripper it can be used in. A smaller-sized sensor offers flexibility to the designer on location of the sensor but trades off on contact area.

Reliability: Long -term reliability translates to lower downtime, fewer recalibration events and better performance over the life of the sensor.

Life of the sensor: A higher number of cycles ensures lower downtime and longer time to replacement. Repeatable performance over the sensor's lifecycle is essential to avoid downtime due to recalibration.

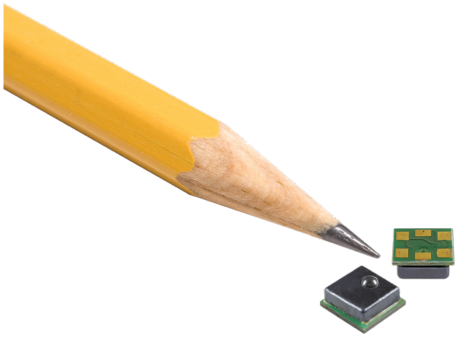
Temperature calibration: A calibrated sensor ensures seamless performance/reduced downtime for recalibration irrespective of temperature condition (local or environmental).

Accuracy: A highly accurate sensor enables better control and more complexity of functions for the robotic gripper

Power consumption: For autonomous robots or where power draw is a concern, a low power sensor works well. For large loads, power becomes less of a concern.

Total costs: Cost of the sensor isn't the only cost – designing the sensor in, testing, validation are all factors to be considered. Calibration, internal diagnostics and application support are all factors that affect the sensor's total cost.

MICROFORCE FMA SERIES SENSORS



HONEYWELL FORCE SENSORS AND BENEFITS

Honeywell's MicroForce FMA Series sensors offer multiple benefits to designers – whether of industrial or medical robots. It's our newest and smallest sensor, designed to meet requirements of robots, digitized output at sensor, temperature compensated and low power.

TABLE 2. HONEYWELL FORCE SENSORS AND BENEFITS	
ATTRIBUTE	**PERFORMANCE**
Digital output	digital output, I^2C or SPI , multiple options
Size	small size, easy to fit into gripper tips
Life of sensor	1 million cycles
Calibration	temperature calibrated to 50°C
Total costs	cost effective, digital output, diagnostics, easy to integrate
Accuracy	2% accuracy, 8% TEB, fine controls possible with the sensor
Reliability	stable over the long term, calibrated during production

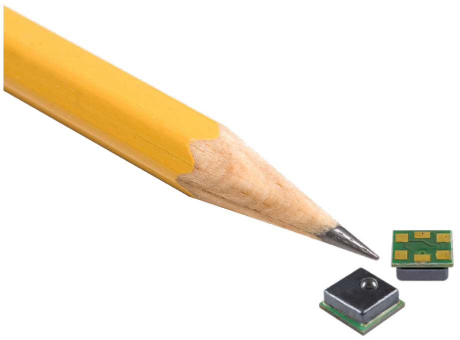


TABLE 3. MICROFORCE VS OTHER TECHNOLOGIES				
ATTRIBUTE	**MICROFORCE**	**LOAD CELLS**	**CURRENT SENSORS**	**FORCE RESISTORS**
Digital output	built in	analog	available	analog
Size	small	larger	N/A[1]	small
Life of sensor	long	long	long	long
Calibration	calibrated	calibrated	periodic recalibration	periodic recalibration
Total costs	lower	higher	higher	higher
Accuracy	high	very high	lower	lower
Long-term reliability	high	high	lower	lower

[1] Not mounted in gripper.

WARRANTY/REMEDY

Honeywell warrants goods of its manufacture as being free of defective materials and faulty workmanship during the applicable warranty period. Honeywell's standard product warranty applies unless agreed to otherwise by Honeywell in writing; please refer to your order acknowledgement or consult your local sales office for specific warranty details. If warranted goods are returned to Honeywell during the period of coverage, Honeywell will repair or replace, at its option, without charge those items that Honeywell, in its sole discretion, finds defective. **The foregoing is buyer's sole remedy and is in lieu of all other warranties, expressed or implied, including those of merchantability and fitness for a particular purpose. In no event shall Honeywell be liable for consequential, special, or indirect damages.**

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Specifications may change without notice. The information we supply is believed to be accurate and reliable as of this writing. However, Honeywell assumes no responsibility for its use.

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