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# E.S.P. For IoT Platforms

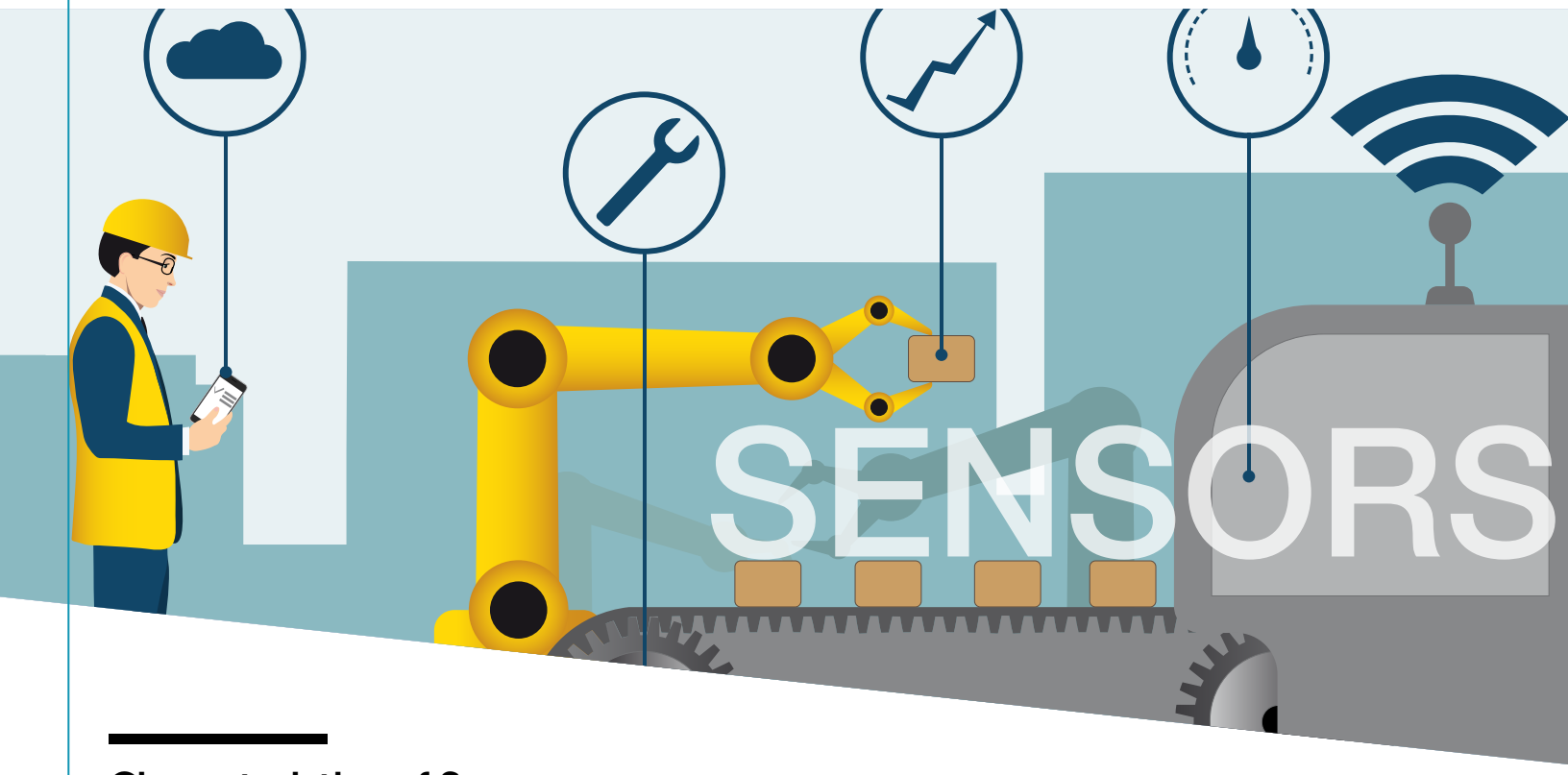
## With IoT, Gaining "Extra Sensory Perception" Starts With The Sensors

WHITE PAPER

## Business Insights Driven By Predictive Analytics Start With Sensors

There is much anticipation of what predictive algorithms will deliver. Although predictive analytics may be the holy grail of the IoT, the journey towards using this tool starts with something more mundane: sensors.

Sensors deployed on the factory floor are the source of the data needed for taking actions in real time and for longer-term predictive analytics. While discussing sensors might not be as cutting edge as discussing other topics around IoT, they are a vital component of an IoT network. If the sensors are inaccurate and unreliable, the resulting data may not mean anything, or worse, may cause you to make the wrong decisions. This paper addresses the important characteristics to consider when selecting sensors.




## Characteristics of Sensors

Although this paper applies to a broad range of sensors, we will only explore temperature sensors. To establish a model for comparison, we will first study the characteristics of the perfect sensor, then we will examine characteristics of a temperature sensor.

### The Perfect Sensor

The perfect sensor can measure temperatures from 0°C to 400°C (Figure 1). The output of the sensor is "0" when the temperature is 0°C and the output is "10" when the sensor reaches full scale at 400°C. For our example, the units of the output do not matter, but in the real world, the unit would most likely be volts.

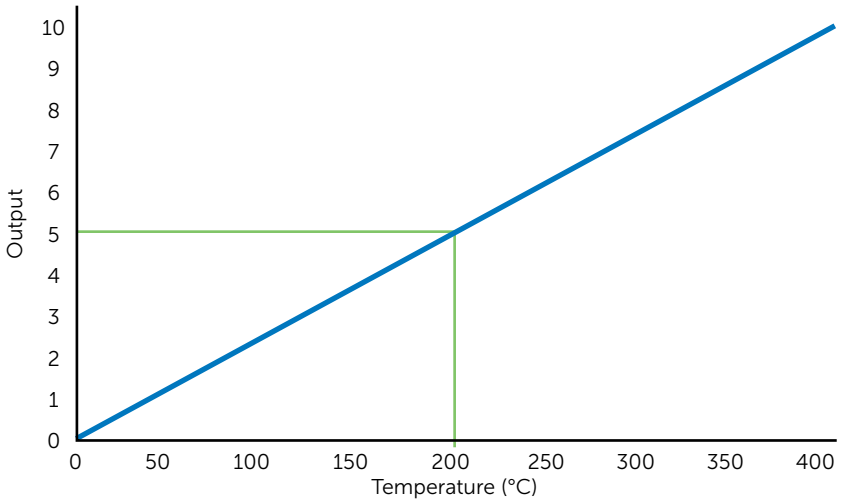



**Figure 1. The ideal temperature sensor.**


Our example sensor is perfectly linear. A step change at the lower end of the sensor's range results in the same magnitude change in the output as the same step change at the higher end of the range.

Our ideal sensor is not affected by anything in its surrounding environment and monitors the temperature of an oven in a local pizzeria. The oven is set to a perfect 200°C and does not waver. The output of our ideal temperature is a perfect, unwavering "5."

Now let's explore the characteristics that are important to consider when specifying a real-world temperature sensor for an IoT platform.

### Accuracy

Accuracy is the ability of a sensor to provide a true measurement of whatever the sensor is monitoring. There is an uncertainty with the measurement, usually represented as a percentage of full scale.

Our real-world temperature sensor has an uncertainty with the measurement of ±10% of full scale. So, while the oven's temperature has not changed, and our ideal sensor accurately reports a "5," our real-world temperature sensor will report a number somewhere between "4" and "6" (Figure 2).

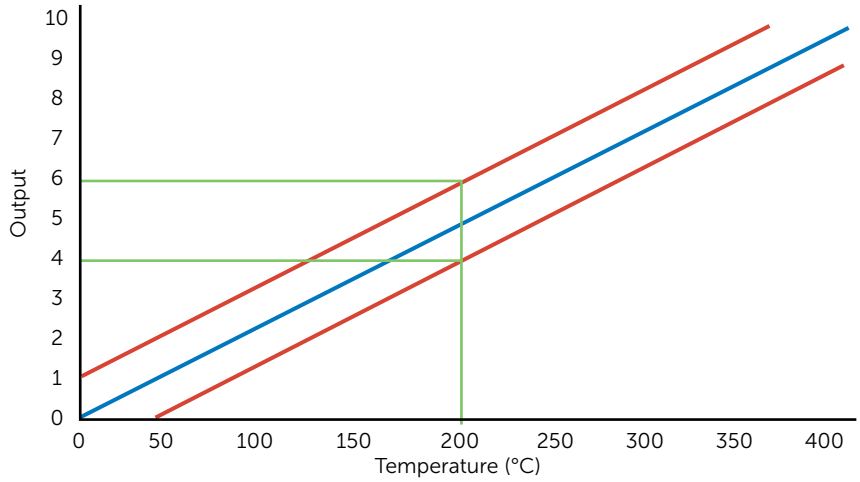



**Figure 2. Sensor's accuracy.**

### Repeatability

A sensor's repeatability allows it to provide a constant output when there is a constant input, when acquiring a new sample.

With our ideal sensor, since the temperature is at a perfect 200°C and is unchanging, the output will be a perfect, unchanging "5" every time we take a sample. With our real-world temperature sensor, our sample is "5.3." Remember, there is an uncertainty in the sensor's measurement. Later, we take another sample and it is "4.6," even though the temperature has not changed. This difference in the samples is representative of the sensor's repeatability.

### Linearity

Linearity is the response curve of the real-world sensor as compared to the ideal sensor's response curve. Our ideal sensor has a perfectly straight response curve with a slope of "1" unit change of output for every 20°C change in temperature - essentially a 20:1 ratio that is constant whether at the lower end of the sensor's range or the higher end (Figure 3).

As it turns out, our real-world sensor is highly non-linear. At midscale, a 120°C increase in temperature yields only a one step change, from "5" to "6." It should have been three steps. If we decrease the temperature by 120°C, the output would be "3," or a reduction of two steps. As you can see, moving equal distances up or down the sensor's temperature range produces results that are not linear.

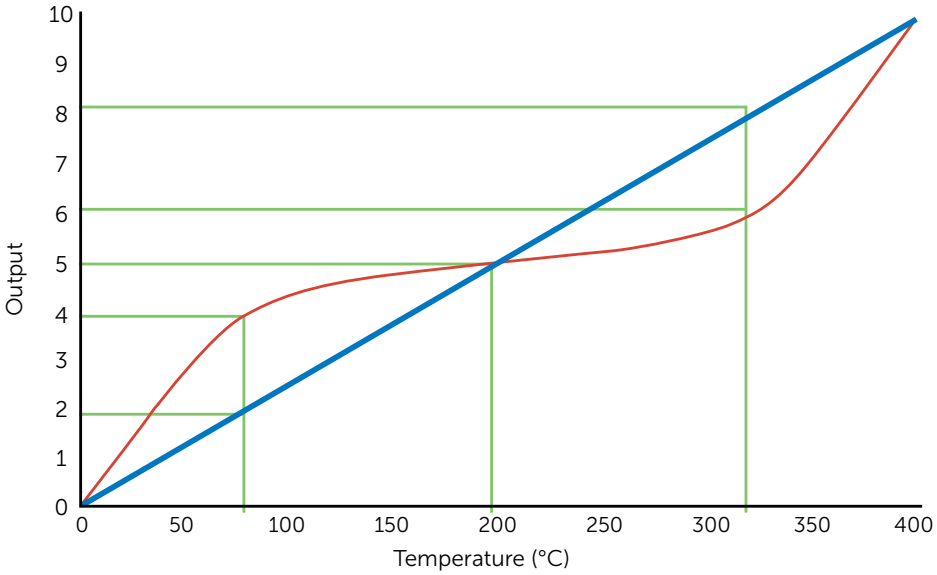
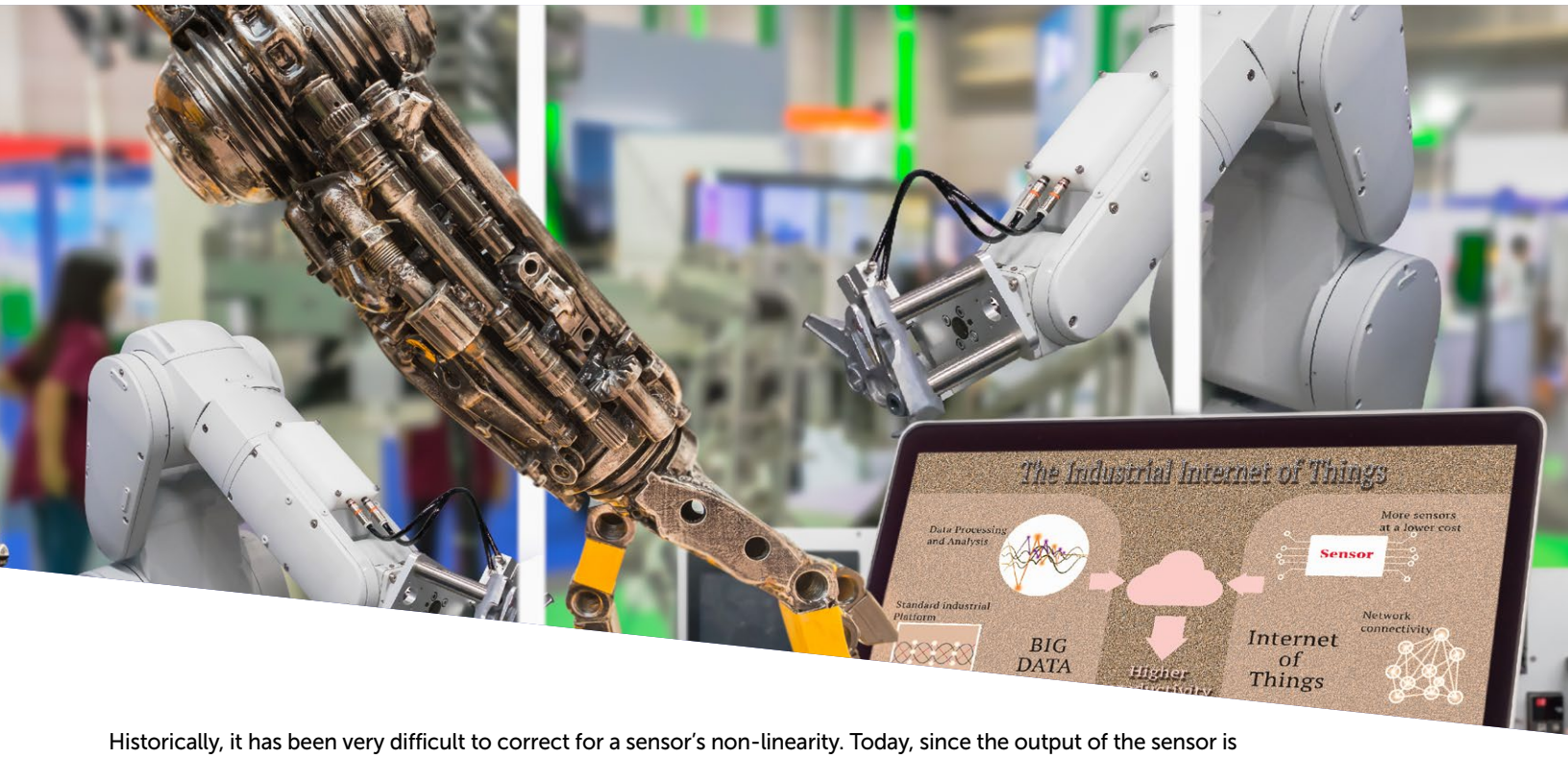



**Figure 3. Sensor's linearity.**




Historically, it has been very difficult to correct for a sensor's non-linearity. Today, since the output of the sensor is digital, it is much easier to correct for a non-linear transfer function. If one can determine the shape of the non-linear curve, an inverted digital curve can be applied to the data to remove the non-linearity.

### Sensitivity

A sensor's sensitivity is the amount the input to the sensor must change to detect any change in the output. In our example, the temperature of the oven must change by >1°C to detect a change in the output of our real-world sensor.

### Environmental Impact

Changes in the environment can impact the performance and accuracy of a sensor. For example, some sensors are particularly sensitive to temperature and humidity.

Our ideal temperature sensor is insensitive to any changes in its ambient environment. However, that is not the case with our real-world sensor. Our real-world sensor is particularly sensitive to changes in the surrounding humidity (Figure 4). For example, increasing humidity increases the angle of the line's slope. With the oven at a stable temperature, the increasing humidity changes the output reading from "5" to "7."

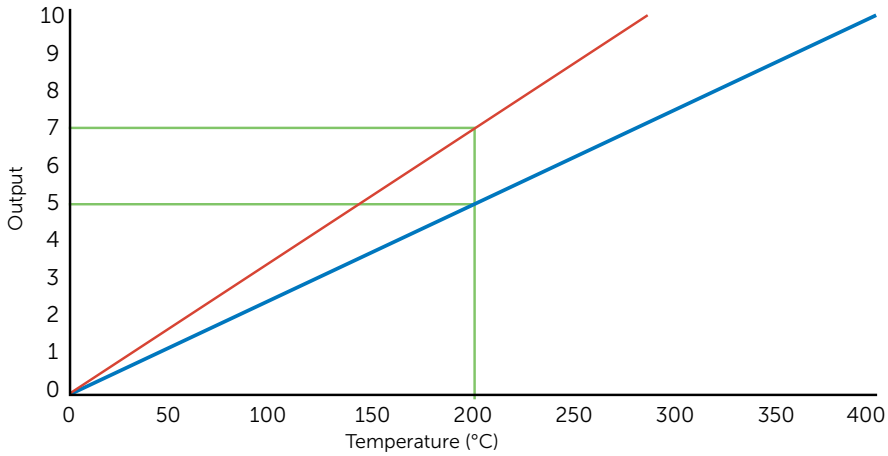
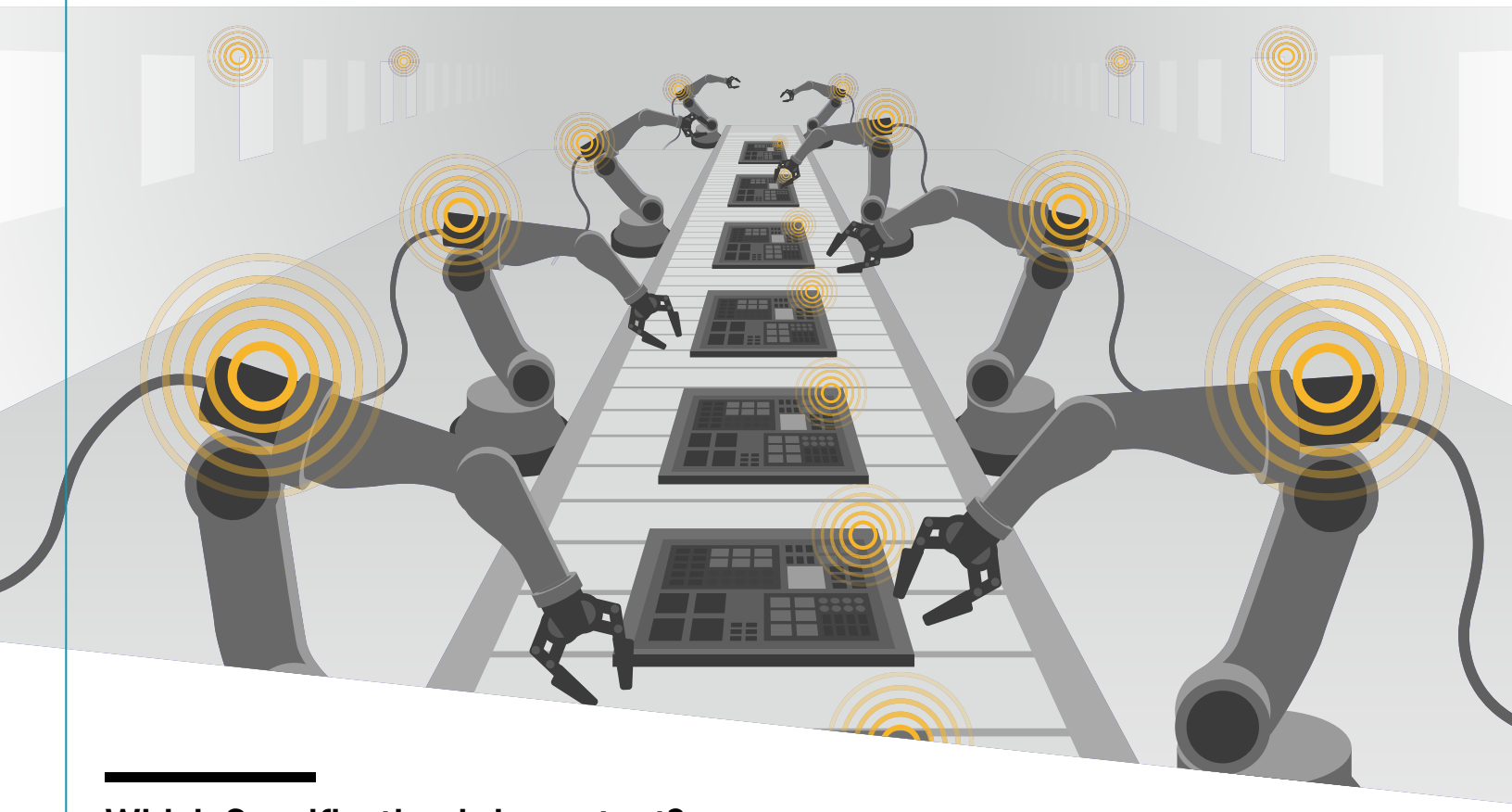



**Figure 4. Impact of changing ambient humidity.**



## Which Specification is Important?

It depends on a couple of factors: the type of sensor and where that sensor will be deployed.

For example, the specifications for a temperature sensor in an office thermostat can be quite lax compared to one deployed to monitor a pharmaceutical process. One might argue though, that the temperature sensor for a pizza oven needs to be accurate and linear for the oven to bake the perfect crust. You do not need, however, to worry about the ambient environment in a data center affecting sensors, as the environment is benign and unchanging.

Accuracy is high on the list for sensors that count things. The accuracy depends on the sensor's sensitivity to what it is counting, for example, radio frequency identification (RFID) tags whizzing by at a high rate of speed or the interruption of a light beam falling on a light sensor.

Linearity and sensitivity may not be that important for black and white surveillance cameras, but they are extremely important to the sensor arrays used in high-end, studio grade video cameras.

One thing to be mindful of is that the tighter the specification, the more expensive the sensor. Depending on the type of sensor, its application, and the number of them being deployed, you might need to make sure you are not over specifying the sensors.

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## The Journey to Predictive Analytics

We have started the journey to predictive analytics at the beginning: with sensors. The data gathered from the sensors is valuable. It can be acted upon in real time or stored and analyzed for long-term trends. Because this data is valuable, it must be protected by the network's infrastructure. That is the next step on our journey. Subscribe to our **blog** to come along for the ride.

For more information on the IoT and automating the factory floor, visit **Panduit's factory floor landing page** on our website.

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