Analog and Digital Transducers — the Advantages of Both

How TE Connectivity's (TE) M3200 Expands Choices for Design Engineers

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INTRODUCTION

We live in an analog world. In fact, most sensing begins in the analog world where the desired information is a continuously variable value or parameter. Traditionally, the signal from the sensor element has been amplified, compensated, and linearized to suit the system to which the transducer is attached, all done in the analog domain. Starting in the mid-1990s, sensors and transducers started to move from purely analog operation to digital protocols, signal processing, and interfaces. Today, that migration is in full swing. The rate at which products cross the analog/digital line varies by industry, but digital now prevails in many application spaces. This doesn't mean the analog transducer industry will shrink and die. There are still many application areas — such as high EMI/RFI environments or legacy analog systems — where the benefits of an analog transducer will always surpass a digital approach.

A PRESSURE TRANSDUCER THAT'S AVAILABLE IN BOTH ANALOG AND DIGITAL VERSIONS

Analog and digital transducers are worlds apart in their technologies, interfaces, output signals, and the terminology used to describe and specify their operation. TE has developed an industrial pressure transducer — the M3200 — that is available in either an analog or digital configuration.

Both versions share these features:

- Perform the same basic function of measuring and reporting the pressure of a gas or liquid in a system, pipe, or storage tank.
- Are identical mechanically and can be interchanged.
- Use the same flexible diaphragm, silicon strain gauge technology, and Wheatstone bridge to convert the applied pressure to an analog voltage signal.
- Digitize the analog signal for further manipulation by the transducer electronics.

The similarities stop there however. Here's how the analog and digital transducers differ, not only in function, but in capabilities and benefits also.

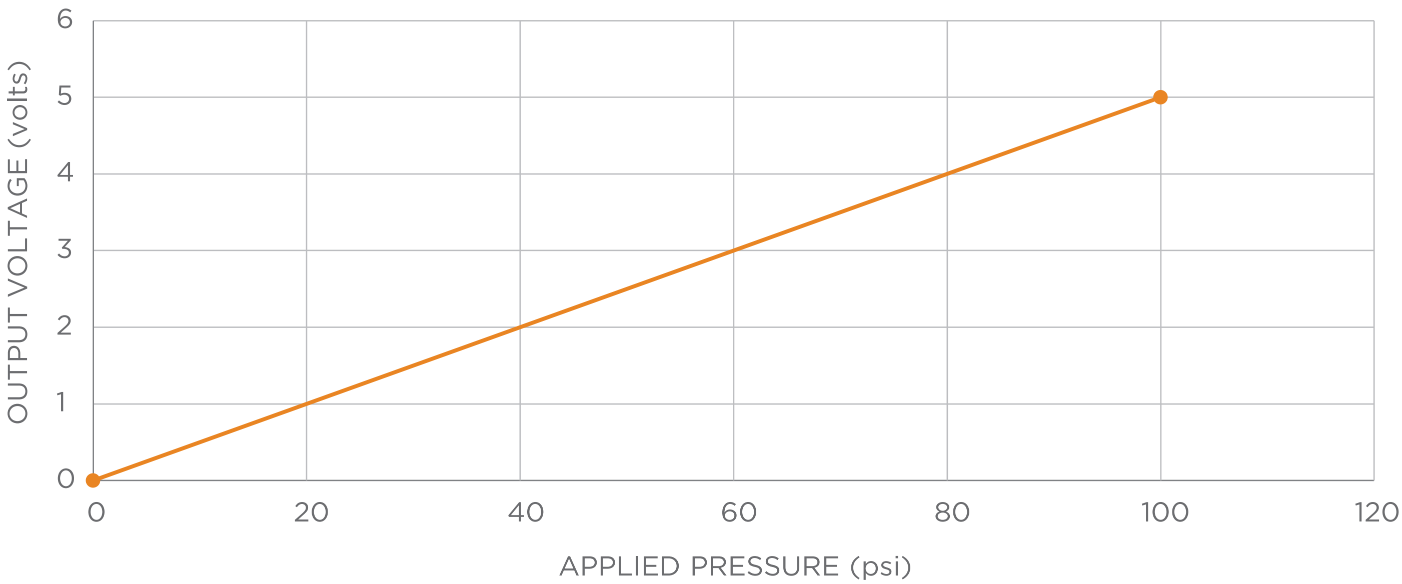
ANALOG — A CONTINUOUSLY VARIABLE OUTPUT

In the analog version of the transducer, the digital signal from the internal A/D is adjusted in several ways. Calibration factors are applied to confirm the sensor meets accuracy specifications. Then temperature correction factors are used to adjust the signal and compensate for ambient temperature. Finally, zero and span calibrations are added that set the output signal in the desired range as dictated by the transducer part number. The result is then converted back to an analog signal by an internal D/A converter, run through a unity gain buffer, and sent to the output pin. The output signal is continuously variable, just like the pressure applied to the sensor. In legacy technologies such as bonded foil strain gauges, the signal was trimmed using resistors applied to a circuit board based on characterization of the sensing element over pressure and temperature. As microprocessors and ASICs became more capable and smaller, many were integrated into pressure transducers. This has resulted in better accuracy, smaller form factors, and in some cases decreased costs.

The M3200 analog transducer provides a variety of output signals as illustrated in the table.

P/N Code	Output Range	Supply Voltage	Ratiometric1
2	0 to 100 mV	5.0 VDC	Yes
3	0.5 to 4.5 VDC	5 ±0.25 VDC	Yes
5	4 to 20 mA	9 to 30 VDC	No
6	0 to 5 VDC	8 to 30 VDC	No
7	0 to 10 VDC	12 to 30 VDC	No

1. The output signal moves up and down in a way that is ratiometric to the supply voltage.



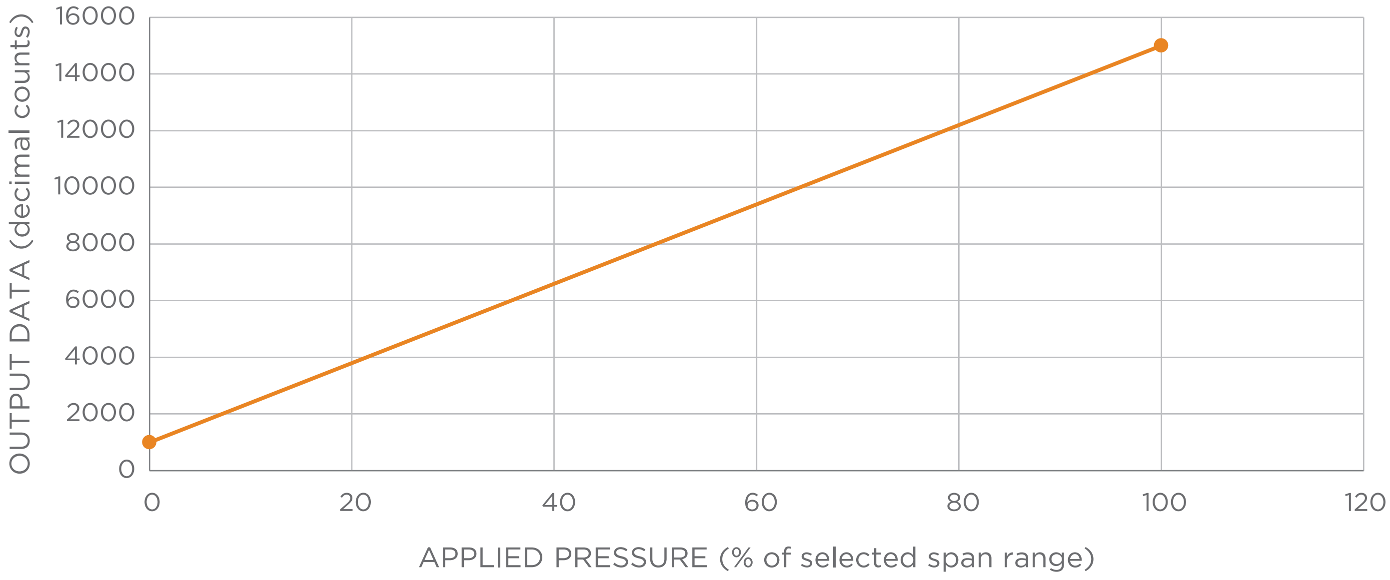
P/N M3264-000005-100PG Analog Transfer Function

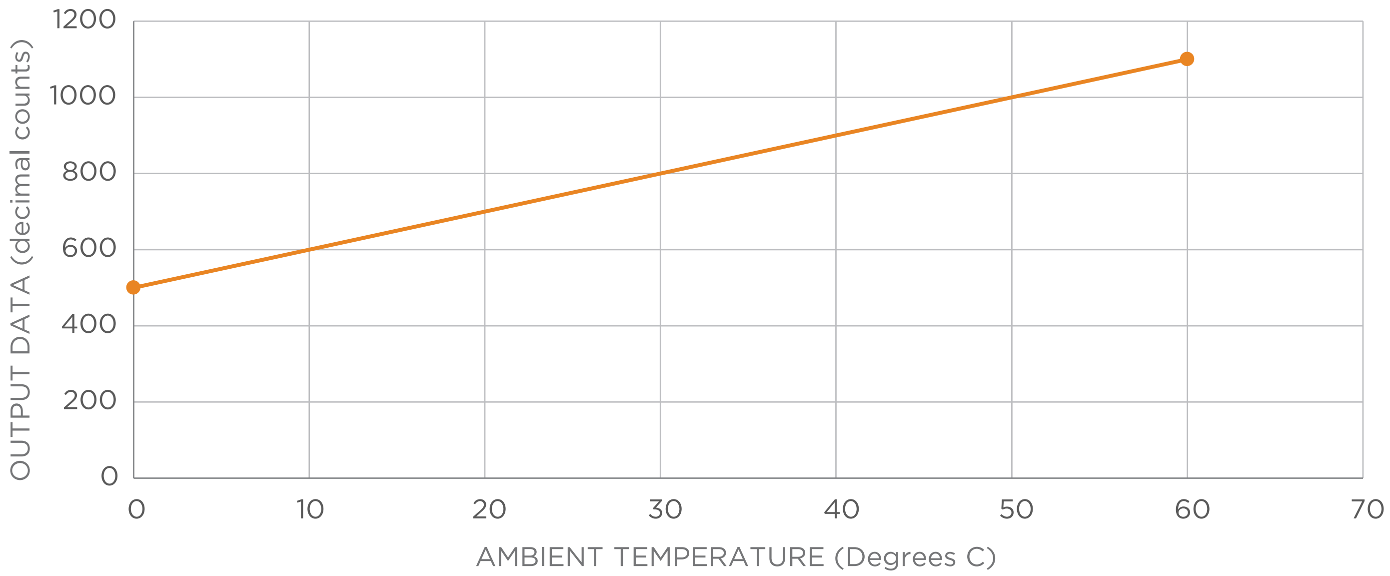
DIGITAL — OUTPUT IN THE 1'S AND O'S OF COMPUTER LANGUAGE

In the digital version of the transducer, a digital signal-processing core manipulates the data where various compensations and corrections are applied. This processed digital data is then stored in registers to be transmitted to the system later. The most common digital communication protocol used by sensors and transducers is Inter-Integrated Circuit (IIC or I^2C). This communication technique is designed so a transducer doesn't take a pressure reading or report it until the system master controller sends a request for the data. Because the need for pressure data is intermittent, the sensor can go to "sleep" (a very low power mode) between requests for data. This helps conserve system energy, an important capability in both battery powered and wireless applications.

Almost all of TE's digital sensor products take a temperature reading at the sensor. This temperature information is important to have. It is used to compensate the pressure signal to provide greater accuracy. The transducer digitizes the temperature data in order to apply it during compensation, and stores the data in a register that can be accessed along with the pressure data. The result is the availability of two sensor readings from a single transducer. The digital data is stored and transmitted in hexadecimal format for efficiency, but for clarity the data sheet and graphs use decimal format (counts) to illustrate the data.

Many of the TE transducers, including the M3200, measure the ambient temperature using the Wheatstone bridge circuit elements. This measurement technique provides the most accurate data for compensating the pressure reading. It also provides a good indication of the temperature of the media applying the pressure to the transducer.





P/N M32JL-000105-100PG Digital Transfer Functions

COMPARISON OF ANALOG VS. DIGITAL SPECIFICATIONS

The table below lists and compares the significant specifications and operating parameters for analog and digital M3200 transducers.

Parameter	Analog	Digital
Output Signal or Data	Continuously variable voltage or current	Serial digital bitstream
Accuracy (pressure)	±0.25% F.S.[1]	±1.0% F.S.
Accuracy (temperature)	N/A[2]	±3°C
Resolution (pressure)	N/S[3]	14 bits (±0.1% F.S.)
Resolution (temperature)	N/S	11 bits (±0.1°C)
Total Error Band	±1.5% F.S.	±2.0% F.S.
Supply Voltage	5.0 to 30 VDC[4]	2.7 to 5.0 VDC
Current (operating)	5 mA	3.5 mA
Current (sleep mode)	N/A	<10μA

1. F.S. = Full Scale Output
2. N/A = Not Available
3. N/S = Not Specified
4. Range varies with P/N and output config

Overall accuracy for a system using analog sensors can be affected by errors downstream of the sensor and how they are managed. In digital systems errors can appear from dither, jitter, and resolution issues.

YOUR DESIGN PARAMETERS — CHOOSING THE BETTER TRANSDUCER FOR AN APPLICATION

With availability in either an analog or digital version, the M3200 pressure transducer significantly expands the choices available to design engineers. While your customer design may require unique or unusual parameters, the cost and space of additional electronics to meet those parameters won't be an issue with the M3200. We offer 7,920 different standard versions of the M3200 so there's a high likelihood that one will fulfill your design engineer's requirement without any additional circuitry. Below is a table showing a list of key design requirements and the best choice to meet those needs.

Design Parameters or Requirements	Analog	Digital
Variable voltage output to system electronics	X	
Variable current output to system electronics (4-20 mA)	X	
Digital bitstream output in I^2C format		X
High accuracy	X	
High resolution		X
Low current sleep mode (battery powered applications)		X
Transducer or media temperature information		X
Very long wire connections (>5 ft or 1.5M)	X	
Interface to wireless communication		X
Interface to Programmable Logic Controller (PLC)	X	
Interface to IoT, IIoT, or M2M applications		X

There are applications and markets for both analog and digital transducers, and each have specific advantages for a particular application. See our case study examples.

A CASE FOR AN ANALOG SENSOR

Some applications have unique conditions that must be considered when deciding on an analog versus a digital transducer. Monitoring the pressure of chemical processes in an oil refinery is a good example. Because of the way a refinery is designed, a pressure transducer is sometimes located hundreds of feet from the control system to which it's attached — requiring a long cable run to make connection. These cable runs make excellent antennas that pick up EMI/RFI/ESD signals from adjacent cabling and machinery. However, this electrical "noise" can overwhelm, distort, or corrupt high-impedance analog signals in the cable.

A common technique to overcome this problem is to use a high current, low impedance transmission method that's immune to the noise sources. The 4-20 mA current loop was developed solely to provide this capability. At the transducer, the pressure signal is used to control the amount of current the sensor draws from the power supply located at the controller location. For a signal level of zero, the transducer draws 4 mA of current. For a maximum signal level, the transducer draws 20 mA. For any signal in between the limits, the current draw will be a value that is ratiometric to the signal level. Everything about this approach is analog. It's an excellent way to help eliminate problems caused by EMI/RFI/ESD. The M3200 pressure transducer is available in an analog 4-20 mA version with 12 different pressure ranges.

A CASE FOR A DIGITAL SENSOR

A new market is emerging for industrial pressure transducers that's referred to as the Industrial Internet of Things (IIoT or Industry 4.0 for short). The basic idea is to populate a factory with sensors and transducers that monitor every critical parameter of the manufacturing process. The collected data is sent to a central computer, or to the cloud, where analytics are applied, and the data is stored. All of this is done in the digital domain for efficiency of communication, analysis, and storage. It makes sense to use a transducer that provides data in a digital format. This reduces system costs and makes it more convenient to interface the transducer to the control electronics.

THE M3200 PROVIDES BROAD DESIGN FLEXIBILITY

Whether your application operates in the analog world or digital world, the availability of sensors and transducers that can operate in either type of application provides tremendous flexibility to designers of these systems. Both the analog and digital versions of the M3200 pressure transducer provide the same basic functions of measuring pressure accurately and sending the data to the control system. Having the option to send the data in either analog or digital formats confirms that the system design will be effective, efficient, and low cost—a desirable result for any of your design needs.

ABOUT TE CONNECTIVITY

TE is a global technology leader, providing sensors and connectivity essential in today's increasingly connected world. We are one of the largest sensor companies in the world. Our sensors are vital to the next generation of data-driven technology. TE's portfolio of intelligent, efficient and high-performing sensor solutions are used for customers across several industries, from automotive, industrial and commercial transportation and aerospace and defense, to medical solutions and consumer applications.

ABOUT THE AUTHOR

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Pete Smith is the Senior Manager, Sensor Product Knowledge and Training at TE Sensor Solutions. With 47 years of experience in product design, manufacturing, and sales of high-tech consumer and industrial products, Pete has wide-ranging expertise in all aspects of product development, engineering, sales, and marketing. In his current role at TE, he serves as a TE subject matter expert, sharing his in-depth sensor knowledge with colleagues, customers, and various external groups. For the last 32 years at TE, Pete has worked exclusively in the sensor technology space. His professional expertise in sensor product applications includes an in-depth understanding of how various sensors enable successful customer designs.

Pete lives in Folsom, California and is an avid skier, biker (bicycle), hiker, and amateur drone operator.

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