
TEMPERATURE TRANSMITTERS

Written By:

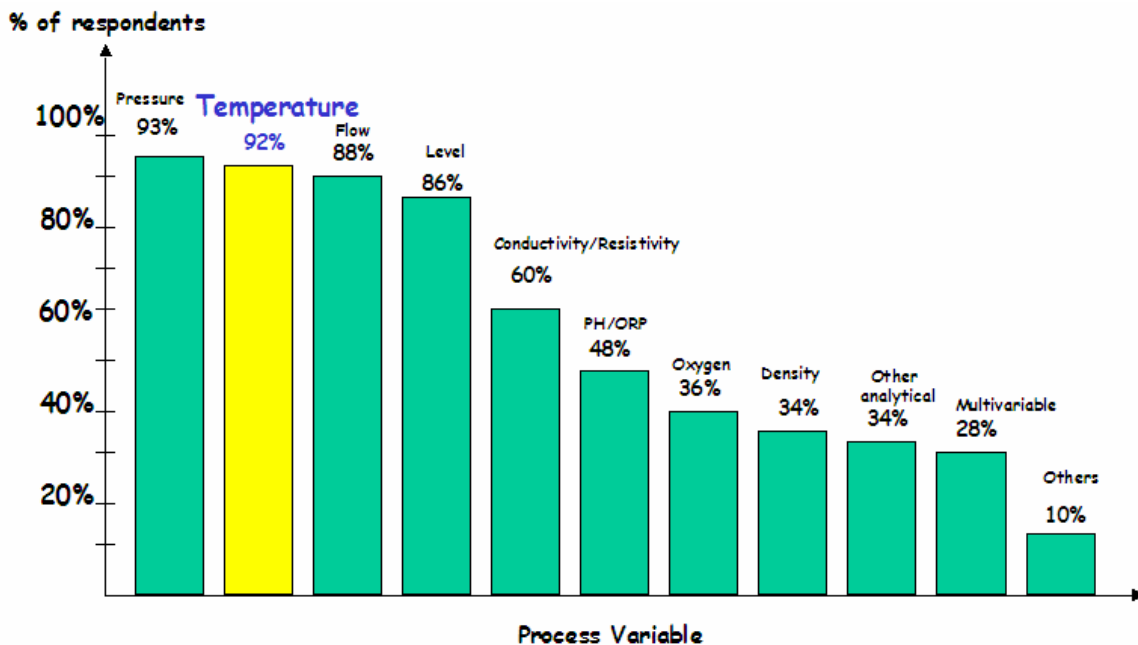
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INTRODUCTION

Advancements in the fields of physics and electronics have been extraordinary in recent years. Without doubt, these two fields of technology have yielded the most impacting and important developments in recent science. Today, people are incapable of living without the ease of use and benefits these advancements in technology provide in our daily lives. The advancements in the process control industry have followed a similar pace. The advent and evolution of microprocessors and electrical components have opened the door to great innovations in the process control industry that offer even greater control over your processes. These advancements have led to new ways of monitoring, sensing and communicating important process variables. In the last 20 years, process control communication has evolved from simple 4-20mA loops to progressively more robust communication standards such as HART, Foundation Fieldbus and Profibus.

This article will focus on one important advancement in particular; the temperature transmitter. The temperature transmitter is one of the most widely used field devices in the industry, with innumerable functionalities and features. According to a Control Engineering Magazine focus study, 92% of respondents indicated they use temperature transmitters to control their processes. Even more impressive, temperature is a basic metric used in the measurement of flow, density and other multivariable measurements. Thus, temperature transmitters extend their influence into multiple process variables.



Source: Control Engineering Magazine 2002 Transmitter Product Focus Study
Values add up to more than 100% due to multiple responses

Figure 1 - Use of Transmitters of Temperature in the industrial processes

MEASUREMENT OF TEMPERATURE

Today temperature is defined as the measure of the average kinetic energy of the molecules of a substance, represented in a numerical scale with larger values indicating a greater average kinetic energy. However, this was not always the case. As you will see, the road to standardized temperature measurement was a long one.

Historians date the first attempt to establish a temperature scale back to 130-200 B.C. by the Greek doctor Galeano. Galeano suggested the sensations of hot and cold be measured in a scale with four divisions, thus giving birth to the first temperature scale. It would still be centuries until well defined temperature standards emerged. With the invention of the first thermometer by Galileo Galilei in 1592, temperature measurement began picking up its pace.

In the following decades, many temperature scales were conceived. All were based on one or more arbitrarily fixed points, but none were universally accepted. In 1714 Gabriel Fahrenheit, a Dutch manufacturer of precision instruments, created the first accurate and repeatable mercury thermometer. His scale, degrees Fahrenheit, became the first universally accepted temperature scale in history. Initially Fahrenheit fixed the zero point of his scale using a mixture of ice and salt, with the upper point being the average temperature of the human body. Fahrenheit later adjusted his scale to the more familiar freezing point of water at 32 degrees.

In 1742, the Swede Anders Celsius created another scale. Celsius set the freezing and boiling points of water as the definition of his scale. Celsius chose "0 degrees" as the boiling point of water and "100 degrees" as the freezing point of water. Later, these points were inverted and the Centigrade scale was born. In 1948 the Ninth General Conference on Weights and Measures changed the name to the "Celsius scale" in his honor.

The Celsius and Fahrenheit scales are both relative, their numerical values of reference are totally arbitrary. Because of the desire for less arbitrary reference points, the additional temperature scales of Kelvin and Rankine were developed. These scales assign 0 to the thermodynamic absolute zero, the theoretical point of zero molecular kinetic energy.

With the creation of universally accepted temperature scales, scientists were now free to research the effects of temperature on various substances. In 1821, Thomas Seebeck discovered that when two different metal wires are joined at two points and one of the points is heated, an electric current will circulate. It was this discovery that led to the modern development of the thermocouple, one of the most used temperature sensors for industrial applications.

By the 20th century, the necessity of universally accepted temperature properties of various materials was clear. This would foster consistency and repeatability within the scientific community and promote scientific advancement. The most recent ratification of temperature standards was on January 1st of 1990 when these scales and values were fully standardized under the assignment of the International Temperature Scale, the ITS-90. In addition, there are localized standards used in the measurement of temperature: ANSI (USA), DIN (Germany), JIS (Japan), BS (UK), etc.

Fixed Points	ITS-90
Oxygen Boiling Point	-182.954°C
Triple Point of Water	+0.010°C
Freezing Point of Tin	+231.928°C
Freezing Point of Zinc	+419.527°C
Freezing Point of Silver	+961.780°C
Freezing Point of Gold	+1064.180°C

Figure 1 - Fixed points of temperature in accordance with the ITS-90

Scales	Absolute Scales		Relative Scales	
	°R	K	°C	°F
Boiling of Water	671.67	375.15	100	212
Freezing of Water	491.67	273.15	0	32
Absolute Zero	0	0	-273.15	-459.67

Figure 2 – Temperature Scale Comparison

From the temperature scale comparison in Figure 2, the following relations between scales can be deduced:

$$\frac{^{\circ}\text{C}}{5} = \frac{^{\circ}\text{F}-32}{9} = \frac{\text{K}-273}{5} = \frac{\text{R}-491}{9}$$

The great progress in the evolution of temperature measurement has concurrently advanced the accuracy, reliability and repeatability of temperature transmitters used in the automation and process control industry. This, in conjunction with the advancement and availability of diverse temperature sensors, has contributed to the continuous improvement of controlled processes and final product quality. We will now discuss some of the details of this new breed of intelligent transmitters.

INTELLIGENT TEMPERATURE TRANSMITTER MARKET

An intelligent temperature transmitter is defined as a transmitter that combines the technology of the temperature sensor with additional electronics. Generally these electronics allow for remote monitoring and configuration of the transmitter parameters. Looking at the market, three distinct lines of intelligent temperature transmitters have emerged. Each has its own advantages and disadvantages based upon application and cost.

1) Explosion Proof and Weather Proof Transmitters

This type of transmitter is normally used in critical applications with high performance requirements. The transmitter is enclosed in a sealed, explosion proof compartment. This enclosure is generally made of stainless steel, but can be any approved explosion proof material. The enclosure generally contains two compartments, separating the electronics and sensor. The primary advantages of this transmitter type is high accuracy, robust safety precautions, reliability and weatherproofing. The primary disadvantage is cost. This type of transmitter generally also includes a local indicator with local adjustment. This allows the temperature to be monitored, and the transmitter adjusted in the field. Example: Smar TT301, TT302 and TT303

2) DIN Rail, Panel Mount Transmitters

This type of transmitter can be mounted to a DIN rail and is generally used for centralized control room installations. Panel mount transmitters are low cost, allow easy installation and maintenance and can be configured for use with a diverse selection of sensor types. The primary disadvantage is the lack of explosion proofing and the tendency to have somewhat lower accuracy due to the long wiring required to mount the sensor remotely. Example: Smar TT411

3) Head Mount Transmitters

This type of transmitter can be mounted directly in DIN connection heads. The primary advantage to this is a low cost of installation, small size and compatibility with a diverse selection of sensor types. Because the transmitter is installed directly in the connection head, electrical connections and sensor wiring is simplified. Example: Smar TT421

The communication protocols used in temperature transmitters have followed the general trend of other field devices in the industry, with the predominant protocols being HART, Foundation Fieldbus and Profibus. Intelligent temperature transmitters are widely available in all these protocols.

EXAMPLES OF 4-20mA HART TEMPERATURE TRANSMITTERS

The block diagram in Figure 3 shows the basic functionality of the TT301 HART temperature transmitter from Smar.

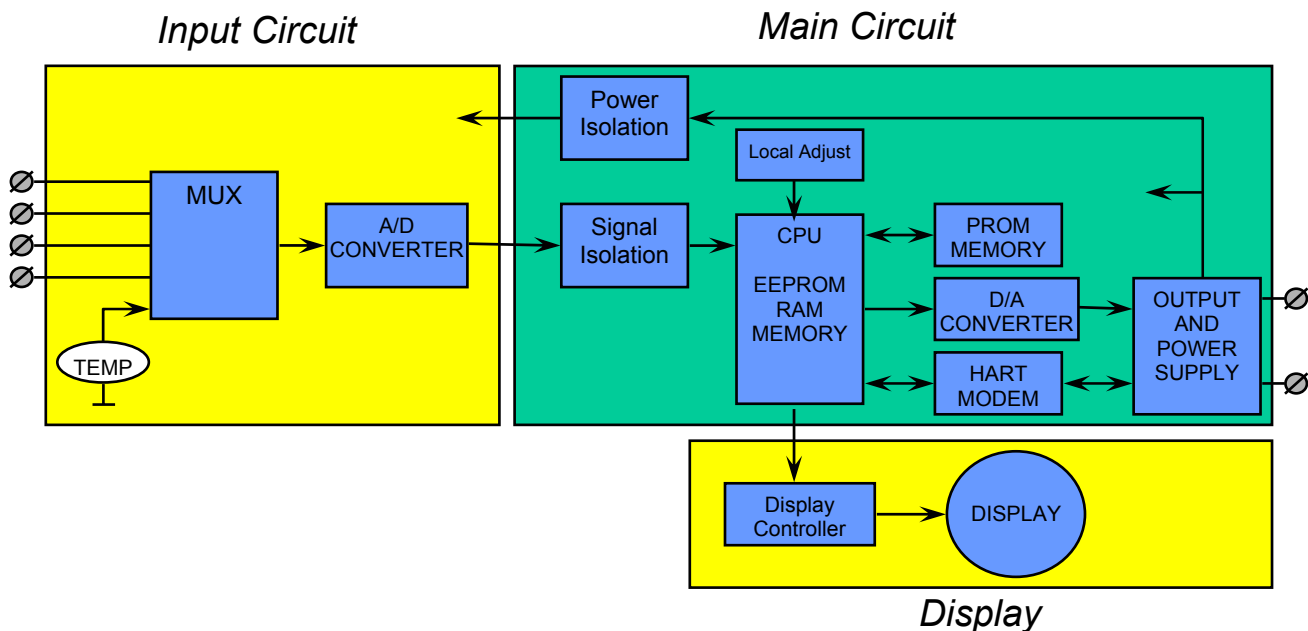


Figure 3 – TT301 Block Diagram

The TT301 Temperature Transmitter has the following characteristics:

- Smart two-wire, 4-20mA loop power transmitter with HART communication
- Measures temperature using resistive sensors (RTD's), thermocouples, ohm, mV, or customizable special sensor types
- Measurement type
 - Single Sensor: 2,3, or 4 wire configurations
 - Dual Sensor: Differential, Average, Maximum, Minimum
- Factory tested isolation
- Cold junction compensation
- Line resistance compensation
- Linearization according to international standards
- Accuracy of 0.02% of basic precision
- PID and setpoint generator
- Self-diagnostics
- Burn-out detection
- Easy upgrade to Foundation Fieldbus and Profibus PA available
- Rotatable Display (permits 4 positions)
- In field assembly
- Explosion proof, weather proof
- Intrinsically safe
- High immunity to EMI and RF
- Local adjustment
- In accordance with the NAMUR-NE43
- Write protection

Benefits:

- Low cost maintenance
 - Auto remote diagnosis
 - local and remote configuration or calibration (re-range)
- Easy installation
 - Rotatable display allows installations in multiple positions and orientations
 - Compatibility with wide range of sensor types allows one model to fit multiple applications in your plant
- Reduction of production costs
 - Reduction of process downtime
 - Better uniformity of the production
 - Reduction in process variability: raw material savings and better final quality of the product due to high accuracy and stability

The block diagram in Figure 4 shows the basic functionality of the TT411 and TT421 HART temperature transmitters from Smar. These transmitters possess most of the same characteristics as the TT301, but are available in different form factors and do not include a local indicator.

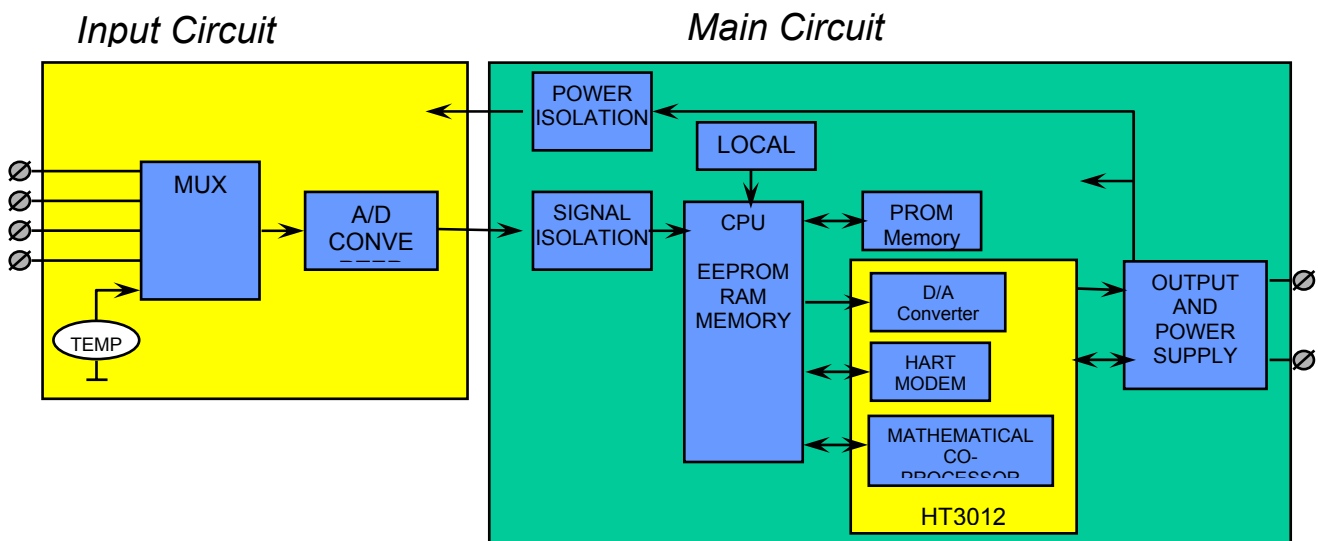
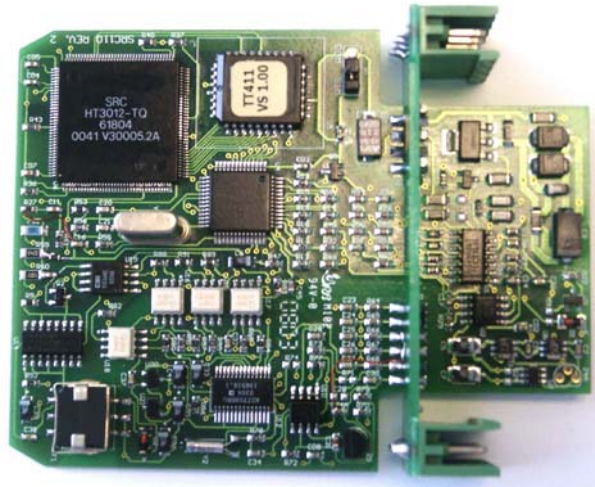


Figure 4 – TT411/TT421 Block Diagram

TT411 HART Temperature Transmitter

- HT3012: High Performance Chip
 - Mathematical Co-processor
 - 15 bits A/D converter
 - HART Modem



- **Benefits:**

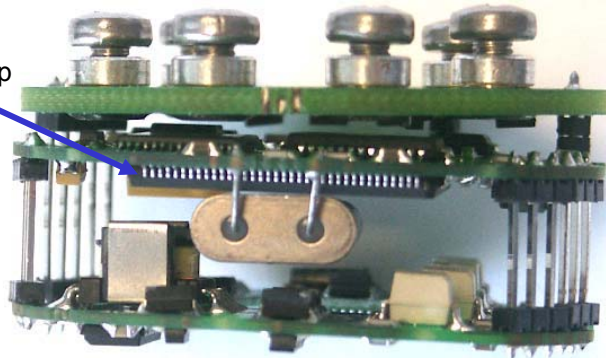
- High performance									
- High accuracy									
- High stability									
- High MTBF									
- Process variability and raw material reduction: Better final quality of the product due to high accuracy and stability									
- Increased safety, reliability and plant availability									
- Cost reduction of engineering and installation									



Figure 5 - TT411 DIN Rail Mountable Temperature Transmitter

TT421 HART Temperature Transmitter

- HT3012: High Performance Chip
 - Mathematical Co-processor
 - 15 bits A/D converter
 - HART Modem



- **Benefits:**

- High performance									
- High accuracy									
- High stability									
- High MTBF									
- Process variability and raw material reduction: Better final quality of the product due to high accuracy and stability.									
- Increase safety, reliability and plant availability									
- Cost reduction of engineering and installation									



Figure 6 - TT421 DIN Form B Connection Head Mountable Temperature Transmitter

RAIL MOUNTED VS. FIELD MOUNTED TRANSMITTERS

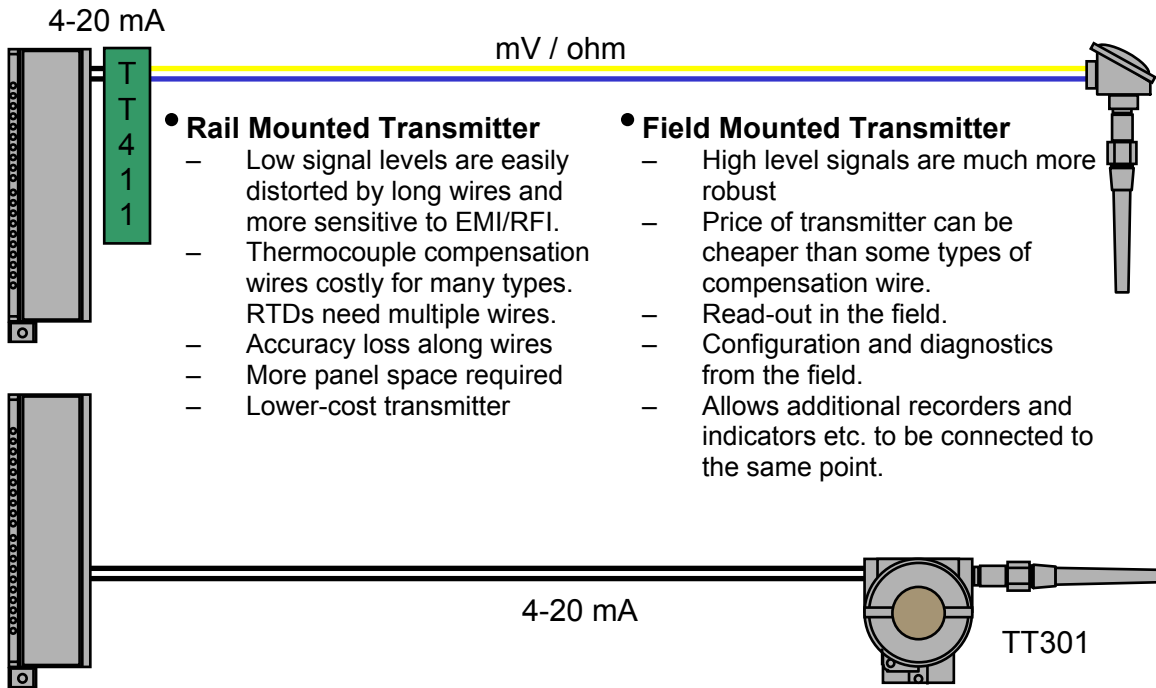


Figure 7 – Rail mount versus Field mount comparison

CONCLUSION

As you have seen, the measurement of temperature has come a long way. Advancements in technology have fueled the process control industry with more diverse, reliable and accurate temperature measurements. The importance of temperature measurement can be seen in the vast amounts of applications that use temperature transmitters to create lower cost and higher quality products. The temperature transmitter has evolved into three distinct versions, each specialized for particular applications. Today there is a temperature transmitter for almost any application and budget. As science and electronic design move forward, the applications for temperature transmitters will only increase.

REFERENCES

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- www.smar.com.br
Smar Equipamentos Ind. Ltda. Rue Dr. Antonio Furlan Jr., 1028, Sertãozinho, Brazil
- Control & Instrumentation Edition 82 – “HART Digital Protocol”, César Cassiolato.