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Embedded System for Temperature Measurement and Control, Choice of Sensor: A Comparative Study

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Abstract: *This paper is about the comparative study and choice of sensor or transducer for design of embedded system for temperature measurement and control in industrial applications particularly related to chemical industries where specific temperature measurement is very much necessary with accuracy. The main part of the design is selection of sensor or transducer, which will give sufficient output in electrical form which can be later measured and control by microcomputer or microcontroller. The study of different sensor and transducer enables a user to select a particular sensor as per the requirements of temperature measurement, control and related environment.*

Keywords: Sensor, Thermocouple, RTD, Temperature range

I. INTRODUCTION

In many chemical processing unit or in power generation unit or in different laboratories, accurate temperature measurement are very crucial. Embedded system is very useful for monitoring and controlling functions like temperature. An embedded system has computer intelligence and dedicated software which perform a single or group of related tasks.

The very important part of any measurement system is selection of sensor or transducers. This paper mainly focussed on selection of sensor or transducer for measurement of temperature. In any control system working in temperature sensitive environment, the temperature measurement and controlling is essential part nowadays. For example for boilers, temperature is important for water and air preheat[1].Therefore selecting a proper sensor or transducer and connecting it to a microcontroller for controlling is a big task. Temperature can be measured and monitor by number of sensor or transducer. But selecting a proper sensor or transducer is not an easy job where accuracy matters. The care should be taken in selecting sensor with different levels of complexity associated with calibration process also. The output of such embedded system may not be similar to actual temperature and result in further wrong processing if calibration is not done properly [2]. The comparative study of some sensor or transducers in this paper will give the idea of selection of sensor or transducer for temperature measurement in industrial applications. It also gives the idea about how to get maximum accuracy in measurement and also helpful in interfacing to microcomputer or microcontroller and the practical interface circuit will be provided for embedded applications with transducers[3].

II. TRANSDUCER SELECTION CRITERIA

The following section gives the basic ideas of different temperature transducers available with their general characteristics. By understanding these characteristics, a proper section of sensor or transducers can be made industrial applications. There are many factors are to be consider when selecting a sensor, they may be,

- Temperature
- Accuracy
- Response time
- Linearity
- Sensitivity

There are three most commonly encountered temperature measurement devices in process. They are;

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2.1 Thermocouple

The simplest temperature sensitive device is thermocouple. It is an electrical device consist of two dissimilar metals forming an electrical junction. A thermocouple produces a output voltage depending on temperature difference as a result of See back effect, and this voltage can be calibrated to measure temperature. Thermocouples are cheaper, interchangeable in system and are come with standard connectors and it can measure a wide range of temperatures. They are self-powered and required no external form of excitation[4].The following table shows different thermocouple and their temperature range;

	Types of Thermocouple	Useful temperature range
1	Iron-Constantan	0^{o} to 1400^{o} F
2	Chromal-Alumel	500^{o} to 2300^{o} F
3	Platinum/Rhodium-Platinum	1000^{o} to 2700^{o} F
4	Copper-Constantan	-300^{o} to 700^{o} F

With these thermocouple, the extension wires are used. They may be of same material or other alloy. When a pair of wires selected for thermocouple, the greater the thermometric difference between them, better is the result. The size of wires and protection of thermocouple are important. The wire size affects both the sensitivity and maximum operating temperature of thermocouple. In most cases thermocouple cannot be used without protection from environment in which they are used. The environment may be a reducing atmosphere or an oxidising atmosphere. The device used for protecting thermocouple is thermocouple wells and protecting tubes. The following figure shows thermocouple basic typical measurement system.

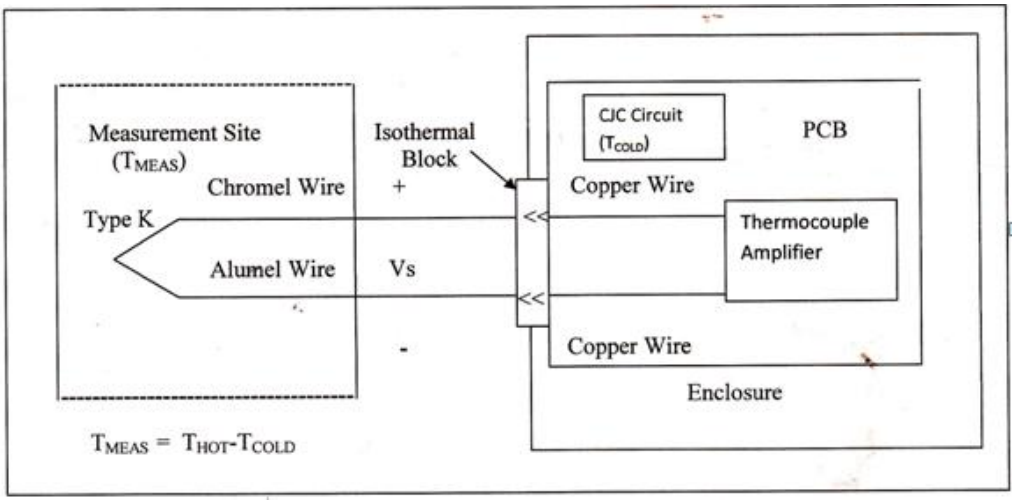

Figure 1: Thermocouple basics-Typical Measurement system

2.2 RTDs

When precise temperature measurement by electrical means is desired, the Resistance Thermometer are used. RTDs has very good repeatability and excellent stability characteristics, therefore very useful in precision sensing applications. RTDs elements are consist of a fine wire wrapped around a ceramic or glass core. The RTD wire are pure material like platinum, nickel or copper. The RTDs convert the temperature in terms of resistance. The important consideration in the selection of thermometer wires are purity, uniformity, stability and high resistance change per degree temperature change. Since the temperature measured by RTDs are actually a resistance measurement, the Wheatstone bridge is used with variation.

2.3 Thermistor

In recent years, thermistors have found increasing use in temperature measurement. These are very small, solid semiconductors made of various metal oxide. They are available in various shape such as rods, beads, washers and

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flakes. It has NTC or PTC nature. The limitation of thermistors is that for temperature less than 0°c and above 70°c, the changes in resistance with temperature is very nonlinear. The temperature sensor selection chart below gives the idea of guide to the pros and cons of RTDs, thermocouple and thermistor [5].

Temperature Mesurement Device Selection Guide			
	Resistance Temperature Detector (RTD)	**Thermocouple**	**Thermistor**
Signal Characteristics	Resistance increases with temperature rise	Voltage increases with temperature rise	Resistance decreases with temperature rise
Temperature Range	-200 to 850°C (-328 to 1562°F)	-270 to 1700°C (-454 to 3092°F)	-73 to 260°C (-100 to 500°F)
Accuracy	Highly accurate	Least accurate	Highly accurate
Shock & Vibration Resistance	Somewhat sensitive to shock and vibration	Generally considered most robust	Somewhat sensitive to shock and vibration
Linearity Across Temperature Span	Linear	Most Non-linear	Non-linear
Accuracy Drift Over Time	Less drift than thermocouple	Highly subject to drift	Less drift than thermocouple
Response Time	Thin-film RTDs – Fast Wire Wound – Moderate	Fastest response	Fast response
Cost	Thin-Film Low	Type E, J, K and T Lowest Type B, S and R Highest	Low

III. Transducer- Microcontroller Interface Option

Once the sensor or transducer based on requirement is selected, then by considering the complexity of the transducer, the transducer and microcontroller interface option is selected with the required hardware and software trade-offs of the microcontroller. Thermocouple, RTDs and thermistor can be used as a sensor and interfaced the output of these sensor which is proportional to temperature. The following figure2 shows the block diagram of typical measurement system of temperature[6].

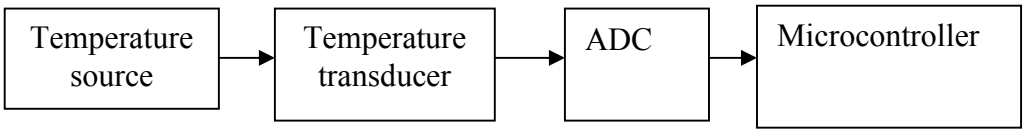

Figure 2

IV. Conclusion

In order to design embedded system for temperature measurement and control particular for industrial application, the selection of sensor or transducer is very important to get accuracy as well as interfacing microcomputer or microcontroller. They are playing very vital role in the system. In addition to this location of sensor, grounding, protection and shielding is also have equal importance. In industrial application temperature is very high, therefore thermocouple is good choice because of their temperature range. It has good grounding and shielding materials. If monitoring temperature range within 50°c, thermistors are useful. They have small heat capacity, fast response but has poor interchangeability and nonlinear characteristics. RTDs measurement are accurate and, can be installed easily, however it expensive and poor response time.

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