SENSORS FOR TEMPERATURE MEASUREMENT: ERROR MEASUREMENT OF TYPE K THERMOCOUPLE

MAULANA BIN HANAPI

Universiti Malaysia Sarawak
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Kpg. Usaha Jaya Baru
96000, Sibu
Sarawak

Nama Penyelia: Rubiyah Hj Baini

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8/04/2002

Rubiyah Hj. Baini

(Supervisor)

Date

To APAK & MAK and to all my colleagues and staffs of Engineering Faculty.

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ABSTRAK

Thermocouple adalah sejenis sensor yang digunakan untuk mengira suhu berdasarkan prinsipalnya yang mana apabila dua logam yang berbeza dicantumkan, perubahan arus elektrik akan berlaku jika terdapat perubahan suhu diantara dua bahagian cantuman iaitu cantuman rujukan dan cantuman pengesan. Projek ini adalah tentang *thermocouple* jenis K yang digunakan dalam alat Penentu Suhu yang terdapat di dalam lab mekanikal di UNIMAS. Alat Penentu Suhu ini juga dikenali sebagai TH1.Objektif utama projek ini adalah untuk mengira ralat yang berlaku di dalam *thermocouple* jenis K untuk alat TH1. Terdapat dua ralat yang akan dibuat iaitu ralat untuk bacaan yang diperoleh melalui eksperimen dan ralat untuk bacaan yang telah dilinearkan. Ralat-ralat ini akan dibandingkan dengan ralat yang telah dispesifikasikan pembuat model TH1.

ABSTRACT

Thermocouple is a type of sensors to measure temperature. It is based on the principle that when two dissimilar metals are joined, a predictable voltage will be generated in accordance to the difference in temperature between the measuring junction and the reference junction. This project is about the type K thermocouple used in Temperature Measurement equipment that is available at UNIMAS' Mechanical Engineering laboratory. The equipment is named TH1. The main objective of this project is to determine the error range occurs in type K thermocouple used in TH1. The error range will consist of error range based on experimental and linearized results. These errors will then to be compared to the manufacturer's specification.

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CHAPTER 1
INTRODUCTION

1.1 GENERAL OVERVIEW

Electronic measurements have become a part of everyday life. Sensors and transducer are the eyes and ears of modern measurement instrumentation and control systems. Many types of machines depend on sensors to provide input data about environment. Carr (1993) claimed that sensors represent both one of the oldest segments of the electronic industry and one of the most modern.

Sensors of all types provide the computer with the information it needs to perform monitoring and control tasks. Development in the use of laser and microelectronics sensors make possible the rapid measurement of physical properties that were previously difficult to measure.

A digital computer requires an input of signals in digital form. However, the plant being controlled has signals that vary continuously with time, i.e. are analogues signal. The analog and continuous time signals measured by the sensor and modified by the signal conditioning circuitry must converted into the form a computer can understand. This is what is referred to here as data acquisition.

Data acquisition is the process of taking analog signals from the real world, processing them, converting them into digital data and finally bringing the resulting digital data into the computer memory. Data acquisition system (DAS) is a system that conditions a number of analog signals and converts them into digital form for processing by a computer. Data from latter are collected automatically by a data acquisition system (DAS), which can report, for example the number of parts being produced per unit time, their dimensional accuracy, their surface finish, their weight, and so on, at specified rates of sampling.

The components of DAS include microprocessors, transducers, and analog-to-digital converters (ADCs). Data acquisition systems are also capable of analyzing the data and transferring them to other computers for purposes such as statistical analysis, data presentation, and the forecasting of product demand.

This project is basically focuses on sensors. As mentioned above, transducer is one of the important parts of DAS. And transducer is a combination of several sensors.

1.2 SENSORS

1.2.1 Definition

People who work with sensors and transducers everyday tend to use these two words somewhat interchangeably in their speech. This is no hard and fast rule as to what distinguishes an electrical from an electrical sensor. Ask any number of engineers or scientists for their definitions of these two terms and you will probably get that many different answers.

As according to Carstens (1993), sensor is a device that converts a quantity or an energy form into an electrical output signal. The form of that output signal, whether it is an ac or a dc signal, whether the signal is digital or analog, to name just a few, is determined by the sensor's electromechanical and/or chemical makeup. He again claimed that the transducer is a device comprised of a sensor whose output signal is modified or conditioned to suit a particular application or needs by its user.

In other study about sensor, Christiansen (1998) claimed that a sensor is basically equivalent to the word of transducer. According to him, a sensor, or transducer is a device that converts energy derived from a physical phenomenon into an electrical current or voltage, for purposes of measurement, control, or information.

Hordeski (1985) stated that a sensor is a device that converts information about the environment or internal state of a system from one form into another. It converts a *measurand* (signal to be measured) into a signal in a different form. The measurand is the input to the sensor and the signal produced by the sensor is the output. In data acquisition system, sensor is an element that converts changes in a physical parameter into electrical signals.

1.2.2 Forms of Sensor Outputs

(I) Analog Signal

Very simply stated, an analog signal is a continuous (not interrupted) data signal comprised of a flow of current or a voltage level whose amplitude, frequency, or phase relationship with some reference signal contains data information. This information represents a proportional relationship or analog of the input *measurand* that is controlling the signal [O' Higgins, 1996].

The *Measurand* is the quantity, or condition that is measured (then sensed and converted into a useable electrical output) by a transducer [Norton, 1989].

Bateson (1999) stated that an analog signal varies in a continuous manner and may take on any value between its limits. An example of an analog signal is a continuous recording of the outside air temperature as shown by **Figure 1.1**. The recording is a continuous line (a characteristic of all analog signals).

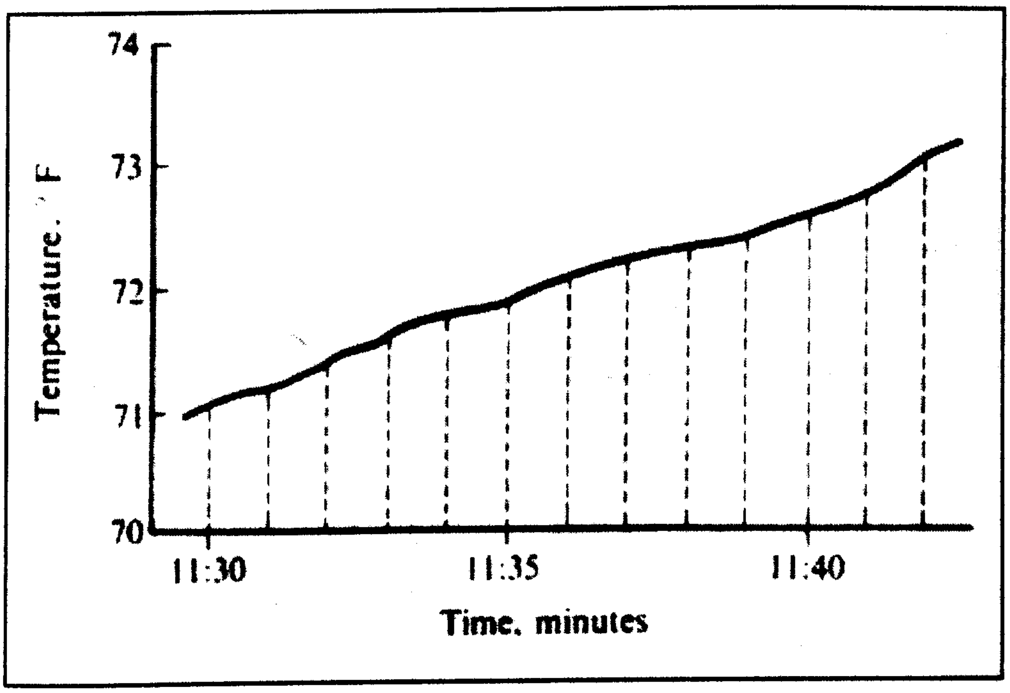

Figure 1.1 : An analog signal of the outside air temperature. [Bateson, 1999]

(II) Digital Signal

According to Carstens (1993), a digital signal is comprised of a series of interrupted flow, or pulses, of current or voltage levels. Each pulses or series of pulses contains the encoded information corresponding to the input data. A decoding process must then be used to decipher the desired information.

The same study on digital signal, Bateson (1999) claimed that a digital signal varies in a discrete manner and may take only certain discrete values between its limits. **Figure 1. 2** shows an example of a digital signal is an outdoor sign that displays the outside air temperature to the nearest degree once each minute. A graph of the signal produced by the sign does not change during an interval, but it may jump to a new value for the next interval.

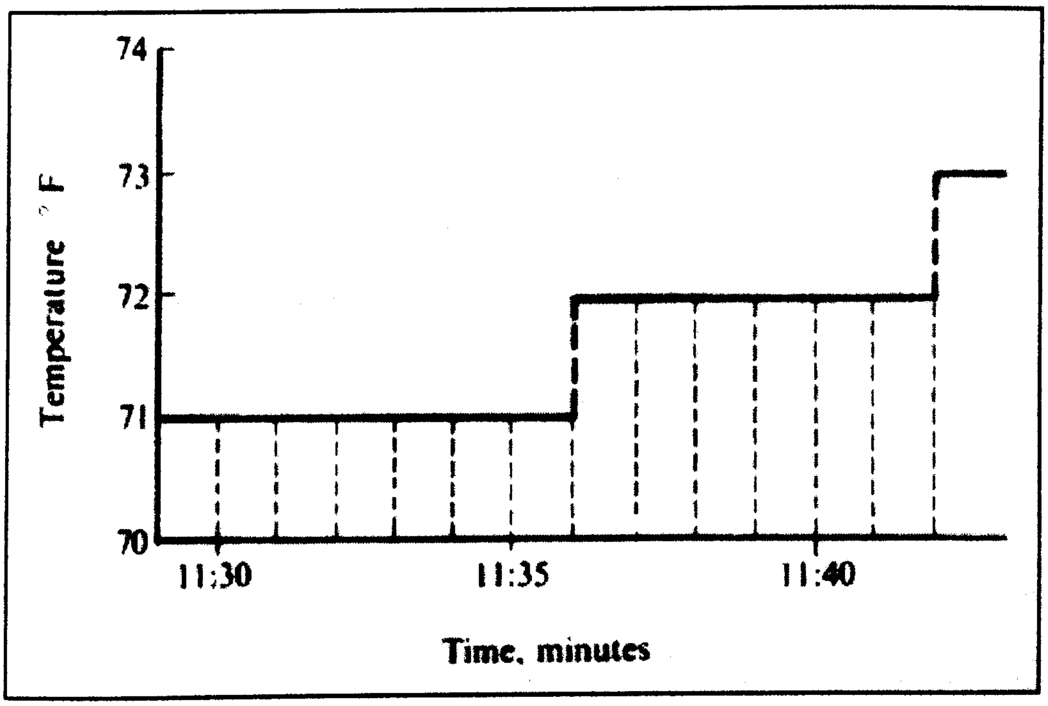

Figure 1. 2: A digital signal of the outside air temperature. [Bateson, 1999]

(III) Carrier Signal

A carrier signal is an electromagnetic wave of constant amplitude that acts as an electromagnetic vehicle for transporting data. Data being transmitted by a carrier may be either analog or digital, depending on the methods used to modulate the carrier [Carstens, 1993].

1.3 MEASUREMENT SYSTEMS

1.3.1 Overview

The simplest measuring system would be a sensing device that also displays the measured value, such as a mercury-in-glass thermometer or pressure gage. If the measured value needs to be recorded at certain times, a human observer with a clipboard, pencil, and wristwatch can be employed for this purpose. In this example, the operator, clipboard, pencil, and wristwatch, become a part of the system.

When a measured value is to be displayed some distance away from the point of measurement, a link between the two points becomes necessary. This link can be mechanical (e.g., an automobile speedomotor cable), pneumatic (a pipe filled with air whose pressure is varied by the sensing device, with a pressure indicator used for display), or electrical (an electrical cable). Electrical wiring is used in electronic measuring systems, in which the sensing device (sensor) has an electrical output and the display device accepts an electrical signal [Nachtigal, 1990].

1.3.2 Basic Electronic Measuring System

A basic electronic measurement system is shown by **Figure 1. 3**. It consists of :

i. The transducer, which converts the measurand into a usable electrical output.

ii. The signal conditioner, which converts the transducer output into the type of electrical signal that the display device will accept.

iii. The display device (or readout device), which displays the required information about the measurand.

iv. The power supply, which feeds the required voltages to the signal conditioner.

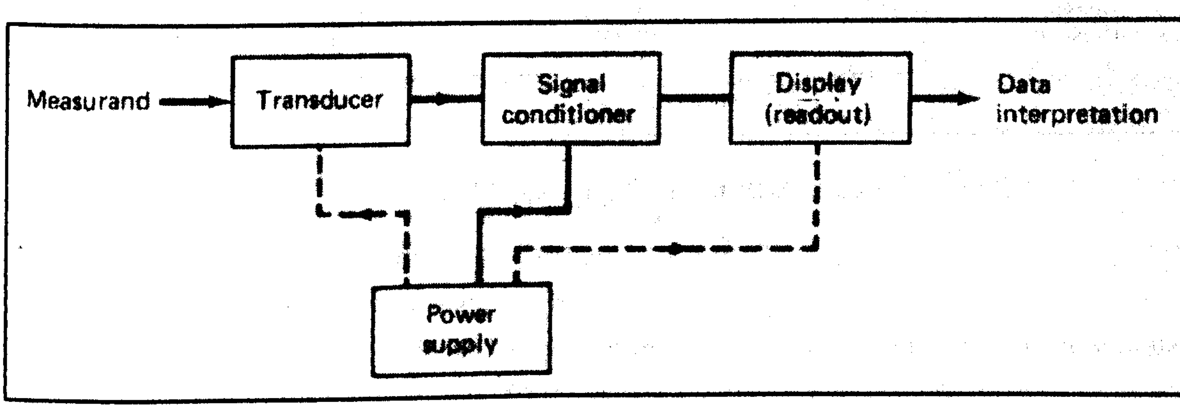

Figure 1. 3: Basic electronic measuring system.[Norton, 1989]

1.3.3 Signal Conditioning

A study regarding to measuring system, Bateson (1999) stated that a signal conditioner is required to convert the sensor output into an electrical (or pneumatic) signal suitable for use by a controller or display device. The sensor and its signal conditioner comprise the two parts of a measuring transmitter which is as shown by **Figure 1. 4** [Bateson, 1999].

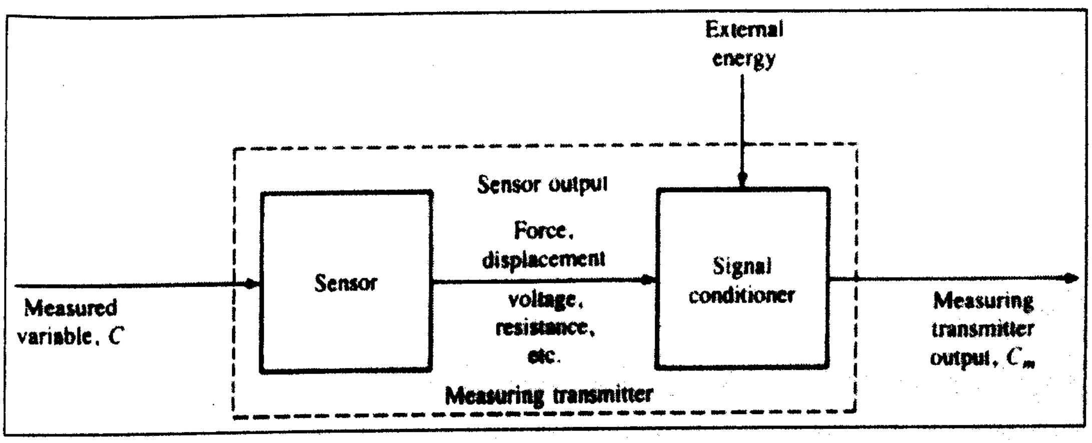

Figure 1. 4: Measuring Transmitter [Bateson, 1999]

Signal conditioning is one of the most important components of any data acquisition system. It is the interface between real-world analog signals and the rest of the system. If the signal conditioner is not specified properly, the data acquisition system most likely will output meaningless information. Data acquisition involves two very important concepts that are *data sampling* and *data conversion*.

(I) Data Sampling

The rate at which need to sample an analogue signal, to get a good digital representation, depends on how fast the signal is changing. It is all about how accuracy the data sampling process to be. Data sampling is a process in which a switch connects momentarily to an analog signal in a sequence of pulses separated by evenly spaced increments of time called the *sampling interval* [Bolton, 1992].

For frequency components the Nyquist criterion demands that the signal be sampled at least twice in each cycle, otherwise the amplitude of this frequency component will distort the signal at lower frequencies.

The Nyquist criterion may be stated as follows: *All the information in the original signal can be recovered if it is sampled at least twice during each cycle of the highest-frequency component* [Kilian, 1996].

If f_h is the highest frequency that occurs in the original signal, then the minimum *sampling rate* is given by the following equations.

$$\text{Minimum sampling rate} = f_s\,(\text{min}) = 2f_h$$

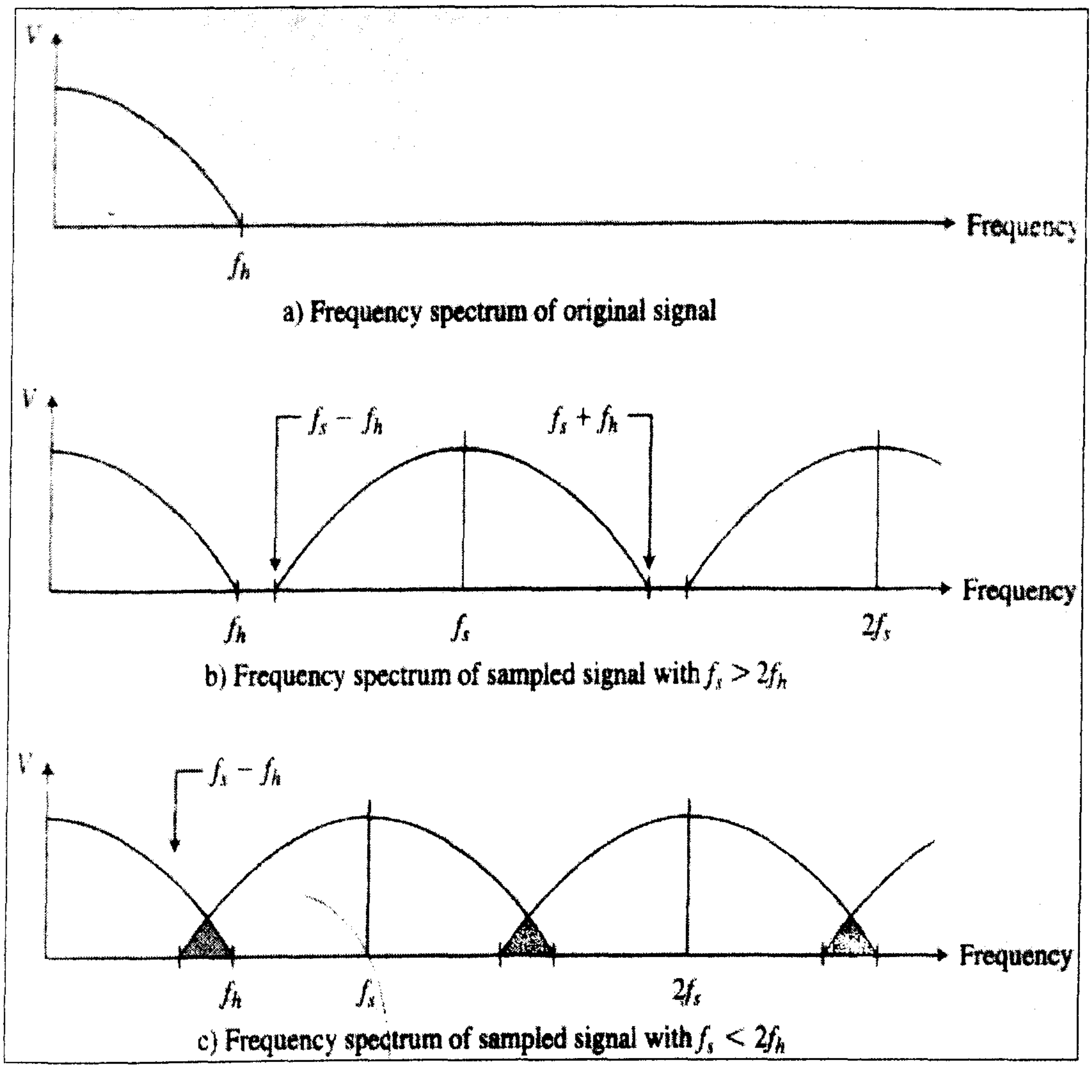

Figure 1. 5 : Frequency spectrum an analog signal [Bateson, 1999].

Figure 1.5a shows how typical *frequency spectrum* of an analog signal. A frequency spectrum is simply a plot of the maximum voltage of each possible component of a signal versus the frequency of the component. The main point in **Figure 1.5a** is that there are no components of the original signal with a