Practical Temperature Measurements*
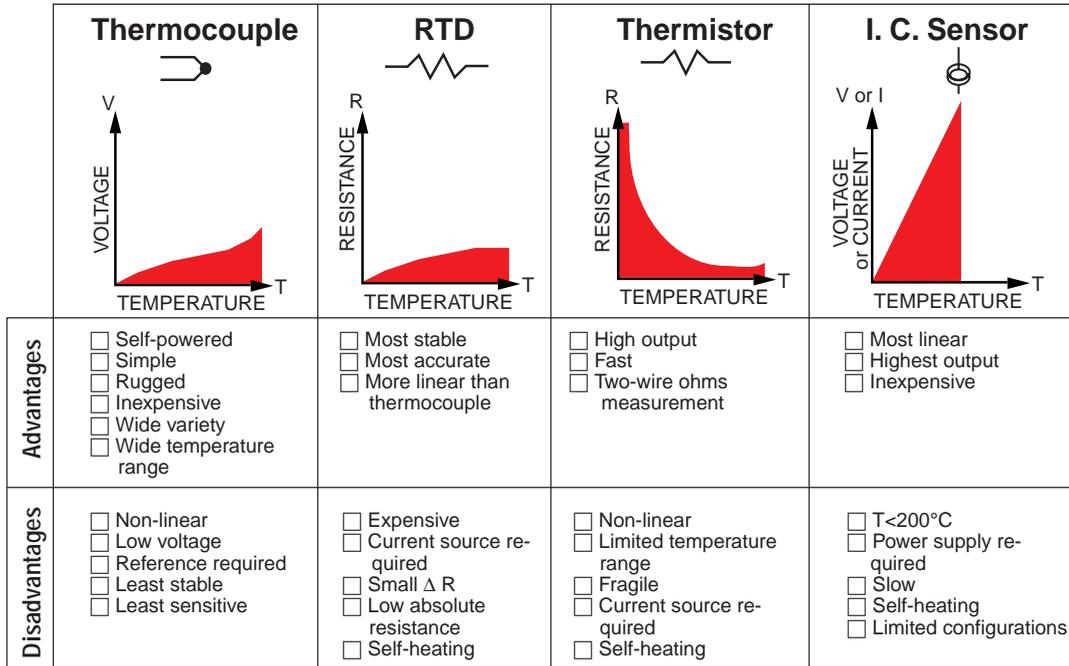

	Thermocouple	RTD	Thermistor	I. C. Sensor
Advantages	☐ Self-powered ☐ Simple ☐ Rugged ☐ Inexpensive ☐ Wide variety ☐ Wide temperature range	☐ Most stable ☐ Most accurate ☐ More linear than thermocouple	☐ High output ☐ Fast ☐ Two-wire ohms measurement	☐ Most linear ☐ Highest output ☐ Inexpensive
Disadvantages	☐ Non-linear ☐ Low voltage ☐ Reference required ☐ Least stable ☐ Least sensitive	☐ Expensive ☐ Current source required ☐ Small Δ R ☐ Low absolute resistance ☐ Self-heating	☐ Non-linear ☐ Limited temperature range ☐ Fragile ☐ Current source required ☐ Self-heating	☐ T<200°C ☐ Power supply required ☐ Slow ☐ Self-heating ☐ Limited configurations

Figure 1

TABLE OF CONTENTS
APPLICATION NOTES-PRACTICAL TEMPERATURE MEASUREMENTS

*Courtesy Hewlett Packard Company

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INTRODUCTION

Synthetic fuel research, solar energy conversion and new engine development are but a few of the burgeoning disciplines responding to the state of our dwindling natural resources. As all industries place new emphasis on energy efficiency, the fundamental measurement of temperature assumes new importance. The purpose of this application note is to explore the more common temperature monitoring techniques and introduce pro cedures for improving their accuracy.

We will focus on the four most common temperature transducers: the thermocouple, the RTD, the thermistor and the integrated circuit sensor. Despite the widespread popularity of the thermocouple, it is frequently misused. For this reason, we will concentrate primarily on thermocouple measurement techniques.

Appendix A contains the empirical laws of thermocouples which are the basis for all derivations used herein. Readers wishing a more thorough discussion of thermocouple theory are invited to read REFERENCE 17 in the Bibliography.

For those with a specific thermocouple application, Appendix B may aid in choosing the best type of thermocouple.

Throughout this application note, we will emphasize the practical considerations of transducer placement, signal conditioning and instrumentation.

Early Measuring Devices - Galileo is credited with inventing the thermometer, circa 1592.[1] In an open container filled with colored alcohol he suspended a long narrow-throated glass tube, at the upper end of which was a hollow sphere. When heated, the air in the sphere expanded and bubbled through the liquid. Cooling the sphere caused the liquid to move up the tube[1] Fluctuations in the temperature of the sphere could then be observed by noting the position of the liquid inside the tube. This "upside-down" thermometer was a poor indicator since the level changed with barometric pressure and the tube had no scale. Vast improvements were made in temperature measurement accuracy with the development of the Florentine thermometer, which incorporated sealed construction and a graduated scale.

In the ensuing decades, many thermometric scales were conceived, all based on two or more fixed points One scale, however, wasn't universally recognized until the early 1700's, when Gabriel Fahrenheit, a Dutch instrument maker, produced accurate and repeatable mercury thermometers. For the fixed point on the low end of his temperature scale, Fahrenheit used a mixture of ice water and salt (or ammonium chloride). This was the lowest temperature he could reproduce, and he labeled it "zero degrees". For the high end of his scale, he chose human blood temperature and called it 96 degrees.

Why 96 and not 100 degrees? Earlier scales had been divided into twelve parts. Fahrenheit, in an apparent quest for more resolution divided his scale into 24, then 48 and eventually 96 parts.

The Fahrenheit scale gained popularity primarily because of the repeatability and quality of the thermometers that Fahrenheit built.

Around 1742, Anders Celsius proposed that the melting point of ice and the boiling point of water be used for the two benchmarks. Celsius selected zero degrees as the boiling point and 100 degrees as the melting point. Later, the end points were reversed and the centigrade scale was born. In 1948 the name was officially changed to the Celsius scale.

In the early 1800's William Thomson (Lord Kelvin), developed a universal thermodynamic scale based upon the coefficient of expansion of an ideal gas. Kelvin established the concept of absolute zero and his scale remains the standard for modern thermometry.

The conversion equations for the four modern temperature scales are:

$$°C = 5/9 \ (°F - 32) \quad °F = 9/5 \ °C + 32$$

$$K = °C + 273.15 \quad °R = °F + 459.67$$

The Rankine Scale (°R) is simply the Fahrenheit equivalent of the Kelvin scale, and was named after an early pioneer in the field of thermodynamics, W.J.M. Rankine.

[1] Refer to Bibliography 1,2,3.