Introduction

- Many embedded systems are required to collect information about the environment.
- Such a system is called a data acquisition system (DAS).
- Sometimes acquisition of data is system’s fundamental purpose: voltmeter, thermometer, camera, etc.
- Other times it is only part, such as in control or communication systems.
### Transducers

**Type** | **Inp->outp** | **Example**  
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Abs→abs | \( x \rightarrow y \) | Thermistor converts absolute temperature to resistance  
Rel→abs | \( \Delta x \rightarrow y \) | Mass balance converts a mass difference to an angle  
Abs→rel | \( x \rightarrow \Delta y \) | Strain gauge converts a displacement to a resistance difference  
Rel→rel | \( \Delta x \rightarrow \Delta y \) | Thermocouple converts a temp. difference to a volt. difference

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**Transducer Linearity**

![Graph](image)

- Average Linearity of Full Scale is 1.28%  
- \( y = 0.055x - 0.167 \)  
- \( R^2 = 0.9976 \)

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**Linear Variable Differential Transducer (LVDT)**

![Diagram](image)

- Ferrite Core  
- 2 kHz Oscillator  
- Active Primary  
- Passive Secondaries  
- \( V_{out} \)  
- Amp  
- displacement \( x \) in mm
Sampling Rate, $f_s$, Less than $2f_{\text{max}}$

Sampling Rate, $f_s$, Greater than $2f_{\text{max}}$

Sampling Rate, $f_s$, Equals $2f_{\text{max}}$

Fixed Sampling Rate
Fixed Sampling Rate

**How Fast Must the ADC Be?**

- **ADC conversion time** must be smaller than quotient of sampling interval by number of multiplexor signals.
- If $f_s$ is sampling frequency, $m$ is number of multiplexor signals, $t_{mux}$ is settling time of the multiplexer, and $t_c$ is ADC conversion time, then without S/H:
  \[ m \cdot (t_{mux} + t_c) < \frac{1}{f_s} \]
- With S/H, must include aquisition time, $t_{aq}$, and aperture time, $t_{ap}$:
  \[ m \cdot (t_{mux} + t_{aq} + t_{ap} + t_c) < \frac{1}{f_s} \]

**Specifications for the Analog Signal Processing**

- A S/H is required if the analog input changes more than one resolution during the conversion time.
- A S/H is required if:
  \[ \frac{dz}{dt} \cdot t_c > 0.5\Delta_z \]

  where $\frac{dz}{dt}$ is maximum slope of ADC input voltage, $\Delta_z$ is the ADC resolution, and $t_c$ is the ADC conversion time.

**Specifications for the S/H**
Temperature Measurement System

- Range of \( T \) is 0 to 50°C with resolution of 0.25°C, and a frequency range of 0 to 0.1Hz.
- Transducer has slope of 10°C/s and resistance:
  \[ R = 100 + 0.4T \]

Temperature Measurement System

- One-pole low-pass analog filter needed to pass signal from 0 to 0.1Hz, reject noise > 0.1Hz, and prevent aliasing.

Temperature Measurement System

- Needed ADC precision is 50°C/0.25°C = 200, so 8-bits.
- Use bridge circuit to convert RTD resistance into voltage.
- ADC range 0 to 5V and \( V_1 - V_2 \) is 0 to 0.0191V, so amp needs gain of 261.
- If ADC conversion time is 25\( \mu \)s, no S/H needed because:
  \[ 10°C/s \cdot 25\mu s = 0.00025°C << 0.25°C \]
- Noise must be less than the resolution (75\( \mu \)V).
   \[ \text{Amplifier noise} \leq \frac{\text{resolution}}{2} = 37\mu V \]

Amplifier and Low-Pass Filter

- Effective output impedance is 100Ω. Input impedance of amp must high enough not to affect ADC (>51.2 kΩ).