Microprocessor-Based Industrial Controllers

Class 4: Controller Examples - 2

July 25, 2019
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Presented by:

This Week's Agenda

Monday	Concepts and History
Tuesday	Microprocessor Architectures
Wednesday	Controller Examples - 1
Thursday	Controller Examples - 2
Friday	Connectivity and Trends

Course Description

Industrial controllers at the device level have a long history. Over time they have evolved from relay based, to discrete logic and finally to microprocessor based logic. While the functions have remained the same, the capabilities and sophistication have grown enormously. In this class we will look at the history and development of the field and then look into the modern architectures which are currently in use. We will take a deep dive into several examples of controllers, including the algorithms and implementations for several. Finally we will look at connectivity and trends in the industry.

Today’s Agenda

- PM Synchronous Motor Control
- Protective Relay Control
- Ratio Control
- Cascade Control
- Quality Control
- Industrial Burner Control
- Conclusion/Next Class

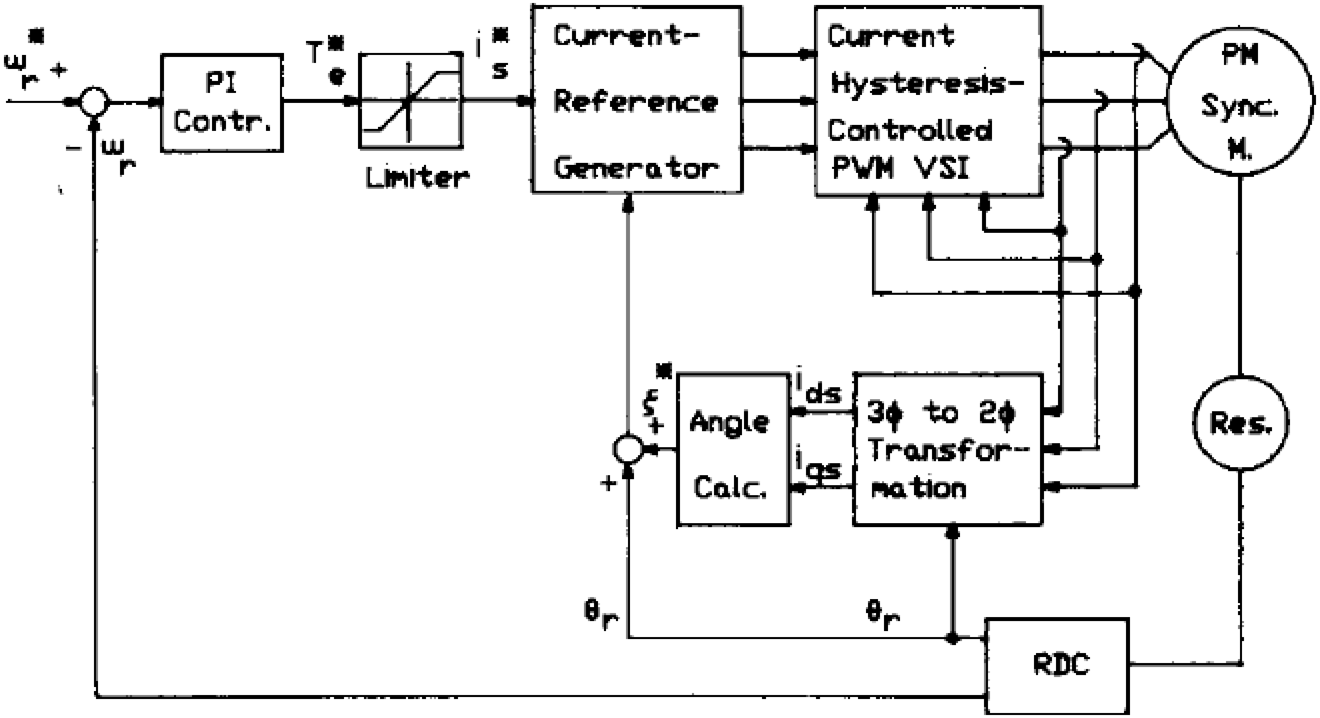
PM Synchronous Motor Control

- The motor under consideration is a Permanent Magnet (PM) synchronous AC three phase device
- We develop a software controller for this device to control speed
- Sampling period and control parameters are determined analytically
- The controller type is PI (Proportional Integral)

PM Synchronous Motor Control

- Attributes desired are smooth starting and acceleration
- Power is via a transistorized inverter
- We employ a current hysteresis-controlled PWM Voltage Source Inverter (VSI)
- Objective: minimize deviation between the reference 3-phase line current commands and the feedback 3-phase line currents through the switching of inverter transistors to achieve maximum torque per ampere

PM Synchronous Motor Control



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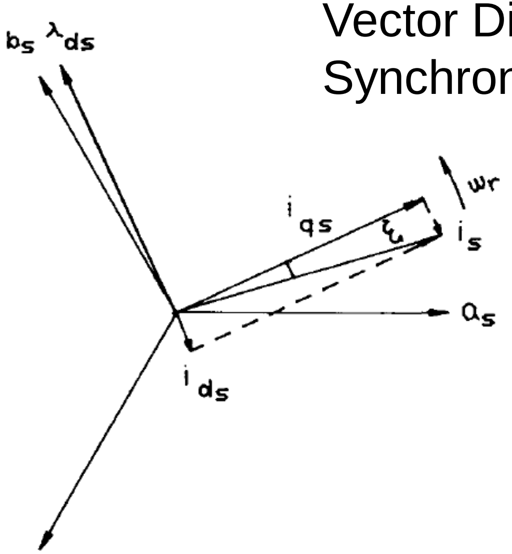
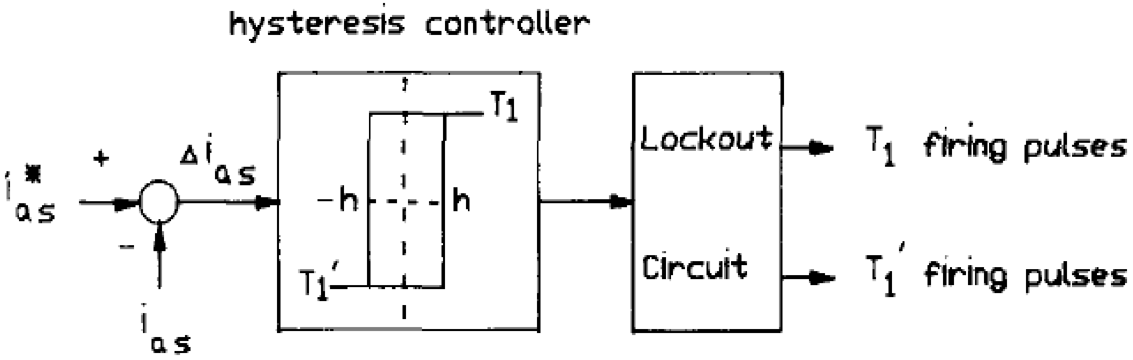
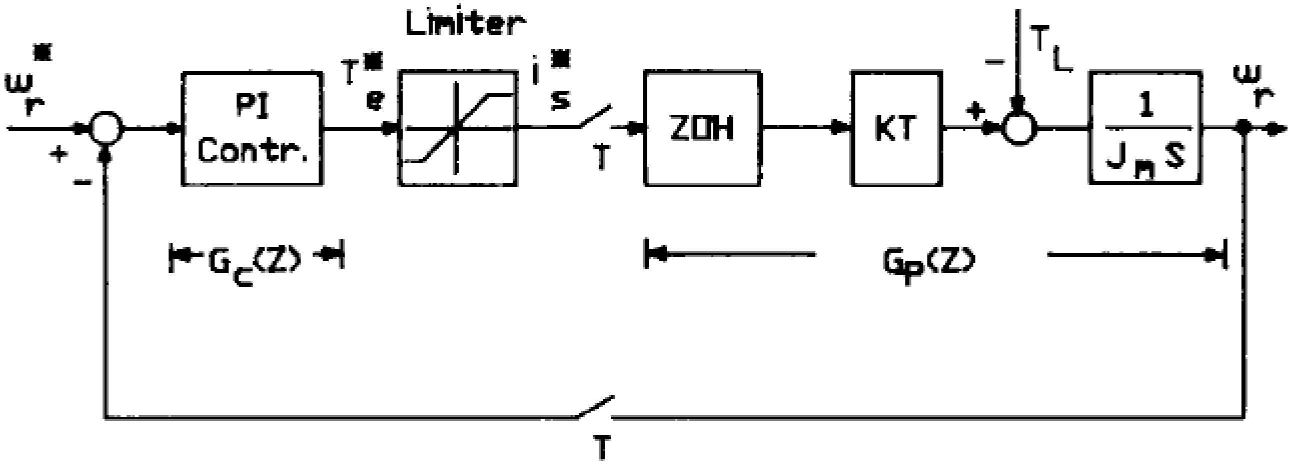
PM Synchronous Motor Control

Vector Diagram for control of the PM Synchronous motor







Simplified Speed Control System Block Diagram

PM Synchronous Motor Control

$$v_{ds} = \frac{p\lambda_{ds}}{\omega_e} + r_1 i_{ds} - \lambda_{qs}\frac{\omega_r}{\omega_e}$$

$$v_{qs} = \frac{p\lambda_{qs}}{\omega_e} + r_1 i_{qs} + \lambda_{ds}\frac{\omega_r}{\omega_e}$$

Voltage Equations

$$T_e^*(kT) = K_p \Delta\omega_r(kT) + K_I \sum_{i=0}^{k} \Delta\omega_r(iT)$$

Torque Equation: the K's are the PI Controller parameters

$$G(w) = \frac{(K_T/J_m)\cdot T\cdot[-(K_I+2K_p)w^2+2K_p w+K_I]}{4w^2}$$

Transfer function

$$N(T_e^*) = \frac{2}{\pi}\left[\frac{T_{e,\max}^*}{T_e^*}\cos\left(\sin^{-1}\frac{T_{e,\max}^*}{T_e^*}\right) + \sin^{-1}\frac{T_{e,\max}^*}{T_e^*}\right]$$

Transfer function in Frequency Domain

$$0 < \frac{(K_T/J_m)\cdot T\cdot(2K_p+K_I)}{4} < 1$$

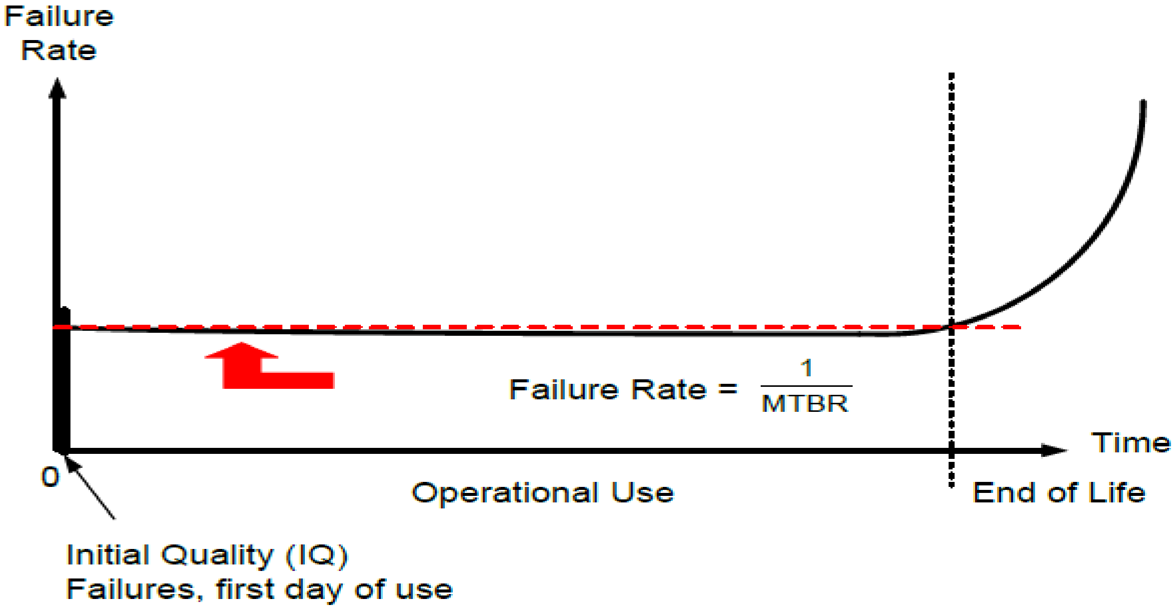
Conditions for stable operation

Protective Relay Control

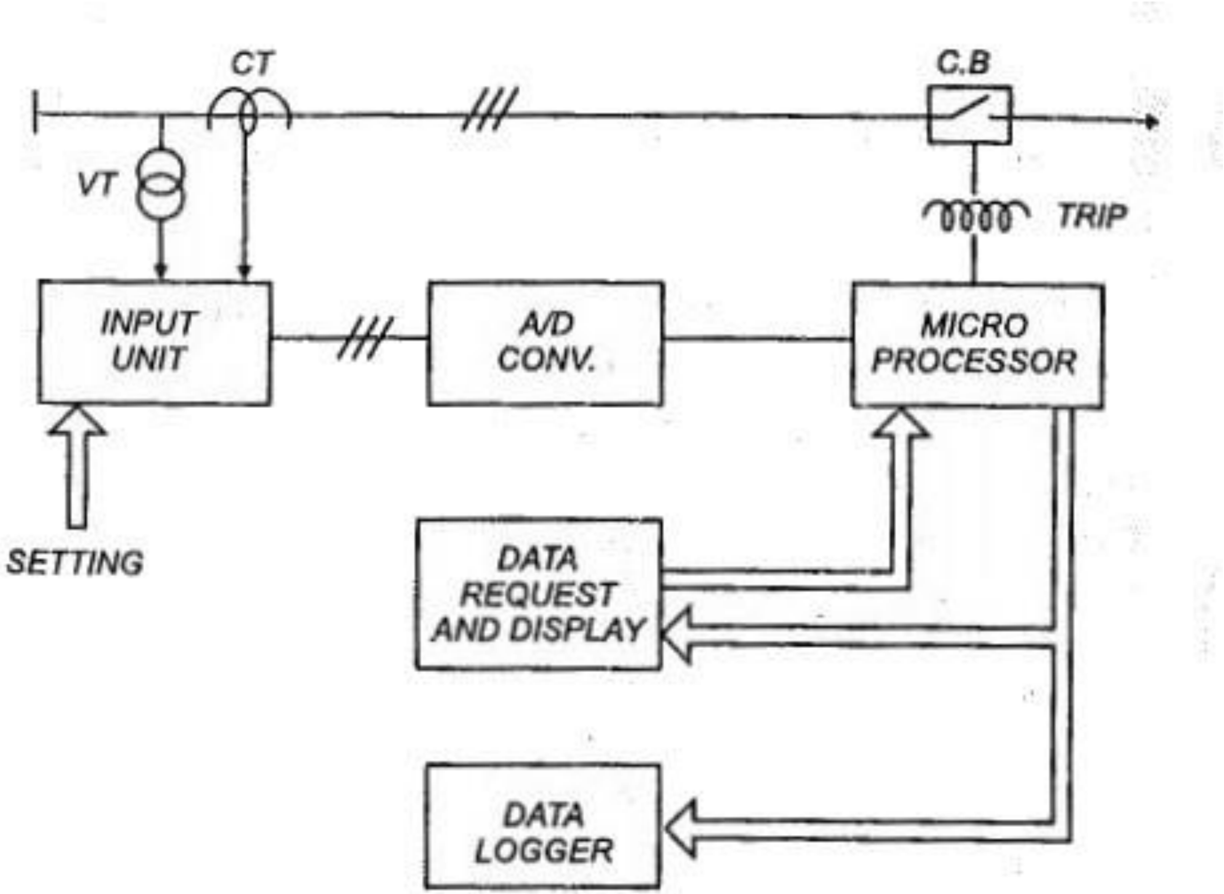
- We are next going to discuss microprocessor-controlled relays used in power system switching equipment
- These systems have to be highly reliable, having long MTBF
- A desired attribute is continuous self-test and feedback
  - Previous systems used relays and discrete electronic components

Protective Relay Control

- By employing a microcontroller these MTBF rates can be achieved and predictive maintenance actions can be taken



Protective Relay Control



Block diagram of a simple Microprocessor based Digital Static Relay

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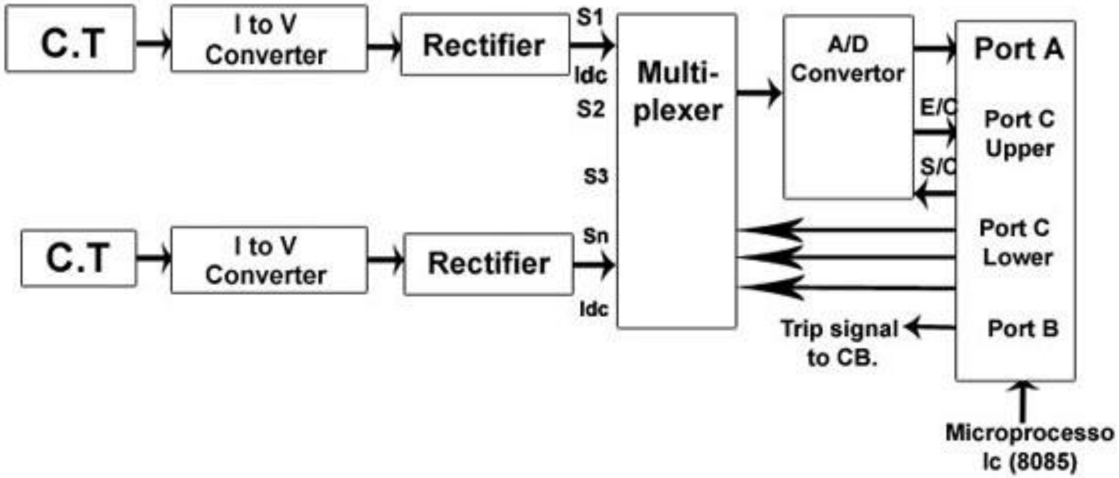
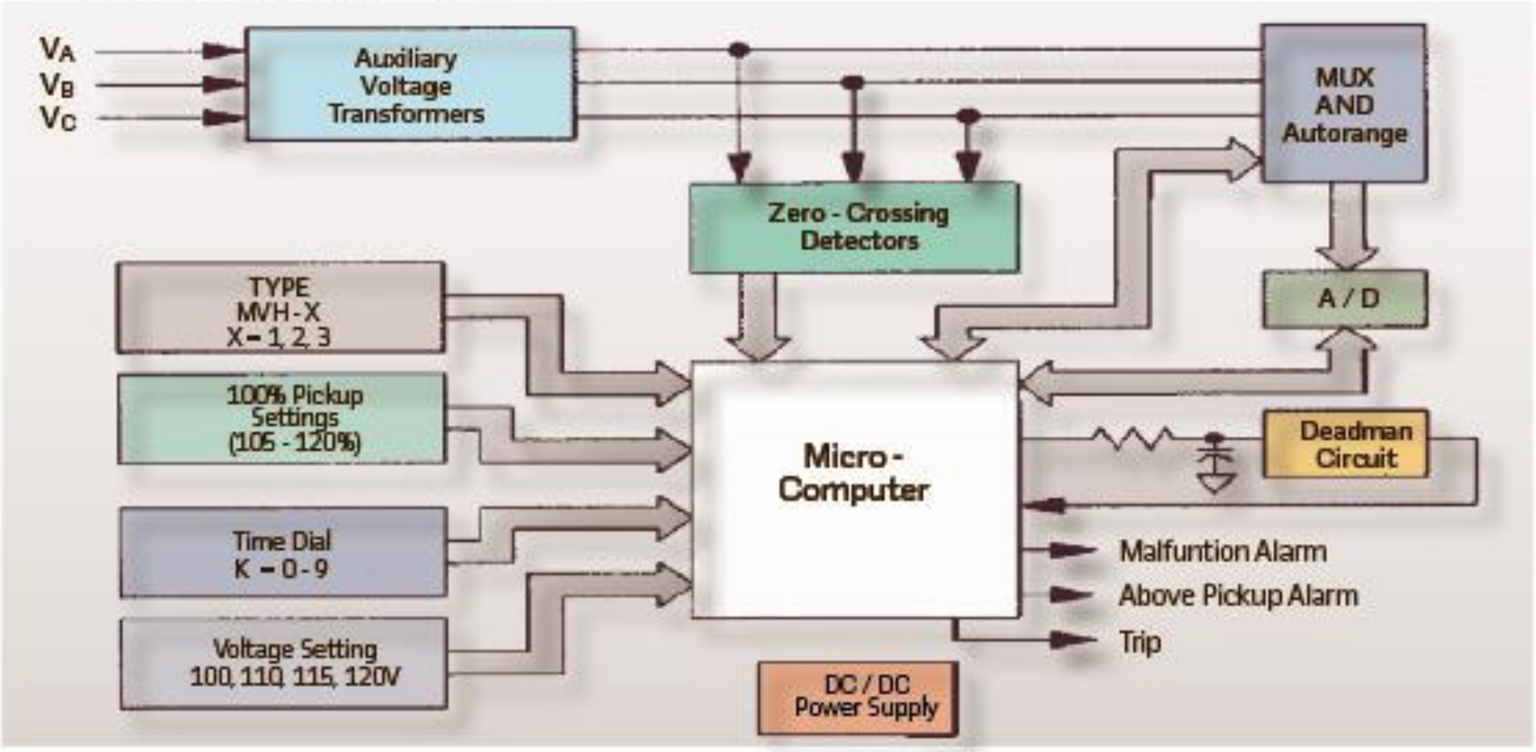
Protective Relay Control



Protective Relay Control

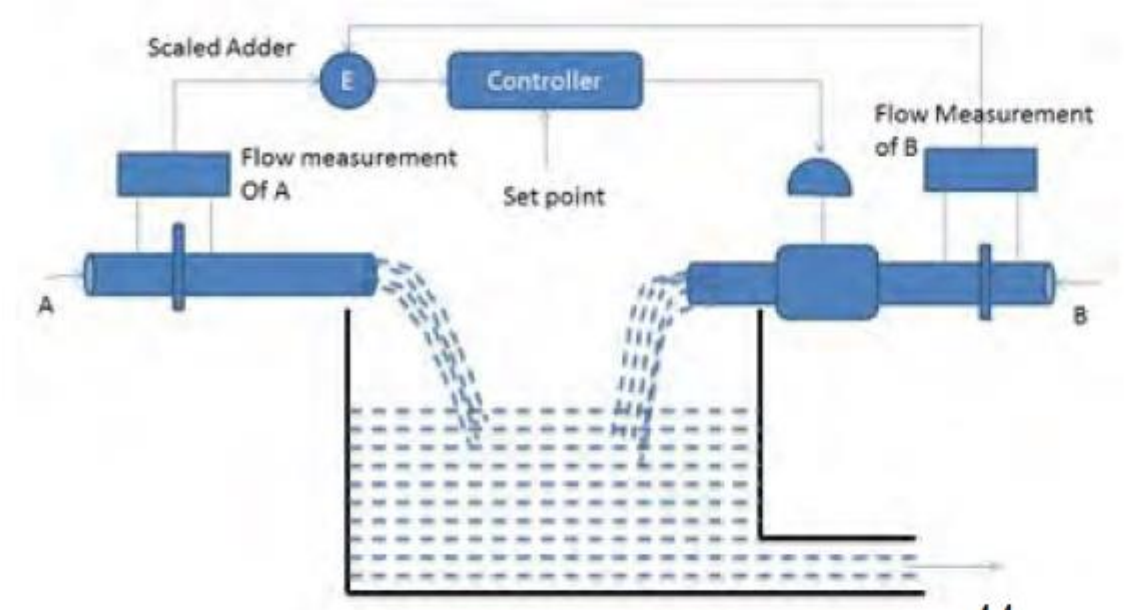
14 **Westinghouse MVH principle**



Ratio Control

- Ration Control is used for blending two liquid sources in a mixing scenario
- We will look at single stage controller
- Two inputs
  - Wild flow (outside demand determines flow rate)
  - Controlled flow (set as % of wild flow)
- This is an example of an open-loop control mechanism

Ratio Control

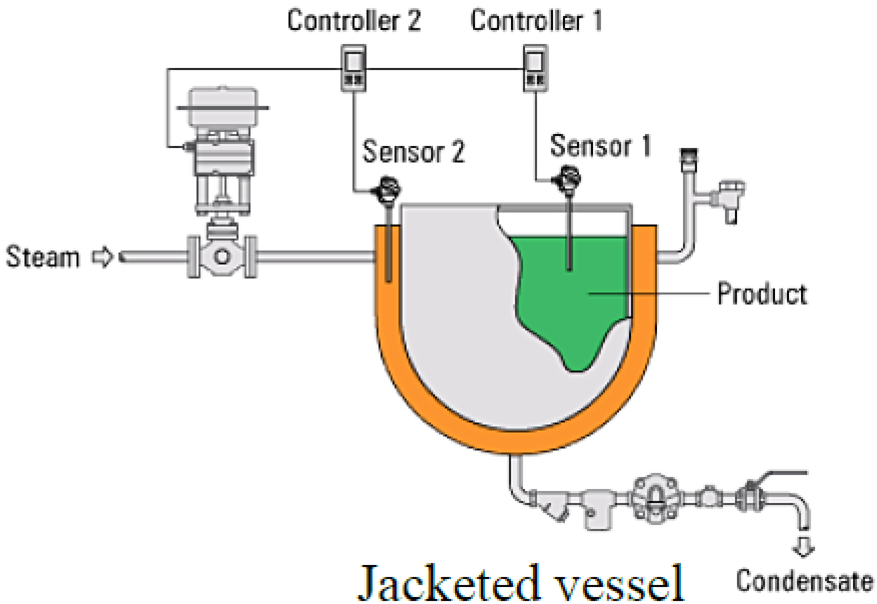


Flow A is the outside Flow
Flow B is the one we control

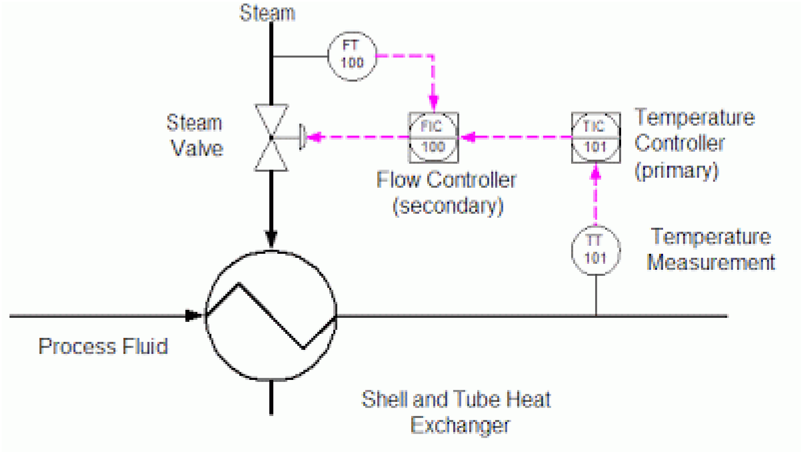
Cascade Control

- We consider 2 interconnected control loops, thus 2 process variables (PV)
- One control output as a result
  - Second loops output becomes setpoint of first loop
- Use when primary PV is slow responding and secondary PV is fast responding (3 – 10x)

Cascade Control



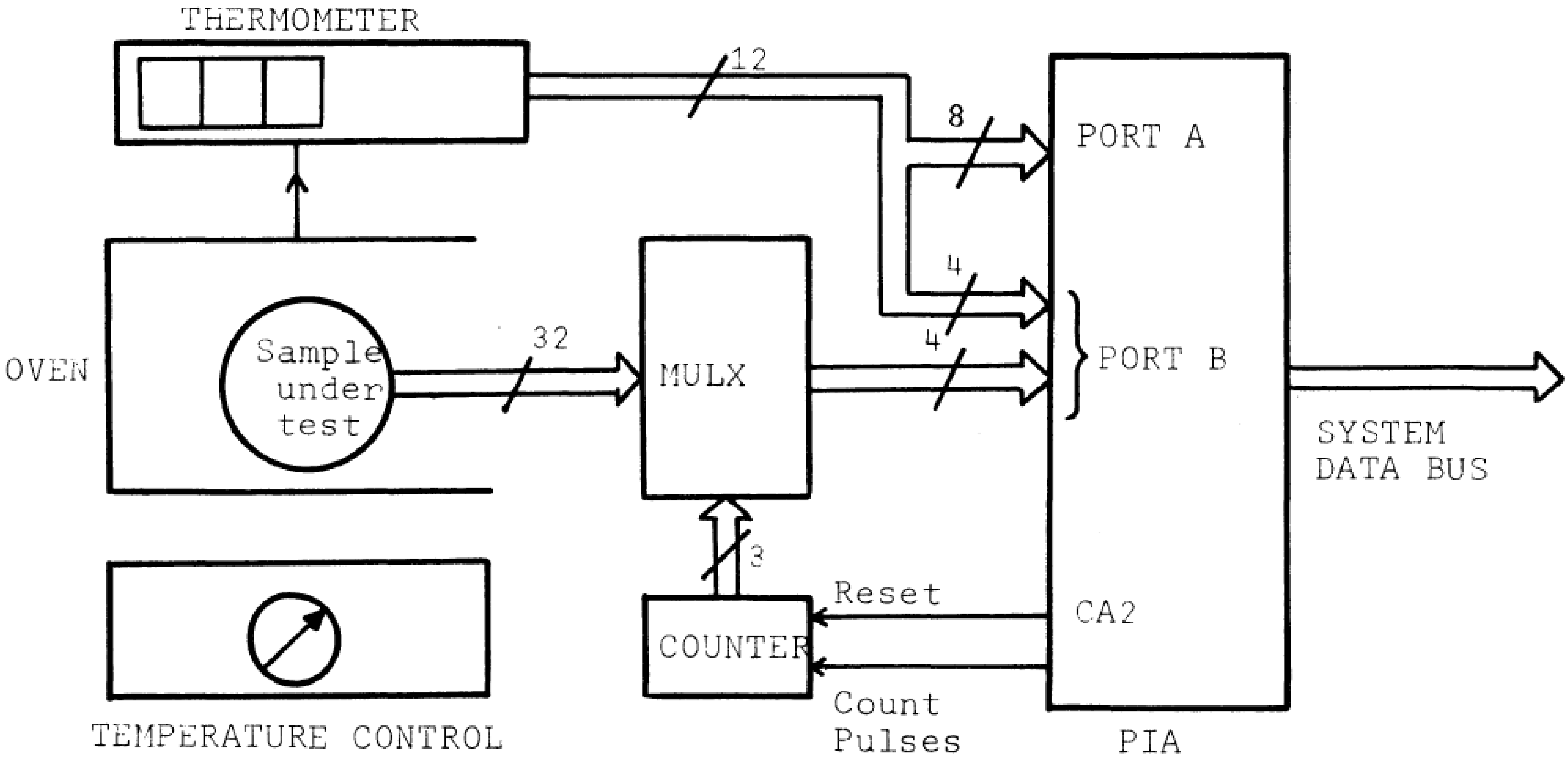
Jacketed vessel



Quality Control

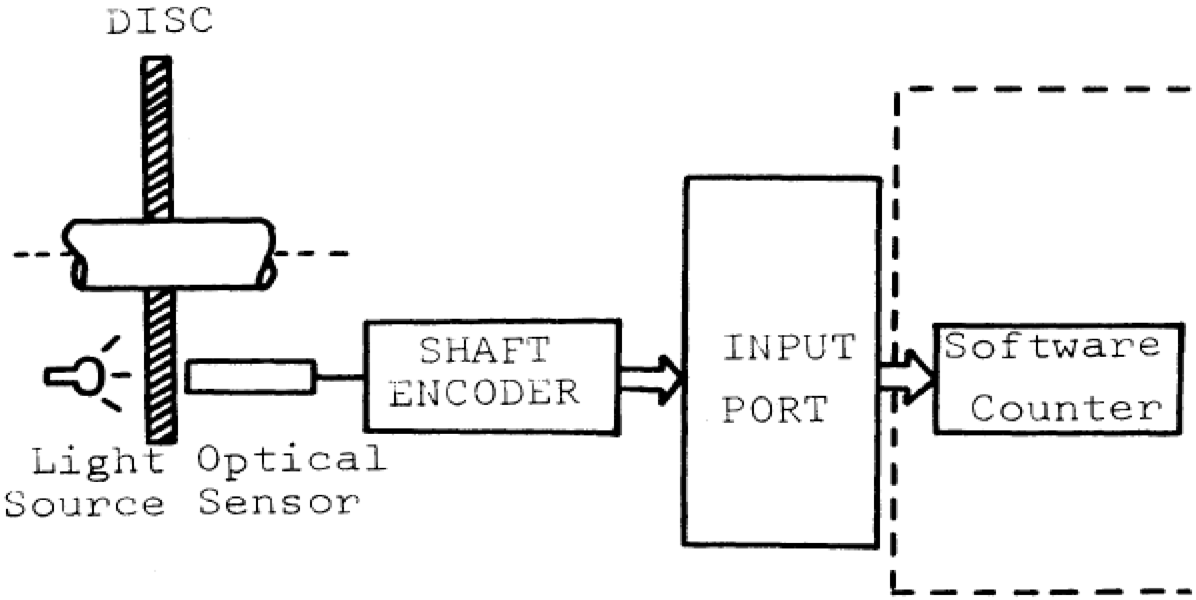
- Microprocessor systems can be used in quality control systems which automatically take action based on process variables and measurements
- A typical use is to subject an item under test to a range of temperature and then to measure response
- If response, the unit under test passes, otherwise it is rejected

Quality Control



Quality Control

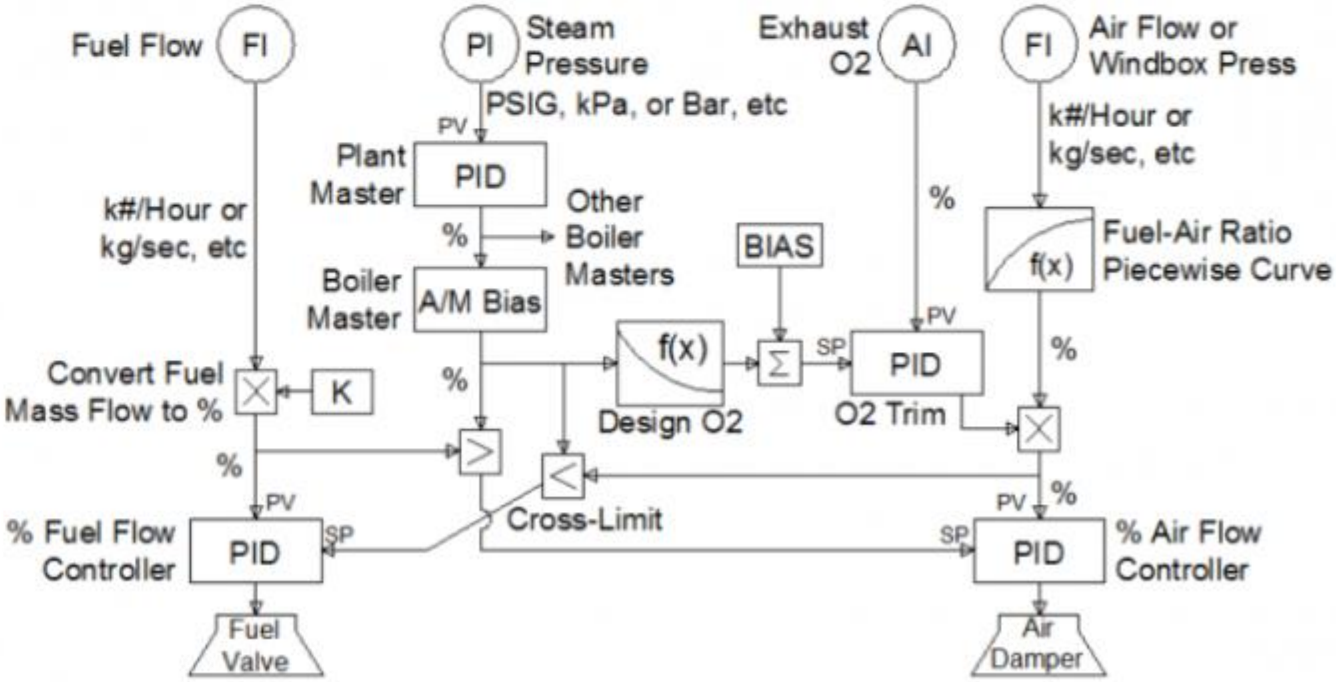
- Another application is to test electric motors over a range of speed and torque values
  - These are compared to determine acceptable operation



Industrial Burner Control

- Combustion Control System (CCS) determines how much fuel and air to put into a commercial burner system, such as those used in large boiler systems
- CCS uses a PID controller
  - Multiple PID controllers for air, fuel, water
  - Interaction must be controlled in order with a precedence scheme depending on operation

Industrial Burner Control



Conclusion/Next Class

- Today we continued looking at examples of Microprocessor Based Industrial Controllers
- We looked at a number of applications over a range of industrial settings and functions
- Tomorrow we will look at connectivity in these devices and future trends