Microprocessor-Based Industrial Controllers

Class 3: Controller Examples - 1

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Digi-Key ELECTRONICS

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

- Algorithm Basics
- Brushless DC Motor Control
- Servo Motor Control
- Hot Air Blower Control
- Conclusion/Next Class

Algorithm Basics

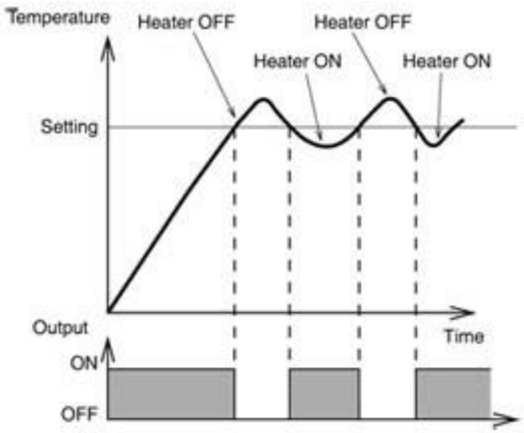
- The algorithms we are looking at are automatic control algorithms. This means that they provide control of a system based on inputs and feedback in a loop structure that attempt to keep the system in a desired state.
- Most such algorithms are tunable, either in development or under operation.
- Depend on a set-point, or desired value. We are looking at the difference between this set-point and the measured value

Algorithm Types

- Control system algorithms come in various types
- Some are:
  - Process Variable
  - On-Off Control
  - Open-Loop Control
  - Feed-Forward Control
  - Closed-Loop Control
  - PID (Proportional-Integral-Derivative)

Algorithm Basics

- On-Off Control: simplest type. Turn system on when a value reaches a set limit. Usually add hysteresis to avoid process disturbances.



Algorithm Basics

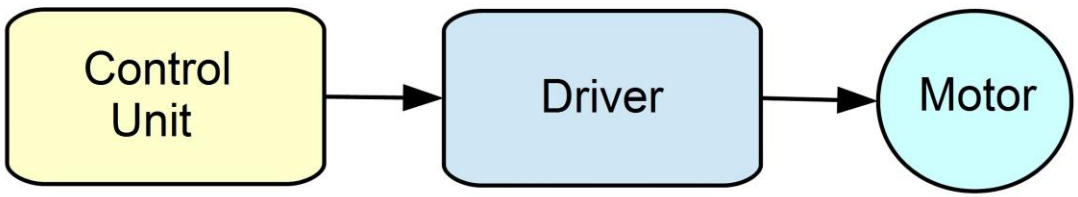
- Open-Loop Control: system calculates the control output independently but does not use feedback or consider disturbances. Not generally used.
- Feed-Forward Control: uses sensors to detect disturbances in the system which are then used to calculate corrective action needed. Requires a good understanding of the process being controlled and can be more complex.

Algorithm Basics

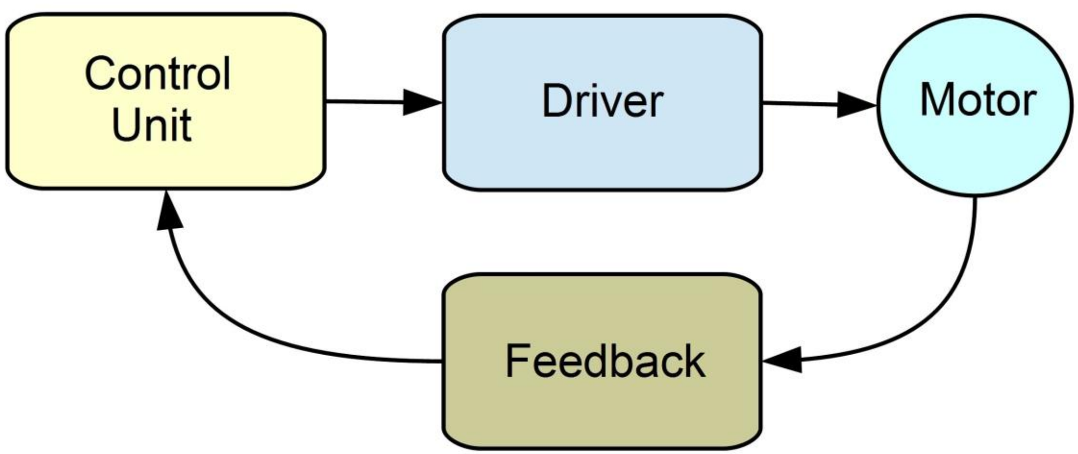
- Closed-Loop Control: uses the difference between an output measurement and the set-point. This is the “error”. The actuator value is modified until the error is minimized to maintain the output at the desired value.
  – Most closed-loop control systems are implemented as PID controllers which helps ensure stable and accurate control.

Algorithm Basics

Open Loop Control System



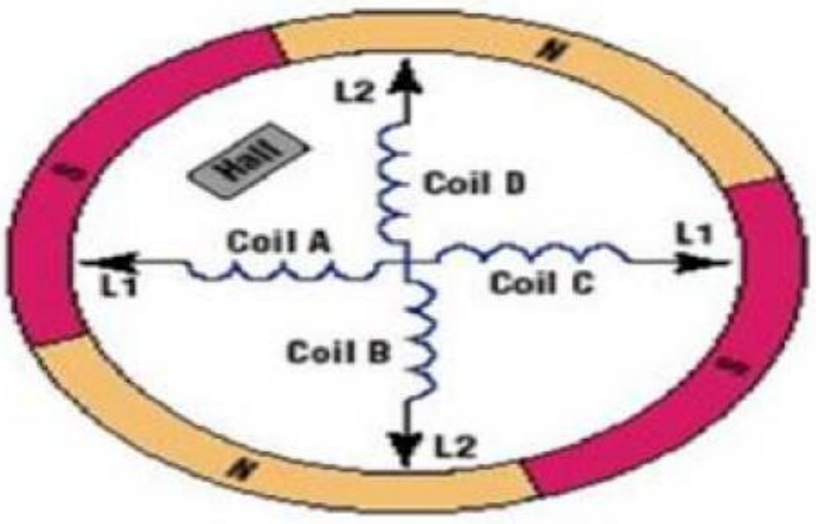
Closed Loop Control System



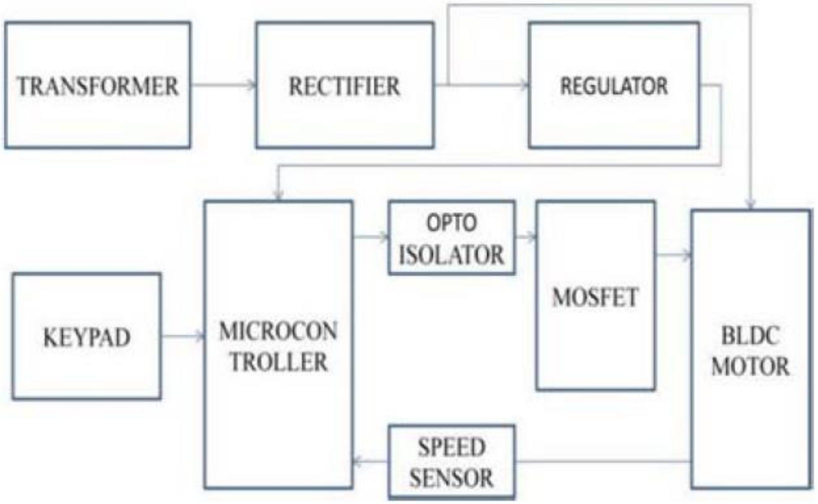
Brushless DC Motor Control

- Brushless motors are finding widespread use due to their reduced size, cost and other favorable attributes over AC motors. In addition, they are powered by 24-volt or 12-volt supplies.
- This example uses a closed loop control technique implemented on an 8-bit microcontroller
- The sensor is a photodiode to count the RPM of the motor
- A MOSFET drives the motor

Brushless DC Motor Control

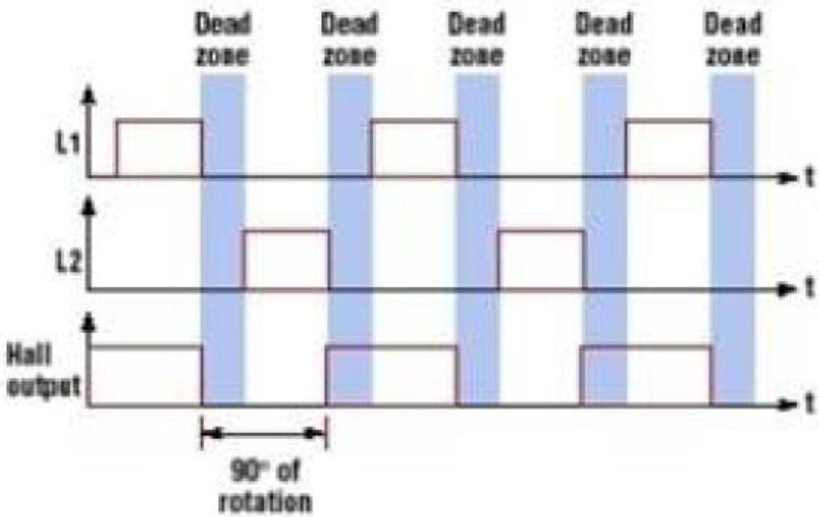


Motor Block Diagram

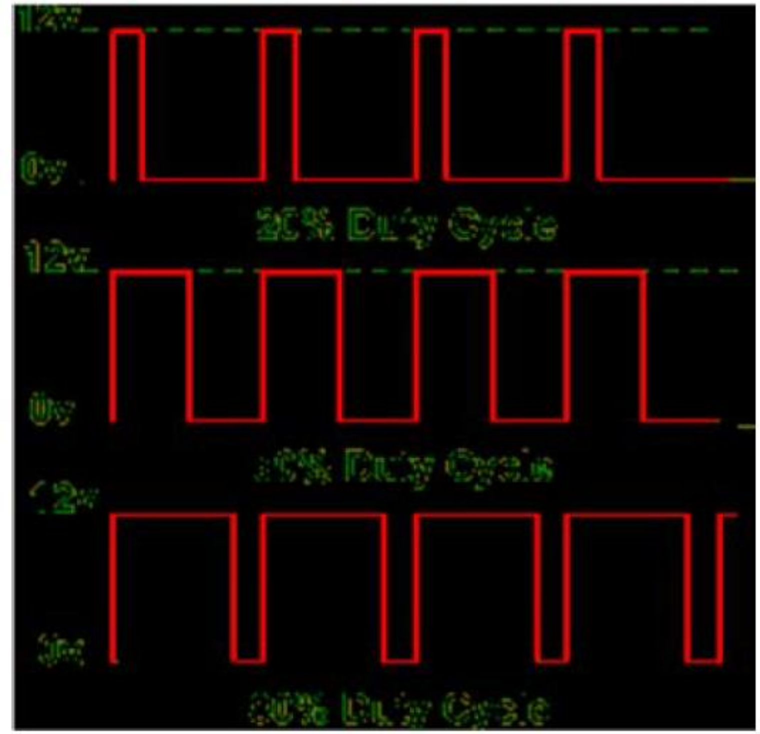


System Configuration

Brushless DC Motor Control



Commutation Timeline



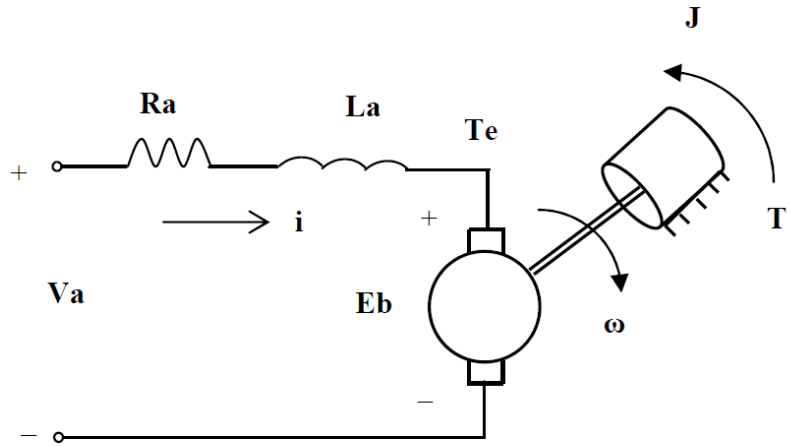
PWM Output

PWM is used to control the motor. The microcontroller, through the input ser-point, generates the pulse to control the motor operation obtaining the desired speed.

Servo Motor Control

- Servo motors provide accurate and speedy motion for devices such as robots or CNC machines
- Precise control must take into account the response of the motor and the load.
- The motor is controlled with a PWM signal, which determines the angle of rotation.
- The control approach used is PID. This is used to generate the signal required.
- The processor used is an ARM processor. This allows many functions, such as control of the operation of the server motor and the action of the system.

Servo Motor Control



Server motor equivalent circuit

$$\begin{bmatrix} \frac{di}{dt} \\ \frac{d\omega}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{R_a}{L_a} & -\frac{K}{L_a} \\ \frac{K}{J} & 0 \end{bmatrix} \begin{bmatrix} i \\ \omega \end{bmatrix} + \begin{bmatrix} \frac{1}{L_a} & 0 \\ 0 & -\frac{1}{J} \end{bmatrix} \begin{bmatrix} V_a \\ T \end{bmatrix}$$

State Space Model

$$\tau_e = \frac{L_a}{R_a} \qquad \tau_{em} = \frac{R_a J}{K^2}$$

Time Variables (electrical and electro-mechanical)

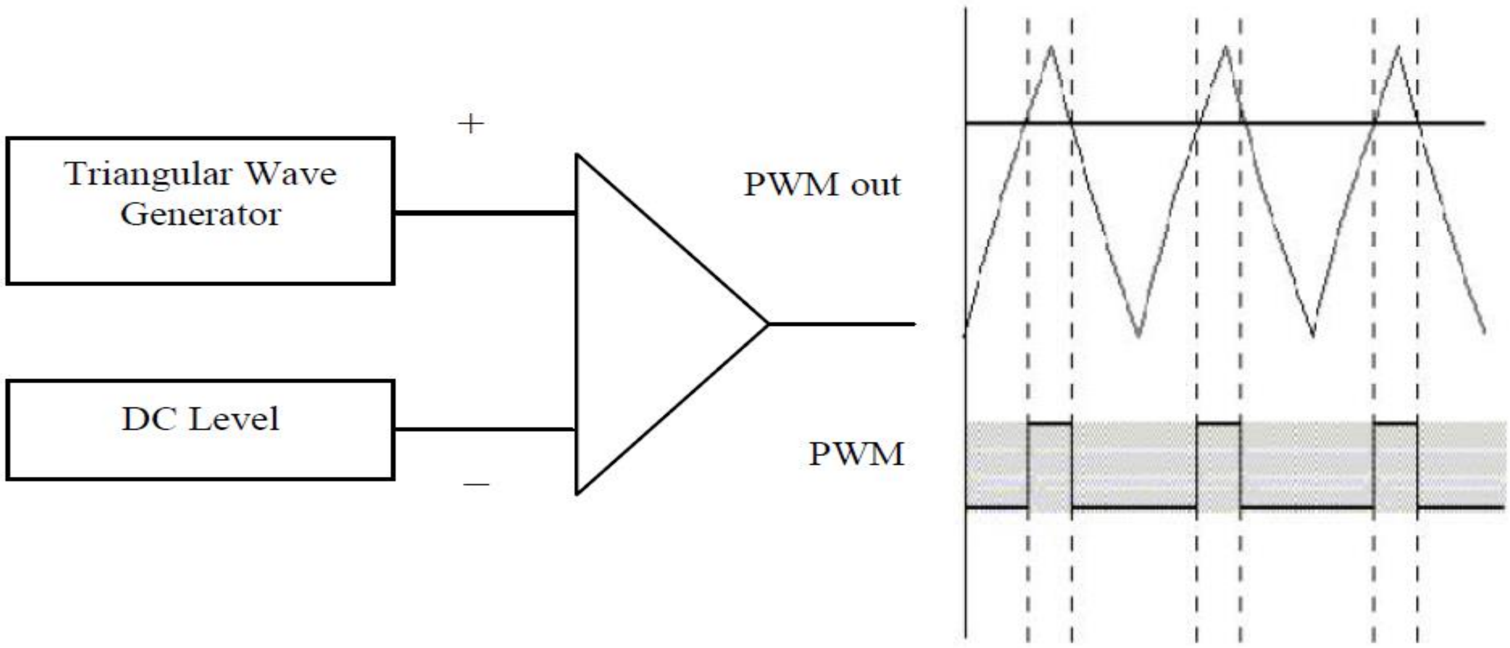
$$H(s) = \frac{\omega(s)}{V_a(s)} = \frac{1}{K} \frac{1}{\left(1 + \frac{R_a J}{K^2} s + \frac{L_a J}{K^2} s^2\right)}$$

Resultant Transfer Function

$$H(s) = \frac{\Omega(s)}{U(s)} = \frac{1}{K} \frac{1}{\left(1 + \tau_{em} s + \tau_{em} \tau_e s^2\right)}$$

Final Time-Dependent Transfer Function

Servo Motor Control

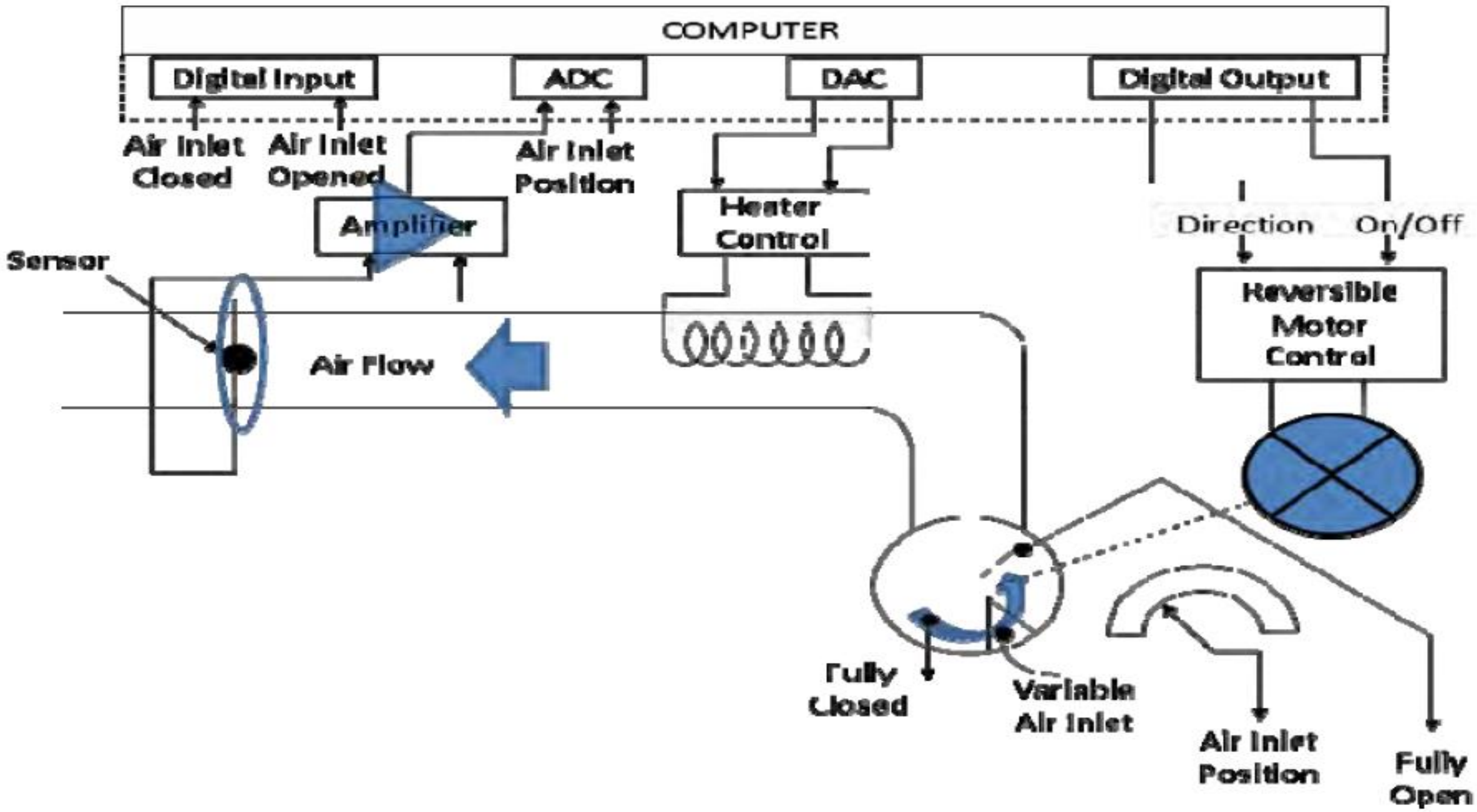


PWM For DC Drives

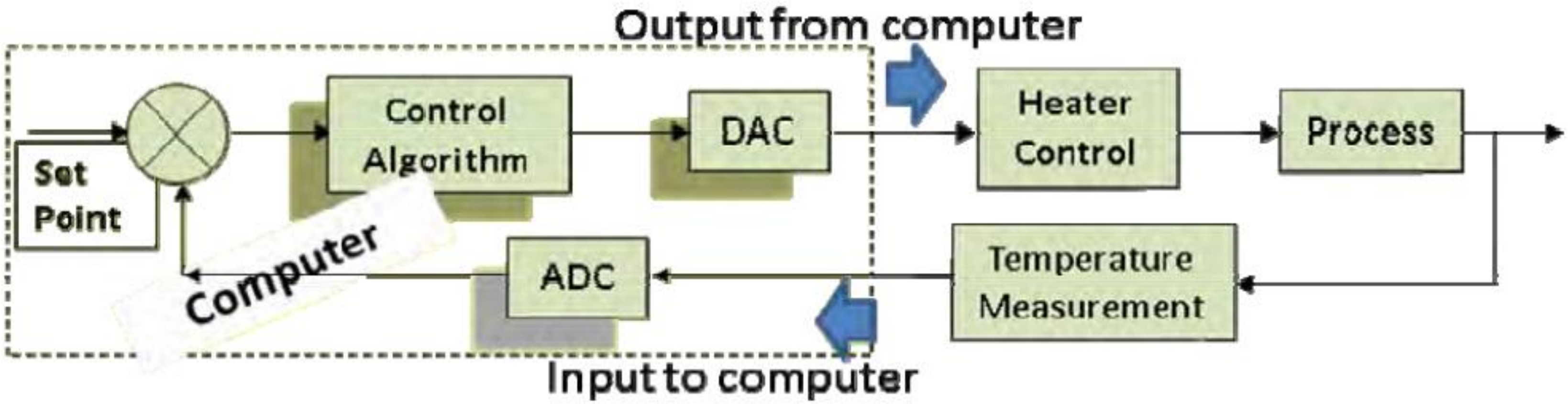
Hot Air Blower Control

- This system blows hot air over a heater element into a tube
- The goal is to control the temperature of the air flow
- Temperature is sensed by a thermocouple
- There is an air inlet valve, a constant speed motor (which can be turned on or off) and a heating element

Hot Air Blower Control



Hot Air Blower Control



The control algorithm in this case is of a closed-loop type designed to keep the temperature constant

Conclusion/Next Class

- In this class we looked a little more closely at the types of algorithms
- We looked at examples including a brushless DC motor, a stepper motor and a hot air blower
- Tomorrow we will look at more examples of control applications