NIDays09

WORLDWIDE GRAPHICAL SYSTEM DESIGN

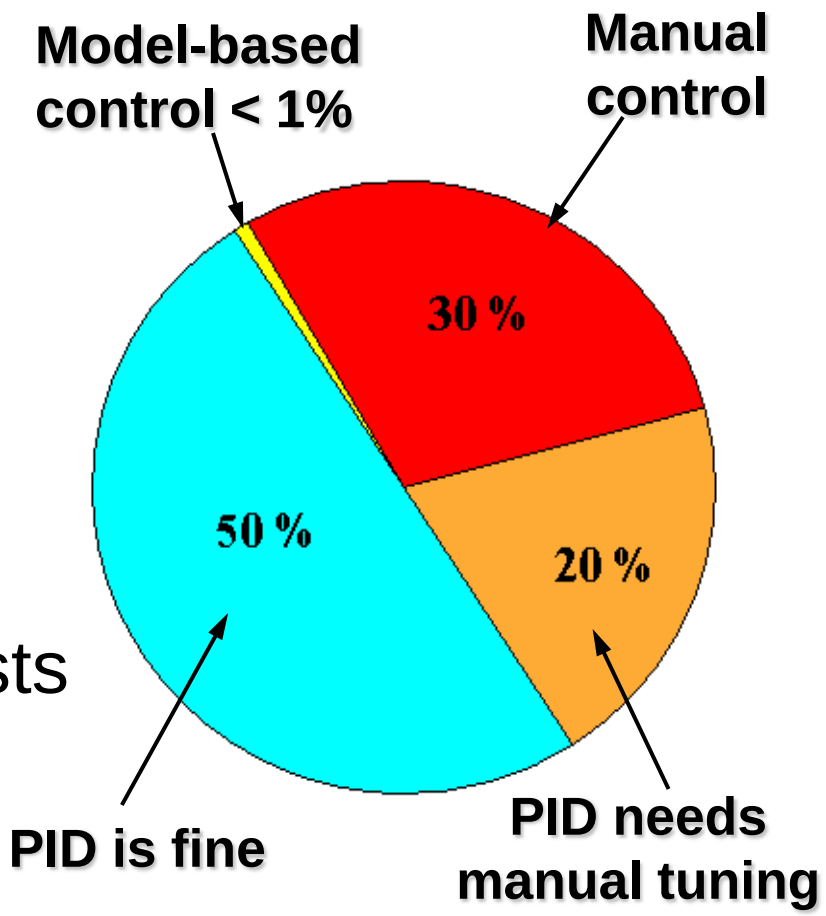
CONFERENCE

NATIONAL INSTRUMENTS

# How to implement conventional and alternate control algorithms using LabVIEW

# Benefits of Advanced Control and Tuning

- A poorly tuned control valve costs additional $880/year*
- A bad pH loop incurred chemical waste of $50,000/month*
- A bad kiln temp loop costs $30,000/month*




*Sources: CyboSoft and ExperTune

# Agenda

- What Is PID?
- How to Improve Performance
  - Hardware considerations
  - Upgrade PID algorithm
  - Advanced controllers
- Conclusion

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- **What Is PID?**
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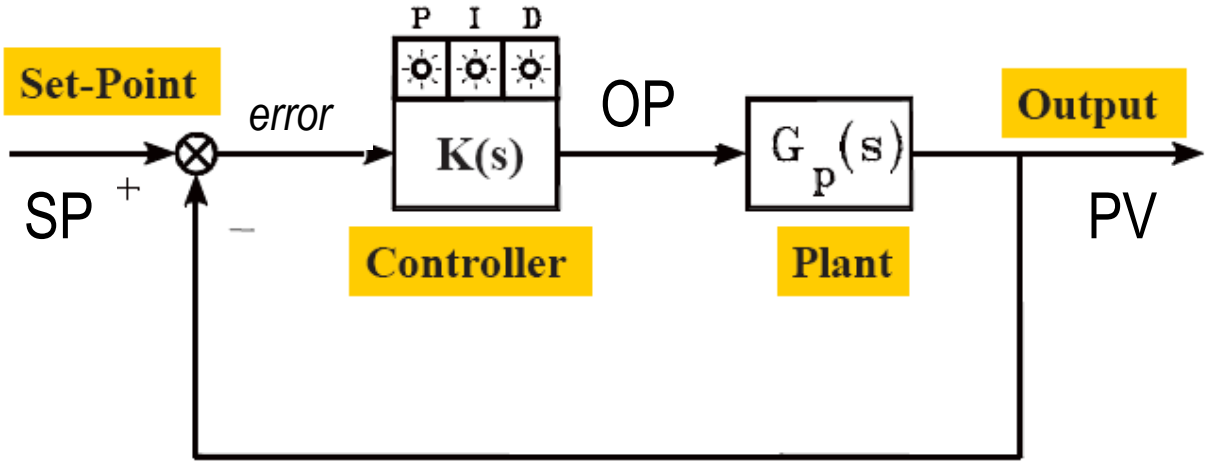
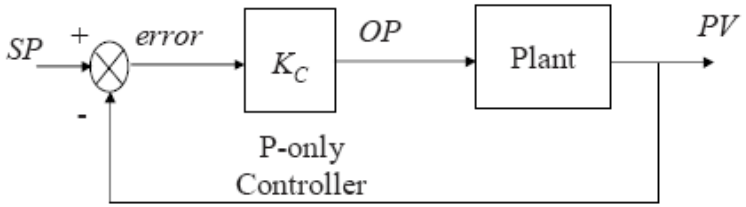
# What Is PID?

- Setpoint (SP) – Desired control point
- Output (OP) – Controller output
- Process Variable (PV) – Plant/process output
- *Error* = SP - PV

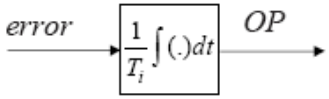


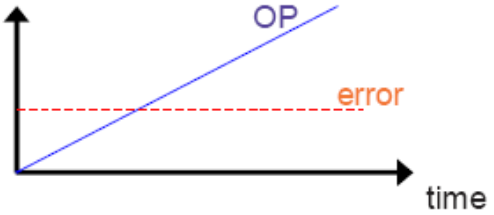
# PID Parameters

- **Proportional**
  - Drive to setpoint
  - Error → 0, OP → 0
  - "Steady-state error"

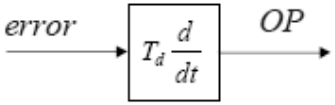


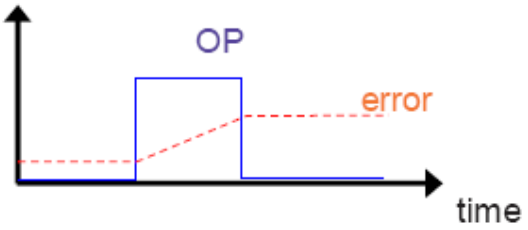

- **Integral**
  - Eliminate steady-state error
  - OP proportional to ∫ error



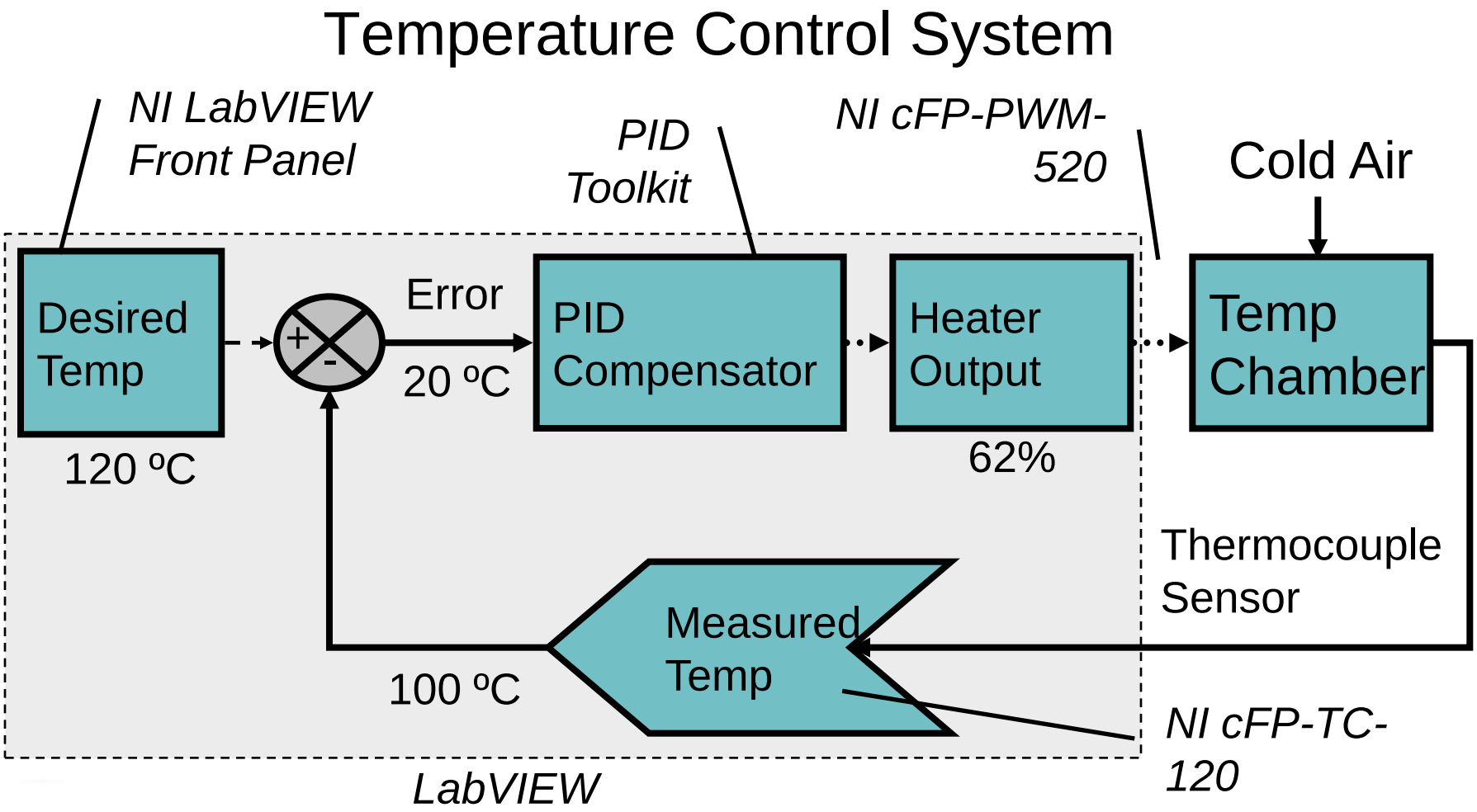

- **Derivative**
  - Increase response rate
  - OP proportional to change of error rate



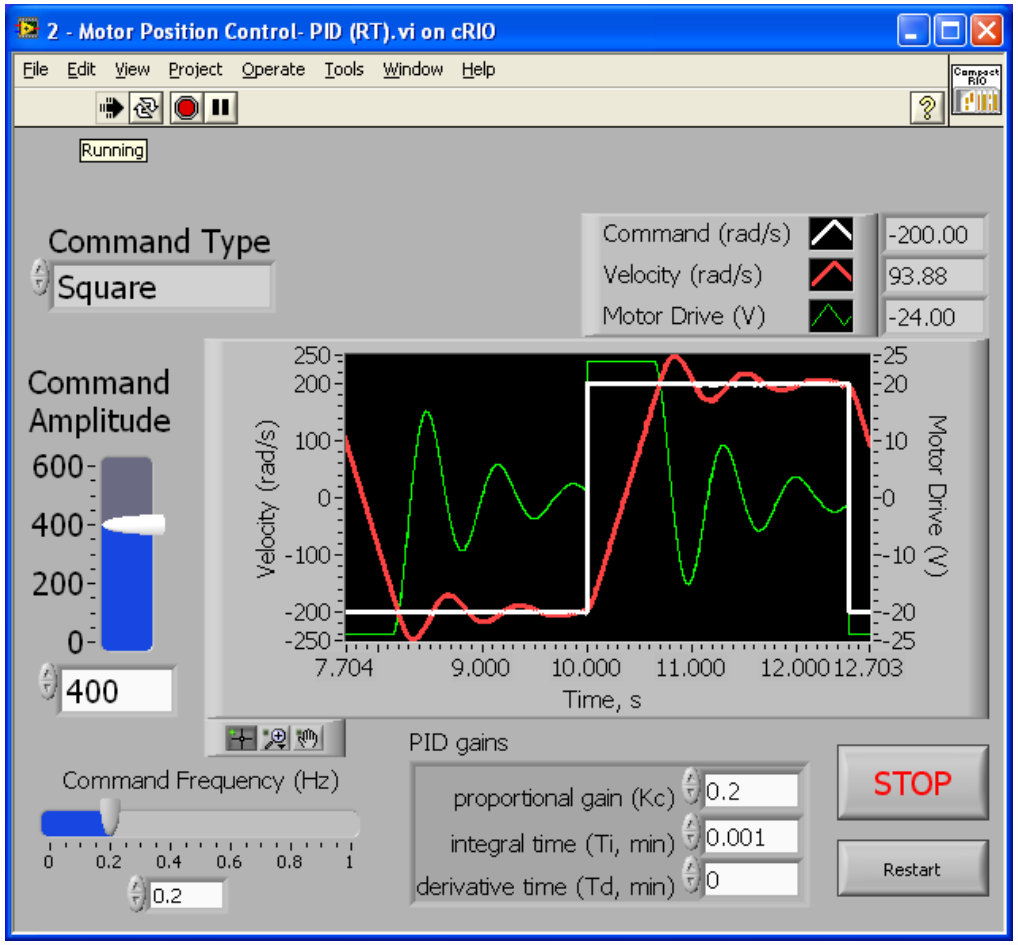
# System to Control

# Control System Diagram



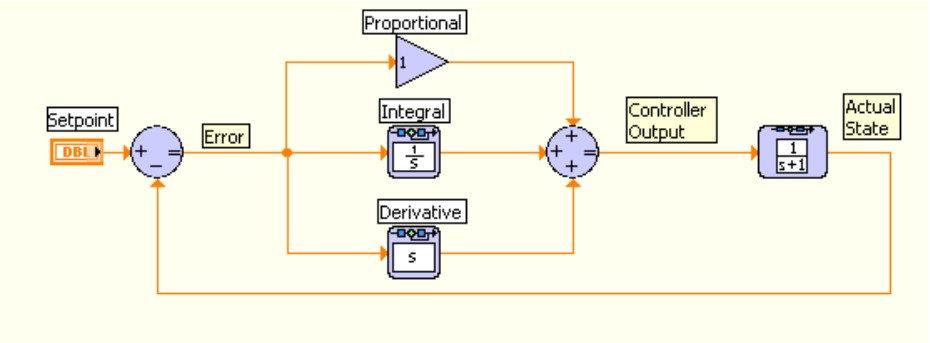
# PID Implementation Demo

DEMO

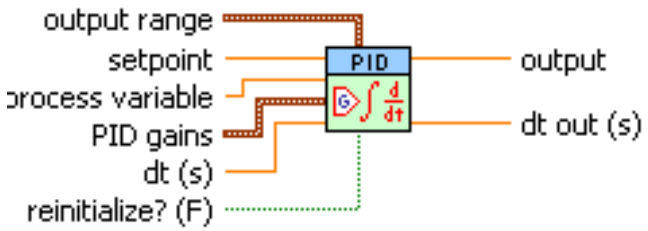


# PID Control – Pros and Cons

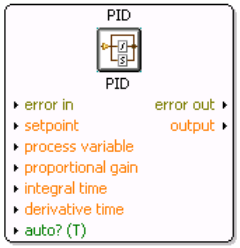
- Advantages
  - Proven
  - Easy to implement
- Disadvantages
  - Not easy to tune
  - Not suitable for all systems
    - Backlash, friction, and more



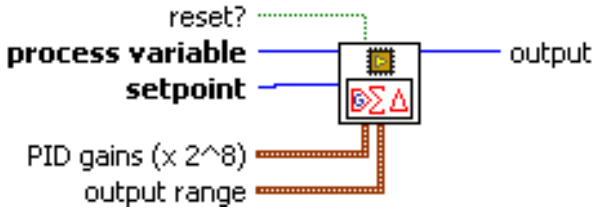
# How to Program PID



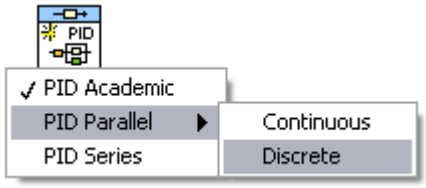

Windows/Real-Time OSs




Function Blocks




FPGA

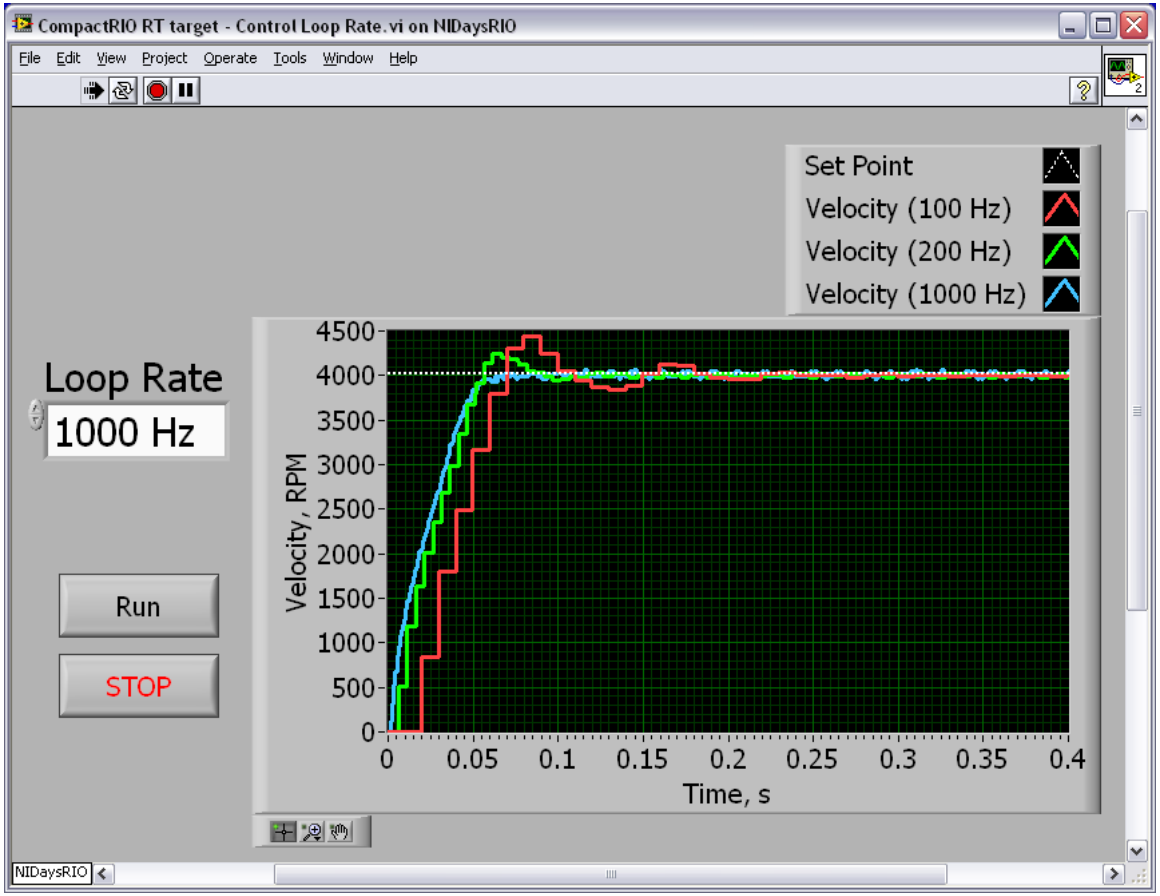



Control and Simulation

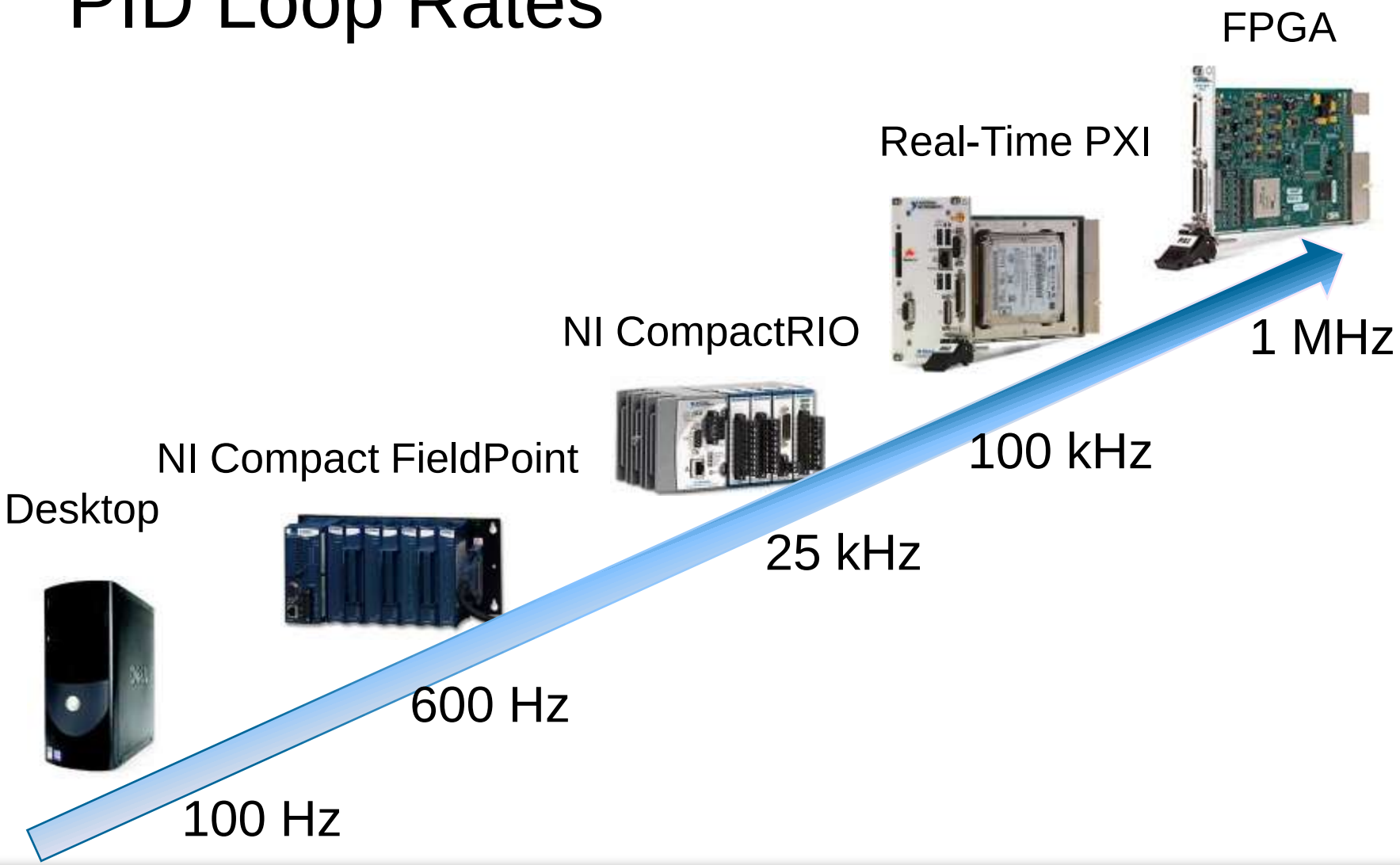
# Agenda

- What Is PID?
- **How to Improve Performance**
  - **Hardware considerations**
  - Upgrade PID algorithm
  - Advanced controllers
- Conclusion

# Benefits of Higher Loop Rates



# PID Loop Rates



# Die-Casting Machine

Aluminium injection plunger movement controlled in a steady closed loop at a speed varying from 0 to 10 m/s

# Agenda

- What Is PID?
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  - Hardware considerations
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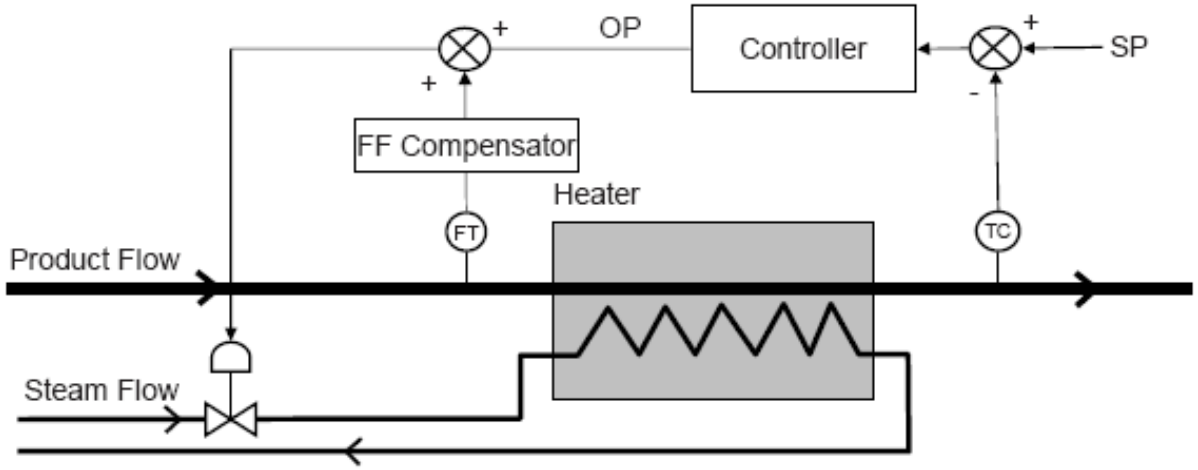
# Upgrade Your PID

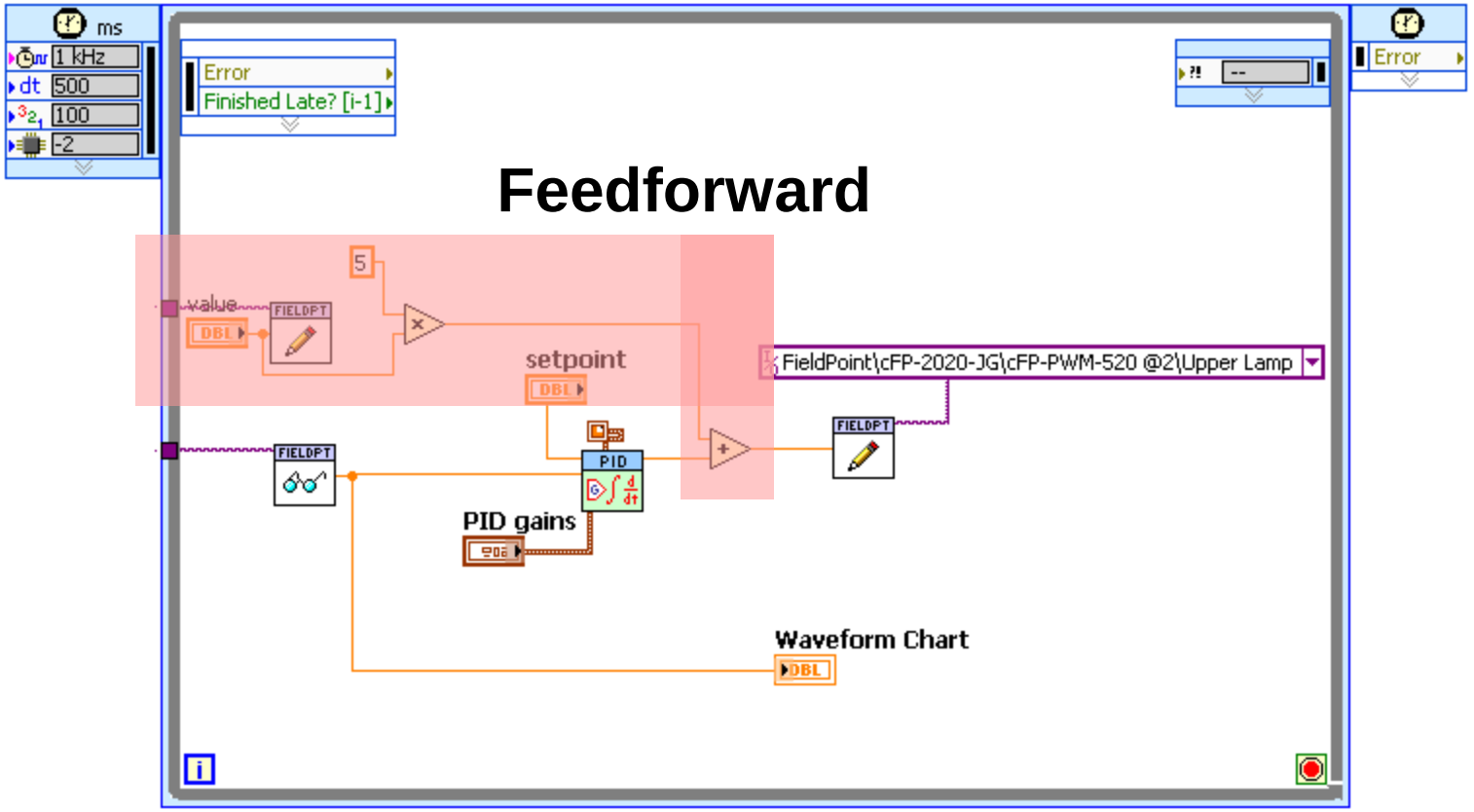
- Disturbances  Feedforward
- Nonlinear  Gain Scheduling
- Time Variant  Adaptive PID

# Feedforward

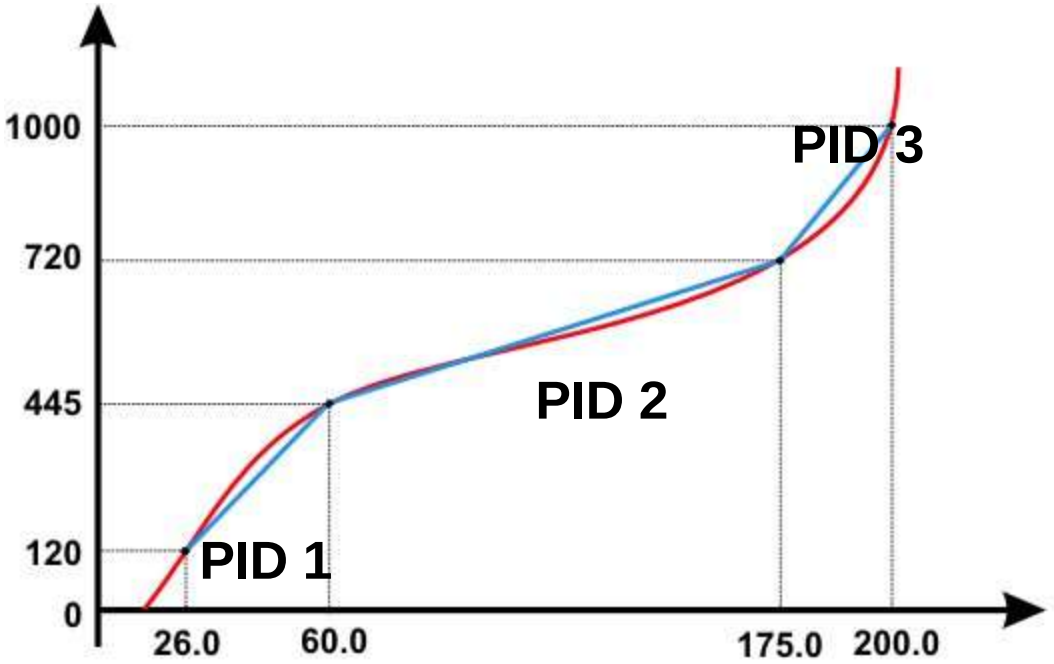
- Commonly used to compensate for a *measurable* external disturbance before it affects a controlled variable
- Example: Product feed rate changes



# Feedforward Example



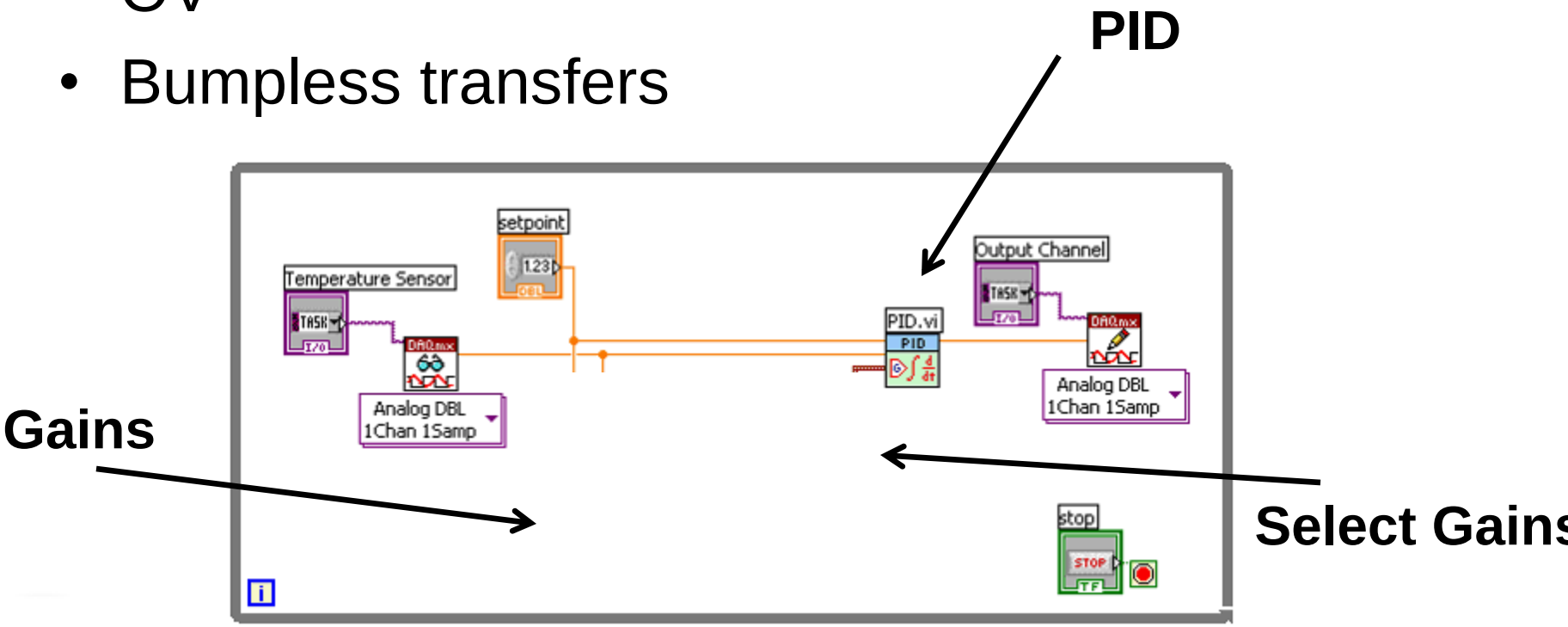
# Gain Scheduling



# Gain Scheduling

DEMO

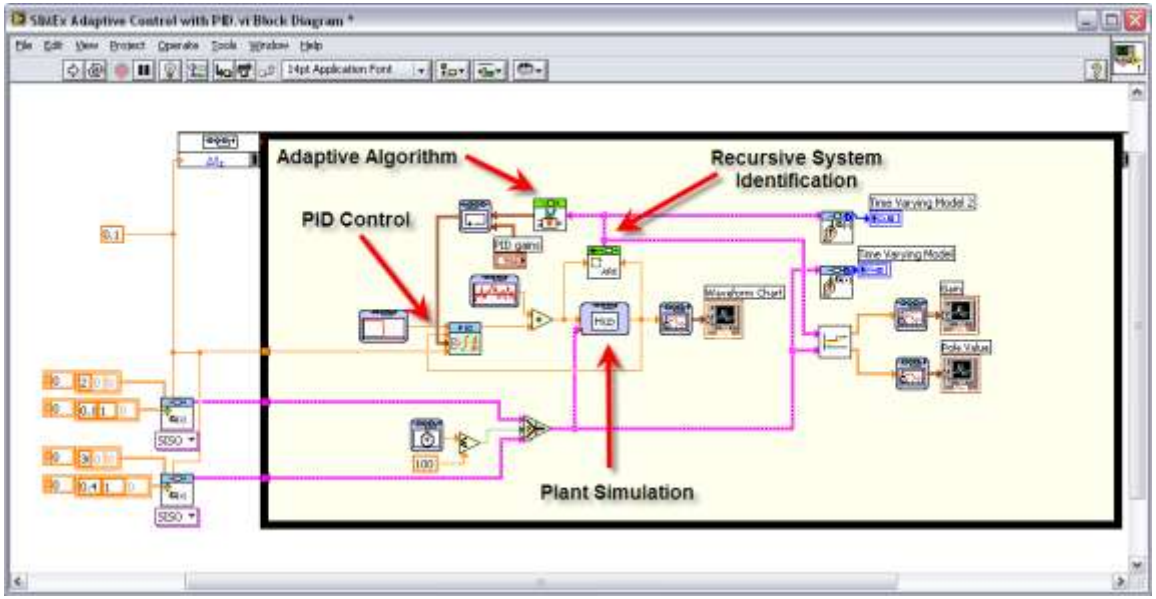
- Used to change gain on real-time depending on OV
- Bumpless transfers



# Adaptive PID

DEMO

- Mix of online system identification and common PID control
- Can handle time-variant systems



# Agenda

- What Is PID?
- How to Improve Performance
  - Hardware considerations
  - Upgrade PID algorithm
  - **Advanced controllers**
- Conclusion

# Advanced Controllers

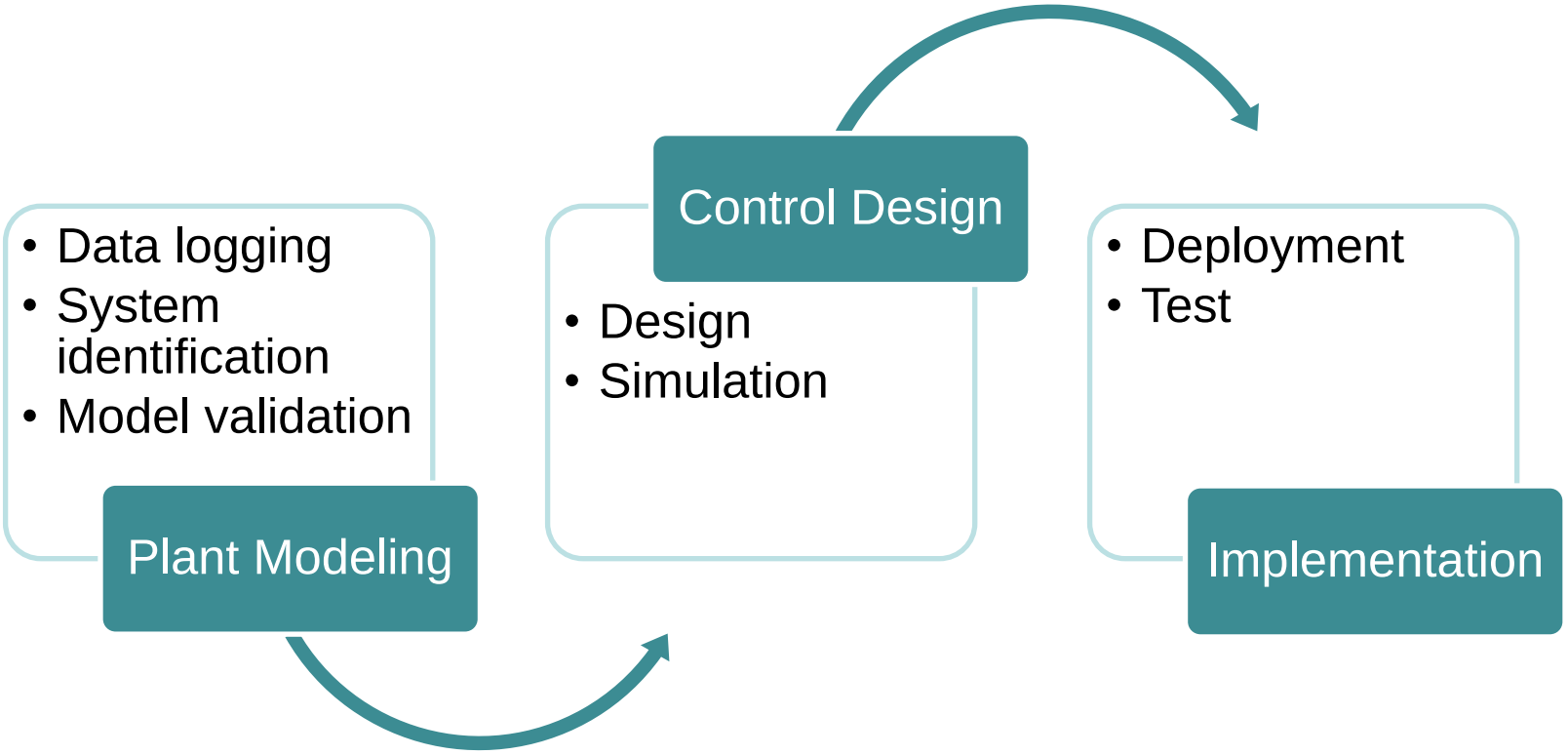
## National Instruments

- Optimal controllers (**LQR, LQG**)
- Model predictive control (**MPC**)
- Kalman filters
- Fuzzy logic

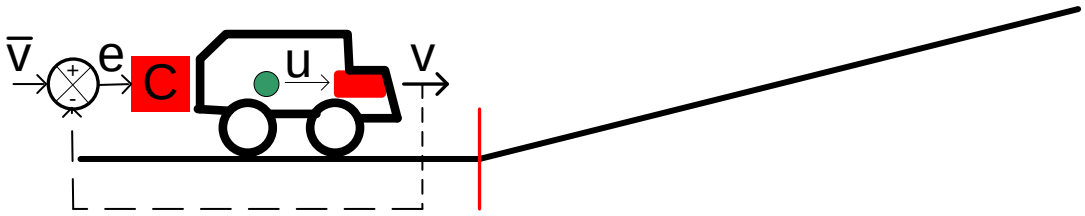
## Third-Party Partners

- Neural networks
- Genetic algorithms
- Model-free adaptive

# How to Create an Advanced Controller

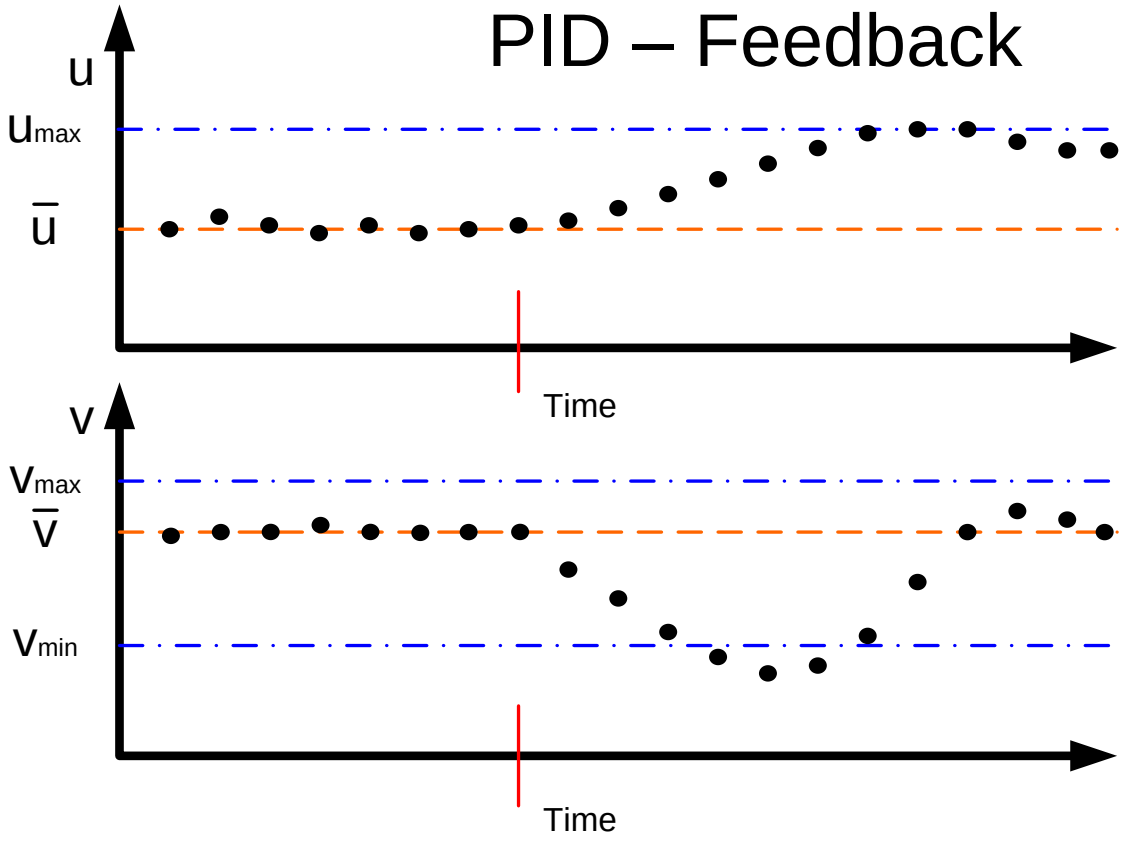


# Example
# Cruise Control




V: Velocity
u: Gas-to-Engine

PID: ‘C’ takes action when ‘V’ is off the setpoint (e <>0)



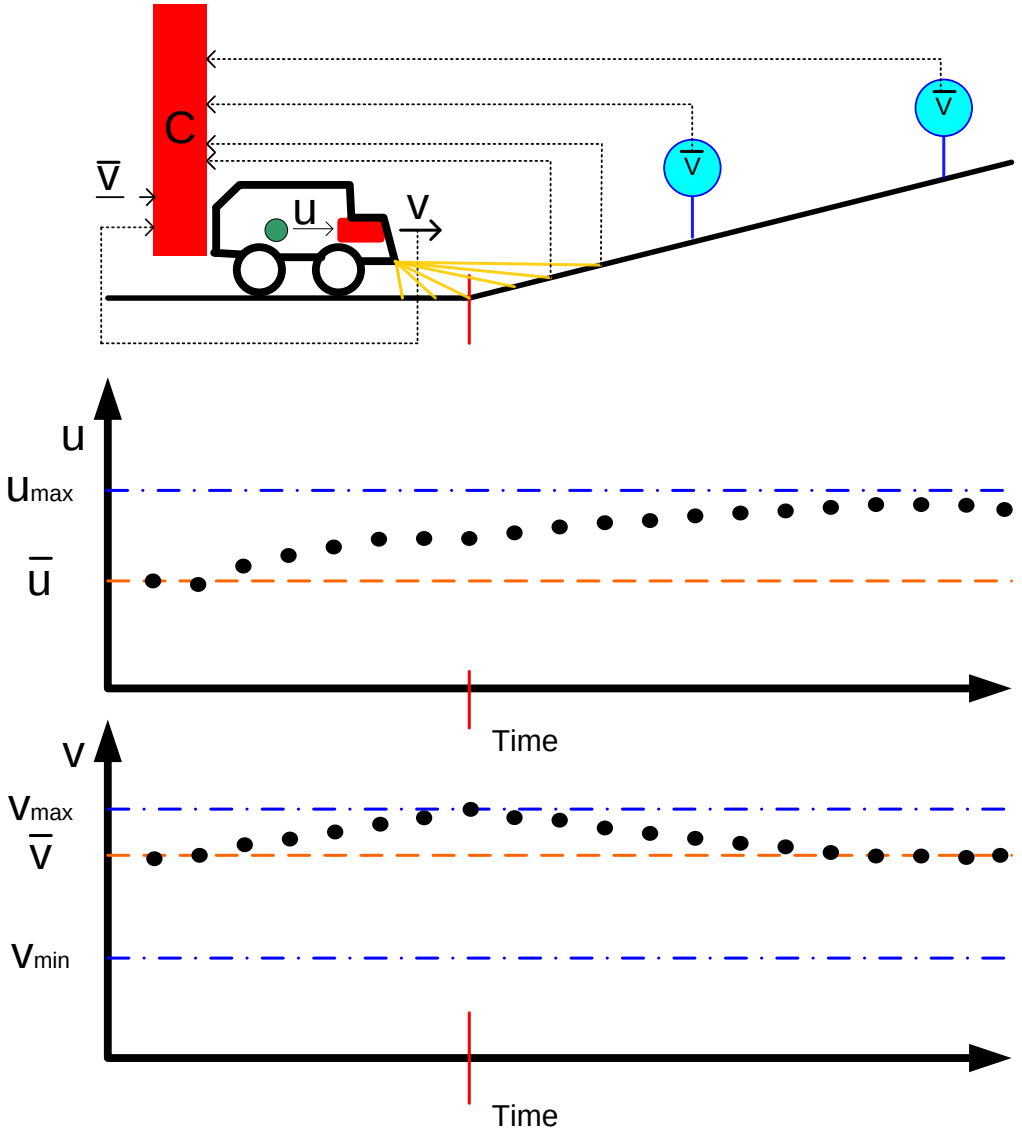
# MPC

'C' takes action due to future changes in:

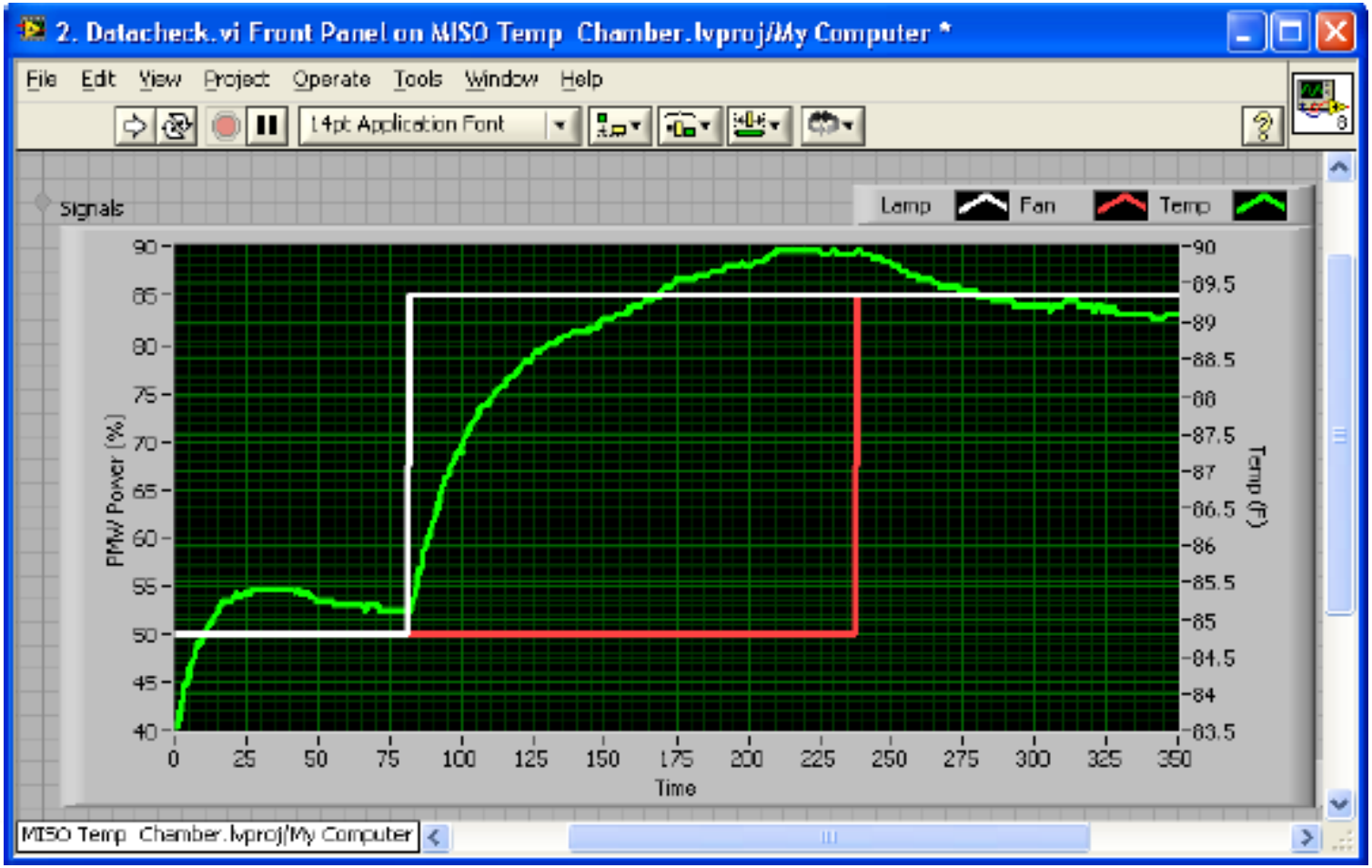
a) Road slope

b) Speed setpoints

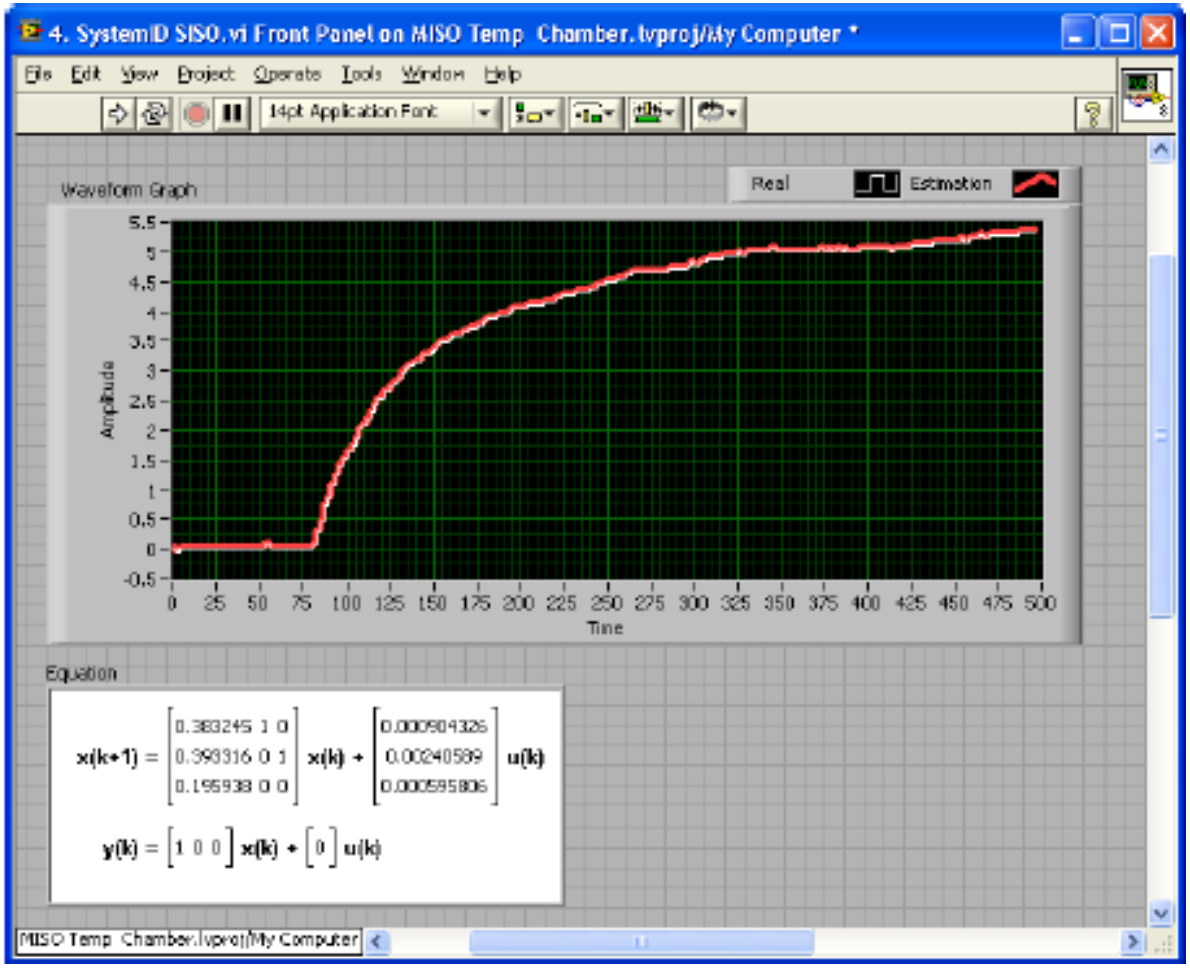
and speed-gas limits



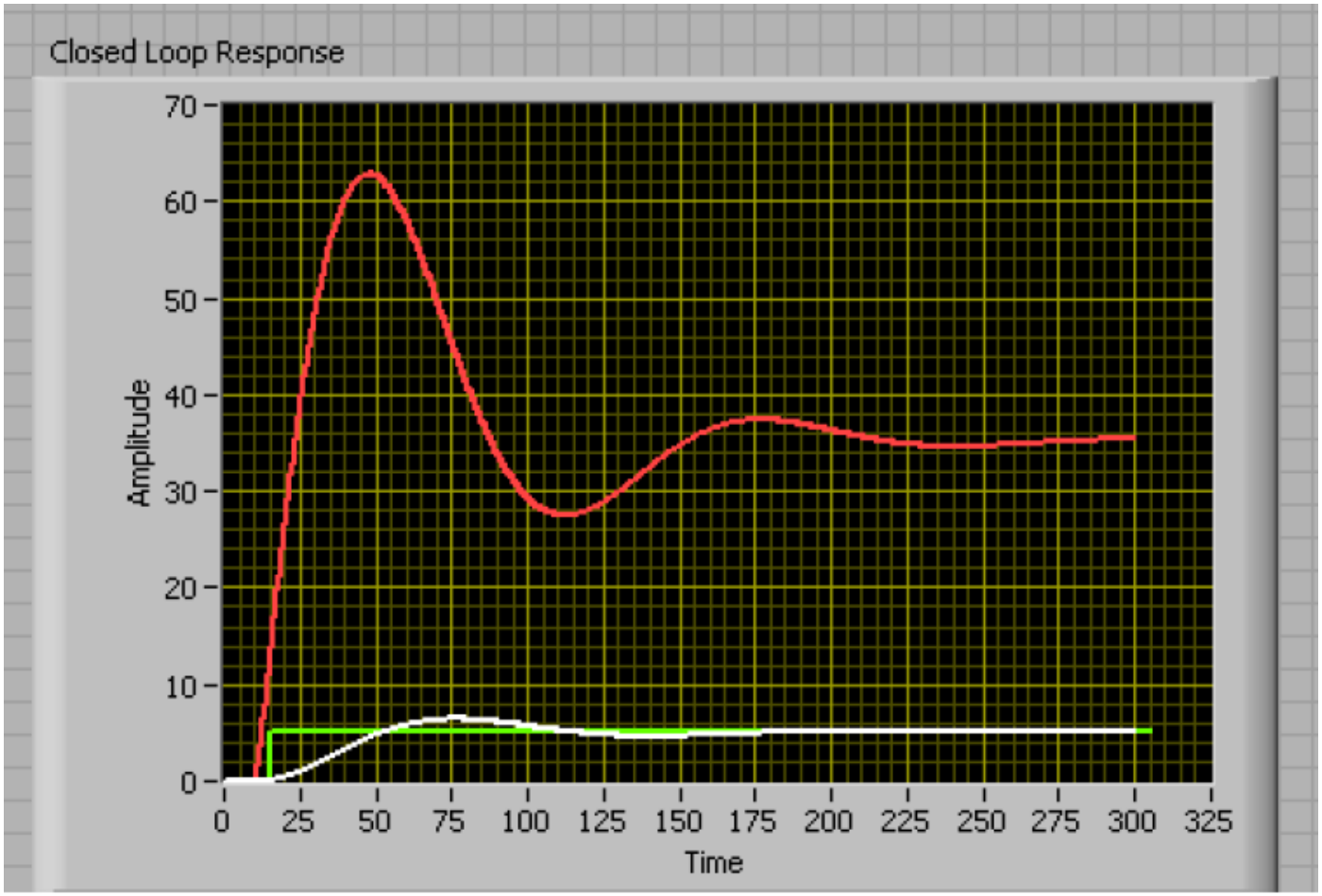
# Temp Chamber – Experiment



# Plant Modeling – Validation



# MPC Control Design



# MPC Control Prototype

DEMO

# Tyco Electronics Implements Model Predictive Control in Production Process

**Application**: Control coating quality when building electrical cable

**Challenge**: Develop a process control that can handle MIMO systems with big delays

**Products**: Compact FieldPoint, LabVIEW Datalogging and Supervisory Control Module, LabVIEW Control Design and Simulation Module

**Key Benefit**: Integrate third-party information systems using a common platform to develop a controller and deploy system

# Advanced Controllers

- Pros
  - MIMO
  - Improved performance
- Cons
  - Model needed
  - Engineering skills

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# Conclusions

- PID
- Consider
  - Upgrading hardware
  - Enhancing PID algorithm
  - Upgrading control algorithm