Control Technology – motion controller and power amplifier

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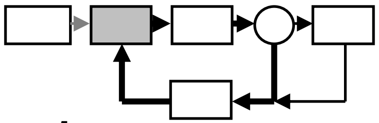
Rik Prins

National Instruments

Agenda

- Controller, the central element
- Tools for controller design in drive systems:
  - in PC-based motion controllers
  - in decentralized controllers
  - control design tools from National Instruments in distributed systems

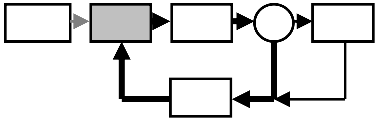


The Controller, the Central Element

- Communication
  - supervisor
  - I/O
- Configuration
  - control parameter
  - stability
- Power supply
  - constant current
  - max. power
  - voltage

Controller Amplifier

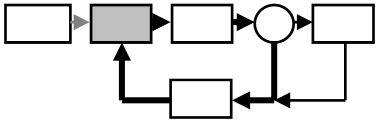
- Requirements
  - construction
  - temperature
  - cycle speed
  - controlled variable
- Sensor
  - resolution
  - measurement variable
- Motor
  - motor type
  - power
- Transmission, Drive
  - reduction
  - mech. play



Selection Criteria for Controller

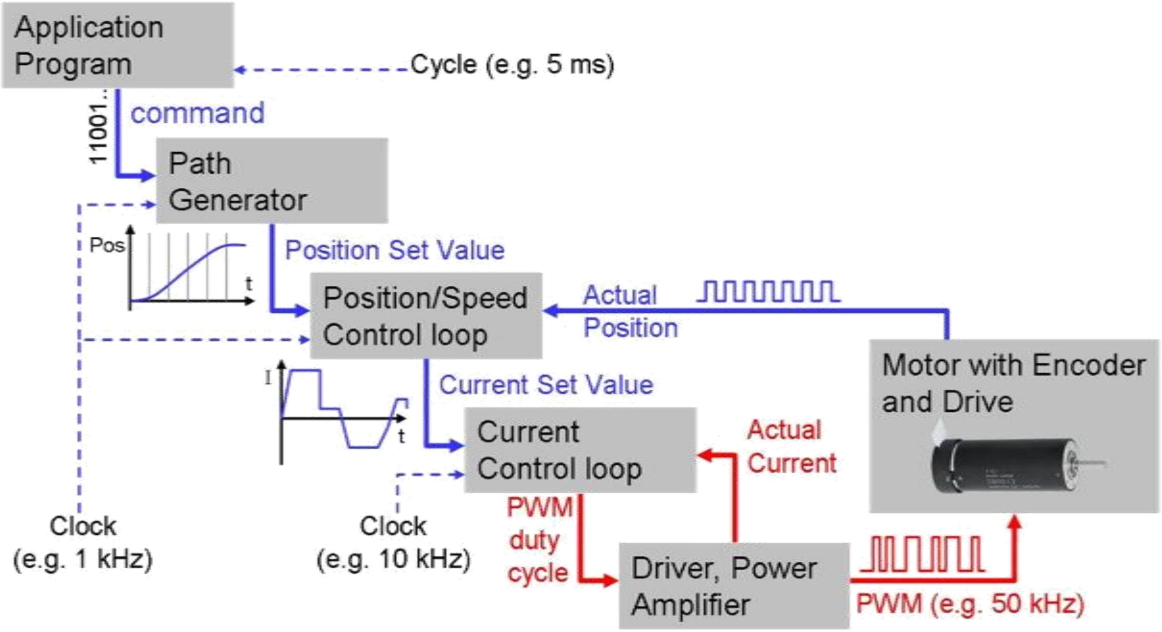
The controller should:

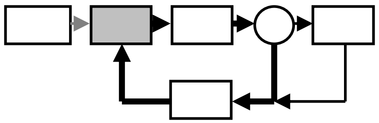
- supply the correct manipulated variable with adequate accuracy in meaningful time
- be able to process information from the current position sensor
- understand commands from the supervisory system
- make the needed power available in conjunction with the amplifier
- support the selected motors (DC or EC)



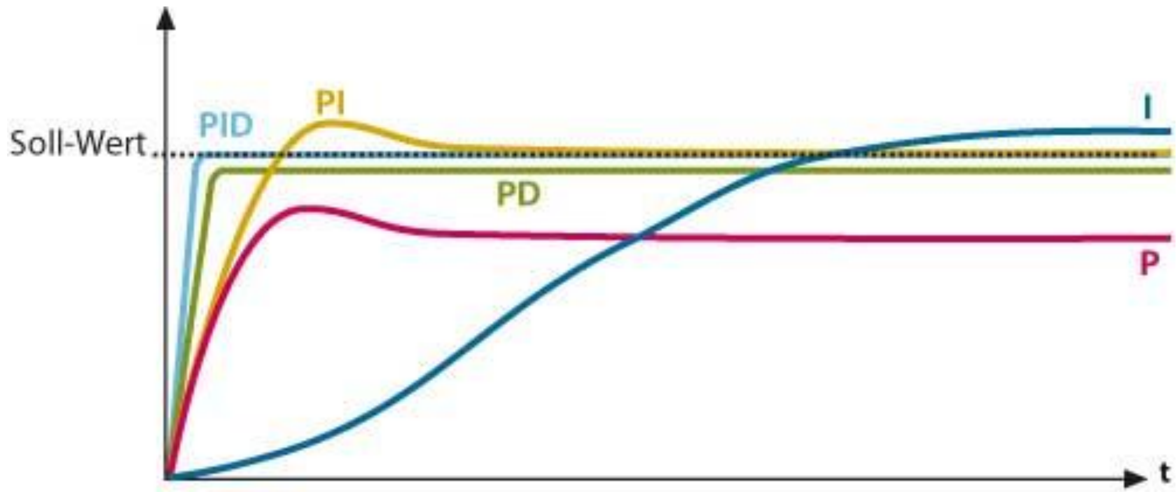
Controller Types

- current regulator
  - (with motor: torque controller)
- speed regulator
- positioning system





How is a Controller Setup?



Kp ↗

Accelerates error correction

Control can be unstable!

Ki ↗

Continuous deviation is avoided!

Control can be unstable

Kd ↗

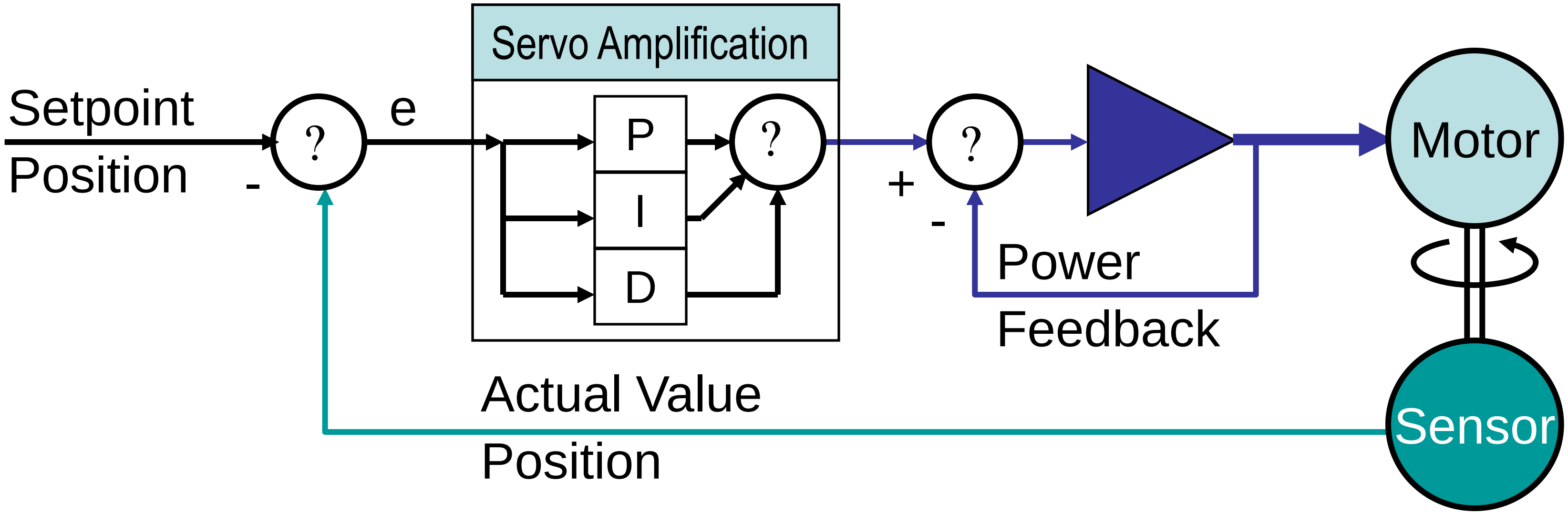
Higher system stability

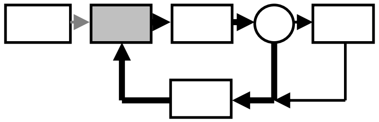
Does not eliminate continuous deviation

PID Parameters

The PID controller describes how:

- the deviation is amplified to create a suitable motor reaction for the decrease of the deviation





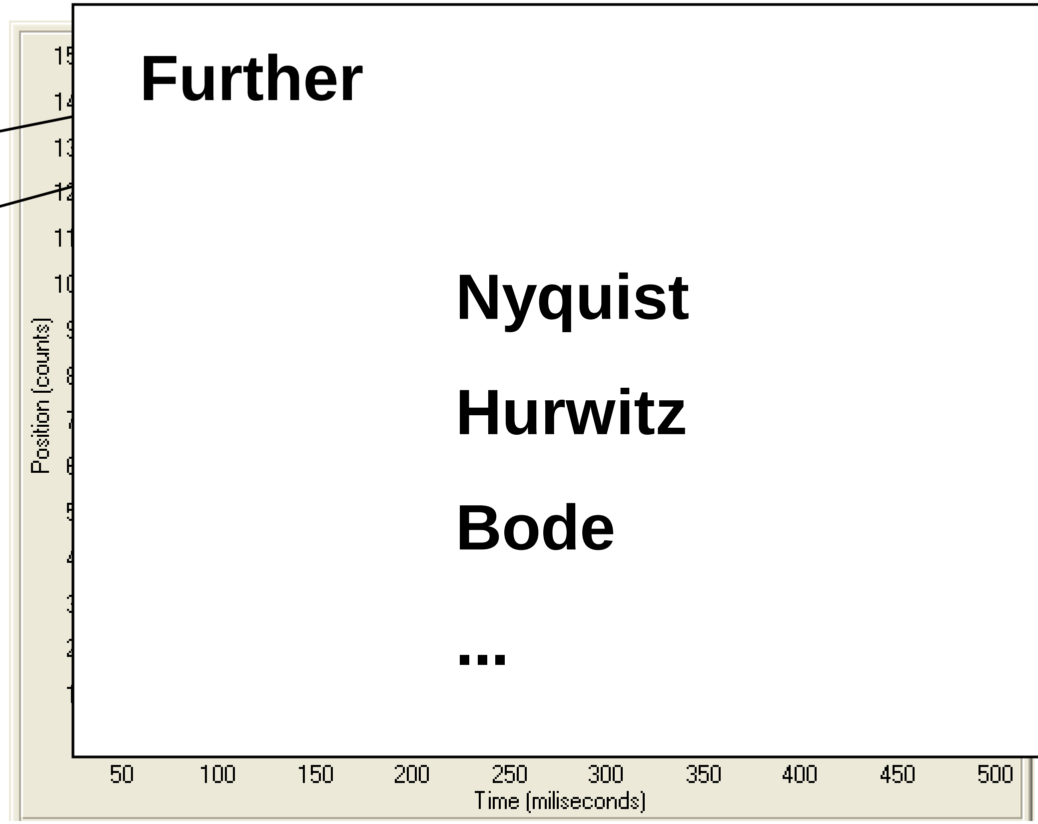
How can I Test my Parameters?

Root Locus Curve

Step Response

Peak Time

Rise Time



Further

Nyquist

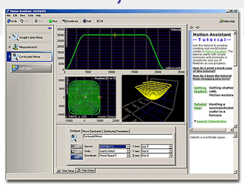
Hurwitz

Bode

...

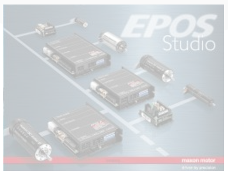
How Does it Function in Reality? Tools for Controller Design

PC based (Plug-In)
PCI, PXI



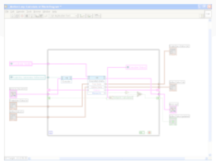
Parameter setting via NI-Motion and configuration tool Measurement & Automation Explorer

Distributed
CANopen

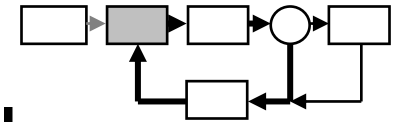


Parameter setting via EPOS Studio

Custom
RTOS, FPGA

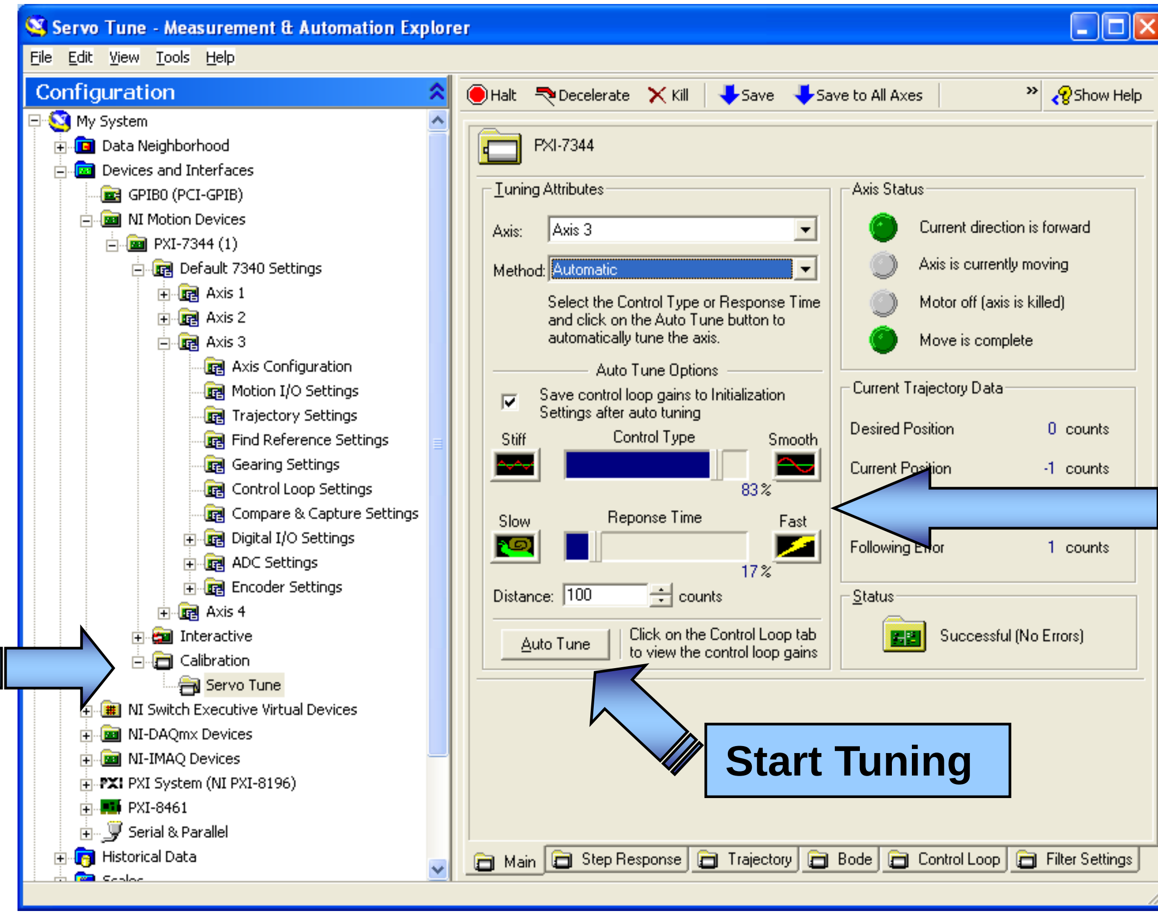


Parameter setting via Control Design Tools from National Instruments



Measurement & Automation Explorer

Automatic Tuning

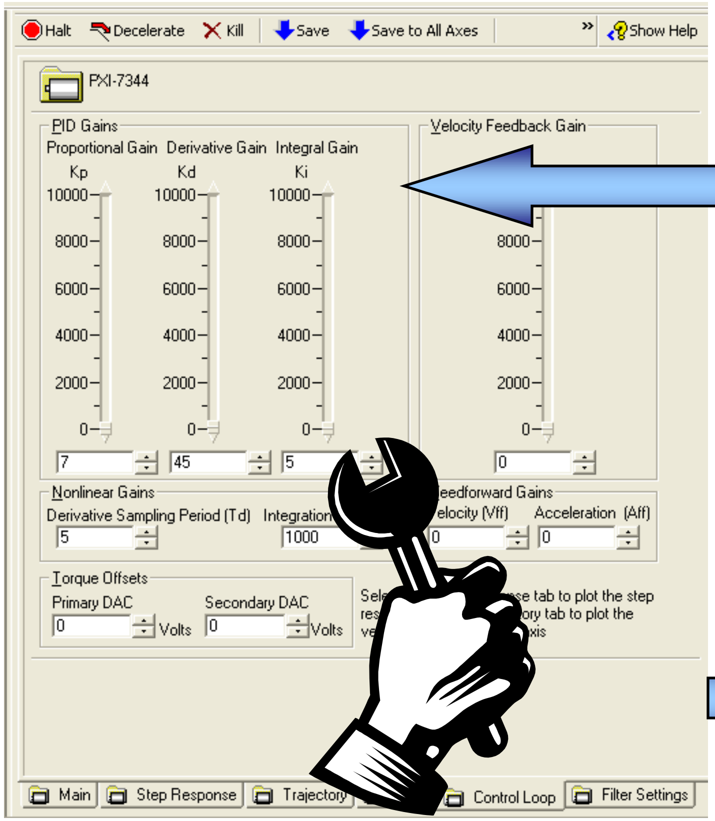


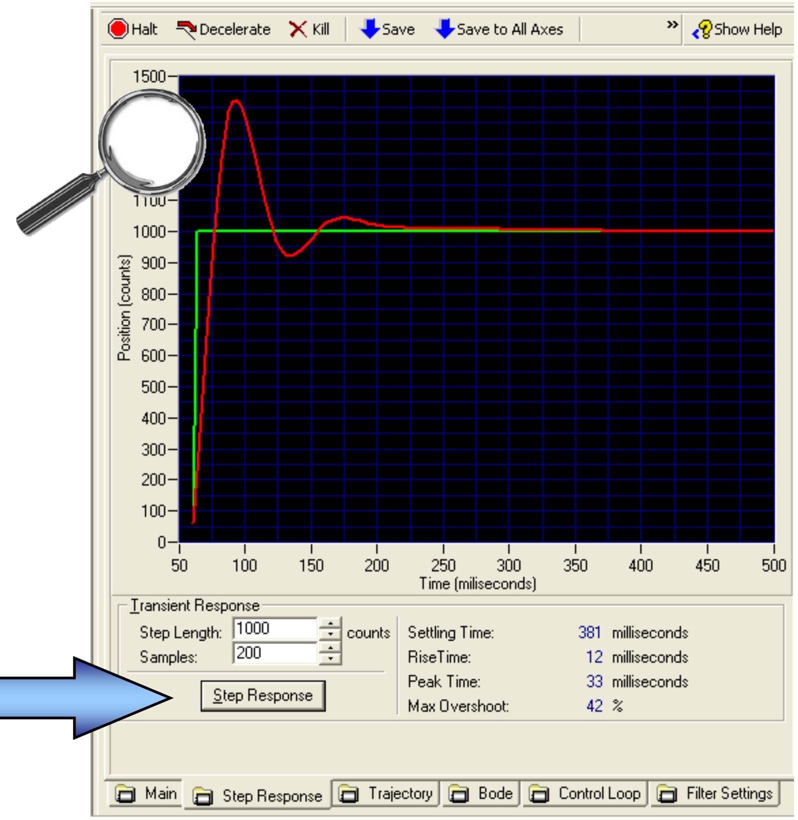
Tuning Parameter

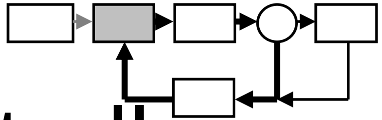
Servo Tune

Start Tuning

Measurement & Automation Controller
Manual Tuning



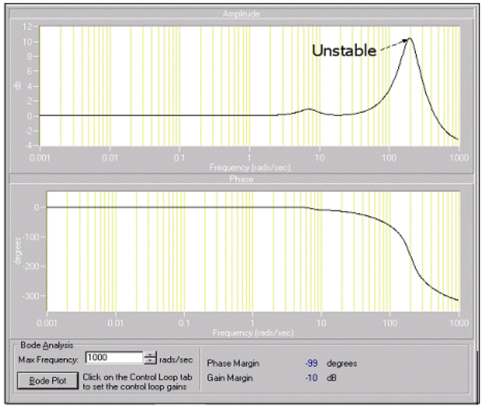




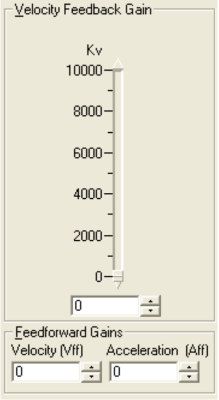
Measurement & Automation Controller

Advanced Tuning

- Bode plots
- Stability in the frequency range



- Advanced control loop parameters
  - **Velocity Feedback Gain (Kv)**
  - **Velocity Feedforward (Vff)**
  - **Acceleration Feedforward (Aff)**

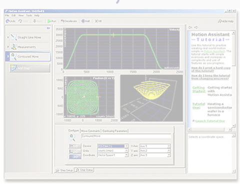


Demo

Measurement & Automation Explorer

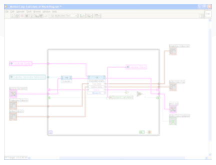
Tools for Controller Design

PC based (Plug-In)
PCI, PXI



Distributed
CANopen

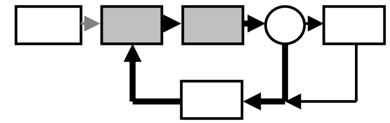
Custom
RTOS, FPGA



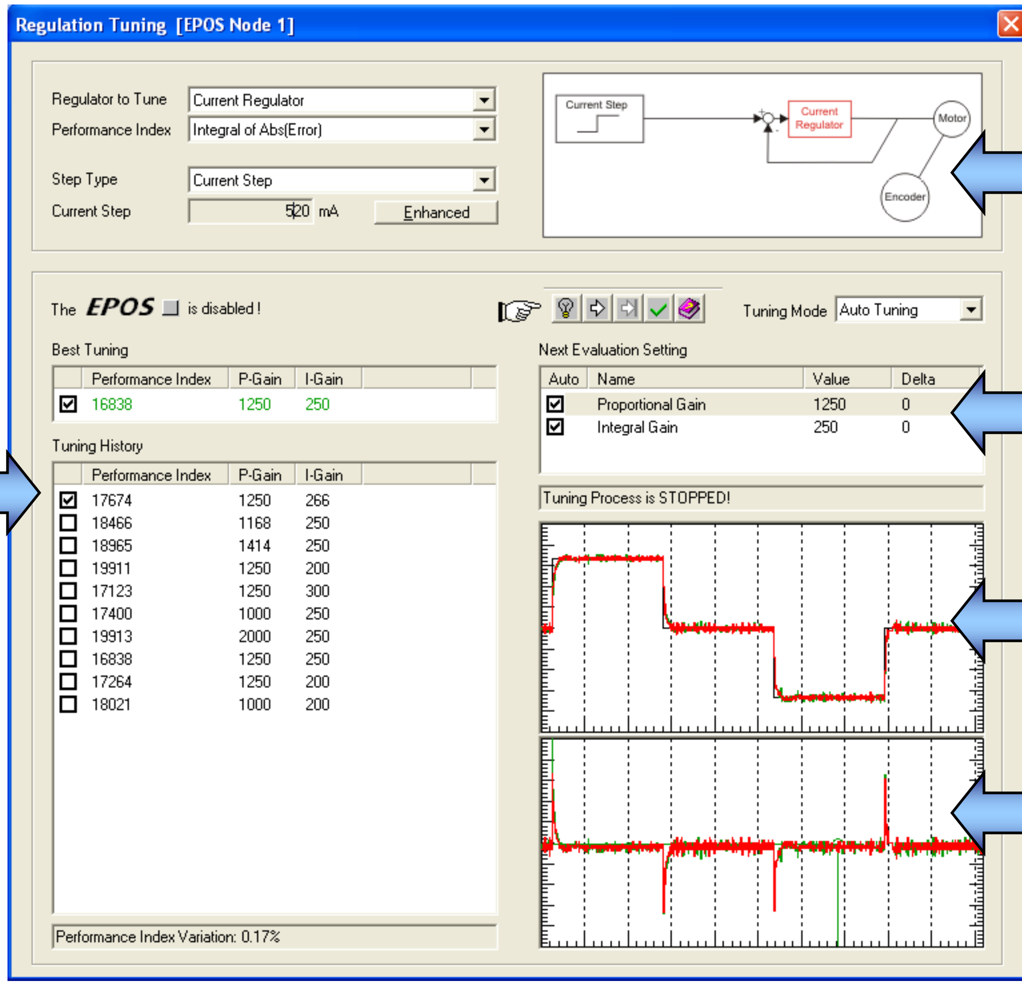
Parameter setting via NI-Motion and configuration tool Measurement & Automation Explorer

Parameter setting via EPOS Studio

Parameter setting via Control Design Tools from National Instruments



Setting of Current Control



Best Tuning

	Performance Index	P-Gain	I-Gain
☑	16838	1250	250

Next Evaluation Setting

Auto	Name	Value	Delta
☑	Proportional Gain	1250	0
☑	Integral Gain	250	0

Tuning History

	Performance Index	P-Gain	I-Gain
☑	17674	1250	266
☐	18466	1168	250
☐	18965	1414	250
☐	19911	1250	200
☐	17123	1250	300
☐	17400	1000	250
☐	19913	2000	250
☐	16838	1250	250
☐	17264	1250	200
☐	18021	1000	200

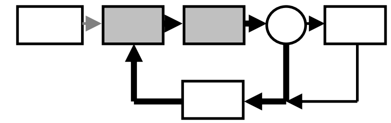
Servo Tune List

Position of Controller

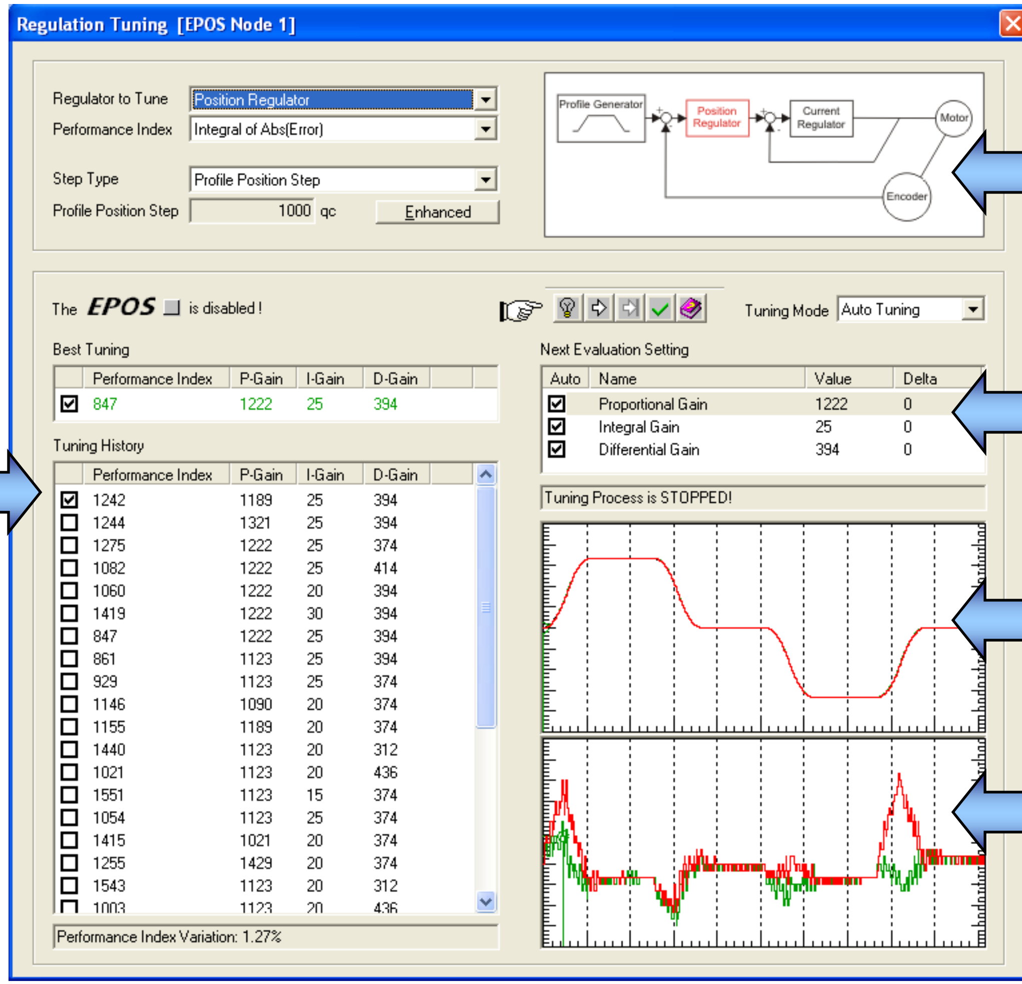
PI Parameter

Current Step

Step Difference



Setting of Position Control



Position of Controller

PID Parameters

Servo Tune List

Position Step

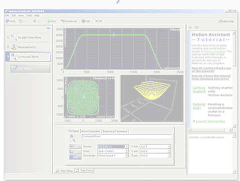
Step Difference

Demo

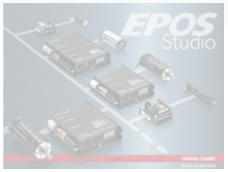
EPOS Studio

Tools for Controller Design

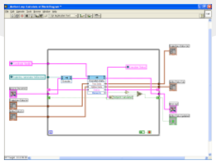
PC based (Plug-In)
PCI, PXI



Distributed
CANopen



Custom
RTOS, FPGA

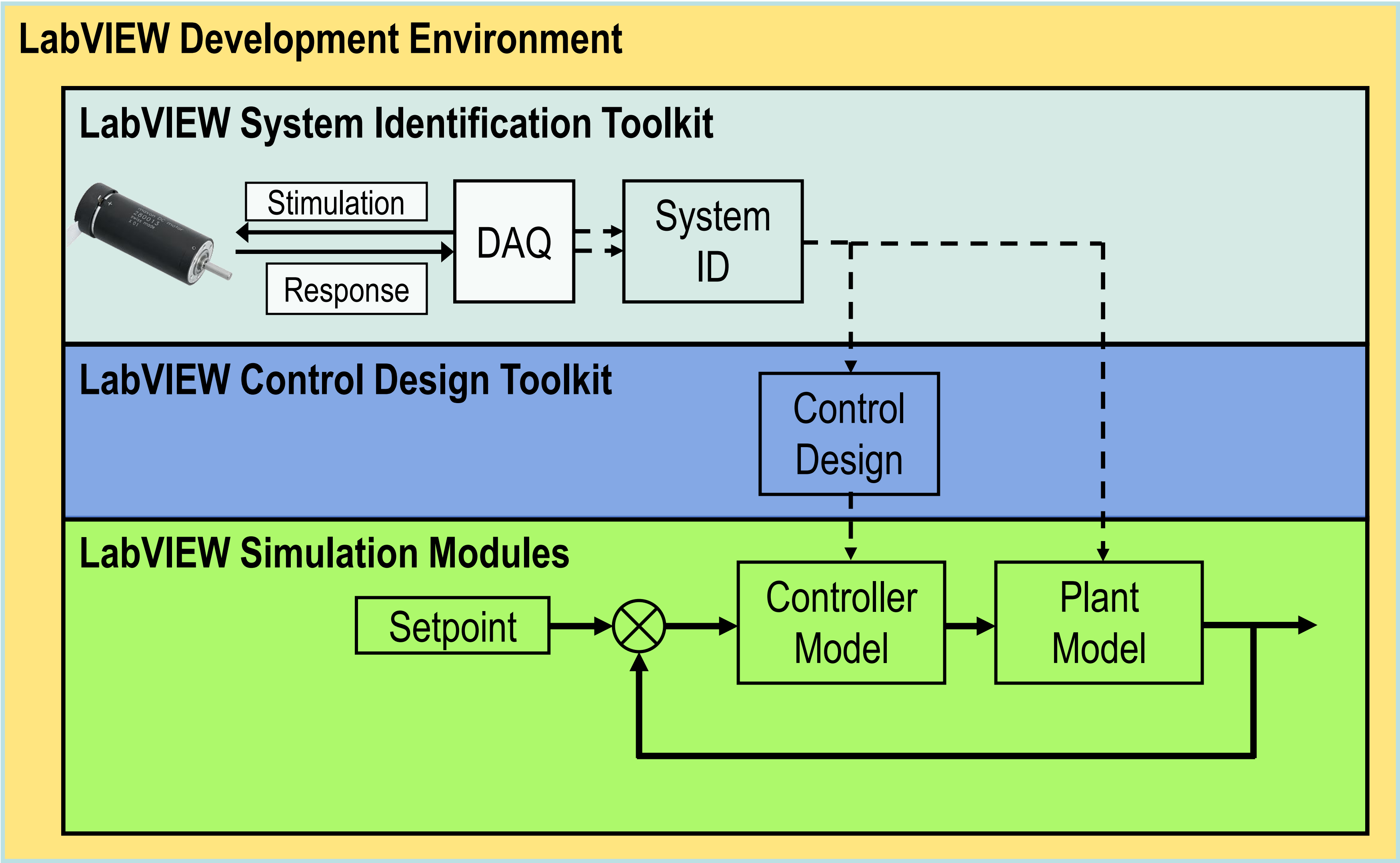


Parameter setting via NI-Motion and configuration tool Measurement & Automation Explorer

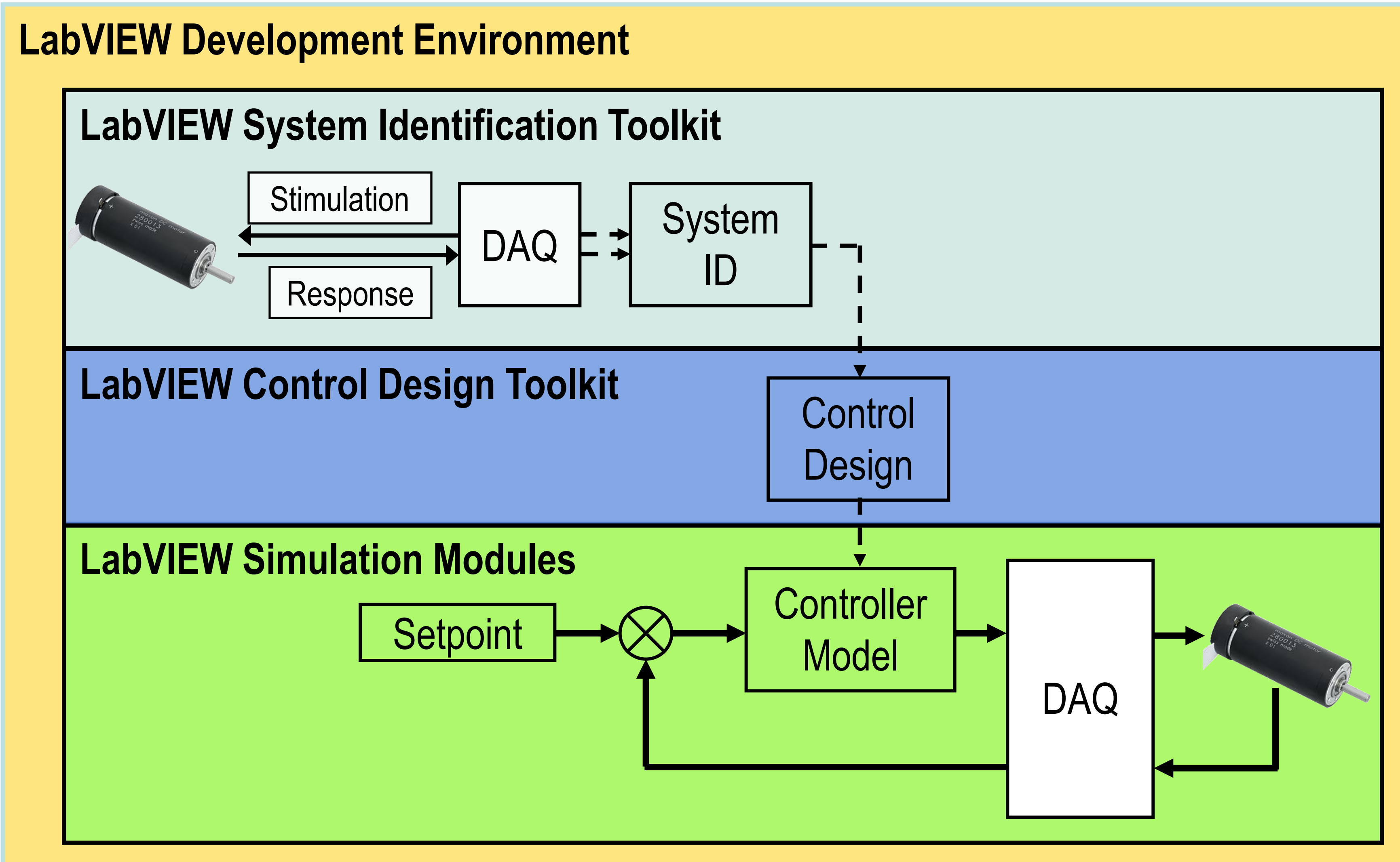
Parameter setting via EPOS Studio

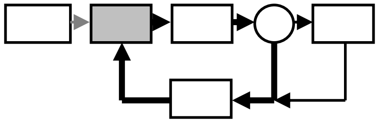
Parameter setting via Control Design Tools from National Instruments

LabVIEW Control Design Tools



LabVIEW Real-Time





Example

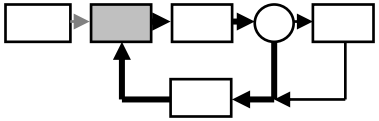
Controller design for a DC servo motor

Step 1: system modeling and analysis

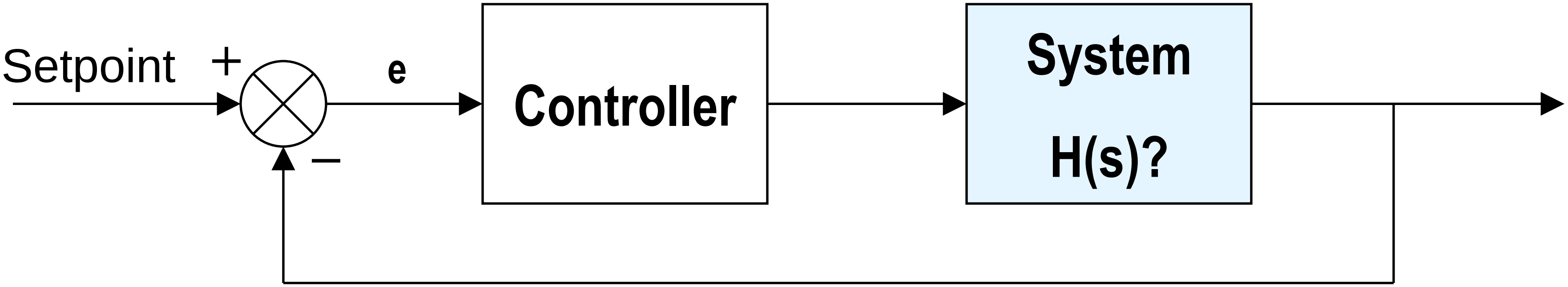
Step 2: controller design

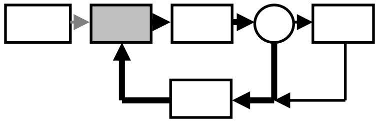
Step 3: simulation

Step 4: implementation of the controller



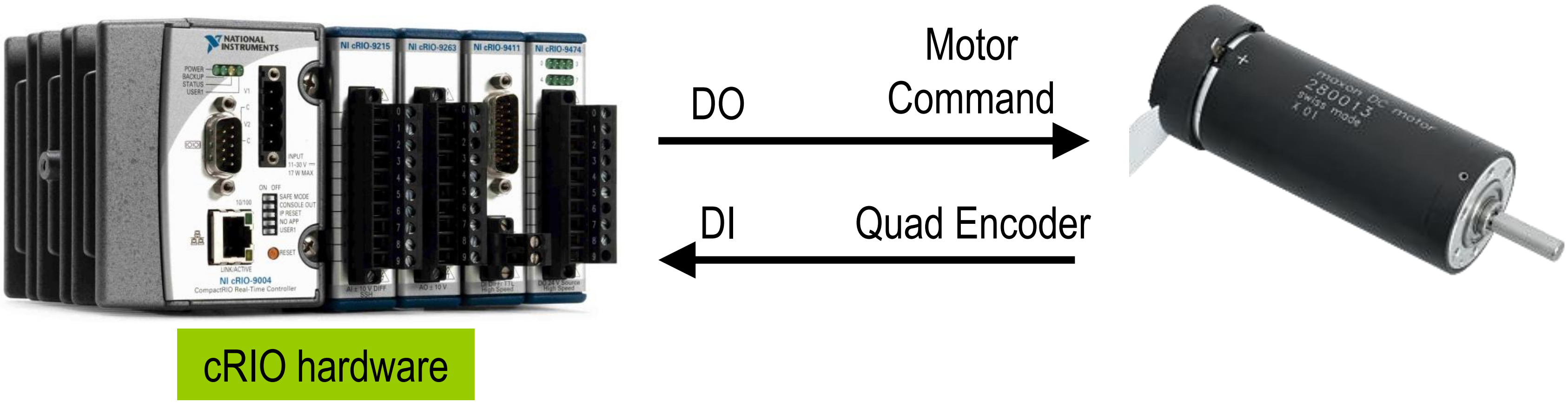
Step 1: System Modeling and Analysis





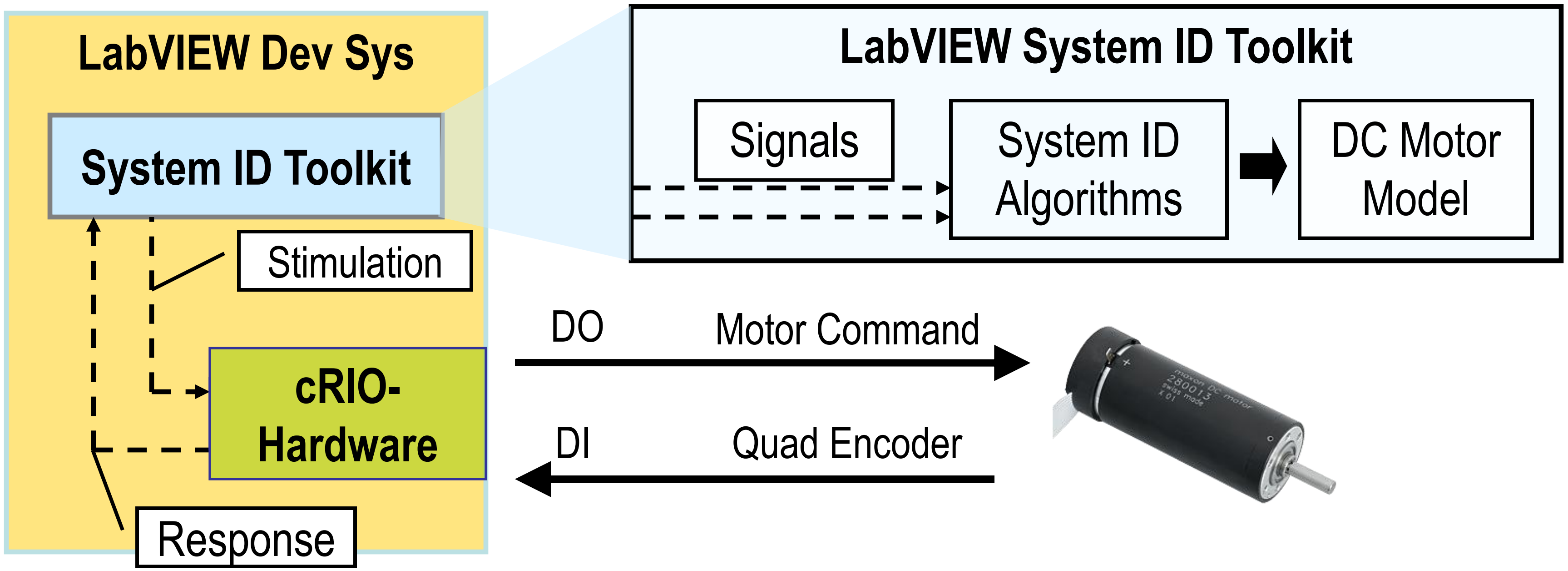
Identification Assembly of a DC Motor System

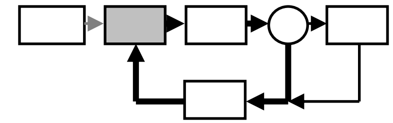
- Output: motor (24V, PWM)
- Input: quadrature encoder (5V, digital)
  - 2000 counts per revolution



Identification of the System Model

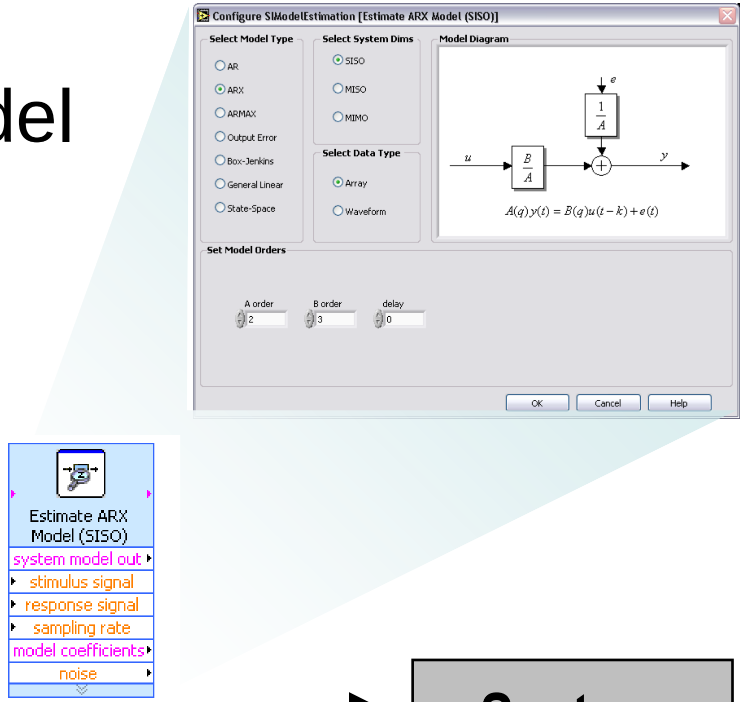
– Stimulation and measurement of the response of the system
– Identification of system coefficients

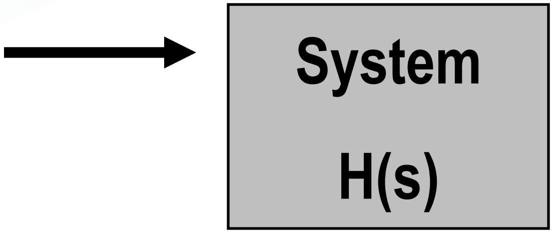


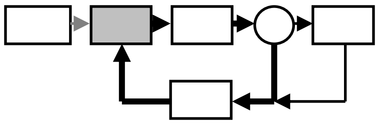


System Identification Toolkit

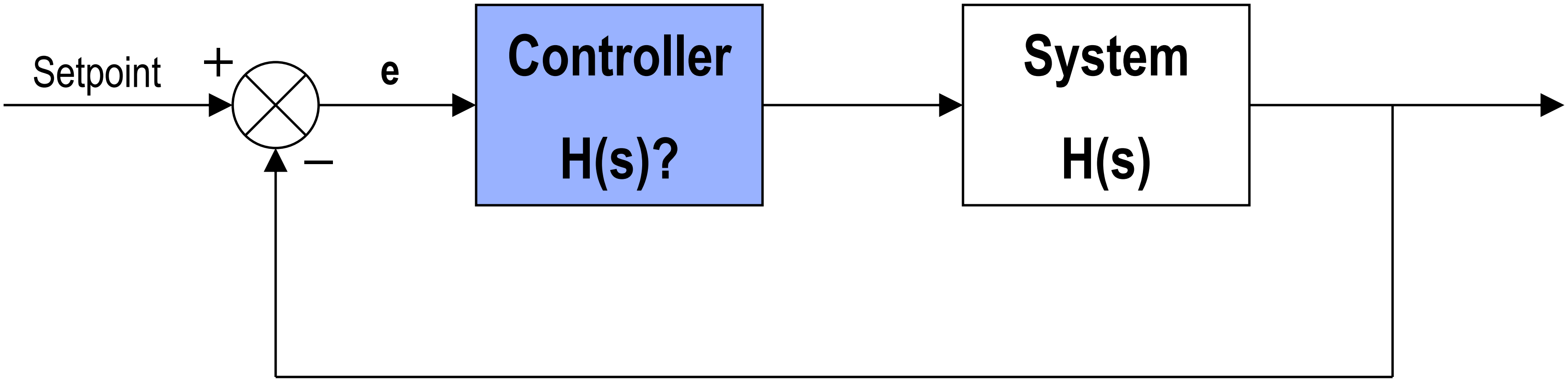
- Created automatically
- Controlled system model
- Based on real signals



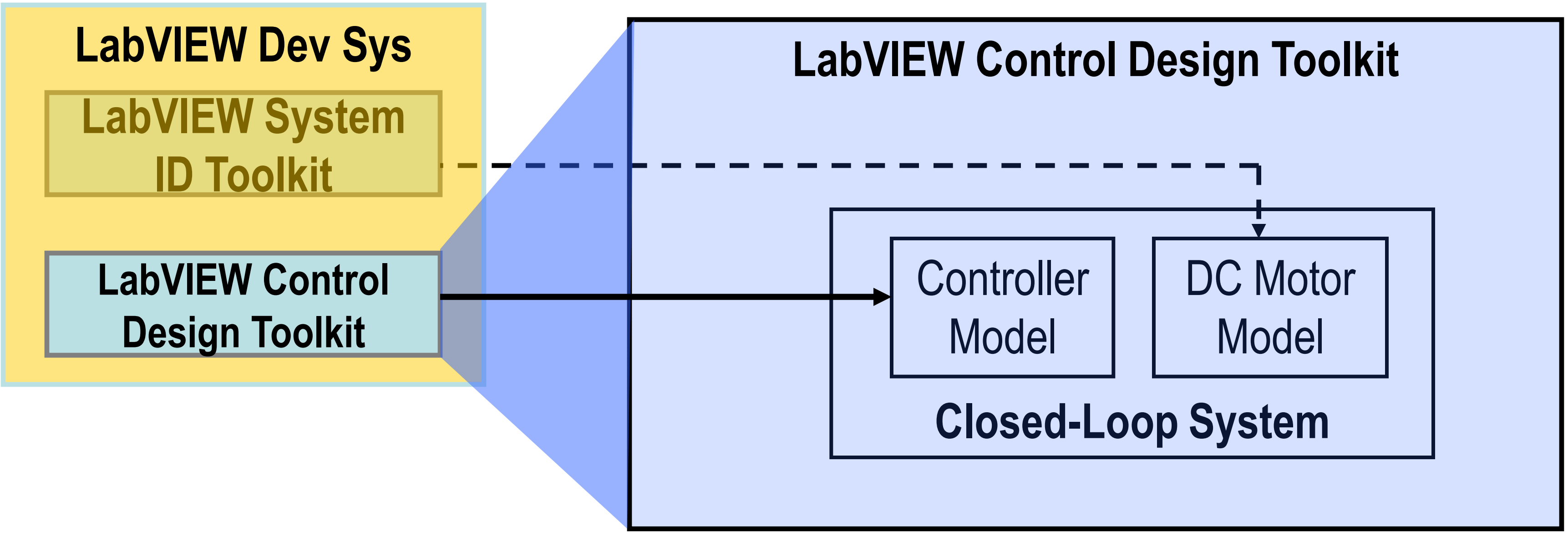




Step 2: Control Design

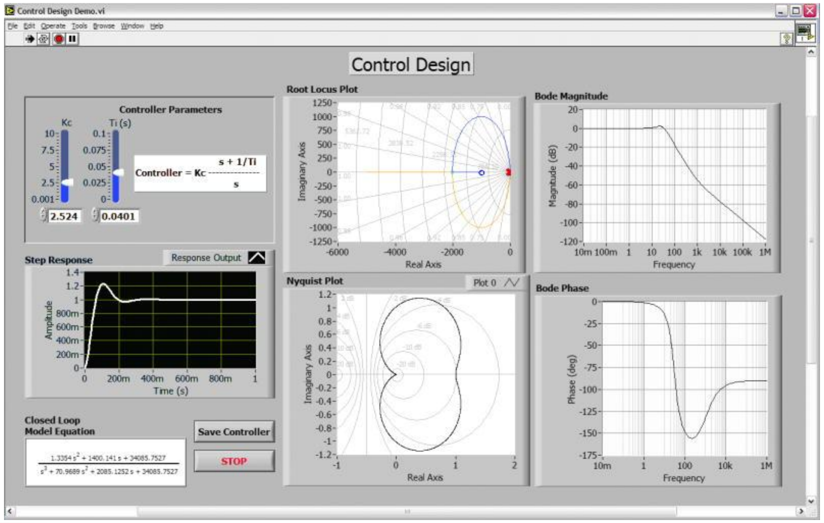


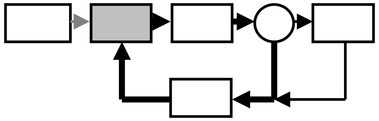
Design and Analysis of the Controller



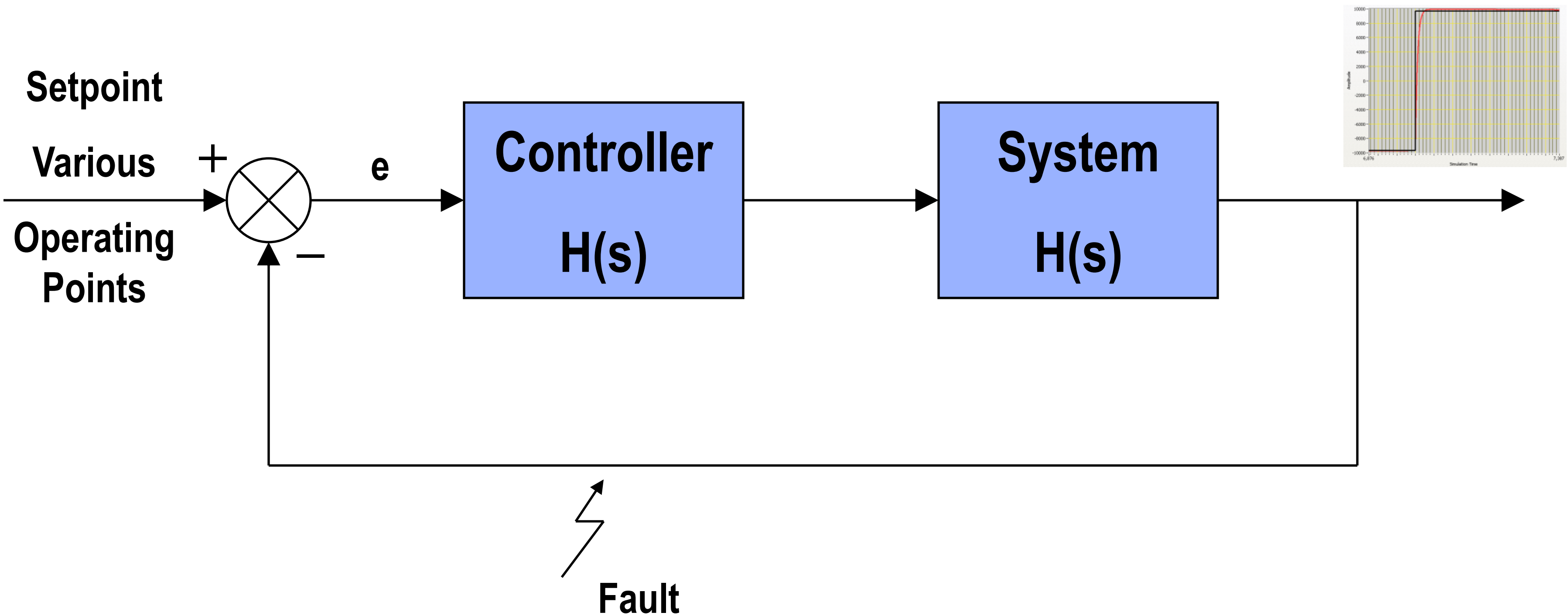
LabVIEW Control Design Toolkit

- Development of control systems with interactive graphical tools such as root locus curves
- Design of controlled system, control models in space-time, transfer function and pole zero form
- Integration of control models with the LabVIEW Simulation Modules
- Analysis of system performance with tools such as zero-pole, step-response and Bode diagrams

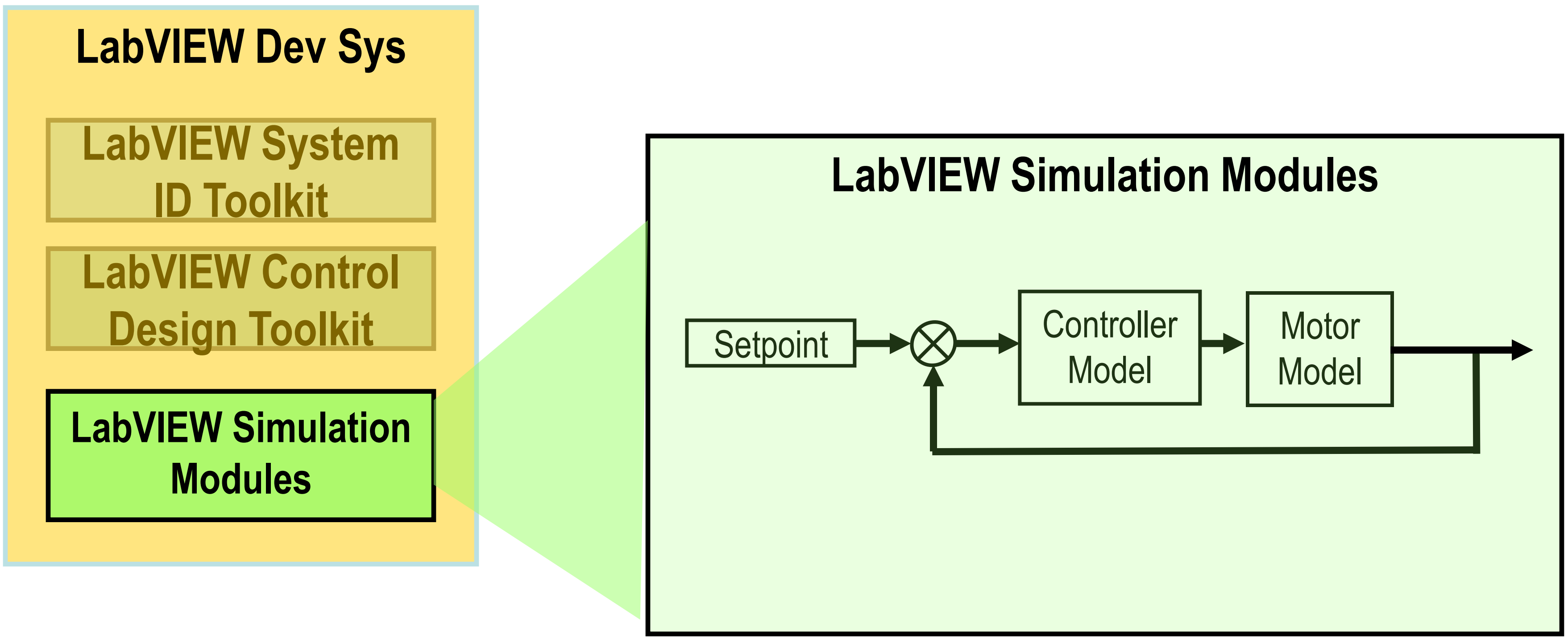




Step 3: Simulation

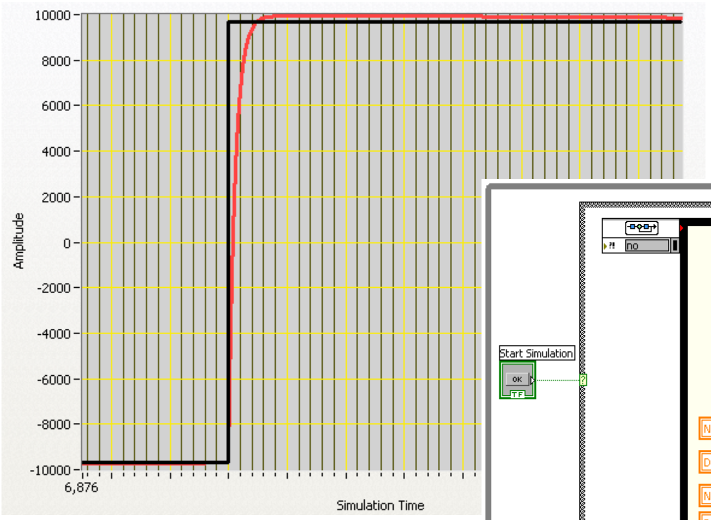


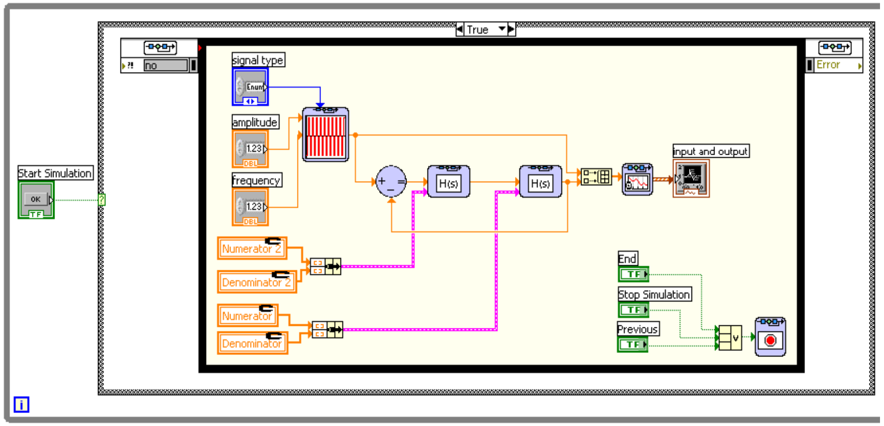
Simulation and Analysis the Entire Track



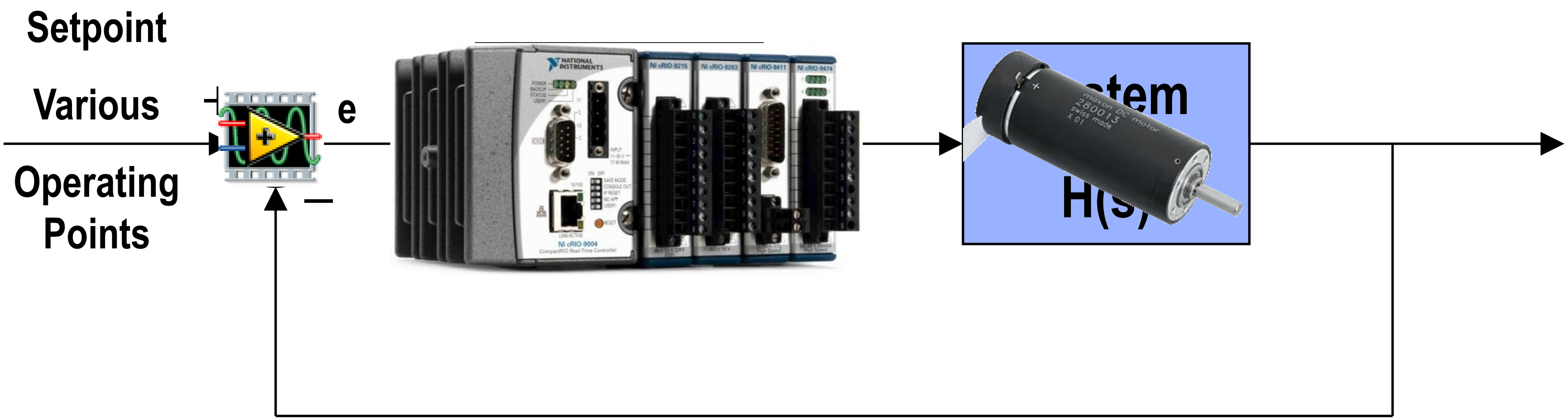
"LabVIEW Simulation Modules" and "Simulation Interface Toolkit"

Simulation of dynamic systems and real-time implementation in LabVIEW





Step 4: Implementation



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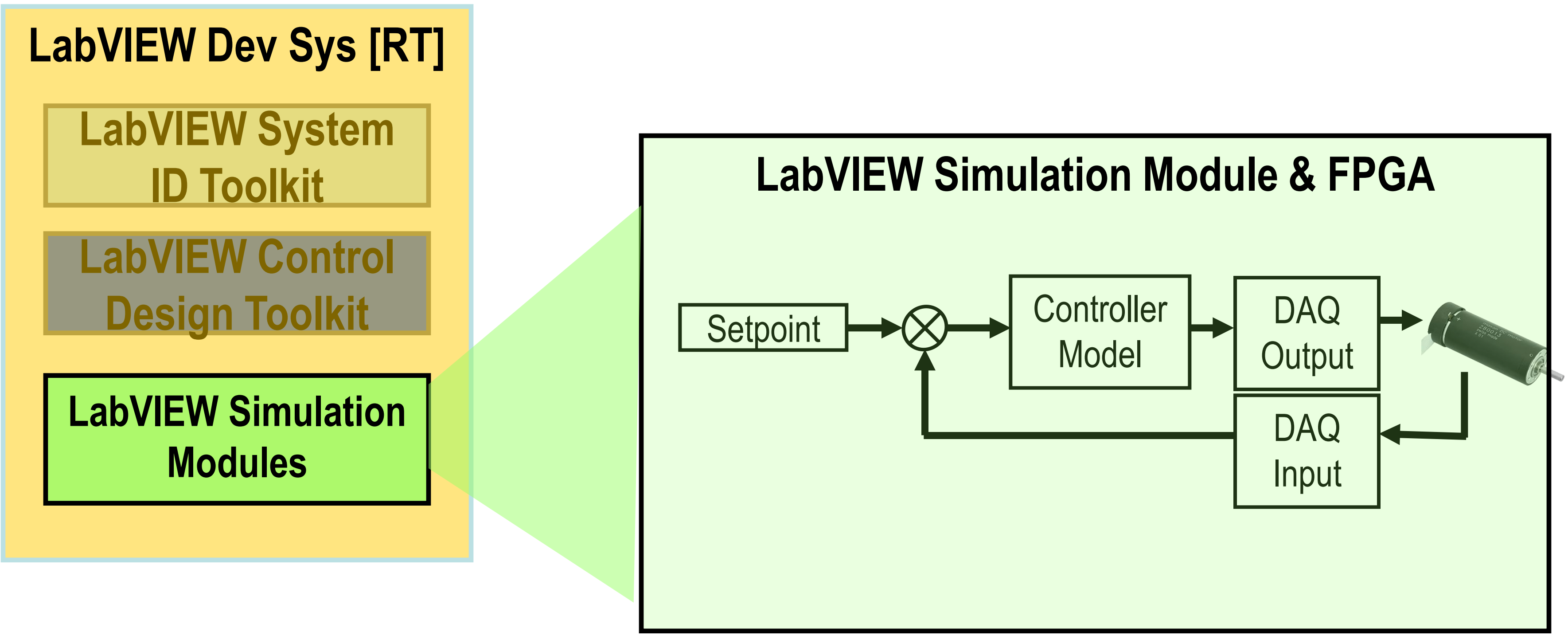
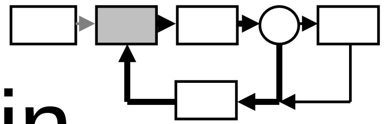
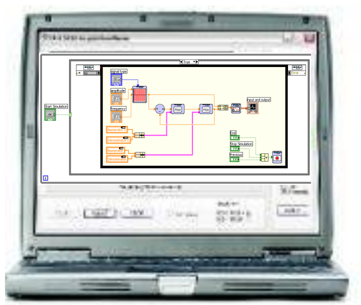




Implementation of the Controller in Real-Time Hardware

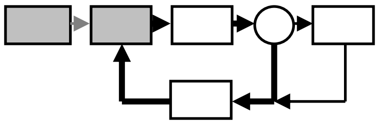
RT & FPGA



Download to HW

Implementation of the controller with the calculated parameters

Execution of the code on real-time hardware



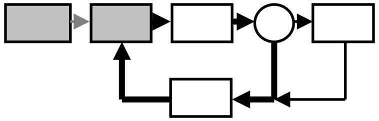
Real-Time Software

LabVIEW Real-Time Module

- Graphical development of real-time applications
- Deterministic design
- Use on embedded hardware targets

LabVIEW FPGA Module

- Graphical programming of FPGAs on "RIO"
- User-specific customization of I/Os
- Implement user-specific time lapses with a resolution of 25 ns



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Step 4: implementation of the controller