

Visual ModelQ Training



Variation of plant gain

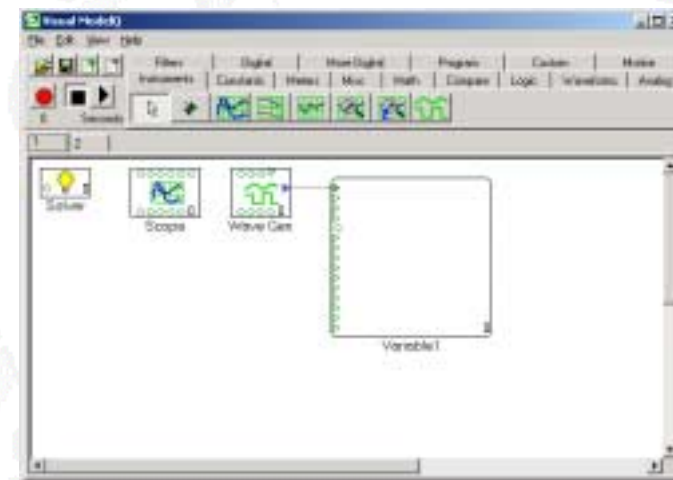
This unit discusses

- Changes in system stability with increasing plant gain
- Adjusting K_P to correct for changing plant gain
- Gain scheduling

Install *Visual ModelQ*

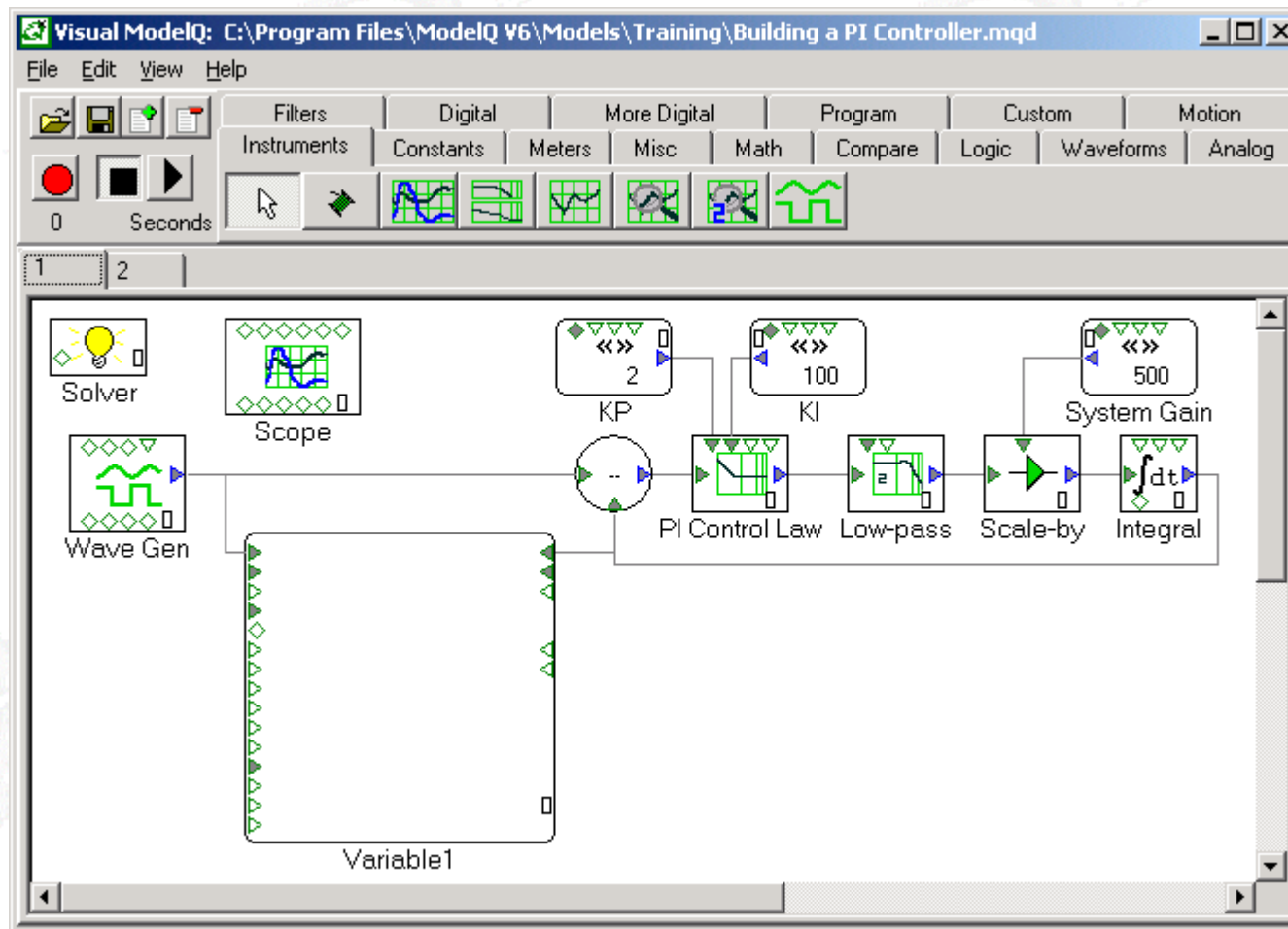
To run *Visual ModelQ* the first time:

- Click here to visit www.QxDesign.com
- Download *Visual ModelQ***
- Run *Visual ModelQ* installation
- Launch *Visual ModelQ* using the Windows start button or clicking on the icon 
- The “default model” should appear



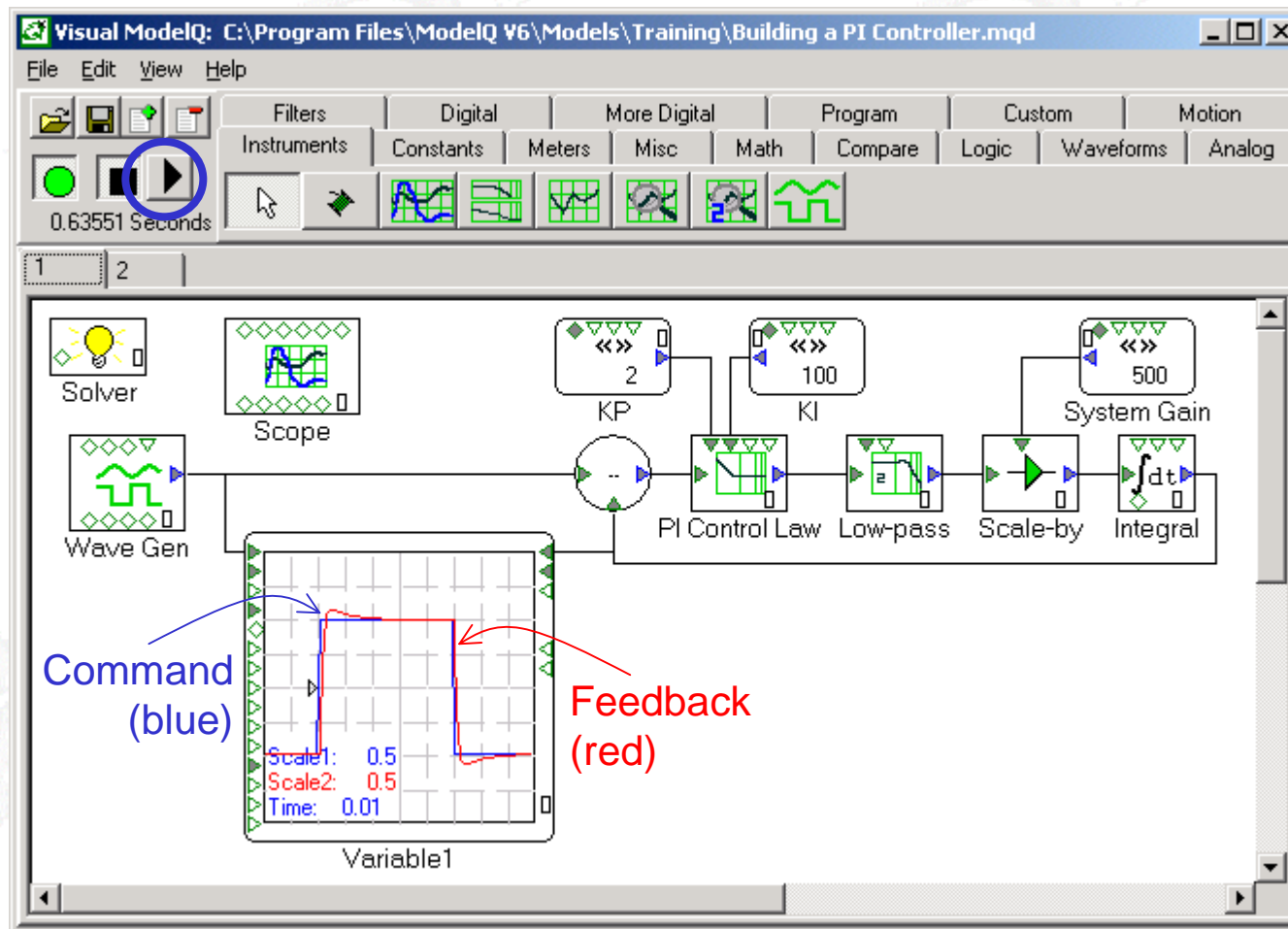
Start with the model “Building a PI Controller”

- Visit www.QxDesign.com/VisualModelQ#Training
- Download “Building a PI Controller.mqd” or build the model yourself using the presentation “Building a PI Controller.pps”



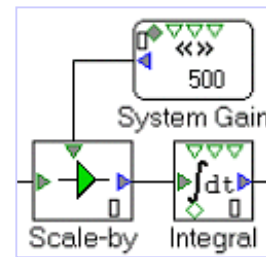
Check performance with the initial values

- Click the run button to see the performance with the initial gains of $K_P = 100$, $K_I = 2$, and with a System Gain of 500.
- Looks good; feedback responds fast, with little overshoot.



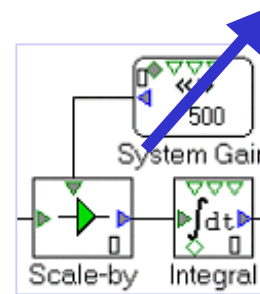
What is plant gain?

- The plant in this model is an integral with a “System Gain” of 500.



- A single integrator with a gain is the most common plant in industrial controls:
 - Inductor in current supply
...applied voltage integrates to current
 - Inertial load in motion control
...applied torque (force) integrates to velocity
 - Temperature bath
...applied heat integrates to temperature
 - Capacitance in a voltage supply
...applied current integrates to voltage

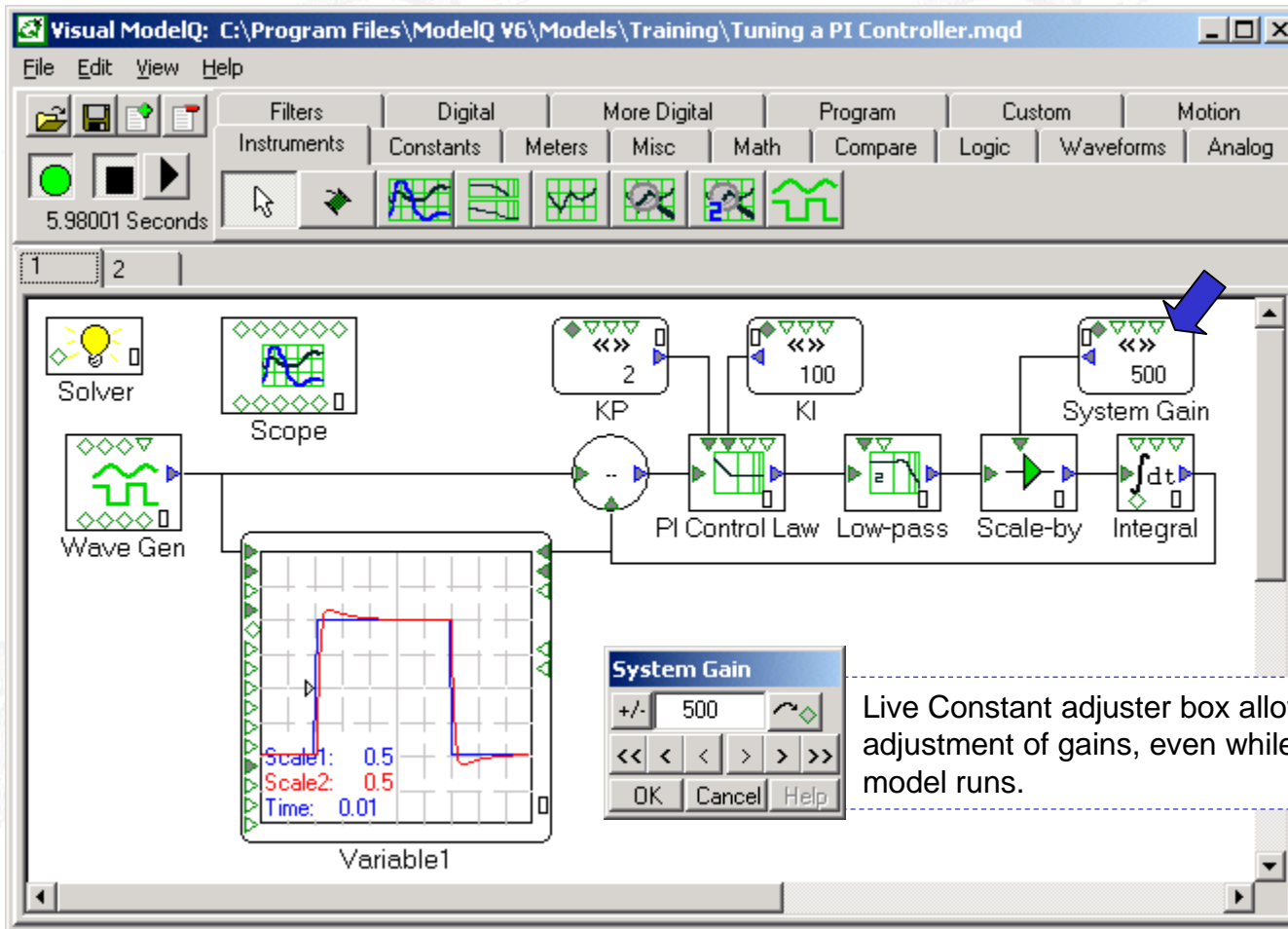
Why does plant gain vary?



- The plant gain often changes with time or operating conditions
 - Inductor in current supply
 - ...inductors saturate: inductance falls when current is high.
 - Inertial load in motion control
 - ...inertia changes with varying loads
 - Temperature bath
 - ...thermal mass varies when fluid level in the bath changes
 - Capacitance in a voltage supply
 - ... capacitance of electrolytic capacitors fall over time

See how varying plant gain affects the system

- Double-click in System Gain for adjuster box.
- While the model runs, increase to 1000, 2000, and so on.



The screenshot displays the Visual ModelQ software interface. The main workspace shows a control system diagram with the following components: a Wave Gen block, a Scope block, a Solver block, a PI Control Law block, a Low-pass filter block, a Scale-by block, and an Integral block. The PI Control Law block is connected to the Scale-by block, which is connected to the Integral block. The Scale-by block has a live constant adjuster box for System Gain, currently set to 500. A blue arrow points to this adjuster box. The Scope block shows a plot of Variable1, which is a square wave. The System Gain adjuster box is open, showing the current value of 500 and navigation buttons. A text box explains that this live constant adjuster box allows for easy adjustment of gains while the model runs.

Visual ModelQ: C:\Program Files\ModelQ V6\Models\Training\Tuning a PI Controller.mqd

File Edit View Help

Filters Digital More Digital Program Custom Motion

Instruments Constants Meters Misc Math Compare Logic Waveforms Analog

5.98001 Seconds

1 2

Solver Scope Wave Gen

KP 2 KI 100 System Gain 500

PI Control Law Low-pass Scale-by Integral

Variable1

Scale1: 0.5
Scale2: 0.5
Time: 0.01

System Gain

+/- 500

<< < > >>

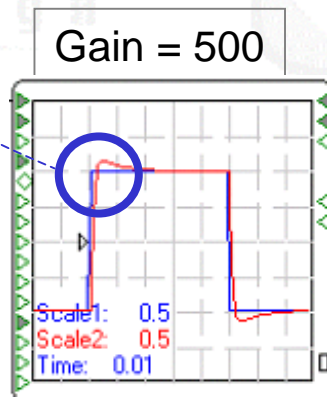
OK Cancel Help

Live Constant adjuster box allows easy adjustment of gains, even while the model runs.

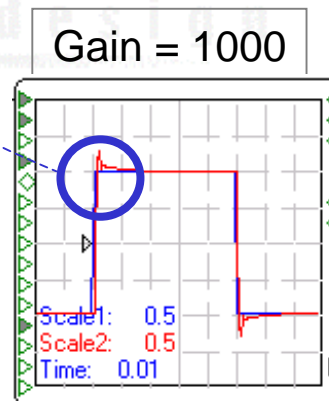
What happens as gain increases?

- Increase the gain from 500 to 2000. The system becomes unstable as the gain increases.

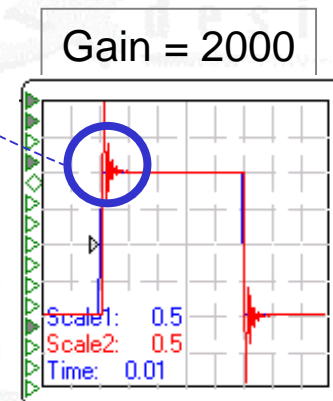
10% Overshoot...
looks good!



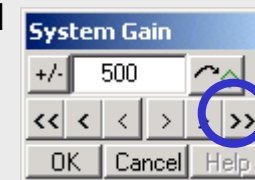
Slight ringing...
questionable



Severe ringing...
not acceptable

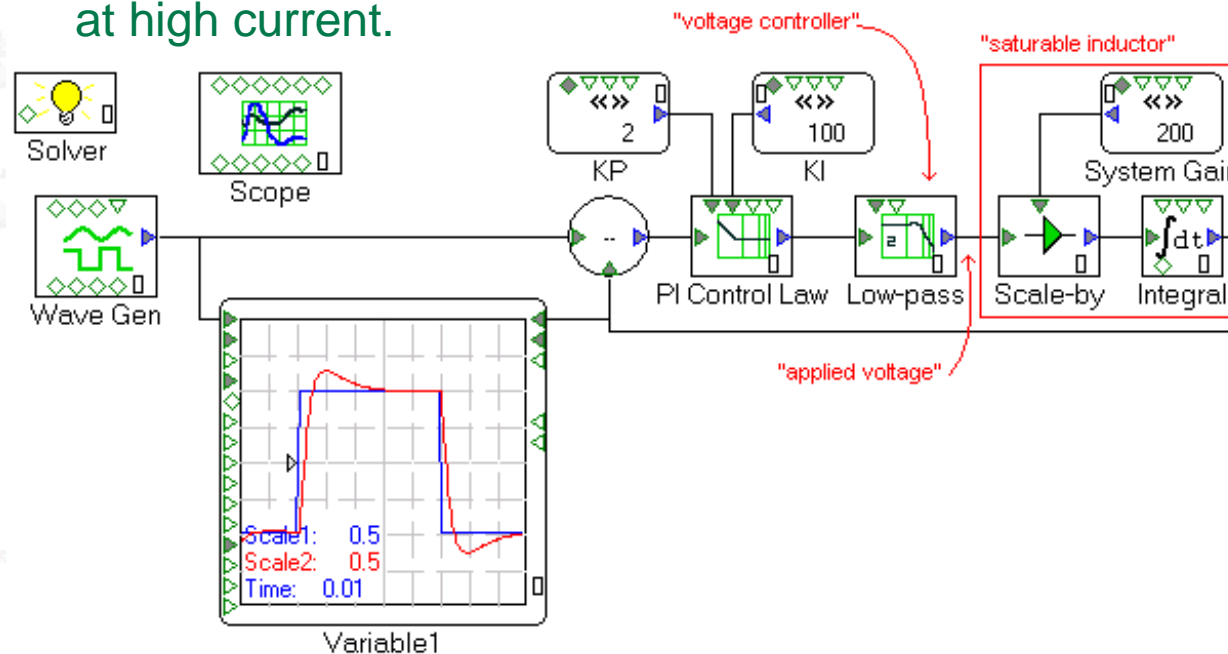


TIP: Use adjustment
such as ">>" (large
increase) to quickly
vary gains while the
model
runs



What's a practical example?

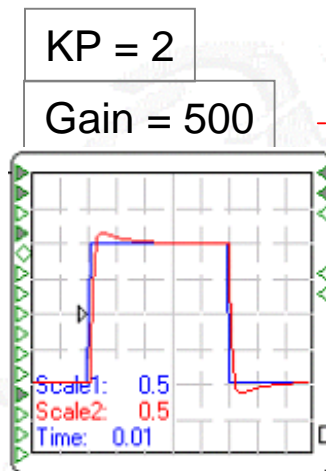
- Current controller with saturating inductor
 - PI control law generates a voltage request.
 - Request feeds “voltage controller” (e.g., power transistor).
 - Voltage controller produces applied voltage.
 - The “gain” of an inductor is $1/\text{inductance}$.
 - Saturation reduces inductance as current increases...higher current causes higher gain.
 - Result: system can be stable with low current, but unstable at high current.



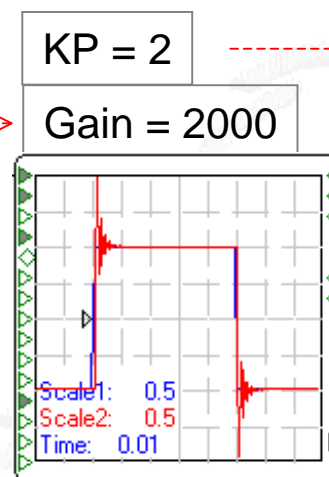
Retuning can solve the problem

- When “System Gain” increases, reducing KP restores stability.
- With most PI controllers, if you reduce KP in proportion to gain increase, the problem is solved.

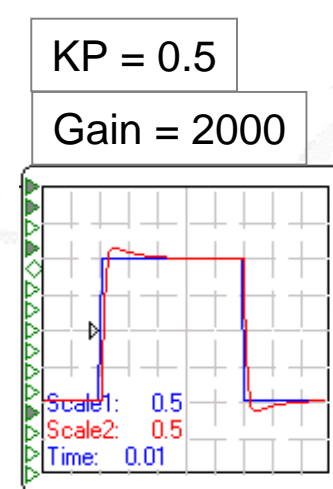
At start, system looks good!



Gain increases 4x;
stability suffers.

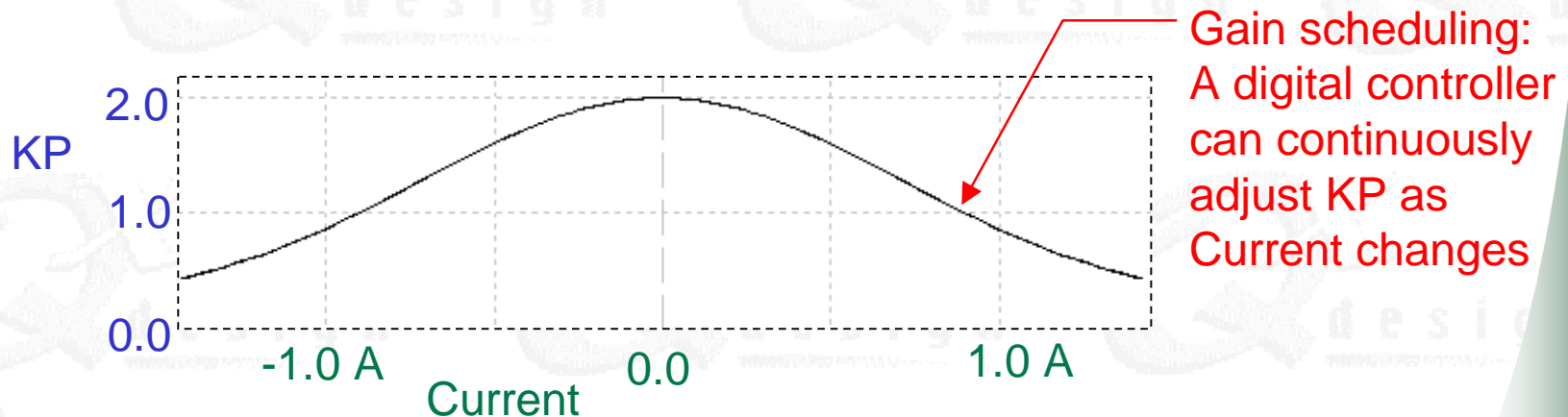


Lower KP 4x;
problem solved.



Gain scheduling: when retuning is impractical.

- If the gain changes during operation (like an inductor), you can't retune to fix the problem.
- The most common solution is to lower K_P so the system is always stable. Problem: K_P may be lowered so much that response is slow when "System gain" is low.
- Another solution is **gain scheduling**, a technique often implemented with digital controllers. With gain scheduling, the digital controller estimates the system gain and adjusts K_P appropriately.
 - For the example of the saturating inductor, K_P could be a function of current.



Visit www.QxDesign.com for information about software and practical books on controls.



Click here for information on [Control System Design Guide \(2nd Ed.\)](#), published by Academic Press in 2000



Click here for information on [Visual ModelQ](#)



Click here for information on [Observers in Control Systems](#), published by Academic Press in 2002