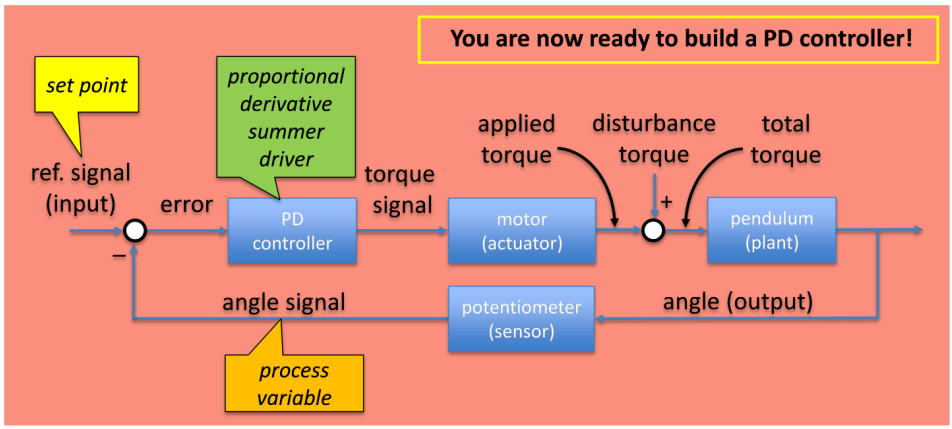
Experiment 6—Building the PD Controller

INTRODUCTION



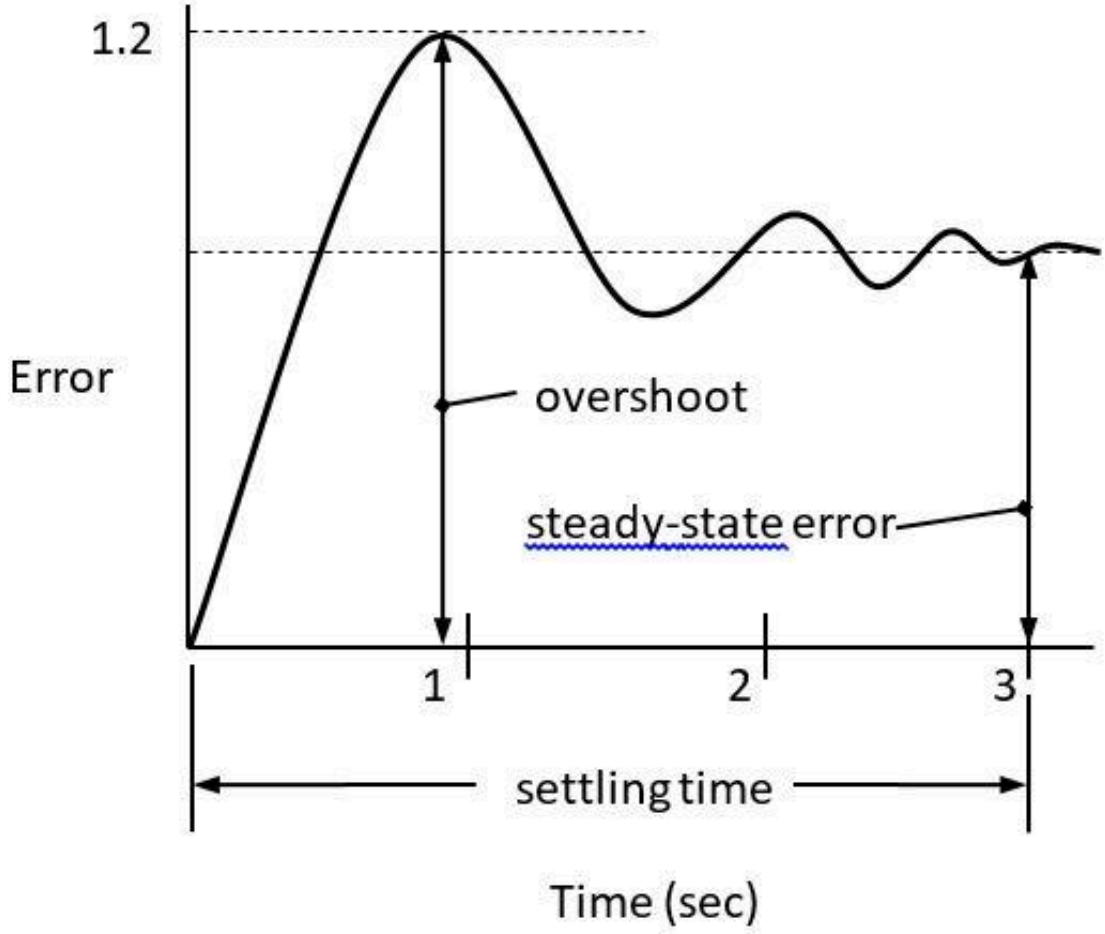
Look at this flow chart. We need to define some new terms before building the PD controller. The **set point** is the physical quantity (the angle) that corresponds to where you want the plant (pendulum) to be. The reference signal is the electrical quantity that corresponds to where you want the plant to be. On the other hand, the **process variable** is the physical quantity where the plant currently is. The difference between the set point and the process variable is the **physical error**. You will design your controller to drive the electrical error to zero to drive the physical error to zero.

We have several terms that describe the way the error goes to zero:

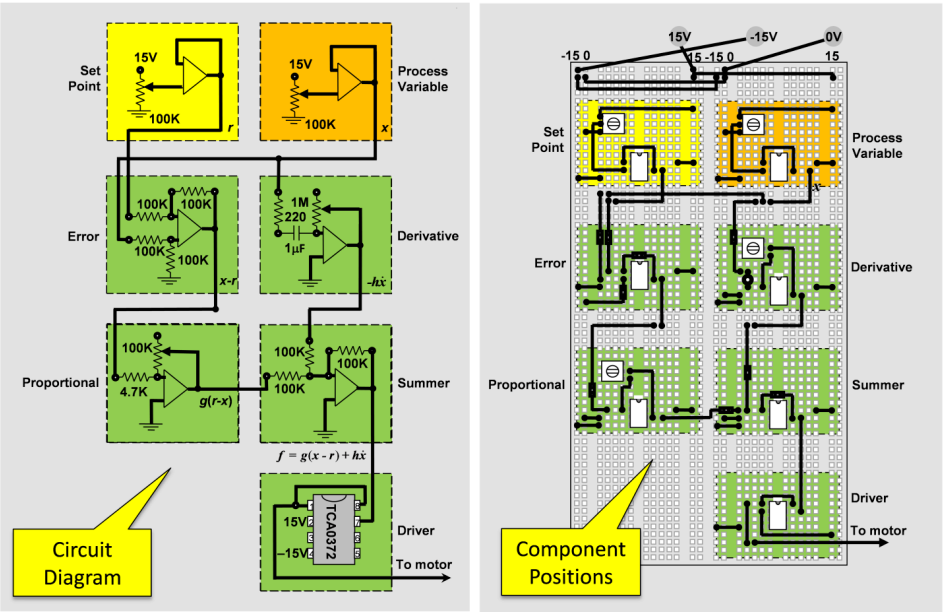
Settling time: The settling time is how long it takes the error to reach its final value.

Peak overshoot: The peak overshoot is the peak value of the error.

Steady-state error: The steady-state error is the value where the error settles (which is not always zero).



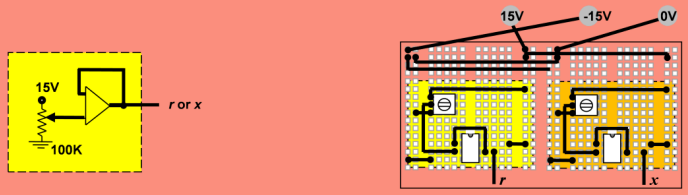
This figure shows the settling time, peak overshoot, and steady-state error of the error signal over time. After you build the PD controller, you will connect it to the pendulum and observe these parameters.



You will take the circuit diagram shown on the left and build it on a breadboard one operation at a time, to get the complete controller shown on the right. Notice that we boxed in the operations.

SET POINT AND PROCESS VARIABLE

Construct the set point and process variable circuits.



The set point and process variable circuits are the same.

- Connect the pot, op-amp, and wires for the set point circuit (top left).
- Repeat for the process variable circuit (top right).

At this point, you have voltage available to the board. You will start by setting up two pots as voltage dividers; one for the set point and the other for the process variable. The buffer op amps prevent the outputs

from effecting the rest of the controller. The difference between their voltage outputs will be the error. When you turn both pots the same amount, the two voltages will be the same and there will be no error. The circuit diagrams for the set point and the process variable are on the left and the placement of the components on the breadboard is on the right.

First, make the power connections to the board. Supply the −15 V, 15 V, and 0 V, as shown. Next, insert the two op amps and the two 100 KΩ pots into the board, as shown. Finally, insert all of the jumper wires to make the needed connections.

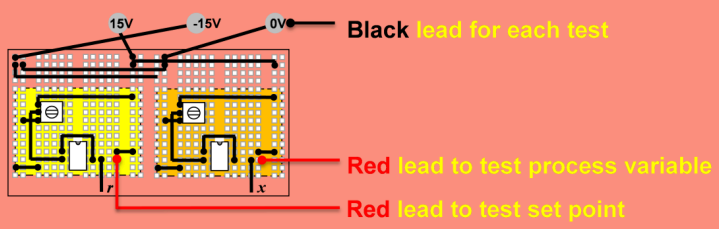
Notice that the orange box is the process variable circuit. The 100 KΩ pot in that box is a “dummy sensor” corresponding to the sensor in the pendulum. We use the process variable circuit during the testing of the PD controller. After building the PD controller, we will replace the dummy pot with the industrial pot in the pendulum.

In addition, you may have noticed that the boxes in the diagrams and the circuits in the previous figures were shaded in different colors (the same color designation that was in the flow chart, from the beginning). The yellow boxes are for the set point, the orange boxes are for the process variable, and the green boxes are for the controller—the error, derivative, proportional, summer, and driver operations.

ORAL TEST 1

+

Conduct the process variable and set point circuit tests



- To begin, place the multi-meter in DC **voltmeter mode.**
- Clip the black lead to the ground.

Let us now quickly test the two circuits. Follow the instructions above to set up the test.

+ **Process variable circuit test**

- Clip the red lead to the process variable output.
- Connect the supply voltage.
- Turn the pot counterclockwise. Is your voltage 0?
- Turn the pot clockwise. Is your voltage 15V?

Set point circuit test

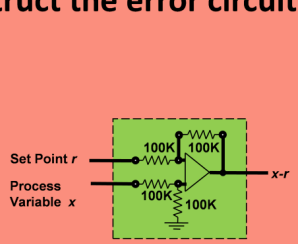
- Switch the red lead to the set point output.
- Turn the pot counterclockwise. Is your voltage 0?
- Turn the pot clockwise. Is your voltage 15V?

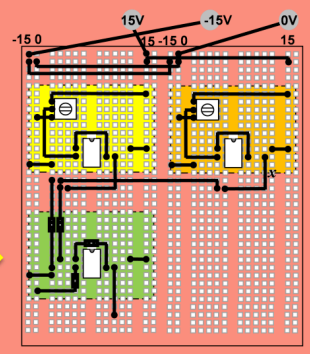
Do not proceed further until you get the desired results.

ERROR COMPARISON

+

Construct the error circuit.





- Connect the components.

Now that you have the set point and the process variable, you need to wire the error. For this, you will connect the third op amp in a unit gain configuration so that its output will be the exact value of the difference

between the process variable and the set point.

Insert the op amp, the 100 KΩ resistors, and the jumper wires, following the previous figures.

ORAL TEST 2

+ **The error circuit test**

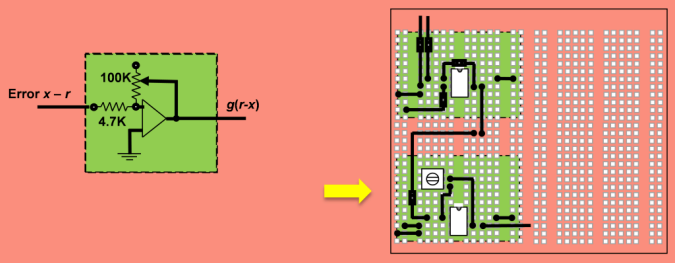
- Switch the red lead to the error output.
- Turn the pot of the set point until the output is 7V.
- Turn the process variable all the way counterclockwise. Is your error output -7V?
- Turn the process variable pot clockwise. As you turn the pot, does the error output increase to 8V?

Do not proceed further until you get the desired results.

PROPORTIONAL CONTROLLER

+

Construct the proportional controller circuit.



- Connect the components.

Now you need to wire the proportional operation. Insert the op amp, the 100 KΩ pot for an adjustable control gain, the 4.7 KΩ input resistor, and the jumper wires.

ORAL TEST 3

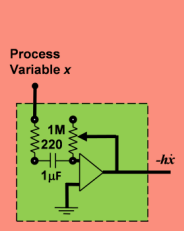
+ **The proportional controller circuit test**
    - Leave the red lead clipped to the error output.
    - Turn the process variable and set point pots all the way counterclockwise. The error output should be 0V.
    - Turn the process variable pot until the error output is 1V.
    - Switch the red lead to teh proportional controller output.
    - Turn the proportional pot all the way counterclockwise. Is the proportional controller output 0V?
    - Turn the proportional pot clockwise. As you turn the pot, does the proportional controller output decrease to -15V?

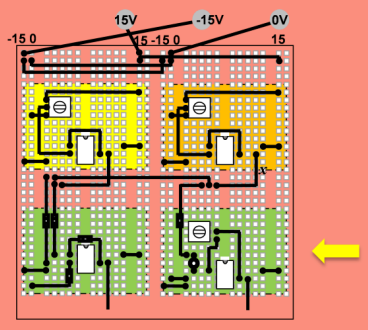
Do not proceed further until you get the desired results.

DERIVATIVE CONTROLLER

+

Construct the derivative controller circuit.





- Connect the components.

Now wire the derivative operation. Insert the op amp, the 1 MΩ pot, the 220Ω resistor, the 1 µF capacitor, and the jumper wires.

ORAL TEST 4

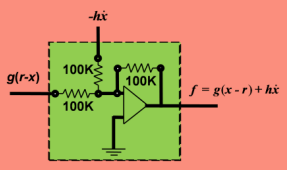
+ **The derivative controller circuit test**

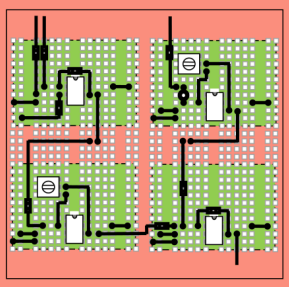
- Switch the red lead to the derivative controller output.
- Turn the process variable pot all the way counterclockwise.
- Turn the derivative controller pot perhaps a quarter turn so the derivative gain is nonzero.
- Turn the process variable pot clockwise. Is the derivative variable output negative *while* turning the pot?
- Turn the process variable pot counterclockwise. Is the derivative variable output positive *while* turning the pot?

Do not proceed further until you get the desired results.

SUMMING THE PROPORTIONAL AND DERIVATIVE CONTROLLERS

Construct the summer circuit.





- Connect the components.

Now wire the summer operation. Insert the op amp, the three 110 KΩ resistors, and the jumper wires.

ORAL TEST 5

The summer circuit test

- **Part 1:** Place the red lead on the proportional controller output and then on the summer output to verify that they are the opposite (for any set point and process variable outputs).
- **Part 2:** While turning the process variable clockwise, verify that the summer output decreases. While turning it counterclockwise, verify that the summer output increases.

Do not proceed further until you get the desired results.

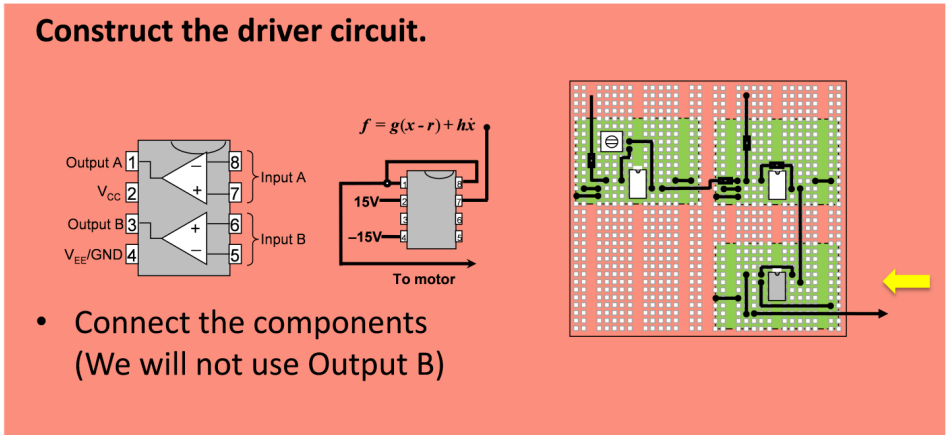
DRIVER

- The summer's current output is too low to drive (power) the physical system (plant) although its voltage output is correct.

- The purpose of the driver is to amplify the summer's current output.
- The key component is the power op amp TCA0372.
- The power op amp looks similar to teh ordinary op amp but the pin connections are different.

Constructing the driver, which is the last step in building the PD controller, connects directly to the plant. You should now be ready to construct the driver.

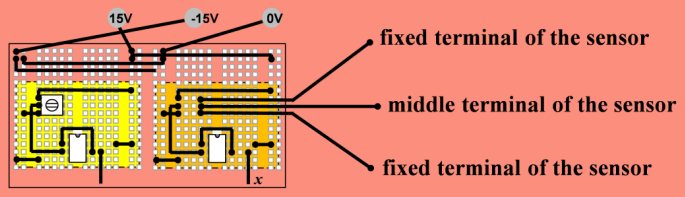
+



Now wire the driver. Insert the TCA0372 power op amp and the jumper wires. At this point, you have completed building the PD controller!

CONNECTING TO THE PLANT

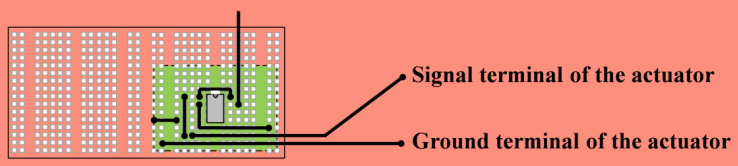
1. Assemble the plant, following the kit instructions.
2. Replace the potentiometer in the process variable circuit with the sensor (industrial potentiometer) in the plant.



You may need to test resistances to determine which wires of the sensor are the fixed and middle terminals.

Now swap out the dummy pot for the industrial pot, following the abovementioned instructions.

3. Connect the actuator (motor) leads to the driver outputs.



Now connect the motor to the driver circuit, following the abovementioned instructions.

TESTING THE PD CONTROLLER

Powering the board and zeroing the pots

- Make sure that the power is still turned off.
- Turn all of the pots counterclockwise.

- Now, turn on the power.

To test the PD controller, you will 1) power the board and zero the pots, 2) calibrate the system, 3) test the proportional controller, and 4) test the derivative controller. Now, begin powering the board and zeroing the pots, following the abovementioned steps.

+ **Calibrating the system**

  - Turn the pendulum to the middle of its range of motion

    Note: the pendulum's range may be more than one revolution

  - Next, look at teh error output.
  - Turn the set point pot until the error output reaches 0 V.

  The middle position is now the equilibrium position of the pendulum!

Calibrate the system, following the abovementioned steps.

ORAL TEST 6

+ **Testing the proportional controller**

  - Move the pendulum away from its equilibrium position until the error output is about 1 volt.
  - Slowly turn the proportional pot clockwise until the pendulum moves back.
  - Turn the proportional pot more (higher proportional gain).
  - Once again, move the pendulum away from its equilibrium position until the error is about 1V, and let go.

- The frequency of the oscillation will increase.
- Find the proportional gain where the system oscillates nicely.

Test the proportional controller, following the abovementioned steps.

ORAL TEST 7

+ **Testing the derivative controller**
    - Tap the pendulum to give it an initial velocity. It will oscillate with very little damping.
    - Slowly turn the derivative pot clockwise.
    - Again, tap the pendulum, the oscillations will damp out more (higher derivative gain).

Test the derivative controller, following the abovementioned steps.

PREVIOUS (/WEBCOM-VIEW-PAGE/4617/65194/65183?PAGE-ID=4274142)

NEXT (/WEBCOM-VIEW-PAGE/4617/65194/65183?PAGE-ID=4274111)