Control Theory

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Measure X axis Voltage

To measure X axis voltage

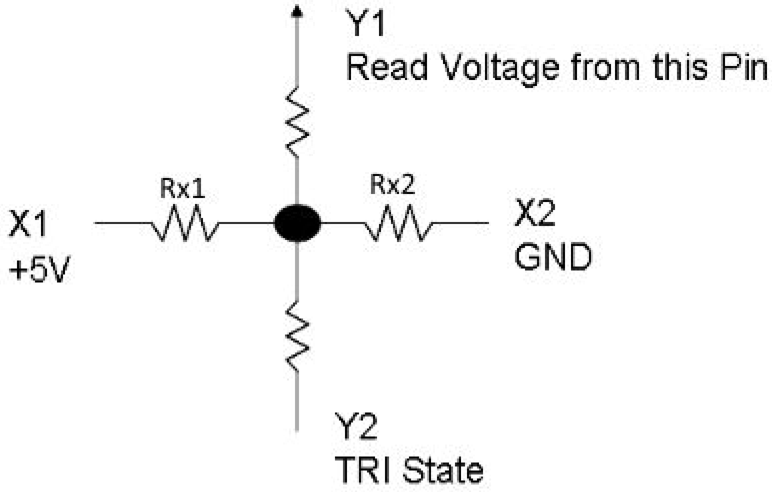
a. We are going to measure voltage on Y1
-> set Y1 pin as INPUT

b. Make Y2 Tristate (remove its influence from circuit)
-> set Y2 as INPUT but LOW

c. Form a voltage divider in X1(+5V) and X2(GND)
-> set X1 as OUTPUT but HIGH
set X2 as OUTPUT but LOW

d. Read the ADC from Y1 pin (analogRead)

Reading of X axis touch position Rx1 and Rx2 Varry according to touch position so the voltage at Y1



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Similarly Measure Y axis Voltage

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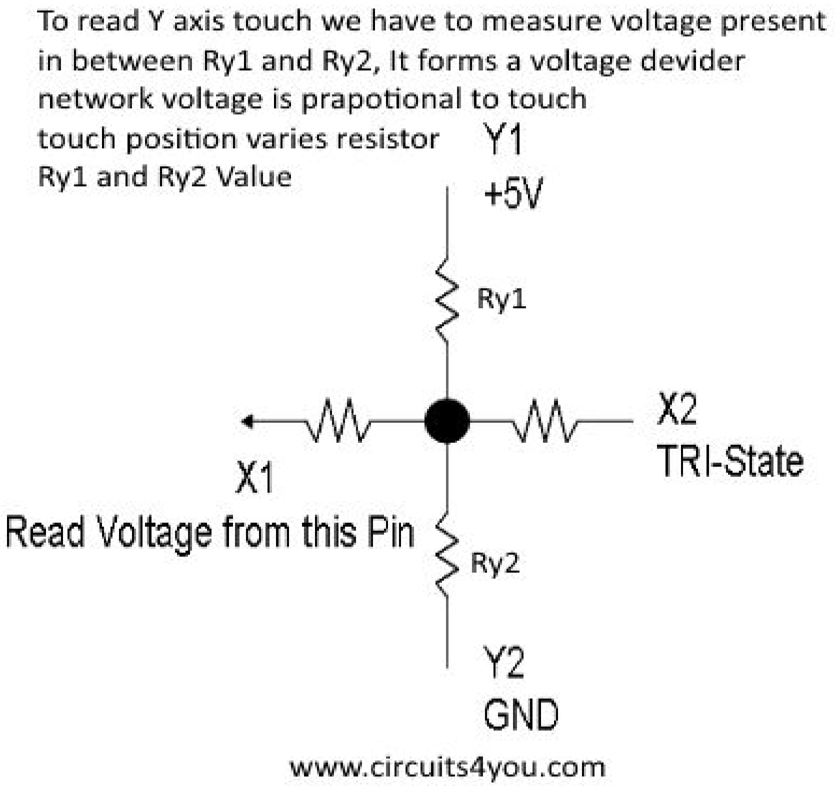

Touchscreen Arduino Code

Write an arduino code that gives the X and Y coordinates of a touch point.

Don't forget to:

- Define your Touch screen connection: (Y+ is A0, X+ is A1, Y- is A2 and X- is A3)

Touchscreen Arduino Code

```
4- Wire Touchscreen Connections
=================================*/
//Define your Touch screen connections

#define XM A3
#define YM A2
#define XP A1
#define YP A0

void setup()
{
   Serial.begin(9600);
}
```

```
void loop()
{
  int X,Y; //Touch Coordinates are stored in X,Y variable
   pinMode(YP,INPUT);
   pinMode(YM,INPUT);
   digitalWrite(YP,LOW);
   pinMode(XP,OUTPUT);
   digitalWrite(XP,HIGH);
   pinMode(XM,OUTPUT);
   digitalWrite(XM,LOW);
   X = (analogRead(YP)); //Reads X axis touch position

   pinMode(XP,INPUT);
   pinMode(XM,INPUT);
   digitalWrite(XM,LOW);
   pinMode(YP,OUTPUT);
   digitalWrite(YP,HIGH);
   pinMode(YM,OUTPUT);
   digitalWrite(YM,LOW);
   Y = (analogRead(XP)); //Reads Y axis touch position

  //Display X and Y on Serial Monitor
   Serial.print("X = ");
   Serial.print(X);
   Serial.print(" Y = ");
   Serial.println(Y);
   delay(100);
}
```

Overview

- What is a PID controller
- P- Proportional Control
  - Examples/Disadvantages
- I- Integral Control
  - Examples/Disadvantages
- D- Derivative Control
  - Examples/Disadvantages
- PID Control
- The basic P controller
- Ball on Beam Lab

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- It is one of the basic types of controllers
- Over-simplified way of ***What it is:***

It's a way to get motors to do what you want them to do efficiently and smoothly.

PID Control

- Use what you know from your sensors to compute an “intelligent” motor output.

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- Think about it as the idea that you need to slow down as you get close so you don't overshoot the target.

The Problem

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What you need is some kind of "control"

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- Assume that the general relationship that an increase in voltage generally results in an increase in speed.
- Want to do is avoid spilling the drink, by causing the arm to overshoot the target value.

P — Proportional Control

- **Step one** is to measure the difference between where the arm is (far from your mouth) and where you want it to be (at your mouth). Call this "**error**".

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- **Step two** is give the motor voltage **P**roportional to the error:

  i.e. supply more voltage further away, and less voltage as you come near.

Disadvantages of P Control

- After you do this, you might see that your drink asymptotically approaches your mouth, but doesn't get there.

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- Due to frictional effects and mathematical reasons, the speed approaches zero faster than the voltage does, and two things may occur:

    1. The motor draws a lot of current (inefficient)

    2. The drink remains out of reach of your mouth — it **undershoots**.

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Now you've got enough voltage!

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And yet, two things may occur:

1. As these little bits of voltage stack up, you get enough energy per charge to get that arm going again — but you might hit yourself with the drink. You've **overshot.**

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1. As these little bits of voltage stack up, you get enough energy per charge to get that arm going again — but you might hit yourself with the drink. You've **overshot.**

2. As you shoot past your target error value, P and I become negative, so your arm switches direction and goes the other way… And overshoots, moving too low, causing the values to switch signs, so it comes back up and hits you in the face again, and then drops too low… You've got an **oscillation.**

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- You want to do is damp things down, chill them out a bit.
- What you do now is measure how fast the error is changing — take its **D**erivative.
- If the error is changing too fast, you cut the voltage. You can do this very quickly because you're a robot.

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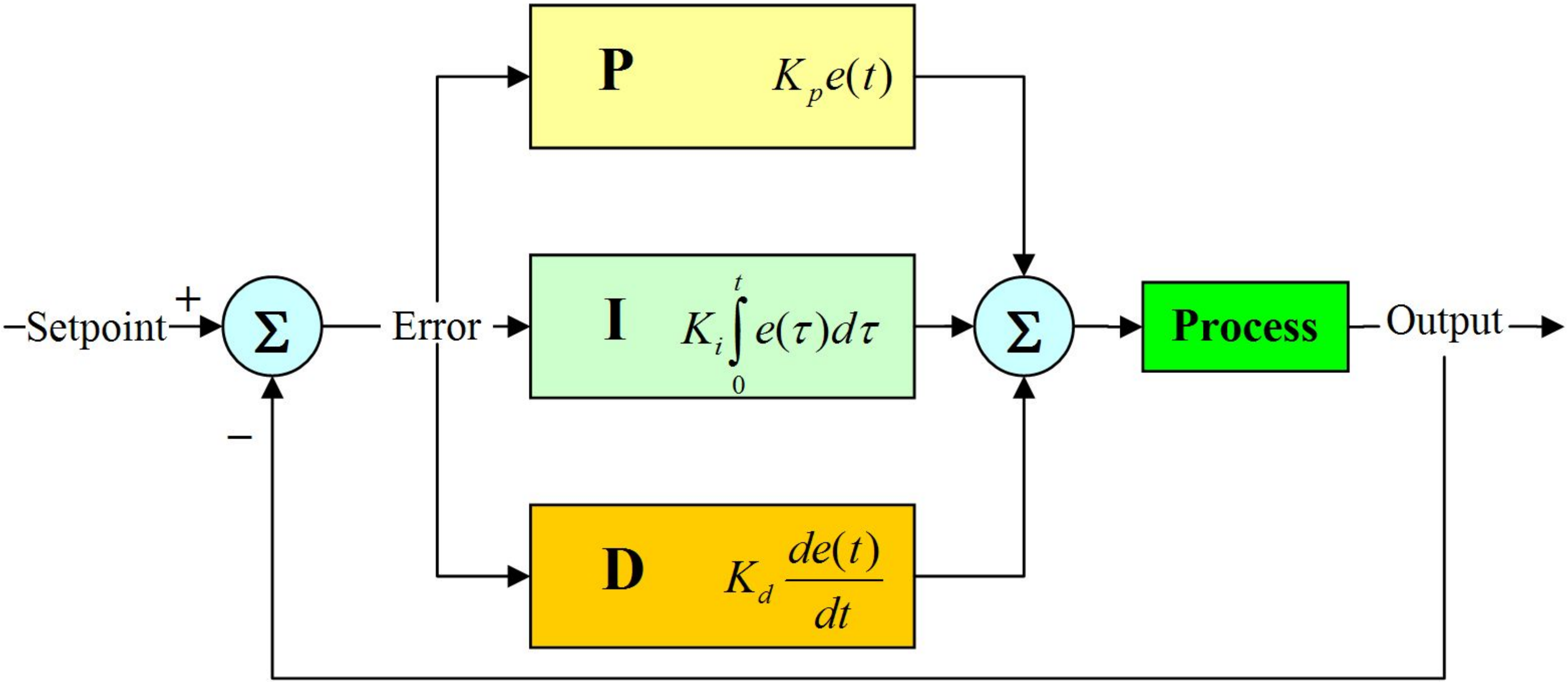
- The combination of the three (not always needed) results in a smooth, efficient motion that draws exactly as much current as it needs to. This is called **PID Control!**


Setpoint
+
−
Σ
Error
P
$K_p e(t)$
I
$K_i \int_0^t e(\tau) d\tau$
D
$K_d \frac{de(t)}{dt}$
Σ
Process
Output

PID Example 2

Want to drive a robot forward 10 metres, and then stop.

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- In this example, measure the distance remaining between our current position and our goal of 10 metres.

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- The idea is that the longer the robot has not made it to the target, the more power should be applied to get it there.
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- I is the sum of the distances you are away each time. It can be calculated by adding up the P value from each loop.

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- Where Kp, Ki, and Kd are values tweaked to get the proper result.
- There are some methods to calculate the values of Kp, Ki, and Kd, but it is generally more effective to find them by trial and error in robotics.

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- Then add Ki until the robot stops within a desired range of the target.

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- The K controller is useful for slow processes, i.e. systems that must change slowly. As the controller speeds up, the controller tends to overshoot the setpoint.
- Additionally, K controllers are susceptible to offset, that is, the controller will approach the setpoint but will stop short due to the amount of control input needed to maintain a particular process state.

How to think of the PID Code

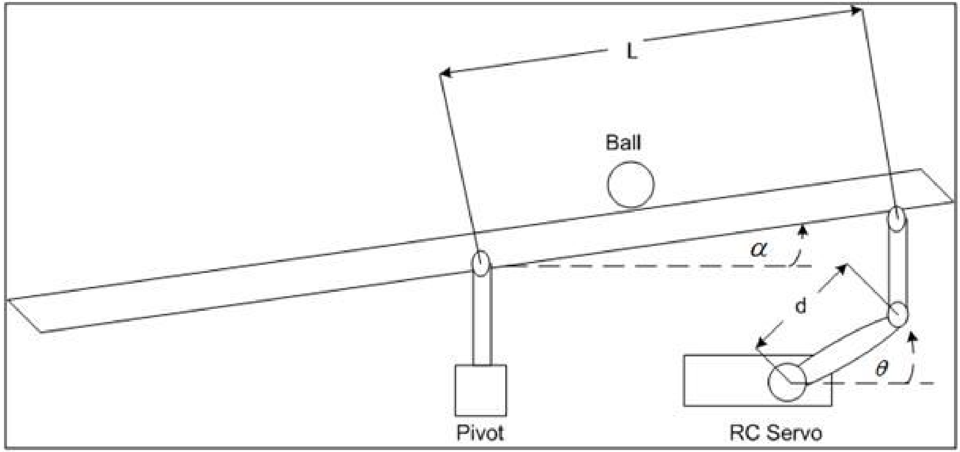
```
previous_error = 0
integral = 0
start:
  error = setpoint – actual_position
  integral = integral + error*dt
  derivative = (error - previous_error)/dt
  output = Kp*error + Ki*integral + Kd*derivative
  previous_error = error
  wait(dt)
  goto start
```

PID Code Lab

- Take an example of a car of speed V
- When you step on the accelerator, your car moves slowly, then faster, and faster still, until you let off the gas pedal.
- Write a general PID code in C to control the car's motion

Balancing Ball on Beam Lab

- The system includes a ball, a beam, a motor and touch screen sensor.



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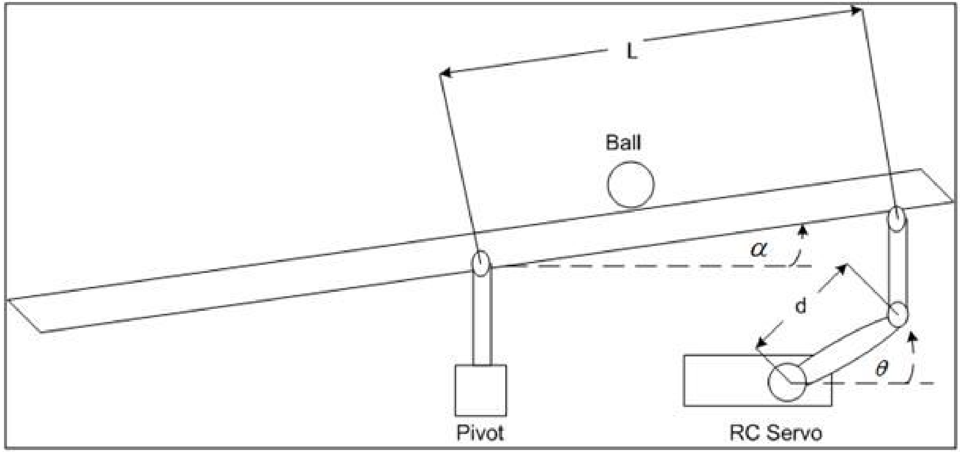

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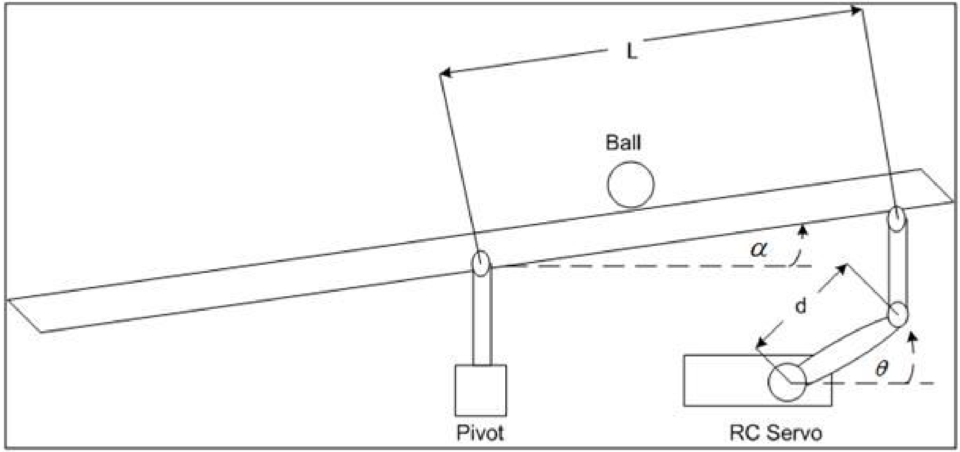

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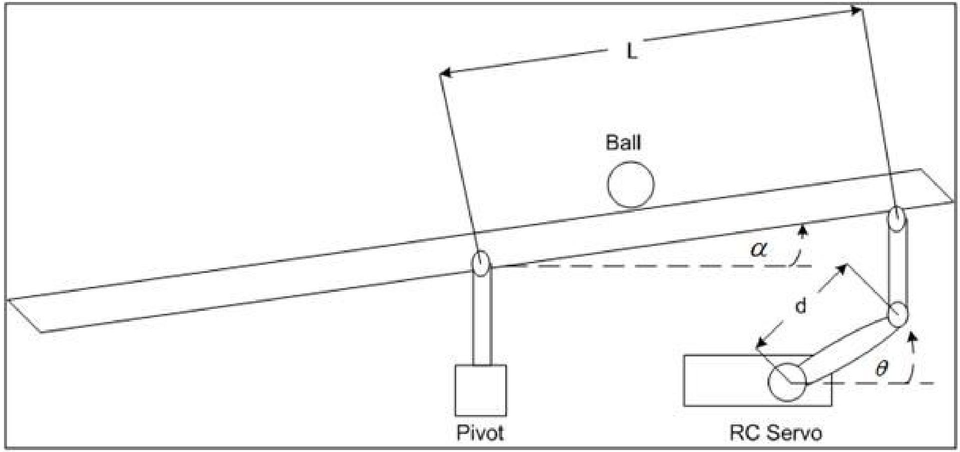

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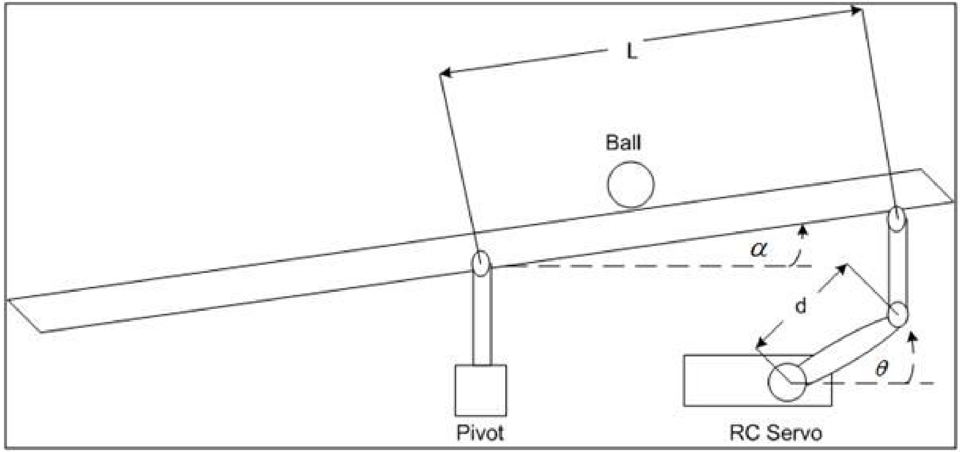
- The difference can be fed back into the controller, and then into the motor in order to gain the desired position.



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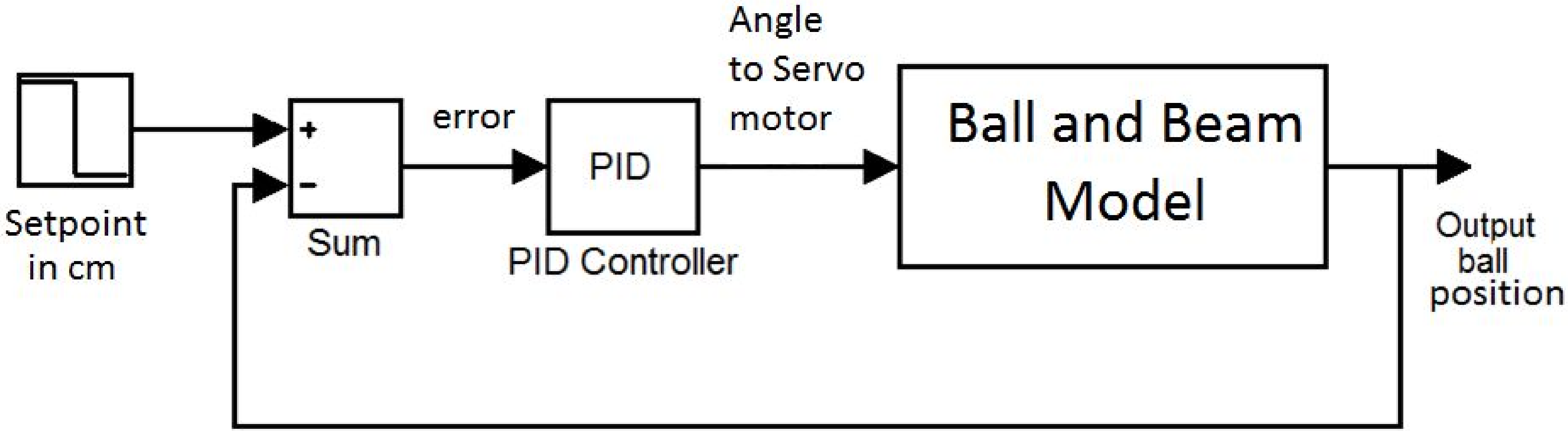
- The aim of the system is to control the position of the ball to a desired reference point, and reject disturbances such as a push from a finger.

Balancing Ball on Beam Lab



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Processing Demo of Lab

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PID(&Input, &Output, &Setpoint, Kp, Ki, Kd, Direction)

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Parameters

Input: The variable we're trying to control (double)
Output: The variable that will be adjusted by the pid (double)
Setpoint: The value we want to Input to maintain (double)
Direction: Direction the output will move when faced with a given error. DIRECT is most common.

Compute()

Description

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Returns

True: when the output is computed
False: when nothing has been done

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Syntax

SetMode(mode)

Parameters

mode: AUTOMATIC or MANUAL

SetOutputLimits()

Description

The PID controller is designed to vary its output within a given range.

Syntax

```
SetOutputLimits(min, max)
```

Balancing Ball on Beam Lab Code Steps

- Include the libraries you're using
- Define servo pin, Kp, Ki, Kd, Setpoint, Input, Output, and ServoOutput
- Initialize your PID object and your Servo
- Start the `setup()`
- After you finish your `setup()`, move to the `loop()`