MICROCONTROLLER SYSTEM CONTROL DESIGN

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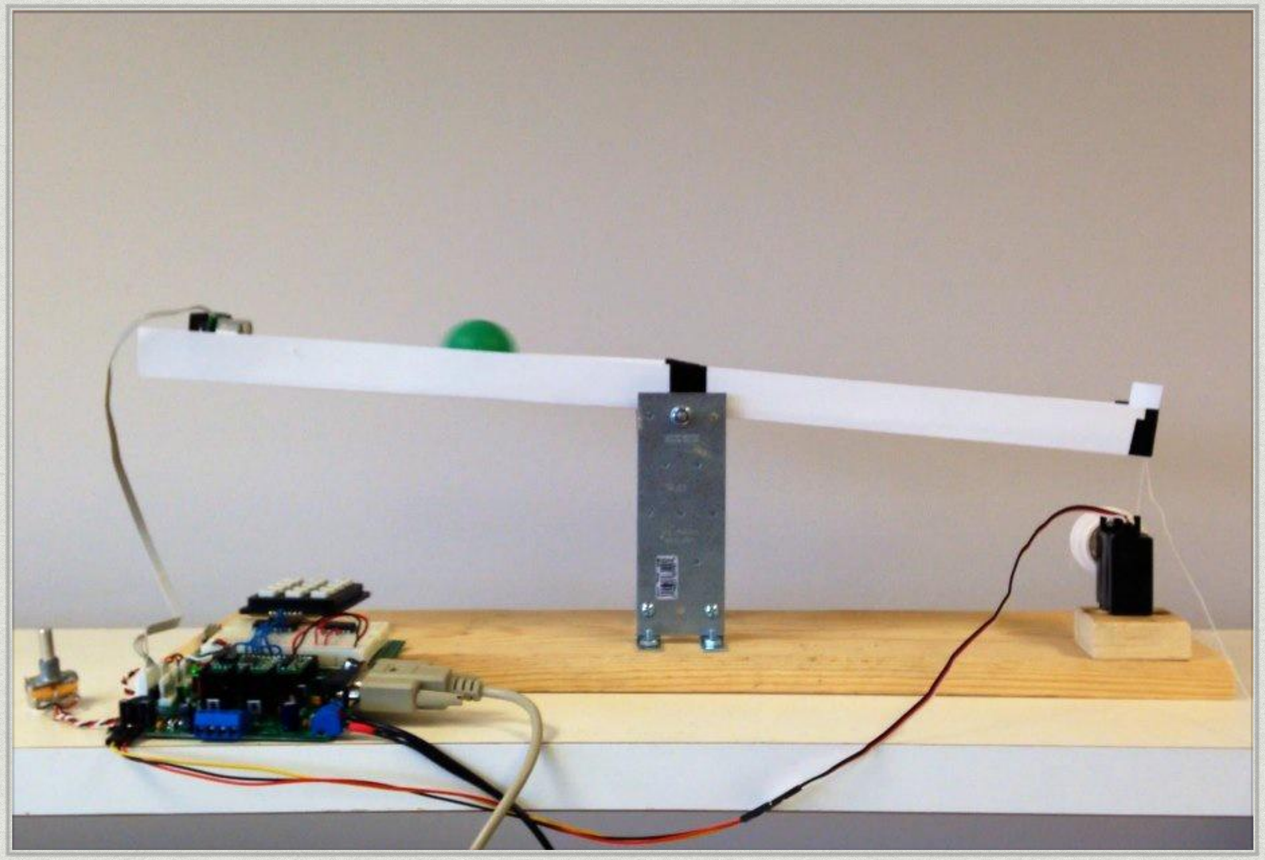
Problem Statement

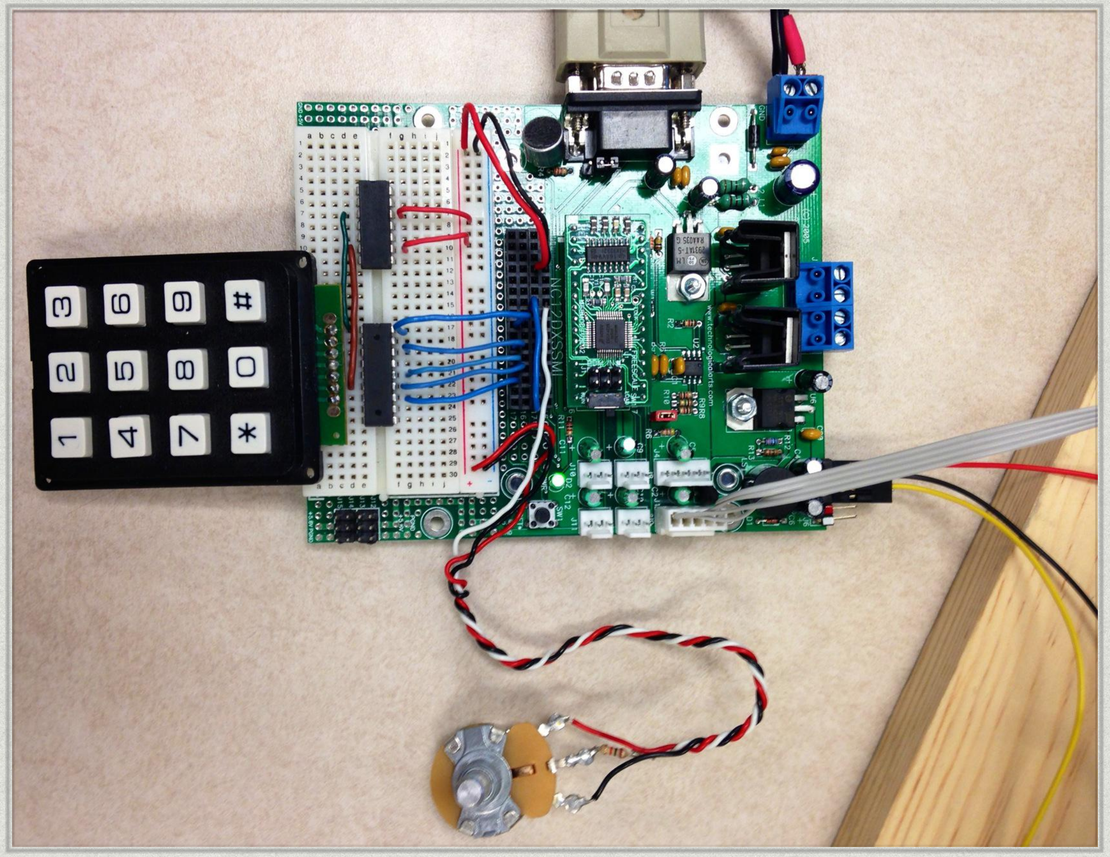
- Create a simple feedback environment that can be used to demonstrate various feedback control systems using a microcontroller

Modes of Operation

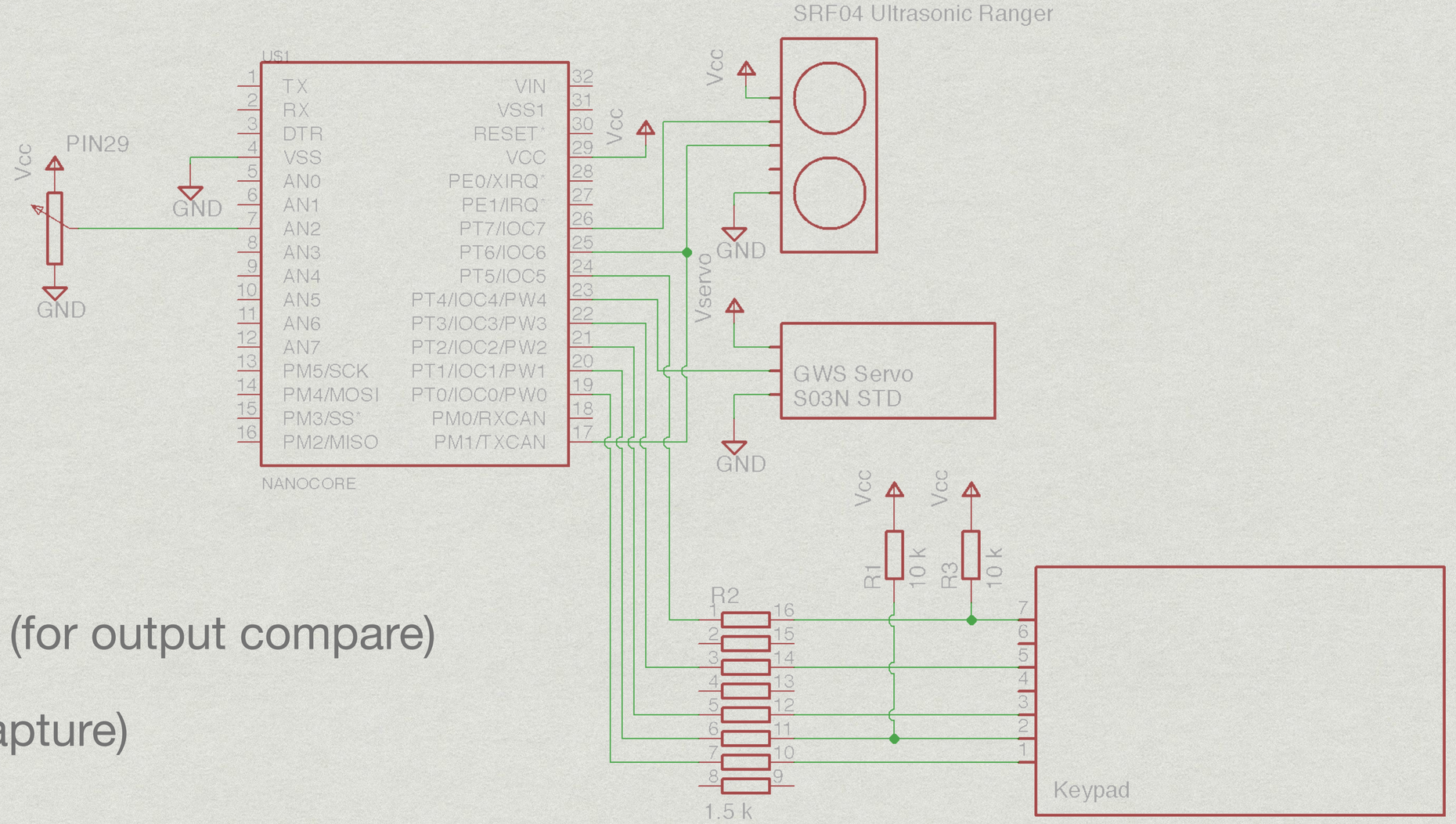
- Manual control
- Proportional positional control
- Proportional-derivative control

Hardware Design





Hardware Design



- PT6-PM1/J1 (for output compare)
- PT7 (input capture)

Software Design

LOW LEVEL

- Sonar (IC, OC)
- Servo control (PWM)
- Potentiometer (AD)
- Keypad (time muxing)

HIGH LEVEL

- Mode switch from keypad (main loop, sets global variable)
- Control (RTI, state machine based on global variable)

Control Structure

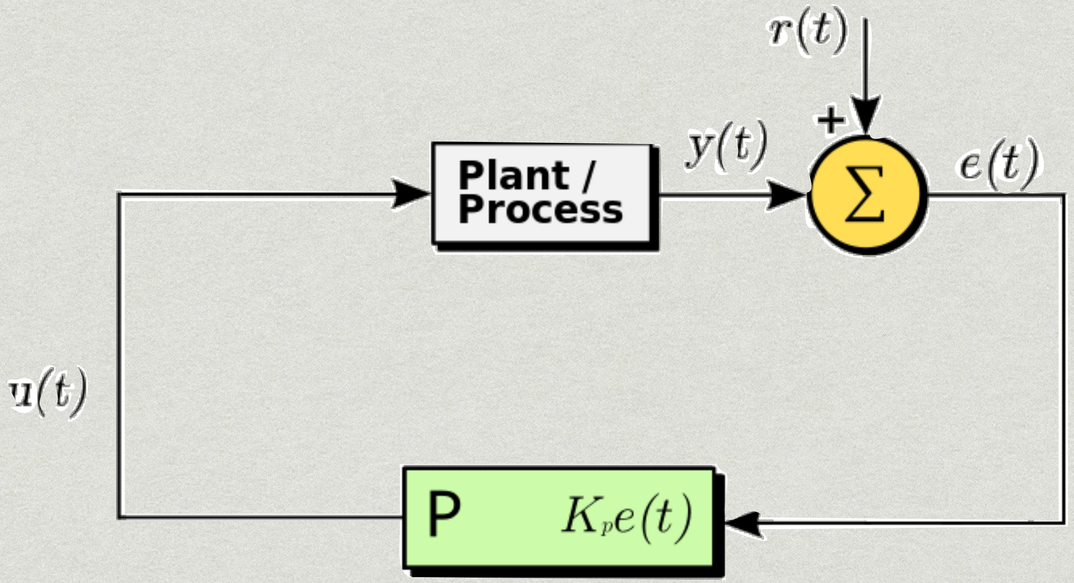
MANUAL CONTROL

- Humans are very good at many kinds of control (ex. adjusting shower temperature without burning oneself)
- Human control can break down when control inputs need to be small.
- Implementation
  - Read analog value on AN02 from trimpot
  - Convert to digital value, store on ATDDDR0L
  - Shift and scale ATDDR0L and store it into PWM Register

Control Structure

PROPORTIONAL CONTROL

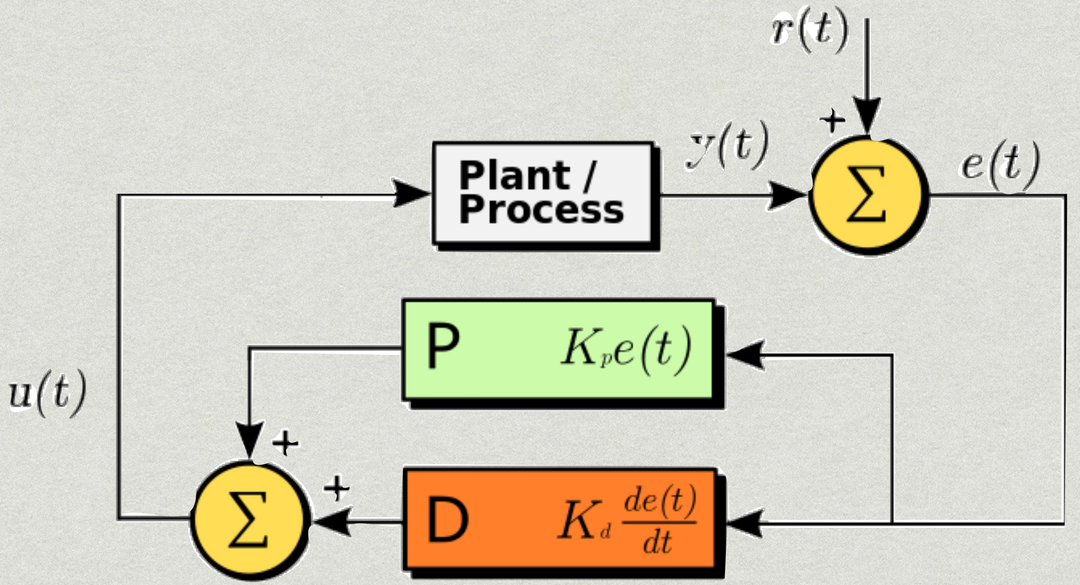
- Uses the sonar to detect the position of the ball
- Assigns a value to the PWM register based on the position of the ball
- Gain (aggressiveness or conservativeness) of the response can be controlled using the potentiometer
- Not stable for large disturbances



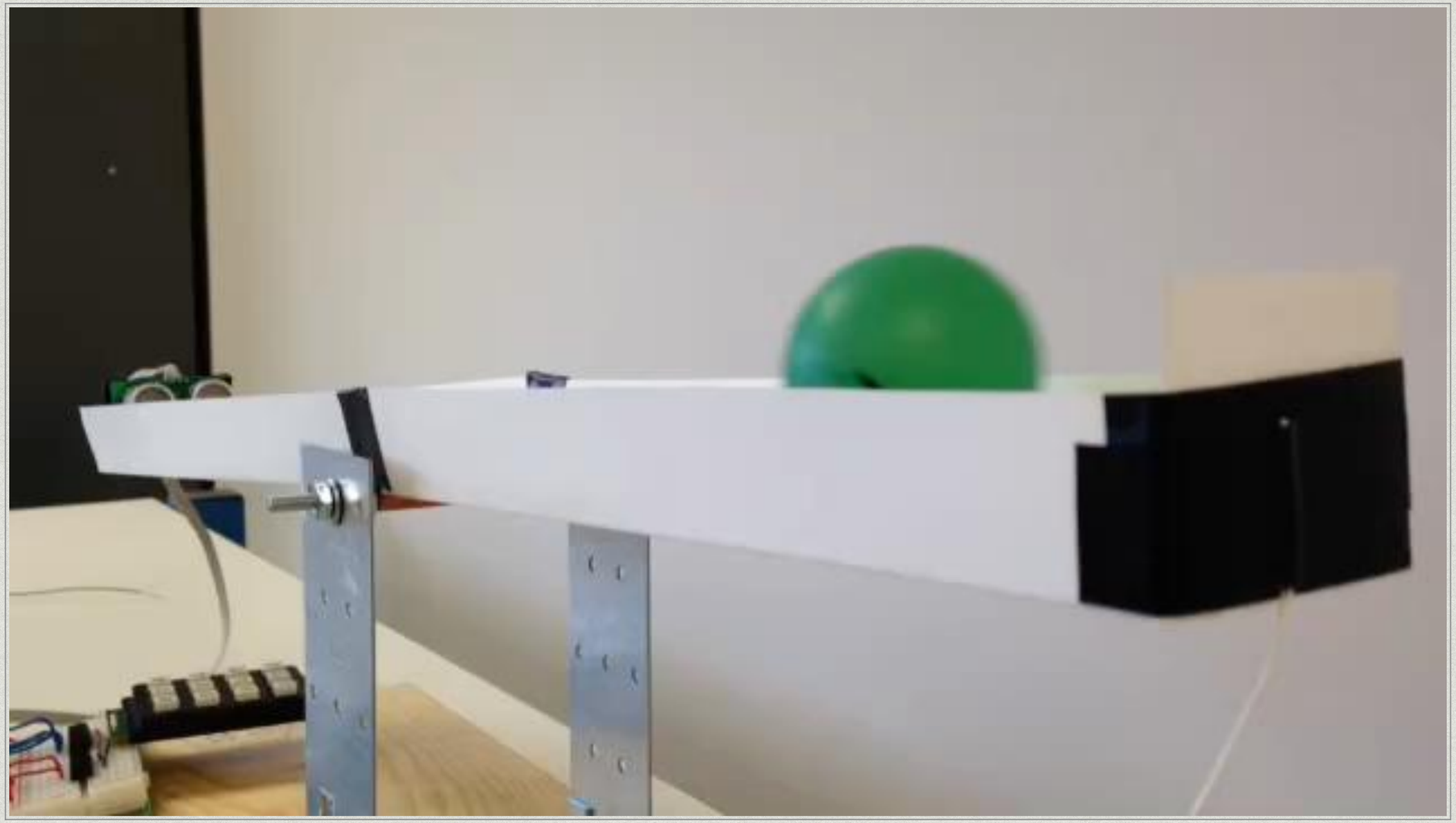
Control Structure

PROPORTIONAL-DERIVATIVE CONTROL

- Uses Sonar to detect the position of the ball like P-only control
- Calculates the ball's approximate velocity based on the previous position of the ball
- Both the ball's position and velocity are used to calculate the controller response
- Derivative Gain can be controlled with the trimpot
- Creates stability for large disturbances, but overly aggressive derivative gain can make small disturbances less stable.



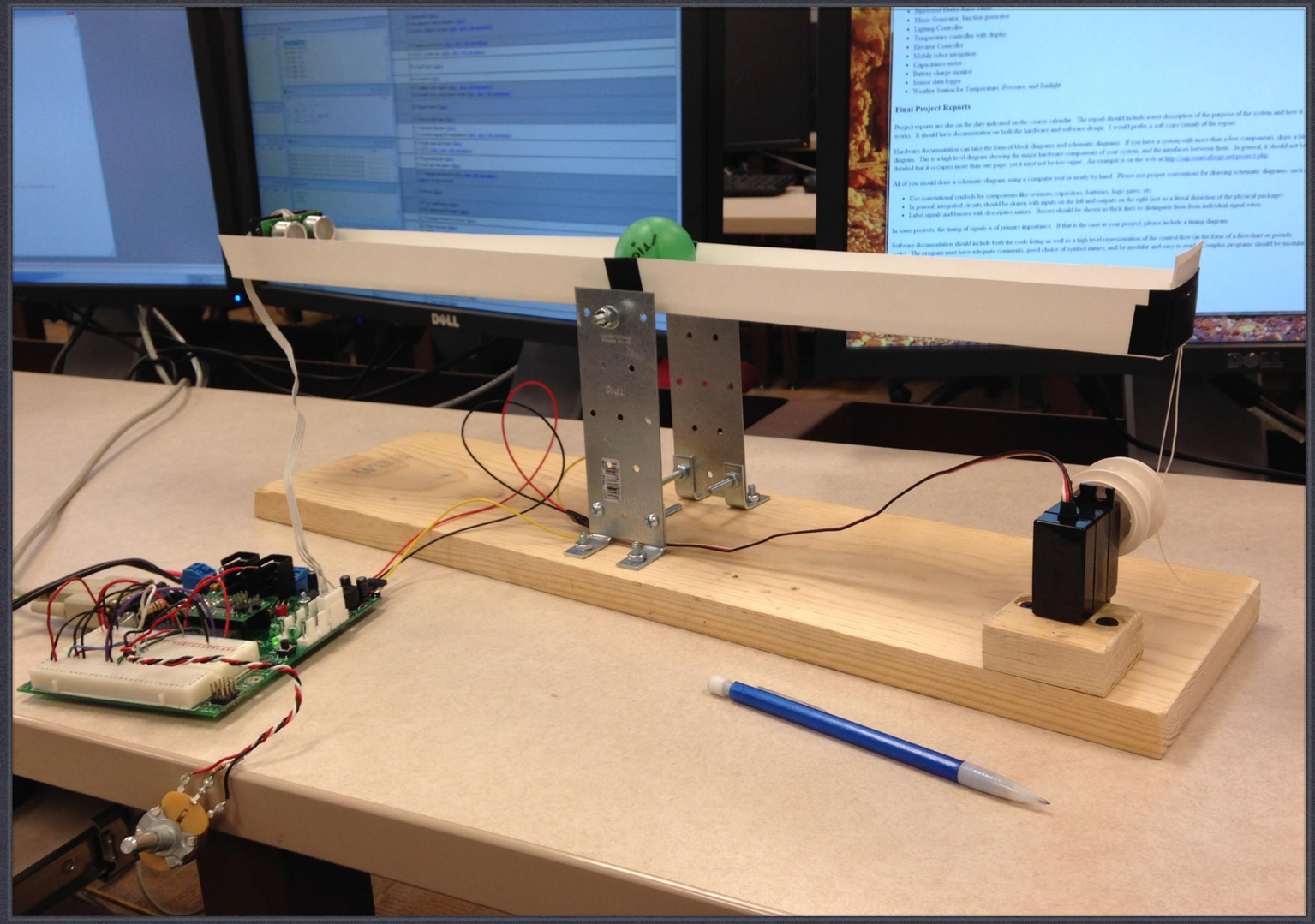
Results



Conclusion

- Hardware/software interfacing
  - Sonar
  - Servo
  - PWM, IC, OC, A/D, RTI
- Control systems and design
  - Manual
  - Proportional
  - P/D
- Demonstration of control
- Limiting factors
  - Speed/resolution of servo
  - Noise in sonar reading
- Improvements
  - Different physical control
  - Multiple sensors
  - More sophisticated control

QUESTIONS



Backup - Code

```
#include <hidef.h>      /* common defines and macros */
#include "derivative.h"      /* derivative-specific definitions */
//#include <stdio.h>       /* contains sprintf() */



/*************************************************************************
 Get a keypress (if any) from the keypad. If a key is pressed,
 it returns its code, which is an integer from 1 (top left) to 12
 (lower right). If no key is pressed, it returns 0. If the same key
 is still pressed from last time, return 0.
*************************************************************************/
int getkey(void);
void DelayuSec(int t);
void interrupt VectorNumber_Vrti rti_isr();
int processPWM(int input);
unsigned int T1;
long PWIDTH;
long PWIDTHLAST = 0;
long DELTAPWIDTH = 0;
unsigned int USEC;
unsigned int DISTCM;
int Kd = 0;
int i = 1;
int state = 3;
int checkkey = 0;
char cbit;


 // Define the Port T bits corresponding to columns
char columnBits[] = {
0x04, // column 0 (left) is pin PT2
0x01, // column 1 (center) is pin PT0
0x08 // column 2 (right) is pin PT3
};
// Define the Port T bits corresponding to rows
char rowBits[] = {
0x02, // row 0 (top) is pin PT1
0x20, // row 1 (2nd) is pin PT5
//0x20, // row 2 (3rd) is pin PT5
//0x08 // row 3 (bottom) is pin PT3
};
```

Backup - Code

```
void main(void) {
  DDRT = 0x5D;    //Set PT6, PT4, PT3, PT2, PT0 as outputs, rest of pins for input.

  ATDCTL2 = 0xC0;   //enable ATD and fast flag clear
  ATDCTL3 = 0x08;   //set ATD for 1 channel conversion
  ATDCTL4 = 0x85;   //set ATD for 2 MHz,2 sample clks,8 bits
  ATDCTL5 = 0xA2;   //right justif, continuous conv, use AN02

  RTICTL = 0x3F;  //Set RTI clock to lognest period
  CRGINT = 0x80;  //RTIE=1 to enable rti interrupts

  PWMPRCLK = 4;   // Set clock prescaler (M=16)
  PWMCLK = 0xFF;  // Select clock SA
  PWMSCLA = 75;   // Divider for clock SA (N=12)
  PWMPOL = 0xFF;  // Positive going pulse
  PWMDTY4 = 7;    // Pulse width 15*100usec
  PWMPER4 = 200;  // Period is 200*100usec
  PWME = 0xFF;    // Enable all channels
  MODRR = 0x10;   // Route PWM channel to PIN 4 on PTT.

  //Setup
  DDRM =  0x00;
  TSCR1 = 0x90;
  TSCR2 = 0x06;

  //Input Capture
  TIOS &= ~0x80;
  TCTL3 = 0x40;
  TFLG1 = 0x80;
  TIE |=  0x80;

  //Output Compare
  TIOS |= 0x40;
  TCTL1 = 0x30;
  TFLG1 = 0x40;
  TIE |=  0x40;

  EnableInterrupts;

  for(;;) {

  checkkey=getkey();
  if (checkkey != 0) {
    state = checkkey;

  }
    _FEED_COP(); /* feeds the dog */
  } /* loop forever */
}
```

Backup - Code

```
// IC7 ISR

void interrupt VectorNumber_Vtimch7 ic7_isr(void) {

 // Test bit EDG3A to see what IC7 was configured to do

 if (TCTL3 & 0x40) { // EDG7A was a 1, meaning IC7 was configured to look for rising

    T1 = TC7;

    TCTL3 = 0x80; // EDG7B:EDG7A = 1:0 to look for falling edge next

 } else {

    // EDG7A was a 0, meaning IC7 was configured to look for falling

      PWIDTHLAST = PWIDTH;

      PWIDTH = TC7 - T1;

    TCTL3 = 0x40; // EDG7B:EDG7A = 0:1 to look for rising edge next

 }

}
```

```
// OC6 ISR

void interrupt VectorNumber_Vtimch6 oc6_isr(void) { // Test bit OL6 to see what OC2 was configured to do

 if (TCTL1 & 0x10) { // OL6 was a 1, meaning OC6 went high upon compare

    TC6 = TC6 + 4; // This is about 10 us

    TCTL1 = 0x20; // OM6:OL6 = 1:0 to go low next

 } else { // OL6 was a 0, meaning OC6 went low upon compare

    TC6 = TC6 + 37500; // This is about 100 ms

    TCTL1 = 0x30; // OM6:OL6 = 1:1 to go high next

 }

}
```

Backup - Code

```
// Keypad

int getkey(void) {

 int col, row, rbit, key;

 static lastKey = 0;

 int keycodes[2][3]= {{1,2,3}, {4,5,6}};



 // Scan across columns 0,1,2

 for (col=0; col<3; col++) {

  // Write a 0 to the bit corresponding to the column;

  // write 1 to all other bits in Port T

  cbit = columnBits[col];

  PTT = ~cbit;



  // Scan across rows 0,1

  for (row=0; row<2; row++) {

  // Get the mask corresponding to this row

   rbit = rowBits[row];



   // Read Port T and check only that bit; a key is

   // pressed if the bit is 0.

   if (!(PTT & rbit)) { // A key is pressed

    //DelayuSec(10000);

    if (!(PTT & rbit)) { // check same key again

     key = keycodes[row][col]; // get keycode

     // If this is still the same key, return 0

     if (key==lastKey) return(0);

     // It is a new key being pressed

     lastKey = key;

     return(key);

    }

   }

  }

 }

// We got to here, so no key is being pressed

lastKey = 0;

return(0);

}
```

Backup - Code

```
void interrupt VectorNumber_Vrti rti_isr() {
  CRGFLG = 0x80;
 if (state == 1) {
  PWMDTY4 = (ATDDR0L/15) + 7;
 } else if (state == 2) {
  if ((PWIDTH > 60) && (PWIDTH <1010)) {
      PWMDTY4 = processPWM(24-(PWIDTH/(55)));
  } else {
  }

 } else if (state == 3) {

  /**************************************
  This is the code for the PD controller.
  From experimentation, the normal range for DELTAPWIDTH is 0 to about 120
  Kd ranges from 10 to about 52 and adjusts the gain of the derivative term
  A smaller Kd produces a more aggresive response (better for stabalizing large disturbances).
  A larger Kd produces a more conservative response (better for stablixing small diestubances).
  **************************************/
```

```
i
f ((PWIDTH > 60) && (PWIDTH < 1010)) {

      Kd = (ATDDR0L/6) + 10;

      DELTAPWIDTH = (PWIDTH - PWIDTHLAST);

      if (DELTAPWIDTH > 150) { //this if statement attempts to get rid of some of large spikes in
                  // DELTAPWIDTH, Only correcting the derivative seems to work best
        PWIDTHLAST = PWIDTH;
        DELTAPWIDTH = 0;
      }

      PWMDTY4 = processPWM(24 - (PWIDTH/55) - (DELTAPWIDTH/Kd));
    }
  }
}
```

Backup - Code

```
int processPWM(int input) {
  int output = 0;
  if (input < 7) {
    output = 7;
  } else if (input > 24) {
    output = 24;
  } else {
    output = input;
  }
  return output;
}
```