Project Title: Pneumatic Exercise Machine

Team Members:
Gino Tozzi
Seok Hyun John Yun

Project Abstract

The goal of this project was to create a very fluid and streamlined method of resistance exercise. Conventional exercise methods require heavy weights and frequent switching of weights over the course of a workout. Using air pressure to create resistance provides a safe and efficient way to work out. In addition, exercise statistics can be tracked for user feedback. Interfacing with a micro-controller offers the ability to track and number of repetitions. By allowing the user to control resistance wirelessly from the handle, the lifter doesn’t have to shift their concentration from working out to change resistance.
Table of Contents

Project Features.............................................................................................................3
Technical Objectives......................................................................................................3
Market Competition Analysis..........................................................................................4
Technical Concepts.........................................................................................................5
Project Diagram.............................................................................................................6
Labor Distribution...........................................................................................................7
Bill of Materials...............................................................................................................7
Appendix..........................................................................................................................8

Table of Tables and Figures

Figure 1: Project Diagram..............................................................................................6
Figure 2: PCB....................................................................................................................8
Figure 3: Circuit Schematics............................................................................................9
Table 1: Labor Distribution..............................................................................................7
Table 2: Bill of Materials..................................................................................................7
Project Features

The system will provide pneumatic variable resistance that can be controlled at the handle.

The primary features are:

- Wirelessly controlled pneumatic resistance
- Detection of a repetition or failure to complete repetition
- Assist function for completion of repetition
- LCD display of resistance intensity and amount of repetitions

Technical Objectives

The pneumatic exercise system will provide a streamlined workout experience with computer feedback and assistance.

Mechanical Design Objectives:

- Provide fluid range of motion for lifter with pulley system
- Feed regulator with appropriate air pressure
- Use electrical air compressor to provide air pressure
- Provide resistant physical motion using pneumatic cylinder piston
Electrical Design Objectives:

- Control air pressure regulator via micro-controller PWM
- Transmit data wirelessly via two XBEE modules
- Use two slotted optical switches to measure displacement of cylinder piston
- Program algorithm that detects failure to complete repetition and automatically decreases PSI
- Use LCD to display resistance intensity and number of repetitions

Market Competition Analysis

There are currently other pneumatic exercise systems on the market. The companies Safe Air Fitness and Keiser both provide various exercise systems. Both companies allow resistance changing only through mechanical means. The Pneumatic Exercise Machine is the only pneumatic resistance system that has an electronic system interfaced with the mechanical system.

The PEM would be marketed as a safe and compact workout system that is just as effective as a traditional weighted plate resistance machine. This unit could be marketed for physical rehabilitation centers, high end gyms, and general household use.
Technical Concepts

There were initially a few different methods of creating a resistance that could be electrically controlled. A motor system was considered. The disadvantages were safety concerns, noise, and potential lack of precision. Muscle wire, commonly used in robotics, was researched. They turned out to be far too fragile to heat and had a very slow resistance change over time. Air pressure is easy to provide via an air compressor or air pressure tank. Electronic air pressure valves are very precise and will allow varying air pressure to be quick and accurate.

The air pressure regulator that was decided upon allows air pressure output to be controlled by a DC voltage 0-5V applied to the regulator. Pulse-width modification is provided with the PIC micro-controller that we used. By running the output of the PWM signal into a low-pass filter, an appropriately constant voltage can be applied to the regulator. Two XBEE modules allow data from buttons on the handle to be sent to the micro-controller wirelessly.

Air pressure is supplied to the regulator with an electric air compressor. The regulator allows air into the double-acting pneumatic cylinder to provide resistance.

The air pressure regulator requires a minimum air pressure input of 105 PSI and can output a maximum of 100 PSI. We scaled the regulator to span from 0-30 PSI linearly over 0-5V DC.

Two optical switches track repetitions when the cylinder piston passes through both optical slots. If one switch has been activated but the other hasn’t, after about five seconds, air pressure will begin to relieve to assist the lifter.
Figure 1: Project Diagram
## Labor Distribution

<table>
<thead>
<tr>
<th></th>
<th>Gino Tozzi</th>
<th>John Yun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminary Research</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Design Phase</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>Purchasing Parts</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Board Construction</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>uP Coding</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>Mechanical Construction</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Test and Debug</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 1: Labor Distribution

## Bill of Materials

<table>
<thead>
<tr>
<th>Component</th>
<th>Qty</th>
<th>Unit Cost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electro-Mechanical Air</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure Regulator</td>
<td>1</td>
<td>$380</td>
<td>$380</td>
</tr>
<tr>
<td>XBEE</td>
<td>2</td>
<td>$25</td>
<td>$50</td>
</tr>
<tr>
<td>LCD Display</td>
<td>1</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Optical Switch</td>
<td>2</td>
<td>$7</td>
<td>$14</td>
</tr>
<tr>
<td>PIC Micro-controller</td>
<td>1</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Air Compressor</td>
<td>1</td>
<td>$90</td>
<td>$90</td>
</tr>
<tr>
<td>Pneumatic Cylinder</td>
<td>1</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Various Electrical Components</td>
<td>1</td>
<td>$10</td>
<td>$10</td>
</tr>
<tr>
<td>Various Mechanical Components</td>
<td>1</td>
<td>$50</td>
<td>$50</td>
</tr>
<tr>
<td>Total Cost:</td>
<td></td>
<td></td>
<td>$594</td>
</tr>
</tbody>
</table>

Table 2: Bill of Materials
Figure 2: PCB
Figure 3: Circuit Schematic
#include <p18f4620.h>
#include <pconfig.h>
#include <delays.h>
#include <UF_LCD.h>
#include <UF_DAC.h>

#pragma config OSC = INTIO67 //select internal oscillator
#pragma config WDT = OFF //turn off watch dog timer
#pragma config LVP = OFF //turn off low voltage program

void main (void) {
    int adc_result; //where we will store the ADC result in
    float temp;
    int ones;
    int tenth;
    int hundth;
    int i;
    int bar;
    int x;
    OSCCON = 0x70; // set internal oscillator at 8MHz
    ADCON1 = 0x0F; // PORTA for I/O
    lcd_init(); //get the LCD up and running
    ADCON0 = 0x11; // select channel4 and enable A/D
    ADCON2 = 0x88; // select internal clock and acquisition time
    lcd_char('V');
    lcd_char('o');
    lcd_char('l');
    lcd_char('t');
    lcd_char('a');
    lcd_char('g');
    lcd_char(':');
    lcd_char(' ');
    TRISDbits.TRISD0 = 0; //Set LED Pin data direction to OUTPUT
    TRISDbits.TRISD1 = 1;
    TRISDbits.TRISD2 = 1;
    TRISC = 0; // set PORTC as output
    PORTC = 0; // clear PORTC
    /*
    * configure CCP module as 4000 Hz PWM output
    */
    PR2 = 0b01111100;
    T2CON = 0b00000101;
    CCP1CON = 0b00111100;
    OSCCON = 0x76;
CCPR1L = 0;
while(1)
{
    if((PORTDbits.RD1)==1)
    {
        LATDbits.LATD0 = 1;
        CCPR1L = CCPR1L + 1;
        Delay10KTCYx(90);
    }
    else if ((PORTDbits.RD2)==1)
    {
        CCPR1L = CCPR1L - 1;
        Delay10KTCYx(90);
    }
    else
    {
        LATDbits.LATD0=0;    // LED ON
    }
    ADCON1 = 0x0A; // PORTA for A/D use
    ADCON0 |= 0x02; // set the Go bit
    while (ADCON0bits.GO == 1); // wait until the Go bit is set to 0
    adc_result = ADRES; // grab our 10-bit answer
    temp = ((float)adc_result/2); // Divide 1024 by 512 which is about 2
    ones = temp/100; //Check the ones place
    lcd_char(ones + 0x30); //Place the ones number on LCD
    temp = temp - (ones*100); //Gets rid of the ones place number
    tenth = temp/10; //Check the tenth place
    lcd_char(tenth + 0x30); //Place the tenth number on LCD
    hundth = temp - (tenth*10); //Gets rid of the tenth place number
    lcd_char(hundth + 0x30); //Place the hundredth number on LCD
    bar = adc_result/51; //Find the total amount of bars
    lcd_command(0xC0); //Place cursor to the next line
    for(i=0;i<=bar;i++){
        if(i==0)
        { //Loop until the value of bar
            lcd_char(0xFF); //0xFF refers to the bar character
        }
        for(i=0;i<=(20-bar);i++){
            if(i==0)
            { //Loop until the value of empty space
                lcd_char(0xFE); //0xFE refers to the blank character
            }
        }
        lcd_command(0x89); //place cursor back at position 9
    }
}