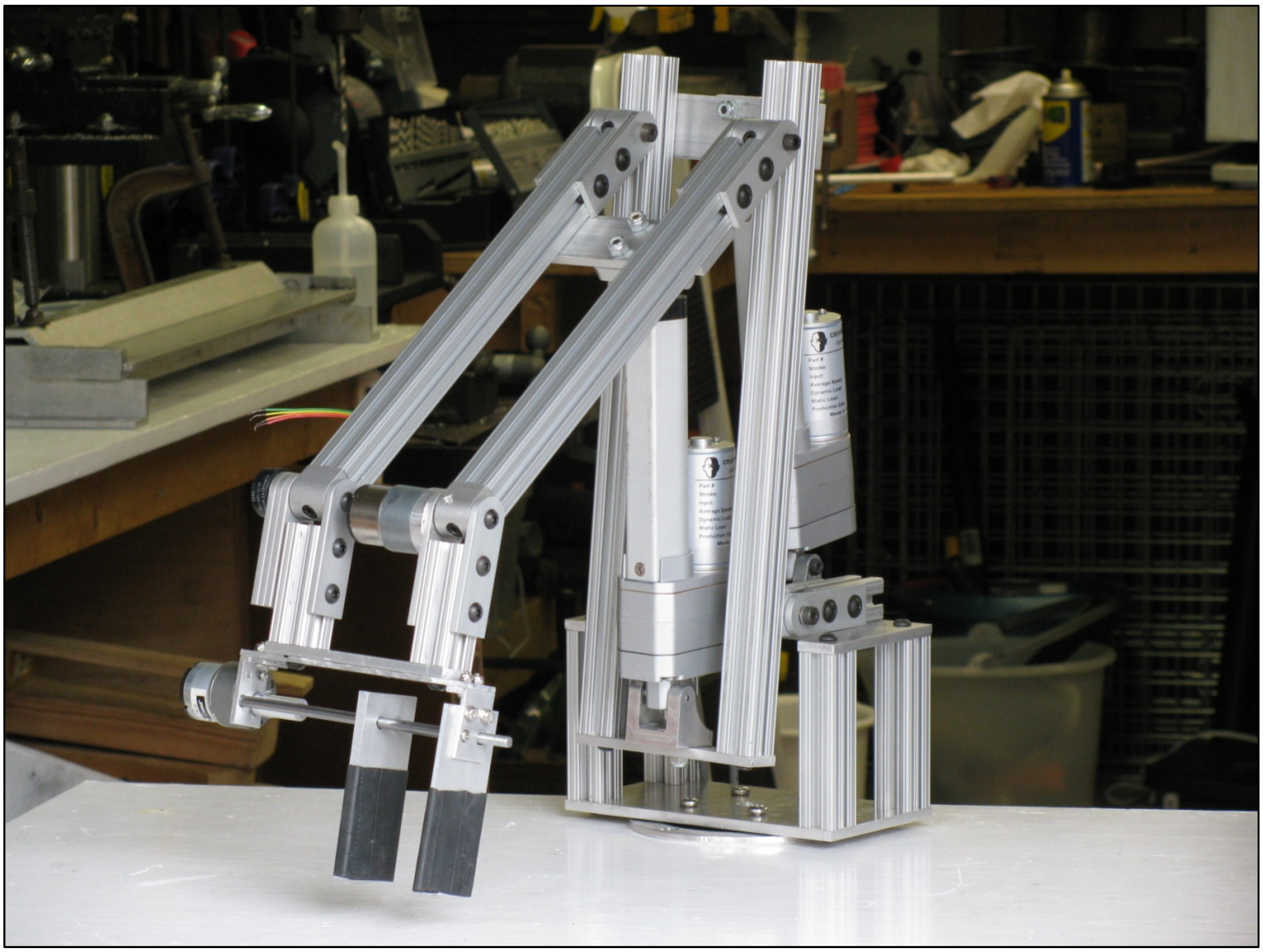
Technology Student Association

National Conference and Competitions

Electronic Research and Experimentation

Internet Controlled Robotic Arm



Baltimore, Maryland

June 28 – July 2, 2010

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Brief Description of Device

This year we began with the concept of creating an Internet controlled arm, operational from any Internet-enabled computer. To succeed in creating this project we focused on three main areas essential to the operation of the arm which were design, construction, and intricate programming, all of which led to the development of the prototype we have on display.

In designing the arm, we utilized Computer Aided Design, or CAD. By first making a three-dimensional assembly, we were able to avoid basic mechanical flaws, enabling us to reconfigure without reconstructing. The design was modeled after the basic principles used in the construction of cranes, yet adapted to a smaller scale, reducing the materials and weight required to meet the goals of the arm.

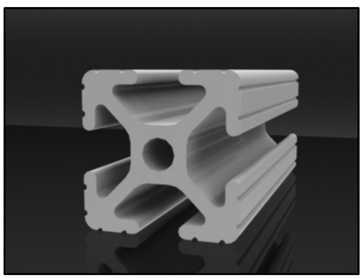


Image 1: *CAD Rendering of the Shape of 80-20 Aluminum.*

The primary material used in the fabrication of the arm was aluminum. Aluminum is lightweight but strong and provides a rigid, parallel structure. To further strengthen the arm we utilized a specific brand of aluminum known as 80-20. The 80-20 is a 6061 aluminum alloy with an anodized finish, but it is the shape of the 80-20 that most increases the strength of the arm. This unique cross section is designed to have mass where stresses are greatest while making it possible to use the voids for connectors and adaptions.

In the process of the arm's development, the programming contained the most complexity. Accomplishing computer-to-circuit-to-arm communications required a variety of different programming languages. After utilizing these codes to make the individual programs, it was essential to make a communication protocol that made the programs act succinctly. This took hours of work and continuous program development with additional time spent troubleshooting.

By breaking our project down into design, construction, and programming we were able to reach our goal and assemble a sturdy, functioning arm.

Project Applications

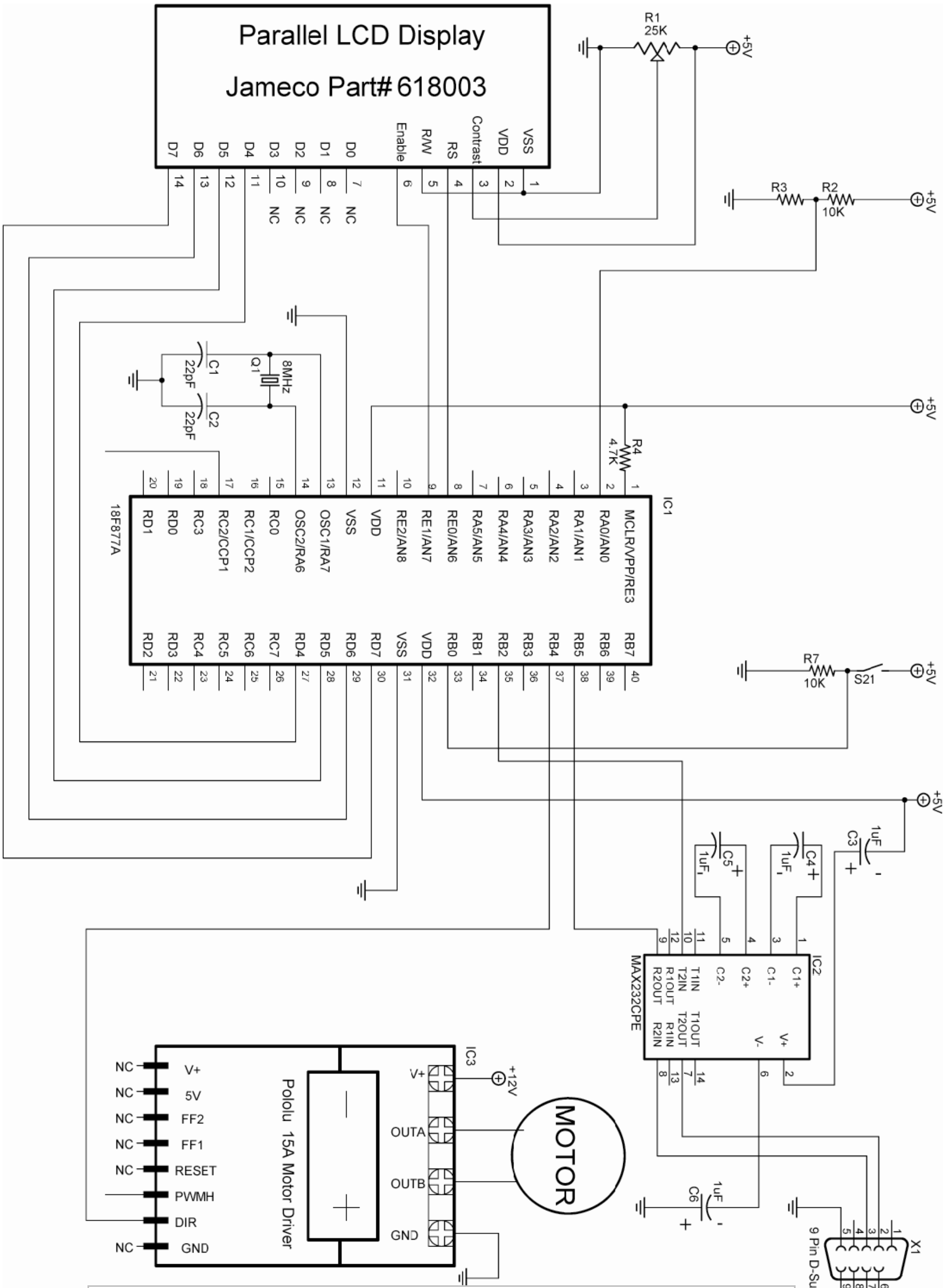
Mechanical arms are a basic necessity in many robotic applications. A functional robot is usually equipped with some sort of arm that utilizes a gripper or a claw device, enabling the robot to accomplish a wider variety of different tasks. From this starting point there were several different applications for an Internet controlled robotic arm.

It was immediately apparent that this kind of robot would be ideally suited for several different types of medical applications. When we began researching, we found several examples of robots capable of precise movements while being controlled remotely from a distance. This would allow specialists in particular surgeries to be able to perform out-of-country operations without even having to leave their location. This could provide more immediate results for many different types of surgeries.

In commercial industries, this kind of robot would be extremely useful with a human interface. It would be very lucrative for international manufacturers to have a robot that could be controlled from a distance from the actual area of production. This would allow wireless access to the robot and bypass hazards in areas unsafe to humans. It would also allow for centralization of industrial processors which increases efficiency in production. Industrial applications and designs could vary, but the basic idea of Internet communication would be valuable and effective.

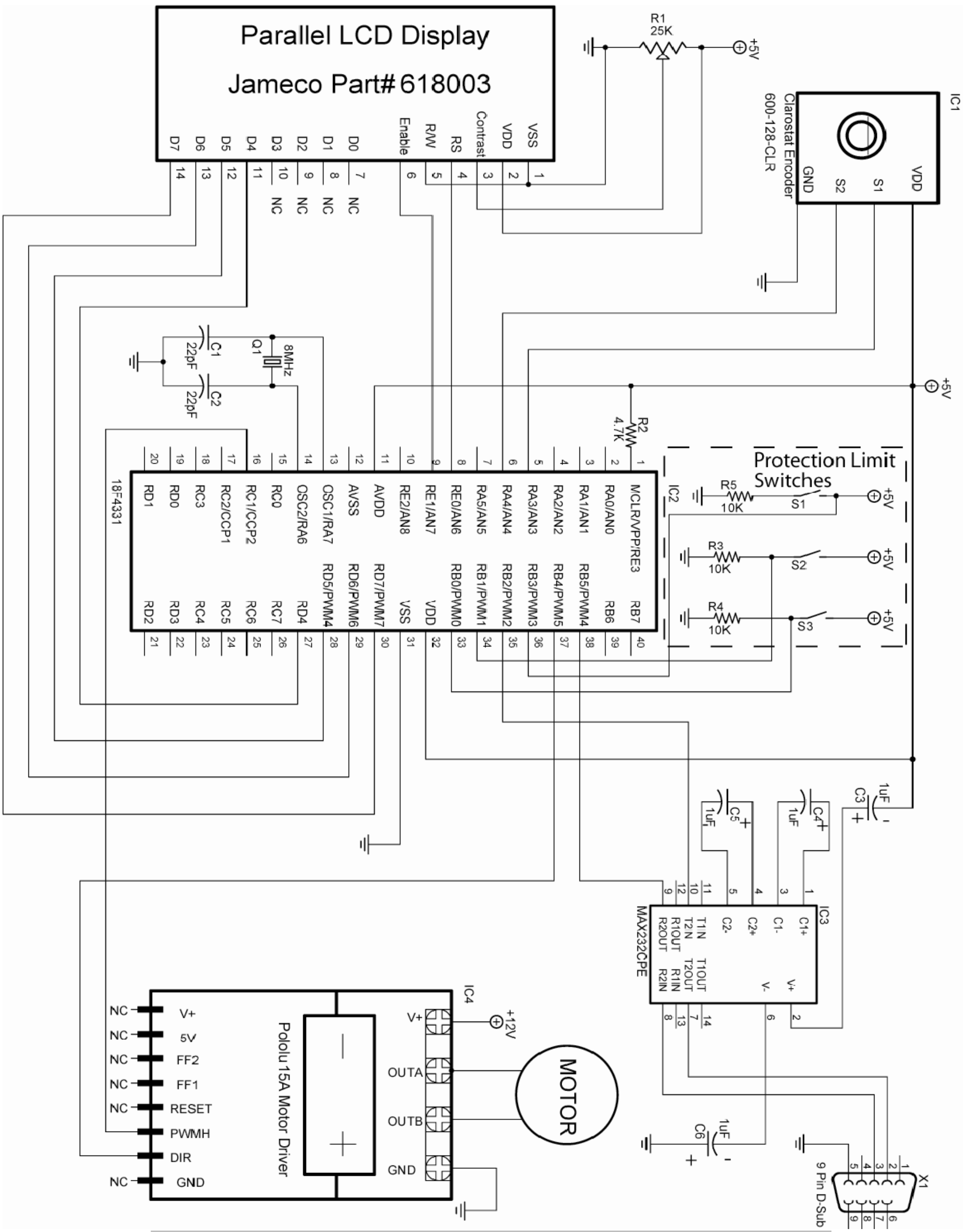
Whether via satellite, hard line, or Wi-Fi, the Internet is accessible from almost anywhere on the planet. It is because of this availability that the Internet has grown so swiftly and facilitated many technological advances. By utilizing the Internet's capabilities, we will be able to control this robot from almost anywhere in the world to accomplish a variety of specialized applications.

Schematics and Diagrams (1)



Schematic 1: The electrical circuit used to operate the motor that opens or closes the gripper.

Schematics and Diagrams (2)



Schematic 2: The Wrist Joint Electrical Schematic. Included Are The PIC Microcontroller, The Encoder, The Motor Driver, And The Motor.

Evidence of Experimentation

Components:

The circuit of the Internet arm consists of several types of components that interact with each other to make the arm move. The first component is the brains of the arm which consists of four Programmable Integrated Circuits, or PIC Microcontrollers. Another type is the MAX32CPE RS-232 serial driver/receiver which lets the PIC microcontrollers receive commands from the server. The third type of component in the circuit is the motor drivers. These permit the PIC microcontroller to move the motors. The final type of component of the arm is the position sensors and limit switches. These allow the PIC microcontrollers to detect the positions of the motors and prevent the arm from injuring itself.

These components interact in various ways. When the circuit sends commands to the server, the server sends this to the RS232 integrated circuit (IC). The RS232 IC receives commands from the server and forwards them to PIC microcontroller. The microcontroller then moves the motors in the correct direction, using the position sensors to keep track of how much they have moved and how much further they have to go. If while the motors are moving one of the limit switches is triggered, the arm ceases its movements and waits for a command to reverse.

Ideas and Testing:

When constructing the circuit initially, we did not know which sensors we would be using. This led to experimenting with the different types of sensors and microcontrollers to fit these sensors. The first sensor with which we experimented was the position sensor. We also had to experiment with different PIC microcontrollers to fit our position sensors. Finally we experimented with limit switches and their placement for complete motor overload protection. In our initial mechanical design we intended to use motors at each joint, which would only require rotational sensing. In order to detect the position of each motor we chose to use quadrature encoder position sensors. As different encoders have different resolutions, we had to experiment with several different models to determine which best fit our needs. We had three different models of encoders to test. The first was a VEX optical shaft encoder. We also had a Honeywell Clarostat 600-128-CBL encoder and finally a few 48 slot encoder wheels and readers for them. This resulted in a design change to use two linear actuators and three normal motors instead of five motors. The linear actuators have built in potentiometer position sensors which completely eliminated the use of our other encoders on them.

In this process, we found the PIC18F4331 microcontroller we had to use for encoders required more complex programming for analog to digital conversion (ADC) than we were used to. We could not merely define the justification of the bits and then which ports were analog to input from them. When we tried this initially we could only read one port if the ports were adjacent. We tested multiple configurations of the circuit to try to get this microcontroller to function as we intended.

After we had all of the hardware developed we worked on preventing the arm from overloading the motors by pushing against the table or some other immovable object. Limit switches proved to be the most efficient solution. We used several different types of switches to achieve maximum protection. The linear actuators had built in limit switches so there was no need for extra limit switches. The turntable had lever switches which were also available for use.

Analysis:

We tested all of these different components of the circuit, and in time we found results. The VEX optical shaft encoders were too large and bulky to be easily mounted where we needed them on the arm. The Honeywell Clarostat 600-128-CBL encoder was small and easily mounted, but it had a 200 rpm limit which would not have worked for our turntable motor. We were able to use it for the wrist of the arm, because it only moves at 4.5 rpm. The slotted wheel method was perfect for the turntable motor. We were able to mount it onto the shaft of the motor and read the positions of a 2500 rpm motor. In the end, we ended up using two of our three possibilities for the encoder.

After further research on the PIC18F4331 microcontroller, we discovered that ADC is dealt with in groups rather than individual ports like most other PIC microcontrollers. We could have input through groups rather than ports, but since this is less common than most other PIC microcontrollers it makes the code more difficult to read. As code reliability is important in any application, we decided to switch microcontrollers to the PIC16F877A, which has the normal PIC microcontroller ADC syntax. This solved our problems with ADC completely.

When testing limit switch positions we discovered that placing two limit switches on the very end of the gripper would best prevent table impact. One other limit switch was necessary to detect when the gripper was fully open, and two more were needed to prevent the wrist from over extending itself. The linear actuators had built-in limit switches and the turntable switches proved to be the most convenient and fortunately were placed such that they could be soldered to without any modification. Mounting separate limit switches would have been far more complicated to mount and less cost effective.

Plan of Work Log

Date	Task & Comments	Time	Team
9/10/2009-9/21/2009	We worked on CAD designs for the arm, we sketched the connecting base plates for the joints on Solidworks. Also included was a Delrin CAD. The main components we selected were aluminum, delrin, and 80/20 because of their light weight and strength. We began GUI encoder programming, changed an osscilator out. We made a simple GUI with Swing JAVA	6 Hours	King Shepard Sorrels Spencer
10/8/2009	Completed part two of the rotational base for the internet arm. We also worked on a second gripper prototype.	3 Hours	King Shepard
10/26/2009-10/29/2009	We started the server-side Java program, creating comunication protocol. Working on serial communication with the PIC microcontroller. We are currently using a socket to communicate over a LAN. We worked further on the user side communications (GUI) for the internet arm. We established new panels and began layout, but had difficulty with the layout. We redrilled and remounted the base motor. Also, the platform was cut to regulation size, and two 30 degree angles were cut to fit the posterboard. We worked further on serial communications and learned how to identify necassary ports.	6.5 Hours	King Shepard Spencer
11/19/2009	We succesfully programmed serial communication link to operate servo	3 Hours	Spencer
12/7/2009-12/10/2009	Testing: we were able to turn a servo motor via PIC microcontroller, and also flash an LED on and off from a PC. We assembled three main segment joints with modified hinges and created a skeleton frame of the arm on Solidworks and finished CAD work of the main table. We outputted the motor encoder target PIC microcontrollers from the PC. A motor controller H-bridge was blown out.	8.5 Hours	King Shepard Sorrels Spencer
12/14/2009-12/17/09	We fixed the motor drivers and worked on outputting integers over a LAN.We worked on designing CAD variations of the pulley design, for operating the arm. We successfully outputted a 16-bit number over the network to command a motor with an encoder. We were able to report the position back to the server.	5.5 hours	King Shepard Spencer
1/7/2010-1/14/2010	CAD designs continue to change, while the GUI and socket communication work continued. We constructed the base of the arm based on the CAD. From this a physical testing prototype was constructed. A motor position was outputted to a PIC microcontroller, but are having difficulties with multiple command strings.	10 Hours	King Shepard Spencer
1/18/2010-1/21/2010	We are having continuing problems with command strings, however have come close to solving it. Two motors now work with PIC Microcontrollers	6.5 Hours	Spencer
1/25/2010-1/28/2010	We have finally decided to switche the pulley system with linear actuators. The reduces PIC Micrcontrollers to two and two serial communicators. We have encoutered difficulties with which we can find no solution thus are continuing testing.	5.5 Hours	Shepard Spencer
2/1/2010-2/4/2010	We made design changes to account for the change to linear actuators. The CAD model was updated for changes.	5.5 Hours	Spencer
2/8/2010-2/12/2010	The computer we had been using for Pic Basic Programming had an unknown glitch when compiling.	6.5 Hours	Spencer
2/15/2010-2/18/2010	New serial ports were installed for more motor communication, and server protocol was made for receiving	7 Hours	Spencer
2/22/2010-2/25/2010	We mounted the third section of the arm on CAD and constructed the segment. Encountered Macro error with motor communication that has not been solved yet	6.5 Hours	King Spencer
3/1/2010-3/4/2010	The arm base was completed and cooling fans were added to the base for colling the electronics. The gripper for the arm, a leadscrew system, was mounted to the arm	7 Hours	Shepard Spencer
3/8/2010-3/11/2010	The final circuit was completed, but burned two LCDs out with high amperage. The fram of the arm with motors is completed, now we are placing sensors on specific areas of the arm.	8 Hours	Shepard Spencer
3/15/2010-3/18/2010	The finalised circuit was debugged and commands from computer work. We wired limit switches on the arm.	6 Hours	Spencer
3/22/2010-3/25/2010	Added astetics to the arm and worked on encoder brackts.	4.5 Hours	Shepard
4/1/2010-4/6/2010	Completed encoder and shaft brackets, set upt testing prototypes. Wrist limit switches programmed.	6 Hours	Shepard
4/8/2010-4/12/2010	Created brackets for specialised limit switches on the end of the arm and mounted on gripper plate	6 Hours	King Spencer
4/13/2010-4/18/2010	Began final documentation and poster, while programming limit switches and making final changes	7 Hours	King Spencer
4/19/2010-4/21/2010	Finalised the poster and technical report for the State Conference	10 Hours	King
5/3/2010-5/10/2010	Began work on the transition from LAN communication to Internet communication. We researched webcams for use on the arm, and ordered 3 Microsoft LifeCam Cinema webcams to begin experimenting with	8 Hours	King Spencer
5/10/2010-5/17/2010	Continued work on programming changes from LAN to Internet communication and also began work on the final housing for the arm inside of our shop.	7.5 Hours	Spencer
5/17/2010-5/24/2010	Successfully were able to control two of the motors of the arm over the internet. Received a new leadscrew for the gripper of the arm and adapted it to our existing gripper. This resulted in higher speed and a smoother running gripper	7 Hours	King Shepard Spencer
5/24/2010-5/31/2010	Were completely able to control the arm over the internet utilising the GUI. Now we have begun work on incoporating webcams into the GUI for remote control over the internet. The gripper is finished and work has begun again on the final housing of the arm	7.5 Hours	King Shepard Spencer
6/1/2010-6/8/2010	We began testing with webcams using JMF studio and FMJ studio; media java programs, possibly being adapted to transmit our webcams. However it can not trnasmit webcams that utilise the same driver, which means we must purchase two other webcams of different manufaturers.	8.5 Hours	Spencer
6/8/2010-6/15/2010	We have finished the final housing of the arm in the shop. We have stopped using JMF and FMJ studios and are writing our own programs, since these two programs are outdated, and non compatible.	10 Hours	King Shepard Spencer
6/15/2010-6/22/2010	Have made two webcams function over the GUI as well as reconfirmed that the arm works over the internet. We have begun working on documentation and posters; updating them from the state versions.	12 Hours	King Shepard Spencer

References

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Sun Microsystems. (2010b). *Java 6 API specification library.* Retrieved June 26, 2010, from: *http://java.sun.com/javase/6/docs/api/*

Resources

Dr. Tim Davis, University Professor of Computer Sciences

David Kundinger, Senior, Mechanical Engineering

Chris Kennedy, Senior, Aeronautical Engineering

Appendix A – CAD Drawings

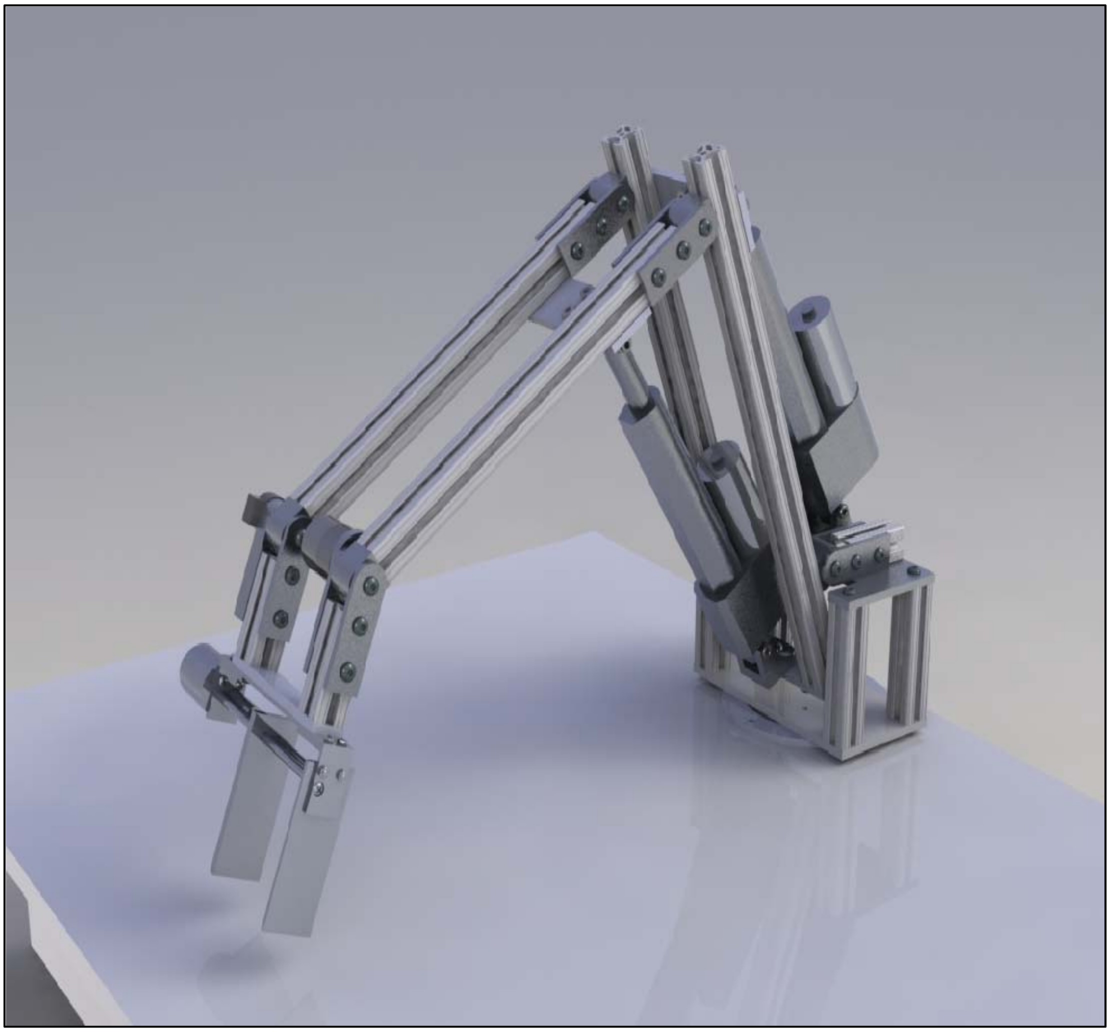
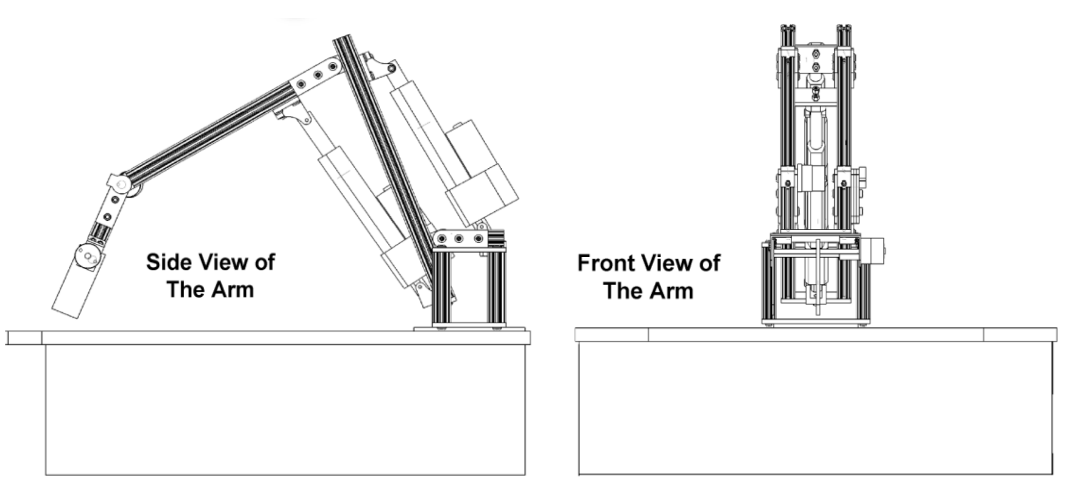
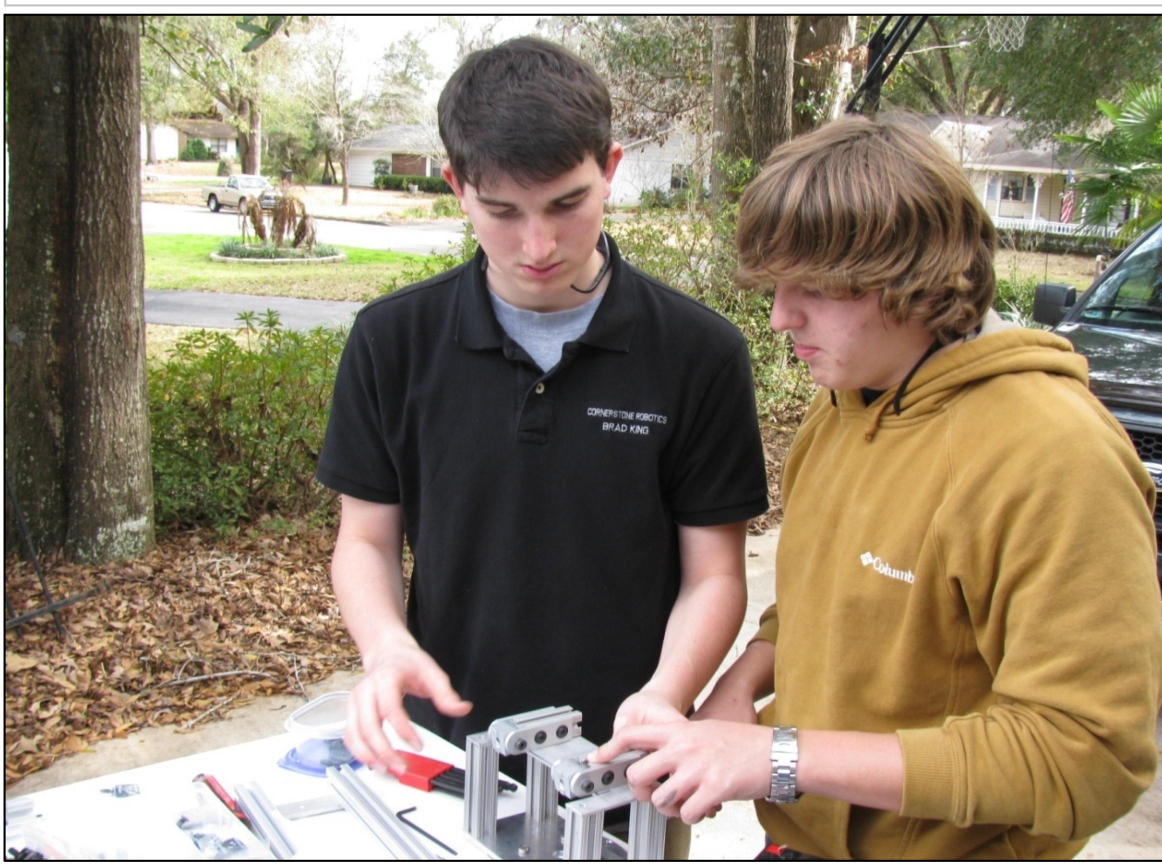


Image 2: *CAD Rendering Of The Final Arm*



Appendix B – Shop Photos

Image 3 (Above): Wiring The Electronics On The Arm.
Image 4 (Below): Beginning Production On The First Arm Prototype



Appendix B – Shop Photos (Continued)

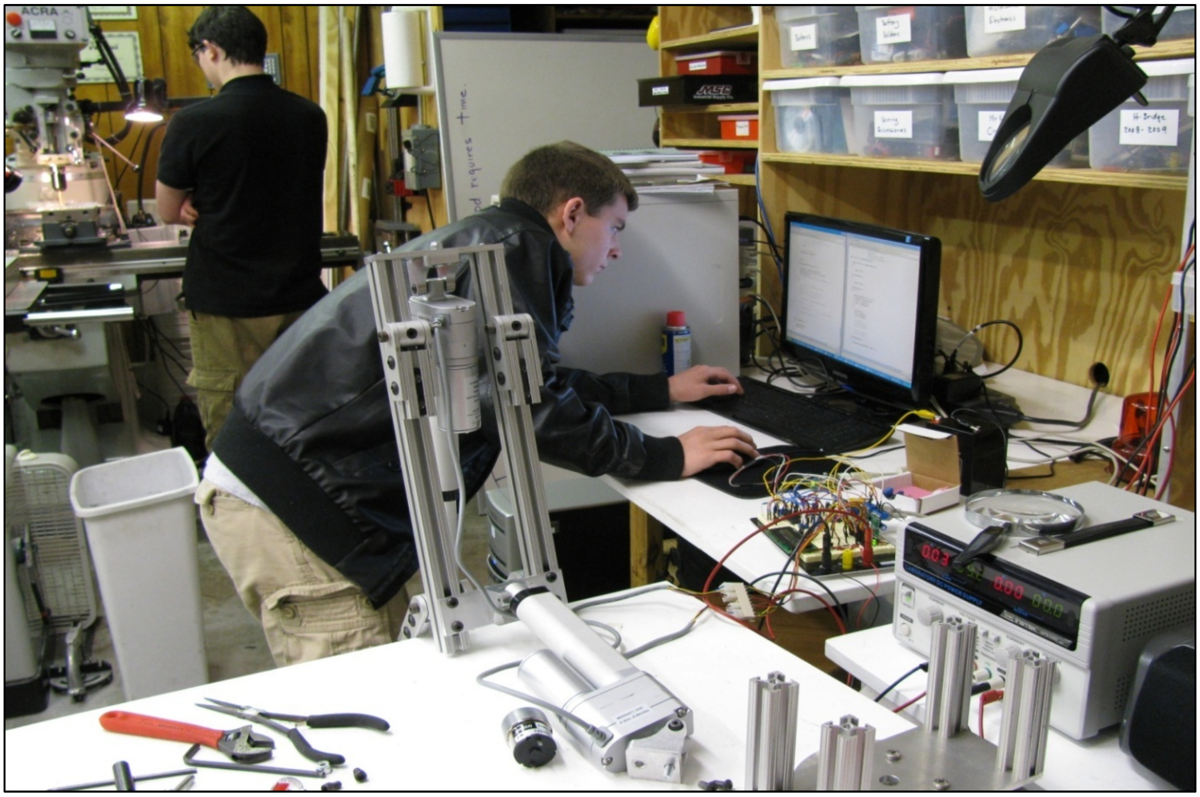
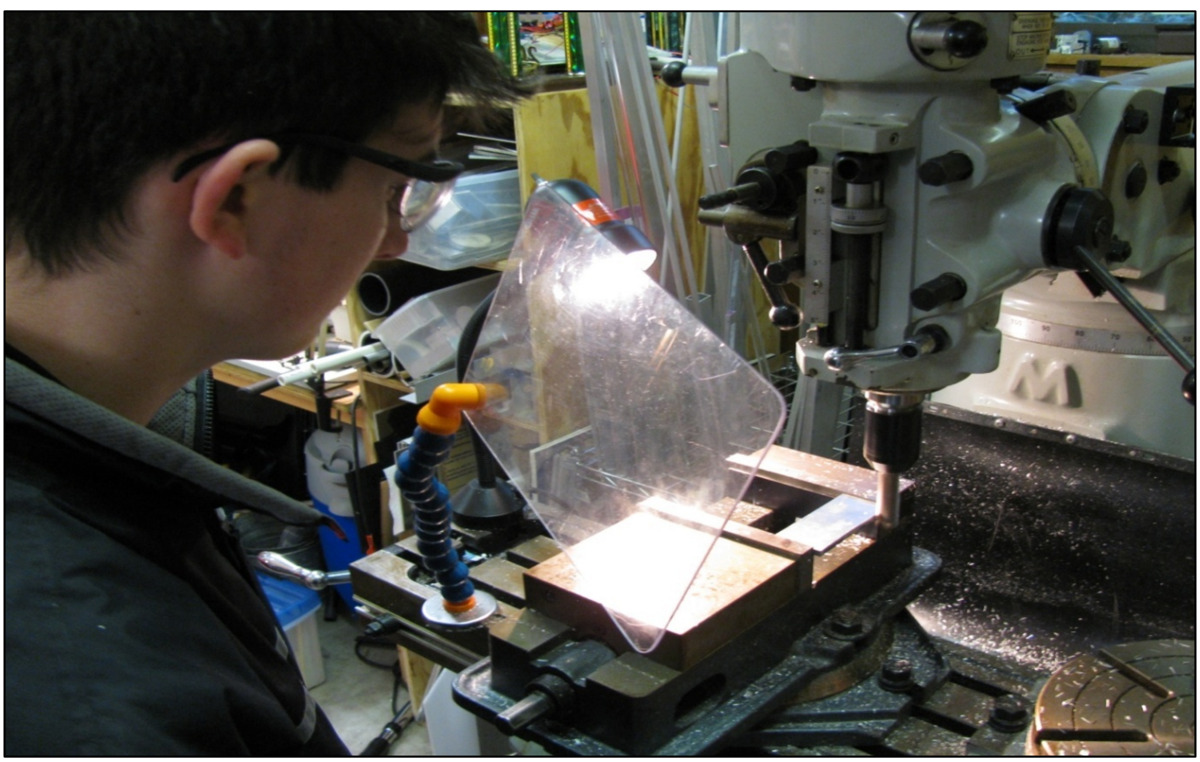


Image 5 (Above): Programming PIC Microcontroller To Control Linear Actuators.
Image 6 (Below): Continuing Production Of The arm Using The Mill.



Appendix B – Shop Photos (Continued)

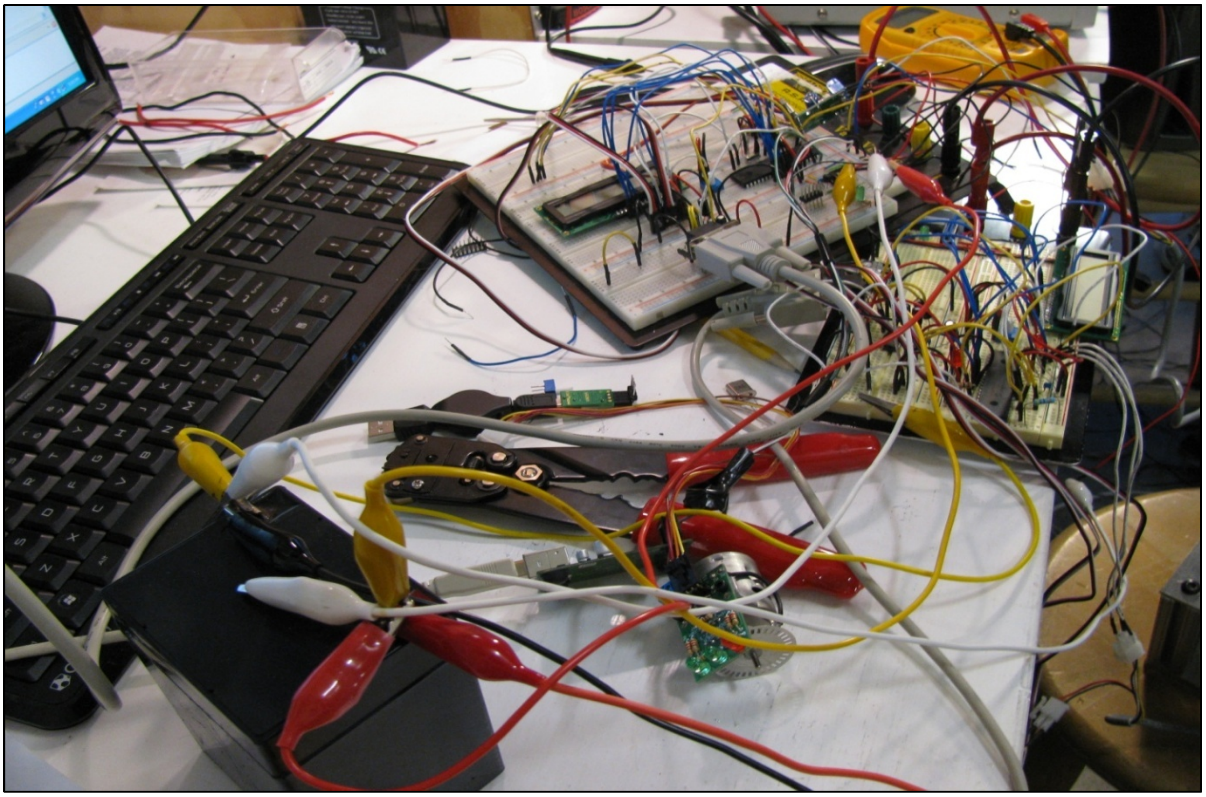
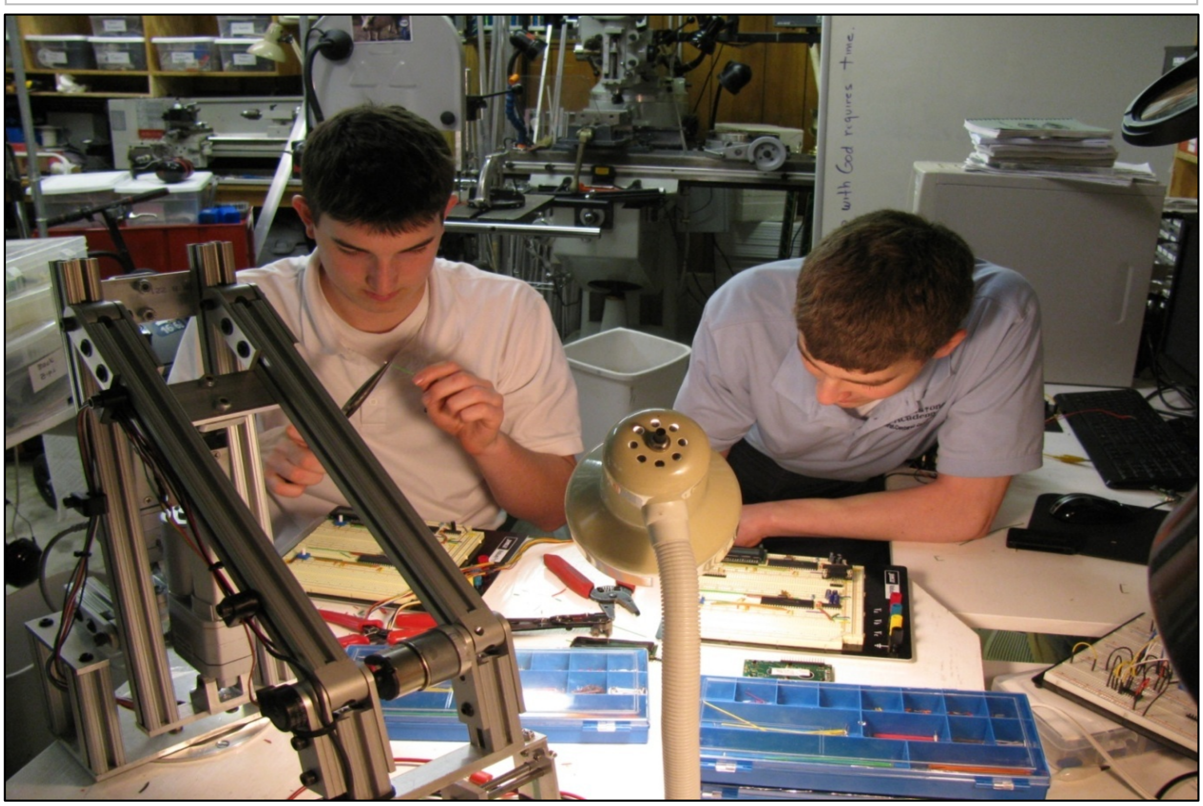


Image 7 (Above): Experimental Circuit For Controlling A Motor
Image 8 (Below): Making The Final Circuits On Breadboards



Appendix C – Linear Actuator Program

```
'---------------Title--------------

' File......877A_linearactuators.pbp
' Started....2/18/10
' Microcontroller used:  Microchip Technology 16F877A
'                        microchip.com
' PicBasic Pro Code: micro-Engineering Labs, Inc.
'                    melabs.com

'--------Program Desciption--------

' Program receives input from the server and
' moves the linear actuators to that position,
' decelerating as it approaches the target. The
' position of the linear actuators is determined
' using Analog-to-Digital conversion on the
' internal variable resistors in the linear
' actuators.

'---------PIC Connections----------

'       16F877A Pin            Wiring
'       ---------             ----------
'         AN0                 Actuator one variable resistor
'         AN1                 Actuator two variable resistor
'         RB3                 Direction for Actuator one on motor driver
'         RB4                 Direction for Actuator two on motor driver
'         RC1                 PWM for Actuator one on motor driver
'         RC2                 PWM for Actuator two on motor driver
'         MCLR                +5V through 4.7K Resistor
'         VDD                 +5V
'         VSS                 Ground
'         OSC1 & OSC2         8 MHz Crystal w/ 2-22 pF Cap. to GND

'-------------Defines--------------
    DEFINE OSC 8
    DEFINE LCD_DREG PORTD    ' Define LCD Data port as PORTD
    DEFINE LCD_DBIT 4        ' Set starting Data bit as RD4
    DEFINE LCD_BITS 4        ' Set LCD bus size as 4
    DEFINE LCD_RSREG PORTE   ' Set LCD Select Register port as PORTE
    DEFINE LCD_RSBIT 0       ' Select Select Register bit as RE0
    DEFINE LCD_EREG PORTE    ' Set LCD Enable port as PORTE
    DEFINE LCD_EBIT 1        ' Select Select Register bit as RE1
    DEFINE LCD_LINES 2       ' Set number of lines on display as 2
    DEFINE LCD_COMMANDUS 2000 ' Set command delay time in micro seconds
    DEFINE LCD_DATAUS 50     ' Set data delay time in micro seconds
    DEFINE ADC_BITS 10        ' Set number of bits in result as 8
    DEFINE ADC_CLOCK 3       ' Set clock source (rc = 3)
    DEFINE ADC_SAMPLEUS 50   ' Set sampling time in micro seconds
    DEFINE CCP2_REG PORTC    ' Set HPWM Channel 2 port to PORTC
    DEFINE CCP2_BIT 1        ' Set HPWM Channel 2 pin to RC1
    DEFINE CCP1_REG PORTC    ' Set HPWM Channel 1 port to PORTC
    DEFINE CCP1_BIT 2        ' Set HPWM Channel 1 pin to RC2

'------------Variables-------------
```

Appendix C – Linear Actuator Program (Continued)

```
    end_limit1       VAR    PORTB.0   ' End limit switch one pin
    end_limit2       VAR    PORTB.1   ' End limit switch two pin
    motor1_dx        VAR    PORTB.3   ' Direction pin for motor one
    motor2_dx        VAR    PORTB.4   ' Direction pin for motor two
    MODE             VAR    WORD      ' WORD for MODE value
    target1          VAR    WORD      ' 16bit WORD variable for target1 from
server
    target2          VAR    WORD      ' 16bit WORD variable for target2 from
server
    motor            VAR    BYTE      ' Motor variable for serial input
    hibyte           VAR    BYTE      ' Upper byte for serial input
    lobyte           VAR    BYTE      ' Lower byte for serial input
    hibyte1          VAR    BYTE      ' Upper byte for Actuator one
    lobyte1          VAR    BYTE      ' Lower byte for Actuator one
    hibyte2          VAR    BYTE      ' Upper byte for Actuator two
    lobyte2          VAR    BYTE      ' Lower byte for Actuator two
    mot_pwr1         VAR    BYTE      ' Actuator one power
    mot_pwr2         VAR    BYTE      ' Actuator two power
    position1        VAR    WORD      ' 10bit variable resistor Actuator one
                                      ' position
    position2        VAR    WORD      ' 10bit variable resistor Actuator two
                                      ' position
    diff1            VAR    WORD      ' Difference in position1 and target1
    diff2            VAR    WORD      ' Difference in position2 and target2
    PICSI            VAR    PORTB.2   ' Serial input pin as RB.2
    PICSO            VAR    PORTB.5   ' Serial output pin as RB.5

'----------Initialization----------

    ADCON1 = %10000100            ' Set AN0,AN1, and AN3 to analog, all other
                                  ' to digital

    CCP2CON = %00111111           ' Set CCP2 to PWM mode
    CCP1CON = %00111111           ' Set CCP1 to PWM mode

    TRISA = %11111111             ' Set all pins in PORTB as inputs

    TRISB = %00000000             ' Set all pins in PORTB as outputs
    PORTB = 0
    TRISC = %00000000             ' Set all pins in PORTC as outputs
    PORTC = 0

    mode = 84                     ' Set RX/TX speed to 84 (9600 baud)

    hibyte1 = 0                   ' Initialize all of the variables
    lobyte1 = 0
    hibyte2 = 3
    lobyte2 = 232
    mot_pwr1 = 0
    mot_pwr2 = 0
'-------------Main Code------------
initial:

    PAUSE 500                     ' Start up LCD
```

Appendix C – Linear Actuator Program (Continued)

```
main:
    ' Set targets
    target1 = hibyte1*256 + lobyte1
    target2 = hibyte2*256 + lobyte2

    ' Check limit switches
    IF end_limit1 = 1 OR end_limit2 = 1 THEN GOTO stop1

    ADCIN 0, position1  ' Read position of Actuator one
    ADCIN 1, position2  ' Read position of Actuator two

    ' Set direction of motors
    IF target1 < position1 THEN
        motor1_dx = 0
        diff1 = position1 - target1
    ELSE
        motor1_dx = 1
        diff1 = target1 - position1
    ENDIF

    IF target2 < position2 THEN
        motor2_dx = 0
        diff2 = position2 - target2
    ELSE
        motor2_dx = 1
        diff2 = target2 - position2
    ENDIF

    ' Move the actuators at a determined motor power
    SELECT CASE diff1
        CASE IS <= 10
            mot_pwr1 = 0
            HPWM 1,mot_pwr1,20000
        CASE IS > 100
            mot_pwr1 = 255
            HPWM 1,mot_pwr1,20000
        CASE IS < 100
            mot_pwr1 = 2*diff1+55
            HPWM 1,mot_pwr1,20000
    END SELECT

    SELECT CASE diff2
        CASE IS <= 10
            mot_pwr2 = 0
            HPWM 2,mot_pwr2,20000
        CASE IS > 100
            mot_pwr2 = 255
            HPWM 2,mot_pwr2,20000
        CASE IS < 100
            mot_pwr2 = 2*diff2+55
            HPWM 2,mot_pwr2,20000
    END SELECT

    GOTO lcd
```

Appendix C – Linear Actuator Program (Continued)

```
    END

lcd:
    ' Output targets and positions
    LCDOUT $FE, 1
    LCDOUT $FE, $80, "T1=",DEC4 target1," Ps1=", DEC4 position1
    LCDOUT $FE, $C0, "T2=",DEC4 target2," Ps2=", DEC4 position2

GOTO serial_input

serial_input:
    ' Check for input from the server
    SERIN2 PICSI, Mode, 10, main, [WAIT(":"),motor,hibyte,lobyte]

    IF motor = 1 THEN
        hibyte1 = hibyte
        lobyte1 = lobyte
    ENDIF

    IF motor = 2 THEN
        hibyte2 = hibyte
        lobyte2 = lobyte
    ENDIF

    target1 = hibyte1*256 + lobyte1
    target2 = hibyte2*256 + lobyte2

GOTO main

stop1:
    ' Stop if a limit switch is triggered and wait for a reverse commmand
    mot_pwr1 = 0
    mot_pwr2 = 0
    WHILE end_limit1 = 1 OR end_limit2 = 1
        ADCIN 0, position1
        ADCIN 1, position2
        IF target1 < position1 THEN
            motor1_dx = 0
            mot_pwr1 = 255
            HPWM 1, mot_pwr1, 20000
            GOTO lcd
        ENDIF

        IF target2 > position2 THEN
            motor2_dx = 1
            mot_pwr2 = 255
            HPWM 2, mot_pwr2, 20000
            GOTO lcd
        ENDIF

        HPWM 1, mot_pwr1, 20000
        HPWM 2, mot_pwr2, 20000

        LCDOUT $FE, 1
        LCDOUT $FE, $80, "T1=",DEC4 target1," Ps1=", DEC4 position1       '
Display speed
```

Appendix C – Linear Actuator Program (Continued)

```
        LCDOUT $FE, $C0, "T2=",DEC4 target2," Ps2=", DEC4 position2

        SERIN2 PICSI, Mode, 100, stop1, [WAIT(":"),motor,hibyte,lobyte]

        IF motor = 1 THEN
            hibyte1 = hibyte
            lobyte1 = lobyte
        ENDIF

        IF motor = 2 THEN
            hibyte2 = hibyte
            lobyte2 = lobyte
        ENDIF

        target1 = hibyte1*256 + lobyte1
        target2 = hibyte2*256 + lobyte2
    WEND

    GOTO main
```

Appendix D – Gripper Motor Program

```
'---------------Title--------------

' File......877A_gripper.pbp
' Started....3/16/10
' Microcontroller used:  Microchip Technology 16F877A
'                        microchip.com
' PicBasic Pro Code: micro-Engineering Labs, Inc.
'                    melabs.com

'--------Program Desciption--------

' The gripper is initialized to the open position
' and then the program waits for serial input from
' the server. If the input is the value 158 then
' the gripper will open if closed, and if the value
' is 246 the gripper will close if open. If

'---------PIC Connections----------

'       16F877A Pin             Wiring
'       ---------             ----------
'         AN0                 Pressure Sensor
'         RB4                 Direction pin on motor driver
'         RC1                 PWM Motor 1 on motor driver
'         MCLR                +5V through 4.7K Resistor
'         VDD                 +5V
'         VSS                 Ground
'         OSC1 & OSC2         8 MHz Crystal w/ 2-22 pF Cap. to GND

'-------------Defines--------------
   DEFINE OSC 8                 ' Define the oscillator at 8 MHZ
   DEFINE LCD_DREG PORTD        ' Define LCD Data port as PORTD
   DEFINE LCD_DBIT 4            ' Set starting Data bit as RD4
   DEFINE LCD_BITS 4            ' Set LCD bus size as 4
   DEFINE LCD_RSREG PORTE       ' Set LCD Select Register port as PORTE
   DEFINE LCD_RSBIT 0           ' Select Select Register bit as RE0
   DEFINE LCD_EREG PORTE        ' Set LCD Enable port as PORTE
   DEFINE LCD_EBIT 1            ' Select Select Register bit as RE1
   DEFINE LCD_LINES 2           ' Set number of lines on display as 2
   DEFINE LCD_COMMANDUS 2000    ' Set command delay time in micro seconds
   DEFINE LCD_DATAUS 50         ' Set data delay time in micro seconds
   DEFINE ADC_BITS 10           ' Set number of bits in result as 8
   DEFINE ADC_CLOCK 3           ' Set clock source (rc = 3)
   DEFINE ADC_SAMPLEUS 50       ' Set sampling time in micro seconds
   DEFINE CCP2_REG PORTC        ' Set HPWM Channel 2 port to PORTC
   DEFINE CCP2_BIT 1            ' Set HPWM Channel 2 pin to RC1
   DEFINE CCP1_REG PORTC        ' Set HPWM Channel 1 port to PORTC
   DEFINE CCP1_BIT 2            ' Set HPWM Channel 1 pin to RC2

'------------Variables-------------

   motor1_dx         VAR    PORTB.4   ' Motor direction pin
   MODE              VAR    WORD      ' WORD for MODE value
   gripper_Action    VAR    BYTE      ' Variable target set up as a BYTE
   motor             VAR    BYTE      ' Motor input variable
```

Appendix D – Gripper Motor Program (Continued)

```
    mot_pwr1          VAR   BYTE      ' PWM motor power
    pressure_sensor   VAR   WORD      ' 16bit WORD pressure sensor value
    limit_switch1     VAR   PORTB.3   ' Open limit switch pin
    PICSI             VAR   PORTB.2   ' Input from serial conneciton pin
    PICSO             VAR   PORTB.5   ' Output to serial connection pin

'----------Initialization----------
    ADCON1  = %10001110            ' Set AN0 to analog, all other to digital
    CCP2CON = %00111111            ' Set CCP2 to PWM mode
    CCP1CON = %00111111            ' Set CCP1 to PWM mode

    TRISA = %11111111              ' Set TRISA register, all ports as inputs

    TRISB = %00001000              ' Set RB.3 to input, all others outputs
    PORTB = 0                      ' Set PORTB to 0V
    TRISC = %00000000              ' Set all pins in PORTC as outputs
    PORTC = 0                      ' Set PORTC to 0V

    mode = 84                      ' Set RX/TX speed to 84 (9600 baud)
    gripper_Action = 158           ' Set gripper_Action variable to 158, or
open
    mot_pwr1 = 0                   ' Set motor power to zero
'-------------Main Code------------

    PAUSE 500                      ' Start up LCD

main:
    ADCIN 0, pressure_sensor       ' Convert the analog value of the pressure
                                   ' sensor on AN0 to a 10bit digital value

    ' Check if the gripper is open or closed
    IF pressure_sensor < 800 THEN GOTO stop1

    IF limit_switch1 = 1 THEN GOTO stop2

    ' Determine gripper action
    IF gripper_Action = 158 THEN
        motor1_dx = 1
        mot_pwr1  = 255
        HPWM 1, mot_pwr1, 20000
        GOTO lcd1
    ENDIF

    IF gripper_Action = 247 THEN
        motor1_dx = 0
        mot_pwr1  = 255
        HPWM 1, mot_pwr1, 20000
        GOTO lcd2
    ENDIF

    GOTO main                      ' Return to main

    END

lcd1:
```

Appendix D – Gripper Motor Program (Continued)

```
    ' Output sensor data and current status - in this case opening
    LCDOUT $FE, 1
    LCDOUT $FE, $80, "Input = ", DEC3 gripper_Action, " OG"       ' Display
speed
    LCDOUT $FE, $C0, "Pressure = ", DEC4 pressure_sensor
    ADCIN 0, pressure_sensor
    SERIN2 PICSI, Mode, 10, main, [WAIT(":"),motor,gripper_Action]
    GOTO main

lcd2:
    ' Output sensor data and current status - in this case closing
    LCDOUT $FE, 1
    LCDOUT $FE, $80, "Input = ", DEC3 gripper_Action, " CG"     ' Display
speed
    LCDOUT $FE, $C0, "Pressure = ", DEC4 pressure_sensor

    ' Check for input from the server
    SERIN2 PICSI, Mode, 10, main, [WAIT(":"),motor,gripper_Action]
    GOTO main

stop1:
    x = 0
    WHILE pressure_sensor < 700
        ADCIN 0, pressure_sensor
        IF gripper_Action = 158 THEN
            motor1_dx = 1
            mot_pwr1 = 255
            HPWM 1, mot_pwr1, 20000
            GOTO lcd1
        ENDIF

        HPWM 1, 0, 20000

        ' Output sensor data and current status - in this case closed
        LCDOUT $FE, 1
        LCDOUT $FE, $80, "Input = ", DEC3 gripper_Action, " C"      '
Display speed
        LCDOUT $FE, $C0, "Pressure = ", DEC4 pressure_sensor

        ' Check for input from the server
        SERIN2 PICSI, Mode, 10, stop1, [WAIT(":"),motor,gripper_Action]
    WEND
    GOTO main
stop2:
    x = 0
    WHILE limit_switch1 = 1
        ADCIN 0, pressure_sensor
        IF gripper_Action = 247 THEN
            motor1_dx = 0
            mot_pwr1  = 255
            HPWM 1, mot_pwr1, 20000
            GOTO lcd2
        ENDIF
```

Appendix D – Gripper Motor Program (Continued)

```
    HPWM 1, 0, 20000

    ' Output sensor data and current status - in this case open
    LCDOUT $FE,1
    LCDOUT $FE, $80, "Input = ", DEC3 gripper_Action, " O"
    LCDOUT $FE, $C0, "Pressure = ", DEC4 pressure_sensor

    ' Check for input from the server
    SERIN2 PICSI, MODE, 10, stop2, [WAIT(":"),motor,gripper_Action]
WEND
GOTO main
```

Appendix E – JAVA Arm Server

```
/**
 * Class ArmServer recieves the connection request from the Client class and
 * sends the data recieved on the socket to the processInput() method of the
 * ArmPrototcol class
 *
* @version 19 April 2010
 */

import java.net.*;
import java.io.*;

public class ArmServer
{
   //Define variables
   public static String inputLine;

   /**
    * Main method
    */
   public static void main(String[] args) throws IOException
   {
      System.out.println("Initializing");

      //Initialize the socket connection

      ServerSocket serverSocket = null;
      try
      {
         serverSocket = new ServerSocket(4444);
      }
      catch (IOException e)
      {
         System.err.println("Could not listen on port: 4444.");
         System.exit(1);
      }

      Socket clientSocket = null;

      try
      {
         clientSocket = serverSocket.accept();
```

```
}
catch (IOException e)
{
   System.err.println("Accept failed.");
   System.exit(1);
}

//Initialize the input and output streams for the socket connection

PrintWriter out = new PrintWriter(clientSocket.getOutputStream(), true);

BufferedReader in = new BufferedReader
(
   new InputStreamReader
   (
      clientSocket.getInputStream()
   )
);

//Establlish arm_protocol object

ArmProtocol arm_protocol = new ArmProtocol();

//Recieve input and process it

while ((inputLine = in.readLine()) != null)
{
   System.out.println("Client: " + inputLine);
   String delims = "[ ]+";
   String[] positions = inputLine.split(delims);
   for(int i = 0; i < positions.length; i++)
   {
      System.out.println(i + ": " + positions[i]);
   }
   arm_protocol.processInput(positions);
}

//Close the socket and the streams

System.out.println("Closing");
out.close();
in.close();
clientSocket.close();
serverSocket.close();
```

```
    }
}
```

Appendix F – JAVA Server Protocol

```
/**
 * Class ArmProtocol recieves the data from class ArmServer and
 * sends it through the RS232 serial COM ports to the microcontrollers
 *
 * @version 19 April 2010
 */
import gnu.io.CommPort;
import gnu.io.CommPortIdentifier;
import gnu.io.SerialPort;
import gnu.io.SerialPortEvent;
import gnu.io.SerialPortEventListener;

import java.io.*;
import java.io.IOException;
import java.io.InputStream;
import java.io.OutputStream;

import java.net.*;

public class ArmProtocol
{
   //instance variables
   int[] oldPositions;

   SerialPort serialPort1,serialPort2,serialPort3,serialPort4;
   InputStream in1, in2, in3, in4;
   OutputStream out1, out2, out3, out4;
   /**
    * Constructor for ArmProtocol objects
    */
   ArmProtocol()
   {
      oldPositions = new int[4];

      for(int position : oldPositions)
      {
         position = 0;
      }

      try
      {
```

```
      connect("COM1");
    }
    catch(Exception e){}

    try
    {
      connect("COM2");
    }
    catch(Exception e){}

    try
    {
      connect("COM7");
    }
    catch(Exception e){}

    try
    {
      connect("COM8");
    }
    catch(Exception e){}
  }
  /**
   * Method connect initializes the COM port identified in portName
   *
   * @param portName Port to be initialized
   * @return void
   */
  void connect ( String portName) throws Exception
  {
    CommPortIdentifier portIdentifier = CommPortIdentifier.getPortIdentifier(portName);
    if ( portIdentifier.isCurrentlyOwned() )
    {
      System.out.println("Error: Port is currently in use");
    }
    else
    {
      if(portName.equalsIgnoreCase("COM1"))
      {
        CommPort commPort = portIdentifier.open("PIC1",2000);
        if ( commPort instanceof SerialPort )
        {
          System.out.println("Setting up COM1");
          serialPort1 = (SerialPort) commPort;
```

```
serialPort1.setSerialPortParams(9600,SerialPort.DATABITS_8,SerialPort.STOPBITS_1,SerialPor
t.PARITY_NONE);

          in1 = serialPort1.getInputStream();
          out1 = serialPort1.getOutputStream();

          serialPort1.addEventListener(new SerialReader(in1));
          serialPort1.notifyOnDataAvailable(true);
        }
        else
        {
          System.out.println("Error: Only serial ports are handled by this example.");
        }
      }
      if(portName.equals("COM2"))
      {
        CommPort commPort = portIdentifier.open("PIC2",2000);
        if ( commPort instanceof SerialPort )
        {
          System.out.println("Setting up COM2");
          serialPort2 = (SerialPort) commPort;

serialPort2.setSerialPortParams(9600,SerialPort.DATABITS_8,SerialPort.STOPBITS_1,SerialPor
t.PARITY_NONE);

          in2 = serialPort2.getInputStream();
          out2 = serialPort2.getOutputStream();

          serialPort2.addEventListener(new SerialReader(in2));
          serialPort2.notifyOnDataAvailable(true);
        }
        else
        {
          System.out.println("Error: Only serial ports are handled by this example.");
        }
      }
      if(portName.equals("COM7"))
      {
        CommPort commPort = portIdentifier.open("PIC3",2000);
        if ( commPort instanceof SerialPort )
        {
          System.out.println("Setting up COM7");
          serialPort3 = (SerialPort) commPort;
```

```
serialPort3.setSerialPortParams(9600,SerialPort.DATABITS_8,SerialPort.STOPBITS_1,SerialPor
t.PARITY_NONE);

          in3 = serialPort3.getInputStream();
          out3 = serialPort3.getOutputStream();

          serialPort3.addEventListener(new SerialReader(in3));
          serialPort3.notifyOnDataAvailable(true);
        }
        else
        {
          System.out.println("Error: Only serial ports are handled by this example.");
        }
      }
      if(portName.equals("COM8"))
      {
        CommPort commPort = portIdentifier.open("PIC4",2000);
        if ( commPort instanceof SerialPort )
        {
          System.out.println("Setting up COM8");
          serialPort4 = (SerialPort) commPort;

serialPort4.setSerialPortParams(9600,SerialPort.DATABITS_8,SerialPort.STOPBITS_1,SerialPor
t.PARITY_NONE);

          in4 = serialPort4.getInputStream();
          out4 = serialPort4.getOutputStream();

          serialPort4.addEventListener(new SerialReader(in4));
          serialPort4.notifyOnDataAvailable(true);
        }
        else
        {
          System.out.println("Error: Only serial ports are handled by this example.");
        }
      }
    }
  }
  /**
   * Class SerialReader recieves any input from the PIC microcontrollers.
   * It is currently unused as communication only is transmitted, not
   * recieved.
   */
```

```
public static class SerialReader implements SerialPortEventListener
{
   private InputStream in;

   /**
    * Constructor for SerialReader objects
    */
   public SerialReader ( InputStream in )
   {
      this.in = in;
   }

   /**
    * Method serialEvent processes any data recieved from the COM ports
    *
    * @param arg0 Serial Input
    */
   public void serialEvent(SerialPortEvent arg0)
   {
   }
}

/**
 * Method processInput parses the String data in the positions array
 * into integers and sends it through the COM ports.
 *
 * @param positions Positions from Client
 * @return void
 */

public void processInput(String[] positions)
{
   String gripper_Action;
   int[] intPositions = new int[positions.length-1];
   for(int i = 0; i < positions.length-1; i++)
   {
      intPositions[i] = Integer.parseInt(positions[i]);
   }

   gripper_Action = positions[positions.length-1];

   try
   {
      for( int i = 0; i < 100; i++ )
```

```
        {
          if(intPositions[0] != oldPositions[0])
          {
            System.out.println("Writing 0," + intPositions[0]/256 + "," + intPositions[0]%256 +
" on COM1");
            out1.write(":".getBytes());
            out1.write(0);
            out1.write(intPositions[0]/256);
            out1.write(intPositions[0]%256);
          }

          if(intPositions[1] != oldPositions[1])
          {
            System.out.println("Writing 1," + intPositions[1]/256 + "," + intPositions[1]%256 +
" on COM2");
            out2.write(":".getBytes());
            out2.write(1);
            out2.write(intPositions[1]/256);
            out2.write(intPositions[1]%256);
          }

          if(intPositions[2] != oldPositions[2])
          {
            System.out.println("Writing 2," + intPositions[2]/256 + "," + intPositions[2]%256 +
" on COM2");
            out2.write(":".getBytes());
            out2.write(2);
            out2.write(intPositions[2]/256);
            out2.write(intPositions[2]%256);
          }

          if(intPositions[3] != oldPositions[3])
          {
            System.out.println("Writing 3," + intPositions[3]/256 + "," + intPositions[3]%256 +
" on COM7");
            out3.write(":".getBytes());
            out3.write(3);
            out3.write(intPositions[3]/256);
            out3.write(intPositions[3]%256);
          }

          if(gripper_Action.equals("Open"))
          {
            System.out.println("Writing 4," + 158 + " on COM8");
```

```
            out4.write(":".getBytes());
            out4.write(4);
            out4.write(158);
          }
          else if (gripper_Action.equals("Close"))
          {
            System.out.println("Writing 4," + 247 + " on COM8");
            out4.write(":".getBytes());
            out4.write(4);
            out4.write(247);
          }
          else
          {
            System.out.println("Writing 4," + 0 + " on COM8");
            out4.write(":".getBytes());
            out4.write(4);
            out4.write(0);
          }
        }
      }
      catch(IOException e)
      {
      }
      oldPositions = intPositions;
    }
  }
```

Date	Task & Comments	Time	Team
9/10/2009-9/21/2009	##	6 Hours	King Shepard Sorrels Spencer
10/8/2009	Completed part two of the rotational base for the internet arm. We also worked on a second gripper prototype.	3 Hours	King Shepard
10/26/2009-10/29/2009	We started the server-side Java program, creating comunication protocol. Working on serial communication with the PIC microcontroller. We are currently using a socket to communicate over a LAN. We worked further on the user side communications (GUI) for the internet arm. We established new panels and began layout, but had difficulty with the layout. We redrilled and remounted the base motor. Also, the platform was cut to regulation size, and two 30 degree angles were cut to fit the posterboard. We worked further on serial communications and learned how to identify necassary ports.	6.5 Hours	King Shepard Spencer
11/19/2009	We succesfully programmed serial communication link to operate servo	3 Hours	Spencer
12/7/2009-12/10/2009	Testing: we were able to turn a servo motor via PIC microcontroller, and also flash an LED on and off from a PC. We assembled three main segment joints with modified hinges and created a skeleton frame of the arm on Solidworks and finished CAD work of the main table. We outputted the motor encoder target PIC microcontrollers from the PC. A motor controller H-bridge was blown out.	8.5 Hours	King Shepard Sorrels Spencer
12/14/2009-12/17/09	We fixed the motor drivers and worked on outputting integers over a LAN.We worked on designing CAD variations of the pulley design, for operating the arm. We successfully outputted a 16-bit number over the network to command a motor with an encoder. We were able to report the position back to the server.	5.5 hours	King Shepard Spencer
1/7/2010-1/14/2010	CAD designs continue to change, while the GUI and socket communication work continued. We constructed the base of the arm based on the CAD. From this a physical testing prototype was constructed. A motor position was outputted to a PIC microcontroller, but are having difficulties with multiple command strings.	10 Hours	King Shepard Spencer
1/18/2010-1/21/2010	We are having continuing problems with command strings, however have come close to solving it. Two motors now work with PIC Microcontrollers	6.5 Hours	Spencer
1/25/2010-1/28/2010	We have finally decided to switche the pulley system with linear actuators. The reduces PIC Micrcontrollers to two and two serial communicators. We have encoutered difficulties with which we can find no solution thus are continuing testing.	5.5 Hours	Shepard Spencer
2/1/2010-2/4/2010	We made design changes to account for the change to linear actuators. The CAD model was updated for changes.	5.5 Hours	Spencer
2/8/2010-2/12/2010	The computer we had been using for Pic Basic Programming had an unknown glitch when compiling.	6.5 Hours	Spencer
2/15/2010-2/18/2010	New serial ports were installed for more motor communication, and server protocol was made for receiving	7 Hours	Spencer
2/22/2010-2/25/2010	We mounted the third section of the arm on CAD and constructed the segment. Encountered Macro error with motor communication that has not been solved yet	6.5 Hours	King Spencer
3/1/2010-3/4/2010	The arm base was completed and cooling fans were added to the base for colling the electronics. The gripper for the arm, a leadscrew system, was mounted to the arm	7 Hours	Shepard Spencer
3/8/2010-3/11/2010	The final circuit was completed, but burned two LCDs out with high amperage. The fram of the arm with motors is completed, now we are placing sensors on specific areas of the arm.	8 Hours	Shepard Spencer
3/15/2010-3/18/2010	The finalised circuit was debugged and commands from computer work. We wired limit switches on the arm.	6 Hours	Spencer
3/22/2010-3/25/2010	Added astetics to the arm and worked on encoder brackts.	4.5 Hours	Shepard
4/1/2010-4/6/2010	Completed encoder and shaft brackets, set upt testing prototypes. Wrist limit switches programmed.	6 Hours	Shepard
4/8/2010-4/12/2010	Created brackets for specialised limit switches on the end of the arm and mounted on gripper plate	6 Hours	King Spencer
4/13/2010-4/18/2010	Began final documentation and poster, while programming the switches and making final changes	7 Hours	King Spencer
4/19/2010-4/21/2010	Finalised the poster and technical report for the State Conference	10 Hours	King
5/3/2010-5/10/2010	Began work on the transition from LAN communication to Internet communication. We researched webcams for use on the arm, and ordere 3 Microsoft LifeCam Cinema webcams to begin experimenting with	8 Hours	King Spencer
5/10/2010-5/17/2010	Continued work on programming changes from LAN to Internet communication and also began work on the final housing for the arm inside of our shop.	7.5 Hours	Spencer
5/17/2010-5/24/2010	Successfully were able to control two of the motors of the arm over the internet. Received a new leadscrew for the gripper of the arm and adapted it to our existing gripper. This resulted in higher speed and a smoother running for thegripper	7 Hours	King Shepard Spencer
5/24/2010-5/31/2010	Were completely able to control the arm over the internet utilising the GUI. Now we have begun work on incoporating webcams into the GUI for remote control over the internet. The gripper is finished and work has begun again on the final housing of the arm	7.5 Hours	King Shepard Spencer
6/1/2010-6/8/2010	We began testing with webcams using JMF studio and FMJ studio; media java programs, possibly being adapted to transmit our webcams. However it can not trnasmit webcams that utilise the same driver, which means we must purchase two other webcams of different manufacturers.	8.5 Hours	Spencer
6/8/2010-6/15/2010	We have finished the final housing of the arm in the shop. We have stopped using JMF and FMJ studios and are writing our own programs, since these two programs are outdated, and non compatible.	10 Hours	King Shepard Spencer
6/15/2010-6/22/2010	Have made two webcams function over the GUI as well as reconfirmed that the arm works over the internet. We have begun working on documentation and posters; updating them from the state versions.	12 Hours	King Shepard Spencer