**Internship Program**

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Requirement:

My aim for this internship is to develop the instrumented chair to guide the elderly people in the sit-to-stand exercise, including the data flow from the armrest to the foot plate. Hopefully, my design can guide their balance during the exercise and have fun when playing with them.

Brief layout of wireless network:

In Figure 1, The SPI communication enables this wireless network to transmit ADC readings of force sensors within the chair.

The LED strips on the armrest seems not very tidy and reasonable so that RF transceiver module transmit all the data from the armrest to the foot plate. There are two force sensors in each armrest, which measure the force in the upper arm and back arm. Importantly, I mounted the speaker in the left armrest and button in the right armrest to enable more functions in the chair. The button is used to control the behavior in the foot plate. When button state is HIGH, only the laser light works to guide the elderly people how to keep balance when they stand on the foot plate.

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| Figure 1: The layout of wireless network in the chair |

Otherwise, the timer interrupts on LED stirps and speaker would work to guide their balance. The speaker would be used to generate tone in the interrupt routine. In order to achieve that, the force sensor readings of the foot plate should be sent to the left armrest, which acts as the transceiver in SPI communication.

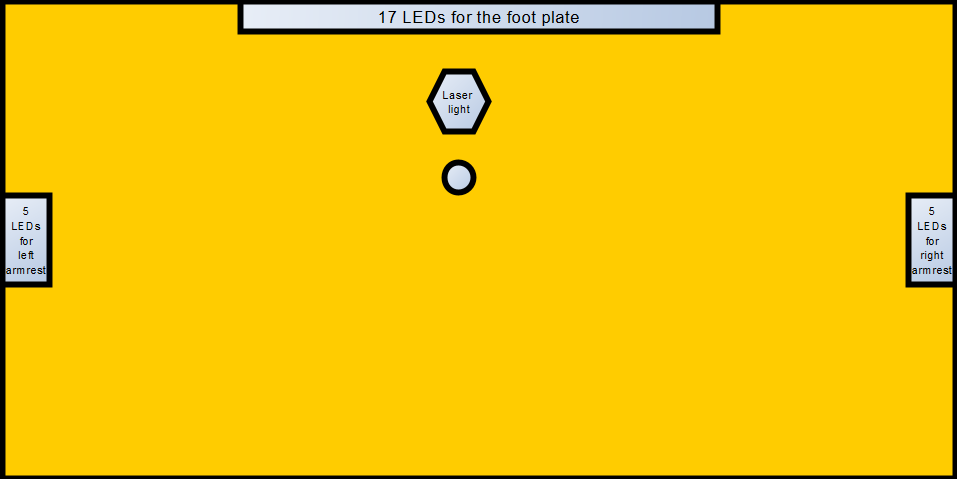
The foot plate acts as a master node, which receives the data from both armrests and transmit its force sensor readings to the left armrest. Most feedback is built in the foot plate, including the laser light and LED strips.

Hardware

1. Layout

In Figure 2 on the page 3, there are 3 LED strips on the top surface of the foot plate. In the middle, there are 17 LEDs for the foot plate, where the middle LED with blue tapes around is always white to divide the LED strip into left and right. In each side of foot plate, there are 5 LEDs respectively for left and right armrest. The laser light with servo motors is mounted with screws behind the LEDs strip. The hole nearby is for the wire of servo motors and laser light down to the Arduino Mega. All the LEDs strips are stabilized by the blue tape and screws. With this design, people have plenty of spaces to stand on the foot plate and see the lighting on LEDs clearly during the exercise.

In Figure 3 on the page 3, there are 4 casings of force sensors to support the base of foot plate. There are high enough to mount the Arduino and let the jumper wires to connect in the strip board. In the middle, there is an Arduino mega 2560, which

Figure 2: The top view of the foot plate

provides enough pins and up to six timers. On each side of the Arduino, there are four amplifier circuits for each force sensors. Besides, there is a strip board to share 5V pins and GND for amplifier circuits, servo motors, laser light and LED strips. Also, this strip board connect the signal pins of LED strips to 470 Ohm resistor before connecting to the microcontroller, which can display enough brightness and save power consumption. There is a nRF24L01 transceiver module below the controller, which builds up the wireless communication. Moreover, three connectors of LED strips are stabilized by the tape and screw, where the jumper wires are extended by joining together.

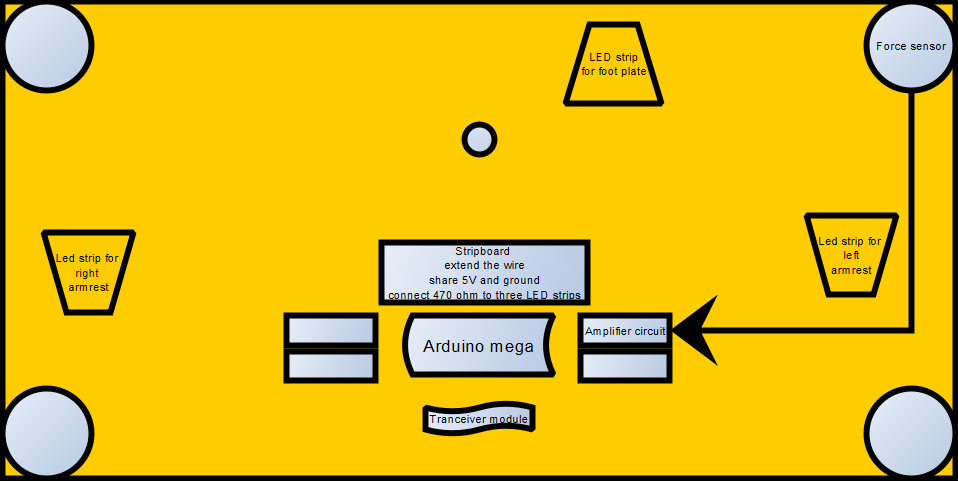
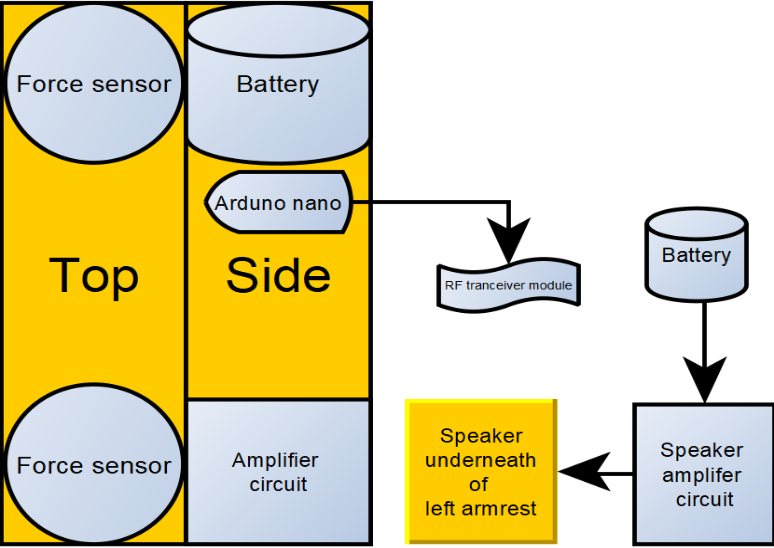
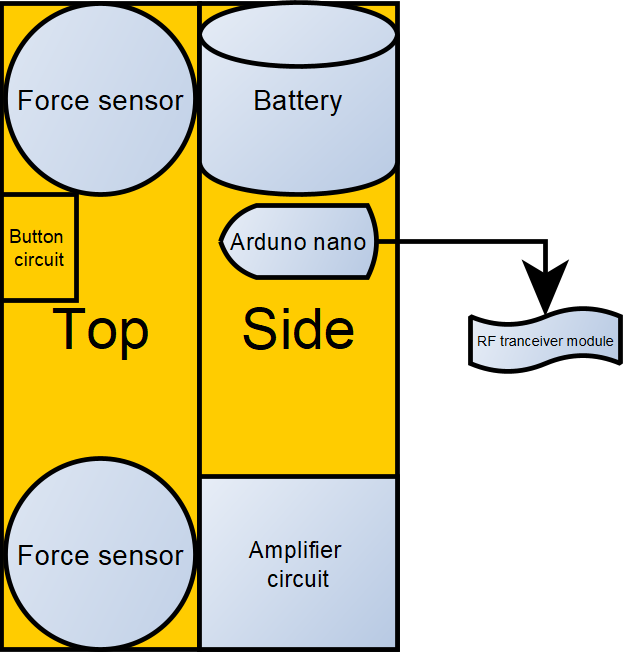
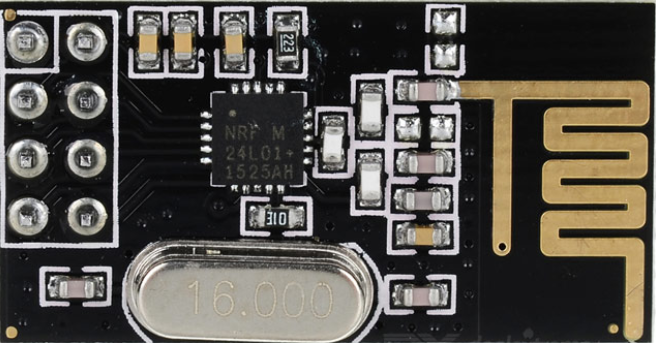


Figure 3: The bottom view of the foot plate

This is the top view and side view of the left armrest. There are two force sensors in the upper and back arm on the top surface. In each side of arm rest, there are two according amplifier circuits. To be more specific, in the inner side, there is an Arduino nano, which connects to the RF transceiver module. However, in the outer side, there is a 9V battery to power up the microcontroller. The speaker is mounted underneath of the arm rest, which is processed by the LM386 audio amplifier in combination with specific capacitors and resistors supplied by 9V battery. Also, the speaker amplifier circuit has enough spaces to share 5V and GND with the amplifier circuit of the force sensors.

This is the top view and side view of right armrest. The design is mostly same as the left armrest for the top view. The only difference is that there is a button circuit near to the upper force sensor, which shares 5V and GND for the force sensors’ amplifier circuits. The side view is exactly same as the left armrest, which has battery for Arduino nano and the amplifier circuits in each side.

1. Components

The wireless network is achieved by the nRF24L01 radio transceiver for the world wide 2.4 GHz ISM band, which can reach up to 100 meters. Also, it can communicate up to 6 other units at the same time with baud rates from 250 kbps up to 2 Mbps.

In Figure 4, PWM audio signal is connected to the 10k potentiometer, which can vary the voltage of audio going through the LM386 audio amplifier. Several capacitors and resistors connected to amplifier has different functions. To be more specific, a 100 nF capacitor between the positive input signal (2) and ground (4), which filters radio interference picked up by the audio input wires. A 470 pF capacitor between pins 4 and 6, for additional decoupling of the power supply to the chip. A 1.2K Ohm resistor

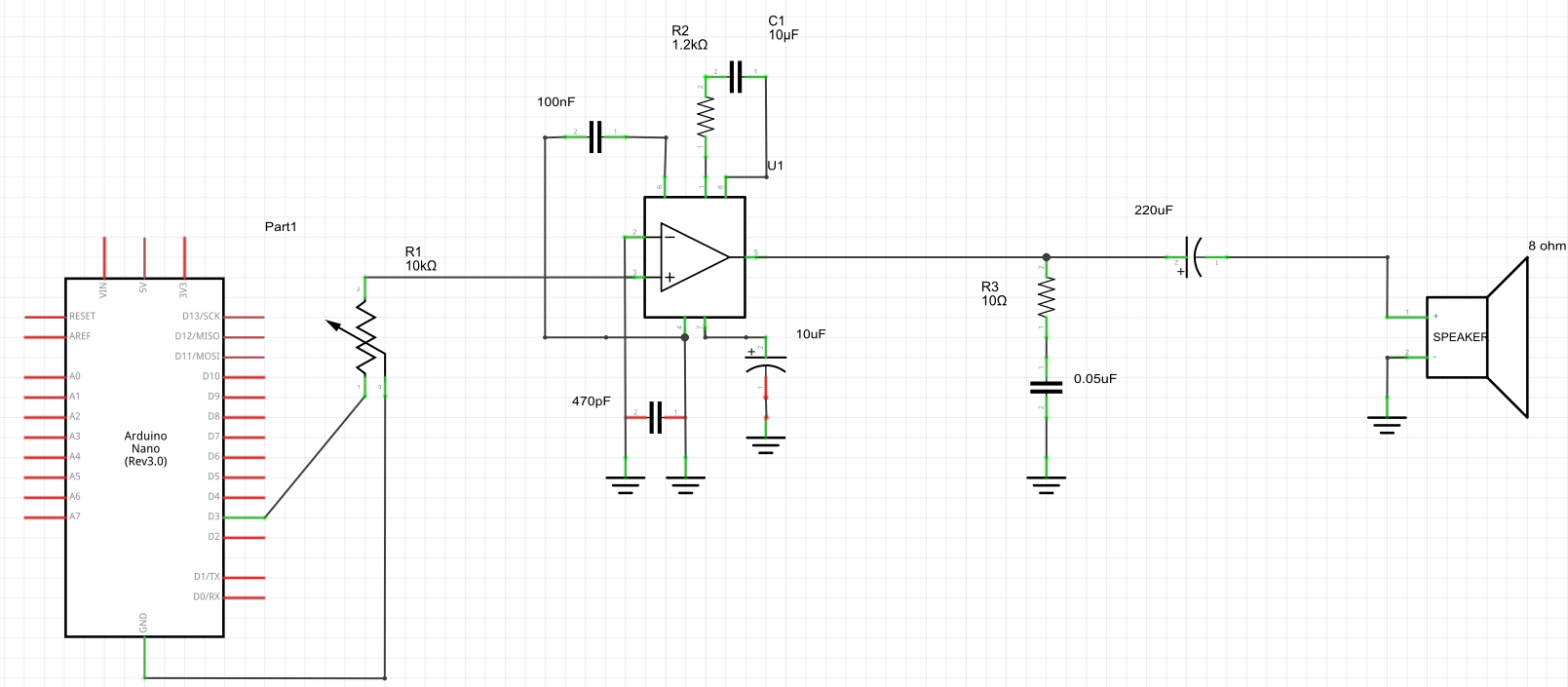
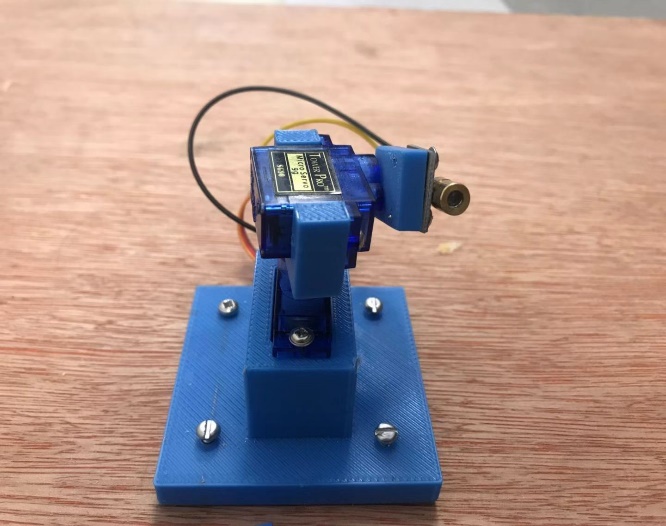


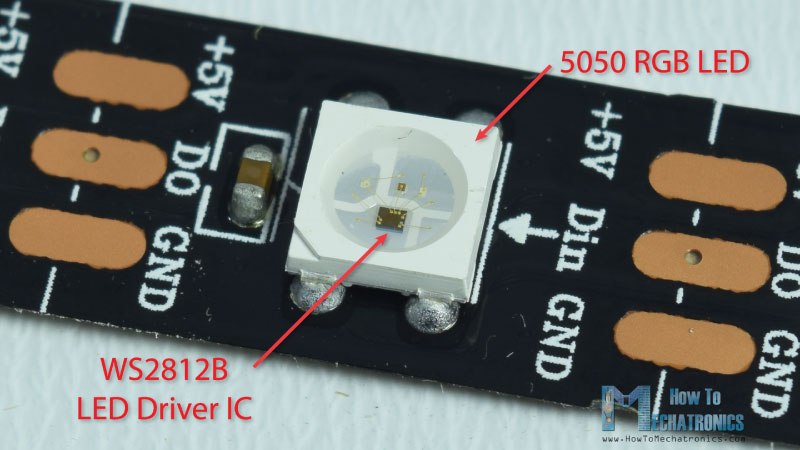
Figure 4: Schematic of speaker amplifier circuit

and a 10 μF capacitor in series between pin 1 and pin 8 is to set the gain to 50 for acceptable volume of output. A 10 μF capacitor in series between pin 7 and ground is to decouple the audio input signal. The load impedance of speaker is 8 Ohm, which is in acceptable range between 4 Ohm and 32 Ohm. With this design, we can clearly hear tone from speaker with acceptable noise interference.

The laser light can move in x and y direction with use of two servo motors in combination, which is stabilized by screw of the Y servo motor. The base is mounted on the top of foot plate in case it moves randomly. This can be used to train people to keep blance on the foot plate by just following the laser light on the wall. Also, it can turn left, right, up and down with the use of motors, where people can capture and move with the defined patterns created by laser light.

Y servo motor

X servo motor

WS2812B is an individally addressable digital LED strip. This type contains the LEDs, with three one-byte data members for each of the three Red, Green and Blue color channel. The data output pad of the previous LED is connected to the Data Input pad of the next LED. We can cut the strip to any size we want, as well as distance the LEDs using some wires. Therefore, I cut the 17 LEDs for foot plate and 5 LEDs for two armrests, which enables 256 brightness and 16777216 full color display.

Software:

A simplified version of the system in the instrumented chair is shown in the flow chart below.

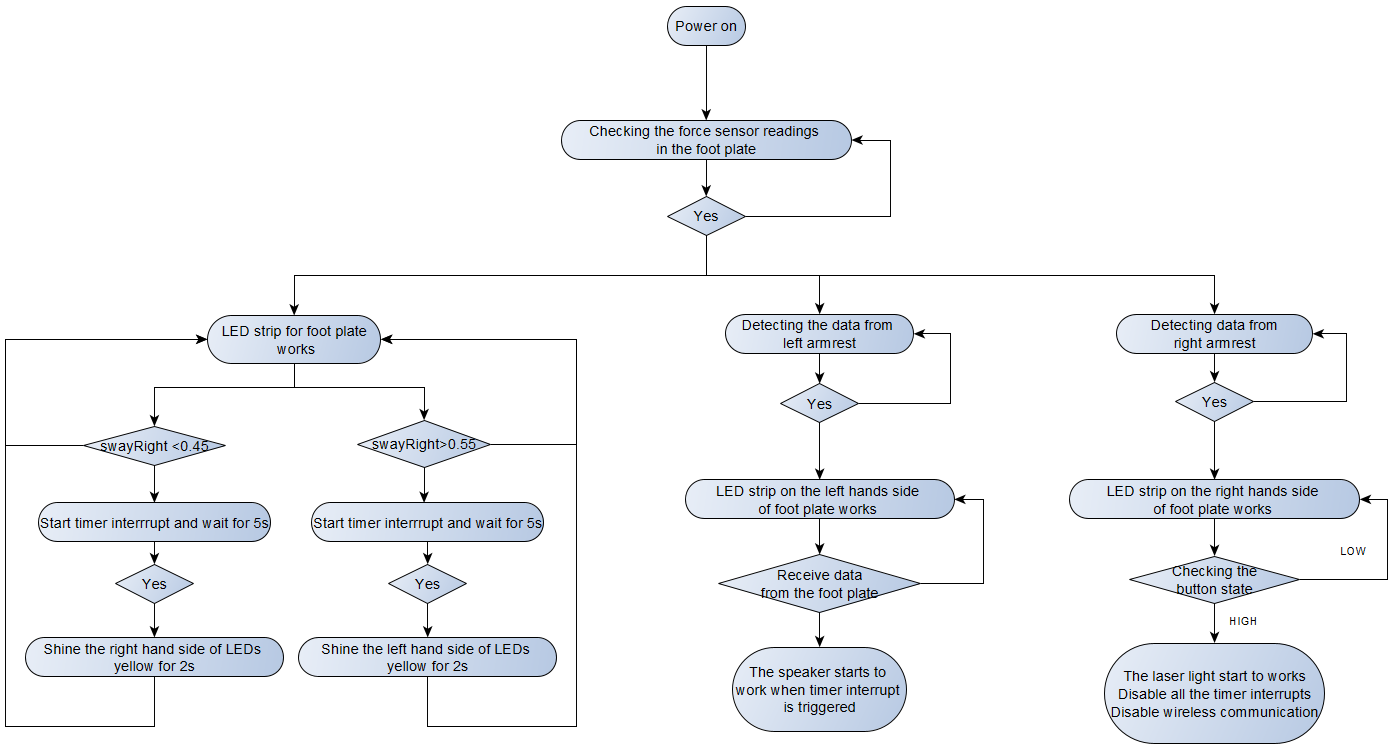


Figure 5: Software system flow chart

1. System explanation

The whole system runs in a big while loop. The first thing is to define all the useful libraries and initializes all the peripheral devices, including LED strips, RF24 transceiver modules, servo motors and a laser emitter module. After initialization, the program would start to check the force sensor readings on the foot plate. Then, the foot plate starts to listen the readings from node 01 (left armrest) and node 02 (right armrest). In the meantime, it transmits its four force sensors’ readings to the left armrest for audio feedback implementation. The LED strips would change its LEDs from red to green according to the force applied. Also, the required force to turn up the green LEDs would be changed to suit different sort of people.

The debounced button in the right armrest would be sent to the foot plate to change the mode of operation. When the button state is HIGH, only laser light and servo motors would work and disabled other functions. However, when the button state is LOW, the timer interrupt overflow is set to delay yellow LEDs 2 second when people sway over defined time. In the meantime, the speaker would work synchronously with the yellow LEDs to give the warning message.

1. Wireless network

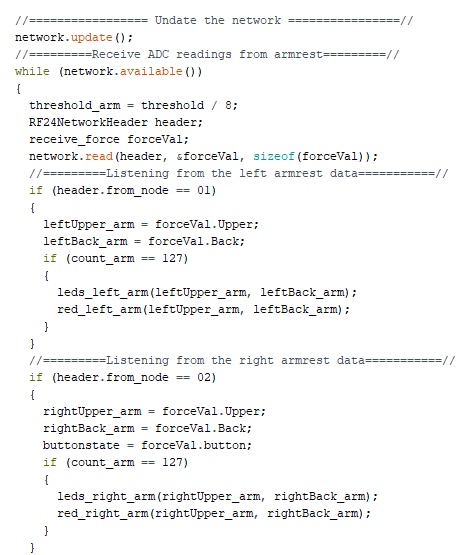


Figure 6: Data received from node 01 (left armrest) and node 02 (right armrest)

As shown in Figure 6 on the page 8, the network would be updated and checked each time in the beginning to receive and transmit data. When the network is available, it would start to turn the slave select LOW in SPI communication to hear the message. In order to hear the message, the recipient address, header would be needed to define. Then using the read () function we read the data and store it into the forceVal variable.

Header.from\_node () function is used to hear message from different logical address in the different communication channels. Hence, in this case, you need to define two different received structures of payloads for left and right armrest.

In Figure 7, with the use of the millis () function, the force sensor readings can be transmitted every 100 milliseconds to the left armrest. In each defined interval, the according force sensor readings and threshold would be updated in the structure of payloads to the defined node.

The boolean variable ok2 can be used to debug in the serial monitor. If it is 1, it means the data have been transmitted to correct node.

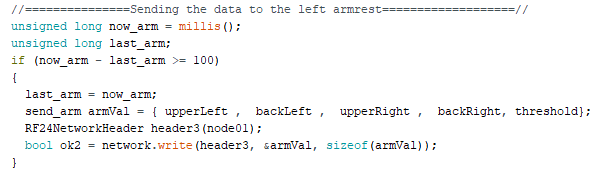


Figure 7: Data transmitted from master node (foot plate) to the node01 (left armrest)

1. Timer 2 interrupt overflow



Figure 8: Set up Timer 2 overflow interrupt

Since delay () function would stop or halt the wireless communciation, the timer overflow interrupt is a better choice.

As can be seen in Figure 8, to enable timer overflow, we must set the TOIE bit on TIMSK2 to use mask so that only the least significant bit is affected. To slow down the timer, we need to increase the divisor value so that I write 1024 maximum value as divisor to the TCCR2B register.

Timer 2 only have to 8 bits, which means it can count up to 127 and then overflow. In Figure 9, I decrement the count\_arm variable to 62 to achieve around 2s delay. While the count\_arm is equal to 127, the interrupt would be disabled and normal operation works. Otherwise, the interrupt would start to work when it is not 127 and start to count down. This is helpful to set the yellow LEDs for around 2s in the interrupt service routine and back to background color when it finishes.

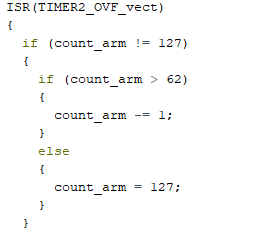


Figure 9: The timer interrupt for arm rest.

1. Serial input and output

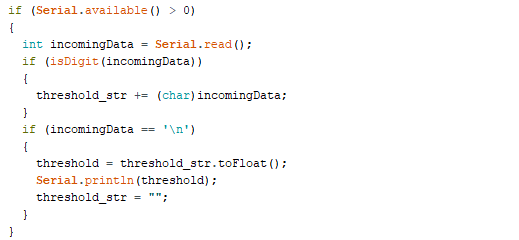


Figure 10: Read the string form the serial monitor

As LEDs would change according to force readings in force sensors, the threshold to turn the each LED from red to green would be different for people. Therefore, we can set different thresholds in Figure 10. ‘\n’ is used to detect the end of string each time and change type of string to the float number in threshold variable. If without serial data, the threshold would be set to default value.

Similarly, the serial output can be directly transferred to the Excel for better analysis. In Figure 11, PLX-DLQ connects the serial communication protocol to the Excel directly. The data would be cleared and timer would be reset when the portocol is connected again. “LABEL” would notify that there are different variables in different columes with order. “Time” would show up the real clock and “Started time” would measure how long you connect the protocol, which can be used in sit-to-stand exercise to compare force values in the line chart.

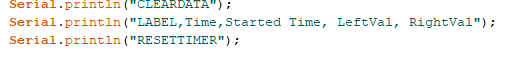


Figure 11: Transfer serial output to excel with use of PLX-DLQ

1. Sit or stand

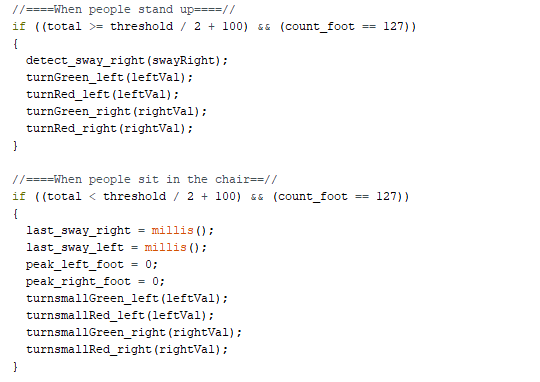


Figure 12: Total force decides two phases

According to data in the line chart in Excel, we can decide two phases depending on the total force as shown in Figure 12. Normally, there is a big transition of force during sit-to-stand exercise and the force needed to light the LEDs would be a large difference. Therefore, we need to design different force readings to light up each blocks of LEDs. When people sit in the chair, the force to turn up each LEDs would be much smaller than that when they stand on the foot plate.

We only consider sway when people stand on the foot plate, where the timer interrupts would be detected. However, the peak force and timer interrupts would not be considered when people sit in the chair and only considered when people try to stand up so that we set the peak force to 0 and refresh last timers. Normally, the green LEDs would not intermediately turn to red so that you need to set LEDs back to red when the force is smaller than defined force

1. Debounce button and laser light

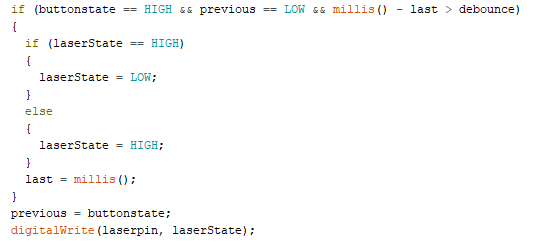


Figure 13: Button state to change the mode of operation

The button state would become 1 only when the button is pressed. Therefore, we need to define the debounce button to control the laser state. In Figure 13, the laser state would change only when previous button state is LOW and new button state is HIGH. With this function, we can change the laser state each time when the button is pressed.

The laser state would be used to define which modes to operate. When laser state is HIGH, only laser light with servo motors would start to work because servo motors would behave weird when the wireless network transmits data or timer interrupts are activated.

As shown in the Figure 14 on the next page, the laser light is moved in left and right direction according to the force values applied in each side of the foot plate. The rotating angle of motor is opposite to the moving directions because of mounting. When difference of force is less than 20, the laser light would point to the middle point. In this case, y servo motor should be detached because y servo motor would move randomly in the middle point when the footplate receives armrest data. Therefore, you can manually move the y motor to adjust to desired height. Finally,

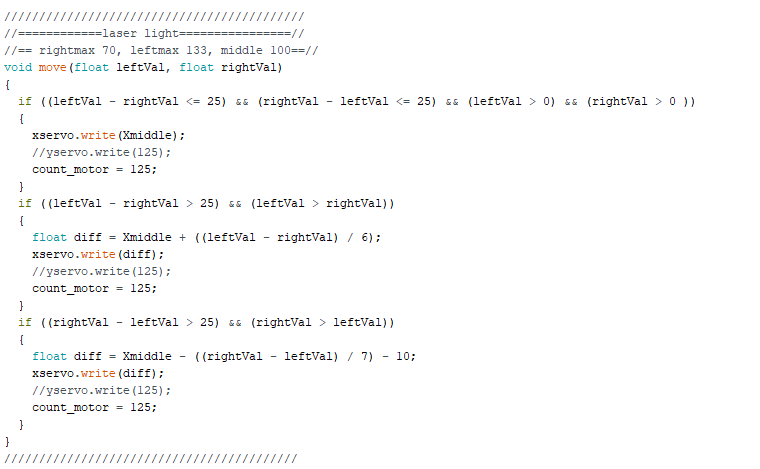


Figure 14: Algorithm for laser light

the algorithm for diff makes sure the x motor rotates around 30 degrees in left and right direction.

Testing procedures:

In the beginning, subject seated on a height-adjustable instrumented chair with their thighs unsupported. This chair was adjusted to the height of subject’s knee and aligned just behind the posterior edge of the foot plate. The subject’s feet were placed in parallel, one on area of each foot plate. Subjects were required to fold their arms across the armrest, keeping their palms on the top of upper force sensor casing. Subjects are given adequate rest between trials to avoid fatigue.

Firstly, subjects should exert the force on both armrest until both side of LEDs turn to purple. In the meantime, subjects should care about yellow LEDs in each armrest and make some allocation of force properly if it happens. After that, subjects start to exert the force to turn all the LEDs of foot plate green before seating off. While seating off, the LEDs of foot plate would start to turn purple and speaker would output “please up” to remind you. At that time, subjects should leave their hand from armrest and start to extend their hips and knees to upright position.

When subjects stand on the foot plate, they begin to focus on their balance on the foot plate. The LED strip of foot plate would guide you how to use force properly on your both feet according to the green LED blocks in left and right side. Also, if you sway more than 5s, it would shine yellow color on the weaker side of LEDs and the speaker would output warning messages simultaneously. Besides, the chair enables the button to encourage you to look forward. When subjects press the button on the top of right armrest, the laser light would start to guide their balance. The subjects can follow the laser point to balance their body.

If you sit back to chair, the whole system would start again to enable multiple train exercises. Most importantly, the useful data can be analyzed everyday in Excel since our data can be transferred directly to excel. Therefore, we hope our design can fit different people and help them keep balance and build the strength.

Data analysis:

Normally, the exercise can be divided into three phases. In preparation phase, it begins with the decrease of vertical force by more than 2.5% of feet weight. The preparation phase lasts until the peak of vertical force was reached, which indicate seat-off. The rising phase starts with the peak vertical force. The end of rising phase was defined as the point when the vertical force reaches body weight after decreasing and increasing again. In stabilization phase, the vertical force oscillates around body weight. The end of stabilization phase was defined as the point when the vertical force oscillates inside the corridor plus/minus body weight. As be seen in the Figure 15 on the page 16, this is how the force readings changes during these three phases. The total force is around 180 when sitting on the chair and then

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| Figure 15: Force readings and sway percentage |

reaches up to 500 when seat off, finally oscillates around 450 in the stabilizing phase. During the exercise, the comparison of LeftVal and RightVal can be seen clearly in the line chart. The LeftVal represents the left side of force sensors readings whereas the RightVal represents the right side of force sensors reading on the foot plate. With these data, we can measure how much force they need to stand up and whether they are using the force properly on their feet. Also, we can measure the percentage of sway during the exercise by looking at the time spent in pie chart.

Moreover, the leftDiff and rightDiff represent the difference in force between upper arm and back arm. When people sit in the chair, these two values would not change and only change in the beginning of rising phase. At that time, they would shift the force needed in feet to the arm. After that, they would totally leave the arm from the chair until the upright position is reached, where people reach the vertical peak force on the foot plate. As you can see, the period for using the force at arm is very short.

Besides, we can measure the approximate weight with use of total force. In experiment, I ask a few of them to try my prototype. The total force is 7.2 times of people’s weight during the stabilizing phase. This number could be more accurate when taking more samples.

These data can be analyzed to see whether they use more force on their arms or on their legs to get up every single day. According to time of sway, do they improve their balance during the exercise? Most importantly, would the design help them strengthen their lower extremities and arms? Therefore, the readings would be very helpful for updating the algorithm in the feedback module.

Conclusion

1. Achievement

This project provides excited feedback modules and platform for subjects to have fun, to build up strength and to improve balance during sit-to-stand exercise. To be more specific, achievement through this project such as:

1. Build up the wireless network between armrest and footplate
2. Design the speaker amplifier
3. Mount the laser light with two servo motors
4. Develop the algorithm for LED strips to light up according to the force applied
5. Timer interrupt to give warning message on the LED strip and speaker
6. Algorithm to move laser light in x direction
7. Button to change the mode of operation in the foot plate
8. Input threshold value in the serial monitor to suit different people
9. Data analysis in Excel
10. Problem analysis
11. The force sensors may not have same offset values because the amplifier circuit is very sensitive for offset setting. The force needed to increase the force sensor readings would be a little bit different. The phenomenon would become more obvious when subjects stand not evenly on the foot plate. This would generate reading difference in the foot plate and armrest.
12. When using many libraries in same Arduino, the conflict between timers would be more serious. This would affect the implementation of hardware. Previously, I want to mount the speaker on the foot plate with SD card module but the servo library and RF24 library affect the performance of audio PWM signal. Besides, the servo library cannot work with RF24 library in the same time, since the transmission would make servo motor move randomly without control.