Samuel J. Ruiz

1001669197

CSE 3442-001

Colorimeter-based Chemical Analyzer

CSE 3442 Embedded Systems I Project

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Jason Losh

Introduction.

The project created for this class was a Colorimeter-based Chemical Analyzer with a microcontroller. The project was built throughout several class labs and involved providing hardware and software solutions. The software for this project was created using Professor Losh's example code as a basis while implementing my own code tailored towards the projects function. I also personally soldered the hardware of this device following the schematics provided by Professor Losh. This device was able to rotate the step motor to analyze the RGB values of light going from an RGB light, through a test tube containing phenol red, into a phototransistor. These RGB values were used to calculate the pH of the liquid inside the tubes.

Theory of Operation

The device built in this class was able to handle multiple chemical test tube samples by rotating a step motor. The main code for the motor was created in Lab 7 and rotated the motor by applying phases of current on the motor to have it turn.

```
 applyPhase(phaseInput){
      (phaseInput){
     0: BLACK_MOTOR = 1; WHITE_MOTOR = 0; YELLOW_MOTOR = 0; GREEN_MOTOR = 0;
 ;
     1: BLACK_MOTOR = 0; WHITE_MOTOR = 0; YELLOW_MOTOR = 1; GREEN_MOTOR = 0;
 ;
     2: BLACK_MOTOR = 0; WHITE_MOTOR = 1; YELLOW_MOTOR = 0; GREEN_MOTOR = 0;
 ;
     3: BLACK_MOTOR = 0; WHITE_MOTOR = 0; YELLOW_MOTOR = 0; GREEN_MOTOR = 1;
 ;
}
phase = phaseInput;
}
```

This would allow the step motor to spin when applying the phases in for loops.

```
 stepCw(){
position++;
phase = ((phase + 1) % 4);
          (phase);
```

```
                    (10000);
}
```

The program functions were called using the virtual COM port connected to UART0 and was capable of making instructions like:

Home: Move the turret to reference position and store it in home.

Turret TUBE: Move turret to tube position

Calibrate: Rotate turret to tube position and displays raw RGB data from A/D converter.

Measure TUBE PH: Rotate turret to tube position and displays pH levels.

```
(isCommand(&data,"tube", 1)){
  uint8_t tube =                (&data, 1);
        (tube){
       0:             (tube0);       ;
       1:             (tube1);       ;
       2:             (tube2);       ;
       3:             (tube3) ;       ;
       4:             (tube4) ;       ;
       5:             (tube5)  ;       ;
         :           ("Invalid Command Parameters\n");       ;
  }

}
```

The device was able to be controlled using an IR remote control and was able to complete the same instructions as the UART0:

```
(code){
      //General Commands: Home, Calibrate
           64:     ();       ; //Power to go to home()
           65:          ();      ; //Skip to go calibrate()
      //Go to Tube X commands
           12:              (tube1);     ; //DIY1 to go to tube 1
           13:              (tube2);     ; //DIY2 to go to tube 2
           14:              (tube3);     ; //DIY3 to go to tube3
           8:               (tube4);     ; //DIY4 to go to tube4
           9:               (tube5);     ; //DIY5 to go to tube5
           10:              (tube0);     ; //DIY6 to go to tube 0/R


       }
```

The calibrate command was used to calibrate the RGB values for the reference tube containing regular water. These RGB value were used in later code to measure the RAW RGB for the test tubes containing phenol red. The process of this calibration required the RGB pwm to be ramped up until the phototransistor reached an R of a certain value.

```
 (pwm < 1023 && r < 3072){
                (pwm, 0 , 0);
                    (3000);
   r =              ();
   pwm++;
}
```

In the measure command, the desired test tube was placed in front of the light sensor. The RGB pwm was ramped up until it reached the pwm value saved from the calibration function. Once all RGB colors were measured, the raw RGB value read from the A/D converter was printed on the screen.

```
(i = 0; i <= pwm_r; i++){
                (i, 0, 0);
                    (3000);
   *r =              ();
}
```

The measured raw values were stored in an excel sheet and later hardcoded in an array and into the program for reference.

The function for measurePh rotated the step motor to the desired tube position and measured the raw RGB value. This value was then compared to the reference sheet to find the two lowest distances from the measured values and then found the closest distance using the Euclidian distance formula. The results were then used to calculate the estimated pH value of the liquid inside the test tubes.

```
 measurePh(uint8_t tube,         *ph){
uint16_t re;
```

```
    uint16_t gre;
    uint16_t blu;
           (tube, &re, &gre, &blu);
    RED_LED = 1;
    GREEN_LED = 0;
    uint8_t i;
           disRef1, disRef2, phRef1, phRef2, phNew;
           red_ref = (       )re / (       )raw_r;
           green_ref = (       )gre / (       )raw_g;
           blue_ref = (       )blu / (       )raw_b;
    //Calculate Distance for current
       (i = 0; i < 5; i++){
               red   = pow((red_ref - (rawReference[i][0])),2);
               green = pow((green_ref - (rawReference[i][1])),2);
               blue  = pow((blue_ref - (rawReference[i][2])),2);
               d = red + green + blue;

          ( i == 0){
            disRef1 = d;
            phRef1 = rawReference[i][3];
        }
               (i == 1){
              (d < disRef1){
                disRef2 = disRef1;
                phRef2 = phRef1;
                disRef1 = d;
                phRef1 = rawReference[i][3];
            }
                {
                disRef2 = d;
                phRef2 = rawReference[i][3];
            }
        }
            {
              (d < disRef1){
                disRef2 = disRef1;
                phRef2 = phRef1;
                disRef1 = d;
                phRef1 = rawReference[i][3];
            }
                   (d < disRef2){
                disRef2 = d;
                phRef2 = rawReference[i][3];
            }
        }
    }
    phNew = disRef1 / (disRef1 + disRef2);
    phNew *= fabs(phRef2 - phRef1);
    *ph = phNew + phRef1;
    RED_LED = 0;
    GREEN_LED = 1;
}
```

Conclusion

In conclusion, this project was designed to analyze the pH values of multiple test tubes mounted on a rotating step motor. The device was able to process commands using the UART0 virtual COM port and IR commands from a control using external timers. The device was able to measure the light values using an RGB light by ramping up the intensity using pulse width modules. The light was then analyzed using a phototransistor and single sequence sampler. The pH of the liquid was then calculated using those RGB values, the reference sheet, and the Euclidian distance formula