
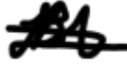






University of British Columbia
Electrical and Computer Engineering
ELEC291/ELEC292 Winter 2025
Instructor: Dr. Jesus Calvino-Fraga
Section 201

Project 2 – Coin Picking Robot

Group A13

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TABLE OF CONTENTS

1. Introduction

2. Investigation

2.1. Idea Generation

2.2. Investigation Design

2.3. Data Collection

2.4. Data Synthesis

2.5. Analysis of Results

3. Design

3.1. Use of Process

3.2. Need and Constraint Identification

3.3. Problem Specification

3.4. Solution Generation

3.5. Solution Evaluation

3.6. Safety/Professionalism

3.7. Detailed Design

3.8. Solution Assessment

4. Life-Long Learning

5. Conclusions

6. References

7. Bibliography

8. Appendices

1. Introduction

Objective

Our objective for this project was to design, program, test and implement a functional coin picking robot. The robot is required to detect and collect coins whilst remaining within a designated area, using perimeter detection to ensure it does not exceed the bounds. It should be able to navigate an area without human control; however, we must also design a remote that is capable of controlling the robot's movements using a joystick. The signal intensity received by the metal detector will be monitored using an LCD located on the remote controller.

Specifications

Our project had to meet the following specifications:

- Programmed in C
- Two microcontrollers in different families
- Battery powered Robot and Remote
- MOSFET drivers for the motors
- Remote must have display, speaker, joystick or equivalent
- Radio communication with JDY-40

A detailed parts list of the robot and the remote can be found in Appendix I. Figures 1 to 4 below present the block diagrams of the hardware and software of the robot and the remote.

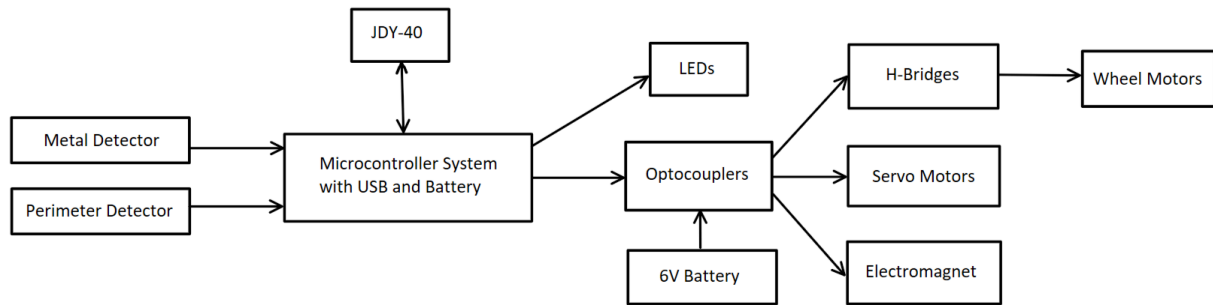


Figure 1: Block diagram of the hardware components of the robot.

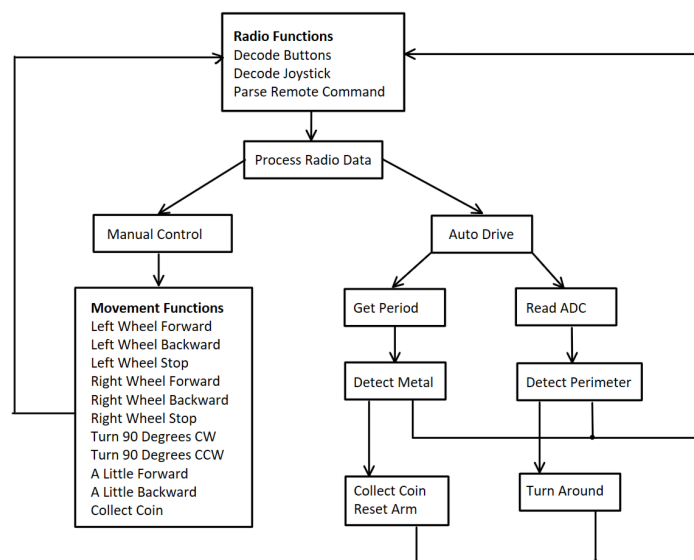


Figure 2: Block diagram of the software components of the robot.

Figure 3: Block diagram of the hardware components of the remote.

Figure 4: Block diagram of the software components of the remote.

2. Investigation

2.1 Idea Generation

Our group outlined the project's requirements and developed a plan of action accordingly. We created a Gantt chart to systematically divide tasks up amongst group members to optimize our time. After establishing the process for implementing the base project, we drafted a document

proposing potential bonus features. In the end we were left with a clear outline guiding us towards the final product.

2.2 Investigation Design

Research & Information Gathering:

- Reviewed datasheets and online resources for key components (e.g., JDY-40, STM32, PIC32, op-amps).
- Consulted lab manuals as well as current and previous course materials to understand sensor and actuator interfacing.

Prototype Circuit Development:

- Built initial prototypes of the metal detector using a Colpitts oscillator and the perimeter sensor circuit.
- Designed and tested op-amp circuits to amplify the low-level signals from the sensors for accurate ADC measurement.

Experimental Measurements:

- Used a Fluke 45 Digital Multimeter and TTI EX354T Power Supply to measure voltages and verify resistor values in the sensor and amplifier circuits.
- Employed an oscilloscope to validate PWM signals and confirm the accuracy of the STM32's GetPeriod function.

Data Collection & Analysis:

- Displayed frequency and voltage information to the PuTTY terminal and compared them with experimental measures to verify accuracy.

Integration Testing:

- Conducted numerous iterations of testing with the PIC32 remote and STM32 robot to evaluate wireless communication, sensor reliability, and overall system responsiveness.
- Confirmed that both automatic and manual modes operated in accordance to design specifications.

2.3 Data Collection

We used several instruments and tools to gather data during testing and implementation. The Fluke 45 digital multimeter was used to measure voltages in the metal and perimeter detection circuits, particularly verifying the peak voltage across the detector capacitors. The TTI EX354T power supply provided a stable voltage for testing the robot's functionality. The oscilloscope played a central role in observing waveforms. It was used to verify the frequency and stability of the Colpitts oscillator, inspect PWM timing for the servos, and measure the voltage generated by the perimeter sensor coils when near the boundary wire. These real-time signals helped us tune component values and detection thresholds. Debugging LEDs were connected to the STM32 and activated when metal or perimeter detection occurred, allowing quick visual confirmation during mobile tests. Internally, the STM32's ADC continuously sampled the perimeter detector voltages and compared them against a reference to trigger avoidance. For metal detection, the STM32's GetPeriod function measured oscillator frequency by timing 60 cycles, providing accurate digital frequency readings. These were used to detect coins as the metal changes the frequency of the oscillator. Together, these tools allowed us to calibrate sensor thresholds, verify circuit behavior, and debug software decisions across the full system.

2.4 Data Synthesis

Real-time outputs from both the GetPeriod function and the ADC readings were printed continuously to the terminal. This allowed us to visualize how the oscillator frequency and

perimeter sensor voltages changed as coins were moved near the detector or as the robot approached the boundary wire. The live serial output provided instant feedback, helping us fine-tune detection thresholds. These terminal readings confirmed that the STM32's internal peripherals were operating consistently and could be trusted for control decisions.

2.5 Analysis of Results

Our group assessed the validity of our conclusions by repeatedly performing tests of the metal and perimeter detectors, and using an oscilloscope to confirm the microcontroller's measurements. By analyzing the oscilloscope data, we could confirm any discrepancies in the microcontroller's readings and adjust our approach accordingly. These tests gave us confidence that our circuitry and our code were working effectively, allowing us to calibrate accurate thresholds for our metal and perimeter detection code.

3. Design

3.1 Use of Process

- **Problem Definition & Requirements:**
 - Identified the need for a coin picking robot that automatically detects and collects coins within a defined perimeter while allowing manual override via a remote.
 - Established constraints including limited project time, component availability, and the requirement to use different microcontroller families (PIC32 for the remote and STM32 for the robot).
- **Subsystem Decomposition:**
 - Divided the project into hardware and software components.

- On the hardware side, implemented sensor circuits (metal detection using a Colpitts oscillator and perimeter detection).
- Discovered that the ADC voltage from the inductor was too low for reliable detection, instead integrated an op-amp circuit for signal amplification.
- **Incremental Software Development:**
 - Integrated sensor readings, wireless communication, and actuator control gradually to simplify debugging and future modifications.
- **Testing and Verification:**
 - Conducted thorough testing using oscilloscopes, multimeters, and debugging LEDs to validate PWM signals, sensor outputs, and wireless communication.
 - Verified that the op-amp amplification provided accurate perimeter detection.
- **Integration & Iterative Refinement:**
 - Combined all subsystems and performed full-system tests in both automatic and manual modes.
 - Iteratively refined both hardware and software until the system met all design specifications and performance criteria.

3.2 Need and Constraint Identification

Our team identified customer, user, and enterprise needs by adopting the perspective of the end user and considering key factors such as customizability, user-friendliness, and accuracy.

Constraints of achieving these needs include our limited project time, resources, and people working on the project. We needed to address these needs before adding any additional features.

The customer's need was for a robot that could reliably locate and collect coins with minimal supervision and emphasizing efficiency. The user's need was centred around implementing an

intuitive remote interface, including real-time data collection, responsive control over the robot, and simple mode switching between automatic and manual operation. The enterprise's needs were addressed by ensuring a robust, cost-effective solution to ensure affordability, maintainability, and scalability. To address these needs, we identified several constraints such as: limited development time, restricted component selection, battery-powered operation, amount of people on each task, and the requirement to use two distinct microcontrollers.

3.3 Problem Specification

From our needs analysis of the project, we specified the following design requirements:

- **Coin Detection:** The metal detector must sense all current Canadian coins when within a few centimeters, with a detection threshold set at approximately 10% above baseline frequency.
- **Coin Pickup:** The electromagnet and servo arm must reliably pick up a coin in a single attempt at least 90% of the time.
- **Boundary Enforcement:** The robot must not leave the designated perimeter; the system must react within 0.5 seconds when a perimeter sensor is triggered.
- **Remote Control:** Commands from the remote should be executed with a latency of less than 100 ms, and the feedback system (LCD and buzzer) must update frequently enough to be useful.
- **Safety and Power:** The design needed to be efficient as it operated on battery power.

Furthermore, we needed to adopt a resilient design to ensure the robot's longevity.

3.4 Solution Generation

We explored a variety design solutions to meet the functional specifications of the coin picking robot, which included successful implementations and discarded approaches:

- **User Input & Remote Interface:**

- We considered using a single joystick versus a PS2 controller for user input on the remote controller.
- Ultimately, the PS2 controller on the PIC32 remote was chosen because it created an intuitive interface that many users may be more familiar with.
- **Wireless Communication:**
 - Used the JDY-40 for its low power consumption, and ease of configuration in the lab environment.
- **Motor Control & Drive System:**
 - Options included direct microcontroller control versus the use of discrete MOSFET drivers.
 - MOSFET drivers were adopted to minimize electrical noise and to ensure robust motor control during coin collection maneuvers.
- **Coin Pickup Mechanism:**
 - Several designs were prototyped, such as mechanical grippers and electromagnet-based systems.
 - The final design utilizes an electromagnet combined with micro servo motors to provide fast, precise coin pickup and deposit.
- **Sensor Integration:**
 - Used a Colpitts oscillator for metal detection as it provides reliable detection of all coin types.
 - For perimeter detection, we designed a circuit that accurately senses the AC field from the perimeter wire.
- **Software & System Control:**

- The remote firmware on the PIC32 was developed to decode PS2 joystick inputs and transmit commands wirelessly, ensuring seamless integration between the two systems.

3.5 Solution Evaluation

We evaluated each solution based on its difficulty of implementation and impact on the final design to identify the most suitable options for the project.

- We had a variety of microcontrollers to choose from, such as the ATMEGA32, LPC824, and the EFM8. We chose to use the STM32 and the PIC32 microcontrollers because of their raw power and because we had previous experiences with these microcontrollers.
- We considered using a joystick and push buttons to control the robot, but we found online documentation on how to implement the PS2 controller in our design. Using a PS2 controller allowed for more input options and more functionality in our project.
- The use of two breadboards in our final design gave us a generous amount of space for circuitry, allowing for cleaner circuits and more extra features.

3.6 Safety / Professionalism

We performed safe and professional practices during the design of our project. This includes following the established laboratory rules such as using safety glasses while soldering components, keeping the laboratory food-free, and turning off the equipment and cleaning the workspace after we finished using it. Additionally, we disconnected the remote and the robot from power while we were working on their circuits. The robot also has a switch to quickly turn off the power in case of an accident.

3.7 Detailed Design

Perimeter Detector Circuit

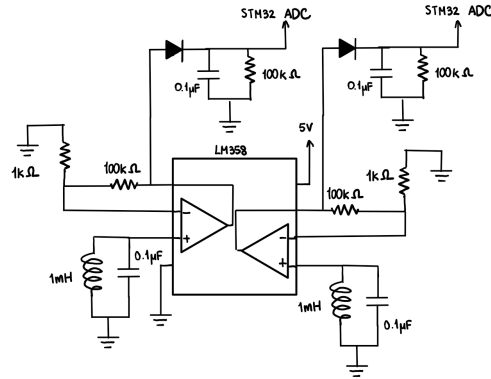


Figure X: Perimeter Detector Circuit.

An inductor in parallel with a capacitor will create a small induced AC voltage when an AC current is next to the inductor. This voltage is amplified with a gain of 100 using an LM358 op-amp. To measure the peak voltage of the induced AC voltage, a peak detector made out of a diode, a capacitor, and a resistor is attached to the output of the op-amp. This voltage is read by the STM32's ADC. Another perimeter detector circuit is placed perpendicular to the first one to ensure the perimeter is detected regardless of the angle of approach.

Metal Detector Circuit

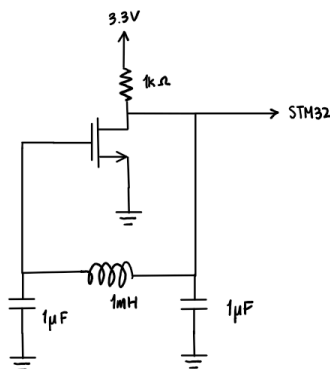


Figure X: Metal Detector Circuit.

The metal detector is a sinusoidal oscillator made of an inductor, two capacitors, an N-MOSFET, and a resistor. When metal is placed next to the inductor, its inductance changes, and will change

the frequency of the oscillator. This change in frequency is measured by the STM32, allowing it to detect metal.

Electromagnet, Servo, and Motor Circuit

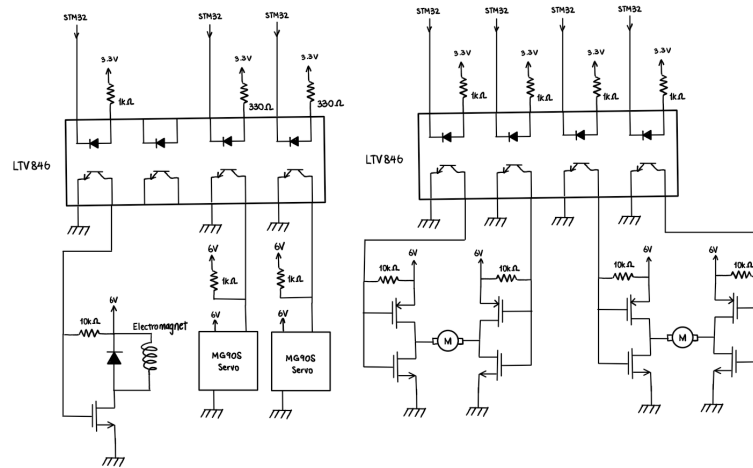


Figure X: Electromagnet, Servo, and Motor Circuit

Two LTV846 optocouplers were used to isolate the electromagnet, the servos, and the motors from the rest of the robot circuit. The motors that control the wheels are in two H-bridge circuits each made out of two P-MOSFETs, two N-MOSFETs, and two resistors, allowing for both forward and reverse rotation in the motors.

Perimeter Circuit

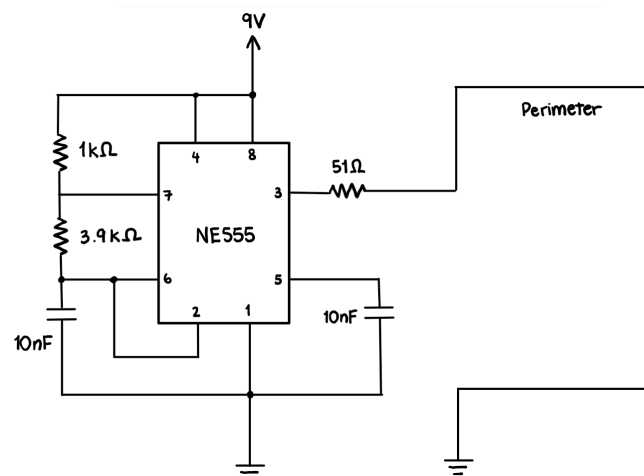


Figure X: Perimeter Circuit

A 555 timer in astable mode produces an oscillating current through a perimeter made of wire. The resistor and capacitor values of the 555 timer were chosen so that it produces a frequency near the 16 kHz resonance frequency of the perimeter detector. A low resistor value is attached to the output of the 555 timer to maximize the AC current, but not too low to generate too much heat.

3.8 Solution Assessment

Many parts of our final design could be assessed by

As shown above in Investigation, we tested our metal and perimeter detectors by comparing the measurements displayed on PuTTY with the oscilloscope. We put metal underneath the metal detector and a wire with an AC current next to the perimeter detector and confirmed that the microcontroller's measurements still align with the oscilloscope's readings. Figure X below shows some data collected during the testing of the perimeter detector.

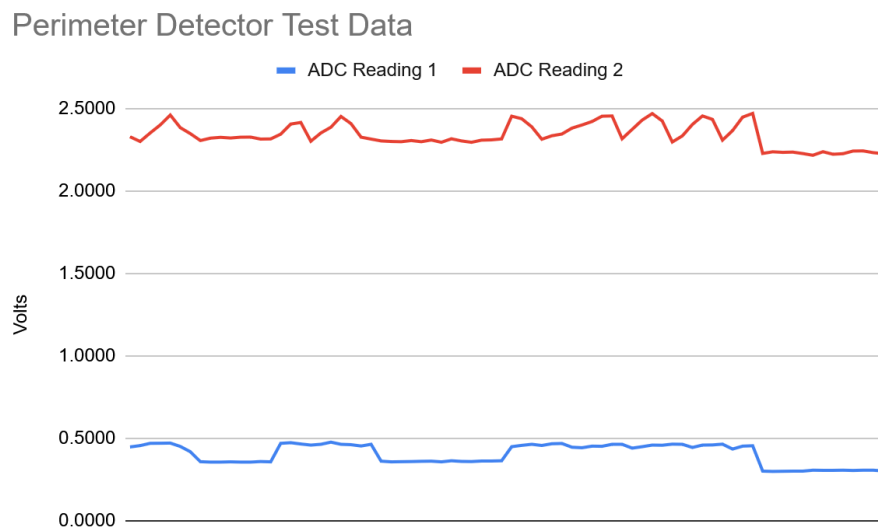


Figure X: Plot of the voltage measured by the STM32's ADC, during times where the perimeter is near and not near the perimeter detector

Some of the strengths of our design include the usage of the PS2 controller, allowing for many possible commands and actions for the robot, as well as the use of two breadboards for lots of space for circuitry. However, improvements to our design could be made, such as the reliability of the metal detector circuit and code.

4. Life-Long Learning

This project required us to apply numerous different concepts and skills we learned from previous courses. Our understanding of MOSFET operation and H-bridge circuits from ELEC 201 helped us design the motor driver circuit to implement bidirectional control of the robot's wheels. Concepts from ELEC 211, such as inductance and induced voltage, were directly applicable in building the perimeter detection system using sensor coils. In tuning the Colpitts oscillator for metal detection, we relied on our knowledge of resonant frequency and LC tank behavior from ELEC 202. These principles guided our component selection and analysis of the oscillator's frequency response to nearby metal objects. Additionally, our programming skills developed in APSC 160 and CPSC 259 were crucial in writing embedded C code for both the STM32 and PIC32 microcontrollers. We used timers, ADCs, PWM control, and UART communication, all requiring careful attention to efficient program structure. By integrating theoretical knowledge with hands-on problem solving, we deepened our understanding of both analog and digital systems, reinforcing the importance of continuous learning across disciplines. Furthermore, we were able to solidify our understanding of previous courses through hands-on experience.

5. Conclusions

Our project is a coin-picking robot that can be controlled manually with a remote and can automatically collect coins by itself. The remote uses a PS2 controller and sends commands through a JDY-40 radio. The robot moves using two motors and wheels and can pick up coins with two servo motors and an electromagnet. The robot has a metal detector and a perimeter detector to automatically detect coins and stay inside a perimeter. The strength of the signal from the metal detector in the robot is displayed on the LCD on the remote and causes a speaker on the remote to beep more frequently. Our design also has extra functionality, such as having complete control of the electromagnet arms of the robot, being able to pause and resume the robot's automatic mode, and displaying the coin count on the LCD. We encountered many problems such as delays debugging the radio communication and difficulties with detecting metal. However, we were able to demonstrate a completed project in the end. We estimate that we spent 60 hours on the project overall.

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8. Appendices

APPENDIX I: PARTS LIST

ROBOT HARDWARE:

- **Robot:**

- 2x Solarbotics GM4, 2x Servo Wheel, Tamiya 70144, 4x AA Battery Holder, 1x 9V cable, 2x MG90S Servo, Coin picker assembly kit, Electromagnet, Chassis Holder, Six Pin Switch

- **Microcontroller Circuit:**

- STM32L051 Microcontroller, BO230XS USB adapter, 2x MBR150 Diodes, LM7805, MCP1700, 6x 0.1uF Capacitor, 2x Push Buttons, 4x 330 Ohm Resistor, 1x Green LED,

2x Red LED

- **Radio Circuit:**

- JDY40 Radio, 1k Ohm Resistor

- **Metal Detector Circuit:**

- 1mH Inductor, 2x 1uF Capacitor, 1k Ohm Resistor, N-MOSFET

- **Perimeter Detector Circuit:**

- LM358 Op-Amp, 2x 1mH Inductor, 4x 0.1uF Capacitor, 2x MBR150, 2x 1k Ohm Resistor, 4x 100k Ohm Resistor

- **Electromagnet, Servo, and Motors Circuit:**

- 2x LTV846, 2x 330 Ohm Resistor, 7x 1k Ohm Resistor, 5x 10k Ohm Resistor, 4x P-MOSFET, 5x N-MOSFET, 1N4148 Diode

ROBOT SOFTWARE:

- **Remote Decoding Functions:**

- `int decodeButton1(char ch);`
- `int decodeButton2(char ch);`
- `int decodeJoystick(char letter, int isYAxis);`
- `int parseRemoteCommand(char *str, RemoteCommand *cmd);`
- `int mapValue(int x, int in_min, int in_max, int out_min, int out_max);`

- **Robot Base Functions**

- `void wait_1ms(void);`
- `void waitms(int len);`
- `void TIM2_Handler(void);`
- `void Hardware_Init(void);`
- `long int GetPeriod(int n);`
- `void PrintNumber(long int val, int Base, int digits);`

- **Radio Functions**

- `void SendATCommand(char *s);`
- `void ReceptionOff(void);`
- `void processRadioData(char *buff, RemoteCommand *currentCmd);`
- `int automode_toggle_check (char button);`

- **Movement Functions**

- `void leftWheelForward(void);`
- `void leftWheelBackward(void);`
- `void leftWheelStop(void);`
- `void rightWheelForward(void);`
- `void rightWheelBackward(void);`
- `void rightWheelStop(void);`
- `void turnAround(void);`
- `void turn90degreesCW(void);`
- `void turn90DegreesCCW(void);`
- `void aLittleForward(void);`
- `void aLittleBackward(void);`

- **Mode Functions**

- `void autodriven(RemoteCommand *currentCommand);`
- `void gameMode(void);`
- `void ManualControl(RemoteCommand *command);`

- **Electromagnetic Functions**

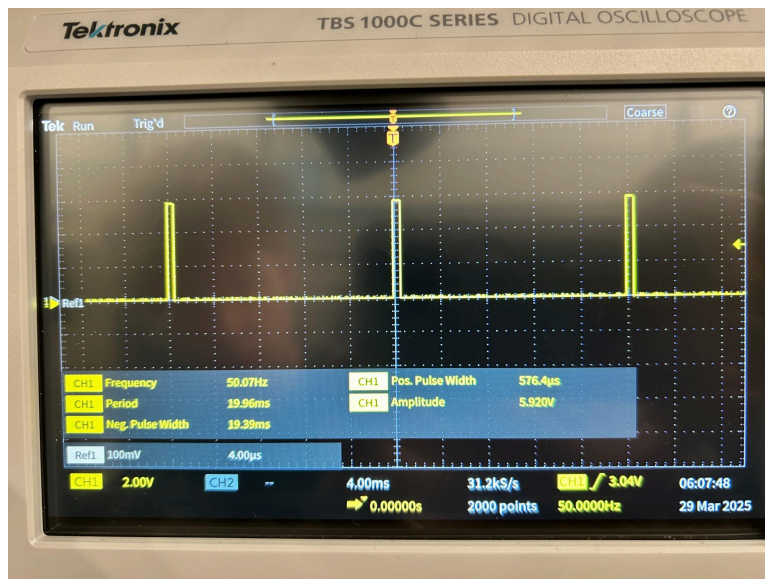
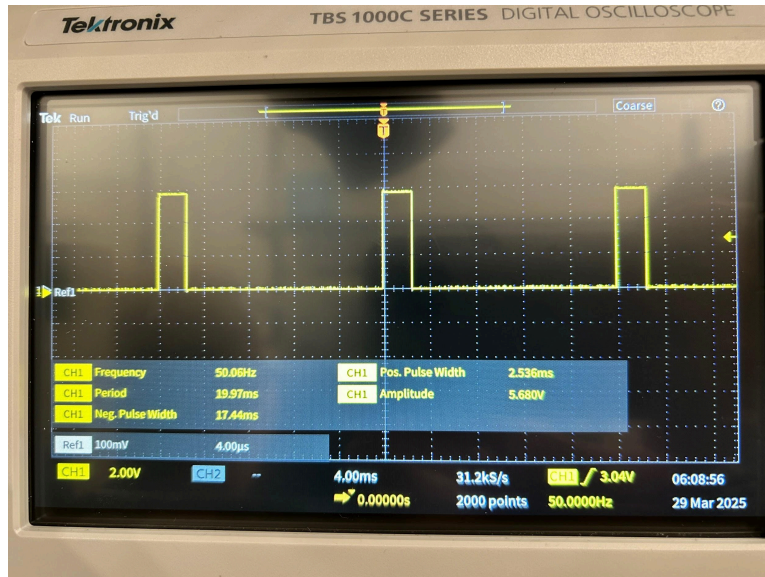
- `int detectMetal(void);`
- `int detectPerimeter(void);`
- `void collectCoin(void);`
- `void resetArm(void);`

REMOTE HARDWARE:

- Microcontroller Circuit:
- Radio Circuit:
- LCD Circuit:

REMOTE SOFTWARE:

APPENDIX II: PWM TESTING WITH THE OSCILLOSCOPE



APPENDIX III: FULL ROBOT CODE

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include "../Common/Include/serial.h"
#include "adc.h"
#include "UART2.h"
```

```

#define F_CPU 32000000L
#define DEF_F 100000L // 10us tick

// Some 'defines' to turn pins on/off easily (pins must be configured as outputs)
#define PB3_0 (GPIOB->ODR &= ~BIT3) // Left Wheel Black
#define PB3_1 (GPIOB->ODR |= BIT3)
// Left Wheel Red
#define PB4_0 (GPIOB->ODR &= ~BIT4) // Off
#define PB4_1 (GPIOB->ODR |= BIT4) // On
// Right Wheel Red
#define PB5_0 (GPIOB->ODR &= ~BIT5) // Off
#define PB5_1 (GPIOB->ODR |= BIT5) // On
// Right Wheel Black
#define PB6_0 (GPIOB->ODR &= ~BIT6) // Off
#define PB6_1 (GPIOB->ODR |= BIT6) // On
// Electromagnet
#define PB7_0 (GPIOB->ODR &= ~BIT7) // Off
#define PB7_1 (GPIOB->ODR |= BIT7) // On

#define PA13_0 (GPIOA->ODR &= ~BIT13) // Radio
#define PA13_1 (GPIOA->ODR |= BIT13)

#define PA6_0 (GPIOA->ODR &= ~BIT6) // LED Debugging
#define PA6_1 (GPIOA->ODR |= BIT6)
#define PA7_0 (GPIOA->ODR &= ~BIT7)
#define PA7_1 (GPIOA->ODR |= BIT7)

// // A define to easily read PA14 (PA14 must be configured as input first)
// #define PA14 (GPIOA->IDR & BIT14)

// A define to easily read PA1 (PA1 must be configured as input first)
#define PA1 (GPIOA->IDR & BIT1)

// A define to easily read PA8 (PA8 must be configured as input first)
#define PA8 (GPIOA->IDR & BIT8)

// LQFP32 pinout
// -----
//          VDD -|1          32|- VSS
//          PC14 -|2         31|- BOOT0
//          PC15 -|3         30|- PB7 (OUT 5) Electromagnet
//          NRST -|4         29|- PB6 (OUT 4) Right Wheel Black (Back)
//          VDDA -|5         28|- PB5 (OUT 3) Right Wheel Red (Forward)
//          PA0 -|6          27|- PB4 (OUT 2) Left Wheel Red (Back)
// (button) PA1 -|7          26|- PB3 (OUT 1) Left Wheel Black (Forward)
//          PA2 -|8          25|- PA15 (Used for RXD of UART2, connects to TXD of JDY40)
//          PA3 -|9          24|- PA14 (Used for TXD of UART2, connects to RXD of JDY40)
//          PA4 -|10         23|- PA13 (Used for SET of JDY40)
//          PA5 -|11         22|- PA12 (pwm2)
// (LED) PA6 -|12           21|- PA11 (pwm1)
// (LED) PA7 -|13           20|- PA10 (Reserved for RXD)
// (ADC_IN8) PB0 -|14        19|- PA9 (Reserved for TXD)

```

```

// (ADC_IN9) PB1 -|15      18|- PA8  (Measure the period at this pin)
//          VSS -|16      17|- VDD
//          -----

/*****
*****

BUTTON VALUE DEFINITIONS
*****
*****/

// Joystick Ranges
#define LEVEL0 0
#define LEVEL1 28
#define LEVEL2 55
#define LEVEL3 82
#define LEVEL4 110
#define LEVEL5 146
#define LEVEL6 174
#define LEVEL7 201
#define LEVEL8 228
#define LEVEL9 255

// Button Values
#define BUTTON_NONE 255
#define BUTTON_ERROR -1

// Buttons 2
#define SQUARE 127
#define O_BUTTON 223
#define TRIANGLE 239
#define X_BUTTON 191
#define R1 247
#define R2 253
#define L1 251
#define L2 254

// Buttons 1
#define START 247
#define SELECT 254
#define START_SELECT 250
#define L3 253
#define R3 251
#define DPAD_UP 239
#define DPAD_DOWN 191
#define DPAD_LEFT 127
#define DPAD_RIGHT 223

// Additional definitions for manual control:
#define MAX_SPEED 100 // Maximum speed value.
#define MAX_TURN 50 // Maximum turning value.
#define SPEED_THRESHOLD 10 // Minimum speed to command a movement.

```

```

// ----- Define servo movement limits and step values -----
#define MIN_ISR_PWM1 60    // Vertical servo upper limit
#define MAX_ISR_PWM1 255   // Vertical servo lower limit
#define MIN_ISR_PWM2 60    // Horizontal servo left limit
#define MAX_ISR_PWM2 255   // Horizontal servo right limit
// Use larger steps and shorter delays for faster movement
#define VERTICAL_STEP 20
#define HORIZONTAL_STEP 20
#define VERTICAL_DELAY_MS 5
#define HORIZONTAL_DELAY_MS 5

/*****
*****
GLOBAL VARIABLE DECLARATIONS
*****
*****/

volatile int PWM_Counter = 0;
volatile unsigned char ISR_pwm1 = 60, ISR_pwm2 = 255;

// Could measure references at startup or hard-code values here
volatile long int reference_frequency;
volatile long int frequency;
volatile long int reference_count;
volatile long int count;
volatile int reference_voltage[2];
volatile int voltage[2];

//RemoteCommand * Controller_Data; //used to store data from PS2 controller
int * mode_flag; //used to check if robot should be in automatic pickup mode

// Global coin counter added for the game:
volatile int coin_count = 0; //

// Structure to hold decoded remote command values
typedef struct {
    int b1;    // buttons1
    int b2;    // buttons2
    int rx;    // Right Joystick X
    int ry;    // Right Joystick Y
    int lx;    // Left Joystick X
    int ly;    // Left Joystick Y
} RemoteCommand;

/*****
*****
FUNCTION PROTOTYPES
*****
*****/

//Remote Decoding Functions

```



```

int decodeButton1(char ch);
int decodeButton2(char ch);
int decodeJoystick(char letter, int isYAxis);
int parseRemoteCommand(char *str, RemoteCommand *cmd);
int mapValue(int x, int in_min, int in_max, int out_min, int out_max);

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void waitms(int len);
void TIM2_Handler(void);
void Hardware_Init(void);
long int GetPeriod(int n);
void PrintNumber(long int val, int Base, int digits);

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//Movement Functions
void leftWheelForward(void);
void leftWheelBackward(void);
void leftWheelStop(void);
void rightWheelForward(void);
void rightWheelBackward(void);
void rightWheelStop(void);
void turnAround(void);
void turn90degreesCW(void);
void turn90DegreesCCW(void);
void aLittleForward(void);
void aLittleBackward(void);

//Mode Functions
void autodrive(RemoteCommand *currentCommand);
void gameMode(void);
void ManualControl(RemoteCommand *command);

//Electromagnetic Functions
int detectMetal(void);
int detectPerimeter(void);
void collectCoin(void);
void resetArm(void);

/*****
*****
REMOTE COMMAND DECODING FUNCTIONS
Based on the Controller Data Encoding Table
:contentReference[oaicite:2]{index=2}&œ<:contentReference[oaicite:3]{index=3}:
Data format: [b1Char][b2Char][rxChar][ryChar][lxChar][lyChar]

```

For example: "NN1515" means no buttons pressed, Right Joystick left & centre, Left Joystick left & centre.

*****/

```
int decodeButton1(char ch) {
    switch(ch) {
        case 'N': return BUTTON_NONE;    // No button pressed
        case 's': return SELECT;          // SELECT
        case 'S': return START;           // START
        case 'Z': return START_SELECT;    // START_SELECT
        case 'U': return DPAD_UP;         // DPAD UP
        case 'D': return DPAD_DOWN;       // DPAD DOWN
        case 'L': return DPAD_LEFT;       // DPAD LEFT
        case 'R': return DPAD_RIGHT;      // DPAD RIGHT
        case 'l': return L3;              // L3 (joystick press)
        case 'r': return R3;              // R3 (joystick press)
        case 'E': return BUTTON_ERROR;    // Error
        default: return 0;                // Unknown value
    }
}
```

```
int decodeButton2(char ch) {
    switch(ch) {
        case 'N': return BUTTON_NONE;    // No button pressed
        case 'X': return X_BUTTON;       // X
        case 'S': return SQUARE;         // Square
        case 'O': return O_BUTTON;       // O
        case 'T': return TRIANGLE;       // Triangle
        case 'r': return R1;              // R1
        case 'R': return R2;              // R2
        case 'l': return L1;              // L1
        case 'L': return L2;              // L2
        case 'E': return BUTTON_ERROR;    // Error
        default: return 0;
    }
}
```

```
int decodeJoystick(char letter, int isYAxis) {
    if(letter < '1' || letter > '9') return -1; // Invalid letter
    int num = letter - '0';
    // For non-inverted joystick, compute midpoint using LEVEL definitions.
    static int mappingX[9] = {
        (LEVEL0 + LEVEL1) / 2, // '1': (0+28)/2 = 14
        (LEVEL1 + LEVEL2) / 2, // '2': (28+55)/2 = 41
        (LEVEL2 + LEVEL3) / 2, // '3': (55+82)/2 = 68
        (LEVEL3 + LEVEL4) / 2, // '4': (82+110)/2 = 96
        (LEVEL4 + LEVEL5) / 2, // '5': (110+146)/2 = 128
        (LEVEL5 + LEVEL6) / 2, // '6': (146+174)/2 = 160
        (LEVEL6 + LEVEL7) / 2, // '7': (174+201)/2 = 187
        (LEVEL7 + LEVEL8) / 2, // '8': (201+228)/2 = 214
    }
```

```

        (LEVEL8 + LEVEL9) / 2    // '9': (228+255)/2 = 241 (integer division)
    };
    // For the y-axis, use an inverted mapping (reverse order).
    static int mappingY[9] = {
        (LEVEL8 + LEVEL9) / 2,    // '1' â†’ highest: 241
        (LEVEL7 + LEVEL8) / 2,    // '2': 214
        (LEVEL6 + LEVEL7) / 2,    // '3': 187
        (LEVEL5 + LEVEL6) / 2,    // '4': 160
        (LEVEL4 + LEVEL5) / 2,    // '5': 128
        (LEVEL3 + LEVEL4) / 2,    // '6': 96
        (LEVEL2 + LEVEL3) / 2,    // '7': 68
        (LEVEL1 + LEVEL2) / 2,    // '8': 41
        (LEVEL0 + LEVEL1) / 2     // '9' â†’ lowest: 14
    };
    if(!isYAxis) {
        return mappingX[num - 1];
    } else {
        return mappingY[num - 1];
    }
}

int parseRemoteCommand(char *str, RemoteCommand *cmd) {
    if(strlen(str) != 6) return 0;    // Expect exactly 6 characters
    cmd->b1 = decodeButton1(str[0]);
    cmd->b2 = decodeButton2(str[1]);
    cmd->rx = decodeJoystick(str[2], 0); // Right Joystick X
    cmd->ry = decodeJoystick(str[3], 1); // Right Joystick Y
    cmd->lx = decodeJoystick(str[4], 0); // Left Joystick X
    cmd->ly = decodeJoystick(str[5], 1); // Left Joystick Y
    return 1;
}

// Mapping function: maps an input value x from [in_min, in_max] to [out_min, out_max].
int mapValue(int x, int in_min, int in_max, int out_min, int out_max) {
    return (x - in_min) * (out_max - out_min) / (in_max - in_min) + out_min;
}

/*****
*****

ROBOT BASE FUNCTIONS
*****
*****/

void wait_1ms(void)
{
    // For SysTick info check the STM3210xxx Cortex-M0 programming manual.
    SysTick->LOAD = (F_CPU/1000L) - 1;    // set reload register, counter rolls over from zero,
hence -1
    SysTick->VAL = 0; // load the SysTick counter
    SysTick->CTRL = SysTick_CTRL_CLKSOURCE_Msk | SysTick_CTRL_ENABLE_Msk; // Enable SysTick
IRQ and SysTick Timer */

```

```

    while((SysTick->CTRL & BIT16)==0); // Bit 16 is the COUNTFLAG. True when counter rolls
over from zero.
    SysTick->CTRL = 0x00; // Disable SysTick counter
}

void waitms(int len)
{
    while(len-->0) wait_1ms();
}

// Interrupt service routines are the same as normal
// subroutines (or C functions) in Cortex-M microcontrollers.
// The following should happen at a rate of 1kHz.
// The following function is associated with the TIM2 interrupt
// via the interrupt vector table defined in startup.c
void TIM2_Handler(void)
{
    TIM2->SR &= ~BIT0; // clear update interrupt flag
    PWM_Counter++;

    if(ISR_pwm1>PWM_Counter)
    {
        GPIOA->ODR |= BIT11;
    }
    else
    {
        GPIOA->ODR &= ~BIT11;
    }

    if(ISR_pwm2>PWM_Counter)
    {
        GPIOA->ODR |= BIT12;
    }
    else
    {
        GPIOA->ODR &= ~BIT12;
    }

    if (PWM_Counter > 2000) // The period is 20ms
    {
        PWM_Counter=0;
        GPIOA->ODR |= (BIT11|BIT12);
    }
}

void Hardware_Init(void)
{
    GPIOA->OSPEEDR=0xffffffff; // All pins of port A configured for very high speed! Page 201
of RM0451

```

```

//GPIOA->OSPEEDR |= 0xfc000000; // Pins PA15, PA14, PA13 configured for very high speed!
Page 201 of RM0451

RCC->IOPENR  |= (BIT1|BIT0); // peripheral clock enable for ports A and B

// Configure the pin used for analog input: PB0 and PB1 (pins 14 and 15)
GPIOB->MODER |= (BIT0|BIT1); // Select analog mode for PB0 (pin 14 of LQFP32 package)
GPIOB->MODER |= (BIT2|BIT3); // Select analog mode for PB1 (pin 15 of LQFP32 package)

initADC();

// Configure the pin used to measure period
GPIOA->MODER &= ~(BIT16 | BIT17); // Make pin PA8 input
// Activate pull up for pin PA8:
GPIOA->PUPDR |= BIT16;
GPIOA->PUPDR &= ~(BIT17);

// // Configure the pin connected to the pushbutton as input

// GPIOA->MODER &= ~(BIT28 | BIT29); // Make pin PA14 input
// // Activate pull up for pin PA8:
// GPIOA->PUPDR |= BIT28;
// GPIOA->PUPDR &= ~(BIT29);

GPIOA->MODER &= ~(BIT2 | BIT3); // Make pin PA1 input
// Activate pull up for pin PA1:
GPIOA->PUPDR |= BIT2;
GPIOA->PUPDR &= ~(BIT3);

// Configure some pins as outputs:
// Make pins PB3 to PB7 outputs (page 200 of RM0451, two bits used to configure: bit0=1,
bit1=0)
GPIOB->MODER = (GPIOB->MODER & ~(BIT6|BIT7)) | BIT6; // PB3
GPIOB->OTYPER &= ~BIT3; // Push-pull
GPIOB->MODER = (GPIOB->MODER & ~(BIT8|BIT9)) | BIT8; // PB4
GPIOB->OTYPER &= ~BIT4; // Push-pull
GPIOB->MODER = (GPIOB->MODER & ~(BIT10|BIT11)) | BIT10; // PB5
GPIOB->OTYPER &= ~BIT5; // Push-pull
GPIOB->MODER = (GPIOB->MODER & ~(BIT12|BIT13)) | BIT12; // PB6
GPIOB->OTYPER &= ~BIT6; // Push-pull
GPIOB->MODER = (GPIOB->MODER & ~(BIT14|BIT15)) | BIT14; // PB7
GPIOB->OTYPER &= ~BIT7; // Push-pull

// Set up servo PWM output pins
GPIOA->MODER = (GPIOA->MODER & ~(BIT22|BIT23)) | BIT22; // Make pin PA11 output (page 200
of RM0451, two bits used to configure: bit0=1, bit1=0)
GPIOA->OTYPER |= BIT11; // Open-drain
GPIOA->MODER = (GPIOA->MODER & ~(BIT24|BIT25)) | BIT24; // Make pin PA12 output (page 200
of RM0451, two bits used to configure: bit0=1, bit1=0)
GPIOA->OTYPER |= BIT12; // Open-drain

// Set up JDY40 output pins

```

```

    GPIOA->MODER = (GPIOA->MODER & ~(BIT26|BIT27)) | BIT26; // Make pin PA13 output (page 200
of RM0451, two bits used to configure: bit0=1, bit1=0))
    GPIOA->ODR |= BIT13; // 'set' pin to 1 is normal operation mode.

    // Set up LED Debugging output pins
    GPIOA->MODER = (GPIOA->MODER & ~(BIT12|BIT13)) | BIT12; // Make pin PA6 output
    GPIOA->OTYPER &= ~BIT6; // Push-pull
    GPIOA->MODER = (GPIOA->MODER & ~(BIT14|BIT15)) | BIT14; // Make pin PA7 output
    GPIOA->OTYPER &= ~BIT7; // Push-pull

    // Set up timers
    RCC->APB1ENR |= BIT0; // turn on clock for timer2 (UM: page 177)
    TIM2->ARR = F_CPU/DEF_F-1;
    NVIC->ISER[0] |= BIT15; // enable timer 2 interrupts in the NVIC
    TIM2->CR1 |= BIT4; // Downcounting
    TIM2->CR1 |= BIT7; // ARPE enable
    TIM2->DIER |= BIT0; // enable update event (reload event) interrupt
    TIM2->CR1 |= BIT0; // enable counting

    __enable_irq();
}

long int GetPeriod (int n)
{
    int i;
    unsigned int saved_TCNT1a, saved_TCNT1b;

    SysTick->LOAD = 0xffffffff; // 24-bit counter set to check for signal present
    SysTick->VAL = 0xffffffff; // load the SysTick counter
    SysTick->CTRL = SysTick_CTRL_CLKSOURCE_Msk | SysTick_CTRL_ENABLE_Msk; // Enable SysTick
IRQ and SysTick Timer */
    while (PA8!=0) // Wait for square wave to be 0
    {
        //eputs("PA8!=0 While Loop in GetPeriod\r\n");
        if(SysTick->CTRL & BIT16) return 0;
    }
    SysTick->CTRL = 0x00; // Disable Systick counter

    SysTick->LOAD = 0xffffffff; // 24-bit counter set to check for signal present
    SysTick->VAL = 0xffffffff; // load the SysTick counter
    SysTick->CTRL = SysTick_CTRL_CLKSOURCE_Msk | SysTick_CTRL_ENABLE_Msk; // Enable SysTick
IRQ and SysTick Timer */
    while (PA8==0) // Wait for square wave to be 1
    {
        //eputs("PA8==0 While Loop in GetPeriod\r\n");
        if(SysTick->CTRL & BIT16) return 0;
    }
    SysTick->CTRL = 0x00; // Disable Systick counter

    SysTick->LOAD = 0xffffffff; // 24-bit counter reset

```

```

    SysTick->VAL = 0xffffffff; // load the SysTick counter to initial value
    SysTick->CTRL = SysTick_CTRL_CLKSOURCE_Msk | SysTick_CTRL_ENABLE_Msk; // Enable SysTick
    IRQ and SysTick Timer */
    for(i=0; i<n; i++) // Measure the time of 'n' periods
    {
        while (PA8!=0) // Wait for square wave to be 0
        {
            //eputs("for loop PA8!=0 While Loop in GetPeriod\r\n");
            if(SysTick->CTRL & BIT16) return 0;
        }
        while (PA8==0) // Wait for square wave to be 1
        {
            //eputs("for loop PA8==0 While Loop in GetPeriod\r\n");
            if(SysTick->CTRL & BIT16) return 0;
        }
    }
    SysTick->CTRL = 0x00; // Disable SysTick counter

    return 0xffffffff-SysTick->VAL;
}

void PrintNumber(long int val, int Base, int digits)
{
    char HexDigit[]="0123456789ABCDEF";
    int j;
    #define NBITS 32
    char buff[NBITS+1];
    buff[NBITS]=0;

    j=NBITS-1;
    while ( (val>0) | (digits>0) )
    {
        buff[j--]=HexDigit[val%Base];
        val/=Base;
        if(digits!=0) digits--;
    }
    eputs(&buff[j+1]);
}

/*****
*****
RADIO FUNCTIONS
*****
*****/

void SendATCommand (char * s)
{
    char buff[40];
    // printf("Command: %s", s);
    eputs("Command: ");
    eputs(s);
    eputs("\r\n");
}

```

```

GPIOA->ODR &= ~(BIT13); // 'set' pin to 0 is 'AT' mode.
waitms(10);
eputs2(s);
egets2(buff, sizeof(buff)-1);
GPIOA->ODR |= BIT13; // 'set' pin to 1 is normal operation mode.
waitms(10);
// printf("Response: %s", buff);
eputs("Response: ");
eputs(buff);
eputs("\r\n");
}

void ReceptionOff (void)
{
    GPIOA->ODR &= ~(BIT13); // 'set' pin to 0 is 'AT' mode.
    waitms(10);
    eputs2("AT+DVID0000\r\n"); // Some unused id, so that we get nothing in RXD1.
    waitms(10);
    GPIOA->ODR |= BIT13; // 'set' pin to 1 is normal operation mode.
    while (ReceivedBytes2()>0) egetc2(); // Clear FIFO
}

/*****
* Process ALL incoming radio data from UART2
*   - If we see a '!' we parse a 6-char command (e.g., "Ns1515")
*     and call ManualControl().
*   - If we see an '@' we respond with frequency data.
*   - Otherwise, we ignore or handle as needed.
*****/
void processRadioData(char *buff, RemoteCommand *currentCmd)
{
    // Read until the FIFO is empty.
    while (ReceivedBytes2() > 0)
    {
        char c = egetc2();

        if (c == '!')
        {
            // We expect the next 6 characters to be the joystick/buttons, e.g. "Ns1515".
            // Read 6 chars (plus 1 for '\0').
            if (egets2(buff, 7) > 0)
            {
                eputs("Received command: ");
                eputs(buff);
                eputs("\r\n");

                // Try to parse into our RemoteCommand struct, then do manual control
                if (parseRemoteCommand(buff, currentCmd))
                {
                    ManualControl(currentCmd); // <--- your existing manual-control logic
                }
            }
        }
    }
}

```



```

        if (currentCmd->b1 == START)
        {
            *mode_flag = 1;
        }
        else if (currentCmd->b1 == SELECT)
        {
            *mode_flag = 0;
        }
        else if (currentCmd->b1 == START_SELECT)
        {
            *mode_flag = 3;
        }
    }
    else
    {
        eputs("Error: unable to parse command!\r\n");
    }
}

else if (c == '@') {
    // Master is requesting frequency data and coin count.
    // Format as "F:xxxxx,C:yyy" where frequency is 5 digits and coin_count is 3
    digits.

    long int freq = frequency *10000; // recalc if needed
    freq = freq / reference_frequency;

    sprintf(buff, "%05ld%02d", freq, coin_count);
    // The radio often needs a small delay
    waitms(5);
    eputs2(buff); // Send back the formatted data string
}
else {
    //eputs("NO DATA\r\n");
}
}

}

/* parseRemoteCommand() parses a string of the form:
    "LX=%d,LY=%d,RX=%d,RY=%d,B6=%d,B7=%d"
    Returns 1 on success, 0 on failure.
*/
//int parseRemoteCommand(char *str, RemoteCommand *cmd)
//{
//    int parsed = sscanf(str, "LX=%d,LY=%d,RX=%d,RY=%d,B6=%d,B7=%d",
//        &cmd->lx, &cmd->ly, &cmd->rx, &cmd->ry,
//        &cmd->b6, &cmd->b7);
//    return (parsed == 6);
//}

//Checks if SELECT or START are Pressed

```

```

//If true, starts or stops automode based on value of autoflag and resets robot to starting
position
//Returns 1 if moving to Manual mode, otherwise returns 0
int automode_toggle_check (char button)
{
    //char * data;
    eputs("automode_toggle_check\r\n");
    if (button == 's') // If SELECT is pressed, turn off automode
    {
        eputs("Turn off Automode\r\n");
        *mode_flag = 0;

        leftWheelStop();
        rightWheelStop();
        resetArm();

        return 1;
    }
    else if (button == 'S') // If START is pressed, turn on automode
    {
        eputs("Turn on Automode\r\n");
        *mode_flag = 1;
        return 0;
    }
    else
    {
        eputs("Automode no effect\r\n");
        return 0;
    }
}

/*****
*****

MOVEMENT FUNCTIONS
*****
*****/

// Functions for controlling the wheels
// Change the wiring to match these functions
void leftWheelForward(void)
{
    PB3_1;
    PB4_0;
}

void leftWheelStop(void)
{
    PB3_0;
    PB4_0;
}

void leftWheelBackward(void)

```

```

{
    PB3_0;
    PB4_1;
}

void rightWheelForward(void)
{
    PB5_1;
    PB6_0;
}

void rightWheelStop(void)
{
    PB5_0;
    PB6_0;
}

void rightWheelBackward(void)
{
    PB5_0;
    PB6_1;
}

void turnAround(void)
{
    eputs("turnAround\r\n");
    // Change this number to make sure the robot turns 90 degrees in this amount of time
    int turning_time_ms = 200;

    // Go backwards for some time
    leftWheelBackward();
    rightWheelBackward();

    // This may need adjustment
    waitms(500);

    // The three lines of code here may not be necessary
    // leftWheelStop();
    // rightWheelStop();
    // waitms(100);

    // Turn clockwise 90 degrees
    leftWheelForward();
    rightWheelBackward();
    waitms(turning_time_ms);

    // PWM_Counter is constantly changing from 1 to 2000 in Timer2; use it for pseudorandom
    numbers
    // Turn clockwise from 0 to 180 degrees more
    waitms((turning_time_ms * PWM_Counter)/1000);

    // The three lines of code here may not be necessary
    // leftWheelStop();

```

```

        // rightWheelStop();
        // waitms(100);
    }

void turn90DegreesCW(void) {
    eputs("turn90DegreesCW\r\n");

    // Turn clockwise 90 degrees
    leftWheelBackward();
    rightWheelForward();
    waitms(600);

    //Stop
    leftWheelStop();
    rightWheelStop();
}

void turn90DegreesCCW(void) {
    eputs("turn90DegreesCCW\r\n");

    // Turn counter clockwise 90 degrees
    leftWheelForward();
    rightWheelBackward();
    waitms(600);

    //Stop
    leftWheelStop();
    rightWheelStop();
}

//Inch robot forward slightly
void aLittleForward(void)
{
    leftWheelForward();
    rightWheelForward();
    waitms(100);
    leftWheelStop();
    rightWheelStop();
}

void aLittleBackward(void)
{
    leftWheelBackward();
    rightWheelBackward();
    waitms(100);
    leftWheelStop();
    rightWheelStop();
}

void autodrive(RemoteCommand *currentCommand)
{
    char buff[16];
    //RemoteCommand currentCommand;

```

```

eputs("autodrive\r\n");

//processRadioData(buff, &currentCommand);

// If a toggle command (SELECT: 's' or START: 'S') was received, handle it.
if (currentCommand->b1 == SELECT)
{
    *mode_flag = 0;
    coin_count = 0;
    return; // Exit autonomous mode and reset coin count to 0
}

//check if pause command was recieved
if(currentCommand->b2 == TRIANGLE)
{
    *mode_flag = 2;
    return;
}

// Drive forward.
leftWheelForward();
rightWheelForward();

// Update frequency measurement.
//frequency = (F_CPU * 60) / GetPeriod(60);

// If metal is detected, pick up the coin.
if (detectMetal())
{
    eputs("while(detectMetal())\r\n");
    collectCoin();
}

// If the perimeter is detected, perform a turn-around.
if (detectPerimeter())
{
    eputs("if(detectPerimeter())\r\n");
    turnAround();
}

// (Any frequency requests are handled within processRadioData.)
// If enough coins are collected, end automode.
if (coin_count == 20)
{
    //processRadioData(buff, &currentCommand); // Check for any pending commands.
    *mode_flag = 0; // Exit autonomous mode.
    coin_count = 0;
}

waitms(50);

```

```

        return;
    }

//Displays countdown and lets user try to pick up as many coins as they can in a given time
//Alternatively: Has set amount of coins to pick up and lets user try to pick up as many as
they can in given time
//If we want to be able to count coins we will need a load cell
void gameMode(void)
{
    eputs("gameMode\r\n");
}

/*****
 * MANUAL MODE
 * This function processes a decoded remote command (RemoteCommand structure)
 * and drives the robot accordingly in manual mode.
 * It adjusts the speed scaling using L1 and R1, toggles the electromagnet with the
 * X button, and calculates forward/reverse speed and turning based on the left
 * joystick's Y and X axes respectively.
 * The thresholds for the deadzone are set using LEVEL4 and LEVEL5.
 *****/

// ----- Control electromagnet servo (raise/lower arm) using DPAD (buttons from set 1)
-----
// Define target servo positions for the electromagnet arm.
void ManualControl(RemoteCommand *command) {
    // ----- Static variables -----
    static int speedFactor = 50;    // Initial speed scaling factor (percentage)
    static int electromagnetOn = 0; // 0: off, 1: on.
    static int firstRun = 1;        // One-time initialization flag

    // Initialize electromagnet state on first run.
    if (firstRun) {
        PB7_0; // Turn electromagnet OFF.
        electromagnetOn = 0;
        firstRun = 0;
        eputs("Initial setup: Electromagnet OFF.\r\n");
    }

    // ----- Adjust speed factor using L1 and R1 (button set 2) -----
    //if (command->b2 == L1) {
    //    speedFactor -= 10;
    //    eputs("L1 pressed: Decreasing speed factor.\r\n");
    //}
    //if (command->b2 == R1) {
    //    speedFactor += 10;
    //    eputs("R1 pressed: Increasing speed factor.\r\n");
    //}
    //if (speedFactor < 0)    speedFactor = 0;
    //if (speedFactor > 100) speedFactor = 100;

    // ----- Control electromagnet on/off (using X and O from button set 2) -----

```

```

if (command->b2 == X_BUTTON) {
    PB7_1;          // Turn electromagnet ON.
    electromagnetOn = 1;
    eputs("X pressed: Turning electromagnet ON.\r\n");
}
if (command->b2 == O_BUTTON) {
    PB7_0;          // Turn electromagnet OFF.
    electromagnetOn = 0;
    eputs("O pressed: Turning electromagnet OFF.\r\n");
}

// ----- Adjust electromagnet arm position using DPAD (button set 1) -----
// Vertical movement (up/down remains the same)
if (command->b1 == DPAD_UP) {
    if (ISR_pwm1 > MIN_ISR_PWM1) {
        ISR_pwm1 -= VERTICAL_STEP;
        waitms(VERTICAL_DELAY_MS);
        eputs("DPAD UP pressed: Moving electromagnet up.\r\n");
    }
}
if (command->b1 == DPAD_DOWN) {
    if (ISR_pwm1 < MAX_ISR_PWM1) {
        ISR_pwm1 += VERTICAL_STEP;
        waitms(VERTICAL_DELAY_MS);
        eputs("DPAD DOWN pressed: Moving electromagnet down.\r\n");
    }
}
// Inverted horizontal movement:
// DPAD_LEFT now increases ISR_pwm2 (moves right) and DPAD_RIGHT decreases ISR_pwm2 (moves
left)
if (command->b1 == DPAD_LEFT) {
    if (ISR_pwm2 < MAX_ISR_PWM2) {
        ISR_pwm2 += HORIZONTAL_STEP;
        waitms(HORIZONTAL_DELAY_MS);
        eputs("DPAD LEFT pressed: Moving electromagnet right (inverted).\r\n");
    }
}
if (command->b1 == DPAD_RIGHT) {
    if (ISR_pwm2 > MIN_ISR_PWM2) {
        ISR_pwm2 -= HORIZONTAL_STEP;
        waitms(HORIZONTAL_DELAY_MS);
        eputs("DPAD RIGHT pressed: Moving electromagnet left (inverted).\r\n");
    }
}

// ----- Compute wheel speeds from joystick positions -----
// Use the global mapValue() function (declared elsewhere) to scale joystick inputs.
int leftSpeed = 0;
if (command->ry < LEVEL4) {
    leftSpeed = mapValue(command->ry, 0, LEVEL4, MAX_SPEED, 0);
} else if (command->ry > LEVEL5) {
    leftSpeed = mapValue(command->ry, LEVEL5, 255, 0, -MAX_SPEED);
}

```

```

}else {
    leftSpeed = 0;
}

leftSpeed = (leftSpeed * speedFactor) / 100;

int rightSpeed = 0;
if (command->ly < LEVEL4) {
    rightSpeed = mapValue(command->ly, 0, LEVEL4, MAX_SPEED, 0);
} else if (command->ly > LEVEL5) {
    rightSpeed = mapValue(command->ly, LEVEL5, 255, 0, -MAX_SPEED);
}else {
    rightSpeed = 0;
}
rightSpeed = (rightSpeed * speedFactor) / 100;

// ----- Debug prints -----
eputs("ManualControl: leftSpeed=");
PrintNumber(leftSpeed, 10, 3);
eputs(", rightSpeed=");
PrintNumber(rightSpeed, 10, 3);
eputs(", speedFactor=");
PrintNumber(speedFactor, 10, 3);
eputs("\r\n");

// ----- Command the wheels -----
if (leftSpeed > SPEED_THRESHOLD)
    leftWheelForward();
else if (leftSpeed < -SPEED_THRESHOLD)
    leftWheelBackward();
else
    leftWheelStop();

if (rightSpeed > SPEED_THRESHOLD)
    rightWheelForward();
else if (rightSpeed < -SPEED_THRESHOLD)
    rightWheelBackward();
else
    rightWheelStop();

//if (decodeJoystick(command->ly, 0) > LEVEL5)
//    leftWheelForward();
//else if (decodeJoystick(command->ly, 0) < LEVEL4)
//    leftWheelBackward();
//else
//    leftWheelStop();

//if (decodeJoystick(command->ry, 0) > LEVEL5)
//    rightWheelForward();
//else if (decodeJoystick(command->ry, 0) < LEVEL4)
//    rightWheelBackward();
//else

```



```

        //    rightWheelStop();

//----- More Driving Functions -----
//Press L3 to turn robot 90 degrees counter clockwise
if(command->b1 == L3)
{
    turn90DegreesCCW();
}

//Press L3 to turn robot 90 degrees counter clockwise
if(command->b1 == R3)
{
    turn90DegreesCW();
}

//Press R1 to inch the robot backward
if(command->b2 == R1)
{
    aLittleBackward();
}

//Press R2 to inch the robot forward
if(command->b2 == R2)
{
    aLittleForward();
}

//----- Collect Coin -----
if(command->b2 == L2)
{
    collectCoin();
}

//

}

/*****
*****
ELECTROMAGNETIC FUNCTIONS
*****
*****/

// Function for detecting metal
// Returns 1 if metal is detected, else 0
int detectMetal(void)
{
    int threshold = 128;

```

```

int voltage_threshold = 1000;

eputs("detectMetal\r\n");
//long int count;

//count = GetPeriod(60);

//frequency = (F_CPU * 60) / count;

//printf("Count = %6d\r\n", count);

voltage[0] = (readADC(ADC_CHSELR_CHSEL8) * 33000) / 0xffff;
voltage[1] = (readADC(ADC_CHSELR_CHSEL9) * 33000) / 0xffff;

// if (count > reference_count + threshold)
// {
//   PA6_0;
//   return 1;
// }

if (voltage[0] < reference_voltage[0] - voltage_threshold || voltage[1] <
reference_voltage[1] - voltage_threshold)
{
    PA6_0;
    return 1;
}

PA6_1;
return 0;
}

// Function for detecting the perimeter
// Returns 1 if perimeter is reached, else 0
int detectPerimeter(void)
{
    int voltage_threshold = 2500;

    eputs("detectPerimeter\r\n");
    voltage[0] = (readADC(ADC_CHSELR_CHSEL8) * 33000) / 0xffff;
    voltage[1] = (readADC(ADC_CHSELR_CHSEL9) * 33000) / 0xffff;

    if (voltage[0] > reference_voltage[0] + voltage_threshold || voltage[1] >
reference_voltage[1] + voltage_threshold)
    {
        PA7_0;
        return 1;
    }

    PA7_1;
    return 0;
}

```

```

// Function for picking up a coin
void collectCoin(void)
{
    eputs("collectCoin\r\n");
    // Move robot backwards (if necessary)
    leftWheelBackward();
    rightWheelBackward();
    //if(automode_toggle_check()){
        //return;
    //}
    waitms(250);

    leftWheelStop();
    rightWheelStop();
    //if(automode_toggle_check()){
        //return;
    //}
    waitms(500);

    // Move arm down from starting position
    while (ISR_pwm2 < 255)
    {
        //if(automode_toggle_check()){
            //return;
        //}
        ISR_pwm2++;
        waitms(5);
    }
    while (ISR_pwm1 < 255)
    {
        //if(automode_toggle_check()){
            //return;
        //}
        ISR_pwm1++;
        waitms(5);
    }

    // Turn on electromagnet
    PB7_1;
    waitms(100);

    // Sweep left and right
    while (ISR_pwm2 > 140)
    {
        //if(automode_toggle_check()){
            //return;
        //}
        ISR_pwm2--;
        waitms(10);
    }
}

```

```

waitms(100);

while (ISR_pwm2 < 160)
{
    //if(automode_toggle_check()){
        //return;
    //}
    ISR_pwm2++;
    waitms(10);
}

waitms(100);

// Move arm above collection box
while (ISR_pwm1 > 130)
{
    //if(automode_toggle_check()){
        //return;
    //}
    ISR_pwm1--;
    waitms(5);
}

waitms(100);

while (ISR_pwm2 > 110)
{
    //if(automode_toggle_check()){
        //return;
    //}
    ISR_pwm2--;
    waitms(5);
}

// Move arm above collection box
while (ISR_pwm1 < 170)
{
    //if(automode_toggle_check()){
        //return;
    //}
    ISR_pwm1++;
    waitms(5);
}

// Turn off electromagnet
PB7_0;
waitms(1000);

while (ISR_pwm1 > 60)
{

```

```

        ISR_pwm1--;
        waitms(5);
    }

    //put coin sound function here

    // Increment the coin counter when a coin is collected
    coin_count++;

    // Return to starting position
    resetArm();

    waitms(1000);
}

void resetArm(void)
{
    // Turn off electromagnet
    PB7_0;
    waitms(100);

    // Move arm to starting position
    while (ISR_pwm2 < 255)
    {
        ISR_pwm2++;
        waitms(5);
    }
    while (ISR_pwm1 > 60)
    {
        ISR_pwm1--;
        waitms(5);
    }
}

/*****
*****

MAIN
*****
*****/

int main(void)
{
    Hardware_Init();
    initUART2(9600);

    // Just so your pointer mode_flag is valid:
    static int mode_value = 0; // 0 = manual, 1 = auto, 2 = paused
    mode_flag = &mode_value;

    char buff[16];
    RemoteCommand currentCommand;

```

```

// Clear screen and print startup messages.
eputs("\x1b[2J\x1b[1;1H");
eputs("\r\nSTM32L051 multi I/O example.\r\n");
eputs("Starting in MANUAL MODE.\r\n");

ReceptionOff();

// Optional: send some AT commands.
SendATCommand("AT+VER\r\n");
SendATCommand("AT+BAUD\r\n");
SendATCommand("AT+RFID\r\n");
SendATCommand("AT+DVID\r\n");
SendATCommand("AT+RFC\r\n");
SendATCommand("AT+POWE\r\n");
SendATCommand("AT+CLSS\r\n");
SendATCommand("AT+DVID0A13\r\n");

// Initialize wheels and electromagnet
PB3_0;
PB4_0;
PB5_0;
PB6_0;
PB7_0;
PA6_1;
PA7_1;

// Measure reference voltages.
reference_voltage[0] = (readADC(ADC_CHSELR_CHSEL8) * 33000) / 0xffff;
reference_voltage[1] = (readADC(ADC_CHSELR_CHSEL9) * 33000) / 0xffff;

while (1)
{
    reference_count = GetPeriod(60);

    if (reference_count > 0)
    {
        break;
    }

    eputs("NO SIGNAL\r\n");
}

reference_frequency = (F_CPU * 60) / reference_count;
// Main loop
while (1)
{
    count = GetPeriod(60);

    if (count > 0)
    {
        frequency = (F_CPU * 60) / count;
    }
}

```

```

    }

    processRadioData(buff, &currentCommand);

    // If robot is paused and unpause command is received.
    if (*mode_flag == 2 && currentCommand.b2 == SQUARE)
    {
        *mode_flag = 1;
    }

    // Run autonomous routine if flag is set.
    if (*mode_flag == 1)
    {
        eputs("AUTONOMOUS MODE ACTIVE.\r\n");
        autodrive(&currentCommand);
        if (*mode_flag == 0)
        {
            eputs("Returning to MANUAL MODE.\r\n");
            leftWheelStop();
            rightWheelStop();
        }
    }
    else if (*mode_flag == 3)
    {
        eputs("GAME MODE ACTIVE.\r\n");
        gameMode();
    }

    waitms(2);
}

return 0;
}

```

APPENDIX IV: FULL REMOTE CODE

```

#include <XC.h>
#include <stdio.h>
#include <stdlib.h>
#include <sys/attribs.h>
#include <string.h>

// ===== CONFIGURATION BITS =====
#pragma config FOSC = FRCPLL           // Internal Fast RC oscillator (8 MHz) w/ PLL
#pragma config FPLLIDIV = DIV_2        // Divide FRC before PLL (4 MHz)
#pragma config FPLLMUL = MUL_20        // PLL Multiply (80 MHz)
#pragma config FPLLODIV = DIV_2        // Divide After PLL (40 MHz)
#pragma config FWDTEN = OFF             // Watchdog Timer Disabled
#pragma config FPBDIV = DIV_1           // PBCLK = SYSCLK
#pragma config FSOSCEN = OFF            // Secondary Oscillator off

// ===== DEFINES =====
#define SYSCLK          40000000L

```

```

#define PBCLK          SYSCLK
#define CHARS_PER_LINE 16
#define DEF_FREQ 2205L
#define Baud1BRG(desired_baud) ( (SYSCLK / (16*desired_baud))-1)

// Macro to convert desired baud rate to BRG value
#define Baud2BRG(desired_baud) ( (PBCLK / (16*desired_baud))-1 )

// ===== LCD PIN DEFINITIONS =====
#define LCD_RS          LATBbits.LATB3
#define LCD_RS_ENABLE   TRISBbits.TRISB3

#define LCD_E           LATAbits.LATA2
#define LCD_E_ENABLE    TRISAbits.TRISA2

#define LCD_D4          LATAbits.LATA3
#define LCD_D4_ENABLE   TRISAbits.TRISA3

#define LCD_D5          LATBbits.LATB4
#define LCD_D5_ENABLE   TRISBbits.TRISB4

#define LCD_D6          LATAbits.LATA4
#define LCD_D6_ENABLE   TRISAbits.TRISA4

#define LCD_D7          LATBbits.LATB5
#define LCD_D7_ENABLE   TRISBbits.TRISB5

// ===== SPEAKER PIN DEFINITIONS =====
#define SPEAKER          LATBbits.LATB12
#define SPEAKER_TRIS     TRISBbits.TRISB12

#define PIN_PERIOD PORTAbits.RA0

// ===== PS2 PIN DEFINITIONS =====
#define PS2_DATA          PORTBbits.RB0      // Input
#define PS2_DATA_TRIS     TRISBbits.TRISB0
#define PS2_CMD           LATBbits.LATB1     // Output
#define PS2_CMD_TRIS     TRISBbits.TRISB1
#define PS2_ATT           LATBbits.LATB2     // Output
#define PS2_ATT_TRIS     TRISBbits.TRISB2
#define PS2_CLK           LATBbits.LATB10    // Output
#define PS2_CLK_TRIS     TRISBbits.TRISB10

// ===== PS2 Button DEFINITIONS =====
#define LEVEL0 0
#define LEVEL1 28
#define LEVEL2 55
#define LEVEL3 82
#define LEVEL4 110
#define LEVEL5 146
#define LEVEL6 174
#define LEVEL7 201

```



```

#define LEVEL8 228
#define LEVEL9 256

// Button Values
#define NONE 255 //Verified
#define SQUARE 127 // verified
#define O_BUTTON 223 // verified
#define TRIANGLE 239 // verified
#define X_BUTTON 191 // verified
#define R1 247 // verified
#define R2 253 // verified
#define L1 251 // verified
#define L2 254 // verified

#define START 247 // verified
#define SELECT 254 // verified
#define L3 253 // verified
#define R3 251 // verified
#define DPAD_UP 239 // verified
#define DPAD_DOWN 191 // verified
#define DPAD_LEFT 127 // verified
#define DPAD_RIGHT 223 // verified

// ===== FUNCTION PROTOTYPES =====
void Timer4us(unsigned char t);
void waitms(unsigned int ms);
void waitus(unsigned int us);
void LCD_pulse(void);
void LCD_byte(unsigned char x);
void WriteData(unsigned char x);
void WriteCommand(unsigned char x);
void LCD_4BIT(void);
void LCDprint(char * string, unsigned char line, unsigned char clear);
void requestSlaveData(void);

// === ADDED/MODIFIED ===
void beepSpeaker(void);
int calcSignalStrength(int frequency);

void UART2Configure(int baud_rate);
int _mon_getc(int canblock);

void PS2_Init(void);
unsigned char PS2_TransferByte(unsigned char outByte);
void PS2_ReadData(unsigned char *d);

// ===== GLOBALS (if you need them) =====
int global_frequency = 0;
int global_coinCount = 0;

volatile unsigned int T2_overflow = 0;

```

```

// ===== LCD ROUTINES =====
void Timer4us(unsigned char t)
{
    T4CON = 0x8000; // enable Timer4, source PBCLK, 1:1 prescaler
    while(t >= 100)
    {
        t -= 100;
        TMR4 = 0;
        while(TMR4 < (SYSCLK/10000L));
    }
    while(t >= 10)
    {
        t -= 10;
        TMR4 = 0;
        while(TMR4 < (SYSCLK/100000L));
    }
    while(t > 0)
    {
        t--;
        TMR4 = 0;
        while(TMR4 < (SYSCLK/1000000L));
    }
    T4CONCLR = 0x8000;
}

void waitms(unsigned int ms)
{
    unsigned int j;
    for(j = 0; j < ms; j++)
    {
        Timer4us(250);
        Timer4us(250);
        Timer4us(250);
        Timer4us(250);
    }
}

void waitus(unsigned int us)
{
    while(us--)
        Timer4us(1);
}

void LCD_pulse(void)
{
    LCD_E = 1;
    Timer4us(40);
    LCD_E = 0;
}

void LCD_byte(unsigned char x)
{

```

```

    LCD_D7 = (x & 0x80) ? 1 : 0;
    LCD_D6 = (x & 0x40) ? 1 : 0;
    LCD_D5 = (x & 0x20) ? 1 : 0;
    LCD_D4 = (x & 0x10) ? 1 : 0;
    LCD_pulse();
    Timer4us(40);
    LCD_D7 = (x & 0x08) ? 1 : 0;
    LCD_D6 = (x & 0x04) ? 1 : 0;
    LCD_D5 = (x & 0x02) ? 1 : 0;
    LCD_D4 = (x & 0x01) ? 1 : 0;
    LCD_pulse();
}

void WriteData(unsigned char x)
{
    LCD_RS = 1;
    LCD_byte(x);
    waitms(2);
}

void WriteCommand(unsigned char x)
{
    LCD_RS = 0;
    LCD_byte(x);
    waitms(5);
}

void LCD_4BIT(void)
{
    LCD_RS_ENABLE = 0;
    LCD_E_ENABLE = 0;
    LCD_D4_ENABLE = 0;
    LCD_D5_ENABLE = 0;
    LCD_D6_ENABLE = 0;
    LCD_D7_ENABLE = 0;

    LCD_E = 0;
    waitms(20);

    WriteCommand(0x33);
    WriteCommand(0x33);
    WriteCommand(0x32);

    WriteCommand(0x28);
    WriteCommand(0x0c);
    WriteCommand(0x01);
    waitms(20);
}

void LCDprint(char * string, unsigned char line, unsigned char clear)
{
    int j;

```

```

    if(line == 2)
        WriteCommand(0xc0);
    else
        WriteCommand(0x80);
    waitms(5);
    for(j = 0; string[j] != 0; j++)
    {
        WriteData(string[j]);
    }
    if(clear)
    {
        for(; j < CHARS_PER_LINE; j++)
            WriteData(' ');
    }
}

// ===== JDY-40 ROUTINES =====

void UART2Configure(int baud_rate)
{
    // Peripheral Pin Select
    U2RXRbits.U2RXR = 4;    //SET RX to RB8
    RPB9Rbits.RPB9R = 2;    //SET RB9 to TX

    U2MODE = 0;            // disable autobaud, TX and RX enabled only, 8N1, idle=HIGH
    U2STA = 0x1400;        // enable TX and RX
    U2BRG = Baud2BRG(baud_rate); // U2BRG = (FPb / (16*baud)) - 1

    U2MODESET = 0x8000;    // enable UART2
}

// Needed to by scanf() and gets()
int _mon_getc(int canblock)
{
    char c;

    if (canblock)
    {
        while( !U2STAbits.URXDA); // wait (block) until data available in RX buffer
        c=U2RXREG;
        while( U2STAbits.UTXBF);    // wait while TX buffer full
        U2TXREG = c;                // echo
        if(c=='\r') c='\n'; // When using PUTTY, pressing <Enter> sends '\r'. Ctrl-J sends
'\n'
        return (int)c;
    }
    else
    {
        if (U2STAbits.URXDA) // if data available in RX buffer
        {
            c=U2RXREG;

```

```

        if(c=='\r') c='\n';
        return (int)c;
    }
    else
    {
        return -1; // no characters to return
    }
}

}

//Functions from Set up Two Timers

void uart_putc (unsigned char c)
{
    while( U2STAbits.UTXBF); // wait while TX buffer full
    U2TXREG = c; // send single character to transmit buffer
}

void uart_puts (char * buff)
{
    while (*buff)
    {
        uart_putc(*buff);
        buff++;
    }
}

unsigned char uart_getc (void)
{
    unsigned char c;

    while( !U2STAbits.URXDA); // wait (block) until data available in RX buffer
    c=U2RXREG;
    return c;
}

void SetupTimer1 (void)
{
    // Explanation here:
    // https://www.youtube.com/watch?v=bu6TTZHnMPY
    __builtin_disable_interrupts();
    PR1 =(SYSCLK/DEF_FREQ)-1; // since SYSCLK/FREQ = PS*(PR1+1)
    TMR1 = 0;
    T1CONbits.TCKPS = 0; // Pre-scaler: 1
    T1CONbits.TCS = 0; // Clock source
    T1CONbits.ON = 1;
    IPC1bits.T1IP = 5;
    IPC1bits.T1IS = 0;
    IFS0bits.T1IF = 0;
    IEC0bits.T1IE = 1;

    INTCONbits.MVEC = 1; //Int multi-vector

```

```

    __builtin_enable_interrupts();
}

volatile unsigned int Tick_Counter=0;
volatile unsigned char Second_Flag=1;

void __ISR(_TIMER_1_VECTOR, IPL5SOFT) Timer1_Handler(void)
{
    // Calculate the signal strength (clamp to 0..100)
    int strength = calcSignalStrength(global_frequency);
    if(strength > 100)
        strength = 100;
    else if(strength < 0)
        strength = 0;

    // Map strength to a beep repetition rate.
    // Here, beepFreq will vary from 5 (for low strength) to 55 (for high strength)
    int beepMinFreq = 5;
    int beepMaxFreq = 30;
    int beepFreq = beepMinFreq + (beepMaxFreq - beepMinFreq) * strength / 50;

    // Clear the timer interrupt flag
    IFS0CLR = _IFS0_T1IF_MASK;

    // Use a state machine to control the on/off period of the beep (without changing the
    speaker pitch).
    // The idea is: a fixed "on" period (250 ticks) and a variable "off" period
    (50000/beepFreq ticks).
    if(Second_Flag == 0)
    {
        SPEAKER = 0;        // Turn the speaker off during the off period.
        Tick_Counter++;
        // Use >= instead of == so that any overshoot still resets the counter.
        if(Tick_Counter >= (50000 / beepFreq))
        {
            Tick_Counter = 0;
            Second_Flag = 1;
        }
    }
    else // Second_Flag == 1
    {
        SPEAKER = !SPEAKER; // Toggle the speaker (this produces the constant pitch square
wave)
        Tick_Counter++;
        if(Tick_Counter >= 250)
        {
            Tick_Counter = 0;
            Second_Flag = 0;
        }
    }
}

```

```

// GetPeriod() seems to work fine for frequencies between 200Hz and 700kHz.
long int GetPeriod (int n)
{
    int i;
    unsigned int saved_TCNT1a, saved_TCNT1b;

    _CP0_SET_COUNT(0); // resets the core timer count
    while (PIN_PERIOD!=0) // Wait for square wave to be 0
    {
        if(_CP0_GET_COUNT() > (SYSCLK/4)) return 0;
    }

    _CP0_SET_COUNT(0); // resets the core timer count
    while (PIN_PERIOD==0) // Wait for square wave to be 1
    {
        if(_CP0_GET_COUNT() > (SYSCLK/4)) return 0;
    }

    _CP0_SET_COUNT(0); // resets the core timer count
    for(i=0; i<n; i++) // Measure the time of 'n' periods
    {
        while (PIN_PERIOD!=0) // Wait for square wave to be 0
        {
            if(_CP0_GET_COUNT() > (SYSCLK/4)) return 0;
        }
        while (PIN_PERIOD==0) // Wait for square wave to be 1
        {
            if(_CP0_GET_COUNT() > (SYSCLK/4)) return 0;
        }
    }

    return _CP0_GET_COUNT();
}

////////////////////////////////////
// UART1 functions used to communicate with the JDY40 //
////////////////////////////////////

// TXD1 is in pin 26
// RXD1 is in pin 24

int UART1Configure(int desired_baud)
{
    int actual_baud;

    // Peripheral Pin Select for UART1. These are the pins that can be used for U1RX from
    TABLE 11-1 of '60001168J.pdf':
    // 0000 = RPA2
    // 0001 = RPB6
    // 0010 = RPA4
    // 0011 = RPB13
    // 0100 = RPB2

```

```

ANSELB &= ~(1<<13); // Set RB13 as a digital I/O
TRISB |= (1<<13);    // configure pin RB13 as input
CNPUB |= (1<<13);    // Enable pull-up resistor for RB13
U1RXRbits.U1RXR = 3; // SET U1RX to RB13

// These are the pins that can be used for U1TX. Check table TABLE 11-2 of
'60001168J.pdf':
// RPA0
// RPB3
// RPB4
// RPB15
// RPB7

ANSELB &= ~(1<<15); // Set RB15 as a digital I/O
RPB15Rbits.RPB15R = 1; // SET RB15 to U1TX

U1MODE = 0;           // disable autobaud, TX and RX enabled only, 8N1, idle=HIGH
U1STA = 0x1400;       // enable TX and RX
U1BRG = Baud1BRG(desired_baud); // U1BRG = (FPb / (16*baud)) - 1
// Calculate actual baud rate
actual_baud = SYSCLK / (16 * (U1BRG+1));

U1MODESET = 0x8000;    // enable UART1

return actual_baud;
}

void putc1 (char c)
{
    while( U1STAbits.UTXBF); // wait while TX buffer full
    U1TXREG = c;             // send single character to transmit buffer
}

int SerialTransmit1(const char *buffer)
{
    unsigned int size = strlen(buffer);
    while(size)
    {
        while( U1STAbits.UTXBF); // wait while TX buffer full
        U1TXREG = *buffer;       // send single character to transmit buffer
        buffer++;               // transmit next character on following loop
        size--;                 // loop until all characters sent (when size = 0)
    }

    while( !U1STAbits.TRMT);     // wait for last transmission to finish

    return 0;
}

unsigned int SerialReceive1(char *buffer, unsigned int max_size)
{

```



```

unsigned int num_char = 0;

while(num_char < max_size)
{
    while( !U1STAbits.URXDA);    // wait until data available in RX buffer
    *buffer = U1RXREG;           // empty contents of RX buffer into *buffer pointer

    // insert nul character to indicate end of string
    if( *buffer == '\n')
    {
        *buffer = '\0';
        break;
    }

    buffer++;
    num_char++;
}

return num_char;
}

// Copied from here: https://forum.microchip.com/s/topic/a5C31000000MRVAEA4/t335776
void delayus(uint16_t uiuSec)
{
    uint32_t ulEnd, ulStart;
    ulStart = _CP0_GET_COUNT();
    ulEnd = ulStart + (SYSCLK / 2000000) * uiuSec;
    if(ulEnd > ulStart)
        while(_CP0_GET_COUNT() < ulEnd);
    else
        while((_CP0_GET_COUNT() > ulStart) || (_CP0_GET_COUNT() < ulEnd));
}

unsigned int SerialReceive1_timeout(char *buffer, unsigned int max_size)
{
    unsigned int num_char = 0;
    int timeout_cnt;

    while(num_char < max_size)
    {
        timeout_cnt=0;
        while(1)
        {
            if(U1STAbits.URXDA) // check if data is available in RX buffer
            {
                *buffer = U1RXREG; // copy RX buffer into *buffer pointer
                break;
            }
            if(++timeout_cnt==100) // 100 * 100us = 10 ms
            {
                *buffer = '\n';
                break;
            }
        }
        num_char++;
    }
}

```

```

        }
        delayus(100);
    }

    // insert nul character to indicate end of string
    if( *buffer == '\n')
    {
        *buffer = '\0';
        break;
    }

    buffer++;
    num_char++;
}

return num_char;
}

// Use the core timer to wait for 1 ms.
void wait_1ms(void)
{
    unsigned int ui;
    _CP0_SET_COUNT(0); // resets the core timer count

    // get the core timer count
    while ( _CP0_GET_COUNT() < (SYSCLK/(2*1000)) );
}

void delaysms(int len)
{
    while(len--) wait_1ms();
}

void ClearFIFO (void)
{
    unsigned char c;
    U1STA = 0x1400; // enable TX and RX, clear FIFO
    while(U1STABits.URXDA) c=U1RXREG;
}

void SendATCommand (char * s)
{
    char buff[40];
    printf("Command: %s", s);
    LATB &= ~(1<<14); // 'SET' pin of JDY40 to 0 is 'AT' mode.
    delaysms(10);
    SerialTransmit1(s);
    U1STA = 0x1400; // enable TX and RX, clear FIFO
    SerialReceive1(buff, sizeof(buff)-1);
    LATB |= 1<<14; // 'SET' pin of JDY40 to 1 is normal operation mode.
    delaysms(10);
    printf("Response: %s\n", buff);
}

```

```

}

void ReceptionOff (void)
{
    LATB &= ~(1<<14); // 'SET' pin of JDY40 to 0 is 'AT' mode.
    delays(10);
    SerialTransmit1("AT+DVID0000\r\n"); // Some unused id, so that we get nothing.
    delays(10);
    ClearFIFO();
    LATB |= 1<<14; // 'SET' pin of JDY40 to 1 is normal operation mode.
}

// ===== SPEAKER AND JDY-40 RECEIVING DATA ROUTINES =====

int calcSignalStrength(int frequency)
{
    int signal_strength = 10000 - frequency;

    if(signal_strength < 0) {
        return 0;
    } else if (signal_strength > 100) {
        return 100;
    }

    return (signal_strength*100)/30;
}

void beepSpeaker(void)
{
    //if(Second_Flag == 0){
    //    SPEAKER = 0;
    //}
    //else if(Second_Flag == 1){
    //    SPEAKER = 1;
    //}
    // Compute signal strength based on the global frequency
    //int strength = calcSignalStrength(global_frequency);
    //if (strength == 0)
    //    return;

    // Determine beep frequency based on strength (example linear mapping)
    //int beepMinFreq = 1;
    //int beepMaxFreq = 10;
    //int beepFreq = beepMinFreq + (beepMaxFreq - beepMinFreq) * strength / 100;

    // Calculate timer ticks for a half period.
    // The Timer1 interrupt will fire every half period so that toggling the pin creates a
    square wave.
    // (SYSCLK / (2 * beepFreq)) gives the number of ticks for a half period.

```

```

//unsigned int halfPeriodTicks = (SYSCLK / (2 * beepFreq)) - 1;

// Reconfigure Timer1 for the desired half period.
//if(Tick_Counter==22050/beepFreq)
//{
//  Tick_Counter=0;

//  __builtin_disable_interrupts();
//}
//__builtin_disable_interrupts();
//PR1 = halfPeriodTicks;    // Set period for half period timing
//TMR1 = 0;                // Reset timer count
//T1CONbits.TCKPS = 0;      // Pre-scaler: 1
//T1CONbits.TCS = 0;        // Internal clock (PBCLK)
//T1CONbits.ON = 1;         // Turn on Timer1 so that its interrupt will toggle the
speaker pin
//__builtin_enable_interrupts();

// Let the beep sound for ~100ms.
// (During this time, Timer1 interrupts will toggle SPEAKER in the ISR.)
//  waitms(100);

// After 100ms, disable Timer1 and turn the speaker off.
//__builtin_disable_interrupts();
//T1CONbits.ON = 0;         // Stop Timer1
//SPEAKER = 0;              // Ensure speaker is low (off)
//__builtin_enable_interrupts();
}

void requestSlaveData(void)
{
    char buff[20];    // Buffer to hold the slave's response
    int timeout_cnt = 0;

    // Clear the receive FIFO so we get a fresh reply from the slave
    if(U1STAbits.URXDA)
        SerialReceive1_timeout(buff, sizeof(buff)-1);

    // Wait for a response with a timeout up to ~50ms
    timeout_cnt = 0;
    while(1)
    {
        if(U1STAbits.URXDA) break;    // Data has arrived
        if(++timeout_cnt > 100000) break; // Timeout after ~50ms
        delayus(100);                // 100us delay per iteration
    }

    // If data is available, read it
    if(U1STAbits.URXDA)
    {

```

```

SerialReceive1_timeout(buff, sizeof(buff)-1);
if(strlen(buff) > 0)
{
    // Debug print of the raw data received from the slave
    printf("Slave says: %s\r\n", buff);

    // === ADDED/MODIFIED ===
    // We now expect exactly 7 characters: first 5 for freq, last 2 for coin count
    // e.g. "1234512"
    if(strlen(buff) == 7)
    {
        char freqStr[6];
        char coinStr[3];

        strncpy(freqStr, buff, 5);
        freqStr[5] = '\0';
        strncpy(coinStr, &buff[5], 2);
        coinStr[2] = '\0';

        global_frequency = atoi(freqStr);
        global_coinCount = atoi(coinStr);

        // Call the speaker beep function based on frequency
        //beepSpeaker(global_frequency);

        // Display signal strength on LCD (line 1)
        char line1[20];
        int strength = calcSignalStrength(global_frequency);
        if (strength > 100){
            strength = 100;
        }
        sprintf(line1, "Strength: %d%%", strength);
        LCDprint(line1, 1, 1);

        // Display coin count on LCD (line 2)
        char line2[20];
        sprintf(line2, "Coin Count: %d", global_coinCount);
        LCDprint(line2, 2, 1);
    }
    else
    {
        // If the message isn't the proper length, just show an error:
        LCDprint("Bad data len!", 1, 1);
        LCDprint(buff, 2, 1);
    }
}
else
{
    printf("No response from slave.\r\n");
    LCDprint("Signal: NONE", 2, 1);
}
}

```

```

else
{
    printf("No response from slave (timeout).\r\n");
    // Optionally, display a timeout message on the LCD.
    // LCDprint("Signal: TIMEOUT", 2, 1);
}

    delaysms(50);
}

// ===== PS2 CONTROLLER BIT-BANGED SPI =====
static void ps2_delay(void)
{
    waitus(10);
}

unsigned char PS2_TransferByte(unsigned char outByte)
{
    unsigned char inByte = 0;
    int i;
    for(i = 0; i < 8; i++)
    {
        PS2_CMD = (outByte & 0x01) ? 1 : 0;
        outByte >>= 1;
        PS2_CLK = 0;
        ps2_delay();
        if(PS2_DATA)
            inByte |= (1 << i);
        PS2_CLK = 1;
        ps2_delay();
    }
    return inByte;
}

void PS2_Init(void)
{
    ANSELBbits.ANSB0 = 0;

    PS2_DATA_TRIS = 1;
    PS2_CMD_TRIS  = 0;
    PS2_ATT_TRIS  = 0;
    PS2_CLK_TRIS  = 0;

    PS2_CMD = 1;
    PS2_ATT = 1;
    PS2_CLK = 1;
    waitms(100);

    PS2_ATT = 0;
    PS2_TransferByte(0x01);
    PS2_TransferByte(0x43);
    PS2_TransferByte(0x00);
}

```

```

    PS2_TransferByte(0x01);
    PS2_TransferByte(0x00);
    PS2_ATT = 1;
    waitms(50);

    PS2_ATT = 0;
    PS2_TransferByte(0x01);
    PS2_TransferByte(0x44);
    PS2_TransferByte(0x00);
    PS2_TransferByte(0x01); // Set analog mode
    PS2_TransferByte(0x03); // Lock configuration
    PS2_ATT = 1;
    waitms(50);

    PS2_ATT = 0;
    PS2_TransferByte(0x01);
    PS2_TransferByte(0x43);
    PS2_TransferByte(0x00);
    PS2_TransferByte(0x00);
    PS2_TransferByte(0x5A);
    PS2_ATT = 1;
    waitms(50);
}

void PS2_ReadData(unsigned char *d)
{
    int i;
    PS2_ATT = 0;
    waitus(20);
    d[0] = PS2_TransferByte(0x01);
    d[1] = PS2_TransferByte(0x42);
    for(i = 2; i < 9; i++)
    {
        d[i] = PS2_TransferByte(0x00);
    }
    PS2_ATT = 1;
}

void Encode_Data(unsigned char * data, char * dest)
{
    unsigned char buttons1;
    unsigned char buttons2;
    unsigned char rx;
    unsigned char ry;
    unsigned char lx;
    unsigned char ly;

    //Encode buttons1 value
    if ((data[3]) == NONE)
    {
        dest[0] = 'N';
    }
}

```

```

else if ((data[3]) == SELECT)
{
    dest[0] = 's';
}
else if ((data[3]) == START)
{
    dest[0] = 'S';
}
else if ((data[3]) == DPAD_UP)
{
    dest[0] = 'U';
}
else if ((data[3]) == DPAD_DOWN)
{
    dest[0] = 'D';
}
else if ((data[3]) == DPAD_LEFT)
{
    dest[0] = 'L';
}
else if ((data[3]) == DPAD_RIGHT)
{
    dest[0] = 'R';
}
else if ((data[3]) == L3)
{
    dest[0] = 'l';
}
else if ((data[3]) == R3)
{
    dest[0] = 'r';
}
else
{
    dest[0] = 'E';
}

//Encode buttons2 value
if ((data[4]) == NONE)
{
    dest[1] = 'N';
}
else if ((data[4]) == X_BUTTON)
{
    dest[1] = 'X';
}
else if ((data[4]) == SQUARE)
{
    dest[1] = 'S';
}
else if ((data[4]) == O_BUTTON)
{

```



```

        dest[1] = 'O';
    }
    else if ((data[4]) == TRIANGLE)
    {
        dest[1] = 'T';
    }
    else if ((data[4]) == R1)
    {
        dest[1] = 'r';
    }
    else if ((data[4]) == R2)
    {
        dest[1] = 'R';
    }
    else if ((data[4]) == L1)
    {
        dest[1] = 'l';
    }
    else if ((data[4]) == L2)
    {
        dest[1] = 'L';
    }
    else
    {
        dest[1] = 'E';
    }

    //Encode rx value
    if ((data[5]) >= LEVEL0 && (data[5]) < LEVEL1)
    {
        dest[2] = '1';
    }
    else if ((data[5]) >= LEVEL1 && (data[5]) < LEVEL2)
    {
        dest[2] = '2';
    }
    else if ((data[5]) >= LEVEL2 && (data[5]) < LEVEL3)
    {
        dest[2] = '3';
    }
    else if ((data[5]) >= LEVEL3 && (data[5]) < LEVEL4)
    {
        dest[2] = '4';
    }
    else if ((data[5]) >= LEVEL4 && (data[5]) < LEVEL5)
    {
        dest[2] = '5';
    }
    else if ((data[5]) >= LEVEL5 && (data[5]) < LEVEL6)
    {
        dest[2] = '6';
    }
}

```

```

else if ((data[5]) >= LEVEL6 && (data[5]) < LEVEL7)
{
    dest[2] = '7';
}
else if ((data[5]) >= LEVEL7 && (data[5]) < LEVEL8)
{
    dest[2] = '8';
}
else if ((data[5]) >= LEVEL8 && (data[5]) < LEVEL9)
{
    dest[2] = '9';
}
else
{
    dest[2] = 'E';
}

//Encode ry value
if ((data[6]) >= LEVEL8 && (data[6]) < LEVEL9)
{
    dest[3] = '1';
}
else if ((data[6]) >= LEVEL7 && (data[6]) < LEVEL8)
{
    dest[3] = '2';
}
else if ((data[6]) >= LEVEL6 && (data[6]) < LEVEL7)
{
    dest[3] = '3';
}
else if ((data[6]) >= LEVEL5 && (data[6]) < LEVEL6)
{
    dest[3] = '4';
}
else if ((data[6]) >= LEVEL4 && (data[6]) < LEVEL5)
{
    dest[3] = '5';
}
else if ((data[6]) >= LEVEL3 && (data[6]) < LEVEL4)
{
    dest[3] = '6';
}
else if ((data[6]) >= LEVEL2 && (data[6]) < LEVEL3)
{
    dest[3] = '7';
}
else if ((data[6]) >= LEVEL1 && (data[6]) < LEVEL2)
{
    dest[3] = '8';
}
else if ((data[6]) >= LEVEL0 && (data[6]) < LEVEL1)
{

```

```

        dest[3] = '9';
    }
    else
    {
        dest[3] = 'E';
    }

    //Encode lx value
    if ((data[7]) >= LEVEL0 && (data[7]) < LEVEL1)
    {
        dest[4] = '1';
    }
    else if ((data[7]) >= LEVEL1 && (data[7]) < LEVEL2)
    {
        dest[4] = '2';
    }
    else if ((data[7]) >= LEVEL2 && (data[7]) < LEVEL3)
    {
        dest[4] = '3';
    }
    else if ((data[7]) >= LEVEL3 && (data[7]) < LEVEL4)
    {
        dest[4] = '4';
    }
    else if ((data[7]) >= LEVEL4 && (data[7]) < LEVEL5)
    {
        dest[4] = '5';
    }
    else if ((data[7]) >= LEVEL5 && (data[7]) < LEVEL6)
    {
        dest[4] = '6';
    }
    else if ((data[7]) >= LEVEL6 && (data[7]) < LEVEL7)
    {
        dest[4] = '7';
    }
    else if ((data[7]) >= LEVEL7 && (data[7]) < LEVEL8)
    {
        dest[4] = '8';
    }
    else if ((data[7]) >= LEVEL8 && (data[7]) < LEVEL9)
    {
        dest[4] = '9';
    }
    else
    {
        dest[4] = 'E';
    }

    //Encode ly value
    if ((data[8]) >= LEVEL8 && (data[8]) < LEVEL9)
    {

```

```

        dest[5] = '1';
    }
    else if ((data[8]) >= LEVEL7 && (data[8]) < LEVEL8)
    {
        dest[5] = '2';
    }
    else if ((data[8]) >= LEVEL6 && (data[8]) < LEVEL7)
    {
        dest[5] = '3';
    }
    else if ((data[8]) >= LEVEL5 && (data[8]) < LEVEL6)
    {
        dest[5] = '4';
    }
    else if ((data[8]) >= LEVEL4 && (data[8]) < LEVEL5)
    {
        dest[5] = '5';
    }
    else if ((data[8]) >= LEVEL3 && (data[8]) < LEVEL4)
    {
        dest[5] = '6';
    }
    else if ((data[8]) >= LEVEL2 && (data[8]) < LEVEL3)
    {
        dest[5] = '7';
    }
    else if ((data[8]) >= LEVEL1 && (data[8]) < LEVEL2)
    {
        dest[5] = '8';
    }
    else if ((data[8]) >= LEVEL0 && (data[8]) < LEVEL1)
    {
        dest[5] = '9';
    }
    else
    {
        dest[5] = 'E';
    }

    //Set last char to terminate data
    dest[6] = '\n';
}

// ===== MAIN PROGRAM =====
int main(void) {

    unsigned char ps2Data[9];
    char buff[80];
    int timeout_cnt = 0;

    // === 1) Basic PIC32 setup ===

```

```

DDPCON = 0;
CFGCON = 0;

TRISBbits.TRISB12 = 0;
LATBbits.LATB12 = 0;
INTCONbits.MVEC = 1;

SetupTimer1(); // Setup timer 1 and its interrupt
// Configure UART2 for debugging at 115200 baud
UART2Configure(115200);

Second_Flag = 0;
while(!Second_Flag);

PR2 = 0xffff; // When TMR2 hits 0xffff resets back to zero
T2CONbits.TCKPS = 0; // Pre-scaler: 1.
T2CONbits.TCS = 1; // External clock

// Configure UART1 for JDY40 communications at 9600 baud
UART1Configure(9600);

delaysms(500); // Allow time for terminal startup

printf("JDY40 PS2 Master Demo. PIC32 as Master.\r\n");

// === 2) Configure JDY40 SET pin (RB14) ===
ANSELB &= ~(1 << 14); // Set RB14 as digital
TRISB &= ~(1 << 14); // Configure RB14 as output
LATB |= (1 << 14); // 'SET' = 1 --> normal operation mode

ANSELB &= ~(1<<6); // Set RB3 as a digital I/O
TRISB |= (1<<6); // configure pin RB6 as input
CNPUB |= (1<<6); // Enable pull-up resistor for RB6
T2CKRbits.T2CKR = 1; // Use RPB6 as input clock

ReceptionOff();
// === 3) Send AT commands to verify/configure JDY40 (optional) ===
SendATCommand("AT+VER\r\n");
SendATCommand("AT+BAUD\r\n");
SendATCommand("AT+RFID\r\n");
SendATCommand("AT+DVID\r\n");
SendATCommand("AT+RFC\r\n");
SendATCommand("AT+POWE\r\n");
SendATCommand("AT+CLSS\r\n");

// Set an example unique device ID (0xABBA)
SendATCommand("AT+RFC013\r\n");
SendATCommand("AT+DVID0A13\r\n");

// === 4) Initialize LCD and PS2 controller ===
LCD_4BIT();

```

```

waitms(50);
LCDprint("PS2 Remote Demo", 1, 1);
LCDprint("Initializing...", 2, 1);
printf("Initializing PS2 and LCD...\r\n");

PS2_Init();
waitms(100);
LCDprint("PS2 Ready!", 1, 1);
LCDprint("Reading data...", 2, 1);

// Configure the speaker pin (RB12) as output
SPEAKER_TRIS = 0; // Set RB12 as output
SPEAKER = 0;      // Initialize the speaker output low

// === 5) Main loop: Read PS2, update LCD, send data via JDY40 ===
while(1) {
    //TMR2 = 0; // Reset timer count
    //T2_overflow=0; // Reset overflow count
    //T2CONbits.ON = 1; // Start timer
    //Second_Flag=0;
    // Check for overflow of timer 2
    //if(IFS0&_IFS0_T2IF_MASK)
    //{
        // IFS0CLR=_IFS0_T2IF_MASK; // Clear overflow flag
        // T2_overflow++; // Increment overflow counter
    //}
    //T2CONbits.ON = 0; // Stop Timer
        // Call the speaker beep function based on frequency
        //beepSpeaker();
        // 5a) Read the PS2 data packet (9 bytes)
        PS2_ReadData(ps2Data);

        // 5e) Construct the PS2 data string to send to the slave JDY module.
        Encode_Data(ps2Data, buff);

        // 5f) Transmit the PS2 data over UART1 (JDY40)
        putc1('!'); // Send the attention character first
        delayms(5); // Short delay
        SerialTransmit1(buff);

delayms(20);

        // Send the request character '@' to the slave
        putc1('@');
        delayms(5);
        // Request data from the slave (this updates the LCD and speaker)
        requestSlaveData();

        // 5h) Small delay to set the pace of communication
        waitms(5);
}

```

```
    return 0;  
}
```

APPENDIX V:

Body Text

APPENDIX VI:

Body Text

APPENDIX VII:

Body Text