The University of Queensland
School of Information Technology and Electrical Engineering
Semester One, 2016
CSSE3010 / CSSE7301 - Project 1
Due for demonstrations: your session week 7, 2016
Weighting: 30% of your overall mark (CSSE3010/7301)

Project 1 – Multi-Communications Platform

Objectives:

- To apply your knowledge and skills developed in project stages 1, 2, 3 and 4 into a combined design.
- To accurately position the pan & tilt system to fire the laser module at a small target.
- To use the serial terminal for systems control.
- To establish a wireless radio communication link using the nRF24L01 chip to a partner's system.
- To establish a wireless optical communication link using the laser module and a partner's photodiode receiver board.
- To apply theoretical knowledge of coding signals with Manchester 2 and Hamming codes.

Introduction:

This assignment will build on your knowledge from stages 1-4. Project 1 is designed to have you demonstrate all you have learned of the NP2, pan & tilt, laser module, joystick module and nRF24L01 radio chip into a single system. If you have completed practicals 1, 2, 3 and 4 to a satisfactory level, completing the basic requirements of this project will be straightforward.

Task Requirements:

Before you are daunted by the amount of tasks, take into account that many are expansions upon one another, for instance to complete task 7, you will have completed tasks 1, 2 and 4.

NOTE: Version Control – You MUST use version control as part of your development process. This means that because the project is a bigger task that the stages, you should have a NUMBER of commits including the FINAL version which is the one being assessed. <u>If that is not the case, you will not be assessed.</u>

<u>myLib Requirements</u>

You are required to use your mylib library files in this project. This includes your LED Bar, joystick, radio and hamming files. You may include other library files in your mylib folder. If you do not use your mylib library, then penalties will apply. See table 1 for the required files to be used in your project, these files must be present in your mylib folder.

Table 1: Required mylib Files

Files
sxxxxxx_lightbar
sxxxxxx_joystick
sxxxxxx_pantilt
sxxxxxx_radio
sxxxxxx_hamming

Task 1: Actuating Pan & Tilt – You must control your pan & tilt system accurately, using the joystick X and Y signals. You will be asked to set your system to pan back and forth and then tilt back and forth. There will be a penalty if there is significant jitter in the pan & tilt as this indicates your PWM is being driven at an incorrect frequency or above its duty cycle limits.

Task 2: Terminal Interface Sending – You must demonstrate your ability to send data from your NP2 board to a terminal program. Your system should print out the pan and tilt angles of your pan & tilt module at least every second, formatted as shown.

For example:

Pan: 43 Tilt: 91

Pan: 44 Tilt: 89

Pan: 41 Tilt: 86

Task 3: Terminal Interface Receiving– You must demonstrate your ability to communicate between your NP2 board and a terminal program. After startup, the WASD keys must be used to control your pan & tilt; ie. pressing W will increase the tilt angle and S will decrease it (in subsequent tasks you must also send messages to your partner by typing them into the terminal – this means that when the input type is not the terminal [e.g. joystick], typed characters will correspond to data to be transmitted - the onboard push button should be used to switch between input types joystick and terminal).

Task 4: Uncoded RF Communication Transmit – You must demonstrate the sending data packets via the nRF24L01. This will be tested by transmitting a string of characters (less than 7 characters long) – which is typed in the USB from a terminal application. If any data is transmitted, 1 mark is awarded; if the correct string and only this string is transmitted, 2 marks are awarded. You must set the type field to be 0xA1. Note: no error encoding is used for RF communications. Note: the format of the packet corresponds to the stage 4 packet format.

Task 5: Uncoded RF Communication Receive – You must demonstrate your ability to receive and interpret packets of information from the nRF24L01. Your tutor will have a working system setup for testing and will transmit to you a string of characters - you must display the received string (preceded by the string “RECEIVED FROM RADIO: “) on a new line from a terminal application through the USB connection. If any data is displayed after the packet is sent, 1 mark is awarded; if the correct string and only this string is displayed, 2 marks are awarded.

For example:

<Packet ‘Alpha’ is sent by tutor> RECEIVED FROM RADIO: Alpha

Pan: 41 Tilt: 86

Task 6: Laser Module Transmission – You must demonstrate your ability to transmit using Manchester 2 Coding modulated communication from your laser module to your laser receiver and display using your logic analyzer. You must accurately position your laser module onto your laser receiver as in Task 2 and then display the received waveform on your logic analyzer. Also, you encode the signal using a (7,4) Hamming code with an additional bit of even parity. Effectively making an (8,4) Block code. Show the modulated 8-bit symbol on the oscilloscope or logic analyzer. *Use NP2 D1 as the laser transmitter and NP2 D0 as the laser receiver.*

$$\mathbf{G} = \left[\begin{array}{ccc|cccc} 1 & 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 1 & 1 & 0 & 0 & 0 & 1 \end{array}\right]$$

The encoding process will implement **y** = **x G**, and add a bit of parity at the start.

(NOTE: the updated matrix above will let you produce all of the below examples)

The order of bit transmission should be with the coded bits C0 up to C7

En-Coded[C0..C7]=(P0 H0, H1, H2, D0 D1 D2 D3), where D0-D3 are the four data bits, H0-H2 are the Hamming (7,4) parity bits and P0 is the parity for the whole codeword. Note, that you could make the calculation for P0 as part of the matrix – however this is not required.

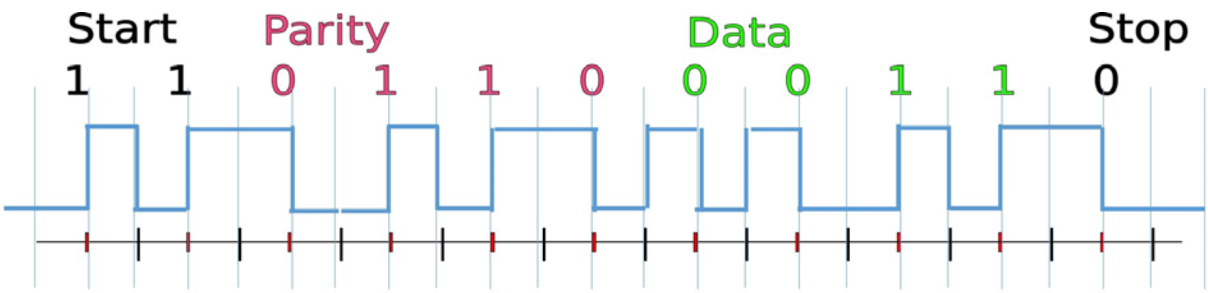
To allow for synchronization at the receiver you should use two start bits which are ‘1’s and a single stop bit, which is a ‘0’, for every encoded word (8 bits). This allows the receiver to be aware of where each encoded word begin and end. **Each encoded word transmitted must contain 4 bits of data and the corresponding Hamming/Parity bits.** The encoded word is transmitted LSB first.

An example of a waveform for the encoded word is shown below. The second 4 message bits are assumed to be ‘0 0 1 1’ (D0..D3) Using the (8,4) Hamming + Parity code the coded word becomes ‘0 1 1 0 0 0 1 1’ (C0..C7). This data is prefixed with 2 start bits, and one stop bit. It is then modulated using Manchester 2. See the diagram below on how this could look.

You should demonstrate that transmission can work with multiple data rates data rates of at least 1K Bits/second and 2K Bits/second. HINT: Each bit period is how many milliseconds?

YOU MUST have a sxxxxxx_hamming mylib file. The function declaration of your Hamming encoder must be:

```
uint16_t hamming_byte_encoder(uint8_t input);
```



Task 7: Hamming Error Insertion – You must be able to insert 1 and 2 bit errors in the transmitted data and parity field . The errors should be inserted using the '!' character, as shown below.

"!<bit mast (hex) >"

e.g. Inserting 1 bit error at data bit 3 – "!80"

Inserting 2 bit errors at bits 0 and 1 – "!03"

No errors – "!00"

Task 8: Laser Module Receiving - Following task 7, you must also receive data communication sent from the laser, to your photodiode and display the received string (preceded by the string "RECEIVED FROM LASER: ") and the raw received data (16 bits) next to it in hexadecimal. **NOTE**: you must display a full byte of reconstructed data, not half bytes. Using the (8, 4) block code you should monitor for errors and correct errors where possible. You should always correct as Hamming suggests, and then check the parity bit for an error. For each received byte display an error mask for the transmitted 16bits. *Use NP2 D1 as the laser transmitter and NP2 D0 as the laser receiver.*

Note the error mask must be displayed for each 16bits transmitted i.e.

"ErrMask = <ERROR_MASK>"

This can be calculated using (`received ^ corrected`) or the XOR operation.

Example:

`Pan: 43 Tilt: 91`

<Sends 'a'> `RECEIVED FROM LASER: a – Raw: 6c1c (ErrMask 0002)`

`Pan: 41 Tilt: 86`

<Sends 'b' > `RECEIVED FROM LASER: b – Raw: 6c27 (ErrMask 0000)`

The function declaration of your Hamming decoder must be:

```
uint8_t hamming_byte_decoder(uint8_t lower, uint8_t upper);
```

Task 9: Duplex Communication – You must implement a duplex communication system using your NP2 to receive signals sent through the laser by replying via the RF communication link. Encoding the laser transmitted data using a Hamming (8,4) code. The encoded data is modulated using Manchester 2 and sent via GPIO (NP2 D1) to the laser module. At the receiver, the data is demodulated and decoded, with error correction if required. The data is then forwarded to the radio module for re-sending. If errors occur, the signal sent via the radio channel should be used to send a negative acknowledgement (i.e. ERROR in RF packet payload), and the signal should be retransmitted via the laser, again. *Use NP2 D1 as the laser transmitter and NP2 D0 as the laser receiver.*

For 2 marks, your system must recognize when the other system’s response is not correct and perform retransmissions via the laser. Only 1 mark is awarded for duplex communication without error correction and retransmissions.

For example:

Other Terminal	**Your Terminal**

<Tutor’s Laser sends ‘’a’>
 	
`Pan: 90 Tilt: 90`
 	
`RECEIVED FROM RADIO: a`
 	
`Pan: 90 Tilt: 90`
 	
`RECEIVED FROM LASER: ` ` ` `- Raw: e20c (ErrMask 8e0c)`
 	
`Pan: 90 Tilt: 90`
 	
`Pan: 90 Tilt: 90`
 	
`RECEIVED FROM LASER: x - Raw: 728d (ErrMask 0000)`
	Pan: 90 Tilt: 90
	
	`RECEIVED FROM LASER: a - Raw: 6c1c (ErrMask 0002)`
	
	`Pan: 90 Tilt: 90`
	
	<your laser sends ‘x’>
	
	`Pan: 90 Tilt: 90`
	
	`RECEIVED FROM RADIO: ERROR`
	
	<your laser resends ‘x’>
	
	`Pan: 90 Tilt: 90`

Code Commenting and Style – Your code should conform to the following style: Comments: Comments should be placed at the front of each function and while/for loop. Key sections of code should be commented. Variable Names: single letter names (ie. i, j, k) should only be used for counters. Each variable should have a name relevant to its use. Spacing: your code should follow the correct 4-space tab indentation for functions and loops.

Workbook – Your work will be marked according to the format outlined:
Objectives of Project
System Block Diagram
State Diagram
Signal Flow Diagram
Flow Charts
Testing Procedure

Mark Deductions
To be specified later.

Challenge

NOTE: You must pass tasks 1-8 in order to be assessed for the challenge. Failure to pass task 1-8 will exclude you from being assessed for the Challenge. Note Challenges 1 and 2 can only be assessed with a partner, not individually.

The Challenge is an optional section for the remaining marks. The following challenges are made to *challenge* you and they will NOT be marked easily. If you are not 100% on the rest of your project, it is strongly suggested you work on those first, as challenge marks are comparatively much harder to obtain.

Challenge 1: Automated Searching – You must program your system to automate the pan & tilt locating your partner's photo-diode to begin the optical data connection. You may assume that the tilt angle will be within 15 degrees either side of horizontal. You must work with your partner to define how the systems will communicate when the connection is made. You must demonstrate complete automation and operational optical link at the two base rates part of the core. You should also demonstrate a maximum searching time of 25 seconds before the connection is made.

Challenge 2: Remote Control – You and your partner must define a protocol of radio communication that allows you to take control of one another's pan & tilt so as to control them remotely. You must demonstrate task 1 and 2 on a partners system while it is powered through the DC jack. You and your partner must also demonstrate simultaneous remote control.

Challenge 3: Automatic Rate Detection and Increased Speed in Laser Communication – You must allow the laser receiver and transmitter to increase the speed of communications. The rate needs to be automatically detected at the receiver by using the properties of the Manchester 2 code. The error rate feedback should be sent via the radio channel. By monitoring this error rate, and when little or no errors occur, an increase in communication speed should be performed. If errors start occurring the date rate should be decreased. You must show the frequency of the transmitted Laser waveform on an Oscilloscope or logic analyzer.

As the due date for the project approaches, your tutor may add some helpful answers to questions that many students are having issues with. Make sure to keep updated on the news group for any of these hints and/or minor changes to the spec (you will also be notified by email if this happens).

PROJECT 1:

DUPLEX COMMUNICATION USING OPTICAL FREE SPACE AND RADIO CHANNELS