User Motion Controlled R/C Tank

by
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Contents 3

1 Chapter 1: Design goals

1.1 Objective Statement

Our objective is to provide the user with an interactive method of controlling a R/C tank via a three vector accelerometer.

1.2 Level-0 Description

Module	User transmitter
Inputs	User motion, XBee wireless interface
Translator	MMA7260 Accelerometer
Outputs	XBee wireless interface, LCD, Piezo

Behavior	__only on startup
	    get accelerometer data
	    calibrate to user relative position
	__end startup
	
	 Get request from tank
	      if(request = ‘n’)
	          clear alarm flag
	          send speed and direction to tank
	      if(request = ‘x’)
	          set alarm flag
	          send speed and direction to tank
	
	 Update LCD with accelerometer data
	
	 __ISR__
	      if(alarm flag is true)
	          toggle Piezo
	      else
	           clear Piezo
	
	      get values from accelerometer
	__END ISR__

Table 1: Level-0 Description for Transmitter

Module	R/C tank receiver
Inputs	Front and back ultrasonic range sensors, XBee wireless interface
Outputs	Right and Left motor, XBee wireless interface

Behavior	`stay in a idle state until a command is received`
	
	`if(motor control)`
	`  update PR1 and PR2`
	`  update motor direction`
	`if(sensor request)`
	`  transmit sensor data`
	
	`wait for next instruction`
	
	`ISR's will handle PWM and sensor control`

Table 2: Level-0 Description for R/C Tank

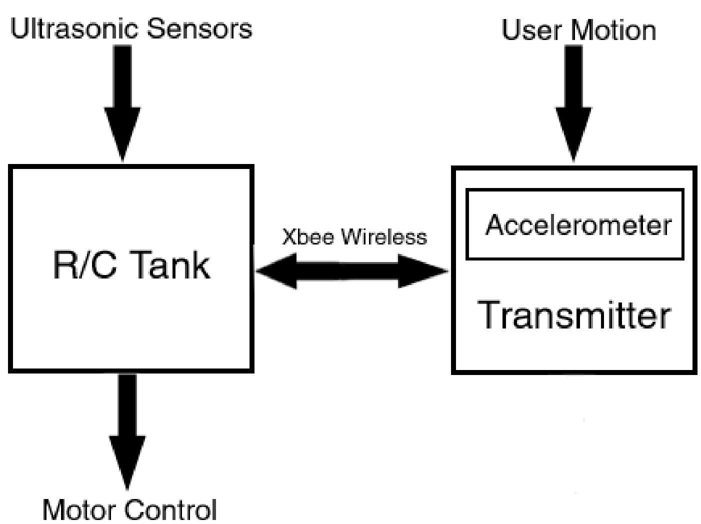

Figure 1: Level-0 Graphical Description

2 Chapter 2: Detailed Design

2.1 Level-1 Description

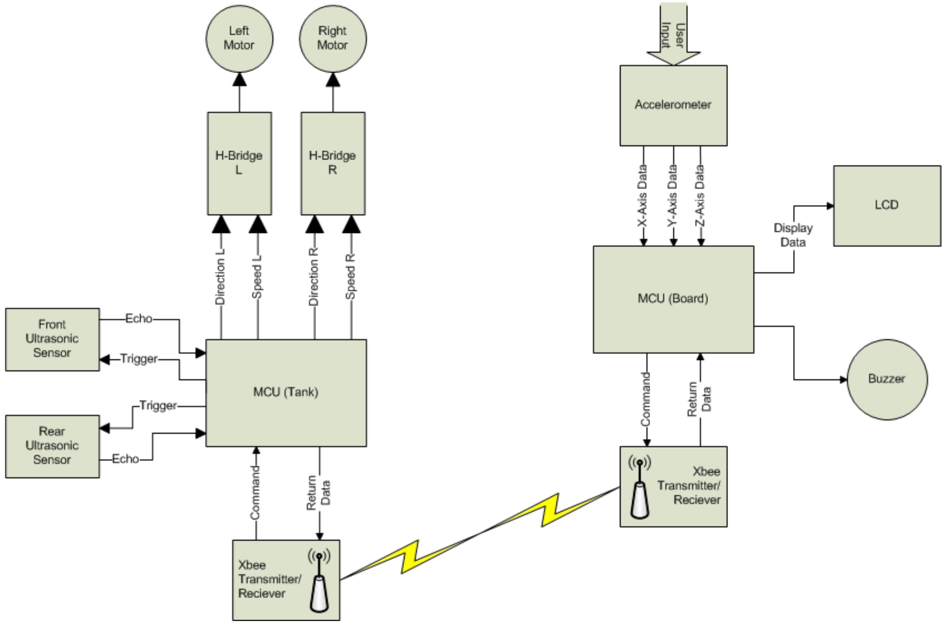

Figure 2: Level-1 Block Diagram

2.1.1 User side

Module	PIC 18F4520 MCU
Inputs	Accelerometer, XBee
Outputs	LCD, Piezo speaker, XBee
Behavior	`Finite state machine in Level-2` See Figure (3).

Table 3: Level-1 Description for PIC 18F4520 MCU

Module	Accelerometer
Inputs	User motion
Outputs	x, y, z vectors acceleration
Behavior	• Collect acceleration from user in x, y, z iteratively • Output to PIC 18F4520 MCU

Table 4: Level-1 Description for Accelerometer

Module	LCD
Inputs	Data and control
Outputs	Viewable text to user
Behavior	• Receive data to display • Output on screen

Table 5: Level-1 Description for LCD

Module	Piezo alarm
Inputs	Input signal, Ground
Outputs	Sound
Behavior	• Receive signal from PIC 18F4520 MCU

Table 6: Level-1 Description for piezo alarm

Module	XBee
Inputs	Data, wireless
Outputs	Data, wireless
Behavior	• Receive mode – Receive data from wireless signal – Send data to PIC 18F4520 MCU • Transmit mode – Receive data from PIC 18F4520 MCU – Send data as wireless signal

Table 7: Level-1 Description for XBee

2.1.2 Tank side

Module	PIC 18F4520 MCU
Inputs	Ultrasonic Sensors, XBee
Outputs	Left Motor H-Bridge, Right Motor H-Bridge, Ultrasonic Sensor Trigger XBee

Behavior	`Round-Robin Interrupt Driven Controller`
	
	`Two Interrupts:`
	`   1. Update motor control signals (High Priority)`
	`   2. Run ultrasonic sensors to update distance (Low Priority)`
	
	`wait for a command`
	`parse command`
	`execute`
	`if(change motor control)`
	`   update PR1 and PR2`
	`   update direction`
	`if(sensor distance request)`
	`   transmit most recently updated senor values`
	
	`High Priority:`
	`   change PWM for motor 1 and motor 2`
	`   clear flag`
	
	`Low Priority:`
	`   trigger sensor to measure distance`
	`   wait for high-to-low transition`
	`   clear timer 3`
	`   wait for low-to-high transition`
	`   store timer 1 value in global variable`
	`   clear flag`
	`   repeat for second sensor`

Table 8: Level-1 Description for PIC 18F4520 MCU Tank

Module	Ultrasonic Sensor
Inputs	Trigger from PIC18F4520 MCU (Tank)
Outputs	Echo Pulse
Behavior	10 μs trigger pulse activates the sensor an echo pulse is returned proportional to the distance from closest object if(echo pulse > 36ms) no object was detected

Table 9: Level-1 Description for Ultrasonic Sensor

Module	H-Bridge
Inputs	PWM and direction bits from PIC18F4520 MCU (Tank)
Outputs	Voltage levels to motor
Behavior	• The duty cycle of the PWM sets the rotation speed of the motor • 1(forward) or 0(reverse) determines direction

Table 10: Level-1 Description for LCD

Module	XBee
Inputs	Data, RX, TX
Outputs	Data, wireless
Behavior	• Receive mode – Receive data from wireless signal – Send data to PIC 18F4520 MCU (Transmitter) • Transmit mode – Receive data from PIC 18F4520 MCU (Tank) – Send data as wireless signal

Table 11: Level-1 Description for Tank XBee

2.2 Level-2

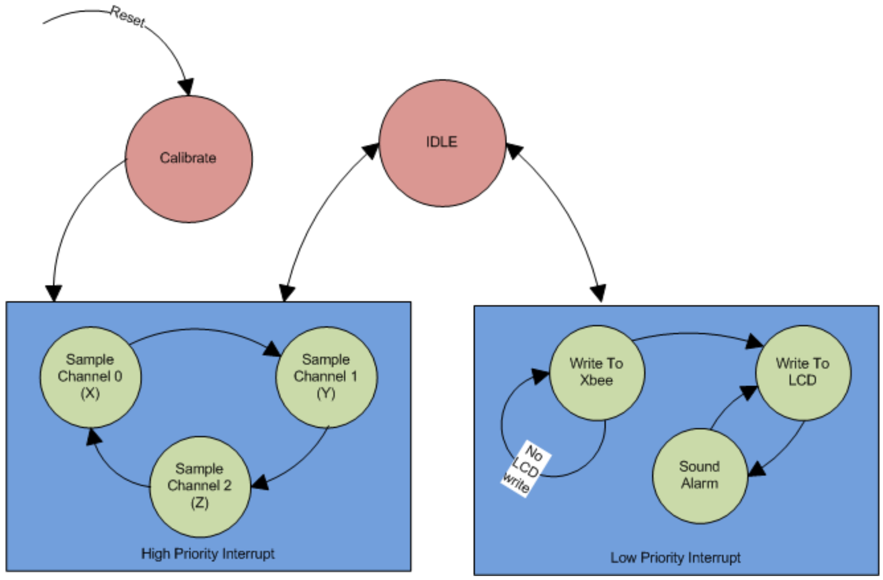

Figure 3: Level-2 FSM for User Transmitter

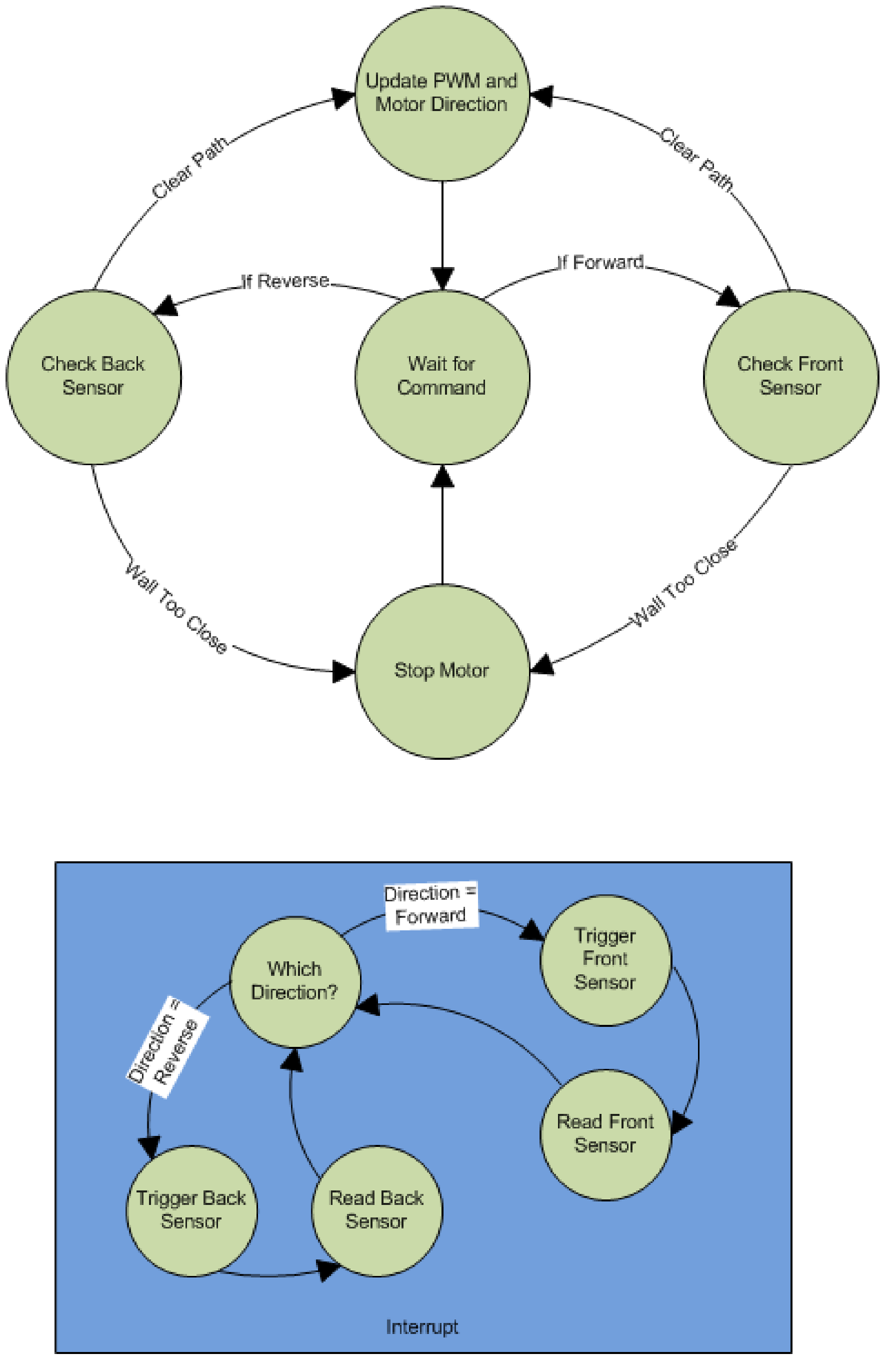

Figure 4: Level-2 FSM for R/C Tank receiver

2.2.1 Communication protocol

A simple communication protocol is established so that both the user interface and the tank may be developed as independent entities. To minimize the parsing and to perform synchronization a command is sent from the tank to the user; this is either the letter ‘n’ or ‘x’ for new value or sound alarm, respectfully.

Once this instruction is sent from the tank, the user transmitter receives this instruction. On either request the direction and speed is sent directly back to the tank. This is done by an integer representing the speed from the x accelerometer value, there are five distinct speeds that the tank decodes into speed and direction. Immediately following this integer value, a character is sent telling the tank to keep on ‘c’enter, ‘l’eft, or ‘r’ight. This was chosen over more complicated protocols to limit the transaction of data across the XBee’s.

2.3 Level-2 Description

2.4 Calculations

150 clock cycles = 1 inch, determined from experiment

$$distance = \frac{1}{2} speedofsound \cdot time \quad (1)$$

$$CalibratedAccelerometer = StartupSample - AccelerometerValue \quad (2)$$

2.5 Technical Requirements

- At least 12 V to power H-Bridge
- Only 3.3 V to power XBee
- Filter capacitors on power rails to remove A/C motor noise

2.6 Bill of Materials

All materials have been purchased in the past or are being supplied by the school

- 2 PIC18F4520 MCU’s
- 1 MMA7260 Accelerometer
- 2 XBee Wireless Transmitter/Receivers
- 2 SRF04 Ultrasonic Sensors
- 1 Modified R/C Tank
- 1 CRYSTALFONTZ LCD
- 2 LM18200 H-bridges
- 1 MAX232N Dual ELA-232 Driver (DIP Package)
- 1 MAX3232CSE ELA-232 Driver (Surface mount)

- 1 SN74LS04N Hex inverter (DIP Package)
- 1 F/CM12P Buzzer
- 1 Null-Modem to AMP9806 Connector
- 3 LM7805AC 5v Regulars
- 2 XBee Breakout Boards
- 1 PicKit2

3 Chapter 3: Implementation

3.1 Milestone I

The goal for milestone I is to get the major functional blocks working. We do not plan to have these blocks working together, only functioning independently.

3.2 XBee

1. Transmit Data
2. Receive Data
3. This will be assisted by eavesdropping using hyper-terminal

Each XBee transmitter/reciever was setup with X-CTU[1] by configuring the XBee's in command mode as instructed by Mechatronics Wiki[2] With no program installed immediate communication is achieved over wireless USART using transparent wireless transmission.

3.3 Accelerometer

1. Generate usable values from the accelerometer by adjusting the sample rate
2. Experimentally check for the range of values that can be read from each axis
3. Allow the accelerometer to be calibrated to any initial position

The accelerometer is tested by writing an interrupt service routine (ISR) that samples eight values from each of the x, y, and z vector directions. This is to ensure that the sampling frequency was great enough and was not being slowed down by other programming tasks. After the total of 24 values were recorded into the x, y, and z arrays, a function is called from the ISR that disables interrupts (so that new values do not alter this test) and prints out the collected results on Hyper Terminal. Once all of the values are printed, interrupts are enabled so that this process continues indefinitely.

The following test was performed on the calibrated output of the accelerometer. Initially the accelerometer was calibrated in the static state sitting on a table; increments based on a degree measurement. The axis's x and z are measured as shown in Figure 5, and y is measured as shown in Figure 6.

Results from this experiment are shown in Table 12. It is noted in the test that the x and y values correspond for their respective angles.

[1] Software downloaded from manufacturers website: http://www.digi.com/support/productdetl.jsp?pid=3352&osvid=57&tp=4&s=316. Accessed 12 April 2009.

[2] XBee_radio_communication_between_PICs. Mechatronics Wiki. http://hades.mech.northwestern.edu/wiki/index.php /XBee_radio_communication_between_PICs. Accessed 12 April 2009.

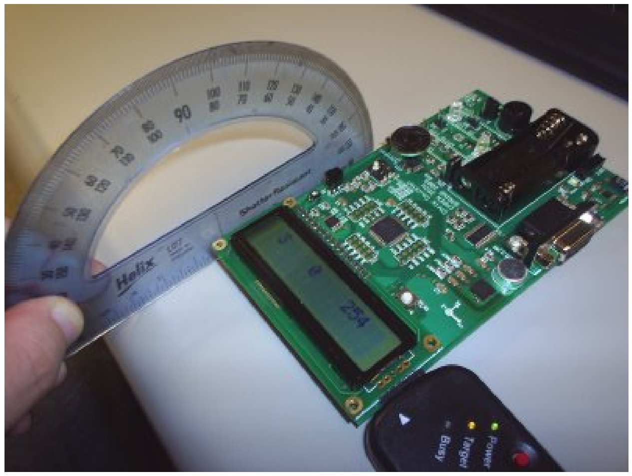

Figure 5: Setup for accelerometer experiment for the x and z axes

Figure 6: Setup for accelerometer experiment for the y axis

Degree	x (calibrated)	y (calibrated)	z (calibrated)
0	0	0	255
15	238	235	
30	223	224	0
45	210	213	
60	198	202	
75	194	196	
90	192	193	57
105	195	195	
120	203	203	
135	213	216	
150	223	224	
165	234	241	
180	253	1	124

Table 12: Experimental results measured for calibrated accelerometer at various angles

3.4 H-Bridge Network

1. Generate individual motor speeds and direction
2. Remove any heat dissipation problems

The H-bridge network is tested by wiring the motors to match the wiring diagram in the datasheet for 754410 chip. The enable bits are fed the PWM from the PIC. The H-bridge reads the amount the pulse is high as an average voltage to determine the speed of the motor. If the pulse is high for 50% of the period, the equvalent voltage is 2.5 V. This is tested by assigning different pulse widths and looking for a change in speed. We found the H-bridge networks to be functioning properly.

3.5 Ultrasonic Sensors

1. Read pulse length using interrupt on pin change
2. Develop formula for translating pulse length to distance (inch or centimeter)

To test the ultrasonic sensors, an interrupt had to be written to trigger the sequnce of events needed to activate and then read the sensor. The first stage of the interrupt is to send a 10 μs pulse to the trigger pin of the sensor. This activates the interal circuitry allowing the sensor to return a pulse on the echo pin that is proportional to the distance of the object detected. To read the length of the pulse, Timer1 is cleared when the echo goes high and read when the echo returns low. The sampled Timer1 value is then diplayed on Hyper Terminal. The ultrasonic sensors functioned properly with very stable distance readings.

3.6 Milestone II

The goal of milestone II is to get the individually functioning blocks integrated as a functioning system.

3.7 Send commands with XBee from spring board to R/C tank.

1. Use a deterministic context free language
2. Calculate motor speed and direction using values from the accelerometer
3. Request sensor data via interrupt
4. Use the R/C tank to interpret command, perform and respond if needed.

3.8 Interpret XBee commands and perform them on the R/C tank

1. Each command needs to be parsed to fulfill the request
2. The request being performed assigns any registers or interrupts needed.
3. If the command is a request for data, the data packet will be transmitted over the XBee module

3.9 Use Accelerometer for intuitive user control

1. Accelerometer is set to the users desired initial position
2. The values from the accelerometer are then generated using this set

3.10 Read distance from the ultrasonic sensors and return data

1. Use an ISR to initialize, capture and return data.
2. The captured value is updated on a regular interval
3. When the distance is requested, the most recently sampled distances are transmitted back with the XBee module

3.11 Final Implementation

Motion from the user's hand provides an acceleration value to be translated into an instruction. This instruction corresponds to the speed and direction of the tank; there are five speeds: forward fast, forward slow, stop, reverse slow, and reverse fast, along single speed left and right. These correspond to the direction of the user's position relative to the accelerometer, that is, during device reset for the user transmitter a sample is taken to offset all other measured accelerometer values, see equation (2)

Problems that occurred during fully operational tank control includes:

- The H-bridges require at least 12 V to operate; our battery only supplied 9.6 V, so we replaced this power supply with a 21.6 V 1200 mAH cordless drill battery.
- Noise from the motors disrupted the control signals. Filter capacitors were placed on all of the power rails to reduce this AC noise.
- The pulse width modulated waveforms and direction signals from the MCU are passed through a restoring buffer. The waveforms are sent through two inverters, and the direction signals are inverted; this allows for a single hex inverter (74LS04) to accommodate all of these signals.
- A TX wire from the user's MCU and the XBee was severed, disabling communication.

References

Software downloaded from manufacturers website: http://www.digi.com/support/productdetl.jsp?pid=3352&osvid=57&tp=4&s=316. Accessed 12 April 2009.

XBee_radio_communication_between_PICs. Mechatronics Wiki. http://hades.mech.northwestern.edu/w /XBee_radio_communicationbetween_PICs. Accessed 12 April 2009.

Equation (1) Dudek and Jenkin. Computational Principles of Mobile Robotics. Cambridge University Press. 2000.

Technical Documents

XBee Manual. http://ftp1.digi.com/support/documentation/90000982_A.pdf. Accessed 12 April 2009.

Ultrasonic sensors. www.acroname.com/robotics/parts/R93-SRF04p.pdf Accessed 22 April 2009.

H-bridges. www.datasheetcatalog.org/datasheet/nationalsemiconductor/DS010568.PDF Accessed 22 April 2009.

Accelerometer. www.freescale.com/files/sensors/doc/data_sheet/MMA7260QT.pdf Accessed 12 April 2009.

Appendix A: Running the Project

- The tank needs to be on before the user transmitter
- Turn on the tank
- Turn on the user transmitter
- If values are not updating on the user transmitter reset the transmitter
- Tilt forward to move the tank forward
- Tilt backward to move the tank backward
- Tilt left to turn left
- Tilt right to turn right

Appendix B: Project CD

Attached.

Appendix C: Project Website

http://352w.blogspot.com/