JNM Technologies

Fluffy Bunny-3000 Series
Automatic Forklift

5/29/2008

DEVRY UNIVERSITY-FREMONT

ELECTRONICS ENGINEERING TECHNOLOGY PROGRAM

AUTOMATIC FORKLIFT SYSTEM

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DEVRY UNIVERSITY-FREMONT

ELECTRONICS ENGINEERING TECHNOLOGY PROGRAM

EET-404 / FINAL REPORT: EVALUATION SHEET

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PROJECT TITLE: AUTOMATIC FORKLIFT SYSTEM

GRADING CRITERIA	**MARK**	**OUT OF MAXIMUM MARKS**
STYLE, ORGANIZATION, CLARITY		10
SPELLING, GRAMMAR, CONCISENESS		5
LABELING, FIGURES, TABLES, PAGES		5
TIME MANAGEMENT		10
TECHNICAL CONTENT / CORRECTNESS		70
TOTAL		100

DATE: _____

GENERAL ED. ADVISOR NAME: Professor Kim Mahler

GENERAL ED. ADVISOR SIGNATURE: _____

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ABSTRACT

The Automatic Forklift System (AFS) is designed to make the process of stocking warehouses safer and more efficient. With current manually operated forklifts, employees are at risk of injury. Employers also spend a lot of money on insurance and paying multiple employees to operate forklifts in their warehouses. The AFS will limit the need for employees to operate forklifts manually. This will not only cut down on long term employer costs, but will reduce the chance of injury among employees as well.

We built a $1/6^{th}$ scale prototype of a single AFS. This model takes pallets to and from the docking area and different aisles. The user chooses what they want the forklift to do by way of the hand-held user interface. The commands from the user are sent wirelessly to the forklift. It then drives itself along predetermined paths, picks up the pallet, and brings it to the desired location. When finished, it returns "home" where it awaits another command. "Home" is the aisle were the forklift parks while waiting for commands; on a full scale electric forklift this would also be where it pulls into its charger.

For safety purposes, the forklift is equipped with a tilt sensor, a wireless camera, front and rear proximity sensors, and emergency shut off buttons. The tilt sensor detects if the forklift tips over; if this happens, the forklift stops and tells the user via the user control that the forklift has tipped over. Once the forklift has been righted, the user may then choose to proceed, or go back home. The front and rear proximity sensors detect if an object is in the path of the forklift; if this happens, the forklift stops and the user control asks the user if it is safe to proceed. The user may check the video feed that shows the area immediately in front of the forklift and determine if the area is clear. Emergency shutoff buttons are located on three sides of the forklift; in case all other safety options fail, someone can push one of the buttons which physically disconnects the power to the motors.

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CHAPTER ONE
INTRODUCTION

1.1

PROJECT SCOPE

The Automatic Forklift System (AFS) is designed to make the process of stocking efficient while decreasing unnecessary work related spending. A one-sixth scale model forklift is being used to demonstrate the feasibility of the project. An operator will control the system at a safe distance away from the forklift, such as in a separate control room, decreasing the risk of work-related injuries with a handheld user interface.

The Automatic Forklift System is capable of the following operations: receiving commands from the operator, navigating through the modeled warehouse, retrieving and placing pallets at desired locations. The AFS utilizes two microcontrollers called Programmable Interrupt Controllers (PIC), many sensors, and various motors. The PICs, one in the forklift and one in the user interface, are programmed with the required algorithms needed to run this project. Several infrared (IR) sensors are used for navigation to follow painted lines on the ground, as well as pallet detection and to see if the forklift falls over. Two ultrasonic range finders are used to detect objects or people in front of or behind the forklift. Two momentary switches, one in each fork, are used to detect a load on the forks. Servo motors are used for steering as well as tilting the forks. Electric motors are used for driving the forklift forward and in reverse, and to raise the forks. There is a camera mounted on the top of the forklift to give the user a visual aid for tracking the forklift. And lastly, there are several emergency shut-off switches placed around the forklift.

In this project there requires a project manager, hardware engineer, and software engineer. Nick Larsen is the project manager, Joshua Quintero is the hardware engineer, and Mai Zoua Vang is of software engineer.

1.2

TARGET USERS

The intended users of the AFS would be distributing centers, as well as any company with a large warehouse that uses forklifts to move pallets. The ideal environment for this system would be warehouses with little to no foot traffic that require a forklift to move pallets from trucks to their respective shelves, or stacks, etc.

Employers will benefit from this system by saving money in the long run. An initial investment in the AFS will reduce the cost of employing multiple forklift operators needed to keep up with the inflow and outflow of large quantities of product. With this system, only one operator would be needed to operate the AFS, and as a possible future enhancement, multiple systems. As you can see, employers stand to benefit from this system.

With the AFS, the risk of injury to employees involving forklifts will be reduced, because there will be no need for an operator on the forklift itself to steer it manually. Thus, the operator will no longer be put into dangerous situations. This lowers the cost of workers' comp. The AFS eliminates the opportunity for human error that may have caused workplace accidents resulting in property damage and bodily harm. This system offers the benefit of safety to employees.

1.3

FUTURE ENHANCEMENTS

With further resources and time we could implement a system that would be superior to today's methods. The AFS would be integrated with a database that keeps track of the inventories through the use of RFID scanners to enter the pallets into the database before moving them. A scale would be added to the forklift to track the weight of each pallet for shipping purposes and to prevent overloading the weight capacity of the forklift. There could also be a manual override for the user to manually operate the forklift for special cases. In the future, the system could be able to operate multiple forklifts at any given time by adding to the software algorithms. Laser navigation could be incorporated to eliminate the need of lines on the warehouse floor. To implement these enhancements, a microprocessor with capabilities greater than the PIC18F452 would be needed for higher order applications.

CHAPTER TWO
ECONOMIC ANALYSIS

2.1

MARKET ANALYSIS

There are at least a handful of companies that currently offer Automatic Guided Vehicle (AGV) forklifts. The majority of AGVs utilize laser guidance or magnetic guidance systems. At first we planned on using magnetic disk navigation, but due to the limitations in the magnetic sensors encountered in the early testing stages, we decided to go with an IR sensor navigation configuration instead. This will allow for a more reliable and accurate navigation system given our time and resources. These other companies also offer manual control of their AGV. At the moment we are not planning on incorporating a manual control into our forklift. All companies, including ours, offer safety options, such as laser or mechanical bumpers that stop the AGV, should something get in the way. Although this market has been well developed by multiple companies, we believe that we can duplicate this technology, with limited means, and offer it at a more affordable price as seen by Table 1.

Table 1: Market Analysis

Company	FMC Technologies www.fmcsgvs.com	Transbotics www.transbotics.com	Savant www.agvsystems.com	**JNM Technologies**
Navigation System	Laser	Laser	Magnet Floor Tape	**Infra Red**
Manual Control	Yes	Yes	Yes	**No**
Safety Options	Yes	Yes	Yes	**Yes**
Price	$250,000	$250,000	$57,750	**$50,000**

2.2.0

BUDGET ANALYSIS

Our total spending for materials and labor for this project is $89,152.61, using a scale model forklift.

We have spent a grand total of $922.25 (See Table 3) on materials compared to our budget estimation of $634.72 (See Table 2). As of today 2008, we have spent approximately $287.53 over budget. In our budget estimation we did not factor in shipping and handling of component parts. This accounts for some of our overspending, alongside expenditures for parts that were not used in the final product after some trial and error. Office supplies are also not included in the estimation.

The total labor cost, to employ a hardware and software engineer, as well as a project manager for this project was $88,230.36. The materials make up 1% of the budget while labor makes up the remaining 99% of the budget (See Figure 1).

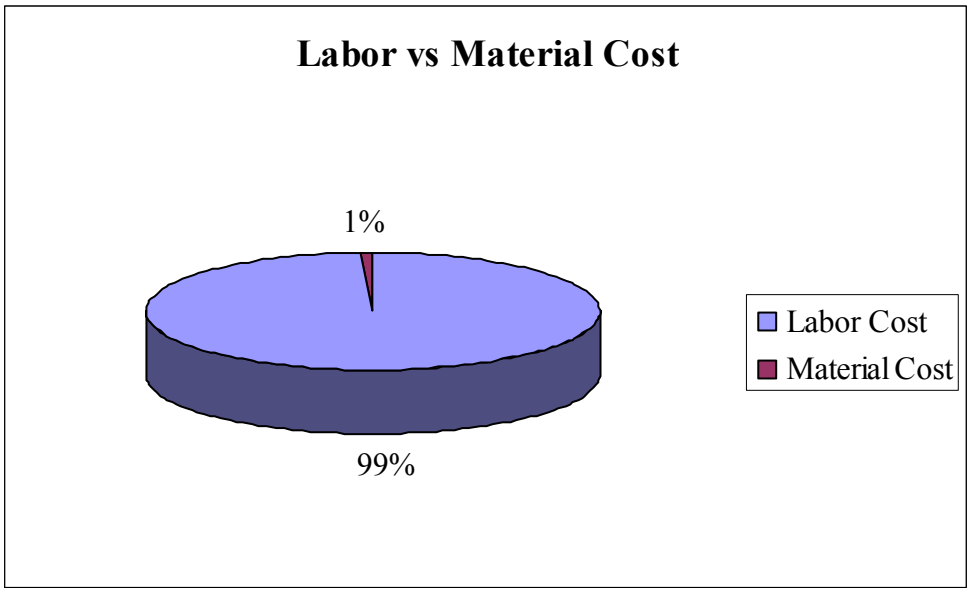


Figure 1: Labor vs Material Cost Pie Chart

2.2.1

MATERIALS

Estimation of material cost (See Table 2) is based on Jameco and SparkFun prices, except for the forklift which we bought online for $109.89, and miscellaneous. The subtotal, excluding tax, of all materials is $592.49. A tax of $42.23 is included based on an 8.75% tax rate, giving us a total estimated cost of $634.72.

According to Table 2, a majority of money will be spent on sensors, the power supply, and the model forklift. The money for miscellaneous items such as resistors, capacitors, wires, and replacement parts will be held in reserve in the amount of $110.

Table 2: Material Cost Estimate

Qty	Description	Retailer	Cost
2	PIC18F452	Microchip	$17.70
1	Power Supply Module	Various	$100.00
1	RF Transmitter and Receiver	SparkFun Electronics	$13.95
4	Sensors	Avago Tech.	$145.16
1	Keypad	Jameco	$9.25
1	LCD	Jameco	$24.95
1	Buzzer	Jameco	$1.59
	Miscellaneous	Various	$110.00
2	PIC Break Out Board Components	Jameco	$60.00
1	Forklift	HobbyTron.com	$109.89
		SUBTOTAL	$592.49
		TAX	$42.23
		TOTAL	**$634.72**

Our total cost for this project was $922.25, but the total cost to replicate this project is only $792.75 (See Table 3). The discrepancy in price is due to some materials being donated to us, as well as some materials purchased were not used in the final product.

Table 3: Actual Cost of Materials

Qty	Description	Gross Cost	Used	Net Cost
1	Forklift	$109.89	1	$109.89
	Office Supplies	$71.24		$71.24
4	Servo and Serial Servo Controller	$60.85	4	$60.85
2	Components for H-Bridge Board	$46.49	1	$23.25
6	Hall Sensors	$27.30	0	$0.00
1	Flexible Stretch Sensor	$31.45	0	$0.00
1	Magnets	$14.55	0	$0.00
	Miscellaneous Components	$221.91		$221.91
8	Components for IR Board	$75.58	6	$56.69
2	Xbee	Donated	2	$73.90
1	Black Box	Donated	1	$11.91
2	Ultrasonic Range Finder	$57.95	2	$57.95
2	433MHz: UM96 Wireless Modem	$93.37	0	$0.00
2	Components for Xbee Wireless Board	$31.27	2	$31.27
1	Wireless Camera	$67.40	1	$67.40
2	Ball Casters	$13.00	1	$6.50
	TOTAL	**$922.25**		**$792.75**

2.2.2

LABOR COST

The total labor cost for this project is $88,230.36 (See Table 5). This is based on the total hours worked for the calculated hourly wage of each team member.

The yearly salary for the hardware engineer, software engineer, and project manager is $193,584, based on the annual income of a full time employee (See Table 4). According to the U.S. Department of Labor, Bureau of Labor Statistics, a survey conducted by National Association of Colleges and Employers in 2005 shows that the median starting salaries for a hardware engineer and software engineer is $51,888 and $52,464, respectively. According to a survey conducted by Abbot, Langer & Associates in 2004, the median salary for a project manager is $89,232.

It took us almost a year to complete the Automatic Forklift System, but we did not work 40 hours a week for 52 weeks. This accounts for the $105,353.64 discrepancy between the yearly labor cost and our actual labor cost. Each employee's earnings are based on the hours he/she worked on this project. The salaries in Table 2 are divided into hourly wage to determine each employee's earning.

The hourly wage for a project manager is $42.90 which is determined by:

$$\frac{\$89{,}232}{year} * \frac{1year}{52weeks} * \frac{1week}{5working\_days} * \frac{1day}{8working\_hours} = \$42.90$$

The hourly wage for a hardware engineer is $24.95 which is determined by:

$$\frac{\$51{,}888}{year} * \frac{1year}{52weeks} * \frac{1week}{5working\_days} * \frac{1day}{8working\_hours} = \$24.95$$

The hourly wage for a software engineer is $25.22 which is determined by:

$$\frac{\$52{,}464}{year} * \frac{1year}{52weeks} * \frac{1week}{5working\_days} * \frac{1day}{8working\_hours} = \$25.22$$

Actual hours worked are as follows:

The 1st semester working hours for each member is 150 hours
The 2nd semester working hours for each member is 420 hours
The 3rd semester working hours for each member is 378 hours
Total hours worked is **948 hours**

Project Manager: 948 hours * $42.90 = $40,669.20
Hardware Engineer: 948 hours * $24.95 = $23,652.60
Software Engineer: 948 hours * $25.22 = $23,908.56
Project Labor Cost = **$88,230.36**

Table 4: Yearly Salaries

Name	**Position**	**Salary**
Nicholas Larsen	Project Manager	$89,232
Joshua Quintero	Hardware Engineer	$51,888
Mai Zoua Vang	Software Engineer	$52,464
	TOTAL	**$193,584**

Source: U.S. Department of Labor Bureau of Labor Statistics

Table 5: Labor Cost

Name	**Position**	**Salary**
Nicholas Larsen	Project Manager	$40,669.20
Joshua Quintero	Hardware Engineer	$23,652.60
Mai Zoua Vang	Software Engineer	$23,908.56
	TOTAL	**$88,230.36**

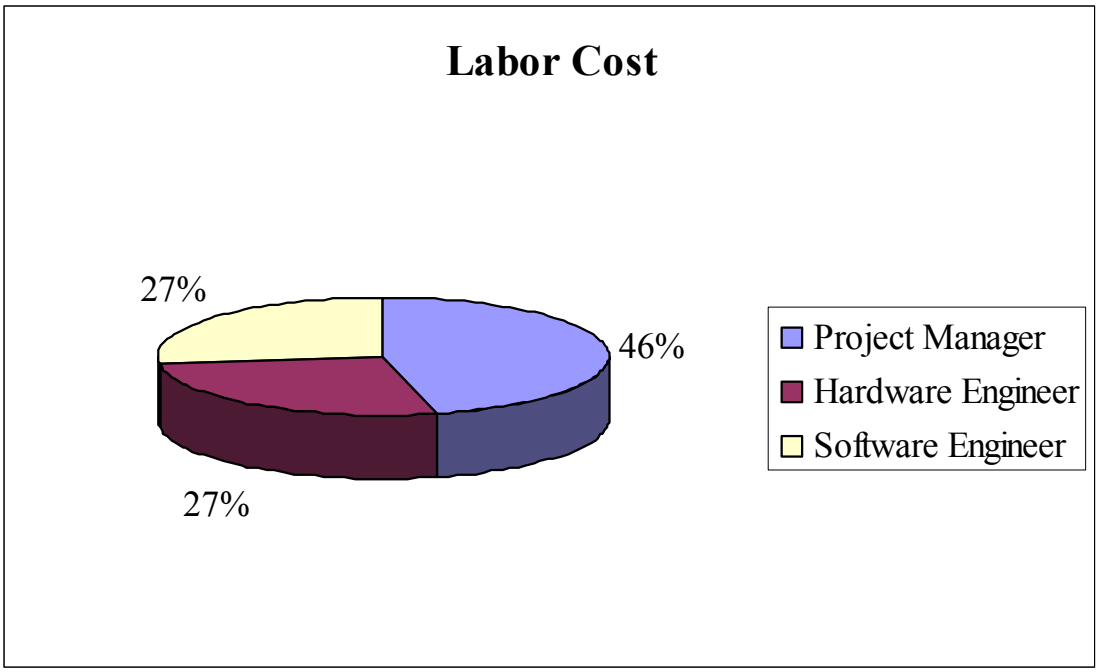


Figure 2: Labor Cost Pie Chart

2.3

GANTT CHART

See Appendix A for complete Gantt chart. On July 18, 2007 our group was formed with Joshua Quintero, Mai Zoua Vang, and Nicholas Larsen. We decided JNM Technologies (the initial of each member) was an appropriate name for our group. We wanted to create a project that was challenging, so we came up with an idea of an R/C blimp with a camera connected to it. This was rejected on August 8, 2007 by Dr. Armulescu because he believed there are too many variables associate with a blimp to be completed within a one year timeframe. So, he suggested a security system of some sort during our meeting with him. We accepted, but only if we did not find a new idea before then. We later proposed an Automatic Forklift System that Dr. Armulescu approved of on the same day, Wednesday August 8, 2007.

We then quickly began working on the initial proposal for the next few days. Mai worked on the description, Joshua worked on the hardware, and Nick worked on the software portion. After that we compiled all our sections into one report and revised it as a team, correcting errors along the way. We met with our English Advisor Kim Mahler on August 13, 2007 for suggestions regarding our proposal. The initial proposal was turned in on August 15, 2007 and was approved by the advisors and the dean on August 16, 2007.

A week later, we started to work on progress report #1 which consists of the introduction. We divided the work into three parts. Nick worked on the target audience, Josh worked on future enhancements, and Mai worked on the scope. We individually worked on our assignments alone until we finished our portions. Once we were finished, we had a meeting to combine our work into a rough draft. We proofread the report as a group before sending the report to

Professor Mahler for corrections on August 29, 2007. She responded with corrections the next day. We then revised it a few more times and submitted it to Dr. Armulescu on Friday August 31, 2007.

We started working on progress report #2 a week after turning in progress report #1. The work was initially divided up with Mai working on the budget, Josh and Nick working on the Market Analysis. We started working on our assigned tasks when it came to our attention that the Gantt chart was due with this report. Josh accepted the assignment of creating the Gantt chart. We met with our English Advisor to help us with the questions we had on Monday September 10, 2007 regarding formats and expectations of the written report. She suggested a lot of ideas and we worked on it before emailing her a revised report to correct. Our corrected essay was returned, and we made the proper revisions. We sent in progress report #2 on Wednesday, September 12, 2007, on time.

We started on progress report #3 a week after turning in progress report #2. Josh started working on the diagrams on Wednesday September 19, 2007. Mai and Nick started working on the explanations for the diagrams when Josh finished the first set of diagrams. Josh finished the diagrams on Monday September 24, 2007. The explained report was finished a day later. On Wednesday September 26, 2007 we turned in progress report #3 to Professors Armulescu and Mahler.

On Monday October 1, 2007 Mai started working on the rough draft by formatting all the chapters in the rough draft. A day later, Nick started working on the Appendix, while Josh updated the Gantt chart. We finished the report on Wednesday October 3, 2007 and turned it in to Professor Kim Mahler and Professor Armulescu.

We met with Kim Mahler on Monday, October 8, 2007 to discuss our power point and final draft. The final draft was due on Wednesday, October 10, 2007. The last milestone for that semester was the EET-400 presentation on October 17, 2007.

On November 5, 2007 Josh and Mai finished the H-bridges that we designed and built to drive the DC motors. The forklift was purchased that same day.

On November 12, 2007 we received the remote control forklift we ordered, and after playing with it to see how it worked as is, we immediately started tearing it apart to make room for our modifications.

On November 7, 2007 we tested the hall-effect sensors and realized that they would have to be too close to the magnets to be practical. Nick built a platform that would get the sensors closer to the floor, but we soon decided that IR sensors would be more practical and scrapped the idea of using the magnets.

On November 28, 2007 we made necessary changes to and submitted progress report #1.

On December 1, 2007 we finally got the programming for the servo motors working. Nick and Josh installed the rear servo motor that steers the forklift.

On December 4, 2007, IT… IS… ALIVE!!! With the servo motor installed and a simple program written to the PIC we were able to make the forklift drive straight then turn and drive in a circle.

On December 5, 2008 we developed a new layout for our navigation lines, which will allow the forklift to more accurately follow designated paths.

We met with Professor Kim Mahler on Friday, December 7, 2007 to discuss our progress report #1, and how we did on our first presentation at the end of last semester.

On December 12, 2007 we made necessary changes to and submitted progress report #2.

Straight line navigation was finally achieved on December 18, 2007, using the mounted IR sensors and comparator boards. We had to play with the angles used to correct the steering, but we finally figured out a method that allowed us to correct the direction of the forklift without overcorrecting and running off of the path.

The Infrared comparator boards and array board were built and completely installed and working by January 17, 2008.

On January 19, 2008 we started testing our wireless modem and ultrasonic range finders. By the end of the day we had both working, but not implemented into the project.

We tried to implement the wireless modem into our project on January 26, 2008, but were met with disappointment. While the wireless modem worked perfectly fine on its own, it did not work when integrated into the user interface and forklift. We spent a lot of time working on this, but due to the upcoming presentation we are putting it off until the next semester.

On January 28, 2008 we were able to get both ultrasonic range finders to work together on the same bus by assigning different addresses to them using I^2C.

Due to the needs of the fork tilt servo to turn a whole 180^os, we had to change the mode of the servo controller from 90^os to 180^os. We were able to get the forklift to navigate along a straight line again using the new servo controller mode on January 31, 2008.

The tilt sensor was installed and working on February 4, 2008.

Although we assigned specific tasks to each member, it was completed with the help of the whole team.

On Monday March 3 we started working on the wireless Zigbee. We achieved communication between the two Zigbee on March 5 including the finalized boards for it.

Progress Report number 1 was turned in on time on March 27, 2008. This included the prologue and the first chapter.

Josh, Mai, and started working on the finalized steering algorithm to follow the line on Friday March 14, 2008. This included how to turn in the intersections and how to place markers on the floor so the forklift can do what we wanted it to do. This was finally dropped on Sunday April 6, 2008.

In doing so, we started rebuilding the whole steering structure in 2 days. This was finished on Tuesday April 8, 2008. This new steering method made the forklifts maneuverability as a real forklift rather than the steering as a cheap RC car.

After this we diligently began work on following the lines in straight line navigation. We finalized this new type of navigation on Friday April 11, 2008.

Since out way of navigating evolved, we needed to move the IR sensors to a more strategic location so that we get correct readings and finished it in 1 day, Friday April 11, 2008.

We composed our turning algorithm and the finalized the intersection layout on April 14, 2008.

Progress report number 2 was turned in on time on April 17, 2008.

We presented our updated on the forklift to Dr. Armulescu as our midterm for our class. This was done on Thursday April 24, 2008.

On Friday April 25, 2008 we started creating the algorithm to make the forklift locate, pick, and place pallets. We finished this on Saturday April 26, 2008.

Progress Report number 3 was turned in on time on May 1, 2008.

All the algorithms were finally integrated to one program on Thursday May 8, 2008. It took 4 days to debug the integration of all of these.

From May 9, 2008 until May 21, 2008 we added more options to the software and add a buzzer for the user interface.

We worked on the finalized report and turned it in on May 22, 2008.

We worked on the presentation from Wednesday, May 14 to Tuesday, May 27, 2008.

CHAPTER THREE
HARDWARE DESIGN

3.1

MECHANICAL DESIGN

The Automatic Forklift System (AFS) utilizes several motors, infrared sensors, and ultrasonic range finders. The motors are used for the basic operation of the forklift. A DC motor raises and lowers the forks, while two continuous rotation servo motors drive and steer the forklift in a tank drive configuration (See Figures 3, 4) and another servo motor tilts the forks. Infrared sensors are used to detect a white line on a black floor for navigation, as well as detect the pallet for accuracy when setting a pallet on top of a stack of pallets. There is another IR sensor pointed to the floor in order to detect the presence of the floor; this is used as the tilt sensor to detect if the forklift falls over.

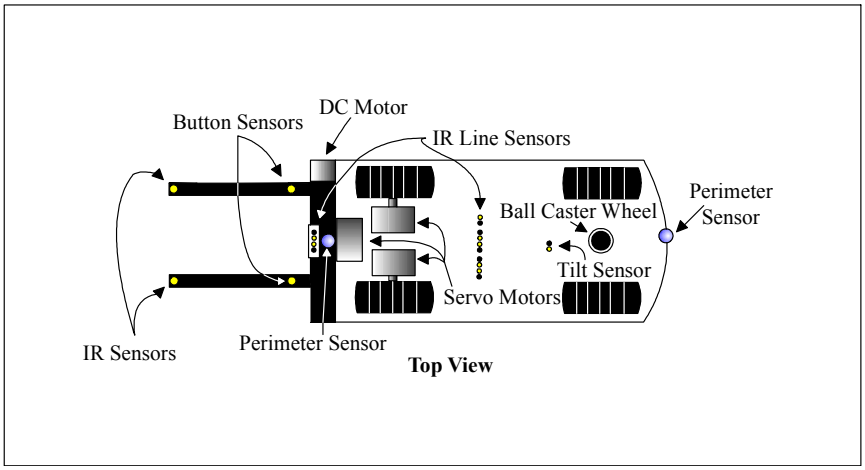


Figure 3: Mechanical Top View

The forklift steers by turning off one motor while keeping the other wheel turning (See Figure 4). The caster wheel is there to decrease the forklift's friction while turning. Even though there are two wheels in the back, they are raised up and are not used in this project. To go straight both wheels must be moving in the same direction and at the same speed.

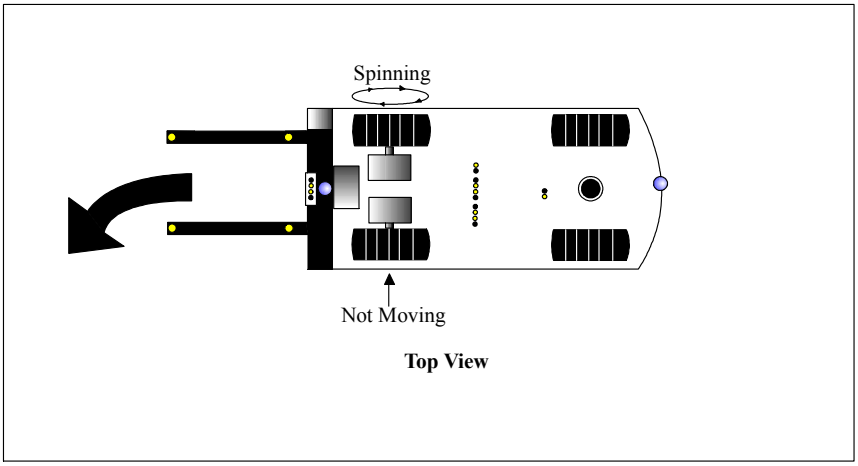


Figure 4: Steering Top View

The forks of the AFS have pressure buttons to detect if there is a load on the pallet or not (See Figures 3, 5,). There is another push button located in the front of the plate where the load will lean on when the pallet is picked up. This is used to detect when the forks are completely inserted into the pallet. Ultrasonic range finders detect obstacles in the path of the AFS, they are shown as perimeter sensors (See Figures 3, 5). Lastly, the wireless Zigbees communicate between the forklift and the user control to send and receive instructions (See Figure 5).

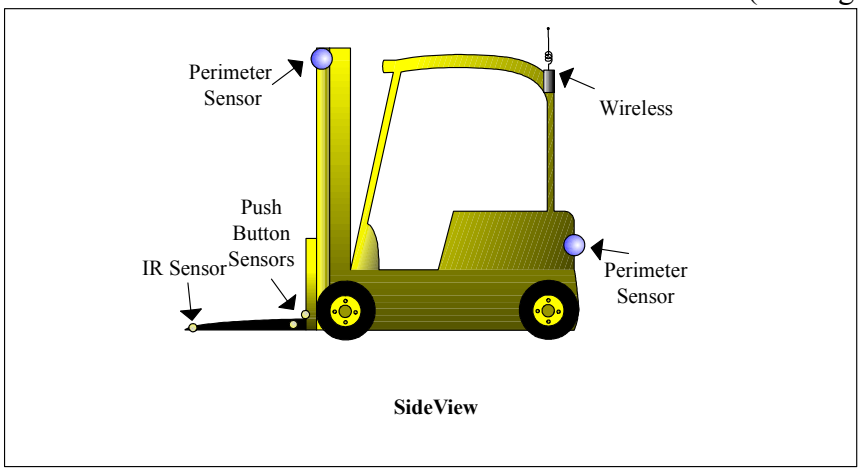


Figure 5: AFS Sensor Location

The forklift senses the pallet with the IR sensors located in the front of the forks (See figure 6). The forklift could detect if there is another pallet on top of it by simply moving the forks up until the correct location is achieved. If there IR sensors detect nothing, then there is not a pallet on top of it.

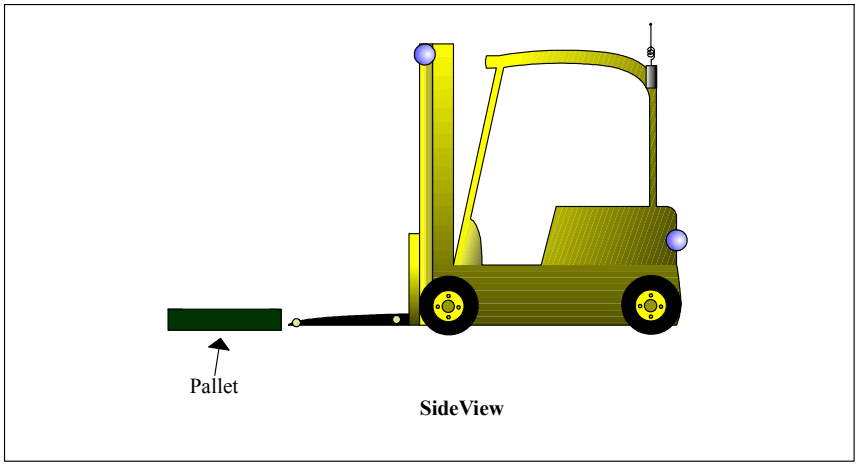


Figure 6: Fork Sensor Location 1

The forklift detects the pallet with the push button located on the plate (See Figure 7). When the forklift lifts the load, the push button on the forks are pushed.

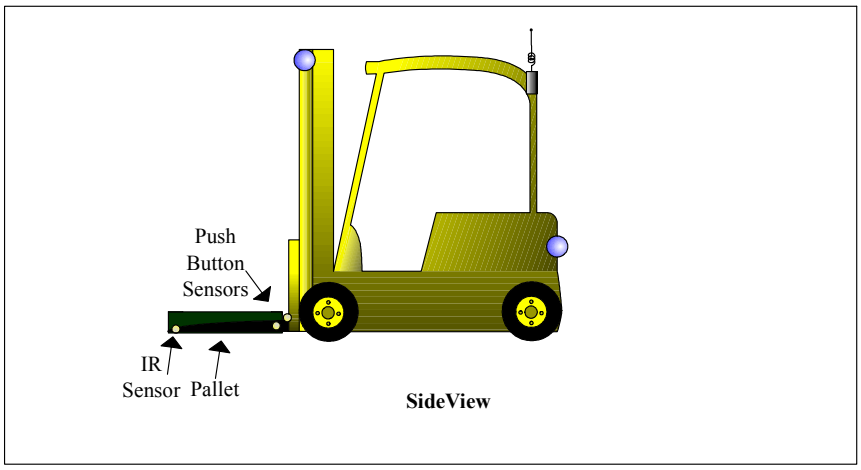


Figure 7: Fork Sensor Location 2

The lines that the forklift follows are ½" wide. Each intersection should consist of a 10" X 10" square (See Figure 8). The forklift detects the presence of the intersection by way of the side IR sensors. If the forklift needs to turn at that intersection it will do so at the instant it detects the first line of the intersection.

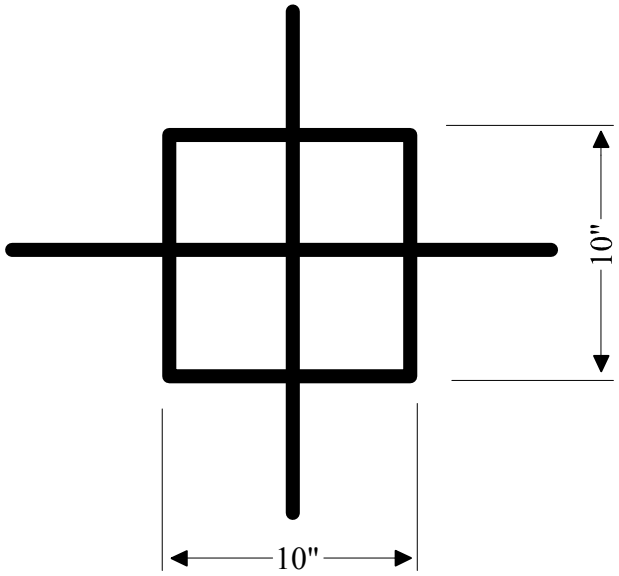


Figure 8: Intersection

3.2

ELECTRICAL DESIGN

When the operator enters a command, the wireless Zigbee in the user control will send a signal to the wireless Zigbee in the forklift, which will be inputted into the PIC microcontroller (See Figures 9 – 11, 13). Depending on the commands, the PIC will drive to the desired location. Predetermined paths will be laid out with white lines on the floor so the AFS can follow the lines and decide which path to take depending on the command given. When the perimeter sensors detect an obstacle in the path of the AFS while it is operating, the PIC stops the movement of the AFS until the obstacle is removed or the safety is manually overridden, telling the AFS it is safe to proceed. When the task is completed, the AFS will return to its staging area to wait for a new command.

With regard to safety, there will be several large pushbuttons that will disable the motors when pushed and stay that way until the button is pushed again. A LED light located beside the button will light up to show that this button has been pushed. This emergency shutdown will be an emergency shut of switch that will physically disconnect power to the motors should all other safety precautions fail.

An onboard camera will allow the user to see what the forklift sees, so that decisions regarding troubleshooting or safety can be made more effectively.

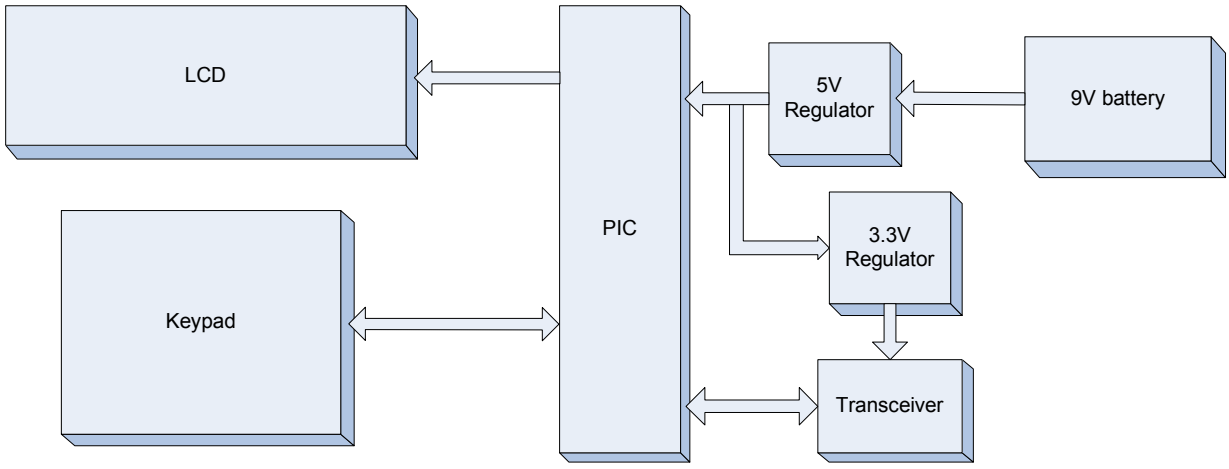


Figure 9: User Interface Hardware Block Diagram

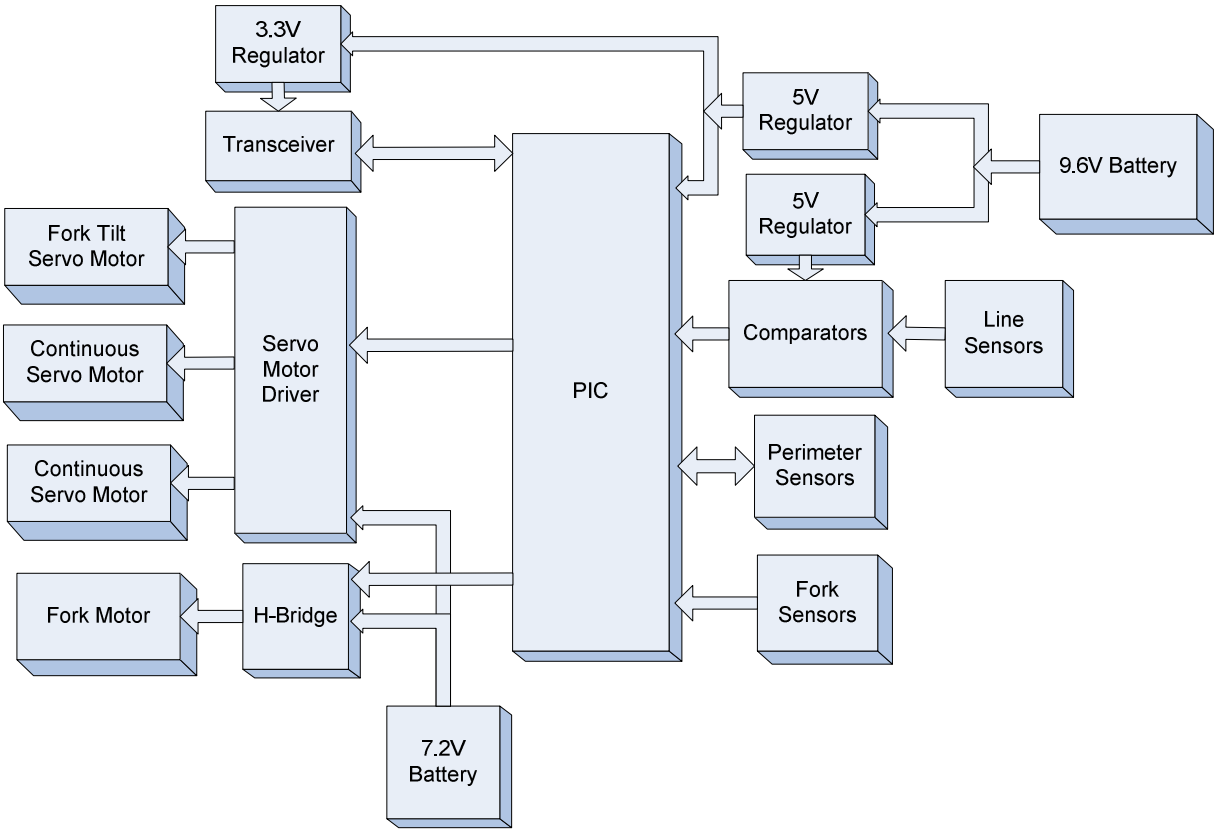


Figure 10: Forklift Hardware Block Diagram

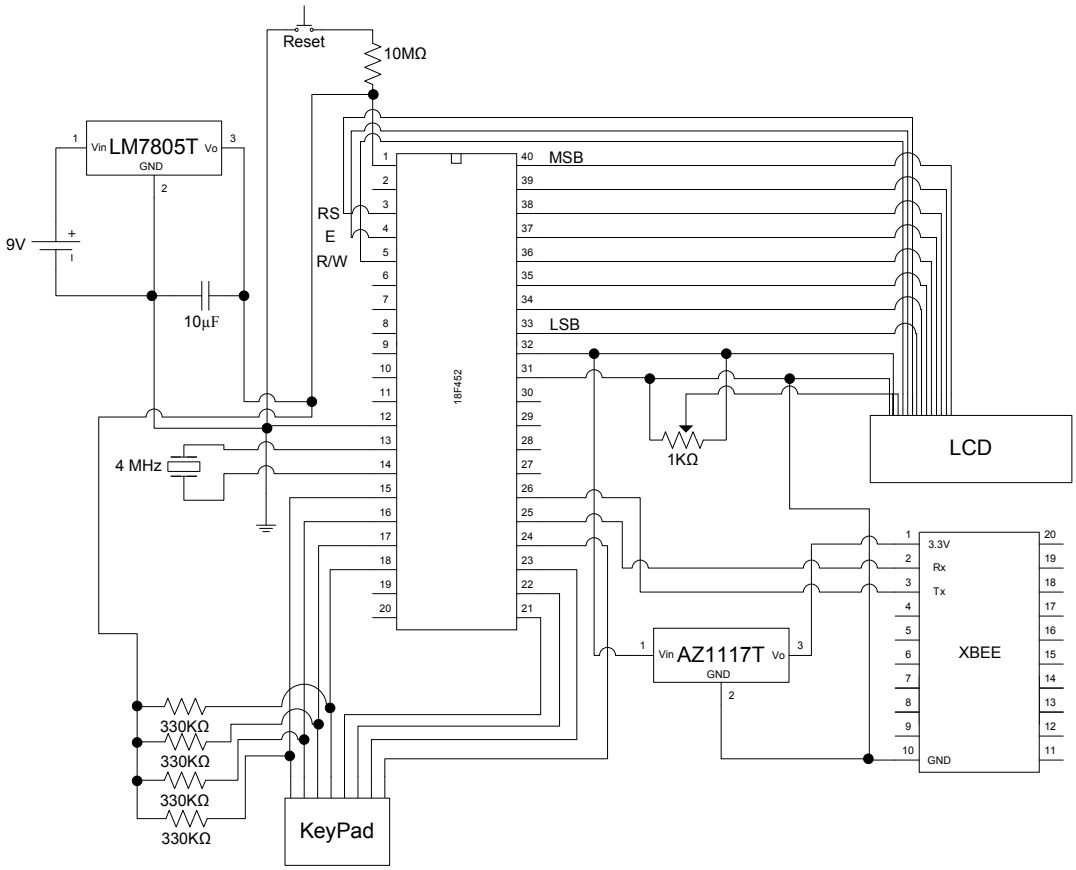


Figure 11: User Interface Hardware Circuit Diagram

The circuit diagram of the user interface shows the components used and their configuration (See Figure 11). The LM805T is a 5V regulator used to bring the voltage from the 9V battery to the needed 5V. This supplies the power to all the components of the receiver. A 10µF capacitor is used to filter out any ripples left from the 5V regulator.

A 4 MHz Crystal Oscillator with buffer is used for the clock of the PIC18f452.

The wireless Zigbee uses TTL UART communication to interface with the PIC microcontroller. The wireless Tx pin is connected to the PIC's Rx pin, and the wireless Rx pin is connected to the PIC's Tx pin. It is powered by the 3.3V regulator. This regulator is supplied by the PIC's 5V regulator.

The LCD used in this project is a JHD204A series with a display content of 20 character x 4 rows. This LCD has 16 pins; the function for each pin is given below (See Table 6). The last two pins, 15 and 16, are for background lighting and are not used in this project.

V_{SS}, V_{CC}, V_{EE}: V_{SS} and V_{CC} are connected to ground and +5V, respectively. The LCD has a 1KΩ potentiometer connected to the V_{EE} pin (Pin 3) and +5V for the user to change the contrast of the LCD.

RS, register select: The register select pin is connected to Pin 3 of the PIC. The LCD contains two registers, one for the instruction command code and the other is the data register. The RS pin is used to select the desired register. When RS=0, the command register is selected, which allows the user to send an LCD command code such as clear display. LCD command codes are the instructions use to configure the LCD setting (See Table 7). When RS=1, the data register is selected, which allows the user to send data to be displayed on the LCD.

R/W, read/write: The R/W pin is connected to Pin 5 of the PIC. It allows the user to write or read information from the LCD. When R/W=1, the user can read from the LCD. When R/W=0, the user can write data to the LCD to be display.

E, enable: This pin is connected to Pin 4 of the PIC and is used to latch the data sent to the data pins of the LCD. A high to low pulse, with a minimum of 450 nanosecond pulse width, is needed to latch the present data at the data pins.

B7-B0, data pins: B7-B0 are the data pins and are connected to Pin 40 – Pin 33 of the PIC, respectively. These pins may be configured as input or output data pins.

Table 6: Pin Descriptions for LCD

PIN	SYMBOL	I/0	DESCRIPTION
1	V_{SS}	--	Ground
2	V_{CC}	--	+5V Power Supply
3	V_{EE}	--	Power Supply to Control Contrast
4	RS	I	RS=0 to Select Command Register, RS=1 to Select Data Register
5	R/W	I	R/W=0 For Write, R/W=1 For Read
6	E	I/0	Enable
7	B0	I/0	LSB Data
8	B1	I/0	Data Bit
9	B2	I/0	Data Bit
10	B3	I/0	Data Bit
11	B4	I/0	Data Bit
12	B5	I/0	Data Bit
13	B6	I/0	Data Bit
14	B7	I/0	MSB Data

Table 7: LCD Command Codes

Code (Hex)	Command to LCD Instruction Register
1	Clear Display Screen
2	Return Home
4	Decrement Cursor (shift cursor to left)
6	Increment Cursor (shift cursor to right)
5	Shift Display Right
7	Shift Display Left
8	Display Off, Cursor Off
A	Display Off, Cursor On
C	Display On, Cursor Off
E	Display On, Cursor On
F	Display On, Cursor Blinking
10	Shift Cursor Position to Left
14	Shift Cursor Position to Right
18	Shift the Entire Display to the Left
1C	Shift the Entire Display to the Right
80	Force Cursor to Beginning of 1st Line
C0	Force Cursor to Beginning of 2nd Line
38	2 Lines and 5x7 Matrix

The input pins to the Keypad are connected to the output pins of the PIC (pins 21 to 24). The output pins of the Keypad are connected to the input pins of the PIC (pins 15 to 18) through 330 ohm resistors (See Figure 11).

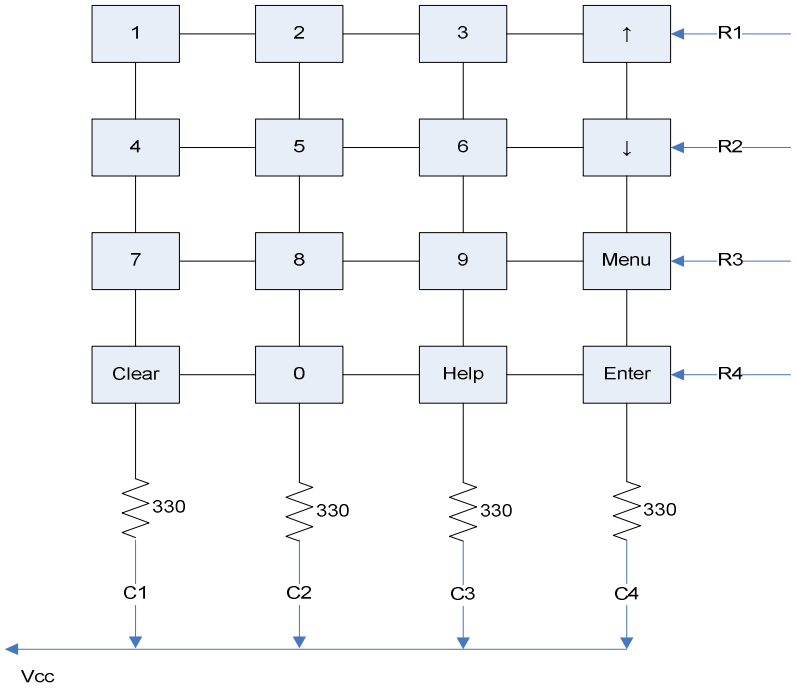


Figure 12: Keypad

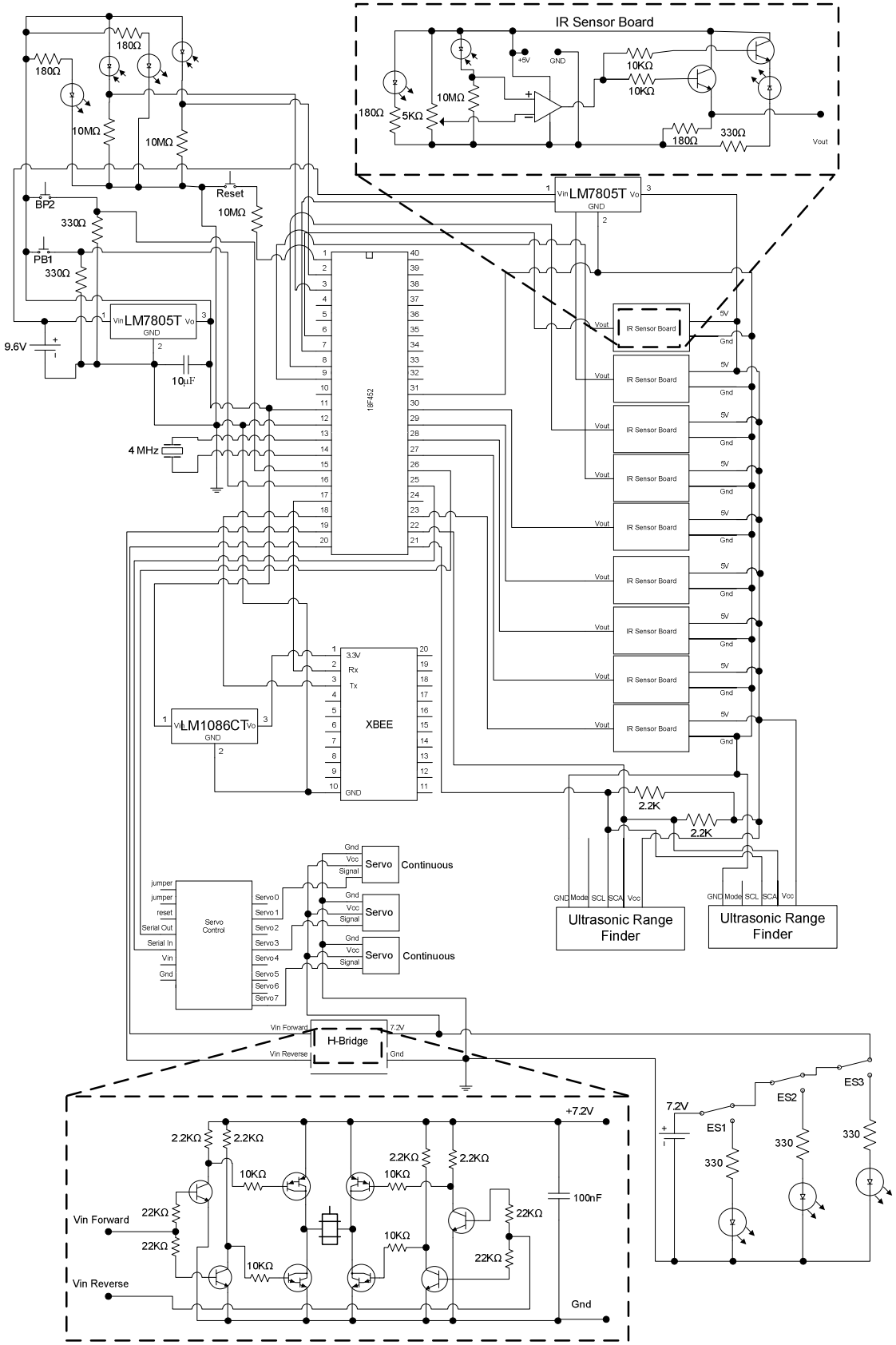


Figure 13: Forklift Hardware Circuit Diagram

There are two power sources in the forklift. One is the 7.2V battery that powers a DC motor and three servo motors. The other battery is a 9.6V battery that powers two 5V regulators which in turn supplies power to the PIC, various sensors, and the wireless.

The IR boards are connected to power and ground through one of the 5V regulators. The outputs of the board are connected to input pins on the PIC. Inside an IR board there is an IR LED and an IR photo transistor. The IR LED has an 180Ω resistor so the LED is supplied with the correct current and voltage. The calculation used to get this resistance is Ohm's Law:

$V=I*R$

Since we are applying 5V and the LED requires an average voltage 1.4V, we expand the equation:

$(V_s-V_L)=I*R$

Also, the LED requires an average of 20mA. We get this equation for R:

$R= (V_s-V_L)/I$

$R = (5V-1.4V)/.02A = 180Ω$

A 10MΩ resistor is connected to one of the inputs of the transistor to dissipate voltage to keep from getting false readings. The other input of the transistor is connected to a potentiometer so that the IR can be calibrated to the desired voltage. The output of the comparator has transistors connected to it, but it needs a resistor on each transistor so one transistor does not take all the current over other transistor. The output pin of the transistor has a 180Ω resistor connected to ground to allow the PIC to see logic high and low. The other transistor is used to light an LED as a visual aid for a high and low so the user can see the status.

The Ultrasonic range finders are powered by the PIC's 5V regulator. The SDA pin is connected to pin 15 on the PIC and the SCL pin is connected to pin 16 on the PIC. Both the SDA and SCL pins require a pull up resistor. The recommended resistance is 1.8KΩ, but we used a 2.2KΩ resistor since this resistor was available.

The servo controller is connected to the UART pins of the PIC for TTL serial communication. The servo controller is powered by the 7.2V battery. The outputs are connected to the signal input of the servos. The servos are connected to the output pins to the servo controller.

Pair of IR LED's and IR phototransistors are used for sensing distances, and is attached to the forks for use in detecting pallets. The outputs are connected to pins 2 and 3 for the Analog to digital converter so the PIC can place a numeric representation of the distance.

Two switches, which are used for detecting a load on the forks, are connected to 5V on one side. The outputs of the switches are connected to pins 2 and 3 for logic high and low inputs. There are 330Ω resistors connecting the output to ground to let the PIC see logic levels.

The H-Bridge board contains many transistors. The smaller transistors control the larger Darlington pair transistors. This is allows to control a large amount of current with a small signal. When the forward pin is enabled, it enables the PNP transistors to close, allowing the motor to go forward. When the reverse pins are enabled, it enables the NPN transistors, allowing the motor to go reverse.

The wireless Zigbee is powered by the 3.3V regulator. It is connected to a virtual UART on the PIC in the forklift. The PIC does not have 2 UART's, so in code a UART is programmed into any desired pins.

For safety reasons there are manual shut off switches in the forklift. This turns off the power supply to all the motors. It is connected in series with the 7.2V batter. If any of these switches are pushed, it will turn off the motors. Also when the button is turned off and LED is turned on to indicate that this button has been pressed.

CHAPTER FOUR
SOFTWARE DESIGN

4.1

USER INTERFACE

Initialization: Figure 14 shows the flowchart of the main program for the user interface. When the PIC is turned on, the PIC initializes with the proper configurations and Global variables are declared and initialized. An interrupt function is declared and is called when any data is received by the RS232 port. The main program then calls the Int_LCD function to configure the LCD with the desired settings (See Figure 15). Once the function is finished executing, it returns the pointer back to the main program. Now the LCD is turned on and ready to receive data from the PIC to be displayed. At this point nothing is display on the LCD.

Screen 1: The Interrupt function is called once the PIC receives a signal from the forklift (See Figure 16). The user interface then sends a signal back to the forklift to establish a 2-way wireless communication. Once the 2-way communication has been established, the Interrupt function calls the Menu function which display two choices to the LCD,"1. Pick up from dock" and "2. Place on dock." Once the Menu function is finished executing, it returns the pointer back to the main program (See Figure 17).

The main program then calls the Check_keys function to check for a key press (See Figure 18.1, 18.2). When a key is pressed, the Key_table function is called by the Check_keys function to take the specified actions associate with that key (See Figure 19.1, 19.2). The Key_table function is called for all the keys except the arrows, menu, and enter keys. If those specified keys are pressed, the Arrow function is called to execute their actions (see Figure 20).

Once either key 1 or 2 has been pressed, the Check_keys function will call the Key_table function. In the Key_table function, the number corresponding to the choice selected is stored in a variable called *Choice* for later use in the Transmit function.

Screen 2: The Key_table then calls the Screen function to determine what message to display next (See Figure 21.1, 21.2). The Screen function calls the Out_LCD_string to display the string that asks the user to verify the choice he has selected from screen 1 (See Figure 22). The pointer then returns to the main program and calls the Check_keys function to check for the user input. The user can either presses 1 to indicate that the choice is correct or 2 to indicate that the choice is wrong.

If the user presses 2 on the keypad, the Check_keys function will call the Key_table which will call the Menu function to display the choices given in screen 1. The user is now back at screen 1 waiting for the user to make a selection.

Screen 3: If the user presses 1 on the keypad, the Check_keys function calls the Key_table which calls the Screen function. The Screen function calls Out_LCD_string to display the string "Aisle:" This is where the user enters the aisle number he wishes to place or pick up the pallet.

The pointer returns to the main program to call Check_keys. Once a number has been pressed, the Key_table will look up the array element corresponding to the key press. If the keypad has

not been pressed more than three times, Key_table will call the Out_LCD function to display and store the characters pressed. In the Out_LCD function, a variable called *counter* is incremented each time a character is display to keep track of the number of keys pressed (See Figure 23). The character is stored in an array called *aisle_number* for later use. After the Out_LCD function displays each character, the pointer returns to the main program to check for another key press.

The user can also press the "Clear" button to clear all the number(s) entered. When the "Clear" button is pressed, the Key_table function calls the Clear function to clear the whole LCD and display the original message in screen 3(See Figure 24).

Once the keypad has been pressed three times, any additional key presses will not be displayed. To move on to the next step the "enter" key must be pressed.

Screen 4: In this screen, the user is asked to verify his inputs from screen 3. Once the "enter" key has been pressed in screen 3, the Check_keys function calls the Arrow function to execute the actions corresponded to the "enter" key. The Arrow function calls the Screen function which calls the out_LCD_string function to display the characters stored in the array *aisle_number*. The pointer returns to the main program to check for any key press.

If the user presses 2, this means that the aisle number entered is wrong. The Key_table function calls the Screen function to take the user back to screen 3 to re-enter the aisle number.

Screen 5: If the user presses 1, this means that the aisle number entered in screen 3 is the correct aisle to pull the pallet from or place the pallet to. The Check_keys function will call Key_table function which will call the Screen function. The Screen function will call the Transmit function (See Figure 25).

In the Transmit function, if the aisle number and *Choice* from screen 1 does not match the preprogram aisle number and choice; the out_LCD_string function will display the message "Invalid Entry" for a second. The pointer will jump out of the Transmit function and go back to screen 3. The user will be asked to enter the aisle number again.

If the aisle number and *Choice* match the preprogrammed aisle number and menu choice, a value will be stored in the variable *selection* (See Table 8).

Table 8: Transmission Values

Value to Transmit	Menu Choice	Aisle Number
0x31	1	2
0x32	1	3
0x33	2	2
0x34	2	3

The pointer exits from the Transmit function and returns to the Screen function. From there, the corresponding value is transmitted wirelessly via the wireless modem to the PIC on the forklift.

The Screen function will call the out_LCD_string function to display the message "Transmitting" to let the user know that the user interface is communicating with the forklift.

If the forklift does not transmit a value back to indicate that it has received the value transmitted by the user interface, then the LCD will continue displaying "Transmitting."

Screen 6: Once the forklift receives the value transmitted by the user interface, it will transmit a confirmation to the user interface. As soon as the user interface receives the confirmation, the Interrupt function is executed to display the message "Operating" to let the user know that the forklift is operating. After the Interrupt function is finished executing, the pointer returns to the main program to check for a key press.

At any given time, the user can press the "Help" button to stop the forklift. The Check_keys function will call the Key_table which will transmit a value to the forklift to tell the forklift to stop. The forklift will send back a confirmation to let the user know that the forklift has stopped. The Interrupt function will be called once the user interface receives the confirmation. The Interrupt function will call the out_LCD_String to display the message "Stop" and give the user the choice to resume or go back to the docking area. The pointer returns to the main program to await the user's selection from the keypad. Key 1 will resume the process and key 2 will return the forklift to the docking area.

If the user chooses to resume the process, the Check_keys function calls the Key_table which calls the Screen function to transmit a value to the forklift to tell the forklift to resume the process. The Screen function will let the user know with an LCD display message that the forklift is operating.

If the user chooses to go back home, the Check_keys function will call the Key_table function to execute the appropriate action. If this is the first time the home has been selected then Key_table will call the Screen function to transmit a value to the forklift to let it know that the user wants the forklift to go back to the Home aisle. The Screen function will call the Out_LCD_string function to display the corresponding messages to let the user know that the forklift is returning home and is operating. The pointer returns back to the main program to check for key press.

If the forklift detects any object in the way or is tilted over, it will send a signal to the user interface. The Interrupt function in the user interface will be executed once it receives the transmitted signal. The user will be asked to resume or go home. The procedure for the choice selection works the same way as the "Help" button procedure.

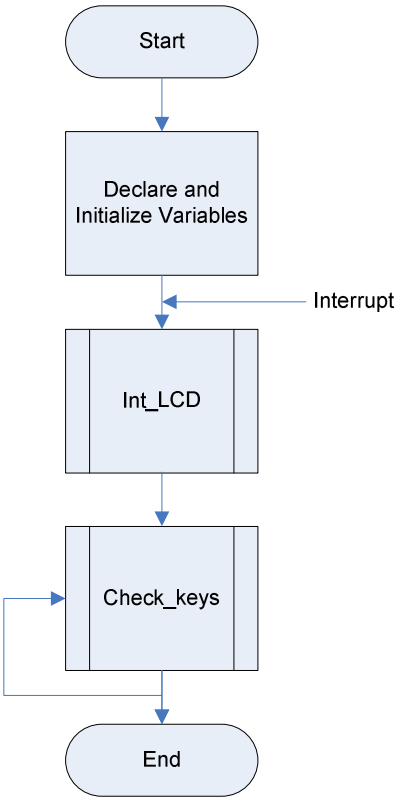


Figure 14: User Interface

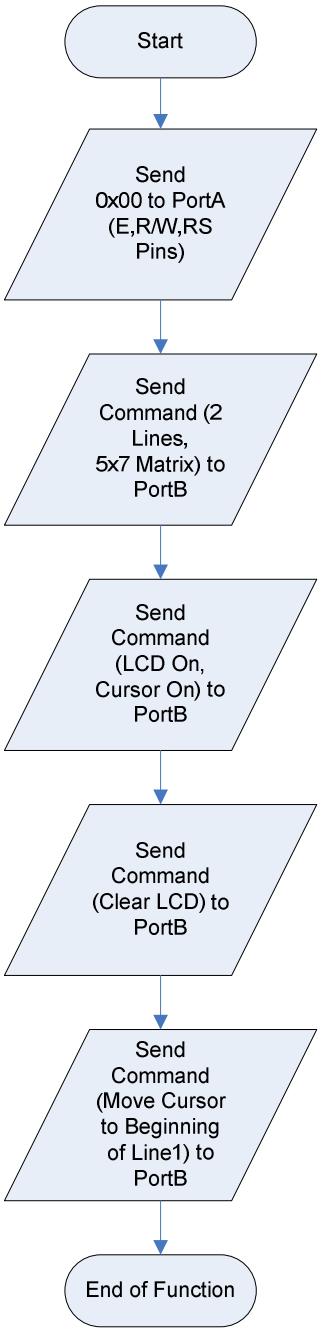


Figure 15: Function - Int_LCD

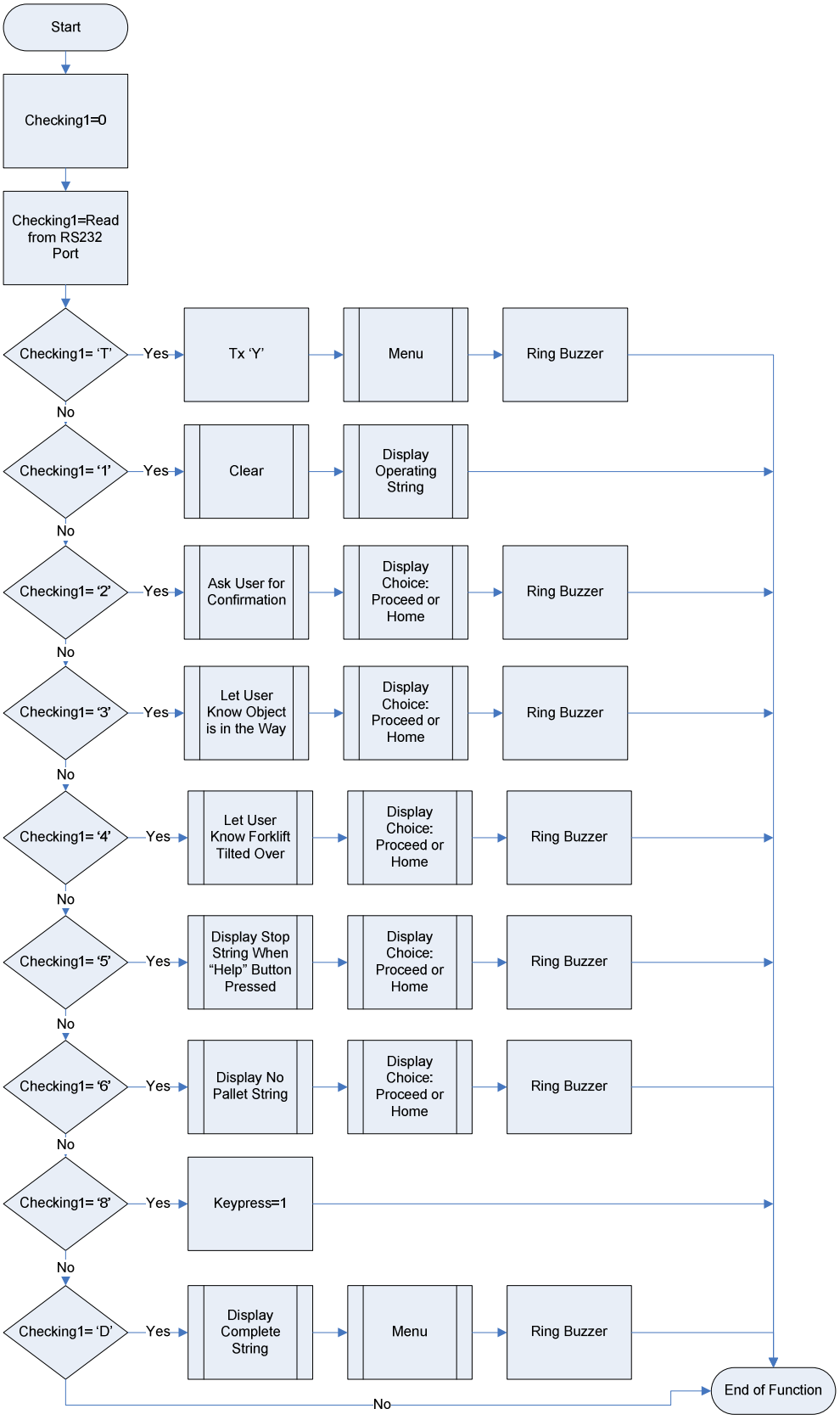


Figure 16: Function - Interrupt

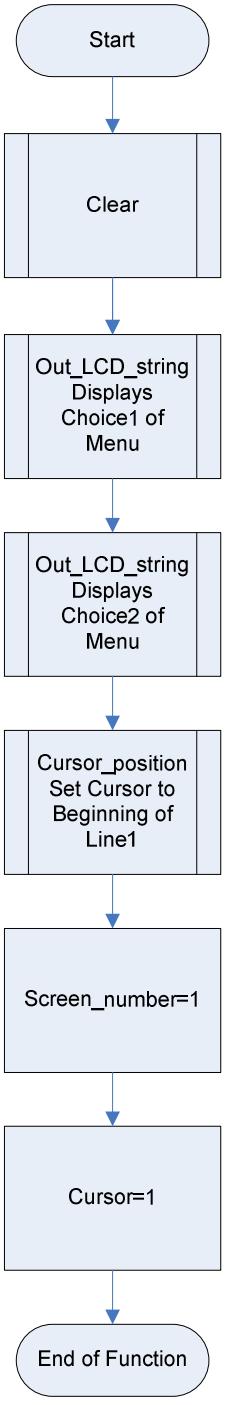


Figure 17: Function - Menu

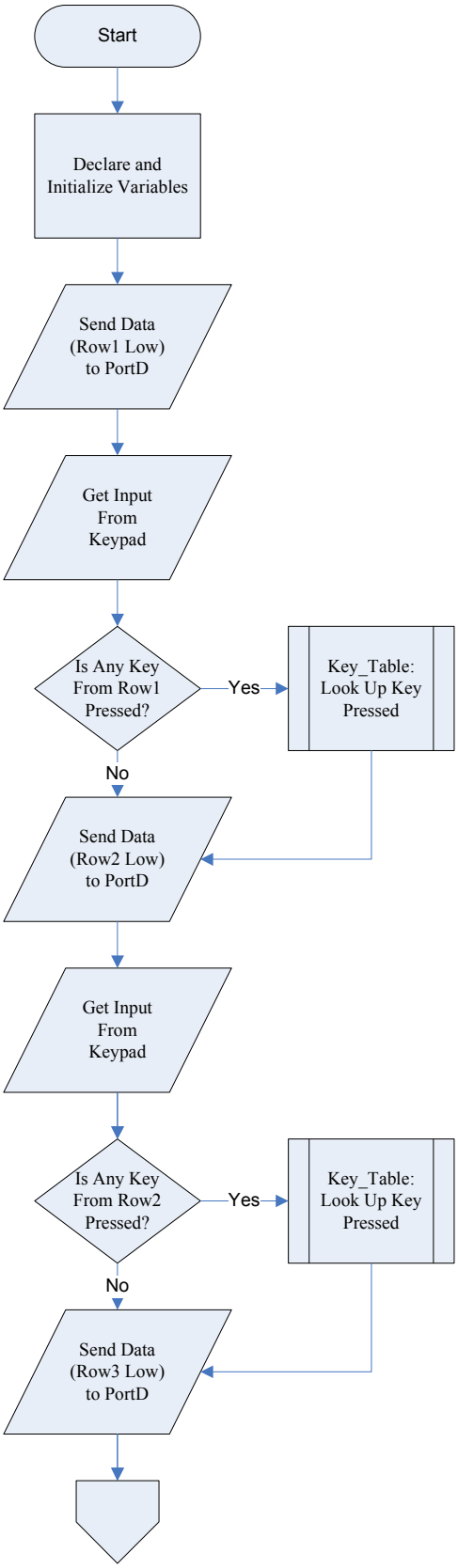
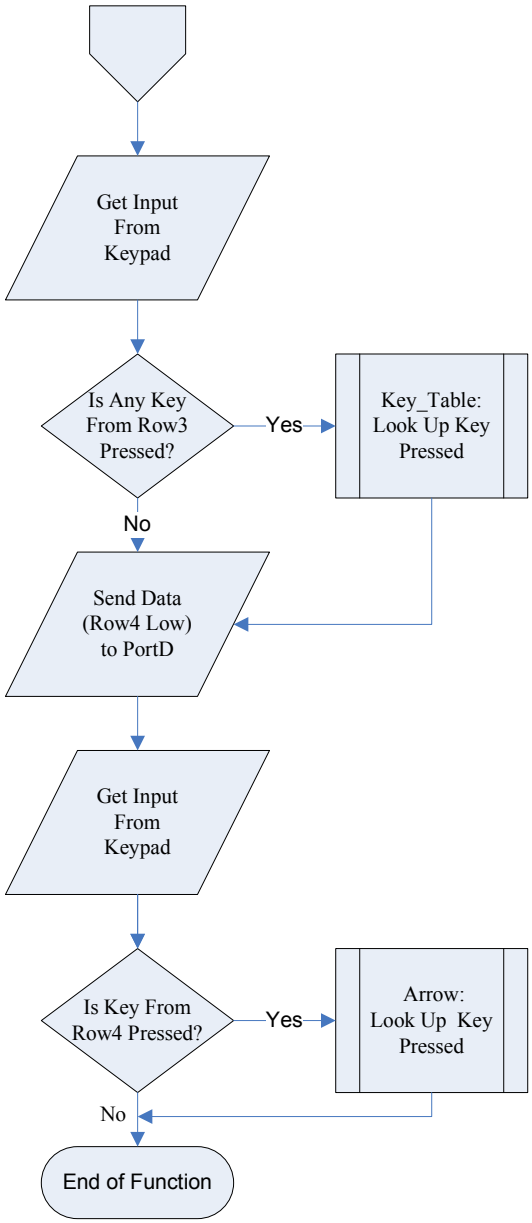


Figure 18.1: Function - Check_Keys



Function 18.2: Function - Check_Keys (cont.)

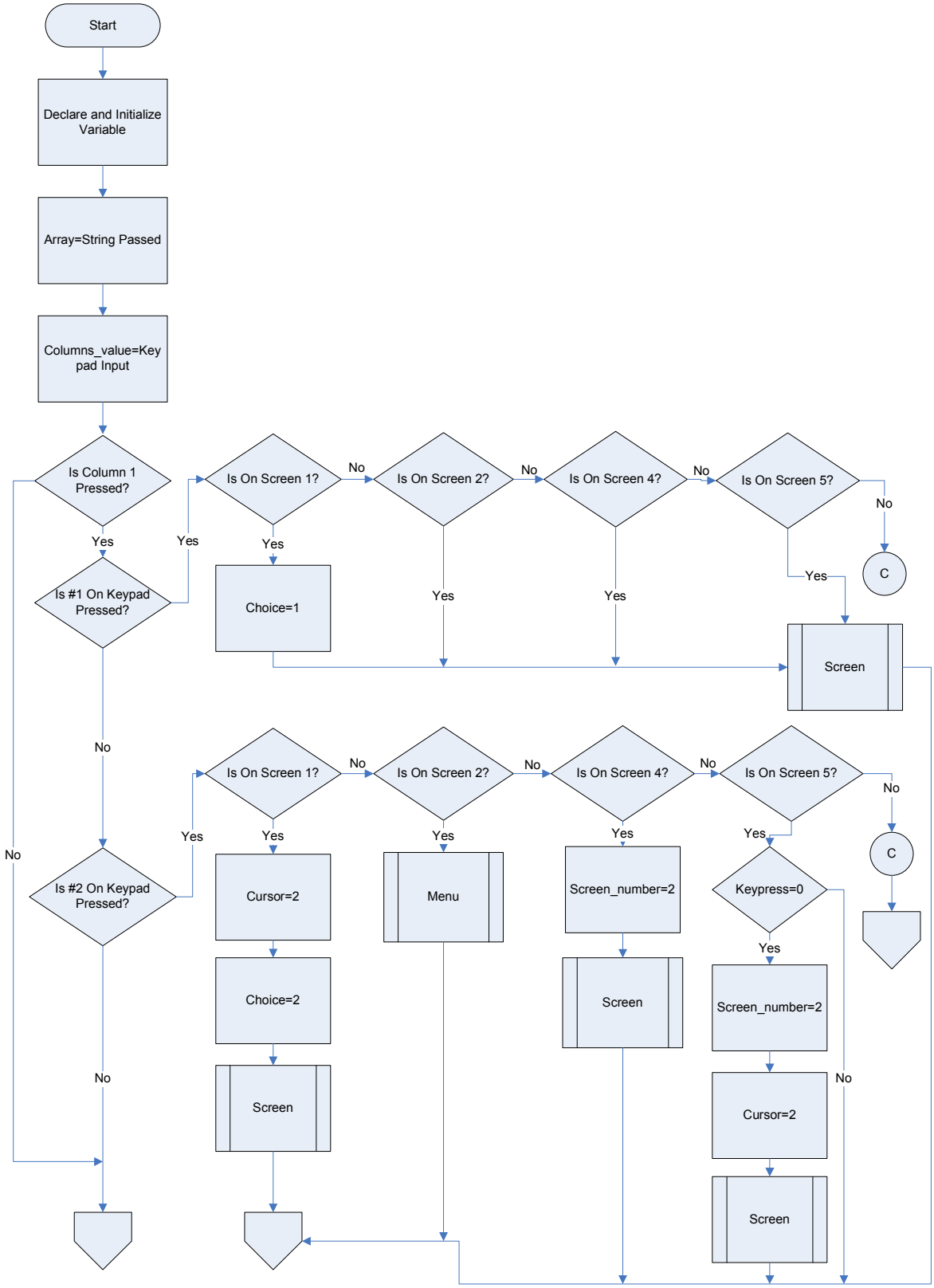


Figure 19.1: Function - Key_table

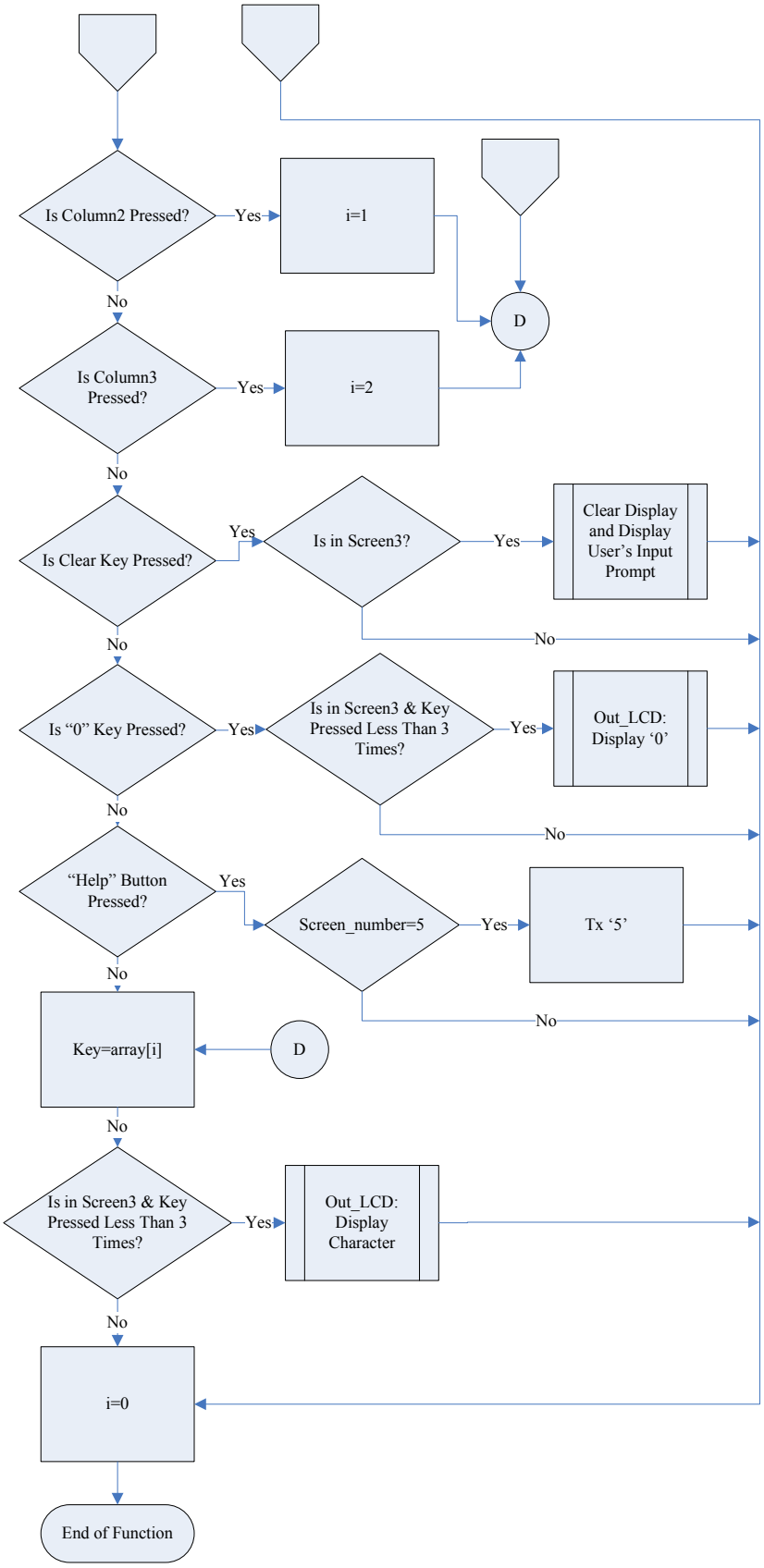


Figure 19.2: Function – Key_table (cont.)

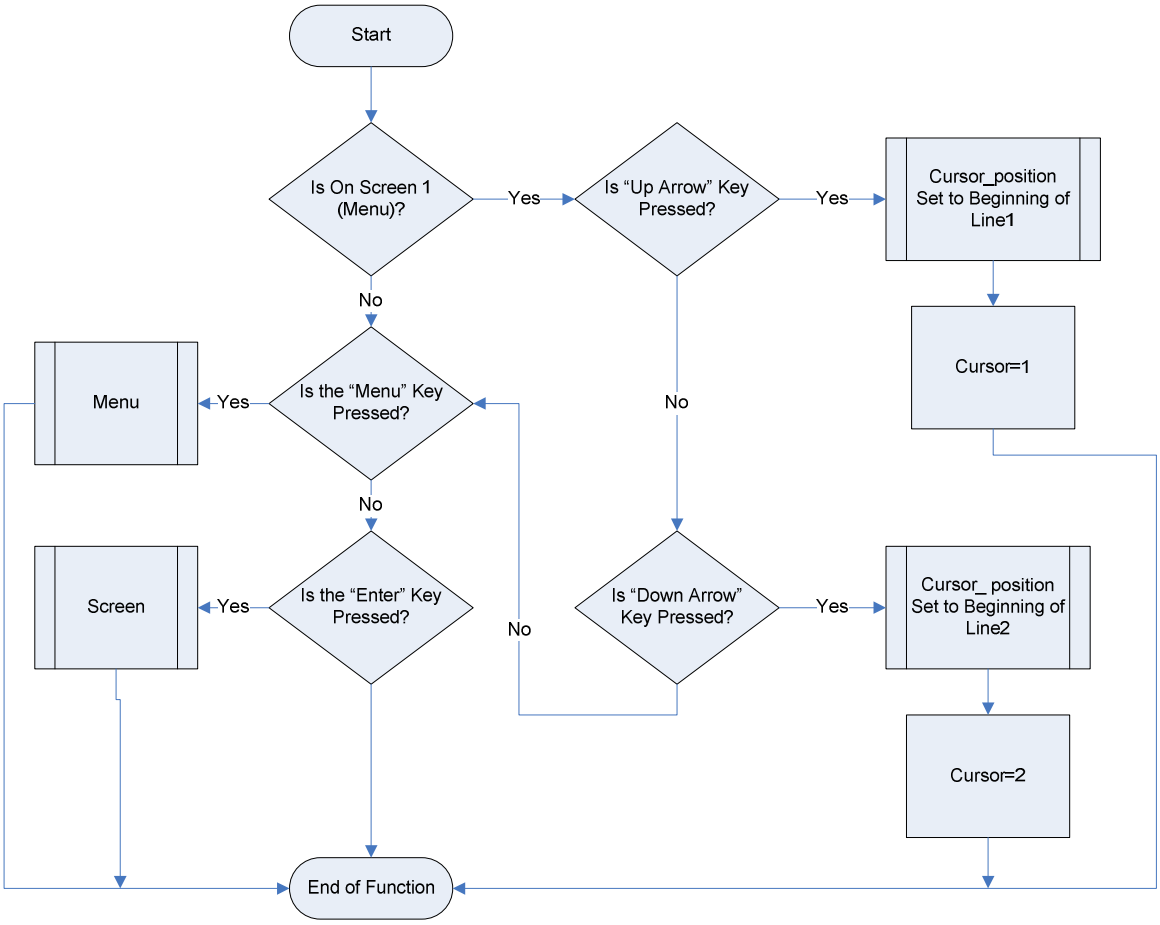


Figure 20: Function – Arrow

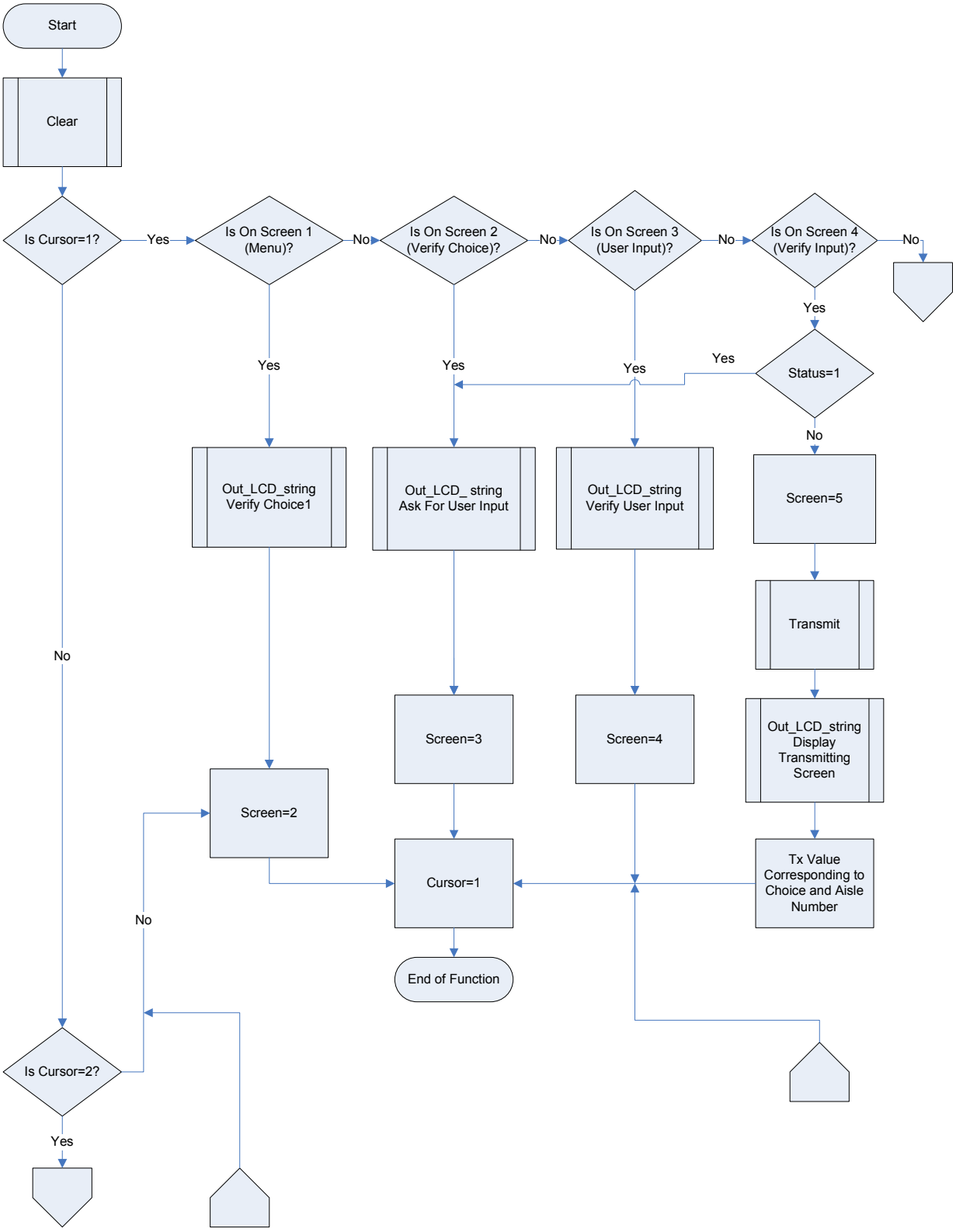


Figure 21.1: Function – Screen

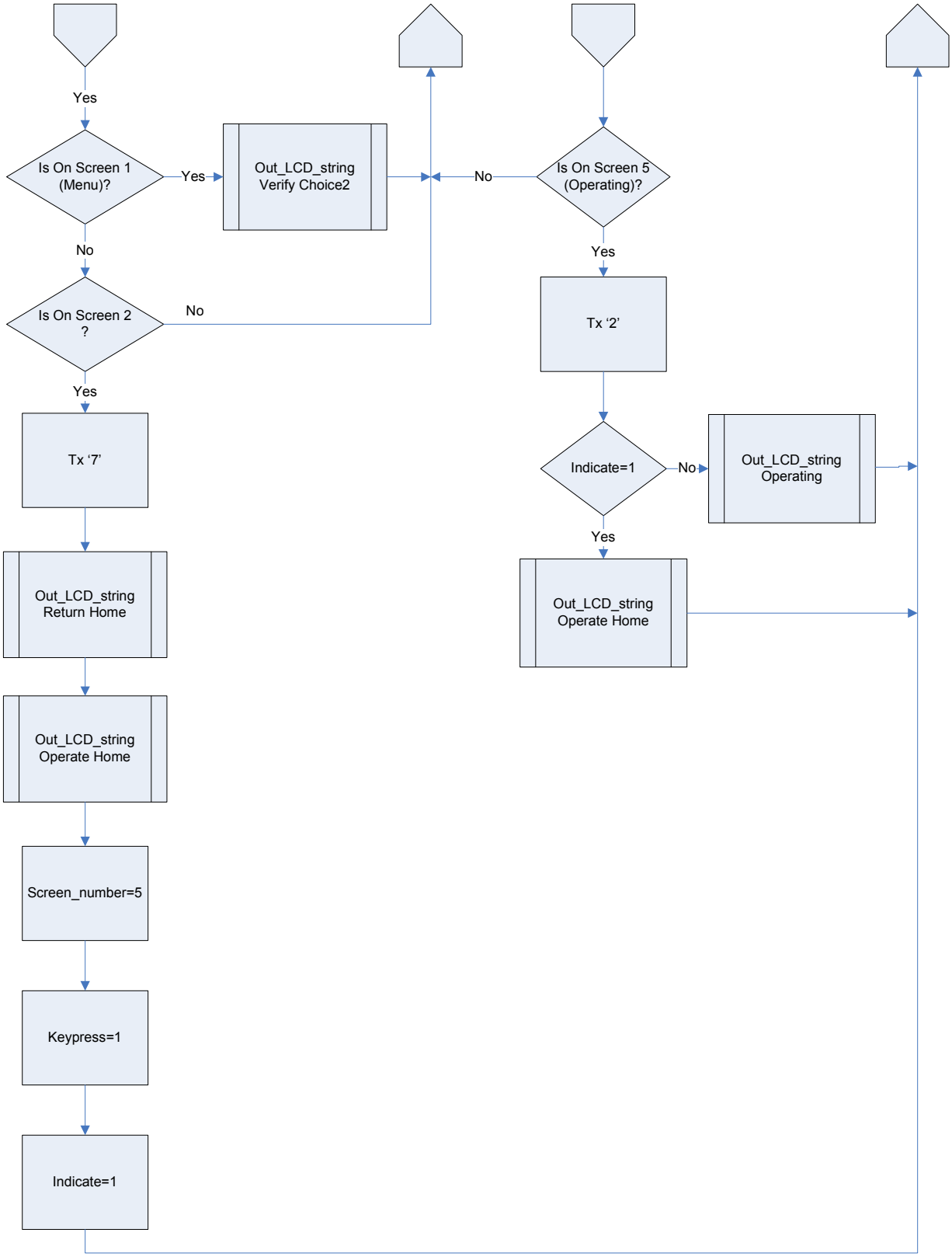


Figure 21.2: Function – Screen (cont.)

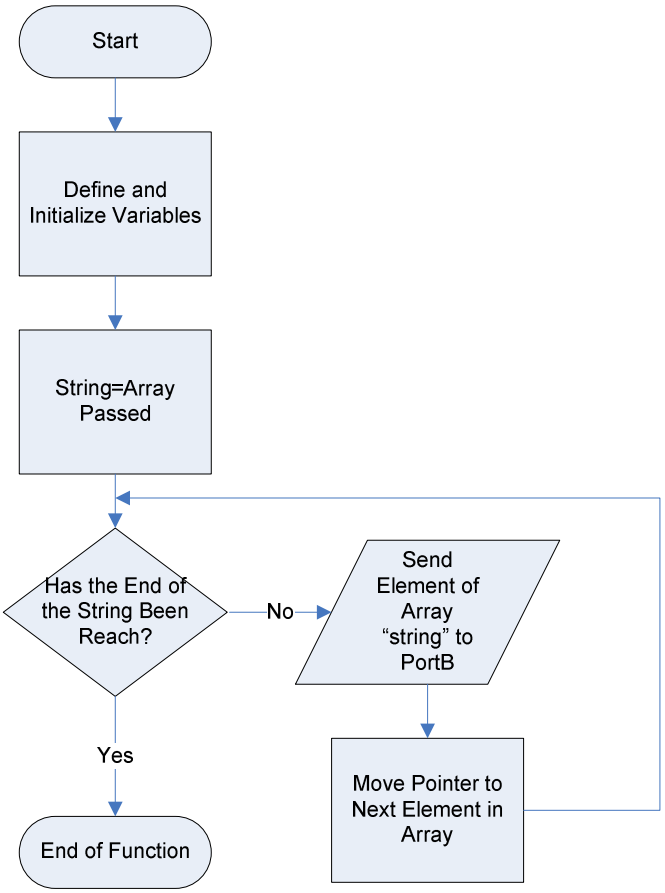


Figure 22: Function - Out_LCD_string

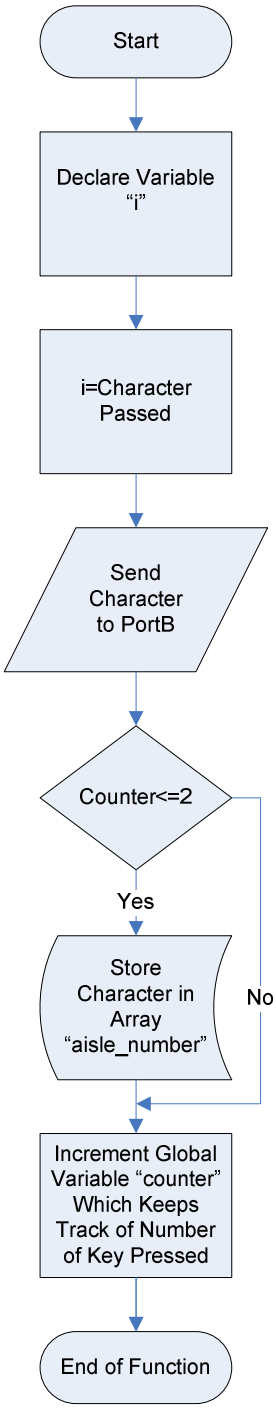


Figure 23: Function – Out_LCD

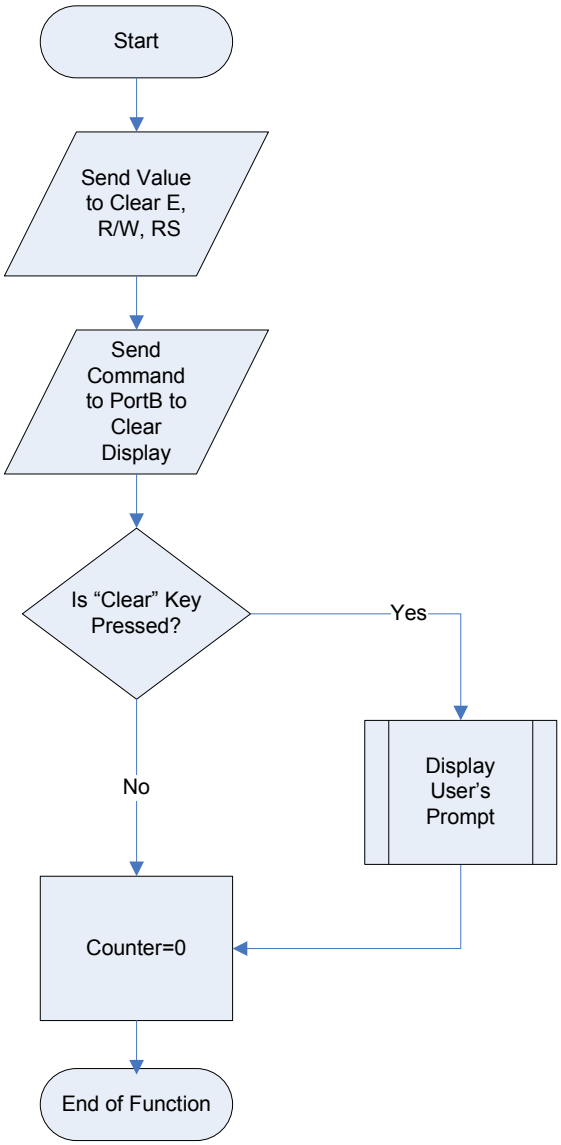


Figure 24: Function - Clear

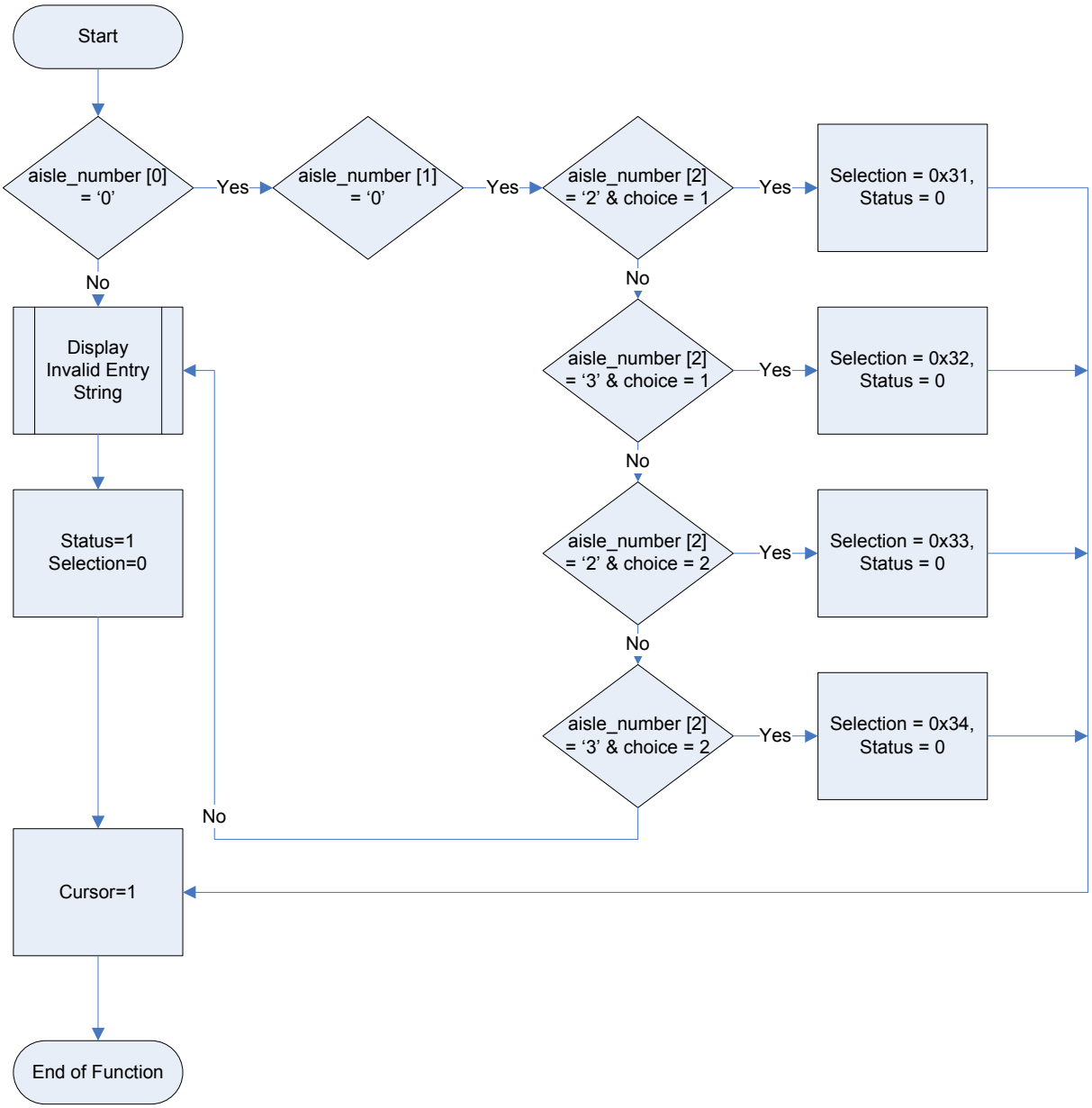


Figure 25: Function – Transmit

4.2

FORKLIFT

Figure 26.1 to 26.4 shows the flowchart of the main program for the forklift. When the PIC is turned on, the PIC initializes with the proper configurations. Global variables are declared and initialized, and an interrupt function is declared for any data received by the RS232 port. The main program transmits a value to the user interface to see if the user interface is turned on. The main program will wait until the user interface has sent back a confirmation character before executing the rest of the main program. Once a 2-way communication has been established between the forklift and user interface, the main program calls the range_finderf function to check for object in front of the forklift. If there is no object, the Tilt_Check function is called to check if the forklift has been tilted over (See Figure 27). If the forklift has not been tilted over, the Lower_Fork function is called to lower the forks to its lowest position (See Figure 28). The Lift_Fork function is called next to lift the forks up 1.5 inches from the ground (See Figure 29). Finally, the Set_Neutral function is called to tilt the forks parallel to the ground (See Figure 30). Once the forklift has initialized the position of the forks, it is ready to receive instruction from the user interface.

When the forklift receives a value from the user interface at its RS232 port, the Interrupt function is called to take in the data. The pointer jumps out of the Interrupt function back to the main program and compares the value received to several preprogrammed instructions. If there is a match corresponding to the value sent, then the instructions corresponding to the value will be executed. Once the instructions are finished, then it will wait for the next command from the user interface. For details see code in Appendix B.

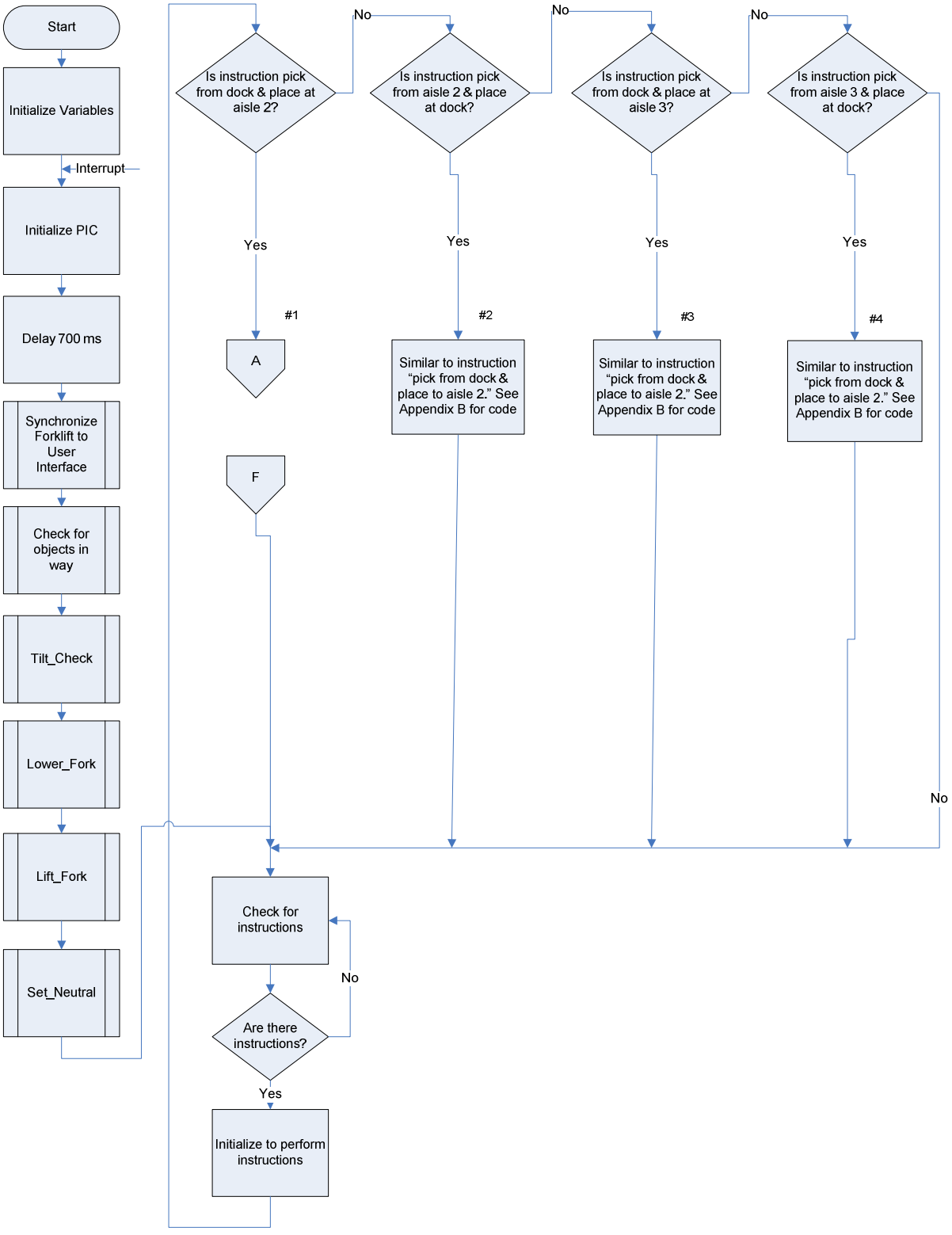


Figure 26.1: Forklift

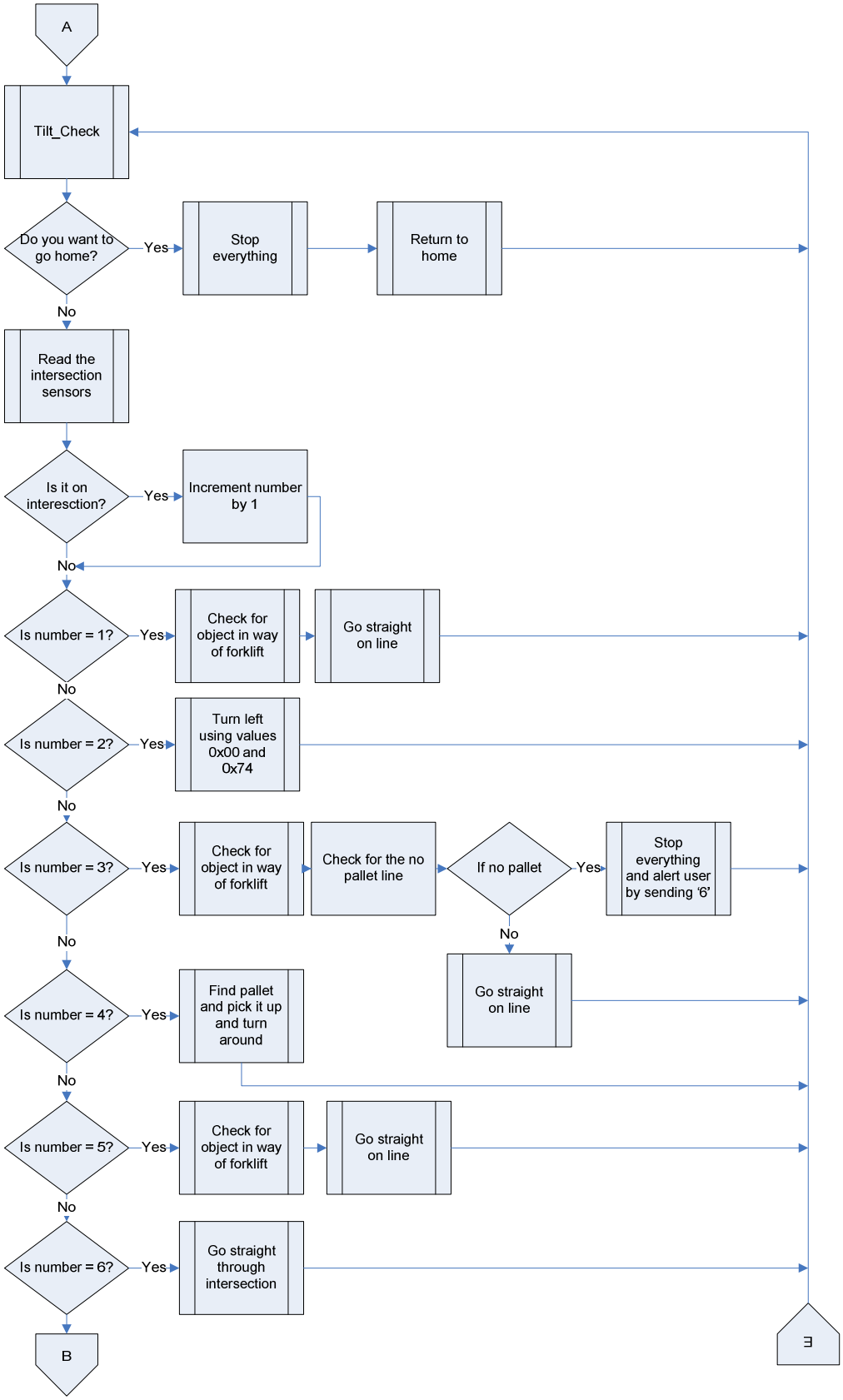


Figure 26.2: Forklift (cont.)

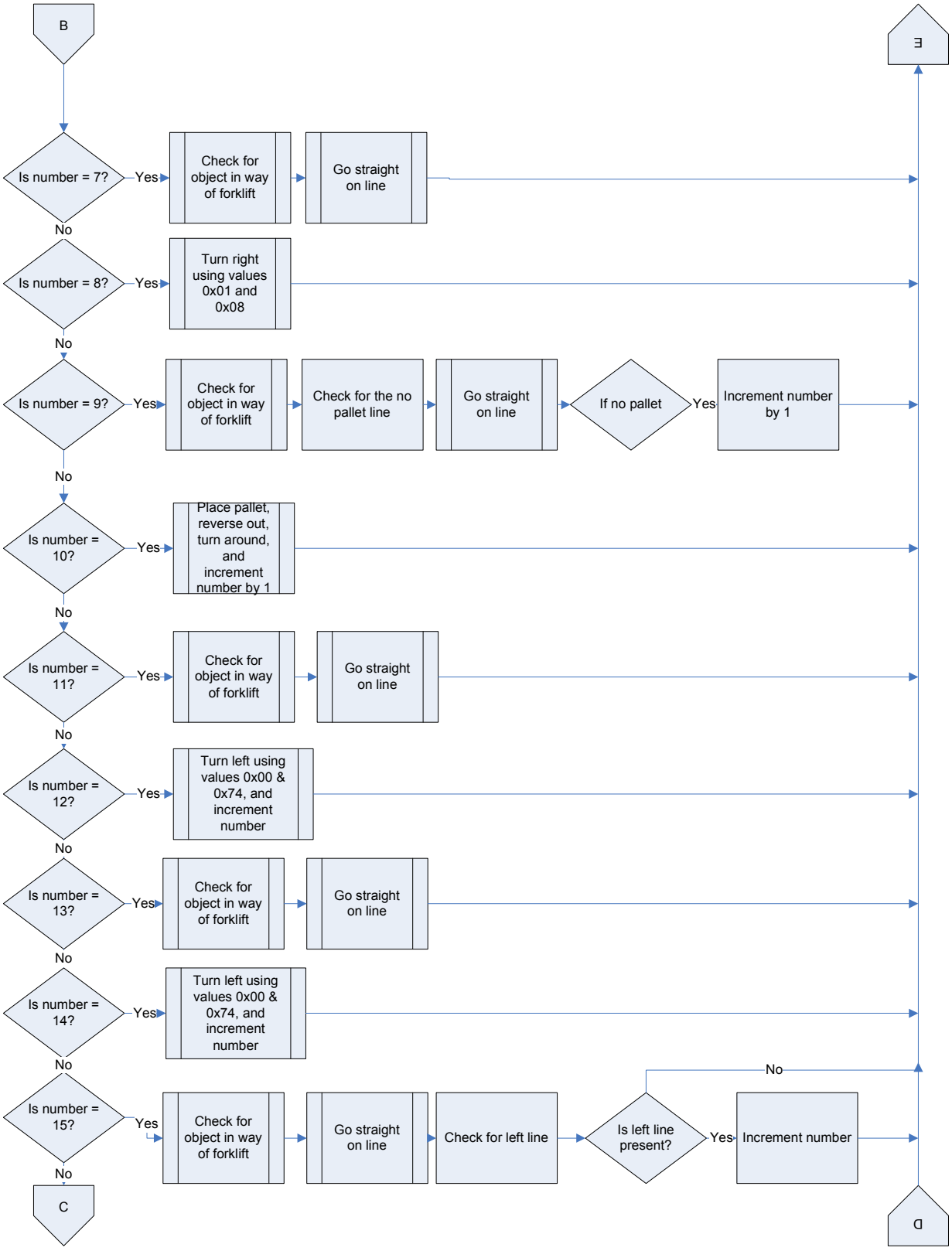


Figure 26.3: Forklift (cont.)

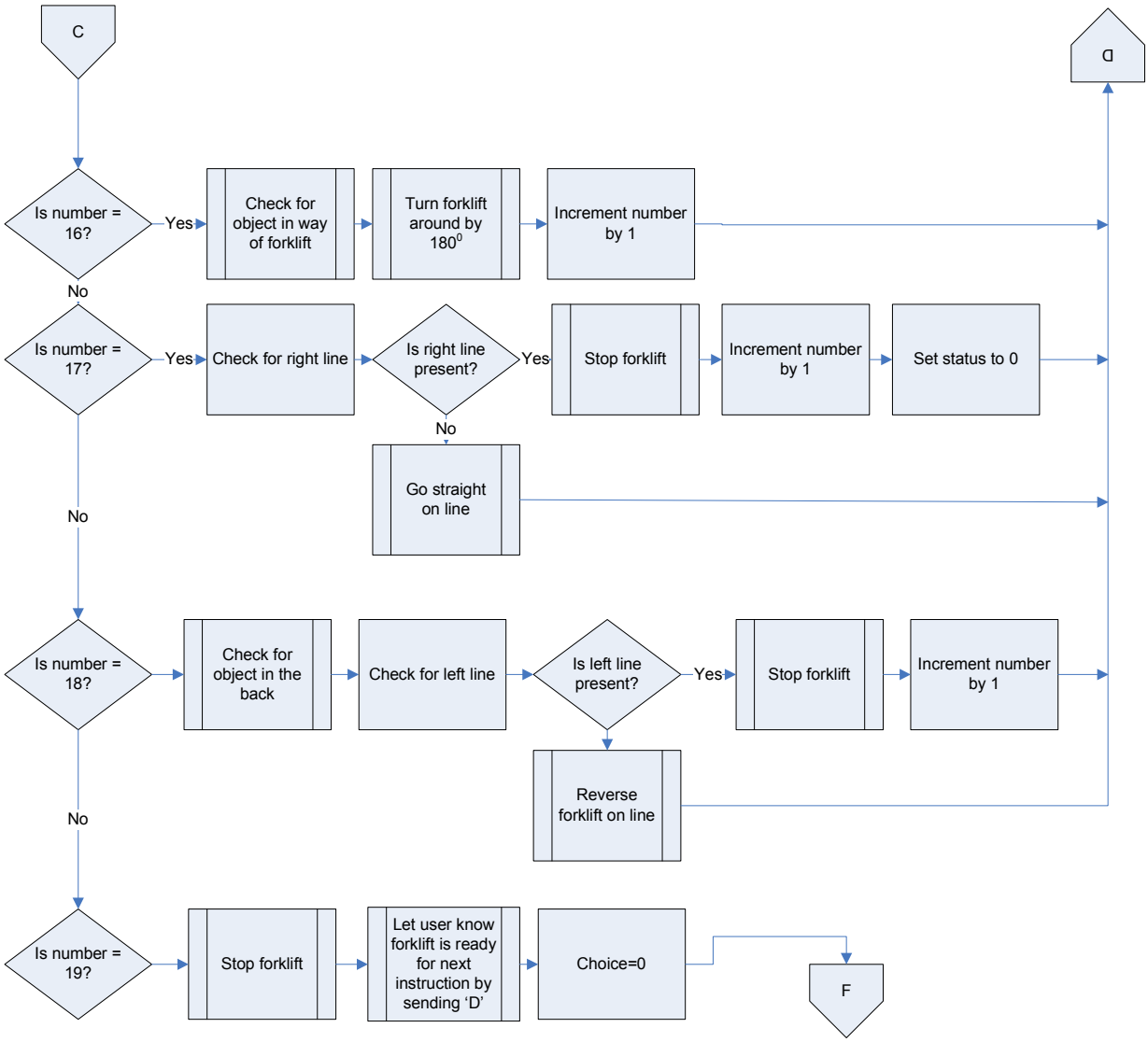


Figure 26.4: Forklift (cont.)

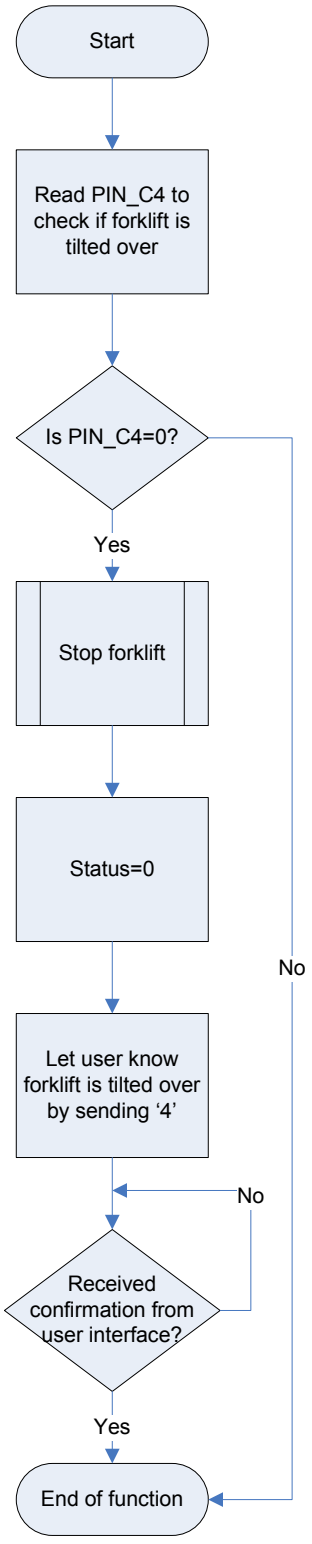


Figure 27: Function - Tilt_Check

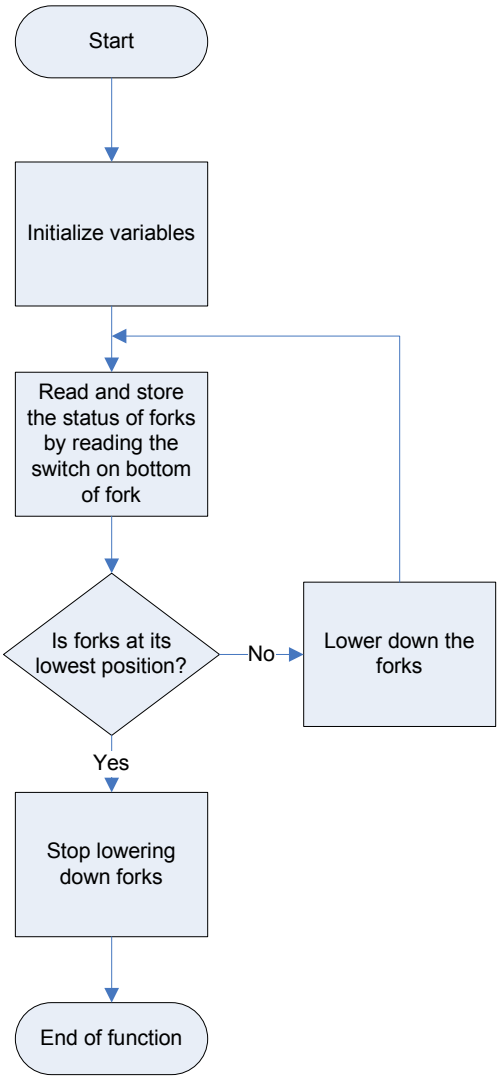


Figure 28: Function - Lower_Fork

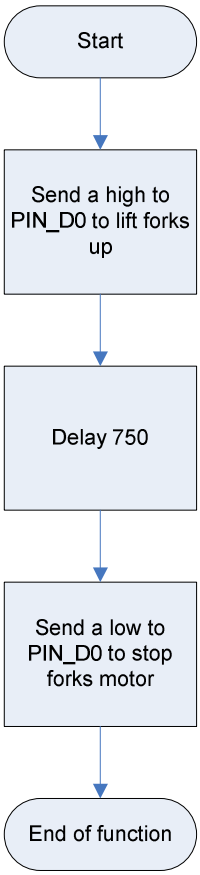


Figure 29: Function - Lift_Fork

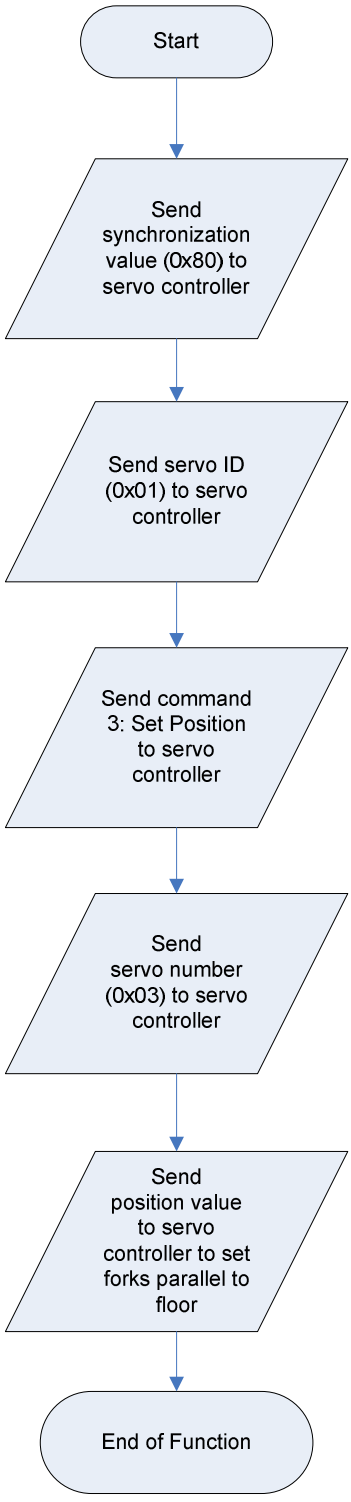


Figure 30: Function - Set_Neutral

CHAPTER FIVE
SERVICE MANUAL

Service Manual

JNM Technologies

Fluffy Bunny-3000 Series
Automatic Forklift

5/29/2008

TABLE OF CONTENTS

HAZARDS

DANGER

Death or serious injury may occur.

Stay clear of moving forklift.

Do not service unless forklift is turned off and disabled.

Do not ride forklift.

CAUTION

Property Damage may occur.

Do not overload forklift.

Do not carry a load downhill.

OPERATING INSTRUCTIONS

Please read the entire manual before using product.

In order to operate the Automatic Forklift System the navigation lines must be mapped on the floor properly, and the forklift programmed to you specific application. Please contact JNM Technologies for assistance.

Set Up and Turning On:

Place forklift in the Home aisle with both the front IR sensors above the navigation line. *Important* Turn on the user interface FIRST. After turning on the user interface, turn on the power to the motors of the forklift via the switch on the underside of the forklift. Then turn on the power to the sensors and PIC of the forklift via the switch on the side.

Operation:

When the first turned on you will see screen 1 which gives you two choices, "1. Pick up from Docks" and "2. Place to Docks." Make your choice by pressing the corresponding number on the key pad, or by using the up and down arrows to highlight your choice then press enter.
The screen will now ask you to confirm your choice. Choose "1. Yes" to confirm and continue to the next screen. Choose "2. No" to return to the previous screen if you made the wrong choice initially.
If you chose "1. Yes" the screen will now ask you to enter the aisle number you wish to bring the pallet to or take the pallet from. When you are done, press Enter. The screen will again ask you to confirm you decision. Choose "2. No" if you entered the wrong aisle number and the screen will ask you to enter the aisle number again.
Choose "1. Yes" to transmit the instructions to the forklift so it can carry out the desired process. While the forklift is operating the screen will display "Operating" until the forklift is done and has returned home, at which time, the first screen will reappear.
At any time during operation, you may hit the "Help" button to stop the forklift. The screen will allow you to choose to continue or to return home. If you wish for the forklift to continue doing what it was doing, choose "1. Continue". Choose "2. Home" if you want the forklift to abort it's current operation and return home.
If at anytime during operation an object or person gets in the way, or the forklift tips over, the forklift will stop and the screen will give you the option to continue or go home. Before choosing "1. Continue" check the live video feed to ensure that the forklift has been up-righted and/or the object has been removed from its path.

ELECTRONIC SYSTEM DESIGN FOR FLUFFY BUNNY-3000

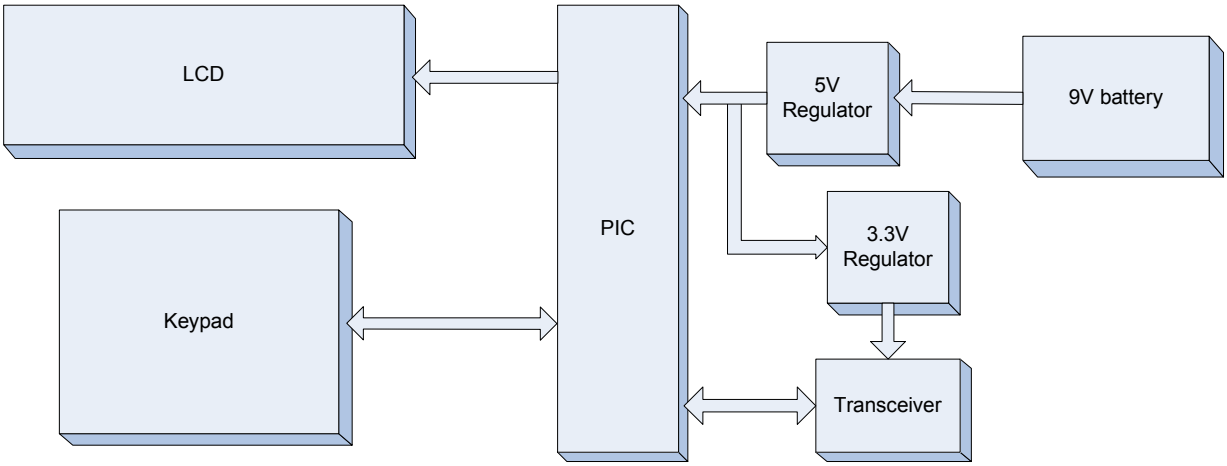


Figure 31: User Interface Hardware Block Diagram

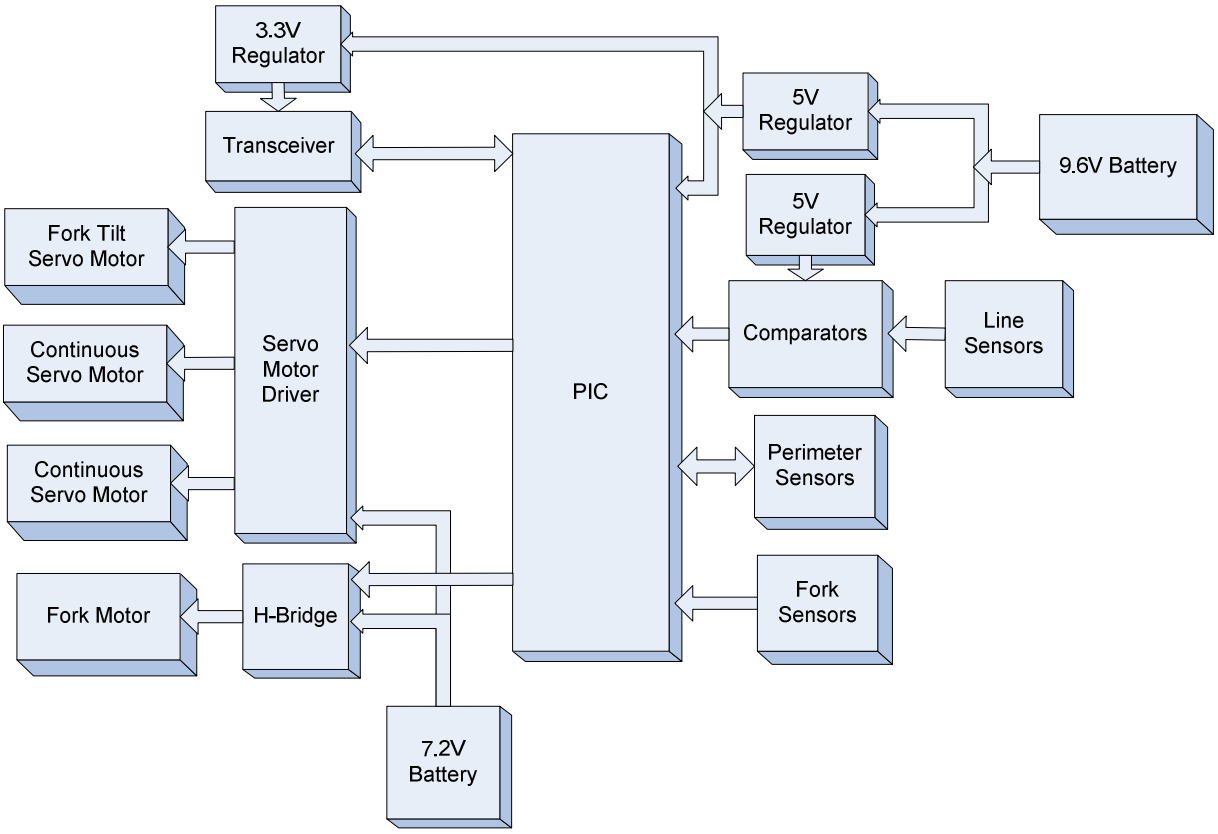


Figure 32: Forklift Hardware Block Diagram

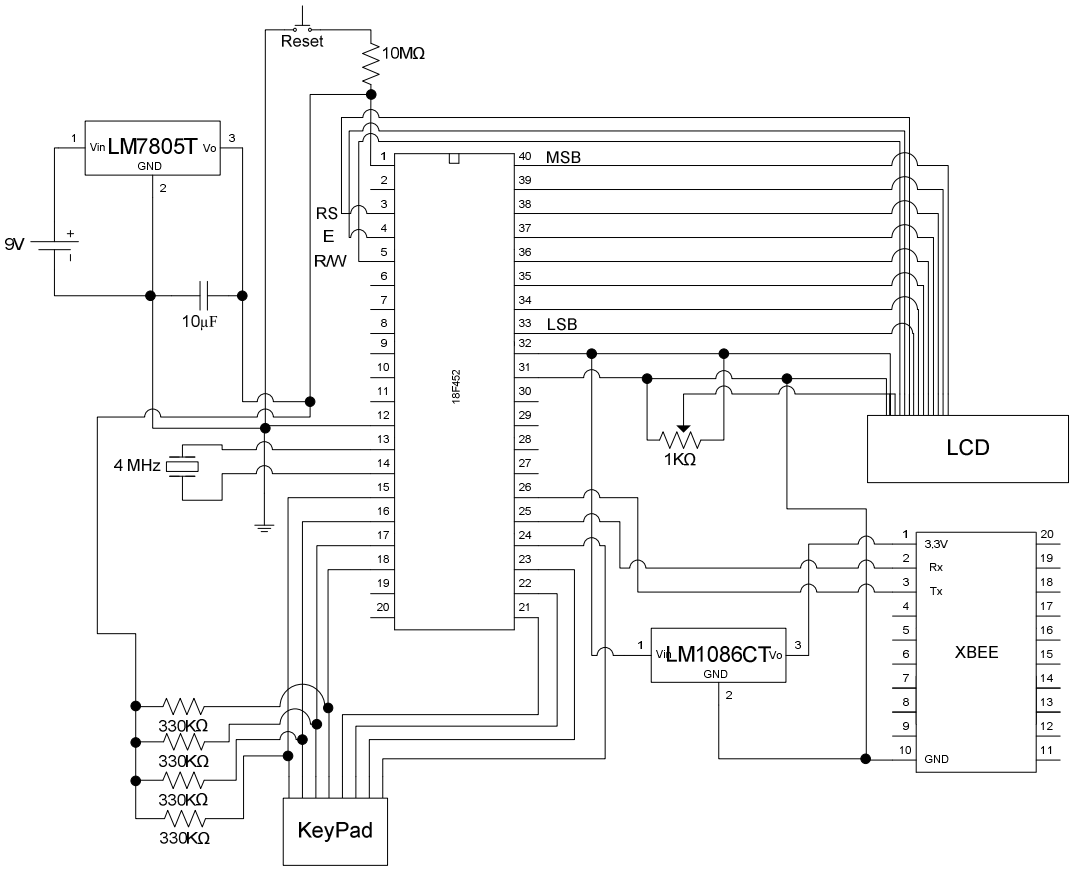


Figure 33: User Interface Hardware Circuit Diagram

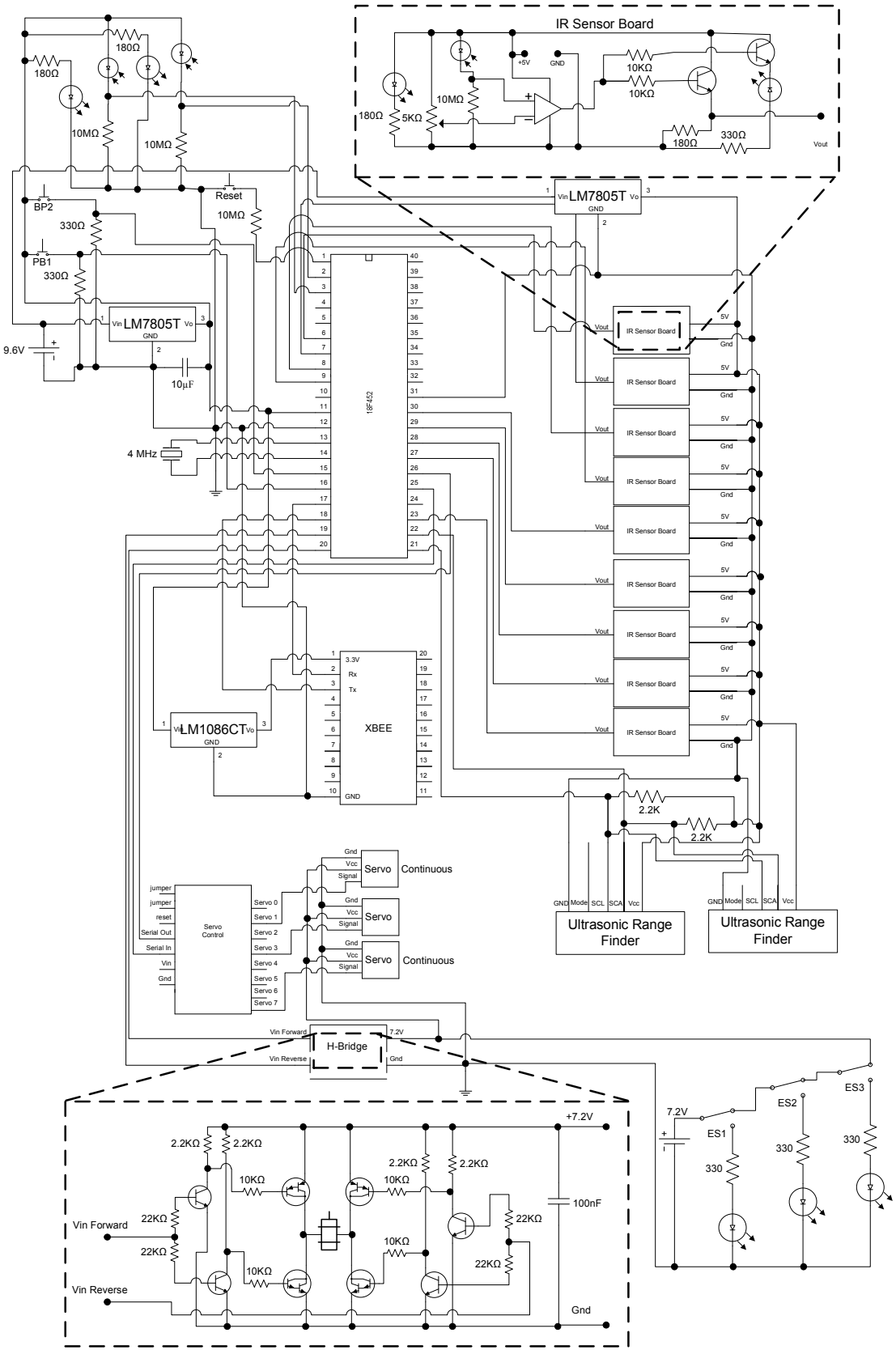


Figure 34: Forklift Hardware Circuit Diagram

OVERALL MECHANICAL COMPONENTS LAYOUT

Figure 35.1: Forklift

1. Front Proximity Sensor (Sonic Ranger)
2. Rear Proximity Sensor (Sonic Ranger)
3. Pallet Sensors (IR Sensors)
4. Load Sensors (Buttons)
5. Pallet Sensor (Push Button)
6. Antenna (Wireless Zigbee)
7. Limit Switch
8. Emergency Manual Shut Off (Both Sides and Back)
9. Video Camera

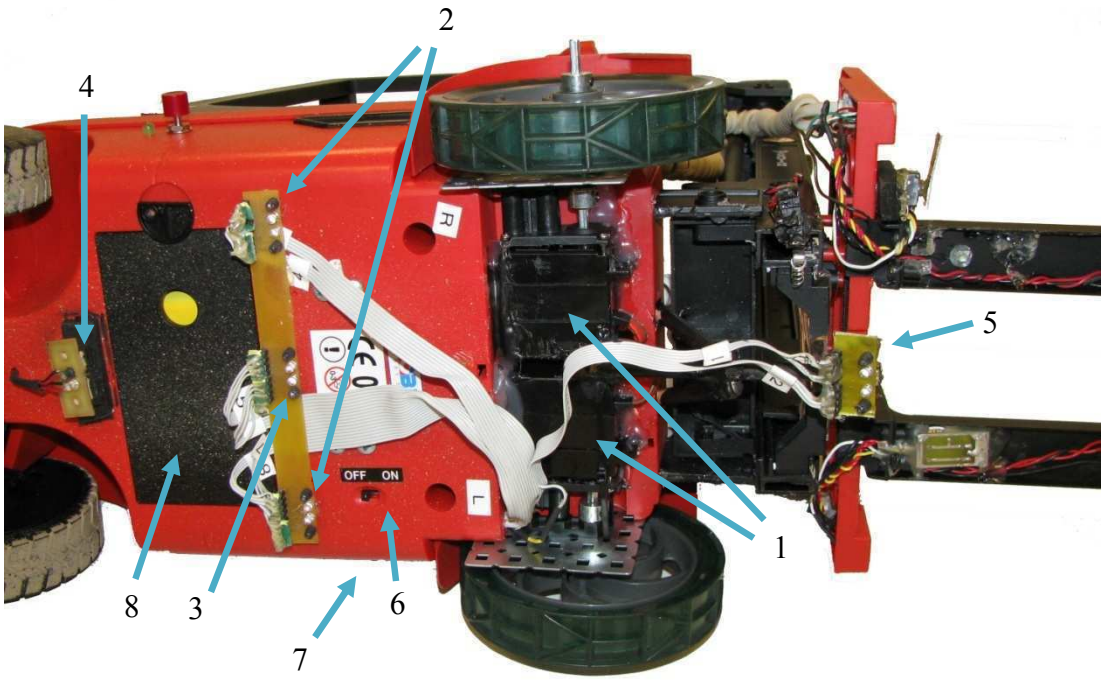


Figure 35.2: Forklift (cont.)

1. Continuous Rotation Servo Motors
2. Intersection Detectors (IR Sensors)
3. Reverse Navigation Sensors (IR Sensors)
4. Tilt Sensor (IR Sensors)
5. Forward Navigation Sensors (IR Sensors)
6. On-Off Switch (For Power to Motors)
7. On-Off Switch (On Side; For Power to PIC and Sensors)
8. Battery Compartment (7.2V)

Figure 36: User Interface

1. On-Off Switch (On Side)
2. Antenna (Wireless Zigbee)
3. LCD
4. Keypad
5. Battery Compartment (9V; On Back)

INTERSECTION LAYOUT

The lines that the forklift follows are ½" wide. Each intersection should consist of a 10" X 10" square (See Figure 36). The forklift detects the presence of the intersection by way of the side IR sensors. If the forklift needs to turn at that intersection it will do so at the instant it detects the first line of the intersection.

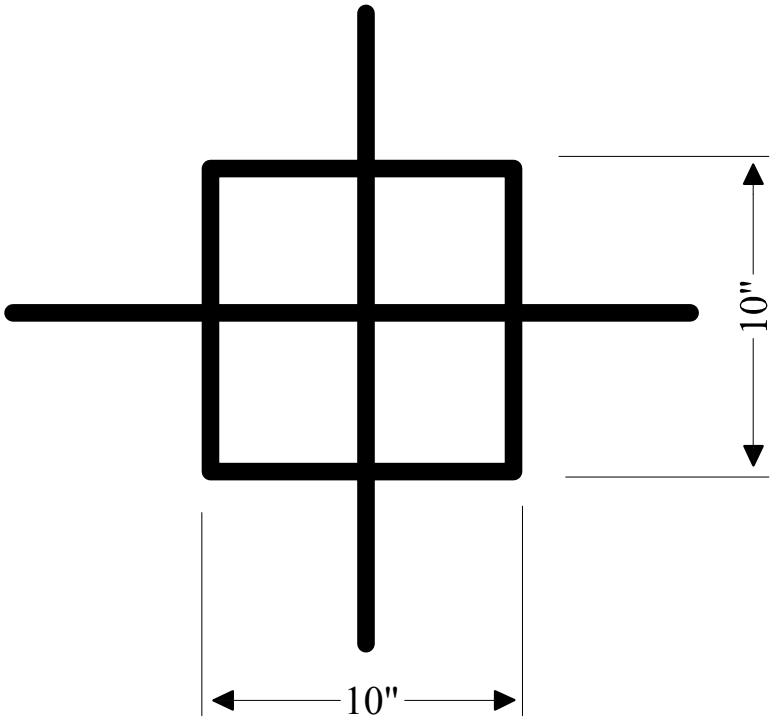
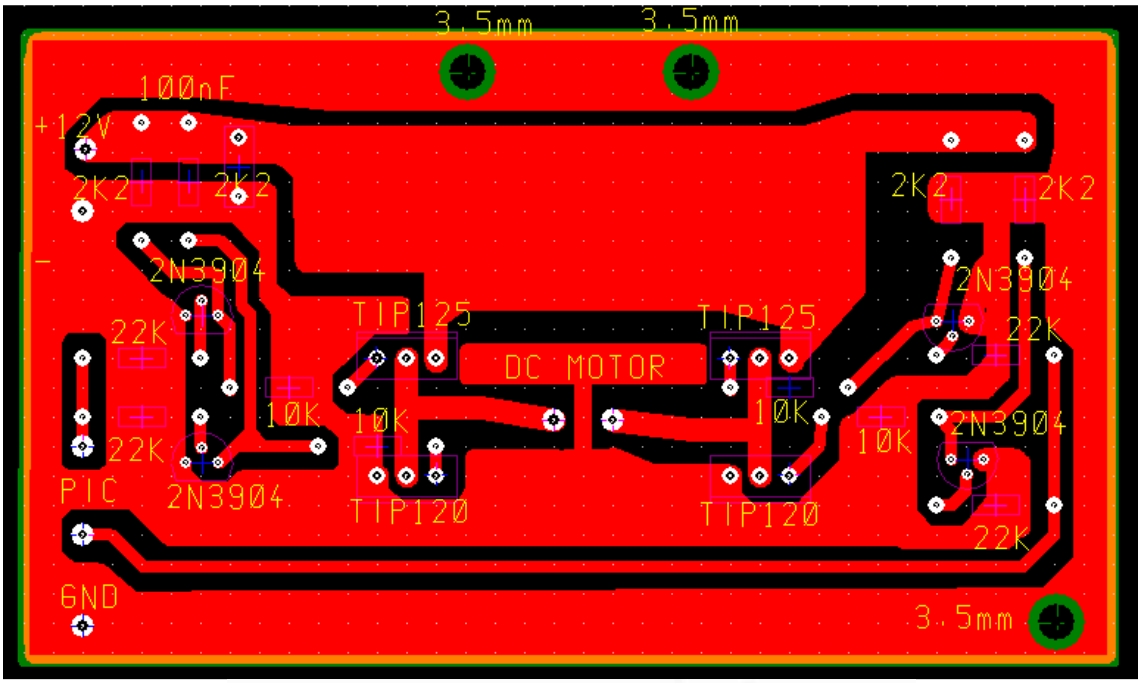


Figure 37: Intersection

OVERALL ELECTRONIC COMPONENTS LAYOUT



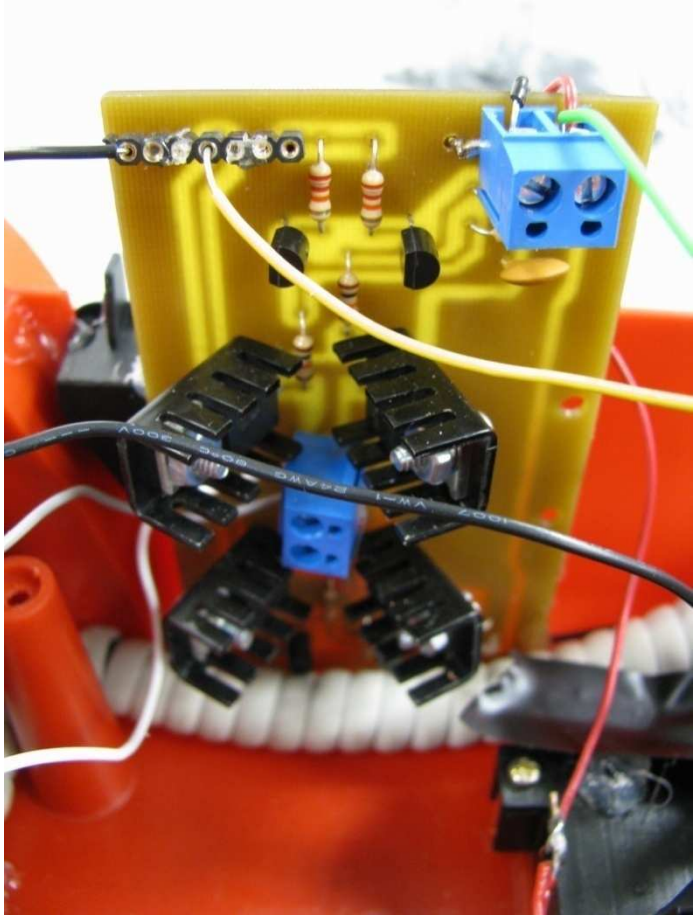
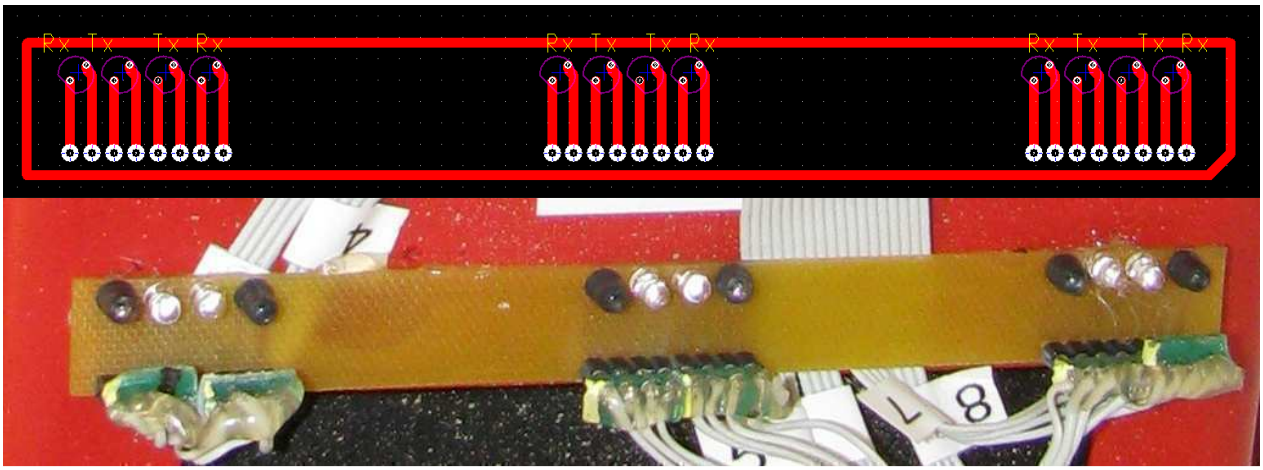


Figure 38: H-Bridge



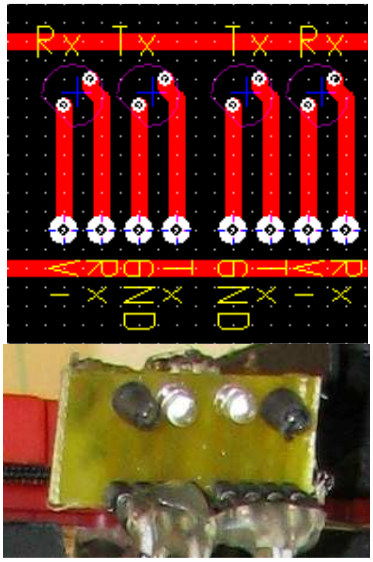


Figure 39: IR Boards

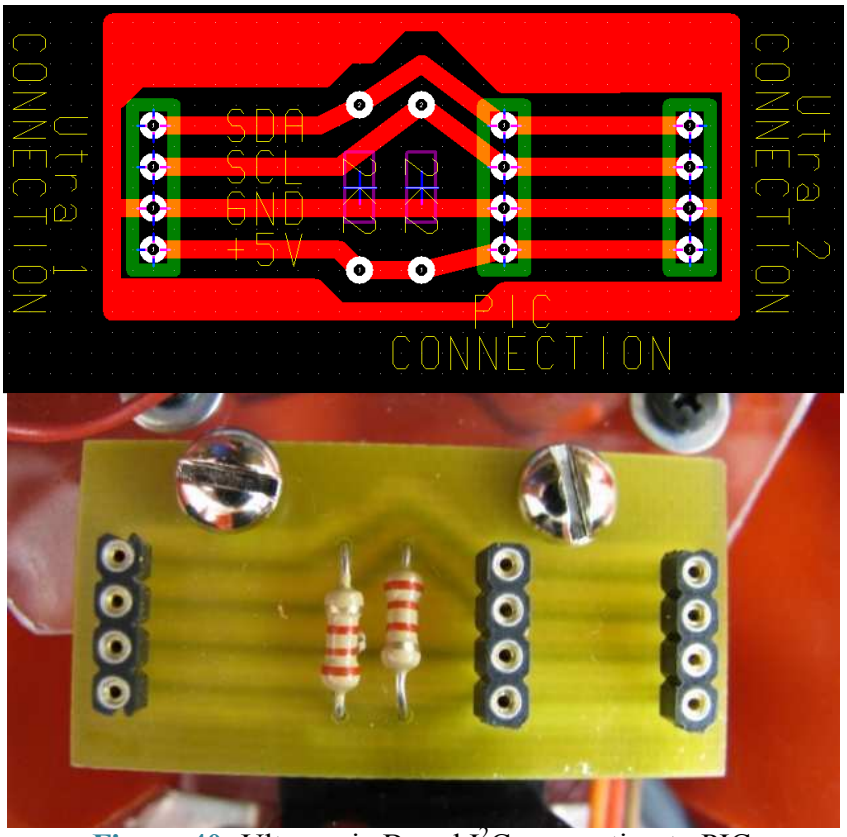
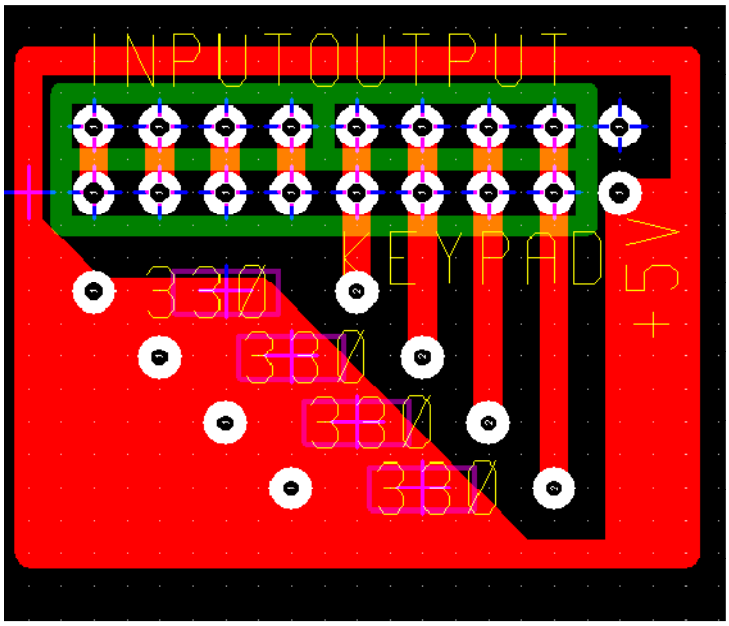


Figure 40: Ultrasonic Board I^2C connection to PIC



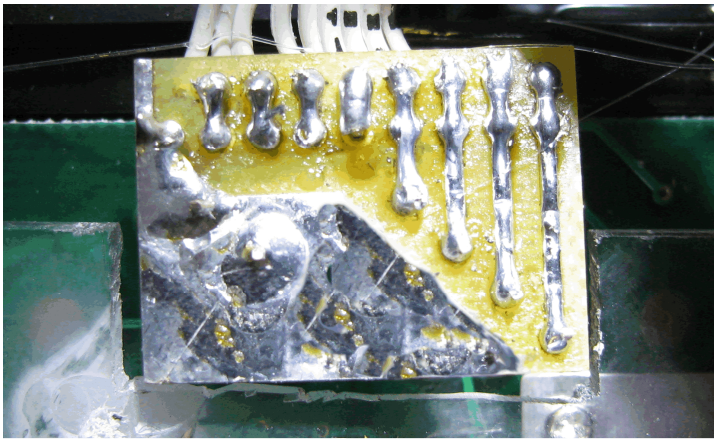
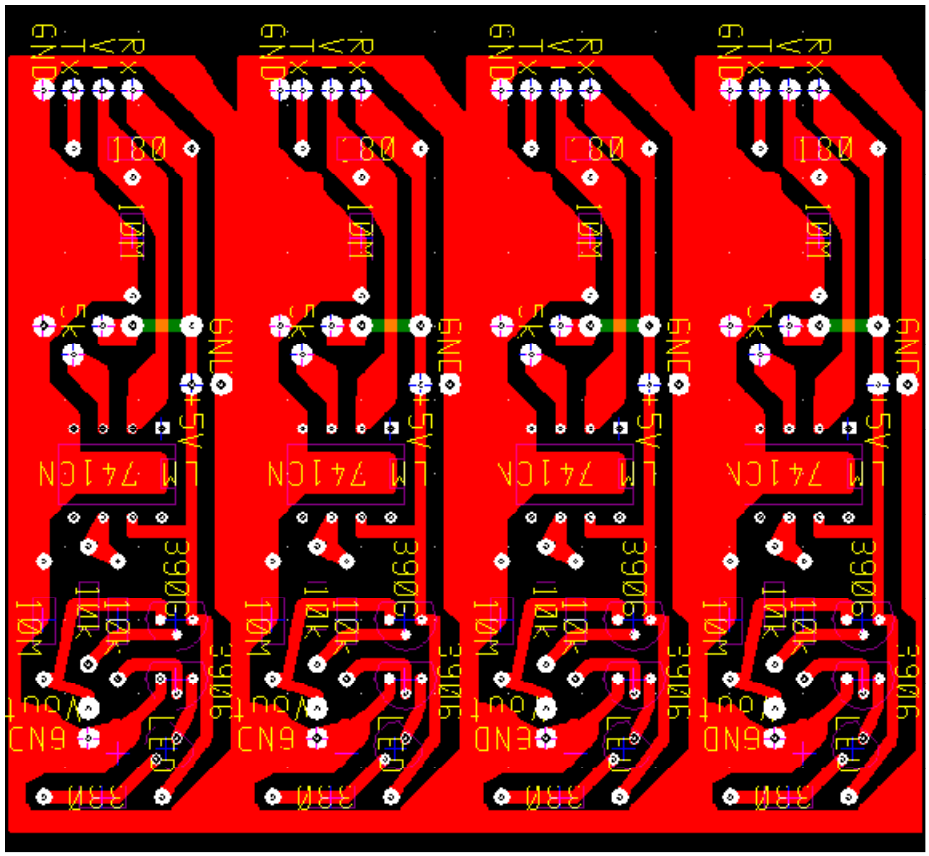


Figure 41: Keypad



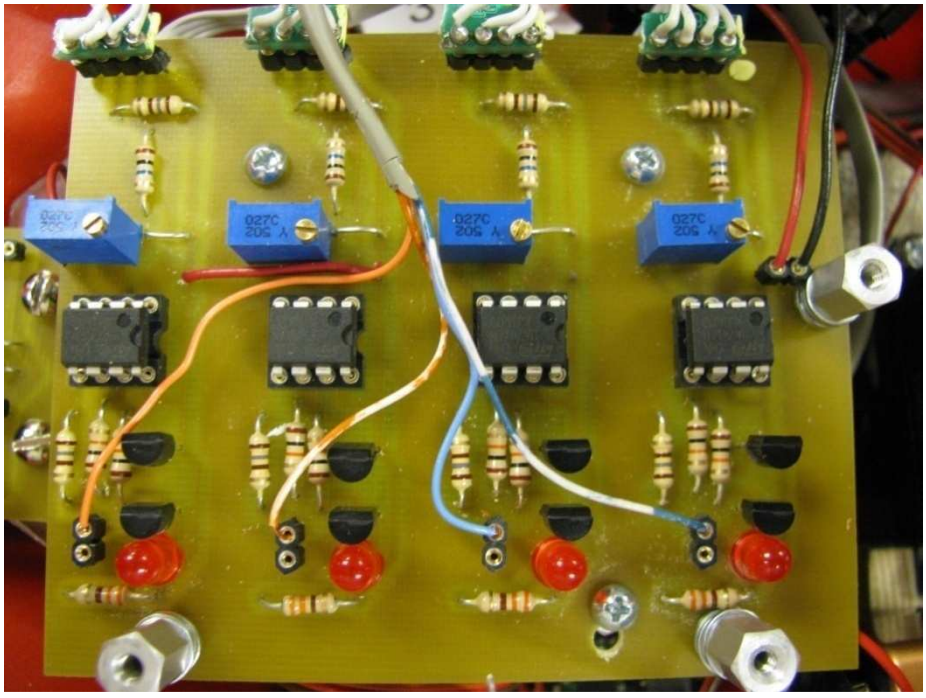


Figure 42: IR Comparator Board

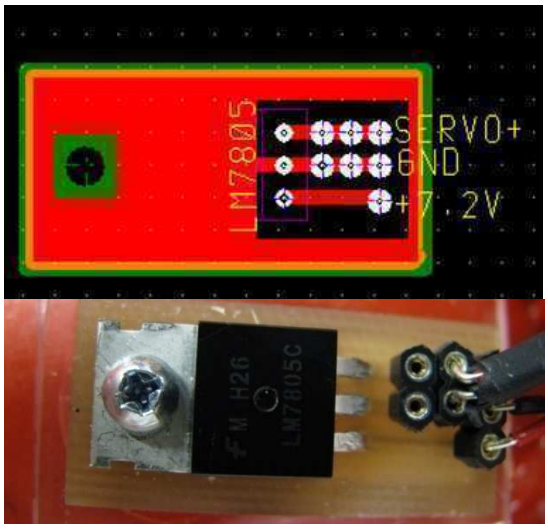


Figure 43: 5V Regulator

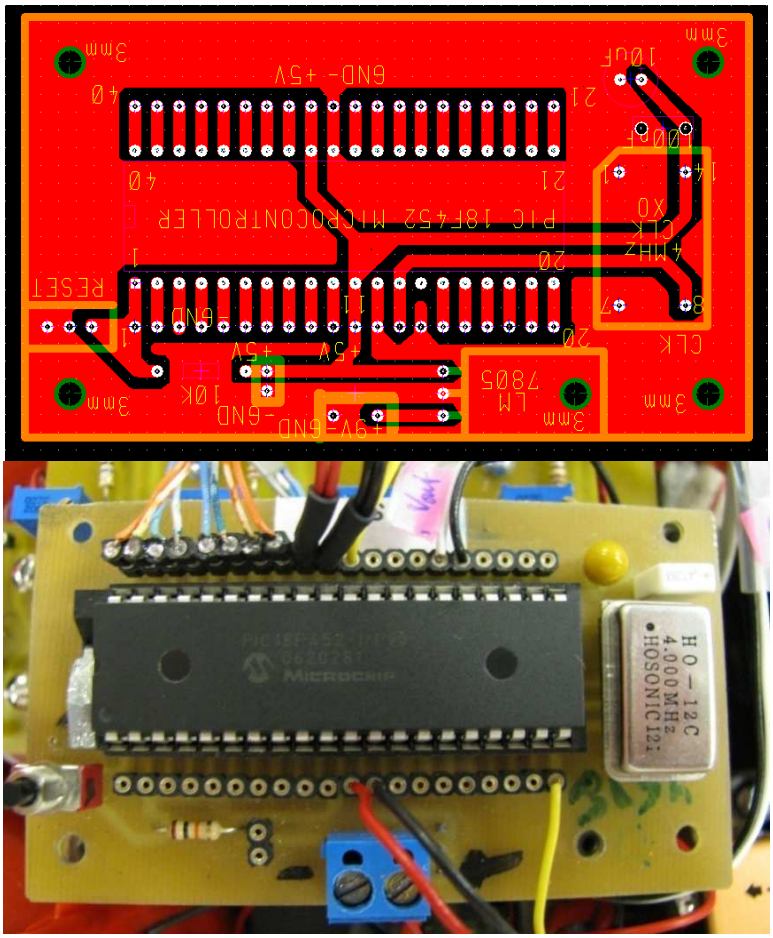


Figure 44: 18F452 PIC Microcontroller board

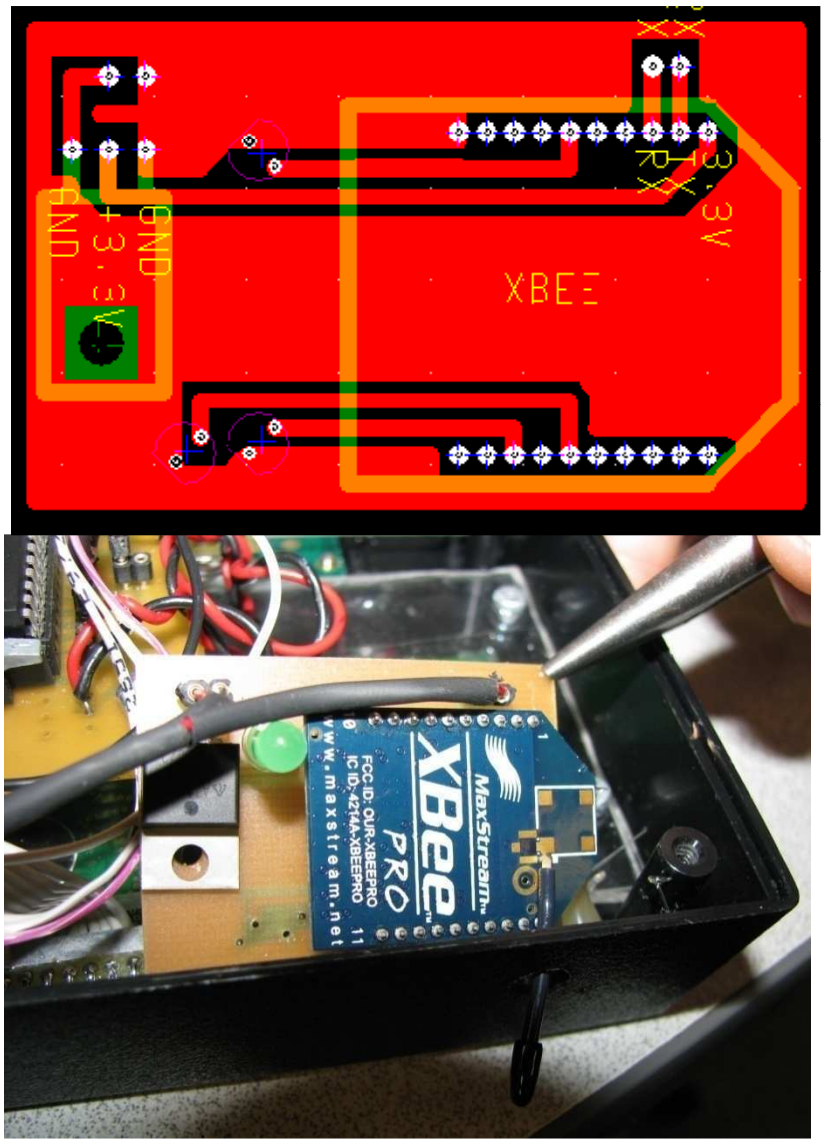


Figure 45: Wireless Zigbee

TROUBLESHOOTING

Table 9: Troubleshooting

No	Problem	Possible Cause	Repair Solution	Observations
1	IR navigation sensors not working properly	Potentiometer is not calibrated properly	Place a white mat under the IR sensors. Adjust the potentiometer on the comparator board until the LED is turned on. Then replace the mat with a black mat and see if the LED is off. If not then adjust the potentiometer until it turns off.	-
2	IR navigation sensor does not give a signal out, but LED on comparator board is working	3906 Transistor is defective.	Replace Transistor	+5VDC when IR comparator board when white mat is under the IR sensors. 0V DC when black mat is under the IR sensors.
3	Servos not steering or tilting forks	Servo controller not receiving or not transmitting data	Check the input to and output from servo controller to determine if the problem lies in the PIC, controller, or the servos themselves. Try restarting the forklift.	A blinking green light on the servo controller indicates that the controller is working properly. A red light indicates that the controller isn't receiving the proper data.
4	Forklift starts turning in circles	IR line sensor is damages or comparator for the IR sensor is not working	• Turn on sensors, but not main power to the motor. Place a white mat under the sensors. Check to see voltage on the output of the sensor. If the voltage is between 3-5 V, this is good. If lower voltage is shown, then sensor is broken. Replace sensor. • Place a black mat under the sensor. Check the voltage; if it is above 3V, then the senor is broken. Replace sensors. • If voltages for the sensor are correct, check # 2 for repairs on comparator board.	
5	Tilt sensor is not working	1. IR sensor is damaged. 2. IR sensor comparator board is not working. 3. IR sensor is positioned incorrectly 4. IR sensor is not calibrated.	1. Check # 4. 2. Check # 4. 3. Bend the sensors to the proper direction toward the floor 4. Turn the potentiometer on the comparator board until the LED light turns on.	
6	Pallet sensor is not working properly or doesn't recognize the pallet is all the way in the	1. Button is disconnected. 2. Button is damaged 3. Wire has a short.	1. Check to see if the button is connected to the microcontroller. 2. Test the button. If damaged	2. Make sure the power to the motors is off. Turn on the power to the microcontroller. Check the voltage input of the

	forks.	4. Button is position improperly	replace button 3. Test the continuity of the wires. If there is a short. Replace the wire 4. Run the forklift with a dummy pallet of a typical load. If it still does not stop, then the button needs to be moved. Check again until it detects the pallet.	fork button. If 5V then power is working correctly. If not then the input is damaged. Check the output of the button. 0V should be present when the button is not pressed. 5V should be present when the button is pressed.

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REFERENCES

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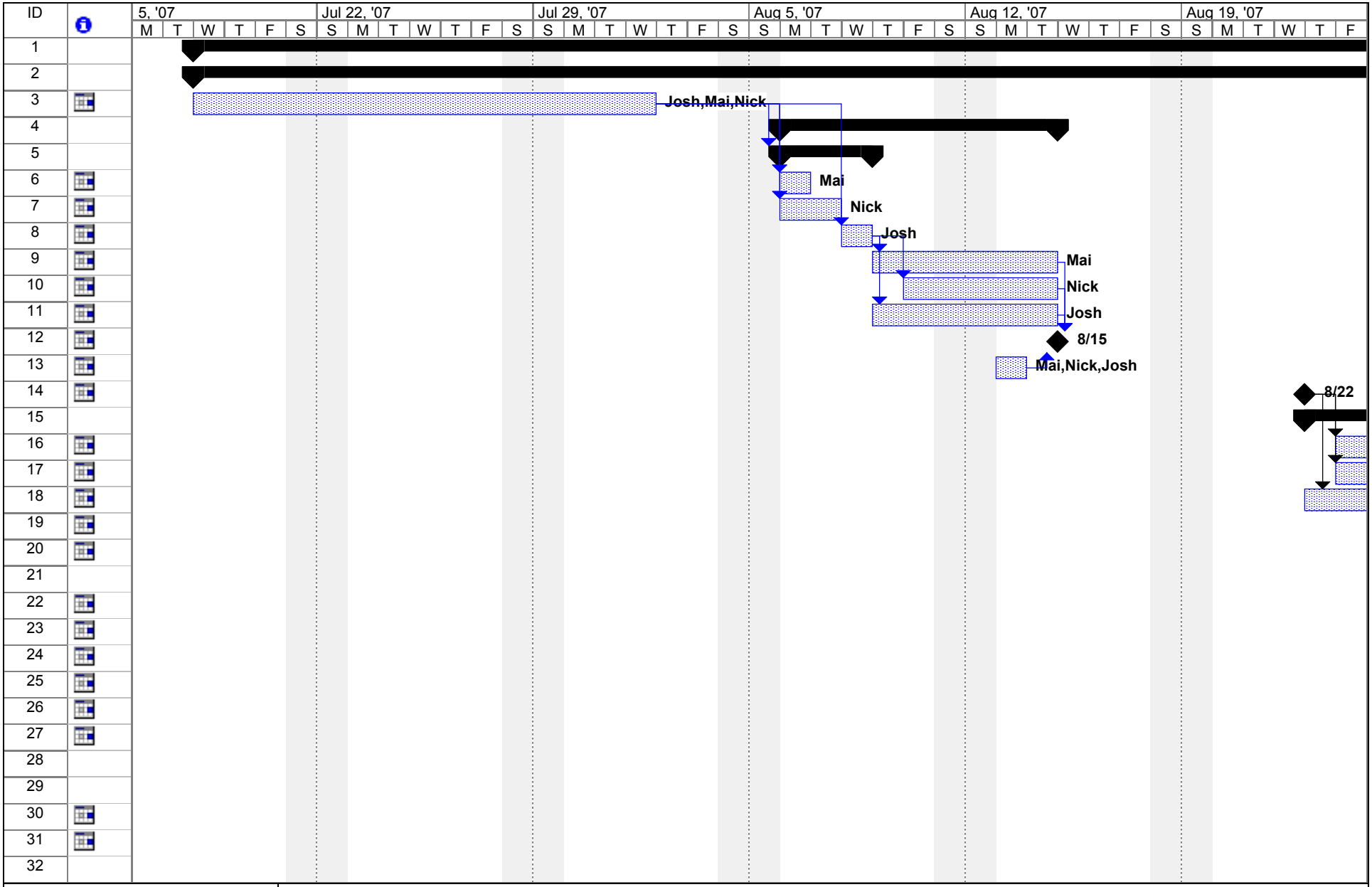
APPENDIX A

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	**Senior Project**	**219 days**	**Wed 7/18/07**	**Thu 5/8/08**		
2	**Semester 1**	**65 days**	**Wed 7/18/07**	**Wed 10/17/07**		
3	Senior Project Formation	11 days	Wed 7/18/07	Wed 8/1/07		Josh,Mai,Nick
4	**Senior Project Initial Proposal**	**7 days**	**Mon 8/6/07**	**Wed 8/15/07**		
5	**Project Ideas**	**3 days**	**Mon 8/6/07**	**Wed 8/8/07**	**3**	
6	Idea 1: Blimp Camera	1 day	Mon 8/6/07	Mon 8/6/07	3	Mai
7	Idea 2: Security System	2 days	Mon 8/6/07	Tue 8/7/07	3	Nick
8	Idea 2: Forklift System	1 day	Wed 8/8/07	Wed 8/8/07	3	Josh
9	Description	4 days	Thu 8/9/07	Tue 8/14/07	8	Mai
10	Hardware Diagram	3 days	Fri 8/10/07	Tue 8/14/07	8	Nick
11	Software Flow Chart	4 days	Thu 8/9/07	Tue 8/14/07	8	Josh
12	Initial Proposal Sent In	0 days	Wed 8/15/07	Wed 8/15/07	10,11,9,13	
13	Meeting With English Advisor	1 day	Mon 8/13/07	Mon 8/13/07		Mai,Nick,Josh
14	Project Acceptance	0 days	Wed 8/22/07	Wed 8/22/07		
15	**Progress Report # 1**	**6 days**	**Thu 8/23/07**	**Fri 8/31/07**		
16	Scope	4 days	Fri 8/24/07	Wed 8/29/07	14	Mai
17	Future Enhancements	4 days	Fri 8/24/07	Wed 8/29/07	14	Josh
18	Target Audience	5 days	Thu 8/23/07	Wed 8/29/07	14	Nick
19	Progress Report Submitted	0 days	Fri 8/31/07	Fri 8/31/07	16,17,18,20	Mai,Josh,Nick
20	Meeting With English Advisor Online	1 day	Wed 8/29/07	Wed 8/29/07		
21	**Progress Report # 2**	**6 days**	**Wed 9/5/07**	**Wed 9/12/07**		
22	Budget	6 days	Wed 9/5/07	Wed 9/12/07	19	Mai
23	Market Analysis	6 days	Wed 9/5/07	Wed 9/12/07	19	Nick,Josh
24	Gantt Chart	4 days	Fri 9/7/07	Wed 9/12/07	19	Josh
25	Progress Report Sent In	0 days	Wed 9/12/07	Wed 9/12/07	22,23,24,26	
26	Meeting with English Advisor	1 day	Mon 9/10/07	Mon 9/10/07		Josh,Mai,Nick
27	Email English Advisor Rough Draft Report # 2	1 day	Tue 9/11/07	Tue 9/11/07		Josh,Mai,Nick
28	**Progress Report #3**	**5 days**	**Wed 9/19/07**	**Tue 9/25/07**		
29	**Hardware**	**5 days**	**Wed 9/19/07**	**Tue 9/25/07**		
30	Diagrams	4 days	Wed 9/19/07	Mon 9/24/07	25	Josh
31	Hardware Write-Up	3 days	Fri 9/21/07	Tue 9/25/07	25	Nick
32	**Software**	**5 days**	**Wed 9/19/07**	**Tue 9/25/07**		
33	Diagrams	4 days	Wed 9/19/07	Mon 9/24/07	25	Josh
34	Software Write-Up	3 days	Fri 9/21/07	Tue 9/25/07	25	Mai
35	Progress Report # 3 Sent In	0 days	Wed 9/26/07	Wed 9/26/07	34,30,31,33	Josh,Mai,Nick
36	**Rough Draft Of Written Report**	**3 days**	**Mon 10/1/07**	**Wed 10/3/07**		

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
37	Formatting	2 days	Mon 10/1/07	Tue 10/2/07	35	Mai
38	Grammar	2 days	Tue 10/2/07	Wed 10/3/07	35	Mai,Nick
39	Diagrams	2 days	Tue 10/2/07	Wed 10/3/07	35	Josh
40	Compilation	2 days	Tue 10/2/07	Wed 10/3/07	35	Josh,Mai,Nick
41	Risks And Contingencies	2 days	Tue 10/2/07	Wed 10/3/07	35	Josh,Mai
42	Safety	1 day	Tue 10/2/07	Tue 10/2/07	35	Mai
43	Appendix	2 days	Tue 10/2/07	Wed 10/3/07	35	Nick
44	Update Gantt Chart	1 day	Tue 10/2/07	Tue 10/2/07	35	Josh
45	Rough Draft Turned In	0 days	Wed 10/3/07	Wed 10/3/07	37,38,39,40,41,42,43,44	Josh,Mai,Nick
46	**Power Point**	**5 days**	**Thu 10/4/07**	**Wed 10/10/07**		
47	Create Cells	3 days	Thu 10/4/07	Mon 10/8/07	45	Mai,Nick
48	Work On Animation	3 days	Fri 10/5/07	Tue 10/9/07	45	Josh
49	Editing	4 days	Fri 10/5/07	Wed 10/10/07	45	Josh,Mai,Nick
50	Meeting With English Adivsor	1 day	Mon 10/8/07	Mon 10/8/07	45	Josh,Mai,Nick
51	**Final Draft of Written Report**	**3 days**	**Mon 10/8/07**	**Wed 10/10/07**		
52	Formatting	2 days	Mon 10/8/07	Tue 10/9/07	45	Josh,Mai
53	Gantt Chart	2 days	Tue 10/9/07	Wed 10/10/07	45	Josh
54	Hardware	2 days	Tue 10/9/07	Wed 10/10/07	45	Nick
55	Software	2 days	Tue 10/9/07	Wed 10/10/07	45	Mai
56	Formatting	1 day	Wed 10/10/07	Wed 10/10/07	45	Josh,Mai,Nick
57	Report Sent In	0 days	Wed 10/10/07	Wed 10/10/07	52,53,54,55,56	Josh,Mai,Nick
58	Final Presentation	0 days	Wed 10/17/07	Wed 10/17/07	57	Josh,Mai,Nick
59	**Semester 2**	**83 days**	**Sat 11/3/07**	**Wed 2/20/08**		
60	Purchased Forklift	1 day	Mon 11/5/07	Mon 11/5/07	58	Josh
61	Completed H-Bridges	2 days	Sat 11/3/07	Mon 11/5/07	58	Josh,Nick
62	Received Forklift	1 day	Mon 11/12/07	Mon 11/12/07	60	Josh,Mai,Nick
63	Tested Hall-Effect Sensors	1 day	Wed 11/7/07	Wed 11/7/07		Josh
64	Progress Report #1	0 days	Wed 11/28/07	Wed 11/28/07	62,63	Nick
65	Program for Servo Motor Completed	4 days	Wed 11/28/07	Sat 12/1/07	64	Josh,Mai
66	Forklift Started Running	1 day	Tue 12/4/07	Tue 12/4/07	63,65	Josh,Mai
67	New Navigation Planned	24 days	Wed 11/7/07	Wed 12/5/07	58	Nick,Josh
68	Meet English Advisor	1 day	Fri 12/7/07	Fri 12/7/07	64	Nick,Josh,Mai
69	Progress Report # 2	0 days	Wed 12/12/07	Wed 12/12/07	64,68	Mai,Nick
70	Forklift follows straight line	3 days	Fri 12/14/07	Tue 12/18/07	67,66	Josh,Mai
71	IR boards built and installed	9 days	Mon 1/7/08	Thu 1/17/08	70	Josh,Nick
72	Meet English Advisor	1 day	Tue 1/15/08	Tue 1/15/08		Mai,Josh,Nick

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
73	Progress Report #3	0 days	Wed 1/16/08	Wed 1/16/08	72	Nick,Mai,Josh
74	Wireless and Rangers working separately	3 days	Thu 1/17/08	Sat 1/19/08	73	Josh,Mai
75	Wireless Modem not working in Project	2 days	Fri 1/25/08	Sat 1/26/08	74	Josh,Mai
76	Both Rangers working on same bus	1 day	Mon 1/28/08	Mon 1/28/08	69	Mai,Josh
77	Mode changed in servo control and Forklift follow line	3 days	Tue 1/29/08	Thu 1/31/08	70	Josh,Mai
78	Tilt sensor is installed and working	4 days	Wed 1/30/08	Mon 2/4/08	70	Nick,Josh,Mai
79	Tilt sensor + straight track + range finder working	3 days	Mon 2/4/08	Wed 2/6/08	76,77	Nick,Josh,Mai
80	Rough Draft	6 days	Wed 1/30/08	Wed 2/6/08	73	Nick,Josh,Mai
81	Final Draft	0 days	Wed 2/13/08	Wed 2/13/08		
82	Presentation	0 days	Wed 2/20/08	Wed 2/20/08		
83	**Semester 3**	**50 days**	**Mon 3/3/08**	**Thu 5/8/08**		
84	Zigbee wireless working	10 days	Mon 3/3/08	Fri 3/14/08		
85	Progress Report #1	0 days	Thu 3/27/08	Thu 3/27/08		
86	Steering Algorithm	16 days	Fri 3/14/08	Sun 4/6/08		
87	Rebuilt Steering	2 days	Mon 4/7/08	Tue 4/8/08	86	
88	Forward straight line navigation finalized	5 days	Mon 4/7/08	Fri 4/11/08		
89	Reconfigured navigation IR sensors	1 day	Fri 4/11/08	Fri 4/11/08		
90	Turning algorithm + intersection layout finalized	1 day	Mon 4/14/08	Mon 4/14/08		
91	Progress Report #2	0 days	Thu 4/17/08	Thu 4/17/08		
92	Midterm Prototype Preview	0 days	Thu 4/24/08	Thu 4/24/08		
93	Forklift locates pallet, picks it up, and reverses out	2 days	Fri 4/25/08	Sat 4/26/08		
94	Progress Report #3	0 days	Thu 5/1/08	Thu 5/1/08		
95	All programs are integrated and hardware finished	4 days	Mon 5/5/08	Thu 5/8/08		



Project: 5-8-08
Date: Thu 5/29/08

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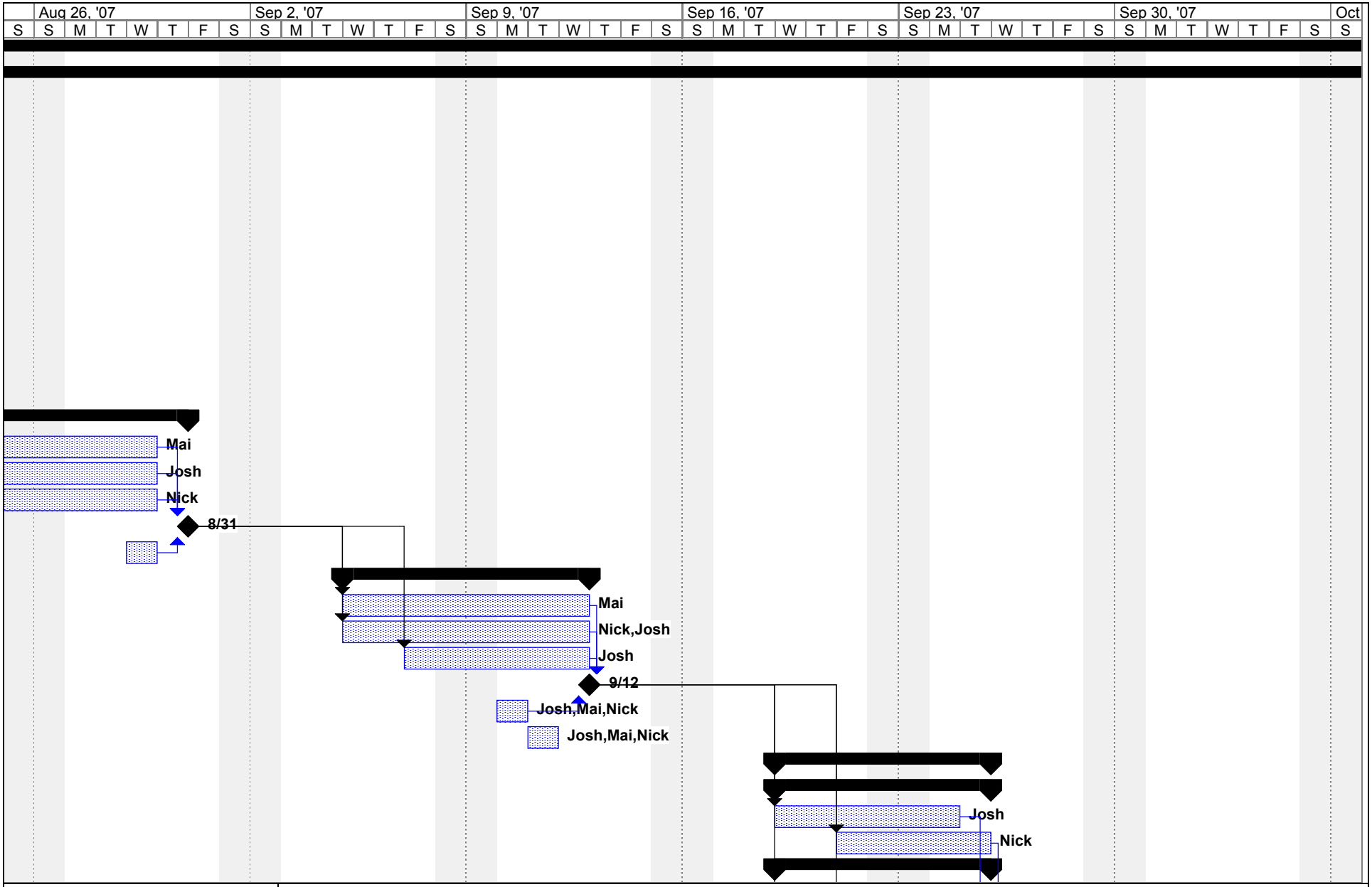

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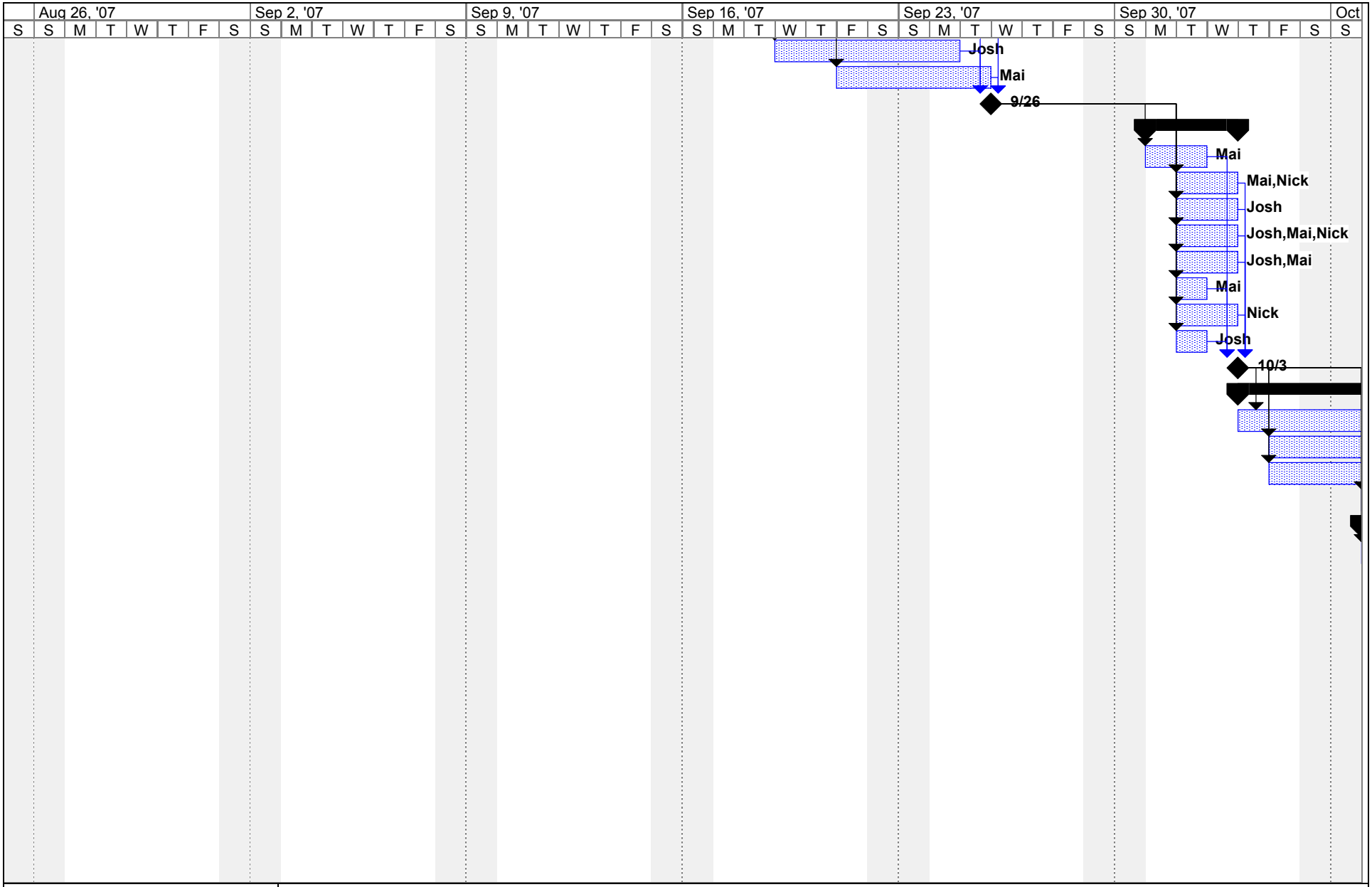

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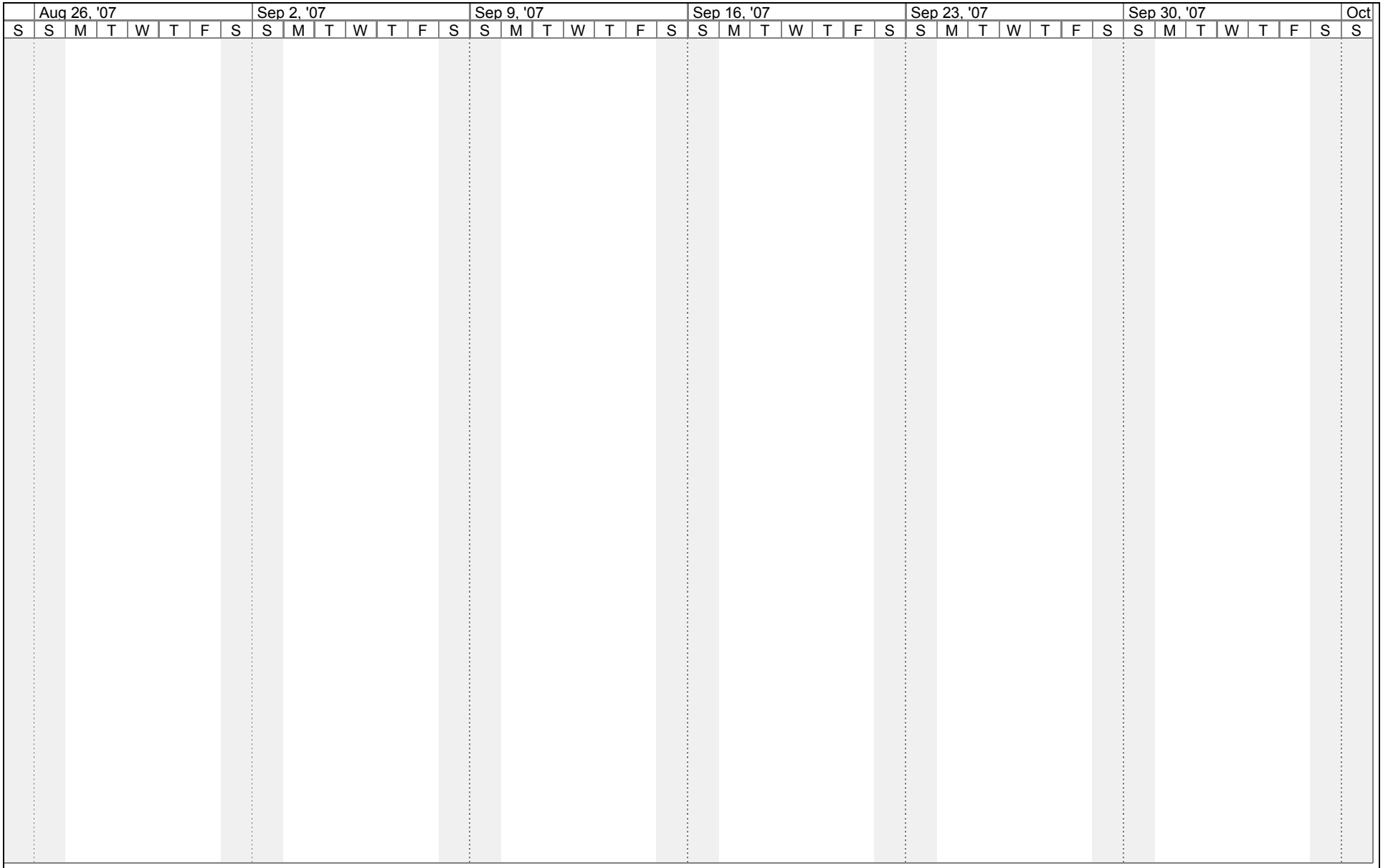
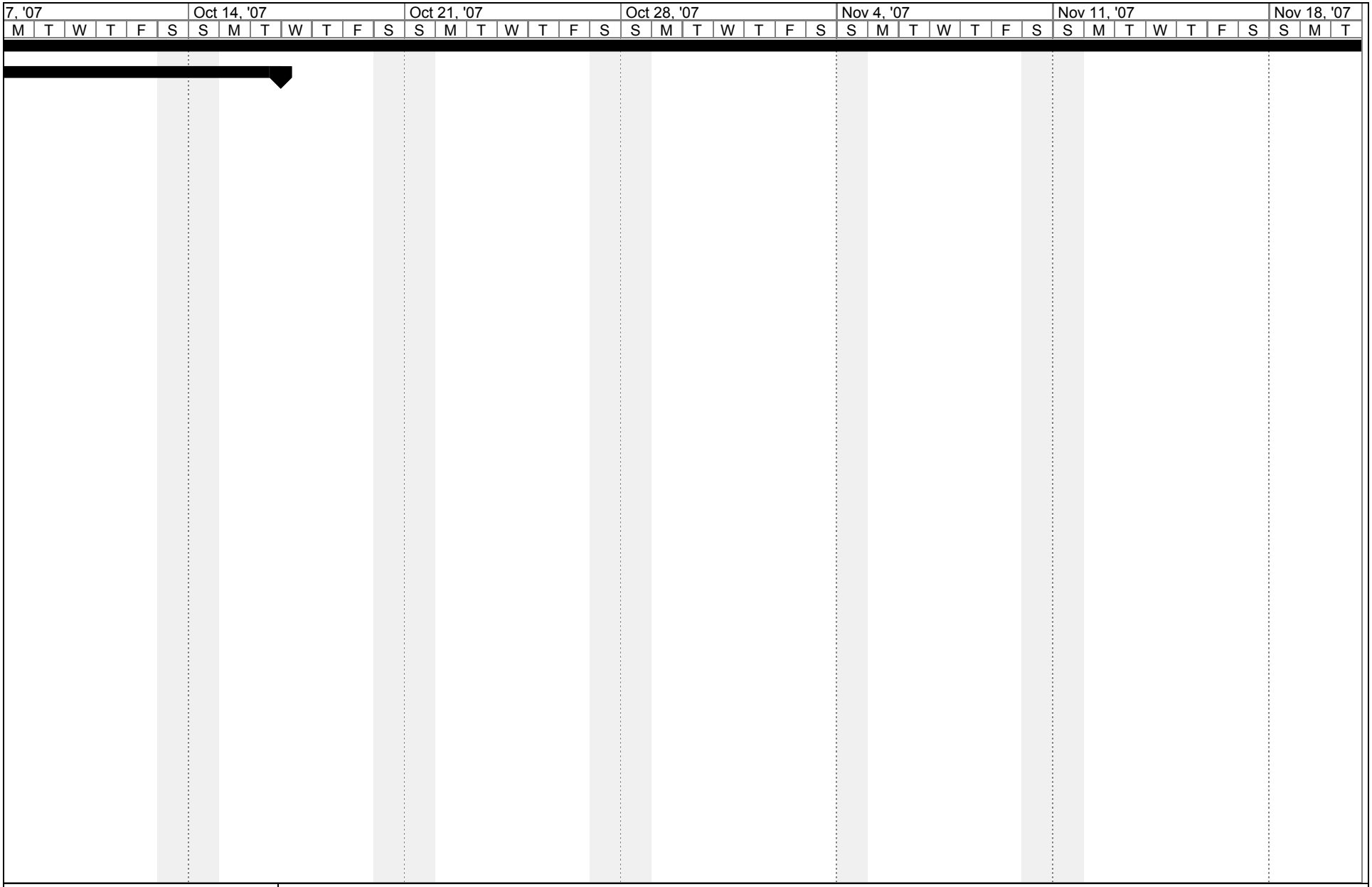


Project: 5-8-08
Date: Thu 5/29/08



Project: 5-8-08
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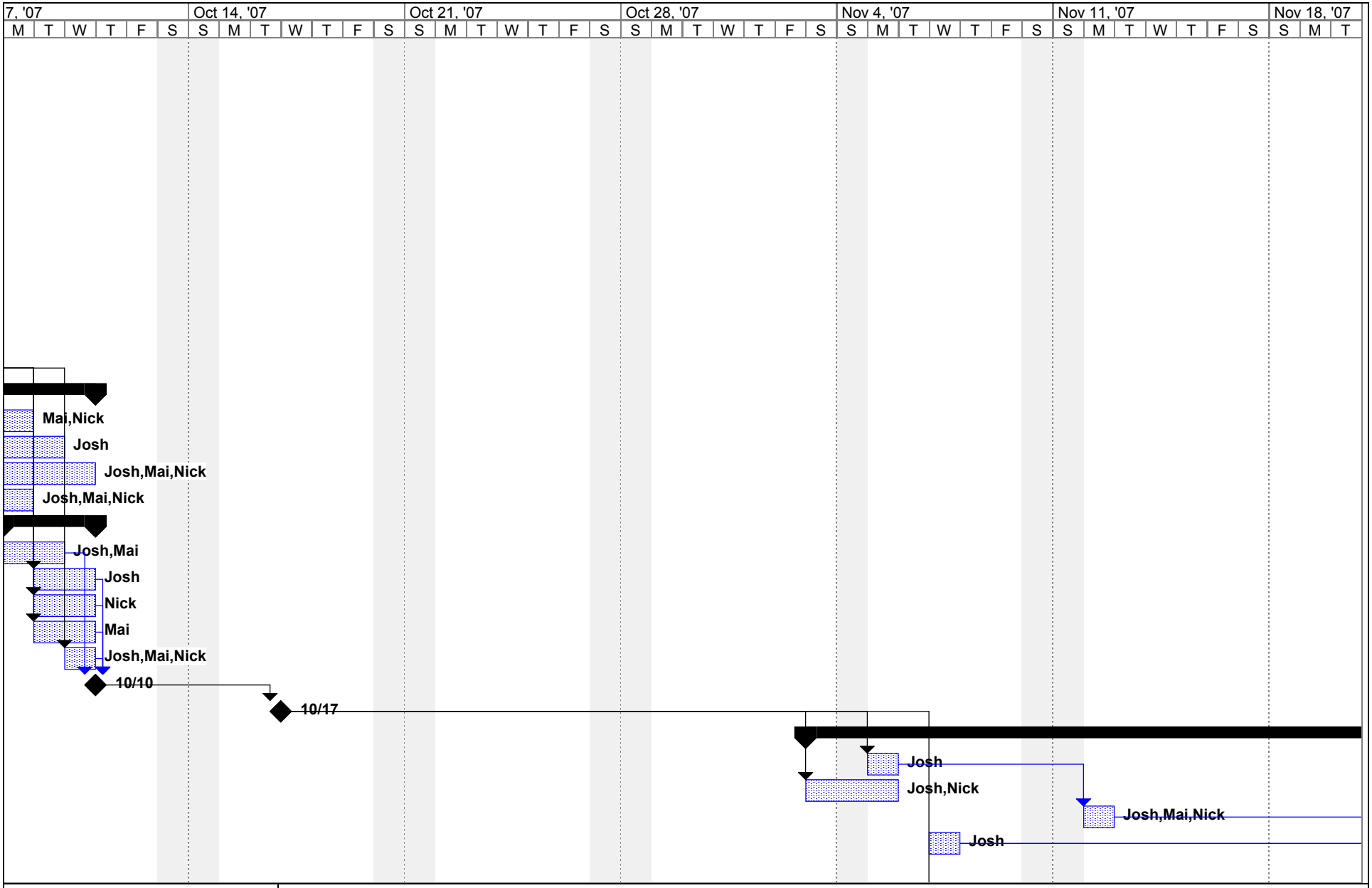

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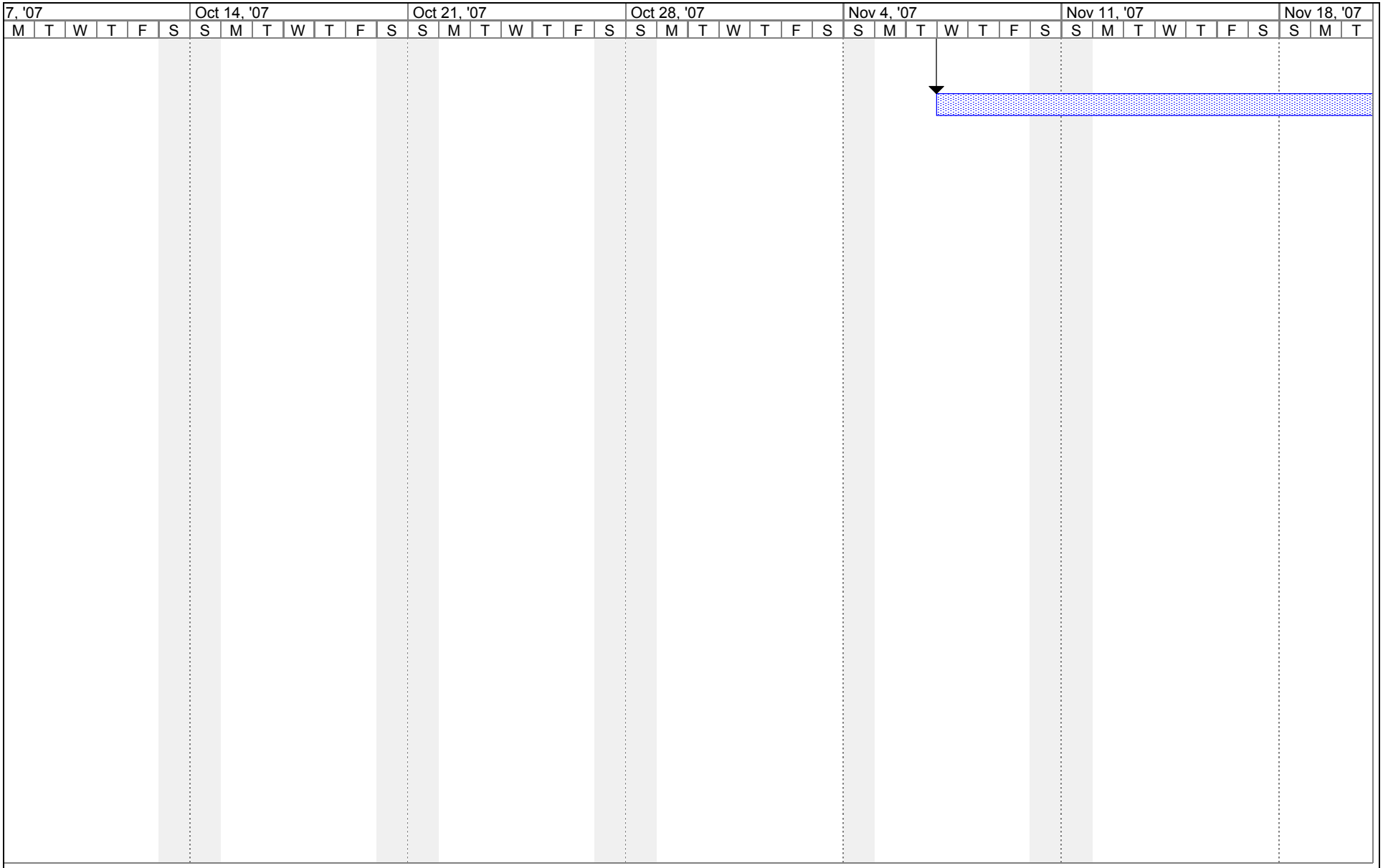

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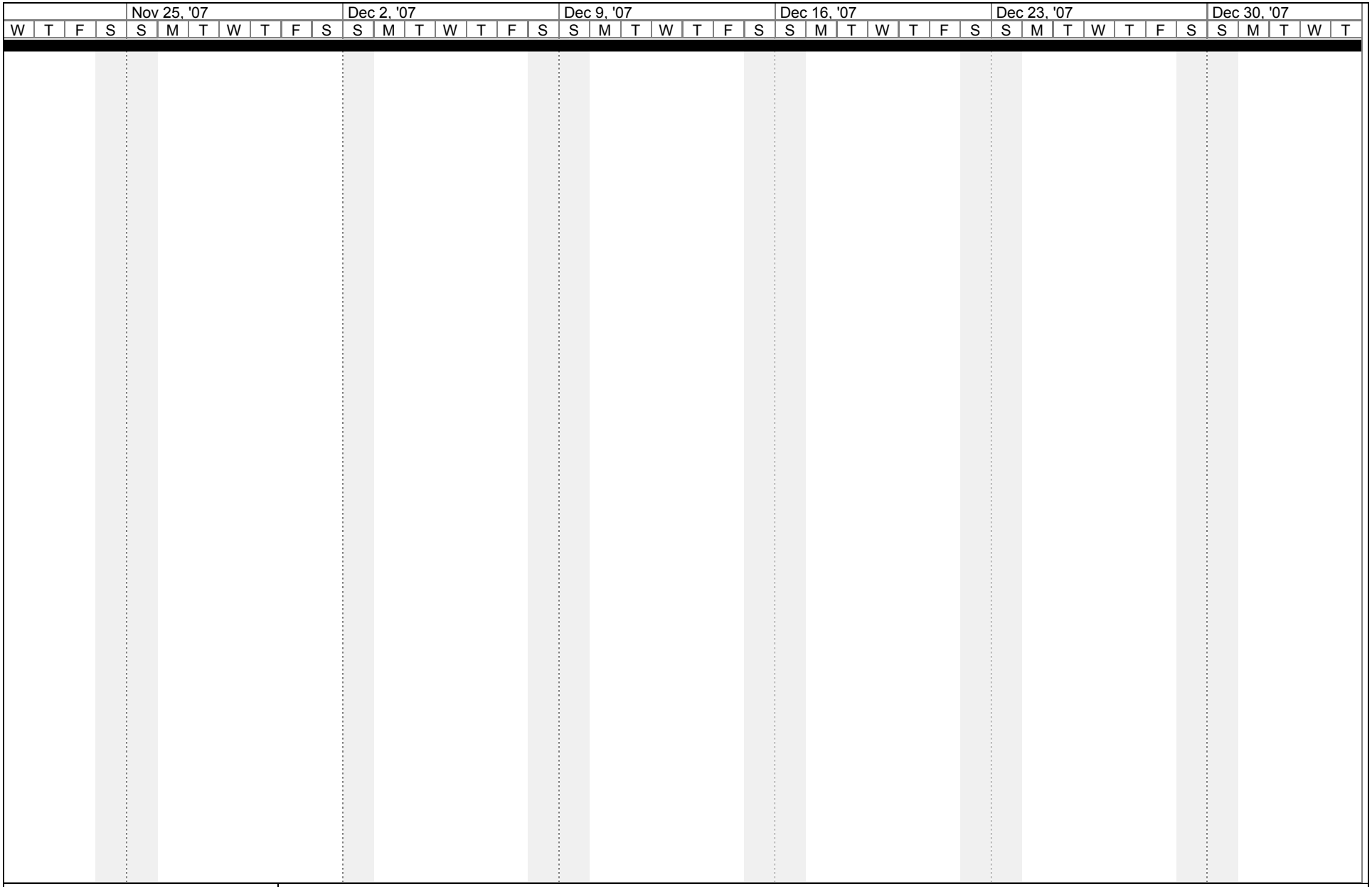
Nov 25, '07
Dec 2, '07
Dec 9, '07
Dec 16, '07
Dec 23, '07
Dec 30, '07
W T F S S M T W T F S S M T W T F S S M T W T F S S M T W T F S S M T W T F S S M T W T
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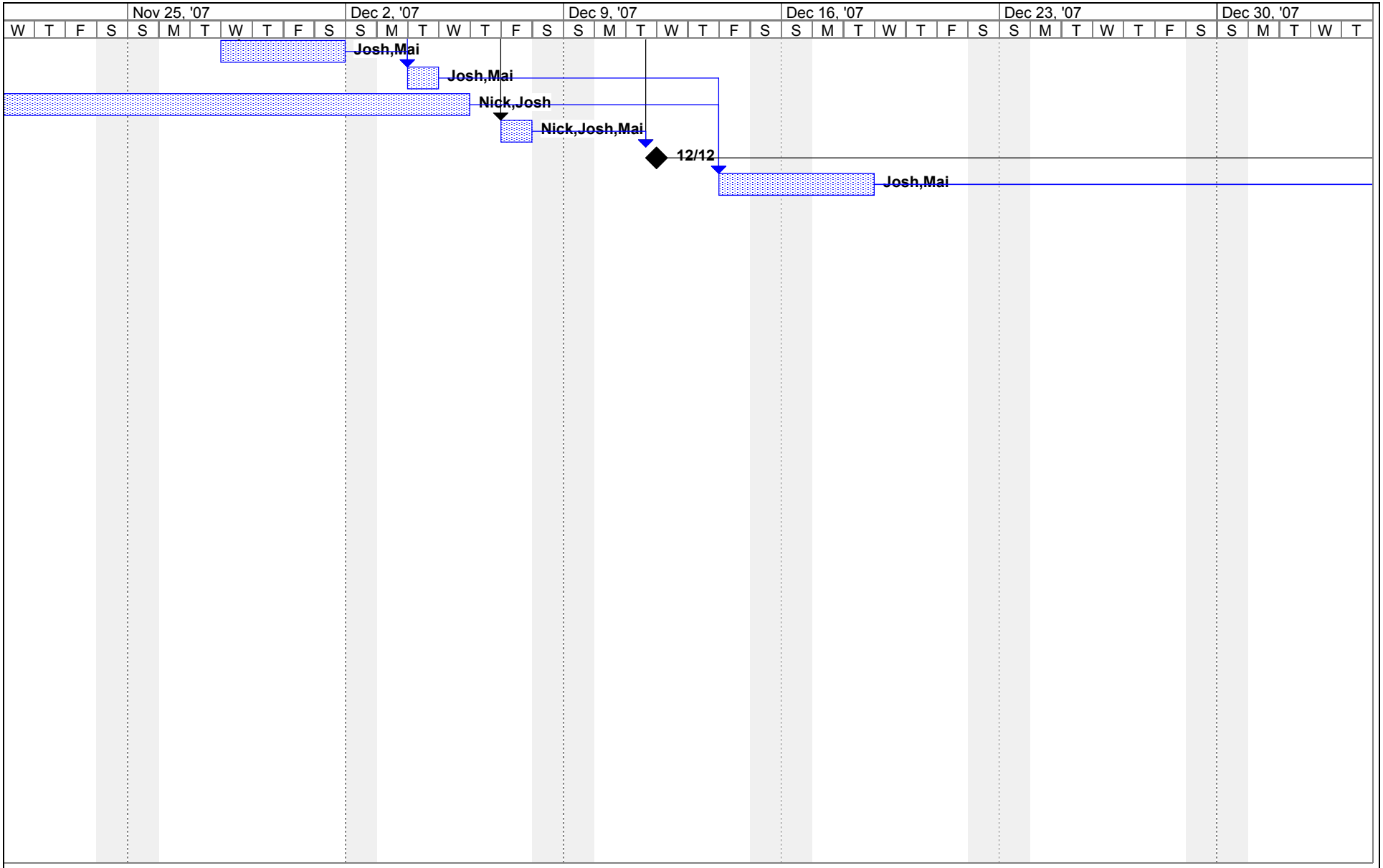

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Task		Milestone		External Tasks	
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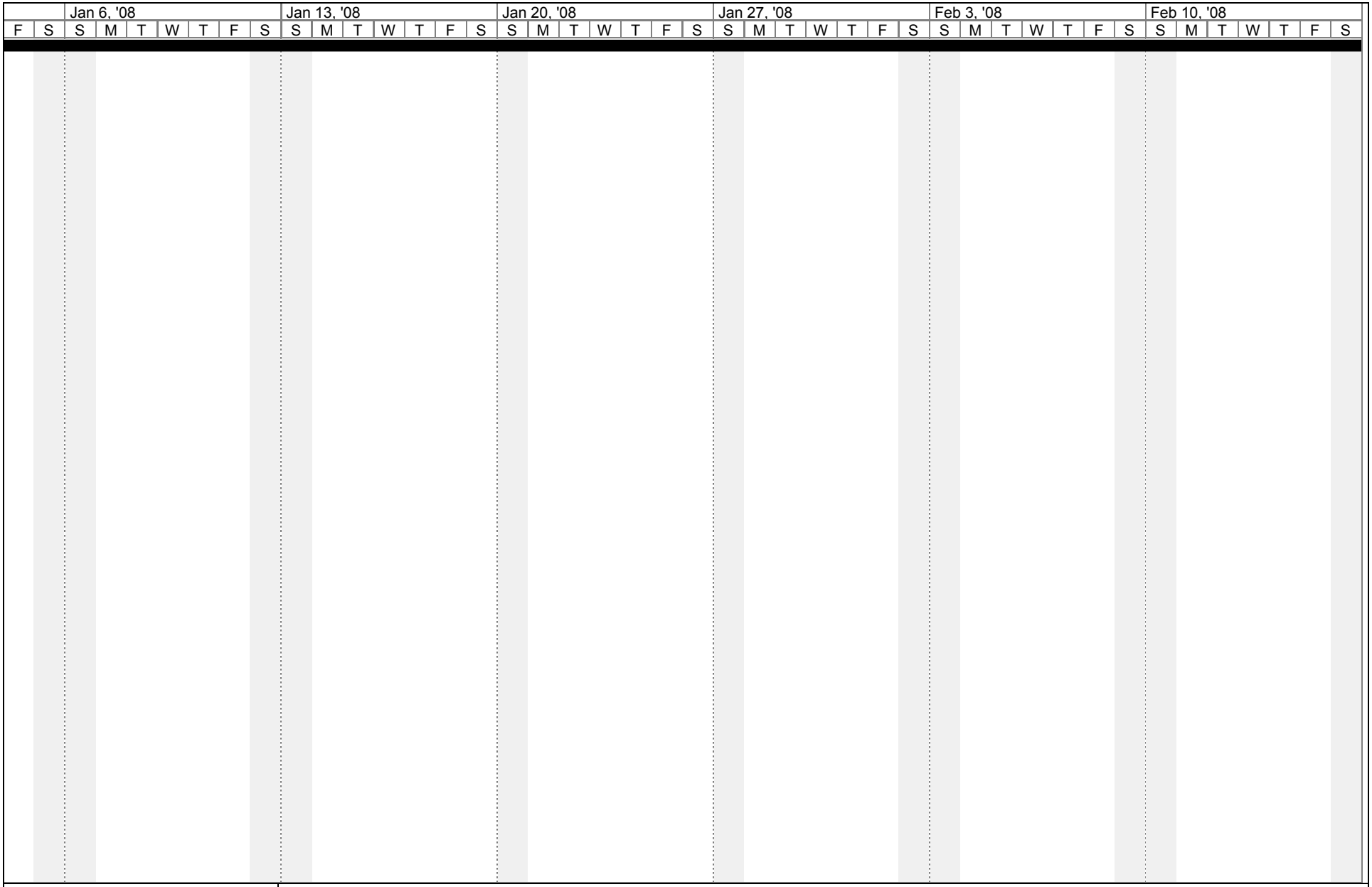

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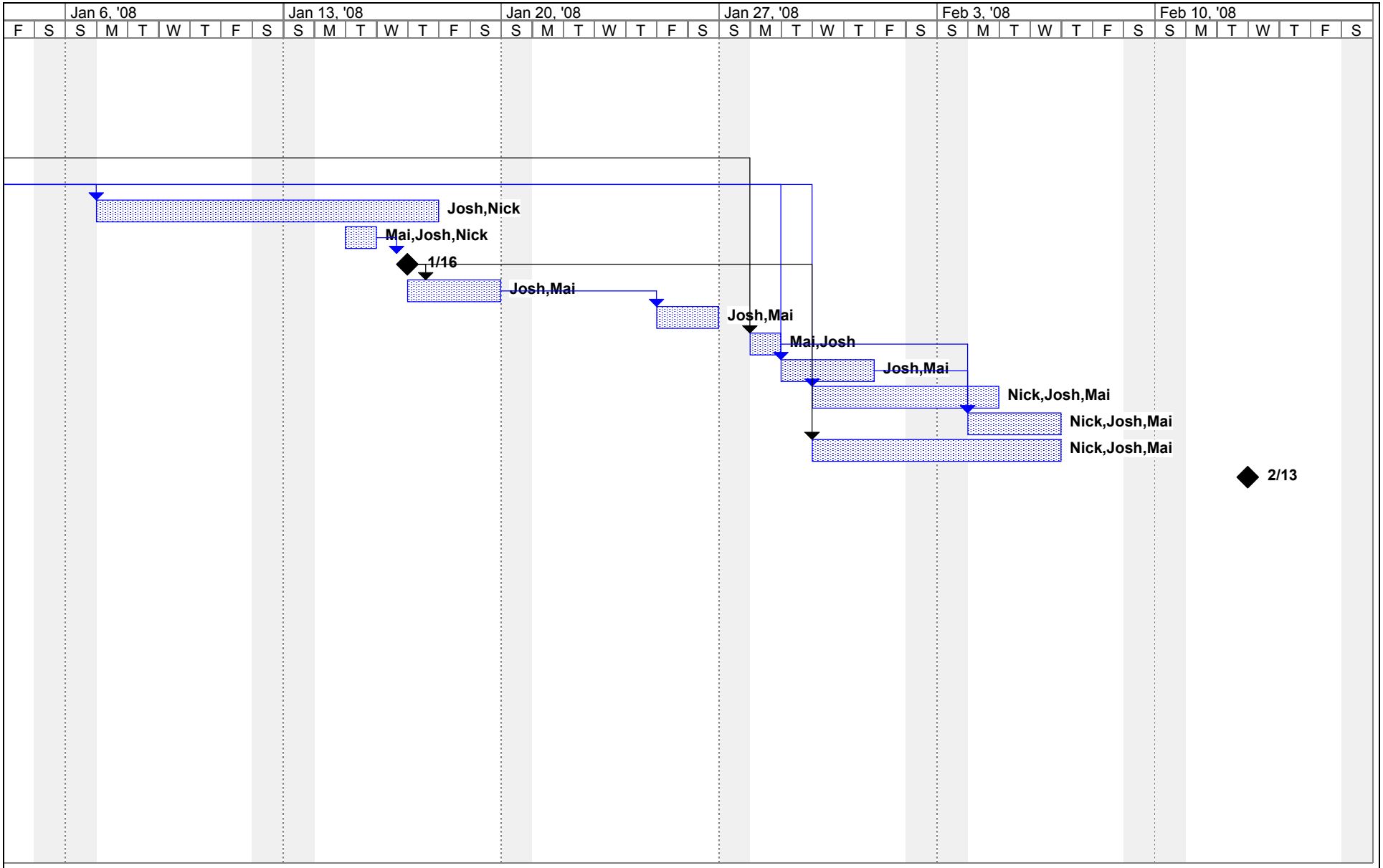

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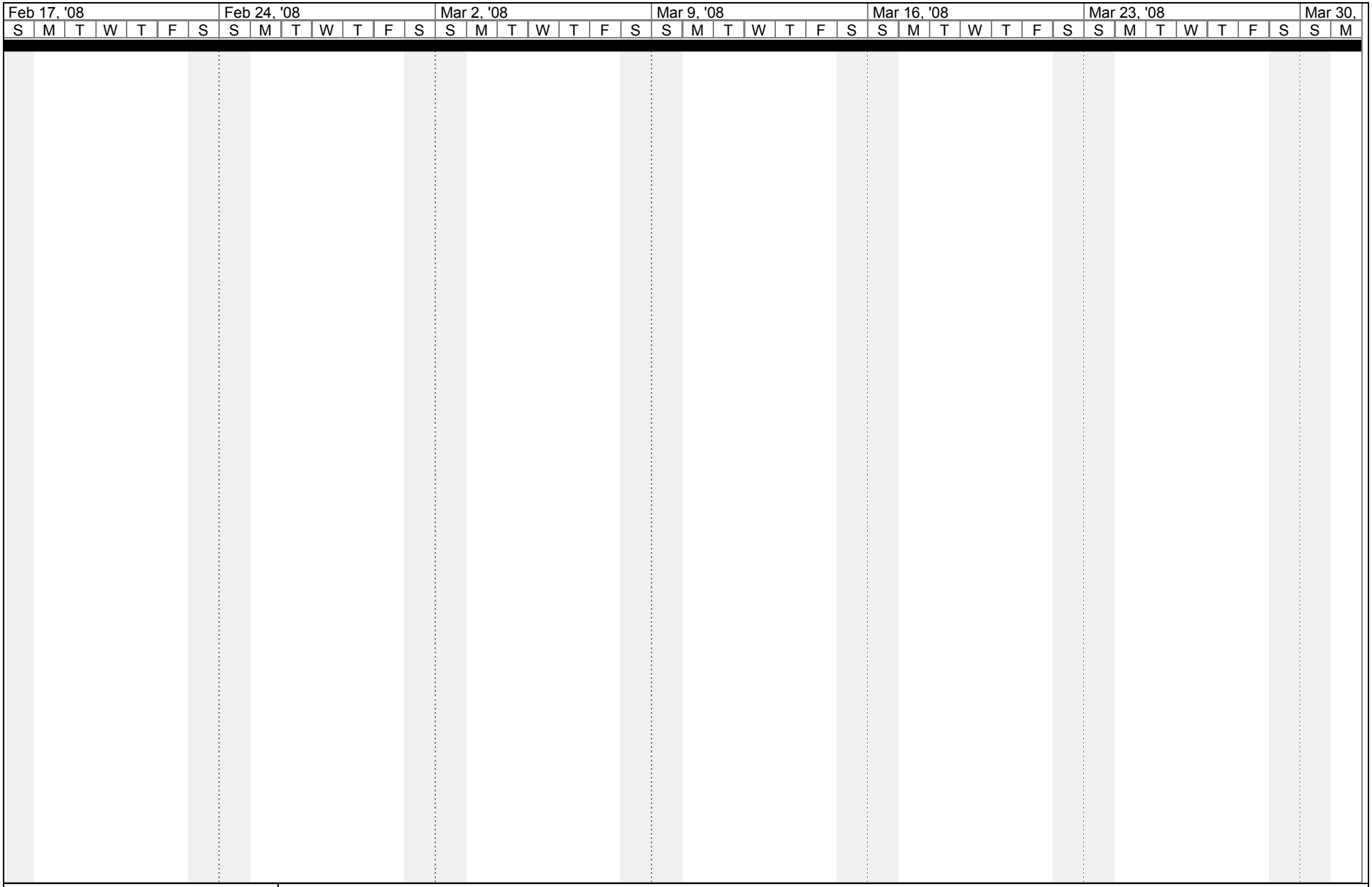

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Date: Thu 5/29/08

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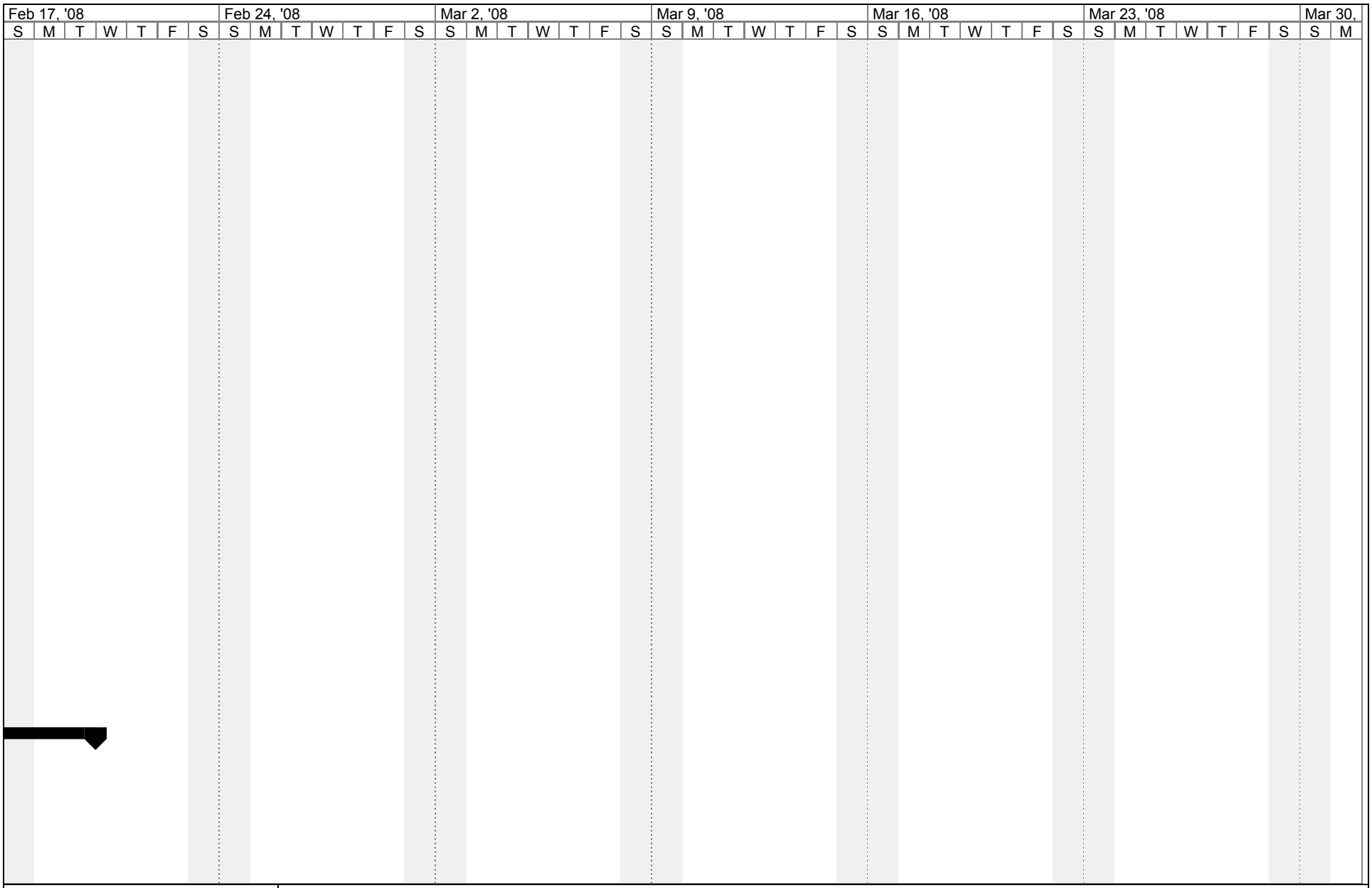

Project: 5-8-08
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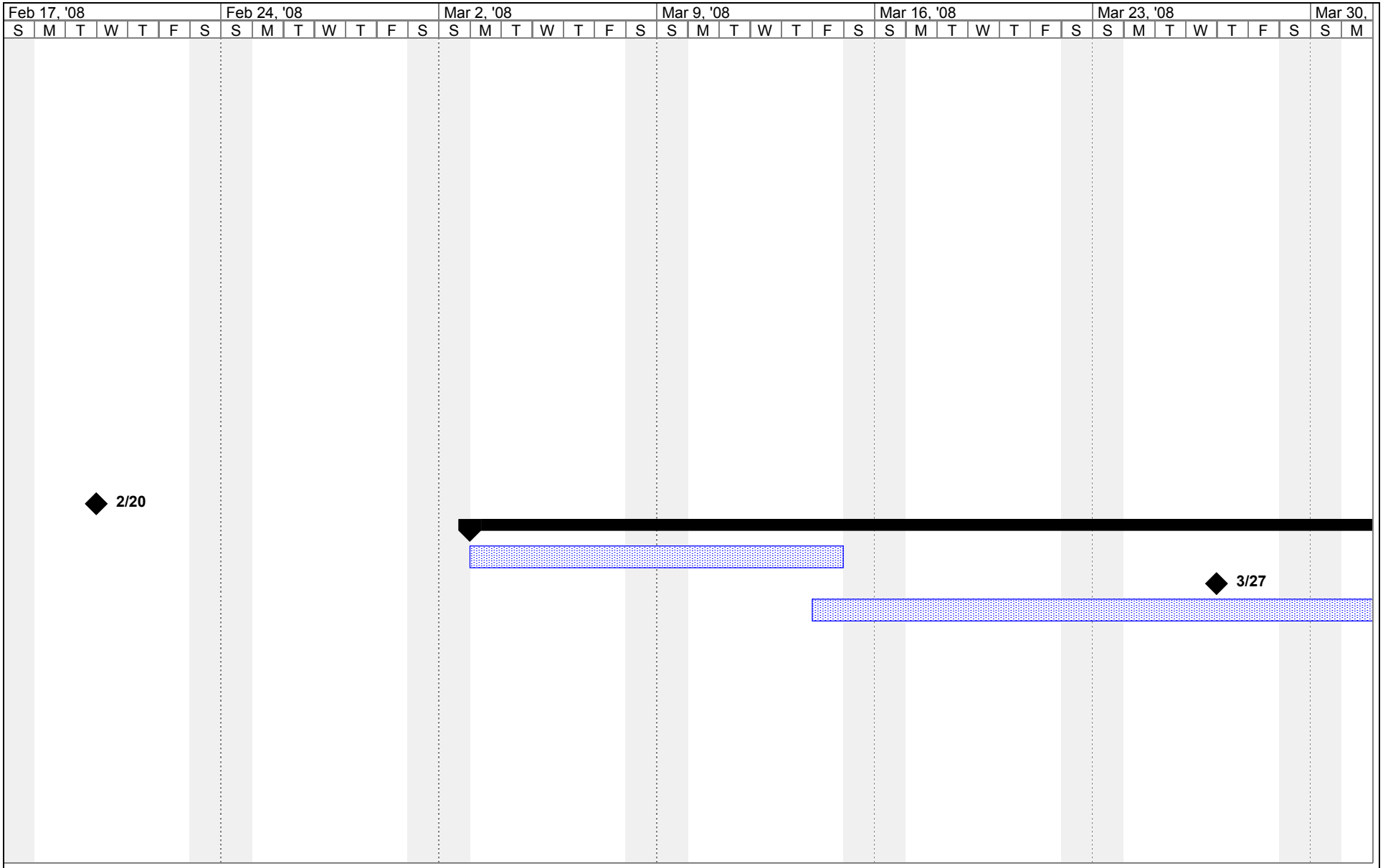

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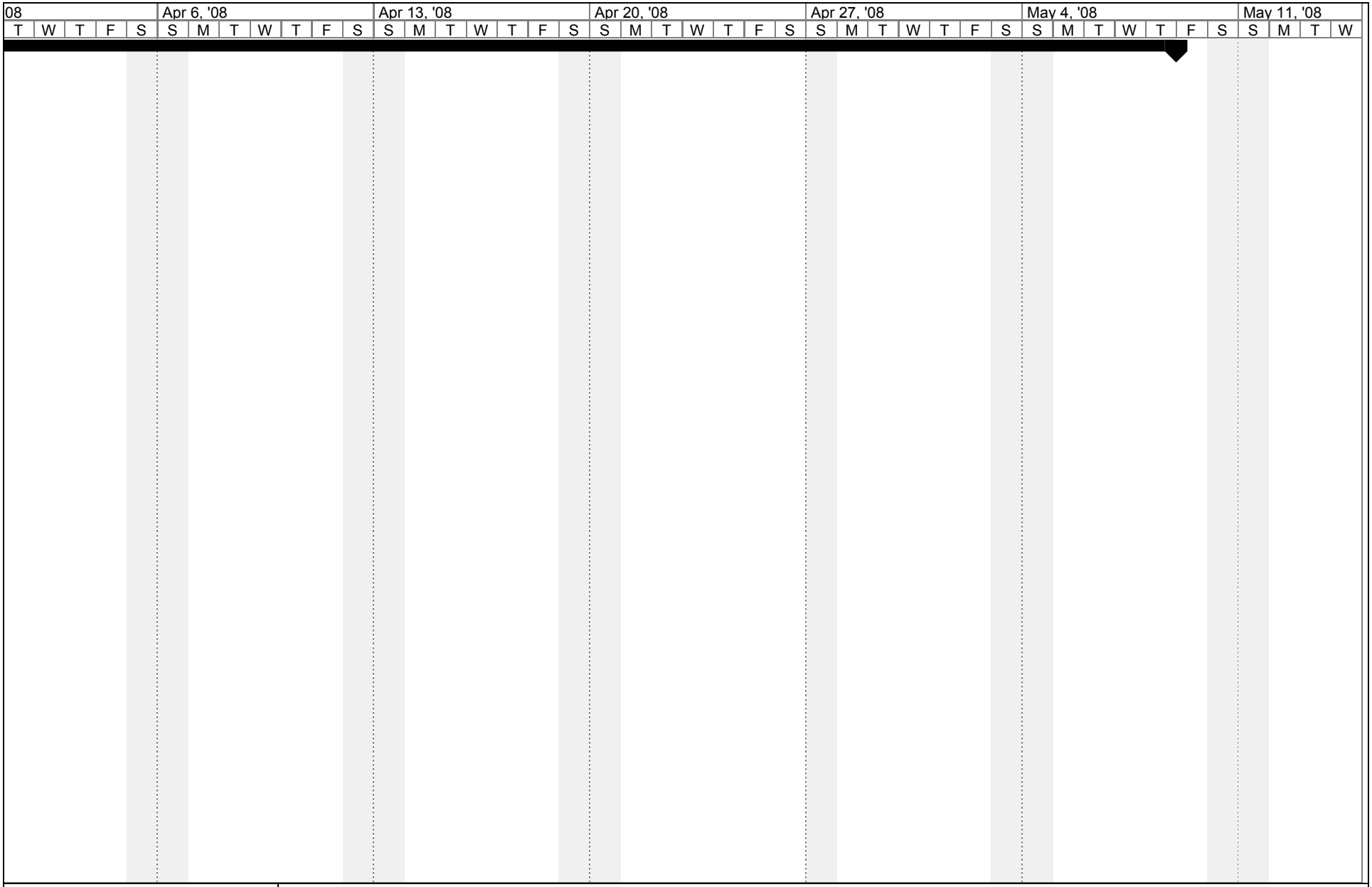

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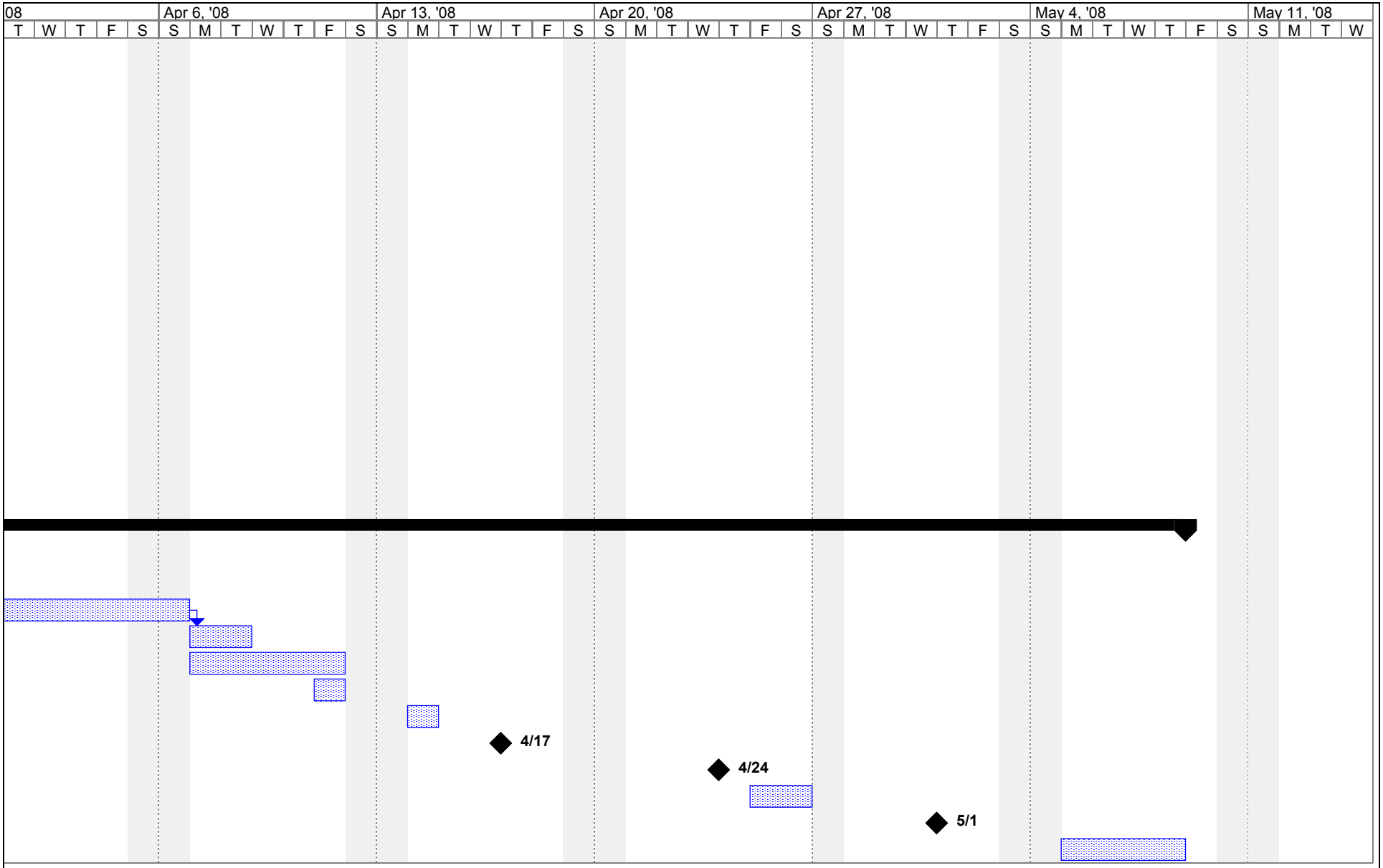

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APPENDIX B

USER INTERFACE

```
C:\Documents and Settings\Joshua\Desktop\senior project\EET404\Final Software Program\test
#include "C:\Documents and Settings\CHOUA\Desktop\Forklift_test\LCD.h"
#include "string.h"

int  screen_number=0;
int  cursor=0;void int_LCD(void);
void Check_Keys(void);
void out_LCD(int i);
void key_table(char *array, int columns_value, int row);
void clear(void);
void arrows(int columns_value);
void out_LCD_string(char *string);
void menu(void);
void screen(void);
void cursor_position(int position);
void transmit(void);

int  counter = 0;         //keep track of the number enter for aisle
int  menu_or_clear=0;
int  choice=0;
int selection=0;
int indicate=0;
int checking;
int status=0;
char aisle_number[]="000";
char array1[]="147";
char array2[]="258";
char array3[]="369";
char string1[]="1. Pick up from dock";
char string2[]="2. Place on dock";
char string3[]="Pick up from dock?";
char string4[]="Place on dock?";
char string5[]="1. Yes   2. No";
char string6[]="Aisle:";
char transmitting[]="Transmitting";
char invalid[]="Invalid Entry";
char complete[]="Task Completed";
char operate[]="Operating";
char verify[]="F: Safe to proceed?";
char stop[]="Stop";
char object1[]="B: Object in the way";
char object2[]="1. Proceed   2. Home";
char tilt[]="Forklift tilts over.";
char no_pallet[]="No pallet";
char home[]="2. Home";
char operate_home[]="Home: Operating";
int keypress=0;      //keep track of number of time home button has been selec


#int_RDA
RDA_isr()
{
   int checking1=0;

   checking1=getc(COM_A);
          if(checking1=='T'){
               delay_us(10);
               putc('Y',COM_A);
               menu();
               screen_number=1;

               output_high(PIN_E0);
               delay_ms(500);
               output_low(PIN_E0);
```

```
        }

        else if(checking1=='1'){      //forklift received command
           clear();
           out_LCD_string(operate);
        }

        else if(checking1=='2'){      //detect object in the way-front senso
           clear();
           out_LCD_string(verify);  //verify
           cursor_position(0x94);
           out_LCD_string(object2); //proceed or home?
           cursor_position(0x94);

           output_high(PIN_E0);
           delay_ms(500);
           output_low(PIN_E0);
        }

        else if(checking1=='3'){   //detect object in the way-back sensor
           clear();
           out_LCD_string(object1);
           cursor_position(0x94);
           out_LCD_string(object2);
           cursor_position(0x94);

           output_high(PIN_E0);
           delay_ms(500);
           output_low(PIN_E0);
        }

        else if(checking1=='4'){   //forklift tilts over
           clear();
           out_LCD_string(tilt);
           cursor_position(0x94);
           out_LCD_string(object2);
           cursor_position(0x94);

           output_high(PIN_E0);
           delay_ms(500);
           output_low(PIN_E0);
        }

        else if(checking1=='5')    //forklift comfirmed button pressed
        {
           clear();
           out_LCD_string(stop);
           cursor_position(0x94);
           out_LCD_string(object2);
           cursor_position(0x94);

           output_high(PIN_E0);
           delay_ms(500);
           output_low(PIN_E0);
        }

        else if(checking1=='6')
        {
           clear();
           out_LCD_string(no_pallet);
           cursor_position(0x97);
           out_LCD_string(home);
           cursor_position(0x97);
```

```
            output_high(PIN_E0);
            delay_ms(500);
            output_low(PIN_E0);
         }

         else if(checking1=='8')
            keypress=1;

         else if(checking1=='D'){
            clear();
            out_LCD_string(complete);
            delay_ms(1000);
            menu();

            output_high(PIN_E0);
            delay_ms(500);
            output_low(PIN_E0);
         }



}



void main()
{


   ext_int_edge(H_TO_L);
   setup_adc_ports(NO_ANALOGS);
   setup_adc(ADC_OFF);
   setup_psp(PSP_DISABLED);
   setup_spi(FALSE);
   setup_wdt(WDT_OFF);
   setup_timer_0(RTCC_INTERNAL);
   setup_timer_1(T1_DISABLED);
   setup_timer_2(T2_DISABLED,0,1);
   enable_interrupts(INT_RDA);
   enable_interrupts(GLOBAL);
  // setup_oscillator(False);

   delay_ms(400);

   int_LCD();

//   menu();

here:


    Check_Keys();
    delay_ms(75);

    goto here;

}

void int_LCD(void)
{
   output_low(PIN_A2);   //enable pin
   output_low(PIN_A3);   //R/W=0 to select write mode
```

```
C:\Documents and Settings\Joshua\Desktop\senior project\EET404\Final Software Program\test
   output_low(PIN_A1);   //RS=0 to select command register

   output_b(0x38);      //int LCD 2 lines, 5x7 (0x3F- 4 lines), 0x38-2 lines
   output_high(PIN_A2); //send H pulse
   output_Low(PIN_A2);  //send H-to-L pulse
   delay_ms(1);

   output_b(0x0F);      //turn LCD on, cursor on
   output_high(PIN_A2);
   output_Low(PIN_A2);
   delay_ms(1);

   output_b(0x01);      //clear LCD
   output_high(PIN_A2);
   output_Low(PIN_A2);
   delay_ms(1);

   output_b(0x80);      //move cursor beginning of line1
   output_high(PIN_A2);
   output_Low(PIN_A2);
   delay_ms(1);
}

void Check_Keys(void)
{
   int answer=0;
   int row = 0;

   row = 0x0E;        //send value 14 to make row1 low
   output_d(row);     //ROW1

   answer = input_c();     //read inputs from keypad
   answer= answer & 0x0F;  //AND input with 0x0F to get lower 4-bits

   if(answer !=0x0F){      //check for key press
   key_table(array1, answer, row);   //if any key from row1 is pressed call
   }                                 // key_table to deal with key press

   row = 0x0D;        //send value 13 to make row2 low
   output_d(row);     //ROW2
   answer = input_c();      //read inputs from keypad
   answer= answer & 0x0F;   //AND input with 0x0F to get lower 4-bits

   if(answer !=0x0F){      //check for key press
      key_table(array2, answer,row); //if any key from row2 is pressed, call
   }                                 //key_table to deal with key press

   row = 0x0B;        //send value 11 to make row3 low
   output_d(row);     //ROW3
   answer = input_c();     //read inputs from keypad
   answer= answer & 0x0F;

   if(answer !=0x0F){      //check for key press
      key_table(array3, answer, row);  //if any key from row3 is pressed, call
   }                                   //key_table to deal with key press

   output_d(0x07);     //send value 7 to make row4 low
   answer = input_c(); //read input from keypad
   answer= answer & 0x0F;

   if(answer !=0x0F && screen_number !=6) //check for keypress and screen numb
     arrows(answer);   //call arrows function
}
```

C:\Documents and Settings\Joshua\Desktop\senior project\EET404\Final Software Program\test

```
//function to display individual character on LCD
void out_LCD(int i)
{
   output_b(i);          //send out character to portb
   output_high(PIN_A1); //RS=1, to select data register
   output_high(PIN_A2); //send high to
   output_Low(PIN_A2);  //low pulse
   delay_ms(50);

  if(counter<=2)        //counter keeps track of number of time key press in
     aisle_number[counter]=i;   //user input screen,if less than 3 times, stor
                                //character pressed in array aisle_number
  counter++;            //increment counter
}

//function to look up key pressed
void key_table(char *array, int columns_value, int row)
 {
    int i = 0;          //array index
    int key='0';        //key holds the number zero of keypad

    if(columns_value==14){ //5
       i=0;             //index is zero
       if(row==14)       //Press #1 on keypad
       {

          switch(screen_number){
             case 1: choice=1;   //select choice1 in Menu, move to verify scre
             case 2:            //verify screen yes, move to user input, screen
             case 4:
             case 5:  screen(); //verify input yes, move to next screen

                     goto end1; //screen() uses to change screen
                     break;
          }
       }

       if(row==13)      // Press #2 on keypad
       {
          switch(screen_number){
             case 1: cursor=2;  //select choice2 in Menu
                     choice=2;
                     screen();  //go to screen2, verify choice
                     goto end1;
                     break;

             case 2: menu();    //select no in verify choice, screen2, go back
                     goto end1; //to Menu
                     break;

             case 4: screen_number=2;  //select no on verify user's input
                     screen();         //call screen to go back to user's inpu
                     goto end1;
                     break;
             case 5:
                    if(keypress==0){
                     screen_number=2;
                     cursor=2;
                     screen();
                     }
                     goto end1;
                     break;
```

```
         }
      }
   }

   else if(columns_value==13){  //column2
      i=1; //index points to 2nd element of defined array
   }

   else if(columns_value==11){  //column3
      i=2;                      //index point to last element of defined arra
   }

   else if(columns_value==7){   //column4
      switch(row){
         case 14:   if(screen_number==3)   //if clear key is pressed
                    {
                       menu_or_clear=1;
                       clear();
                    }
                    break;

         case 13:   if(screen_number==3 && counter<=2)
                       out_LCD('0');
                    break;

         case 11:   if(screen_number==5)         //if stop button is pressed
                       putc('5',COM_A);
                    break;

         default:   break;
      }
      goto end1;
   }

   else{
   }

   key = array[i];

   if(screen_number==3 && counter<=2 )
      out_LCD(key);

end1: i = 0;

 }

void clear(void)
{
   output_low(PIN_A2);   //enable pin
   output_low(PIN_A3);   //R/W
   output_low(PIN_A1);   //RS

   output_b(0x01);      //clear display
   output_high(PIN_A2);
   output_Low(PIN_A2);
   delay_ms(50);

   if(screen_number==3 && menu_or_clear==1){
      cursor_position(0x02);
      out_LCD_string(string6);   //show screen 3: user input
      cursor_position(0x94);
   }
```

```
C:\Documents and Settings\Joshua\Desktop\senior project\EET404\Final Software Program\test
   counter=0;
}

void arrows(int columns_value)
{
   if(screen_number==1) //enable up and down arrows only in the menu screen
   {

      if(columns_value==14)
      {
         cursor_position(0x02);   //Move cursor to beginning of line 1(up arro

         cursor=1;
      }

      if(columns_value==13)
      {
         cursor_position(0x94);      //Move cursor to beginning of line 2(down

         cursor=2;
      }
   }   //end enable up and down arrow keys

      if(columns_value == 11 && screen_number<4)     //the 2nd key is the menu
      {
         menu();
      }

      if(columns_value == 7)      //the enter key
      {
         screen();
      }
}

void out_LCD_string(char *string)
{
   unsigned int i;
   for(i=0;i<strlen(string); i++)
   {
   output_b((int)string[i]);
   output_high(PIN_A1);
   output_high(PIN_A2);
   output_low(pin_A2);
   }
}

void menu(void)
{
   menu_or_clear=0;

   clear();

   out_LCD_string(string1);
   out_LCD_string(string2);

   cursor_position(0x80);    //move cursor to beginning of line 1(up)

   screen_number = 1;
   cursor = 1;
   choice=0;
   keypress=0;
   indicate=0;
   aisle_number[0]="0";
```

```
C:\Documents and Settings\Joshua\Desktop\senior project\EET404\Final Software Program\test
   aisle_number[1]="0";
   aisle_number[2]="0";

}

void screen(void)
{
   clear();

   if(cursor==1)
   {
      switch(screen_number){
            case 1:    cursor_position(0x81);      //verify choice 1 on menu
                       out_LCD_string(string3);
                       break;
            case 2:    cursor_position(0x02);
       scrn3:          out_LCD_string(string6);   //show screen 3: user input
                       cursor_position(0x94);
                       screen_number=3;
                       goto end2;
                       break;
            case 3:    cursor_position(0x80);      //screen 4: verify aisle en
                       out_LCD_string(string6);
                       cursor_position(0x89);
                       out_LCD_string(aisle_number);
                       screen_number=4;
                       cursor_position(0x97);
                       out_LCD_string(string5);
                       cursor_position(0x97);
                       goto end2;
                       break;
            case 4:    cursor_position(0x80);      //screen 5: transmitting
                       out_LCD_string(transmitting);
                       screen_number = 5;
                       transmit();
                       if(status==1){
                          clear();
                          cursor_position(0x02);
                          goto scrn3;         //Entry invalid- go back to user
                       }

                       putc(selection,COM_A);  //input screen to reenter aisle

                       goto end2;
                       break;

          case 5:    putc('2',COM_A);
                     clear();
                     if(indicate==1)
                        out_LCD_string(operate_home);
                     else
                        out_LCD_string(operate);

                     goto end2;
                     break;
      } //end switch statement
   } //end cursor=1 if statement

   if(cursor==2)
   {
      switch(screen_number){
            case 1:  cursor_position(0x83);
                     out_LCD_string(string4);   //verify choice 2 on menu
```

```
                        break;
             case 2:  putc('7');
                        clear();
                        out_LCD_string(home);
                        delay_ms(1000);
                        clear();
                        out_LCD_string(operate_home);
                        screen_number=5;
                        keypress=1;
                        indicate=1;
                        goto end2;
                        break;
      }
   }

    cursor_position(0x97);
    out_LCD_string(string5);
    cursor_position(0x97);
    screen_number=2;

end2:    cursor=1;
}

void cursor_position(int position)
{
      output_low(PIN_A2);   //enable pin
      output_low(PIN_A3);   //R/W
      output_low(PIN_A1);   //RS

      output_b(position);      //move cursor to beginning of line 1(up arrow)
      output_high(PIN_A2);   //0x02 beginning position of line 1
      output_Low(PIN_A2);      //0x94 beginning position of line 2
      delay_ms(50);
}

void transmit(void)
{

    if(aisle_number[0]=='0'){

       if(aisle_number[1]=='0'){
           if(aisle_number[2]=='2' && choice==1){
              selection=0x31;
              status=0;
              goto en;
           }
           else if(aisle_number[2]=='3' && choice==1){
              selection=0x32;
              status=0;
              goto en;
           }
           else if(aisle_number[2]=='2' && choice==2){
              selection=0x33;
              status=0;
              goto en;
           }
           else if(aisle_number[2]=='3' && choice==2){
              selection=0x34;
              status=0;
              goto en;
           }

       }
```

FORKLIFT

C:\Documents and Settings\Joshua\Desktop\senior project\EET404\Final Software Program\test
```
#include "C:\Documents and Settings\CHOUA\Desktop\user interface\track\adc2.h"

void left_motor(int msbb, int lsbb);
void right_motor(int msb, int lsb);
void stop(void);
void tilt(void);
int adc(int channel);
void tilt_back(void);
void tilt_forward(void);
void lower_fork(void);
void lift_fork(void);
void straight(void);
void pick_pallet(void);
void slow_straight(void);
void turn(int a, int b);
void turn_around(void);
void time_off(void);
void range_finder_check(void);
void pallet_detect(void);
void place_pallet(void);
void place_reverse(void);
void keypad_stop(void);
void return_home(void);
void parking(void);
void dock(void);
void straight_left_turn(void);
void aisle_lane(void);
void btwn_int2_int1(void);


void adc(void);
void i2c_dly(void);
void i2c_start(void);
void i2c_stop(void);
unsigned char i2c_rx(char ack);
int1 i2c_tx(unsigned char d);
void range_finderf(void);
void range_finderb(void);
void neutral(void);
void reverse(void);




int lightsensor1=0;
int rangehigh1=0;
int rangelow1=0;
int status=0;
int front_left;
int front_right;
int number=0;          //keep track of cross line
int rright_sensor;     //sensor #4,PIN_E1
int lleft_sensor;      //sensor #8,PIN_D7
int center_right;      //sensor #5
int center_left;       //sensor #6
int position=0x6B;
int keypad='0';
int checking=0;
int choice=0;
int verify=0;
int int_time=0;
int home=0;
```

```
C:\Documents and Settings\Joshua\Desktop\senior project\EET404\Final Software Program\test
#int_RDA
RDA_isr()
{


   checking=getc();


   int_time=get_timer0();


   if(checking=='Y')
   {
   }

   else if(checking==0x31 || checking==0x32 || checking==0x33 || checking==0x3
   {
      delay_us(10);
      putc('1');
      delay_us(10);
      choice=checking;
   }
   else if(checking=='2')      //user selects choice to proceed with program
   {
   }

   else if(checking=='5')      //stop button on keypad has been press
   {
     putc('5');            //send signal to user to confirmed forklift has
     keypad_stop();
   }//received the stop signal

   else if(checking=='7')
      home=1;



   set_timer0(int_time);

}

void main()
{



   ext_int_edge(H_TO_L);
   setup_adc_ports(AN0_AN1_AN3);
   setup_adc(ADC_CLOCK_DIV_8);
   setup_psp(PSP_DISABLED);
   setup_spi(FALSE);
   setup_wdt(WDT_OFF);
   setup_timer_0(RTCC_INTERNAL|RTCC_DIV_256);
   setup_timer_1(T1_INTERNAL|T1_DIV_BY_8);
   setup_timer_2(T2_DISABLED,0,1);
   setup_timer_3(T3_DISABLED|T3_DIV_BY_1);
   enable_interrupts(INT_RDA);
   enable_interrupts(GLOBAL);
//   setup_oscillator(False);

   delay_ms(700);
   stop();
```

```
   putc('T',COM_A);

repeat:
   if(checking=='Y')
      goto prog;
   else
      goto repeat;

prog:
   range_finderf();
   tilt();

   lower_fork();                //position forks (1.5" above ground)at the
   lift_fork();                 //start of program
   neutral();

prog1:

   status=0;

   number=1;



//start from home to pick pallet from docking area and place on aisle2
//then go back home
if(choice==0x31){

loop1:
   tilt();

   if(home==1)
   {
      stop();

      goto hm;
   }

   rright_sensor=input_state(PIN_D4);      //check for intersection
   lleft_sensor=input_state(PIN_D7);

   if(rright_sensor==true && lleft_sensor==true)
      number++;

   switch(number){
        case 1: range_finderf();
                straight();
                break;
        case 2: turn(0x00,0x74);
                break;
        case 3: range_finder_check();
                lleft_sensor=input_state(PIN_D7);
                if(lleft_sensor==true){
                    stop();
                    putc('6');
                    delay_ms(100);
                }

                else
                    straight();
                 break;
```

```
C:\Documents and Settings\Joshua\Desktop\senior project\EET404\Final Software Program\test
        case 4:  pallet_detect();
                 break;
        case 5:  range_finderf();
                 straight();
                 break;
        case 6:  straight();
                 time_off();
                 number++;
                 break;
        case 7:  range_finderf();
                 straight();
                 break;
        case 8:  turn(0x01,0x0A); //right turn
                 break;
        case 9:  range_finderf();
                 lleft_sensor=input_state(PIN_D7);
                 if(lleft_sensor==true){
                    straight();
                    number++;
                 }

                 else
                    straight();
                 break;
        case 10: place_reverse();
                 break;
        case 11: range_finderf();
                 straight();
                 break;
        case 12: turn(0x00,0x74);
                 break;
        case 13: range_finderf();
                 straight();
                 break;
        case 14: turn(0x00,0x74);
                 break;
        case 15: range_finderf();
                 straight();
                 lleft_sensor=input_state(PIN_D7);
                 if(lleft_sensor==true)
                    number++;
                 break;
        case 16: range_finderf();
                 turn_around();
                 number++;
                 break;
        case 17: rright_sensor=input_state(PIN_D4);
                 if(rright_sensor==true){
                     stop();
                     delay_ms(100);
                     number++;
                     status=0;
                 }
                 else
                    straight();
                 break;
        case 18: range_finderb();
                 lleft_sensor=input_state(PIN_D7);
                 if(lleft_sensor==true){
                    stop();
                    number++;
                 }
                 else
```

```
                    reverse();
                 break;
        case 19: stop();
                 putc('D');
                 choice=0;
                 goto prog1;
                 break;


   }

   goto loop1;
}


else if(choice==0x32){

loop50:
   tilt();

   if(home==1)
   {
      stop();

      goto hm;
   }

   rright_sensor=input_state(PIN_D4);      //check for intersection
   lleft_sensor=input_state(PIN_D7);

   if(rright_sensor==true && lleft_sensor==true)
      number++;

//start from home to pick up pallet from dock area and place it on aisle3. The
//go to home.

   switch(number){
        case 1: range_finderf();
                straight();
                break;
        case 2: turn(0x00,0x74);
                break;
        case 3: range_finder_check();
                lleft_sensor=input_state(PIN_D7);
                if(lleft_sensor==true)
                {
                    stop();
                    putc('6');
                    delay_ms(100);
                }

                else
                    straight();
                 break;
        case 4:  pallet_detect();
                 break;
        case 5:  range_finderf();
                 straight();
                 break;
        case 6:  straight();
                 time_off();
                 number++;
                 break;
```

```
        case 7:  range_finderf();
                 straight();
                 break;
        case 8:  straight();
                 time_off();
                 number++;
                 break;
        case 9:  range_finderf();
                 straight();
                 break;
        case 10:  turn(0x01,0x0A); //right turn
                 break;
        case 11:  range_finderf();
                 lleft_sensor=input_state(PIN_D7);
                 if(lleft_sensor==true){
                    straight();
                    number++;
                 }

                 else
                    straight();
                 break;
        case 12: place_reverse();
                 break;
        case 13: range_finderf();
                 straight();
                 break;
        case 14: turn(0x00,0x74);
                 break;
        case 15: range_finderf();
                 straight();
                 break;
        case 16: straight();
                 time_off();
                 number++;
                 break;
        case 17: range_finderf();
                 straight();
                 break;
        case 18: turn(0x00,0x74);
                 break;
        case 19: range_finderf();
                 straight();
                 lleft_sensor=input_state(PIN_D7);
                 if(lleft_sensor==true)
                    number++;
                 break;
        case 20: range_finderf();
                 turn_around();
                 number++;
                 break;
        case 21: rright_sensor=input_state(PIN_D4);
                 if(rright_sensor==true){
                     stop();
                     delay_ms(100);
                     number++;
                     status=0;
                 }
                 else
                    straight();
                 break;
        case 22: range_finderb();
                 lleft_sensor=input_state(PIN_D7);
```

```
                if(lleft_sensor==true){
                   stop();
                   number++;
                }
                else
                   reverse();
                break;
        case 23: stop();
                putc('D');
                choice=0;
                goto prog1;
                break;
   }

   goto loop50;
}



else if(choice==0x33){
loop51:
   tilt();

   if(home==1)
   {
      stop();

      goto hm;
   }

   rright_sensor=input_state(PIN_D4);      //check for intersection
   lleft_sensor=input_state(PIN_D7);

   if(rright_sensor==true && lleft_sensor==true)
      number++;

//start from home to pick up pallet from aisle 2 and place it on dock. Then go
//to home.
   switch(number)
   {
        case 1: range_finderf();         //start from home
                straight();
                break;
        case 2: turn(0x01,0x0A);         //turn right toward aisle
                break;
        case 3: range_finderf();
                straight();
                break;
        case 4: turn(0x01,0x0A);         // turn into aisle 2
                break;
        case 5: range_finder_check();
                lleft_sensor=input_state(PIN_D7);
                if(lleft_sensor==true)
                {
                    stop();
                    putc('6');
                    delay_ms(100);
                }

                else
                    straight();
                break;
        case 6: pallet_detect();         //pick pallet and turn around
```

```
            break;
        case 7: range_finderf();
            straight();
            break;
        case 8: turn(0x00,0x74);         //turn left toward docking area
            break;
        case 9: range_finderf();
            straight();
            break;
        case 10:straight();              //pass thru intersection
            time_off();
            number++;
            break;
        case 11: range_finderf();
            lleft_sensor=input_state(PIN_D7);   //check for empty dock are
            if(lleft_sensor==true){
               straight();
               number++;
            }
            else
               straight();
            break;
        case 12: place_reverse();         //place pallet and turn around
             break;
        case 13: range_finderf();
             straight();
             break;
        case 14: turn(0x01,0x0A);         //turn right toward home
             break;
        case 15: range_finderf();
             straight();
             lleft_sensor=input_state(PIN_D7);  //check for home position
             if(lleft_sensor==true)
                number++;
             break;
        case 16: range_finderf();
             turn_around();         //turn 180 degree
             number++;
             break;
        case 17: rright_sensor=input_state(PIN_D4);
             if(rright_sensor==true){
                 stop();               //straighten out forklift
                 delay_ms(100);
                 number++;
                 status=0;
             }
             else
                straight();
             break;
        case 18: range_finderb();            //reverse to home position
             lleft_sensor=input_state(PIN_D7);
             if(lleft_sensor==true){
                stop();
                number++;
             }
             else
                reverse();
             break;
        case 19: stop();                    //stop and wait for instruction
             putc('D');
             choice=0;
             goto prog1;
             break;
```

```
   }
   goto loop51;
}


else if(choice==0x34){
loop52:
   tilt();

   if(home==1)
   {
      stop();

      goto hm;
   }

   rright_sensor=input_state(PIN_D4);      //check for intersection
   lleft_sensor=input_state(PIN_D7);

   if(rright_sensor==true && lleft_sensor==true)
      number++;
//start from home to pick pallet from aisle 3 and place it on dock. Then go to
//home.
    switch(number)
   {
        case 1: range_finderf();         //start from home
                straight();
                break;
        case 2: turn(0x01,0x0A);         //turn right toward aisle
                break;
        case 3: range_finderf();
                straight();
                break;
        case 4: straight();
                time_off();
                number++;
                break;
        case 5: range_finderf();
                straight();
                break;
        case 6: turn(0x01,0x0A);         // turn into aisle 2
                break;
        case 7: range_finder_check();
                lleft_sensor=input_state(PIN_D7);
                if(lleft_sensor==true)
                {
                    stop();
                    putc('6');
                    delay_ms(100);
                }

                else
                    straight();
                break;
        case 8: pallet_detect();         //pick pallet and turn around
                break;

        case 9: range_finderf();
                straight();
                break;
        case 10: turn(0x00,0x74);         //turn left toward docking area
                break;
        case 11: range_finderf();
```

```
               straight();
               break;
        case 12:straight();              //pass thru intersection
               time_off();
               number++;
               break;
        case 13: range_finderf();
               straight();
               break;
        case 14:straight();              //pass thru intersection
               time_off();
               number++;
               break;
        case 15: range_finderf();
               lleft_sensor=input_state(PIN_D7);   //check for empty dock are
               if(lleft_sensor==true){
                  straight();
                  number++;
               }
               else
                  straight();
               break;
        case 16: place_reverse();         //place pallet and turn around
                 break;
        case 17: range_finderf();
                 straight();
                 break;
        case 18: turn(0x01,0x0A);         //turn right toward home
                 break;
        case 19: range_finderf();
                 straight();
                 lleft_sensor=input_state(PIN_D7);  //check for home position
                 if(lleft_sensor==true)
                    number++;
                 break;
        case 20: range_finderf();
                 turn_around();         //turn 180 degree
                 number++;
                 break;
        case 21: rright_sensor=input_state(PIN_D4);
                 if(rright_sensor==true){
                     stop();               //straighten out forklift
                     delay_ms(100);
                     number++;
                     status=0;
                 }
                 else
                    straight();
                 break;
        case 22: range_finderb();            //reverse to home position
                 lleft_sensor=input_state(PIN_D7);
                 if(lleft_sensor==true){
                    stop();
                    number++;
                 }
                 else
                    reverse();
                 break;
        case 23: stop();                    //stop and wait for instruction
                 putc('D');
                 choice=0;
                 goto prog1;
                 break;
```

```
C:\Documents and Settings\Joshua\Desktop\senior project\EET404\Final Software Program\test
   }
    goto loop52;
}


  goto prog1;

hm:  return_home();
  goto prog1;



}


void i2c_dly(void){
}

void i2c_start(void)
{
   output_high(SDA);
   i2c_dly();
   output_high(SCL);
   i2c_dly();

   output_low(SDA);
   i2c_dly();
   output_LOW(SCL);
   i2c_dly();
}

void i2c_stop(void)
{
   output_low(SDA);
   i2c_dly();
   output_high(SCL);
   i2c_dly();
   output_high(SDA);
   i2c_dly();
}

unsigned char i2c_rx(char ack)
{
   char x, d=0;
   int portc4=0;

   output_high(SDA);

   for(x=0;x<8;x++)
   {
      d<<=1;
      do{
         output_high(SCL);
         portc4 = input_state(SCL);
      }

      while(portc4==0);
      i2c_dly();
      if(input_state(SDA))
         d |=1;
      output_low(SCL);
   }
   if(ack)
```

```
C:\Documents and Settings\Joshua\Desktop\senior project\EET404\Final Software Program\test
   output_low(SDA);
   else
   output_high(SDA);
   output_high(SCL);
   i2c_dly();
   output_low(SCL);
   output_high(SDA);
   return d;
}

int1 i2c_tx(unsigned char d)
{
   char x;
   static int1 b;
      for(x=8; x; x--)
      {
         if(d&0x80)
            output_high(SDA);
         else
            output_low(SDA);
            output_high(SCL);
            d<<=1;
            output_low(SCL);
      }

      output_high(SDA);
      output_high(SCL);
      i2c_dly();
      b=input_state(SDA);
      output_low(SCL);
      return b;
}

void range_finderb(void)
{
   checking=0;

   i2c_start();      //send start sequence
   i2c_tx(0xE2);     //SRF02 I2C address with R/W bit clear
   i2c_tx(0x00);     //SRF02 command register address
   i2c_tx(0x50);     //command to start ranging in inch
   i2c_stop();       //send stop sequence

   delay_ms(70);

   i2c_start();      //send start sequence
   i2c_tx(0xE2);     //SRF02 I2C address with R/W bit clear
   i2c_tx(0x01);     //SRF02 light sensor register address
   i2c_start();      //send a restart sequence
   i2c_tx(0xE3);     //SRF02 I2C address with R/W bit set

   lightsensor1=i2c_rx(1);   //get light sensor and send acknowledge.
                            //internal register address will increment automati
   rangehigh1=i2c_rx(1);   //get the high byte of the range and send acknowled
   rangelow1=i2c_rx(0);      //get low byte of the range-note we don't
                            //acknowledge the last byte.
   i2c_stop();

   if(rangelow1<28 && rangelow1>7){
     stop();              //E2: stop the motors
     status=0;
     putc('3');
chk6:
```

```
C:\Documents and Settings\Joshua\Desktop\senior project\EET404\Final Software Program\test
     if(checking=='2' || checking=='7')
     {
     }
     else
      goto chk6;

   }
}

void range_finder_check(void)
{
   int lightsensor=0;
   int rangehigh=0;
   int rangelow=0;
   checking=0;

   i2c_start();      //send start sequence
   i2c_tx(0xE0);     //SRF02 I2C address with R/W bit clear
   i2c_tx(0x00);     //SRF02 command register address
   i2c_tx(0x50);     //command to start ranging in inch
   i2c_stop();       //send stop sequence

   delay_ms(70);
   //read the light sensor value from register 1 and the range result from
   //registers 2 & 3.

   i2c_start();      //send start sequence
   i2c_tx(0xE0);     //SRF02 I2C address with R/W bit clear
   i2c_tx(0x01);     //SRF02 light sensor register address
   i2c_start();      //send a restart sequence
   i2c_tx(0xE1);     //SRF02 I2C address with R/W bit set

   lightsensor=i2c_rx(1);   //get light sensor and send acknowledge.
                            //internal register address will increment automati
   rangehigh=i2c_rx(1);   //get the high byte of the range and send acknowledg
   rangelow=i2c_rx(0);      //get low byte of the range-note we don't
                           //acknowledge the last byte.
   i2c_stop();


  if(rangelow<28 && rangelow>7){
    stop(); //E0: stop the motors
    number++;
    putc('2');
chk4:
    if(checking=='2' || checking=='7')
    {
       putc('8');
    }
    else
      goto chk4;

   }

}

void pallet_detect(void)
{
      pick_pallet();

bk4:
      range_finderb();
      reverse();
```

```
      lleft_sensor=input_state(PIN_D7);
      if(lleft_sensor==true)
         turn_around();
      else
         goto bk4;

  status=0;
  number++;
}

void range_finderf(void)
{
   int lightsensor=0;
   int rangehigh=0;
   int rangelow=0;
   checking=0;


   i2c_start();      //send start sequence
   i2c_tx(0xE0);     //SRF02 I2C address with R/W bit clear
   i2c_tx(0x00);     //SRF02 command register address
   i2c_tx(0x50);     //command to start ranging in inch
   i2c_stop();       //send stop sequence

   delay_ms(70);
   //read the light sensor value from register 1 and the range result from
   //registers 2 & 3.

   i2c_start();      //send start sequence
   i2c_tx(0xE0);     //SRF02 I2C address with R/W bit clear
   i2c_tx(0x01);     //SRF02 light sensor register address
   i2c_start();      //send a restart sequence
   i2c_tx(0xE1);     //SRF02 I2C address with R/W bit set

   lightsensor=i2c_rx(1);   //get light sensor and send acknowledge.
                            //internal register address will increment automati
   rangehigh=i2c_rx(1);   //get the high byte of the range and send acknowledg
   rangelow=i2c_rx(0);      //get low byte of the range-note we don't
                            //acknowledge the last byte.
   i2c_stop();


  if(rangelow<28 && rangelow>7){
    stop();              //E0: stop the motors
    status=0;
    putc('2');
chk5:
     if(checking=='2' || checking=='7')
     {
     }
     else
         goto chk5;

   }

}


void left_motor(int msbb, int lsbb)
{
   putc(0x80,COM_B);   //synchronization
   putc(0x01,COM_B);   //device ID (8 servos) = 0x01
```

```
C:\Documents and Settings\Joshua\Desktop\senior project\EET404\Final Software Program\test
   putc(0x03,COM_B);   //command 3: set position (8bits)
   putc(0x07,COM_B);   //servo number
   putc(msbb,COM_B);   //MSB
   putc(lsbb,COM_B);   //7-bits LSB (right), 6B
}


void right_motor(int msb, int lsb)
{
   putc(0x80,COM_B);  //synchronization
   putc(0x01,COM_B);   //device ID (8 servos) = 0x01
   putc(0x03,COM_B);   //command 3: set position (8bits)
   putc(0x01,COM_B);   //servo number
   putc(msb,COM_B);   //MSB
   putc(lsb,COM_B);   //7-bits LSB (left),95
}

void stop(void)
{
   putc(0x80,COM_B);  //synchronization
   putc(0x01,COM_B);   //device ID (8 servos) = 0x01
   putc(0x03,COM_B);   //command 3: set position (8bits)
   putc(0x01,COM_B);   //servo number
   putc(0x00,COM_B);   //MSB
   putc(0x7F,COM_B);   //7-bits LSB, central (127)

   delay_ms(20);

   putc(0x80,COM_B);  //synchronization
   putc(0x01,COM_B);   //device ID (8 servos) = 0x01
   putc(0x03,COM_B);   //command 3: set position (8bits)
   putc(0x07,COM_B);   //servo number
   putc(0x00,COM_B);   //MSB
   putc(0x7F,COM_B);   //7-bits LSB, central (127)
}

void tilt(void)
{

   if(input_state(PIN_C4)==0)
   {
      stop();
      status=0;
      putc('4');
chk7:
      if(checking!='2')
         goto chk7;
   }

}

int adc(int channel)
{
    int value=0;

    set_adc_channel(channel);
    delay_us(15);
    value=read_adc();

    return value;
}

void tilt_back(void)
```

```
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{
   int position_upper=0;
   int position_lower=0;
// maximum tilt back of the fork.
loop11:
   if(position<0xDE)
   {
      if(position>0x7F)
      {
         position_upper=0x01;
         position_lower=0x7F&position;
      }
      else{
         position_upper=0;
         position_lower=position;
      }


      putc(0x80,COM_B);   //synchronization
      putc(0x01,COM_B);   //device ID (8 servos) = 0x01
      putc(0x03,COM_B);   //command 3: set position (8bits)
      putc(0x03,COM_B);   //servo number
      putc(position_upper,COM_B);   //MSB
      putc(position_lower,COM_B);   //7-bits LSB (right), 0xDF (maximum tilt b

      position=position+0x0F;
      delay_ms(250);
      goto loop11;
   }

}

void tilt_forward(void)
{
   int position_upper=0;
   int position_lower=0;

loop12:
   if(position>0x6B)
   {
      if(position>0x7F)
      {
         position_upper=0x01;
         position_lower=0x7F&position;
      }
      else{
         position_upper=0;
         position_lower=position;
      }

// maximum tilt forward of the fork.
      putc(0x80,COM_B);   //synchronization
      putc(0x01,COM_B);   //device ID (8 servos) = 0x01
      putc(0x03,COM_B);   //command 3: set position (8bits)
      putc(0x03,COM_B);   //servo number
      putc(position_upper,COM_B);   //MSB
      putc(position_lower,COM_B);   //7-bits LSB (right), 6B

      position=position-5;
      delay_ms(250);
      goto loop12;
   }
}
```

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```
void lower_fork(void)
{
    int fork_status=0;
    int fork=0;

keep_lowering:

    fork_status=input_state(PIN_A2);

// if the fork is at its minimum position, the switch is turned on (giving
// 4-5V). If the fork is not at its minimum position, the switch will give a
// reading below 0.5V. The PIC does not compare analog, so first the input val
// from the switch needs to be converted to digital. We used the PIC A/D
// converter. The PIC18F452 A/D has 10 bits. We can used 8-bit or 10-bit. In
// this case, we are using 8-bit. Any reading from the switch that give out
// voltage greater than 4V (0xCC- digital equivalent) will stop the fork from
// lowering down.

    if(fork_status==true)
    {
       if(fork !=0)
          output_low(PIN_D1);    //stop lowering fork
       fork=0;
    }
    else
    {
       if(fork != 1)
          output_high(PIN_D1);

       fork=1;
       goto keep_lowering;
    }


}

void lift_fork(void)
{
   output_high(PIN_D0);
   delay_ms(750);
   output_low(PIN_D0);
}

void straight(void)
{

// To go forward, the two front IR sensors are used. Read front two sensors
    front_left=input_state(PIN_A5);       //#2 sensor
    front_right=input_state(PIN_A4);      //#1 sensor

// check front sensors state and apply corrective actions
      if(front_left==true && front_right==true)
      {
        if(status !=1)
        {
           right_motor(0x00,0x6B);      //6B
           delay_ms(20);
           left_motor(0x01,0x13);      //250//95
        }

      status=1;
      }
```

```
      if(front_left==false && front_right==true)
      {
         if(status != 2)
         {
            right_motor(0x00,0x78);
            delay_ms(20);
            left_motor(0x01,0x13);
         }
      status=2;
      }

      if(front_left==true && front_right==false)
      {
         if(status !=3)
         {
            right_motor(0x00,0x6B);     //6B
            delay_ms(20);
            left_motor(0x01, 0x0E);
         }
         status=3;
      }

   // if both sensors go off the white line, the forklift will try to find the
   // line again, by turning in the direction of the sensor that last seen the
   // line. The positions of the sensors are stored in memory. If both sensors
   // see the line and both go off the line simultaneously, then the forklift
   // perpendicular to the line. This defeat the purpose of following a line.
   // Thus, the forklift will stop.

       if(front_right==false && front_left==false)
       {

         switch(status){
            case 1: stop();
                    break;

            case 2: right_motor(0x00, 0x78);   // stop right motor
                    delay_ms(20);
                    left_motor(0x01, 0x13);
                    break;

            case 3: right_motor(0x00, 0x75);
                    delay_ms(20);
                    left_motor(0x01, 0x06);   //slow down left motor
                    break;
         } //end switch statement

       } //end if statement
}

void pick_pallet(void)
{
  int value=0;      //left fork IR sensor
  int value1=0;     //right fork IR sensor
  int pushbuttonR=0;

  status=0;

loop4:
  straight();

  value = adc(0);
```

```
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  value1 = adc(1);

  if(value>0xCC || value1>0xCC) // 0x99=3V, 0xCC=4V
    {
       stop();
       delay_ms(10);
       lower_fork();

loop3:
       pushbuttonR=input_state(PIN_C0);  //read the side button on fork

       if(pushbuttonR==true)    //check to see if pallet is completely
       {                                 //on the forks before it is pick up
         stop();
         lift_fork();
         delay_ms(100);
         tilt_back();
         status=0;

       }

       else
       {
         status=0;
         slow_straight();
         goto loop3;
       }
    }

  else
    goto loop4;
}

void reverse(void)
{

// To go forward, the two front IR sensors are used. Read front two sensors
   center_right=input_state(PIN_D5);  //#5 sensor
   center_left=input_state(PIN_D6);

// check front sensors state and apply corrective actions
      if(center_left==true && center_right==true)
      {
        if(status !=1)
        {
           right_motor(0x01,0x0E);      //6B
           delay_ms(20);
           left_motor(0x00,0x70);      //250//95
        }

      status=1;
      }

      if(center_left==false && center_right==true)
      {
         if(status != 2)
         {
            right_motor(0x00,0x7F);
            delay_ms(20);
            left_motor(0x00,0x70);
         }
         status=2;
      }
```

```
      if(center_left==true && center_right==false)
      {
         if(status !=3)
         {
            right_motor(0x01,0x0E);     //6B
            delay_ms(20);
            left_motor(0x00, 0x7F);
         }
         status=3;
      }

   // if both sensors go off the white line, the forklift will try to find the
   // line again, by turning in the direction of the sensor that last seen the
   // line. The positions of the sensors are stored in memory. If both sensors
   // see the line and both go off the line simultaneously, then the forklift
   // perpendicular to the line. This defeat the purpose of following a line.
   // Thus, the forklift will stop.

       if(center_right==false && center_left==false)
       {

         switch(status){
            case 1: stop();
                    break;

            case 2: right_motor(0x00, 0x7F);   // stop right motor
                    delay_ms(20);
                    left_motor(0x00, 0x70);
                    break;

            case 3: right_motor(0x01, 0x0E);
                    delay_ms(20);
                    left_motor(0x00, 0x7F);   //slow down left motor
                    break;
         } //end switch statement

       } //end if statement
}

void slow_straight(void)
{

// To go forward, the two front IR sensors are used. Read front two sensors
    front_left=input_state(PIN_A5);
    front_right=input_state(PIN_A4);

// check front sensors state and apply corrective actions
      if(front_left==true && front_right==true)
      {
        if(status !=1)
        {
           right_motor(0x00,0x78);      //6B
           delay_ms(20);
           left_motor(0x01,0x06);      //250//95
        }

      status=1;
      }

      if(front_left==false && front_right==true)
      {
         if(status != 2)
```

```
         {
            right_motor(0x00,0x7F);
            delay_ms(20);
            left_motor(0x01,0x06);
         }
      status=2;
      }

      if(front_left==true && front_right==false)
      {
         if(status !=3)
         {
            right_motor(0x00,0x78);     //6B
            delay_ms(20);
            left_motor(0x00, 0x7F);
         }
         status=3;
      }

   // if both sensors go off the white line, the forklift will try to find the
   // line again, by turning in the direction of the sensor that last seen the
   // line. The positions of the sensors are stored in memory. If both sensors
   // see the line and both go off the line simultaneously, then the forklift
   // perpendicular to the line. This defeat the purpose of following a line.
   // Thus, the forklift will stop.

       if(front_right==false && front_left==false)
       {

         switch(status){
            case 1: stop();
                    break;

            case 2: right_motor(0x00, 0x7F);   // stop right motor
                    delay_ms(20);
                    left_motor(0x01, 0x06);
                    break;

            case 3: right_motor(0x00, 0x78);
                    delay_ms(20);
                    left_motor(0x00, 0x7F);   //slow down left motor
                    break;
         } //end switch statement

       } //end if statement
}

void neutral(void)
{
   putc(0x80,COM_B);   //synchronization
   putc(0x01,COM_B);   //device ID (8 servos) = 0x01
   putc(0x03,COM_B);   //command 3: set position (8bits)
   putc(0x03,COM_B);   //servo number
   putc(0x00,COM_B);   //MSB
   putc(0x6B,COM_B);
}




void turn(int a, int b)
{
      int count=59;
```

```
loop10:
      right_motor(a,b);   // stop right motor
      delay_ms(20);
      left_motor(a,b);

      if(count==0){

         front_left=input_state(PIN_A5);
         front_right=input_state(PIN_A4);

         if(front_left==true || front_right==true)
         {
             status=2;
             time_off();
         }
         else
         {
             count=3;
             goto loop10;
         }

      }

     else
     {
         count--;
         goto loop10;
     }
     number++;
}

void turn_around(void)
{
      int count=60;

loop12:      right_motor(0x01,0x08);   // stop right motor
      delay_ms(20);
      left_motor(0x01, 0x08);

      if(count==0){

         front_left=input_state(PIN_A5);
         front_right=input_state(PIN_A4);

         if(front_left==true || front_right==true)
         {
          status=2;
          straight();
         }
         else{
            count=3;
            goto loop12;
         }

      }
      else{
         count--;
         goto loop12;
      }
```

```
}

void time_off(void)
{
    int timer=50;    //timer=2.5 seconds
    int time=0;

    set_timer0(1);

    while(timer !=0){
             time=get_timer0();
             straight();

             if(time==0)
             {   set_timer0(1);
                 timer--;
             }
    }
}

void place_pallet(void)
{
b:   rright_sensor=input_state(PIN_D4);

   if(rright_sensor==false){
      straight();
      goto b;
   }


   else{
      stop();

      tilt_forward();
      delay_ms(500);
      lower_fork();
      delay_ms(500);
      status=0;
   }

}

void place_reverse(void)
{
      place_pallet();

bk4:
      range_finderb();
      reverse();

      lleft_sensor=input_state(PIN_D7);
      if(lleft_sensor==true)
      {
         stop();
         lift_fork();
         neutral();
         delay_ms(100);
         turn_around();
      }

      else
         goto bk4;
```

```
  status=0;
  number++;
}

void keypad_stop(void)
{

     stop();
     status=0;
lpf:
     checking=getc();

     if(checking=='2')
     {
     }
     else if(checking=='7')
        home=1;

     else
      goto lpf;

}

void return_home(void)
{
   status=0;
   if(number==1)
   {

rp:   range_finderb();            //reverse to home position
      lleft_sensor=input_state(PIN_D7);
      if(lleft_sensor==true){
         stop();
          putc('D');
          choice=0;
      }
      else{
          reverse();
          goto rp;
      }
   }

   else if(choice==0x31 || choice==0x32)
   {
      if(number==3 || number==4)
          dock();
   }

   else if(choice==0x33)
   {
      if(number==5 || number==6)
      {
         aisle_lane();
         straight_left_turn();
      }

   }

   else if(choice==0x33 || choice==0x34)
   {
      if(number==3)
         btwn_int2_int1();
```

APPENDIX C