Project Proposal and Feasibility Study

ATTACH

(Automatic Trailer Tracking and Car Hitching System)

Calvin College
ENGR 339/340

Senior Design Team 5
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Abstract

Several drivers face difficulties aligning their vehicles in order to hitch unto their trailers. It is with the goal of making this process easier and hassle free that team ATTACH has taken up the project to design and develop a navigation/guidance system to aid with the hitching process. The ATTACH system will include a display that will aid the driver in navigating the vehicle towards the hitch in order to align the hitch system of the vehicle with that of the trailer. In addition the display will provide an indication of the remaining distance between the vehicle and the trailer as well as obstacle detection and warning. These features incorporated together will ease the entire hitching process by reducing the number of attempts considerably. Research into the feasibility of implementing this design will not be bounded to a prototype model but marketing and distribution information would be sought for a production model. The team is currently looking at marketing the final product at a national level within the United States. After some research and market survey it was estimated that there exists an estimate of over forty million possible customers for the product. This target customer population establishes a promising market potential for this product. Team ATTACH is currently on schedule and is in the initial testing phase of the various components of the system. The team is currently on track to have a prototype of the product ready and functioning by senior design banquet night in the spring semester.

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1. Introduction

Anyone who has attached a trailer of any size to their vehicle would understand how difficult and frustrating the entire process can be. This often begins with several attempts on the part of the driver to align the ball on the car with the hitch on the trailer. The driver in making these attempts often rely on others to guide them in the process. This is usually followed by attaching both ball and hitch together only after a successful attempt. This describes the difficulty faced by people who use trailers for various purposes.

ATTACH (Automatic Trailer Tracking and Car Hitching System) system basically provides navigational aid to assist with aligning the trailer hitch system with that of a vehicle. The system features include a navigation aid and distance measurement display, and an obstacle detection and warning system which would detect the presence of an obstacle between the vehicle and the trailer.

The members of team ATTACH are currently enrolled in ENGR.339/340, which is the capstone course for the engineering program at Calvin College. The design process involves taking the idea from conception through planning, design and implementation of a prototype model.

This report is written for this course as a preliminary analysis of the overall design and feasibility.

Team ATTACH consists of four members: Daniel Ateru (electrical and computer engineering concentration) is from Nigeria in West Africa. Daniel is interested in signal analysis and hardware implementation. UB Essien (electrical and computer engineering concentration) is also from Nigeria. UB's interest is in digital electronics and control systems. Clarence Medema (mechanical engineering concentration) is from Chicago, Illinois. Clarence is interested in thermodynamic and energy conservation. Sumanth Sampath (electrical and computer engineering concentration) is from India, a central Asian country. Sumanth's interest includes power systems, power generation and distributed generation technology.

2. Definition of Terms

Table 2.1. Definition of Terms

ATTACH	Automatic Trailer Tracking And Car Hitching
MCU	Micro controller Unit
LCD	Liquid Crystal Display
LED	Light Emitting Diode
PCB	Printed Circuit Board
IR	Infra Red
NIR	Near Infra Red
ADC	Analog to Digital Converter

3. Design and Educational Objectives

ATTACH hopes to accomplish various design and educational objectives which include learning about the design process and the procurement of a marketable design.

3.1 Objectives and Design Functionality

ATTACH seeks to design a system that navigates the driver of a vehicle to back up the automobile in order to align the hitching system of the automobile with that of the trailer. First and foremost, this device would is estimated to function within a minimum working distance of ten to twelve feet. Therefore drivers would need to have backed up their vehicles within this working distance to have the system run efficiently. The accuracy and precision of this device is an important goal of this design, but aiming for a hundred percent accuracy will add to overall cost of system design. System design will take this key factor into consideration, and a prototype model will be implemented to function with an estimated accuracy of five percent or less. Once the two systems are aligned, an added feature of this system is to measure the remaining distance between the trailer and the vehicle. This design will also incorporate obstacle detection and warning system to ensure that the system operates safely.

3.2 Educational Opportunities

The project is an opportunity for the team members to learn more about controls systems, automation, system and software integration, project planning and implementation, budgeting, teamwork and organization. In addition to learning new material and developing skills, opportunities also exist for members to meet and work with experienced professionals.

3.3 Conditions for Success

Based on the stated objectives, our project will be successful if we achieve the following:

- Electrical Display system
    - Displays the position of the vehicle relative to the hitch on the trailer.
    - Displays the distance between the vehicle and the trailer
    - Directs the driver to accurately align vehicle and trailer.
    - Detects and warns the driver of obstacles.
- Mechanical aspect of this project would include :
    - Packaging product in an aesthetically pleasing form.
    - Designing a test bench for calibration of device.
    - Mounting design for system components.
    - Conduct environmental test on device.

4. Design Norms

During a project or design, a team must take into consideration the applicable design norms. This is important because as Christian engineers, we are called by God to use our talents in the best ways possible and to utilize available resources in a most efficient manner to solve problems. It is also important to consider applicable design norms when carrying out a design because the design affects God's creation in one way or another and we are called to be agents of renewal in our world. It is important that the design focuses on the individual. It is also very important for the design to have positive effects on the creation. The Attach project includes cultural appropriateness, transparency, integrity, caring and trust.

4.1 Cultural Appropriateness

This norm deals primarily with the ability of this system to fit into the culture in which it would be used. The design incorporates optoelectronics and relatively simple and available technology that is currently used in numerous consumer product designs in both developed and developing countries. This assures us that the product will fit well into the cultures which it is planned to be introduced. The user interface is simple and straightforward and would be easily understood by any automobile operator. The system would be initially sold in the United States and would be subsequently introduced to other developed countries that value independence and are accustomed to similar optoelectronic devices. We also acknowledge the impact of cultural differences that exist in different countries. Therefore cultural perceptions would be incorporated into the production phase of the product to provide for a relatively smooth introduction phase, hence building market potential for the product in the global market. The primary source of information to determine feasibility would be through research.

4.2 Caring

The design is caring as it seeks to eliminate the primary frustration experienced by campers during the hitching process. It is also designed to be affordable by any automobile owner.

4.3 Transparency

The design will be as transparent as possible and documentation will be written, explaining the function of each component. Documentation written for the whole design will accurately and reliably indicate to users how the system works. Furthermore, a simplified user's manual would be produced to help consumers understand how to work the system.

4.4 Trust

As Christian engineers, it is our design goal to make this product accurately locate the position of the hook and display the distance between the trailer and the vehicle. Temperature, stress and drop tests would be performed on the system to confirm robustness. The voltages and currents involved in the design are relatively low and present no electrical hazards whatsoever. The IR radiation in use is also harmless. Therefore, the overall design is reliable and safe.

5. Project Alternative Design Solutions

Our system should be able to automatically detect the position of the hitch (Trailer end. see figure 4.1) and successfully steer the vehicle operator in the right direction for a successful hitch. Some wireless communication between the trailer and the vehicle that can accurately locate the position of the hook will be required.

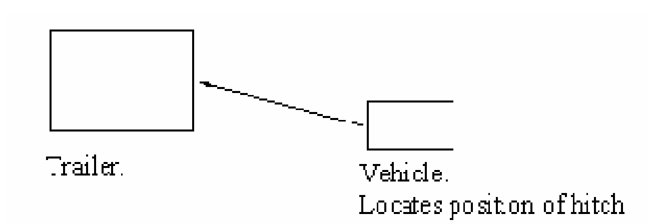


Figure 5.1. Vehicle locating position of Hitch on Trailer

The following design alternatives were considered for the possibility

5.1 Ultrasonic Transducer system:

The ultrasonic transducer system will involve implementing a transceiver at the trailer that dictates the position of the hitch to the display. A rotating ultrasonic transducer with a narrow beam angle sends a signal to the transceiver on the trailer which then reflects the signal back to the hook. A second transducer located above the hook then picks up the signal and relays it to the microcontroller unit which calculates the position of the trailer. The microcontroller then sends the signal to the display unit in the vehicle.

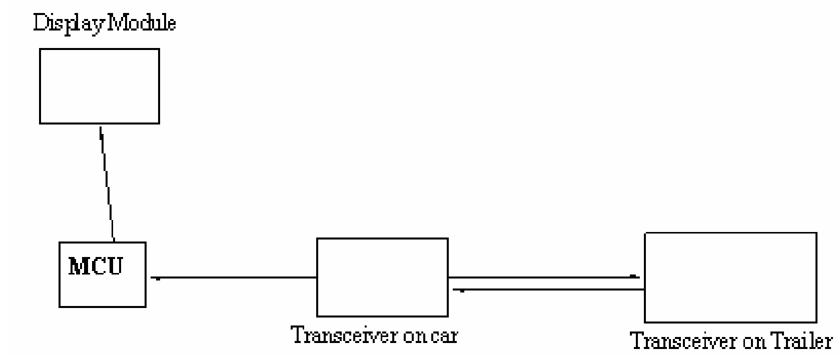


Figure 5.2. Block Diagram for Ultrasonic Transducer System

The primary setback of this design is the cost it incorporates. Also a transducer with a relatively small beam angle (less than five degrees) will be hard

1) Optoelectronic System
2) Camera and Screen system

Table 5.1 Decision Matrix for Design Solution

serial #	Goals	Assigned	Sensor	Summation	Score
1	Determine position	10	Optoelect.	10+10+7+6+8+5=46	85%
2	Measure distance	10	Ultrasonic	5+10+8+5+6+4+5=42	78%
3	Robust	8	Camera	5+5=10	19%
4	Safety	5			
5	Reliability	6			
6	Cost	10			
7	Size	5			
Total		54			

5.2 Optoelectronic System

The optoelectronic system involves the use of infrared light to determine the position of the hitch and the distance between the vehicle and the trailer. A narrow infrared beam perpendicular to the trailer is sent from above the hitch on the trailer to an array of infrared photodiodes. The current emitted from the photodiodes is then sent to a circuit that drives an LED display array. The relative position of the hook on the vehicle to the hitch on the trailer directly corresponds to the lit LED’s on the display. With this information, the driver knows whether to steer the vehicle left or right. The distance between the trailer and the car is determined easily because the proportional relationship exists between photodiodes and light intensity. A proportional relationship also exists between light intensity and distance. The MCU is used for the calibration.

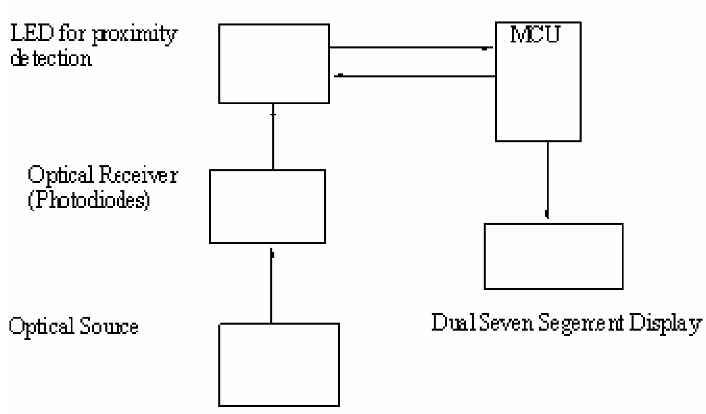


Figure 5.3. Block Diagram for Optoelectronic System

5.3 Decision Matrix for Design Solutions

A decision matrix was used to choose the appropriate design solution.

Table 5.2 Decision Matrix for Design Solution

serial #	Goals	Assigned	Sensor	Summation	Score
1	Determine position	10	Optoelect.	10+10+7+6+8+5=46	85%
2	Measure distance	10	Ultrasonic	5+10+8+5+6+4+5=42	78%
3	Robust	8			
4	Safety	5			
5	Reliability	6			
6	Cost	10			
7	Size	5			
Total		54			

6. Design

The choice of system design for ATTACH is the most important aspect of the project. Two key designs were considered and these include: an ultrasonic system, and optoelectronics. Each of these designs options offered their own benefits, but the final choice of the intended design for ATTACH is optoelectronics.

6.1 Criteria for Selection

The criterion used for selecting an optoelectronic sensor was made based on the initial goals of the design. ATTACH design goals are:

1. Locate the hitch on the trailer.
2. Measure the distance between vehicle and trailer.
3. Cost effective.

The choice of a working principle for ATTACH was made based on Table 4.1 in section six.

6.2 Optoelectronics

Optoelectronics is defined as the study and application of electronic devices that interact with light.[1] Therefore optoelectronic devices are electrical –to-optical and optical-to-electrical transducers or instruments that use these devices for their operation.

6.3 Decision

The criterion for selecting optical components was based on cost.

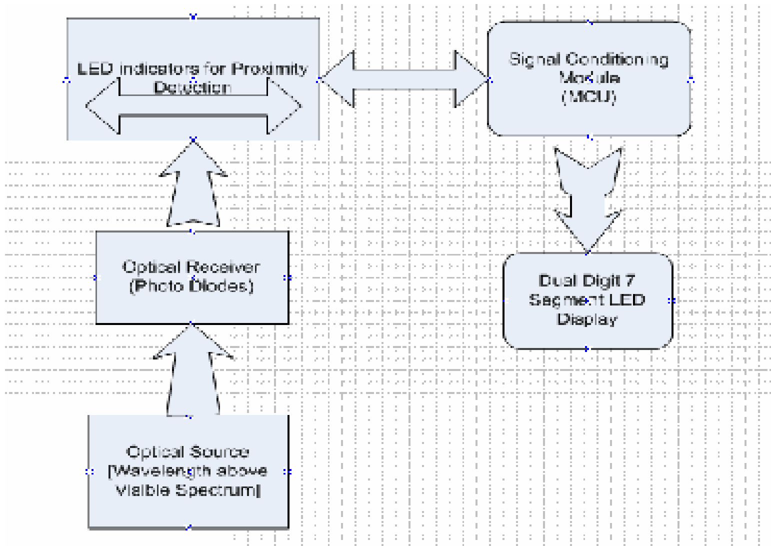


Figure 6.1 Block Diagram of System

6.3.1 Components of System

The components of this system are IR LED, NIR Photodiodes, a microcontroller unit (MCU), 2 digit 7-segment LED display, and 3mm and 5mm visible LEDs.

6.3.2 Mode of Operation

The mode of operation of the prototype can be summarized as:

- Optical source emits light of specific wavelength which is sensed by photodiodes. Photodiode produces voltage proportional to incident light.
- Signal is conditioned and used to drive display.
- Distance from trailer is provided on display. The direction to stir towards is also provided on display.

6.4 Optical System Design

The components of the ATTACH design is made of a Microcontroller unit, an LED display system, and photo diodes.

[1] “optoelectronics”www.wikipedia.org

6.4.1 Power system Requirement

ATTACH system is made up of three modules which are optical source module, a receiver module and a display module. The optical source module will be mounted on the trailer; the receiver module will be mounted behind the vehicle and the display module will be mounted on the dash board of the vehicle. A requirement for the system design is supplying power to these modules so that they can communicate effectively with each other.

6.4.1.1Criteria for Selection

The choice of a power supply system for ATTACH revolved round the following criteria:

1. Power requirement of the system.
2. Current and voltage ratings for system components.
3. Product life cycle.

6.4.1.2 Alternatives

The following alternatives were carefully weighed against each other to select an appropriate power system for ATTACH. These alternatives were:

1. Individually powered modules.
2. Sharing power supply of the vehicle.

6.4.1.3 Decision

Individually powered modules were chosen as the best alternative for this design. The reason for this selection was the advantages that this option had over its alternative. These advantages include:

- Each circuit is distinctively different from the others and would only work best if powered individually.
- Sharing power supply system of vehicle would make system installation and testing more difficult and might involved warrant y and other legal issues.

6.4.2 Micro Controller Unit (MCU)

6.4.2.1 Introduction

The MCU is an integral part of the entire system. It is going to be the brains of the entire system by performing necessary functions such as computing, comparing and driving the display system.

The MCU is going to receive analog signals either in form of current or voltage from the various photodiode sensors and has to perform certain functions with the received signals such as processing the received pulsed signal from the IR LED emitter circuit, comparing the current/voltage received from the various IR photodiodes, computing which photodiode is receiving the maximum signal from the IR LED emitter, computing the remaining distance between the trailer and the vehicle based on the strength of the signal received from the IR LED emitter circuit, converting the analog data to a digital one, and, finally, driving the 2 digit 7-segment display system and the guidance/ obstacle warning LEDs on the display system. The MCU also drives the ultrasonic transducer, which will be used for obstacle detection, and performs the necessary calculations to determine the presence of an obstacle in the path between the trailer and the vehicle.

6.4.2.2 Necessary Specifications of the MCU

There are various specifications that the MCU must meet in order the complete the necessary task requirements. Some of the specifications that the MCU must meet are the following:

1. Must have an A/D converter of 10-bits or more and sufficient input channels
2. Must have one or more comparators
3. Must be easy to program
4. Must be programmable in a language that is easy to learn and understand
5. Must be able to handle multiple interrupts
6. Must have sufficient memory to store the program
7. Must have sufficient I/O ports to handle several inputs from the photodiodes and outputs to drive the display system
8. The part must be easily available and cost effective
9. Must be easily integrated into the entire system
10. Documentation about the MCU must be readily available, including tutorials, manuals, and data sheets.

6.4.2.3 Decision

Team ATTACH has chosen the **PIC16F877A** microcontroller to be implemented into the design of the navigation/guidance system. Several processors were analyzed and compared and the team finally settled on this particular processor. A table of several processors from the PIC16F87XA family is shown below. This processor was chosen as it met or exceeded all the criteria established above for a microcontroller. Also, this processor has been used for similar applications by various other users. There are several source codes available online for various applications, which will help in testing the MCU for basic functionality.

Table 6.2 PIC16F87X Family Device Features

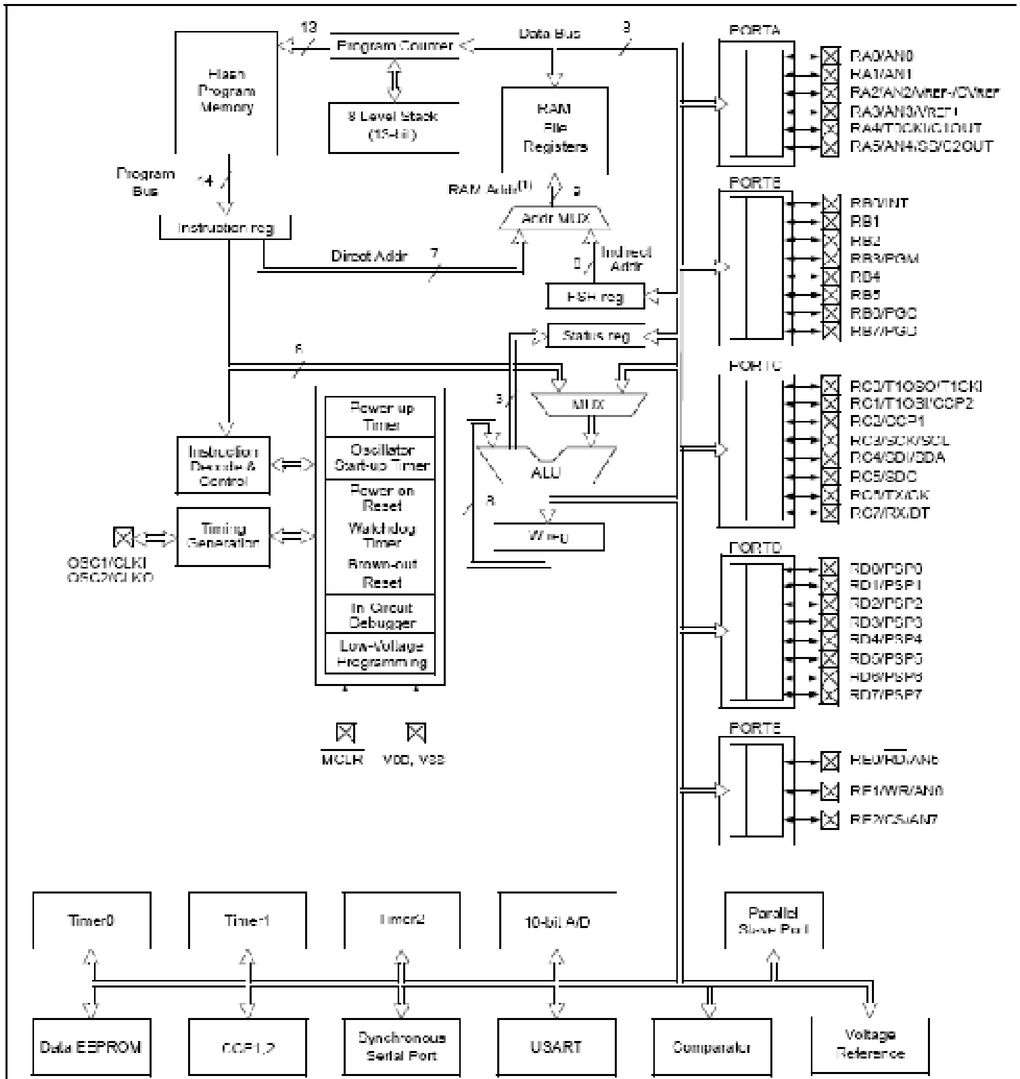
Key Features	PIC16F873A	PIC16F874A	PIC16F876A	PIC16F877A
Operating Frequency	DC – 20 MHz	DC – 20 MHz	DC – 20 MHz	DC – 20 MHz
Resets (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
Flash Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	368	368
EEPROM Data Memory (bytes)	128	128	256	256
Interrupts	14	15	14	15
I/O Ports	Ports A, B, C	Ports A, B, C, D, E	Ports A, B, C	Ports A, B, C, D, E
Timers	3	3	3	3
Capture/Compare/PWM modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	5 input channels	8 input channels
Analog Comparators	2	2	2	2
Instruction Set	35 Instructions	35 Instructions	35 Instructions	35 Instructions
Packages	28-pin PDIP 28-pin SOIC 28-pin SSOP 28-pin QFN	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN	28-pin PDIP 28-pin SOIC 28-pin SSOP 28-pin QFN	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN

The processor is also programmed in PicBasic, which is a version of BASIC programming language. All the manuals, tutorials, and data sheets are readily available online from www.microchip.com. Also, the PicBasic compiler is available for use at Calvin College, thus reducing the cost of developing the prototype.

6.4.2.4 Specifications of the PIC16F877A Microcontroller

The PIC16F877A microcontroller is a high-performance RISC CPU. It has only 35 one-word instructions to learn and understand, thus making it simple to use and program. The processor operates on a 20MHz clock, thus making it fast enough for all of our processes and necessary computations. In regards to memory the microcontroller features up to 8K x 14 words of Flash Program Memory, up to 368 x 8 bytes of RAM, and 256 x 8 bytes of EEPROM Data Memory. Though the specific size of our final program has not been determined, the amount of memory available in this processor should meet all our requirements. The microcontroller features a 10-bit 8 input channel A/D converter; it also has two analog comparators built into the system with various features such as Programmable on-chip voltage reference (Vref) module, programmable input multiplexing from device inputs and internal voltage reference, and the comparator outputs are externally accessible. The microcontroller features a total of 33 I/O pins, which is sufficient for all our input and output needs.

A block diagram of the functionality of the PIC16F877A microcontroller is given below. It shows the various relations between the several components that make up the system, as well as the various I/O ports available to the user. Also, a table describing the various pin outs is given below for the microcontroller. Both the tables are obtained from the PIC16F877A data sheet.



Device	Program Flash	Data Memory	Data EEPROM
PIC16F874A	4K words	192 Bytes	128 Bytes
PIC16F877A	8K words	368 Bytes	256 Bytes

Note 1: Higher order bits are from the Status register.

Figure 6.2 PIC16F877A Block Diagram

Table 6.3 PIC16F877A PINOUT DESCRIPTION

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKI	13	14	30	32		ST/CMOS(4)	Oscillator crystal or external clock input.
OSC1					I		Oscillator crystal input or external clock source input. ST buffer when configured in RC mode; otherwise CMOS.
CLKI					I		External clock source input. Always associated with pin function OSC1 (see OSC1/CLKI, OSC2/CLKO pins).
OSC2/CLKO	14	15	31	33			Oscillator crystal or clock output.
OSC2					O		Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode.
CLKO					O		In RC mode, OSC2 pin outputs CLKO, which has 1/4 the frequency of OSC1 and denotes the instruction cycle rate.
$\overline{MCLR}$/VPP	1	2	18	18		ST	Master Clear (input) or programming voltage (output).
$\overline{MCLR}$					I		Master Clear (Reset) input. This pin is an active low Reset to the device.
VPP					P		Programming voltage input.
							PORTA is a bidirectional I/O port.
RA0/AN0	2	3	19	19		TTL	
RA0					I/O		Digital I/O.
AN0					I		Analog input 0.
RA1/AN1	3	4	20	20		TTL	
RA1					I/O		Digital I/O.
AN1					I		Analog input 1.
RA2/AN2/VREF-/CVREF	4	5	21	21		TTL	
RA2					I/O		Digital I/O.
AN2					I		Analog input 2.
VREF-					I		A/D reference voltage (Low) input.
CVREF					O		Comparator VREF output.
RA3/AN3/VREF+	5	6	22	22		TTL	
RA3					I/O		Digital I/O.
AN3					I		Analog input 3.
VREF+					I		A/D reference voltage (High) input.
RA4/T0CKI/C1OUT	6	7	23	23		ST	
RA4					I/O		Digital I/O – Open drain when configured as output.
T0CKI					I		Timer0 external clock input.
C1OUT					O		Comparator 1 output.
RA5/AN4/$\overline{SS}$/C2OUT	7	8	24	24		TTL	
RA5					I/O		Digital I/O.
AN4					I		Analog input 4.
$\overline{SS}$					I		SPI slave select input.
C2OUT					O		Comparator 2 output.

Table 6.4 PIC16F877A PINOUT DESCRIPTION

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
							PORTB is a bidirectional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	33	36	8	9		TTL/ST[1]	
RB0					I/O		Digital I/O.
INT					I		External interrupt.
RB1	34	37	9	10	I/O	TTL	Digital I/O.
RB2	35	38	10	11	I/O	TTL	Digital I/O.
RB3/PGM	36	39	11	12		TTL	
RB3					I/O		Digital I/O.
PGM					I		Low voltage ICSP programming enable pin.
RB4	37	41	14	14	I/O	TTL	Digital I/O.
RB5	38	42	15	15	I/O	TTL	Digital I/O.
RB6/PGC	39	43	16	16		TTL/ST[2]	
RB6					I/O		Digital I/O.
PGC					I		In circuit debugger and ICSP programming clock.
RB7/PGD	40	44	17	17		TTL/ST[2]	
RB7					I/O		Digital I/O.
PGD					I/O		In-circuit debugger and ICSP programming data

Table 6.5 PIC16F877A PINOUT DESCRIPTION

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
							PORTC is a bidirectional I/O port.
RC0/T1OSO/T1CKI	15	16	32	34		ST	
RC0					I/O		Digital I/O.
T1OSO					O		Timer1 oscillator output.
T1CKI					I		Timer1 external clock input.
RC1/T1OSI/CCP2	16	18	35	35		ST	
RC1					I/O		Digital I/O.
T1OSI					I		Timer1 oscillator input.
CCP2					I/O		Capture2 input, Compare2 output, PWM2 output.
RC2/CCP1	17	19	36	36		ST	
RC2					I/O		Digital I/O.
CCP1					I/O		Capture1 input, Compare1 output, PWM1 output
RC3/SCK/SCL	18	20	37	37		ST	
RC3					I/O		Digital I/O.
SCK					I/O		Synchronous serial clock input/output for SPI mode.
SCL					I/O		Synchronous serial clock input/output for I^2C mode.
RC4/SDI/SDA	23	25	42	42		ST	
RC4					I/O		Digital I/O.
SDI					I		SPI data in.
SDA					I/O		I^2C data I/O
RC5/SDO	24	26	43	43		ST	
RC5					I/O		Digital I/O.
SDO					O		SPI data out.
RC6/TX/CK	25	27	44	44		ST	
RC6					I/O		Digital I/O.
TX					O		USART asynchronous transmit
CK					I/O		USART1 synchronous clock.
RC7/RX/DT	26	29	1	1		ST	
RC7					I/O		Digital I/O.
RX					I		USART asynchronous receive.
DT					I/O		USART synchronous data.

Table 6.6 PIC16F877A PINOUT DESCRIPTION

Pin Name	PDIP Pin#	PLCC Pin#	TQFP Pin#	QFN Pin#	I/O/P Type	Buffer Type	Description
							PORTD is a bidirectional I/O port or Parallel Slave Port when interfacing to a microprocessor bus.
RD0/PSP0	19	21	38	38		ST/TTL(3)	
RD0					I/O		Digital I/O.
PSP0					I/O		Parallel Slave Port data.
RD1/PSP1	20	22	39	39		ST/TTL(3)	
RD1					I/O		Digital I/O.
PSP1					I/O		Parallel Slave Port data.
RD2/PSP2	21	23	40	40		ST/TTL(3)	
RD2					I/O		Digital I/O.
PSP2					I/O		Parallel Slave Port data.
RD3/PSP3	22	24	41	41		ST/TTL(3)	
RD3					I/O		Digital I/O.
PSP3					I/O		Parallel Slave Port data.
RD4/PSP4	27	30	2	2		ST/TTL(3)	
RD4					I/O		Digital I/O.
PSP4					I/O		Parallel Slave Port data.
RD5/PSP5	28	31	3	3		ST/TTL(3)	
RD5					I/O		Digital I/O.
PSP5					I/O		Parallel Slave Port data.
RD6/PSP6	29	32	4	4		ST/TTL(3)	
RD6					I/O		Digital I/O.
PSP6					I/O		Parallel Slave Port data.
RD7/PSP7	30	33	5	5		ST/TTL(3)	
RD7					I/O		Digital I/O.
PSP7					I/O		Parallel Slave Port data.
							PORTE is a bidirectional I/O port.
RE0/$\overline{RD}$/AN5	8	9	25	25		ST/TTL(3)	
RE0					I/O		Digital I/O.
$\overline{RD}$					I		Read control for Parallel Slave Port.
AN5					I		Analog input 5.
RE1/$\overline{WR}$/AN6	9	10	26	26		ST/TTL(3)	
RE1					I/O		Digital I/O.
$\overline{WR}$					I		Write control for Parallel Slave Port.
AN6					I		Analog input 6.
RE2/$\overline{CS}$/AN7	10	11	27	27		ST/TTL(3)	
RE2					I/O		Digital I/O.
$\overline{CS}$					I		Chip select control for Parallel Slave Port.
AN7					I		Analog input 7.
VSS	12, 31	13, 34	6, 29	6, 30, 31	P	—	Ground reference for logic and I/O pins.
VDD	11, 32	12, 35	7, 28	7, 8, 28, 29	P	—	Positive supply for logic and I/O pins.
NC	—	1, 17, 28, 40	12,13, 33, 34	13	—	—	These pins are not internally connected. These pins should be left unconnected.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

6.4.3 Display

The team had to decide on a suitable user interface that would be most appropriate to indicate the position of the automobile relative to the position of the hook. The options in consideration include the following:

1. Light Emitting Diodes (LED's) in conjunction with a seven segment display.
2. Liquid Crystal Display (LCD)

A decision matrix was used to choose the appropriate display based on the following criteria.

1. Cost
2. Complexity
3. Appearance
4. Reliability

Table 6.7. Decision Matrix for Deciding between LED and LCD Display System

Criteria	**LED's**	**LCD**
Complexity	10	8
Appearance	8	10
Cost	10	5
Reliability	10	10
Total	95%	82%

The team decided to incorporate an LED display in conjunction with a seven segment display based on the result of the decision matrix.

6.4.4 Optical Source

The options in consideration for our optical source include:

1. IR Laser Diode
2. IR LED

The optical source is to have a wavelength above that of the visible spectrum. More testing helped us in the decision process. A decision matrix was used to choose the appropriate display based on the following criteria.

1. Beam Angle
2. Beam Power / Intensity
3. Dispersion
4. Cost

Table 6.8. Decision Matrix for Deciding between IR Laser diode and IR LED

Criteria	**IR Laser Diode**	**IR LED**
Beam Angle	10	4
Intensity	10	5
Dispersion	10	7
Cost	7	8
Total	92.5%	60%

The team decided to incorporate the IR Laser Diode based on the result of the decision matrix.

a. Working Distance

The team decided that a minimum working distance of about 8 feet would be suitable for drivers to begin the alignment process. Therefore, it is necessary that that the photodiodes used are able to recognize the IR signal form at least 8 feet away.

b. Number of LED's Required

For the optical source, a single LED is required

c. Emitter Circuitry

The design circuitry required depends on the optical source to be used.

6.4.4.1 IR LED

The intensity of the regular IR beam is not very strong for our application and will have to be distinguished from ambient IR. This can be accomplished by oscillating the beam at about 40 KHz. The circuit shown accomplishes this purpose.

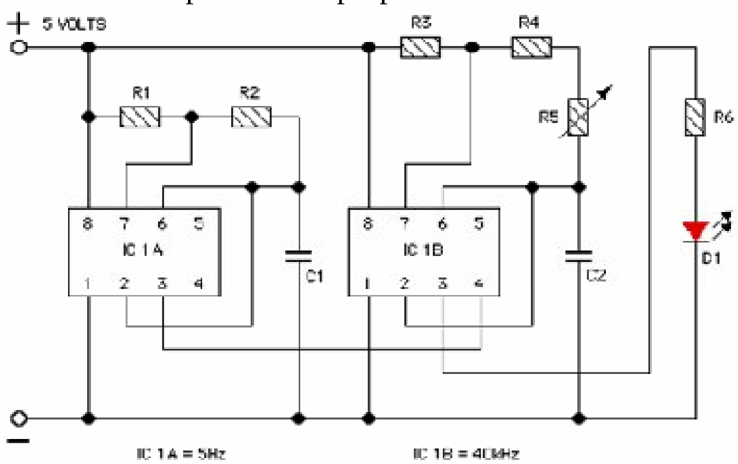


Figure 6.3. IR LED Driver / Oscillator
IC 1A and IC 1B are LM555 IC Chips

6.4.4.2 IR Laser Diode

The IR Laser Diode is distinguishable from ambient IR and would not require pulsing. The simple setup shown in Figure6.4 would be sufficient.

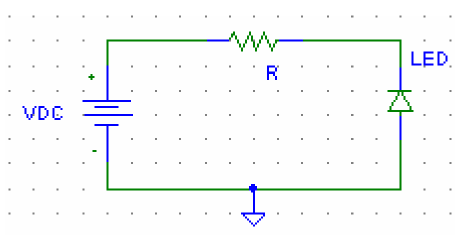


Figure 6.4. IR Laser Diode Driver

6.4.4.3 Optical Receiver

The optical receiver for our system is simply an array of IR photodiodes with a maximum sensitivity of 940nm. The array is to have 25 photodiodes equally spaced at about 1.2 cm apart. The receiver would be interfaced with the LED display via the microcontroller unit which would condition the signal received and light up the LED's at the defined conditions.

7. Project Management

7.1 Team Organization, Responsibilities, and Composition

Team ATTACH is composed of three electrical engineers and one mechanical engineer. This team is unique in the sense that the team members represent three countries which include Nigeria, India and the United States. The team supervisor is Dr. Steve VanderLeest, an electrical engineering professor. ATTACH is a team project that has been undertaken for Engineering 339/340, a capstone course in Calvin's Engineering curriculum. Various duties have been assigned to each member of the team in addition to the overall function of conception and development of the product. Ub Essien has taken the responsibility of being the team secretary, a task that involves taking minutes of the team meeting as well as any other meeting that should take place and transferring them to the main server, keeping the team accountable to each other, keeping the team updated on upcoming deadlines and milestones, and writing and submitting the status report for each week to the team supervisor. Clarence Medema's expertise in the field of business earned him the right to act as the team treasurer, his job function involves managing the budget for the team, distributing and accounting of the allocated funds for the team, and doing a through economic analysis of the product including a market analysis of the final production model. Sumanth K. Sampath has the responsibility of setting up, maintaining and updating the team website, doing research on various topics for the team and briefing the team on the details as when the need arises for such research, and researching the various parts need for the product development and forming a list of possible vendors. Daniel Ateru was placed in charge of parts procurement, a task that would involve interacting with the various vendors and getting information regarding the specifications of their products and the best price that they can offer us, as well as formulating a price list for the various parts needed for both the prototype and possible mass production in the future.

In addition to these duties all members participate in conception, design, and development of the product. Each team member was assigned charge of a subsystem and is responsible for the proper eventuation of that subsystem. A team mentor has been assigned in person of Mr. Gustavo Velazquez, whom we are scheduled to meet with in the spring. The team is also receiving lots of support and guidance from Professor Ned Nielsen of Calvin College, in addition to the support from the team supervisor.

The team meets regularly twice a week to update the team regarding the progress achieved by each team member, in addition to brainstorming on topics such as the working principle of the product, possible road blocks in product development, and general housekeeping, such as documentation as deemed necessary. The meetings tend to be semiformal with the team establishing an agenda for each meeting. Each member is also accountable to weekly goals assigned. It was unanimously decided that 3 excuses be awarded each member after which further failures to fulfill team demands would be reported to the team advisor.

8. Preliminary Feasibility Analysis

The final goal of this project is to design and develop a production model of a complete navigational aid and hitching mechanism, with the aim of eventually mass producing the product for the household consumer. The secondary objective is to build a working prototype that validated the design. The main target for this product would be families that own a trailer. With this in mind, the main challenge for this team would be to produce these products within a

particular price range, which would make it affordable by the majority of trailer owners. A market survey was conducted in order to get an understanding of the market and the price ranging needed for the product. Moreover the feasibility of each of the component of the complete system will also be discussed in detail and separately in this section.
At this point in the project it is this team's strong belief that the overall system is feasible both from a financial as well as a technical perspective.

9. Task Specifications

The design of the system is divided into the following task specifications**.**

ATTACH System Design	Estimated Duration (hrs)	% of Task Completed	Total Hours Spent (hrs)
Determine Overall Goals	8	100%	12
Develop basic design specs	28	75%	22
Documentation of PPFS	50	100%	35
Preparation for Presentation of Project for First Semester	16	100%	16
Overall System Design	**1119**		**141**
Photodiode circuit			
Determine the Photodiode specifications	4	100%	4
Prepare parts list + Vendors	15	100%	8
Procure parts	3	60%	1
Calculate power rating of circuit.	2	100%	1
Procure electronic components.	5	0%	
Design and Fabricate PCB	**54**	0%	
1) Find PCB manufacturers + prepare price list	8	0%	
2) Design the PCB	40	0%	
a) Determine the circuit needed to complete necessary tasks	22	0%	
b) Map the circuit using PSpice software	10	0%	
c) Run simulations to test the circuit using the PSpice software	5	0%	
d) Draw the final circuit on the CAD software in preparation	3	0%	
3) Fabricate the PCB	6	0%	
a) Finalize and decide on the PCB fabricator	3	0%	
b) Place order for the PCB	3	0%	
Test the Photodiodes for basic functionality	4	100%	4
Documentation	10	10%	1

Assemble components / solder parts onto PCB	15	0%	
Test the finished product for proper functioning	25	0%	
Integrate the entire system with the fabricated casing	4	0%	
Power System			
Estimate power requirement of transducer/ receiver/ transmitter circuit.	3	70%	2
Research power supplies: external batteries vs. using car battery	7	100%	4
Use decision matrix to choose power system.	3	100%	1
Prepare parts list + possible vendors of the product	5	100%	4
Place order for the parts	2	0%	
Integrate the power system with the whole system	2	0%	
Casement and Mounting			
Take electrical components and consider case needs	5	100%	3
Propose possible casements for each piece of the system: Transmitter, Photodiode Receiver Array, and Display Module	4	100%	7
Layout cases for each component	5	100%	5
Design and draw up bracket or mounting system for each piece: Transmitter and Receiver Modules	12	100%	8.5
Collect information including prices for proposed design	8	0%	
Draw up parts list + possible vendors for current proposed design(s)	5	0%	
Place order for/ procure the necessary raw materials	3	0%	
Fabricate the casements and mounting systems	12	0%	
Transducers			
Establish behavior of Ultrasonic transducers in air	6	100%	13
Define transducer specification	5	100%	3
Establish list of transducers	3	100%	3
Make decision on which transducer to use (Decision Matrix)	2	100%	2
Develop list of vendors + prices for the parts	3	100%	3
Contact vendors + buy transducers with driver circuits	4	0%	
Explore different applications with transducers	5	0%	
Test basic transducer functions (echo ranging)	8	0%	
Design and Fabricate PCB for Object/Obstacle Detection	**54**	0%	
1) Find PCB manufacturers + prepare price list	8	0%	
2) Design the PCB	40	0%	
a) Determine the circuit needed to complete necessary tasks	22	0%	
b) Map the circuit using PSpice software	10	0%	
c) Run simulations to test the circuit using the PSpice software	5	0%	
d) Draw the final circuit on the CAD software in preparation	3	0%	
3) Fabricate the PCB	6	0%	
a) Finalize and decide on the PCB fabricator	3	0%	
b) Place order for the PCB	3	0%	
Documentation	10	30%	2

Assemble the entire system including soldering parts onto PCB	25	0%	
Test the entire system for proper functioning	30	0%	
MCU			
Establish MCU specifications needed	12	100%	15
Make decision on which MCU to use (Decision Matrix)	2	100%	1
Research and explore the different applications of the chosen MCU	10	60%	8
Learn programming language	80	0%	
Establish list of possible vendors	5	0%	
Buy MCU + Programming board for MCU + Compiler	2	0%	
Download all the necessary additional software, MCU manual, compiler manual	3	65%	2.5
Documentation	6	20%	1
Programming of MCU			
Get familiar with Programming board + MCU	25	0%	
Test MCU with simple programes	10	0%	
Develop algorithm for position sensing	40	0%	
Write out the program based on the developed algorithm	3	0%	
Program the MCU	20	0%	
Test the programmed MCU for proper functioning + Debugging	50	0%	
Integrate the MCU with the entire system including soldering onto PCB	5	0%	
Testing of the entire system and refinement as needed	25	0%	
Documentation	6	0%	
Display System			
Establish criteria for choosing display system	3	100%	4
Make decision on what kind of display system to use (Decision Matrix)	2	100%	2
Research different products from outcome of decision matrix	3	100%	3
Establish list of vendors + parts list + price list	5	100%	3
Purchase necessary parts	2	0%	
Assembly/Preliminary testing	6	0%	
Basic testing/Implementation	10	0%	
Integrate the entire system with the fabricated casing for the Display System	4	0%	
Documentation	4	20%	1
IR LED Emitter Circuit			
Define specifications of the IR LED emitter needed	5	100%	6
Make decision on which IR LED emitter to use (Decision Matrix)	3	100%	1
Establish list of vendors + price list	3	100%	2.5
Purchase Emitters	2	100%	0.5
Preliminary Testing for proper functioning of IR LED	8	100%	8
Design and Fabricate PCB for pulsing the IR LED at 40KHz	**46**	0%	
1) Design the PCB	40	0%	
a) Determine the circuit needed to complete necessary tasks	22	0%	
b) Map the circuit using PSpice software	10	0%	
c) Run simulations to test the circuit using the PSpice software	5	0%	
d) Draw the final circuit on the CAD software in preparation	3	0%	

2) Fabricate the PCB	6	0%	
a) Finalize and decide on the PCB fabricator	3	0%	
b) Place order for the PCB	3	0%	
Integrate the IR LED with the PCB circuit	4	0%	
Test the entire system for proper functionality	30	0%	
Integrate the entire system into the fabricated casing	3	0%	
Documentation	8	45%	3
Budget	**74**		**18**
Prepare monthly budget	24	50%	10
Prepare and maintain budget of prototype	30	30%	5
Prepare budget of future production model	20	30%	3
Market Survey and Analysis	**37**		**5.5**
Collect data regarding current vehicle inventories and sales in Michigan	10	100%	3
Determine possible market using the data gained regarding total sales	8	40%	1
Collect data regarding sales of Trailers in Michigan in the past year and past 5 years	5	30%	1
Develop questionnaire regarding use of trailer by customers + send out survey to the Calvin Community	3	50%	0.5
Collect and compile data received from the questionnaire survey	7	0%	
Develop the optimum pricing for the final production model based on surveys	4	0%	
Total Number of Hours Estimated to be spent on Project	**1230**		
Total Number of Hours spent on the project thus far	**164.5**		
Estimated number of hours remaining to be spent on project	**1065.5**		

10. Testing

A test was conducted to verify distance measurement feature of the design and the following data were taken.

Table 10.1. Experimental Results

Distance (in)	Voltage (V)	Distance (	Voltage (V)
0	0.46	9.6	0.22
1	0.35	11.2	0.21
2.5	0.29	13.6	0.21
3.5	0.27	16	0.21
4	0.26	22.2	0.19
4.9	0.25	25.6	0.19
6	0.24	35.6	0.16
7.5	0.23	16	0.16

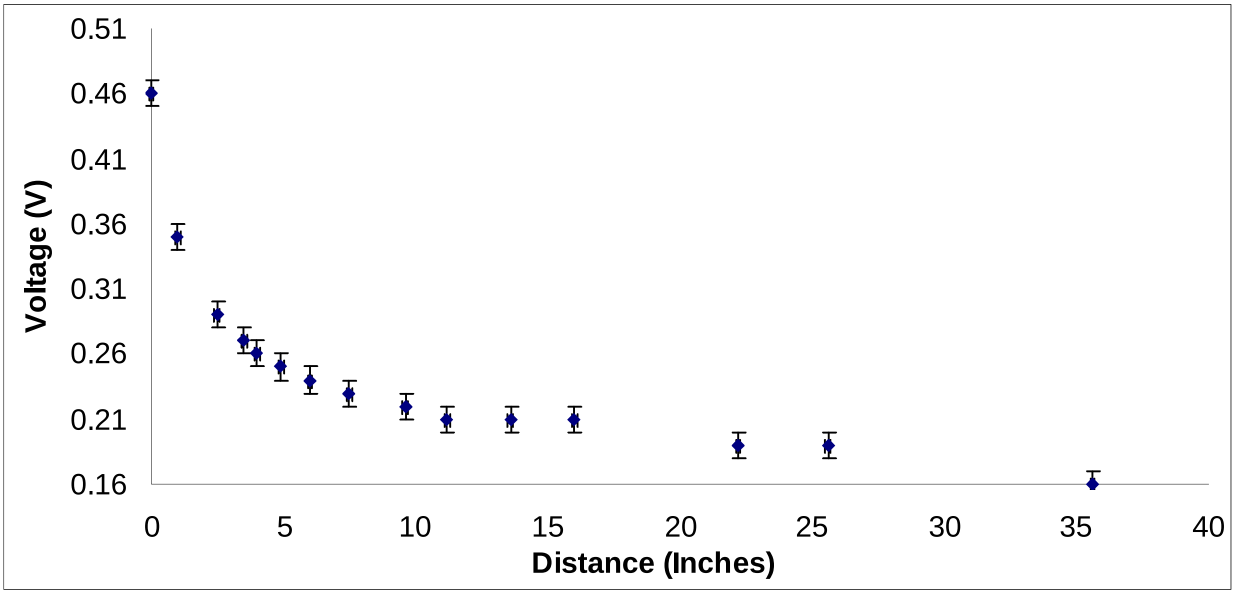


Figure 10.1. Experimental Results

10.1 Analysis of result
There exist a relationship between the voltage and the strength of the emitter light from the optical source. This relationship can be interpolated and used to measure distance between the optical source and the receiver.

10.2 Constraints.

The beam emitted from the optical source (IR LED emitter) was broadly divergent and decreased significantly in strength as it propagated from the source. Therefore data was taken for distance ranging from 0 to 3.25feet.

10.3 Proposed Solution

An IR laser diode module would replace the IR LED emitter circuit. Laser diodes have more streamlined and significant stronger beams that dissipate over a much greater distance.

11. Budget

11.1. **Project Budget**

The preliminary parts list was put together to test the design philosophy and feasibility of the prototype design. This prototype budget has been refined over the semester to its current form (Table 11.1). The team is currently working with a prototype budget of $300.00 of which $14.21. Table 11.2 shows all project expenses to date.

Table 11.1 Preliminary Part List / Prototype Budget

Part	Vendor	Part #	Unit Cost	Estim. Qty.	Total Cost
Infrared Emitter	digikey.com	QEC113-ND	$0.45	1	**$ 0.45**
Infrared Detector- Photodiodes	digikey.com	160-1032-ND	$0.39	30	**$ 11.70**
2 7-Segment LED display system	eio.com	man6410	$0.80	1	**$ 0.80**
3mm LED for Guidance System (red)	eio.com	L-314veac	$0.36	8	**$ 2.88**
5mm LED for Guidance System (green)	eio.com	L-5t47plg61c-d1	$0.36	1	**$ 0.36**
12- 15V battery	digikey.com		$5.00	3	**$ 15.00**
A/D converter	maxim-ic.com		$ 3.70	2	**$ 7.40**
LED Display Driver	maxim-ic.com		$ 3.70	2	**$ 7.40**
MCU	microchip.com		$ 5.97	1	**$ 5.97**
Printed Circuit Board	pcbexpress.com				
EPIC PIC PROGRAMMER	melabs.com		$ 99.95	1	**$ 99.95**
Total Cost					**$ 151.91**

Table 11.2 Project Spending to Date

Part	Vendor	Part #	Unit Cost	Parts Ordered	Total Cost
Infrared Emitter	digikey.com	QEC113-ND	$0.45	6	**$ 2.70**
Infrared Detector- Photodiodes	digikey.com	160-1032-ND	$0.39	9	**$ 3.51**
2 7-Segment LED display system	eio.com	man6410	$0.80	10	**$ 8.00**
A/D converter	maxim-ic.com		-	2	**$ -**
LED Display Driver	maxim-ic.com		-	2	**$ -**
MCU	microchip.com		-	0	**$ -**
Total Cost					**$ 14.21**
Initial Funds					**$ 300.00**
Project Spending					**$ 14.21**
Available Funds					**$ 285.79**

* The A/D converter, LED Display Driver & MCU for the prototype have been donated to project

12. Project Risk Identification and Contingencies

12.1 LED Replacement

One major risk to the success of the project is the possibility that the maximum distance at which the photodiodes will be able to accurately pick up the light from the LED will not be enough for our requirements. This problem is inherent to the characteristics of the LED and photodiodes specified in the design. If this does prove to be a problem, the plan of action is to replace the IR LED with an IR Laser LED. This switch will increase the costs by as much as $20.00. The increased power would greatly increase the working range of the unit but the additional cost should be avoided if at all possible. Another alternative would be the use of a more powerful and only slightly more expensive LED, but currently an LED to fit that need has yet to be identified.

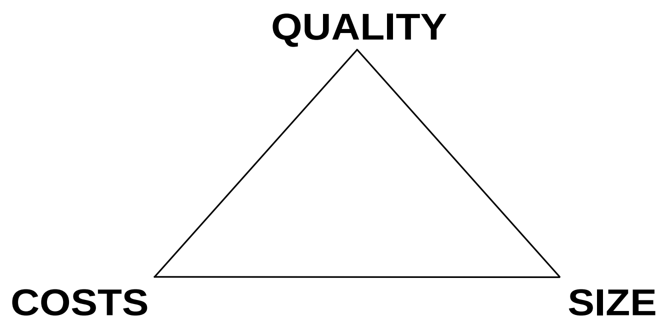
12.2 PCB Failure

A second risk is failure in the design of the PCB. This could arise from problem in the design or manufacture of the board. Because the PCB is such an important piece to the operation of the system, the best solution to such a problem is to identify and correct whatever faults occur and have a new board created for the prototype.

12.3 Cost Inflation

The number one concern that arises from the consulting meeting with Mr. C. Spoelhof was keeping cost down to a marketable level. In the case of any part of the current design failing and requiring changes that will raise the overall costs of the system, the best course of action will to try and find ways to cut costs in other areas as needed and possibly sacrificing in the areas of product size or measurement quality to still produce a product at a price that will make it competitive in the open market.

Figure 12.1. Decision Triangle



13. Conclusion

As of today, the feasibility phase of this project stands at 60%. We do believe that a design of the prototype is feasible. Therefore, design of the prototype will be implemented within the limits of the resources given to the team. Above all, the project will be completed on schedule.

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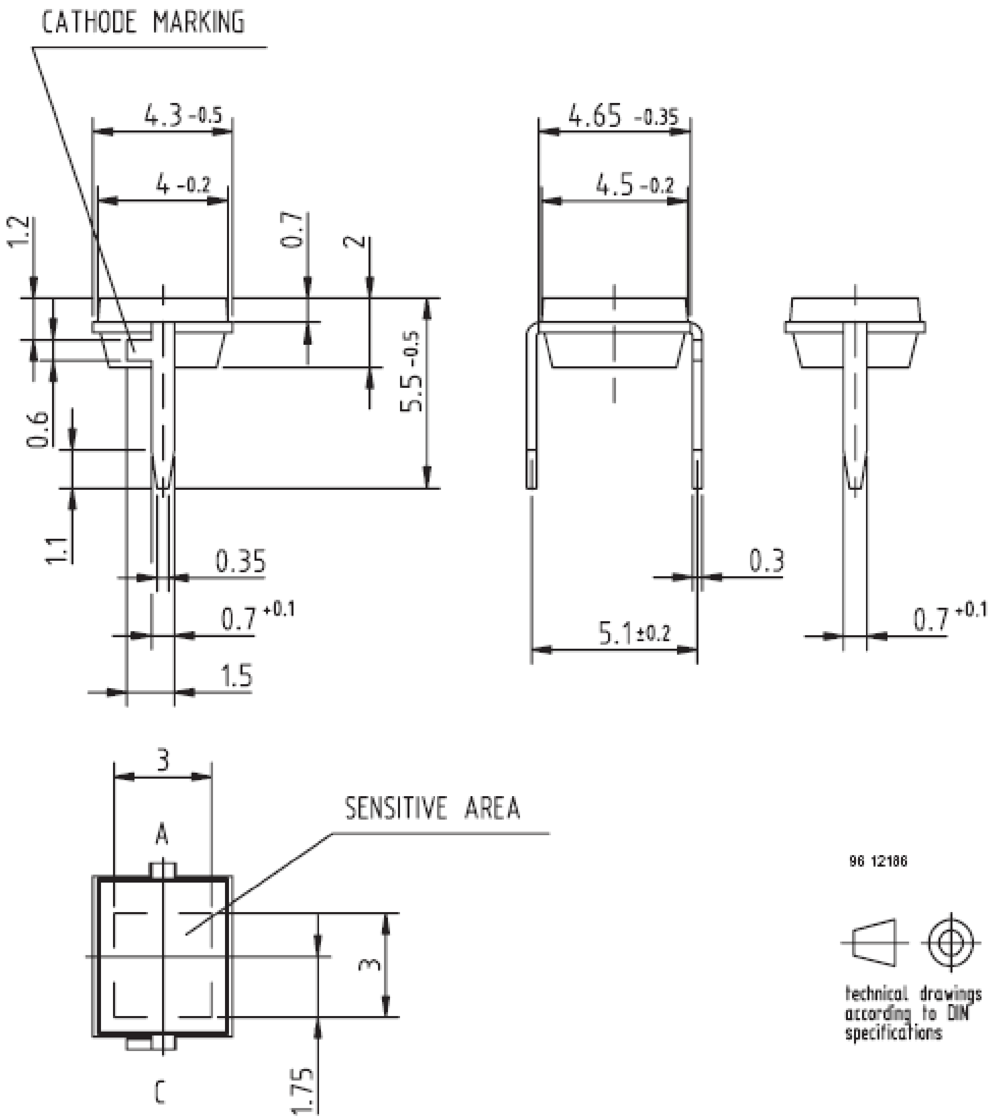
Acknowledgements

We acknowledge Professors VanderLeest and Nielson both of Calvin College's Engineering department for their contributions and assistance at various stages of our project design. In addition, we are also grateful to Mr. C. Spoelhof, our industrial consultant, for helping us review, and identify the bottlenecks and potential solutions in our project.

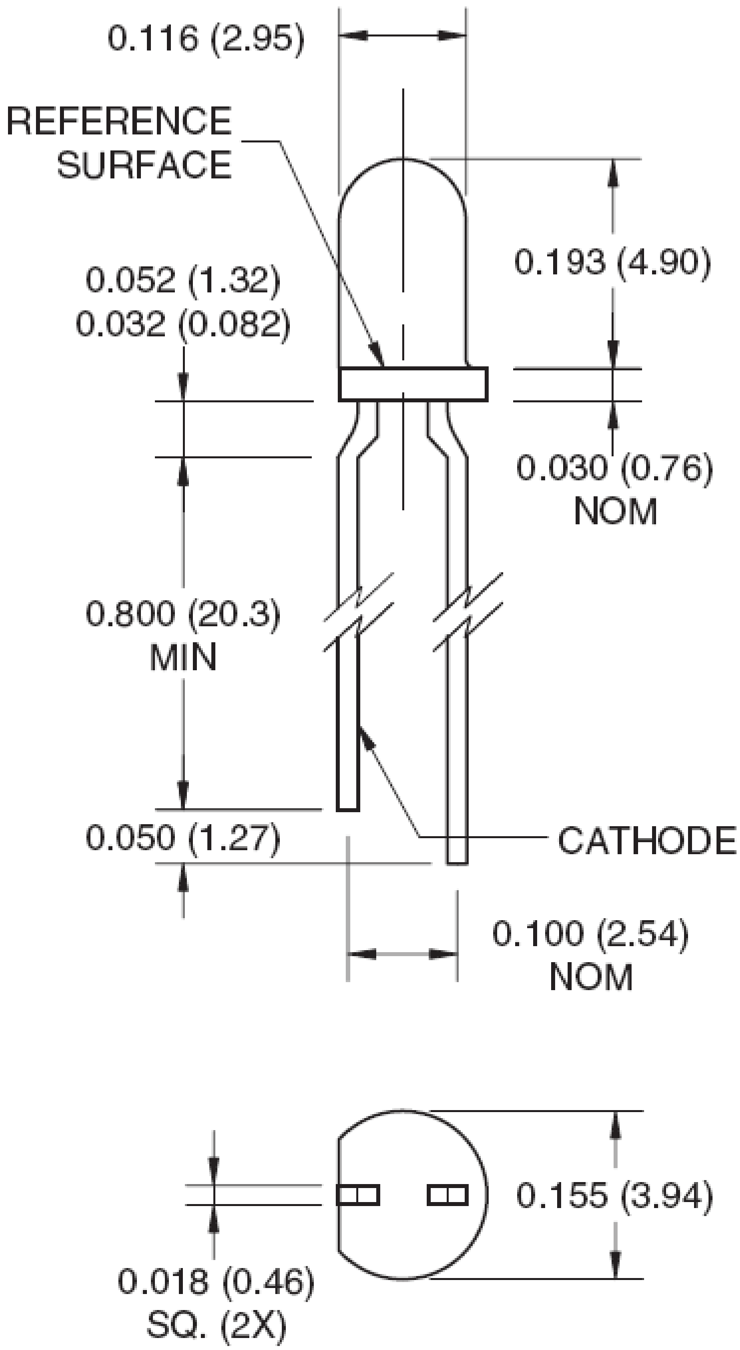
Appendix

Appendix 1.1
BPW34 Photodiode



Dimensions in mm www.vishay.com

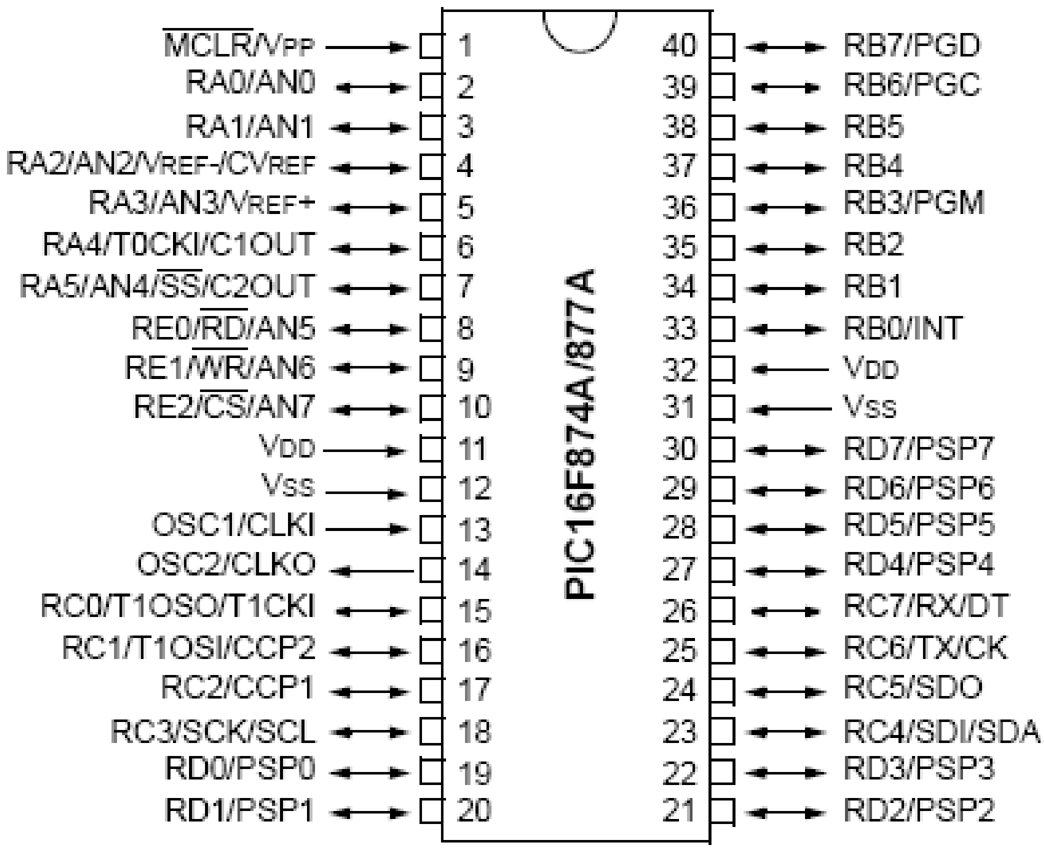
<u>Appendix 1.2</u>
QEC113 Infrared Light Emitting Diode



Dimensions in inches (mm)
www.fairchildsemi.com

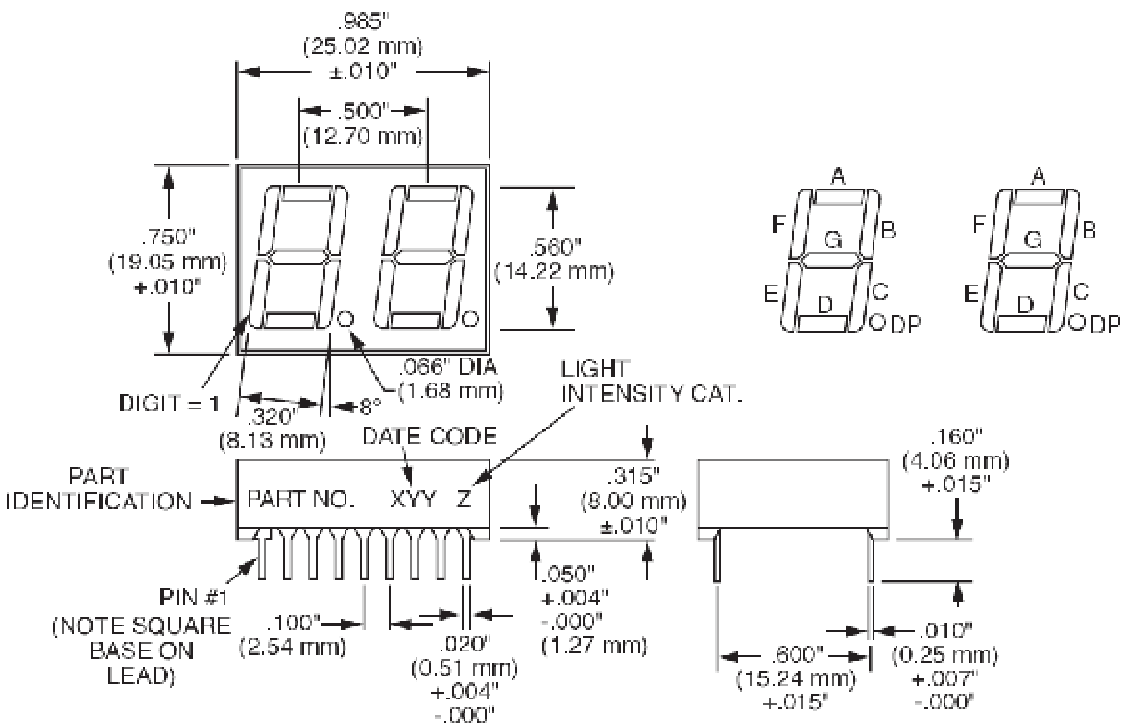
Appendix 1.3

PIC16F877A Microcontroller



www.microchip.com

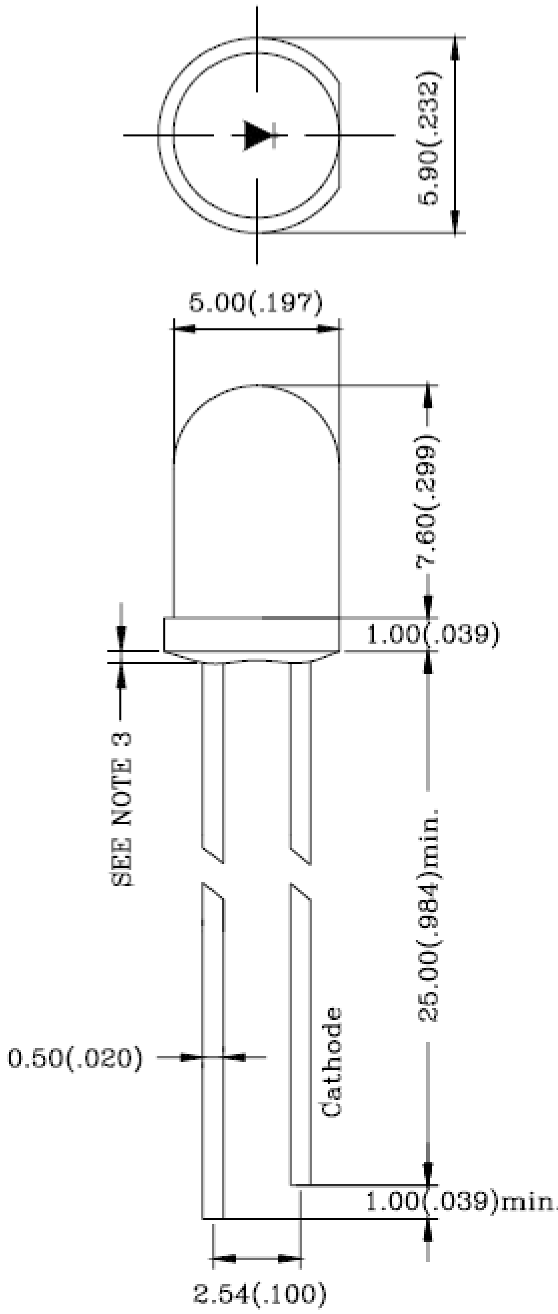
<u>Appendix 1.5</u>
MAN6410 Series Two Digit Seven Segment Display with DP



www.eio.com
Though this is manufactured by Fairchild Semiconductor we found and purchased this unit at eio.com

Appendix 1.6

Para Light L-5T47LPG61C-D1 (Visible Green LED)

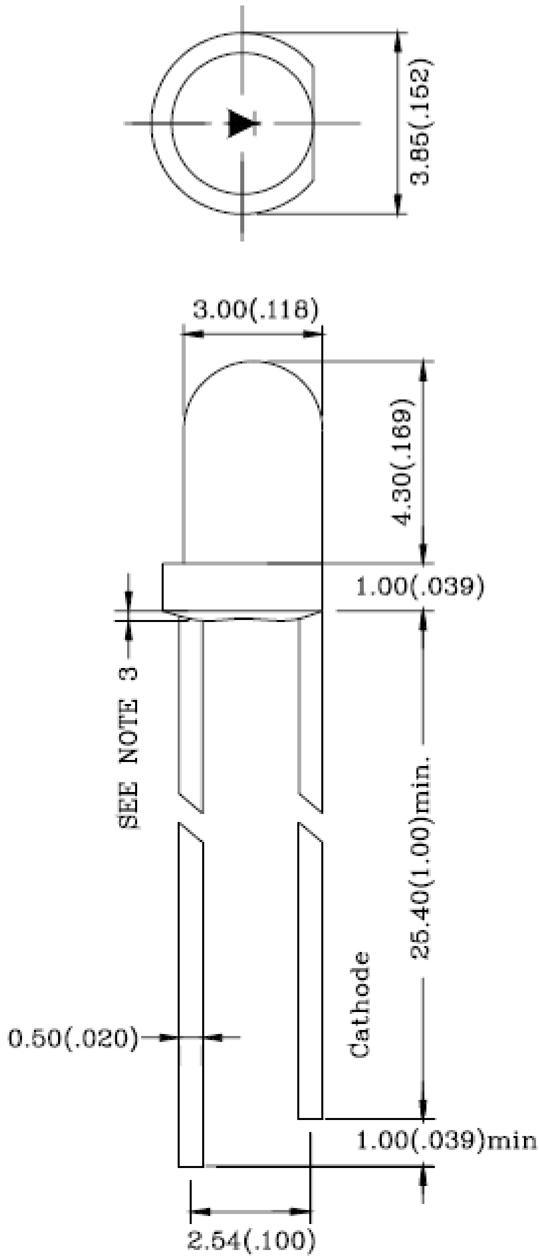


Dimensions in millimeters

www.eio.com

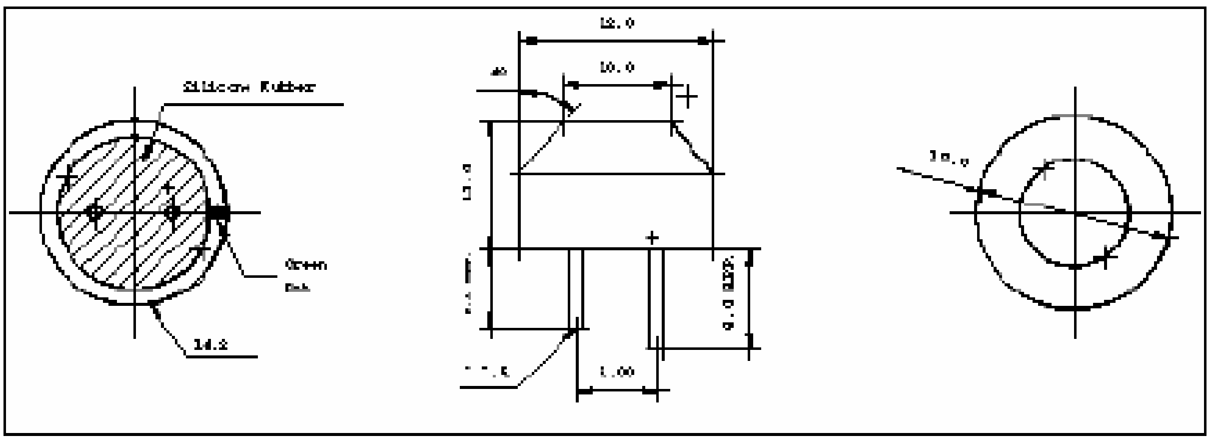
Appendix 1.7

Para Light L-314VEAC (Visible Red LED)



Dimensions in millimeters
www.eio.com

<u>Appendix 1.8</u>
40KPT18A Ultrasonic Transducer



http://senscomp.com/

<u>Appendix 1.9</u>
Initial Testing of Parts