Protected IR Input System

Project Report

By Kevin Ersoy

Senior Project

ELECTRICAL ENGINEERING DEPARTMENT

California Polytechnic State University

San Luis Obispo

2009

Table of Contents

Figures

Tables

Acknowledgements

I would like to express my deepest gratitude to Brad Lesko from Fox Thermal Instruments Inc. He presented me with this great opportunity for a very interesting project. He also funded the project from beginning to end, including hourly wages.

I would also like to deeply thank Professor Derickson for his aid and advice, not only on this project, but throughout my college career. He has always been my “go to” professor when I had problems or questions. I have two favorite professors in the EE department, and it goes without saying, Professor Derickson is on my list.

Lastly, I would like to thank Charles Guggenheim and the rest of the engineering crew at Fox Thermal Instruments Inc. for all their assistance and support.

I. Introduction

Over the next decade, optical communication devices will flood the digital communications market. The shortest time to get a message from one point to another is by transmitting it at the speed of light. A transmitter may code a message onto a channel and send it out using pulses of light, while a receiver will decode the light back into the original message.

This project, rather than making use of this high speed, will concentrate more on the properties of the light signal. Light may be projected through a variety of mediums. Its ability to pass through objects like glass, plastic, and water make it very useful for projects that require isolation of certain components.

Many products already make use of this property of the light signal. Anything that uses an LED for communications, like a remote control for a television, is taking advantage of the fact that the light may be projected through the plastic shield of the LED, across space, and pass through the plastic cover on the infrared receiver on the front of the television. Some products may use this property without the need to transmit a signal, but rather to transmit light itself. Flashlights, light bulbs themselves, televisions, digital clocks, windows in your home, and cell phones are among many products that rely on the fact that light may be passed through different mediums.

This project will yield a system may detect a desired button press by sensing a finger in proximity. This will be done by taking advantage light's ability to permeate glass and its ability to reflect off the human body. Similar to devices in airport restrooms that determine when it's time to flush, or turn on the

faucet, this system will be designed for a much shorter range of reflective sensing. Figure A, below, gives some idea about the layout of the system. The IR light will be transmitted and received after being reflected by a finger within the actuation distance. To protect against false triggers, a machined part will be used to channel the light.

False triggers on the system could be anywhere from a nuisance to a catastrophe. This system will be used in flow meters in dangerous environments while controlling critical process variables. It needs to function properly and ignore false triggers.

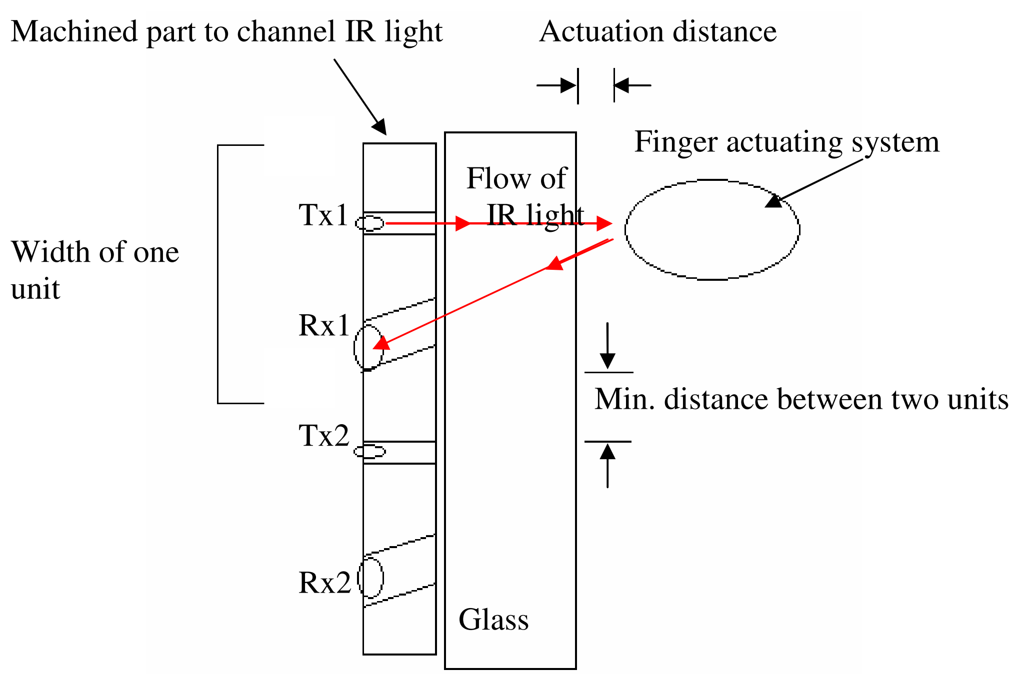


Figure A: This is a cross sectional view of two systems in proximity with a definition for actuation distance, width of one unit, and distance between units. Tx1 and Tx2 are IR emitting diodes as seen in Figure B. Rx1 and Rx2 are 38kHz infrared receivers as seen in Figure C.

Figure B: 950nm IR emitting diode to be used for this project. Digi-Key p/n 425-1940-5-ND

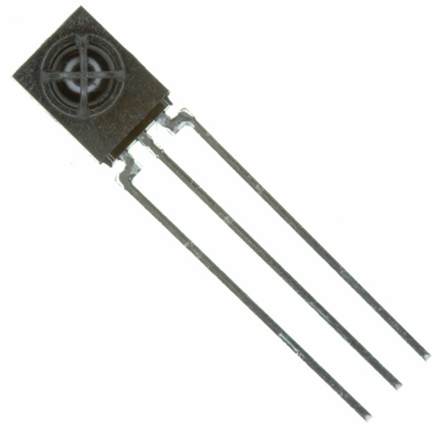


Figure C: 3V 38kHz IR receiver to be used in this project. Digi-Key p/n 425-2528-ND

II. **Background**

Fox Thermal Instruments, Inc.[1] is a company that manufactures flow meters. These meters are purchased by a variety of clients for a variety of situations. In all cases, they are used to measure the flow rate of a gas. In a more specific case, a client may purchase a meter to install in a methane pipe in a factory that has a dangerous level of methane in the atmosphere. It is accepted that the gas from the atmosphere will enter the meter regardless of sealing techniques. If a spark occurs in the electronics, it could explode, along with the factory. To combat this, electronics to be placed in factories with dangerous levels of combustible gas must be inside explosion proof enclosures. The gas will still enter as accepted, but the job of the explosion proof enclosure is to prevent the explosion from leaving the enclosure. In other words, it will sacrifice the electronics to save the factory.

These flow meters are equipped with multiple analog outputs and alarm settings for levels of flow. More specifically, there is a 4-20mA output for flow which the customer may scale. Typically, 4mA is set to 0 flow, and 20mA is set to the max flow that the meter was calibrated to. Sometimes, this number needs to be changed by the customer to equip the meter for a different process or for testing. Before the customer may open the enclosure, they must shut down the factory and exchange all the combustible gasses in the atmosphere for air. Once that is complete, they may unscrew the large cover on the explosion proof

---

[1] www.FoxThermalInstruments.com

enclosure to access the buttons that were visible behind the glass on one side. See figure 2, below, for details.

This process produces a large time frame in which the factory must be at least partially non functional. To prevent this long process for a simple change in variables in the meter, the buttons should be accessible without opening the enclosure. That's where this project comes in. Each button will make use of an infrared emitting diode as a transmitter and a commercial IR receiver as in a typical television. The light will be channeled at an appropriate angle out of the glass face, then if reflected back (by a finger pressing the glass over a button), it will impact the receiver. Power levels and modulation techniques will be discussed later in this document.

The technique being used is very similar to that of an automated faucet in a bathroom, as seen in figure D. Actually, the only difference in the two systems is that the faucet relies only on the propagation of the IR light through air before human skin reflects it back, while the protected IR input system relies on the propagation through glass; of course the actuation distance is controlled at a much larger length in the faucet's system.

Figure D: IR proximity sensor controlled faucet produced by Kohler. You can clearly see the two windows in the stem for the IR emission and reception.

III. Requirements

The main requirement associated with this project is to create accessibility to buttons that lay behind a pane of glass. This requirement is to be met by building a protected IR input system that adheres to the following conditions:

-Produce the described IR input system with an actuation distance of <1cm.
-Total cost for four units should be less than 15 dollars.
-The output should be a digital signal that may be debounced and filtered by a microprocessor.
-Total footprint per unit should be less than 7cm x 3cm.
-Units must function in direct sunlight and under fluorescent lights.

IV. Design

A. Mechanical Assembly

The mechanical assembly of this system entails the circuit board on which the devices are to be mounted, the clear medium through which the IR signal should be transmitted, and an enclosure (if necessary). The circuit board should be mounted with proximity to the clear medium such that the reflection of the emitter IR signal is not reflected towards the receiver by the exit path. Any IR signal reflected by the glass should be contained and discarded. This calls for a barrier between the transmission point and reception point of the IR signal.

The index of refraction of the clear medium should be such that a significant signal strength may be received after having been transmitted through it twice. This project will make use of glass with a refractive index of [insert refractive index of glass used here].

The angle of the IR emission device and the IR receiver should be such that the reflected signal is successfully transmitted at the correct reflection point. This angle should be set by a machined part to produce the same output repeatedly.

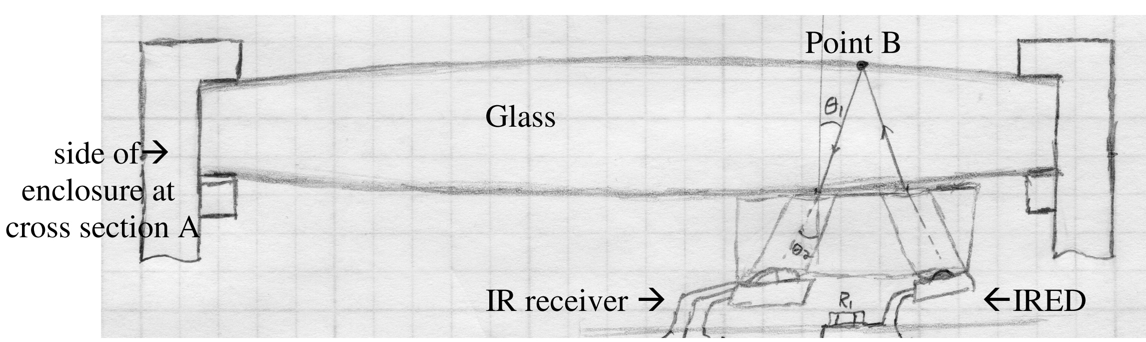


Figure 3: Mechanical assembly of system while viewing cross section A from figure 2. The IR emitting diode is at the right and the IR receiver is at the left. The light travels through the glass face and is reflected down at point B by a finger on the glass.

B. Electrical Assembly

The electrical assembly of this system is completely contained on the circuit board behind the clear medium. There are two main parts to the electrical assembly. The first part is the IR emitter circuit. An oscillating driving voltage should be produced either by a microprocessor or an oscillating circuit. This voltage should oscillate from 0V to 5V with a frequency appropriate to the filter of the receiver circuit. This project will make use of a 38 kHz signal, as this is a common IR modulation frequency. This voltage will be divided down to the appropriate voltage that produces the appropriate power output from the IR emitting diode (IRED). The IRED will also have a resistor in series as another way of limiting the power output. This first part of the circuit will produce the emitted IR signal. As such, it should be produced by a microprocessor if multiple systems are to be used in proximity, as this is the only way to produce modulated digital words with the IR signal.

The second part of the electrical assembly is the receiver circuit. This circuit will be comprised of a commercially available IR receiver chip tuned to the frequency produced by the emitter. This receiver will produce a digital output (active low) after receiving the modulated IR signal. To accomplish this, the signal must be internally limited to prevent railing, and demodulated to produce the digital pulse. The output will remain low for a device specific period before returning high, should the signal continue to be transmitted. This feature prevents multiple trigger events do to a single input reflection. The low output may also be sent high if the IR signal is no longer available. Thus, the digital output of the receiver circuit may be low for 0 seconds up to device

timeout depending on the input signal. This feature allows for a digital word to be transmitted and received appropriately without large distortion. The digital output of this circuit may be sent to the digital input of a processor to determine the digital word, however, if a single system is implemented, the digital low may be used in any number of ways to actuate devices or trigger external circuits.

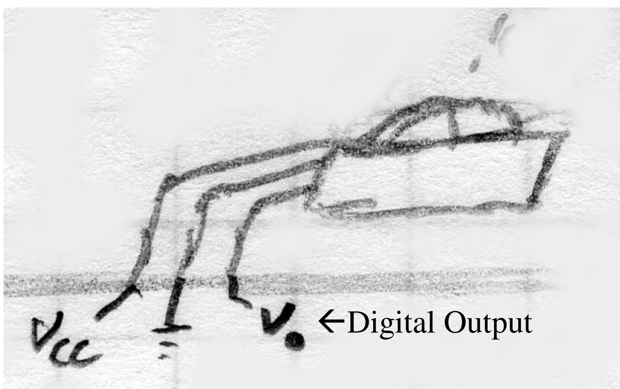


Figure 4: IR receiver circuit

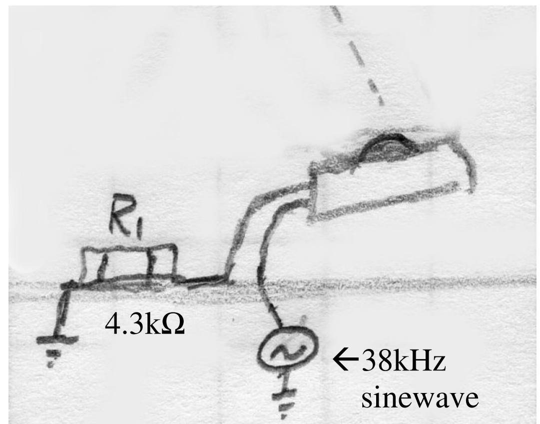


Figure 5: IR transmission circuit

C. Optical Assembly

As covered briefly in the mechanical assembly section of this document (above), the optical assembly of this system is critical in its operation. The IRED should be angled such that no light may enter the receiver device that is undesired. Light reflected immediately off the clear medium during the exit route should be extinguished or blocked. Likewise, the receiver device should be angled such that the previously stated hurdle is made easy. The wide angle of reception of the receiver should be used to such an extent that only reflection due to appropriate actuation may produce an output. The angle of refraction both entering and exiting the clear medium should be taken into

account when deciding on the distance between to the circuit devices, as the light will bend upon changing mediums (air -> glass -> air). This can be accomplished by setting an angle on the receiver device such that light must travel higher than the lower junction from air to glass, however, a more useful and more reproducible approach would include a machined part with “tunnels” guiding the IR light.

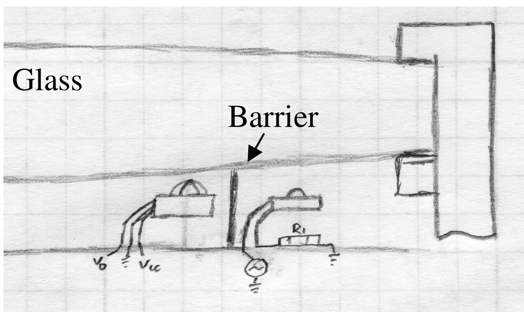


Figure 6: Optical circuit without machined part to channel light depicted at cross section A from figure 2.

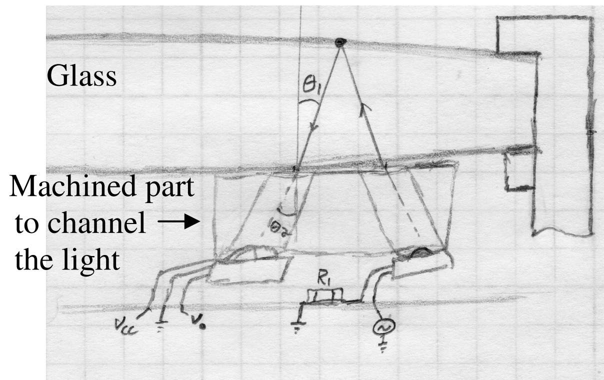


Figure 7: Optical circuit with machined part to channel light depicted at cross section A from figure 2.

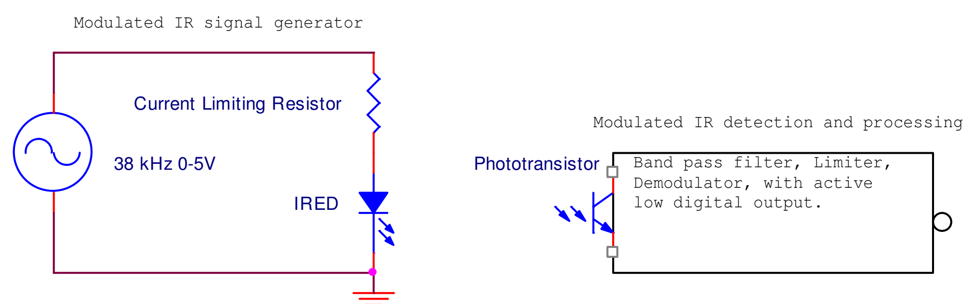


Figure 8: Circuit diagram of system

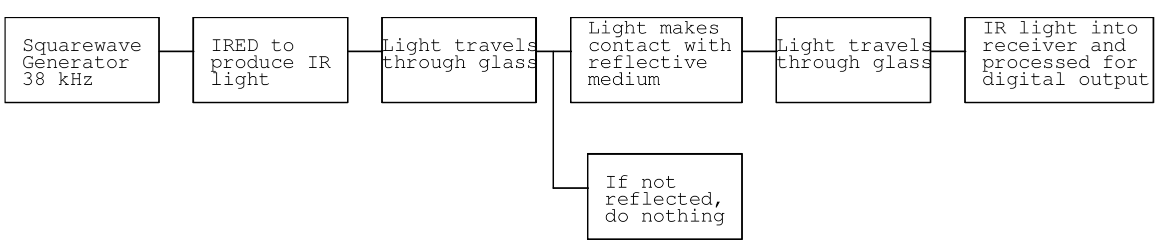


Figure 9: Flow of system

Figures 8 and 9 above are electrical and logical progressions of the system respectively. Figure 8 shows a simple driving circuit on an IRED, with a phototransistor receiving the signal attached to a black box representing the IR receiver IC used in this project. Figure 9 shows the driving source producing the IR signal which is transmitted through the glass where it is then either reflected back towards the receiver to produce the proper output, or is not reflected to produce no output.

V. Development and Construction

Specifications

A merit of successfully developed system will be based on the specifications in table 1, below. These specifications are required for sizing constraints and prevention of false triggers on the system.

The footprint must be such that a four unit system may fit into the enclosure depicted in figure 2 while leaving room for an LCD screen.

The distance from the glass that the system should actuate at is important because if it happens to lay within the glass, it may not be reached, and the system will not work. Likewise, if the point of actuation is too high above the glass, moving your finger to button three after pressing button 1 might incorrectly trigger button two. For example, the user should not have to pull their finger 2 inches off the glass before moving across the string of buttons.

The distance between two proximate inputs is important because we don't want two buttons to trigger with a finger in one place. There should be enough distance between buttons such that a finger sliding across the two buttons should trigger one, then neither, then the other. There must be a small region such that nothing is triggered in between two buttons to ensure only one button is actuated at a time.

Specifications:

Specification	*Minimum*	*Typical*	*Maximum*
Footprint (4 buttons)	5.6 cm x 3 cm	7.2 cm x 3 cm	9 cm x 3 cm
Actuation distance from glass	0.2 cm	0.5 cm	1 cm
Distance between proximate inputs	1.4 cm	1.8 cm	-

Table 1: Specifications for Project

Key Areas of Concern

Unintended actuation of the output of any receiver in this system could be catastrophic if the unit is used as a process variable in a larger system. The sun contains IR light which may be cause for concern if this system was working with DC levels of IR power. Using the 38 kHz carrier frequency with a filter for such on the receiver prevents the sun light from actuating the output.

Another unintended actuation may be caused by accidental reflection. If multiple systems are used in proximity, the reflection of one signal may spread to two or three receivers, causing multiple outputs when only one is desired. This may be prevented by transmitting a digital modulated word rather than continuous oscillation.

Accidental reflection may be caused by more than an intended reflection. Supposing the device is operated outside, perhaps near a tree. If leaves fall towards the reflection point, they may trigger the output at an undesired time.

Available footprint on the circuit board may also be an area for concern. This system cannot be compressed to small quarters. The necessary footprint, as yet to be determined, must be made available with the proper distance from the clear medium as well as parallel to it.

Construction

The first prototype constructed may be seen in figure 11, below. It consisted of the IRED and IR receiver depicted in figures B and C above. It also consisted of a machined piece of plastic intended to channel the IR light signal. The electrical circuitry was constructed on a breadboard and connected to the prototype for testing; results of that

testing may be seen in the next section of this report. This initial system functioned in a basic sense; however the actuation distance was too high. A simple angle change and/or power reduction in the IRED could solve this problem.

After initial testing, a new challenge was presented to me not initially intended in this project. The ability to know if the user is holding the button or if it was simply pressed is important information. Unfortunately, after the receiver output times out, it returns to steady state, even if the signal is still being received. My solution to this problem, since access to a PIC was available, was to have the PIC drive the IRED's at 38kHz for 50ms, then stop for 100ms, and continue in that pattern. This allows the receiver to reset and accept a new trigger. If the user holds the button, the output waveform will follow the input waveform as shown in figure 12, below.

Although solving the new challenge, this technique presented the system with more noise. After testing the new driving signal, the new problem was light flickering inside the enclosure triggering the outputs of all receivers at once. A system that never stops triggering is obviously not going to function correctly.

The final prototype, as may be seen in figure 13, corrected for this by completely protecting the receivers on all sides except what shines down through its channel. Also, the IRED's were completely encapsulated in their channels in an attempt to prevent residual light from contaminating the system.

One last thing to consider while constructing this prototype is the angle change as the light passes from glass to air. The difference in refractive index was significant enough to cause concern. As we know from physics, n1(sin[theta1])=n2(sin[theta2]). As far as transmission is concerned, this change is irrelevant, since the IREDs are parallel to the normal of the glass plane. Upon reflection however, given the distance from the glass

through the channel to the receiver the change in refractive index adjusts the angle by about 18 degrees. This is accounted for in the new machined part.

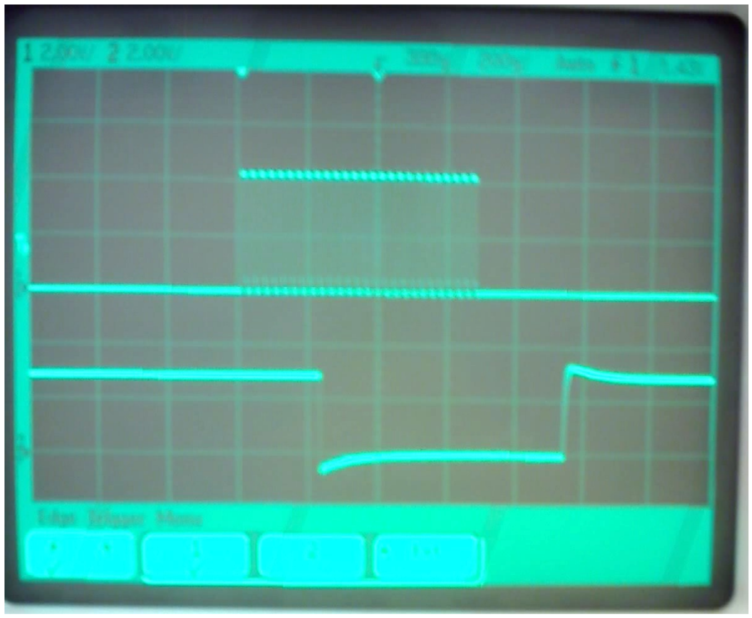


Figure 13: Modulation of driving signal. The IRED's are driven by the top signal and the receivers output the bottom signal.

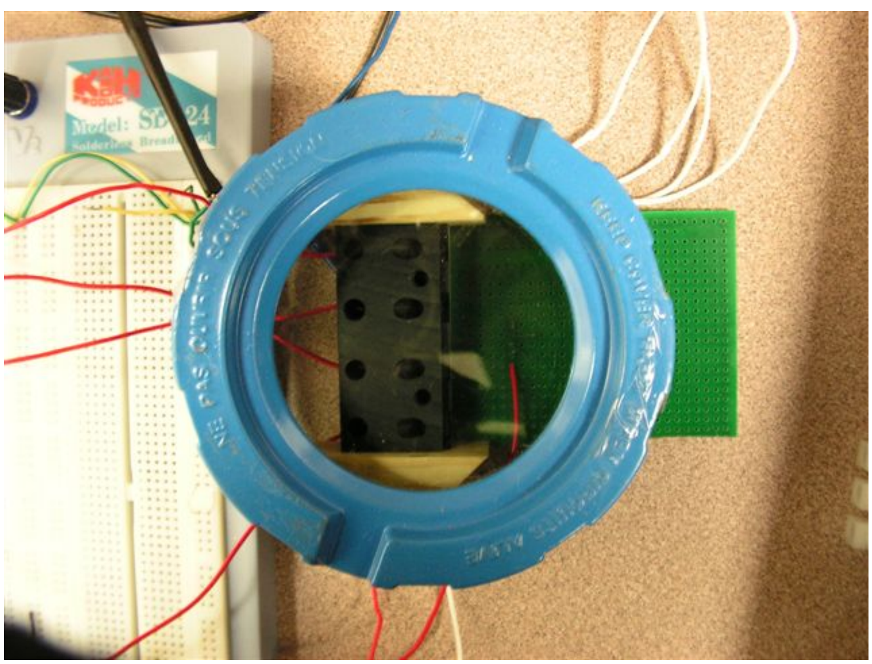


Figure 14: Final prototype design presented inside enclosure. As you can see, the new machined parts completely encapsulate the IREDs and IR receivers.

VI. Implementation and Testing

Prototype 1 Evaluation:

For the purpose of testing the chosen parts, a prototype was constructed using the IR emitting diodes seen in figure B and the 38kHz IR receivers seen in figure C. They were mounted to a PCB and covered with the machined part with channels in it. A side view of this part may be seen in figure A. This prototype was covered with a thick pane of glass is depicted in figure 3. The active low digital output of one of the receivers was probed and the scope was set to trigger on its change. With the IR emitting diodes being driven at 38kHz with about 1mW of power, the system was about to produce appropriate outputs.

With a finger at a distance of 0.5" from the top of the glass, the output triggered for the time specified in the datasheet. An issue that was brought up was that waving your hand over the glass within the actuation distance caused multiple output triggers. This is a good reason to reduce the actuation distance as much as possible. With an actuation distance of <1cm, it would be much less likely that multiple triggers will occur. Also, the digital outputs of the four buttons in the flow meter, where this system will be implemented, are sent into a main processor that will take care of debouncing the inputs and preventing multiple unwanted triggers. Correcting for this is not within the scope of this project, but without a processor, a 555 timer setup as a 1 shot could maintain one output given many triggers. The circuit setup for this is presented in figure 12, below.

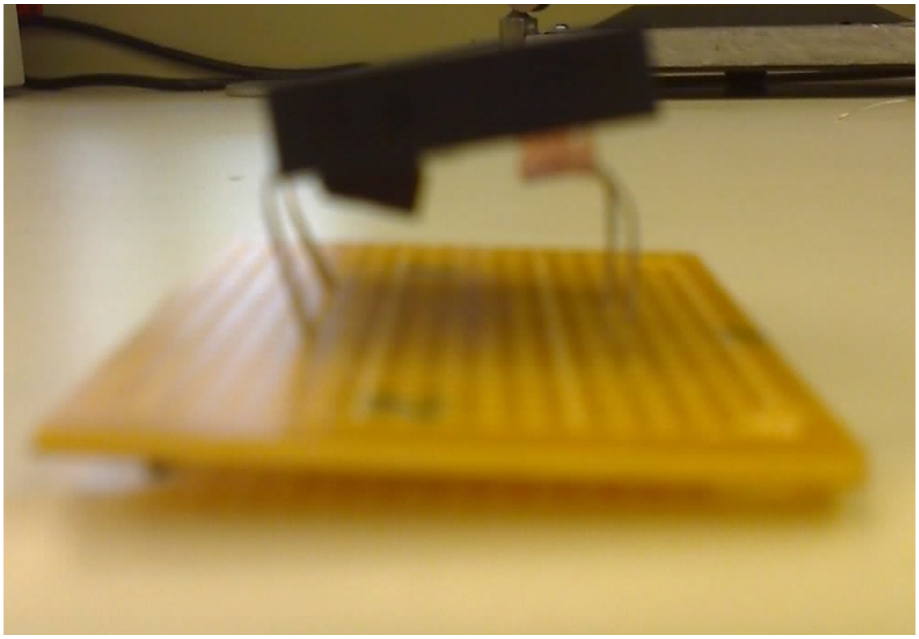


Figure 11: Prototype 1 with IR emitting diodes (right) and 38kHz IR receivers (left) mounted to PCB (bottom) and channeled with a machined part (top). Better image of machined part may be seen in figure A

Prototype 2 Evaluation:

After implementing the new machined parts which encapsulate the transmitters and receivers, light noise was no longer a problem. Using the pulsed driving signal gave us the ability to know if the user was holding the button down, or if they simply pressed it. This was done by counting the number consecutively received signals and anything more than 4 signals was considered a hold. The processor would consider the button held until 2 consecutive signal periods passed with no signal received.

Also, the angle produced by the machined part places the point of actuation about 0.5 cm above the surface of the glass. This is the desired distance to prevent cross talk and inaccessibility. This distance may be displaced if the IREDs are driven with too much power, or not enough power. The power used in the final design is 1.25mW. This

value was decided upon after testing a variety of power settings. A pot is used to verify the proper power from unit to unit.

VII Conclusion

The protected infrared input system senior project has provided me with over two hundred hours of practical experience. Researching the technology and parts available, then taking that and building a working model is exactly what I intend to do in the work force. A problem is presented to you, and you must find an efficient solution. This project has given me confidence that I can solve any problem bestowed upon me. Given the proper resources and time, anything can be accomplished.

This project was definitely a success. After making prototypes and testing different power levels and driving signals, a final design was settled upon. This design combines all the experience I underwent into a fail proof final product. One great thing about this product is that it may be used for many different applications. The technology I took advantage of is very prominent and versatile. It may be scaled down to simple on off operation, or used for remote communication; I simply took it and molded it into my solution.

The most difficult aspect of this project was preventing cross talk between buttons and saturation of the receivers. This was achieved by using a machined part to encapsulate the receivers and transmitters. This machined part also provided channels to adequately direct the light.

I am extremely pleased with the results of this project. Professor Derickson has been a great mentor and Brad Lesko at Fox Thermal Instruments Inc. was kind enough to take me under his wing. Not everybody gets to partake in a senior project that will actually be implemented in a product sold worldwide. If there are any questions or concerns regarding this project, please feel free to email me at kersoy@calpoly.edu.

VIII **Bibliography**

www.wikipedia.com
-Refractive index
-Remote control

http://www.us.kohler.com/onlinecatalog/newproducts_detail.jsp?section=2&prod=Insight%20Faucets%20-%20KBIS%202009
-Commercial faucets with Insight technology

http://www.ikalogic.com/ir_prox_sensors_40khz.php
-Background information on modulated IR proximity sensing technology

www.foxthermalinstruments.com
-Images of the meter this project will be implemented in

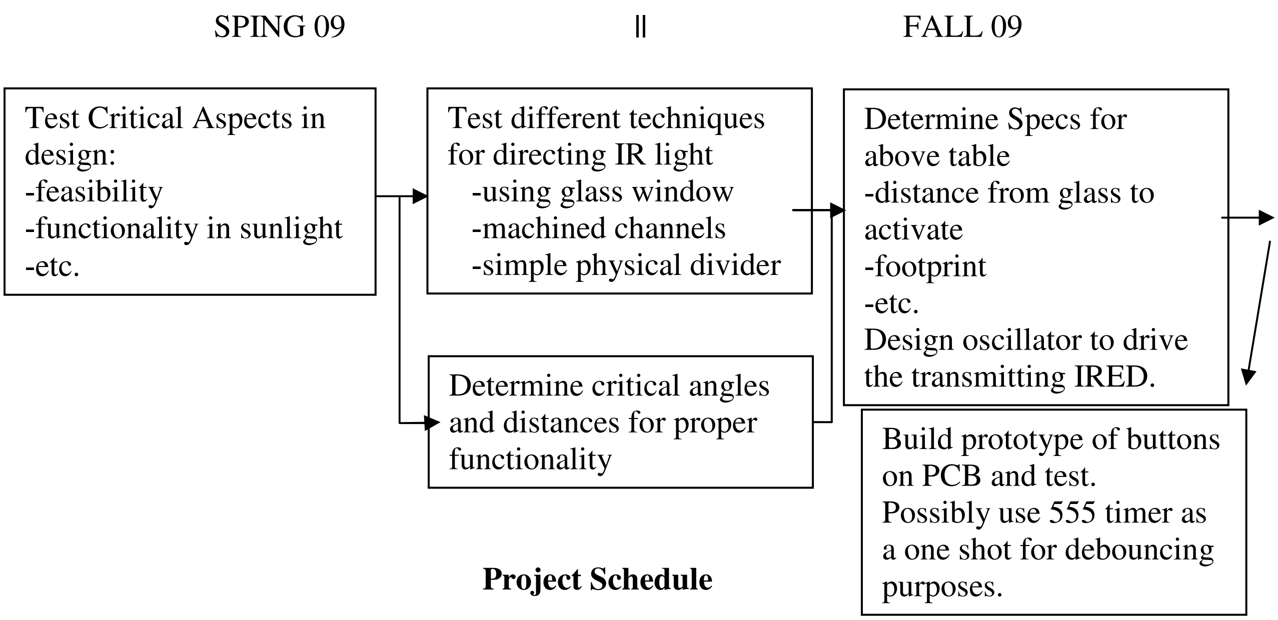
www.digikey.com
-Parts, part numbers, and photos of parts

Appendix A: Parts and Costs

Description	Part Number	Cost
950nm IR emitting diode	Digi-Key p/n 425-1940-5-ND	$0.16 x 4
3V 38kHz IR receiver	Digi-Key p/n 425-2528-ND	$0.67 x 4
Machined Parts	Purchased in runs of 1000	$4.87 x 1
	total	$8.19

Table 2: Parts and Costs

Appendix B: Project Schedule



Project Schedule

Appendix C: Project Preliminary Information

Abstract:

The result of this project is a product that may be used to apply a digital input to a system without physically touching a device. The combination of a modulated IR signal and reflective technology produces this remote actuation. The signal emitter should produce the modulated IR light, and the receiver should continuously wait for this signal to be received. If the IR signal should encounter an obstruction causing reflection at the appropriate distance, it will be reflected directly into the receiving device. This project may be extended to include multiple duplicate systems in proximity by transmitting a modulated digital word with the IR light or by channeling the light thus reducing the divergence of it.

Resource Requirement:

Student Supplied:

1ea	Breadboard
1ea	Blank PCB
10ea	Variety of IRED choices
10ea	Variety of IR receiver choices with 38-40 kHz filters.
1ea	Clear medium (glass) as to be used in final product
1ea	Machined part to lock optical angles

Lab Supplied:

Oscilloscope
DC power supply
Function generator
Leads (banana banana, banana grabber, scope probe)

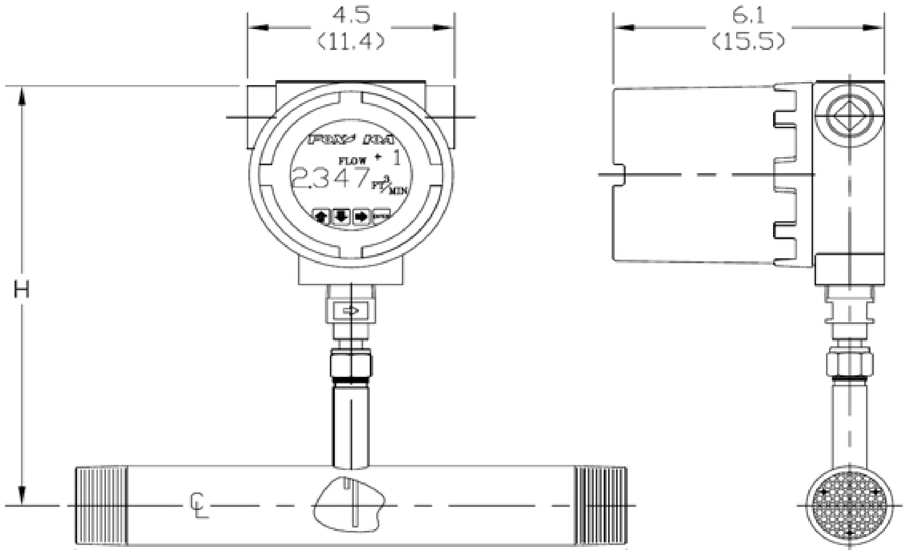


Figure 1: Fox Thermal Instruments flow meter installed in a 2" gas pipe.

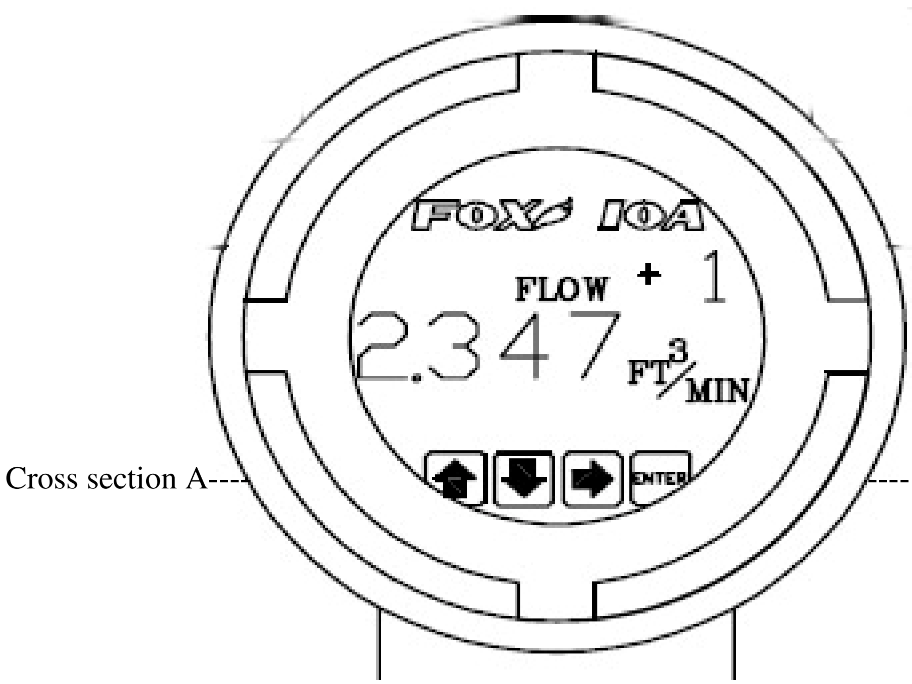


Figure 2: Close up of the meter face in Figure 1. The four buttons at the bottom are to be replaced with the IR input systems. Cross section A, displayed is referenced in subsequent figures.

Overview:

As can be seen in Figure 1, this protected IR input system is to be incorporated with a mass flow meter produced by Fox Thermal Instruments, Inc©. This meter is used to monitor the flow of a desired gas type through pipes of many sizes. Given the explosive environments in some plants, a unit with an explosion proof enclosure may be provided (Figures 1 and 2). The user may make adjustments to the readout or analog outputs but accessing the four buttons on the display board, as can be seen in Figure 2. The display board, along with the buttons, is behind a pane of glass which is about ¼'' thick. Traditionally, the user would have to rid the plant of explosive gases before opening the enclosure the access the buttons. This prevents production for a given time period. The protected IR input system will create access to the buttons without opening the enclosure. This will be done with reflective technology, using modulated infrared light.

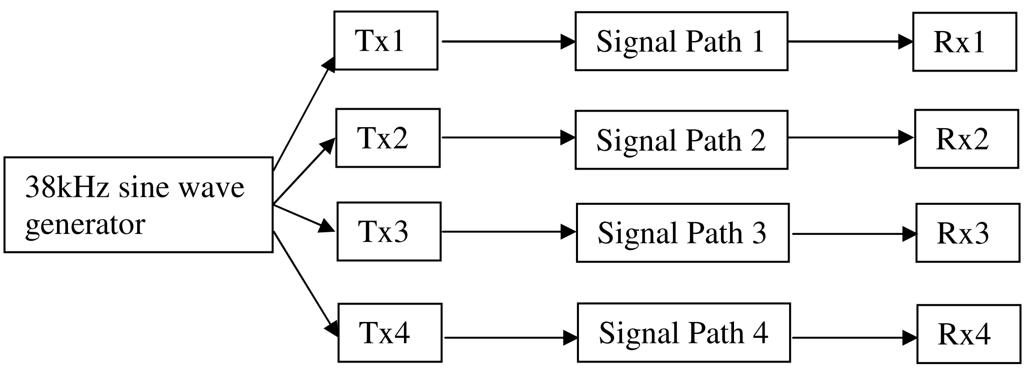


Figure 10: Block Diagram of System. Tx represents the IR emitting diode in figure B. Rx represents the 38 kHz receiver in figure C. The signal paths are open circuits until a finger is sensed in proximity with the glass.

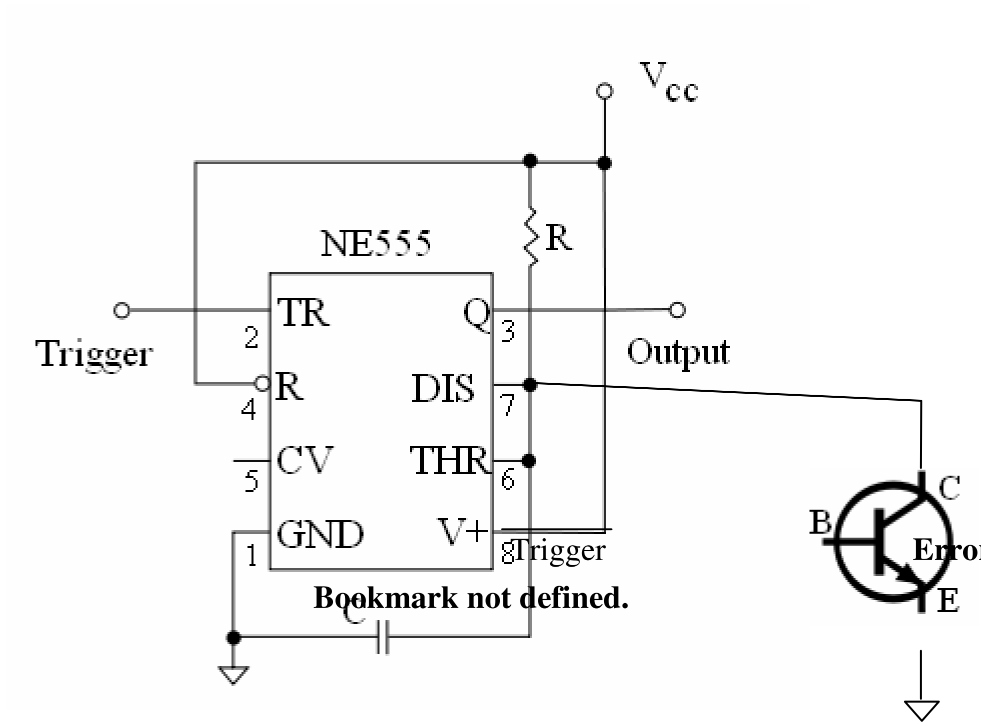


Figure 12: 555 timer in monostable mode (one shot) setup to debounce digital output of the protected IR input system. The trigger is the opposite of the digital output from the protected IR input system.