Design Specifications for a Dynamic Pupil in a Prosthetic Eye

November 01, 2004

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 340 Design Specifications for a Dynamic Pupil in a Prosthetic Eye

Dear Dr. Rawicz:

The attached document, *Design Specification for a Dynamic Pupil in a Prosthetic Eye*, outlines the overview of the design specifications for our project in ENSC 340. This design specification provides an overview of our system and the design implementations of the system hardware, microcontroller firmware and communication protocols. The goal of this project is to improve the cosmetic aspects of an artificial eye that replaces the real eye of a patient in circumstances that surgery does not provide necessary means to improve the health of the diseased eye.

Prosthetic eyes have been used to replace fatally diseased human eyes since the beginning of the 19th century. Ocularists, people who custom-make the prosthetic eyes, have quite improved the cosmetic aspects of these eyes as far as color matching between the real eye and the artificial eye in a patient is concerned, both in the eye ball and the iris. Being able to utilize a dynamic pupil in an artificial eye would tremendously improve the esthetic of such eye and make them very similar to a functioning healthy human eye.

Our team, Dyno I, consists of four talented, enthusiastic and hard-working forth year engineering students. These individuals include: Nima Kokabi, CEO; Houman Hatamian, CFO; Ali Taheri, CTO; and Arash Taheri, COO. Please feel free to contact us at ataheri@sfu.ca if you have any questions.

Sincerely,

Nima Kokabi

Nima Kokabi
CEO
Dyno I

Enclosure: *Design Specifications for a Dynamic Pupil in a Prosthetic Eye*

Design Specifications for Dynamic Pupil in a Prosthetic Eye

Members: Nima Kokabi
Houman Hatamian
Ali Taheri
Arash Taheri

Contact Person: Arash Taheri
ataheri@sfu.ca

Submitted To: Dr. Andrew Rawicz-ENSC 340
Steve Whitmore-ENSC 305
Mike Sjoerdsma
School of Engineering Science
Simon Fraser University

Date of Submission: November 01, 2004

Design Specifications for a Dynamic Pupil in a Prosthetic Eye

Executive Summary:

We at Dyno I propose to design a dynamic pupil that will be utilized in a prosthetic eye. This pupil will consist of a custom-made LCD. Furthermore, to control the intensity of the ambient light, we utilize a super small micro controller which will be programmed in a way that when used in conjunction with LCD, the overall system would replicate the functionality of a real pupil. Dyno I consists of four engineering students from Simon Fraser University, who bring extensive experiences and ideas to the design of our project. Our products must be conventional to the highest quality and usability standards. Dyno I will require approximately $4500 in order to fulfill the financial needs of this project. This project is partially founded by Dr. Peter Dolmen, who is one of the most well-known ophthalmologists in the area of research in British Columbia. Moreover, due to the high financial costs, we will try to obtain more funding through SFU as much as possible.

The integration and development of our project contains two different sections. Phase one of our project develops a dynamic pupil utilized in a prosthetic eye. This artificial eye contains an LCD which is sensitive to the intensity of ambient light in its surroundings; therefore, size of the pupil changes according to the intensity of light.

In phase two of our project, Dyno I members try to move the project even further ahead, making it actually practical for future patients.

This document outlines the Design specifications of the first phase of our project at Dyno I.

Design Specifications for a Dynamic Pupil in a Prosthetic Eye

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Design Specifications for a Dynamic Pupil in a Prosthetic Eye

1. Introduction:

Prosthetic eyes have been used to replace fatally diseased human eyes since the beginning of the 19th century. Even though the cosmetic aspects of the artificial eyes have come a long way since its inception, a major short coming still exists in modern designs of these eyes. Ocularists, people who custom-make the prosthetic eyes, have quite improved the cosmetic aspects of these eyes as far as color matching between the real eye and the artificial eye in a patient is concerned, both in the eye ball and the iris. Being able to utilize a dynamic pupil in an artificial eye would tremendously improve the esthetic of such eye and make them very similar to a functioning healthy human eye.

We at Dyno I propose to design a dynamic pupil that will be utilized in a prosthetic eye. This pupil will consist of a custom-made LCD. Furthermore, to control the intensity of the ambient light, we utilize a super small micro controller which will be programmed in a way that when used in conjunction with LCD, the overall system would replicate the functionality of a real pupil.

This design specification document provides high level design overview of the first phase of the project and the specific features and tasks of corresponding subsystems. The key subcomponents that will be discussed in this document include a custom-made LCD, a super-small microcontroller, a photodiode, a crystal, and a battery.

1.1. Acronym:

CPU:	Control Processing Unit	**I/O:**	Input/Output
LPM:	Low Power Mode	**HPM:**	High Power Mode
DCO:	Digitally Controlled Oscillator	**FLL:**	Frequency Locked Loop
ACLK:	Auxiliary Clock	**DAC:**	Digital to Analog Converter
MCLK:	Main Clock		
SMCLK:	Sub-Main Clock		

1.2. Intended Audiences:

This document is provided for managers, designers, and marketing personnel. Managers are able to use this document as a guide for scheduling and other managements. Designers may use this document as a guideline for the development of the system. Finally, marketing personnel may look at this document as a guide for product promotion.

2. System Overview:

The following sections of the document provide the system overview of the design of our project at Dyno I.

2.1. Phase One:

Figure 2.1.1 below illustrates the overall high level design of our dynamic pupil system in a prosthetic eye. The operation begins with a light sensor monitoring the intensity of ambient light around the eye. In fact, the diode converts the light intensity to an electrical signal that can be constantly monitored by a control unit. The control unit in turn controls the LCD that replicates the pupil. This pupil effectively opens up and closes similar to a real pupil according to the intensity of the ambient light. The higher the intensity of the light, the smaller the pupil becomes; as a result, less light is allowed to enter the eye. Similarly the lower the intensity of the light, the larger the pupil diameter becomes which causes more light to enter the eye.

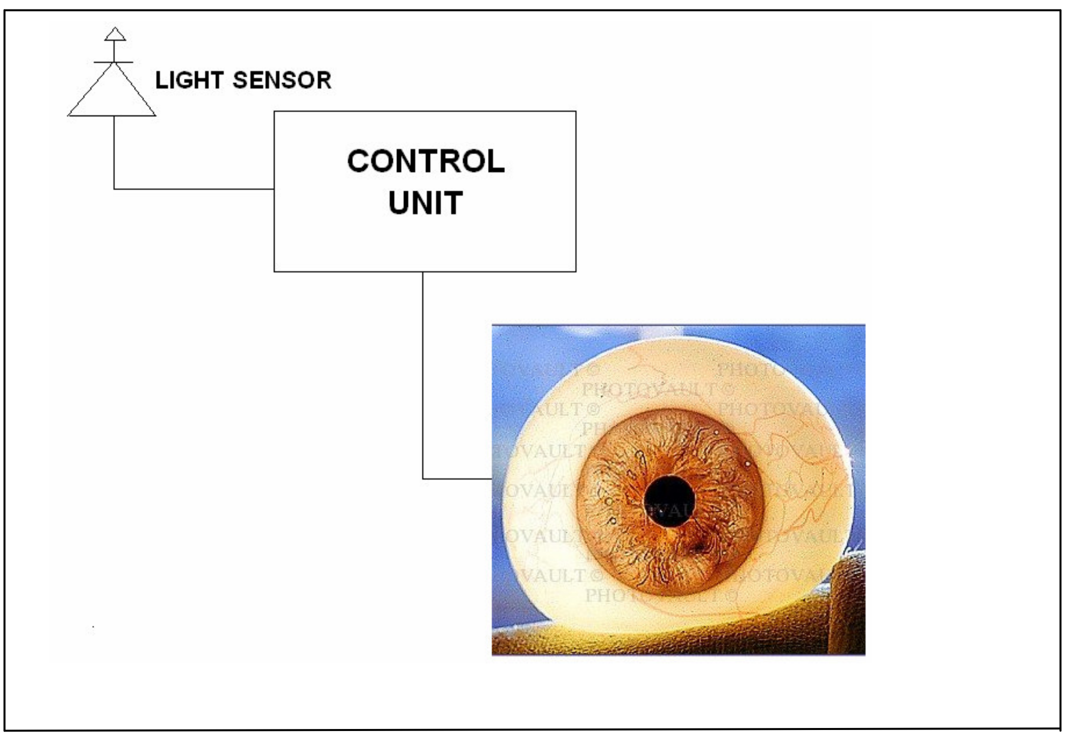


Figure 2.1.1: Overall High Level Design of the Dynamic Pupil System

Figure 2.1.2 illustrates how a typical eye would look at different ambient lights. The eye on the left side is situated in a dim ambient light which has caused the pupil to open up a great deal. On the other hand, the same eye when placed in a bright environment shows a very small pupil. This is shown in the eye on the right hand side of figure 2.1.2.

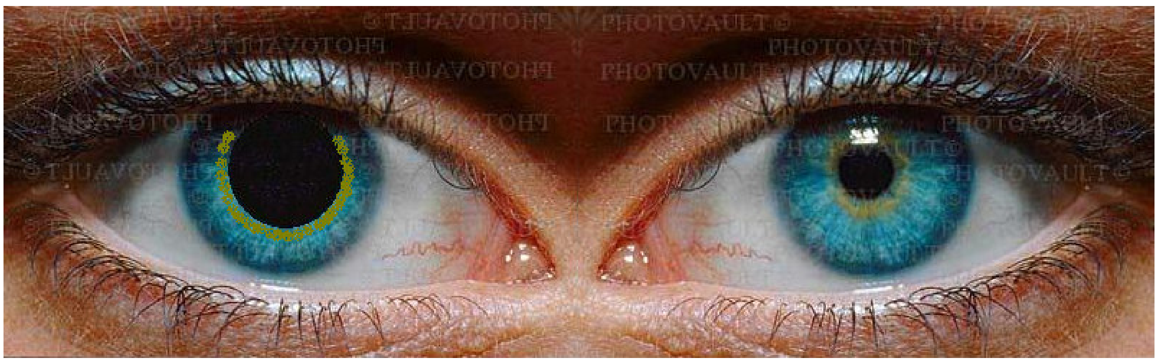


Figure 2.1.2: Illustration of a typical eye at different Ambient Lights

The uniqueness of the dynamic pupil prosthetic designed by Dyno I is that the entire circuitry is so incredibly small that it can be situated in the front portion of the prosthetic eye. The circuitry is also designed to be heat sensitive so that when placed in the initial mold of the artificial eye, it can be easily cured along with mold at high temperature for sterilizing purposes. The small size of this system also bears the advantage of this system being easy to be used by patients. They can use the same procedure used to clean current prosthetic eyes without worrying about any external components or connections.

Figure 2.1.3 on the next page illustrates the overall flow chart of our design. As the figure represents, the photodiode acts as a light sensor in detecting light from the surroundings. The Microcontroller monitors the different intensities of the ambient light. When intensity of light increases, microcontroller notices this difference and forces the size of the pupil to decrease. Furthermore, decreasing the intensity of ambient light forces the size of pupil to increase by the aid of microcontroller. However, when intensity of light stays constant, no difference is detected by the microcontroller; as a result, size of the pupil stays the same. Furthermore, as it's shown in the flow chart, after increasing or decreasing the size of the pupil, the system goes back to the original monitoring mode in order to start monitoring the intensity of the ambient light, as this loop continues for ever.

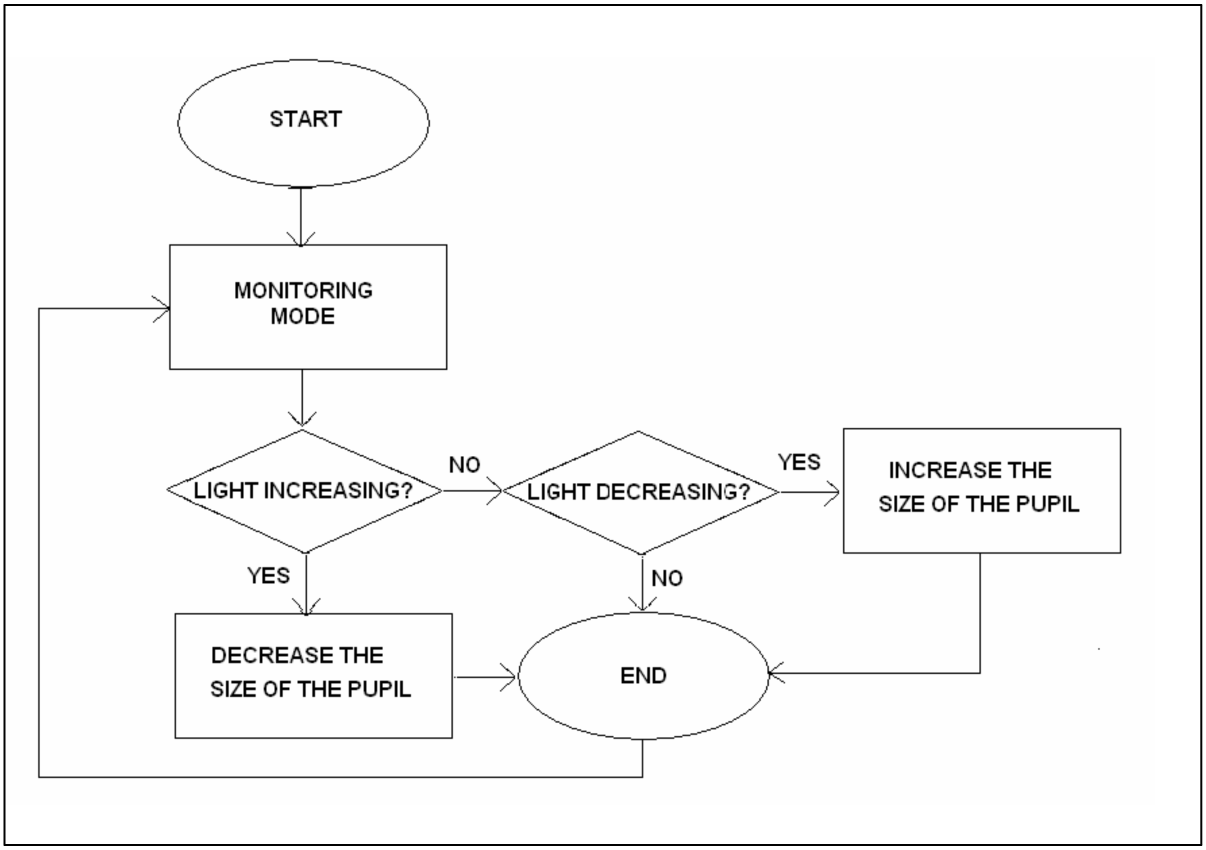


Figure 2.1.3: Overall Flow Chart Design of the Project

The biggest complication faced by our group in designing the dynamic pupil system is that we have to design the whole system, including the battery and the circuit board, small enough that it can be fit into the mold that forms the front of the artificial eye. Figure 2.1.4 on the next page shows the major components of an artificial eye, which consists of an orbital implant as well as the front portion of the artificial eye, which is mainly made by plastic mold, custom-built to fit individual patients.

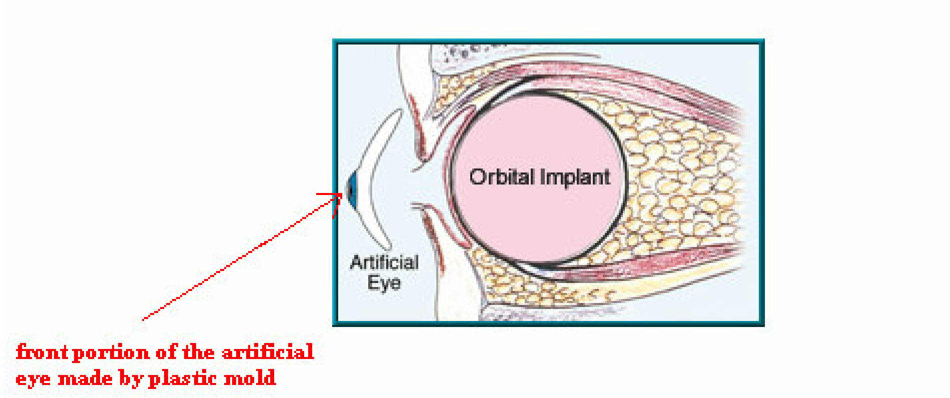


Figure 2.1.4: Major Components of an Artificial Eye

As you can see from the above figure, the front portion of the artificial eye has a very limited space to work around with. The other issue present is that an ocularist uses a rather high temperature of 105^0C for half an hour in order to cure the mold. Therefore, the dynamic pupil system in our case has to withstand this high temperature since it is being situated in the mold before it's been cured. One of the difficulties we had was to find batteries, microcontrollers, as well as custom-made LCDs that would be resistant to this high temperature, which was achieved after hard and long research hours.

Following figure is a block diagram of our proposed design. This design consists of a photodiode, a super small microcontroller, and a custom-made LCD powered by a thermal resistant extended life lithium ion battery. Figure 2.1.5 represents an overview of our design. However, different components of the project will be discussed in much more detail throughout this document.

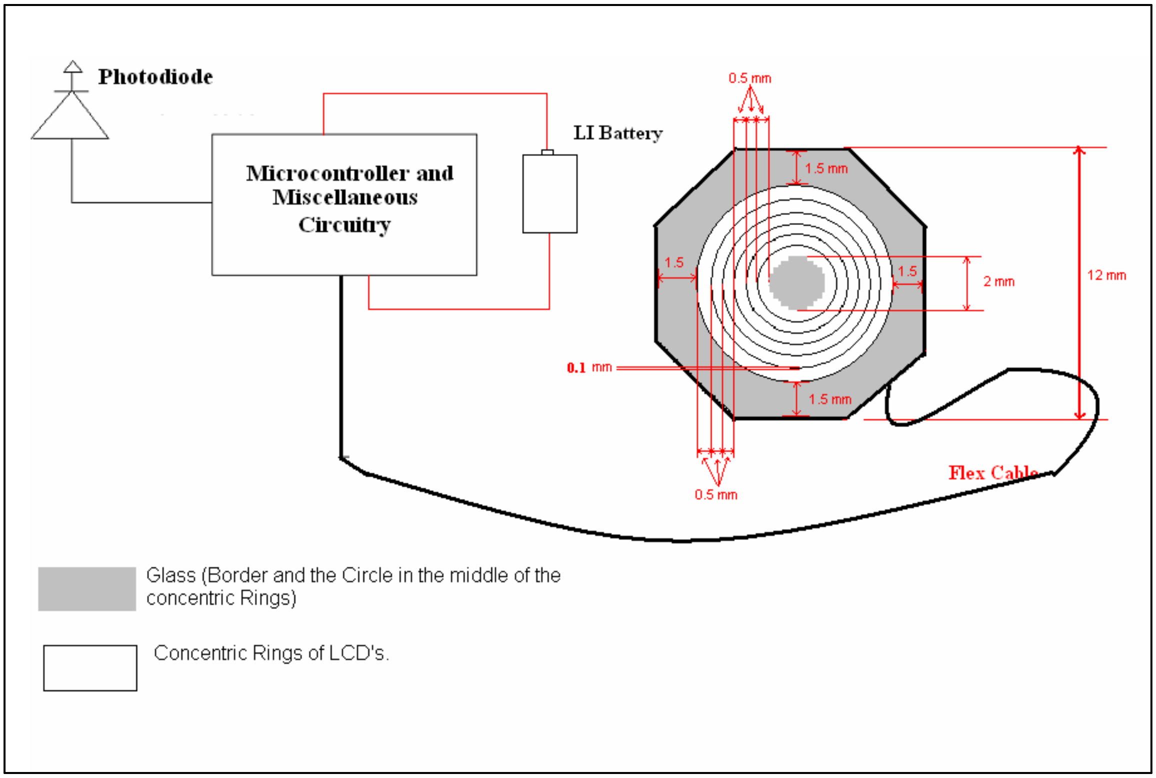


Figure 2.1.5: Overview of Design Specifications Block Diagrams

As mentioned previously, the above block diagram is the illustration of our proposed design at Dyno I. As a result, the dimensions specified on different parts of the above diagram were slightly changed after discussing our LCD manufacturer.

3. Design Decisions:

This section of the document outlines the key decisions made in our design and the reasoning behind them.

3.1. Physical Requirements:

As discussed previously, because the overall system of our design will be placed in an artificial eye, one of the main difficulties facing us in the design of the project is space limit. As a result, the custom-made LCD, the microcontroller, the battery, and the photodiode are chosen to be as small as possible in order to overcome this problem. Dimensions and physical properties of these four main parts will be discussed in detail in the hardware section of this document.

3.2. Communication Between Devices:

In order to communicate between the light sensor, photodiode, and the custom-made LCD, we decided to use a super-small microcontroller named as "MSP430 Family". One of the most important reasons behind choosing this microcontroller is that it contains and LCD Driver. Furthermore, this group of microcontroller has a very small size, which will be a perfect choice in our case, due to the limited space we have. This microcontroller will be discussed much more in detail in the hardware section of the document.

3.3. Power Supply:

We have used a very small battery as the voltage source in our design. This brand is named "BR1225A/HB". The main reason behind choosing this battery is its capability of having very low power consumption.

4. System Hardware:

This section of the document covers the hardware specifications for the LCD, microcontroller, battery, and the light sensor. Each part will be discussed in a section in detail.

4.1. Microcontroller:

The Texas Instruments MSP430 family of ultra low power microcontrollers consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low power modes is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that attribute to maximum code efficiency.

The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 6µs. The MSP430x41x series are microcontroller configurations with one or two built-in 16-bit timers, a comparator, 96 LCD segment drive capability, and 48 I/O pins. Typical applications include sensor systems that capture analog signals, convert them to digital values, and process the data and transmit them to a host system. The comparator and timer make the configurations ideal for industrial meters, counter applications, handheld meters, etc. **(Source: TI Manual Book for MSP430 Series)**

This microcontroller is the communicating device between the photodiode, which acts as a light sensor, and the custom-made LCD. This communication is discussed in detail below:

- The communication is functioned between the photodiode and the Custom-Made LCD by the aid of microcontroller.
- The main and only communication is between the light sensor and the LCD.
- The photodiode detects the ambient light from the surroundings and passes the data to the microcontroller.
- The microcontroller processes the data. It compares the new values received from the photodiode with the old values stored.

- By comparing the old values with the new ones, the microcontroller decides what task should be performed. For example, if the microcontroller senses that the intensity of light is increased, it decides that the size of the pupil should be decreased. (In fact, some of the rings on the LCD will shut down to make the size of the pupil smaller.)

- When the microcontroller chooses the task to be performed, it communicates with the LCD. Basically, it will send a message to the LCD and orders the pupil to increase or decrease according to the task.

- Communication part of our product is done by computer programming. There are three languages in which the microcontroller can be programmed: Assembly Language, C, and C++. We at Dyno I decided to use C in programming our microcontroller.

- After the microcontroller sends the message to the LCD, the size of the pupil increases or decreases accordingly.

The Pin layout of this microcontroller used in our design is illustrated in the following figure:

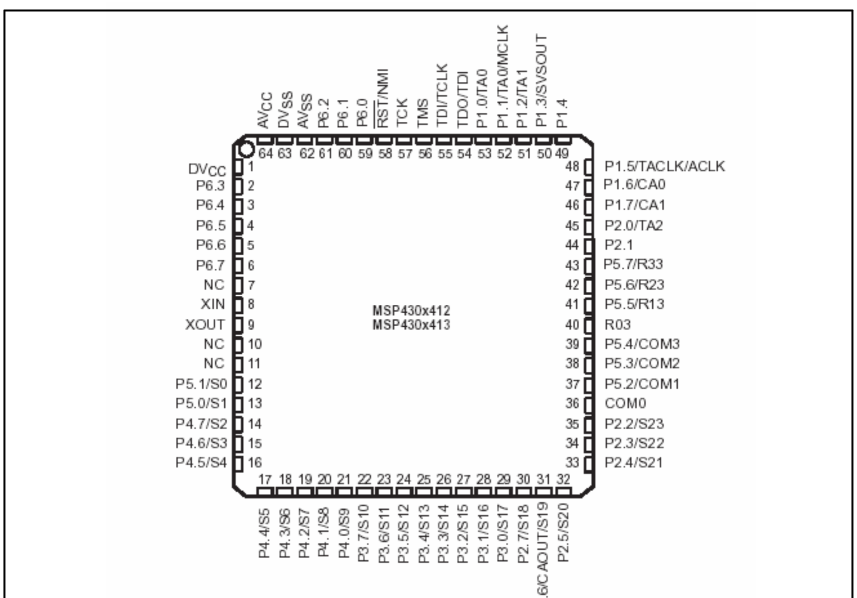


Figure 4.1.1: Pin Layout Representation of the MSP430 Microcontroller

4.1.1. Memory and I/O:

It is important to mention that there are sex 8-bit I/O ports implemented in this microcontroller. These six ports are ports one to 6:

- All individual I/O bits are independently programmable.
- Any combination of input, output, and interrupt conditions is possible.
- Edge-selectable interrupt input capability for all the eight bits of ports P1 and P2.
- Read/write access to port-control registers is supported by all instructions.

4.1.2. Power Saving Features:

The microprocessor has sleep-and-wake up features. As a result, we are allowed to save power by putting the processor to sleep.

The microcontroller is able to go to LPM (Low Power Mode) when the patient is sleeping with close eyes. It is also able to switch back to regular mode, when the patient opens his/her eye(s). This function of the microcontroller will also help the batteries to prevent them from being wasted. In fact, the microcontroller is able to sample each second to see if the eye is placed in the darkest environment possible. If so, the whole system shuts down. On the other hand, when the patient opens his/her eye(s), the unit is capable of detecting light and changing back to the regular mode.

4.1.3. Important Features:

Some of the most important features of the MSP430 Microcontroller are listed in Table 4.1.3.1 on the next page:

Table 4.1.3.1: Several Features of MSP430 Microcontroller

- Low Supply-Voltage Range, 1.8 V . . . 3.6 V
- Ultralow-Power Consumption:
  - Active Mode: 200 µA at 1 MHz, 2.2 V
  - Standby Mode: 0.7 µA
  - Off Mode (RAM Retention): 0.1 µA
- Five Power-Saving Modes
- Wake-Up From Standby Mode in less than 6 µs
- Frequency-Locked Loop, FLL+
- 16-Bit RISC Architecture, 125-ns Instruction Cycle Time
- 16-Bit Timer_A With Three† or Five‡ Capture/Compare Registers
- Integrated LCD Driver for 96 Segments
- On-Chip Comparator
- Brownout Detector
- Supply Voltage Supervisor/Monitor - Programmable Level Detection on MSP430F415/417 devices only
- Serial Onboard Programming, No External Programming Voltage Needed Programmable Code Protection by Security Fuse
- Bootstrap Loader in Flash Devices
- Family Members Include:
  - MSP430C412: 4KB ROM, 256B RAM
  - MSP430C413: 8KB ROM, 256B RAM
  - MSP430F412: 4KB + 256B Flash 256B RAM
  - MSP430F413: 8KB + 256B Flash 256B RAM
  - MSP430F415: 16KB + 256B Flash 512B RAM
  - MSP430F417: 32KB + 256B Flash 1KB RAM
- Available in 64-Pin Quad Flat Pack (QFP) and 64-pin QFN
- For Complete Module Descriptions, Refer to the *MSP430x4xx Family User's Guide*, Literature Number SLAU056

(Source: Texas Instruments Manual for MSP430 Series)

4.2. LCD:

- In order to have a better design and make the product more practical for the patients, the best thing to do is that the boarders around the concentric rings of LCD be as small as possible. The LCD is chosen to be 12.0 mm by 12.0 mm. All dimensions of different parts of the LCD will be shown later throughout the document.

- Instead of using pins around the octagonal LCD, a flex cable is used in order to occupy less space. This cable is located in one of the sides of the LCD. There are eight wires coming out of the cable and the distance between each pair is 0.50 mm. This description is shown if Figure 4.2.1 on the next page:

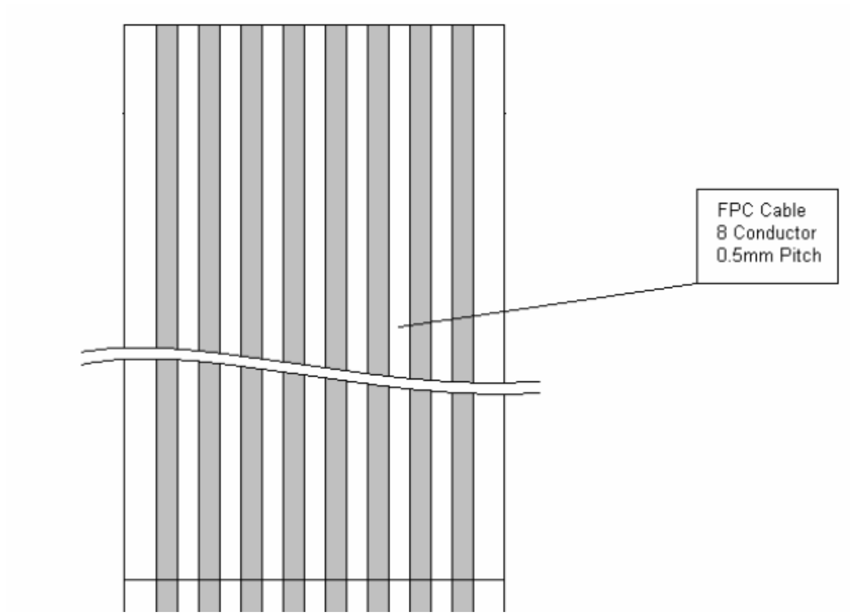


Figure 4.2.1: Representation of the Flex Cable which will be Located on the LCD

- The width of each concentric ring of LCD is 0.5 mm. The gap between two consecutive rings is 0.03 mm. The Iris is about 3.0 mm and the width of the boarders is 1.00 mm. All dimensions will be shown later in this section.
- The gap allowed for Icon Control Trace Routing is 1.00 mm.
- The thickness of LCD is set to be about 1.9 mm.
- The reason that the overall design of LCD is chosen to be so small is to be able to fit the whole system inside the pupil of the artificial eye.

4.2.1. General Specifications:

The following lists some general specifications about the custom-made LCD:

- **Technology:** TN Positive Image
- **Segments/Commons:** 7 Segments/ 1 Common
- **Segments:** (7 Segments) Icons: Ring 1 to Ring 6 (Circular Bands/ no text), and Iris.

- **Duty:** 1:1 Static
- **Bias:** ½
- **Rear Polarizer:** Transmissive
- **Interconnect:** 1 Ledge, 8 Conductor FPC using 0.5 mm Centers.
- **Glass Size:** See Diagram
- **Viewing Area:** See Diagram
- **Glass Thickness:** 1.1 mm (2.9 mm Total)
- **PPC Cable Length:** 12.7 mm
- **Viewing Angle:** 6:00
- **Operating Temp:** -30 to +105 deg C
- **Storage Temp:** -40 to +105 deg C

The overall design of the custom-made LCD is shown on the next page.

It'll be discussed later in the document that only five pins of the Flex Cable will be used in our design.

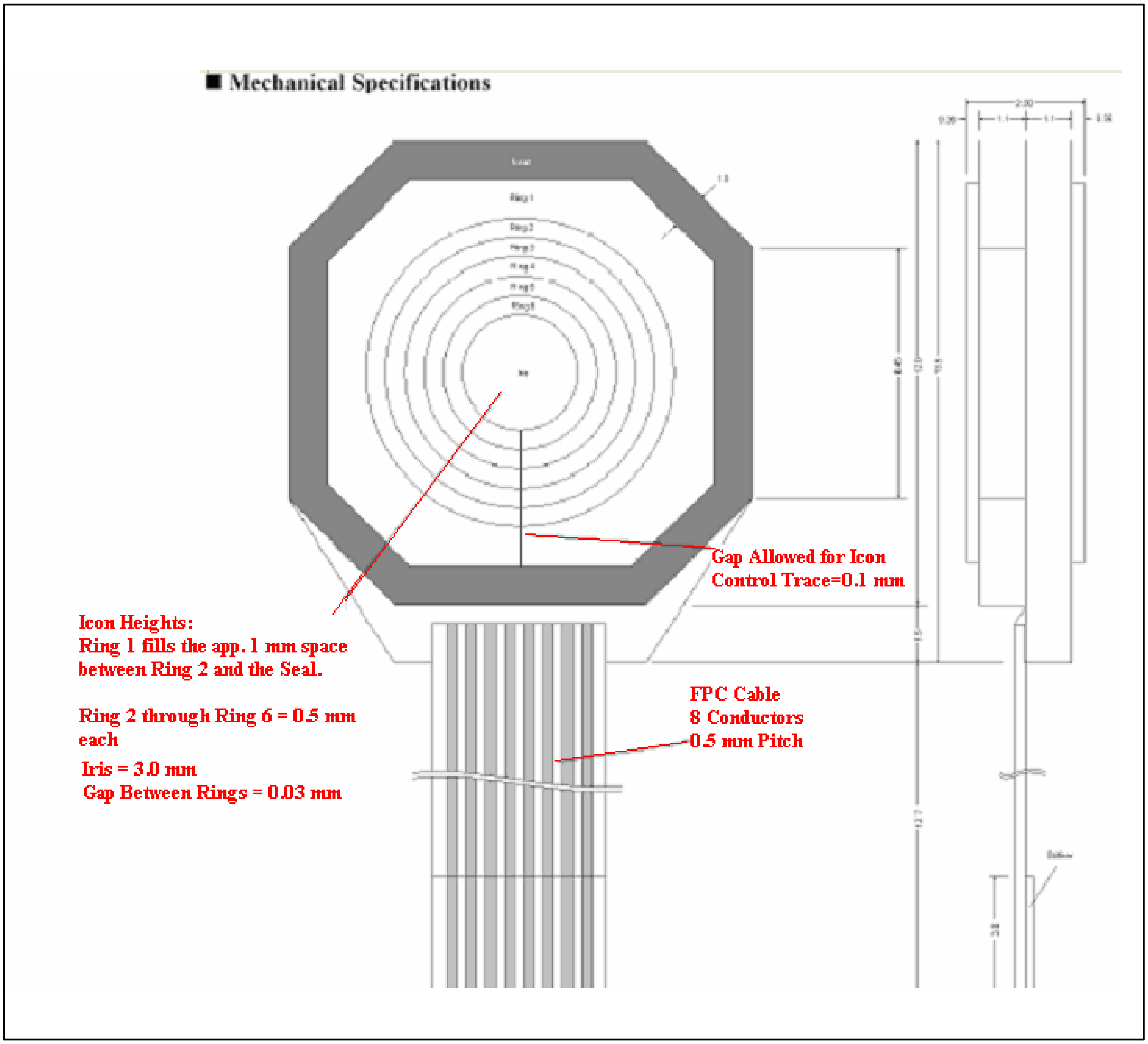


Figure 4.2.1.1: The Overall Design of the Custom-Made LCD

4.3. Photo-Diode:

As mentioned previously, photo-diode is used as a light sensor in our design at Dyno I. In fact, it is the photo-diode which initiates the overall process by detecting the intensity of light from the surroundings and passing the values as voltages to the microcontroller. The photo-diode being used in our project is the "PDB-C139-ND" Brand. Figure 4.3.1 illustrates the physical characteristics of this light sensor.

Photo Detectors

Fig.	Active Area (mm sq)	Short Circuit Current (Isc) (uA) Typ.	Dark Current (Id) (nA) Max	Sensitivity Wavelength (nm) Min.	Peak	Max.	Junction Capacitance (pF) Typ.	Response RL=1KOhm (ns) Typ.	Viewing Angle (2x Theta)	Digi-Key Part No.	Price Each 1	25	100	250
Blue Enhanced PhotoConductive Detectors, Curve Line B														
2	4.10	67	30	400	950	1100	18	50	61	PDB-C139-ND	1.50	1.45	1.37	1.30

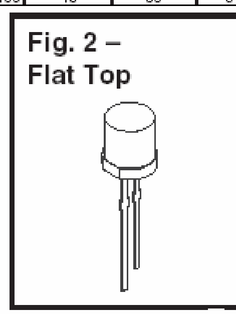


Figure 4.3.1: Specifications of PDB-C139-ND Photo-Diode

The photodiode is preferred to be as small as possible in order to be able to be localized inside the artificial eye. As a result, our grouped picked a photodiode, which has an active area of about 4.10 mm^2.

4.4. Battery:

In order to be able to fit the whole circuit inside the pupil of an artificial eye, Dyno I members decided to use super-small batteries in the design of the project. The dimensions specifications of the battery used in our project are shown in Figure 4.4.1 on the next page.

The MSP430 Microcontroller has the ability to go to LPM when applicable. This is one of the advantages of the microcontroller as it helps the battery not to be wasted when the patient closes his/her eye(s).

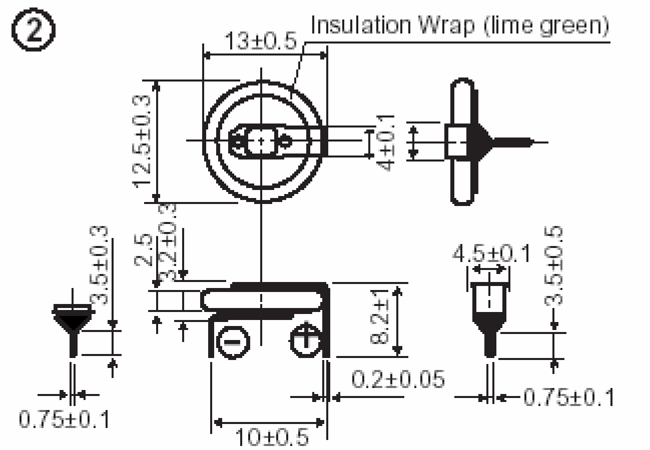
Model No.	Dimensions/mm
BR1225A/HB	

Figure 4.4.1: Model Number and Dimensions of the Battery used in our Design

4.5. Crystal:

The clock system in the MSP430x41x family of devices includes support for a 32768-Hz watch crystal oscillator, an internal digitally-controlled oscillator (DCO) and a high frequency crystal oscillator. This system is designed to meet the requirements of both low system cost and low-power consumption. The FLL+ features a digital frequency locked loop (FLL) hardware which in conjunction with a digital modulator stabilizes the DCO frequency to a programmable multiple of the watch crystal frequency. The internal DCO provides a fast turn-on clock source and stabilizes in less than 6 µs. The FLL+ module provides the following clock signals:

- Auxiliary clock (ACLK), sourced from a 32768-Hz watch crystal or a high frequency crystal.
- Main clock (MCLK), the system clock used by the CPU.
- Sub-Main clock (SMCLK), the sub-system clock used by the peripheral modules.
- ACLK/n, the buffered output of ACLK, ACLK/2, ACLK/4, or ACLK/8.

5. Overall Design Descriptions:

5.1. Design Schematic Description:

Figure 5.1.1 below illustrates the overall design of the project and the connectivity between the different components:

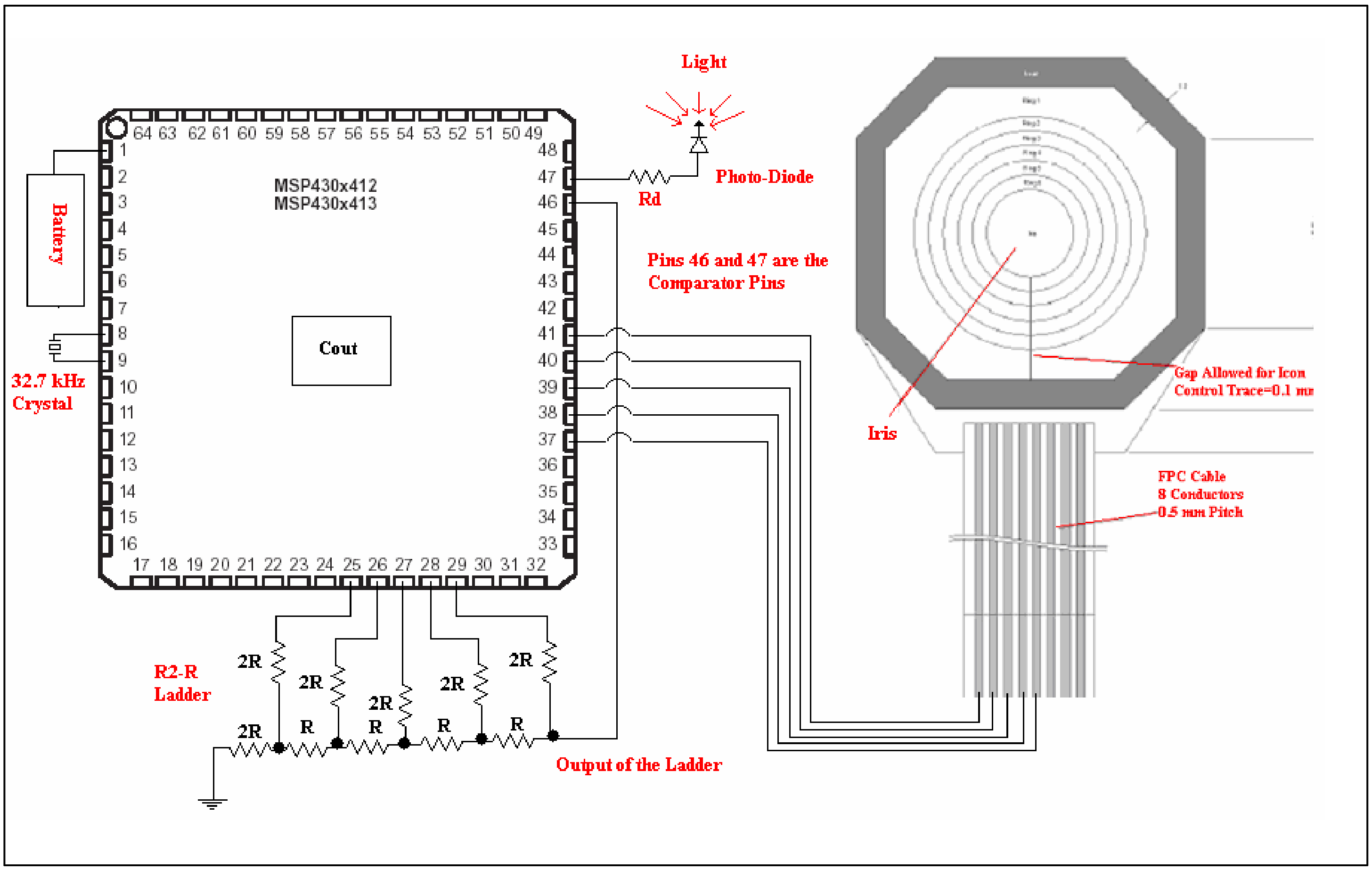


Figure 5.1.1: The Overall Circuitry of Our Design

- The first pin of the MSP430 Microcontroller is connected to the battery, which is the power supply to the whole system.

- Pin 8 and pin 9 of the microcontroller are used to connect the LFXTL Crystal to the system.

- Pins 25 through 29 are used to build an R-2R ladder. The purpose of this R-2R ladder is to provide the system with a DAC (Digital to Analog Converter). This ladder is shown in much detail in the following figure:

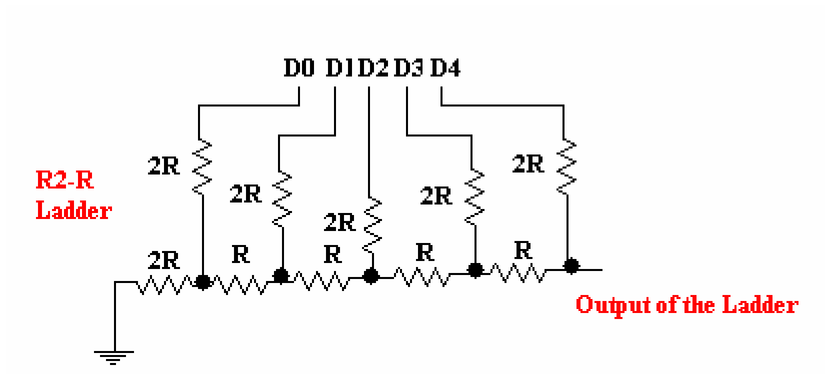


Figure 5.1.2: R-2R Ladder System

It should be mentioned that only one of the pins, between the five pins of the ladder, will be high. Knowing the fact that the input to the Digital pins of the ladder is 5 Volts, the following Table illustrates the Analog Outputs:

Table 5.1.1: Analog Outputs at Different Inputs

D0 D1 D2 D3 D4	Analog Outputs
1 0 0 0 0	0.15625 V
0 1 0 0 0	0.3125 V
0 0 1 0 0	0.625 V
0 0 0 1 0	1.25 V
0 0 0 0 1	2.50 V

- Pins 46 and 47 of the microcontroller are used as two comparators for the system. As it is illustrated in Figure 5.1.1, Pin 46 is connected to the output of the R-2R ladder network. This Voltage output will be compared with the voltage value received by the photo-diode, which is connected to pin 47. The differences between these two voltage values are taken. The less the difference between these two values, called Vref, the darker environment the artificial eye is placed in. As a result, the rings on the LCD will turn on and off accordingly.

- As illustrated in Figure 5.1.1, the custom-made LCD is composed of five rings. These rings will turn on and off according to the intensity of ambient light detected by the photo-diode. Table 5.1.2 in the following illustrates at what voltages what rings will be on which ones will be off.'

Table 5.1.2: Status of the Rings at Different Voltages

Vref	Status of the Rings
Less than 0.15625 V	Rings 1 through 5 are ON
Between 0.3125V and 0.15625 V	Rings 2 through 5 are ON
Between 0.625 V and 0.3125 V	Rings 3 through 5 are ON
Between 1.25 V and 0.625 V	Rings 4 and 5 are ON
Between 2.50 V and 1.25 V	Only Ring 5 is ON
Between 5.00 V and 2.50 V	All Rings are OFF

In other words, the higher the Vref, the higher the intensity of light, and therefore, the smaller the number of rings would be.

5.1.1. Operating Modes of the Microcontroller:

The MSP430 has one active mode and five software selectable low-power modes of operation. An interrupt event can wake up the device from any of the five low-power modes, service the request and restore back to the low-power mode on return from the interrupt program.

The following six operating modes can be configured by software:

- Active mode AM;
  - All clocks are active

- Low-power mode 0 (LPM0);
  - CPU is disabled
    ACLK and SMCLK remain active, MCLK is available to modules
    FLL+ Loop control remains active

- Low-power mode 1 (LPM1);
  - CPU is disabled
  ACLK and SMCLK remain active, MCLK is available to modules
  FLL+ Loop control is disabled

- Low-power mode 2 (LPM2);
  - CPU is disabled
  MCLK and FLL+ loop control and DCOCLK are disabled
  DCO's dc-generator remains enabled
  ACLK remains active

- Low-power mode 3 (LPM3);
  - CPU is disabled
  MCLK, FLL+ loop control, and DCOCLK are disabled
  DCO's dc-generator is disabled
  ACLK remains active

- Low-power mode 4 (LPM4);
  - CPU is disabled
  ACLK is disabled
  MCLK, FLL+ loop control, and DCOCLK are disabled
  DCO's dc-generator is disabled
  Crystal oscillator is stopped

5.2. Flow Chart Description:

In this part of the document, the flow chart of the design will be discussed in detail.

At the beginning of the process, Vref is initialized to 0.156 V. Then Vcout is checked. Whenever Vcout is checked to have the digital value of 0, some number of rings is set to turn ON according to the value of Vref. (These values are shown in the Flow Chart). Whenever Vref exceeds 2.5 Volts, all rings are shut OFF. This loop goes on for ever!

The Flow Chart representation of the design is show on the next page.

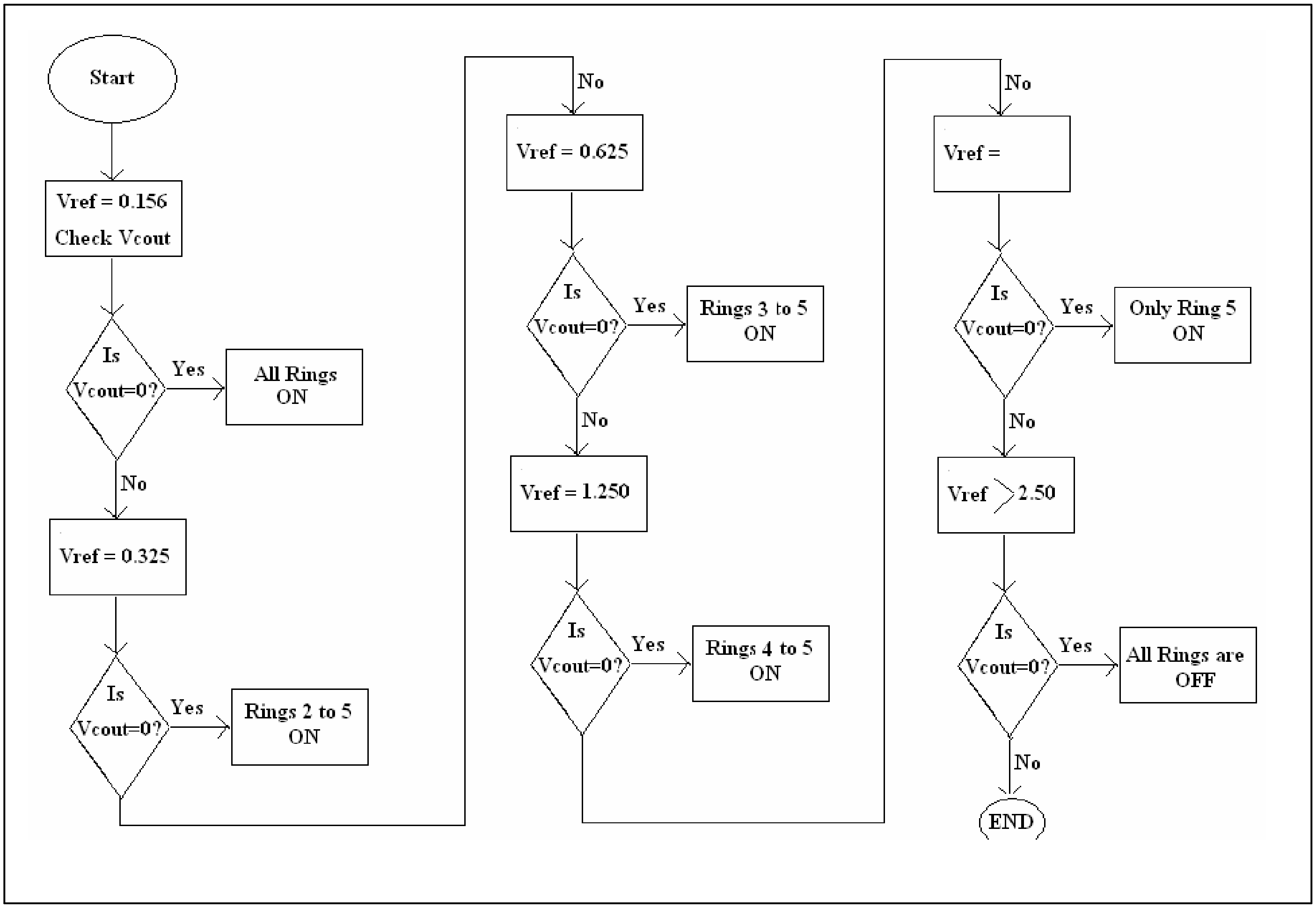


Figure 5.2.1: Flow Chart Representation of the Design

6. User Interface:

One of the best features of our dynamic pupil product is its user friendly interface. In fact, the user (patient) doesn't need to bother him/her with punching buttons in order to be able to communicate with the product. The patient only needs to do a surgery in order to place the artificial eye on his/her face. The reason is that, as mentioned previously, our product has the ability to distinguish between the dark and light environments. As a result, our product performs its work whenever necessary and shuts down when the patient is in sleep.

7. Test Plan:

This section outlines testing procedures for the communication subsystem of the design. Incremental testing will be conducted as we integrate each subcomponent into a complete system. Note that this section only provides the test plans for phase one.

7.1. Communication Testing:

In order to ensure proper communication between the subsystems within our product, some tests shall be applied to the system. One of the main tests that should be performed is dynamicity of the pupil in different environments.

In order to perform this test, when the device is ready, it should be taken to dark and light environments. By increasing the intensity of light, the pupil of the artificial eye should decrease in size. On the other hand, by taking the product to darker environments, the size of the pupil is expected to increase.

Another important test before integration of our product is to test the LPM (Low Power Mode) capability of our device. As mentioned previously, one of the features of our device is to shut down the whole system when there is absolutely no light in the surroundings, which is when the patient closes his/her eye(s). This feature will allow the battery to survive longer time by not wasting the power. In fact, whenever the patients go to sleep by closing the eyes, no light will be detected by the photodiode. As a result, the microcontroller shuts down the whole device and prevents loss of power. On the other hand, by closing the eyes, intensity of ambient light increases; as a result, system goes back to its original mode. This test shall be performed by the emulator provided from TI.

8. Conclusion:

This document has outlined the design specifications for the first phase of the *Dynamic Pupil in a Prosthetic Eye* for visually impaired. The specifications given in this document are tentative and shall be modified as necessary during the course of our development. This document, nevertheless, will provide a clear guideline to the completion of our product.

We at Dyno I, aim for completion of the phase one by the beginning of December, 2004. However, if time permits, we plan to incorporate some features of phase two into our prototype.

We at Dyno I, hope these functional specifications will provide our audiences with essential insights of our product.

9. References:

- http://dkc3.digikey.com/PDF/T043/1367.pdf
- Texas Instruments Manual Book for MSP430 Series Micro-Controller