Photography Solutions Inc.

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March 1, 2003

Mr. Lakshman One
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RE: ENSC 440 Project Design Specifications

Dear Mr. One

Attached you will find the Photography Solutions Inc. group's *Design Specifications document for the Darkroom Automation System* which outlines and explains the design and functionality of our project for ENSC 440 this semester.

We are in the process of designing and implementing a kit that would digitize an older and failing enlarger device used in large format photography. This kit provides consumers with a user interface from which they could fully control the Beseler 45S enlarger device. Please keep in mind that our product can be implemented on almost all such enlarger devices, since their principles of operation are essentially the same.

The purpose of this design specification is to detail the design of our system. This document is broken down into two main sections, the Base (user interface) and Head Unit (located inside the enlarger unit) Design. This document does not go into detail about the software and hardware coding since we have not reached that stage of development; however, it does discuss a higher-level design overview and discusses how each component fits in.

Photography Solutions Inc. consists of four innovative, experienced and hard working engineering students: Roham Bazarjani, Marijana Cosovic, Hans Johnson and Staphae Lansana, whom are most committed and enthusiastic towards following through with this design project. For more information, do not hesitate to contact us by e-mail at **shrm-440@sfu.ca** or visit our website: **http://www.sfu.ca/~rbazarja.** We look forward to hearing any comments or questions that you might have.

Sincerely,
Hans Johnson.

Hans Johnson
President and CEO
Photography Solutions Inc.

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Design Specifications For The Darkroom Automation System

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1 Executive Summary

The current design project being taken on by the team at Photography Inc is called *The Dark Room Automation System.* It is intended not only to replace the failing electronic components of the Beseler Photographic Enlarger, but to also provide our consumers with a modern, state of the art user interface. The system that is currently in design is considered to be an upgrade kit for the Beseler Photographic Enlarger, but our product can be implemented on almost all such enlarger devices since their principles of operation are essentially the same.

This upgrade kit will consist of two main units, the Head and Base Unit. The user can indirectly communicate with the head unit (located inside the Beseler enlarger frame) through the user interface unit (a.k.a. the base unit), enabling the user to fully control the enlarger device through a keypad.

The Base Unit will perform the following major functions:

- Process filter settings entered by the user through the keypad.
- Retrieve previously stored filter settings as requested by the user.
- Acquire exposure time (timer) from the user.
- Capable of uploading all previously stored filter settings to host computer via serial port.

The Head Unit will perform the following functions:

- Acquire correct filter values based on the filter settings obtained from the base unit.
- Determine the current filter positioning based on feedback logic.
- Direct motors to slide filters until the desired color intensities are reached.
- Controls the exposure time based on user-inputted timer value obtained from the based unit
- Updates the LED displays to display current light intensity levels obtained from light sensors.

A working prototype of the Dark Room Automation System will be available in late April 2003.

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2 Introduction

The Darkroom Automation System provides full digital control of the Beseler 45S enlarger and its computerized color heads. Our kit would greatly simplify the work of the photographer when producing prints in dark room photography. This kit also provides the following advantages/functionalities:

- Provides closed loop control of the filter, compensating for the effects of an aging bulb.
- Maintains a library of filter settings, with one entry for every negative printed.
- Eases the mundane tasks of creating " ring around" sheet and test strips.
- Allows the photographer to manipulate the images in a manner that was not previously possible.

This system will consist of two major components: an electronics package installed within the enlarger head (Head Unit), and a separate, wired remote control unit (Base Unit) used for the user interface. Our upgrade kit without the head unit (which is inside the enlarger), along with the Beseler 45S is illustrated in Figure 1 below.

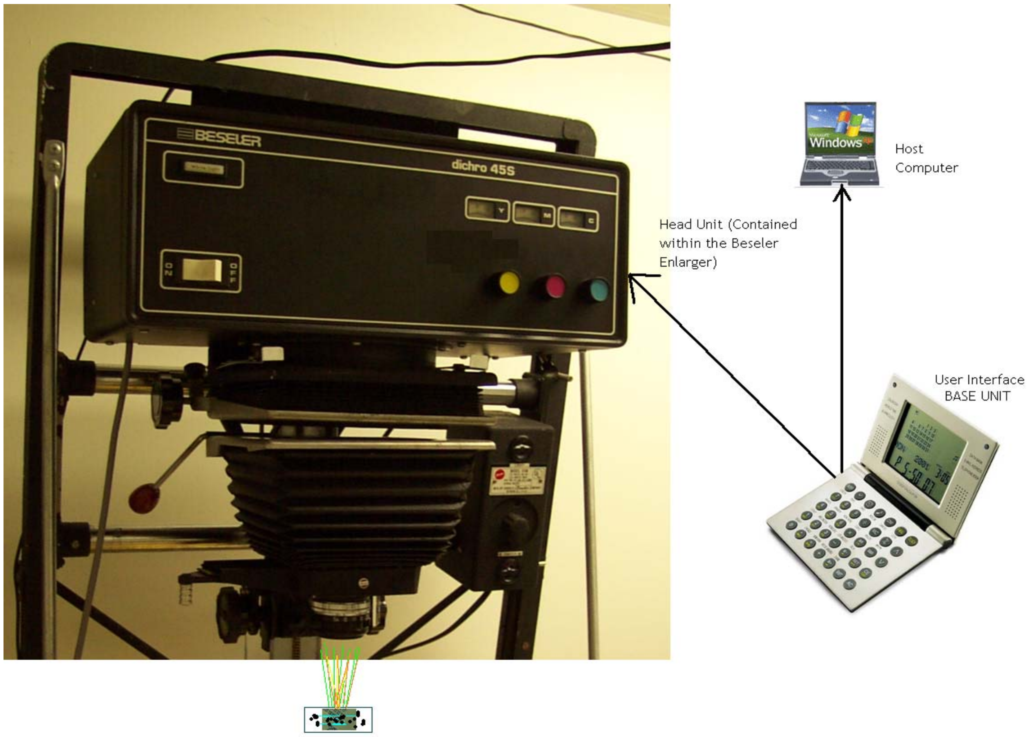

Figure 1: Dark Room Automation System Overview

2.1 Scope

This document outlines in detail, the design specifications of our final product. It contains thorough design and functionality plans that we have for this project. Our design team will be the main individuals using this document, for design and functionality reference throughout the semester on the way to developing a prototype.

2.2 Intended Audience

This document is intended for use by design engineers, and project management internally. It will also be used by the course instructor, Lakshman One to assess our overall design. This report will give a good description of what needs to be done (overall) and then go into detail about exactly how everything is going to be implemented. As stated above, this document will serve as a guide to follow on route to the successful development of the first prototype.

2.3 Glossary of Terms

Head Unit: The light source mounted on the chassis.
Base Unit: The remote control system consisting of the main computer.
Filter Values: A measure of intensity of each of the colors.
Unipolar Motor: Motor that have 5 or 6 leads as oppose to four leads in bipolar motor
Stepper Motor: Motors that move by sending then current pulses
Light Chamber: Area in the head unit containing the light bulb and filters
Latching Solenoid: A solenoid that remains energized or de-energized indefinitely.
Photo Diode: Light sensing diode that outputs a current proportional to the light intensity.
Dead Time: A measure of the length of time the solenoid can be energized

2.4 Acronyms

LED: Light emitting diode
OLED: Organic Light Emitting Diode
PLED: Polymer Light Emitting Diode
PWM: Pulse Width Modulation
CAN: Control Area Network
PC: Personal Computer

3 The Head Unit

Figure 2 below illustrates the communication between the different components inside the head unit of the Besseler 45S.

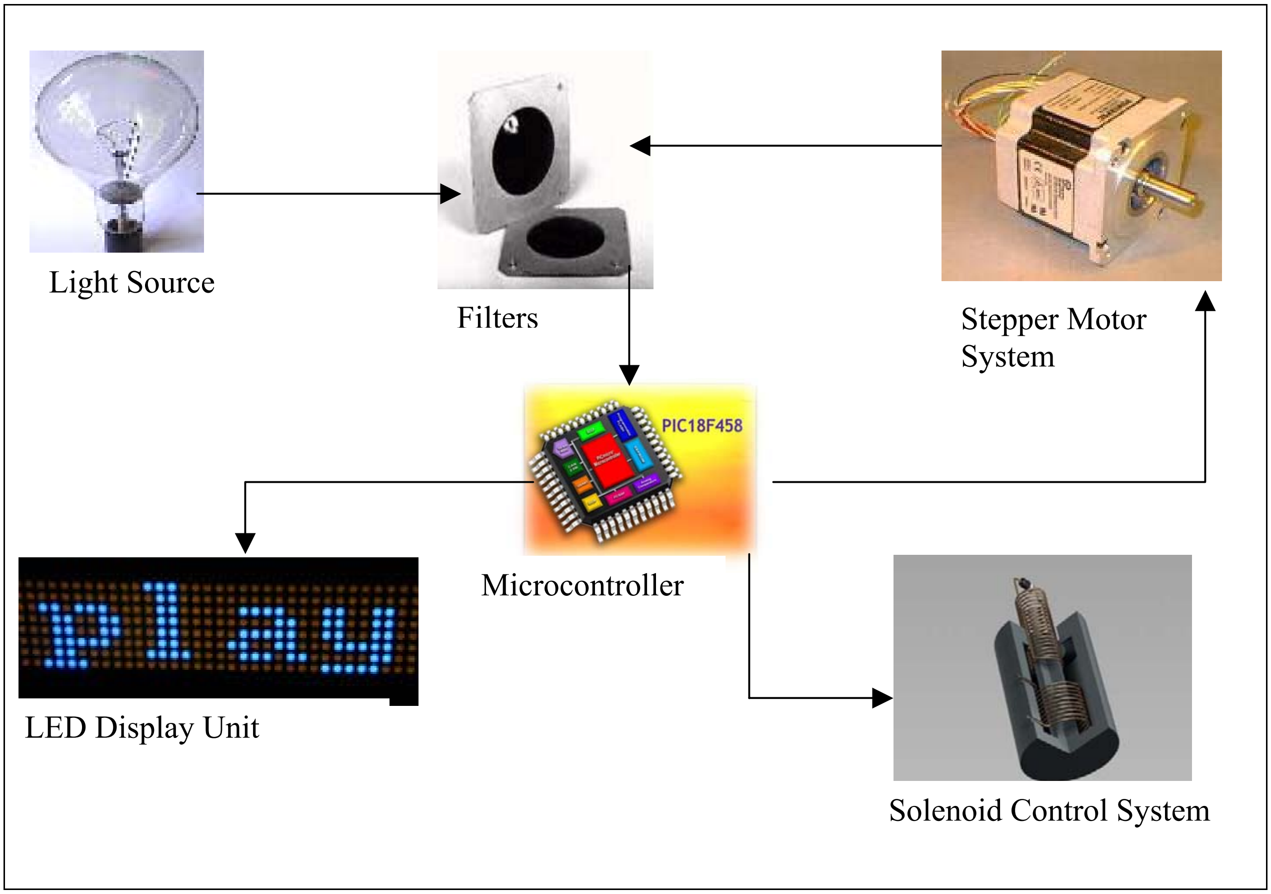

Figure 2: Head Unit Block Diagram

The head unit consists of three electro-mechanical units and one display unit (user interface), which communicate with each other, and with the base unit through a microprocessor. The three Electro-Mechanical units are:

- The Motor System
- The Solenoid System
- The Light Detection and Amplification System

The Display Unit is simply an LED matrix display

The microprocessor receives input signals from the Light Detection and Amplification unit and also from the Base Unit. The microprocessor can communicates with the Base Unit through a CAN interface. The Solenoid system (exposure time) is also controlled by the microprocessor. The motor system input is driven by signals from the microprocessor as well. The system of motors controls the positioning of the three light filters located in front of the light bulb. At all times, the current filter settings will be displayed on the Display Unit.

3.1 Motor System

3.1.1 Motor Type

An AP-60 floppy disk stepper motor is use to control the alignment of the color filters. The AP-60 is a four phase unipolar stepper-motor. This motor is specifically chosen because it can be obtained from old costless floppy diskettes. We could have also used a servomotor instead or a stepper motor; both would provide the precision positioning required for our application. However, the repeatability or positioning required for the stepper motor depends on the geometry of its rotor whereas the repeatability of the positioning required for the servomotor depends on the stability of an analog control circuitry. Therefore, a stepper motor was chosen for the following reasons:

- The analog control circuitry may be prone to noise and instability issues, especially when operated in a noisy environment. Therefore, stepper motors would better suit this application.
- Stepper motors can be operated in a simple open loop configuration where high-speed acceleration is not a requirement, but servomotors always require a closed loop control circuitry.
- Since controlling the position of the filters in front of a light bulb does not involve high acceleration, we finally chose to use a stepper motor over a servomotor.

The only disadvantage of using a stepper motor is that this type of motor does not provide a very large torque; however, our application does not require a lot of torque. Thus, with the appropriate gearing, this motor would be perfectly suitable for our application.

3.1.2 Motor Control

The control circuitry for the stepper motors involves turning the currents in its windings on and off (for movement) and also switching their polarity (changing direction). This mechanism requires the construction of some form of external circuitry whose positioning control signal to the motor is dependent on the light intensity. To control the AP-60 stepper motor, we use a UCN5804 controller. Other integrated circuit motor controllers such as the DVR101 were also attractive, but did not meet our requirements. Given our limited PCB space and budget, and the fact that we required two DVR101 motor drivers to control a single stepper, we decided to use the UNC5804. Only one UCN5804 is needed to control a single stepper motor. The UCN5804 looks very attractive for our application, and has the following desired features:

- Low power requirement of CMOS logic.
- High output voltage and output current of a BJT logic.
- Gives complete control and drive over a four-phase unipolar stepper motor with a continuous current of 1.25 A per phase and an output voltage of 35 V.
- Ground clamp and diodes to protect it against transient inductance from the motor windings.
- A thermal protection circuitry to protect the chip when facing excessive temperatures.

However, its control is limited to one motor.

3.1.3 Solenoid System

3.1.3.1 Latching Solenoid

A latching solenoid is used to lock the shutter in a given position (open/close) without the need for a constant supply of power. Given that the shutter will not be required to be stay in one position for an indefinite period of time, the latching solenoid is the favorite choice among others types of solenoids (i.e. push-pull and rotary-solenoids). In addition, this type of solenoid has the following advantages:

- A very fast response time.
- Holds in either push or pull (close/open) state for an indefinite period of time.
- Holds it's current position without any additional need for power.
- Develops an attractive force in the de-energized state.
- Applies a very high power to meet our speed, torque and force requirement without excess power consumption or heat dissipation.

However, latching solenoids are not good solutions in applications where the energizing time is required to be very short. Given that our application does not require such constraints, the latching solenoid is therefore a good design choice.

The latching solenoid must have enough strength to open and close the shutter, which as previous tests have indicated, does not require much driving force.

The Latching Solenoid Control Circuitry uses a PWM signal to control the energizing and de-energizing of the solenoid. There are other integrated circuits that handle the generation of a PWM signal very efficiently. However, they are expensive and take up a lot of precious PCB space.

Therefore we decided to use the PWM output capabilities of PIC18F458 micro-controller. The following additional advantages are achieved through using the PIC18F458 as the solenoid controller:

- 1,2 or 4 PWM output signals.
- Selectable PWM polarity.
- Programmable PWM dead time.
- Variable bit-resolution based on frequency of pulse.

Nonetheless, the ICs designed specifically for solenoid control usually have some sort of protection circuitry against transient magnetization; a protection circuitry that the PIC18F458 lacks. Nevertheless, the protection circuitry can be easily designed with the use of diodes and resistors.

3.1.4 Light Detection and Amplification Circuitry

3.1.4.1 Photodiode

We use photodiodes to sense the light intensity (filter values), and based on their output signal, we adjust the filters until the desired filter values are reached. For the purpose of reading the light intensity in the mixing chamber, we will use the PT380 photodiode. The following is a list of advantages that comes along with the selection of the PT380:

- Does not have any built in visible light cutoff filter like the PT381F. Thus it has a very wide spectra density.
- High photosensitivity.
- Wide temperature operating range; -45 to +85 degrees Celsius.
- Collector-emitter voltage of 35 V, and a collector current of 20 mA.
- Very small rise time that is constant for output loads in the range of 1-10 kΩ.
- It has a response time that does not rise appreciably with small loads.

Despite its numerous advantages, the following features of the PT380 photodiode limit its use to low noise environments:

- A large junction capacitance leads to instability.
- Large parasitic and shunt resistance that generates a noise known as Johnson.

In effect, the non-ideal photodiode is a current source in parallel with a capacitor and a resistor. All such non-idealities were taken into consideration in the design process.

3.1.4.2 Amplifier

A current that varies with light intensity is generated between the terminals of the photodiode. This current needs to be converted into a voltage level before it can become useful to us. To achieve this conversion, we will use a trans-impedance amplifier. We chose the microchip OPA655 over other Opamps because of the following advantages:

- A 400Mhz unity gain bandwidth.
- Very low distortion; 90dB at 500Mhz.
- High output current in the order of 60mA.
- Fast overdrive recovery.

However, like all other Opamps, this device is prone to stability issues and performance issues when in the presence of noise (due to its differential input and common mode capacitances). We are aware of these non-idealities and limitations, and our amplifier circuitry will been designed with stability and noise performance taken into account.

3.2 Head Unit User Interface: Display Unit

3.2.1 LEDs

The positions of the three filters in front of the light are encoded into numeric values known as filter values. These filter values will be made available to the user through the use of LEDs. The most important criteria in the selection of LEDs for the user interface are their low cost compared to OLEDs and PLEDs. The prices of LEDs varies depending on their life span and how much current they draw from a source of power; however, cost is more important to us since all LEDs will offer the same type of performance that is required by our design. We have decided to use red LEDs instead of white or blue LEDs for the following reasons:

- The cost of red LEDs is low.
- Work from a 3-5 V supply.

Nonetheless, LEDs have many disadvantages over other displays like OLEDs and PLEDs, which are listed below:

- If LEDs are to last longer than 50khrs, they need to be handled with absolute care
- Their color and efficiency varies with temperature.
- LED is a point source, so light shaping is required to make the segment shape.

Since none of these disadvantages are of major concern in our design, the low cost of LEDs outweigh their disadvantages.

3.2.2 LED Control

A decoder circuitry is required to control the LED display. Given the number of LEDs required for our design, the decoder circuitry can be very complex and will use up a lot of resources from the microprocessor. An Integrated Circuit LED driver was chosen for the following reasons:

- Design of a decoder circuitry will require a lot of time that we cannot afford at this stage of development.
- Digital and Analog brightness control.
- An SPI interface, making it easy to communicate with micro-controllers serial interface.
- An 8x8 static RAM that reduces the overhead memory requirement on the micro-controller.

Due to the reasons above, we decided to use the MAX7219 LED driver. We have alternative choices of LED drivers, like the PCA9551; however, we selected MAXIM 7219 over others because of the following advantages:

- Low cost (MAX7219).
- LED matrix control capability.
- 150-µA low-power shutdown mode.
- Analog and digital brightness control.
- A scan limit register that allows the user to display from 1 to 8 digits.
- A test mode that forces all LEDs on.

3.3 Microcontroller

Given the processing and peripheral interfacing needed in the design of the head unit, we have chosen to use the Microchip PIC18F458 as our micro-controller. This processor will have the following responsibilities:

- Handles communication between the head unit (Rabbit micro-controller) and the Base Unit via CAN bus interface.
- Scanning the output of the photodiodes, converting the scanned values to digital (via onboard A/D converter) signals and displaying them on the LED matrix.
- Controlling and adjusting the positioning of the Motors until the correct color mixtures are present in the mixing chamber.
- Energizing the solenoid with a critical timing constraint.

We decided to use PIC18F458 instead of other microprocessors because of the following desired features:

- Linear programming memory addressing up to 2 Mbytes.
- 16-bit capture input to capture the photodiode output with a maximum resolution of 6.25ns.
- CAN controller with a CAN bus message rate of 1Mps provides an easy interface with the Rabbit 3200 micro-controller.
- Priority level of interrupt.
- In circuit serial programming.
- 4 PWM output with 10-bit resolution to control the Solenoid
- Watchdog timer with its own on-chip RC oscillator.
- 10-bit A/D conversion with a maximum of 8 channels.

3.3.1 Software

Software Programming will be done mostly in C and Assembly Language. The programs will be downloaded to the microprocessor through the RS-232 serial communication Interface.

3.4 Serial Line Driver

In order to download the software code into the ROM of the PIC18F458, a serial cable is required to connect the PIC18F458 to a host PC on which the code is developed. The RS-232 serial connector was chosen for the following reasons.

- The PIC18F458 has master serial communication ports, which could be used for serial communication.
- The RS-232 is the most common serial interface and is supported by all PCs.
- Serial Interface is less prone to interference.

We could have used a USB connector or a Firewire as the interface; however, both are more expensive than an RS-232 solution, and we do not stand to gain any major advantage from their use.

The PIC18F458 and other drivers operate in a voltage range of 3.2- 5 V. However, the RS-232 requires a +12V and –12 V supply. There are numerous serial line drivers that could provide this voltage level, however, we chose the MAX232 since it is designed specifically for this purpose.

3.5 Environmental Requirement

All the hardware selected operate in commercial temperature ranges and in non-condensing humid condition

3.6 Enclosure Requirement

The enclosure has not yet been designed. However, we intend to make it as small as possible without compromising the internal components, and also making it very aesthetically pleasing to the users.

4 Base Unit

Figure 3 below illustrates the communication between the different components on the base unit.

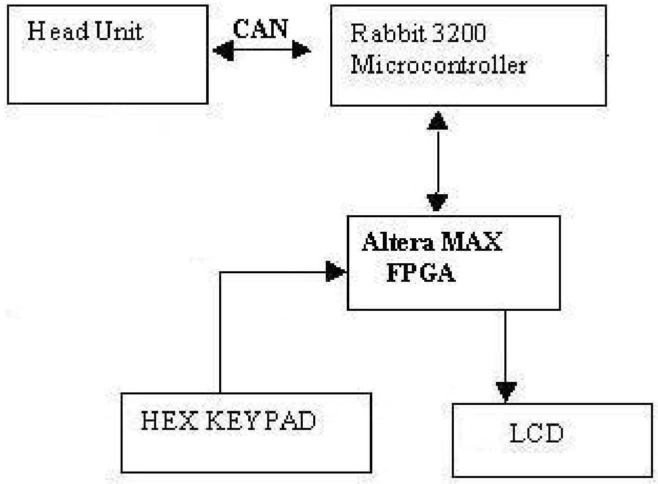

Figure 3: Base Unit Block Diagram

4.1 CPU

The main CPU for the base unit is the Rabbit RCM3000 micro-controller. It provides us with a nice set of features, including a large number of serial ports, reasonable amounts of RAM and storage, and the ability to connect to an external I/O bus.

4.2 FPGA

An Altera MAX7128SLC84 FPGA will be used to interface the keypad and LCD to the Rabbit MCU, as well as the switches. The FPGA will contain code to scan the keypad for key presses, and it will raise an interrupt with the CPU if this occurs.

4.3 Power Supply

The base unit is powered using a small switching power supply. It connects to the wall, using a standard IEC (Computer Style) power cable. This power supply was selected because it is small, compact, and provides both 5V and 12V at reasonable current levels.

4.4 Switches

The base unit will have a connection for a footswitch, via an 1/8" headphone style connector. The switch will be a simple mechanical doorbell type button, and will be read by the FPGA as active low.

4.5 Keypad

In order to meet our requirements for the keypad, we chose to use the Storm GFX Illuminator from Storm Data Entry Technology. This keypad provides red LED Backlighting, rugged, splash-proof design, user designed legends, and it comes in a hex style configuration.

4.5.1 Keypad Layout

The layout of the keypad is illustrated in Table 1 below:

1	**2**	**3**	**UP**
4	**5**	**6**	**DOWN**
7	**8**	**9**	**MENU**
ENTER	**0**	**CANCEL**	**F/T**

Table 1: Keypad Button Layout

When pressed, the F/T Button will cause the enlarger to toggle the state of the shutter. For example, this would be used when one desired the shutter to stay open, while focusing the image.

4.5.2 LED Intensity

The intensity of the LED backlighting will be controlled via an N-Channel enhancement MOSFET connected between the anode terminal and ground. The MOSFET will be driven by a PWM output generated by the Rabbit micro-controller.

4.5.3 Scanner/Decoder

The key-presses will be detected by logic within the Altera FPGA device. It will scan the keypad, decode the results, and then notify the CPU.

4.6 LCD Display

In order to meet the requirements for the LCD Display, we selected the Optrex F-51320GNB-LW-AB. This display provides the following attractive features:

- 128x64 Pixel Display (In Graphics Mode)
- Built in character generator, so the display can be used as an alphanumeric
- White on Blue backlighting
- Built in Contrast Control through software

4.6.1 Host Communications

The LCD will communicate with the Rabbit CPU via the Altera FPGA device. The FPGA will be responsible for the exact timing of the signals being sent to the LCD, while the host CPU will have full control over writing to the various registers within the LCD.

4.6.2 Backlight Intensity

The intensity of the LED backlighting will be controlled via an N-Channel enhancement MOSFET connected between the anode terminal and ground. The MOSFET will be driven by a PWM output generated by the Rabbit micro-controller.

4.7 Controller Board

The main circuit board for the base unit shall be a fabricated PCB. The primary reason for this is the sheer number of bus lines that need to be sent form place to place. Not to mention the overall complexity of the wiring that needs to be done. In this design, no surface mount parts are used, other then the LCD connector and a few resistors and capacitors.

4.7.1 CAN Interface

The CAN interface is provided by a Microchip MCP2510 device. It connects to the Rabbit via an SPI Serial port, and will provide full connectivity to the Head unit (PIC micro-controller). The physical interface to the CAN network is provided via a MCP2551 line driver. The main advantage of this form of communication (other than noise tolerability) is the nominal 1Mbps data rate.

4.7.2 1-Wire Interface

The Dallas 1-Wire interface, used for monitoring the coin cell (back-up battery) is connected to another serial port on the Rabbit microcontroller. The interface used here, is a DS2480B, which interfaces RS232 to the Dallas 1-Wire standard.

4.7.3 Back-up Battery Monitoring

The status of the Coin cell is monitored via a Dallas DS2450 quad channel A/D, which is connected to the 1-Wire bus. The battery is connected to channel D of the A/D, for monitoring purposes. The other 3 channels are exported to a pin header to support future expansion.

4.7.4 RS232 Interface

The controller board provides an RS232 serial interface to support communications between the Rabbit MCU and a host computer. The primary purpose of this is to backup the photography database, and potentially to permit field software updates. The serial line driver used is a MAX233, which converts the RS232 from CMOS levels to the standard RS232 levels using an internal charge pump.

5 Conclusion

In this document, we have outlined the various functional and design requirements of the Dark Room Automation System. We realized that this project contains many different components, which are all intertwined. This means that the correct design and use of each and every component is essential to the correct operation of our unit as a whole. Therefore, we found it much more understandable to break our report down into two parts: the Head and Base Unit Design. We first explained the desired functionality of each separate unit (overview). Then went through what components were required to achieve such functionality. The next major step was to choose and explain why one specific component was more attractive and applicable over another. In order to do this, one must have a clear picture of their design functionality and criteria, along with an idea of the advantages and disadvantages of the different components that can been used. With the use of this report as our design guide, we now know exactly which components are to be used, and how each are interconnected. All that remains is the software development of our devices, which will commence soon, as our group looks forward to the completion of our prototype in late April of 2003.

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6 References:

http://pdfserv.maxim-ic.com/arpdf/MAX7219-MAX7221.pdf
http://www.densitron.com/em/products/latch.html
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