

March 9, 2006

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

Re: ENSC 440 Design Specifications for Edema Measurement System

Dear Dr. Rawicz:

The attached document, *Design Specifications for Edema Measurement System (EMS)*, outlines the design specifications for our ENSC 440 project. Vedo Medico's prototype, Edema Measurement System, is being designed to provide medical professionals with an easy to use device to accurately measure the amount of swelling of limbs in patients.

The purpose of this document is an in-depth look at the design requirements that EMS will meet upon completion of the working prototype. The overall system design, system hardware and software, and user interface design specifications are outlined in the document.

Vedo Medico consists of five talented fourth year Systems engineering students: Ali Khan, Sepehr Mogharei, Arthur Papian-Gorji, Babak Shafiei, and Branko Zdravkovic. Please feel free to contact us with any questions or concerns regarding our project. We can be reached by telephone at 778-885-6059, or by email at [vedo-medico-ensc440@sfu.ca](mailto:vedo-medico-ensc440@sfu.ca).

Sincerely,

*Babak Shafiei*

Babak Shafiei  
VP Operations  
Vedo Medico

Enclosed: *Design Specifications for Edema Measurement System (EMS)*



Design Specification:  
Edema  
Measurement System

**Project team:** Ali Khan  
Sepehr Mogharei  
Arthur Papian-Gorji  
Babak Shafiei  
Branko Zdravkovic

**Contact person:** Babak Shafiei  
vedo-medico-ensc440@sfu.ca

**Submitted to:** Dr. Andrew Rawicz  
Steve Whitmore

**Issue date:** March 9, 2006

**Revision:** 1.0

## Executive Summary

If you can't prevent a disease, the next best thing you can do to protect your health is to detect the symptoms of a disease early. Build-up of excess fluids in body tissues (edema) is one of the major signs of heart failure. This early sign of heart failure can easily be detected by monitoring the amount of swelling in a patient's leg. Constant monitoring of the swelling of various limbs can provide medical professionals with key information for proper diagnosis. Vedo Medico's Edema Measurement System (EMS) provides a non-invasive and accurate measurement of edema in the patient's limbs.

The Edema Measurement System is designed with the user in mind. EMS presents users with reliable information through an easy to use interface. The EMS is composed of four main components: EMS Inflation Unit (IU), EMS Enclosure System (ES), EMS Control Unit (CU) and PC Diagnostic System. The software/hardware design specifications that are required for acquiring, storing and analyzing the measurements are provided in this document. The ideas presented in this document also correlate with the *Functional Specification of EMS* [1].

The 13 week cycle of the proof-of-concept phase is projected for completion by April 2006.

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## GLOSSARY

AC	Alternating Current
ATmega169	Low-power CMOS 8-bit microcontroller by Atmel
AVR Butterfly	Evaluation board for the Atmel ATmega169
CU	Control Unit
DataFlash	Memory chip included in AVR Butterfly for storing data
Edema	Swelling caused by excess fluids in body tissue
EMS	Edema Measurement System
ES	Enclosure System
Ghosting	Shadowing effect on the LCD, when LCD segments are not properly turned off
IU	Inflation Unit
MCU	Microcontroller Unit
PC	Personal Computer
PRR	Power Reduction Register
RXC Flag	Receive Complete bit of UCSRA
RXEN	Receiver Enable bit of the UCSRB Register
SOF	Start of Frame
TXC Flag	Transmit Complete bit of UCSRA Register
TXEN	Transmitter Enable bit of the UCSRB Register
UBRR	USART Baud Rate Register
UCSRA	USART Control and Status Register A
UCSRB	USART Control and Status Register B
UCSRC	USART Control and Status Register C
UDR	USART I/O Data Register
UDRE Flag	Data Register Empty bit of UCSRA Register
USART	Universal Synchronous and Asynchronous serial Receiver and Transmitter

## 1 Introduction

### 1.1 Scope

This document outlines the hardware and software design specifications for the Edema Measurement System. The design of each component is discussed and proposed solutions are provided. Vedo Medico's team of engineers intend to meet all specification outlined in this document; however, the proof-of-concept prototype might deviate slightly from the designs provided. Overall, Vedo Medico will use this document as a guideline in designing the EMS device and for assessing the effectiveness of the end result.

Please refer to the *Functional Specifications for EMS* [1] for the list of functional requirements that are being implemented in this document.

### 1.2 Intended Audience

The ideas presented in this document are intended for Vedo Medico's team of Design Engineers to assist in the development process of the EMS device. In addition, this document will be used by the Project Manager to better manage the required development times for each component of the EMS device.

For the general public, the document is mostly intended for consulting engineers and not recommended for the end users of the product, due to the technical nature of this document. Regardless, the document is available to all interested parties.

## 2 System Requirements

General functional requirements of the EMS diagnostics device are presented in the following sections.

### 2.1 System Overview

The main function of the EMS device is to detect the change in volume of the lower part of the leg caused by edema, which could be a potential symptom of health risks such as heart disease and kidney failure. The high level model of the functional operation of the EMS is shown in Figure 1.

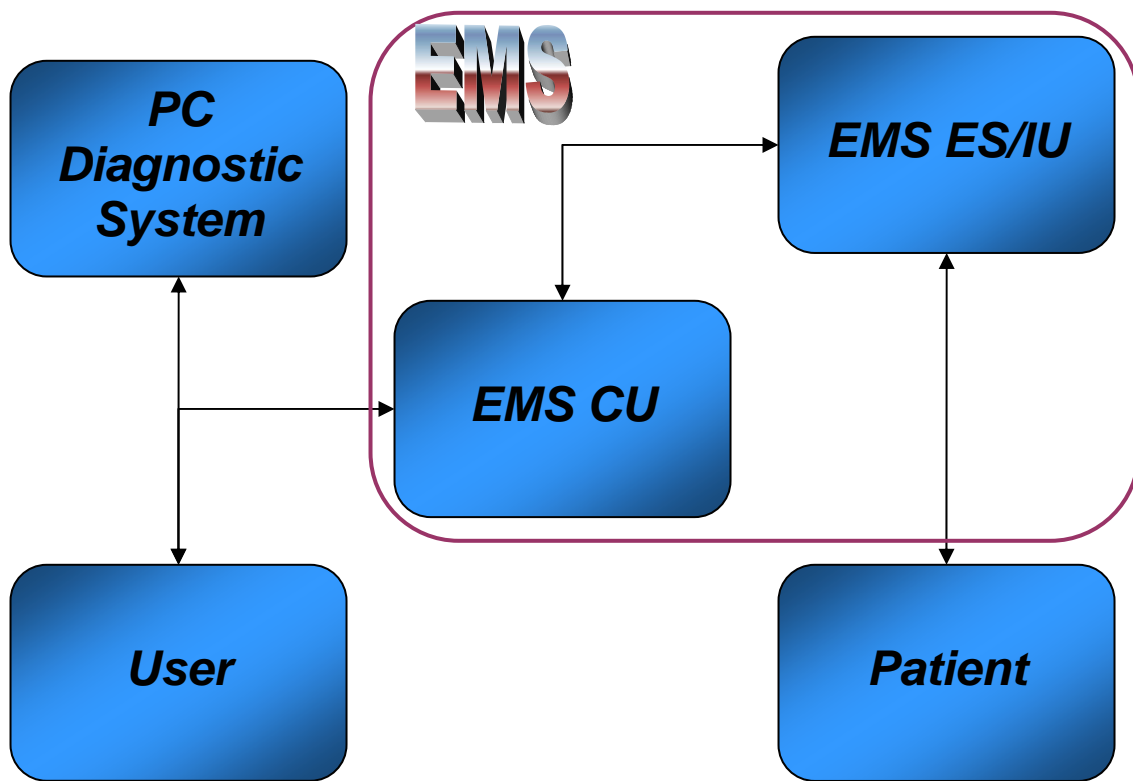
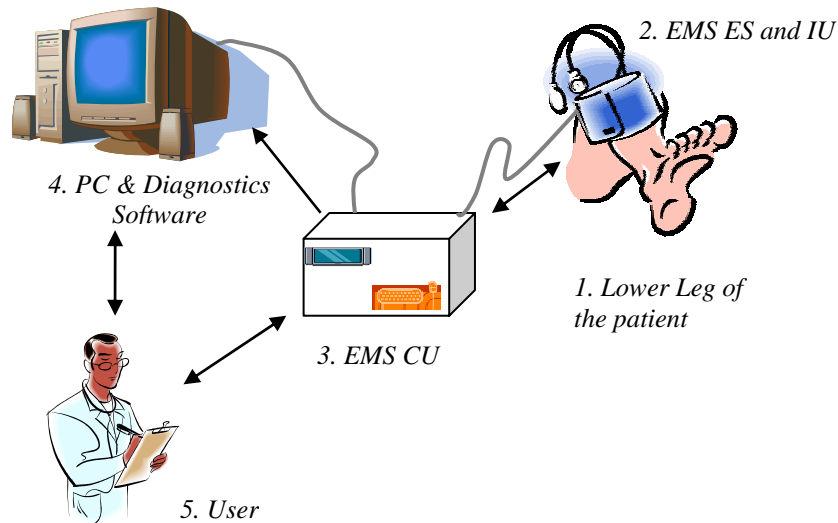


Figure 1 - EMS System Overview

The EMS device will consist of four main functional components. The EMS Enclosure System (ES) is the mechanical component which will surround the patient's leg. The EMS Enclosure System (ES) will send results to the EMS CU, which itself could be interfaced to the PC GUI and diagnostics software. Control of air in the Enclosure System is carried out by the Inflation Unit (IU). The user would be able to directly interact with the EMS Control Unit (CU), and will have access to the diagnostic results on the PC software and the Control Unit itself. Figure 2 **Error! No bookmark name given.** shows the interaction between user and peripheral devices.

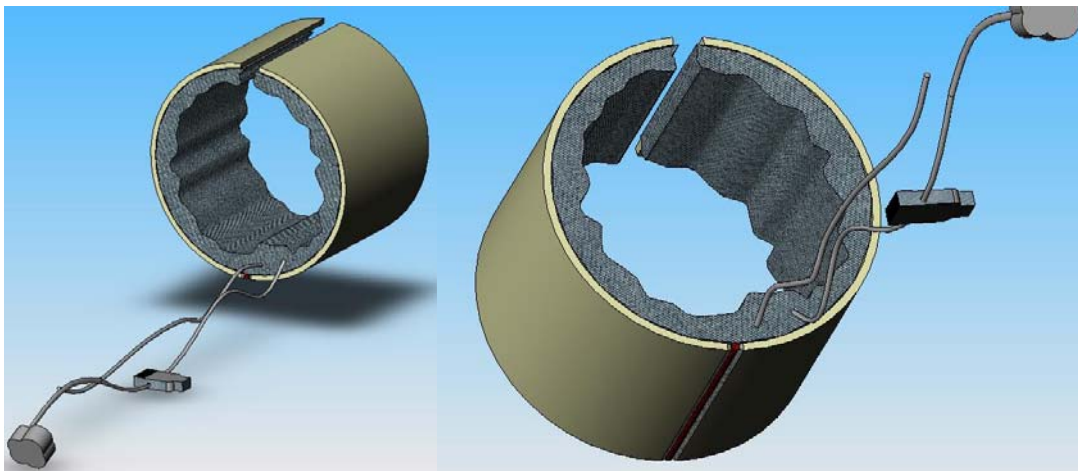




**Figure 2- Interaction between user and peripheral devices**

The user is able to operate the EMS using the Control Unit to measure the volume of the patients' leg. This is done by inflating the bladder in the ES and then wrapping it around the limb. The volume of the limb exerts a force on the bladder causing a change in the pressure of the bladder. This pressure is measured by a pressure sensor and gets stored into the CU. The EMS CU unit will store sufficient data for a set number of patients on the data memory unit. The measurement data can be transferred to a PC based software capable of handling the results and storing results in a larger database. The user would be able to retrieve and analyze instantaneous results directly from the EMS CU, and make comparative analysis with previously taken measurements stored on the PC based diagnostics software.

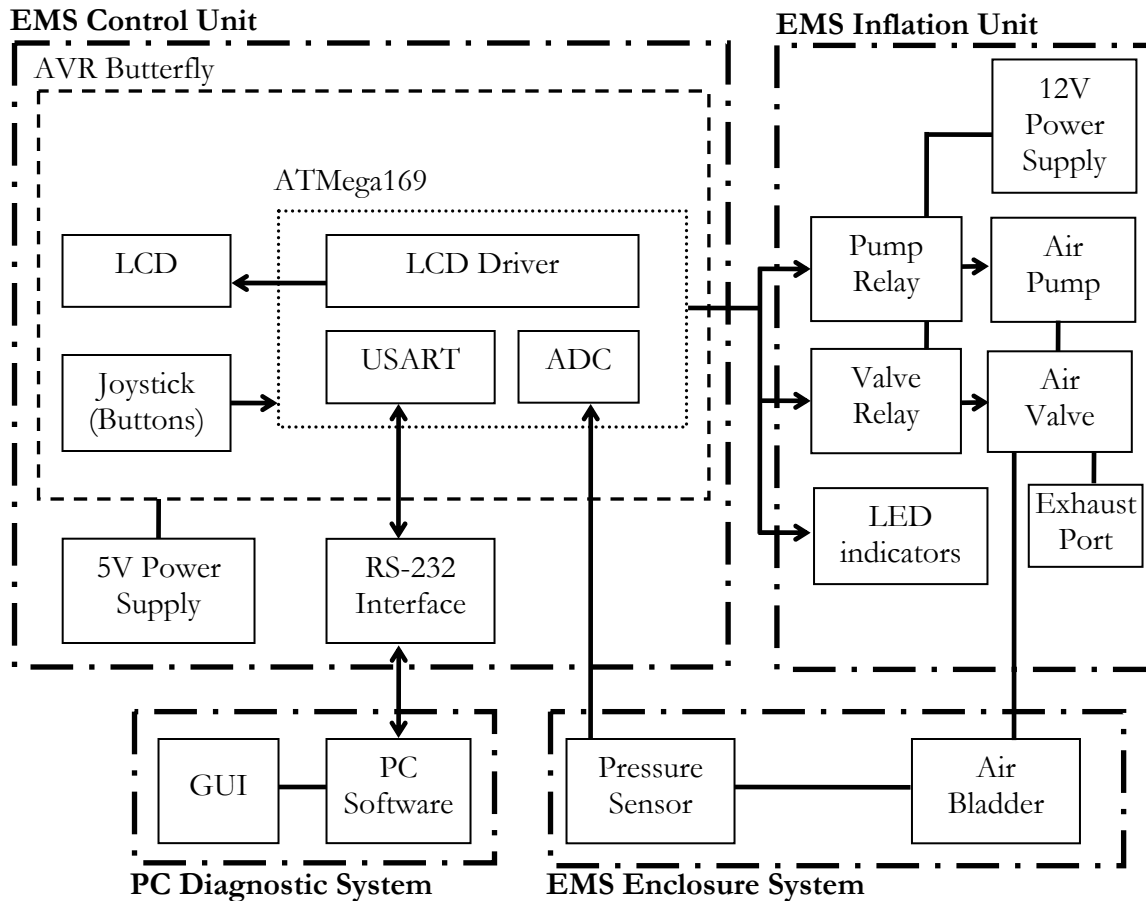
The overall design of the EMS device is shown in Figure 3.



**Figure 3 – EMS Overall Design**

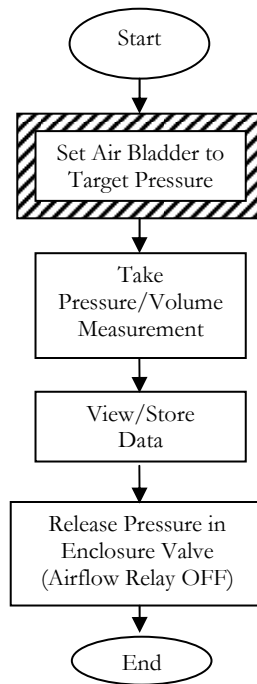
### 3 Hardware Overview

The overall hardware overview of the Edema Measurement System (EMS) is outlined in Figure 4.



**Figure 4 – EMS Hardware Overview**

Each component of the device is described in more detail in subsequent sections of this report. The overall integrated EMS device follows a simple procedure to measure the amount of swelling, see Figure 5. When the Air Valve Relay is off, air is not allowed to escape the Enclosure System, when it is on the air will freely escape. When the Pump relay is on, the pump will be working and filling up the bladder, when the relay is off the pump does not operate.



**Figure 5 – EMS Measurement Procedure**

### ***3.1 Control Unit***

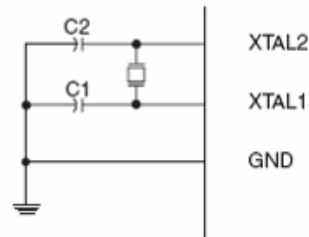
#### ***3.1.1 Microprocessor***

The main component in the EMS system is the AVR ATmega169 Microcontroller. The main benefits of this 8-bit microcontroller for the EMS are listed below:

- RISC architecture with 130 Powerful Instructions and ability to program in C/Assembly Language
- 4 MBit DataFlash for storing patient data (information/measurements)
- 16-bit Timer/Counter unit allows accurate program execution timing
- 4 X 25 Segment LCD Driver for controlling LCD to display information/measurements
- 53 Programmable I/O Lines for connecting external components (e.g. Pressure Sensor)
- Five Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down and Standby, thus ensuring minimal power consumption when using a battery
- Programmable Serial USART used for serial communication with PC software
- JTAG Interface used for programming/debugging

The overall pin layout for EMS using the ATmega169 microprocessor is provided in Appendix A.

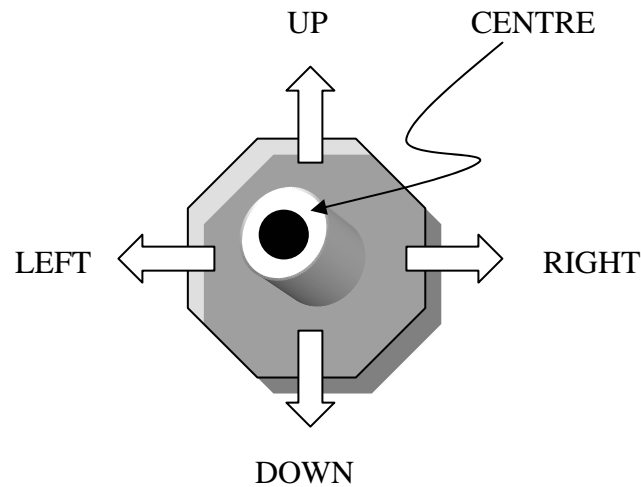
In order to use LCD, A/D conversion and timers for switching relays we need to setup the Real Time Counter. We can achieve this by using the 32.768 KHz Crystal Oscillator that is connected to the microcontroller between ports XTAL1 and XTAL2 (Figure 6).



**Figure 6– 32 KHz Crystal Oscillator Connections**

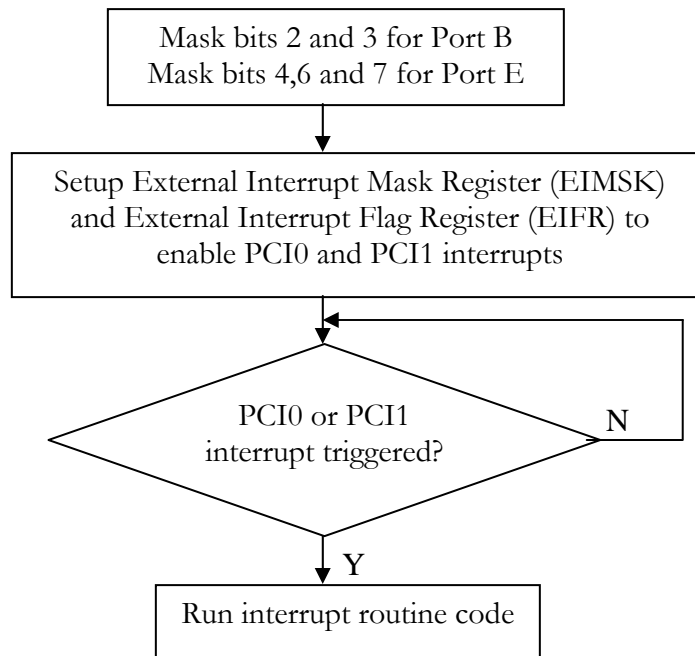
### 3.1.2 Buttons

One main advantage of the AVR Butterfly is the 4-way “joystick” style button provided. This arrangement allows for an easy-to-use user interface. The joystick has 4-directions and a centre push position, see Figure 7. This meets the functional requirements [R47] and [R48]. By using the joystick, the user will be able to toggle through the different menus to access the various features of the EMS device.



**Figure 7– Joystick Layout**

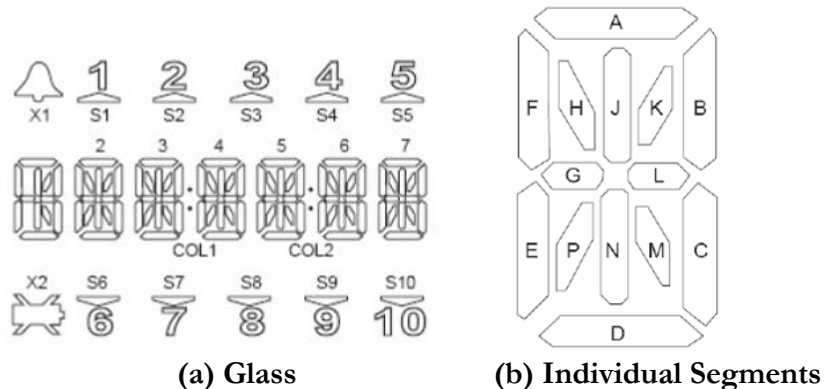
In order to detect which button is pressed on the joystick, we need to use the Pin Change Interrupts (PCI0 and PCI1) provided by the ATMega169 microcontroller to detect changes in the port pins. Since the joystick uses both Port B and E, we will configure one port to use PCI0 interrupt (i.e. Port E) and the other port to use PCI1 interrupt. Thus for the PCI0 interrupt bits 2 and 3 will be masked, and for PCI1 bits 4, 6, and 7 will be masked. The overall procedure for reading the joystick input is provided in Figure 8.



**Figure 8– Flow chart for handling joystick input.**

### 3.1.3 LCD

As part of the AVR Butterfly package, an integrated LCD is also included. The LCD will be used provide key information to the user, such as measurement value, patient idea, etc. The LCD supports scrolling of text and the layout of the glass and individual segments are shown in Figure 9.

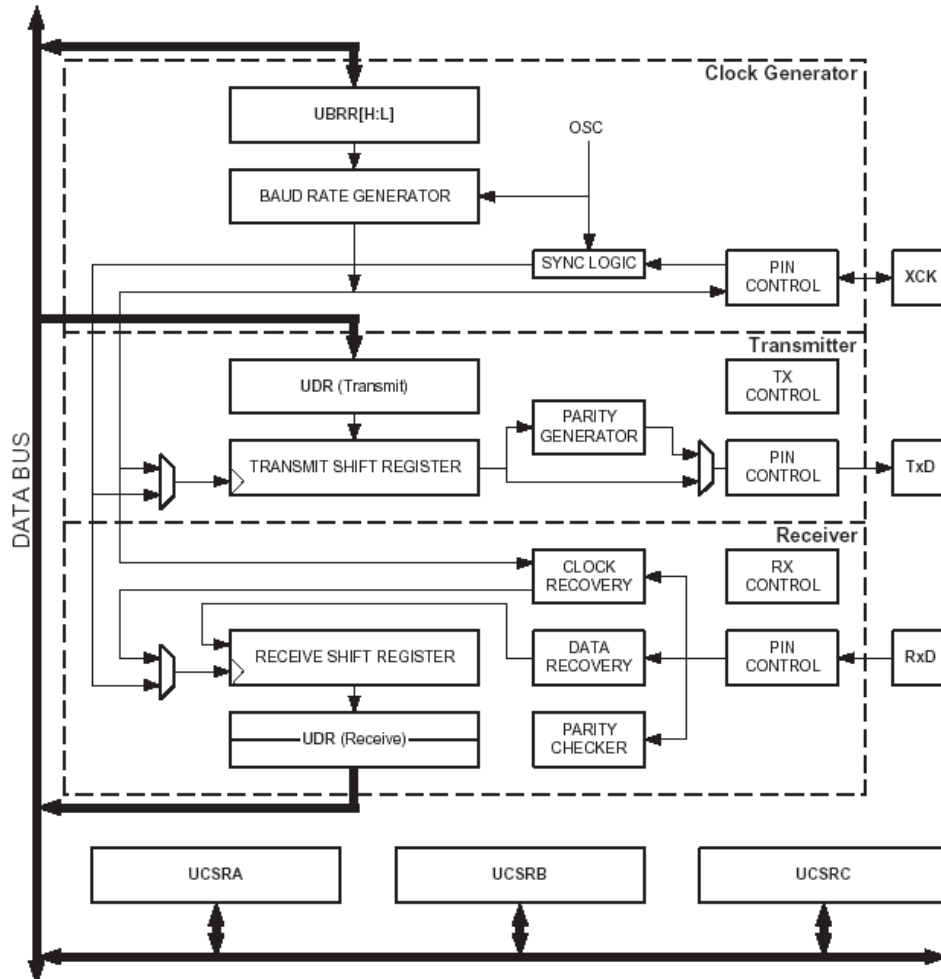


**Figure 9– LCD layout**

To insure proper display of text on the LCD Display the correct refresh rate must be set. To prevent flickering of the display to the human eye, the refresh rate should be higher than 30 Hz and to make sure there is no ghosting in the LCD, the refresh rate should be below 100Hz [2].

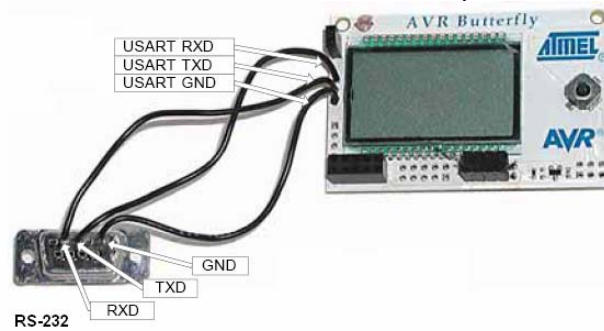
### 3.1.4 USART (RS-232 Communication)

In order to upload and download the data from the control unit, we will be using serial communication. For this purpose, the USART module of the ATmega169 chip will be explored. A simplified block diagram of the USART is shown in Figure 10.



**Figure 10 – USART Block Diagram**

The physical connection of the RS-232 to the AVR Butterfly is shown in Figure 11.



**Figure 11– Connections of UART (RS-232) to AVR Butterfly**

To enable the USART module, various bits in the Power Reduction Register – PRR (Figure 12) must be written to logic 0. This register provides a method to stop the clock to individual peripherals to reduce power consumption.

Bit	7	6	5	4	3	2	1	0	
	-	-	-	PRLCD	PRTIM1	PRSPI	PRUSART0	PRADC	PRR
Read/Write	R	R	R	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

**Figure 12– Power Reduction Register – PRR**

Before any communication can take place the USART baud rate, frame format and transmitter / receiver mode need to be set. Since we don't have any need for serial communication with interrupts, we will be using the asynchronous operation with polling and a fixed frame format.

#### 3.1.4.1 *Transmitting operations*

Patients data already stored in the memory module of the control unit will be sent to PC together with the values of measurements that have been taken. To do this transmission operation, USART transmission needs to be enabled through the bits of the UCSRB register.

#### 3.1.4.2 *Receiving operations*

As proposed in the functional specification, the data containing patient numbers needs to be uploaded to the control unit device. Again, this will be done through serial asynchronous communication using USART module. In order to enable USART receiver, we need to set the Receive Enable bit in the UCSR Register.

As already mentioned, communication between EMS control unit and PC will be with 8 bit frames, 1 stop bit and no parity, at speed of 9600 bauds.

After Asynchronous Serial Communication is successfully established, we plan to implement RS232 to USB conversion of signals obtained from USART module, time permitting.

Data will be sent between the CU and the PC using packets containing a Patient number, and the measurement data. Since we will be storing no more than 5 patient measurements on the device, 6 bits will be sufficient for representing this data and will also allow for future upgrades in memory. The measurement data will be 10 bits since the ADC has a maximum resolution of 10 bits. This gives us packets that are 2-bytes long; see Figure 13.

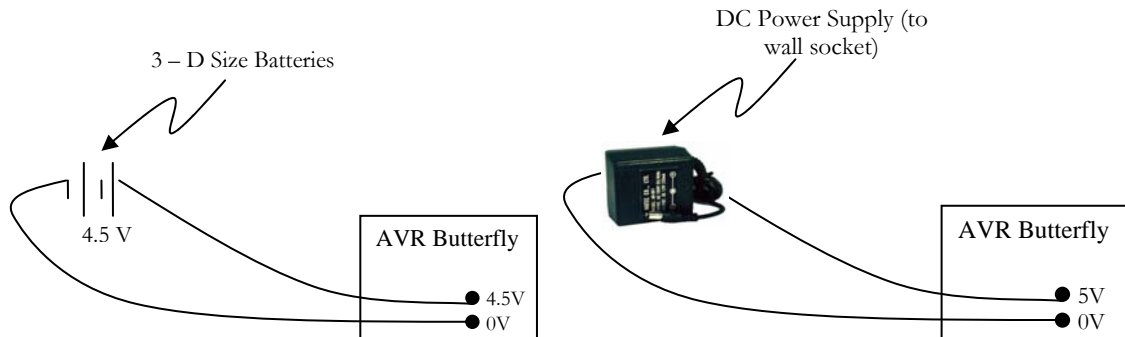
Patient Number (6 bits)	Measurement Data (10 bits)
-------------------------	----------------------------

**Figure 13– Data packet format for CU-PC communication**

#### 3.1.5 *Power Supply*

The ATmega169 processor requires a 1.8-5.5 V supply to operate and the integrated AVR Butterfly requires a 3-5.5 V supply to operate. Both units do not consume more than 400mA

of current [3]. Thus for powering the Butterfly we will use a 4.5V supply. Two methods of powering the Butterfly will be provided. First method is by using a battery unit composed of 3 D size batteries (1.5 V each) connected in series. The second method is using a 5 V DC power supply that plugs into a regular AC wall socket. Figure 14 shows how the power supplies will be connected to the AVR Butterfly.



**Figure 14– Power supplies for AVR Butterfly**

### 3.2 Inflation Unit

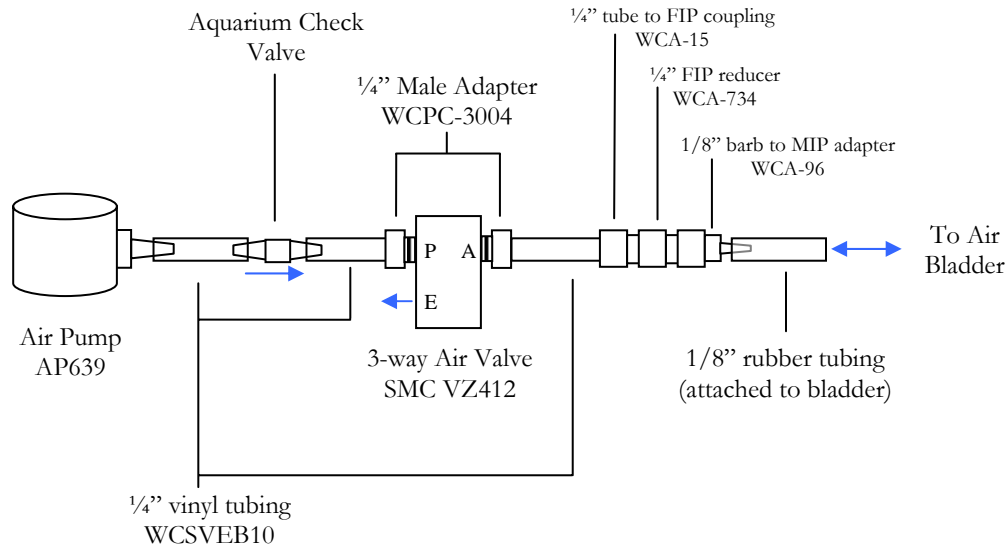
The purpose of the EMS Inflation Unit is to execute active inflation of the air bladder, allow for deflation of the bladder, and maintain a constant volume of air in the system when neither inflating or deflating. The Inflation Unit is comprised of an air-pump to inflate the bladder connected via a 3-way solenoid air valve; this setup allows air to exit the bladder when needed. Table 1 shows the summary of the inflation unit components.

Component	Parts	Description
Air pump	Intex - Model AP639	12V DC Air Mattress Pump
3-way Air Valve	SMC VZ412	12V DC solenoid actuator air valve
Relays	842 SPDT PC Relay	5V coil voltage, PCB mounting, 3A handling
Power Supply	120VAC/12VDC Plug-in Transformer/Supply	6A current handling
Air Check Valve	Aquarium Check Valve (Part # 228225)	Polypropylene, fits 1/4" tubing
Air Tubing	WCSVEB10 - 1/4" clear vinyl tubing	1/4" outer diameter (OD), 10' length
Tubing Adapters	WCA-734, WCPL-3004, WCA-96, WCA-15	various brass/plastic couplings to interconnect rubber air bladder hose, 3-way valve, tubing and pump

**Table 1– Inflation Unit parts list**

During normal operation, an air path exists from the bladder to the outlet of the air pump, through the 3-way valve. To prevent air leaking from the inflated bladder via the pump inlet, a one-way check valve is installed inline between the 3-way valve and the pump. The check valve enforces air to move uni-directionally, preventing backflow and hence leakage. The air system connections are shown in the following Figure 15:





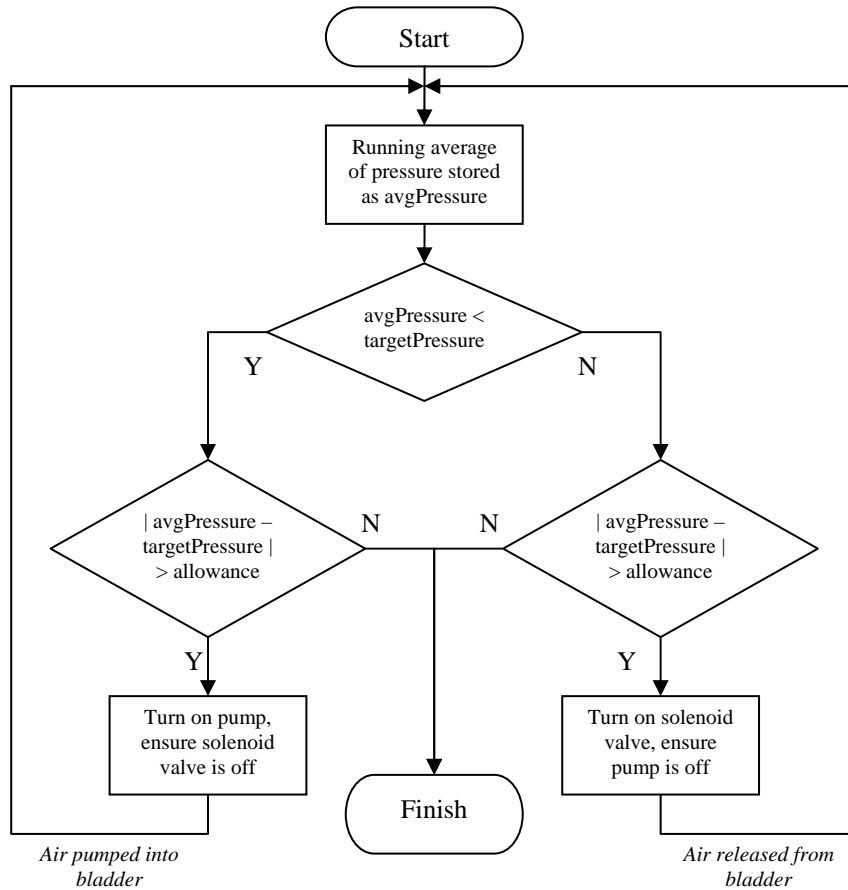
**Figure 15– Inflation Unit Connections**

Both the pump and the solenoid are operated via two separate single-pole-double-throw (SPDT) relays with a 5VDC coil. These relays are controlled by the microcontroller via the LSB and MSB of Port E. The state of the air system is fully determined by the state of the relays controlling the air pump and air valve. Table 2 outlines the various states possible when turning the air pump on/off, or energizing the solenoid valve.

<b>Air Pump State</b>	<b>Solenoid Valve State</b>	<b>System State</b>
OFF	OFF	Air sealed in bladder & tubing
ON	OFF	Pump fills bladder with air
ON/OFF	ON	Air exits bladder via valve exhaust

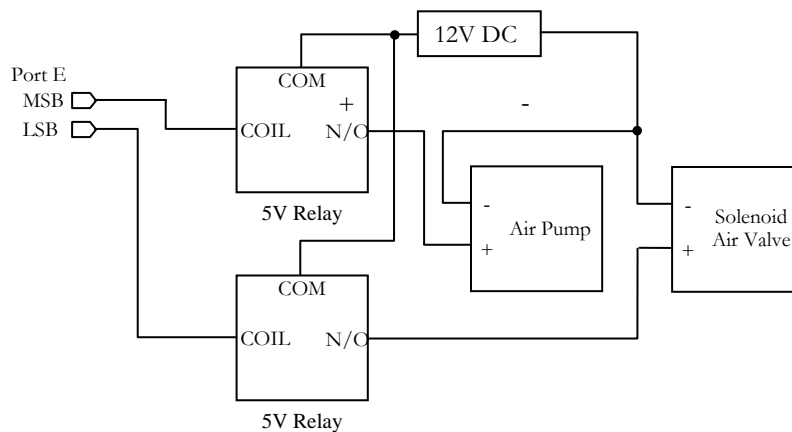
**Table 2 – Inflation Unit State**

The procedure in which a target air pressure is maintained in the bladder is shown in Figure 16.



**Figure 16 – Air Control Flow Chart**

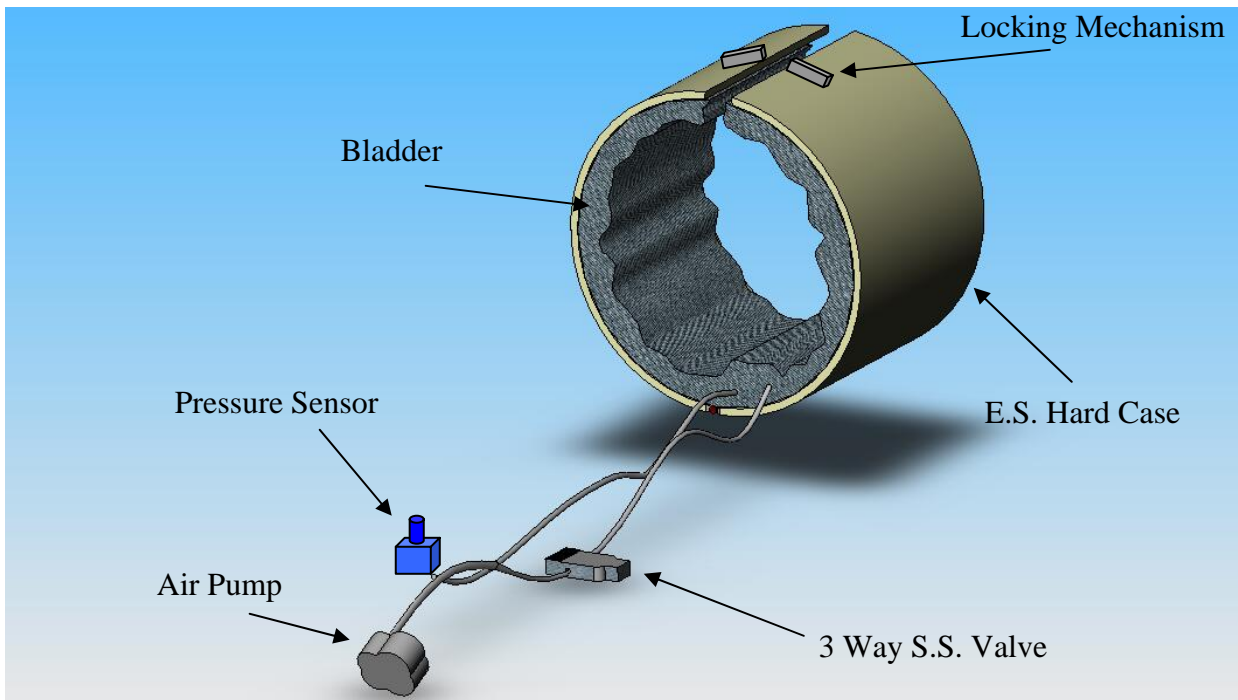
The electrical schematic showing how the relays, pump and solenoid are connected to the microcontroller is below, Figure 17.



**Figure 17 – Inflation Unit Electrical Schematic**

### 3.3 Enclosure System

The enclosure system is responsible for the measurement of the limb volume. Figure 18 shows the ES components and parts. The bladder is a hollow, non-latex, and enclosed cuff that when is inflated, it will be wrapped around the patients limb. This complies with the functional requirement [R10]. The outside shell is made out of hard material (hard plastic) to create pressure between the limb and the bladder. Air pump inflates the bladder through a 3 way solenoid switch valve by a small plastic tube connected to the bladder. Another tube connects the pressure sensor to the bladder. The following subsections describe each individual component that is involved in measuring the pressure due to the compression of the bladder between the hard casing and patients' leg.



**Figure 18 – Enclosure System Diagram**

#### 3.3.1 Air Bladder

The air bladder is a Latex-free pressure cuff that will hold the air needed for making the pressure measurements, see Figure 19.

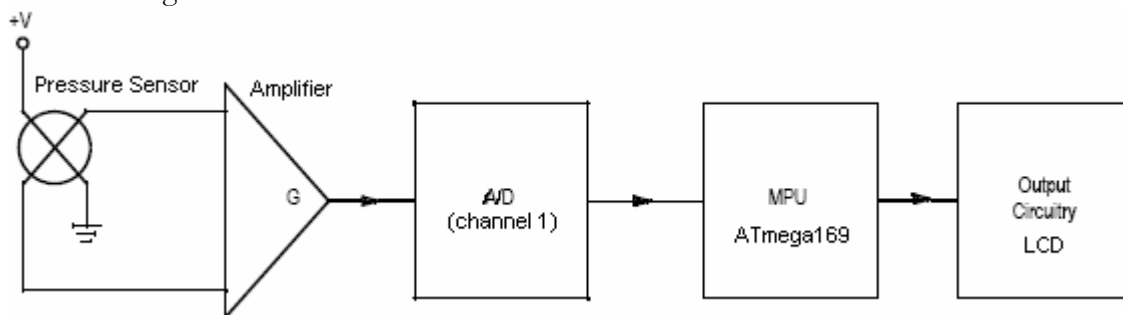


**Figure 19 – Air Bladder**

The air bladder has two tubes attached to it. One tube is attached to the pressure sensor, while the other tube is connected to Inflation Unit.

### 3.3.2 Pressure Sensor

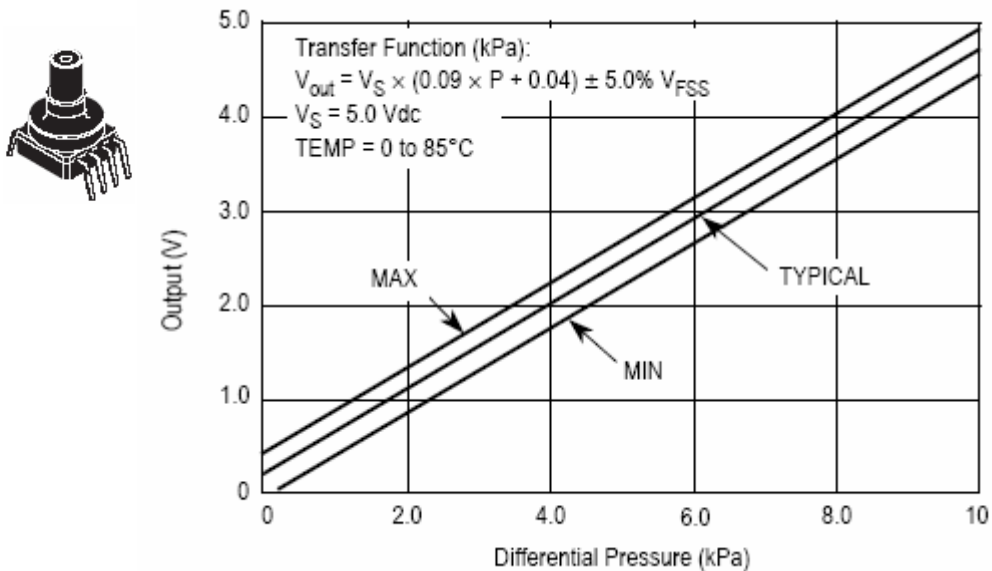
In order to measure the pressure in the ES shown in Figure 18, we will use a MPVZ5010 series sensor. These are the most popular silicon pressure sensors (piezoresistive bridges) that produce a differential output voltage in response to pressure applied to a thin silicon diaphragm. Output voltage for these sensors is generally between 25 to 50 mV full scales. To interface this type of sensor to the micro-controller, we need to amplify the relatively small output voltage, scale the analog signal into a range that is appropriate for analog to digital conversion (calibration) and then feed it to the A/D channel of the micro-controller. The calibrated data is then displayed on the LCD via I/O ports. A block diagram of this procedure is shown in Figure 20.



**Figure 20– Block Diagram Pressure Sensor ADC**

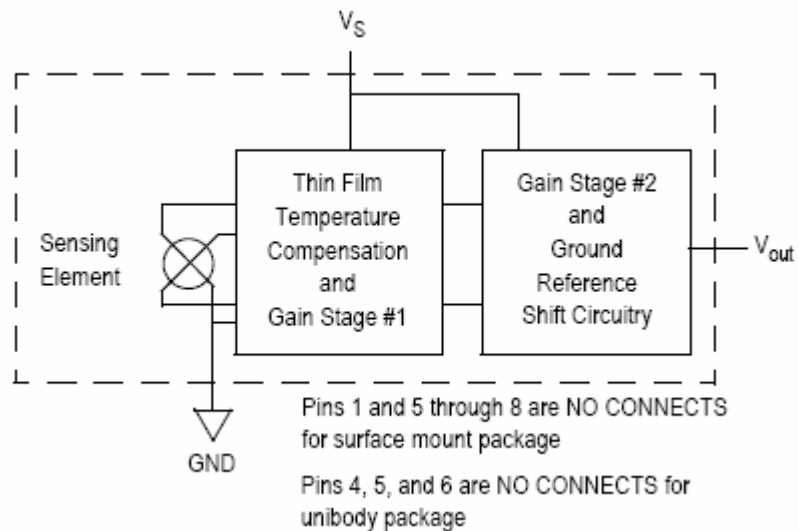
#### 3.3.2.1 MPX2200 sensor series

This type of piezoresistive sensor is temperature calibrated which makes them ideal for this prototype design. Figure 21 shows the relationship between the output voltage produced by the sensor versus the pressure applied. Since, our voltage supplied to the sensor is between 3.5 – 5 Vdc, we are going to expect the same range of output voltage. It is evident from the figure, that the relationship is fairly linear; however we still need to filter out the signal as it does contain 5% error.



**Figure 21 – Pressure Sensor Output Voltage vs. Differential Pressure**

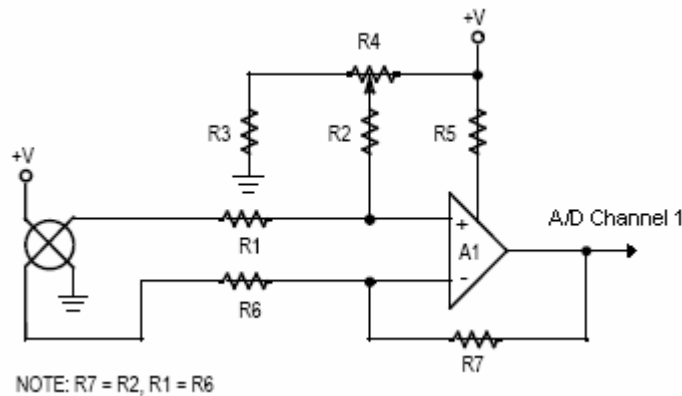
Figure 22 shows the surface mount of the sensor to be used in a circuit along with the microcontroller. The ground connection will be connected to the same ground line of the microcontroller and ( $V_S$ ) will be supplied by the micro-controller (close to 5 V). It should be noted that it takes the sensor up to a maximum of 20ms to warm up, so the initial samples should be ignored.



**Figure 22 – Pressure Sensor Schematic**

### 3.3.2.2 Signal Amplification

A low cost interface designed specifically for pressure sensors is shown in Figure 23. It uses one op amp (A1) and several resistors to amplify and level shift the sensor's output. After the signal has been amplified it will go through the A/D channel 1 of the microcontroller. At this stage, the signal is checked to see if it's valid. For example, if the previous value is off by a certain range (will be measured experimentally), it will ignore the value and take another sample. This is due to the fact that, pressure sensors are quite sensitive about changes in pressure. To minimize this problem, we will make sure that for most parts the air contained in the ES has settled for certain amount of time before analyzing it.



**Figure 23 – Signal Amplification Circuit**

### 3.3.2.3 A/D conversion

In order to operate the A/D, we first need to select the pre-scale factor; which is the ratio of input clock to the A/D. This can be done by setting the bits 1-3 of the ADPS Byte. To enable the A/D conversion in the ATmega169 chip (AVR butterfly), flags in the ADCSRA byte need to be set. By setting bit 7 of this byte to 1, we can turn on the A/D conversion. Bits 6 and 7 correspond to the auto triggering and starting conversion mode. The function that handles A/D conversion, will then store the digital value in the memory to be displayed on LCD.

### 3.3.2.4 Calibration

This process takes the longest to develop as it requires various experimental measurements of different volumes. To calibrate our sensor, our goal is to get a linear relationship between pressures applied to the sensor versus the output voltages. This can be done by measuring different volumes of air and recording the corresponding voltages. The result should be in some form of increasing linear relationship according to the sensor specifications. Using the closest approximation, we can take the slope of this relationship and apply the formula in our software. Since, it's linear we can assume that it applies to every point on the graph within the range. If the result is non-linear, we will try to break it down into several linear regions and by offsetting each region, we will be able to get a close approximation of the value.

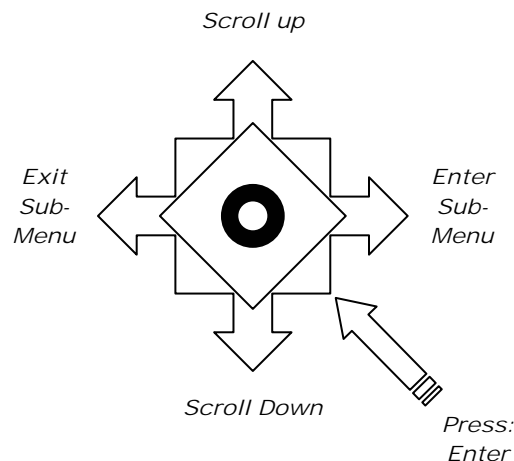
## 4 Software Overview

### 4.1 CU User Interface

The User Interface of the device is the bridge between the outside world and the internal functions of the EMS device. This user interface will be equipped with the following external hardware to communicate with the user:

- 4 way directional button (Joystick switch)
- 100 segment LCD display
- On board integrated Speaker for sound generation
- LED lights (One set for pump, and one for solenoid switch valve)

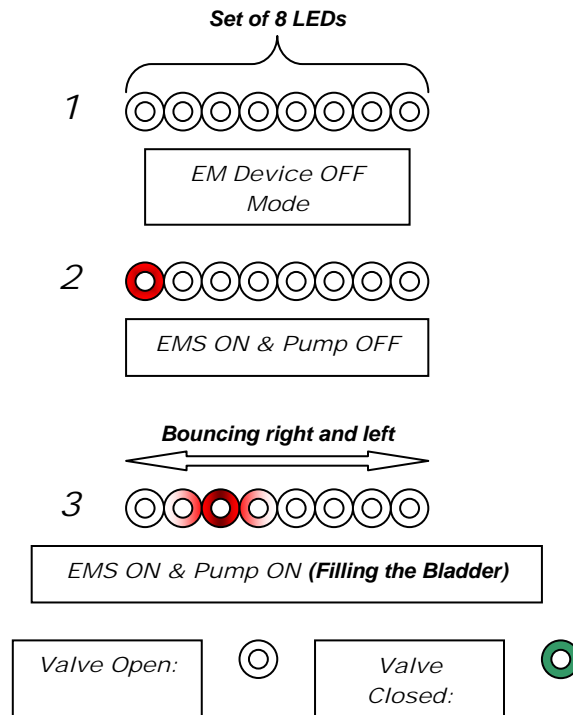
To operate the AVR Butterfly a joystick is used as the user input. The 4 way directional button will give the user the physical ability to navigate through the menus of the device, and make necessary changes in the database stored on the chip. Figure 24 shows the EMS menu actions that the joystick performs.



**Figure 24 - Joystick switch on AVR Butterfly**

The 100 segment LCD display will be guiding the user by showing him/her the various choices made on the menu. This meets the functional requirements [R52] and [R53].

The user will be aware of the pumps status through a series of LED lights shown in Figure 25.



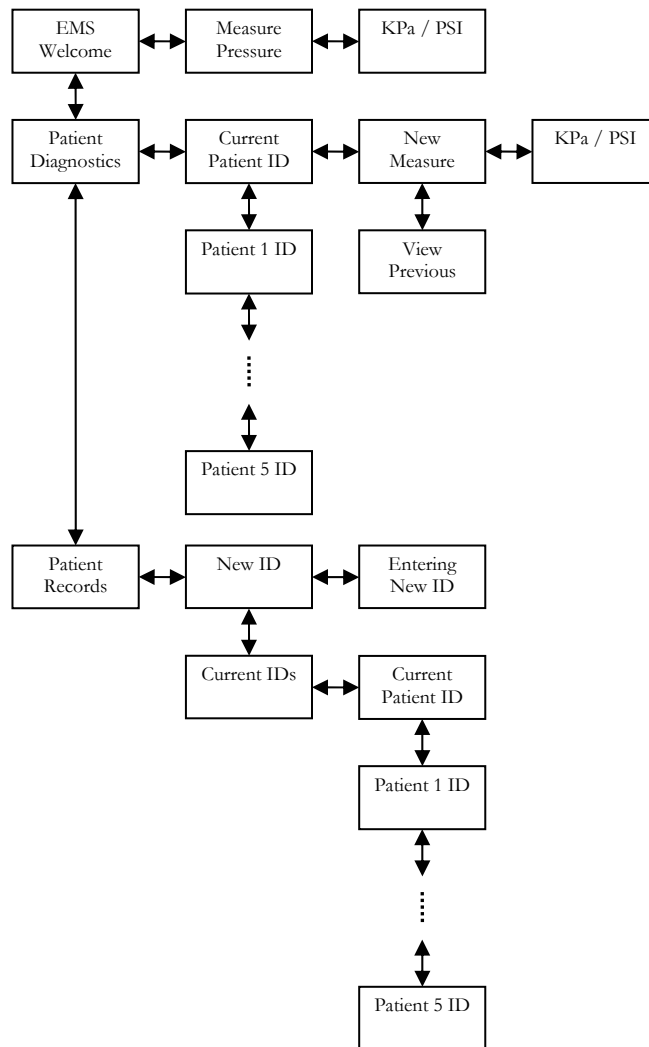
**Figure 25 - LEDs used for user interface**

If time permits, the on board integrated Piezo speaker of the AVR Butterfly will be used as a back up user interface unit for confirming choices made on the menu, by creating various sounds for confirmation of some of the menu choices.

## 4.2 EMS Menu Chart

The EMS user interface system is turned on by pressing the joystick up key once. The first thing to be shown on the LCD display is the “EMS Welcome” message. The current menu selection will be displayed at all times. The user can go to a sub-menu or execute a command by moving to the right, or exit a sub-menu or command by moving the joystick to the left. By scrolling up and down the user can easily toggle between sub-menu choices. The overall design for the EMS menu is shown in Figure 26.





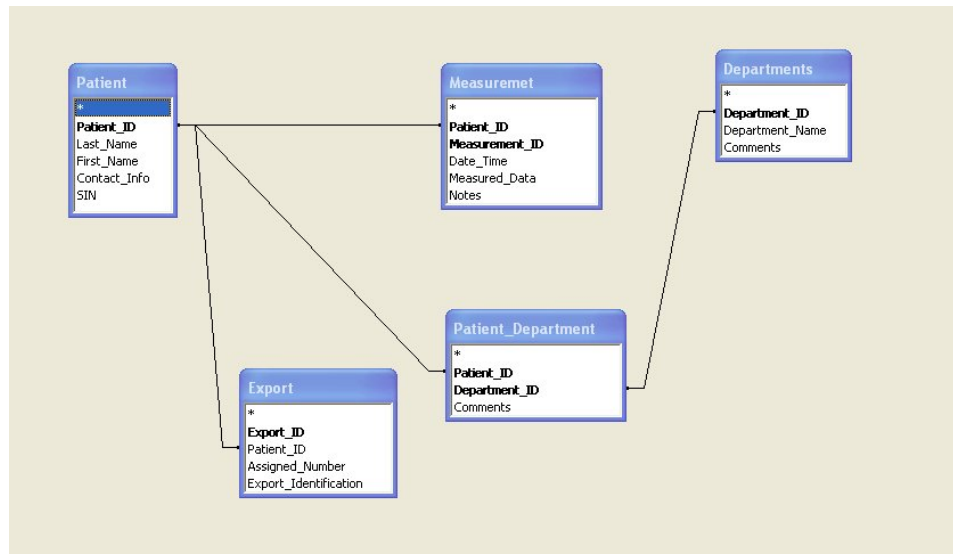
**Figure 26 - EMS Menu System**

### ***4.3 PC Software User Interface***

#### ***4.3.1 Database***

The software that will be working on the PC side is designed as a simple 2-tier application with the front-end tier written in Microsoft Visual Basic and the back-end tier written in Microsoft Access. The Access database will have five objects with 3 of those designed as strong object with separate keys, and 2 designed as aggregations – objects that won't be able to exist by themselves.

The design of the database supports further changes and development. Figure 27 shows the objects inside the database and relationships among them.



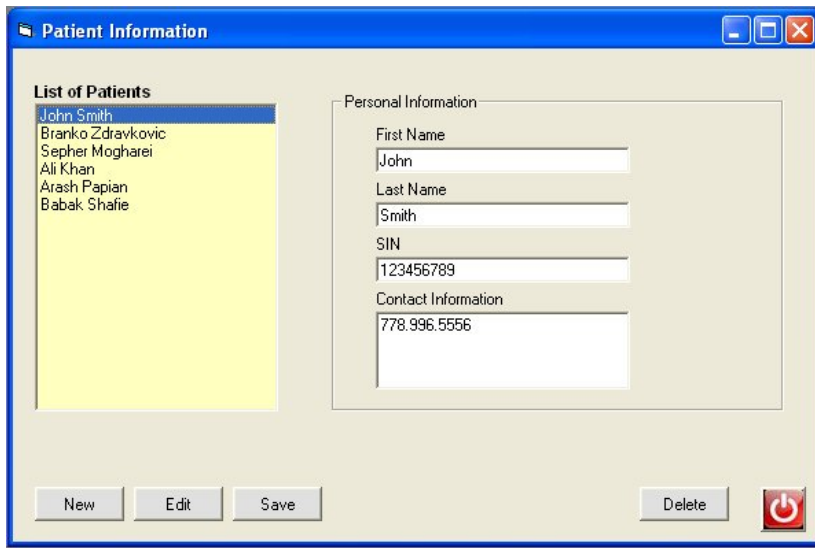
**Figure 27 - PC Client Database Design**

#### 4.3.2 *Communication*

Database will be accessible from Visual Basic part of the application using ActiveX Data Object component. The communication between Visual Basic forms and serial port will be established using I/O ActiveX controls. Data frames will be sent using the speed of 9600 bauds with no parity checks and 8-bit format with 1 stop bit.

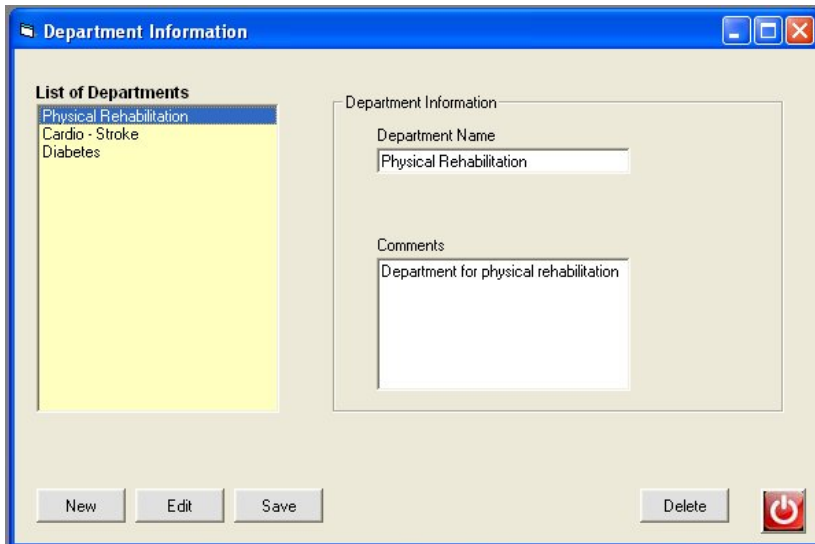
#### 4.3.3 *Data Entry Forms*

We designed the forms in a user friendly manner while focusing on our client needs and established procedures. The application has 3 separate parts. The purpose of the first part is to enter the data related to departments and patients. Patient information contains the first and last name, SIN, and contact information. The patient list is given as an aid for easier orientation and better presentation of data in the entry form. Also the form includes buttons for adding, editing, storing, and deleting patients from the database. Figure 28 shows the Patient Information data entry form.



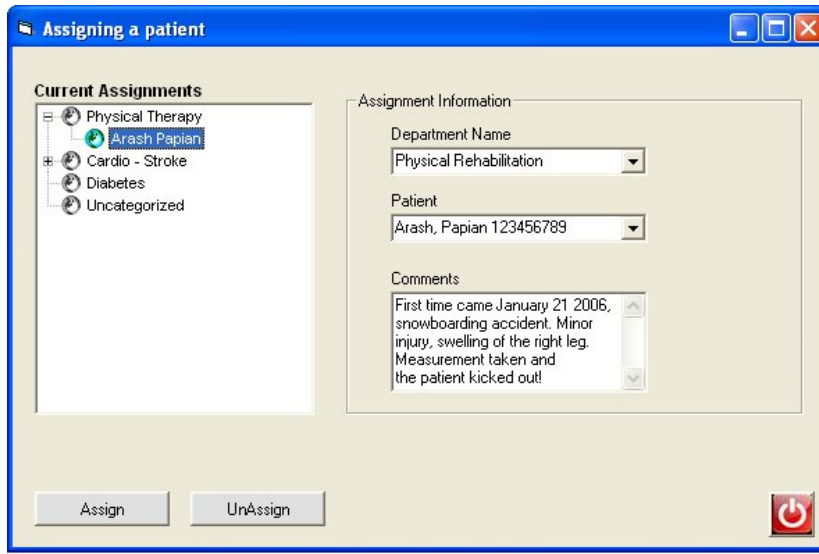
**Figure 28 - Patient Information Data Entry Form**

The Department Information form is very similar to the previous one and deals with operations regarding current departments that are being added or already inside the database. The form is shown on Figure 29 below.



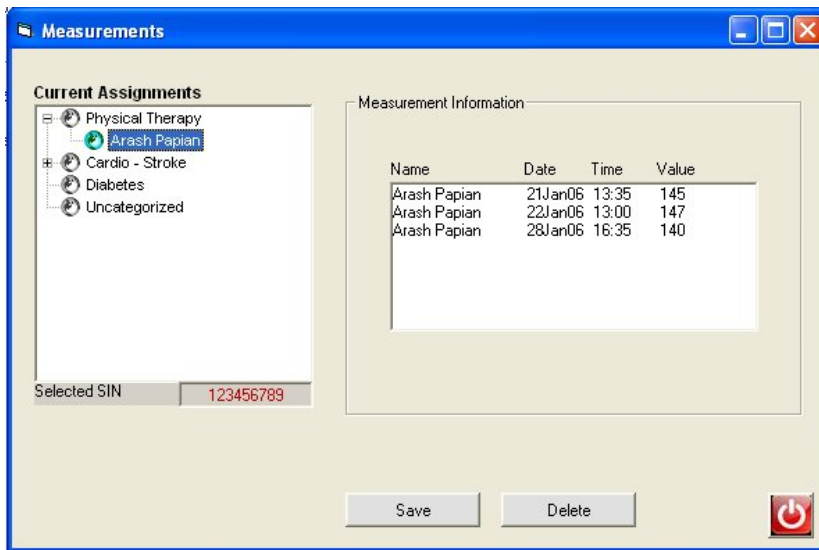
**Figure 29 - Department Information Data Entry Form**

The patients can be assigned to a department shown in Figure 30.



**Figure 30 - Assigning a Patient Data Entry Form**

To observe, edit, or delete the measurements obtained from the EMS device, we use Measurements data form. After selecting the patient from the corresponding department on the left side of the form, the user will be able to see all measurements performed and recorded for the selected patient in format: Patient Name, Date, Time, and Value. SIN number field is presented as a reference so that 2 patients with a same name can be distinguished. The Measurement form is shown in Figure 31 below.

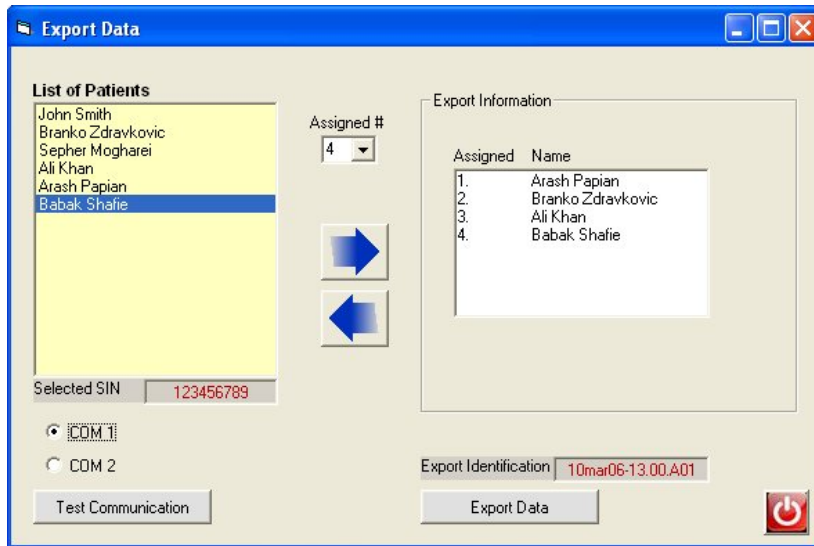


Name	Date	Time	Value
Arash Papian	21Jan06	13:35	145
Arash Papian	22Jan06	13:00	147
Arash Papian	28Jan06	16:35	140

**Figure 31 - Measurement Data Form**

The third and final part of the application deals with exporting the patient list to the EMS device and importing the data from the EMS device. To export the data, the Export form is used. This form is used to test and initiate the communication. The right port needs to be chosen before the test can be performed. After testing, user can export the data to the EMS

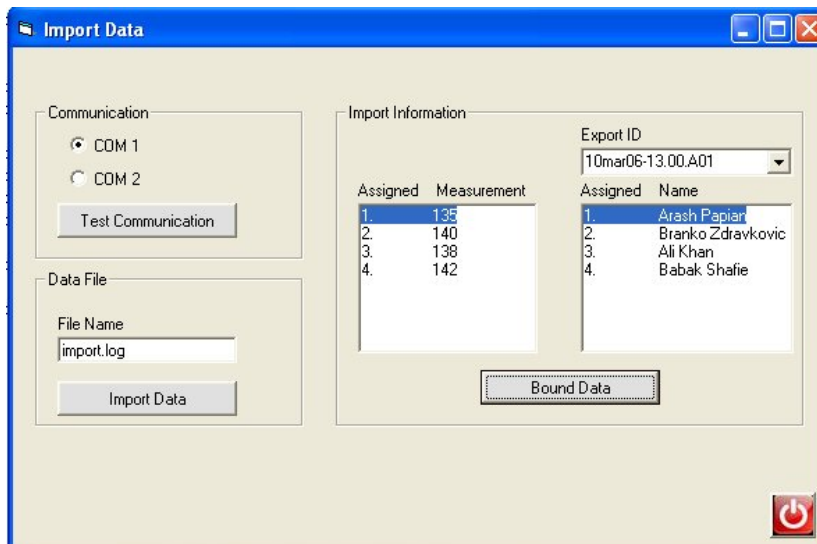
device by clicking the corresponding button. The export identification code will be generated as explained in the Communication part of this document. Figure 32 shows the Export data form.



Export Information	
Assigned	Name
1.	Arash Papian
2.	Branko Zdravkovic
3.	Ali Khan
4.	Babak Shafie

**Figure 32 - Export Data Form**

The last form is used to import the measurement data from the EMS device shown in Figure 33.



Import Information	
Assigned	Measurement
1.	135
2.	140
3.	138
4.	142

**Figure 33 - Import Data Form**

## 5 Conclusion

The design specifications outlined in this document clearly define the technical requirements will be met by the proof-of-concept and final production model of the Edema Measurement System. The design of the proof-of-concept model is well underway and upon completion of the product in April 2006, all requirements pertaining to the proof-of-concept model will be met. This document in conjunction with *Functional Specification for EMS* will serve as key guidelines for the development of the EMS device.

## 6 References

- [1] Vedo Medico, “Functional Specification for EMS”, Simon Fraser University, Burnaby, BC, Canada, February 2006.
- [2] “AVR Butterfly Users Guide”, [www.atmel.com](http://www.atmel.com), 2005. [Viewed March 6, 2006]
- [3] “ATMega169 Users Guide”, [www.atmel.com](http://www.atmel.com), 2005. [Viewed March 6, 2006]
- [4] “MPX2200 Pressure Sensor Datasheet”, [www.freescale.com](http://www.freescale.com), 2005. [Viewed March 6, 2006]
- [5] “Blood Pressure Cuffs”, [www.trimlinemed.com](http://www.trimlinemed.com), 2006. [Viewed March 9 2006]

## Appendix

**6.1 Appendix A – Microcontroller**

<b>PIN</b>	<b>PIN Connection</b>	<b>Notes</b>
PA0	LCD BP1	
PA1	LCD BP2	
PA2	LCD BP3	
PA3	LCD BP4	
PA4	LCD27	
PA5	LCD28	
PA6	LCD29	
PA7	LCD4	
PB0	RXD/DataFlash CS	UART connection
PB1	TXD/DataFlash SCK	UART connection
PB2	DataFlash SI	Might be used for Relays
PB3	DataFlash SO	Might be used for Relays
PB4	Joystick Port Centre	Joystick Centre Push
PB5	Not Used	
PB6	Joystick Port A	Joystick Up
PB7	Joystick Port B	Joystick Down
PC0	LCD10	
PC1	LCD7	
PC2	LCD23	
PC3	LCD22	
PC4	LCD8	
PC5	LCD5	
PC6	LCD26	
PC7	LCD25	
PD0	LCD15	
PD1	LCD16	
PD2	LCD18	
PD3	LCD13	
PD4	LCD11	
PD5	LCD12	
PD6	LCD14	
PD7	LCD9	
PE0	AVR RxD (see Fig. A2)	
PE1	AVR TxD (see Fig. A2)	
PE2	Joystick Port C	Joystick Right
PE3	Joystick Port D	Joystick Left
PE4	Not Used	Might be used for Pressure Sensor
PE5	Not Used	Might be used for Pressure Sensor
PE6	Not Used	Might be used for Pressure Sensor
PE7	DataFlash RST_Flash	
<b>PIN</b>	<b>PIN Connection</b>	<b>Notes</b>

<b>PF0</b>	Not Used	
<b>PF1</b>	Not Used	Might be used for LED
<b>PF2</b>	Not Used	Might be used for LED
<b>PF3</b>	Not Used	Might be used for LED
<b>PF4</b>	JTAG1	
<b>PF5</b>	JTAG5	
<b>PF6</b>	JTAG3	
<b>PF7</b>	JTAG9	
<b>PG0</b>	LCD21	
<b>PG1</b>	LCD20	
<b>PG2</b>	LCD6	
<b>PG3</b>	LCD19	
<b>PG4</b>	LCD17	
<b>PG5</b>	Not Used	
<b>RESET</b>	RESET (see Fig. A2)	
<b>XTAL1</b>	Crystal Oscillator Input	
<b>XTAL2</b>	Crystal Oscillator Output	
<b>AREF</b>	VCP (see Fig. A2)	Analog Reference for ADC
<b>AGND</b>	GND Supply	
<b>AVCC</b>	V <sup>+</sup> Supply	Connected using a low- pass filter
<b>LCDCAP</b>	Capacitor	Capacitor used to stabilize Voltage to LCD
<b>VCC</b>	V <sup>+</sup> Supply	Connected to power supply
<b>GND</b>	GND Supply	Connected to power supply

**Table A1 – ATmega169 Pin Connections for EMS device**



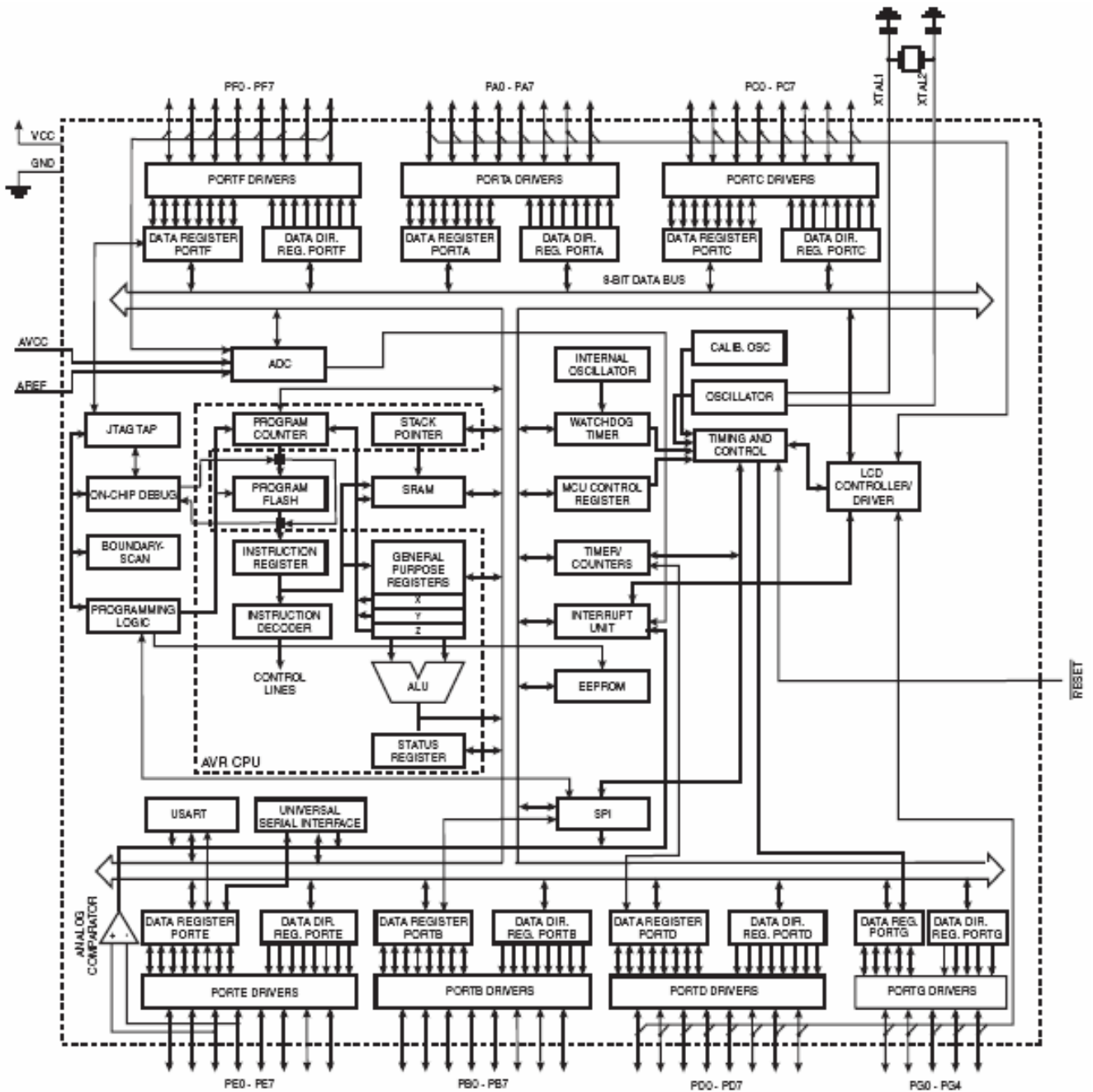


Figure A1 – ATMega169 Block Diagram

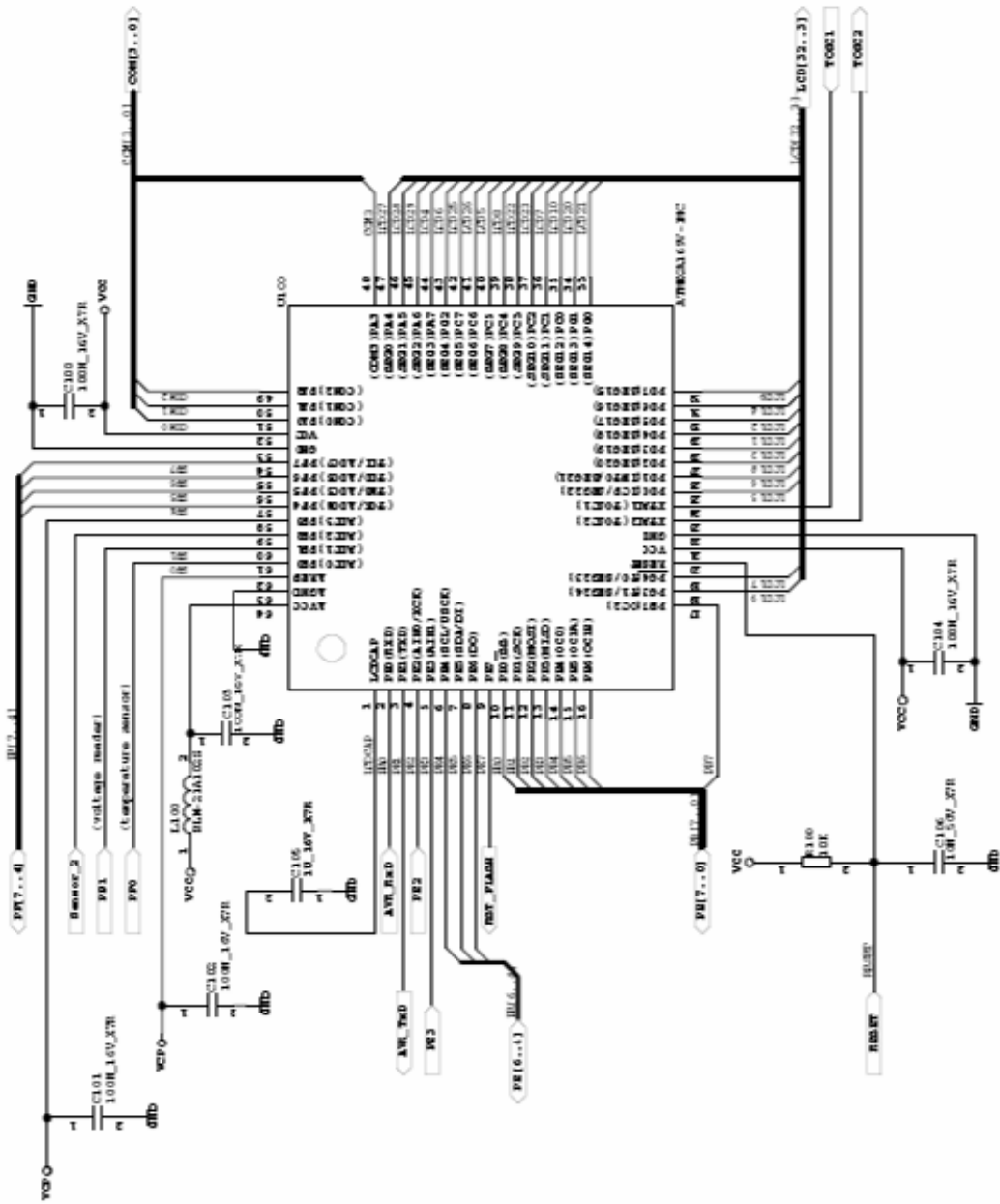


Figure A2 – AVR Butterfly Schematic