IJETCR Open Access
ISSN: 2348 - 2117
International Journal of Engineering Technology and Computer Research (IJETCR)
Available Online at www.ijetcr.org
Volume 3; Issue 5; September-October-2015; Page No. 90-99

# Design and Development of Iontophoresis Power Supply and Data Acquisition System Using AVR Microcontroller

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**Abstract**

Flexible and user friendly low cost AVR microcontroller based Iontophoresis power supply and data acquisition with computer interface is designed, constructed, tested and is presented.

Most of the Iontophoresis study based experiments need monitoring of some parameter like, conductivity, to this effect the power supply is equipped with a Data Acquisition System (DAS). The computer side program processes the incoming data and stores in computer files for further use in suitable format.

The two way communication between the microcontroller and the computer side controlling program is implemented using serial port in RS232 configuration. Newer PC's are not equipped with serial ports and laptops rarely have a serial port, to this effect, a USB to serial converter is used so that the instrument can directly be attached to USB port of a computer or laptop for control and data acquisition.

***Key Words:*** *Iontophoresis, Power supply, Data Acquisition system, ADC, Trans-dermal drug delivery, Microcontroller.*

## 1. Introduction

Iontophoresis is one of the areas with brisk research activity related to pharmaceutics, medicine drug delivery and pharmacology. In science, technology and health sciences where controlled experimentation had limitations due to constraints of implementation and monitoring of the research processes this system is expected to be of use. One of such areas in the field of health sciences is at the focus of researchers in new drug delivery systems, namely trans-dermal drug administration based on Iontophoresis. In this process medicinal patches are designed and stuck to the patient's skin and the drug is gradually absorbed through the skin of the patient. Different techniques are being examined and studied for the administration of drug using this approach. Iontophoresis is one of the techniques in which the drug transport across the skin is enhanced using external stimuli like application of electrical pulses of desired short durations. This approach makes use of repeated application of electric pulses which in turn demands for a power supply capable of serving this requirement.

With automation and availability of advanced instruments there is growing need of computer interfacing of traditional instruments so that data from experiments could be captured automatically. In view of this a data acquisition system (DAS) is designed and constructed that is cost effective and user friendly and can be adapted to different application with little or no modification. The research in the field of microsystems is progressively directed towards smart electronic interfacing which provides the ability of performing complex operations. Specially designed interfacing electronics for specific applications improve the performances and provide a user-friendly environment. Data acquisition system is extensively employed in a number of automatic test and measuring data via controlling program. The measured data could be stored in the PC in a file for further processing and the data can be displayed numerically or graphically as a curve on the screen.

As an attempt to attend to the need of such an instrument capable of delivering controlled electrical pulses, a microcontroller based power supply is designed, constructed and tested. The power supply with flexible design and user friendly features can be easily adapted to Iontophoresis studies in different regimes. Pulse duration, duty cycle can be controlled from the panel of the power supply that has three buttons and a Liquid Crystal Display (LCD). The on time and off time can be individually set to the desired value from 0 to 10 second and this range can be suitably modified by minor changes



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in the firmware of the microcontroller based power supply. Two terminals are provided on the main panel for taking the output, a LED on the main panel shows the ON or OFF state of the output.

The Iontophoresis study experiments need monitoring of some parameter like, conductivity etc, to this effect the power supply is equipped with a Data Acquisition System (DAS). For this purpose the 10 bit ADC from the microcontroller used in the power supply is employed. The computer side program processes the incoming data and stores in computer files for further use in suitable format. The microcontroller firmware has provision to transmit the data at pre decided intervals of time as needed.

The two way communication between the microcontroller and the computer side controlling program is implemented using serial port in RS232 configuration. The 10 bit of ADC data is split into two parts 8 bit and 2 bit the two bytes are sent one by one using serial communication. The 6 free bits from the MSB can be used for tracking data consistency by appending suitable code. The serial communication is implemented using 8 bit of data, one start bit, one stop bit and no parity at a baud rate of 9600. Newer PC's are not equipped with serial ports and laptops rarely have a serial port, to this effect, a USB to serial converter is used so that the instrument can directly be attached to USB port of a computer or laptop for control and data acquisition.

**2.** Microcontroller Atmega32

The ATmega32 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture from Atmel Corporation. By executing powerful instructions in a single clock cycle, the ATmega32 achieves throughputs approaching 1 MIPS per MHz allowing the system designed to optimize power consumption versus processing speed.

**A. Main features**

- In system programmability.
- Powerful instruction set.
- On chip 10 bit ADC.
- On chip serial port.
- Availability of powerful development environment IDE's.
- High level language programming support.

The pin diagram of ATmega32 in 40 pin PDIP package is shown in figure 1.

The AVR core of microcontroller combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

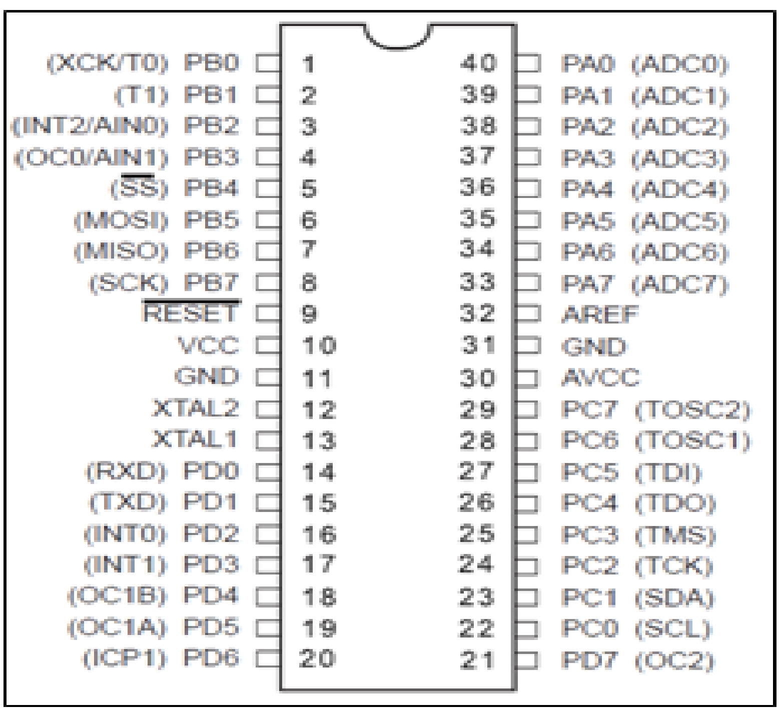


**Fig.1 Pin diagram of Atmega32 in 40 pin PDIP package.**

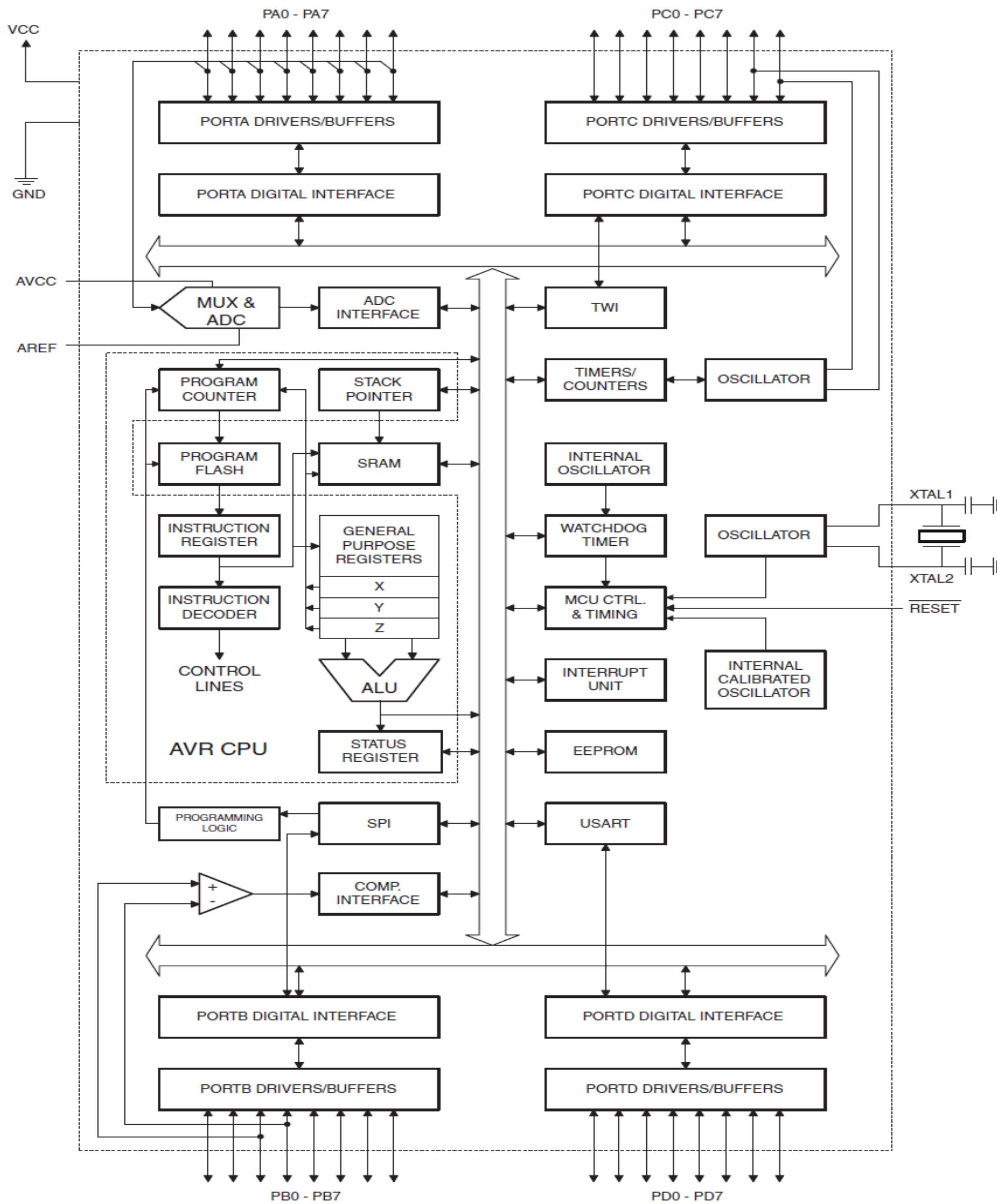


**Fig.2 Block diagram of Atmega32.**

The ATmega32 provides some salient and peripheral features as: 32K bytes of In-System Programmable Flash Program memory with Read-While-Write capabilities, 1024 bytes EEPROM, 2K byte SRAM, 32 general purpose I/O lines, 32 general purpose working registers. Three flexible Timer/Counters with compare modes, Internal and External Interrupts, a serial programmable USART, a byte oriented Two-wire Serial Interface, an 8-channel, 10-bit ADC, a programmable Watchdog Timer with Internal Oscillator, an SPI serial port, and six software selectable power saving modes. The Idle mode stops the CPU while allowing the USART, Two-wire interface, A/D Converter, SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the oscillator, disabling all other chip functions until the next External Interrupt or Hardware Reset. In Power-save mode, the Asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping.

The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC, to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low-power consumption. In Extended Standby mode, both the main oscillator and the asynchronous timer continue to run. The device is manufactured using Atmel's high density nonvolatile memory technology. The On chip ISP Flash allows the program memory to be reprogrammed in-system through an SPI serial interface, by a conventional nonvolatile memory programmer, or by an On-chip Boot program running on the AVR core. The boot program can use any interface to download the application program in the Application Flash memory. Software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega32 is a powerful microcontroller that provides a highly-flexible and cost-effective solution to many embedded control applications.

The ATmega32 AVR is supported with a full suite of program and system development tools including: C compilers, macro assemblers, program debugger / simulators, in-circuit emulators, and evaluation kits.

## 3. Methods & Materials

The microcontroller used, i.e. Atmega32 belongs to the AVR family of microcontrollers with advanced features and resources. The implementation of the Iontophoresis power supply and data acquisition involved the utilization few of its most important capabilities like I/O ports, Serial communication, Analogue to Digital Conversion (ADC). Port B was used for interfacing LCD display, and port C used for switches and relay with appropriate configuration.

### 3.1 I/O Ports

Atmega32 has four bidirectional ports i.e. in all 8 × 4 = 32 lines that can be used either as input lines or as output lines depending on the requirement using the corresponding data direction register (DDR). All the lines can individually configured as input or output.

### 3.2 Driving Relay.

The four ports of the microcontroller are not intended for high current application and rather are intended for driving logic circuitry. Commonly used relays working at 12V DC have resistance in the range of few tens of Ohms to few hundreds of ohms thus requiring currents to the tune of few tens on milliamperes to few hundred milliampere. Thus to drive a relay a simple technique is to use a NPN transistor with base driven by the port via a resistance of say 1KΩ and collector connected to the supply via relay winding and emitter connected to ground.

### 3.3 Serial Communication.

The Universal Synchronous and Asynchronous serial Receiver and Transmitter (USART) is a highly flexible serial communication device and its functioning is controlled by writing appropriate value to the configuration register UBRR.

### 3.4 On chip ADC.

The ATmega32 has a 10-bit successive approximation ADC with 8 independent inputs (Port A pins). The device also supports 16 differential voltage input combinations. Two of the differential inputs (ADC1, ADC0 and ADC3, ADC2) are equipped with a programmable gain stage, providing amplification steps of 0 dB (1x), 20 dB (10x), or 46 dB (200x) on the differential input voltage before the A/D conversion. Seven differential analog input channels share a common negative terminal (ADC1), while any other ADC input can be selected as the positive input terminal. If 1x or 10x gain is used, 8-bit resolution can be expected. If 200x gain is used, 7-bit resolution can be expected. In actual implementation the pin 32 i.e. AREF is connected to a reference voltage say +5V and at the end of conversion the result is sent to the desired output.

## 4 DESIGN CONSIDERATION

The Iontophoresis power supply and data acquisition system was designed keeping in view the requirements of researchers studying Iontophoresis through bio membranes. The power supply part basically is a controlled pulse generator that can provide electrical pulses of the desired duration. The data acquisition part has to monitor an analogue input under program control and then send the resulting data to the controlling program. The Analogue input monitoring is implemented using the built in 10 bit ADC of the microcontroller and the communication is implemented using the on chip USART for serial communication. For ease of operation a LCD display is provided that displays the current setting of the duration and interval between two consecutive pulses. The power on task of the instrument is to initialize all the ports and peripherals attached including the serial port, LCD display and the input keys.

### 4.1 Circuit Diagram

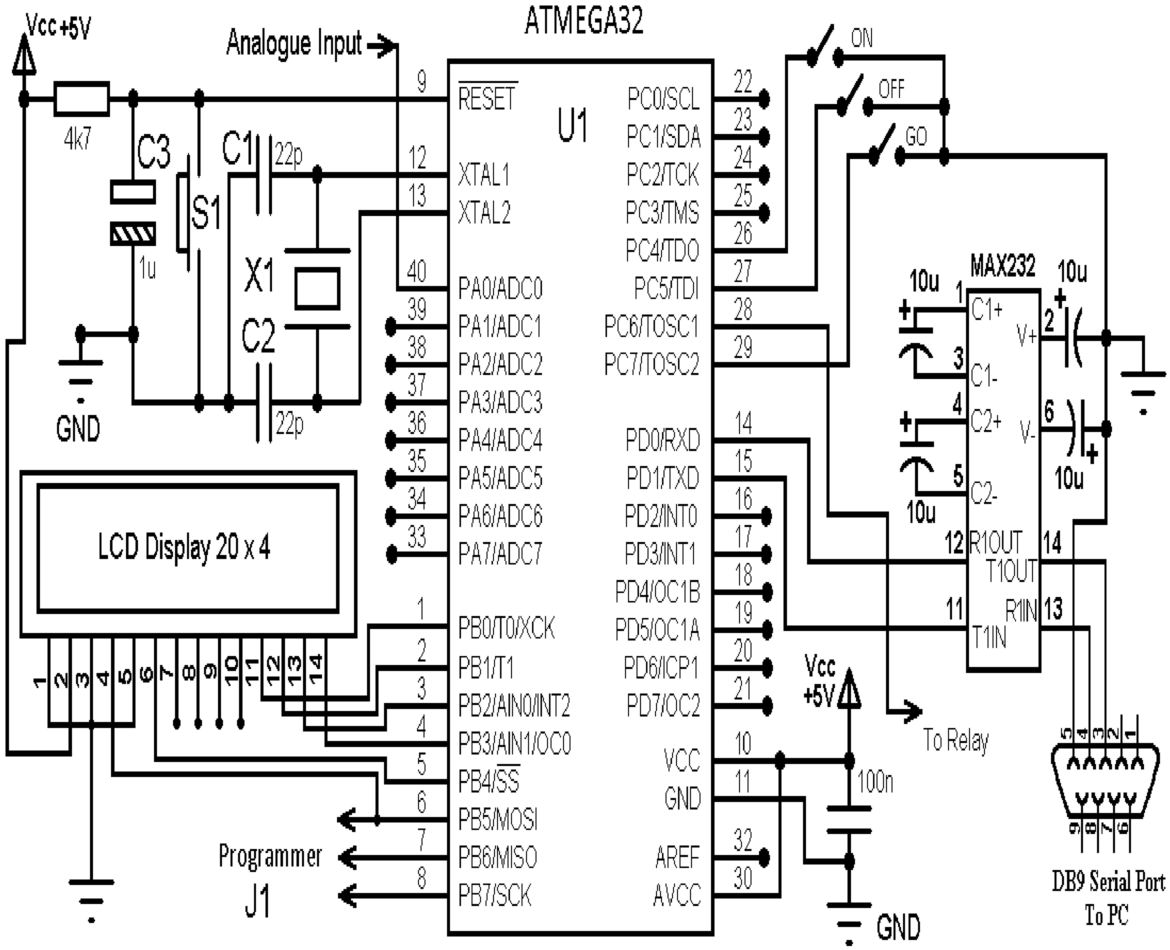


**Fig. 3 Detailed circuit Diagram of Iontophoresis Power supply and data acquisition system**

At power on the yellow power indicator LED glows and the instrument displays basic information on the LCD displays along with the default values of ON and OFF times (1s each). There are two buttons on the panel that allow choice of ON time and OFF time, on pressing the corresponding button the time is incremented by one unit and when it reaches the maximum programmed limit it rolls back to initial default value. This allows for the control and adjustment of the duration for which the supply is in ON state and the duration between two consecutive pulses namely the OFF time.

**4.2 Front Panel of power supply**

The third button is the 'GO' button which is to be pressed after setting the timings, on pressing of this button the pulse generation of the instrument begins and based on the selected ON and OFF time, it keeps on generating pulses of duration equal to the selected ON time separated by in interval of OFF time. This feature makes the power supply highly flexible in that the experimenter can have the time schedule of his choice to study the Iontophoresis. The three buttons, the ON, OFF and GO buttons are connected to port bits PC4, PC5 and PC7 respectively that are already configured as input pins whereas the pin PC6 is used as an output pin to drive a relay switching the power ON and OFF.

The data acquisition system was constructed on a standard AVR board fitted with minimum required system; IC bases, crystal etc. and ISP port for in system programming. The circuit was carefully constructed using necessary decoupling and taking care of stray pickups. The complete assembled circuit is shown in Fig. 5 below; the circuit board is placed in a plastic housing.


**Fig 4 shows front panel of power supply**

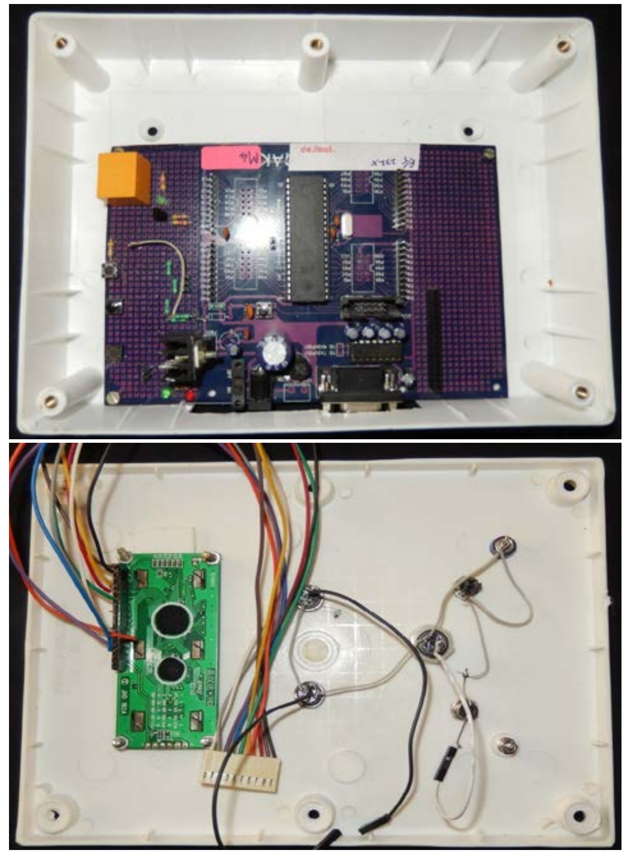

**Fig. 5 Microcontroller based power supply and Data acquisition System**

The top cover of this plastic casing serves as the main panel shown in earlier Figure. The switches, the terminals, the LCD and the LED's are mounted on this panel and necessary connecting leads are routed to their respective port pins using suitable connectors, the back view of this cover panel is shown in Fig. 5. The entire assembly is fixed in a plastic casing and connections are brought out for Power supply and serial port or the USB to serial converter. The analogue input for the ADC is taken out using a coaxial cable and the leads are left for direct connections with the input signal source.

The system was thoroughly tested for performance and the performance evaluated over prolonged period of time to check the timings. As is expected by a microcontroller based system the timing was found to be accurate for over several hours of continuous operation. The performance of ADC was also tested by giving standard input voltages and measuring corresponding ADC output, the results were very much in agreement, too close comparison was not found necessary as the functions implemented by the microcontroller were highly reliable.

The Iontophoresis power supply and DAS functions under the control of computer side controlling program, necessary computer software is developed, debugged and implemented in visual basic to make it user friendly with the help of powerful GUI interface. When switched on the hardware prompts for setting the ON and OFF time and at the press of the GO button it starts the timing and generation of the output voltage pulses at the set timings. The voltage can be adjusted using an external potential divider to obtain the desired output current. The computer side controlling program initializes the ports and sends a signal to the DAS to sample the input and convert it to digital form and send back to the controlling program. On receipt of the request, the DAS converts the input into digital form and sends it over the serial port at a baud rate of 9600. The ADC output is 10 bit therefore two bytes of data is transmitted to the controlling program. The controlling program displays the incoming data both graphically and numerically on the computer screen as shown in the screenshot shown in Fig. 6. To track the functioning serial number of readings being received is also shown on the screen. The observations are recorded at preset time interval and after the preset number of observations is reached, the data is saved in a file for future use, processing and analysis.

**4.3 Iontophoresis Cell (Franz Cell)** As the instrument has to go with Iontophoresis experiment, the live testing of the instrument was done using an Iontophoresis cell shown in Fig. 5. The Iontophoresis cell (the Franz cell) has two compartments, the donor and acceptor compartments and the acceptor compartment is provided with an outer jacket for water circulation to maintain temperature. For the purpose of measuring extent of permeation through the biomembrane a custom made conductivity cell was used. The cell was kept in the lower part of the cell i.e. the acceptor compartment and the leads of the conductivity cell were brought out through the side limb of the cell. These leads connect to the measuring circuitry of the data acquisition system.

**Fig. 6 Iontophoresis (Franz) cell used.**

**4.4** Bio Membrane

To study the permeation of chemical through biological membrane, for testing and evaluation purpose we used the hen egg membrane. The egg membrane was obtained from egg by dissolving the outer shell in dilute hydrochloric acid and removing the egg white and yoke from the membrane. Egg membrane kept in distilled water is shown below and the other image show egg membrane mounted in the cell paper clamps are used to hold the two compartments together.

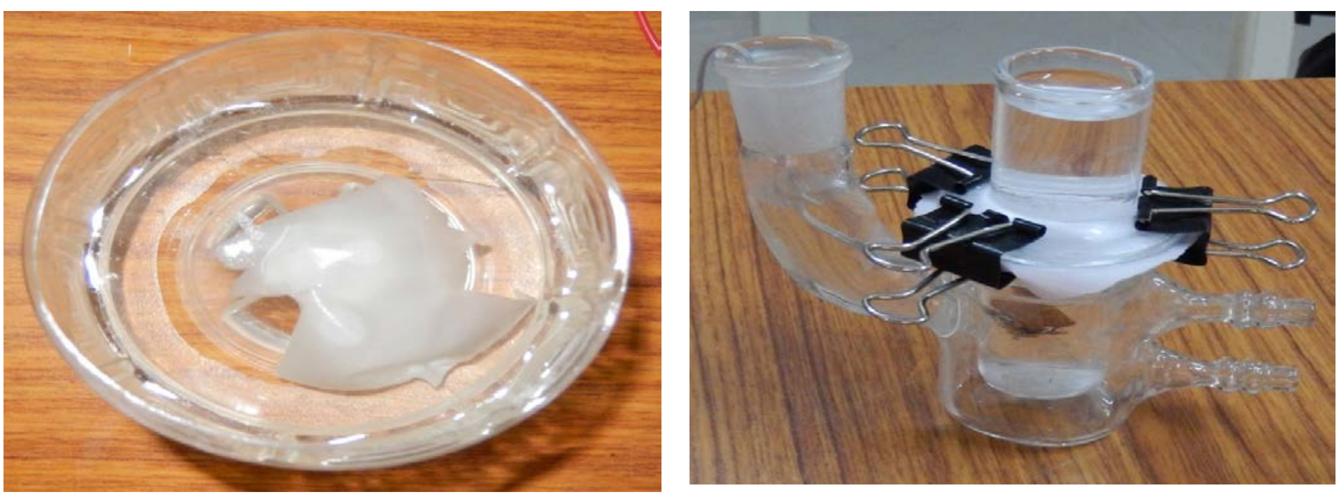

**Fig.7 Bio-membrane and Franz Cell.**

Distilled water was used in the acceptor compartment and sodium chloride (NaCl) solution was kept in the donor compartment. To estimate the extent of transport we used conductivity cell to measure the conductivity in the accepter compartment. The conductivity probe was placed in the acceptor compartment and magnetic stirrer pin was also placed in this compartment. The conductivity cell was not calibrated as arbitrary readings and the performance of the system was of interest, calibration of the cell would yield actual values. The experiment was set to record readings every 10 seconds.

**DATA ACQUISITION SOFTWARE (CONTROLLING PROGRAM)**

The controlling program was developed in visual basic to keep it user friendly and easily deployable. The main opening screen shows three buttons namely, GO, TEST and END, the Go button is to start a sequence of measurements at preset intervals of time, the test button is for testing a single observation and the end button is to stop the program. The main screen displays some static information and in addition to this there are two text boxes in the left hand side panel. These two boxes show the serial number of the reading being processed and recorded the box is labeled accordingly. The other text box shows the actual value of ADC value read from the microcontroller based data acquisition circuitry.

The ADC value can be stored in a computer file for further processing or it can be pre-processed to calculate desired parameter based on the cell constant etc and stored for further processing, in the present setup the ADC values are stored and rest of the processing is implemented separately. The important features of the computer side controlling program include the use of MSComm controlled that provides interface for serial communication with the external hardware. The hardware used implemented the serial communication with 8 data bits, one start bit, one stop bit and no parity therefore; the MSComm was also configured accordingly.

The experiment was designed to collect readings every 10 seconds therefore the program sends request to the hardware to sample the incoming data every 10 seconds and send back the result. For timing purpose timer control was used, this timer control is capable of providing 1 ms time steps, for 10 s the timer was initialized accordingly by setting the respective property to appropriate value. After every 10 seconds the program sends a ASCII character the request code to the microcontroller, as soon as the microcontroller receives this codes it starts converting the input at ADC0 and the converted value i.e. the digital equivalent of the input analogue signal is split into two bytes and sent back to the controlling program using serial port. This data is then received by the controlling program and decoded back to calculate the ADC value and displays the result in the second text box marked as (ADC / Resistance), for finding of the resistance from ADC value the cell constant is also needed. The duration after which the readings are sampled was 10 seconds, however it is not rigid as the initiation of the readings is done by this program, if the timer is configured to take readings after say 5 seconds, the timer property time interval can be set accordingly. To change this duration a text is provided in the revised version of the program to read in the timing interval and set the timer property timer.interval accordingly. This makes it highly flexible and practically any interval can be selected.

A typical screenshot while the experiment was in progress is shown in Fig. 8 the performance of the Iontophoresis power supply and data acquisition system was found to be satisfactory and consistent with the expectations.

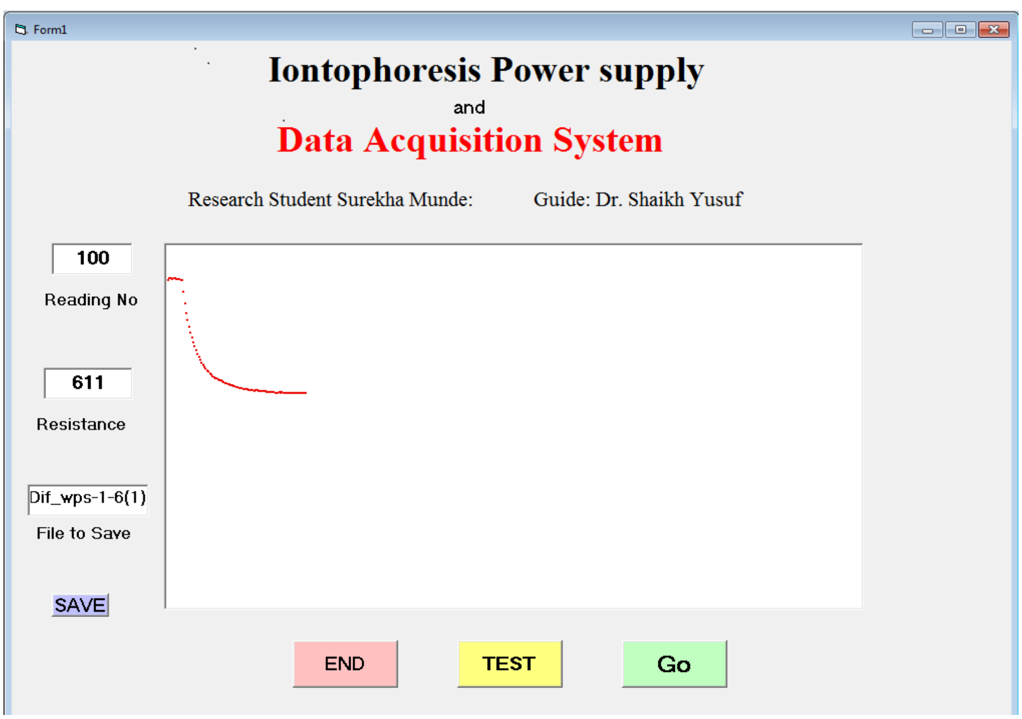


**Fig. 8 Screen of Data Acquisition Software while recording resistance of the cell**

## 5 Results & Discussions

Typical resistivity versus time graph plotted in excels using the data file from the setup designed is shown in Fig. 9. The plot shown in Fig. 9 corresponds to the screenshot of Fig. 8, compared with another plot taken with the Iontophoresis supply switched off. The effect diffusion through the membrane with and without IPS is clearly visible as reduction in resistivity.

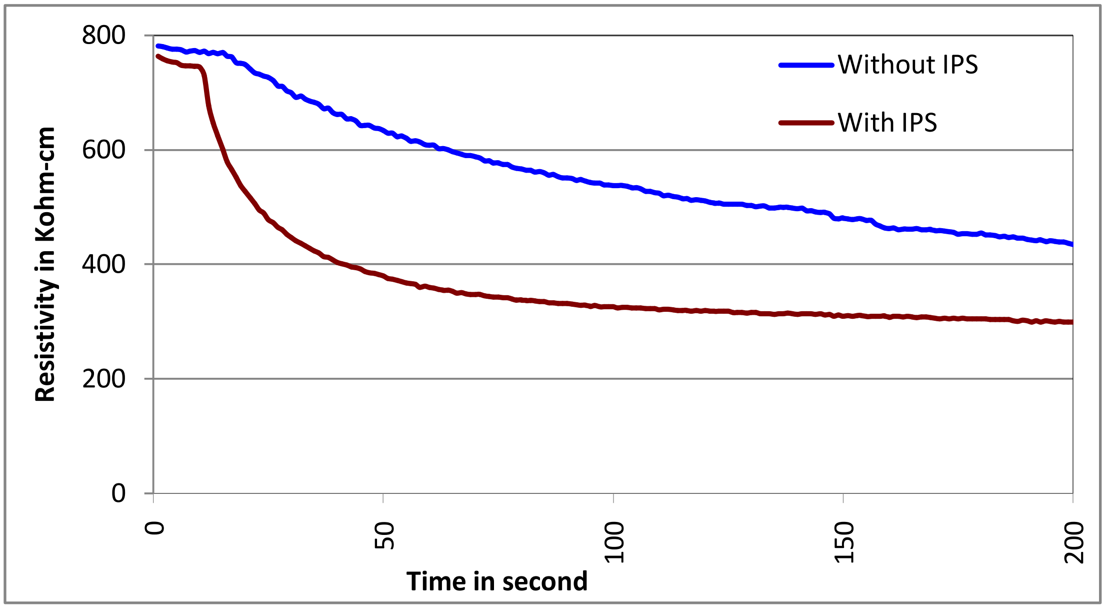


**Fig. 9 Resistivity vs. time graph for data from fig 8 compared with another data**

## 7 CONCLUSION

The Iontophoresis power supply and data acquisition was designed, constructed and tested. The instrument developed contained desired features of Iontophoresis power supply as well as data acquisition system. For controlling the instrument and for data acquisition system serial communication was implemented and computer side controlling program developed in VB. This system had a measuring accuracy of one part in 1024 which is fairly good and acceptable for most of the routine laboratory experiments. Further advantage is that for unattended experiments, tedious task of recording observations over a long time is simplified and ready to use data is available.

The system was constructed using a general purpose low cost AVR development board using a crystal frequency of 11.0592 MHz. The microcontroller program was developed in AVR GCC. The instrument has in system programming port so that for minor changes or radical modification, modified firmware can easily be downloaded into the microcontroller.

## 9. Acknowledgement

The authors thank UGC for providing grants to carry out this research work. This work is part of research project "Design and development of Embedded System based flexible and user friendly Iontophoresis power supply and data acquisition system using AVR microcontroller with computer interface" granted by UGC F-47-038/12(WRO). The facilities provided by Maulana Azad College, PG and Research Centre are also

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