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Design and Development of Ionization Chamber for Detection of X-Ray Beam AT INDUS-2 RRCAT

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***Abstract* – The goal of this paper was to design and develop a Microcontroller based data acquisition unit for detection of X-ray flux through Ionization chamber that will remotely control and monitor the ultra-low current signal detection analog module precisely. This application will be useful to measure the intensity of x-ray flux through the ionization chamber in a beam line of synchrotron radiation source which is mounted in INDUS-2. The beam line area is highly restricted because of hazardous radiation, so through this application remote interfacing provides for the ultra-low current signal detection card that can be controlled by personal computer. To design a perfect embedded system there are many issues like designing a proper PCB, to achieve the specified resolution of the ADC used in chip, code developed using any compiler should be within the limit of the memory of the microcontroller system and integrity of the devices used in the circuit. Initially explore and gain the knowledge of embedded systems by doing a small project and writing the code for the same, and gain a knowledge how the system works. Programming has done in assembly language 8051, for schematic design PCB design tool ORCAD (VERSION 9.0) use.**

***Keywords* – DAS, Ionization Chamber, Microcontroller, X-Ray Beam.**

I. INTRODUCTION

The data acquisition system for ionization is required for measurement of x-ray flux in INDUS-2 Beam lines at RRCAT, Indore. The project works comprise of the development of ultra-low current signal detection card and data acquisition system based on micro controller 80C552. Indus-2 is a synchrotron radiation source of nominal electron energy of 2.5 GeV and a critical wavelength of about 4 angstroms. A synchrotron is a particular type of cyclic particle accelerator in which the magnetic field and the electric field are carefully synchronized with the travelling particle beam.

Regarding synchrotron, beam lines refer to the instrumentation that carries beams of synchrotron radiation to an experimental end station, which uses the radiation produced by the bending magnets in the storage ring of a synchrotron radiation facility.

A beam of X-ray passes through the ionization chamber. Which is used for the detection or measurement of ionizing radiation. When the gas between the electrodes is ionized by x-ray beam the ions and dissociated electrons move toward the electrodes of the opposite polarity, thus creating an ionization current which may be measured by an electrometer. 1 – 1.5 KV is applied between the electrodes. The applied voltage allows the device to work continuously by mopping up electrons and preventing the device from becoming saturated.

This originated current range of 1nA is to be amplified up to 10 volts using Gated Integrator programmable gain amplifier. This analog signal is required to be converted to the digital signal using microcontroller 80C552.

The work involves development of art works for the PCB's and its assembly, testing and integration with the system. It also involves the necessary software development in assembly language of 80C552 to work as a slave to the master control software by communication over serial port.

II. REQUIREMENT OF TECHNOLOGY

In a synchrotron radiation source beam lines are dedicated for application likes X-ray lithography, angle dispersive X-ray diffraction tech for material structures etc. In all such experiments Beam intensity is a major parameter and is required to be monitored continuously. Ionization chamber is one of the simplest detector which can be used directly, in a non eclipse mode in real time experiment. In ionization chamber beam is passed through a gas filled chamber in which electrodes are formed by two parallel plates. Gas inside the chamber gets ionized and develops ultra low current in the electrode circuit. This ultra low current is the measures of beam intensity, converted in voltage form & given to the data acquisition system for monitoring. Aim of the project is Development of microcontroller based data acquisition card for detection of X-ray flux by an Ionization chamber. The project works comprise of the development of ultra-low current signal detection card and data acquisition system based on micro controller 80C552.‖

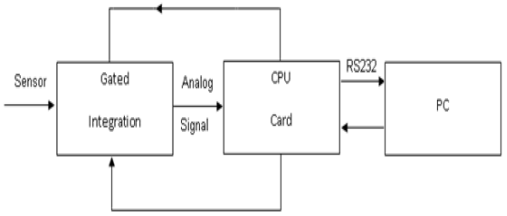

Fig.1. Function Block Diagram of 80c552

The 80C552/83C552 (hereafter generically referred to as 8XC552) Single-Chip 8-Bit Microcontroller is manufactured in an advanced CMOS process and is a derivative of the 80C51 microcontroller family. The 8XC552 has the same instruction set as the 80C51. Three versions of the derivative exist:

- 83C552—8 kbytes mask programmable ROM
- 80C552—ROMless version of the 83C552

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· 87C552—8 kbytes EPROM (described in a separate chapter)

The 8XC552 contains a non-volatile 8k × 8 read- only program memory (83C552), a volatile 256 × 8 read/write data memory, five 8-bit I/O ports, one 8-bit input port, two 16-bit timer/event counters (identical to the timers of the 80C51), an additional 16-bit timer coupled to capture and compare latches, a 15- source, two-priority-level, nested interrupt structure, an 8-input ADC, a dual DAC pulse width modulated interface, two serial interfaces (UART and I2C-bus), a watchdog‖ timer and on-chip oscillator and timing circuits. For systems that require extra capability, the 8XC552 can be expanded using standard TTL compatible memories and logic.

In addition, the 8XC552 has two software selectable modes of power reduction—idle mode and power-down mode. The idle mode freezes the CPU while allowing the RAM, timers, serial ports, and interrupt system to continue functioning. The power- down mode saves the RAM contents but freezes the oscillator, causing all other chip functions to be inoperative. The device also functions as an arithmetic processor having facilities for both binary and BCD arithmetic plus bit-handling capabilities. The instruction set consists of over 100 instructions: 49 one-byte, 45 two-byte, and 17 three-byte. With a 16 MHz (24 MHz) crystal, 58% of the instructions are executed in 0.75 ms (0.5 ms) and 40% in 1.5 ms (1 ms). Multiply and divide instructions require 3 ms (2 ms).

Features

· 80C51 central processing unit

· 8k × 8 ROM expandable externally to 64 kbytes

· ROM code protection

· An additional 16-bit timer/counter coupled to four capture registers and three compare registers

· Two standard 16-bit timer/counters

· 256 × 8 RAM, expandable externally to 64 kbytes

· Capable of producing eight synchronized, timed outputs

· A 10-bit ADC with eight multiplexed analog inputs

· Two 8-bit resolution, pulse width modulation outputs

· Five 8-bit I/O ports plus one 8-bit input port shared with analog inputs

· I2C-bus serial I/O port with byte oriented master and slave functions

· Full-duplex UART compatible with the standard 80C51

· On-chip watchdog timer

· Three speed ranges:
– 3.5 to 16 MHz
– 3.5 to 24 MHz (ROM, ROMless only)

III. RESULTS

Table 1: Results for different integration time

Integration time in ms	Programmable gain	Output Analog voltage (arbitrary unit)
20	01	[=a00D0]
25	01	[=a00F4]
50	01	[=a0346]
30	01	[=a018C]
75	01	[=a039A]
80	01	[=a03A3]
60	01	[=a03A3]
05	01	[=a00A9]
40	01	[=a025A]
25	01	[=a03AE]

Input values: set parameters
Integration time 10ms, Programmable gain 01, High voltage current 945AU

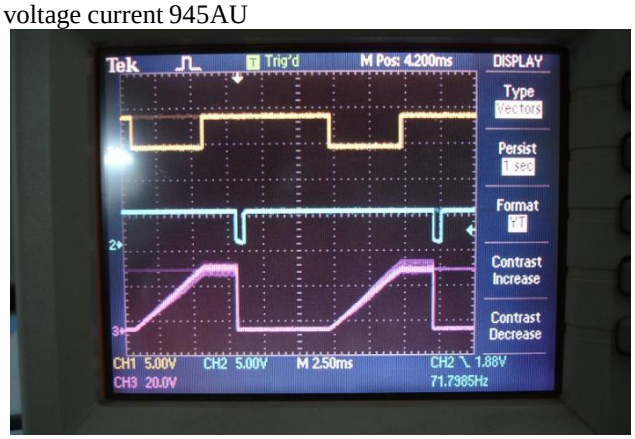

Fig.2. Result on oscilloscope

Three channels shown in above Fig. In which channel one –yellow‖ square wave is used to hold and integration time in which off time is hold and on time is the integration time,second channel –blue‖ is used to reset and third channel –pink‖ is used for reading analog voltage output where horizontal edge shown holding time, rising edge shown integration time and after rising edge it reads ADC voltage before reset after reset it starts reading for the next cycle. Command –aAD‖is used to know the analog current value here measured analog output is 945AU.

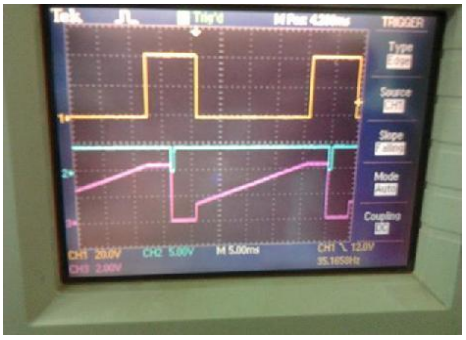

Fig.3. Result on oscilloscope

Integration time 20ms
Programmable gain 01
Analog voltage [=a00D0]

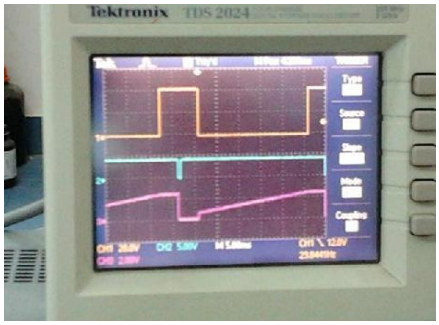

Fig.4. Integration time 80ms, Programmable gain 01, Analog voltage [=a03A3]

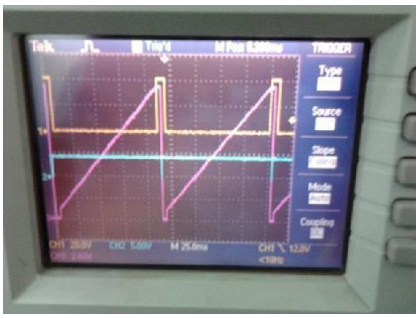

Fig.5. Integration time 110ms, Programmable gain 01, Analog voltage [=a03AE]

Fig.6. Integration time 95ms, Programmable gain 01, Analog voltage [=a0950]

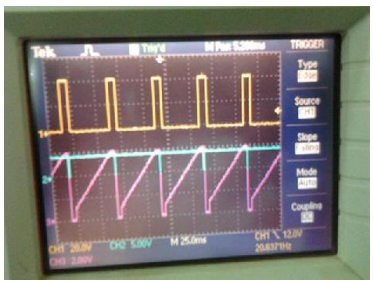

Fig.7. Integration time 40ms, Programmable gain 01, Analog voltage [=a025A]

IV. Conclusion

Microcontroller 80C552 based CPU card is developed and its programming is written in assembly language 8051, data acquisition card is used for the continuous measuring an intensity of x-ray beam of INDUS-2 RRCAT. The analog signal coming from the electrometer amplifier unit in digitized form is developed and tested. Its results are observed by oscilloscope. The output is obtained without overshoot.

The hardware also features to set the configuration for parameters like Integration time, Programmable gain and HV from CPU card. The developed hardware is working satisfactory at RRCAT, Indore.

Future Scope:

The present unit is based on all in one type Philips microcontroller 80c552 it has 10 bit ADC and limited memory enhance either with the new microcontroller like ADuc832 which has 12 bit ADC and 64k of flash ROM a compact and more precise measurement system can be design also the system use RS-232 communication link to transport data to master PC. This can be upgraded to either USB or ETHERNET with new microcontrollers.

Presents the 32k of RAM unit can handle data up to 6 hours these can increase further. In this 80C552 microcontroller based CPU card ADC resolution is increased. Ionization chamber must be incorporated with multiple units at a time.

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