Microcontroller based Remote Terminal Unit Universal Card in Reactors

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***Abstract*— RTU-UNIVERSAL card is a microcontroller based module developed to process Digital inputs, Analog inputs and Relay outputs of any real time data acquisition system used in process industries like nuclear power plants. This AT89C51RD2 based card focuses on the development of diagnostic software in C language to process digital inputs, analog inputs and relay outputs as well as checking the healthiness of RTU–Universal module. It acquires field signals from various sensors like K-type thermocouples, Limit Switches, Transmitters, and Leak Detectors etc. and sends digitalized data packets through Ethernet to the nearest LCC for Distributed Digital Control System (DDCS) display. The module also generates control outputs in the form of potential free contacts to Control Heater, Valves, etc.**

***Index Terms*— Data Acquisition System, Distributed Digital Control System, Microcontroller, Remote Terminal Unit.**

I. INTRODUCTION

Nuclear electricity in India is presently from Pressurized Heavy Water Reactors (PHWRs). Presently 15 reactors are operating, and 8 more are under construction. With 250 reactor-years of operating experience, India is one of the advanced countries in nuclear energy. PHWRs will saturate at about 10 GWe. In order to satisfy the energy requirements, with fuel derived from internal resources, it is possible to build FBRs with energy capacity. It is estimated that, indigenous Fast Breeder Reactors (FBRs) will contribute 200 GWe by 2052. This will account for about 16 % of total energy production in at that time.

A nuclear reactor and process control systems consists of various continuous process signals from the various sensors and transmitters placed at different locations in the field including hazardous area. The accurate measurement of these process parameters are very important in order to carry out control operation properly. This is because in high voltage transmission systems, fault levels are generally high, which if not cleared rapidly, can cause system instability as well as extensive damage and hazards to personnel. Speed of operation, selectivity, reliability and security of the trip decision assume more importance at higher operating voltages as they handle bulk of power. Hence this laid to the foundation for testing of different parameters or signals coming from the reactor/field.

The scope of present work includes the design, development and testing of 16 Channel digital input, 8 channel analog input and 8 channel relay output module using the fundamentals of switching theory and logic design.

The typical applications where the RTU-UNIVERSAL module is used are Nuclear Plants, Power Stations, Fertilizer Industry, Refineries, Chemical plants, Breweries and Marine Applications.

II. REMOTE TERMINAL UNIT (RTU)

Remote terminal unit is one of the independent safety related system of PFBR. Nearly 20,000 signals from the plant are processed, stored & analyzed on this computer system thus enabling the operators and designers to access the plant data in any permutation and combination. The Reactors in the world are protected by automatic shutdown systems which become effective upon irregularities in plant operating conditions. The success of FBR can be attributed to the robust design & manufacturing practises, excellence in quality and overall, efficient personnel qualification through systematic training and reliable predictive condition management practises. The construction and working of microcontroller based RTU-Universal module is a data acquisition PFBR cards are helpful for accurate measurement.

Each RTU board supports In-System Programming (ISP) of micro-controller in the field. Test programs have been developed using KEIL ‘C’ cross compiler for offline diagnostics of the respective features of the board. The test program for the board shall be downloaded on to the flash memory of micro-controller, through RS232 interface cable using FLIP GUI tool from DS by putting toggle switch in program mode. Test programs loaded on to the flash memory of micro-controller can be directly executed after keeping toggle switch in RUN mode and giving reset to micro-controller through RESET switch present on the facial panel of each RTU boards.

III. RTU-UNIVERSAL CARD

RTU-UNIVERSAL CARD is one of the most important modules in the Remote Terminal Unit (RTU). These modules are located near the Reactor Systems and can be communicated with control block through Ethernet cables. This module has got 16 channels for Digital Inputs, 8 channels for analog inputs and 8 channels for Relay Outputs. The RTU gets the digital inputs and analog inputs from the field signals and are processed using AT89C51RD2 Micro-controller which is inbuilt in the module.

Data Acquisition is sampling of the real world to generate data that can be manipulated by a processor. Data typically involves acquisition of signals and waveforms and processing these to obtain desired information. Collecting data is a tedious and time consuming process, this process of Data acquisition is carried out by the RTU-UNIVERSAL module. The components of this system include appropriate sensors that convert any measurement parameter to an electrical signal, which is acquired by the data acquisition hardware.

The RTU-UNIVERSAL module performs various types of physical measurements such as temperature, pressure, flow, strain position and speed using electronic equipment. The data collected is usually sent to a computer for analysis and display. Data acquisition and control systems also take action based on the data they receive.

IV.SYSTEM DESCRIPTION

In this section the system description of my model is explained with block diagram of RTU Universal card and main IC's used.

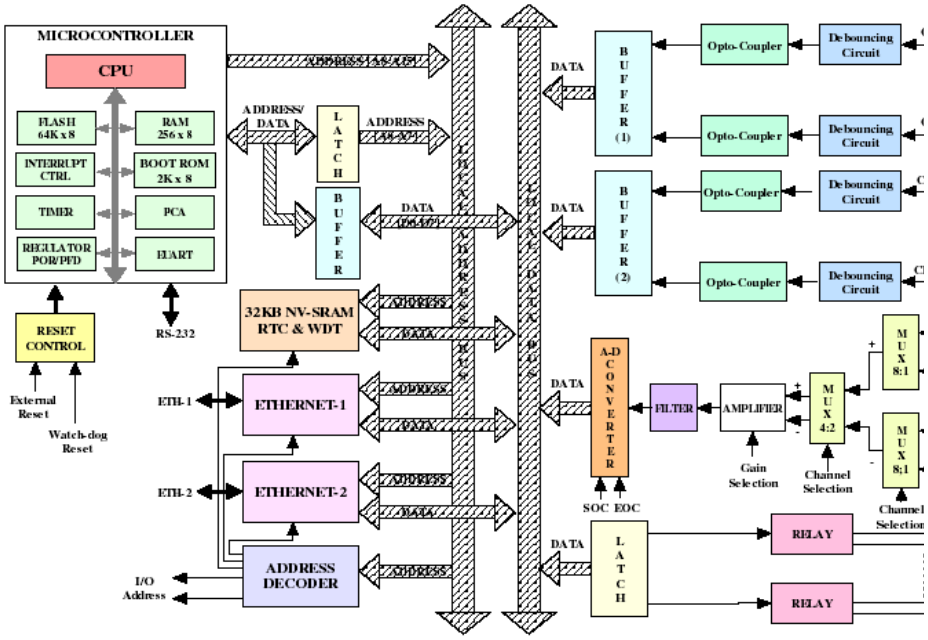


Fig.1 Block diagram of RTU Universal Card

A) *AT89C51RD2 MICROCONTROLLER*

AT89C51RD2 is a high performance CMOS Flash version of the 80C51 CMOS Single chip 8-bit microcontroller. It contains a 64K byte Flash memory block for code and data. The Flash memory can be programmed either in parallel mode or in serial mode with ISP capability or with software. The programming voltage is internally generated from the standard Vcc pin.

The fully static design of the AT89C51RD2 allows reducing system power consumption by bringing the clock frequency down to any value, including DC, without loss of data. This MC has 2 software-selectable modes of reduced activity and an 8-bit clock pre-scalar for further reduction in power consumption. The added features of the AT89C51RD2 make it more powerful for applications that need pulse width modulation, high speed I/O and counting capabilities such as alarms, motor control, corded phones and smart card readers.

B) *DS 1554 Real Time Clock IC*

The DS1554 is a full-function, real-time clock/calendar (RTC) with an RTC alarm, watchdog timer, power-on reset, battery monitor, and 32k x 8 nonvolatile static RAM. It also contains its own power-fail circuitry, which automatically deselects the device when the VCC supply enters an out of tolerance condition. This feature provides a high degree of data security during unpredictable system operation brought on by low VCC levels.

C) *NM 7010B + REV-1.0 ETHERNET MODULE IC*

NM7010B+ is the network module that includes W3150A+ (TCP/IP hardwired chip), Ethernet PHY (**IP101A**), MAG-JACK (RJ45 with X'FMR) with other glue logics. It can be used as a component and no effort is required to interface W3150A+ and PHY chip.

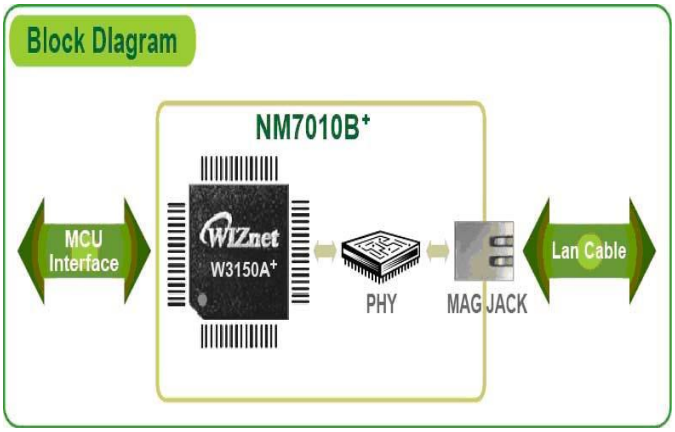


Fig.2 Block Diagram of Ethernet module

D) MAX 232A – RS232 DRIVER/RECIEVER

The MAX 232A contains 4 sections: Dual Charge-Pump DC-DC voltage convertor RS232 Drivers, RS232 Receivers and receiver transmitter enable control inputs. The MAX220–MAX249 has two internal charge-pumps that convert +5V to ±10V (unloaded) for RS-232 driver operation. The first converter uses capacitor C1 to double the +5V input to +10V on C3 at the V+ output. The second converter uses capacitor C2 to invert +10V to10V on C4 at the V- output.

V.HARDWARE DESCRIPTION

A) TEST PROCEDURE

Each RTU board supports In-System Programming (ISP) of micro-controller in the field. Test programs have been developed using Keil 'C' cross compiler for offline diagnostics of the respective boards. These test programs of respective boards shall be downloaded on to the flash memory of micro-controller, through RS232 interface cable using FLIP GUI tool from Display Station (DS) by putting toggle switch in program mode. Test programs loaded on to the flash memory of micro-controller can be directly executed after keeping toggle switch in RUN mode and giving reset to micro-controller through RESET switch present on the facial panel of each RTU boards.

B) EQUIPMENT REQUIRED

- RTU boards along with Back plane
- DC Power Supply of 5V@50A
- Analog Voltage Source (0-10VDC)
- Field interrogation voltage of 24VDC @1.6A for Digital Inputs
- Decade Resistance Box
- One RS 232 cable
- PC with OS
- FLIP GUI software from ATMEL
- Keil 'C' Cross Compiler for software development
- I/O simulator for 16 Channel 16Channel DI-RO Board

VI.SOFTWARE DIAGNOSTIC

A) EMBEDDED C

To test the Health status of the modules we have developed diagnostic software using KEIL'S (C51) compiler in C language. C language is a general purpose programming language that provides Code efficiency, Elements of structured programming and a rich set of operators.

C 51 optimizing C compiler is a complete implementation of the American National Standard Institute (ANSI), standard for C language. The C 51 compiler is not a Universal C compiler adapted for the 8051 target. It is a ground-up implementation, dedicated to generating extremely fast and compact code for 8051 processor. The C51 compiler provides us with the flexibility of programming in C and code efficiency and speed of Assembly language. Since the C51 compiler is a cross compiler, some aspects of C programming and the standard libraries are altered and enhanced to address the peculiarities of an embedded target processor.

B) KEIL'S SOFTWARE

KEIL was founded in 1986 to market add-on products for the development tools provided by many of the Silicon vendors. KEIL implemented the first C compiler designed from the ground-up specifically for the 8051 Micro Controller. The KEIL 8051 development tools are designed for the complex problems faced by embedded software developers. KEIL MicroVision-4 IDE simplifies project development and application testing.

C) SOFTWARE DECOMPOSITION

The software is decomposed into following test modules:-

1) RTC & Memory Test:

The RTC setting and reading is done successively to get the time stamp and yearly calendar information. The test passes only if set and read date-time-stamp are same.

This performs the memory address and data bus test. Predefined cross-talk patterns 0x55 and 0xAA are sequentially written to and read back from byte accessible memory location of the micro-controller and compared. The memory test is declared passed if the data patterns matches else declared failed along with error bits. Both manual and automatic mode test software is developed for ease of diagnosis and troubleshooting.

2) Digital Input Test:

In this test 24VDC is switched on/off to the digital input to make the opto on/off. The 16-DI channel outputs are in logic LOW/HIGH as per the 24VDC is on/off. The data patterns for various switch positions are acquired and compared with the expected patterns. Pass/fail criteria are decided on the basis of comparison & visual indication from LEDs on each channel. The faulty channels are displayed in case the comparison fails.

3) Relay Output Test:

Each of the relay contact is tested by energizing/de-energizing the coil and reading the status of NO/NC contact through LED indication provided on front facia as well as that mounted on IFM. All 8-channels are checked by writing walk-in '0', walk-in '1' and cross talk patterns and comparing with LED status to declare channel healthiness. The test is done in both manual and auto mode.

4) Digital I/O Test:

This test is performed for both DI and DO in combination. The 16-relay contacts (8-NO+8-NC) are connected to 16-DI channel and the predefined data patterns are written to relay channels and the 24VDC supply is switched onto each DI channel. The opto output through Schmitt inverter is read by CPU and compared with applied patterns and the channel healthiness is declared. Here the switching of 24VDC through NO/NC contacts onto the DI channel opto-coupler results opposite data patterns and accordingly comparison is done.

5) Analog Input Test:

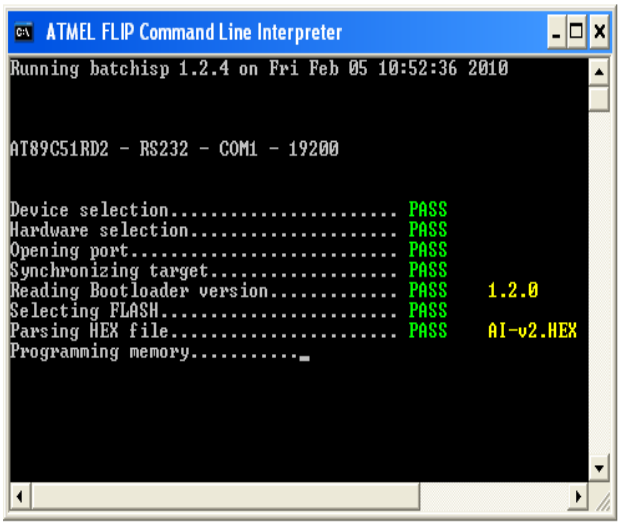
This test will check for value of analog input signal. The analog signal is converted to digital by using ADC.

VII.SIMULATION RESULTS

Configure the bin setup to test the boards. Apply power to the Bin and Display station put ON/OFF switch in ON position and PROG-RUN Switch in PROG position on Facia then Download the test software into the Flash memory of microcontroller from ATMEL Flip GUI tools of DS later change the toggle switch to 'RUN' position and reset the push button switch and observe the LED status on Fascia for healthy indications. Establish Hyper terminal (Terminal.EXE) in display station for interacting with the microcontroller control and data register .The test routines for RS232 communication test, Downloading of Test software, Program Execution Test, Memory & Board Healthiness Test, Digital input, Analog input and Relay output tests will be shown below.

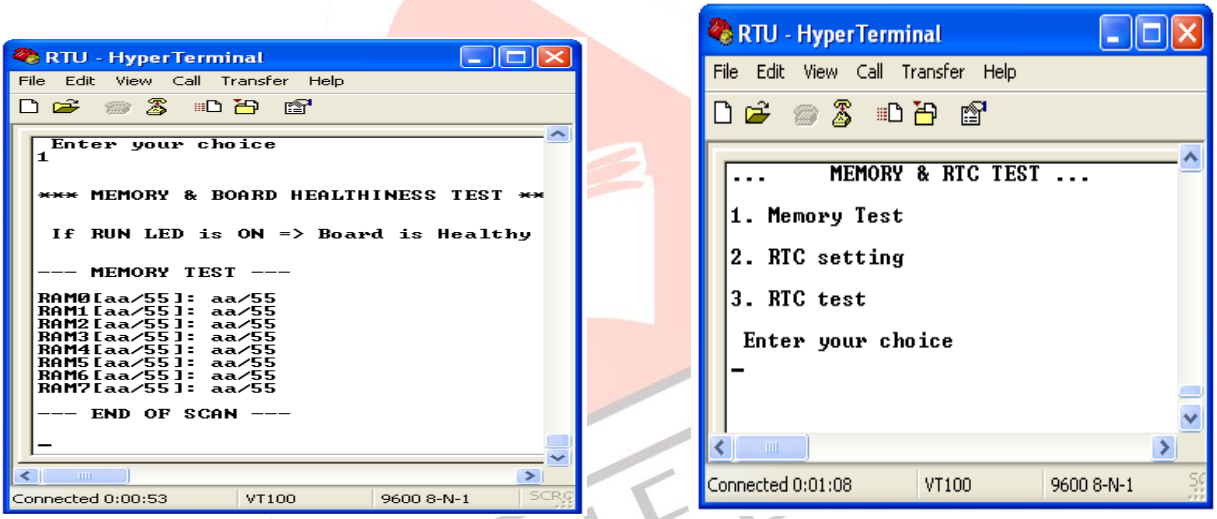
A) *RS232 Communication Test:*

Before establishing RS232 communication, put the toggle switch in PROG mode. Reset through push button switch, Select ATMEL Flip from screen, Target Device AT89C51RD2, Communication Medium- RS232,Select Port – COM1,Select Baud Rate – 9600 and Connect. Then RS232 communication is established and Screen will appear as below



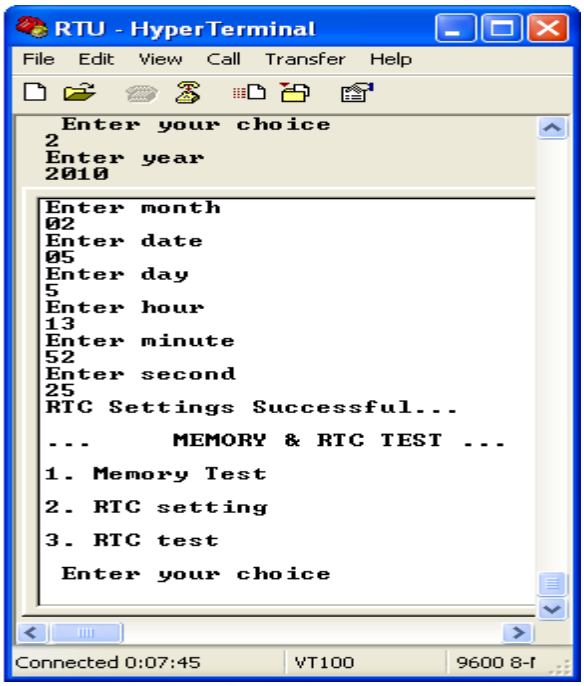
B) MEMORY AND RTC TEST:

Select the file for testing Memory & RTC portion of DS1554 chip in RTU Board and follow the procedure of downloading the test routines. After downloading the appropriate software, change the baud rate of com port to 9600.Change the switch position on fascia of RTU board to RUN mode and reset, the following menu will be displayed as shown below



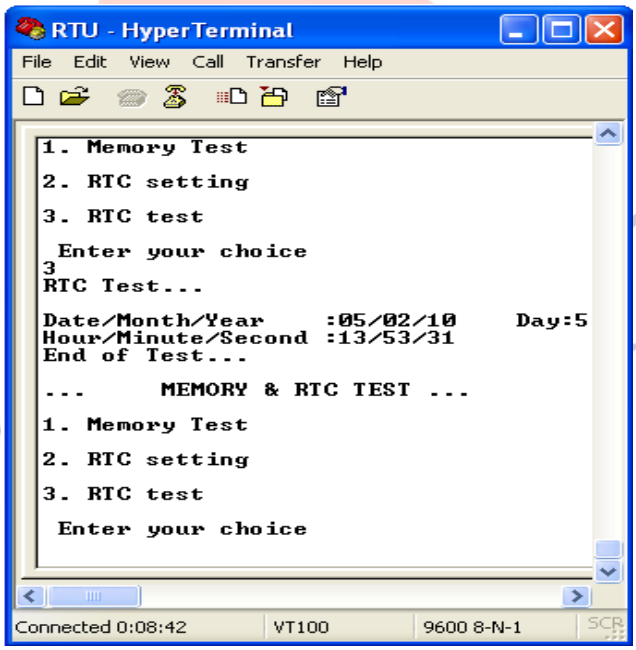
RTC Setting:

This test will set the date and time entered, into the DS1554 IC RTC register. Once the time is set, "RTC Settings Successful" will be displayed as shown below.\



RTC Test:

This test will read the date and time set inside the DS1554 IC RTC register. The time will be displayed as shown in screen 20. This test can be repeated several times to see for the time change.



C) DIGITAL INPUT TEST:

This test will check for the status of 16 digital inputs and glow the respective LED on the board. RTU-DI board requires digital input simulator as an input source. After programming the microcontroller, apply DI simulator to change the state of each channel and observe the corresponding LED status on the fascia panel and also the corresponding value through hyper terminals connected to both Ethernet ports of the RTU Board.

D) ANALOG INPUT TEST:

This test will check for value of analog input signal. RTU card requires 0 - 10V DC source to simulate various input conditions. Download the application program into microcontroller and apply the various input signal voltages from 0 to 10V to 8 channels of the card. Take the channel readings through the Hyper-Terminal of PC.

E) RELAY OUTPUT TEST:

This test will allow you to feed the RELAYs and respective LED will glow on the board. Observe the status of the LED's and their corresponding read back status. I/O simulator circuit is shown in Annexure-X. Monitoring of Relay Contact change over can be done on the fascia panel.

VIII.CONCLUSION

RTU universal card is designed and the development of diagnostic software for UNIV-RTU has been successfully completed and various features of the board also been tested. The test software works in both manual and auto mode. In auto mode the error detection logic has been implemented for memory, DI, RO and AI test. This enable us to easily find the bit error/channel error if any. The program can further be improved to implement the diagnostic features for LAN and the test software can be downloaded to target to test LAN connectivity. This will help immensely towards transmitting and receiving packets of information via LAN and can provide data communication to/from other data acquisition and control systems in the plant.

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