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Remote Terminal Unit Based PCB for Industrial Sensor Data Handling and Management

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***Abstract*—The paper presents the design of Remote Terminal Unit (RTU) on printed circuit board (PCB). It is engineered for industrial sensor data handling and management. The RTU integrates multiple sensor interfaces, signal conditioning, data acquisition, and communication protocols to monitor and control industrial processes. The Traditional Programmable Logic Controllers (PLCs) face challenges like frequent phasing out, Limited I/O expansion and high costs, which this RTU based PCB aims to overcome the proposed solution and offers long-term supportability, easier scalability and cost-effective alternative for PLC in industrial automation**

***Keywords*—remote terminal unit, industrial automation, microcontroller, programmable logic controller.**

I. INTRODUCTION

In modern industrial automation, real time monitoring and control are important aspects that optimizes the performance and enhances the safety. Industries such as manufacturing, energy generation and infrastructure has so many sensors and they need the monitoring, variable processing and relay controlling. The software that used is KiCad. It is PCB design software.

A. Challenges with traditional PLCs.

- Frequently Phasing Out of PLCs: PLC system are often phased out or replaced with newer models (in terms of hardware and software) and customers need latest version of PLC in their industries
- Limited I/O Expansion: Traditional PLCs offer limited expansion for input/output (I/O) modules.
- High Cost: PLC system and Human machine (HMIs) are expensive in terms of investment and also for maintenance, upgradation.

There is clear need of flexible, scalable and cost effective solution. Microcontroller and FPGA based this PCB can provide all these needs.

B. Objective.

The primary objective of this paper are:

- To design Remote terminal unit (RTU) based printed Circuit Board that can interface with multiple industrial sensors and overcome the limitation of traditional PLCs.
- To enable Ethernet and Modbus connectivity with Supervisory Control and data acquisition system (SCADA).
- To implement fast variable processing and relay control.
- To present an Expandable and reducing long-term costs.

II. ARCHITECTURE

The proposed RTU design consist of so many components. The simple Architectural block diagram of this RTU based PCB shown below.

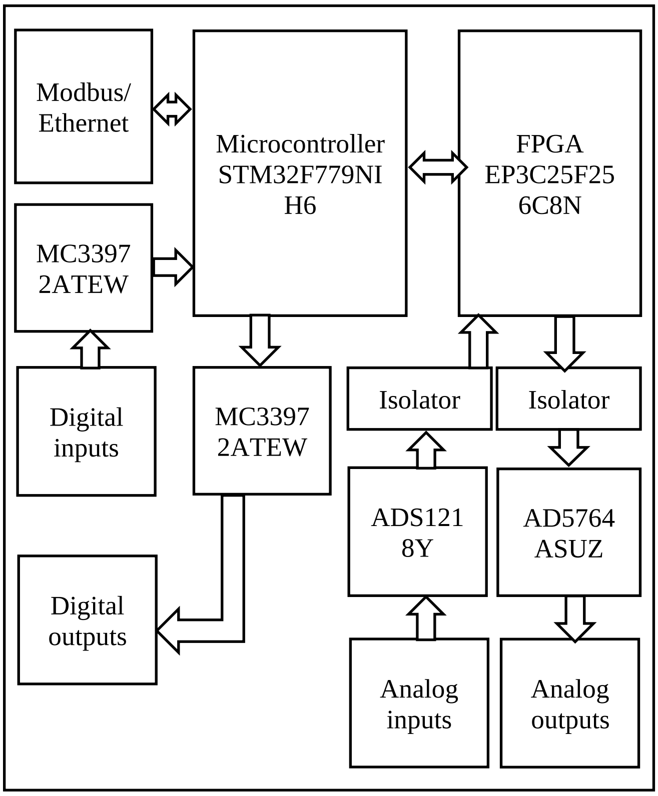

Fig 1.: Block diagram of RTU design

A. Hardware Design

Microcontroller Unit (MCU): The STM32F779NIH6 microcontroller is low power operated on 3.3V DC. It serves the core processing unit.in my RTU design it handles the digital inputs, outputs and communication with all integrated circuits (ICs). It has the internal memory and also flexible for external memory. In my design I connected the SDRAM with this microcontroller The number of I/O ports are 168.

Field programmable gate array (FPGA): The FPGA EP3C25F256C8N is the device from cyclone III manufacture by intel (formerly Altera). It is low voltage operating device. The core voltage is 1.2V and range of I/O voltage is 1.2V to 3,3V. I connected external flash memory with this FPGA in the design. Number of I/O in this device is 156.

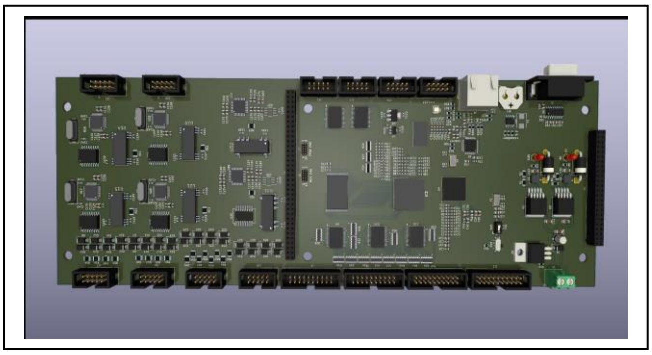

Fig2: 3D model view in KiCad of RTU

Power Management: The need of voltages in this system are 24V, 5V,3.3V,1.2V and 2.5V. for the regulation of 5V and 3.3V 'LM2576HVS-ADJ' is used. For the 1.2V and 2.5V 'AZ1117' and 'TLV1117' are used.

Isolators: ADuM1401BRWZ and ADuM261N are used to separate high voltage signals from sensitive components like MCU and FPGA.

Memory: MT48LC4M32B2B5-6A_AAT_L (SDRAM) a Synchronous dynamic random access memory module used with MCU for volatile memory storage. Capacity of this SDRAM is 128Mb (4M X 32 bit). It is used for storing runtime program execution data. S29GL064N90TFI073 (NOR Flash) is 64Mb device that provides non-volatile memory storage. It is connected with FPGA.

B. Sensor Interface

Digital I/O: The Digital sensors used in this project operates at 24V DC, which is standard voltage level in industrial environments. The output of the sensors will either a high(24V) or low (0V). The logic level will be 1 or 0.
The MC33972AREW is designed to interface 22 high voltage inputs or outputs. It can handle the high voltage up to 26V. It includes the fault detection mechanism such as overvoltage and short circuit. It communicates with the Serial Peripheral Interface (SPI) with MCU.
Analog I/O: In industries there are two types of Analog I/O voltage type and current type. The ADS1218Y is Analog to digital converter. It operates in range of 2.7v to 5.25V. The

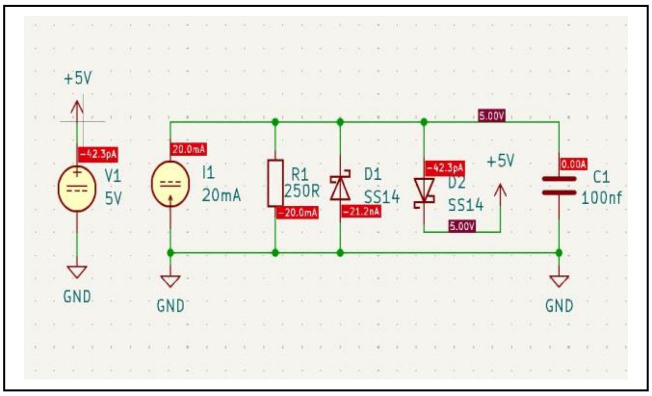

Fig3: DC operating point Simulation of 4-20mA Analog input

Analog current sensor output is 4-20mA/0-20mA that converts into 0-5V. ADS1218Y can read signals in the range of 0-5V and convert it into Digital signal so MCU can read signal.

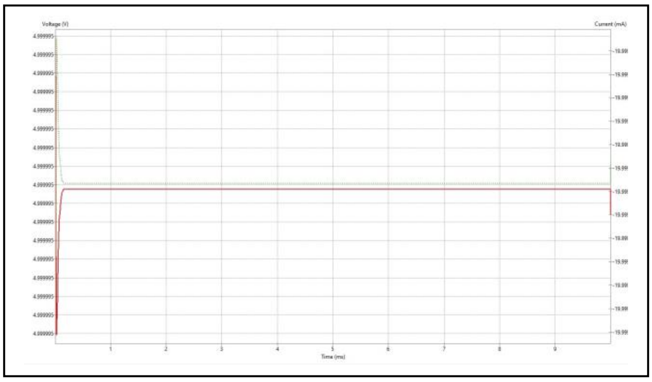

Fig4: Transient Analysis simulation of 4-20mA Analog input.

The simulation is simulated in Ki Cad inbuilt simulator using spice model. Figure 2 and 3 are simulation of Analog input signals. C1 capacitor is used as the Load for simulation purpose ADC will replace it in PCB. that converts into the 5V for the processing and analysis. The 250ohm of Resister is used for conversion of current to voltage. Same value of the Resister is used for the 0-20mA. Diode D1 and D2 are used for protection purpose. The 5V Analog input can be Directly connect to the ADS1218Y, but 10V Analog signal is converted into 5V using voltage divider rule. The value of both the resisters are 10k ohm that divide the 10V into the 5V output.

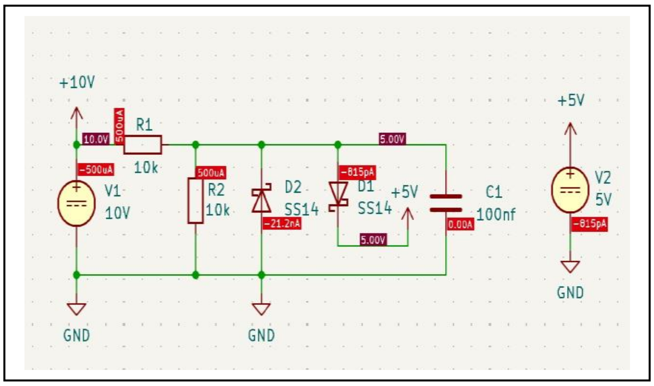

Fig5: DC operating point simulation of 10V Analog input.

Diode D1 is for protecting against negative voltage spikes. When voltage drops below ground, the diode will conduct. Diode D2 is protecting against voltage spikes that exceed 5V. it is for overvoltage protection.

C. Comminication

Modbus is used in Master slave configuration, where master device communicates with multiple slave. Modbus is designed for transmiting the data on networked interface that allows multiple devices to communicate. It can be used over Ethernet also known as Modbus TCP/IP. Modbus ensures that the data exchange is consistent .

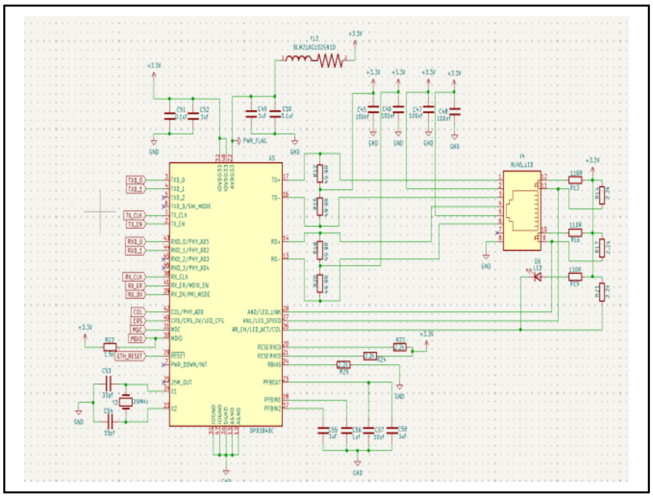

Fig6: Transient Analysis Simulation of 10V Analog input.

For the Communication to SCADA, DP83848C Ethernet PHY with an RJ45 connector used. The figure7 the schematic diagram is drawn in KiCad. DP83848C allowing the system to be connected to local area network (LAN) or Internet. It provides high speed communication in long distance.

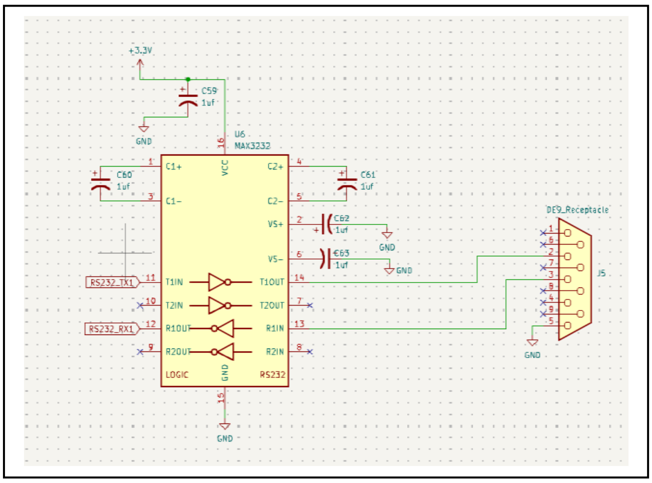

Fig7: Schematic diagram of DP83848C for Modbus TCP/IP.

There is also another option of Serial Communication (RS-232) (Modbus RTU 232) via MAX3232 transceiver with DB9 connector. RS-232 will provide the point to point communication between this PCB to external Devices (SCADA, HMIs etc.)

III. FIRMWARE IMPLEMENTATION

I used two Software for creating the Code and used them to upload code. STM32CubeIDE for the microcontroller and Quartus II for FPGA. This is the main logic that uploaded in this system. The logic program is in C language. User can update the Firmware and that allows customization and expansion.

A. STM32CubeIDE Firmware

The STM32CubeIDE use for STM32 microcontrollers. The

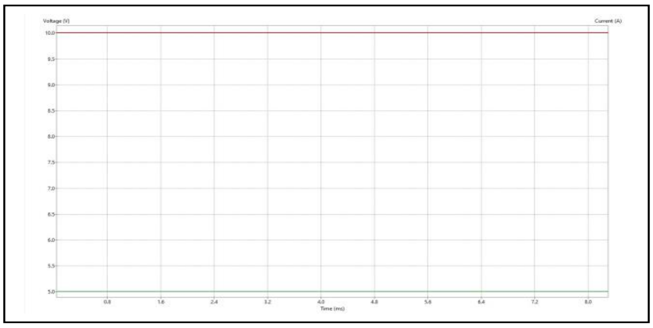

Fig8: Schematic Diagram of MAX3232 for Serial communication (RS-232).

Firmware development in it involves C/C++ code for management of communication, GPIOs and application Logic. In this RTU the microcontroller handles the SCADA communication (Ethernet, serial communication) and Digital sensor's inputs.

B. Quartus II Firmware

It involves the designing of digital circuits using HDL (hardware Description language). In RTU it handles the High speed Analog I/O and communicate with SCADA through microcontroller. The FPGA act as Co-processor with Microcontroller.

IV. CONCLUSION AND FUTUREWORK

This paper has presented the design of PCB based RTU for Industrial sensors data handling and management in Ki Cad Software, that includes the flexibility, scalability and cost effective alternative of traditional PLC system. Due to limitation of PLCs, such as frequent phasing out, limited I/O expansion, high cost, the RTU-PCB provides the solution of this industrial automation. The future work will be on Prototyping, Testing and implementation in Automation System.

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