A LOW POWER REMOTE DATA ACQUISITION & CONTROL MODULE FOR OIL INDUSTRY

Mostafa Abd-El-Barr, W. Raad, and Naser Al-Salhabi
King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia

ABSTRACT. This paper discusses the design details of an oil application based on a new low power remote data acquisition & control module. This module has the added advantages of simplicity in terms of the reduction in number of chips, unique power down mode, protection against host failure, in addition to its enhanced versatility. The designed system is completely capable of monitoring and controlling the oil level in an oil industrial site. It is also capable of communicating with a host PC situated few kilometres away for analysis of information in normal and emergency situations. It is hoped that the proposed system will lead to further development in the oil industry automation.

1. INTRODUCTION

Advances in microtechnology and the high demand to meet the needs of highly innovative applications with supreme performance and low cost in areas such as consumer electronics, process control, and hazardous industrial areas, have motivated the utilization of the so called *embedded controllers* or microcontrollers. Embedded controllers form the heart of remote data acquisition modules used in industry. They generally consist of a CPU, RAM, EPROM or EEPROM, and a number of interrupt sources plus I/O [1,2,3]. Some embedded controllers contain A/D converters and watch dog timers [4]. Remote data acquisition modules consist basically of a microcontroller and an A/D converter plus the necessary signal conditioning in one module ready to interface to a sensor or a number of sensors situated in the industrial site. These modules, which can communicate with a host PC serially and receive commands from it in the form of ASCII codes, have been commercially available for some time [5,6]. Some of these remote data acquisition modules were used in oil industry to control the oil level in oil wells [7]. Few of these modules have the capability to interrupt a host PC in case of emergency [8]. However, existing data acquisition modules still lack the capability to protect the system in the case of a host failure, to detect a power failure, plus the limitation of having only one serial port (UART) and having to add a separate A/D converter to the module. The remote data acquisition module has the additional feature of a watch dog timer which ensures an orderly reset of system without erroneous execution of code in case of host failure. The new module has also two serial ports, and has the additional feature of power down mode in case of no activities. In the hazardous industrial sites, and especially in oil industry, it is not possible to place a PC for acquiring information and controlling oil pumps because of the harshness of the environment. The remote data acquisition module is usually situated in the vicinity of the oil tank where the temperature and other conditions are not suitable for the PC.

In this paper, a simple and low power remote data acquisition & control based system has been proposed for monitoring and controlling the oil level in an industrial oil site.
This paper is organized as follows. Section 2 describes the hardware design of the proposed system. Section 3 describes the software design of the proposed system. In section 4, we

explore the idea of using the proposed system in a networked environment of oil wells. Section 5 presents some concluding remarks.

2. HARDWARE DESIGN OF THE SYSTEM

The enhanced type remote data acquisition module we are presenting in this paper is dedicated for use in the oil industry, where it is difficult to place a PC to monitor the oil level in oil tanks, because of the oil hazardous environment. For this purpose, we have used a remote data acquisition module which is connected remotely to a host PC serially though a twisted pair cable, and can interrupt the host and informs it in case of abnormal conditions by sending commands through RS232 to the PC situated few kilometres away in an air-conditioned building. In order to accommodate the distance requirements, a modem is used for communication (See Fig. 1).

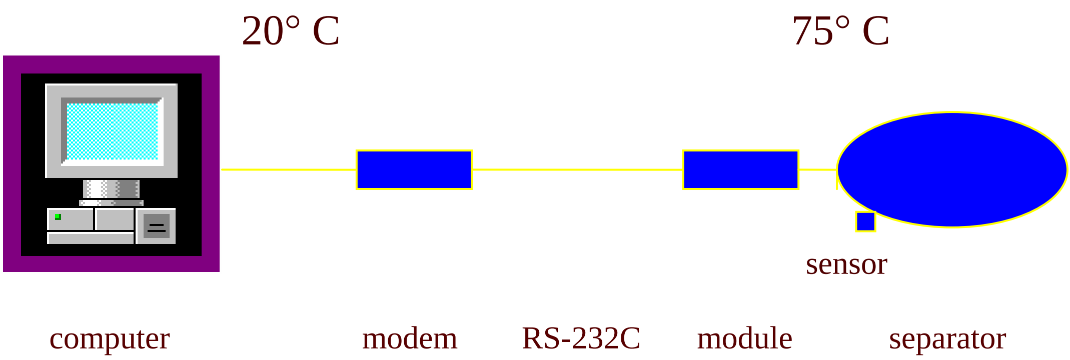

Figure 1: Remote data acquisition from a separator using a remote data acquisition module

The selected data acquisition module for the designed system is based on the CMOS version 87C552 microcontroller, which is an enhanced version of the 8051 family. This chip has an 8051 microcontroller, built in eight channel 10-bit A/D converter, a built in analogue multiplexer and 40 digital I/O lines all on the same chip. This helps cutting down on chip count plus adding more functionality. The digital I/O lines have been optically isolated to secure the system against catastrophic events. The reason behind selecting a module with an eight channel A/D converter is to make it upgradable for future arising requirements in the oil site such as the need to monitor the temperature or presence of poisonous gases for instance. A new feature has been added to the module which did not exist in the previous modules and that is its capability to monitor its power supply, detect a power loss in its earliest stages, and initiate a power down to save the data in the controller. In addition to the 87C552 microcontroller, the module has a TTL- RS232 converter for voltage level compatibility. For a block diagram of the new module, see Fig. 2.

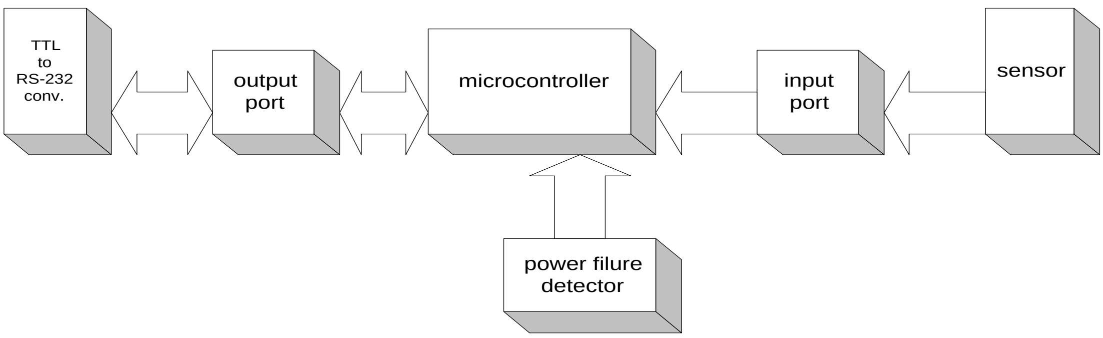

Figure 2: The block diagram of the remote data acquisition module

The new module has also a power down mode for power saving. In this mode, the CPU and the clock freeze, and the RAM holds its data. The current consumption is brought down to 50 μA in power down mode. On site, the data acquisition module is placed near the oil pump adjacent to the oil tank as shown in Fig. 3.

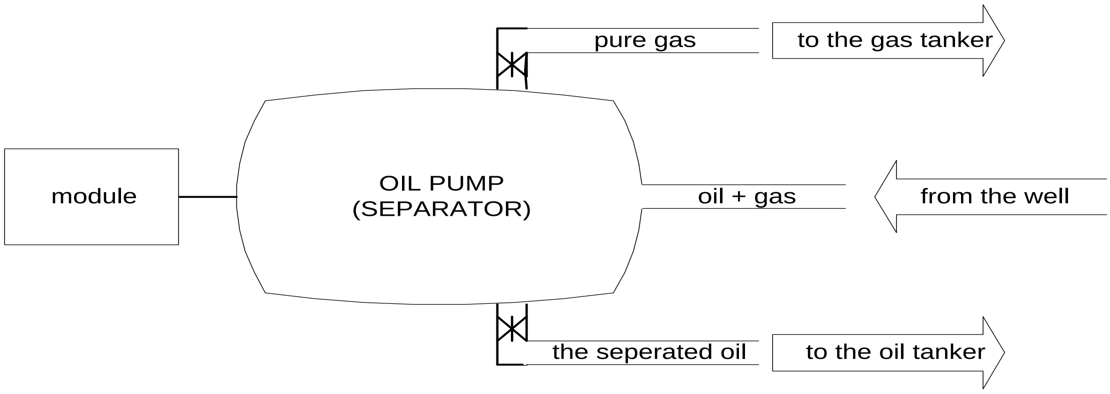

Figure 3: The remote data acquisition module located near the oil pump

Consider, for example, the case of an oil tank of height 100 feet with crude oil density equal to 0.75. In this case, 1 foot of oil produces a pressure of 0.4335X 0.75= 0.325125 psi. So 100 feet of oil will give a pressure = 32.5125 psi. A 0-50 psi pressure sensor is then selected. After review of a number of pressure sensors, we selected a suitable fully signal conditioned pressure sensor fabricated for use in harsh environments. The sensor produces output 0-5 volts. Our module can easily accept this range of voltage because it is TTL compatible. The data acquisition module turns the pump motor on through a suitable relay when the oil level is below a low-level threshold, and turns the pump motor off when the oil level is above a high-level threshold. The sensor can take any voltage between 9-20V. Hence we have chosen a common 20V power supply connected locally to the module. The sensor output is connected to the voltage inputs of the module and the digital outputs DO1 and DO0 are connected to suitable relays for turning the pump motor on and off. See Fig. 4.

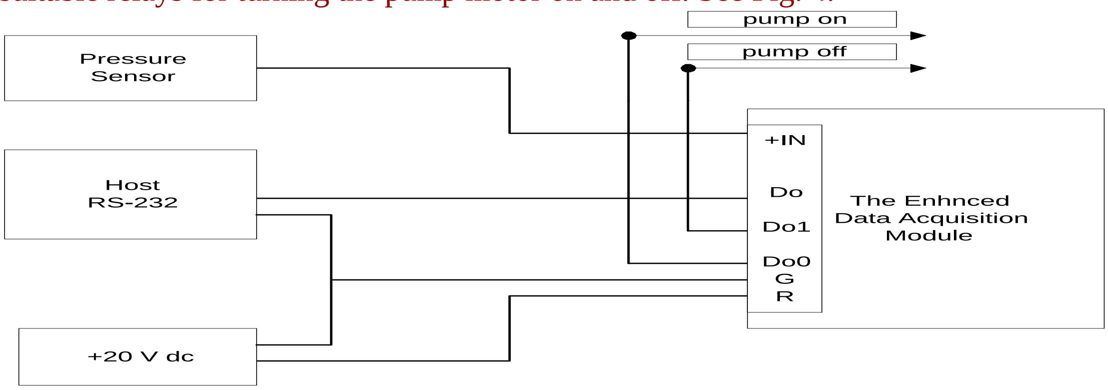

Figure 4: Schematic of connections to the module, sensor and the host computer

Apart from the control function, we would like to monitor the actual oil level continuously to be aware of any malfunction in piping and pump condition. For example, Pump burnout could be understood when oil level stays below the lower threshold level steadily. The remote data acquisition module is connected remotely to a host PC situated in an air conditioned building few kilometres away from the hazardous oil site through a twisted pair of wires using RS232.

Since this distance is beyond the capability of the RS232, a pair of modems are used, one on the PC side and one on the data acquisition side. A manually set modem has been chosen with an auto answer back feature to be able to connect the data acquisition module with very simple or even no handshaking. See Fig.5. The module has the capability of being interfaced to a local dummy terminal for enabling the routine engineer to see the messages being communicated between the remote module and the host PC. The dummy terminal can be connected easily using the second serial port of the module with very simple initializations that can be done locally from a keypad on the module. The module has also the capability to generate baudrates up to 375K, in addition to the ability to change the local baudrate of the module through the use of dip switches on the module. Care should be taken to match the baudrate and communication protocol on the module side and on the host side.

3. SOFTWARE DESIGN OF THE SYSTEM

The module is completely capable of monitoring and controlling the level of oil in the oil tank uninterrupted. It reads the output of the pressure sensor periodically and converts it to a digital value using the built in A/D converter. It then compares the read value with the high and low thresholds to take the right decision.

Sample commands look like the following:

$RDX

Where $ sign makes the module alert that the host would like to communicate with it, and RD means read data from channel number X of the module.

$RR

Means reset remotely the module .

$FXXX

Means every XXX seconds data is sent back.

In case of emergency, the module can interrupt the host and send to it the status of the oil level and pump. When the host requests some data from the remote module, the module should respond with a * followed by the required data. A high and a low threshold is set for the oil level. In case the oil level increases beyond the high level, the data acquisition module should close the pump and interrupt the PC informing it of the abnormal condition. If the oil level decreases below the low level, the module should open the valve, and also a low-level alarm condition should be detected by the host. Communication between the PC and the remote module is performed in ASCII codes. When an abnormal condition exists, the module interrupts the host by sending the # sign. The module expects an acknowledgement from the host. If no acknowledgement is sent within a prespecified time, the module transmits the interrupt again assuming a collision has occurred. The module is programmed in this application in two different modes: a local mode and a remote mode. The local mode has been added for troubleshooting purpose. In this mode, the maintenance engineer or operator can request to know the oil well status by punching a certain command on a keypad on board, and viewing the status on a local terminal which can be interfaced to the module through its extra serial port. The operator can also program the baudrate, or reset the system locally. All of these options are made possible using the available external interrupts on the module. The remote mode is the normal working mode of the system. In this mode, the host PC can always communicate with the remote module and request information about the oil well status. The serial interrupt, which is used for communicating with the PC has always a higher priority over the external interrupt. An interesting feature has been added to the design, and that is the ability to change priority levels of different interrupts used by using simple switches on board. This feature makes the system robust for the possible changing environment in the industrial oil site which might enforce changing priority levels of control parameters in the future. A dedicated external interrupt has been assigned for controlling the high-level oil threshold and the low-level oil threshold so that the operator has a full control over changing these values in the local mode. This makes the designed system adaptable to possible changes in these parameters. As a simple experiment, a Qbasic program has been written and tested for remote communication between a host PC and the data acquisition module using RS-232C from a short distance, and simulating the oil pump motor by a small DC motor. We have actually tested the system by simulating the detection of a high-level threshold and a low-level threshold by the host PC, and verifying the process of successfully sending multiple character commands to the remote module serially using a baudrate of 1200. See the program listing in the Appendix A.

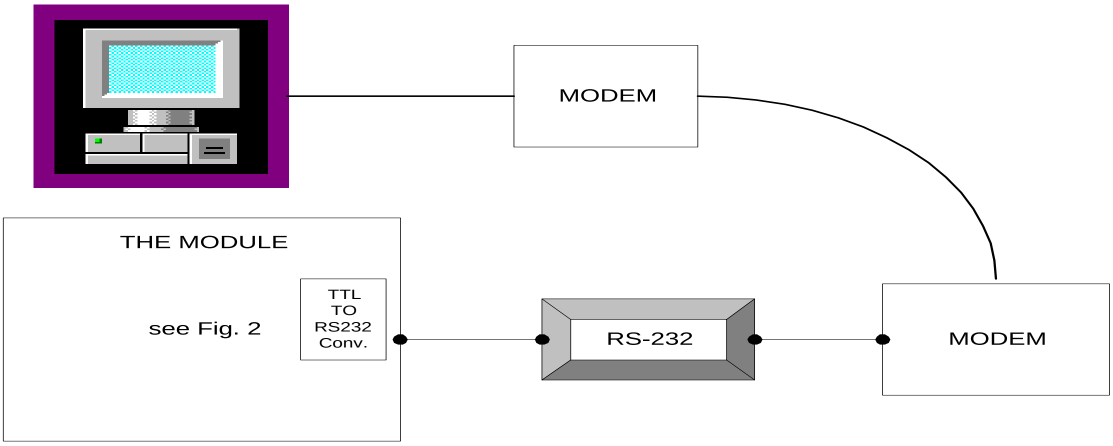

Figure 5: Connections between host PC, modem and remote data acquisition module

4. A MULTI-WELL CONFIGURATION

The existing RS232 interface which has been used to test the proposed system for the oil industry has its disadvantages. The main disadvantage of the RS232 standard is that it is designed for point to point communication. Multiple module communication is only possible with daisy chain connection. The reduced reliability of a daisy chain scheme is a disadvantage.

Hence we are looking at using the RS485 standard which gives excellent noise immunity, and allows the oil wells to be connected in what is called a *multidrop* connection. We can connect 32 oil wells together using an RS485 standard, for a distance up to 1200 meters. Using this standard also allows the modules to communicate with each other and with the host PC serially at baudrates which can reach up to 10 Mbaud. But there is a compromise between distance and speed. The main disadvantage of this multidrop scheme is that the standard is not supported by the current PC hardware, therefore an RS485 driver card for the host PC should be added. In a multidrop configuration, all remote data acquisition modules in different oil wells are networked together in a master/slave architecture using a single pair of wires. One of the disadvantages of such a scheme in oil industry is the possibility of collision in message communication among the modules. Unexpected delays might occur in case of collision. In hazardous industrial sites such a matter should be taken seriously because there are dangerous alarm conditions which cannot wait. For this reason we have looked at protocols such as CSMA/CD, but programming such a protocol on the current microcontroller-based module is very costly, so we are currently investigating the possibility of using the module based on the 87152 microcontroller, which supports a multi-protocol serial communication, among which is the CSMA/CD protocol. See Fig. 6.

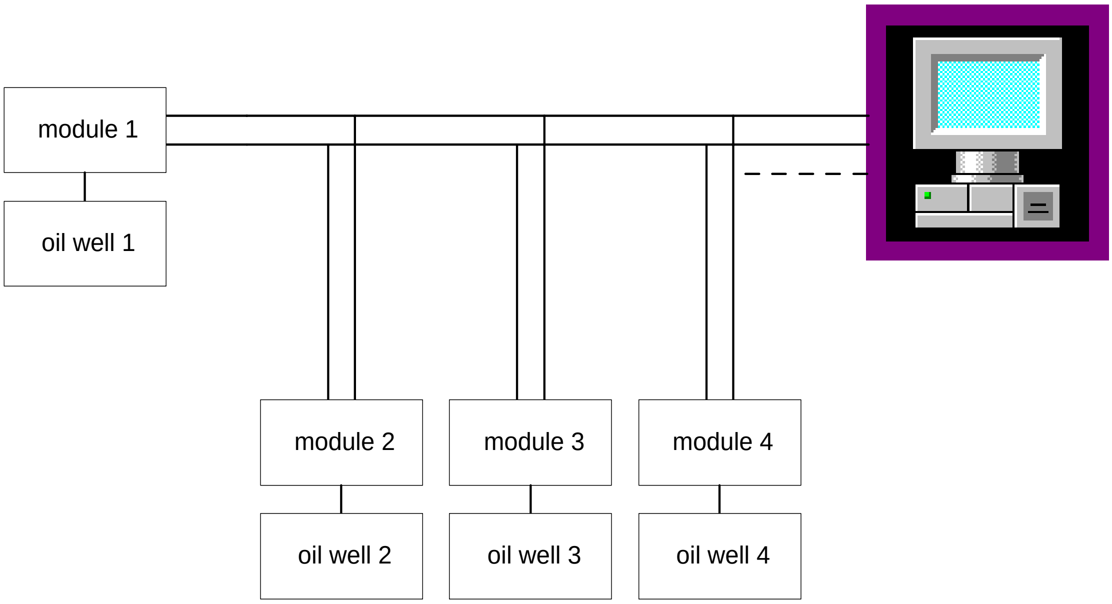

Figure 6: Networked remote data acquisition modules

5. CONCLUDING REMARKS

In this paper, we have introduced a low power remote data acquisition & control module which has the ability to monitor and control oil level in an industrial oil site locally and remotely from a host situated few kilometres away through a twisted pair of wires. The module designed has an additional feature of being connected with other modules in different oil wells in a mutidrop scheme. We are currently investigating the Inter-Integrated Circuit (I^2C) bus new technology which has a two-line multimaster/multislave network interface with collision detect. We are also in the process of investigating the use of new developed tools to speed up the system development process and make it more efficient.

ACKNOWLEDGEMENTS

We would like to acknowledge the continued support of KFUPM .

REFERENCES

[1] Yeralan, S., Ahluwalia, A. Programming and Interfacing the 8051 Microcontroller, Addison-Wesley, 1995.
[2] Mackenzie., I.S., The 8051 Microcontroller, Prentice Hall, New Jersey, 1992.
[3] Embedded Controller Handbook, Intel, 1988.
[4] 80C51-Based 8-Bit Microcontrollers Data Handbook, Philips, 1993.
[5] Austerlitz., H., Data Acquisition Techniques Using Personal Computers. San Diego, Academic Press, 1991.
[6] Morris, Henry " Signal Conditioning Becoming I/O Processing" Control Engineering, August 1994, pp.54-61.
[7] Ozkul, T., Data Acquisition and Process Control Using Personal Computers. Marcel and Decker Publishing, New York, U.S.A, 1995.
[8] Ozkul, T., Raad, W., "Remote Data Acquisition Module With Interrupt Capability", in proceedings of ICECS' 95, 17-21 December 1995, Amman, Jordan, pp.474-477.

APPENDIX A