Control and Monitoring of Corrosion in SAE 1018 Carbon Steel Pipelines Using Microcontrollers dsPIC 30f3013

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In this work the design of a system for controlling and monitoring corrosion occurring in SAE 1018 carbon steel pipelines carrying potable water at a region of Hidalgo State, Mexico, is proposed through the system implementation based on a microcontroller dsPIC[MR] which owns an Analog-Digital Converter (ADC) with resolution of 12 bits. Additionally, the controller has the capability of multiplexing 10 analog channels for conversion. The obtained main results show that the medium and the operating conditions are not the causing of system faults.

Introduction

Nowadays, digital systems design based on logic gates and flip-flops into integrated circuits is no longer used; instead of that, PLDs (Programmable Logic Device), CPLDs (Complex Programmable Logic Device) and FPGAs (Field Programmable Gate Array) are employed through the application of HDL (Hardware Description Language), and in a complementary way the microcontrollers and dsPICs programmed in low level language, such as Assembler which allows higher control of the electronic device (1).

With the evolution of microcontroller-based digital systems was more boom and implementation of embedded systems, which are smaller than the systems implemented in the PLC (Programmable Logic Controllers) and therefore less expensive. Should be mentioned that unlike PLC-based systems, systems that use microcontrollers are more complex in its design.

The impact of these systems is such that they are in any part of our daily routine such as: home appliances, electronic control of an automobile, electronic instrumentation, sensor networks for monitoring and surveillance, portable devices such as mobile phones and PDA (Personal Digital Assistant), industry and trade among others.

The purpose of this paper is to design a digital system that allows monitoring and control of the variables present a system potable water supply municipality from Zapotlán de Juarez, State from Hidalgo, Mexico with purpose to keep the pipeline in optimal conditions and potable water in to parameters required to fulfill its purpose of human consumption.

For system design uses a microcontroller dsPICMR 30F3013 because it has an integrated Analogic Digital Converter with capacity of 10 multiplexed analog channels.

Method and Material

The variables involved in the referred embedded system were determined starting from the field study taking into account the behavior of a pipeline carrying potable water and manufactured from SAE 1018 carbon steel, which suffered faults that are manifested as cracks. The employed techniques for the variables behavior study were Electrochemical Impedance Spectroscopy (EIS) and Scanning Electron Microscopy (SEM) (2). The proposed sensors for the system design are presented in Table I.

TABLE I. Characteristics of Measuring Instruments.

Variable	Range	Principle
Temperature	0 – 100 ºC	RTD – Pt100
Chloride	0 – 250 mg/L	Volumetry
pH	0 – 14	Potentiometry
Flow	0 – 50 L/s	Turbulence
Pressure	0 – 10 kg/cm^2	Bellows – LVDT
Conductivity	0 – 200 µS/cm	Resistive
Velocity	0 – 1800 rpm	Electric

Besides of parameters obtained, it is necessary to consider aspects involving the pumping system such as:

1. Starting and stopping the motor - pump.
2. Setpoint speed motor - pump.

It is important to monitor the variables of the system must select an appropriate sensor for measuring range and with this, the study of the variables were found between the minimum and maximum expected.

Looking Table I, 7 analog inputs are required for each variable and 2 extra digital inputs, one for starting and stopping of the motor - pump and another for the setpoint speed of the motor - pump (initialization state).

In the microcontroller is considered the initialization state as the default configuration of the system using the reset such as Master Clear.

Microcontroller

The use of dsPIC 30F3013 microcontroller has been proposed, because its main features are: a set of 83 instructions, 16-bit registers, working at 30 MIPS (Million Instructions per Second), supports 21 interrupts from different sources, 3 timers-counters of 16-bit, one analog-digital converter of 12 bits, among others. This device has a sampling rate of 200 Ksps (Kilo sample per second) capable of multiplexing 10 analog channels to the analog-digital conversion, as shown in Figure 1 (3). It also has two reference voltages can be modified according to system requirements.

Microchip's DSP technology has enhanced the following modules:

1 .- Arithmetic capability by high-speed multiplier 17bit by 17 bit.

2 .- 40 bits for Arithmetic Logic Unit (ALU).

3 .- 40-bit in two accumulators.

4 .- Data records and 16-bit pointers.

5 .- DSP instructions have been developed for optimum performance in real-time (4).

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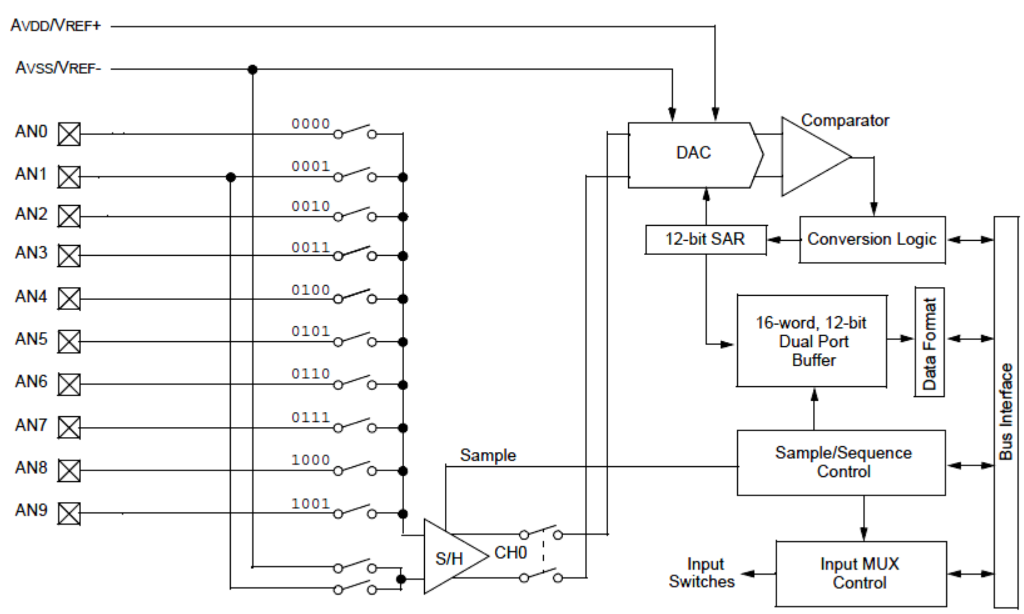


Figure 1. 12-Bit ADC Functional Block Diagram.

To prepare the ADC should do the following procedure:

1. Port configuration.
2. Channel selection.
3. Selecting the ADC reference voltages.
4. Definition of time between ADC conversions.
5. Specified the interrupt control.
6.Definition of output format.

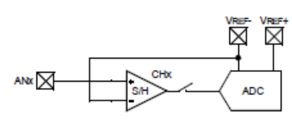
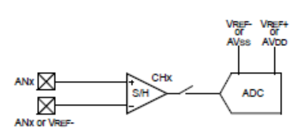
ADC Acquisition Time

For correct conversion should be specified the conversion time per bit, which is called TAD (The A / D conversion time per bit). For a conversion with a resolution of 12 bits it is necessary 14 TAD, see Equation 1 (4). In the case of DSPIC 30F3013 TAD period depends from oscillator which is using and the prescale value for sampling in other words can be changed the oscillator frequency and the number of bits to select an ideal value of approximately (TAD) 334 nanoseconds (4).

$$TAD = \frac{TCY(ADCS + 1)}{2} \qquad [1]$$

In the equation, TCY is the oscillator frequency and ADCS is a value of 5 bits, which can reach a sampling rate of 200 ksps (see Table II).

TABLE II. Bit ADC extended conversion rates.

dsPIC30F 12-bit ADC Conversion Rates						
Speed	**TAD Minimum**	**Sampling Time Min**	**R_S Max**	**VDD**	**Temperature**	**Channels Configuration**
Up to 200 ksps(1)	334 ns	1 TAD	2.5 kΩ	4.5V to 5.5V	-40°C to +85°C	
Up to 100 ksps	668 ns	1 TAD	2.5 kΩ	3.0V to 5.5V	-40°C to +125°C	

Digital Analog Converter allows enabling the generation of an interrupt (Interrupt Service Routine ISR), see Figure 2 (4) and (5).

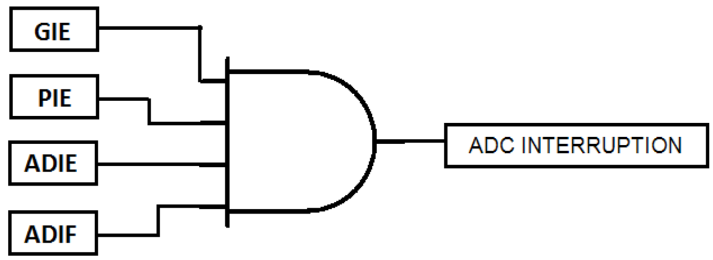


Figure 2. Interruption by ADC.

To generate an ADC interrupt must be considered the bits: GIE (Global Interrupt Enable), PEI (Peripheal Interrupt Enable), ADIE (ADC Interrupt Enable) and ADIF (ACD Interrupt Flag, which is set by hardware when a finishes a conversion).

To design the system uses interrupts to read analog signals, which are provided by different sensors for each physical variable of study.

Results and Comments

System Requirements

The basic system function is to extract potable water from a well, reason why it is required control the velocity of the motor-pump set and measure water properties through variables such as temperature, pH, chloride concentration, and conductivity, in real time; as well as the discharge pipeline pressure; which makes possible to ensure the infrastructure care but especially guarantee the water quality and the corrosion faults prediction. The channels selected by variable are shown in Table III.

TABLE III. ADC analogic channels selected.

Variable	Analogic channel	Binary format
Temperature	AN0	0000
Chloride concentration	AN1	0001
pH	AN4	0100
Flow	AN5	0101
Pressure	AN6	0110
Conductivity	AN7	0111
Velocity	AN8	1000

To decode the results of the conversion - Analog - Digital for each channel, interrupts are used by multiplexing the inputs in ADC. As shown in Table III, an0 analog channel takes the analog signal to delivers the temperature sensor that is in the range of 0 - 100 °C, once conversion is performed A/D displays the result in a LCD (Liquid Crystal Display). The programming language of low level used to develop algorithm variables monitoring and control of corrosion is assembler.

The firmware and the microcontroller make the embedded system, an embedded system is that special purpose designed to perform one or more dedicated functions, sometimes with restrictions on real-time processing (6), an embedded system is a combination of computer circuits software and integrated into a device for purposes such as controlling, monitoring and communication without human intervention (7). Embedded system design should be considered in general the system accuracy, execution time and energy consumed (7); the methodology used in development of the embedded system is by hierarchies due to the cyclical nature of the measurements of variables physical.

Addition use the Arrhenius equation (8) to predict the lifetime of the mechanical structure, such as transportation systems and mechanism of piggyback cars that use strings, the equation is implemented in the algorithm to control corrosion pipe function of temperature.

Considering industrial instrumentation for the measurement of variables shown in Table I, is required communication protocol standard from 4 to 20 mA (1 to 5 V with 250Ω resistor in parallel with the input of the dsPIC), and with reference minimum of 1 V using a Zenner diode and 5 V at the maximum reference, taken from the supply to the microcontroller. Figure 3 shows the interconnection diagram of the embedded system.

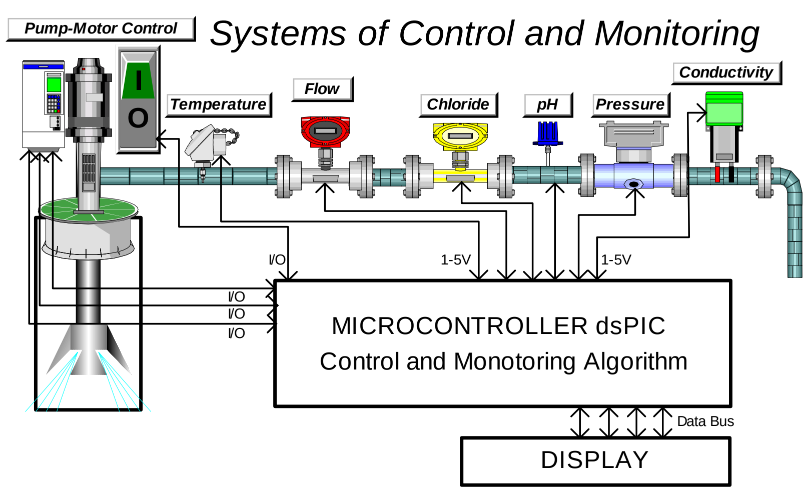


Figure 3. Systems of Control y Monitoring by Corrosion.

Arrhenius equation (Equation 2) predicts that in reactions to the case study of corrosion in the pipeline, the speed increase with temperature is nonlinear and depends on three factors a) the fraction of molecules with energy equal Ea or greater, b) the number of collisions that occur per second c) the fraction of collisions with the appropriate orientation (8) and (9).

$$k = Ae^{-Ea/RT} \qquad [2]$$

where:
A = Constant
R = Universal Gas Constant
Ea = Energy Collisions
T = Temperature

An important point is: the higher the value of Ea, the lower the value of k and slower rate of reaction (9).

Conclusions

The dsPIC 30F3013 has a high performance DSP allowing working with Fast Fourier Transform for processing of sampled signals; the above mentioned allows concluding that the medium (potable water) and the operating conditions (pressure, flow, and velocity) are not the causing of system faults.

Acknowledgments

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