A Simple Microcontroller-Based 4-20 mA Current Loop Receiver for Sensors with Current Transmitters

A. Surachman, A. Suhendi, M. Budiman, M. Abdullah, and Khairurrijal *)

Physics of Electronic Materials Research Division

Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung

Jalan Ganesa 10, Bandung 40132, Indonesia

krijal@fi.itb.ac.id

Received date : 27 April 2010
Accepted date : 29 Mei 2010

Abstract

A current loop receiver system based on a microcontroller has been developed. The current loop receiver system can serve 8 gas sensors with 4-20 mA outputs, which are handled by employing a multiplexer. The data acquisition of the system is composed of a common operational amplifier-based current loop receiver, a CD4051 multiplexer, an ADS7822 serial analog to digital converter (ADC), and an AT89S52 microcontroller. The measured gas concentration is displayed on the 7-segments or transmitted to a personal computer via the RS232 serial communication to be processed by the Microsoft Excel. Additional functions such as gas concentration level warning and error code display are also provided.
Keywords: 4-20 mA, Current loop, Microcontroller, Receiver, Transmitter

1 Introduction

The 4-20 mA current loop, which consists of a 4-20 mA transmitter connected to a sensor, a loop power supply, and a loop receiver to monitor / control process, is a common method of transmitting sensor information in many industrial process-monitoring applications. Transmitting sensor information via a current loop is useful when the information has to be sent to a remote location over long distances [1]. In present industrial applications, many sensors used to measure physical parameters such as temperature, pressure, speed, flow rates, etc. are equipped with the 4-20 mA transmitters [2]. Therefore, a loop receiver to convert the 4-20 mA signal into a voltage level is required.

In this paper, we report on the 4-20 mA loop receiver based on an AT89S52 microcontroller. The loop receiver was designed by using a common operational amplifier (op-amp) and discrete electronic components. The interface between the loop receiver and a microcontroller was realized by an analog to digital converter (ADC). The data acquisition was performed by the microcontroller. Evaluation on the developed system will be discussed.

2 Hardware and Software

The hardware of the 4-20 mA current loop receiver based on AT89S52 microcontroller was designed by considering the constraint that the sensor has a 4-20 mA output and a loop power supply with a configuration called as the ISA Type 3 (3-wire type transmitter) as shown in Figure 1 [3]. The current ILOOP flowing in the loop gives rise to a voltage drop in

the resistor R of the current loop receiver. The voltage drop is read and processed by the microcontroller.

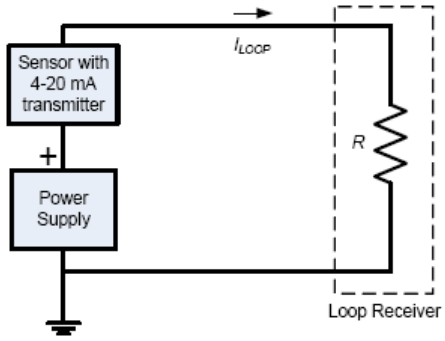

Figure 1 Configuration with 3-wire type transmitter (ISA Type 3)

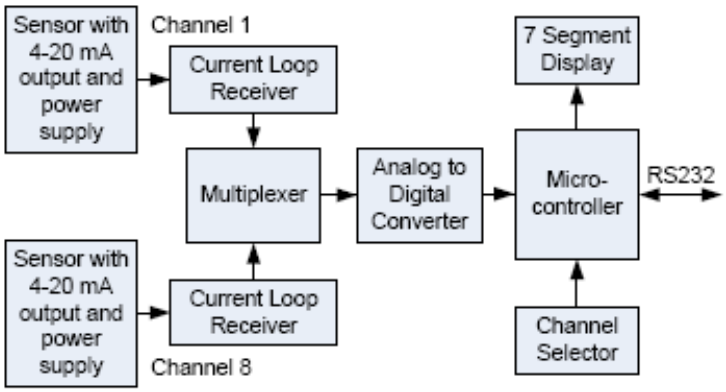

Figure 2 Block diagram of microcontroller-based loop receiver

Figure 2 describes the block diagram of the microcontroller-based current loop receiver. There are 8 channels for serving the sensors with 4-20 mA outputs, in which each channel has a current loop receiver. In order to process outputs of the current loop receivers, a multiplexer is employed to select the channel. Since the current loop receiver output is an analog voltage, an analog to digital converter (ADC) is applied. The digital output of the ADC is then sent to the AT89S52 microcontroller to be displayed by the 7-segment display. The data can be transmitted via the RS232 serial communication to be processed next.

The electronic circuit of 4-20 mA current loop receiver is given in Figure 3. It is actually a current to voltage converter. Noting that the internal resistance of the op-amp is infinity, no current flows through the resistor R2 and the voltage difference between the inverting and non-inverting inputs is zero. Therefore, the loop current IIN is converted into the voltage drop of IIN • R1 and the output voltage of the current loop receiver VOUT is equal to IIN • R1. The diode D is to protect the op-amp from the unexpected negative input current.

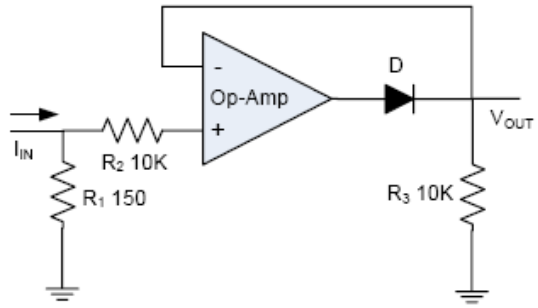

Figure 3 Electronic circuit of current loop receiver

Since the system in Figure 2 has 8 channels, a multiplexer (MUX) based on the CD4051 [4] is operated as given in Figure 4. In order to select a channel, 3 lines of the ports 3.4, 3.5, and 3.6 of the microcontroller are applied to the inputs A, B, and C of the multiplexer. The output of the multiplexer is connected to the input of the ADC.

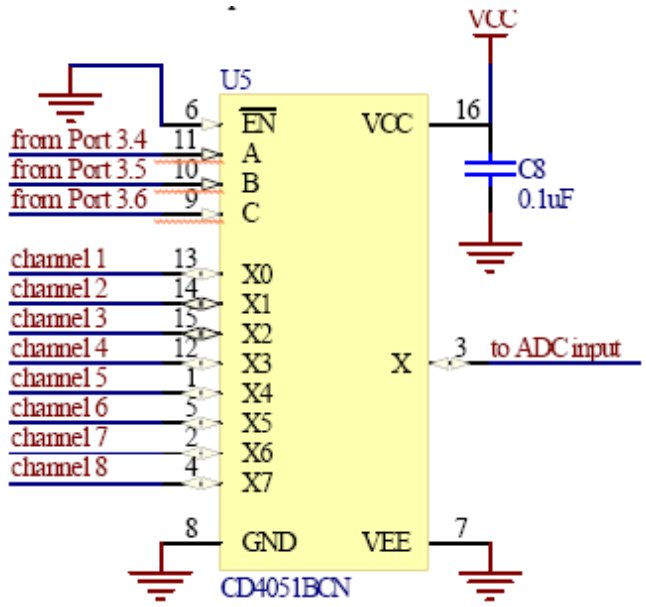

Figure 4 Multiplexer with 8 Inputs

The analog output voltage of the current loop receiver is read by the ADS7822 serial ADC via the pin IN+. The ADS7822 communicates with the microcontroller via a synchronous 3-wire serial interface (DCLK, CS, and OUT) [5] as shown in Figure 5. The ADC then sends its output, which is serial bits of the converted analog voltage, to the port 2.7 of the microcontroller.

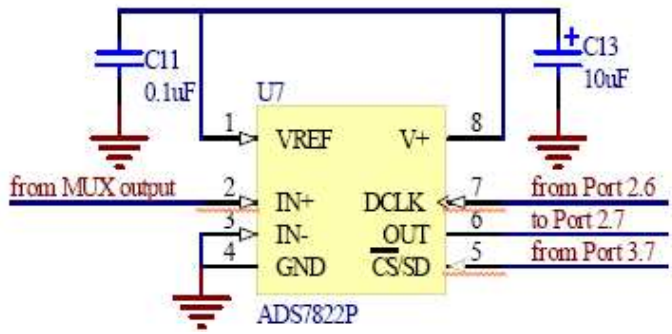

Figure 5 The ADS7822 Serial ADC and its connection to multiplexer and microcontroller

The AT89S52 microcontroller with 8 kilobytes flash memory is the heart of data acquisition of the current loop receiver system. It selects a channel to be served, displays the value of physical parameter measured by the sensor, and sends the measured data to a personal computer. Figure 6 illustrates the flowchart of main program applied to the microcontroller-based current loop receiver system. After initialization process of the hardware, the microcontroller starts to select a channel of the current loop receiver. Then, ADC is asked to start conversion and send the conversion results to the microcontroller. Next, the microcontroller processes the data and transmits them to the 7 segments display and the personal computer via the RS232 to be processed by the Microsoft Excel.

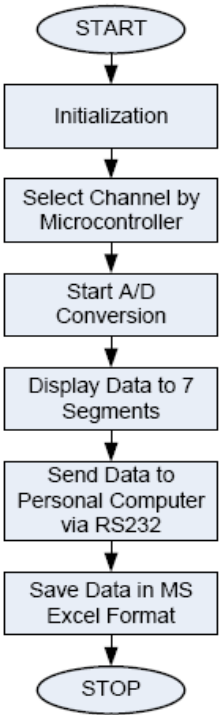

Figure 6 Flowchart of main program

3 Characterization Results and Discussion

The microcontroller-based current loop receiver system was calibrated by employing a constant current source of the Fluke Model 5100B Calibrator [6] as represented by the block diagram in Figure 7. The current provided by the Calibrator, which was varied from 0 to 30 mA with the interval of 0.1 mA, is fed to the current loop receiver system and the digital output is sent to the personal computer via the RS232 serial communication to obtain a calibration graph.

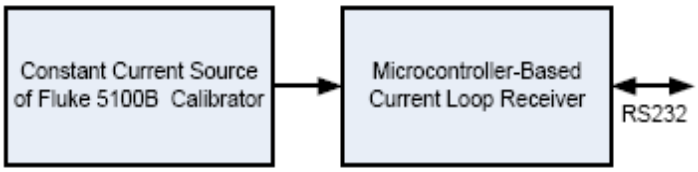

Figure 7 Block diagram of calibration process

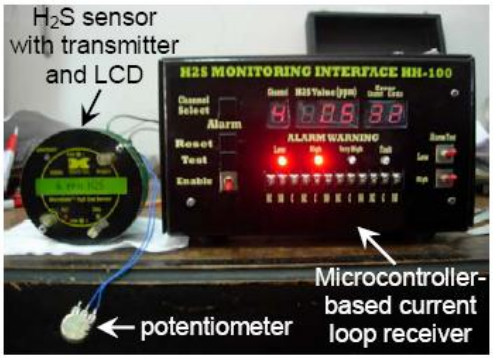

Figure 8 Testing process of microcontroller-based current loop receiver system

After the calibration process, the current loop receiver system was tested by connecting it to a commercial H_2S gas sensor with a 4-20 mA output and an LCD display [7] as illustrated in Figure 8. Since the H_2S gas sensor is based on the change in electrical resistance, the sensor was replaced by a potentiometer. In addition, the sensor displays the H_2S gas concentration in the range of 0 to 100 ppm. Therefore, the H_2S concentration to be displayed by the microcontroller-based current loop receiver system is scaled as

$$H_sS\,(ppm) = \frac{100}{6}(I_{IN} - 4) \qquad (1)$$

Where I_{IN} is in mA. Simulation of H2S gas concentration was done by rotating the potentiometer. It was found that the concentrations displayed by the LCD of the commercial gas sensor and the 7-segments of the current loop receiver system are the same.

Table 1 Warning and error codes.

Warning Code	Gas Conc. (ppm)	Error Code
Low	10 – 20	1
High	20 – 50	2
Very High	> 50	3
Fault	< 0	4
Normal	0 – 10	-

As shown by the front panel of loop receiver in Figure 8, the single 7-segment in the left side indicates the channel number, the three 7-segments in the center displays the gas concentration, and the two 7-segments in the right side are for the error channel and the error code. The four LEDs below the 7-segments denoted as Low, High, Very High, and Fault are for warning the gas concentration level. The error codes and the warning codes are tabulated in Table 1.

4 Conclusion

We have developed the microcontroller-based current loop receiver system. The system can be used to serve 8 gas sensors with 4-20 mA outputs. The data acquisition of the system is composed of a current loop receiver, a CD4051 multiplexer, an ADS7822 serial ADC, and an AT89S52 microcontroller. The measured gas concentration is displayed on the 7-segments or transmitted to a personal computer to be processed by the Microsoft Excel.

5 References

[1] Datel, Inc., DMS Application Note 20 “4-20 mA Current Loop Primer”.
[2] Omega, Inc., DMS Application Note 20 “4-20 mA Current Loop Primer”.
[3] ANSI/ISA-50.1-1982 (R1992), Compatibility of Analog Signals for Electronic Industrial Process Instruments.
[4] Texas Instruments, Inc., CMOS Analog Multiplexers/Demultiplexers with Logic Level Conversion, (2000).
[5] Texas Instruments, Inc., ADS7822-12-Bit, 200kHz, microPower Sampling Analog to Digital Converter, (2006).
[6] Fluke Corp., 5100B Series Calibrator Instruction Manual, (1992).
[7] Detcon, Inc., Detcon Model TP-524C Hydrogen Sulfide Sensor, (2003).