A Simple Low-cost Controller for Air Sampling System

Yun-Taek Im [a*], Min-Su Kim [a], Jae-Ha Song [a], and Young-San Choi [a]
[a] *Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon 34057, Korea.*
HANARO Management Division.
[*] *Corresponding author: ytim@kaeri.re.kr*

1. Introduction

Linear systems show predictable responses of the system with analysis or simulation. However, a typical system is a nonlinear system, which is complex and inefficient to design by predicting the exact response of a nonlinear system. Probably, linear approximations simplify the design of the nonlinear system. Nevertheless, this approximation is unsuitable for design the nonlinear system when the unknown part, such as the black box, of the system exists. In this case, using several nonlinear elements, such as quantization and saturation, is another design method [1].

In this paper, a nonlinear airflow controller is realized at a low cost by applying a commercial microprocessor. The controller reads the airflow rate with the ADC module built into the microprocessor as well as uses the built-in Pulse Width Modulation (PWM) module to control the speed of the pump. Quantization, saturation, and time delay techniques are used to control nonlinear signals for stable operation, and the proposed airflow controller can be used for an air sampling system.

2. Air Flow Controller Implementation

2.1 Non-Linear System

There are three nonlinear features in the proposed airflow control system. First, the motor (or pump) used for controlling the airflow rate operates according to the duty cycle of the PWM signal. The airflow depends on the rotational speed of the motor and the load condition of the pump. In other words, the flow rate shows a nonlinear response depending on the status of the load, even though the number of rotations of the motor increases linearly. Second, the flow sensor used in this paper does not generate output voltage signals in proportion to the flow rate [2]. Third, the linearity of the unknown system (or black box) is also unpredictable. Accordingly, it is assumed as a nonlinear system. Apart from these features, the airflow of the controller may vary over atmospheric pressure or temperature changing.

It is impractical to reflect all of these nonlinear properties into design systems. Instead, a nonlinear system can be controlled when the input signal is sufficiently small to reduce the effect on stability. This technique applies a signal-dependent variable gain, such as quantization, saturation, or both, into the system design. The advantage of the proposed controller is that its tunes one variable (time delay). Thus, it is easy to use compared to a Proportional-Integral-Derivative (PID) controller that tunes three variable (gains of P, I, and D). These methods are suitable for systems requiring a slow response rather than a fast response, or continuously operating for a long time to reflect the change of atmospheric pressure or temperature. For example, the proposed system is for sampling air, it is necessary to maintain a constant airflow rate, rather than a fast response.

2.2 Implementation

A microprocessor (Atmega128) is applied to control nonlinear airflow [3]. The ADC Module built into the microprocessor reads the voltage signal, or flow rate, generated by the flow sensor. The duty cycle of the built-in PWM is adjusted to control the rotation speed of the motor by comparing it to the set-point value. To ensure sufficient stable operation, the input signal was quantified, and saturated concerning for the excessive input, so that the input level is limited. The minimum step of the quantization is determined by the PWM resolution. These processes reduce excessive input level and make the system response smooth. The response, or the output voltage of the flow sensor, is measured using a moving average technique to reduce noise. Time delay is required to reach a steady state. In the steady-state, the saturated input signal allows the minimum adjustment of the duty cycle. The peak detector senses the maximum signal from the flow sensor, and the output signal of the flow sensor passes through the low-pass filter and becomes the input signal of the ADC. Fig. 1 shows all functional block diagrams of the control system, and Fig. 2 shows the implemented airflow control system.

3. Conclusions

This paper describes the design method of airflow controllers. Nonlinear systems can be operated using methods of quantization, saturation, and time delay. A low-cost commercial microprocessor (Atmega128) is applied, which includes built-in ADC and PWM modules. The proposed controller can be used to sample air for a long time.

REFERENCES

[1] Gene F. Franklin, J. David Powell, and Abbas Emami-Naeini, "Feedback Control of Dynamic Systems 4th," Chap. 5, Prentice-Hall, 2002.
[2] Honeywell, Installation Instructions for the AWM3000 Series, 2002.
[3] 8-bit Atmel Microcontroller with 128Kbytes In-system Programmable Flash, 2011. Atmel Corporation.

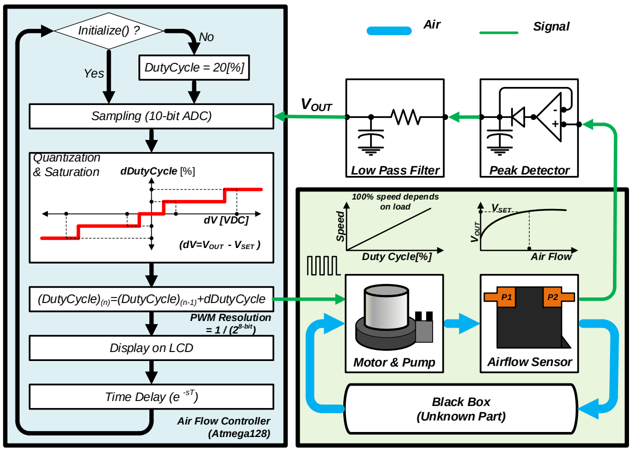

Fig. 1. Function block diagram of the airflow controller.

Fig. 2. Implemented airflow controller.