ACOUSTIC COMMUNICATION IN AIR SUPPLY LINE REALIZING MULTIPLEX CONTROL OF ACTUATORS

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ABSTRACT

Pneumatic actuators have been widely utilized for various purposes and have the important role for operating production facilities in plants with their advantages of light weight, low cost, safety, and high compliance. However, driving them needs not only the air supply line from compressor but also many electrical lines from valve controller, making the pneumatic drive system complicated.

In this paper, we propose a new pneumatic control system using acoustic communication in an air supply line. This system needs two technical challenges; acoustic operating system and power supply device for each local module. This report shows experimentally the potential to realize simple pneumatic drive system without electrical lines.

KEY WORDS

Pneumatic system, Acoustic operating system, Power supply device

INTRODUCTION

Conventional pneumatic system used in the production facility of a factory consists of many pneumatic actuators, many controllers, and a compressor. In addition, pneumatic actuator needs not only the air supply line from compressor but also many electrical cables from valve controller such as power supply lines and control lines. Therefore, many cables occupy the space in a factory, making pneumatic system complicated. Generally a pneumatic system used many pneumatic actuators, making pneumatic system more complicated. Thus, many researches have always been done in order to solve this problem [1-3].

In this paper, we propose a new pneumatic control system using acoustic communication in an air supply line. We call this system as a multiplex pneumatic device drive system. This system needs two technical challenges; acoustic operating system and power supply device for each local module. Acoustic operating system enables to control many pneumatic actuators independently through acoustic communication in air supply line. Power supply device realizes an off-grid local controller by generating electrical power from the energy of compressed air. Therefore, this system with these two technical challenges realizes simple pneumatic
drive system without electrical lines.

**DESIGN OF A MULTIPLEX PNEUMATIC DEVICE DRIVE SYSTEM**

This system proposed in this paper is a new pneumatic control system, which is named as a multiplex pneumatic device drive system. The basic idea of this system is to realize a simple and compact pneumatic drive system without electrical lines. As shown in Figure 1, this new system is realized by using two key components; acoustic operating system and power supply device for each local module.

![Figure 1 A multiplex pneumatic device drive system](image)

Acoustic operating system is the important key control method used for this proposed system. Acoustic operating system aims at the deletion of control lines using acoustic communication in air supply line from compressor. First, we have investigated the acoustic transfer properties for the acoustic communication in air supply line and the high-quality acoustic operating system is realized using the optimal carrier frequency selected by basic experiments of acoustic transmission properties in air tube. As shown in Figure 2, a basic experiment of acoustic transmission properties in an actual air supply line consists of an oscillator, a receiver, a multifunction generator, an oscilloscope and an air supply line of nylon tube with 10 [m] in length, 10 [mm] in outer diameter and 7.5 [mm] in inner diameter. In this experiment, Harmonic sinusoidal waves from 50 to 10000 [Hz] in frequency are generated by a multifunction generator and waveform received with the receiver is recorded with an oscilloscope. As the result of this experiment, high receiving sensitivity is obtained with the acoustic sinusoidal wave of 50 to 2500 [Hz] [4].

![Figure 2 Basic experiments of acoustic transmission properties in air tube](image)

Next, the acoustic communication in air supply line suffers under the influence of the sound noises caused by an air compressor. The peculiar frequency of the sound noises caused by an air compressor is investigated. The experiment which measures the sound caused by an air compressor was conducted at the place 2 [m] from an air compressor and the peculiar frequency is investigated by processing by FFT (Fast Fourier Transformation). As a result, the peculiar frequency of the sound noises is around 10 to 1000 [Hz].
As shown in Figure 3, it is found that the optimal frequency of the acoustic communication system is the carrier frequency of 2400 [Hz] from these experimental results.

![Figure 3 Experimental results of acoustic transmission properties and acoustic noises in air tube [4]](image)

As shown in Figure 4, transmitter system modulates the digital serial communication codes to acoustic waves by a microcomputer (PSoC) with the carrier frequency of 2400[Hz]. The modulated waves generated by transmitter system are shown in Figure 5, where an example of digital serial communication code with 8-bits (01010110) is shown. The received wave is represented by the wave of the yellow line in Figure 7 and the demodulated serial 8-bits communication code (01010110) is represented by the wave of the pink line. As shown in Figure 5, the transmitter system has been realized by a PSoC.

![Figure 4 Diagram of transmitter system](image)

Serial communication code

Sine wave for driving an oscillator

![Figure 5 Example of modulated waves generated by transmitter system](image)

The receiver system located near each actuator receives the acoustic waves and demodulates the waves into digital serial communication codes. The frequency demodulation method of receiver system is designed by a PSoC as shown in Figure 6. The demodulated waves generated by receiver system are shown in Figure 7, where an example of digital serial communication code with 8-bits (01010110) is shown. The received wave is represented by the wave of the yellow line in Figure 7 and the demodulated serial 8-bits communication code (01010110) is represented by the wave of the pink line. As shown in Figure 7, the transmitter system has been realized successfully by a PSoC. The digital serial communication code is the control codes of each actuator. Therefore, the acoustic communication system is able to control a number of actuators independently.

![Figure 6 Diagram of receiver system](image)

Received a transmitter waves

Demodulated waves

![Figure 7 Example of demodulated waves generated by receiver system](image)
POWER SUPPLY DEVICE

An electrical power supply device for each local module consisting of an air-motor, a generator, batteries, a PSoC, and solenoid valves is developed as shown in Figure 8. It generates electrical power from the compressed air and realizes an off-grid local controller. This device utilizes a generator driven by an air-motor, which is rotated by compressed air. Generated power is stored in rechargeable batteries (Li-Po) and is supplied to valves and electrical circuits, resulting in independent power supply.

Figure 8 Configuration of an electrical power supply device

An experimental result showing the performances of developed power supply device is shown in Figure 9 [4]. This experiment is conducted with driving the cylinder sequentially by repeating on/off motions with 0.6 [Hz]. As a result, the developed device achieved autonomic cylinder driving for over 20 hours and it will fill the performance applicable to a multiplex pneumatic device drive system.

Figure 9 Drive experimental result of power supply device [4]

EXPERIMENTAL RESULTS

A prototype drive system is shown in Figure 10, which has a nylon air supply line of 10 [m] in length, 10 [mm] in outer diameter, and 7.5 [mm] inner diameter, and is equipped with three modules. Each local module consists of a power supply device, a receiver system and a pneumatic cylinder. As a result of the examination with the air pressure of 700[kPa], this prototype works well and successfully controls a number of actuators independently. The power supply device also works well.

Figure 10 Experimental system of prototype drive system

CONCLUSIONS

We have proposed in this paper a new pneumatic control system to realize a simple and compact pneumatic drive system without electrical lines. This system consists of two key components; acoustic operating system and power supply device for each local module. Acoustic operating system and power supply device are developed and it was found that they have the performance applicable enough to a multiplex pneumatic device drive system. An evaluation experiment shows the prototype drive system works well without electrical lines.
REFERENCES


