# An FSK based industrial analog signal transmission

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**Abstract**

An FSK (Frequency-Shift Keying) based industrial analog signal transmission is proposed in this paper. Due to the advantage of digital transmission, such as noise immunity and error check, the digital transmission is more and more popular. The FSK is a simple kind of basic digital transmission. Although the analog signal modulation is already well-known and mature, but it is easily interfered by the noise, especially in an industrial environment. When the carried frequency is occupied, the alternative frequency is necessary. However, it is a tough work for sure. The FSK based wireless transmission is used to perform a wireless transmission of analog signal in the industry. It also has good effects of removing the wiring from device to device, and breaks the restriction of the device movement. Experimental results show that the proposed method can work well, and the wireless transmission bandwidth achieves 16kHz.

*Keywords*: FSK, Wireless, Industrial communication, Active filter

## 1. Introduction

In recent years, the IoT (Internet of thing) concept is more and more concerned by every citizen. It is not only used in a residential environment, but can also be utilized for both agricultural and industrial application. The “IIoT” (Industrial Internet of thing) will also be proposed by this trend. The concept of IIoT focus more and emphasizes the communication of machine to machine, and machine to user, so interface between the facility’s sensor is the key point of this concept [1]-[2].
The connection between the machines always uses the physical wire in the traditional way. However, the defect is the signal type and transmission way might be limited by the distance [3]. It also causes the system couldn’t change the transmission dynamically at times when the emergency events occur. [4] also uses the MCU (Micro Control Unit) which carry the RTOS(Real-time operating system) to collect multiple sensors data in the industrial environments.
In this paper, the wireless connection is concerned to replace the physical wire between the machine to machine. Although the analog signal modulation has been used for a long while, [5] mentions that digital modulation has advantage of better noise immunity, robustness to channel impairments, easily multiplexing of various forms of information and detect and correct transmission errors by accommodated digital error-control codes.
Because of the reasons stated above, the goal on this paper is put the eye on transmit the analog signal by digital modulation. The paper is focused on the analog signal because there are many continuous analog signal on a machine, such as voltage, current or temperature of

the machine. [6] collects all the information to monitor by digital wireless transmission, then the emergency events are detected by comparing the original waveform. In [7], the MCU is used to sample the analog signal from sensors in the industrial environment, and the sampled data are transmitted by the wireless signal to the master for monitoring. However, both of two papers never discussed about reconstruction of signal.

## 2. System Architecture

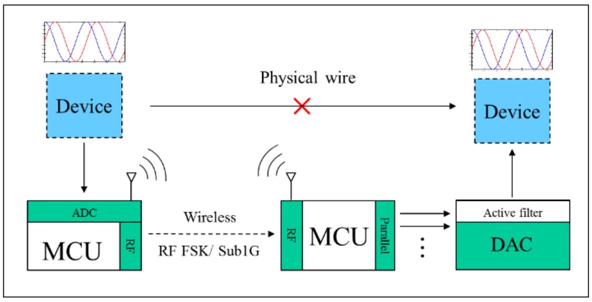


Fig. 1. The figure of system architecture

Fig. 1 shows the proposed system architecture in this paper. It consists of two MCUs. These two MCUs not only response for digital data transformation, the most important thing is to fulfill the wireless communication. Due to the setting in this paper is the unidirectional transmission, the following section is divide into two parts with transmitter and receiver to introduce in detail.

### 2.1 *Transmitter*

In the transmitter, the MCU enables a timer to trigger ADC (analog-digital converter) to sample the analog signal. When the sampling amount reaches the goal of RF (radio frequency) packet length, the MCU will turn the RF transmission on to transmit the whole packet to the receiver. Since the hardware blocks of RF and ADC are independent on the MCU. When the MCU performs a RF transmission, the ADC can also keep sampling to the signal, so that the data never lost.

### 2.2 *Receiver*

The receiver has the same design with the transmitter. In addition to enabling a timer to turn on the RF reception within a fixed period. The parallel transmission is used to send the digital data from the receiver to the external DAC (digital-analog converter). By the repeatedly receiving and converting, the analog output signal will last continuous conversion.

### 2.3 *Parallel Digital Analog Converter circuit*

The DAC7821 IC is adopted in the DAC circuit, which is produced by the Texas Instrument. The reason to use the parallel transmission from MCU to the external DAC circuit is the transfer speed. Due to the requirement for real time convert of the analog signal, the serious communication might cause further delay to the system which is called the latency.

### 2.4 *Active filter circuit*

Due to that the system in this paper uses the digital modulation of wireless communication to transmit, the analog signal data will be sampled to non-continuously digital data. Because of the DAC performs the zero-order hold for discrete-time signal, means that the data will also become unsmooth caused by the reconstruction on DAC. The active filter is designed to resolve this problem. The low pass active filter is implemented with a 4 order Butterworth filter. The goal expects that the analog signal within the setting passband can be send wirelessly and successfully and smoothly output results.

## 3. Experimental Results

In the experiment process, the function generator is used to produce standard sinusoidal waveform. The MCU samples this signal by a fixed period. The transmitter sends the sampling data to the receiver by RF, then the receiver can transmit the data to the DAC circuit. After the conversions on DAC circuit, an oscilloscope is used to observe and compare the output result of the active filter circuit and the input source signal.

### 3.1 *The maximum Bandwidth of system*

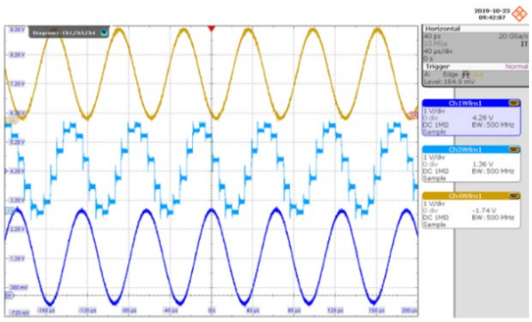

Fig. 2. The comparison of whole system output and input result

The highest sampling rate of the ADC and DAC in the paper is set on 160kS/s. The maximum passband width is set in 16 kHz because the expectation of this paper is that the input signal to be at least consistent with 10 digital data to be reconstructed. In the oscilloscope waveform of Fig. 2, Ch4 (brown curve) is the waveform produced by the function generator; Ch3 (light blue curve) is the output after DAC; and Ch1 (indigo curve) is the result of the filter which is also the signal after the reconstruction. The Fig. 2 shows that the 16 kHz sinusoidal wave input signal can be reconstructed by 10 digital data.

### 3.2 *Latency*

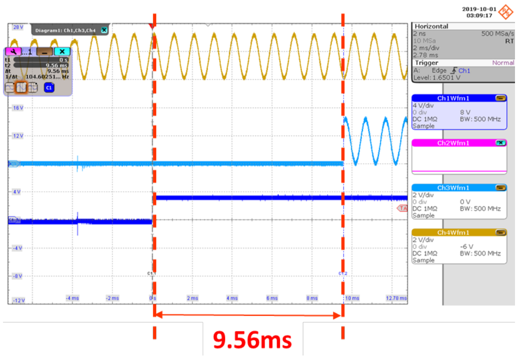


Fig. 3. The latency of input to output

The latency on the wireless communication is unavoidable. The experiment measures the effect of the latency on the result. The experiment is used an IO output pin on MCU to indicate the moment from the first ADC trigger. The interval to the first sinusoidal signal of the DAC conversion means the latency. The oscilloscope shows the result which in the Fig. 3, the Ch4 (brown curve) is the input signal; Ch3 (light blue curve) is the result of the DAC circuit output; and the two dotted lines are used to mark the latency time by the rising edge (first trigger) in Ch1 and the first complete of DAC. It is observed that from the first signal sampling to the DAC conversion, the total latency takes about 9.56ms.

### 3.3 Timer occupy by Hardware switching

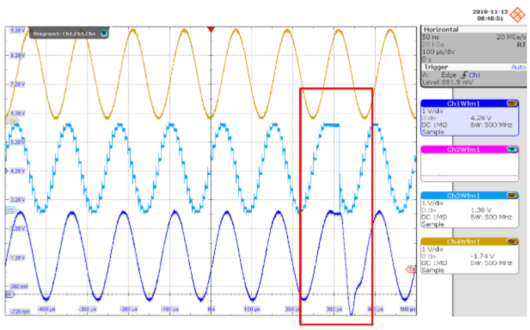

Fig. 4. The situation of hardware switching

Due to hardware limitation of the MCU, when the CPU is interrupted by RF receiver routine, the output pin can't be set. It causes the system can't update the DAC output in a fixed-length duration time. The reason is that the most of MCU never support hierarchy interrupt, when receiver interrupt, output timer interrupt for DAC update is disable. As shown in Fig. 4, the experiment is performed to measure this non-updating duration. In every 43.75us of transmission frame, there is about 3.2 ms of non-working interval.

### 3.4 *Mixed frequency*

The experiment is hoping that the system not just transmits the data with fixed or single frequency, but transmits the reality analog signal. Hence the experiment adds multi frequency to a signal in order to simulate it, and observe the result to know whether reconstruction is successful or not. This experiment also tests the filter performance of its exact bandwidth.

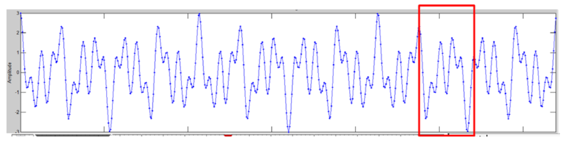

Fig. 5. The waveform data with 4kHz, 8kHz and 16kHz mixed frequency sinusoidal wave

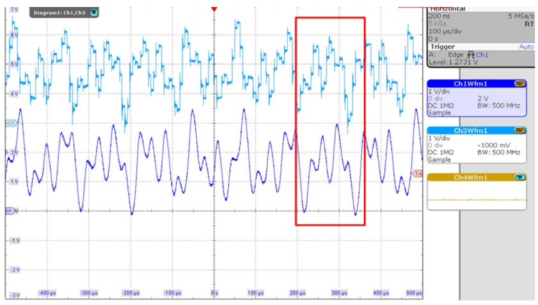

Fig. 6. The DAC output and active filter result of 4kHz, 8kHz and 16kHz mixed frequency sinusoidal wave

First of all, the waveform of the mixed frequency form 4 kHz, 8 kHz and 16 kHz sinusoidal waveform is produced as shown in Fig. 5. The Fig. 6 is measured from the output of DAC circuit. Ch3 (light blue curve) is the DAC output result and Ch1 (indigo curve) is the signal after filter.
The red square in the Fig. 5 and Fig. 6 marks the difference between the original signal and the signal after filter. From the result, it proves that within the 16 kHz bandwidth, all of the signal can reconstruct to the original signal successful.

### 3.5 *Signal noise ratio (SNR)*

SNR is defined as the ratio of signal power to the noise power. Since the analog continuous signal is transmitted wirelessly, the SNR is used to judge how much noise is in the output signal. In this paper, the measurement of

SNR is based on the frequency domain after the Fourier Transform. Fig. 7 shows the spectrum of the signal waveform. According to the frequency domain, calculate the energy of input signal and the noise except for the input signal. The last, the SNR can be calculated by (1), and it is effective evaluate the system.

$$SNR(dB) = 20\log_{10}\left(\frac{A_{signal}}{A_{noise}}\right) \quad (1)$$

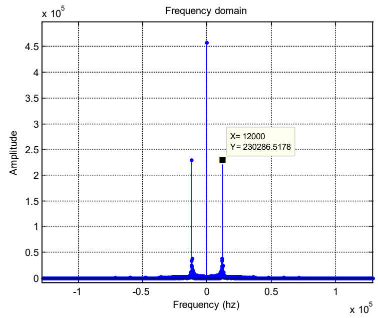


Fig. 7. The frequency domain figure of output result

Table 1. SNR of each signal input frequency

| | | Signal noise ratio |
|---|---|---|
| **Input Signal Freq.** | 1k | 152.96dB |
| | 2k | 116.093dB |
| | 4k | 98.0937dB |
| | 8k | 68.1dB |
| | 10k | 62.6037dB |
| | 16k | 41.3466dB |

As mentioned above, due to the system only used MCUs to fulfill the RF reception and multiple IO to transmit the signal data, the reconstructed signal will have some vacant of signal in every transmission frame. The fixed duration reduces the SNR. The related data is measured as shown in Table 1, the lower effect to the lower frequency signal. It also shows the lower signal will have better SNR.

## 4. Conclusion

In this paper, the digital modulation is used to conduct the wireless communication. The system with digital modulation have the advantages of noise immunity and error checking with error-control codes. Moreover, the transmission power and transmission rate can be flexibly adjusted in the digital modulation.

As shown in experimental results, that the proposed system could effectively remove the equipment wiring in the industrial environment. Moreover, the system successfully simulate the situation of variety frequency waveform in the industrial environment, and reconstruct the output signal to the original continuous signal with a very low error.

The system which implement in this paper is proved that it can transmit the continuous analog signal by the wireless effective.

## References


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