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A Study of Cantilever Beam Vibration Wireless Transmission System

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Abstract

ZigBee is a wireless communication technology which based on IEEE 802.15.4 protocol, communicating within short distance and with low power. ZigBee is applied in cantilever beam vibration measurement system in this paper, and the old wired transmission system are substituted by IEEE 802.15.4, software and sensor circuit are designed, reliable data transmission method and half byte compression algorithm are analyzed, and also provide basis and data analyzing solution for dynamics model of cantilever beam which using piezoelectric transducer. Experimental results show that with wireless ZigBee transmission solution and compression algorithm, the acquisition data of 150 bytes per second can be achieved, which will improve the quality of vibration analysis.

Keywords: ZigBee; Piezoelectric Transducer; Compression Algorithm; Cantilever Beam.

1. INTRODUCTION

Zigbee is a wireless standard for personal area network, sensor monitoring and control, which is designed for low power, short-range communications between wireless devices. Now there a wide application of Zigbee technology in many fields[1-4].

In many industrial processes, one of the major problems is the data sharing by cable connections, cable and wire may cost much. Also measurement and control end device boards placed on the moving elements of various machines are strongly exposed for mechanical damage. Wireless ZigBee technology can eliminate these problems.

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Piezoelectric ceramics (PZT) as the effective sensor is widely used in vibration testing. The PZT used as actuators and sensors were adopted in the forms of surface-bond sensors and actuators on a beam to control actively the vibration responses. The feedback signals of PZT sensor are received by end device of Zigbee solution, and the data are transmitted to coordinator by end device and then through RS232 serial port to central computer. The received data can be displayed and stored on computer for deeper analysis.

2. SYSTEM ARCHITECTURE

CC2430 processor is used as Zigbee transmission and receiving device in this paper.
The CC2430 is a true System-on-Chip (SoC) solution specifically tailored for IEEE 802.15.4 and Zigbee applications. The CC2430 combines the performance of the leading CC2420 RF transceiver with an industry-standard enhanced 8051 MCU, combined with the industry leading Zigbee protocol stack (Z-Stack). The CC2430 is suited for systems where ultra low power consumption is required.
The system topology architecture is presented as Figure1. PZT sensors are placed on cantilever beam, connected with end device. Coordinator is laid on central management room, and connected management computer by serial port. PZT sensor is responsible for vibration signal conversion and end device for data acquisition (Analog to Digital). The acquired data are transmitted by end device with wireless 2.4GHz frequency to coordinator. When data arrived to coordinator, they are sent to management computer through serial port.

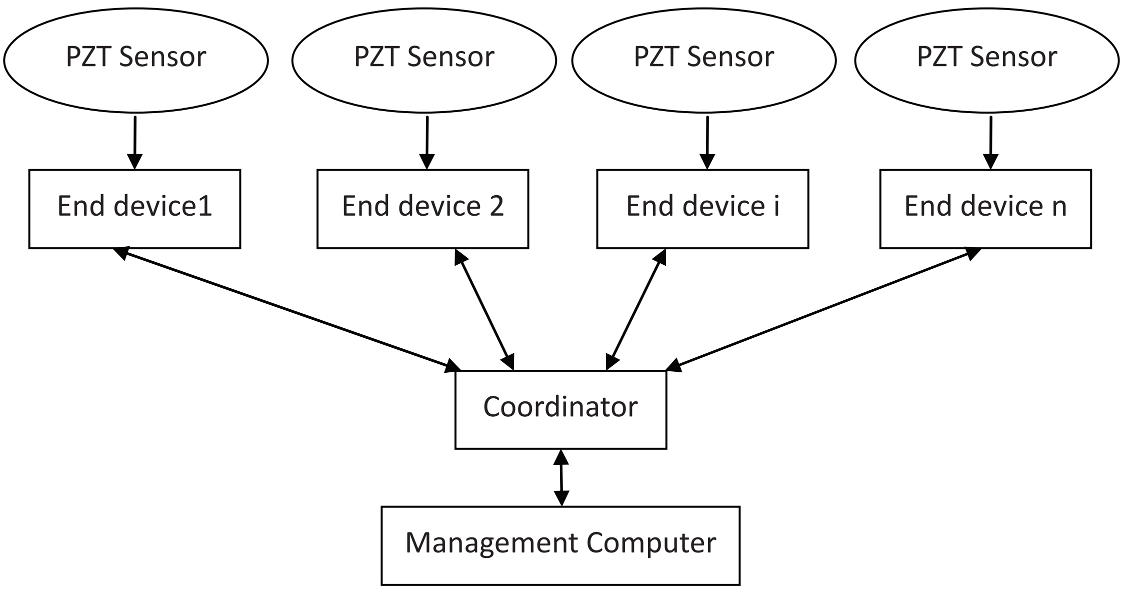

Figure 1: System Architecture.

3. HARDWARE DESIGN

3.1 PZT Sensor Circuit

PZT sensor output signal should be amplified by amplifier. The OPA128 is an ultra-low bias current monolithic operational amplifier. Using advanced geometry dielectrically-isolated FET inputs, this monolithic amplifier achieves a performance level exceeding even the best hybrid electrometer amplifiers[6]. The PZT signal amplifying circuit is depicted as Fig2.

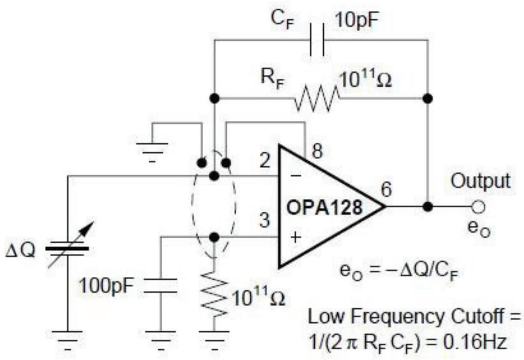

Figure 2: Piezoelectric Transducer Charge Amplifier.

3.2 Coordinator Hardware Design

Coordinator is in charged of communication with each end device, and data transmission with management computer. The hardware schematic chart is depicted as Fig.3. CC2430 SoC is taken as the processor of coordinator. In which pins TXD and RXD are connected to management computer serial port with a level translation chip MAX3232. Fig 4 is the coordinator module.

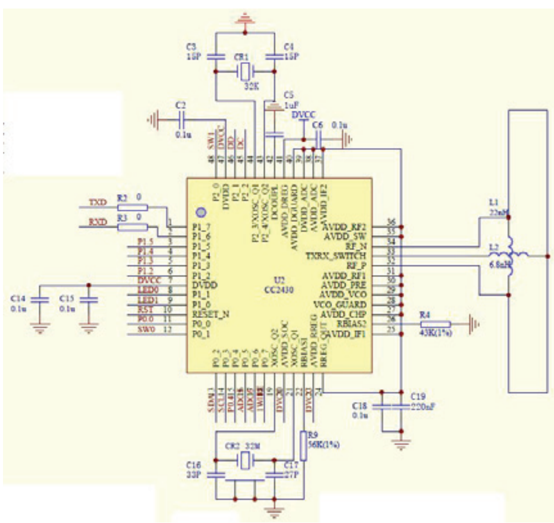

Figure 3: Coordinator Schematic Circuit Diagram.

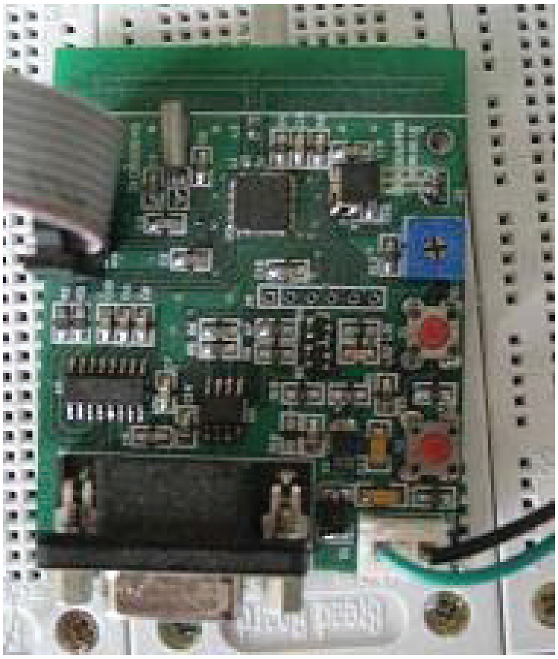

Figure 4: Coordinator Module.

3.3 End Device Hardware Design

End Device is responsible for data acquisition, analog to digital conversion and communication with coordinator. For simplicity, only end device module is presented in Fig5.

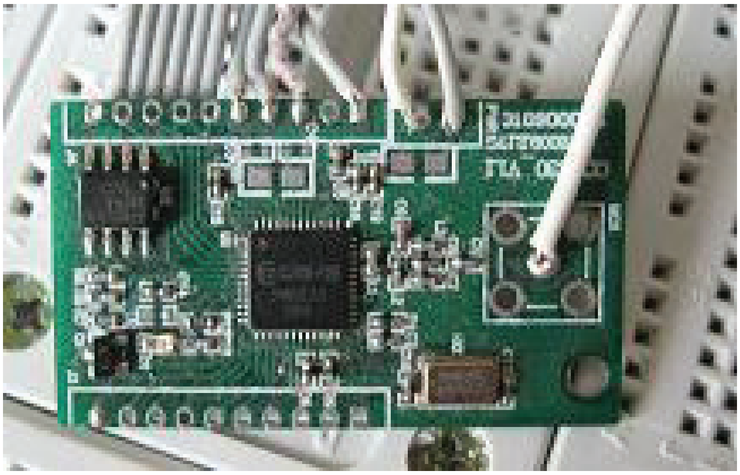

Figure 5: End Device Module.

4. SOFTWARE DESIGN

4.1 Software Work Flow

Software work flow is presented as Fig6. Coordinator and end device are all worked based on multi task handling mechanism. The messages, events, interrupts, timers can trigger the task handling. To communication events, there are two messages can trigger task handling, they are : SPI_INCOMING_ZAPP_DATA and AF_INCOMING_MSG_CMD.

SPI_INCOMING_ZAPP_DATA: When serial port received data, this message is sent and coordinator receiving events is triggered;

AF_INCOMING_MSG_CMD: This is an indication of an incoming AF (Application Framework) message received by OTA (Over-The-Air).

In this flow chart, when end device received message of AF_INCOMING_MSG_CMD, if command parsing result is start A/D, data acquisition will be triggered.

The ADC of end device supports up to 14-bit analog-to-digital conversion. According to the output of sensor, we set 8-bit resolution in this paper.

4.2 Software Work Flow

When a start command received, End Device first executes one AD conversion, and this first AD results is called base in my paper. End device will execute 150 times AD conversion within one second. The each conversion result are Byte[i] (i=5,6,…,154), which is one byte. These latter AD converting results will be stored in half byte which is 4 bits space. The stored half byte is the result of Data[i] minus base. By this way, the data are compressed and can save half of memory space.

Each time there are 150 data are acquired, they are:

$$data = \{data[0], data[1], ...data[149]\}; \tag{1}$$

Take the first data as the base of this list of data (a frame), that is:

$$base = data[0]; \tag{2}$$

Each data can be compressed by:

$$byte[i] = data[i-4] - base;$$
$$byte[i] = byte[i] << 4; \tag{3}$$
$$byte[i] = byte[i] \,\&\, (data[i-4+1] - base);$$

With this compression algorithm, the memory can be saved for about half of that without compression.

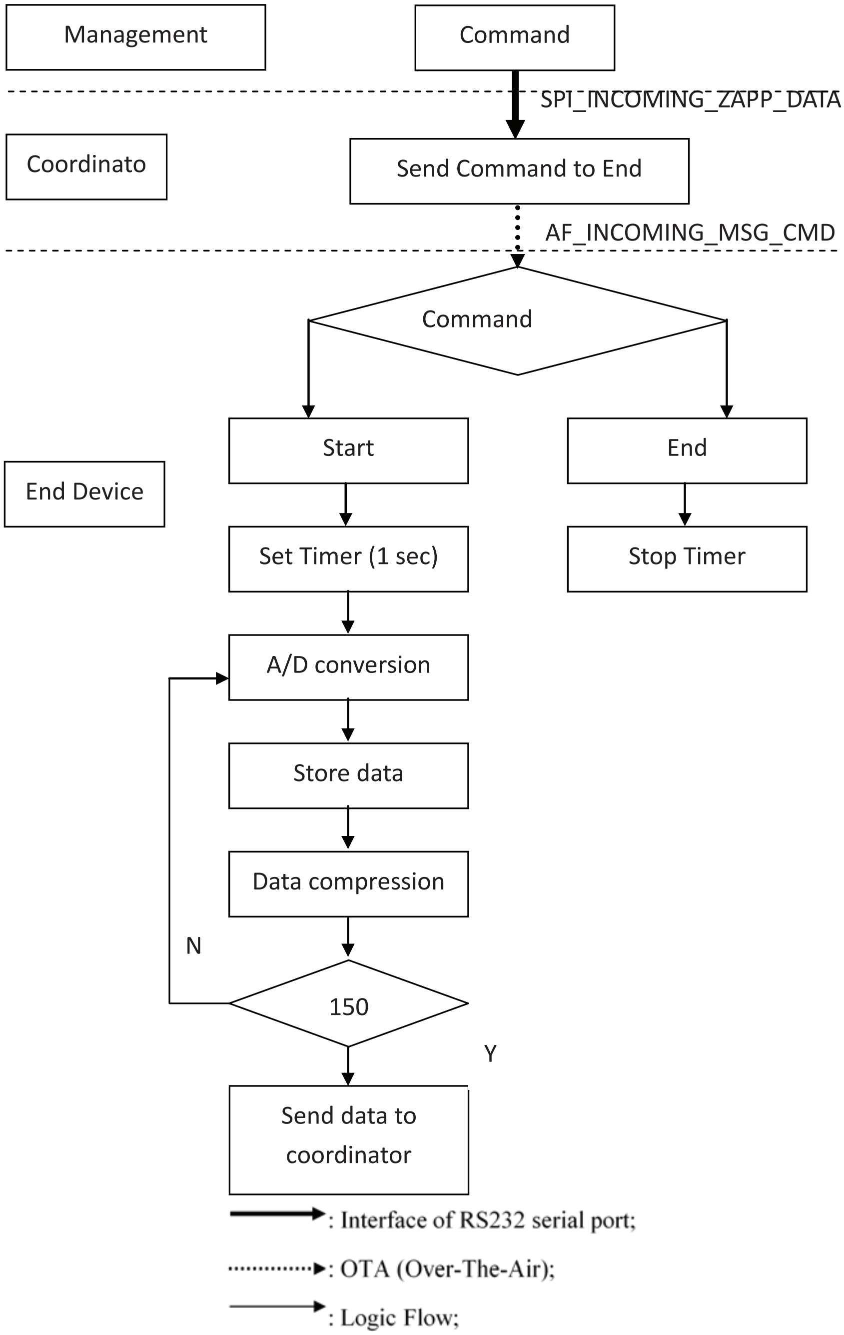

Figure 6: Software Work Flow.

4.3 Data Package Format:

Error! Reference source not found. is the format of data package which is a frame sent by end device to coordinator.

Table 1: Frame Format

Byte[0-3]	Byte[4]	Byte[5]		Byte[i]	Byte[155]
Head	Base	Data[1]-base	Data[2]-base	……	Checksum

The total frame length is 156 bytes, and first byte is package head, the second byte is the first AD conversion results, the last byte is checksum of the frame (except for the checksum byte), and the rest bytes are AD conversion results been compressed.

- **Head:** "AD01", "AD02", ……,"ADFF", is the sequence number of each end device in the same destination group.
- **Base:** The first AD conversion result.
- **Data[i]-base:** The compressed AD conversion result.
- **Checksum:** The total sum of the former bytes.

5. CONCLUSION

The sample data are stored on the management computer in text file. We input the 1.542VDC into end device, after the AD conversion, the output digital value should be calculated as follows.

$$\frac{V_{REF}}{V_{IN}} = \frac{2^7}{x} \text{ , where } V_{IN} = 1.542V, V_{REF} = 3.3V \text{ , so: } x = 0x3b$$

And the actual AD sample result is:

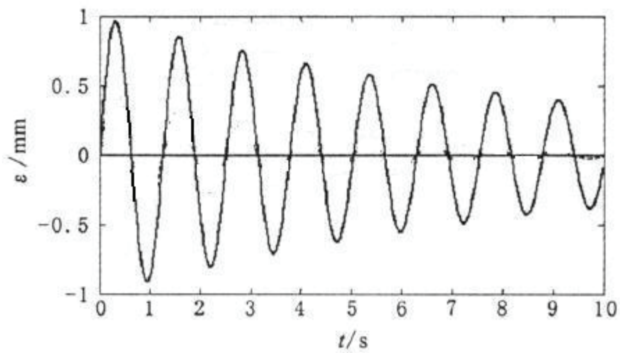

Figure 7: Acquired Data With Compression.

Acquired data graph shows that with wireless ZigBee transmission solution and half byte compression algorithm, the acquisition data of 150 bytes per second can be achieved, which will increase the bytes number and then improve the quality of vibration analysis.

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