

The Design of Multi-sensor Flame Detector Based on Information Fusion Technology

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Abstract—The flame monitoring system plays an important role in keeping large-sized boiler furnaces safe and substantial. Its core and the most complex component is the flame detector. Due to the unique environment of a boiler furnace, the flame detector is easy to be disturbed while working, resulting in errors in judgments, leading to serious consequences. The paper applies information fusion technology in the flame detector, and proposes the usage of dual sensors.

Index Terms—Flame detector; information fusion; multi-sensor; PIC single-chip microcomputer

I. INTRODUCTION

With the rapid development of industry in our country, boilers are used more and more widely in many fields such as fuel electric plants, urban heating system, fossil power stations, blast furnace gas combustion and so on, so the boiler flame monitoring system is not only essential, but its effectiveness is requested increasingly, and it plays an important part in monitoring flame combustion inside of boilers [1]. The role of the flame monitoring system is mainly manifested in two parts: First, it ensures boiler furnaces safe, that is it stops to supply fuel when the flame muffle burner is fireless, to avoid explosion caused by huge fuel accumulation; second, it ensures boiler furnaces substantial, that is it keeps supplying fuel when the flame muffle burner has adequate fire, to avoid waste.

II. FLAME MONITORING SYSTEM

A. Components of The Flame Monitoring System

Generally speaking, the flame monitoring system is composed of the following components: a flame detector mainly composed of photoelectric detective circuits, signal conditioning circuits (mainly amplifying and shaping signals), Microprocessor system, I/O circuits and wind cooling system composed of blowers, blower ducts, blower bases and control boxes.

B. Functions of The Flame Monitoring System

The flame monitoring system stores the everyday burning conditions of the boiler furnace in the form of signals from 0 volt to 5 volt, as historical data supplied to the boiler control system, in order to provide necessary data for the control system to manage the boiler furnace safely.

It would send a warning message in the form of an electric signal, at the same time the led lights alarm, when the boiler furnace runs at low load, that is when one or more muffle burners are fireless inside of the boiler (for example 0~0.5V).

It supplied signals for the control system to judge by logic control whether to start to sweep the furnace, whether to cut the main fuel valve, whether the oil gun can be controlled, whether the coal pulverizer can stop or start. It collects, stores and memories flame signals in the boiler furnace, to provide data for the flame monitoring system to do hardware self-check.

III. FLAME DETECTOR

The core and the most complex component of flame monitoring system is the flame detector.

A. Working Principle of The Flame Detector

Radiant intensity signals of the flame sent by a muffle burner change into relevant voltage strength signals by the photoelectric sensor. The voltages are so low that they need to be turned into standard analog signals, which would be processed in the single chip microcomputer and change into relevant controlling signals to be output. The flame detector has functions of collecting, processing input signals and output control signals.

B. Problems of The Flame Detector and Solutions

1) Problems of the flame detector

Problems of the flame detector are “peeping” and “unseeing”: and “peeping” means that when the muffle burner is fireless, the relevant search unit would output a signal with fire, due to the flame background; “unseeing” means that when the muffle burner flame is still enough, the relevant search unit output a signal without fire, due to the shielding effect of the fire background. Moreover, there are other kinds of disturbance including furnace wall reflection, slack, and smoke and so on. If both of the conditions happen frequently, the normal operation of the boiler would be adversely affected, leading to serious consequences.

2) Solutions

Information fusion means a multi-level and many-sided process, during which multi-source data is detected, mixed, interrelated, estimated and assembled in order to achieve accurate and identity estimates, as well as complete and timely situation assessment and treat

assessment [2]. Dual sensors are used to detect the same flame based on the method of information fusion. Through experiments, we found that ultraviolet radiation sent by flame is weaker than other kinds of radiation because of the narrow spectrum of ultraviolet, but the group of infrared and visible light sensors sent strong signals. It is effective. The visible light sensor detector checks flame conditions by detecting the visible light in the flame, and confirms its state based on the flicker frequency and identity of the flame. It is able to filter infrared radiation from soot, hot smoke, and the furnace wall. Infrared flame detector makes use of the changing voltage signals caused by flame wave motion in the sensor to judge whether the flame is still [3]. The signals detected by both kinds of sensors are processed first, and then they are synthetically processed in the single chip microcomputer. In this way, signals can be detected more accurately, and problems of “peeping” and “unseeing” can be solved.

C. Components of The Flame Detector

The flame monitoring system is mainly composed of the following components: Photoelectric sensors, signal conditioning circuits, signal control circuits, signal output circuits.

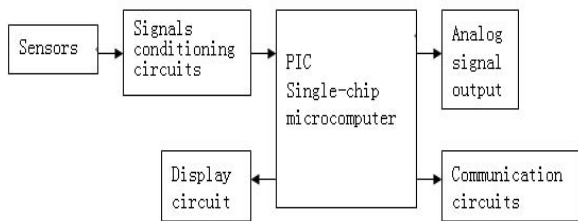


Figure 1. Block diagram of the flame detector

1) Photoelectric sensors

Photoelectric sensors include the photosensitive resistor, the photosensitive diode, and the phototransistor and so on. Through comparison, the phototransistor is selected. Compared to the photosensitive resistor and the photosensitive diode, it has the following advantages: the phototransistor has the function of transforming light signals into electrical ones, the same as the photosensitive diode, besides it has the function of enlarging electrical signals. It has a large base area but a small emitter area, in order to expand the area of accepting illumination, because the incident light is mainly absorbed by base area. Signals from the phototransistor are input to amplifying circuits, as a result, the muffle burner could achieve the task of detecting the average intensity of the flame.

The model of the infrared phototransistor selected is PT334-6B, with a centre wavelength of 980 nm. The wavelength of the infrared from the flame concentrates from 900nm to 1000nm, beyond the range of the wavelength of slag, smoke, and the infrared radiation of the furnace wall, so their disturbance can be filtered out. I_c is only determined by H —the illumination of the incident light, when U_{CE} —the voltage of the phototransistor is big enough. The model of the visible light phototransistor selected is kvs-2023; with a centre wavelength from 600nm to 700nm.

2) Signals conditioning circuits

Signal conditioning circuits make use of integrated operational amplifiers to amplify and shape the weak voltage signals. The model of the low velocity amplifier selected is LM358, with two isolated, high-gain and internal frequency-compensation operators inside. It is able to work either powered by a single-supply source, or at the dual-power mode. In the recommending working conditions, the current and the voltage of the power are not relevant. It is applied in sensing amplifiers, DC gain blocks, and all the other conditions when operational amplifiers can work with a single-supply [4].

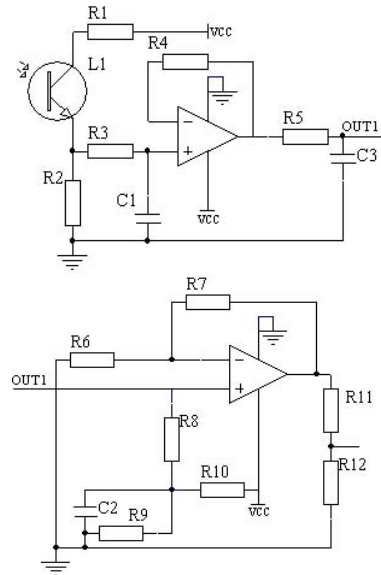


Figure 2. Signal conditioning circuits

As shown in figure 2, the output voltage of the photoelectric transforming circuit or the input voltage of the amplifier is V , equaling I multiplying R_2 . I is the photo conversation current or the current flowing through the resistor R_2 . Selecting proper resistance values of R_1 and R_2 to make the phototransistor work at the linear area, we can see from the character diagram that with the increasing flame intensity, the photo current increases in accordance with the performance curve, followed by the increasing voltage of V [5]. Then the voltage of V transforms into the voltage signal between 0V and 5V which could respond the flame intensity through two amplifiers.

The flicker frequency of the flame from the muffle burner is lower than 200Hz in a general way, according to that, two low pass filters are equipped respectively after the sensor and the first amplifier, with an upper frequency limit of 200Hz.

3) Signal processing circuits

Signal processing circuits are the single-chip microcomputer unit. The voltage signals are input to the single-chip microcomputer unit after the signal conditioning circuits first, and then through A/D transformation they transform into digital signals that the single-chip microcomputer unit can process. After process inside of the single-chip microcomputer unit, the signals are output through the D/A chip which are used on the one hand to drive the relay to do on-off control, on

the other hand to input to other control equipment to reserve.

The model of the core of the single-chip-microcomputer system selected is PIC16F877A. It has a CPU using RISC structure and respectively has 33, 35, 38 items of instructions. It uses Harvard Dual-bus structure, with a rapid running velocity, a low working voltage, low power dissipation and strong directive driving capacity to input and output. It has a low price. It is able to program one time with a small volume. It has several A/D channels applicable to dual-sensors, with a low high-frequency noise, anti-interference and is fit for the industrial fields and vile environment. Based on the advantages below, PIC16F877A is helpful to increase the veracity of the flame signals, the anti-interference of the flame detector, and the intelligent to process signals [6].

In the design, AN0 and AN1 are used to input the analog signals. D ports are used to output digitals to the nixie tubes to show the voltage intensity. Due to that PIC16F877A has only one ADC; the two analog signals are sampled at different time.

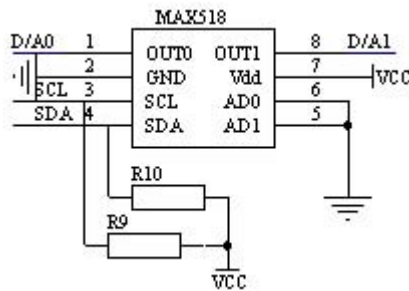


Figure 3. Cording diagram of PIC16F877A and D/A

MAX518 is used to expand the output port of D/A module droved at the I²C working mode. Figure 3 is the cording diagram of PIC16F877A and MAX518, which is a 8-byte D/A chip with a dual-line serial port, and supports the communication between multiple devices, and is able to work only with a 5-volt single power. As shown in figure 4, only two pins of the chip are needed for its communication with the single-chip microcomputer. The pull-up resistors R9 and R10 are used to pull the pins SCL and SDA respectively into to a high power level, when the I²C bus is idles.

4) Communication circuits

PIC single-chip microcomputer communicates with the host computer in the way of serial communication. The chip MAX232 is selected, because it is the especial interface circuit designed for RS232 standard of the host computer, supplied by a 5-volt single power.

The CMOS data from PIC single-chip microcomputer is first input to MAX232 through the pin T2IN and

changes into RS232 data. Then the RS232 data is brought to the plug of DB9 of the host computer. The third step, the RS232 data from DB9 is input into MAX232 through the pin R2IN, and then changes into CMOS data, which is input into the single-chip microcomputer through R2OUT at last. After the process, communication between PIC single-chip microcomputer and the host computer is completed, as shown in figure 4.

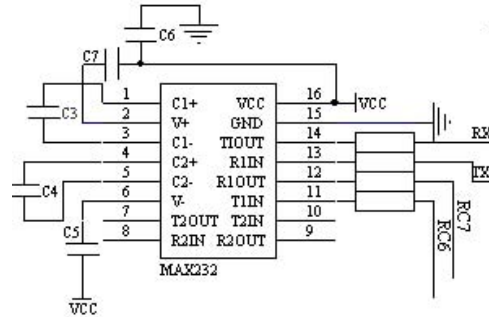


Figure 4. serial communication circuits

IV. CONCLUSION

The flame monitoring system is essential to ensure the safety of the boiler, which is widely used in the fields including electricity, metallurgy, and petroleum, chemical and so on. Its core is the flame detector. However, the single-sensor flame detectors now widely used have several shortcomings such as defects in gathering information, and low accuracy. Foreign researchers focus on the application of image detection technology, but they are expensive and their effects still need to be improved. The dual-sensor flame detector is able to integrate different kinds of radiation of the same flame, result in high accuracy and moderate cost. Therefore, research on multi-sensor flame detectors has great significance.

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