

## Research Article

### Study on the Engine Electronic Ignition System Based on SCM and LabVIEW

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**Abstract:** To improve the operating performance of the electronic control ignition system and meet the requirement of the experiment teaching, an electronic control ignition system based on Lab VIEW and micro-controller was developed in this study. The system was composed of the ignition control circuit, signal processing circuits of various sensors and system software, which combined the functions of data acquisition, analysis and control. According to the working principle of the ignition system and working parameters, the cylinder block temperature signal, throttle position signal and power supply voltage signal were used as the correction references for the ignition advance angle. So the processing circuits of the sensors were designed based on the selection of the sensors and analysis their working principle or characteristic. The software of the host computer was visual and easy to control the slave computer, which realized the control for the ignition timing and dwell time. The experiment results indicated that the system developed in this study was reliable and that the data communication between the host computer and the slave computer reached the expected requirement. The research results provided a foundation for the further study and performance optimization.

**Keywords:** Correction references, data communication electronic ignition system, host computer, slave computer

## INTRODUCTION

With the development of microprocessor with higher integration degree and more complex control function, people put forward more and more requirements for cars in power, economy and comfort. The electronic control ignition system allowed the engine to operate in under various working conditions, so it has become the mainstream of today's electronic ignition systems development. Domestic and foreign-controlled ignition system improved the gasoline engine power, economy and emissions performance mostly through controlling the ignition advance angle.

Foreign advanced automobile industrial countries have better test equipment than our country and their technology is also more advanced. They often use engine, platform or simulation platform and advanced instruments to test the ignition performance, which can help people to and provided a good foundation for the research of the ignition system (Hu *et al.*, 1999). In contrary, the test technology and equipment was poor, so the research and production of the test platform become popular in china (Song, 1997; Cai, 1996).

Document (Gong *et al.*, 2005) controlled the ignition timing by way of looking the table based on the study of the engine combustion and the ignition advance angle MAP. Document (Song and Jia, 2010) developed the electronic control ignition system for the GDI engine. Many GDI gasolines made by the domestic

research institutes were fitted by the PFI (port fuel injection) gasoline and the DI (direct injection), so the research of the corresponding ignition system had an important significance (Yu, 2003).

To improve the operating performance of the electronic control ignition system and meet the requirement of the experiment teaching, an electronic control ignition system based on Lab VIEW and micro-controller was developed in this study. The system developed in this study was reliable and that the data communication between the host computer and the slave computer reached the expected requirement.

## HIGH-ENERGY IGNITION SYSTEM AND ITS WORKING PRINCIPLE

The high-energy ignition system of the engine was composed of the microcontroller circuit, the sensor input signal processing circuit and ignition driver circuit components. The prototype electronic ignition control system structure shown in Fig. 1. After the data was processed by the signal processing circuit, it was put into C8051F020 microcontroller. Based on these signals, the microcontroller implemented the calculation and timely operated the primary ignition circuit and the ignition system gained the required high-voltage in secondary coil. According to the battery voltage signal, the MCU modified the ignition timing and dwell angle.

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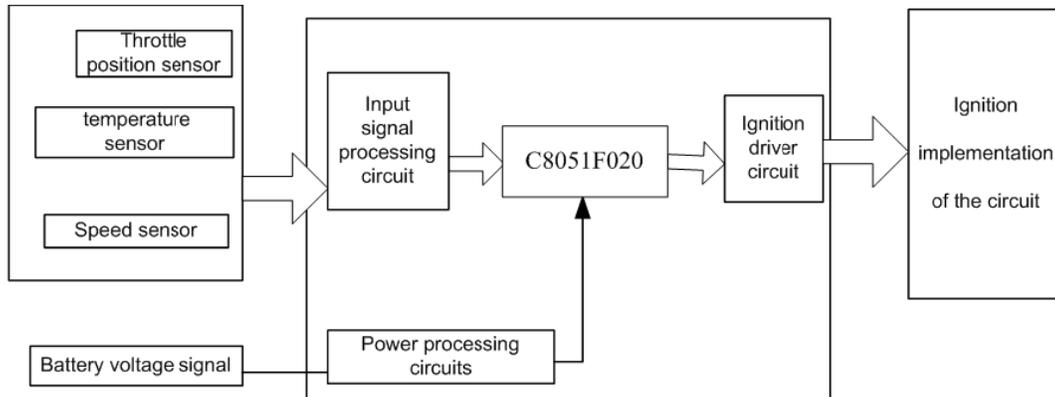


Fig. 1: Engine electronic ignition control system diagram

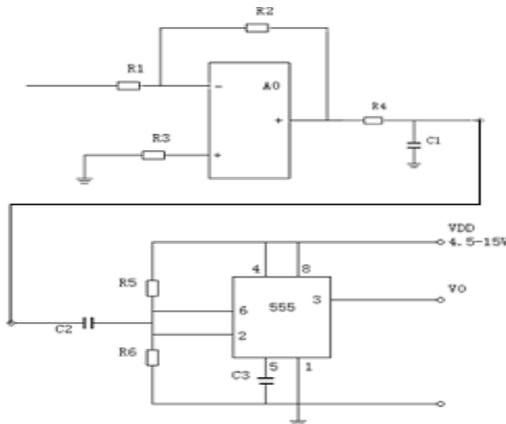


Fig. 2: Speed signal processing circuit

**Main sensors and corresponding processing circuit:**

The sensor was one of the key links of the entire test system performance. Its measurement task was to obtain efficiently from the measured object. So the sensor played an importance role in the system. To achieve the overall function of the system, the sensor selection was critical in the system (Rong, 2010).

**Speed sensor and its measuring principle:** Speed is one of the main parameters in the engine electronic ignition system to determine the ignition timing and its measurement accuracy directly determined the stability of the ignition system. If disturbed, the system was likely to be caused into the state of serious instability. It is the correct speed signal processing appears particularly important. Common used speed sensor included magnetic, hall and photoelectric sensor. This article used photoelectric sensor to measure the speed. The signal from the photoelectric sensor was subject to filtering, amplifying and shaping circuit. Engine works in a poor environment. There are much sources of interference, especially the speed sensor is non-electrical signals into electrical signals, the mechanical vibration of the engine may produce a large interfering signals. This will generate the error waveform (Yunpeng, 2005). Therefore, the speed signal used shaping circuit

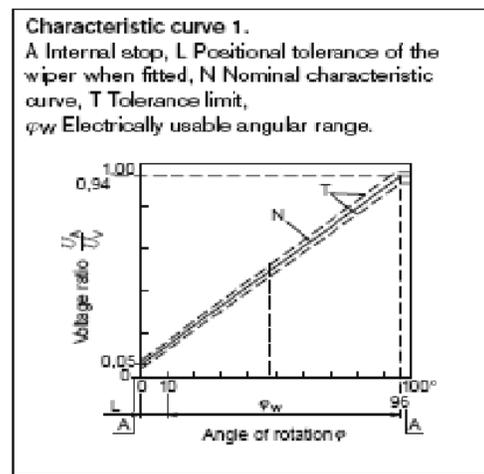


Fig. 3: Working Characteristics of the Sensor

which is characterized by a positive feedback loop. Positive feedback to the comparator circuit can improve the anti-jamming capability of the circuit. Its signal processing circuit was shown in Fig. 2. The engine speed was calculated by a time interval of the two pulse signal and calculated by the formula (1) as follows:

$$n = 30 / [(N \times 65536 + T_2 - T_1) \times 0.000016] \quad (1)$$

**Working characteristic of the throttle position sensor and processing circuit:**

The system used a throttle position sensor of BOSCH 0280122201 (Ma, 2010), the basic working principle of an active contact on the resistor body sliding resistance value changes caused by the change in output voltage, which can be measured corresponds to throttle opening (Wang, 2008).

Figure 3 showed the output characteristics of the sensor. Between 0~5V, the output voltage of the throttle position sensor changes its signal filtered to the A/D converter and processed by the ECU. The throttle position sensor processing circuit was shown in Fig. 4.

**Cylinder Temperature measuring principle and signal processing:**

The best temperature of the engine

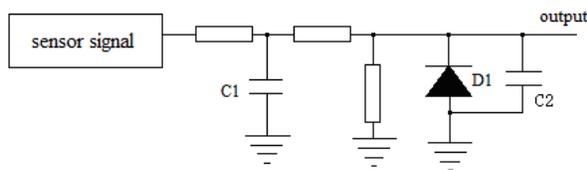


Fig. 4: Throttle position sensor processing circuit

cylinder block was between 80°C~90°C because most performance indicators of the engine may be best in that temperature range. Such as the combustion in each cylinder, the fit clearance between various parts, the best dynamic and so on. The temperature of engine cylinder has an important effect on the performance of the electronically controlled system. The fuel injection and the ignition timing were corrected according to the cylinder block temperature, which made the engine work stably under various working conditions. For example, when the engine works in the state of the cold start and warming-up, it need more fuel than that in the a heat state. So the ignition timing should be in advance. Therefore the cylinder temperature sensor should be installed to measure the cylinder temperature which was used as the correction signal of the ignition timing. The cylinder temperature has a very important significance on the engine control system. Therefore, the cylinder temperature was selected as one of the correction signal.

Most of the NTC thermostat semiconductors are the spinel structure or other structure of the oxide ceramic and they have a negative temperature coefficient. Resistance values can be expressed as the following formula (2):

$$R_T = R_{T_0} \times \exp[B_n(1/T - 1/T_0)] \quad (2)$$

In which,  $R_T$  and  $R_{T_0}$  was expressed respectively the resistance value of temperature  $T$  and  $T_0$  and  $B_n$  is a material constant. Ceramic grain results from the resistivity change due to the temperature change, which is determined by the semiconductor properties (Zhou, 2008). The thermostat is used for sensing temperature.

Therefore, once a steady current is given to the thermostat, two ends of the measuring resistor will get a voltage. The temperature can be calculated by the following formula (3):

$$T = T_0 - K.U \quad (3)$$

In which,  $T$  is the measured temperature,  $T_0$  the temperature parameter about thermistor characteristics,  $K$  the coefficient about thermistor characteristics and  $U$  two ends of thermistor.

According to the formula (3), if we can measure thermal voltage across the resistor and know the parameters  $T_0$  and the coefficient  $K$ , then we can calculate the thermal resistance and ambient temperature which is the measured temperature. The relationship of resistance varies with temperature changes into the relationship of the voltage varies with temperature. Conditioning circuit was shown in Fig. 5.

In the pre-measurement signal channel circuit, the amplifier is a very important part. The amplifier will directly affect the authenticity and reliability of the sampling data. The system uses the AD620 amplifier (Zhang, 2009). AD620 amplifier has high accuracy, easy to use, low noise characteristics and the gain range from 1 to 1000. The voltage signal of cylinder temperature put in amplifier AD620 from pin 2 and pin 3, between amplifier AD620 pin 1 and pin 8 was connected to one resistance to adjust the magnification. The relationship between the variable resistor  $R_G$  and the gain  $G$  of the AD620 is expressed by the formula (4):

$$R_G = 49.4K\Omega/G - 1 \quad (4)$$

According to the formula (4), if the gain is valued 100, the resistance of the resistor  $R_G$  will be 500Ω.

**Influence of battery voltage on ignition performance:** The battery voltage has an important influence on the ignition timing. The change of the

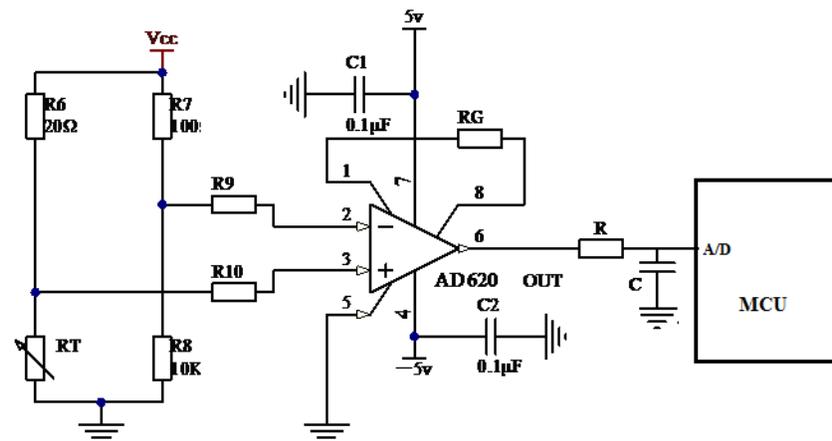


Fig. 5: Temperature processing circuit

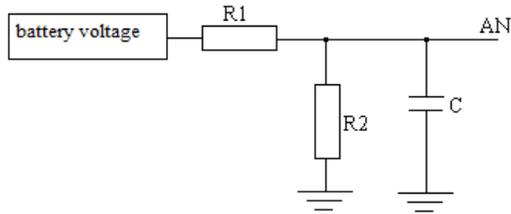


Fig. 6: Battery Voltage Signal Processing Circuit

voltage may cause the ignition timing to be advance or to put off.

The battery voltage was generally up to 14V. And when it was powered on, the voltage may drop to 8V. The voltage in that range can not be sent directly to the microcontroller A/D converter to implement conversion. So it should be converted in the range of 0~5V. And then the battery voltage signal was sent into A/D conversion pin after antihypertensive treatment. The battery voltage signal processing circuit designed was shown in Fig. 6, in which resistors R1 and R2 formed a voltage divider circuit. The voltage will be kept in the range of 0~5V through the circuit.

**Ignition drive circuit:** Switch transistor was used to control the primary ignition coil. When it was turned off, a high voltage will be generated in the secondary coil, which enabled the spark plug breakdown and discharge. The switch speed will affect the secondary voltage. The switch transistor of IGBT has the advantages of small drive power, low saturation voltage, high voltage resistance and fast switch speed, so the IGBT was selected in this study. The ignition drive circuit was shown in Fig. 7.

The optocoupler component was used to isolate the microcontroller from the ignition driver circuit, which may make the microprocessor system have a strong anti-jamming capability.

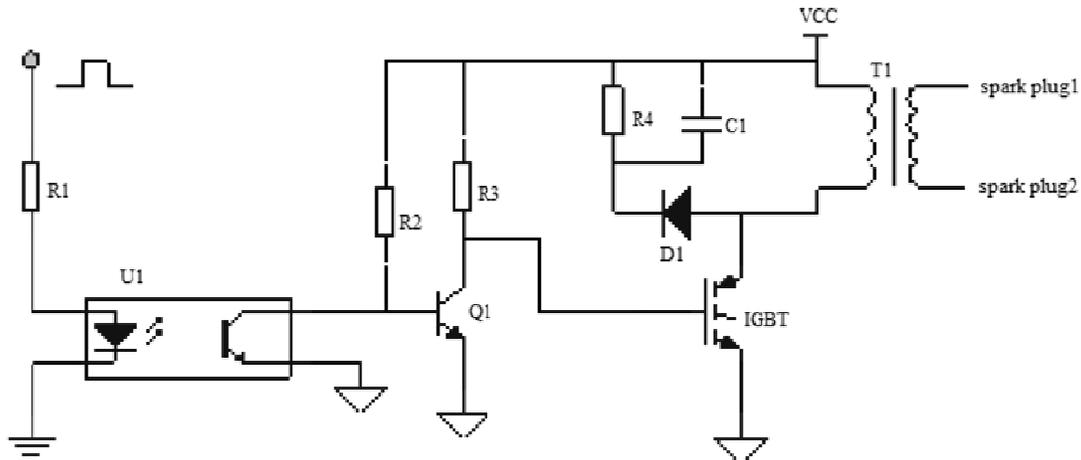


Fig. 7: Ignition drive circuit

## SYSTEM SOFTWARE DESIGN

The ignition controller used serial communication circuit between the host and slave computer. System software design included the host computer program, slave computer program and serial communication program design. Serial communication was mainly to complete the data transmission, including monitoring data, modification and reading the MAP data.

**Basic requirement of the system design:** There are four basic requirements in the process of the system design.

- The system reliability is the primary measurement index, which is determined by the harsh nature of the operation characteristics of continuous operation the control scene
- The scalability of the control system, namely, the system may control a variety of different signals and process different parameters
- Good adaptability to environment, namely, the system should have the property of shockproof, damp-proof, anti-impact and so on. In addition, it should be taking into account the real-time and reliability in poor working conditions.

**Requirements for the system microcontroller:** Considering that there are many influence factors for the system design, such as variety of sensors, some required processing signals, a large amount of computation, real-time requirements. So the following factors should be considered in the selection of the microcontroller.

- The internal bus frequency is high enough
- The data memory, program memory and storage capacity are large enough to be able to store

programs and data, such as the ignition advance MAP angle and the close angle MAP

- A/D conversion channels are rich enough to collect the battery voltage, temperature signal and throttle position signal and so on and the data acquisition precision should meet the requirement of the system
- There are rich interrupt sources and interrupt priority, which may make the right judgment and response to various events timely
- The chip should have a high interference immunity, high temperature resistance and stability for its poor working environment

**Selection of the MCU:** Comprehensive consideration for the above requirements and commonly used chip laboratory, the 8-bit microcontroller C8051F020 was selected in this study. And the data in its RAM can be modified in real time when the program is running. The chip has a wealth of peripherals and the interrupt sources and has strong anti-jamming capability and is suitable for the system design. In addition, C8051F020 MCU has the following characteristics.

- It has two 8-channel A/D converter modules with 8/10 bit accuracy, in which ADC1 is the type of the eight bit successive approximation converter and its conversion rate is programmable up to 500ksps. The channel may be selected by the analog multiplexer
- The two 12-Bit D/A converters were used to convert the 12-bit digital quantity to the voltage. And they can produce the continuous changed waveforms and its two-way output signals may be synchronized
- C8051F020 MCU has three kinds of serial port and it includes SMB serial bus interface, SPI serial bus interface and two enhanced UART asynchronous serial interface. Three serial interfaces may communicate with the peripherals with the serial communication.

**Software design of the slave computer:** The MCU chose in this study supported the C programming language. Compared with the assembly language, C language has the advantage of the strong source code readability, rich library functions, good portability and easy to modify and so on. Therefore, the study chose C language to program. The software developed in this study used the idea of modular and included 3 modules and it included the main program, the host computer software and the slave computer software. The main program is the center module of the whole software, including initialization after the system was powered on and a main loop-body.

The entire program started from the main function after the system was powered on. And the main function

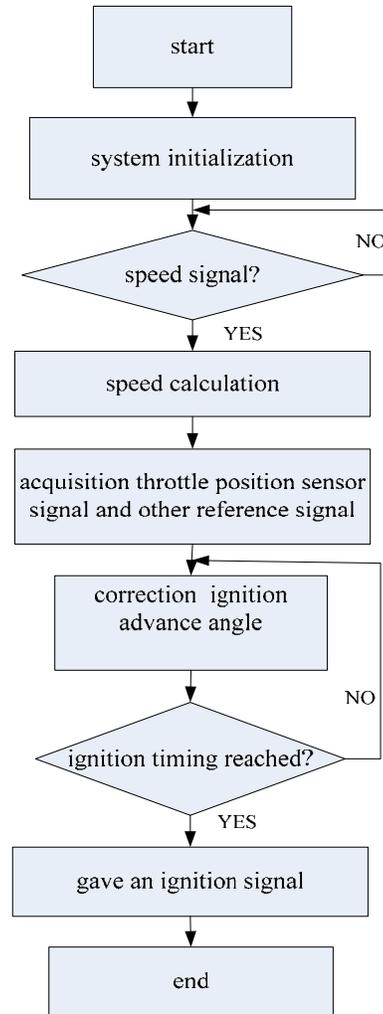


Fig. 8: Main program flow chart of the system

called other functions to run. Specifically, the functionality of the initial program include initialization of all sampling and related variables, system clock setting, internal microcontroller module control register settings, such as A/D conversion system, timers and interrupt enable function. Figure 8 was the main program flow chart of the system and Fig. 9 is measurement speed calculation subroutine flowchart.

**Software design of the host computer:** Real-time monitoring the operating conditions and ECU internal data information of the system may help people to judge, evaluate, analyze and research the operating effect and the existing problems of the system. The results facilitated to improve and adjust timely the controller according to the field test situation. Therefore, the host computer monitoring program was developed by using the software of Lab VIEW. And its main function was to draw the curve of the throttle, speed and voltage signal versus time for real-time monitoring the

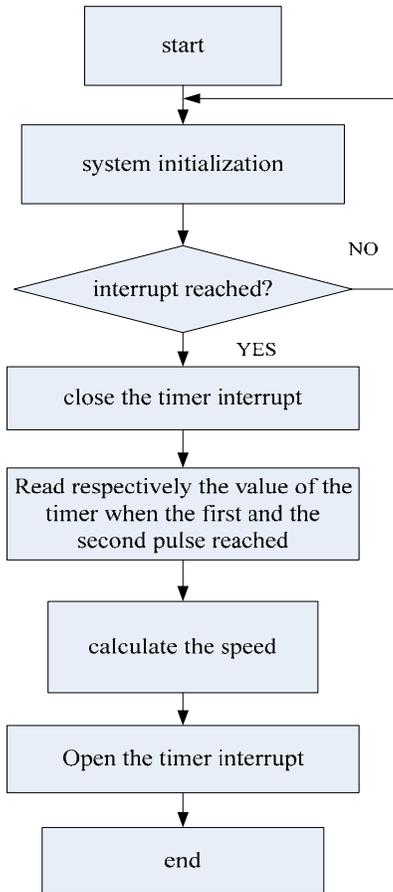


Fig. 9: Speed measurement program flow chart

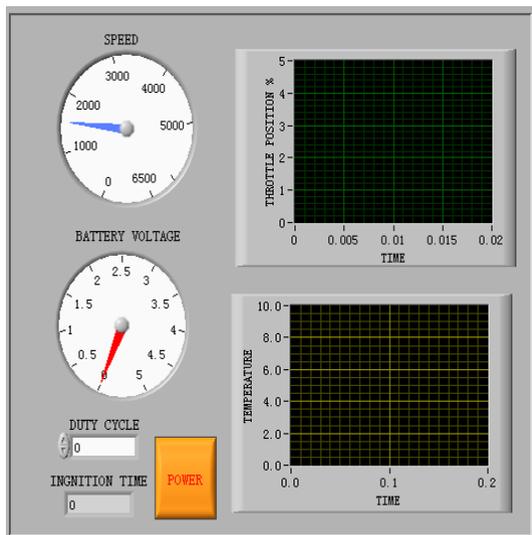


Fig. 10: host computer data monitoring interface

operating parameters of the system. In addition to the basic functions, it also can exchange data with the slave computer and control the slave computer. The host computer data monitoring interface developed in this study was shown in Fig. 10.

**Serial communication of the system:** The serial communication module was mainly used for communication between the ignition controller and the host computer. The communication data included two parts, one was the data that the slave computer sent to the host computer such as ignition advance angle, dwell angle, battery voltage and so on, the other part was the data that the slave computer received from the host computer to modify the ignition advance angle and dwell angle.

The Lab VIEW library provided serial communication function, which was used to design serial communication between the host and slave computer. Lab VIEW provided a powerful VISA library, which (the Virtual Instrument Software Architecture) was a general term of the standard I/O function library and its relevant norms that were used for instrument programming. VISA library was used to realize the computer program control for the instrument in the virtual instrument environment.

The serial communication protocol between the host computer and the slave computer was provided in this study. The protocol content setting included baud rate 9600, no parity check, data bits 8, stop bit 0 and user-defined software handshaking. The setting of the host computer was completed through the VISA Configure Serial Port functions.

The baud rate of the slave computer was determined by the timer mode control register of TMOD, the serial port control register SCON and PCON. In this study, the timer 1 was selected to control the baud rate. The working mode was set as mode 2. The oscillation frequency of the quartz crystal was 11.059MHZ. The serial communication mode was set as operating mode 1. The baud rate was calculated by the formula (5):

$$\text{Baud rate} = \frac{\text{oscillation frequency of the quartz crystal}}{[32 \times 12(256 - TH1)]} \quad (5)$$

In which, the TH1 is the value of the register of the timer1. According to the formula (5), the register of TMOD was set as 20H, SCON 50H and PCON 00H. Figure11 was the system serial communication interrupt subroutine flowchart.

## EXPERIMENT

In this study, we made an experiment on to test the stability of the system. The Fig.10 and 11 were the drive signal of the ignition system with same analog engine speed. And at the same time, changing the temperature or throttle position or other parameters, the system may gave the different ignition drive signal with different duty cycle that was corrected according to the correction parameters.

Figure 12 provided the ignition drive signal when the engine speed was 5300r/min and the duty cycle was

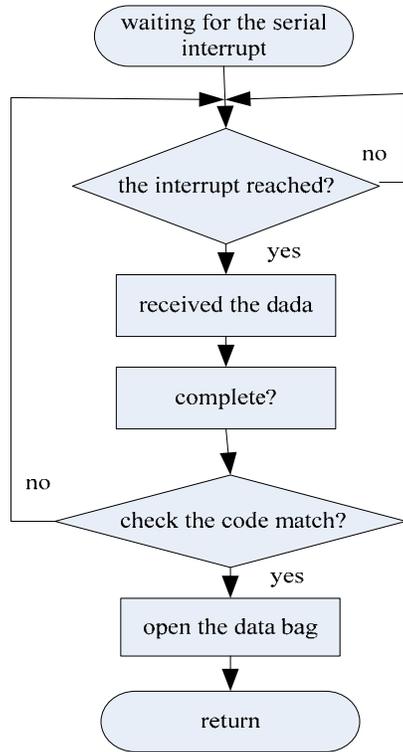


Fig. 11: Serial communication sub-program flow chart



Fig. 12: Ignition drive signal when duty cycle 20 and speed 5300 r/min



Fig. 13: Ignition drive signal when duty cycle 30 and speed 5300 r/min



Fig. 14: Ignition drive signal when duty cycle 30 and speed 4300 r/min

set as 20. When the engine speed kept invariant and the duty cycle was revised as 30 by the host computer, the

slave computer will output the different ignition drive signal, which was shown in Fig. 13. When the analog speed was 4300 r/min and the duty cycle was 20, the ignition drive signal shown in Fig. 14 was different from the Fig. 12.

The experiment results showed that the ignition system developed in this study was reliable, the developed software of the host and slave computer meet the requirement and it reached the expected requirement.

## CONCLUSION

In this study, the cylinder block temperature signal, throttle position signal and power supply voltage signal were selected as the correction references for the ignition advance angle and an electronic control ignition system based on Lab VIEW and micro-controller was developed. The experiment results showed that the designed sensor signal processing circuits had a good anti-jamming performance, the system can accurately control the ignition and the data communication between the slave computer and the host computer can reach the expected requirement. The research results provided a foundation for the further study.

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