

DESIGN AND IMPLEMENTATION OF AN AUTOMOBILE ENGINE TESTER BASED ON TYPE MC9S12XET256 MCU

Miaozhong SUN^{1,*}, Yin LEI¹, Weihao ZHOU¹, Qiao WEI¹, Feifei SONG¹

*As the engine is a key power device of automobile, automobile engine testers are necessary to be explored to test the engine's performance parameters in order to evaluate the running conditions. Based on the Freescale MC9S12XET256 microcontroller unit (MCU), an automobile engine tester is developed through designing the hardware circuits and the software. This tester is able to measure and display simultaneously eight performance parameters of engine sensors and one parameter of electrical device on a liquid crystal display (LCD) of 240*320 resolution ratio through programming the Analog to Digital (A/D) module and the ILI9325 chip drive interface. The system software interface, the programming flow chart and the main programming codes are described. The designed tester is verified to be reliable through testing relative sensors on an electronic control experimental rig of PASSAT automobile.*

Keywords: Microcontroller Unit (MCU), Automobile Engine Tester, Sensor, Data Acquisition, Liquid Crystal Display (LCD)

1. Introduction

The engine is one of the key parts of the automobile, and it is the motive power device called 'the heart'. Therefore, it is necessary to test the comprehensive performance parameters of the engine in order to evaluate the maintenance effects of the whole vehicle. The automobile engine tester is important equipment for the fault diagnosis and maintenances of the engine. It can test and analyze the various parameters of the engine electrical parts [1, 2].

With the rapid development of China's automobile industry, microcomputer control technology is widely used in automobiles; therefore, fault diagnosis level on automobile electronic control systems is getting higher and higher in aspects of the maintenance technologies. It is very difficult for the traditional methods of vehicle maintenance to challenge the new technologies. Today, automobile testers have been developed into comprehensive testing and analysis instruments that possess a wide range of testing contents [3, 4]. In foreign

¹ College of Mechanical Engineering, Tianjin University of Science & Technology, Tianjin Key Laboratory of Integrated Design and On-line Monitoring for Light Industry & Food Machinery and Equipment, Tianjin 300222, PR China. E-mail: sunmzh66@sina.com.

countries, the work on automobile engine testers started earlier, and their designed testers have been used widely in automobile maintenance areas. But in China, the research on automobile engine testers is still in the preliminary stage. At present, according to the kinds of the operating platforms, there are two kinds of testers, one is the PC type tester and the other is the portable microcontroller type tester. The PC type tester is a computer type engine tester based on a center personal computer, which carries out testing functions through testing interface modules and testing programs. It is able to be developed into an ignition displayer and an automobile multi-meter that has almost all testing functions. This kind of PC type instrument can process data and real-time signals more lively and richly, becoming a kind user interface to be operated more easily. In addition, it can achieve the online help and the data automatic analysis from the system equipped with the automobile database, and also can process automatically the testing data to make the engine fault analysis simple and exact [5, 6, 7]. But this kind of tester is very inconvenient to carry and operate because of its big volume and weight. Therefore, it is necessary to explore a new small and portable automobile tester that will bring a wide market prospects in China [8, 9].

Microcontroller unit (MCU) is a microcomputer system of large-scale integrated circuits assembling central processing unit (CPU), program memory (ROM), data memory (RAM), a variety of I / O interfaces, timer / counter, interrupt system and other function components such as A/D, D/A, etc.[10].

Freescall microcontroller core MC9S12X is mainly based on the enhanced 16 bit CPU including the calculating logic unit, control unit and a set of registers. It also includes three kinds of memories (Flash, RAM, EEPROM), voltage regulator, and single line background debugging module (BDM), phase-locked loop (PLL), reset generation module and running monitoring module, watchdog module, page mode control module of program memory, and a synthesis system of control functions such as interrupt timer, interrupt management, read and write control, operating mode, and I/O interface (for bus extension) that can be used for parallel input and output. Freescall Company offers a wide range of products and new developed products, also offers overall and clear products for automobile electronic control systems [11].

In this paper, an automobile engine tester is designed, which is mainly composed of the Freescall microcontroller MC9S12XET256 and a liquid crystal display (LCD). The tester can process nine channel signal synchronization acquisition and their data display on the LCD. It can display the performance parameter voltages of automobile engine electrical parts, such as intake air temperature sensor, oxygen sensor, air flow sensors and throttle position sensor, etc. The designed tester with the MC9S12XET256 MCU is very small, easy to carry, and has a strong ability of anti-interference, very suitable for popular testing.

2. Design of Hardware

Many sensors are mounted on the electronic control system of automobile engine such as air flow sensor, throttle position sensor, cooling water sensor, intake temperature sensor, crankshaft position sensor and knock sensor, etc. These sensors and other electrical devices output analog signals in 0-5V voltage scope corresponding to voltage scope of A/D data acquisition module in the freescale MCU. Therefore, the output signals of sensors and electrical devices needn't be amplified or attenuated to be connected with the port of A/D module.

System Framework. The system framework of the automobile engine tester includes three main parts: the MCU minimum system circuit, the A/D data acquisition Module circuit and the liquid crystal display circuit, based on a MC9S12XET256 center control chip. The MCU samples simultaneously nine channel analog signals and converts them to digital signals; finally output their data results to the liquid crystal display (LCD). Fig.1 shows the system framework of the automobile engine tester.

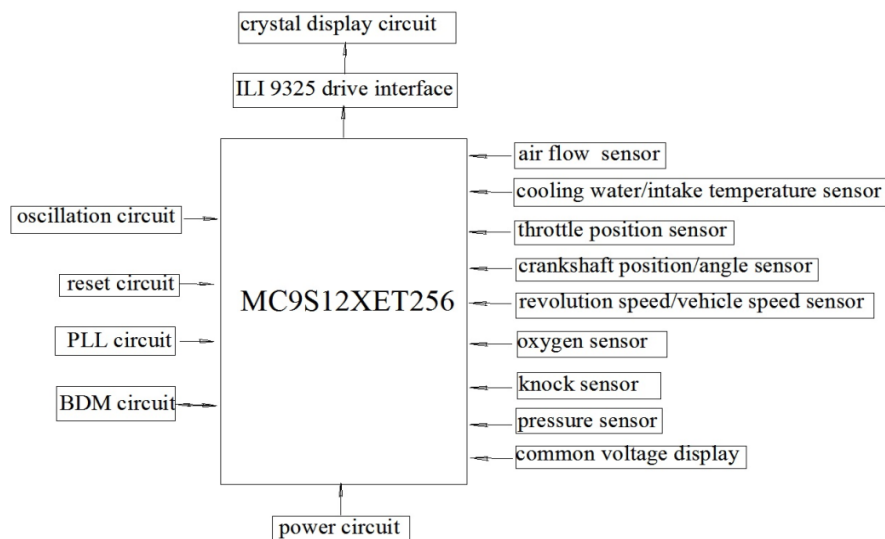


Fig. 1 the system framework of the automobile engine tester

3. Design of the System Circuit.

Circuit of the Minimum MCU System. MC9S12XET256 type MCU belongs to S12 series microcontroller unit of the Freescale semiconductor corporation, which possesses 16 bit CPU, 25MHz bus clock frequency, 64KB Flash memory, 4KB RAM, 1KB EEPROM, 91 pins of I/O, 16 channel 8/10/12 bit A/D module, 8 channel 8 bit ECT, 112 pin LQFP package, high effective programming and background debug functions, etc. The minimum system of MCU mainly

consists of the center CPU, reset circuit, oscillation circuit, BDM circuit, PLL circuit, power circuit [12] as seen in fig. 2.

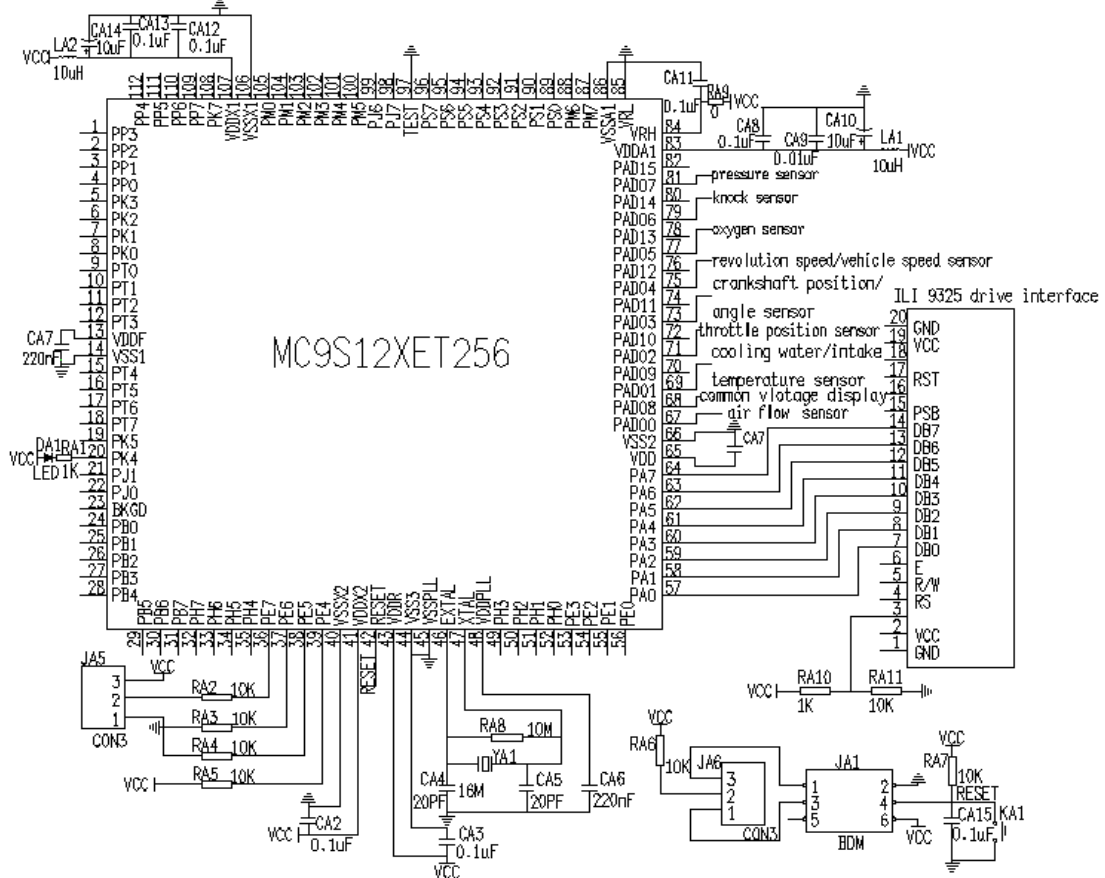


Fig. 2 the system circuit diagram (including the minimum system)

A/D Data Acquisition Module. The A/D module of MC9S12XET256 MCU uses the mode of successive approximation, which has such functions as 16 channel analog signal input, 8/10/12 bit converting precision, multichannel data continuous acquisition, single converting and continuous converting modes. Analog signals can be input into the MCU through the 16 channels of the PAD port in 0-5V voltage scope. The A/D module possesses up to 27 registers that mainly include ATDCTL0-ATDCTL5 control registers, ATDDIEN input enable register, ATDSTAT0 state register, ATDSTAT2 state register and ATDDDR0-ATDDDR15 result register [13]. Nine channel continuous data acquisition can be carried out by setting the above registers in this system.

Liquid Crystal Display Module. A thin film transistor (TFT) liquid crystal display with resolutions of 240RGBx320 dots is used in this system platform which links to a single chip driver ILI 9325. ILI9325 has four kinds of system interfaces

which are i80-system MPU interface (8-/9-/16-/18-bit bus width), VSYNC interface (system interface + VSYNC, internal clock, DB[17:0]), serial data transfer interface (SPI) and RGB 6-/16-/18-bit interface (DOTCLK, VSYNC, HSYNC, ENABLE, DB[17:0]). In this system, ILI9325 adopts the MPU interface (8 bit bus width) [14,15]. The ILI9325 drive interface with 20 pins is revealed in the left side of the Fig. 2. Table 1 lists the meaning of each pin of ILI 9325. The DB0-DB7 pins respectively link to the PA0-PA7 port of the MCU to transmit the data.

Table 1

The Meaning of Each Pin of ILI 9325

Pin	Pin name	Meaning	Pin	Pin name	Meaning
1	GND	Ground	15	PSB	Parrel/Serial selection
2	VCC	Power voltage	16		Null
3		Component voltage input	17	RST	Restart
4	RS	chip selection	18	NC	Null
5	R/W	Read/Write	19	VCC	Power voltage
6	E	Null	20	GND	Ground
7-14	DB0-DB7	Data0-7			

4. Design of the System Software

Software Framework. This tester system software mainly consists of three parts: data acquisition program, liquid crystal display program and main program. The data acquisition program aims to get the digits of AD0-AD8 channel signals with the help of A/D conversion. The liquid crystal display program realizes the interface display on the TFT displayer with different colors and specified characters. The main program includes the PLL module initialization, the A/D module initialization and the display module initialization etc. Fig.3 shows the system software framework.

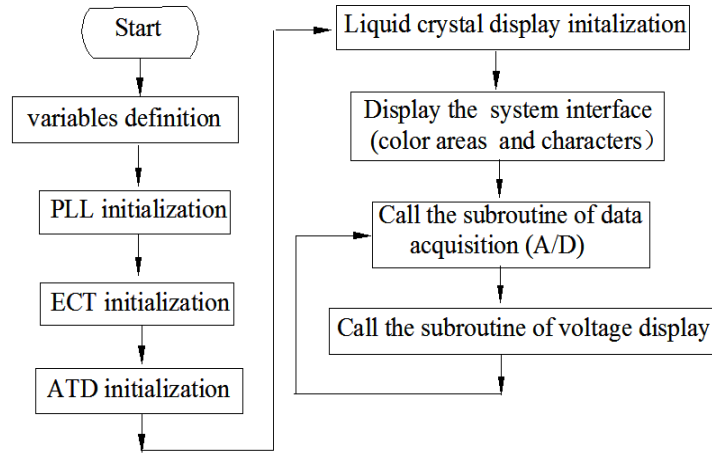


Fig. 3 the System Software Framework

5. Main Module Initialization

A/D Initialization Programming. A/D initialization programming codes are listed and explained as followed.

```
Void INIT_AD (void)
```

```
{ ATD0CTL2 = 0x40; //start A/D, clear zero, disenable interrupt.
```

```
ATD0CTL1_SRES = 0; //select 8 bit A/D conversion.
```

```
ATD0CTL3 = 0xC8; //nine channel conversion at each time, right alignment.
```

```
ATD0CTL4 = 0x01 ;} //set A/D clock frequency 8MHz.
```

Liquid Crystal Display Initialization Programming. In programming, a function named void ILI9325_Initial(void) is used to initialize the liquid crystal display, and a function named void Show_RGB (unsigned int x0,unsigned int x1,unsigned int y0,unsigned int y1,unsigned int Color) is also used to show a color of rectangle area. In the function, x0 and x1 indicates respectively the starting horizontal coordinate and the end horizontal coordinate, y0 and y1 denotes respectively the starting vertical coordinate and the end vertical coordinate. Owing to the resolutions of 240RGBx320 dots of the liquid crystal display, the pixel dots of the horizontal coordinate and the vertical coordinate are respectively 0-239 and 0-319. Color expresses the value of displaying color. Fig. 4 shows the definition of Color value. Two bytes are used to determine the Color. The high 5 bits of the high byte represent the red color and the low 3 bits represent the green color. The high 3 bits of the low byte represent the green color and the low 5 bits represent the blue color. For example, the hexadecimal numeral of the blue color can be written as 0x001F, that is 31. If other colors need be selected, the Color values are only

changed. Maximum 65536 kinds of colors can be displayed through mutual combination of red, green and blue.

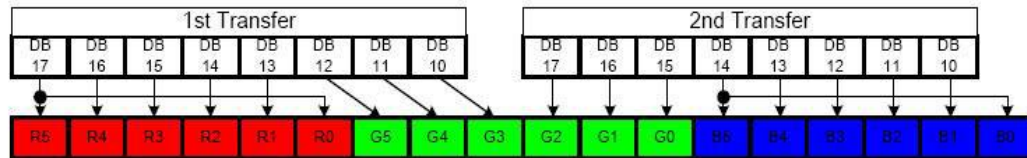


Fig. 4 the definition of Color value

A function named `Void ILI9325_Initial (void)` is called whose programming codes for initializing the ILI 9325 port are listed as follow.

```
Void ILI9325_Initial (void)
```

```
{CS_dir = 1; RS_dir = 1; RW_dir = 1; RD_dir = 1; RES_dir = 1;
DataPort_dir = 0XFF; CS = 1; RES = 1; RS = 0; RW = 1; RD = 1} // define each
function pin.
```

A function named `show_RGB` is called to realize the color background area display by using horizontal, vertical coordinate and color to be input.

```
Void Show_RGB (unsigned int x0, unsigned int x1, unsigned int y0,
unsigned int y1, unsigned int Color) //x0 is a beginning horizontal coordinate, x1 is
an end horizontal coordinate, y0 is a beginning vertical coordinate, y1 is an end
vertical coordinate. Color is an input variable of color.
```

```
{Unsigned int i, j; //Define integer i,j.
```

```
LCD_SetPos (x0, x1, y0, y1); //Call a function to decide a color background
area
```

```
For (i = y0; i <= y1; i++) //Circle vertical coordinate.
```

```
For (j = x0; j <= x1; j++) //Circle horizontal coordinate.
```

```
Write_Data_U16 (Color); //Call a function to decide color display.
```

Design of the Software Interface. The software interface is designed to present like Fig. 6. It consists of three areas: the top area of the tester subject and the institution, the middle area of common electrical part voltage display and the under area of eight channel engine sensor voltage display.

(1) The top area is designed with 240*60 dots and cyan background. From (8, 10) coordinate, a title labeled 'AUTOMOBILE ENGINE TESTER' is displayed with white characters and blue background, and from (20, 28), (20, 42) coordinate, two titles named 'Vehicle Engineering and Tianjin Uni of Sci & Tech' are showed with yellow characters and magenta background.

(2) The middle area is formed with 240*22 dots and blue background. From (5, 64) coordinate, the ninth channel labeled 'Common Voltage Display' is displayed with red characters and green background.

(3) The under area is the main part of eight channel engine sensor voltage display, which is designed with 240*235 dots and red background. On the background, from eight coordinates i.e. (20,104), (20,122), (36,136), (20,154), (36,168), (20,186), (36,200), (20,218), (36,232), (20,250), (20,268), (20,286), eight sensor names are displayed with white characters and blue background. On the right sides of each sensor name, sampled digital voltages are showed with red characters and cyan background.

A function named LCD_PutString is used to output color characters and their color background in a defined area. Main programming codes for forming color background and character output in the system interface as seen in Fig. 6 are listed as follow.

Show_RGB(0,239,0,60,Cyan); //240*60 dots and Cyan background area output.

LCD_PutString(8,10," AUTOMOBILE ENGINE TESTER ",White,Blue);
// From (8,10) coordinate, display AUTOMOBILE ENGINE TESTER with white color and blue background.

```
LCD_PutString(20,28," Vehicle Engineering ",Yellow,Magenta);
LCD_PutString(20,42,"Tianjin Uni of Sci & Tech",Yellow,Magenta);
Show_RGB(0,239,61,83,Blue);
LCD_PutString(5,64,"Common voltage display",Red,Green);
Show_RGB(0,239,84,319,Red);
Show_RGB(10,229,94,309,Yellow2);
LCD_PutString(20,104,"1.Air Flow Sensor:",White,Blue);
LCD_PutString(20,122,"2.Cooling Water/Intake",White,Blue);
LCD_PutString(36,136,"Temp Sensor:",White,Blue);
LCD_PutString(20,154,"3.Throttle Position",White,Blue);
LCD_PutString(36,168,"Sensor:",White,Blue);
LCD_PutString(20,186,"4.Crankshaft Position/",White,Blue);
LCD_PutString(36,200,"Angle Sensor:",White,Blue);
LCD_PutString(20,218,"5.Revolution speed/Vehicle",White,Blue);
LCD_PutString(36,232,"Speed Sensor:",White,Blue);
LCD_PutString(20,250,"6.Oxygen Sensor:",White,Blue);
LCD_PutString(20,268,"7.Knock Sensor:",White,Blue);
LCD_PutString(20,286,"8.Pressure Sensor:",White,Blue);
```

6. Experimental Validation

The designed automobile tester is tested on an experimental rig of electronic control system of PASSAT automobile which mounts its relevant engine sensors and electrical parts. Three sensors and one electrical part are connected with the tester by using A/D wires. The automobile runs at the idle condition. Fig. 5 shows the case of testing and voltage values of relevant sensors. These values are precision and reliable because the rig has been tested strictly by the manufacturer. So the testing results can be compared with them.

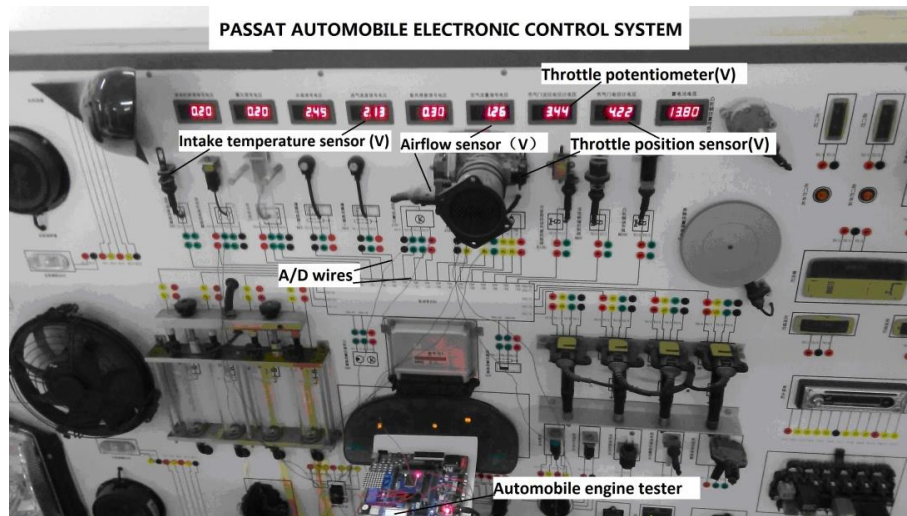


Fig. 5 the testing case of the experimental rig of PASSAT automobile electronic control system

In order to valid the reliabilities and effects of the tester, it is used to measure the parameters of some engine sensors and electrical parts on the experimental rig. AD0, AD1, AD2, AD8 channels of the tester respectively link to the airflow sensor, the intake temperature sensor, the throttle position sensor and the throttle potentiometer (an electrical part) with eight wires as seen in Fig. 5 (names marked). Fig. 6 display the testing interface when the rig runs at the idle condition.



Fig. 6 the testing interface

In the Fig.5, the voltage value of the airflow sensor is 1.260V, the intake temperature sensor's is 2.130V, the throttle position sensor's is 4.220V and the throttle potentiometer's (common voltage display) is 3.440V. Table 2 lists the data of the rig, the tested data and their comparison errors

Table 2

The Data of the Rig, the Testing Data and Their Comparison Errors

Sensor	Airflow sensor(V)	Intake temperature sensor (V)	Throttle position sensor(V)	Throttle potentiometer(V)
Experimental rig display	1.260	2.130	4.220	3.440
Tester Display	1.236	2.272	4.236	3.600`
error (%)	1.905	6.667	0.379	4.651

According to the results of the table 2, the maximum error is 6.667%, the others are respectively 1.905%, 0.379% and 4.651%. Therefore, the designed tester is approved to be reliable and effective that it can be used to measure the performance parameters of automobile engine sensors and electrical parts.

Conclusions

In view of shortcomings of high weight and inconvenient carry of PC type automobile engine tester, a set of automobile engine tester has been designed and implemented by using C language and constituting the hardware of the Freescale MC9S12XET256 MCU and the TFT liquid crystal display with resolution of 240RGBx320 dots. It can sample simultaneously night channel signals of the engine sensors and the common electric part, and display accurately their digital voltages in order to evaluate rapidly the running conditions of the automobile electrical parts. In the software design, the key programming problems of A/D data acquisition and liquid crystal display drive interface have been solved successively, and the software interface of the tester has been carried out to be operated easily. Finally the designed tester has been tested on the experimental rig of the PASSAT automobile electronic control system. The data results have proved that this tester is reliable.

Acknowledgements

This work was supported by the college student laboratory innovation foundation of Tianjin University of Science and Technology under grant No.1601A105.

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