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Simulation Design of DC Motor Control System Based on MC9S12D64 MCU

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ABSTRACT
In order to simulate motion condition of industry motor such as automobile air-conditioning motor, automobile idle valve motor and automobile water cooling motor etc., hardware and software simulation design of direct current (DC) motor control system are carried out based on MC9S12D64 MCU in this paper. Through analyzing and comparing a sampled voltage data, MCU controls a DC motor to rotate or not to rotate, and give an alarm with a buzzer and a red LED light according to requests. The scheme of hardware circuit is performed. The programming flow chart and the main programming codes are presented. This system is proved to be reliable by an experimental rig.
Keywords - MC9S12D64, analog voltage, pulse width modulation, motor control, programming

I. INTRODUCTION

At present, Motor is one of the electromechanical devices that applied most widely in field of industry. There always exists an important topic that technicians explore how to control the motor. With regard to the motor control way, the traditional way is to use analog devices to control the motor. Although the control system that consists of these analog devices is uncomplicated and possesses a low cost, its reliability is not high and it is difficult to upgrade its devices. Therefore, motor digital control systems have been exploited and applied gradually through embedded microcontroller units in recent years [1-5]. YAO Jin et al [3] described the technical keys of circuits of outside equipment in the control of electric motors that guided loading ROM,A /D element of converting, interfaces of sensors and so on. MENG Qingbin et al [4] realized the three phase six step PWM control of the brushless DC motor. ZHAO Xin et al [5] introduced that the control system and the return to zero control system were debugged on the developed combination vehicle instrument. In this paper, based on MC9S12D64 MCU an experimental rig is exploited which assembles a module of analog voltage sampling, a data display module of five nixie tubes, a module of DC motor driver circuit and an alarm module for motor start and stop (buzz or flash).The programs to perform all kinds of functions of the above modules are debugged successfully, forming a big powerful system software. This DC motor control system is able to simulate perfectly running conditions of industry motor. The experimental rig is specially fit for integrative experiment teaching of motor control in universities [6].

II. MOTOR CONTROL SCHEME

In order to perform the common running condition of industry motor, a scheme is carried out as follows: an analog voltage is sampled to achieve a digit to be input into MCU memory and to be displayed with five nixie tubes. The MCU PWM function is used to output an assigned frequency impulse signal of certain duty ratio to control the motor speed. The duty ratio is equal to the sampled voltage that is able to be adjusted by a rheostat through a rotary knob. A voltage threshold value is set to be 1000mV to decide whether the motor runs or does not run. If the sampled voltage is greater than the threshold value, the motor runs. At the same time, the buzzer and the red LED light is not working. On the contrary, the motor don't run, the buzzer and the light is alarming.

III. SYSTEM HARDWARE DESIGN

The MC9S12DJ64 MCU is a 16-bit device composed of standard on-chip peripherals including a 16-bit central processing unit (HCS12 CPU), 64K bytes of Flash EEPROM, 4K bytes of RAM, 1K bytes of EEPROM, an 8-channel IC/OC enhanced capture timer, two 8-channel, 10-bit analog-to-digital converters (ADC), a 8-channel pulse-width modulator (PWM), a 8-channel IC/OC enhanced capture timer,11 I/O ports including 91 I/O pins etc. The MC9S12DJ64 has a function of background debug module. With the help of this function a compiled program of C language can be downloaded easily to the MCU flash memory. The MCU PLL circuit allows power consumption and performance to be adjusted to suit operational requirements [7].
The motor control system consists of these parts as follows: MC9S12D64 MCU, oscillation circuit, reset

circuit, BMD circuit, power circuit, buzzer circuit, red LED light circuit, motor driver circuit, voltage sampling module and five nixie tubes display module etc. Figure 1 shows the framework of the motor control system.
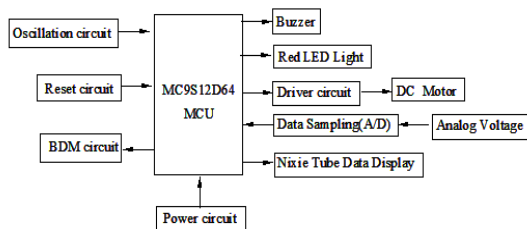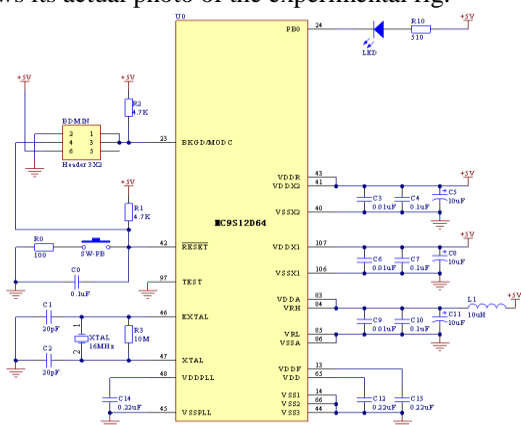

Fig.1 Frame of motor control system

3.1 Minimum System Circuit

The Minimum system is made up of a reset circuit, an oscillation circuit, a BMD circuit and the MC9S12D64 MCU in order to perform normal working of the motor control system [8]. Figure 2(a) displays the minimum system circuit and figure 2(b) shows its actual photo of the experimental rig.

(a)   Minimum system circuit

(b) Actual photo of minimum system
Fig. 2 MC9S12D64 minimum system

3.2 Circuit Module Design and Total System Circuit
(1) DC motor control module

A type SA60 chip that developed by the America Apex company is used in the motor driver part. SA60 is a PWM type chip that is able to offer maximum 80V power voltage for the motor and provide continuously a 10A current for the load. Its maximum analog voltage is 5V and its PWM carrier wave frequency can reach 250 kHz. S60 chip has been applied mainly in field of middle or little type DC motors. A type AVC roller DC motor made in Taiwan is selected. The motor speed can be controlled by average voltage of a PWM signal that is produced by the MC9S12D64 MCU and is applied to the motor. Fine speed adjustment will be obtained through less than 2 kHz PWM frequency and less than 1000 rpm motor rotation speed. The PP5/KWP5/PWM5（111）pin of the MCU is used to be connected with the input port of the motor.

(2)Voltage analog to digital (ATD) module
Two rotary knobs are designed in the experimental rig to adjust corresponding rheostats to change the voltage (0-5V). The output voltage pin of the first rheostat links to MCU PAD14/AN14(80) and the other pin to MCU PAD06/AN06(79). We choose the second rheostat that links to NO.6 channel of the ATD port.

(3) Buzzer and LED alarm module
The MCU PWM3/KWP3/PP3(1)pin links to the buzzer input port to control a voice. The PWM signal must be amplified to drive the buzzer membrane to make the voice. Different duty ratios of the PWM signal can produce different voices. Also the MCU PWM6/KWP6/PP6(110) pin links to the LED input port, and the duty ratio of the PWM signal is able to be changed to control the flash strength of the red LED light.

(4)Five nixie tubes display module
The sampled voltage value is displayed with five nixie tubes that assemble a TEC9607 chip. The TEC9607 uses a driver circuit of serial common-anode CMOS5×8.It consists of clear circuit, oscillation circuit, bit scanning driver circuit, 5×8 bit shifting register circuit, 5×8 bit data latch circuit, multi-channel selector, common-anode driver circuit. It can be connected with a serial port or a parallel port of a lot types MCU and offer specially five LED nixie tubes to display decimal digits [9].

MC9S12D64 MCU transfers data to TEC9607 through the SPI communication. In order to perform the process, TEC9607 serial bit shifting pin(SCP) must link to MC9S12D64 pin PWM2/KWP2/PP2(2),data latching pin(LCP) to XADDR15/PK1(7) and serial input data pin(SI) to PWM1/KWP1/PP1（3）.The circuit diagram of the DC motor control system is showed in figure 3.
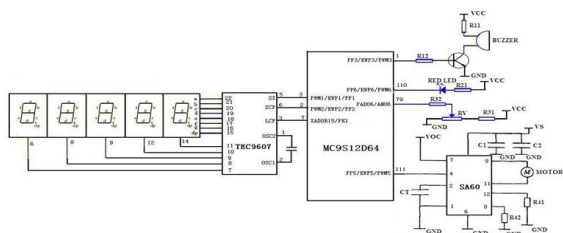
Fig. 3 Circuit diagram of the DC motor control system

IV. DESIGN OF SYSTEM SOFTWARE

4.1 Programming flow chart

The Freescale MCU has more superiorities than the type 8051 MCU in aspect of programming. For example, Registers of I/O ports can be easily set up to control running conditions of peripheral equipments. The C language program compiled by PC can be easily downloaded to the MCU flash memory and erased with more than one hundred thousand times. We use CodeWarrior5.1 to compile the C language program of the DC motor control system. The programming flow chart is presented in Figure 4.
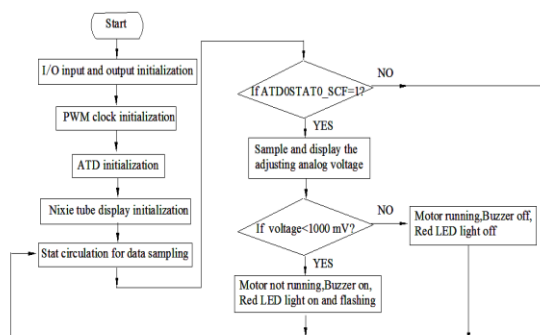

Fig. 4 Programming flow chart

4.2 Programming for Pulse Width Module (PWM)

In the figure 3, the input ports of the buzzer, the LED light and the DC motor are connected with the PWM3 pin, the PWM6 pin and the PWM5 pin of MCU respectively. MCU can adjust the duty ratios to control the running conditions of the above equipments. The programming procedure for the PWM initializing subroutine is described as follow. ①Shut PWM channels, PWME=0. ②Choose the PWM signal polarity. Set PWMPOL register. ③ Set clock mode registers :PWMCLK,PWMPRCLK, PWMSCLA and PWMSCLB. ④ Choose alignment modes. Set PWMCAE. ⑤Define duty ratios and period. Set PWMDTYx and PWMPERx. ⑥Enable PWM channels. PWME=0xFF.

4.3 Programming for Analog Voltage Sampling (ATD)

In the figure 3, the output analog voltage port links to the AN06 pin of the MCU AN port. The procedure of the ATD initializing subroutine is described as follow. ①Set ATD control ATDCTL1-4 registers according to transfer bits, scanning mode, sampling time, clock frequency and flag check modes. ② Start ATD transfer through writing ATD control register ATDCTL5. ③ATD data transfer is finished to set interrupt processing enable until ATDSTAT0_SCF=1.

4.4 Programming for Five Nixie Tubes Display

The voltage value is displayed with the five nixie tubes whose control chip is TEC9607.MCU transfers data to TEC9607 through SPI communication. TEC9607 SCP(clock) pin links to MCU PWM2 pin, TEC 9607 LCP (chip select) pin to MCU PK1 pin, and TEC9607 SI(data) pin to MCU PWM1.They are set high voltage to be effective. The subroutine procedure is described as follows.

①DDP_DDRP1 = 1 ,   DDP_DDRP2 = 1 , DDRK_BIT1=1,The data direction of these pins is set to output. PTP_PTP1=0, PTP_PTP2=0, PWM1 and PWM2 are initialized to be low voltages, showing no data transfer. PORTK_BIT1=1, Chip select is effective to present 5×8 data are locked in the data register. ②Data display is initialized to show zero. ③Call for data display subroutine. This subroutine need transform ten-thousand bit, thousand bit, hundred bit, ten bit and own bit into corresponding numerical codes that is able to be displayed in five nixie tubes.

4.5 Main Programming Codes and Analysis

In order to control the DC motor, an analog voltage need be sampled first and then displayed with five nixie tubes. Here the sampled decimal data need be transformed into corresponding numerical codes. the sampled voltage is compared with the threshold value(1000mV) to define the running conditions of the motor whether it start or doesn't start. The main programming codes are listed as follows.

EnableInterrupts;//Enable interrupts.
for(;;) // Circulate at the all time.
{ if (ATD0STAT0_SCF) {   // If ATD0STAT0_SCF=1,start to sample data, or wait.
PWMDTY5 =ATD0DR0L; //The duty width is equal to the sampled data value of the NO.6 channel of the ATD0.
ADCH6_value=ATD0DR0L*20;   //The actual voltage (mV) is 20 times than the sampled value.
i4= ADCH6_value /1000 - ADCH6_value /10000 *10 ; //Obtain thousand bit.

i3 = ADCH6_value /100 - ADCH6_value /1000 *10 ;   // Obtain hundred bit.
i2 = ADCH6_value /10 - ADCH6_value /100 *10 ; // Obtain ten bit.
i1 = ADCH6_value % 10 ; // Obtain own bit.
ledCONTROL(i4*1000+i3*100+i2*10+i1*1);
//Display voltage value(mV).
if(ADCH6_value<1000){PWMDTY5=0;PWMDTY3=ATD0DR0L;
PWMDTY6=ATD0DR0L;PORTA_BIT7 = 1;}//The motor doesn't run. The buzzer works and the red LED light flashes.
if(ADCH6_value>=1000){PWMDTY5 =ATD0DR0L;PWMDTY3 =0;
PWMDTY6=0;PORTA_BIT7 = 1;} // The motor runs. The buzzer doesn't work and the red LED light doesn't flash.
ATD0STAT0|=0x80; // Keep ATDSTAT0_SCF=1.
delay();//Call for the delay subroutine.
}}

V.   EXPERIMENT TESTING

We exploit an experimental rig that integrates the DC motor control system. The software of the control system compiled by the CodeWarrier5.1 platform is debugged repeatedly to be correct finally. Then it is downloaded to the flash memory of MCU by a BDM debugger. Figure 5 shows the running cases of the experimental rig. The labeled modules are arranged in corresponding places in the rig. Figure (a) presents the case that the sampled voltage value is 728 mV (<1000mV), the motor doesn't run, the buzzer works and the red LED light flashes. Figure (b) presents the case that the sampled voltage value is 1128 mV (>1000mV), the motor runs, the buzzer doesn't work and the red LED light doesn't flash. Through the testing, the system is proved to be reliable and successful, and it can simulate actual running cases of industry DC motor control.

(a)   DC motor stop

(b)   DC motor running
Figure 5   Testing cases of the experimental rig

VI.   CONCLUSIONS

MC9S12D64 MCU is utilized to carry out a simulation design for the DC motor control system in this paper. Hardware is designed including the MC9S12D64 minimum system, the circuit of analog voltage sampling, the alarming circuits of buzzer and LED light and the data display circuit of five nixie tubes etc. C language is used to be compiled for the system with the help of CodeWarrior5.1. Finally the designed system is tested on an experimental rig, and it is proved to be successful. It can simulate the running case of the industry DC motor control.

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