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EMBEDDED HIGH POWER CONTROL DRIVER DESIGN WITH CMAC BASED LEARNING CONTROLLER

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Abstract. *This work implements a low cost, powerful, small sized, and user friendly control driver system by integrating an embedded controller, driver, DC/Brushless DC motor, and necessary feedback interface. The control driver system has a PIC microcontroller as the control kernel and the control and communication program is built in the PIC program memory. Motor driver uses 3-phase gate driver to drive high-efficiency power MOSFET with three half-bridge pairs, which can drive DC/Brushless DC motors under 30A current. The designed control driver has universal serial interface to communicate with host computer, such as RS232/422, SPI, I2C and USB. The developed control driver is beneficial to DC/Brushless DC motor or robotic control system. The experimental results demonstrate the developed control driver achieves high performance, high efficiency, small size and low cost features. Moreover, a built-in intelligent CMAC (Cerebellar Model Articulation Controller) based controller improves the robustness and alleviates the dependency on exact system model.*
Keywords: Embedded system, Microcontroller, Servo system, CMAC, PID, Control driver

1. **Introduction.** Many DC motors or robotic systems require DC/Brushless DC servo controller to control their motion. Small sized and high performance driver integrated with controller and communication interface becomes more and more important. However, small size and larger power usually is a trade-off issue. To solve this problem, integrated high performance chip into the control driver is inevitable and always is a challenge. Market product did not open their technology. This work aims to develop its own technology and applies it to motion control of robot. All the circuits design, PCB layout, and control program are completed in our laboratory.

Generally, a servo control driver includes communication port, I/O, controller, driver, and feedback signal modules [1]. Many companies developed their product to satisfy users' requirements. Figure 1 shows Faulhaber's SC series motion controller [2], and it provided 24V4A power and achieved small size and high performance speed control ability. The built-in control program received the control command via UART port and accordingly executed the corresponding motion. Figure 2 is a smart motor which integrated controller, driver and motor, and a user just sends command to communication port and the controller will execute corresponding motion also. Such highly integrated technology is a design trend. However, Faulhaber and Smart motor is generally used in small power field and is not available for large power application. Also, integrated intelligent controller [3-5] to enhance the robustness and overcome the system uncertainty is an important technology. To develop a high-power and high performance control driver to benefit the motion control application is our objectives.

FIGURE 1. Photo of Faulhaber SC series speed controller

FIGURE 2. Photo of smart motor integrated with control driver

2. **Hardware Architecture of Embedded Control Driver.** As described above, a control driver usually includes communication, I/O, controller, driver, and feedback signal modules. Considering our motion control requirements, the block diagram of the control driver is shown as Figure 3.

There are many microcontrollers that can satisfy the requirements of control driver as described above. Users can choose 8-bit, 16-bit, or 32-bit microcontroller as the control kernel to achieve their performance requirements. Here, we choose dsPIC33EP512MU810 [6] 16-bit RISC microcontroller as the control kernel. dsPIC33EP512MU810 reaches up to 70 MIPs and single-cycle multiply and accumulates ability; therefore, it can execute high performance control algorithm calculation. Moreover, up to seven PWM generators, up to 32 A/D channels, 32-bit position counter, nine 16-bit Timers/Counters, I2C, UART, SPI, CAN and interrupt module all are integrated in a single chip, which significantly simplified the PCB layout and minified the PCB size.

In Figure 3, gate driver plays an important role to drive the power MOSFET pairs. Here, we use MCP8024 [7] chip as the gate driver. Following the using steps of datasheet, it can achieve high efficiency on-off switch control of power MOSFET pairs, shoot-through protection, overcurrent and short circuit protection. Moreover, thermal shutdown, undervoltage and overvoltage lockout protection are all integrated into this chip. It improved the driver efficiency.

Referring to [7], MCP8024 has a communication port which is used to receive the command for planning the working state. Also, host computer sends the six PWM signals

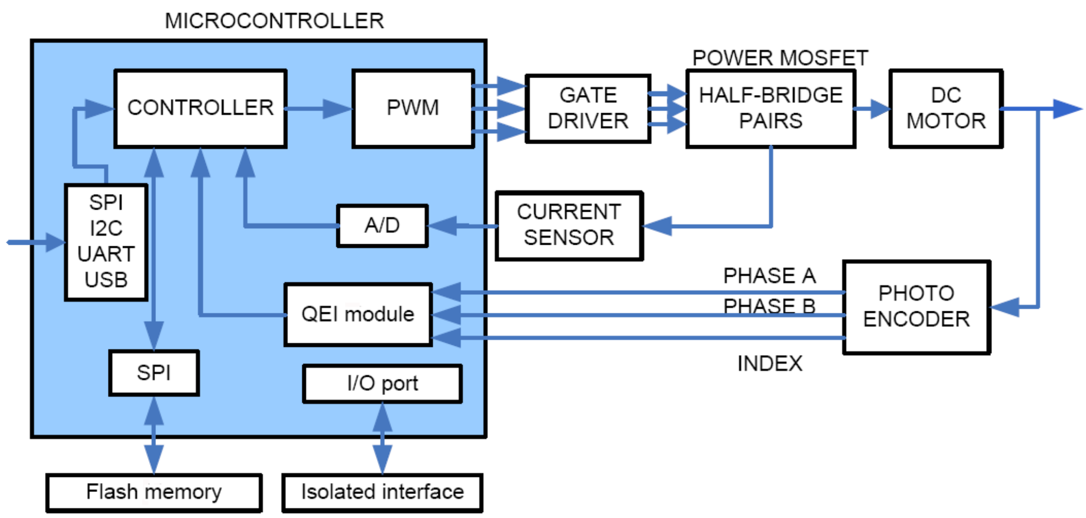

FIGURE 3. Block diagram of motion control driver

(DC motor is 4) to MCP8024, and MCP8024 will govern the on/off state of power MOSFET pairs. Figure 4 is the photo of developed control driver. We produce 10 prototypes taking only 500 US dollars and lower than market product. Although many details are under tuning, basic function is working well. High performance commercial control driver is expensive. Its price is usually more than 400 US dollars.

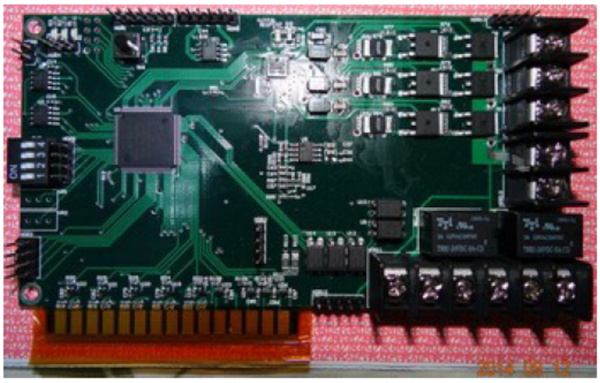

FIGURE 4. Prototype of proposed control driver

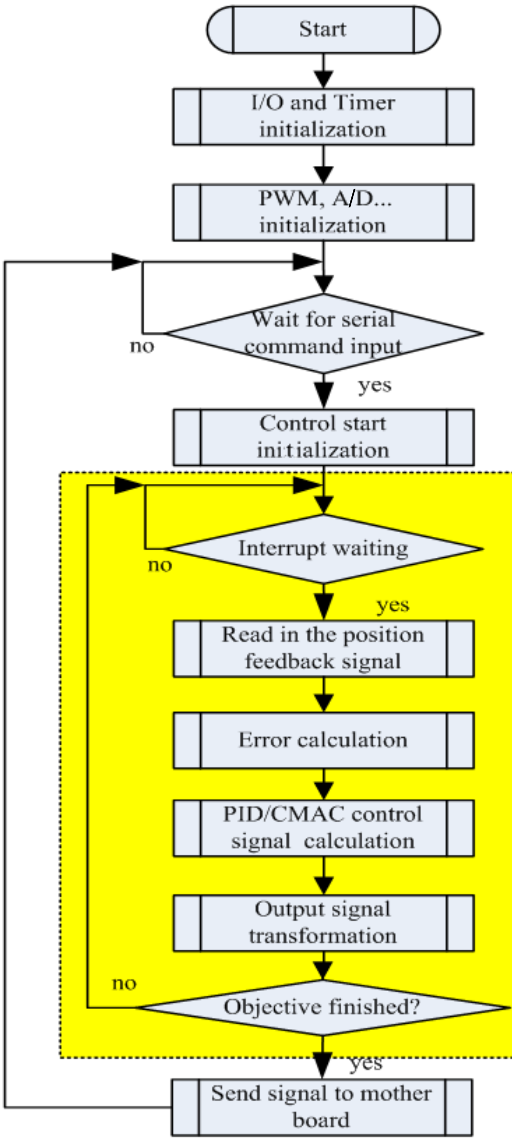

FIGURE 5. Main control program flowchart of proposed control driver

3. **Software Programming of Control Driver.** As shown in Figure 3, the program design includes two parts, main control program and communication program. The main control program receives a UART/SPI/I2C serial command and executes closed-loop servo control alone. Here control algorithm used PID or hybrid CMAC based controller [8-11]. Using dsPIC33EP512MU810 as the control kernel, it needs some peripheral initialization, including interrupt mode, serial mode, PWM mode, gate driver initialization and the necessary I/O setting. Figure 5 shows the main control program flowchart of the control driver. The main control loop runs with 1 ms control cycle and is enough to execute traditional or intelligent control algorithm.

The developed control driver can work alone or just play a slave to receive the host command. Here we show the host computer transferred the command to the control driver via serial port. Figure 6 is the software flowchart of PC terminal. Usually, multi-axis servo system requires multiple control drivers. To guarantee the command can be sent to the desired driver, identity code must be inserted into the command packet.

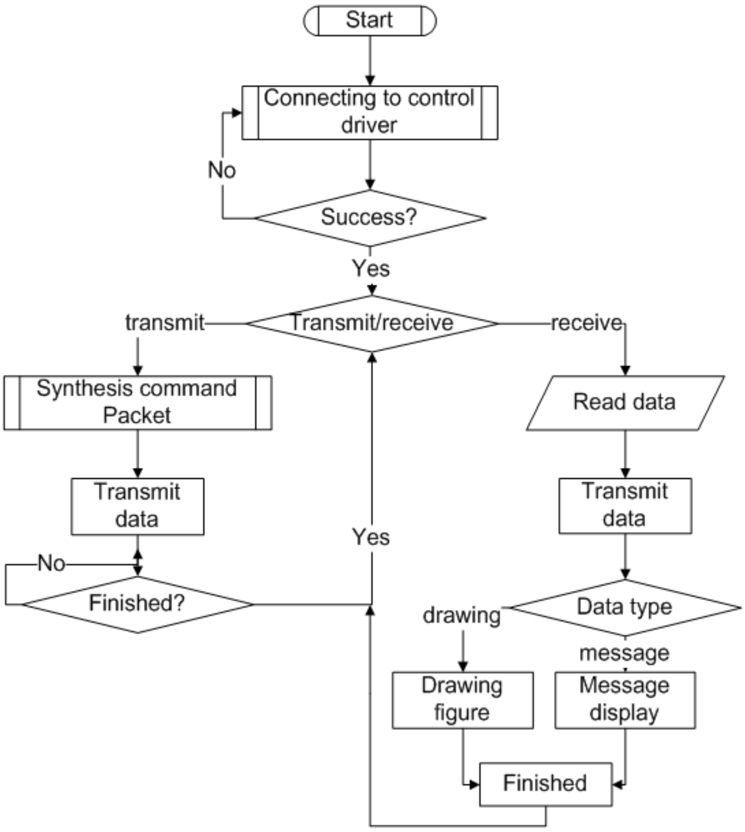

Figure 6. Communication program flowchart of PC terminal

4. **Experimental Results and Discussion.** In order to demonstrate the feasibility of the developed control driver and the proposed scheme, an experimental DC servo system is developed as shown in Figure 7. The DC motor is Minertia Motor RM series [12] (120W) and the test data are recorded on MPLAB workspace and plot using EXCEL software. The test system has a rough mathematical model. Using simple system identification scheme [13], the control block diagram is shown as Figure 8, in which θ_d denotes the desired output, θ the real output, e the error signal, u the control signal, ant $n(t)$ the noise.

4.1. **PID controller test.** Let the PID controller of Figure 8 be expressed as

$$G_c(S) = K_p + K_I \frac{1}{S} + K_D S \tag{1}$$

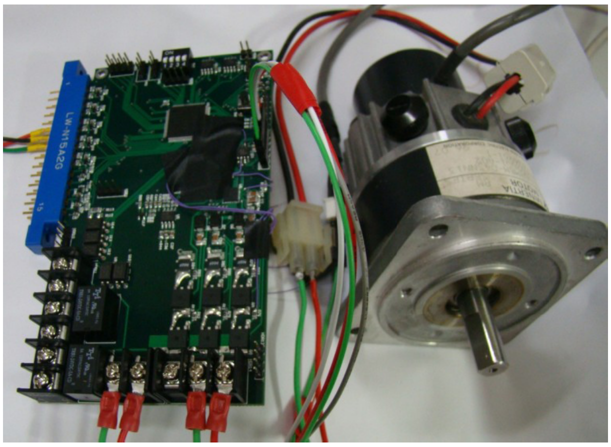

FIGURE 7. DC servo control system

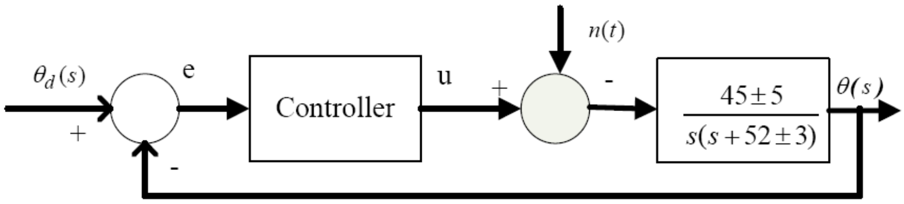

FIGURE 8. Control block diagram of DC servo control system

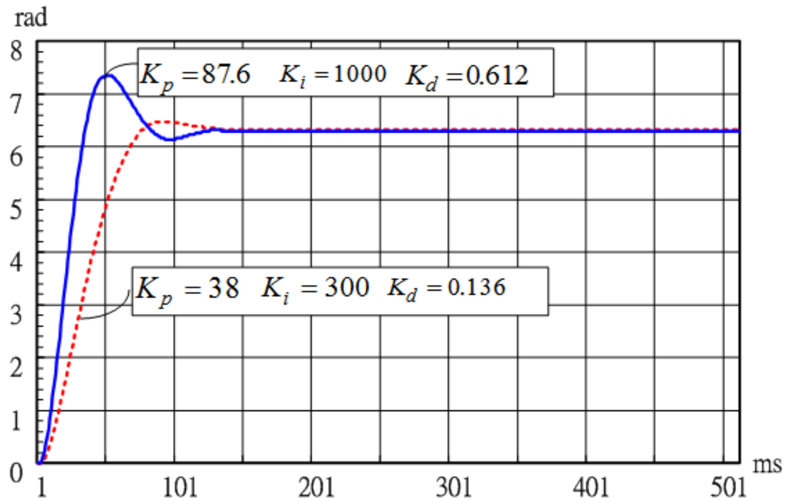

FIGURE 9. Time response for PID controller test

TABLE 1. Design parameters of CMAC-NN

$q_{\max}$	A^*	$x_{1\max}$	$x_{1\min}$	$x_{2\max}$	$x_{2\min}$	β	k_p	k_d
7	4	8	-8	40	-40	0.9	62	0.141

Using root locus scheme and letting the motor rotate one circle, the test result is shown as Figure 9. It is clear larger K_p value has larger overshoot and the precise position control is achieved.

4.2. **CMAC based hybrid controller test.** Using intelligent CMAC based learning controller, described in [9], the time response is shown in Figure 10. The associated design parameters of CMAC scheme are listed in Table 1. It is clear, the CMAC based scheme achieves better performance, such as fast and without overshoot.

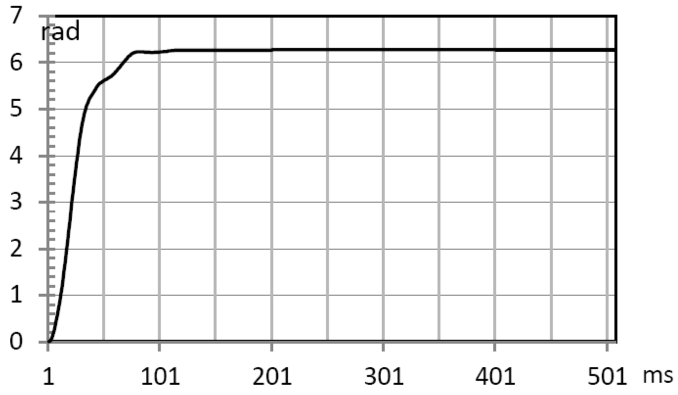

FIGURE 10. Time response for hybrid CMAC based controller test

5. **Conclusion and Future Work.** This paper proposes a high performance control driver design integrated with CMAC based learning scheme to achieve precise and robust control. It alleviates the dependency on exact mathematical system model. However, many detail parameters adjustment and soft program design are under ongoing. Applying the control driver to servo control platform, such as robotic system, is our next objective and will appear soon in near future.

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