Design of Programmable Control Electric Current Drive Based on ATmega8

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Abstract. This paper provides the design project of programmable control electric current drive based on programmable control interface used ATmega8 as core to control drive. The electric current drive adopts Buck converter to achieve input/output power conversion. The feedback loop uses voltage and current double feedback adjustment to control PWM drive circuit, so that the output of Buck converter could be adjusted. According to set value, the programmable control interface control current drive outputs the matching value by high frequency PWM output. The performance experiments is done, the results indicate that the output of programmable control electric current drive has much higher reliability and faster responding, satisfied design demand.

1. Introduction
Magnetorheological Fluid Damper (MRFD) is a new type of controllable damper based on the fast and reversible rheological characteristics of magnetorheological fluids in the field of vibration control of tank armored vehicle suspension system [1-2]. According to the controllable rheological characteristics of magnetorheological fluid under the action of magnetic field, the magnetorheological damper can adjust the viscosity of magnetorheological fluid by controlling the current of excitation coil under the external vibration environment.

2. Overall Plan
The programmable current driver is mainly composed of current driver and programmable interface, as shown in Figure 1.

Figure 1. Systematic block diagram
The current driver is composed of Buck converter [3], feedback loop and PWM control circuit. After the Buck converter realizes power conversion, the output primary voltage and current are sampled by sampling feedback loop; the current output target value given by PC is received by programmable interface circuit; the CTR signal is generated after comparing the target value with the primary output sample value, and the current mode PWM control is carried out, and the electricity is adjusted by double feedback regulation. At the same time, the sampling values of voltage and current output are fed back to the controller through the programmable interface circuit for real-time display.

Under the load condition of MFRD (load $R_{\text{MFRD}}=1.5\Omega$), the specifications of programmable current driver are as follows:

1) Input voltage $V_i=24V(\pm 4V)$;
2) The output voltage $V_o$ can be adjusted from 0 to 5V, and the output current $I_{\text{omax}}=3A$;
3) Output response time (0A changes to 3A) $\leq 1\text{ms}$;
4) It has the function of over-current protection;
5) The output current can be set by keyboard and adjusted step by step;
6) It has programmable interface to communicate with computer.

3. Current Driver Design

3.1. Buck Converter Design

Buck converter consists of input protection diode D1, switch Q, current transformer T, continuous current diode D2, energy storage filter inductor L, output filter capacitor C and output current sampling resistance $R_{Io}$, as shown in Figure 2.

![Buck converter circuit](image)

**Figure 2.** Buck converter circuit

In steady-state operation, the Q-turn-on time under the control signal is set as $T_{\text{ON}}$, and the input provides energy to the inductor L and the output. When Q-cut-off time is $T_{\text{OFF}}$, the energy in the inductor L forms a current loop through the continuous-current diode D2, and continues to supply power to the load. If the inductance current is continuous and does not decrease to zero within a switch period $T_s$ ($T_s=T_{\text{ON}}+T_{\text{OFF}}$), the mode is continuous on mode. In this case, the relationship between output and input voltage is expressed as

$$V_o = V_i D,$$

In style: $D=T_{\text{ON}}/T_s$ is the duty cycle of the PWM signal output from the drive circuit controlled by PWM. By adjusting D, the output voltage can be adjusted and constant voltage can be achieved.

Current transformer T and current sampling resistor $R_{Io}$ are used to sample and detect the main circuit current of Buck converter. They are used to provide current feedback loop. Their current output signal is compared with the target value to realize output current regulation and constant current. They are also used for current indication of output current and power protection (e.g. current limiting protection or shutdown protection). Protection).
3.2. Feedback Loop Design

The output voltage and current are controlled by current driver by voltage and current double feedback regulation, as shown in Fig. 3.

The output voltage \( V_o \) is divided by resistor \( R_1 \) and \( R_2 \), then \( V_{ot} \) is obtained, which is fed to the ADC interface of SCM in the program-controlled interface circuit (the voltage dividing reason is that the maximum acquisition value of SCM A/D is 5V); the output current sampling voltage \( V_{Io} \) is amplified by \( U_{2A} \) standardization, and then \( I_{ot} \) is obtained, which is also fed to the ADC interface of SCM. \( V_{ot} \) and \( I_{ot} \) are used as output feedback voltage and current values of current driver for system precision control and display.

At the same time, \( V_o \) obtained \( V_{UI} \) after \( R_3 \) and \( R_4 \) partial voltage, is fed into Operating Amplifier \( U_1 \) to compare with the set value \( V_{set} \) of the target voltage output by programmable interface circuit (the reason for dividing voltage is that the range of output voltage of MCU is 0-5V); \( I_{ot} \) is fed into Operating Amplifier \( U_{2A} \) to compare the set value \( U_{2A} \) of the target current value for output. \( V_{set} \) and \( I_{set} \) are used as reference voltage for voltage and current feedback regulation.

When \( I_{ot} < I_{set} \), \( U_{2B} \) output is 0, light emitting diode DR is on; when \( V_{UI} < V_{set} \), \( U_{1A} \) output is 0, light emitting diode DG is on. When DR or DG is turned on, the CTR of the transmitter of the optocoupler TLP521 generates signal, acts on the PWM control driving circuit, adjusts the duty cycle of the PWM output, and makes the switch in the Buck converter adjust dynamically and linearly until the \( I_{ot} \) and \( V_{ot} \) are greater than or equal to \( I_{set} \) and \( V_{set} \), the system is stable (because of the load and internal power consumption, both \( I_{ot} \) and \( V_{ot} \) are large. In the case of equal to or equal to \( I_{set} \) and \( V_{set} \), there is no theoretical existence). So that the voltage and current can be stably regulated by double feedback. When the load changes, \( I_{ot} \) and \( V_{ot} \) also change, and their regulation process is consistent with the above process.

Using voltage and current double feedback control, a deep negative feedback amplifier is constructed by high-speed operational amplifier LM358 to amplify the output error. At the same time, the double feedback error amplifier uses the same feedback control channel (composed of optical isolation), which realizes the linear regulation of current mode PWM and avoids the misalignment of double feedback control. High precision output control is realized.

3.3. PWM Control Drive Design

The PWM control drive circuit adopts the high performance fixed frequency current mode PWM integrated controller chip UC3843[4-5] of Unitrode Company, as shown in Figure 4.
The current in Buck's main circuit is detected by current transformer T. The induced current generated on the secondary side is converted to voltage by sampling resistance RQ. After RC filter circuit, it is fed to the same input of current sampling amplifier (Namely current sampling input ISENSE). The reverse input voltage of current amplifier in UC3843 is usually clamped at 1V. When the ISENSE voltage reaches the threshold, the push-pull output stage of the device stops output, and the high frequency switch is switched off immediately, thus limiting the current. The signal CTR generated by the feedback loop after voltage and current double feedback regulation is fed into the compensating foot COMP of the error amplifier of UC3843 to form a feedback compensation network and control the push-pull output stage to output the corresponding PWM signal to drive the switch Q.

4. Design of Programmable Interface
The program-controlled interface circuit uses ATmega8 of AVR series MCU as microprocessor[6]. The circuit is shown in Fig. 5.

PC transmits the target voltage and current value of MRFD current driver to ATmega8 system through RS485 serial communication. After operation, two DC voltage signals (0~5V) are obtained from ATmega8 two PWM output channels after passive filtering. The current driver outputs the set value of the target voltage Vset and the set value of the target current Iset as the reference voltage of the feedback loop for voltage and current double feedback regulation. At the same time, ATmega8 two A/D acquisition channels ADC1 and A DC2 collect Iset and Vset. After calculation, the actual output voltage and current values of the current driver are obtained and sent to the embedded controller through serial communication.
In order to facilitate debugging, the keyboard can set the values of $V_{\text{oset}}$ and $I_{\text{oset}}$ without communication between the current driver and the embedded controller, and display the corresponding data information through LCD.

The output of setting values $V_{\text{oset}}$ and $I_{\text{oset}}$ replaces D/A converter by high frequency PWM, which not only optimizes the circuit structure, avoids the quantization impact (spike error) caused by D/A conversion, but also improves the stability of system control and reduces the output delay time.

The software part of the program-controlled interface circuit mainly includes five parts: ADC acquisition program, PWM output program, keyboard scanning program, RS485 communication program and LCD display program. The main flow chart of the program control link software is shown in Fig. 6.

### Figure 6. Flow chart of program-controlled interface software

5. **Performance Test of Programmed Current Driver**

Fast output response and high reliability are the key requirements of programmable current driver. For this reason, two performance tests of output current and output response are carried out.

#### 5.1. Output Current Test

The current output terminal and RS485 serial port of the programmable current driver are connected to the MRFD and PC serial ports respectively. The test conditions are $V_i=24\text{V}$ and $R_{\text{MRFD}}=1.5\Omega$. Different serial commands are sent to measure the corresponding output current. The test results are shown in Tables 1 and 2.
Tables 1 and 2 show that before the output current value reaches the limit current value, with the increase of the given target voltage value, the target current value increases correspondingly. The error of the measured output current value relative to the target current value and the error of the executed current value relative to the measured current value in LCD display are very small ($\gamma \leq 0.98\%$). When the output current reaches the limit current value, even if the target voltage value continues to be increased, the output current value does not exceed the limit current value, which indicates that the output precision of the current driver is higher ($\gamma \leq 0.98\%$) and has good over-current protection function.

| Target voltage (mV) | 300  | 600  | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 5000 |
|---------------------|------|------|------|------|------|------|------|------|------|------|
| Target current = Target voltage /1.5(mA) | 200  | 400  | 667  | 1000 | 1333 | 1667 | 2000 | 2333 | 2667 | 3333 |
| Measured current (mA) | 203  | 401  | 665  | 1004 | 1334 | 1674 | 1996 | 1998 | 1999 | 1999 |
| Executive current (mA) (LCD display) | 205  | 398  | 662  | 1006 | 1330 | 1673 | 1998 | 1999 | 1999 | 1999 |
| relative error ($\%$) | 0.98 | -0.75 | -0.45 | 0.2 | -0.3 | -0.06 | 0.1 | 0.05 | 0 | 0 |

5.2. Output Response Time

Output response time refers to the time that the current driver receives serial commands until the output reaches a stable value. The measurement method is as follows: RXD of RS485 communication receiving terminal of current driver connects a monostable trigger circuit. When the current driver receives the communication instruction of PC, the monostable trigger circuit triggers. This moment represents the initial time of output response of current driver. The monostable touch is measured by two channels CH1 and CH2 of oscilloscope, respectively. The output of the power circuit and the output of the current driver measure the output response time.

According to the above method, the current driver connects the load of $R_L=1.7\Omega$, sets the initial voltage output to 0V, then transmits the communication instruction of 5V output voltage through PC to limit the current 3A. When the output of the current driver changes from 0 to 3A, the output response is shown in Fig. 7.
As can be seen from Figure 7, when the current driver receives the serial communication instruction of the maximum output voltage, the monostable circuit trigger (CH2 channel) reaches a stable output voltage after about 800 µs. At this time, the output current is about 3A, and the output response time is faster.

6. Conclusion
In this paper, according to the requirement of magnetorheological damper for current driver, from the angle of frequency response and programmable continuous adjustability, a programmable current driver based on Buck converter topology is designed, which meets the application requirement of driving MRFD. Compared with single-ended forward converter, single-ended flyback converter, push-pull converter and bridge converter, the main topology of Buck converter has more advantages in its conversion efficiency. The performance test shows that the average conversion efficiency of the current driver is 87%, which is higher than that of other topologies, but this index is far lower than the highest one in China. The improvement of efficiency index is directly related to a series of engineering applications such as power consumption, volume and heat dissipation of the driver. The improvement of efficiency index requires not only theoretical calculation, but also optimization design of index and improvement of engineering manufacturing process, such as switching frequency, energy storage inductance L and output filter capacitance C in Buck main topology. The matching of key components, the loss design of energy storage inductance, the parameter selection of filter capacitor and other engineering problems are all key technologies to be further studied.

7. References
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