The Design and Research of Digital Voltage Regulation System for YA7232B Machine Tool

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Abstract. YA7232B machine tool is widely used in industrial area. However, the voltage regulator circuit is composed of discrete components. That’s the reason why the dynamic response performance and reliability of it are reduced. In order to solve the above problem, we integrate those components into the STM32F103ZET6. More importantly, we write a set of software to ensure regulator circuit updated by us to be operated stably.

Introduction

Although the YA7232B worm wheel grinding machine is widely used in industrial production, there are still some shortcomings such as: The electrical part of the larger space[1], and its regulator circuit using 8-bit DA conversion circuit, RC oscillator circuit, due to the discrete components with large parts density, drifting and aging in capacitance, inductance and another energy storage components, the voltage ripple coefficient is larger, reducing the inverter and frequency conversion circuit dynamic response performance indicators, stability and reliability[2]. So to improve the electrical performance of YA7232B voltage regulator system, has become an urgent need to solve the problem.

Digital Voltage Regulator System Design

The original YA7232B worm grinding wheel grinding machine is divided into digital converter, DC amplifier, integrated amplifier and rectifier pusher modules, these modules are built by a large number of separate components, the circuit design is completed so can not update, can not find the problem when machines failure.

In order to make up for defects of the original system, this paper digitize with embedded design method, integrated the separate element in ARM, to realizes the original system function[3]. As shown in picture 1:

Figure 1. YA7232B digital voltage regulator module.

After the transformation, the teeth number directly into the corresponding digital signal by ARM, which will greatly improve the accuracy of the output voltage, and the system has high integration, low energy consumption and fast operation.
Hardware Circuit Design

The system to ARM processor as the core, digital-analog conversion circuit and voltage, current feedback circuit for the auxiliary circuit together constitute the system hardware structure. As shown in picture 2:

![Figure 2. Digital voltage regulator system hardware circuit.](image)

ARM master circuit is based on the chip STM32F103ZET6 as the core, which is consist by system power supply, system reset, clock system, GPIO, RS232 serial port and another modules.

Voltage and Current Feedback Circuit

Voltage and current feedback loop send the rectified voltage and current values to ARM, at the same time, installed the AD829 high-speed operational amplifier to increase the feedback signal drive capability, installed the BAV99 switch diode to limit input signal of transformer, as shown in picture 3.

![Figure 3. Voltage and current feedback circuit.](image)

When the machine is running normally, the voltage regulator system work, then the feedback transformer will rectify the voltage value back to the regulator control circuit[4], the ARM main chip for real-time monitoring, when the rectified voltage does not meet the standard voltage range, ARM master chip issue instructions includes adjust and stop.

D / A Conversion Circuit

D / A conversion circuit is converted the output digital signal of the ARM to 0 ~ 5V DC voltage, sent to the pulse conversion module, due to the weakness signal of D/A conversion, the circuit installed AD829 high-speed operational amplifier to improve the output signal drive capability. As shown in picture 4.
Digital Voltage Regulator Software System Design

Create a Task Module

According to the workflow of the digital voltage regulator module, this paper is based on the Keil uVision5 platform for programming and debugging, in the main function to create RD Message task, Bus Ready task, Bus Load task, Bus Download task, Bus Stop task, these five tasks, described below.

Software Description of the Working Process

Begin with the zero state of initial voltage, give motor a PLC enable signal, it gets ready. The system voltage is set to 60V at the same time, because in the actual work, to 0V as the initial voltage will cause error protect of the system. Then encoder read the signal, the motor voltage began to load, rose to a stable value, the grinding machine began grinding the workpiece. Revoke the PLC enable the motor enter the unloaded state, the voltage begins to decrease, but if it will drop to zero depends on continue grinding or stopping. Workflow diagram shown in picture 5.

The workflow of the grinding machine is embodied in the program as four tasks, namely Ready, Load, Download and Stop, where Bus Load task is the design focus of this paper. The details of the input and completeness of the load and download are shown in table 1.
<table>
<thead>
<tr>
<th>state</th>
<th>Semaphore</th>
<th>Ready</th>
<th>Load</th>
<th>Download</th>
<th>Stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>RD_Encoder</td>
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<td>1</td>
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<td>0</td>
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<tr>
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<td>0</td>
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<tr>
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<td>0→1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Bus_Download_Completed</td>
<td>1</td>
<td>0</td>
<td>0→1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1. Motor status Corresponding semaphore.**

**Bus Load Task**

In engineering practice, the value of large motor is very high, the motor work with a large inductive load, so we take into account the voltage rise may be too fast on the system and the damage to the motor, S curve acceleration and deceleration control are widely used. Correspondingly, it is reasonable to add a soft-start module to the program. This design allows the voltage from zero slowly raised to the rated voltage, in practical applications, could protect the motor, and extend its service life. There are similar considerations in Bus Download task.

In the program design, we use for cycle to make it shown S-shaped acceleration curve rise by 50 times climbing staircase, to instead of instantaneous rise voltage. During the debugging process, the initial bus voltage is set to DC60V, the bus voltage is loaded to 50% ~ 80% of the target voltage in 500ms ~ 800ms, the target value is reached after 1.5S. The voltage loading speed is set according to Equation (1):

\[
t_{\text{temp}[i]} = \left[\frac{V_{\text{Init}} + \frac{(V - V_{\text{Init}}) \times (i + 1)}{50}}{k}\right]
\]

\[i = \text{temp} \mod 4095\]

After system voltage reaches the target value, the machine starts grinding, and voltage remains constant until workpiece is grinding completed.

**RD Message**

The number of teeth of the workpiece through the three 8421 rotary encoder input, respectively, the message send to ARM through 8421 code. The information reading program as follows:

```c
uint16_t x,temp=0;
temp = GPIO_ReadInputData(GPIOF);    // Read teeth number from GPIOF;
temp = ~temp;                       // Put all temp bits to 1;
temp &= 0x0FFF;                    // Clear the high four;
x = temp&0x000F;                   // Input the bit ;
x = x+((temp&0x000F)>>4)*10;        // Input ten-bit ;
x = x+((temp&0x0F00)>>8)*100;       // Input hundred-bit;
```

The voltage-teeth number relation of original machine measured in the engineering practice, fitted it into corresponding function, made look-up table and entry ARM. ARM read teeth number and call the look-up table, get the corresponding voltage value at fastest speed, this approach is accurate and concise, for the integer operation of initial function which known input and output range, this is the most efficient method[5].

**Summary**

Based on the ARM chip, the digital voltage regulating system is described in hardware module and software task. Compared with the original system, the electrical system volume and power...
consumption will be greatly decrease. The next step is to design and research frequency conversion section of the YA7232B electrical system, to further improve the performance of the entire electrical system.

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References


