# Design of Tension Control System of Multi Function MTS-1A Type Belt Conveyor

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***Abstract* — With the rapid development of textile industry, the requirement and the production efficiency of clothing processing technology is higher and higher. We analyze the key technology-tension control system and compare it with the similar products at home and abroad in this paper, finally we present a design scheme of the system. In order to make the system have a rapid and a stable performance, PID algorithm is adopted in software design. At the same time, some anti-jamming techniques have been taken into consideration and put into the experiments. The technology index of tension control system has met the expected effect and met the requirements of production process.**

***Key words - CAN control module; PID algorithm; touch force sensor***

## I. Introduction

As people's living standard is going through unceasing improvement and the textile industry are achieving rapid development, the requirements of processing technology and production efficiency of clothing are higher and higher. In detail, it reflects in the requirements for the uniformity and dimensional accuracy of elastic tension of some high-grade underwear fabrics while going through sewing processing. Ordinary original manual work and simple processing equipment can not meet the requirement of the existing technology, besides, and its sewing speed is extremely low so as to lead to huge waste of human resources and make the production cost very high. In particular, because the current labor law is issued to increase labor costs, the equipment efficiency becomes very important. Some domestic garment factories can't meet these requirements so as to make many underwear orders of many well-known brands at home and abroad lost. Although there are related equipments abroad, due to their high prices, they fail to gain the popularity.

We develop a device to solve the mal-development of existing process and to improve the production efficiency in this paper. It uses the popular microcomputer control technology at present, and with high speed data processing ability, it can automatically identify pressure sensor, achieve automatic shifting and adjust the elasticity of belt. It is believed that if the equipment is developed and put into use, it can gain a large number of orders for garment processing enterprises and save certain expenses.

## II. The Design of Hardware Circuit

### *A. The Memorizer Design.*

In order to prevent data disappearance after power off, the process parameters set in the system should be stored in memorizer. This system adopts the ATMEL company's memorizer -93 c86 of block serial-EEPROM, and it adopts low-power technology, and can be achieved by DI pin (or the DO pin) to write (or read), 2k bytes. The device can withstand 1 million times of writing/erasing, and the data stored in the device have a life expectancy exceeding 100 years; its high speed operation can resch 3 MHZ; It has wide voltage working range, 1.8 v to 6 v. The memorizer can choose 8 bit or 16 bit structure, and automatically clear the memory while writing. Here the SOIC is used to encapsulate. The circuit principle diagram is as shown in figure 1.

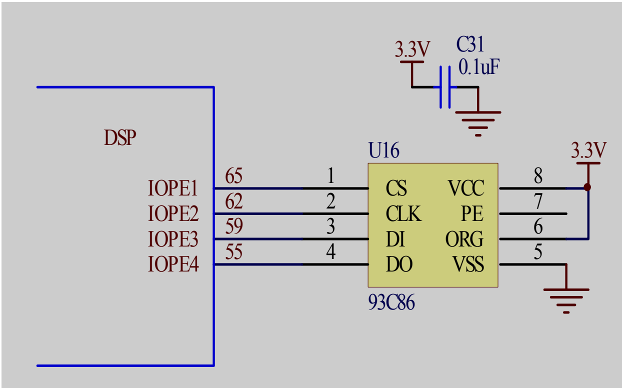


Figure 1. The circuit principle diagram of memorizer.

For 93 C 86 belongs to SPI serial storage, use IO interface originally attached to DSP to simulate SPI communication module, processors can be used to realize data write and read of memorizer. SPI is a high speed synchronous serial I/O port, and it allows the length of the programmable serial bit stream (1-16) with programmable transmission speed move into or remove from the device. The data stored by this system are mostly double byte, so 16 structure have been chosen, and ORG is used to meet high level; CS is the selected signals, when IOPE1 outputs the high level, the read operations are effective; IPOE2, IPOE3, IPOE4 respectively provide the clock signals, read and write signals. 93C86's pin functions are as shown in TABLE I.

TABLE I. 93 C 86'S PIN FUNCTION

| Pin Names | functions |
|---|---|
| CS | Chip select signal |
| SK | clock input |
| DI | Serial data input |
| DO | serial data out |
| VCC | Power source (1.8V-6V) |
| GND | grounding |
| ORG | Storage structure choice |
| PE | write protection |

*B. The Circuit Design for Power-fail Protection.*

In the practical application of system, there are two commonly seen situations: the first one is that processor program goes through "off tracking" due to an instantaneous under-voltage of system voltage so as to make the system not be able to work normally; The second is that the system goes through power down accidentally and the important data loss can't be recovered. In order to avoid the two kinds of situations as far as possible, one needs to add the power down detection and the protection circuit to improve the security of data about the system.

Power down detection and protection circuit can be used to detect the drop of power supply voltage. When the power supply voltage has not dropped to the voltage while normal work would be jeopardized, the system could give out timely warning signal, then after DSP system receive this signal, it immediately executes the task of protecting the data of the interrupted service. And when the interference pulse is over or the system re-continue its work, DSP would continue its work. The circuit principle diagram is as shown in Figure 2

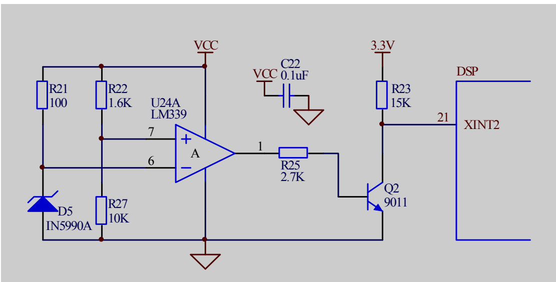


Figure 2. The power detection circuit.

IN5990 is the regulator tube of 3.9 V, when the system works normally, the comparator outputs the high level, and the transistor conducted, XINT1 foot should be low level; When 5 V voltage power has dropped suddenly less than 4.5 V, the comparator outputs low level, and the transistor stops, then a positive pulse comes from XINT1 to stop the operation of program towards data storage, and further to prevent the loss of well-set technological parameter.

*C. The Circuit Design of Counter Module.*

The counter circuit diagram consisted by UGN - 3501 - T Hall sensor is as shown in Figure 3. UGN - 3501 is typical single-ended output integrated Hall sensor, and it has better linear in 0.15 T ~ 0.15 T magnetic induction intensity. If it exceeds this range, it will present a saturated state. Because UGN - 3501 - T has the high sensitivity, it can feel small magnetic field change. When magnetic induction goes through Hall sensor location, the sensor outputs a peak pulse of 20mV, and after amplified by LM358, it could drive 9013 triode, and make this triode complete the process of conduction and cut-off. Besides, the sensor could generate the count pulse after Schmidt gate. DSP processor goes through the external count and its interruptions to get accumulative pulse. Here, TCLKINA is external counter tube feet.

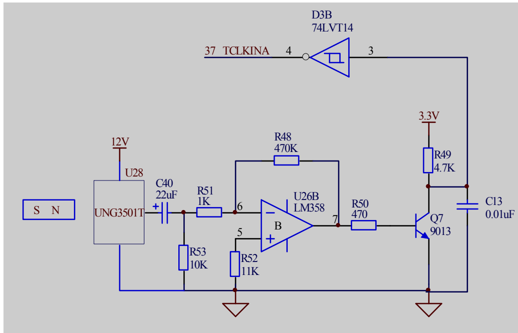


Figure 3. The counter module circuit.

*D. The Circuit Design of Shaking and Winding Alarm.*

Shaking device mainly uses 555 timer as the timer element to form the mono-stable trigger.

When IOPA7 feet outputs low level, it will come across negation gate, triode functions, 555 timer TRIG, THOLD's voltage is 0, and the OUT end outputs high level, at ordinary times. After the gate, triode conduction, 555 timer TRIG, THOLD voltage is 0, the OUT side output high level, and optical coupler MOC3041 breakovers, start thyristor and machine functions.

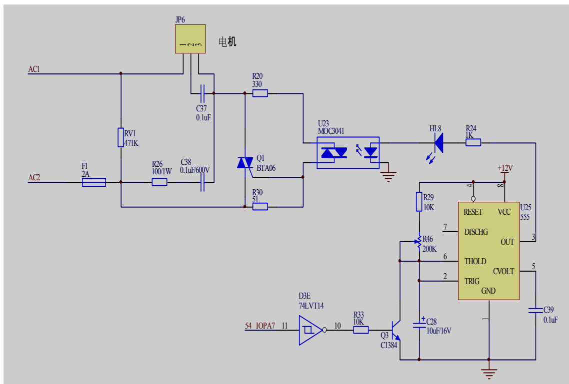


Figure 4 The shaking and alarm circuit.

When IOPA7 feet outputs high level, it will come across negation gate, triode will be cut-off, and the capacitor C5 charging immediately. After a period of time, when 555 timer TRIG, THOLD's voltage is greater than 2/3 VCC, the OUT end outputs low level, optical coupler MOC3041 stops, thyristor stops, and machine stops running.

When the elastic winding, alarm switch will be closed, and the buzzer gets electrified, and the device will alarm.

## III. The System Design of DSP Software

The Software Design Plan.

The software system design is composed of embedded DSP program written by C language, which is mainly used to realize the control of the tension control transmitting system and other detections.

The software system design is basically composed the following program modules:

The main controlling program

Button interruption handler: when there is a button press, an external interruption would occur, and the CPU reads the key values and processes.

Counter interrupt handler: record the number of sewing needle.

Sewing machine speed interruption handler: measuring the speed of the sewing machine and display it.

The CAN communication interruption handler: receive the commands of upper machine and upload related data.

DSP main uses C language to conduct function code writing, C language is a kind of compiled programming language, which combines the characteristics of several high-level languages, and has the function of assembling language. C language has rich function library, fast computing speed, high compiling of efficiency and strong portability, besides it can realize the control of the hardware system directly. C language is a structured programming language, which supports top-down structured programming techniques used widely in current program design. In addition, the C language program has perfect module structure, which provides a strong guarantee for modularized program design method used in a software development. Therefore, applying C language program design has become a mainstream of software development. Applying C language to write the target system software can greatly shorten the development cycle and obviously increase the readability of the software, which could make the improvement and expansion become easier, thus to develop a system with larger range and better performance. The software uses CCS2000 integrated debugging environment for development and design

The Design of Controlling Algorithm.

Proportional-integral-differential (PID) algorithm is one of the most commonly seen control algorithm in industry. In PID control, the algorithm can calculate the responses of proportion, integral and differential and their sum to calculate the real output. Therefore, understanding each PID parameters is very important for adjusting PID controller.

The influence of the proportion: the proportionate parameters depend on the errors, which is the difference between the set point and process variables. Proportion gain (Kp) is the ratio of output and error. In general, increasing the proportion of the control system gain can improve the response speed of system, which will also reduce the steady error (the difference between the set point and process variables). However, if the proportional gain is too large, the process variables will start to go through concussion. If Kp undergo further increase again, the volatility would increase, and the system will become unstable.

The influence of the integral: error and time points existed before the integral parameter stable the errors. Therefore, the integral responses would go through a continuous increase of the time until the error is zero. Even so, the process of integral is likely to affect overshoot, shock, and/or stability of the system.

The influence of the integral: Differential parameters of PID algorithm predict the errors that may appear, for the differential parameters responses are the integrals of error change. Therefore, in general, the differential process reduces overshoot and shock. On the other hand, very small differential gain (Td) is used in most of the actual control systems, because the differential responses are very sensitive to the noise process variable signals. If the feedback process variables represent noise, differential parameters can cause instability of the system.

In practical application, one can based on the characteristics of controlled object and the requirements of controlling performance to adopt the composition of different controllers to consist

Proportion (P) controller

$$u(t)=K_P e(t) \tag{1}$$

Proportion+ Integral (PI) controller

$$u(t)=K_P [e(t)+\frac{1}{T_I}\int_0^T e(\tau)d\tau] \tag{2}$$

Proportion +Integral+ Differential (PID) controller

$$u(t)=K_P [e(t)+\frac{1}{T_I}\int_0^t e(\tau)d\tau + T_d\frac{de(t)}{dt}] \tag{3}$$

In the equation, KP represents proportion amplification coefficient; TI represents the integral time. TD represents differential time.

It is necessary to adjust the proportion of amplification coefficient KP and integral time TI and differential time TD properly to conduct PID control, which could make the whole controlling system get good performance.

In the digital controlling system, PID controller is achieved by PID controlling algorithm program of computer. Computer direct digital controlling systems are mostly sampling - data controlling system. Getting into computer’s continuous - time signal, must sample and sum the quantity first, then turn it into digital quantity, only in this way, one could enter the computer's memory and register. When it comes to calculation and processing procedures in digital computer, no matter the calculation belongs to integral or differential, numerical calculation is the only choice to be used to approximate the outcome.

In digital computer, the realization of the PID controlling law also must use the numerical approximation method. While the sampling periods are short, the summation can be used to replace integral and difference quotient to replace differential coefficient, and turning the continuous time differential equation of the PID algorithm to discretion-time PID algorithm difference equation.

While taking equation (3) into consideration and rectangular integral are put into use, there is

$$\frac{1}{T_I}\int_0^t e(t)d\tau = \frac{T_S}{T_I}\sum_{J=0}^{K} e(j) \qquad (4)$$

Difference quotient is used to replace differential coefficient

$$T\frac{de(t)}{dt} = \frac{T_d}{T_S}[\text{e(k)-e(k-1)}] \qquad (5)$$

Put equation (4) and (5) into equation (3), PID algorithm becomes

$$\text{u(k)}= K_P\,[\text{e(k)}+ \frac{T_S}{T_I}\sum_{J=0}^{K} e(j) + \frac{T_D}{T_S}(e(k)-e(k-1))] + u_0 \qquad (6)$$

or

$$\text{u(k)}= K_P\,\text{e(k)}+ K_I\sum_{J=0}^{K} e(j) + K_D[e(k)-e(k-1)] + u_0 \qquad (7)$$

$$K_I = \frac{K_P T_D}{T_I} \qquad K = \frac{K_P T_D}{T_S}$$

In the equation, $u_0$ represents the base value of controlled variable, i.e., k represents the control at 0;

U (k) k represents the control of the Kth sampling; Kp represents proportion amplification coefficient; KI represents integral amplification coefficient; KD represents differential amplification coefficient; TS represents sampling period.

Equation (7) is a recursive form of digital PID algorithm, which is called complete quality PID algorithm. In the equation, to get the sum, one must store all the past values of past systematic deviation e (j) (j = 1, 2, 3,....k). The algorithm could get the whole output u (k) of controlling quantity, which is the absolute value of controlling amount. In the controlling system, the control quantity determines the position of the actuator, for example, in valve control, for example, the output of this algorithm corresponds to the position of the valve (opening). So, this kind of algorithm is called "location algorithm".

The incremental PID controlling algorithm

While executing agency doesn't need the absolute value of controlling value, but the increased value of controlling value (such as PID incremental algorithm should be used while driving a stepping motor in this system).

Through location algorithm one can calculate out

$$u(k) = K_P[e(k) + \frac{T_S}{T_I}\sum_{j=0}^{k} e(j) + \frac{T_D}{T_S}(e(k)-e(k-1))] + u_0 \qquad (8)$$

Then get

$$u(k-1) = K_P[e(k-1) + \frac{T_S}{T_I}\sum_{j=0}^{k-1} e(j) + \frac{T_D}{T_S}(e(k-1)-e(k-2))] + u_0 \qquad (9)$$

Subtracting the two equations, the incremental algorithm of controlling value could be got

$$\Delta u(k) = u(k) - u(k-1)$$

$$= K_P\,\{\text{e(k)-e(k-1)}+ \frac{T_S}{T_I}e(k) + \frac{T_D}{T_S}[e(k)-2e(k-1)+e(k-2)]\} \qquad (10)$$

Equation (10) is called incremental PID algorithm.

Sum the incremental PID algorithm (10) one could get

$$\Delta u(k) = q_0 e(k) + q_1 e(k-1) + q_2 e(k-2)$$

(11)

In the above equation

$$q_0 = K_P\,\{1+\frac{T_S}{T_I}+\frac{T_D}{T_S}\}$$

$$q_1 = K_P\,\{1+2\frac{T_D}{T_S}\} \qquad (12)$$

$$q_2 = K_P\frac{T_D}{T_S}$$

In equation (11) one can't get PID expression, or get the direct relationship between the P, I and D, one could only get the influences of teach error towards controlling function. From equation (11), one can know digital incremental PID algorithm, as long as the recent three sampling value error e (k), e (k - 1), e (k - 2) are stored, the work is well done.

$$\text{Target value}= \frac{\text{Full pressure value} - \text{Light pressure value}}{1000} \times \text{Tension value}$$

The system needs the sampling output pressure value of real-time control close to the target value

There is a saturation exists in this system. While the control variable reaches certain value, the output of the system variables will longer grow, and the system goes into a saturated zone, which requires control variables of the system must be limited within a certain range, namely

$$u < u_{\max}$$

If the calculated quantity is beyond the scope of the above mentioned control, and the system doesn't execute the calculation value of controlling value but the most value $U_{\max}$ of the controlling value, or the control can't reach the desired effect, even cause oscillation.

## IV. The Summary of Debugging and Development of System

The Debugging of Power Circuit.

First, check whether there is a short circuit among power sources. Then plug in power socket, and measure whether the + 5 v, + 12 v, + 24 v voltage are accurate with a multimeter. Finally, measure whether the output voltage of U11 feet is 6 3.3 V.

The Debugging of Input Channel.

- Pressure rod weight is 5g;
- Instrumentation amplifier gain G = 5 + 200 k/RG

5.6K<RG<6.6K;

35.30<G<40.71;

- Due to the fact that the reference voltage is 5 v, the corresponding digital quantity range of AD7894 is 0-16384

When the sensor loads nothing: the output voltage of the sensor should be between 0.6 - 15.6mv. Adjust gain fine-tuning resistance-R44, one could make the output voltage of amplifier be between 0 and 0.6 V.

When the sensor gets full-loaded: the output voltage of the sensor should be between 120.6 -135.6mv. Adjust gain fine-tuning resistance-R44, one could make the output voltage of amplifier be between 4.5 to 5 v.

- Boot and conduct zero calibration and full scale calibration check, and the system would store each parameter value of each calibration.

The Debugging of Voltage Regulation Circuit.

After heating the temperature sensor, voltage on both ends of the semiconductor cooling, which is measured by multimeter, goes up, and the status indicator HL7 brightens showing that the width of PWM pulse increases; When the hearing substance around temperature sensor is removed, the voltage of semiconductor cooling chip goes down, and the status indicator HL7 dims showing that the width of PWM pulse decreases.

While the system is running, the state light HL5, HL6 flashing, and the pulse would control the servo drive.

The Debugging of Key Processing Circuit.

Oscilloscope is used to inspect XINT1 interruption pin, when there is a button press, there will generate a positive pulse at XINT1; Add electrical level 01, 10,11 to A1, A0 respectively; Multimeter measured the electrical level of 1 y0, 1 y1, y2 are 0 respectively. Adjust LCD brightness potentiometer, it shows normal on the display screen.

The Debugging of Signal Circuit.

Using high-speed optical coupling isolation and filter circuit and effectively inhibit the external circuit interference on the system, after the examination, when external switch actions, there is no obvious jitter at pin.

In development phase, prototype is normal in control and operation situation, and has stable performances, all indicators have reached the expected requirements. Because we use gear transmission, at beginning, the noise is louder, yet through later research of using the belt transmission, through belt transmission the predetermined effect is achieved and the noise problem is solved making our products gain a firm foothold in the international market.

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