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Position control for machine tools

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ABSTRACT

Closed loop control systems offers an excellent means of achieving precision movement with big loads and high forces. The paper presents an example for setting up of a Programmable Logic Controller (PLC) axis module for controlling the movements of a machine tool. Also we present the programming and the adjusting principles.

1. Introduction

For many years, the PLC has gained an acceptance in numerous areas of industry, from simple machine control to many thousand I/O, specific task oriented process control. In more recent years, motion control has gained acceptance due to particular benefits brought about by utilizing the technology available in both servo and motion controller products. One reason for the dramatic rise in the adoption of the electronic method can be found in looking at previous solutions. Mechanical systems, such as main shafts, cams, linkages and differential gears, may be a satisfactory solution, but with drawbacks. For controlling the movements of an axis of a machine the new tendencies is to use a Programmable Logic Controller which commands several I/O modules and some specific modules dedicated to this function.

Elementary movements are managed from the main sequential control program of the machine, but these are performed and controlled by the movement modules. For each axis used the module has one channel.

On each channel an incremental or absolute encoder measures the position, and an analog output controls a speed drive. In this paper we will refer to the movement modules produced by SCHNEIDER ELECTRIC for the PREMIUM range of products. The block diagram of a channel is presented in fig.1.

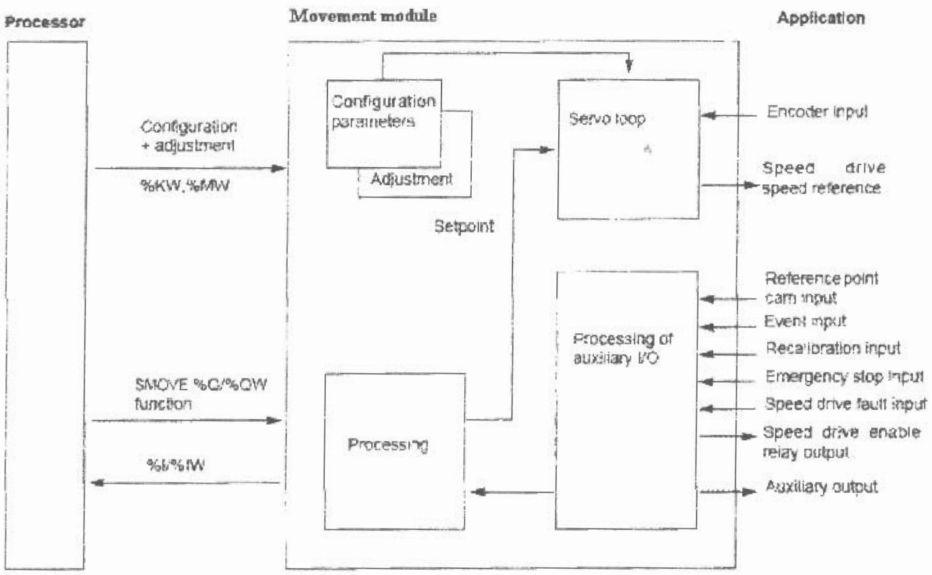

Figure 1. The block diagram of a channel associated with a machine tool axis.

For each of the axes, axis control modules provides:

Inputs:

• An input for the acquisition of position measurements:

- Either via an RS 485 type incremental encoder (maximum frequency 500 kHz without multiplication, 1 MHz with multiplication by 4). The module will perform the multiplication by one or by four as required.

- Or an absolute encoder, 16 to 25 data bits, with serial link and transmission according to SSI protocol (clock frequency 200 kHz).

• An input serving as a reference point cam (if an incremental encoder is selected),

• An event input,

• An emergency stop input,

• A recalibration on the fly input,

• A speed drive fault input.

Outputs:

• An ± 10 V analog output isolated from the logic part of the module, with a resolution of 13 bits + sign for controlling a speed drive connected to a self-starting synchronous DC motor, or to a self-controlled asynchronous DC motor.

• A relay output to enable the speed drive.

• A solid-state auxiliary output.

1. Configuring an axis channel

This procedure consists in defining the parameters, which enables the operation of the axis control module to be adapted to the machine that is to be controlled. The modern equipments can be configured using a software tool.

Axis configuration parameters: units of measurement, type of encoder, encoder resolution, maximum and minimum position limits, maximum speed, maximum setpoint, maximum acceleration, the type and direction of the reference point are linked to the machine and cannot be modified by the program.

The measurement units are used to select the physical units in which the speed and position measurements will be expressed.

Other parameters used for configuration are the type and the characteristics of the position encoder used. The following types can be use: incremental or absolute encoder.

The resolution is the distance corresponding to an encoder increment. Since the value is not generally an integer, it is expressed in terms of the following ratio:

$$R = \frac{D}{N}$$

Where:

• D= distance traveled by the moving part

• N= number of encoder points corresponding to the distance.

The upper and lower limits of the axis correspond to the mechanical limits of the axis. These limit values are themselves limited depending on the resolution value selected.

It is essential that the coherence of the resolution, maximum speed and maximum setpoint parameters is maintained; otherwise incoherent servo loop behavior will result.

3. Example of configuration

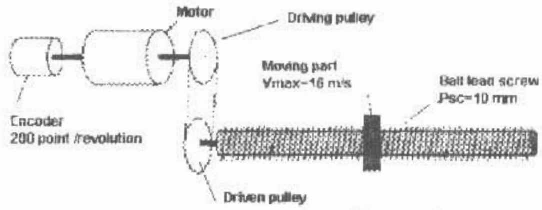

Figure 2. Example of an axis

In the example presented in figure 2, the axis is controlled by a motor which can run at n_0 =3000 [rpm]. The voltage which must be applied to the input of the speed drive to obtain n_0 is U0=10000 [mV]. The encoder is mounted on the motor shaft. It should be noted that an incremental encoder with N=200 points/revolution is being used. In order to obtain a better resolution will multiply by 4 of the encoder signals by selecting this function from the configuration editor. The movement is transmitted from the motor shaft to the ball lead screw using a cogged belt drive. The screw pitch is p_{sc}=10 [mm]. The driving pulley and the driven pulley are identical there for transmission ratio i_c=1.

The resolution is calculated using the following formula:

$$R = \frac{D}{N_e} = \frac{p_{sc}}{N_e} = \frac{p_{sc}}{4 \cdot N}$$

Where N_e is the number of points of an encoder used without multiplication with 4, function for which the resolution is equal to the encoder used with this function.

The maximum desirable linear speed is v_{max}=16000 mm / min.

The maximum setpoint U_{max} is the voltage that must be applied to the input of the speed drive to obtain a speed equal to the maximum speed.

In this case: $U_{max} = \dfrac{v_{max} \cdot U_0}{p_{sc} \cdot n_0 \cdot i_c}$ [mV]

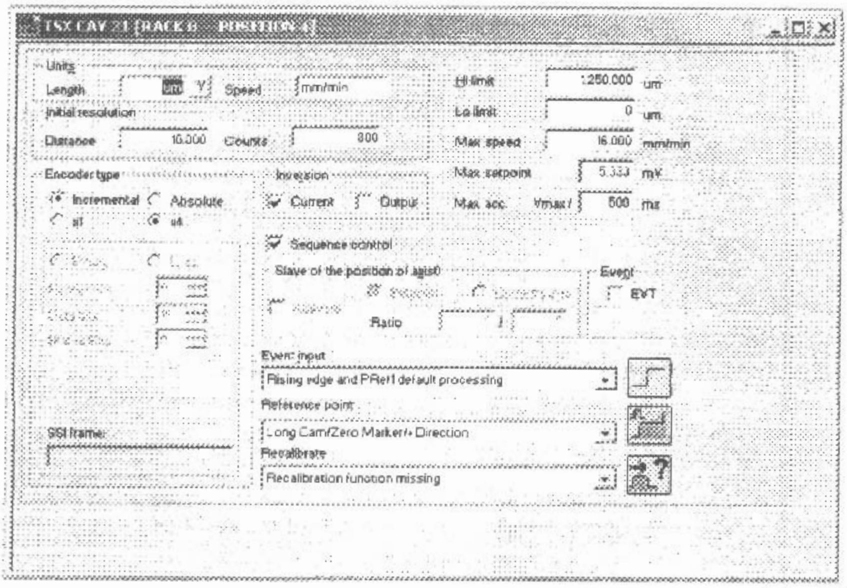

Figure 3. The configuration screen for a channel of a movement module TSX CAY21-Schneider Electric.

3. Programming principle

A movement is initiated by executing an SMOVE control function in the PL7 program. The characteristics of movements are described using syntax similar to that for a numerical control program block written in ISO language. For this reason a PLC that commands a movement module is well suited for implementing a NC for controlling a machine tool

The syntax for SMOVE control function is:

SMOVE %CHxy.i(N_Run,G9_,G,X,F,M)

Where

%CHxy.i = address of the axis control module in the PLC configuration

x = rack number

y = position of the module in the rack

i = channel number

N_RUN = 0 to 32767, number identifying the movement performed by the SMOVE function. Identifies the current movement in debug mode.

G9_ = type of movement

90: movement to an absolute position value,

91: movement to a relative value with respect to the current position.

98: movement to a relative value with respect to memorized position PREF (position PREF is memorized using instruction code G07).

G = instruction code,

09 : move to the position and stop

01: move to the position without stopping

32: prepare machining command

30: simple machining

10: move until an event is detected and stop

11: move until an event is detected without stopping

14: reference point

05: await an event

07: memorize the current position when an event occurs

62: forced reference point

X = coordinates of the position to be reached or towards which the moving part must move (in the event of a move to a position without stopping).

This position can be:

• Immediate

• coded in an internal double word %MDi or internal constant %KDi (this word can be indexed).

The unit in which these values are expressed is defined by the configuration parameter **Length Unit of measurement:** this parameter is set in the configuration screen: mm (default unit),

F = speed of movement of the moving part. This speed can be:

• immediate

• coded in an internal double word %MDi or internal constant %KDi (this word can be indexed).

The unit of speed depends on the selected unit of position:

Speed = u x 1000/min where u = selected unit of length

Example: if the unit of length chosen is the mm (default unit) the unit of speed is:
mm x 1000/min --> mm/min
M = Word coded on 4 four-bit bytes (in hexadecimal) 16# which gives the possibility of:
• optional activation of the triggering of the application event processing for instructions: 10, 11, 05 and 07. This function is selected by setting to 1 the four-bit byte number 3.
• setting the **auxiliary discrete output** associated with the channel to 0 or 1 for instructions: 01, 09, 10,and 11. This function is selected by writing a specific value in the four-bit bytes number 2 and number 1.
Four-bit byte no. 2:
- 0 = **Unchanged:** no modification of the output
- 1 = **synchronous with the movement:** assignment of the output at the start of execution of the instruction
- 2 = **following the movement:** assignment of the output at the end of execution of the instruction
Four-bit byte no. 0:
- 0 = forcing of the output to 0 (AUX 0 box not checked)
- 1 = forcing of the output to 1 (AUX 0 box checked)

. The adjustment parameters

The adjustment parameters are linked to operation of the axes. They generally require the operations on and movements of the moving part to be known. These parameters are adjusted in online mode but they are initialized in offline mode.

Axis operating parameters are:
-Resolution correction, encoder offset
-Motion control: deviation, recalibration, overspend, etc.
• Stop control: delay, speed, target window, etc
• Servo (position loop): position gain, feedforward coefficient, etc
• Commands: soft limits, acceleration, acceleration profile, etc
• Manual mode: Speed, reference point value, etc

The program can modify these parameters.

Position control loop block diagram is shown in figure 4.

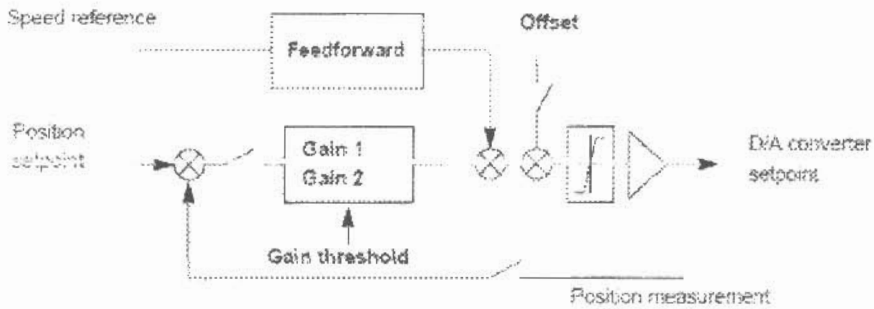

Figure 4. Position control loop block diagram

The position and speed references are calculated as a function of the movement (speed, target position) required by the user and the parameters defined in the parameter adjustment screen.

Feedforward is expressed as a percentage. 100% corresponds to the value that would totally absorb the position error at constant speed for a speed drive, which has no continuous error. In some cases, the position error passes a minimum with a possible change of sign when the feedforward gain increases.

The offset is a value added to the value of the analog output calculated by the loop.

Gain 1 is used for high speed. Gain 2 is used for low speed. Gain2 should be adjusted for machines that are subject to friction. Normally Gain 1=Gain 2

The position gain is applied as follows:
• if current speed < 3 x Threshold / 2 : Gain 1
• if 3 x Threshold / 2 > current speed • Threshold / 2: Gain = (Gain 1+Gain 2)/2
• if current speed < Threshold / 2: Gain 2

The gain threshold is selected at the speed above which friction is eliminated.

Using this Gain adjustment parameter, the module calculates the proportional gain coefficient KP:

$$Kp = C \cdot U_{max} \cdot Gain$$

Where:
C: constant,
Umax: value of the speed drive setpoint to achieve speed VMAX (Umax<9V).

In figure 4 is presented the adjustment screen in which we can see the adjustment parameters for the application defined in section 2 of this paper. After we adjusted all the parameters we could control the mobile part so that we obtained a maximum value for the position error equal with 30 μm suitable for the machine tool used for this experiment.

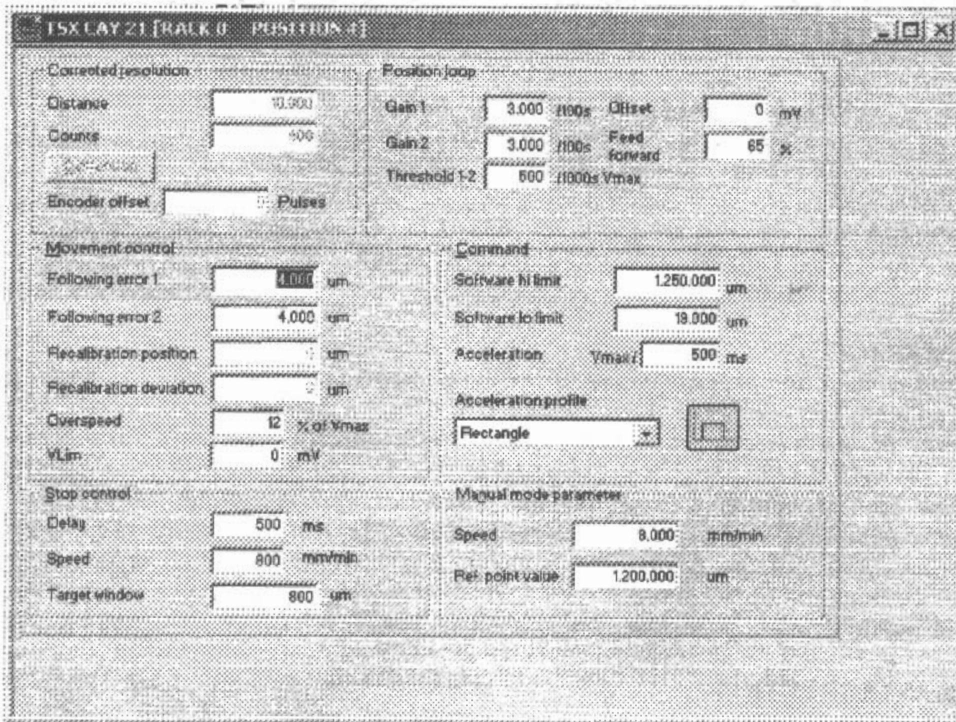

Figure 4. The adjustment screen for a movement module

5. Conclusion

Using a movement control device is a necessity for implementing the control system of machine tools for which the high precision is one of basic characteristics.

Depending on the complexity of the machine tool the command system can be implemented with a CNC or a PLC.

The implementation realized with a PLC that has a movement module is suitable for many types of applications; the precision of the position is not different from the precision of the position realized with a CNC.

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Controlul poziției organelor mobile ale mașinilor unelte

Rezumat

Sistemele de control cu bucla închisă prezentate oferă mijloace excelente pentru obținerea preciziei de poziționare necesară mașinilor unelte . Această lucrare prezintă un exemplu de configurare a unui modul. de control al axelor, din structura unui P.L.C, pentru controlul mișcărilor organelor mobile ale unei mașini unelte. Sunt prezentate de asemenea principiile de programare și de reglare a parametrilor specifici acestor module.