

1 STEPPER MOTOR TEST FOR TRI PLC.

1.1 OVERVIEW

This document provides additional details on the PLC program, “StepperTest V2_01.PC6” and the Weintek HMI program, “Stepper HMI V1_00.emtp”. The following sections will give you a bit of a hint into how this program functions and my approach to PLC programming.

This PLC code was, originally, written for a Triangle Research Fx1616-BA PLC. It has been simplified to run on nearly all current TRI PLCs. This code is designed to test and exercise a single stepper motor using an external stepper driver. The PLC provides the step and direction signals to the stepper driver.

A Weintek MT8070iE HMI provides the user interface. The HMI is connected to the PLC using an RS-232 cable. The PLC code does not require the HMI to function. The PLC code can be run on PLC hardware using the On-Line Monitoring. The PLC code can be tested using the i-TRiLOGI Programmable Logic Simulator without any PLC hardware.

This PLC code uses a combination of ladder logic TBASIC custom functions. The code is split between these two programming languages to take advantage of what each language does best.

This PLC code uses a single state machine to handle the execution of single stepper commands and sequencing of multiple stepper commands. The PLC code supports the use of a single limit switch input that indicates when the stepper based system is in the home position. timing requirements to control a single stepper motor and a single limit switch.. The state machine is based on the PLC’s sequencer mechanism and sequencer Seq4 handles the state machine for the PLC’s stepper channel #1.

1.2 CH1 STEPPER CONTROL.

The PLC code is responsible for the sequencing of a set of firmware commands that configure and control the operation of an external stepper driver. The PLC uses two OUPUTs to control the external stepper driver and these OUTPUTs provide direction information and a pulse for each step.

1.2.1 PLC Command Interface.

A set of 32-bit registers provide the command and numeric arguments to support the command. The registers are as follows:

Variable Name	Ch1CmdArg	Ch1Arg1	Ch1Arg2	Ch1Arg3
Usage	Command	1 st Position	2 nd Position	Repeat Cnt
Location	DM32[1]	DM32[2]	DM32[3]	DM32[4]

The Ch1CmdArg provides the command or operation to be performed. The supported commands are as follows:

Command Name	Value	Description
RezeroValve	0	Reposition the stepper motor so that the valve is at the “home” position. This position is defined as that point at which the limit switch goes from opened to closed as the valve is rotated towards the closed position. No arguments are used by this command. A very low step rate is chosen so that the movement command can be aborted without the system losing step due to inertia.
RelativePosition	1	Reposition the stepper motor by the number of steps specified by the first argument, Ch1Arg1. If Ch1Arg1 is a positive number the stepper will rotate in the direction to open the valve. If Ch1Arg1 is negative the stepper will rotate in the direction to close the valve. The 2 nd argument is not used. The 3 rd argument specifies the number of times to repeat the command. The limit switch is ignored.
AbsolutePosition	2	Position the stepper motor to the absolute position determined by the first argument, Ch1Arg1. The “home” position found by the “FindHome” command is position 0. Positive numbers for Ch1Arg1 will position the valve that many steps from the home position. Negative numbers will position the valve that many steps more closed than the “home” position. The 2 nd argument is not used. The 3 rd argument is forced to 1 so that the command only executes one time. The limit switch is ignored. You can specify Ch1Arg1 so that the stepper will be commanded to hammer the valve either full open or full closed stops. This may result in damaging the valve and will result in the stepper system getting lost. Just thought I’d warn you.
AlternatePosition	3	This command will move the stepper motor to the position specified by Ch1Arg1, pause and then move to the position specified by Ch1Arg2 and pause. The number of times that the stepper motor moves is determined by the value of repeat count stored in Ch1Arg3.
RandomPosition	4	This command is similar to the AlternatePosition command. The difference is that the position that the stepper moves is a random number. The range of the random movements is bounded by the values of Ch1Arg1 and Ch1Arg2. Ch1Arg1 is. The number of times that the stepper motor moves is determined by the value of repeat count stored in Ch1Arg3.

1.2.2 PLC Configuration Interface.

A set of 32-bit registers define the operational parameters for the stepper motor behavior. These registers are visible in DM32[] but are copied to non-volatile memory so that the configuration data is not lost when the system is powered down. The configuration registers are as follows:

Variable Name	Ch1PosMax	Ch1PPS	Ch1Acc	Ch1Delay
Usage	Full open position in steps.	Target step rate in pulse/second	Number of steps to take to get to the rate specified by Ch1PPS	Delay in 0.1 seconds after each motion command
Location	DM32[11]	DM32[12]	DM32[13]	DM32[14]

1.2.3 PLC RELAY Usage

The following RELAYS are involved in the control of stepper channel #1:

RELAY Name	SaveParams	Ch1HomeCmd	Ch1Cmd	Ch1CmdCmp	Ch1PosKnown
Usage	Set by HMI to indicate that a configuration parameter has been changed.	Set by CH1 state machine to indicate that the special "FindHome" command is to be processed.	Set by the HMI to start execution of a stepper command.	Set by PLC hardware to indicate that a motion command has completed.	Set by state machine following the successful execution of the "FindHome" command
RELAY #	7	8	9	10	11

1.2.4 HMI Interface.

The 32-bit DM32[] values, RELAYS, INPUTs described in the previous subsections are directly accessible by the HMI. Please refer to Figure 1 for the details about the HMI screen.

The top most box labeled, "Stepper Ch1 Status", shows the status for the CH1 stepper system.

- **Limit Switch:** This is the current state of the limit switch input to the PLC that when "closed" indicates that the Ch1 valve is nearly closed. This input is used by the "Rezero Valve" command to set the home position by carefully moving the stepper towards the closed position and stopping as soon as the Limit Switch closes.
- **Absolute Position:** current position of the stepper motor with the "home" position being 0.
- **Relative Position:** current position following the execution of a movement command relative to the last position of the stepper. If the stepper was at absolute position 1000 and was moved 100 steps towards full closed, the relative position after the move would be -100.
- **Repeat Count:** this register is loaded with the "Repeat Count" of the command and following each movement command is decremented. When this value hits 0 the sequence of commands has completed
- **SM Seq4 Status:** This is the current state of the stepper controller state machine based on sequencer, Seq4.

CH1 Control/Configuration Screen

Stepper Ch1 Status

Limit Switch	Absolute Position	Relative Position	Repeat Count	SM Seq4 Status
Closed	0	0	1	Idle

Start

CH1 Command	Position #1	Position #2	Repeat Count
Rezero Valve ▼	0	1000	1

Stepper Ch1 Configuration

PPS	Accel	Max Pos	Delay
2000	100	2200	1.0

Figure 1 HMI Interface for CH1

The middle box shows the stepper command interface. The changeable values in this area include:

- CH1 Command:** This sets the value of Ch1CmdArg. The HMI uses a pulldown menu to select one of the 5 stepper commands. The commands are:
 1. Rezero Valve, 0
 2. Move Relative, 1
 3. Move Absolute, 2
 4. Alternate Seek, 3
 5. Random Seek, 4
- Position #1:** This is the first argument, or Ch1Arg1, for the command. This field is used by all of the stepper commands except "Rezero Valve". For the "Move Relative" command this value is the distance in steps to move (both positive and negative values can be specified). For the "Move Absolute" command this field specifies the absolute position for the stepper to be moved. For the "Alternate Seek" command this field specifies the position of the 1st, 3rd, 5th ... movement command. For the "Random Seek" command this field specifies the lower bound of the random positions to use.
- Position #2:** This is the second argument, or Ch1Arg2, for the command. This field is used only for the "Alternate Seek" and "Random Seek" commands. For the "Alternate Seek" command this field specifies the 2nd, 4th, 6th ... positions for the stepper movement. For the "Random Seek" command this field specifies the upper bound of the range of random positions.
- Repeat Count:** This is the second argument, or Ch1Arg3, for the command. This field specifies the number of times that the command is to be executed. This field defaults back to 1 for both the "Rezero Valve" and "Move Absolute" commands.

The “Start” button sets the PLC RELAY, Ch1Cmd, that starts the processing of the selected command. While processing a command the “Start” button will turn red and the label will change to “STOP”. Pressing the button when it is red will clear the PLC RELAY, Ch1Cmd and this will stop all but the “Rezero Valve” commands.

The bottom box is the configuration information for this stepper channel. The configuration information is changeable from the HMI and the changes are stored in the PLC non-volatile memory. These are the parameters that can be configured:

PPS: Stepper maximum pulse rate per second.

Accel: Stepper motor acceleration range in steps. This is the number of steps that the stepper hardware in the PLC will use to accelerate the stepper up to the maximum speed determined by the PPS parameter. Accel is, also used to de-accelerate the stepper. As an example if the Accel parameter is set to 100 and the stepper is commanded to move 1000 steps, the first 100 steps will be used to accelerate to 1000 PPS, then next 800 steps will be at 1000 PPS and the last 100 steps will be used to deaccelerate the stepper back to 0 speed.

Max Pos: this is the maximum number of steps that the valve is to be opened relative to the home position. This test software only uses this parameter for the “Rezero Valve” command.

Delay: this is the delay time in seconds following each movement command. The minimum delay is 0.1 seconds and the maximum delay is 999.9 seconds.

1.3 CH1 STEPPER STATE MACHINE

Figure , is a classic state diagram that describes the Ch1 Stepper State Machine. The PLC COUNTER, Seq4, is used as the state counter for this state machine. The notation, Seq4:n where n is the state number is used throughout this document. This is the same notation that you will find in the ladder logic.

As a brief reminder, a state machine is a classic computer science design approach to deal sequential systems. The circles in Figure represent the states. The arrows that go from one state to the next represent the state transition rules.

I use state machines for most of my PLC programs. I have found state machine approach to be the easiest to design, easiest to debug and the easiest to maintain. Enough said.

1.3.1 State 0, IDLE

State 0, Seq4:0, is the IDLE state. This state is entered on power on reset and after the completion of stepper movement commands. This is where the state machine “sits” waiting for things to do. On entry to this state the custom function, Ch1Init, is called to provide initialization of the system.

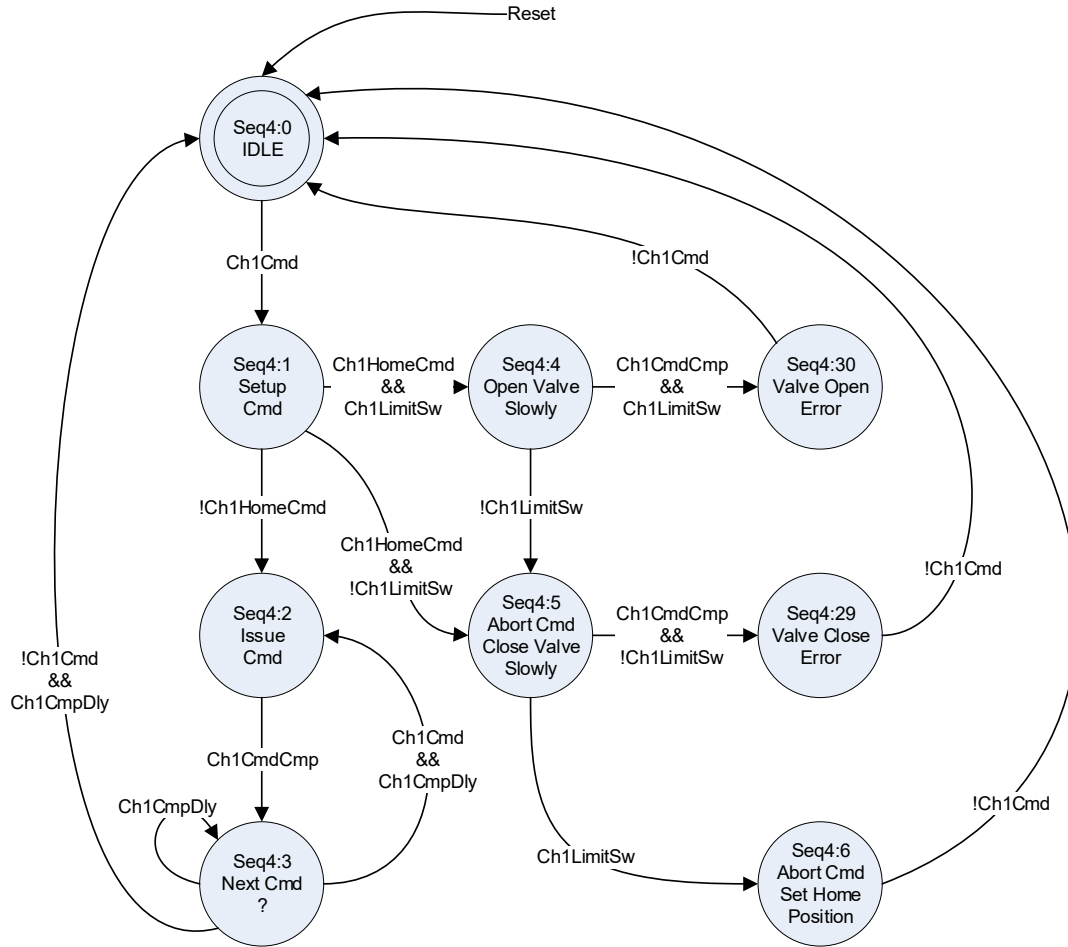


Figure 2, Ch1 Stepper State Diagram

1.3.2 State 1, Setup Cmd

State 1, Seq4:1, is entered from State 0 only when the Ch1Cmd RELAY is true. Ch1Cmd, when true, indicates that a stepper motor command is to be executed. On entry to this state the custom function, Ch1CmdInit, is called to validate the stepper command and it's arguments. If the command is a "Rezero Valve" command the RELAY, Ch1HomeCmd is set. The "Rezero Valve" requires specialized processing and uses States 4,5, 6 and possibly 29 or 30 on error conditions. The setting of the Ch1HomeCmd determines the state that follows State 1.

1.3.3 State 2, Issue Cmd

State 2, Seq4:2 is entered from State 1 is the RELAY, Ch1HomeCmd is false. On entry to this state the custom function, Ch1CmdIssue, is called. This custom function issues the stepper motor command to the PLC stepper motor hardware as determined by the values in the DM32[] registers described earlier. The state machine remains in this state until the RELAY, Ch1CmdCmp, is true. This RELAY indicates that the motion command has completed and the stepper motor has come to a halt.

1.3.4 State 3, Next Cmd

State 3, Seq4:3 is entered from State 2 after the motion command completes as indicated by the RELAY, Ch1CmdCmp. The custom function, Ch1CmdNext is called on entry to this state. This custom function decrements the running count of commands and when the count reaches 0, the custom function clears the RELAY, Ch1Cmd. The RELAY, Ch1Cmd was set by the HMI and is cleared by the PLC when all associated motion commands are completed.

The TIMER, Ch1CmdDly is active while in this state, when the TIMER runs out and sets the Ch1CmdDLY contact the state machine will transition either to State 2 or State 0 based on the the RELAY, Ch1Cmd.

1.3.5 State 4, Open Valve Slowly

State 4, Seq4:4, is entered from State 1 if the RELAY, Ch1HomeCmd, has been set and the limit switch, Ch1LimitSw, is true indicating that the valve is closed.

On entry to this state the custom function, Ch1SlwOpen is called. This issues a motion command to slowly open the valve. When the limit switch, Ch1LimitSw, goes false, the state machine transitions to State 5.

1.3.6 State 5, Close Valve Slowly

State 5, Seq4:5, is entered from State 1 if the RELAY, Ch1HomeCmd has been set and the limit switch, Ch1LimitSw, is false or from State 4 when the Ch1LimitSw goes false. In both cases the valve is known to be open.

On entry to this state the custom function, Ch1SlwClose, is called. This custom function issues two motion commands. The first command terminates any active motion command to stop the stepper in its tracks. The second motion command slowly closed the valve.

The transition of the limit switch from false to true causes the state machine to transition to State 6. This is the point at which the valve has just been detected to close.

1.3.7 State 6, Set Home Position

State 6, Seq4:6, is entered from State 5 when the limit switch, Ch1LimitSw is true.

On entry to this state the custom function, Ch1SetHome, is called. This custom function issues stepper motion stop command to command terminate the slow close command issued in State 5. At this point the stepper has moved the valve to the closed position. The custom function sets this position as the “home” position and clears the RELAY, Ch1Cmd, to indicate that the motion command(s) to rezero the valve have completed without error. The next state will be State 0.

1.3.8 State 29, Valve Close Error

State 29, Seq4:29, is an error state. This state is entered from State 5 if the limit switch does not transition to “closed” or true continuation before the slow close motion command completes. The state machine will remain in this state until the Ch1Cmd RELAY is cleared. This RELAY can be cleared from the HMI by pressing the “STOP” button.

1.3.9 State 30-, Valve Open Error

State 30, Seq4:30, is an error state. This state is entered from State 4 if the limit switch does not transition to “closed” or true continuation before the slow close motion command completes. The state machine will remain in this state until the Ch1Cmd RELAY is cleared. This RELAY can be cleared from the HMI by pressing the “STOP” button.