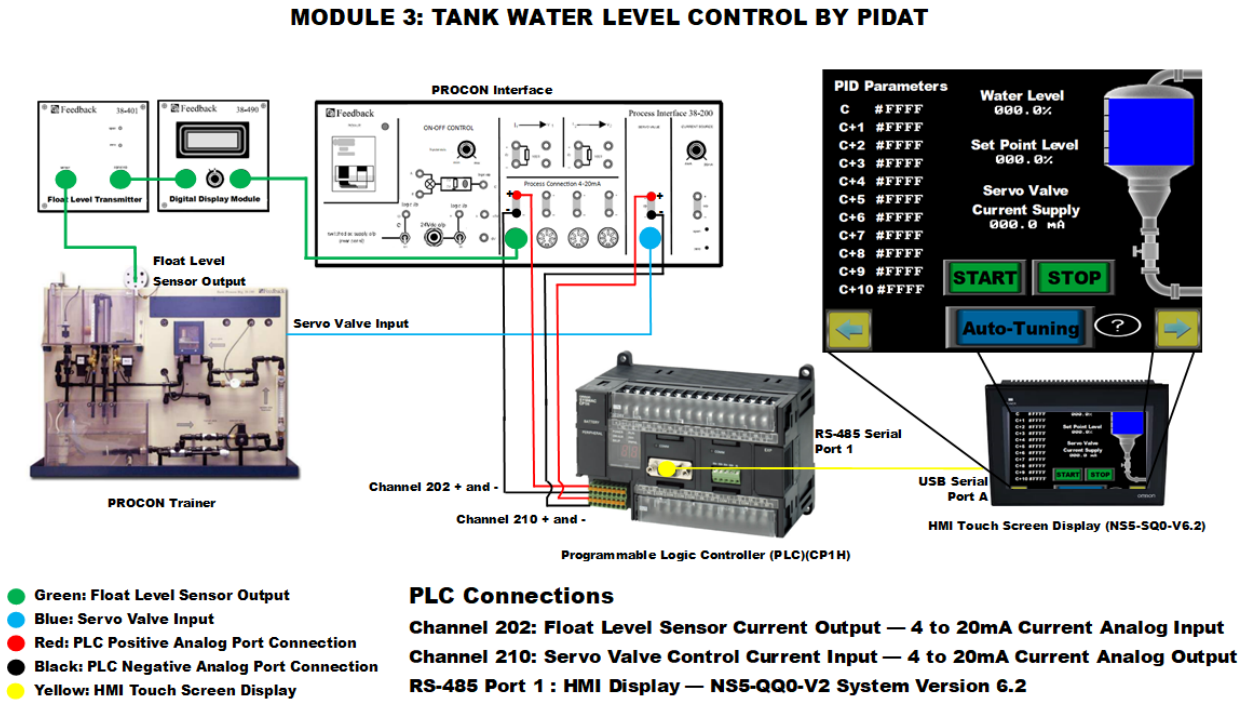
PROJECT DESIGN: TANK WATER LEVEL CONTROL BY PIDAT

The goal of this project is to design and implement a Proportional–Integral–Derivative (PID) Model with and without PID–AutoTuning (PIDAT) to control the tank water level. The input or measured variable is the water level given by the float level sensor to the current analog input of the PLC. On the other hand, the output or the controlled variable is the servo valve opening controlled by the PLC current analog output. An HMI design was provided for the user interaction to change the set value, P, I, D, and sampling period of the PID system.

I. SYSTEM SETUP



The setup is composed of the following components: Programmable Logic Controller (PLC), PROCON Trainer, Float Level Transmitter (FLT), Digital Display Module (DDM), PROCON Interface, and an HMI Display. The built-in Float Level Sensor (FLS) of the PROCON trainer is connected to the float level transmitter for output adjustment of the maximum and minimum limits. It will then pass through the DDM for a digital display

to the user then proceed to the PROCON interface which will separate the positive and negative signal for each ports. This will be the positive analog current input to the channel 202 of the PLC which will be treated as the measured variable of the PID model. A program uploaded in the PLC will compute and control the controlled variable. The output will be a 4-20mA current from channel 210 that will be connected to the Servo Valve section of the PROCON interface and to the built-in servo valve of the PROCON trainer via DIN Cable. This completes the input, process, and output of a basic implementation of a PID. Additional feature to the setup is a touch screen HMI design connected by RS-485 cable at a serial port to modify the PID parameters as well as observe the input and output values as numerical and graphical display.

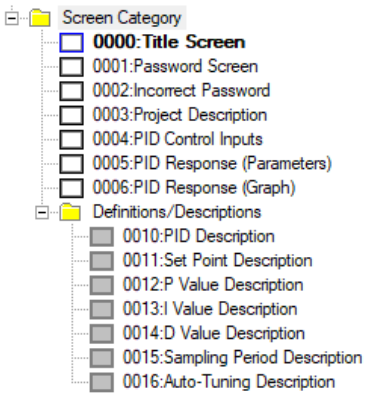
II. PLC Input/Output Assignment

PLC Input/Output	PLC Address	Function/Description
Input	CH 202	Float Level Sensor Output Current
Output	CH 210	Servo Valve Input Current Control

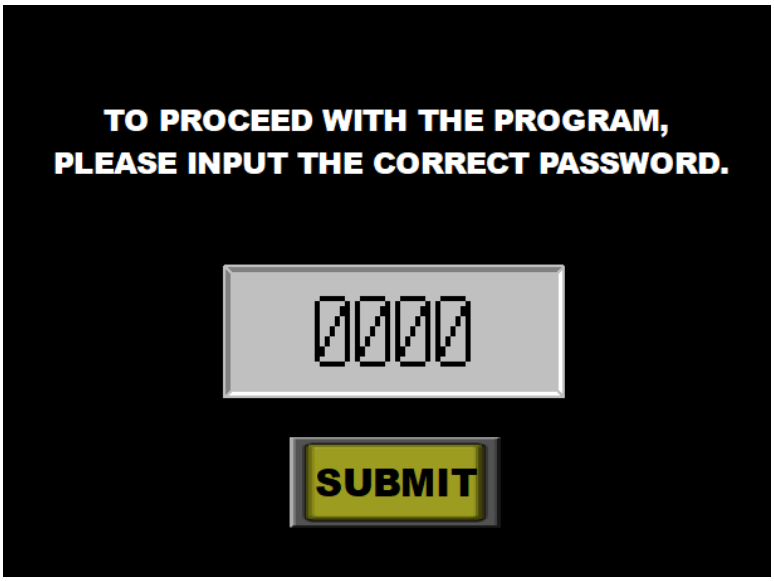
The sole input of the PLC in this project design is the float level sensor output current connected to the channel 202 or the analog current input of the PLC. On the other hand, the sole output of the PLC is the servo valve input current that is controlled through the channel 210 or the analog output channel of the PLC.

III. HMI DESIGN

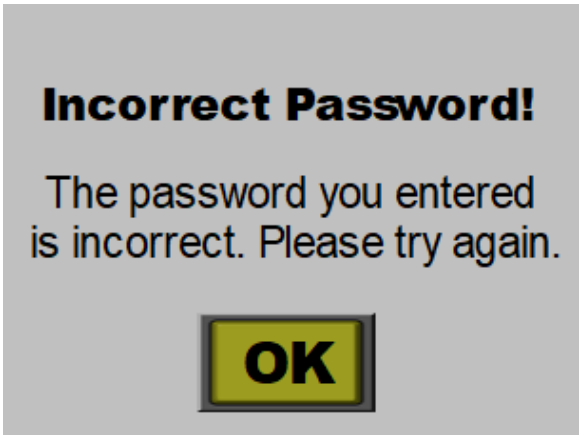
The HMI design for this project consists of multiple screen displays wherein each screen have their specific purpose or function such as project description, parameter control, or monitoring of the PID response.



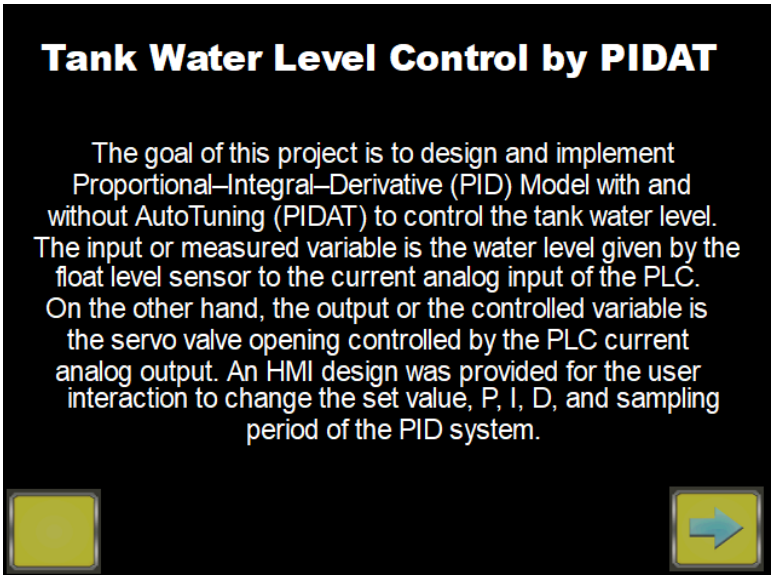
Although 14 screen display are used in the program, only 3 are primarily concerned with the PID model parameter control and response display while the other screens are either used as user authentication by password verification or project and content descriptions as useful hints to the user.



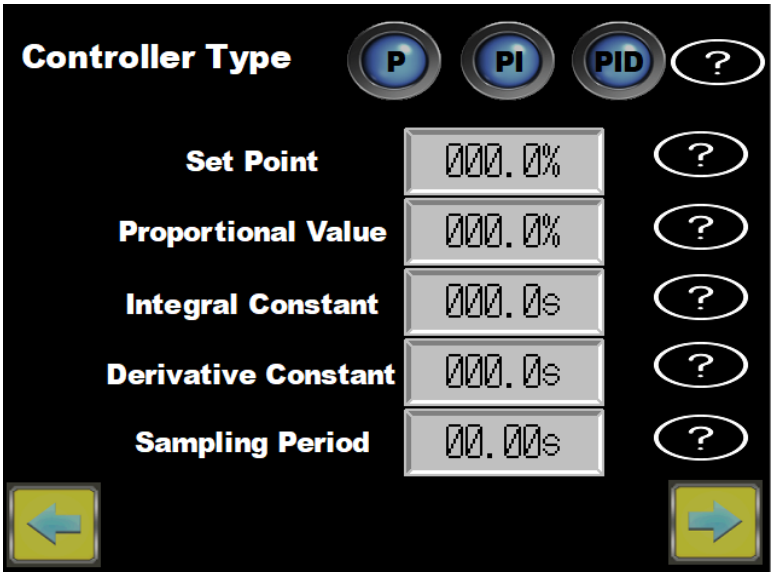
At the password screen, the only way the user can proceed to PID screens is to enter the correct password which is “1234” in BCD otherwise, the incorrect password screen will be shown.



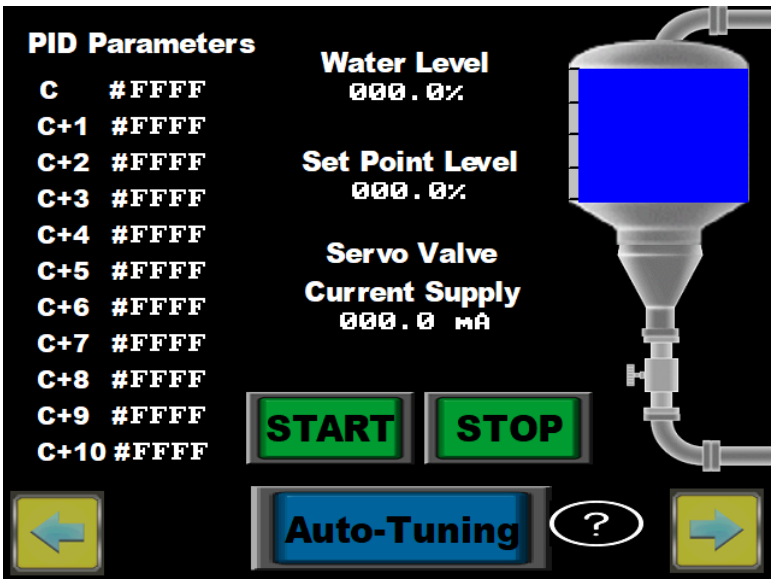
The incorrect password screen is intended as a pop-up screen to remind the user to retry submitting a different password since the password entered is incorrect.



Once the correct password has been submitted, the project description will be displayed which briefly explains the project content. The main PID screens are treated like adjacent screen pages. A button is shown in the main PID screen which acts as a next or previous page button in the bottom left and right part of the screen.

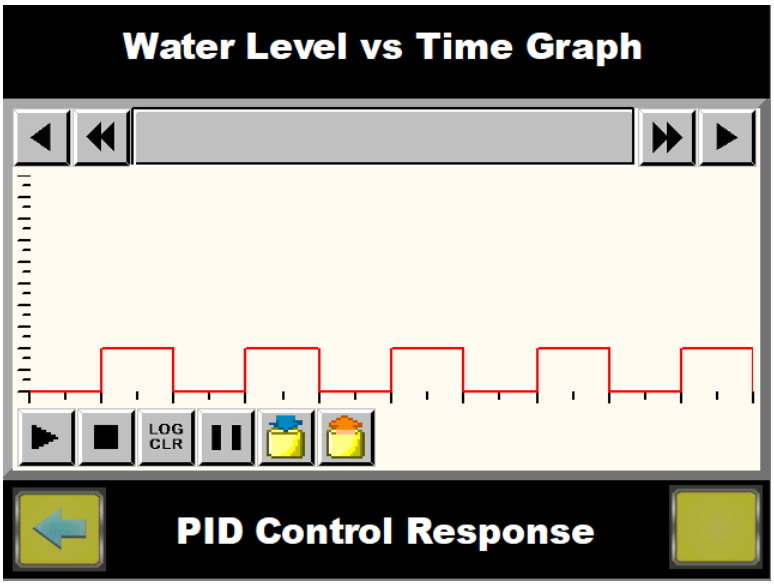


The PID control inputs screen allows the user to select only one controller type: P type which only uses proportional value, PI type which uses both proportional and integral value, or PID type which uses proportional, integral, and derivative values. If the user proceed to the next page or screen and starts the program, the default controller type will be used which is the P type with a default set point value, p value, and sampling period.

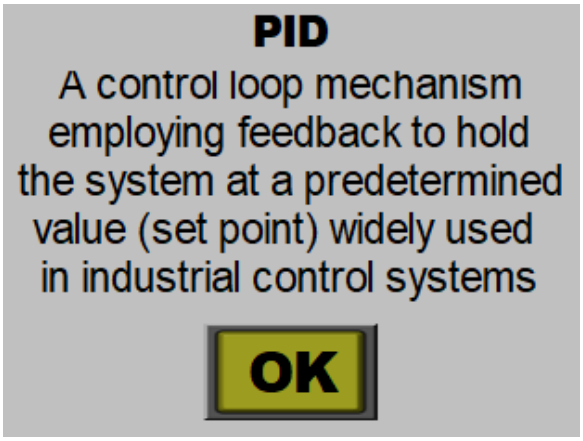


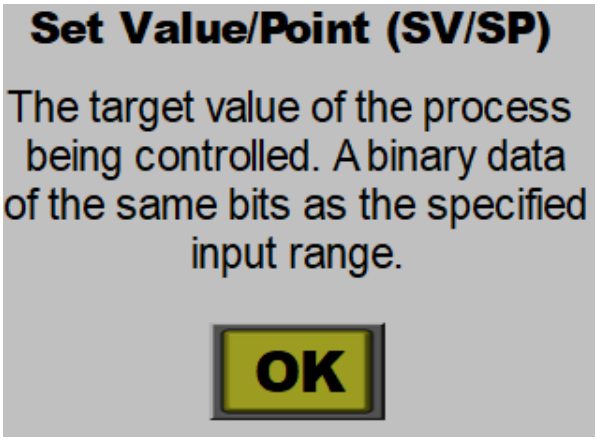
The PID response parameter screen shows the following:the main PID parameters as it is stored in the data memories, the water level or input of the PID, the set point or the target of the PID, the servo valve current supply or the output of the PID, a tank display which adjusts the water level corresponding to the input, the start and stop buttons for the

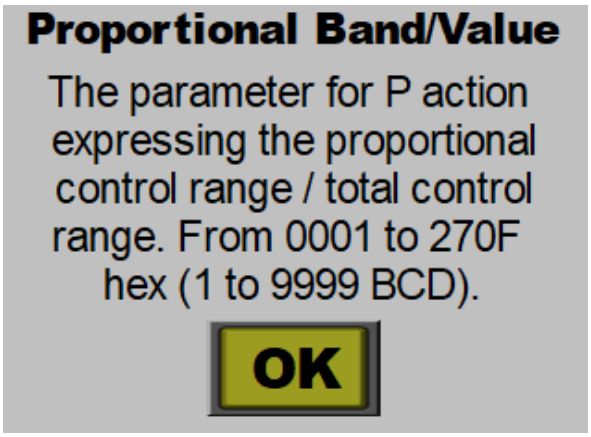
program, and the auto-tuning button which is used to start the automatic tuning of the PID.

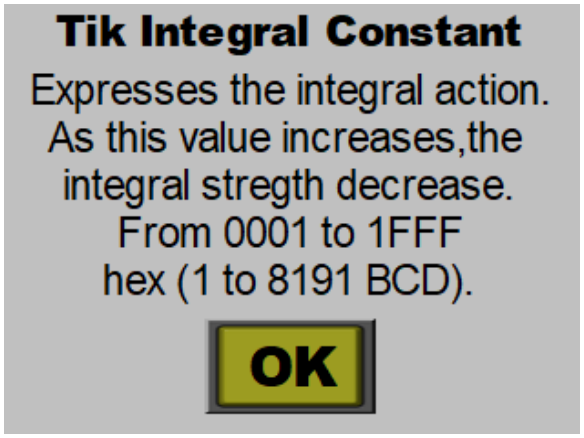


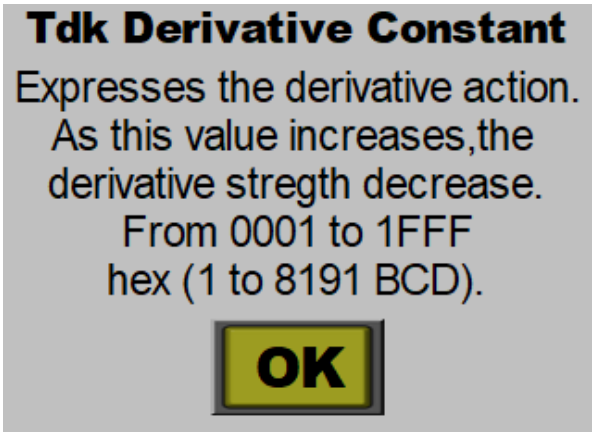
The last of the main PID screens, the PID response graph screen, shows a data log graph which plots the water level at the numeral value axis against time. Both the current water level and the set point is graph at once. The red plot is the set point and the blue is used for the current water level. The graph can store the data for future references.

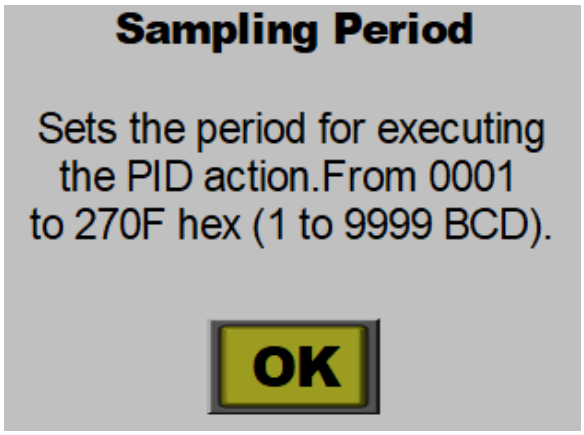


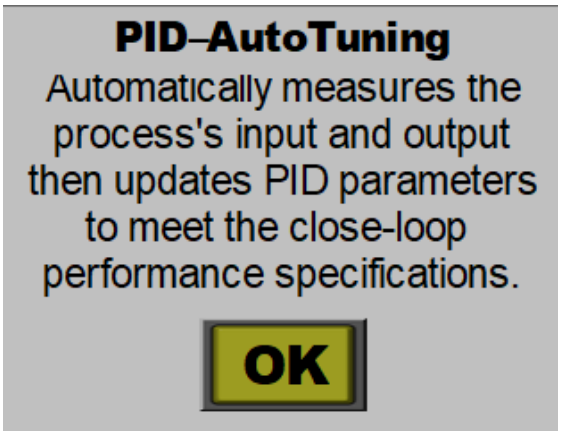




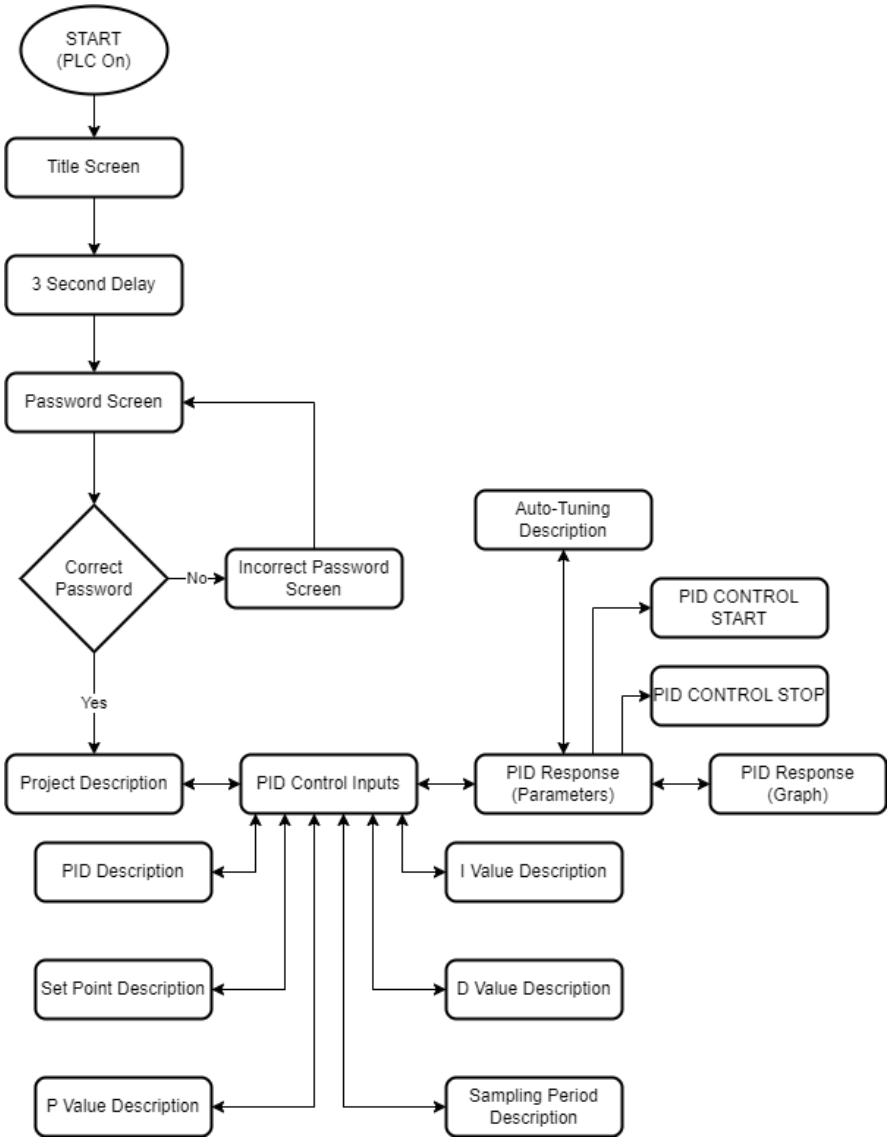








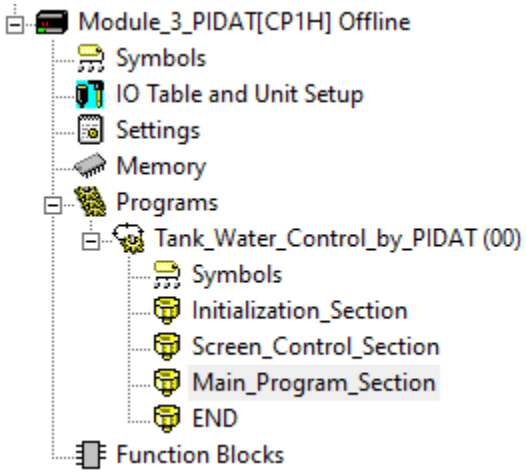
The following are the pop-up description screen that are shown whenever the corresponding hint button (question mark logo) has been pressed.



The program is configured in such a way that the first screen displayed is the title screen followed by the password screen after a short delay. If the password submitted is correct, the project description screen will be displayed otherwise the incorrect password screen will be displayed. The project description, PID control input, PID response parameters and graph screen are designed like adjacent pages which can be controlled but the forward or backward page button (arrow logo). At the PID control inputs and response screens, several description screens are available to be shown when the corresponding button has been pressed (question mark logo).

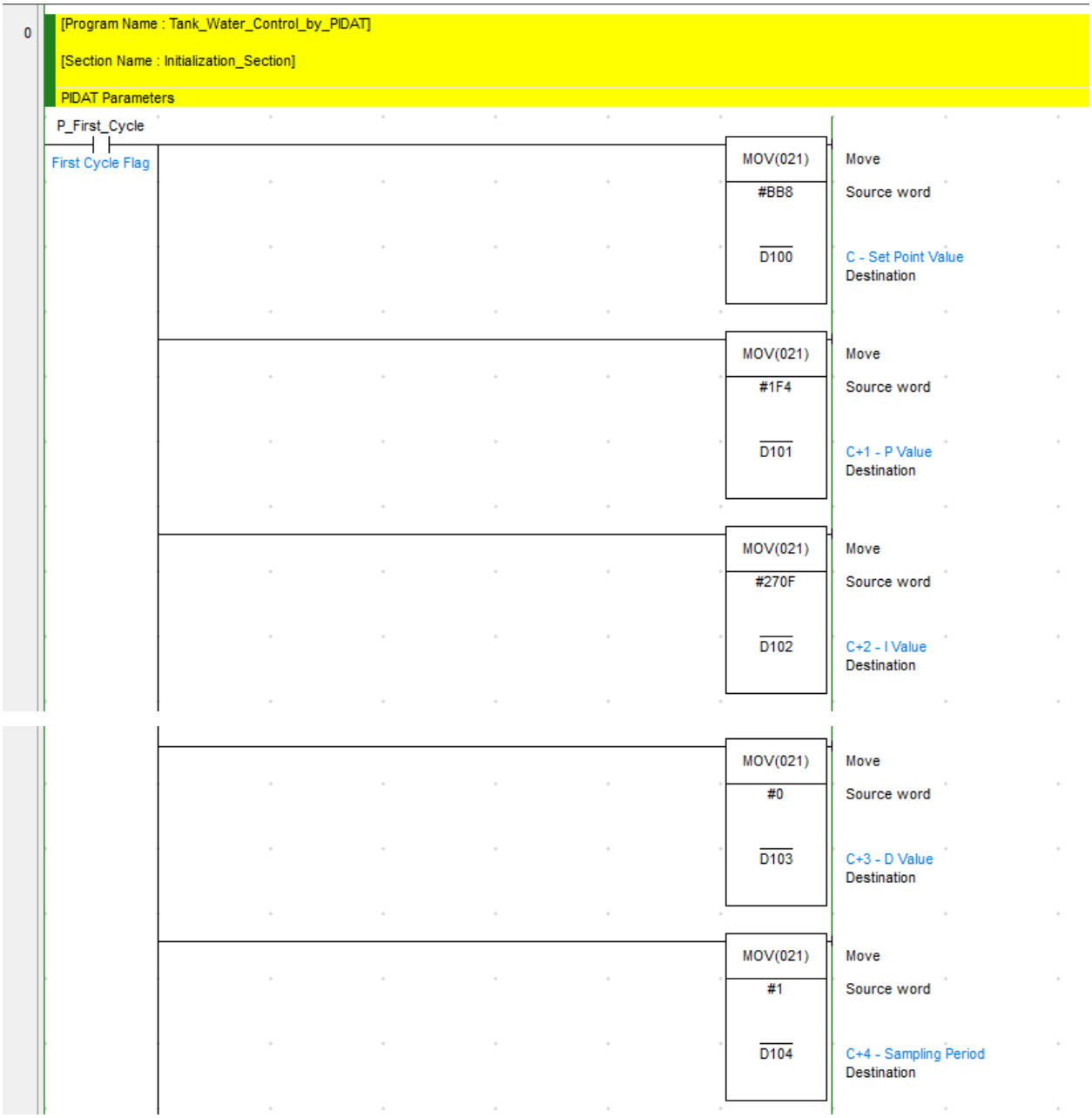
IV. PLC LD PROGRAM

The Programmable Logic Controller (PLC) used in the project is CP1H thus, the program code and functions will be based on the CP1H series.



The PLC program is mainly divided into three sections: Initialization section, screen control section, and main program section. The initialization is used to set or clear the initial values for the data memories that will be used in the main program. The screen control section is just as alternative from using command button in the HMI design. It is also used to control the delay as well as conditions on how to switch from one screen to another.

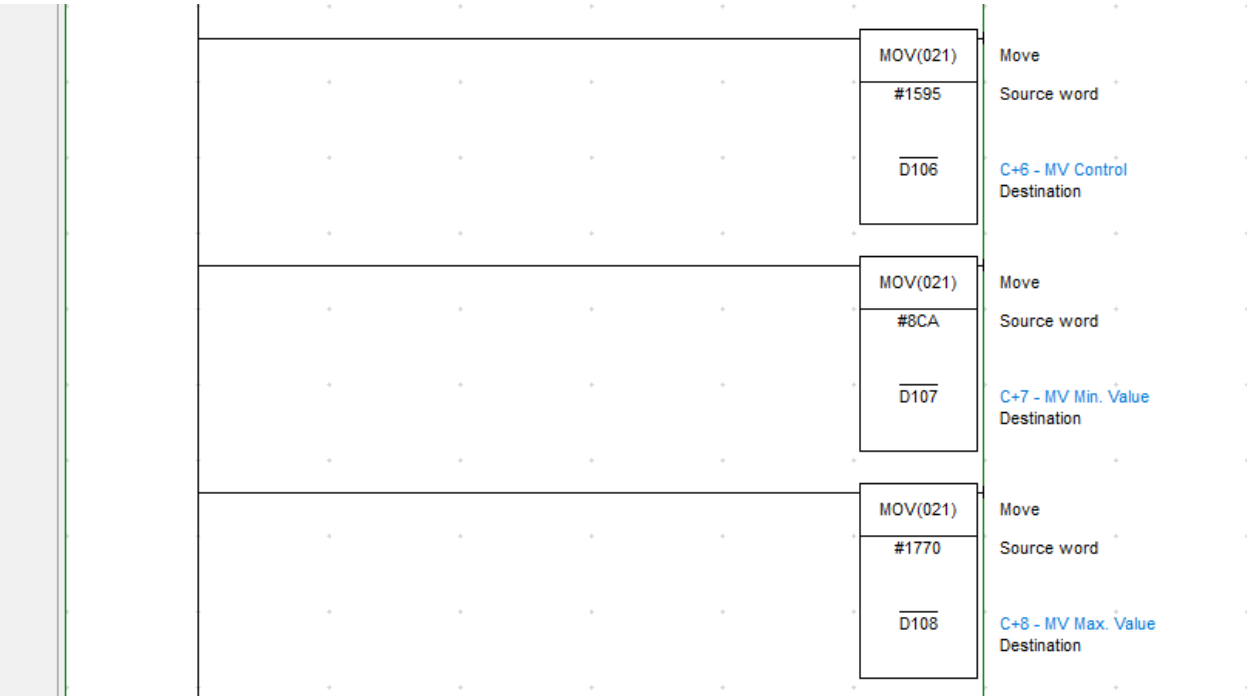
A. Initialization_Section



The parameters C to C+4 are the basic parameters settings of a PID Model. It has an initial or default values but the user can change the value at the HMI design. The value ranges are also implemented on the HMI design to avoid exceeding the limit. C or SV is the target value of the PID process being controlled which will be ranged based on the measured variable input range. C+1 or P value is for the proportional control range while C+2 or I value is for the integral and C+3 or D value for the derivative of the PID model.

C+4 is just the sampling period that ranges from 0.01s to 99.99s. The P, I, and D value range can be modified in C+5.

This parameter is further divided into specific PID settings. Bit 00 is for forward or reverse action, but in this case, the PID control for the water tank system used is the reverse action. Bit 01 is for the PID constant change whether it is enabled only at the start of execution or also at each sampling period which is also the control for changing the setting range of the P, I, and D. Bit 03 is set as 0 so that the manipulated or controlled variable will output 0% when measured variable is equal to the set value. Bit 04 to 15 is for the 2-PID parameter specifically the filter coefficient which has a default value of 0.65.

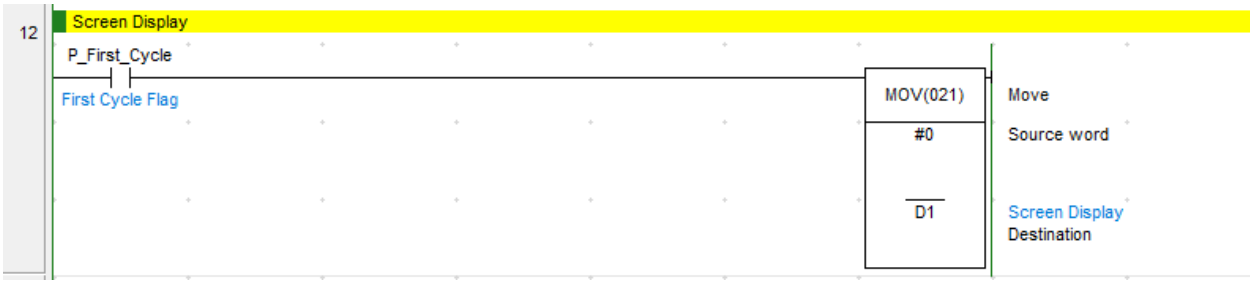


C+6 is basically the control settings for the C+7 and C+8 or the maximum and minimum values of the controlled variable. Bit 00 to 03 and 08 to 11 are just the designation of data bits for output and inputs, respectively. Since the resolution set on the

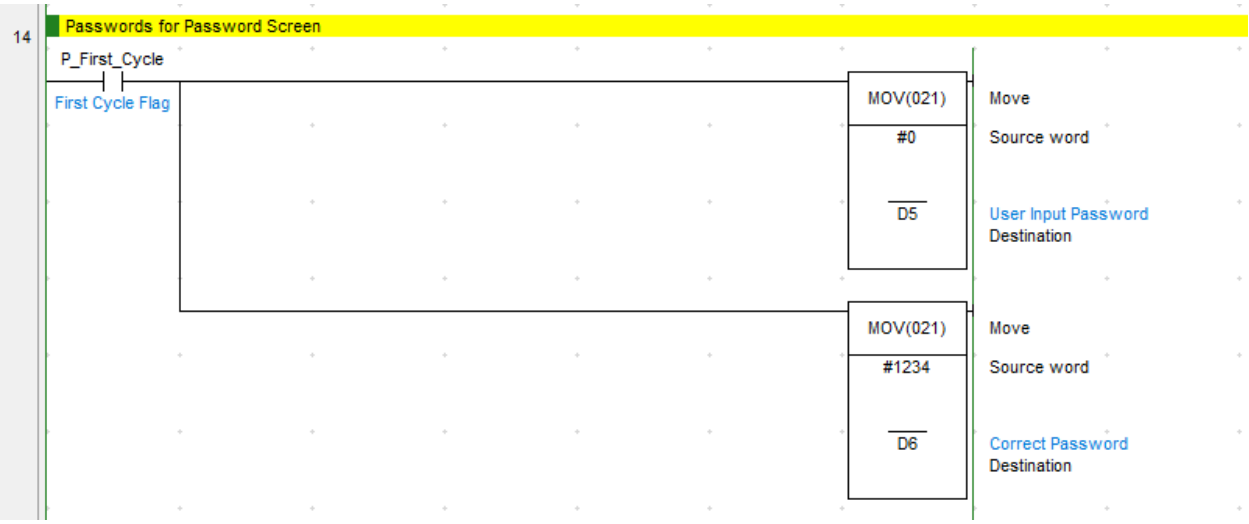
PLC settings is 6000, the equivalent word is #1770 or binary 0001 0111 0111 0000 which only uses 13 bits thus, using the value #5 to the respective bits. Bits 04 to 07 is for determining the I and D units whether it is based on sampling period multiple or by 100ms. In this case, the choses parameter is to base on 100ms. Bit 12 is for determining whether or not the limit control will be applied on the controlled variable which just specify whether to use C+7 and C+8 or not. A value of 1 means that it will be used as well as the other parameters included in the C+6.

C+9 is only composed of autotuning command and the autotuning gain. Changing the bit 15 state will control the PID autotuning process. Bits 00 to 11 for the AT gain can be ignored so the default gain is 1.00.

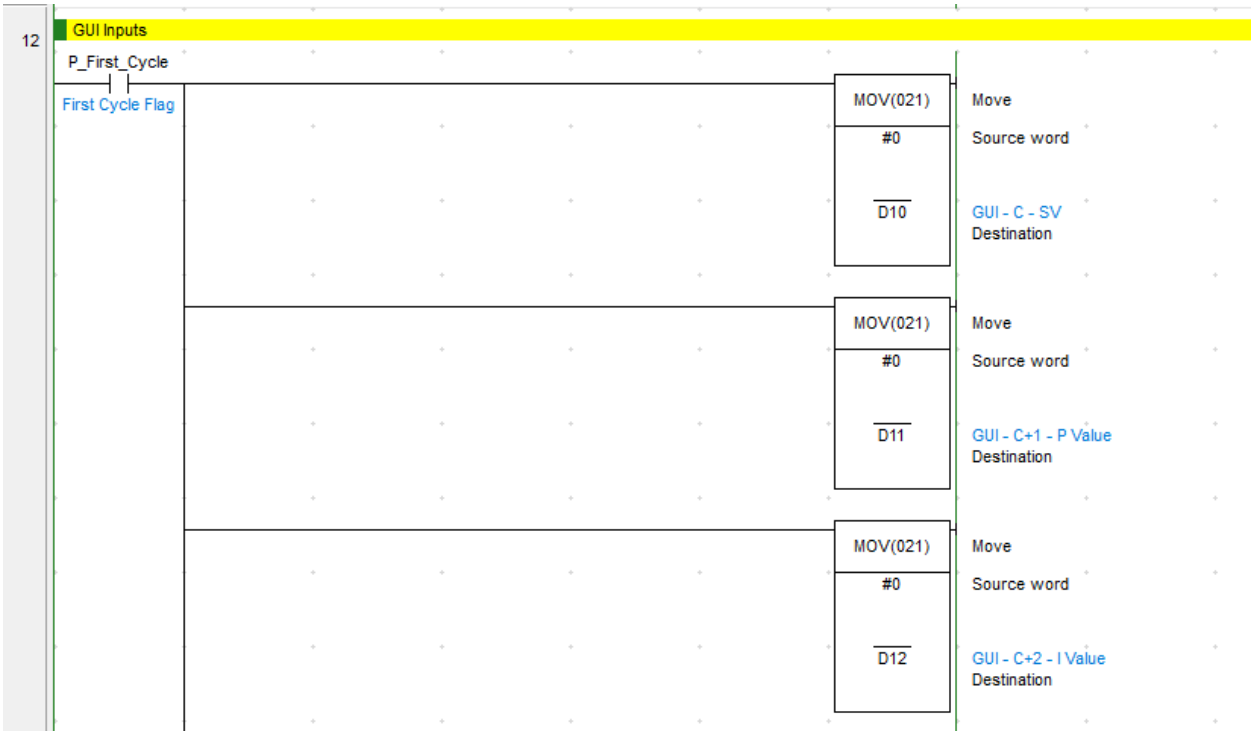
C+10 sets the hysteresis when the limit cycle is generated which has a default hysteresis of 0.20%.

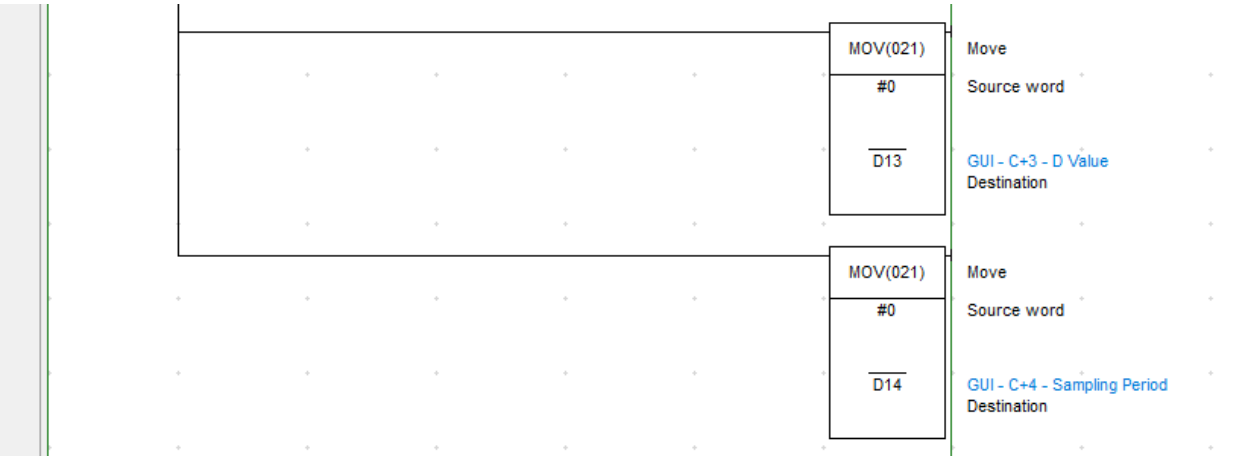


Data memory 1 or D1 is configured as the allocation address for the current screen displayed in the program thus, clearing the D1 at the initialization of the program will display the screen 0 or the title screen.

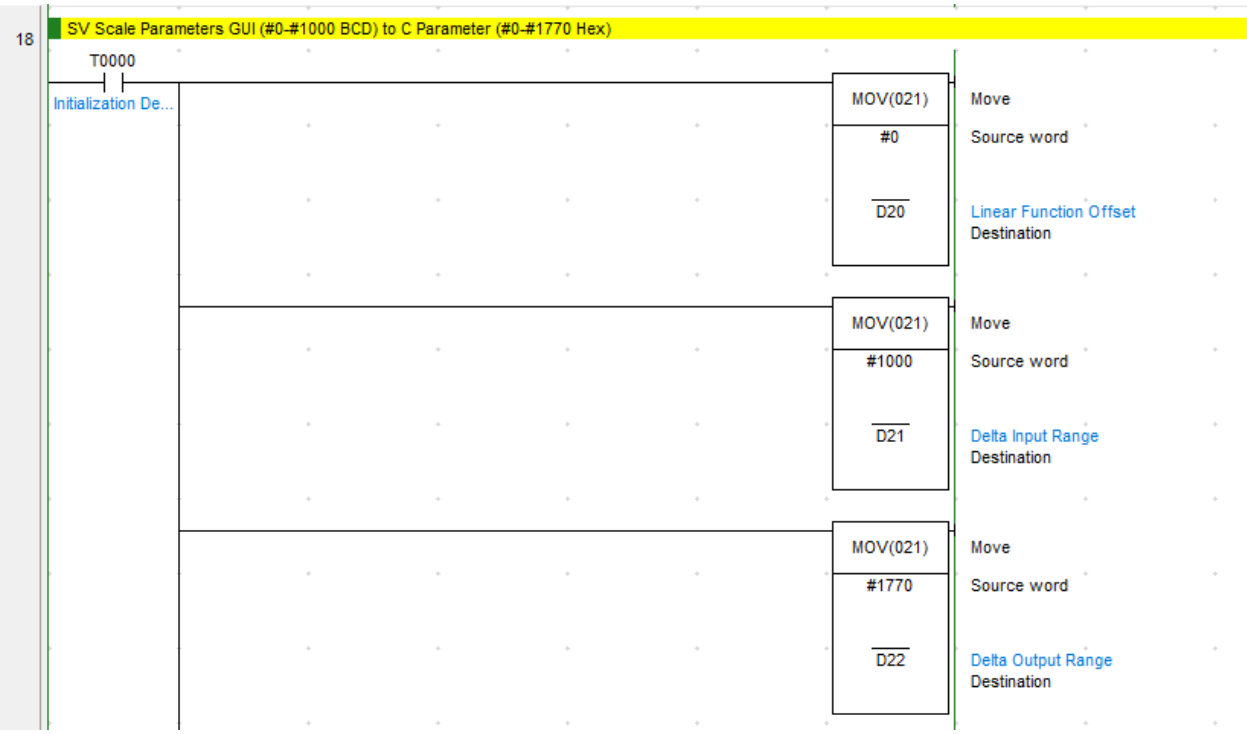


The password screen allows the user to input a numerical value. The value must be the same as the configured “correct password” of “1234” for the user to proceed with the main program. The D5 is used to store the user input password while D6 is for the admin or the programmer’s configured “correct password”.

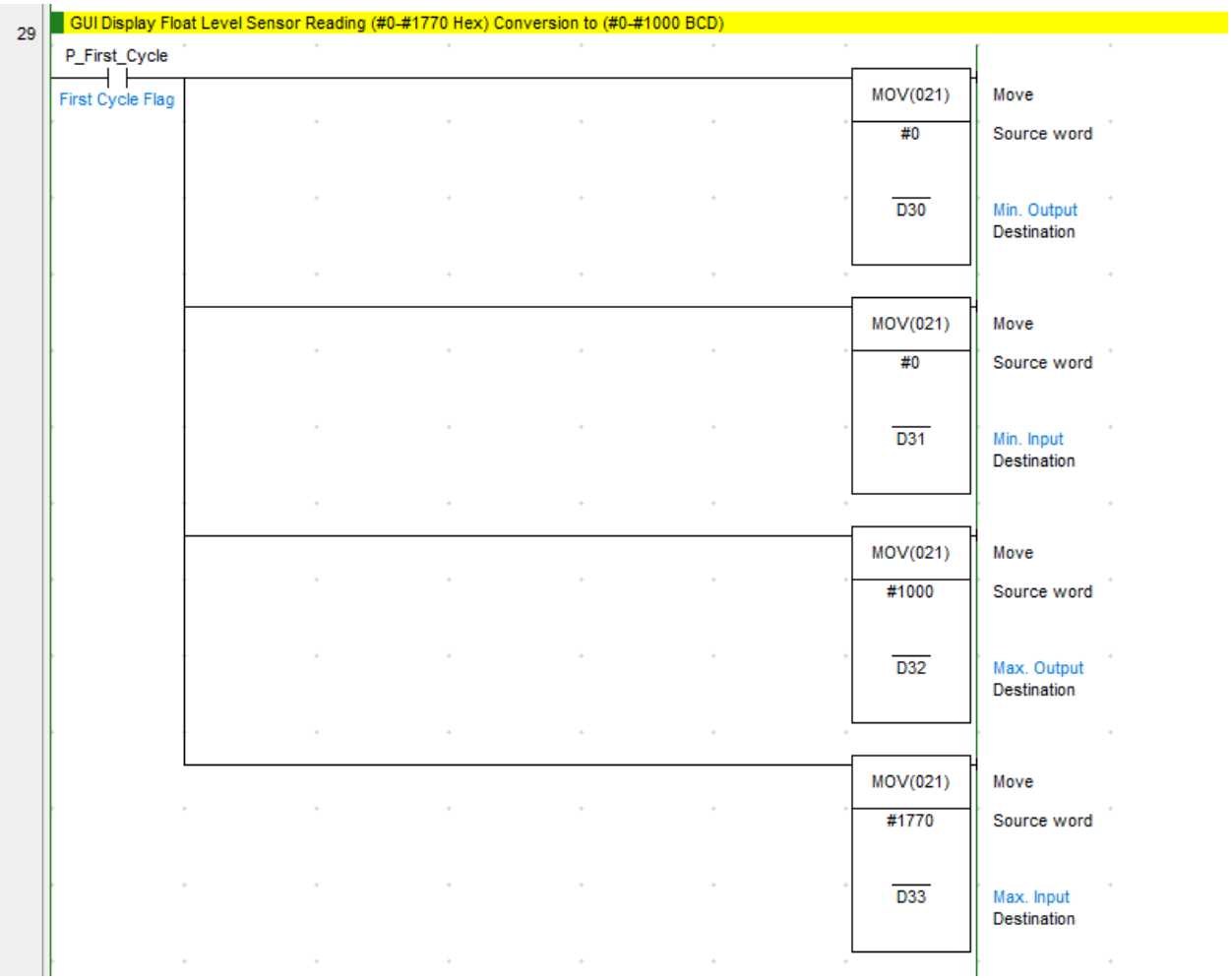




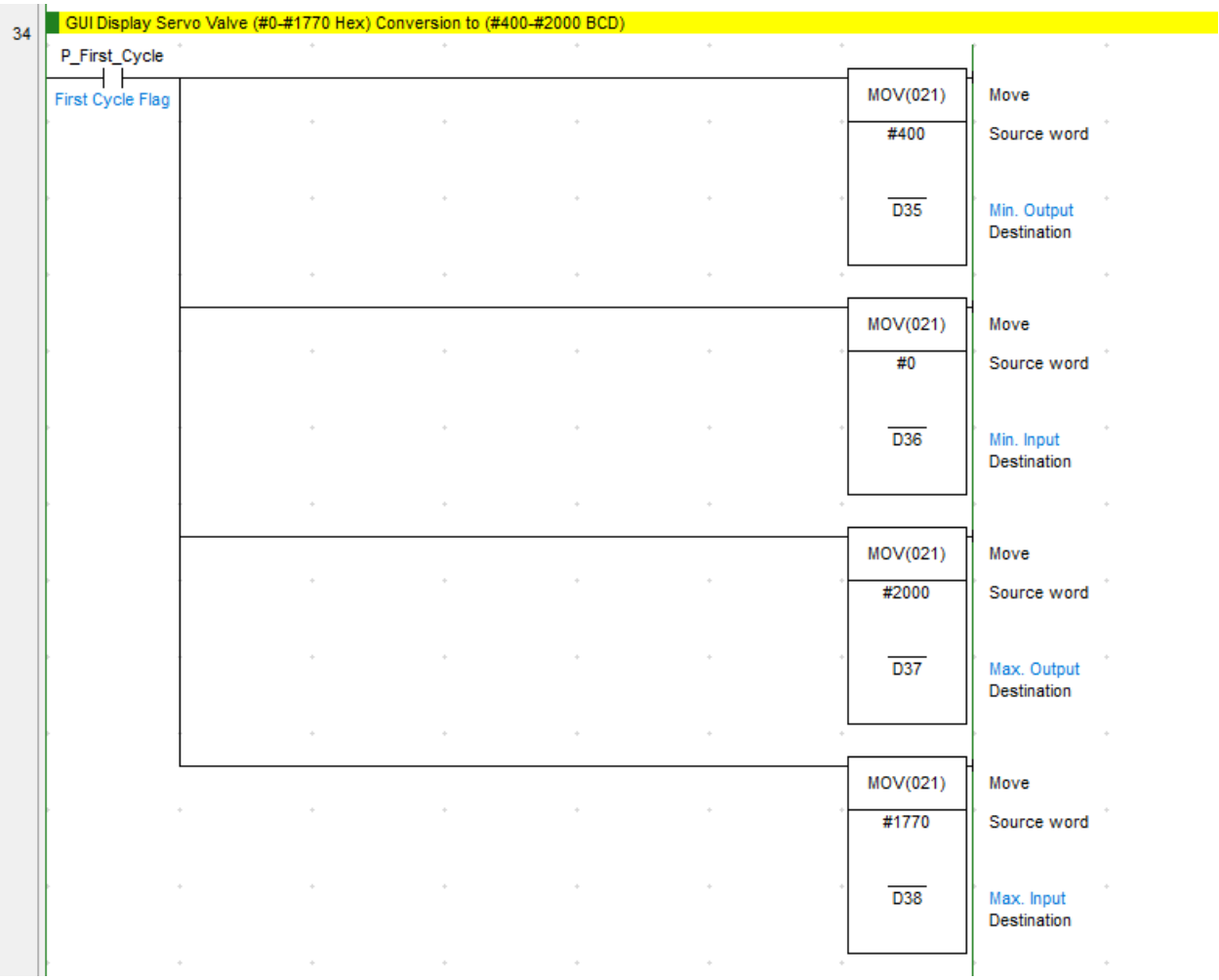
Aside from the PID parameters, a separate DM are used for the initial input from the GUI or HMI. Since it is BCD, it still must be converted or scaled before transferring the equivalent value to the PID parameters.



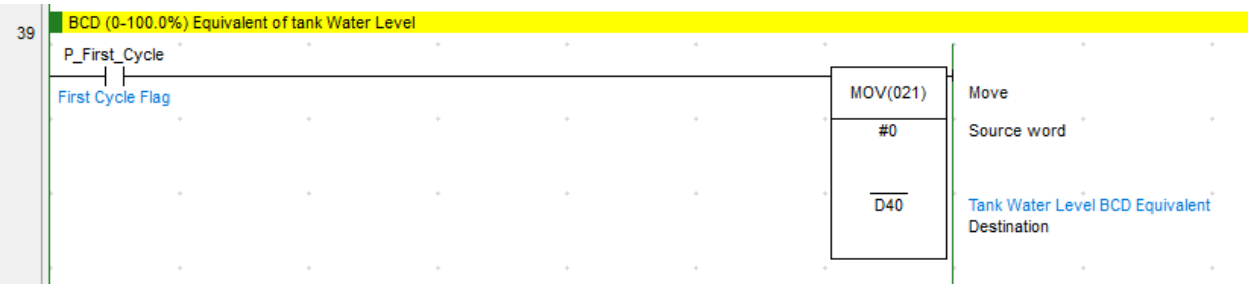
Another process that uses a specific parameter is the SCL3 which is for scaling the BCD input for SV to the accepted range of SV in C parameter of PID. From an input of 0 to 1000 (0-100.0%) BCD it is scaled to #0 – #1770.



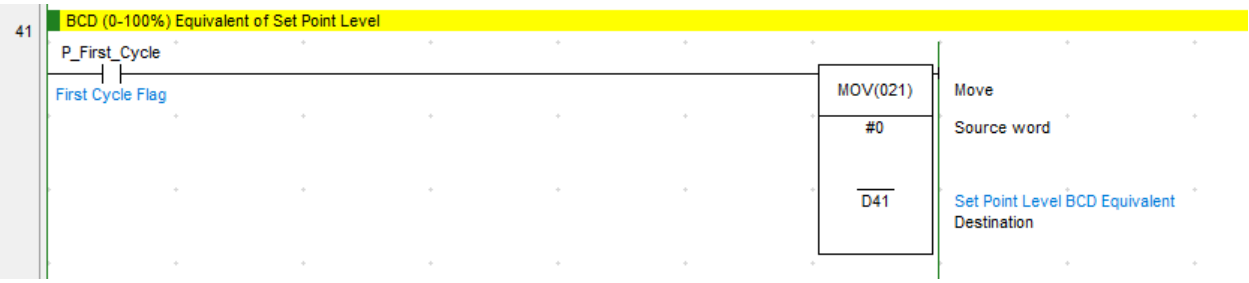
A conversion from binary to BCD will be implemented in the program thus, the following data memories are used as the SCL parameter for converting an input range #0 - #1770 hex to an output range #0 - #1000 in BCD.



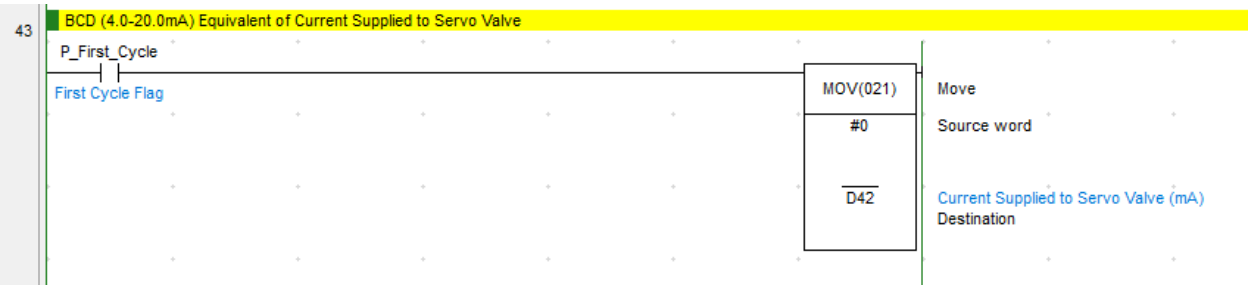
A conversion from binary to BCD will be implemented in the program thus, the following data memories are used as the SCL parameter for converting an input range #0 - #1770 hex to an output range #400 - #2000 in BCD.



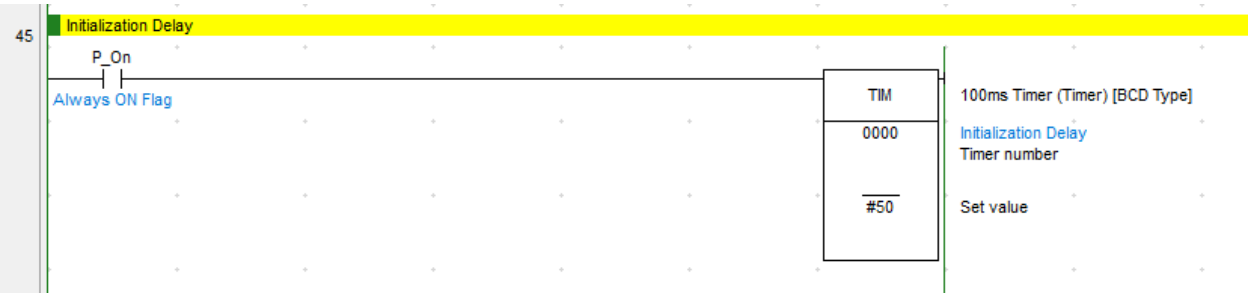
The BCD equivalent of tank water level will be stored in D40 as the output of an SCL in the main program.



The BCD equivalent of set point level will be stored in D41 as the output of an SCL in the main program.

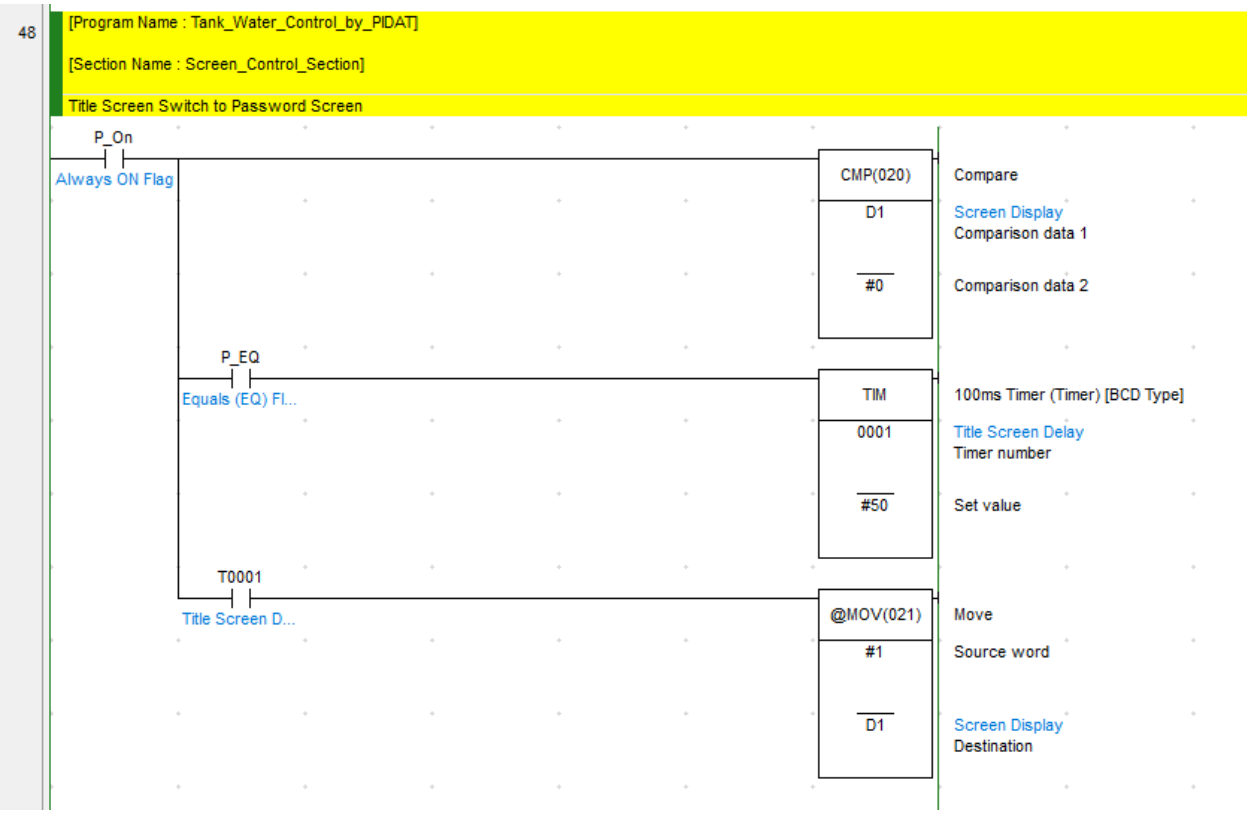


The BCD equivalent of current supplied to the servo valve will be stored in D42 as the output of an SCL in the main program.

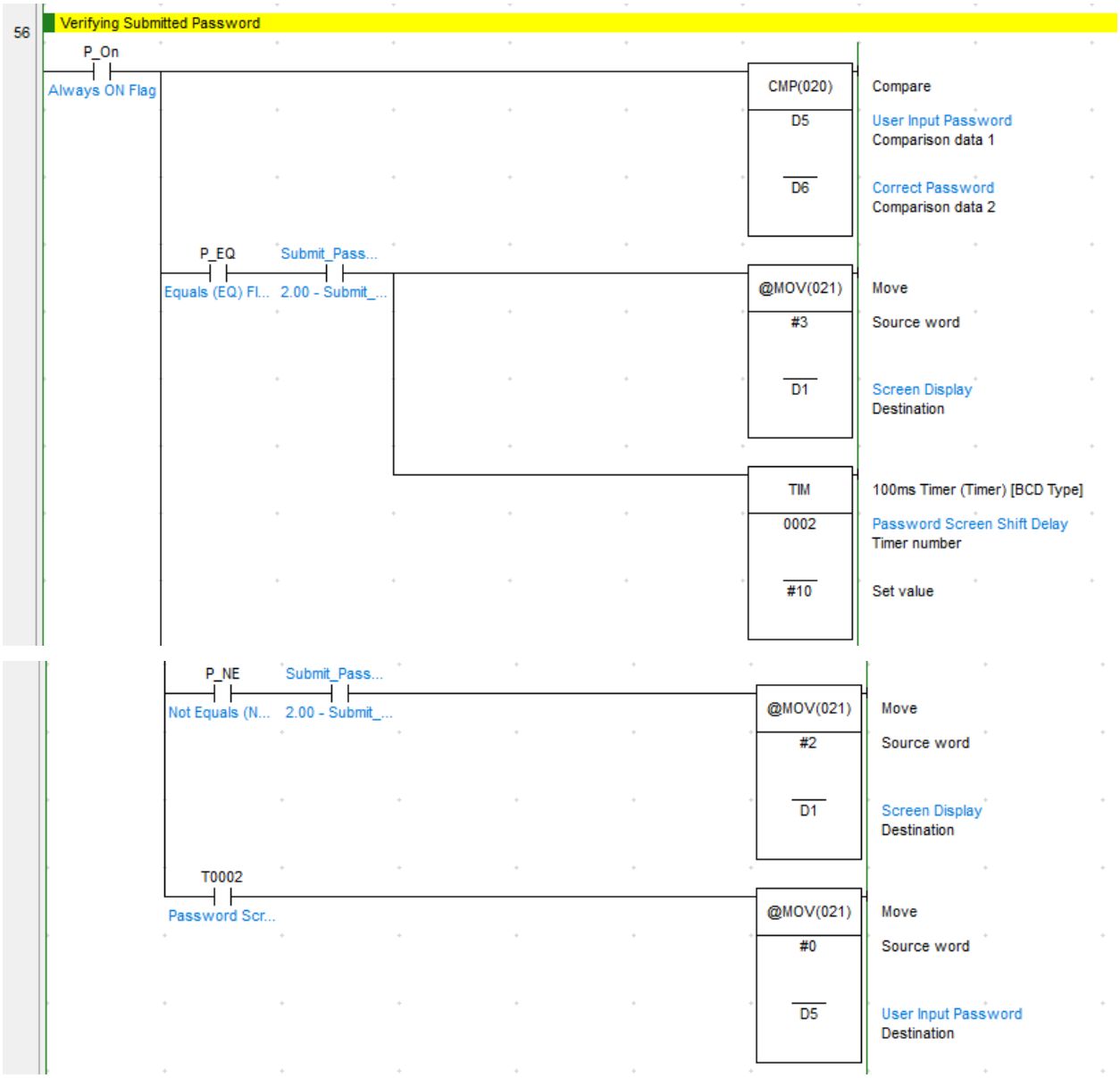


A short delay was implemented to allow the system to finish the initialization. This timer will be used before the other program or function is allowed to run to avoid any possible error at the start.

B. Screen_Control_Section

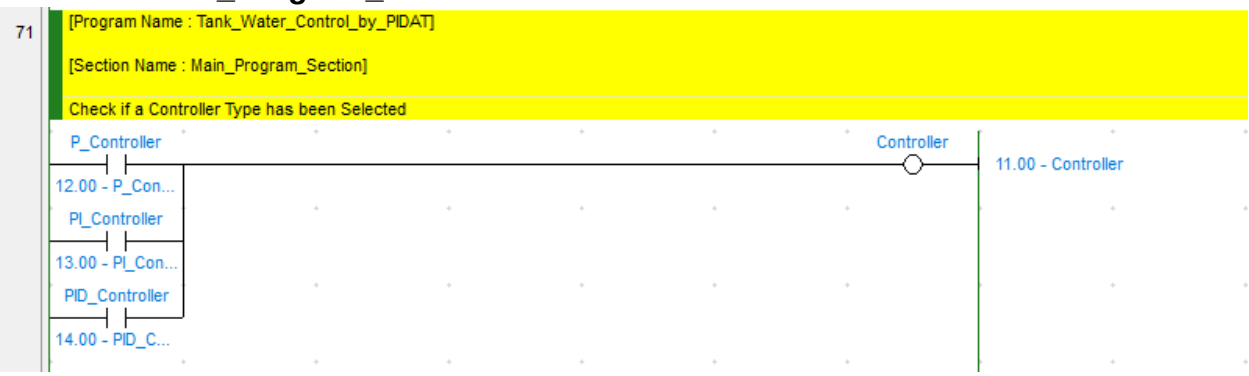


The first part of the second section is used to enable a delay whenever the current screen displayed is the title screen before it automatically shifts to the password screen.

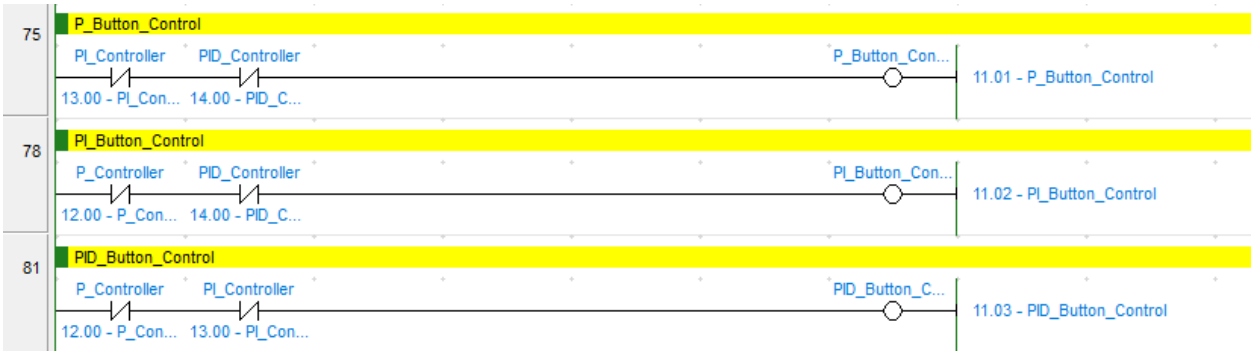


The second part of the second section is just in the verification of the password submitted in the password screen. If the password submitted is incorrect, the screen will display the pop-up incorrect password screen. However, if the password submitted is correct, the screen will shift to the main PID screen specifically the project description while clearing the data from the user input password.

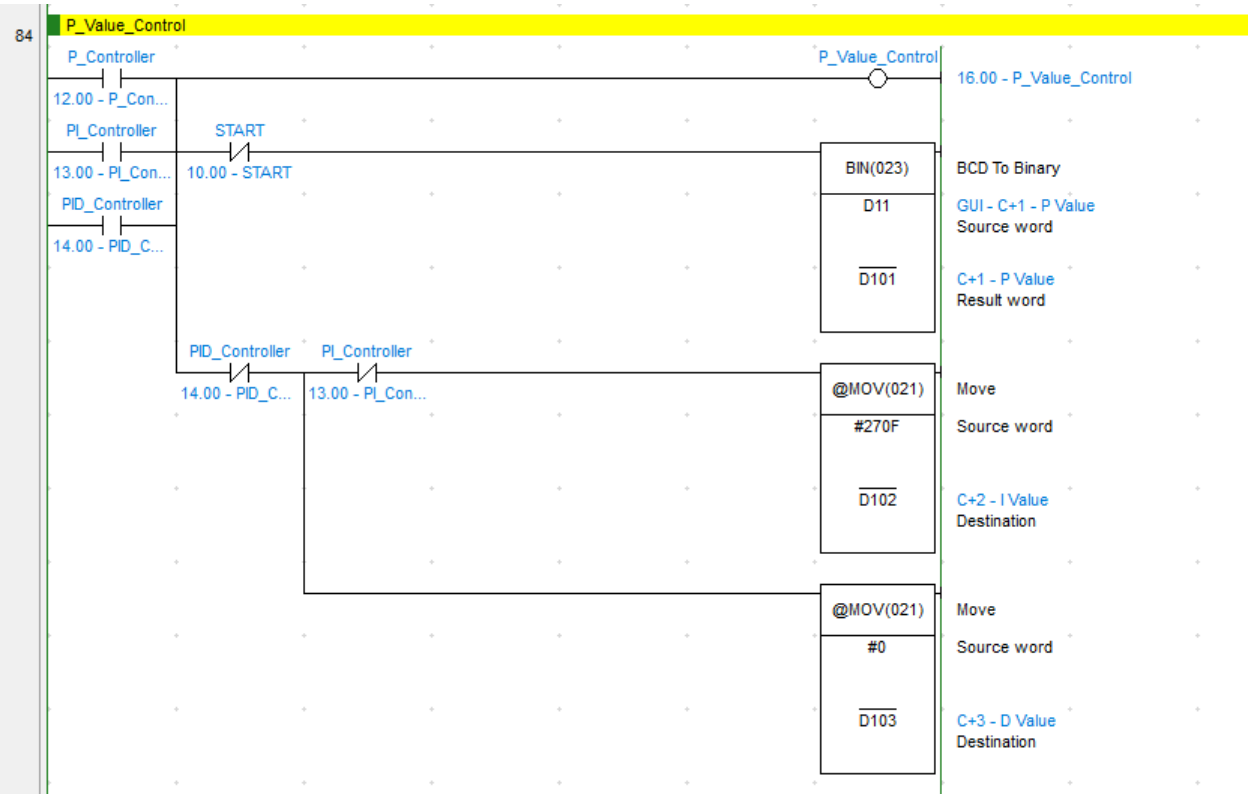
C. Main_Program_Section



The first part of the third section, the main program section, is to determine whether a controller has been selected or not. This will be used in the HMI control flags and latter part of this program wherein it can be used as a control that only when a controller has been selected, the program will allow the user to change the value.



Aside from determining whether a controller has been selected, the three rungs are used as indicator whether the other buttons has been pressed. For example, the P_Button_Control will be enabled provided that the PI and PID button has not been pressed. This is used as a control flag in the HMI design so that only one button can be pressed at a time but all button are allowed to be pressed when no button has been pressed.



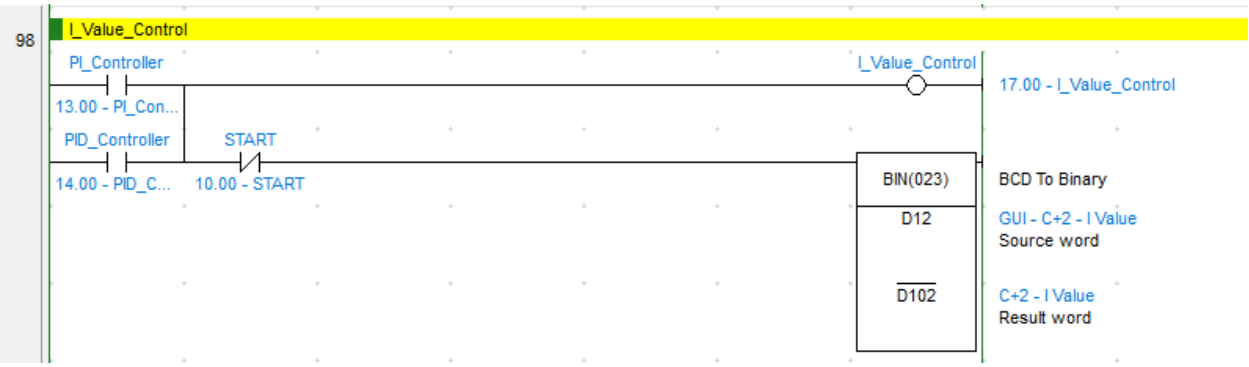
Whenever any type of controller has been selected, the P_Value_Control will be enabled. This will control whether the P value numerical input will be allowed to be changed or not.

When P type controller has been selected, only the SV, P value, and sampling period will be allowed to be change. Both C+2 and C+3 parameters of the PID will be configured so that the PID to only acts as proportional controller.

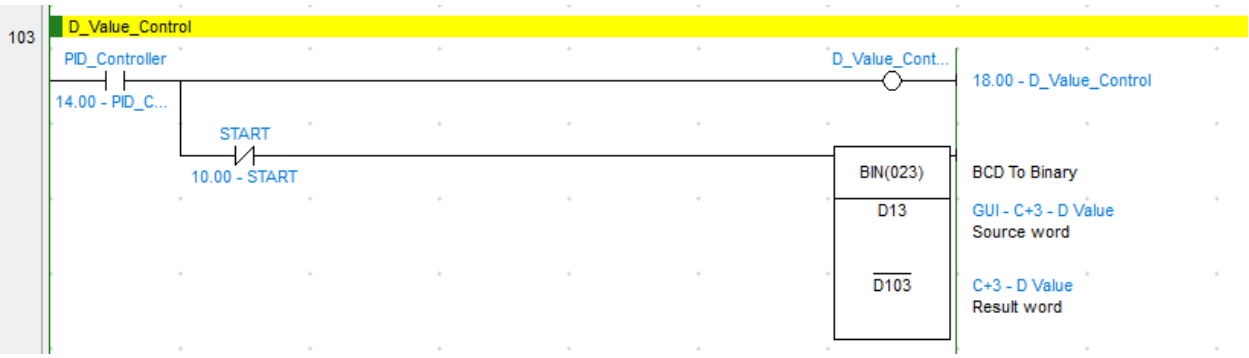
When PI type controller has been selected, only the SV, P value, I value, and sampling period will be allowed to be change. The C+3 parameter of the PID will be configured so that the PID to only acts as proportional-integral controller.

When PID type controller has been selected, the parameters SV, P value, I value, D value, and sampling period will be allowed to be change. This makes the PID to act as proportional-integral-derivative controller.

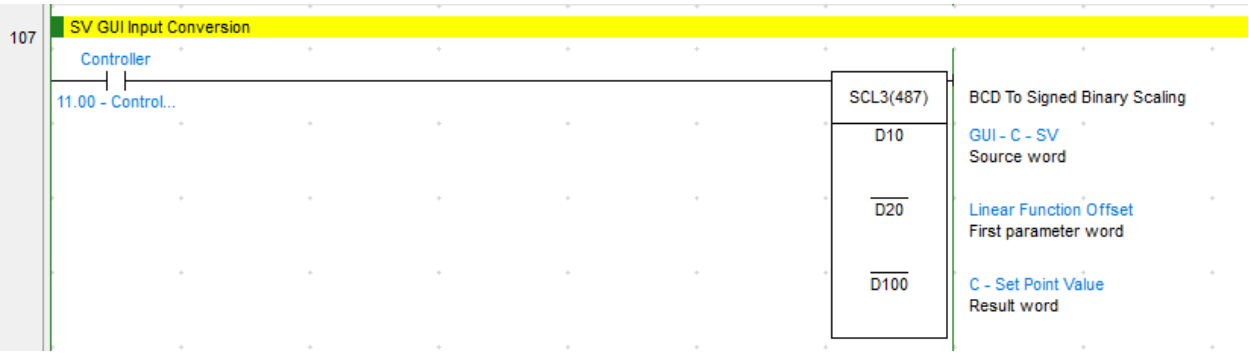
Only when the “START” is enabled will the program disable the conversion or change to the PID parameter C+1



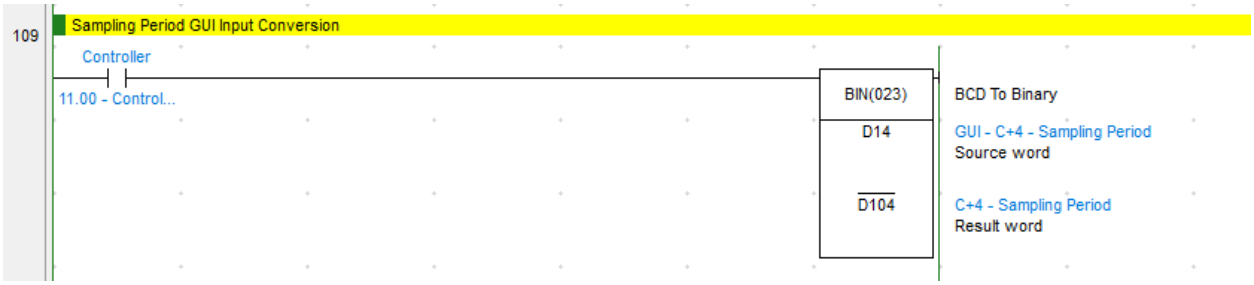
When either PI or PID type controller has been selected, the program will display and allow change to the I value. Only when the “START” is enabled will the program disable the conversion or change to the PID parameter C+2.



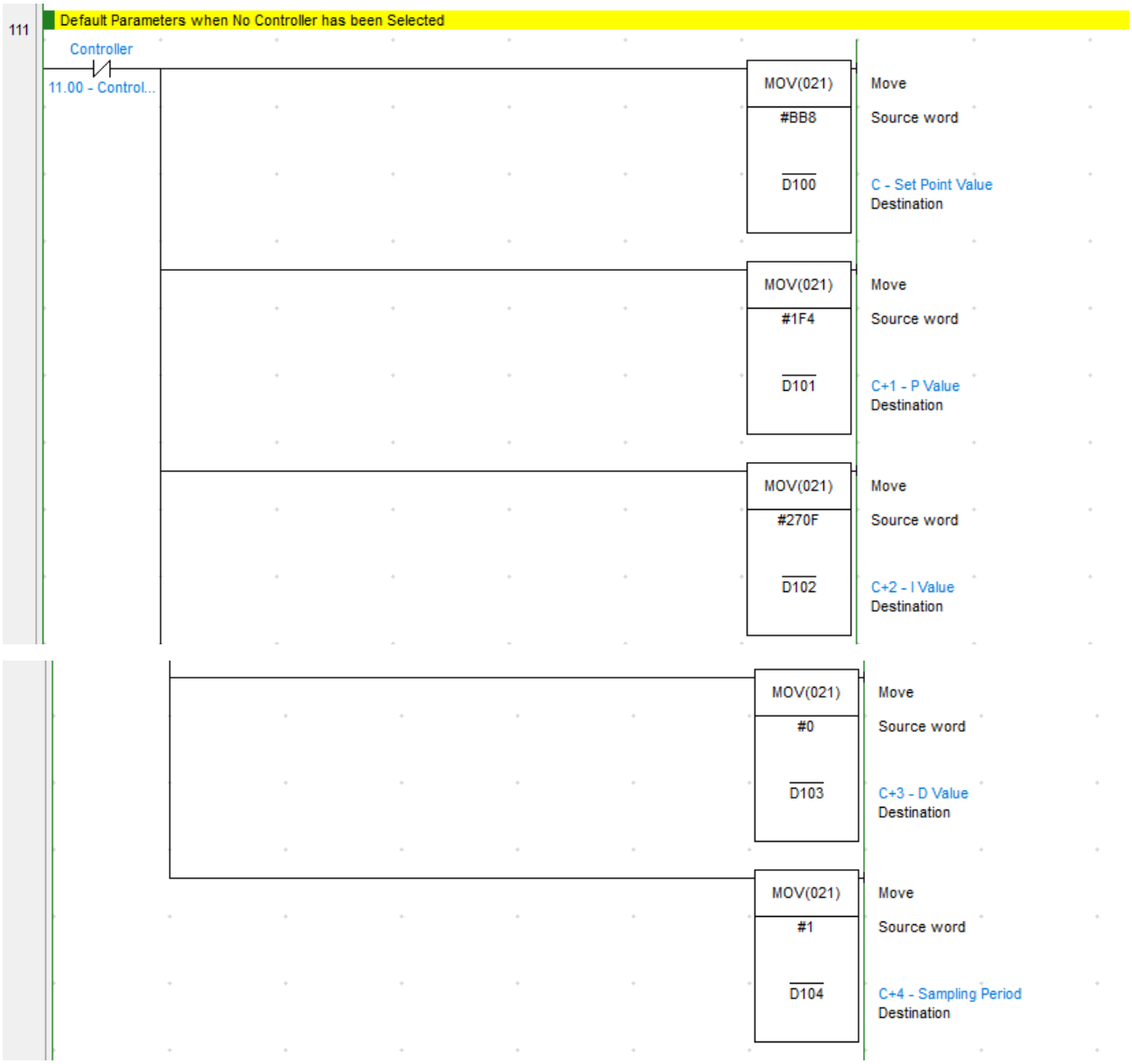
When PID type controller has been selected, the program will display and allow change to the D value. Only when the “START” is enabled will the program disable the conversion or change to the PID parameter C+3.



When any type of controller has been selected, the program will display and allow change to the set point value.

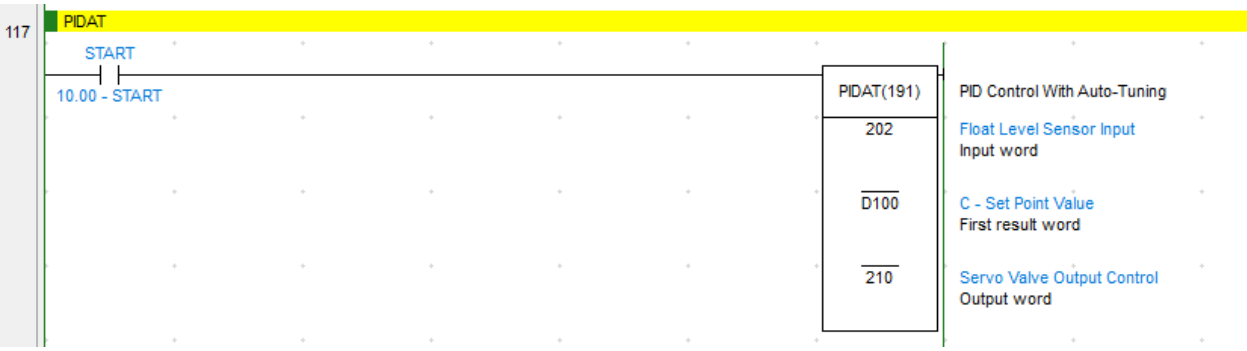


When any type of controller has been selected, the program will display and allow change to the sampling period.

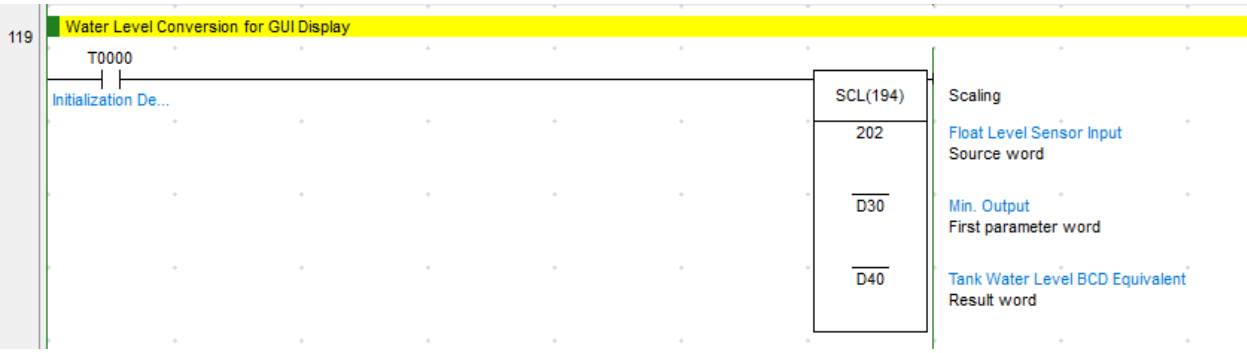


When no controller has been selected, the default values are loaded into the PID parameter. The controller will be a P type with an SV of 50% the input range while a sampling period of 0.01s.

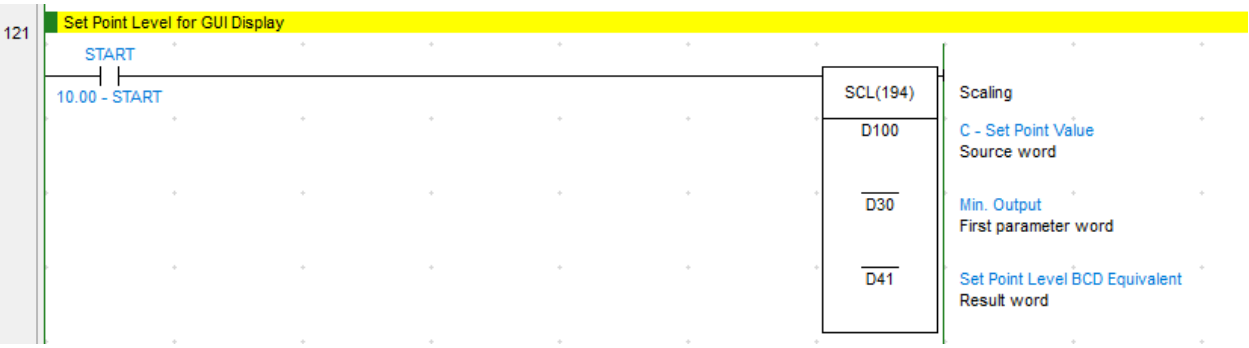
The PID will only actually start when either the HMI “START” push button has been pressed or a digital input signal at channel 0.00 of the PLC. This will continue to latch and will only end whenever the HMI “STOP” push button has been pressed or a digital input signal at channel 1.00 of the PLC.



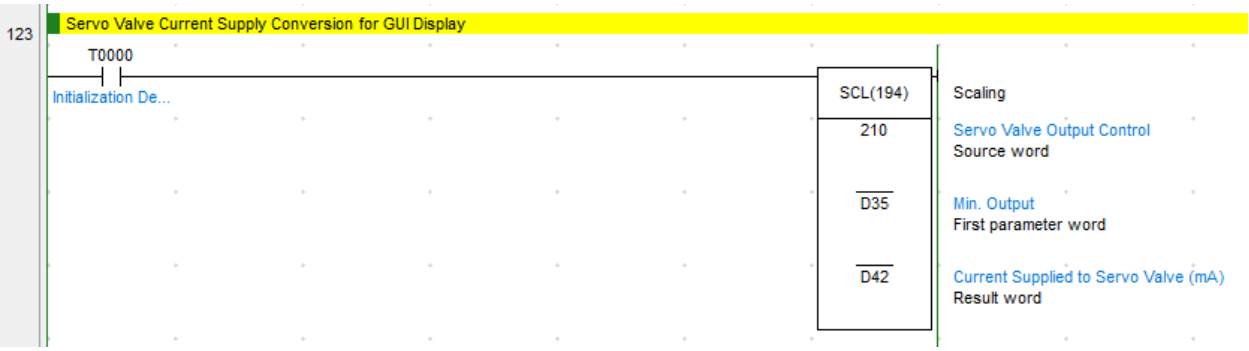
Once “START” is enabled, the PLC will begin to perform PID based on the values stored in the SV, P, I, D, and sampling period.



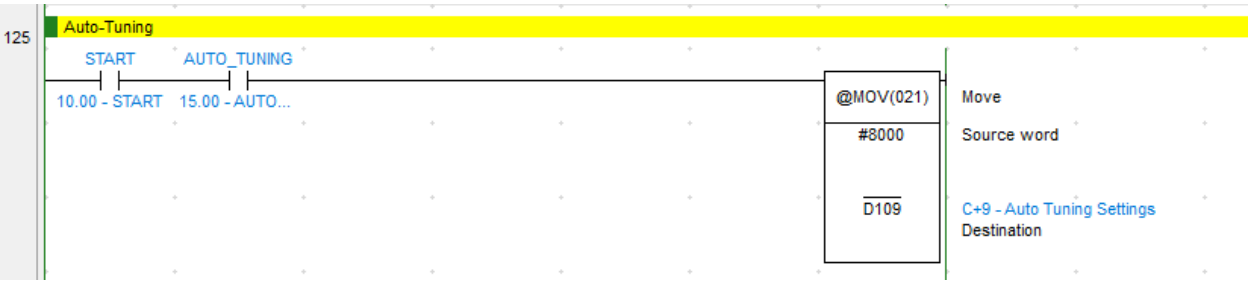
At any point in the program, the user can monitor the current water level in the tank through the HMI numerical display. The SCL conversion of the input uses the parameters configured at the initialization section.



At any point in the program, the user can monitor the set point value or target water level of the tank through the HMI numerical display. The SCL conversion of the input uses the parameters configured at the initialization section.



At any point in the program, the user can monitor the current supplied to the servo valve through the HMI numerical display. The SCL conversion of the input uses the parameters configured at the initialization section.



At any point in the PID process, the user can enable the autotuning which will automatically tune the P, I, and D parameters of the system. Once done, the PID parameter specifically C+9 bit 15 will return to 0.