MAKER: Instructional Module on Use of a Programmable Logic Controller for Smart Traffic Light Control

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Abstract

A Smart PLC Traffic Light system using a smart PLC controller logic has been developed. Traffic light system is being controlled for each light based on traffic flow using proximity sensors that detect presence of vehicles at the intersection of roads. The smart traffic light system consists of a Click PLC, proximity sensors, and a traffic light apparatus.

Motivation

Traffic light systems are available all around the world. They are a great tool for preventing accidents at the intersection of roads and for controlling traffic flow at intersections. In the old system, the traffic control is done by setting predetermined time for each Red, Green and Yellow on each road. Predetermining the time for each light can be impeding traffic flow, because a driver can be at the intersection waiting for the red light to change to green based on the predetermined time while traffics in other directions are with no traffic at all. Traffic light The Smart PLC Traffic Light system using a Click PLC controller was developed to solve the problems identified in the old traffic light cycle system.

At the 1999 Annual International EMME/2 Conference of Chicago, Illinois, a paper on improving reliability of Traffic using intersection delay was presented by Aashtiani et al.. Delay estimation at intersections was determined with or without signals. This detailed research really highlights the needs of improving traffic light control and also the challenges that we are facing.

The objective of this lesson plan is to develop a Smart PLC Controller logic based traffic light simulator system. The system consists of a several proximity sensors, a Click PLC, power supply, and 2 sets of green-yellow-red lights to simulate the traffic light controlled by a ladder logic program.

As compared to fixed time control systems, the foundation of a dynamic system is actually a detector which is nothing more than a simple device that communicates with the traffic light and informs it about traffic conditions in real time. This time, the traffic light can not only adjust timing, but also solve traffic congestion by changing the cycle of the traffic light as soon as the traffic in the intersection gets heavy with cars.

This project is using proximity sensors to simulate the switches or cameras that in a real scenery will communicate to the PLC about the traffic condition

In this project the cycle of the traffic light will be change by the Smart Traffic Light Controller depending of traffic in the intersection. There will be different times on for the Green and Red lights depending of the input, and the Yellow light will be kept constant on for 2 seconds.

Per example, If inputs, Sensor 1 and Sensor 2 or Sensor 5 and Sensor 6 are on and inputs Sensor 3 and Sensor 4 or Sensor 7 and Sensor 8 are off the PLC controller will run a program M10, if inputs Sensor 3 and Sensor 4 or Sensor 7 and Sensor 8 are on and inputs Sensor 1 and Sensor 2 or Sensor 5 and Sensor 6 are off the PLC controller will run a program M11.

Project System Platform

An automated system typically consists of controller, sensors, lights, and system structure. Table 1 lists the components of the platform used for this project and cost.

Item	Description	Quantity	Cost
Click PLC	Model C0-00DR-0	1	$68
Proximity Sensor	Double M12 PW PNP NO	8	$192
Color Light	24-Volts and 12- Volts	2 red, 2 green, 2 yellow	$24
Power Supply	24-Volt	1	$45
Power Supply	12-Volt 25-Watt	1	$27
PLC Software	Software	1	$0
Wood Platform	Wood 20x20 inc	1	$10
Wires	Black/red/green	1 pack	$7

Table 1. Project Platform and Cost

The Smart Traffic Light

This system has been designed to demonstrate how a traffic light in an urban intersection will work controlled by a Smart Traffic Light System. Following is a detailed description including the physical design, input and output assignments, the system schematics, and the ladder logic programing of this smart system. Fig. 1 shows the finished design of the system.

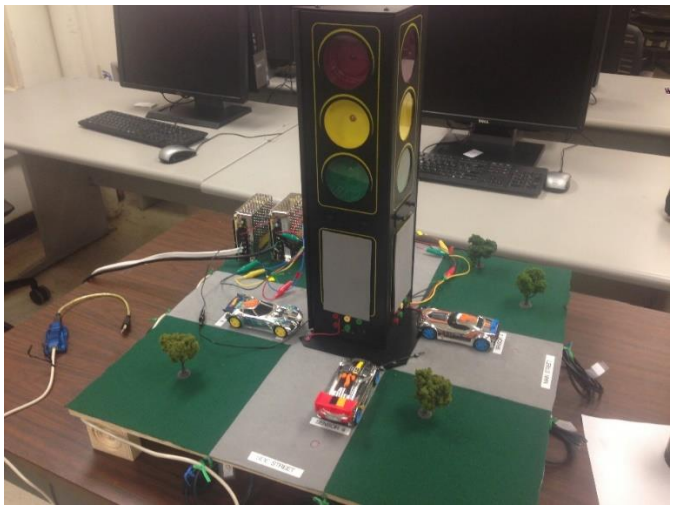

Fig. 1. Smart Traffic Light

Physical System Functionality and Layout

The Smart Traffic Light system is using a normal cycle light of 10 seconds (Fig. 2), the Smart Traffic Light system will execute this routing until there is not heavy traffic for neither of the street in the intersection.

There are 8 proximity sensors (Sensor1 through 8) installed under the ground to detect the traffic on the intersection and send a sign to the PLC to let it know to act smart

If there is a heavy traffic in the Main street, Sensor 3 and Sensor 4 will be ON or Sensor 7 and Sensor 8 will be ON. In either case the Smart Traffic Light Controller will change the cycle light allowing the green light of the Main street to be a 15 second making the red light of the Side street stay ON longer.

If there is a heavy traffic in the Side street, Sensor 1 and Sensor 2 will be ON, or Sensor 5 and Sensor 6 will be ON. In either case the Smart Traffic Light Controller will change the cycle light allowing the Green light of the Side street to be a 15 second making the Red light of the Main street stay ON longer.

If an emergency vehicle approach to the intersection with the siren ON, the Smart Traffic Light Controller will make the red light of the traffic light blinks for both street warning the drivers coming for all directions to stop allowing the emergency vehicle cross the intersection without any delay and safe.

All of this is possible by the smart decision of the Smart Traffic Light Controller.

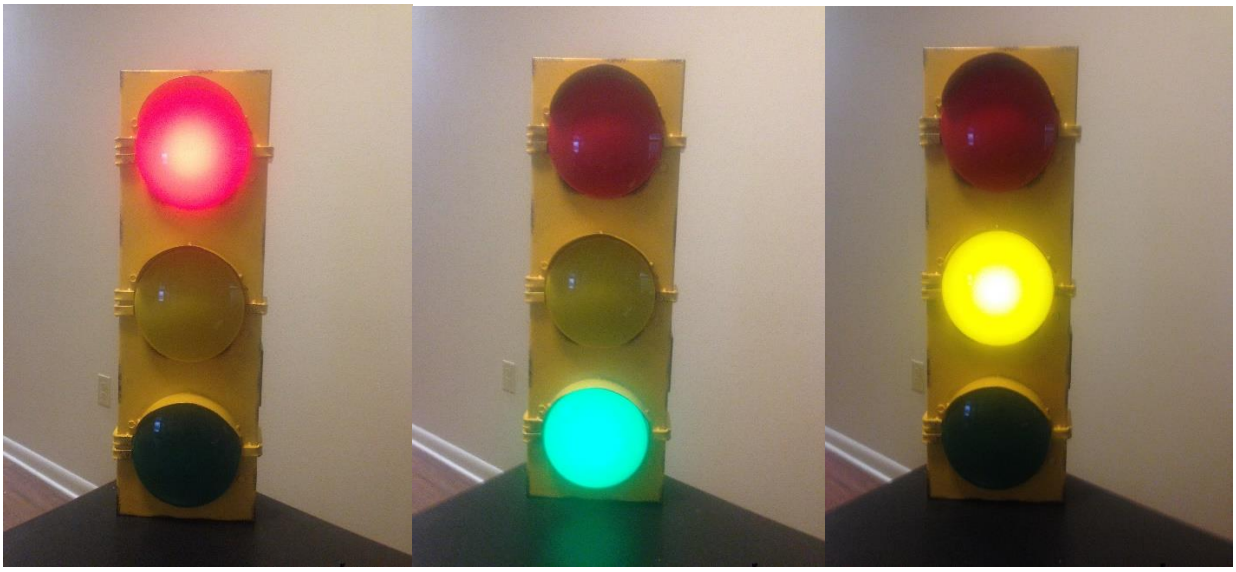

Fig. 2. Traffic Light Cycle

INPUT / OUTPUT Port Assignments

The system has eight inputs and six outputs. The inputs are the 8 sensor in the ground and the six Output are the 2 traffic lights (2-green, 2-yellow, 2-red) for the intersection.

Table 2 shows the I/O address for each I/O.

INPUT ADDRESS	INPUT DEVICE NAME	OUTPUT ADDRESS	OUTPUT DEVICE NAME
I:00/01	Sensor 1	O:00/01	Side Green
I:00/02	Sensor 2	O:00/02	Side Yellow
I:00/03	Sensor 3	O:00/03	Side Red
I:00/04	Sensor 4	O:00/04	Main Yellow
I:00/05	Sensor 5	O:00/05	Main Red
I:00/06	Sensor 6	O:00/06	Main Green
I:00/07	Sensor 7		
I:00/08	Sensor 8		

Table 2. Input/Output Device Addresses

System Schematics

The Smart Traffic Light Controller consists of a Click PLC, Model C0-00DR-0, a 24-volt power supply to fit the PLC, 8 proximity sensors located under the ground (Fig.3.) closed to the intersection. A 12-volt power supply is used to power 4 output lights. The other 2 output lights are powered by a 24-volt power supply. This project has 4 output lights of 12-volt and 2 output lights of 24-volt.

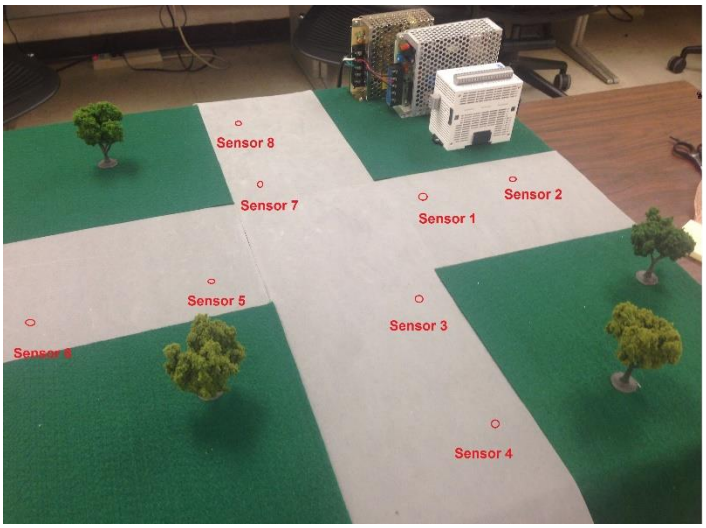

Fig.3. Locations of the 8 sensors

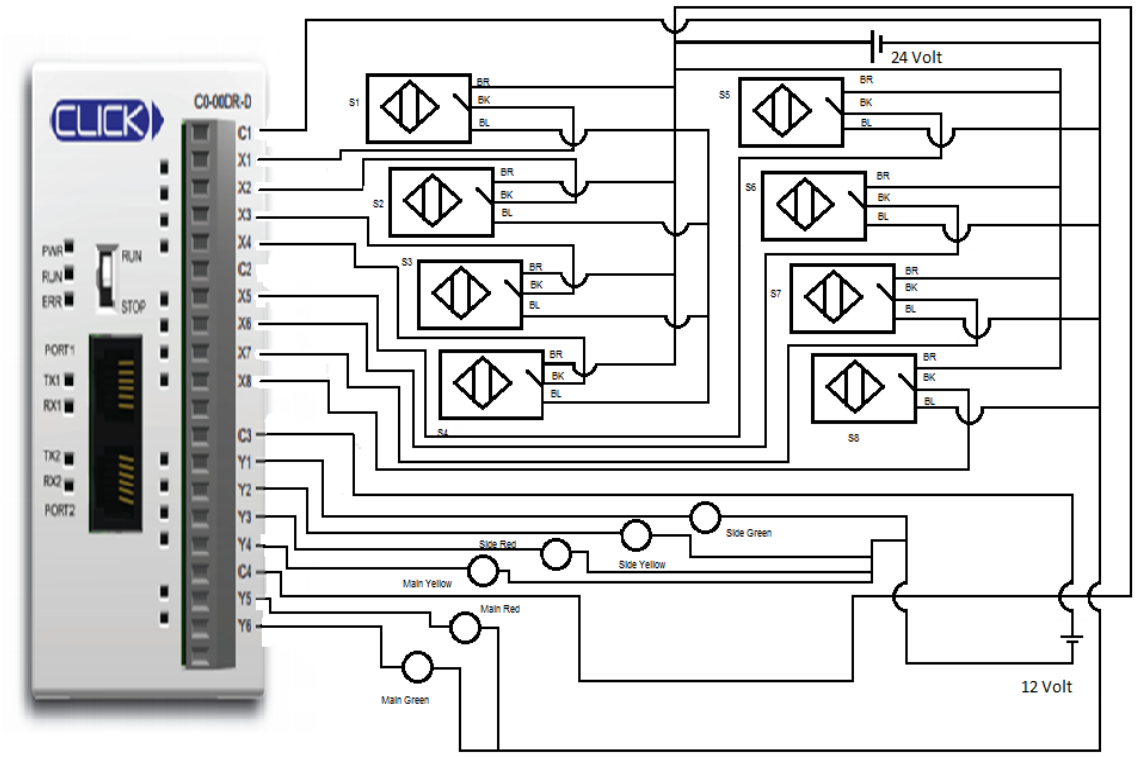

Fig. 4. System Schematic of the Smart Traffic Light

Students complete three activities: 1) Familiarization with the Click PLC; 2) Click Programing Software and Basics of Ladder Logic; and 3) Build and test the Smart Traffic Light Controller

Activity 1: Familiarization with the Click PLC

Objectives

- To became familiar with the Click controller
- To run Click software
- To connect the Click controller to the computer

The Click Programmable controller, model: CO-OODR-D permits hardware devices such as timers, counters, and relays to be replaced by a ladder logic program. A set of instructions representing the logic is written and downloaded into the Click PLC memory to execute them following the order of instructions to interpreter the sign from its input devices and operate its output devices.

The Click Controller, model C0-00DR-D from Koyo can be programmed by using the Click programming software from the Automation Direct website (www.automationdirect.com). The Click controller is connected to the computer through the USB port (Fig. 5).

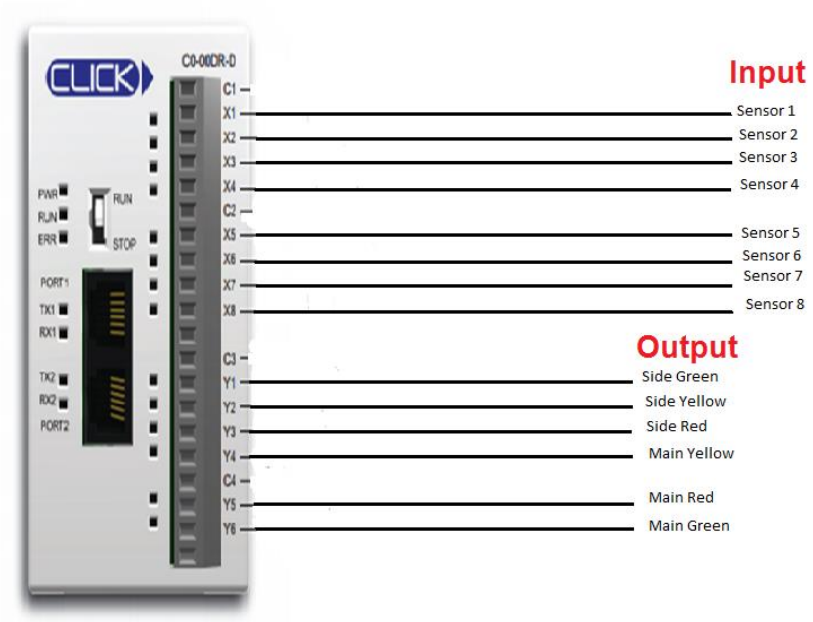

Fig. 5. Adapter to connect the Click to a computer

Fig. 6. Click Controller, Model C0-00DR-D showing the inputs and outputs

PLC inputs X1 through X8 are connect to the proximity sensors and are activated by a 24-VDC power supply, this is an external source that also supply power to the Click.

PLC outputs are marked as Y1 through Y6, they are connect to a 6 output lights and powered by a 24-VDC voltage and a12-VDC voltage.

Procedure Summary

In this lesson you will familiarize with the Click controller communication, basic functions, such as open a project, and saving a project.

Procedure

1. Connect the Click to the power supply and the computer.
2. Turn on the computer and load the Click programming software.

Creating a New Project or Open a project

1. Choose the New command in the File menu to Start a new project or choose Open Project command
2. You will Open Project1 to see an example of the ladder logic programming.
3. The project 1 is display in the Ladder View Window.

Saving a Project to a file

1. Now you will save the project in the computer memory. To save the project to choose the Save or Save As command in the File menu
2. This will open the Save As commando where you will type the project filename.
3. Click Save button in the dialog box, so the project will save with the extension CKP after the name.
4. Click Close Project from the File Menu. Click Exit from the File Menu to close the software.

Activity 2: The Click Programming Software and Basics of ladder logic

Objectives

- To create a project and edit a project using PLC ladder program
- To print a project
- To learn how to use on delay timer and a subroutine

The Click programming software is used to program and control the Click PLC creating, editing and monitoring PLC ladder program that can stored in the Click memory. The Click programming software is free and can be downloaded from the website of Automation Direct (www.automationdirect.com).

The Click programming software runs under the Microsoft Windows environmental, Fig. 7 shows a view of the program open and the several elements to start a program.

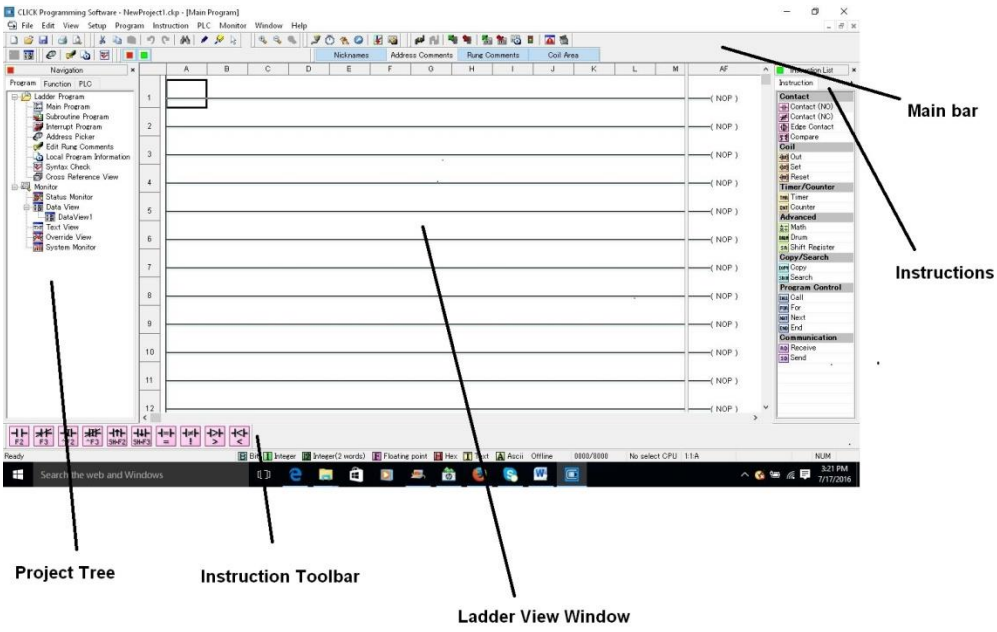

Fig. 7. The Click software and its elements

The PLC ladder program is the main component of the project. The PLC runs the program following the inputs to control its outputs.

Procedures

1. Connect the Click to the computer.
2. Turn on the computer and load the Click programming software.

Creating a New Project

1. Choose the New command in the File menu to Start a new project.
2. Name the project and save it.
3. Now you are ready to type your first ladder logic program.
4. You have several programs to type from the File name Projects.
5. After you finish typing it you can click the Save button in the dialog box to save the project. It will be saved with the extension CKP after the name.
6. Now you can check for errors, click on Syntax Check under Program menu.
7. With no errors you are ready to write the project in the PLC.
8. Click Write Project into PLC under PLC menu.

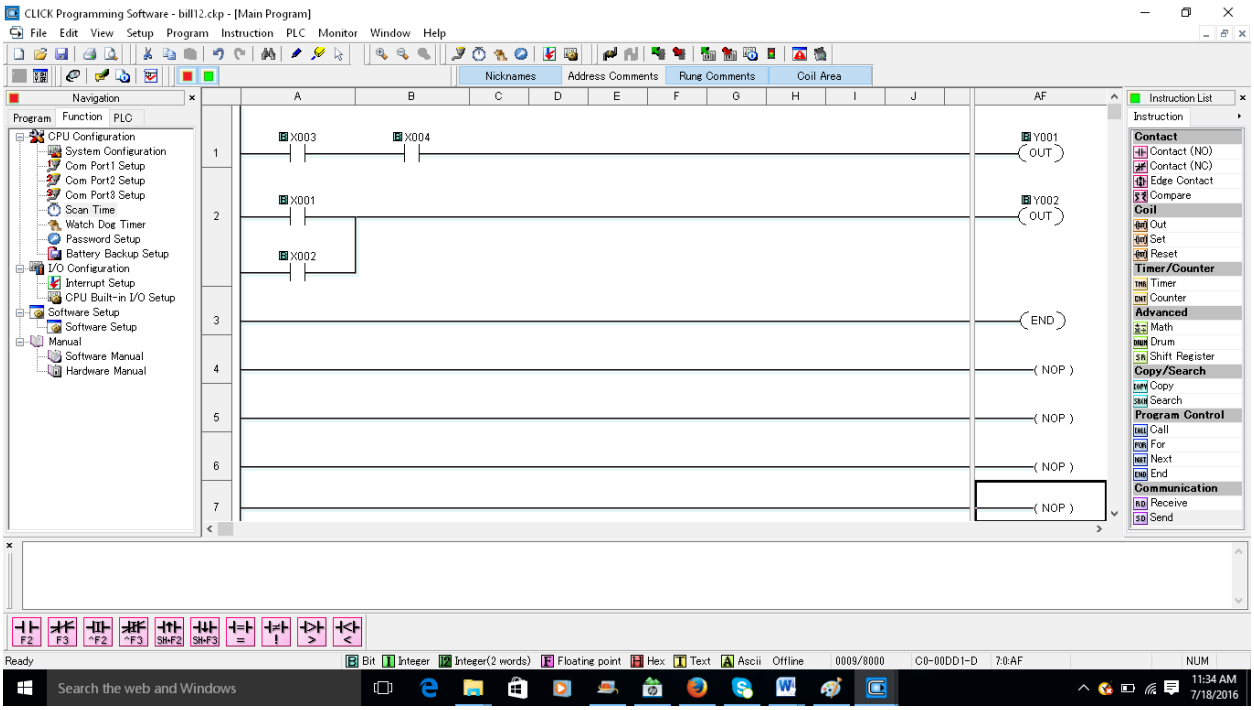

Figure 8: Sample 1 - Ladder logic program using an AND and OR statements

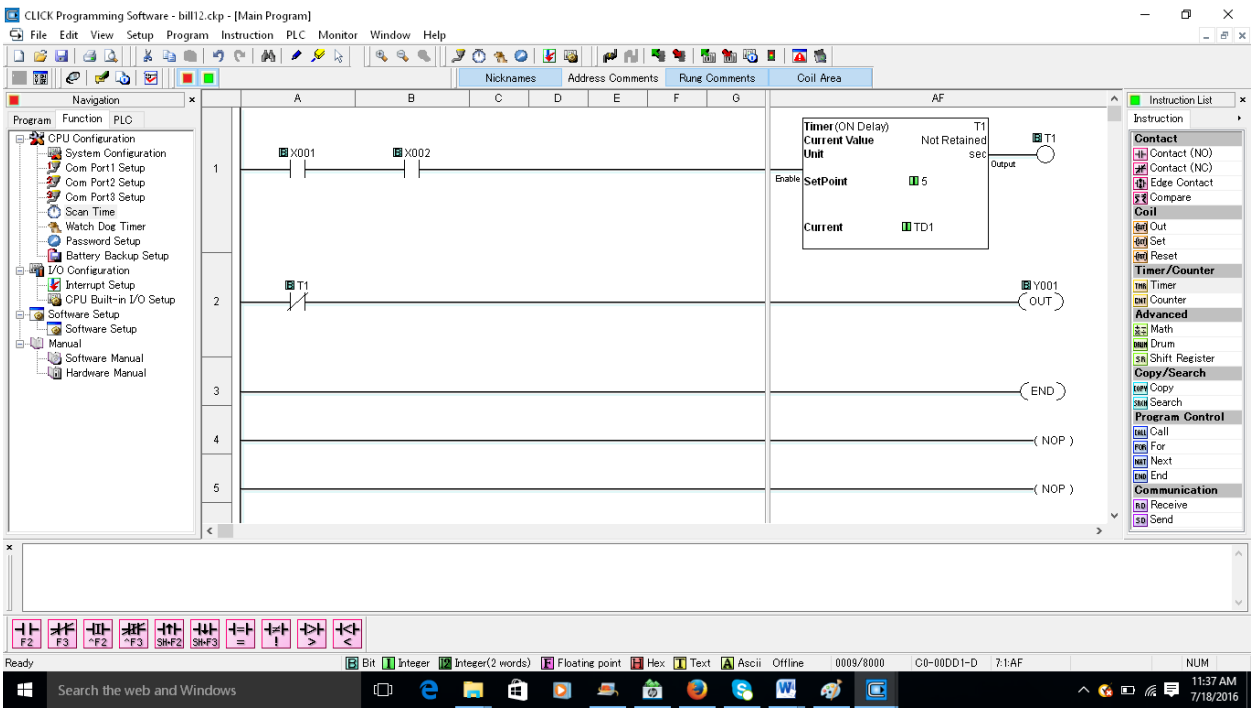

Figure 9: Sample 2: Ladder logic program using a Timer

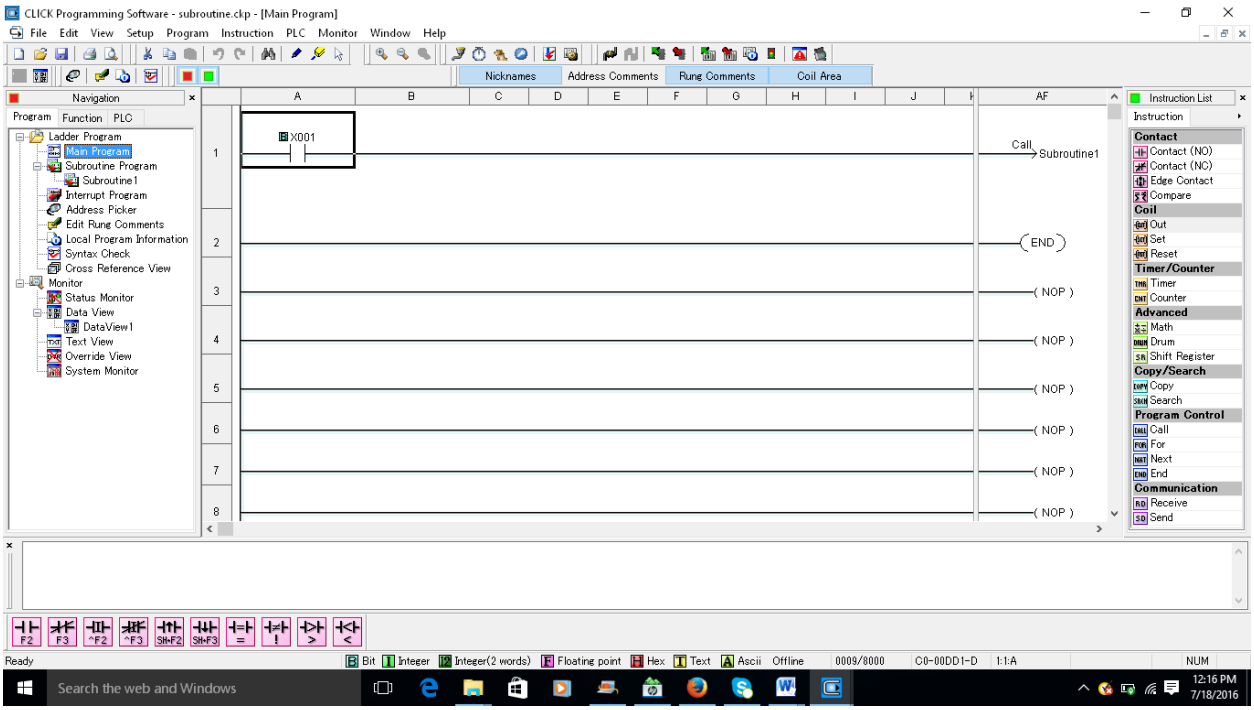

Figure 10: Sample 3 - Ladder logic program using a Main program and a SubRoutine

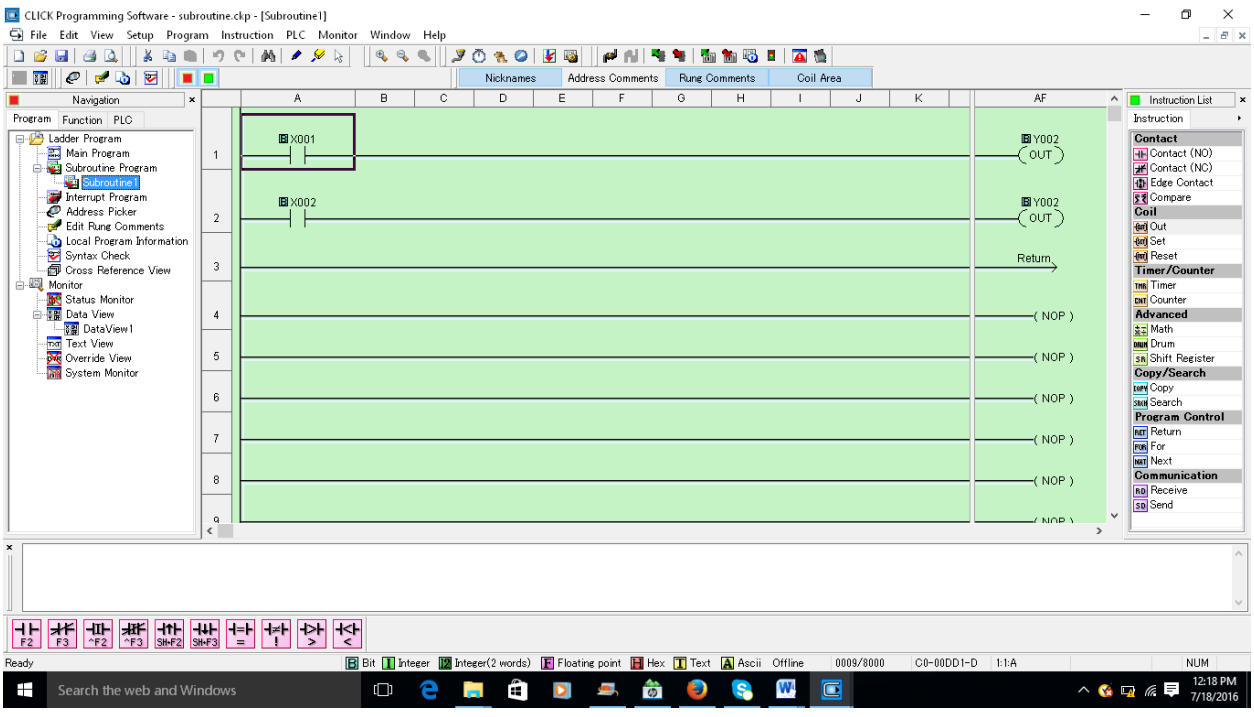

Figure 11: Sample 4 - A Subrouting program

Activity 3: Building and testing the Smart Traffic Light Controller

Objectives

- To build a Smart PLC Traffic Light Controller
- To create a project using PLC ladder program

The Smart Traffic Light Program

The ladder logic program for the traffic light intersection with lights facing North /South (Main Street) and West /East (Side Street) the normal cycle time is 12 seconds.

For the Main street the Green light is on for 5 seconds, followed by the Yellow light for 2 seconds, and then the Red light that is on for 5 seconds. For the Side street the Red light is on for 7 seconds, followed by the Green light is on for 3 seconds, then the Yellow light for 2 seconds shows the end the normal cycle. This is the synchronization sequence and frequency of the lights for the normal cycle of the Main and Side street this in this project.

If traffic is detected in the Main street the Smart Traffic Light will change the time of the cycle of the traffic light allowing the drivers on the main street go through the intersection making the traffic flow smugly. For Main street the Green light will be on for 15 seconds, following by the Yellow light on for 2 seconds, then the Red light will be on for 5 seconds. While in the Side street the Red light will be on for 17 seconds, followed by the Green light on for 5 seconds, and followed by the Yellow light on for 2 seconds.

If traffic is detected in the Side street the Smart Traffic Light will change the time of the cycle of the traffic light allowing the drivers on the Side street go through the intersection making the traffic flow smugly. For Main street the Green light will be on for 15 seconds, following by the Yellow light on for 2 seconds, then the Red light will be on for 5 seconds. While in the Main street the Red light will be on for 17 seconds, followed by the Green light on for 5 seconds, and followed by the Yellow light on for 2 seconds.

And if an emergency vehicle or a police car with the siren on approach to the intersection the Smart Traffic Light system will flash the Red light on both street to make all traffic from all direction to stop allowing the emergency vehicle cross the intersection fast and safe.

All of these tasks are possible by the 8 sensors installed in the ground closed to the intersection, the ladder logic programing, the PLC who makes all of this possible and the lights that give directions to the drivers how to proceed at the intersection.

This program uses timers to accomplish this task.

Ladder Logic Program

One of the major challenges of the smart traffic light system was how to make the light from the main street (cycle green-yellow-red) synchronizes with the light of the side street (cycle red-green-yellow). I could accomplish this task using several OnDelay timers as show in Figs.12-14.

For this project uses a 12 seconds (green-red-yellow) for a normal cycle traffic light, and for heavy traffic will be using a cycle of 22 seconds (green-red-yellow).

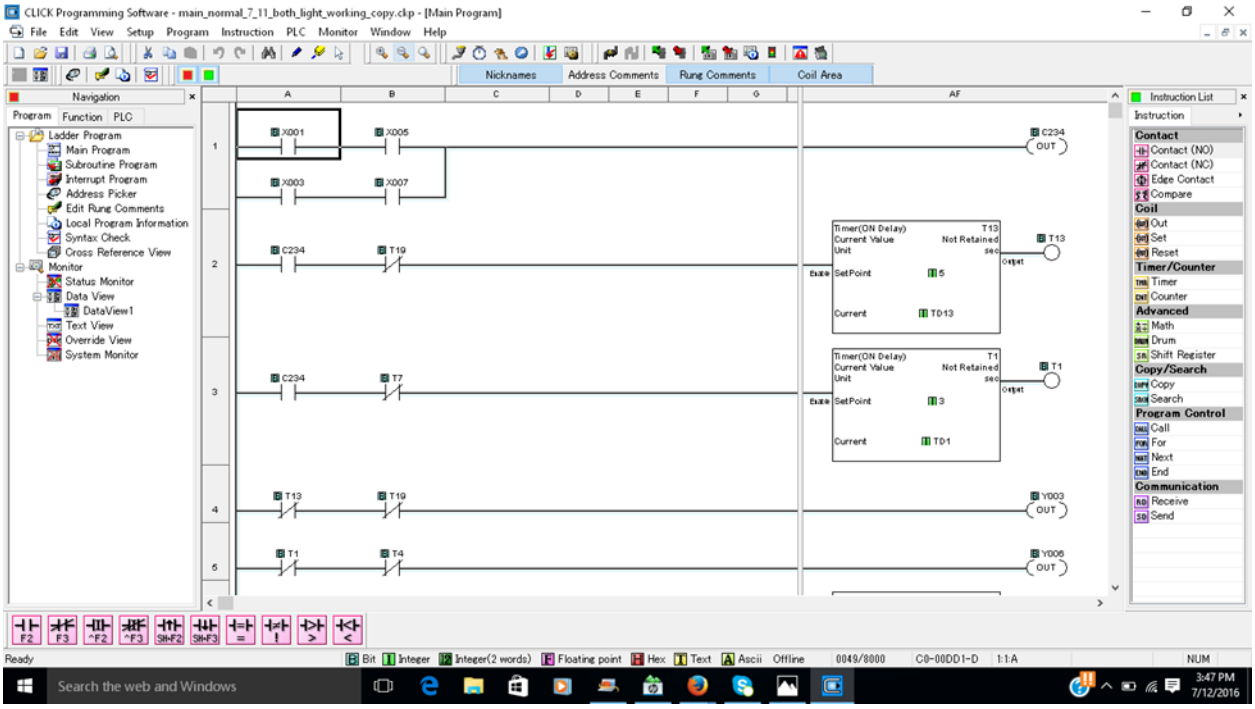

Fig. 12. Ladder logic- Synchronization of the main street light and side street light.

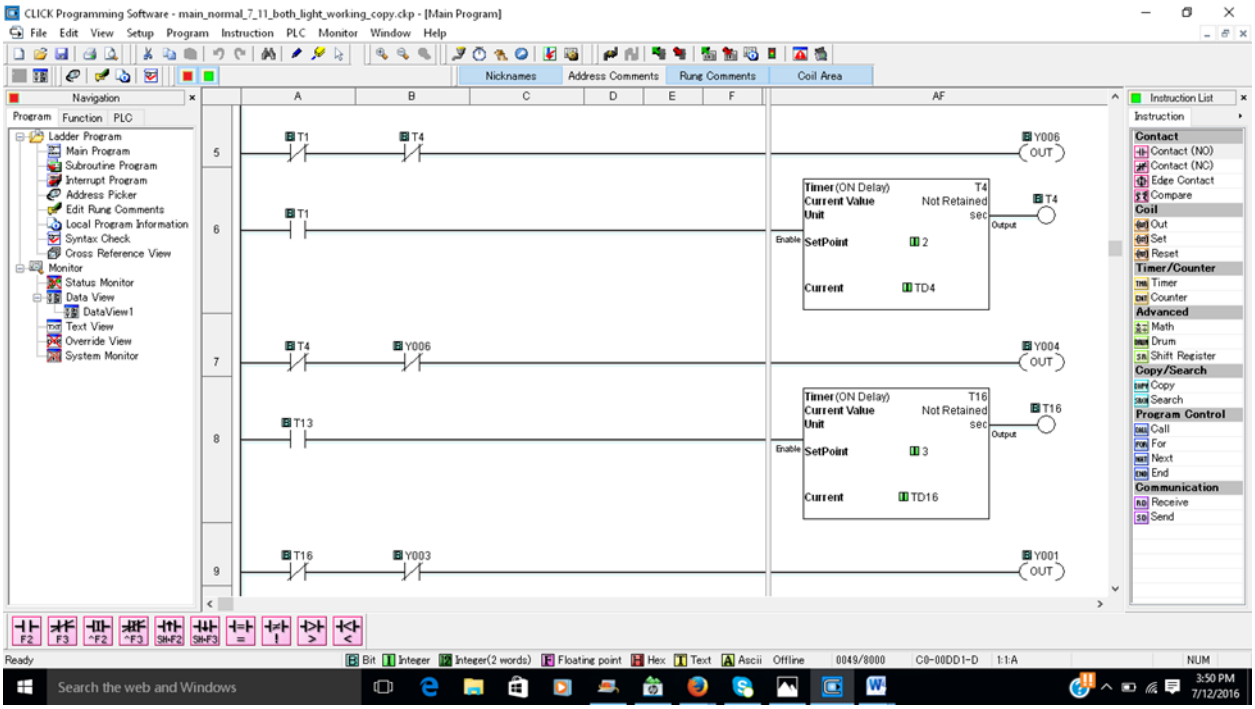

Fig. 13. Ladder logic- Synchronization of the main street light and side street light.

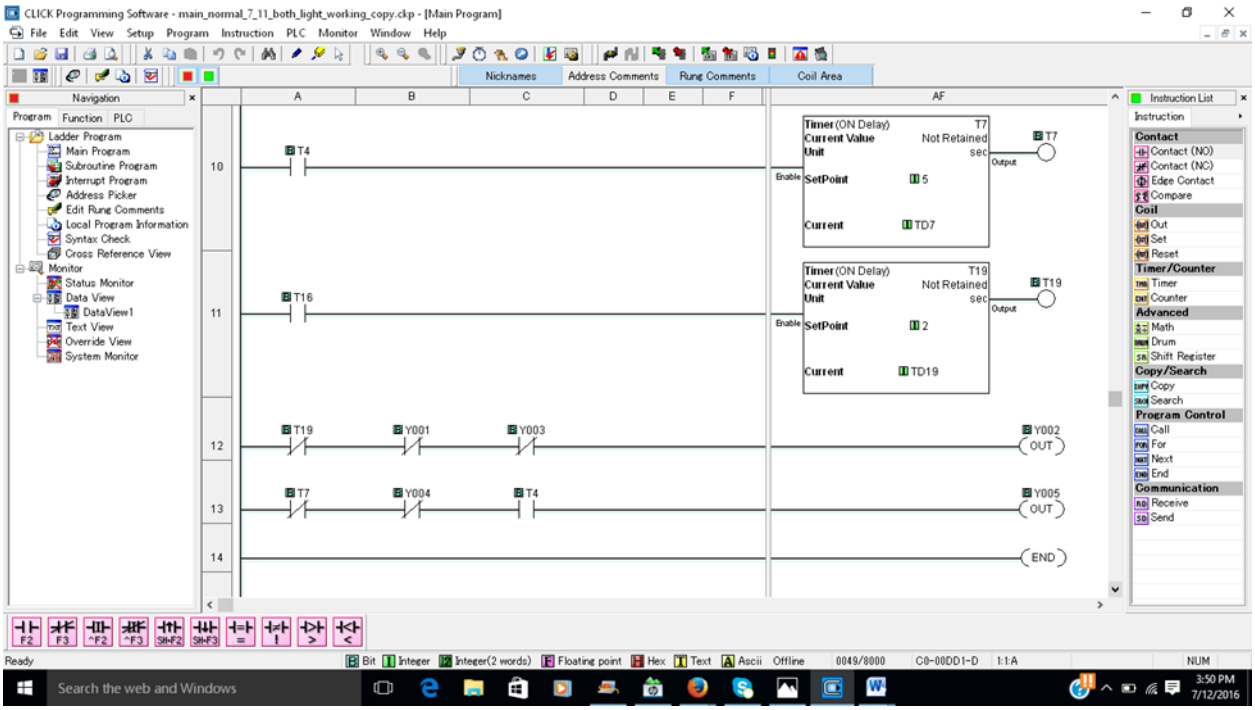

Fig. 14. Ladder logic- Synchronization of the main street light and side street light.

Ladder Logic Program of the Smart PLC Traffic Light Controller

The ladder logic project of the Smart PLC traffic Light Controller consists of one main program and 3 subroutines. The main program will call any of the subroutine depending of the traffic. The sensors will indicate to the PLC controller to call the subroutine needed for the specific traffic situation at the moment. The main program and the subroutines are show in Fig.15 through Fig. 26 .

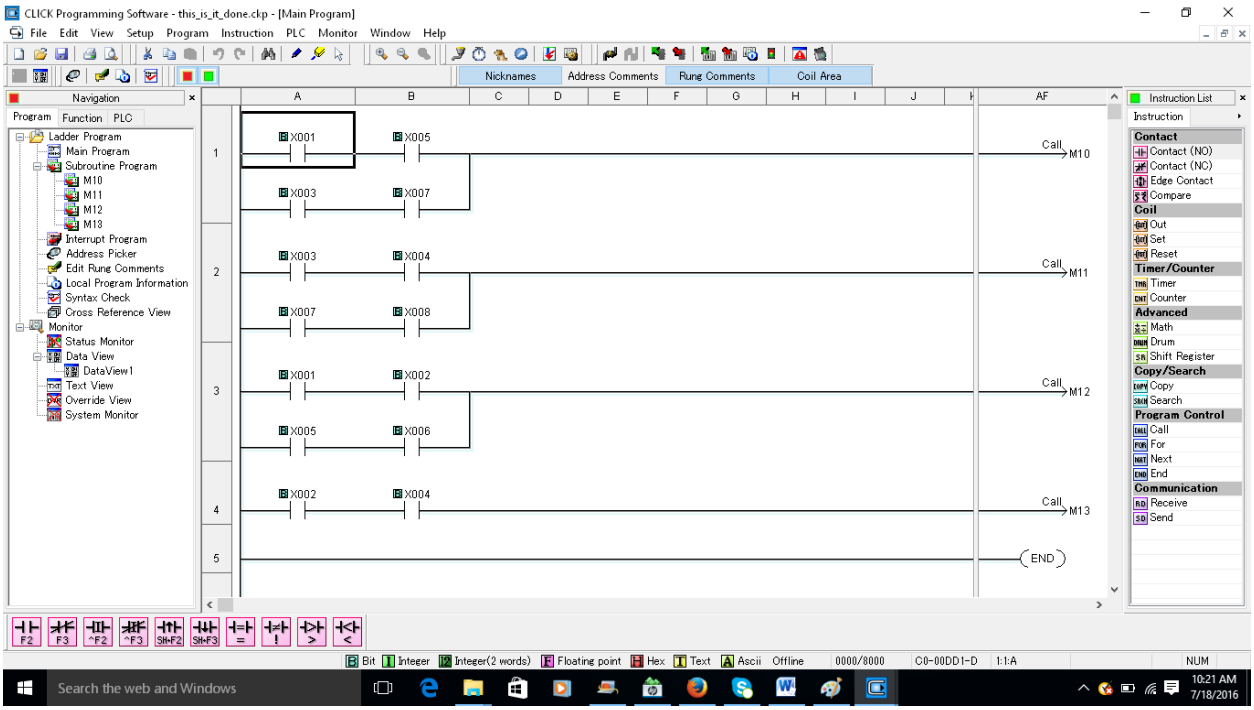

Fig. 15. The Main program

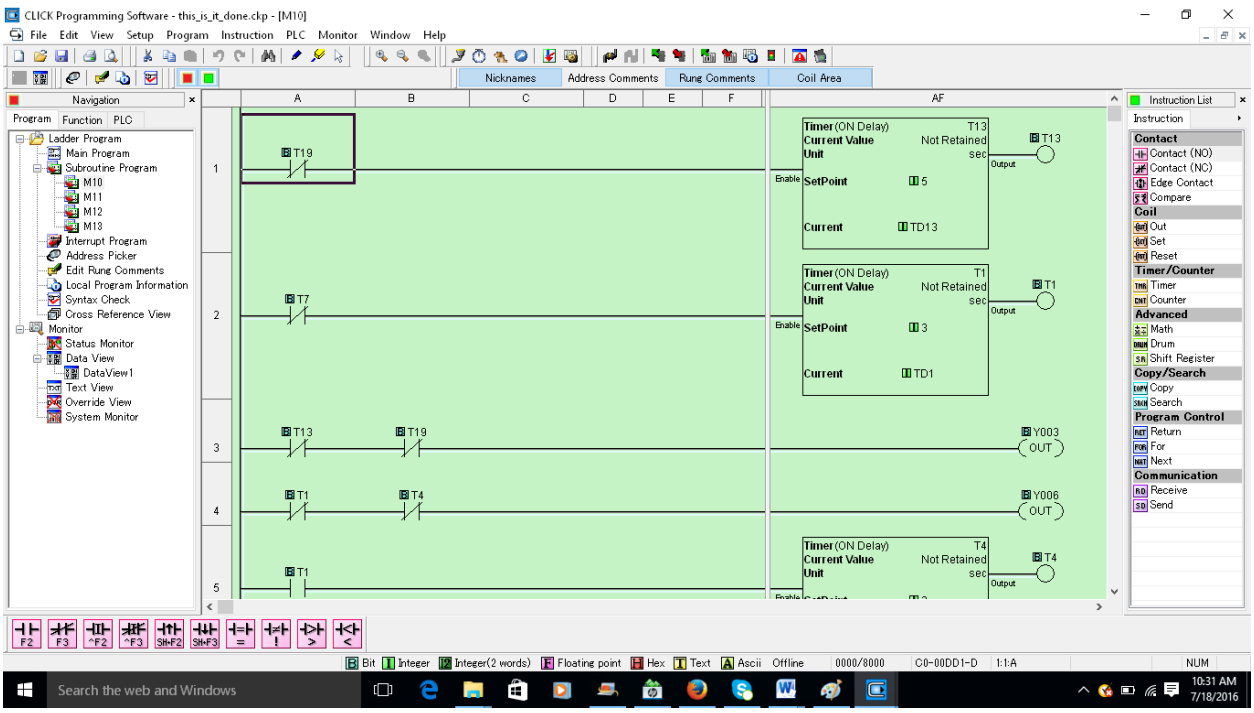

Fig. 16. M10 Subrouting

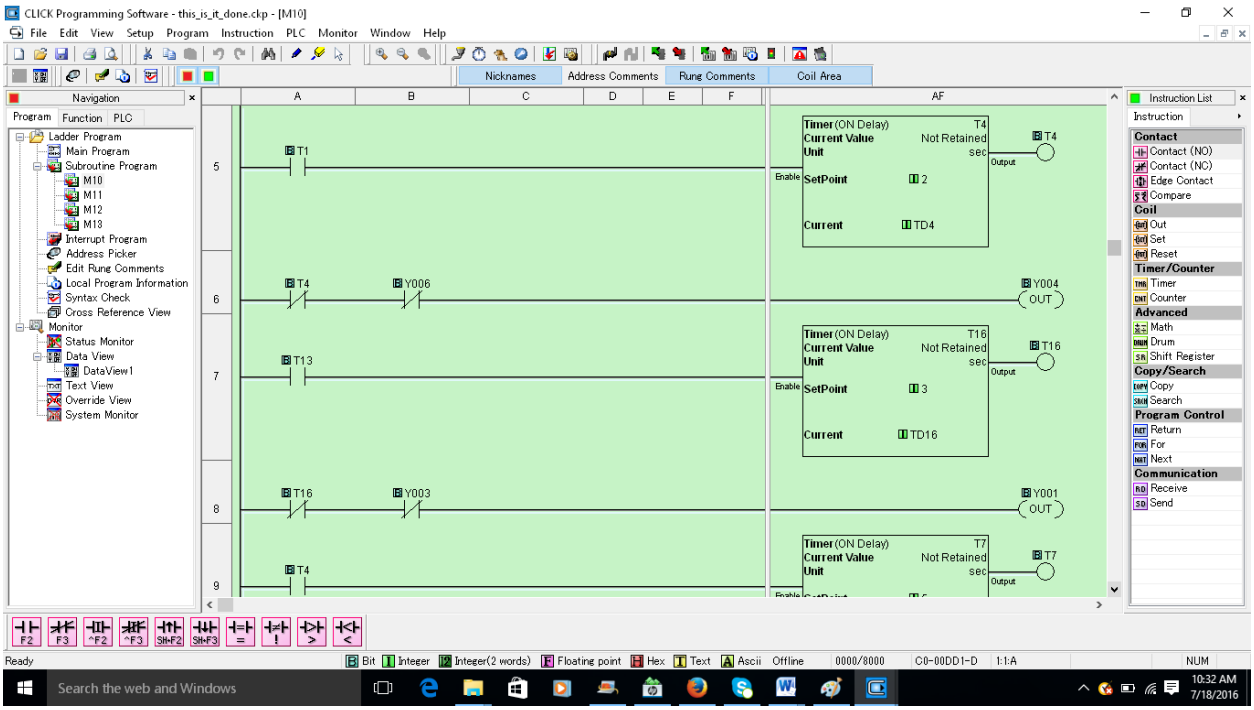

Fig. 17. M10 Subrouting - continuation

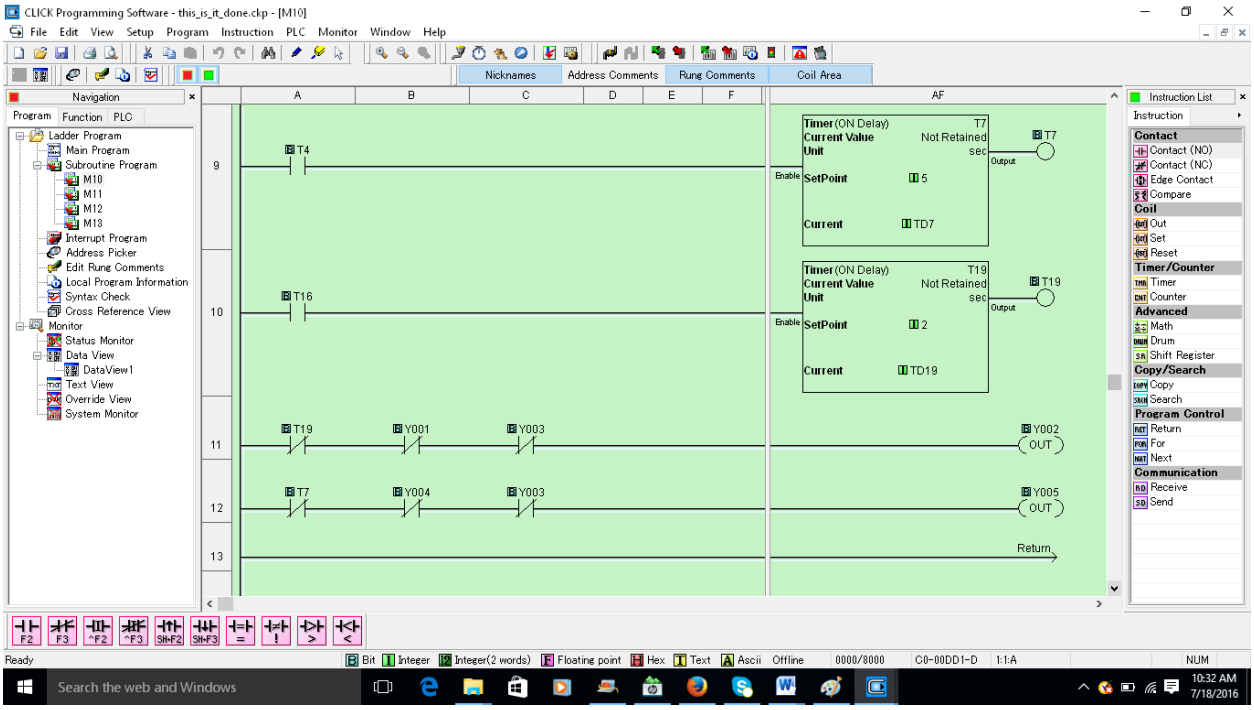

Fig. 18. M10 Subrouting – continuation

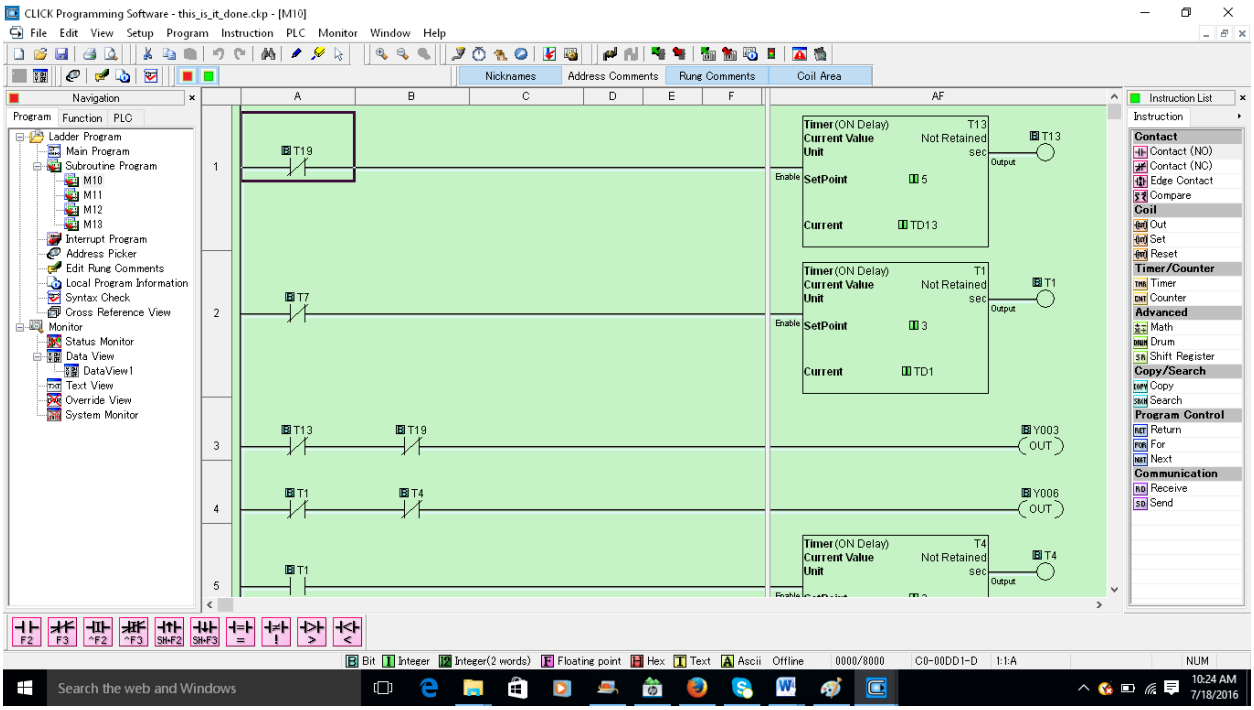

Fig. 19. M11 Subrouting

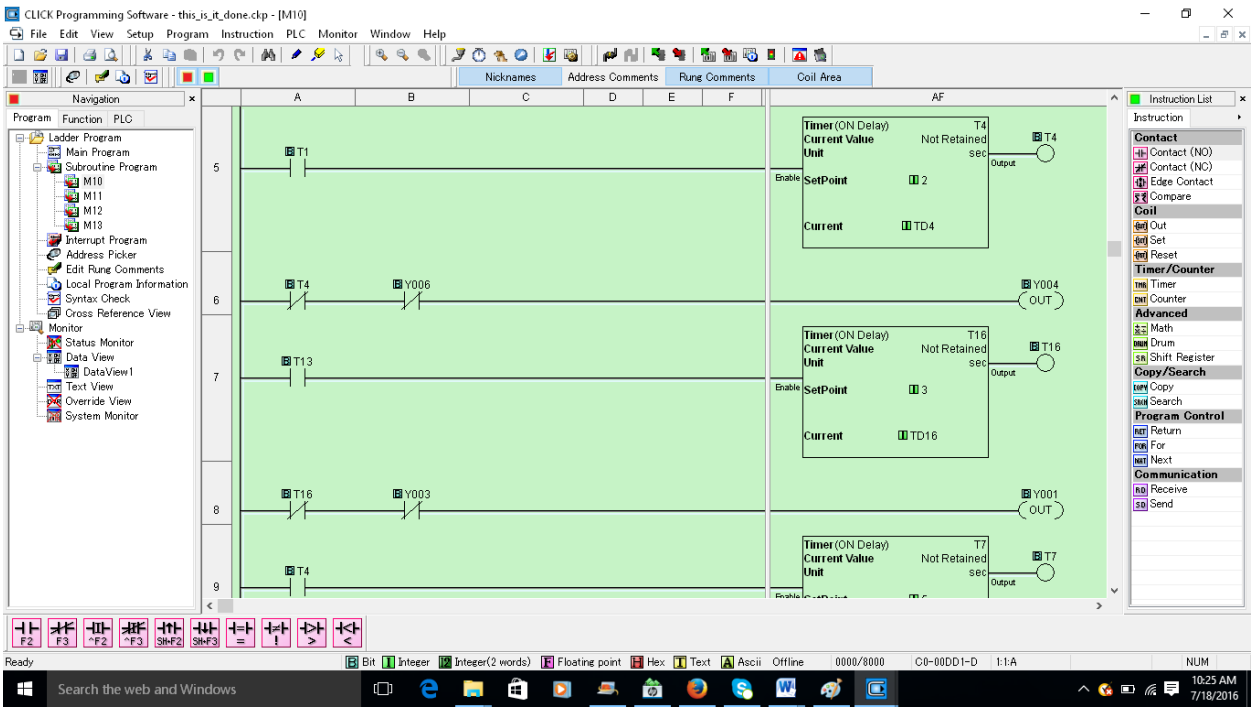

Fig. 20. M11 Subrouting – continuation

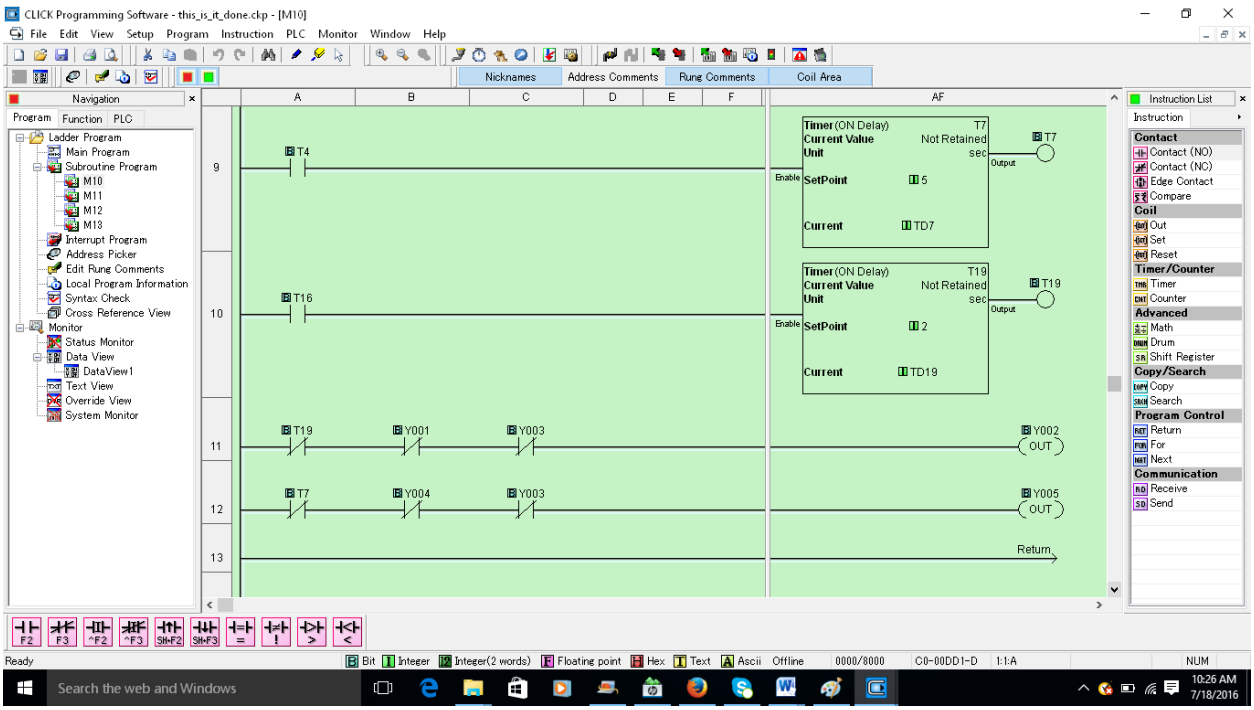

Fig. 21. M11 Subrouting – continuation

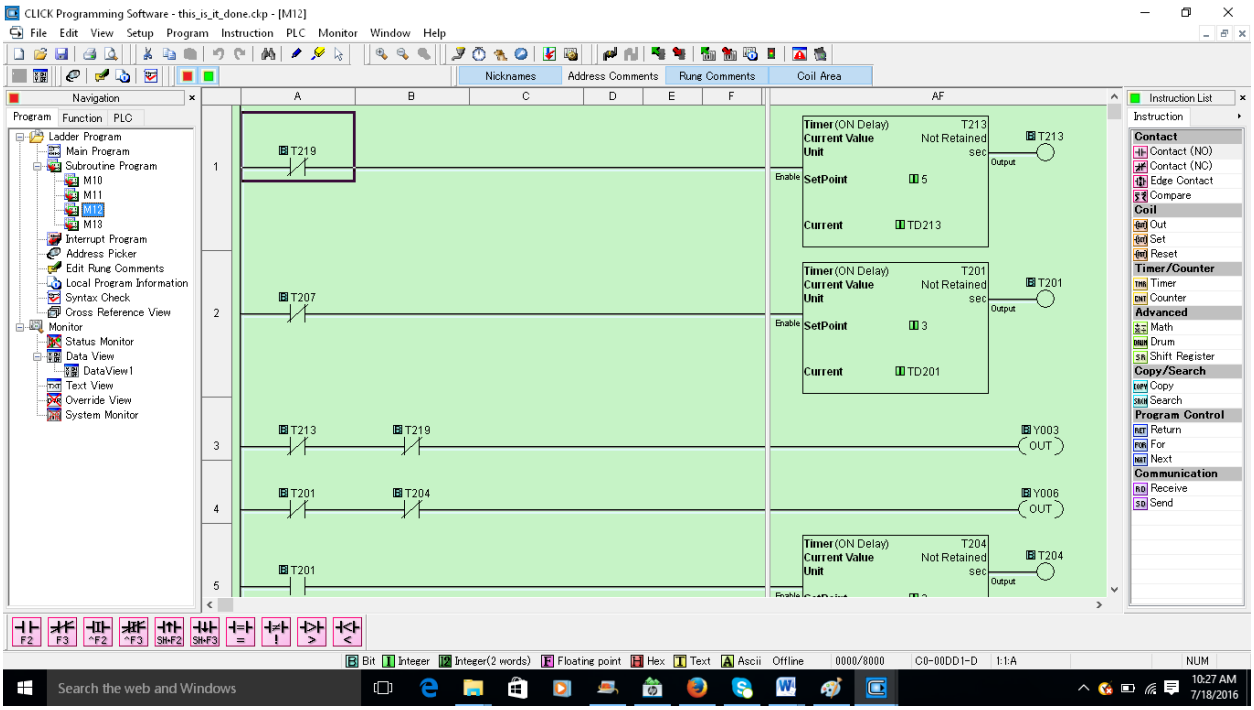

Fig. 22. M12 Subrouting

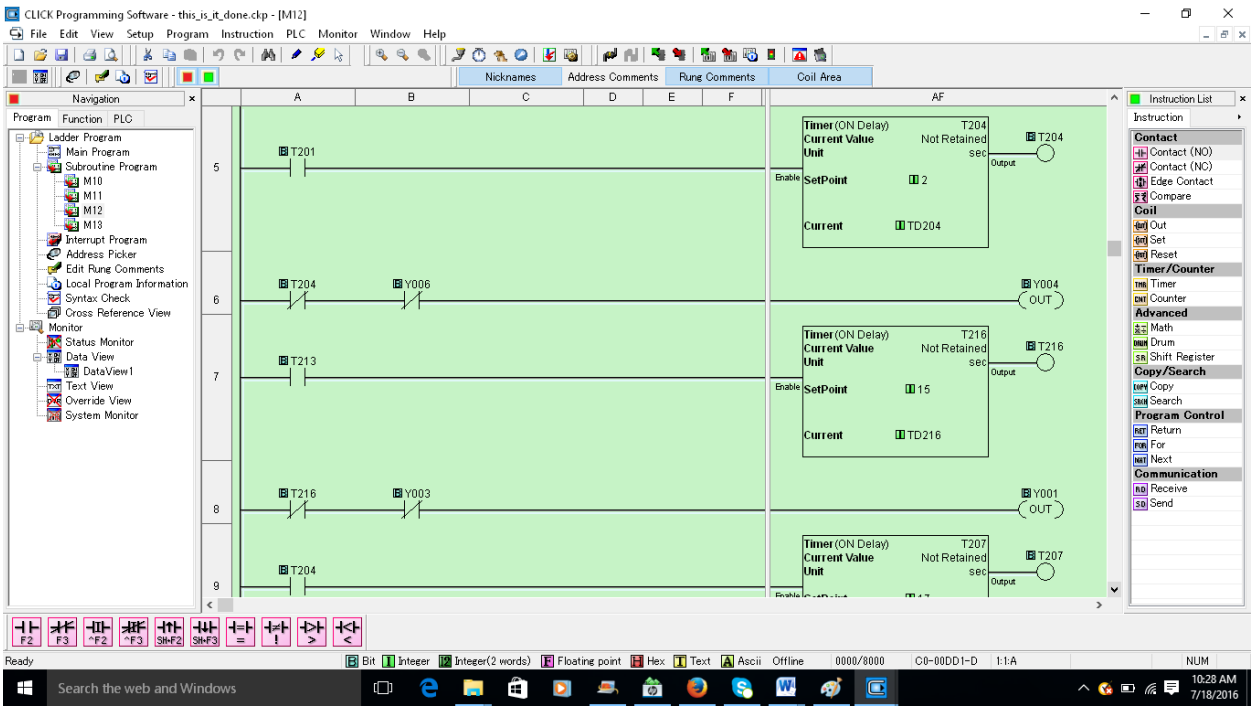

Fig. 23. M12 Subrouting - continuation

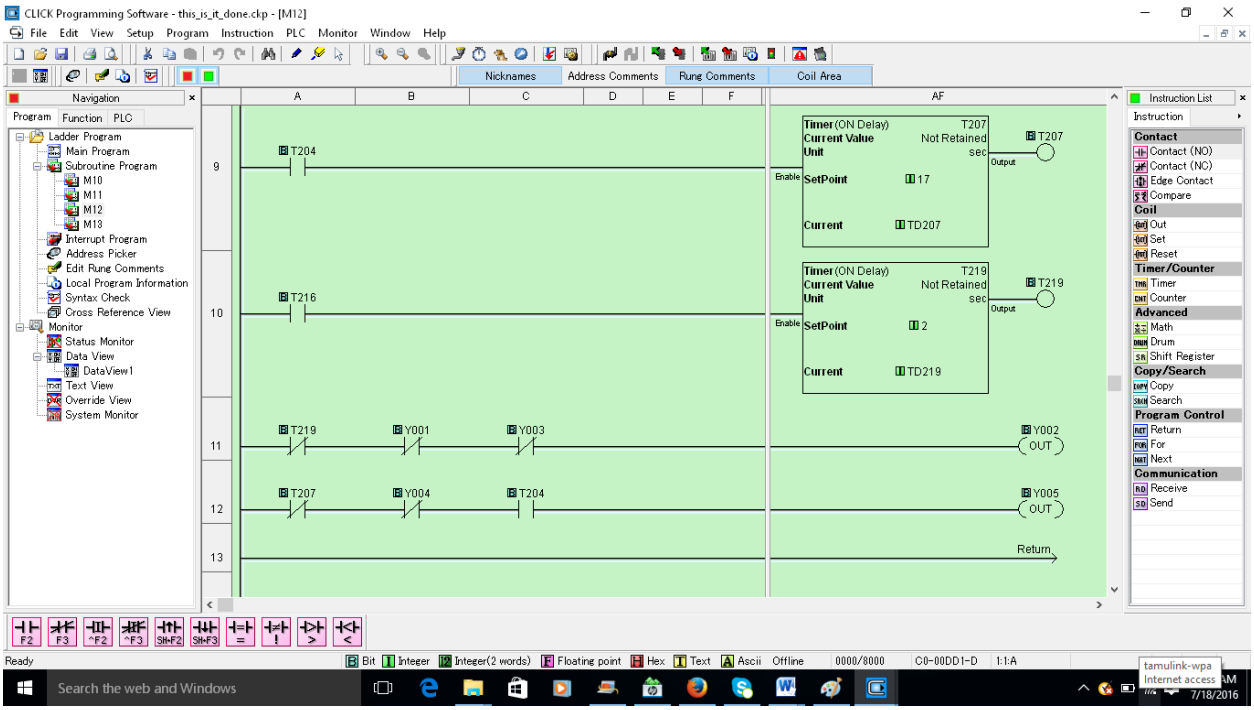

Fig 24. M12 Subrouting - continuation

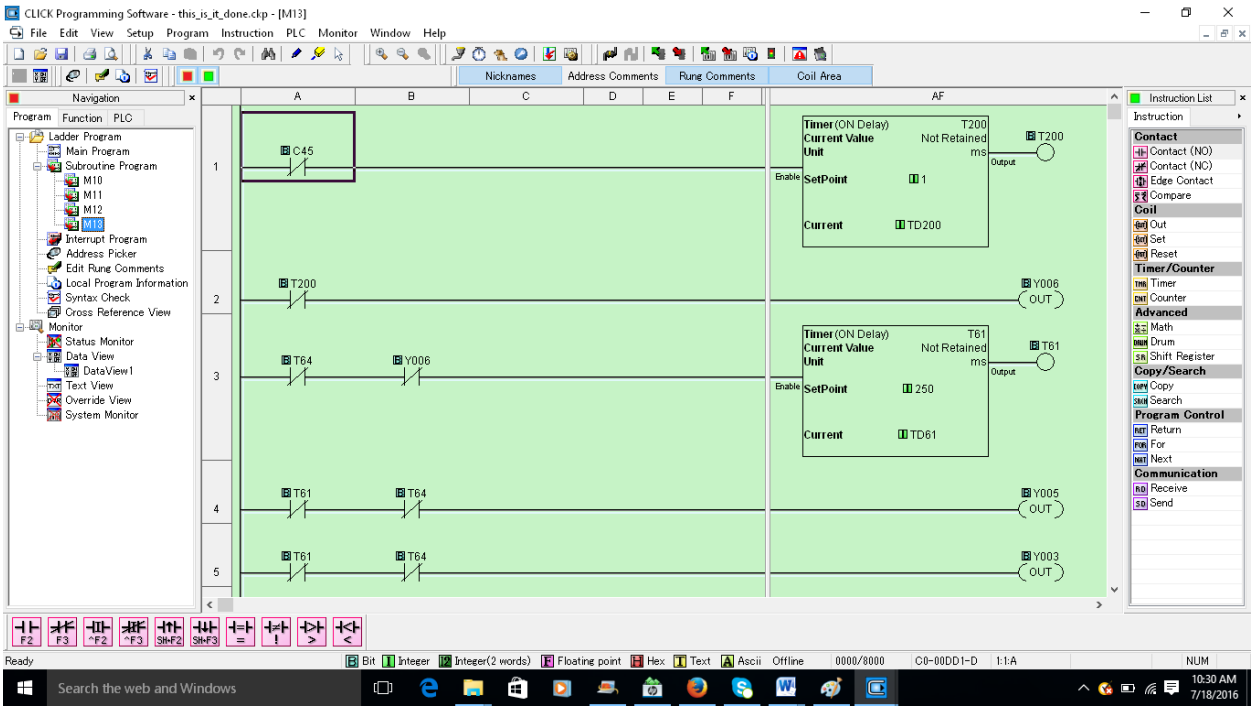

Fig. 25 M13 Subrouting

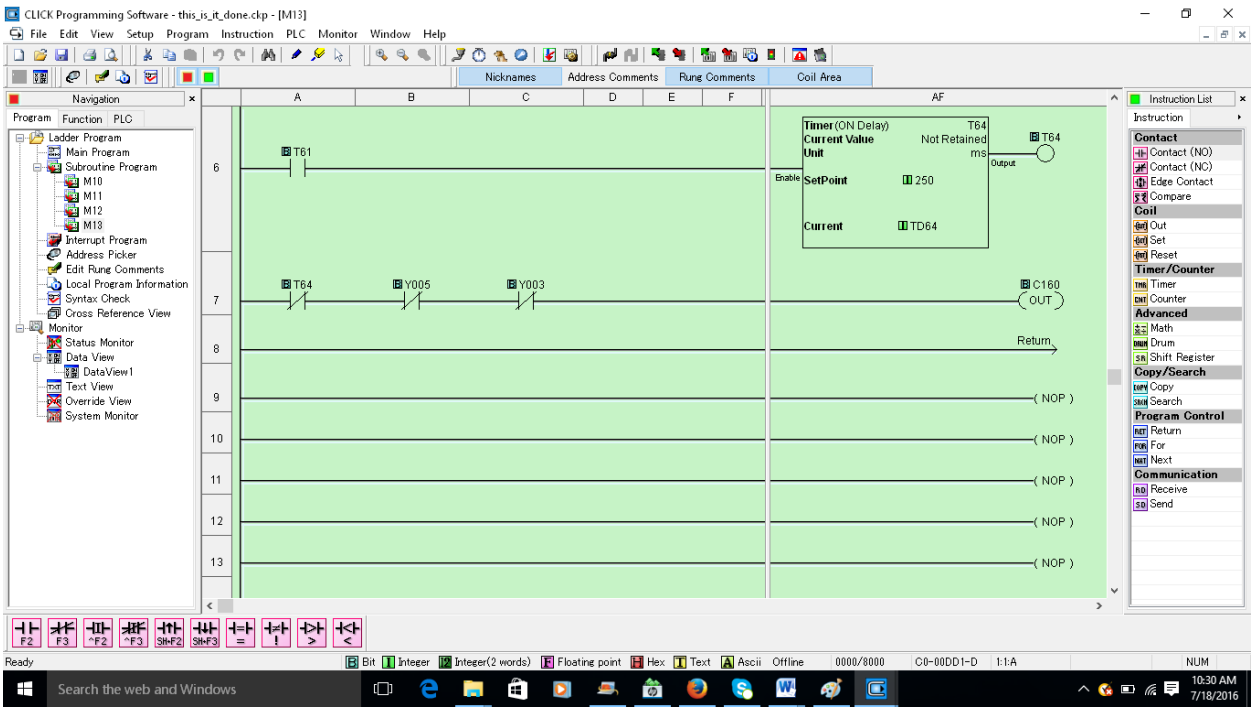

Fig. 26. M13 Subrouting - continuation

Additional Multimedia support materials

www.youtube.com/watch?v=qDuCusvU-mY

www.youtube.com/watch?v=LM8U9FCMDx0&list=PLdnqjKaksr8qRPCFkU2Q8XQe0bfo99rs6

Relays

www.youtube.com/watch?v=STKH6Rp7rX8

Introduction to PLCs

www.youtube.com/watch?v=d8jASbyqO6M

How to program a PLC

www.youtube.com/watch?v=1CMA9g27QmI

Conclusion and Future Directions

This learning activity provides an excellent opportunity for students to integrate their knowledge of PLC, input, ladder programing logic, output and the connection between them to create a Smart PLC system to control a Traffic Light.

Challenges of the Smart PLC Traffic Light Controller: This project intentionally leaves a margin for students to go farther with their work. Student teams can modify or expand the project considering the pedestrian crossing the intersection, and also thinking in drivers who want to do a left turn in any of the streets.

ACKNOWLEDGEMENTS

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7. Automation Direct, www.automationdirect.com