2-D LOCATION POINTING SYSTEM FOR INDIVIDUAL COMPONENT ON DEVICE UNDER TEST USING LABVIEW (HARDWARE AND IMAGE PROCESSING)

CH'NG KHAI CHIAH

A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering (Hons.) Electrical and Electronic Engineering

Faculty of Engineering and Science
Universiti Tunku Abdul Rahman

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

Signature : ____________________

Name : CH'NG KHAI CHIAH

ID No. : 08UEB04268

Date : ____________________

APPROVAL FOR SUBMISSION

I certify that this project report entitled **"2-D LOCATION POINTING SYSTEM FOR INDIVIDUAL COMPONENT ON DEVICE UNDER TEST USING LABVIEW (HARDWARE AND IMAGE PROCESSING)"** was prepared by CH'NG KHAI CHIAH has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Engineering (Hons.) Electrical and Electronic Engineering at Universiti Tunku Abdul Rahman.

Approved by,

Signature : ____________________________

Supervisor : Mr. See Yuen Chark

Date : ____________________________

Specially dedicated to

my beloved family,

supervisor Mr. See Yuen Chark,

and partners Ms. Chung Ka Siew, Mr.Cheng Xuan Teng

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ABSTRACT

Nowadays, electronic components are getting complex in design and smaller in size. In order to maintain efficiency while engineers perform validation, probing and component searching, a high performance system that can assist them in completing the tasks smoothly is needed. This issue has motivated the researchers to design a system that is capable of enhancing the users' experience in component searching and probing. Users can easily search a component from a high density circuit board as long as the schematic diagram of the particular board is available. This application has two major parts: hardware implementation and image processing. A personal computer acts as a host for the whole system which integrates image capturing device, NI sbRIO-9632XT and EAGLE to work together as a component locating system. User can perform probing with the installed probe holder. The programming implementation of the system uses LabVIEW 2011, licensed by National Instruments. LabVIEW FPGA Module is used to configure onboard NI sbRIO-9632XT device in order to interface with the hardware including motors, LED, LCD, switches and etc, from the 2-D Location Pointing System. The image capturing device, which is C170 Logitech Webcam of the system is processed by LabVIEW Vision Acquisition Software.

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LIST OF SYMBOLS / ABBREVIATIONS

AC	Alternating Current
API	Application Programming Interface
DC	Direct Current
DRAM	Dynamic Random Access Memory
DUT	Device Under Test
FPGA	Field-Programmable Gate Array
FTP	File Transfer Protocol
GUI	Graphical User Interface
HTTP	Hypertext Transfer Protocol
IMAQ	Image Acquisition
LabVIEW	Laboratory Virtual Instrumentation Engineering Workbench
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
NI	National Instruments
OS	Operating System
PC	Personal Computer
PCI	Peripheral Component Interconnect
RF	Radio Frequency
RIO	Reconfigurable Input/Output
sbRIO	Single Board Reconfigurable Input/Output
SMTP	Simple Mail Transfer Protocol
SSL	Secure Socket Layer
TLS	Transport Layer Security
USB	Universal Serial Bus
VHDL	VHSIC Hardware Description Language
VHSIC	Very High Speed Integrated Circuit
VI	Virtual Instrument

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CHAPTER 1

INTRODUCTION

1.1 Background

Since technological advancement began, electronic gadgets have played an important role in daily life to fulfil our present needs. Consumer's requirements on the technology of electronic devices are getting higher in order to help us act and think better. As the technology of electronic devices is getting complicated, it is undoubtedly that the number of components included in design of electronic devices will exponentially increase with the trend of complexity.

To maintain the reliability and quality of the electronic gadgets, engineers in test development department play an important role in validating the functionality of the products. One of the most important tasks is to perform device under test (DUT). The term DUT is refers to any electronic assembly under test. When the DUT is a complicated board, the process of probing is undeniably time consuming as the engineers have to be focused to look for the location of individual component to be probed on the DUT.

1.2 Motivation

DUT, as known as Device Under Test can be includes any electronic assembly under test. Among of electronic assembly, the most common device is printed circuit board (PCB) with surface mount technology components. As technology has improved many packages have decreased in size. These are shown in Figure 1.1 and Figure 1.2. Table 1.1 shows the main package of resistor sizes.

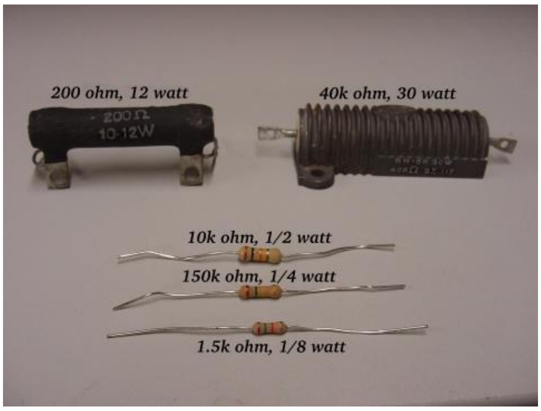

Figure 1.1:Typical Resistors

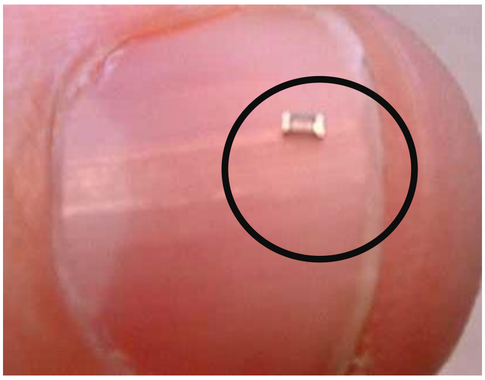

Figure 1.2: SMD Resistors

Table 1.1: Main Package of SMD Resistor Sizes

Package Style	Size (mm)	Size (Inches)
2512	6.30 x 3.10	0.25 x 0.12
2010	5.00 x 2.60	0.20 x 0.10
1812	4.6 x 3.0	0.18 x 0.12
1210	3.20 x 2.60	0.12 x 0.10
1206	3.0 x 1.5	0.12 x 0.06
0805	2.0 x 1..3	0.08 x 0.05
0603	1.5 x 0.08	0.06 x 0.03
0402	1 x 0.5	0.04 x 0.02
0201	0.6 x 0.3	0.02 x 0.01

It is still easy to identify component from printed circuit board if typical electronic components are used, as in Figure 1.3. Due to introduction of surface mount technology and the increment of package density, surface mount devices are relatively tiny compare with typical components when it mounted on the printed circuit board as in Figure 1.4.

Figure 1.3: Typical PCB

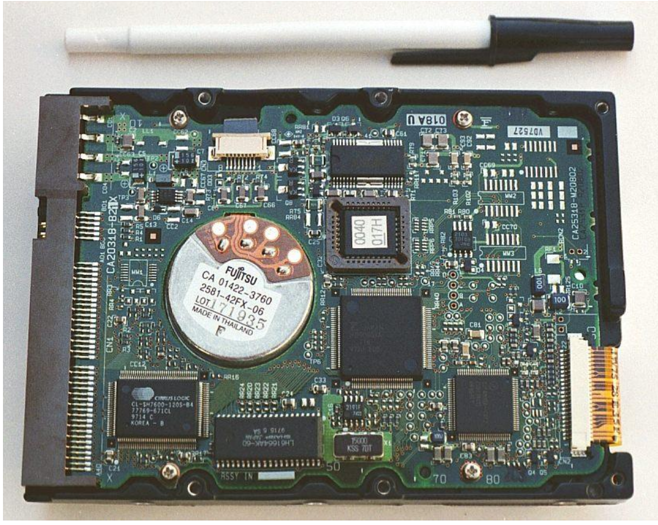

Figure 1.4: Surface Mount PCB

It is time consuming when engineers need to identify a particular component within the printed circuit board as tiny as shown in Figure 1.4 in order to perform probing, validation or testing. Although engineers will refer to schematic layout and components' label to find out the position of particular component, but it is not efficient without get assistant from the pointing system.

1.3 Project Scope

The Project aims to build a platform which consists of two motors rotate in x and y axis. Laser pointer is moved in two axes so it can point on the particular component of the object. The area of pointing is limited by the size of the platform and movement length of respective motors.

Besides, a lockable multipurpose flexible holder is designed not only to hold the test probe during the probing process, but also to hold other devices when necessary, such as soldering lead.

First of all, the project focuses on the structure design of the platform. Size of workable DUT is limited, depends on the coverage of camera and size of structure.

The whole structure is designed in order to be able to hold the motors, camera, laser pointer, and all the circuitry components.

Next, the project focuses on the programming and software implementation. Graphical User Interface is designed so that user can communicate with the whole 2-D location pointing system. A lockable multipurpose flexible holder is designed to assist user do probing and soldering. In order to provide user convenience while using holder, the lock can controlled by voice command.

There are few limitations when using the system. Firstly, the system is able to search component on the front side of DUT only. Secondly, camera is fixed install on top of the structure, hence the area captured is fixed and limited. Lastly, user need to placed DUT at fixed location to obtain template before the system run image locating itself.

1.4 Aims and Objectives

The aim of this project is to speed up the component searching process. There are two sections in this project, where two main objectives are to be delivered. The first section is to study and identify the displacement control of the motors while second section aims to create an image locating function. In interest of this objective, some tasks are set to be fulfilled as following:

- To learn to operate LabVIEW as a programming tool
- To study pre-defined functions available in LabVIEW that enable it to connect to external application
- Build up a platform that allow user to do probing component searching on DUT.
- Identify the location of DUT by camera capture process.
- Create link between PC and platform with appropriate software.
- Create GUI on PC so user can control the platform.

CHAPTER 2

LITERATURE REVIEW

2.1 National Instruments LabVIEW

LabVIEW, also known as Laboratory Virtual Instrumentation Engineering Workbench is a system design platform and graphical development environment for visual programming language from National Instruments. It used to develop sophisticated measurement, test, and control systems using intuitive graphical icons and wires that resemble a flowchart (National Instruments, 2012).

Figure 2.1: LabVIEW 2011 Interface (National Instruments, 2012)

LabVIEW is different from most other general-purpose programming languages. It provides faster programming due to its graphical programming features, known as G Programming. Users only program with drag-and-drop, graphical function blocks instead of writing lines of text such as C programming codes. In other words, G programming is typically easier to quickly understand because they are largely familiar with visualizing.

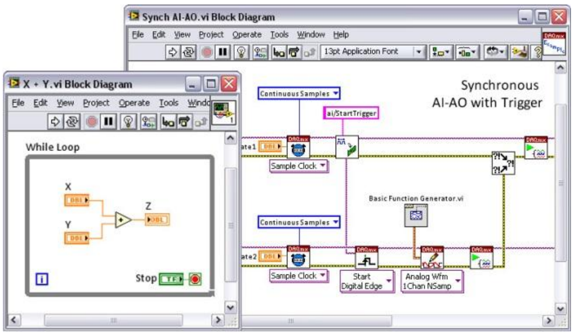

Figure 2.2: Graphical Programming and Dataflow (National Instruments, 2012)

2.1.1 LabVIEW 2011

LabVIEW 2011 is the latest version of system design software from National Instruments. It increases development efficiency to interact with almost any hardware device or deployment target. The following table shows the new features in NI LabVIEW 2011:

Table 2.1: New Features in NI LabVIEW 2011 (National Instruments, 2012)

New Features	Descriptions
Improved Stability	-Several changes were made that impact the time it takes to launch LabVIEW and load VI hierarchies.
Feedback-Driven Improvements	-Improved LabVIEW usability -Redesigned Block Diagram Objects -Front Panel Enhancements -LabVIEW Environment Enhancements.
UI Enhancements	-New palette of controls and indicators.
Asynchronous Call by Reference	-Improve the execution time of the calling VI by allowing the subVI run in parallel with the calling VI

Improved Real-Time Deployment	-Greatly reduce deployment times.
Edit-Time Improvements to LabVIEW FPGA	-Node framework is highly optimized to speed up the loading of larger Vis -Nodes have been reimplemented to remove any edit-time performance issues. -Interface has been rearchitected to provide a far more responsive editing experience. -FPGA compilation is optimized to be up to 80% faster.
New Math and Signal Processing Functions	-Provides new built-in algorithms in geometry, linear algebra and signal processing areas.
Application Builder API	-Provides application builder Vis to build, deploy or clean build specifications.
Improved Support	-Introducing easier way to report crashes. -New features have been added to help visualize which assemblies have been loaded in LabVIEW memory. -Give option of visiting the NI website to download the appropriate software needed to run their executable.

2.2 Electrical Motors

Electrical motors play a role in converting electrical energy into mechanical energy. Force is generated through the interaction of magnetic fields and current-carrying conductors. In an electrical motor the moving part is called the rotor and the stationary part is called the stator.

2.2.1 Types of Motors

Motors can be powered by either direct current or alternating current, Figure 2.3 shows the categorization of electrical motors:

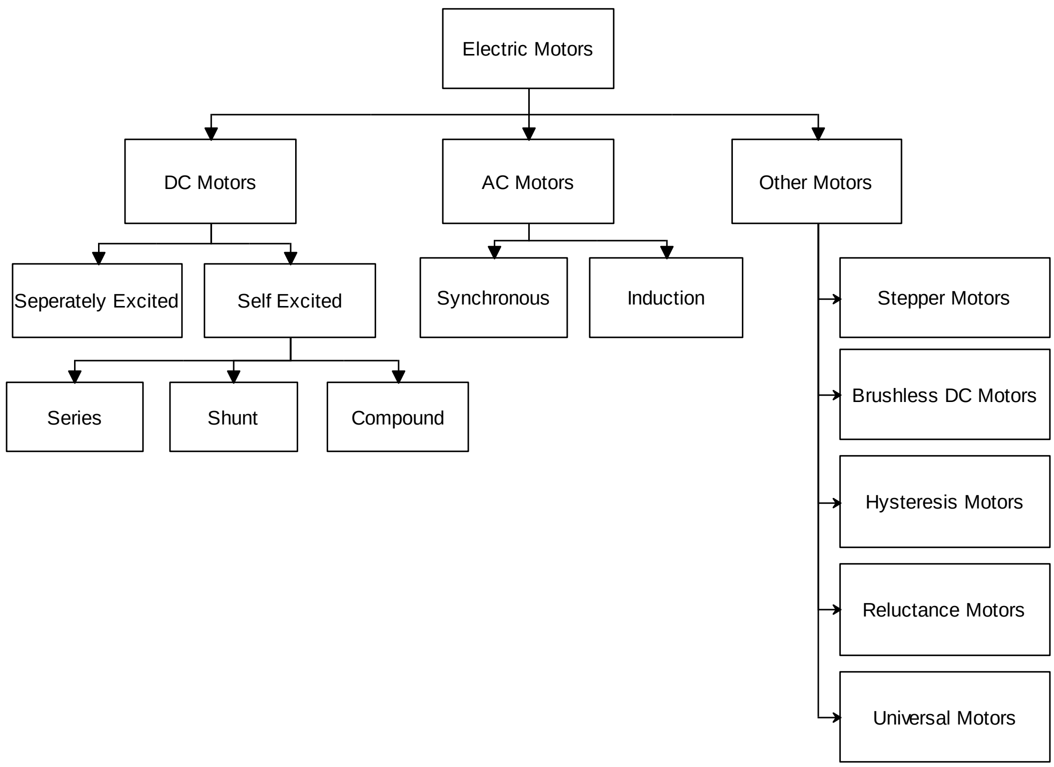

Figure 2.3: Types of Electric Motors

2.2.1.1 DC Motors

DC motors as the name implies use direct-unidirectional current. DC motors are used in special applications where high torque starting or smooth acceleration over a broad speed range is required. The main advantage of DC motors is the motor rotating speed control does not affect the quality of power supply. Speed of motor can be controlled by adjusting the armature voltage and the field current. Figure 2.4, 2.5 and 2.6 show the characteristics of a DC shunt, series and compound motor respectively.

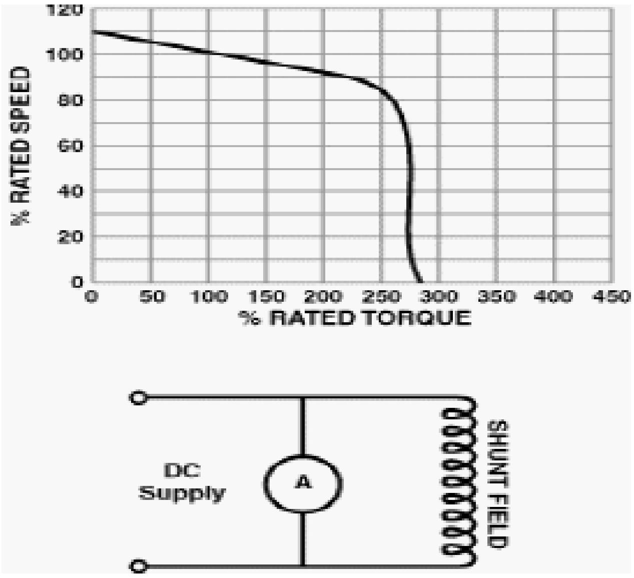

Figure 2.4: Characteristics of DC Shunt (Rodwell International Cooperation,1999)

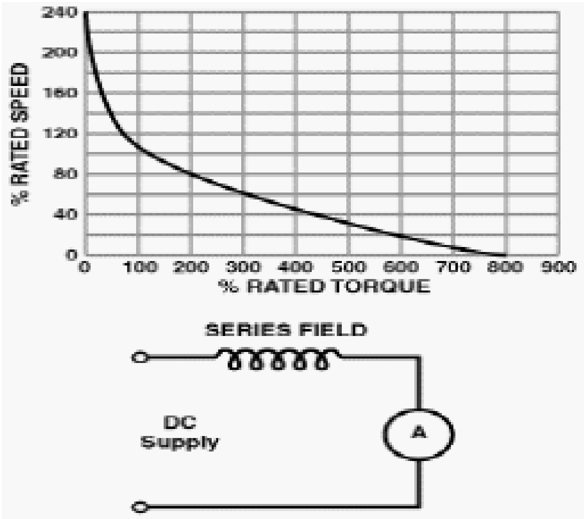

Figure 2.5: Characteristics of DC Series Motor (Rodwell International Cooperation, 1999)

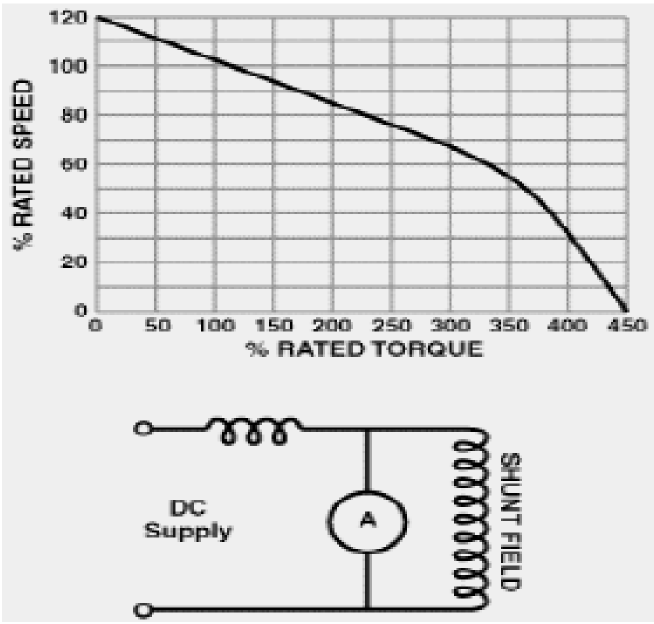

Figure 2.6: Characteristics of DC Compound Motor (Rodwell International Cooperation,1999)

There are disadvantages of using DC motors. First of all, DC motors will cause brush wear since they need brushes to connect the rotor winding. Sparks from the brushes may cause explosion if the environment contains explosive materials. Furthermore, RF noise from the brushes may interfere with nearby electronic devices such as television.

2.2.1.2 AC Motors

AC motors use an alternating current which reverses its direction at regular intervals. There are two main electrical parts: the stationary part called stator and the rotating part called rotor. A synchronous motor runs at constant speed fixed by frequency of the system. It suited for applications that start with a low load since it has low starting torque and requires direct current for excitation.

Induction motors are most common motors due to their simple design, inexpensive and easy to maintain, and can be directly connected to an AC power source (Bureau of Energy Efficiency India, 2005). Induction motors can be classified into two main groups: Single-phase and three-phase induction motors. Single-phase induction motors is commonly used in household appliances such as washing machine and fans. For three-phase motors, they are used in industry such as pumps, compressors and conveyor belts. Figure 2.7 shows an induction motor:

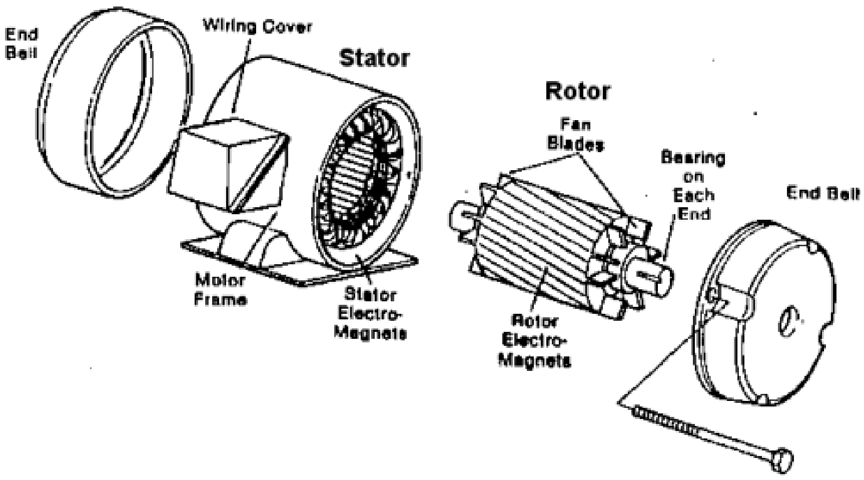

Figure 2.7: An Induction Motor (Automated Buildings)

2.2.1.3 Stepper motors

Rotor of stepper motor is built by a permanent magnet and rotates according electromagnetic fields created by electromagnets on the stationary portion that surrounds the motor, which is stator. The stepper motor's resolution is the degrees rotated per pulse. Figure 2.8 shows one complete rotation of a stepper motor.

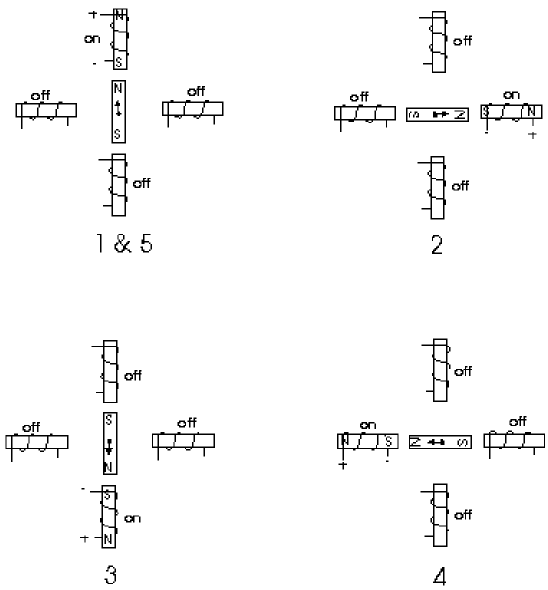

Figure 2.8: A Complete Rotation of Stepper Motor

The operation of a stepper motor requires a control unit, driver and power supply. Control unit is used to supply impulses with frequency which proportional to the speed of the motor.

The advantage of a stepper motor is that is can operate within an open loop, it means no feedback from motor is required. The available step angels of stepper motor provides fix location that rotor will stop rotate. Stepper motors usually found in photocopiers, printers, x-y plotters, heating and ventilation.

2.3 Laser Pointer

2.3.1 Introductions

The word LASER is an acronym that stands for "light amplification by stimulated emission of radiation." The theory used to produce laser was published in 1958 by researchers at Bell Labs. At 1962, semiconductor laser was invented by using semiconductor material, produced non-visible infrared radiation at beginning. The Figure 2.9 shows the design of semiconductor laser:

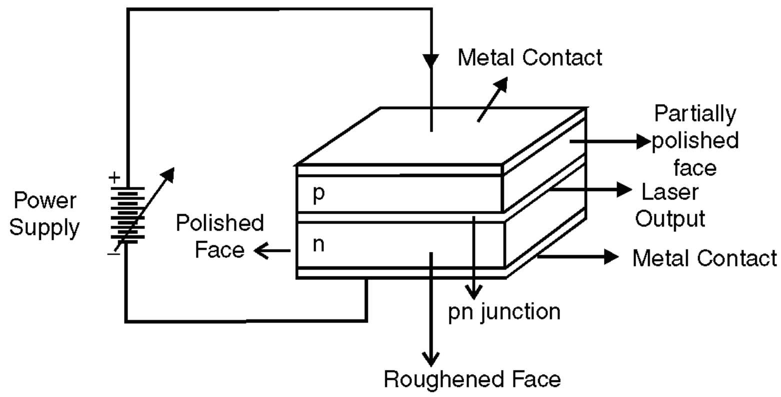

Figure 2.9: Semiconductor Laser Design

Current semiconductor lasers can produce visible light. Semiconductor lasers used in laser pointers are also known as diode lasers were originally invented as a handy tool for lecturers or speakers to focus attention on particular part of a screen or blackboard. Since semiconductor electronics become less expensive to produce since 1990s, laser pointers have become cheaper and are now bought primarily for the sake of being a novelty electronics item. Figure 2.10 shows an example of red laser pointer:

Figure 2.10: Red Laser Pointer

2.3.2 Types of Laser Pointer

Laser pointers come in different types that have different strength and ability. Three basic power levels of laser pointers can be found in market are:

Table 2.2: Types of Laser Pointers (Jim Samposzi, 2009)

Types	**Descriptions**
Red and Orange Pointers	- First type of laser pointer introduce during 1980s. - Battery powered laser diodes put into the device. -Wavelength: 633nm-670nm
Green Pointers	-Introduced during 2000's and much more complicated than the simpler red laser pointers. -Uses a radiation that is more chemically complex than red and orange laser pointers. -Wavelength: 532+ nm
Blue Pointers	-Latest type of laser and costly -A boost of the strength of green laser pointer. -Wavelength: 473 nm

International Electrotechnical Commission (IEC) standard has classified laser pointers into several classes. Lasers are classified to ensure that the risk of accidental exposure is minimized. There are five classes of laser: 1, 2, 3A, 3B and 4. Table 2.3 indicates the classes of lasers and their brief descriptions:

Table 2.3: Classifications of Laser Pointers (World Health Organization, 1998)

Class	Descriptions
1	-Output power below the level which eye injury can occur.
2	-Maximum output power limited to 1mW. -Avoiding eye exposure to the laser emitted.
3A	-Maximum output power up to 5mW. -Hazardous when viewed with optical aid.
3B	-Output power up to 500mW. -Sufficient to cause eye injury but do not have sufficient power to cause a skin injury.
4	-Output power greater than 500mW. -Capable to cause eye and skin injuries. -It will be a fire hazard if output powers are high.

2.3.3 Comments

A laser is a light source that can be dangerous to people exposed to it. Even low power laser can cause a bright flash, a dazzling effect, and temporary loss of vision in the affected eye. In general, laser pointers are classified as Class 1, Class 2 or Class 3B products (World Health Organization, 1998). The use of Class 3B laser pointers up to 5mW may be justified for some applications in the workplace.

There are some safety precautions when using laser pointers. First of all, always ensure that the laser pointer is pointed away from user and others before turning it on. Secondly, prevent direct contact between the eyesight and laser light source. For the high power laser pointers, prevent any skin contact with the laser since it might cause burnt on skin surface.

2.4 Image Processing

2.4.1 Edge Detection

Edge detection refers to the process of identifying and locating sharp discontinuities in an image (Raman Maini & Dr. Himanshu Aggarwal). Edge detection is the beginning step in object recognition, hence it is important to choose an appropriate edge detection technique by understanding the differences between various techniques.

Two categories can group the majority of different methods: Gradient based and Laplacian based Edge Detection. Gradient based method detects the edges by looking the maximum and minimum in the first order derivative of the image while Laplacian method searches for zero crossings in the second order derivatives of the image to find edges (Raman Maini & Dr. Himanshu Aggarwal). Some advantages and disadvantages of Edge Detection Techniques can be classified in Table 2.4:

Table 2.4: Advantages and Disadvantages of Edge Detectors (Raman Maini & Dr. Himanshu Aggarwal)

Operator	**Advantages**	**Disadvantages**
Classical (Sobel, Prewitt, Kirsch)	Simplicity, Detection of edges and their orientations	Sensitivity to noise, Inaccurate

Zero Crossing (Laplacian)	Detection of edges and their orientations. Having fixed characteristics in all directions.	Responding to some of the existing edges, Sensitivity to noise.
Laplacian of Gaussian (Marr-Hildreth)	Finding the correct places of edges, testing wider area around the pixel.	Malfunctioning at the corners, curves and where the gray level intensity function varies, not finding the orientation of edge because of using the Laplacian filter.
Gaussian (Canny, Shen-Castan)	Using probability for finding error rate, Localization and response. Improving signal to noise ratio, better detection specially in noise conditions	Complex computations, false zero crossing, time consuming

As mentioned from the table above, Canny's edge detection algorithm performs better than all these operators under almost all scenarios.

2.4.2 Pattern Matching

Pattern matching is the process of finding the location of a sub image, called template inside an image (Jignesh N Sarvaiya, Dr. Suprava Patnaik and Salman Bombaywala, 2009). With pattern matching user create a template or that represents the object for which user is searching. Pattern matching algorithms are some of the most important functions in image processing because of their use in varying applications such as alignment, gauging and inspection (National Instruments, 1999).

There are different pattern matching techniques:

Table 2.5: Different Techniques of Pattern Matching

Techniques	***Comments***
Cross Correlation	-Correlation process is time consuming. -Matching process can be speed up by reducing the size of the image and restricting the region in the image.
Pyramidal Matching	-The image and the template can be reduced to ¼ of their original size. -Matching is faster.
Scale-Invariant Matching	-Good technique for patterns those are not scaled or rotated. -Scaled and rotated image will require exhaustive rotations of the template.
Image Understanding	-Speed up the searching process by reduces the amount of information needed to fully characterize an image or pattern. -Include geometric modelling, efficient non-uniform sampling and extraction of template information that is rotation and scale independent.

2.4.3 Other Searching Techniques

2.4.3.1 Binary Shape Matching

It performed by extracting parameters from a template object that represent the object's shape and are invariant to the rotation and scale of the shape (National Instruments, 1999). Figure 2.11 (a) shows the shape template, Figure 2.11 (b) shows the original grayscale image, Figure 2.11 (c) shows the binary version of the image and Figure 2.11 (d) shows the output of the shape matching function.

Figure 2.11: Binary Shape Matching (National Instruments, 1999)

2.4.3.2 Blob Analysis

Blob (Binary Large Object) analysis scans through the image and detects all the particles in the image in order to build a detailed report on each particle. The main different of blob analysis with others technique is it provides a powerful and flexible way to define own searching or matching parameters. Figure 2.12 shows a sample list of parameters can be obtained. It thresholds the source image in binary image and removing particles that touch the border of the image.

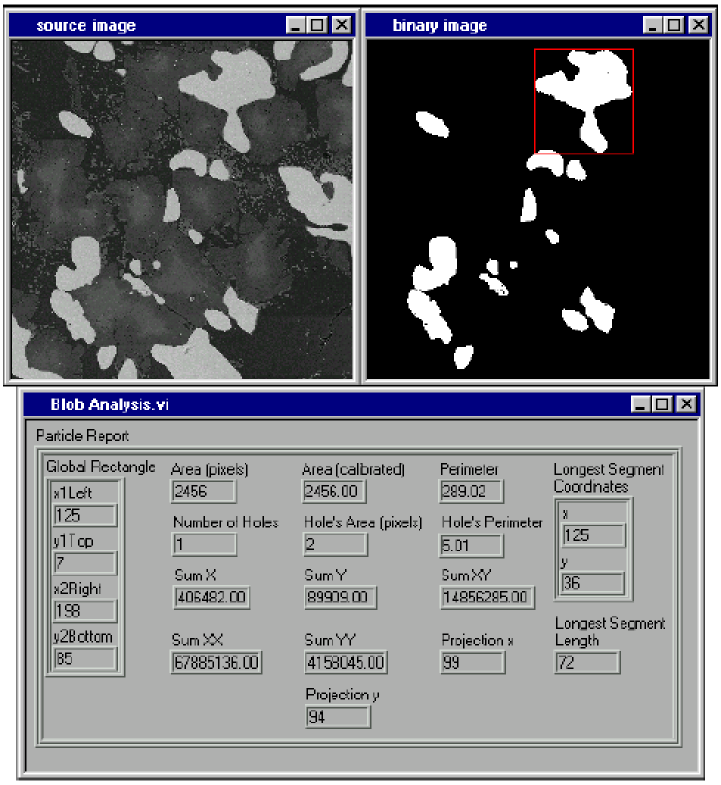

Figure 2.12: List of Parameters Extracted from a Particle in a Binary Image (National Instruments, 1999)

The major drawback of blob analysis is not practical in searching appliation for the image that have low contract and highly reflective parts.

CHAPTER 3

METHODOLOGY

3.1 Overview

Figure 3.1 shows the overall block diagram for 2-D Location Pointing System for Individual Component on Device Under Test. The whole system is controlled by National Instruments sbRIO-9632XT embedded control and acquisition devices, which connected to a PC as host by RJ45 cross cable. LabVIEW 2011 consists of development system, application builder, FPGA module, Real-Time module and Vision development are used as communication medium between host (PC) and client (NI sbRIO-9632XT). A mechanical structure is built to hold motors, camera, microphone, laser pointer, holder and all the circuitry board.

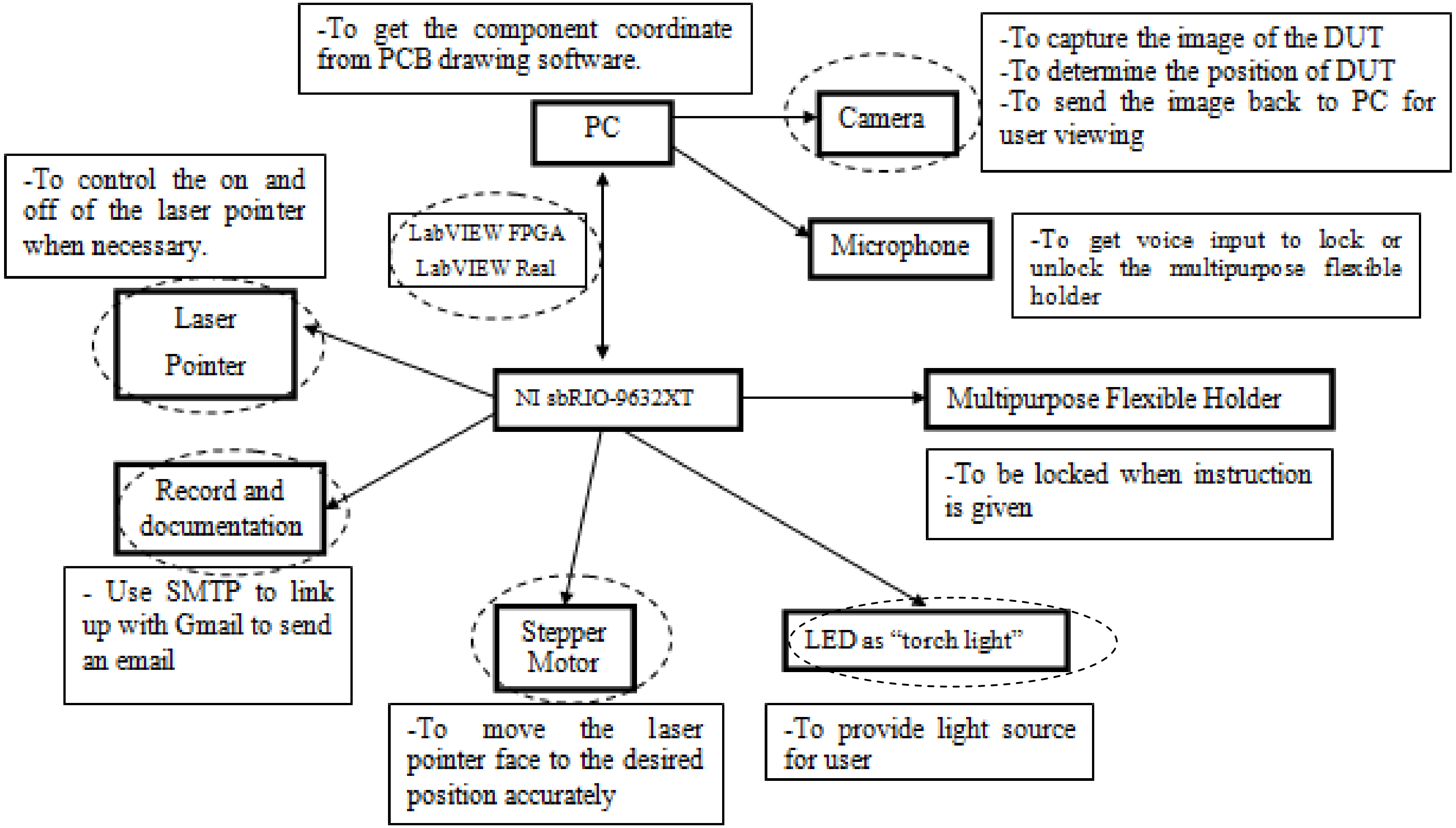

Figure 3.1: Overall Block Diagram for 2-D Location Pointing System for Individual Component on Device Under Test

Most of the devices are connected to NI sbRIO-9632XT board except camera and microphone. Both of these devices are plugged into USB port of PC. The system architecture can be simplified into Figure 3.2:

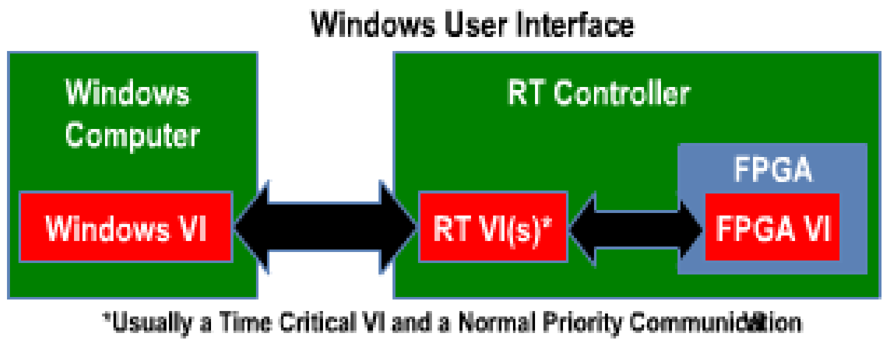

Figure 3.2: Windows User Interface

Graphical Programming will be used in the whole system operation. LabVIEW 2011 is the software that developed by National Instruments to do the compilation on graphical programming. The programming concept flow of the system can be shown in Figure 3.3:

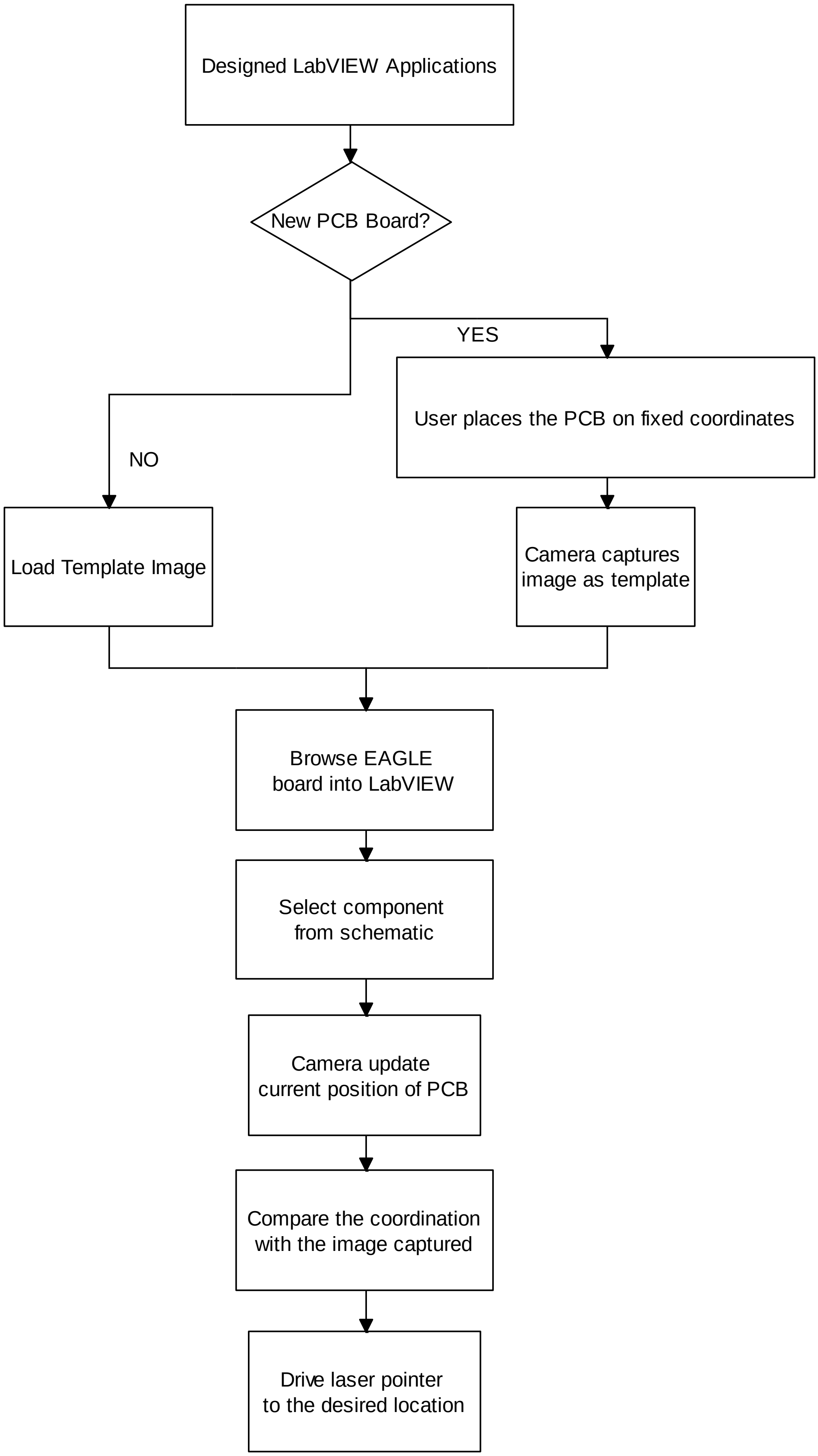

Figure 3.3: Flowchart of System Programming Concept

3.2 Mechanical Structure

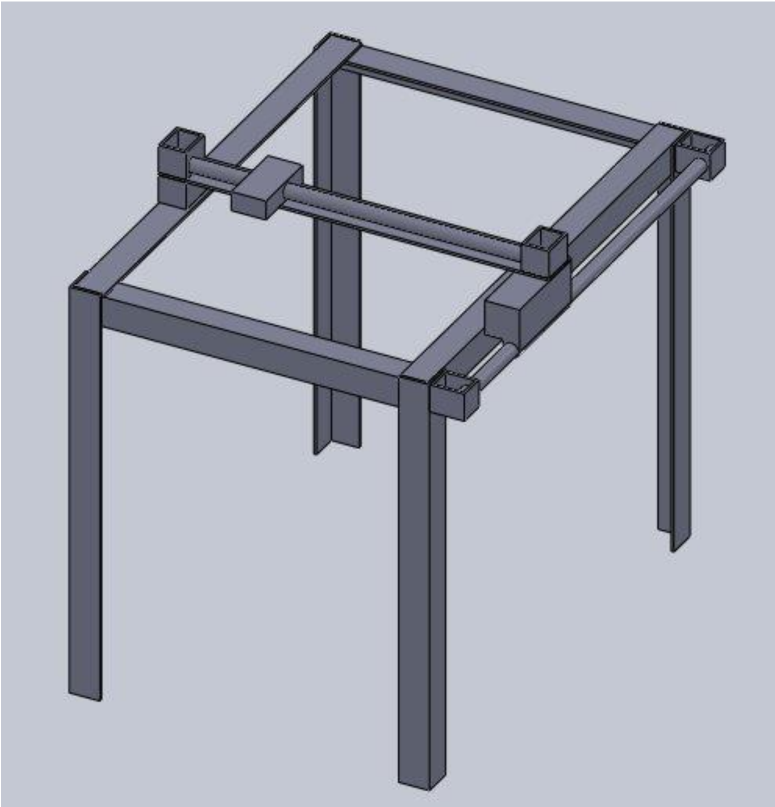

Figure 3.4: Draft Mechanical Structure Design

The main material use for the structure is aluminium angle bars with 30cm x 6 and 40cm x 2 length. Two bars are connected by using bolts, washers and nuts. Apart from that, two stainless steel rods are used to form the tracks for x axis and y axis movement.

Motors will be mounted on the aluminium angle bars with connection of rubber belts to opposite edge. Figure 3.4 shows the mechanical structure design of the system. Gears are mounted on motors' shaft so it can drive the rubber to move the laser pointer in one direction.

3.3 NI sbRIO-9632XT

National Instruments Single-Board Reconfigurable I/O device is an embedded control and acquisition device with the integration of real-time processor, FPGA, and I/O on a single printed circuit board. Figure 3.5 shows the image of NI sbRIO-9632XT:

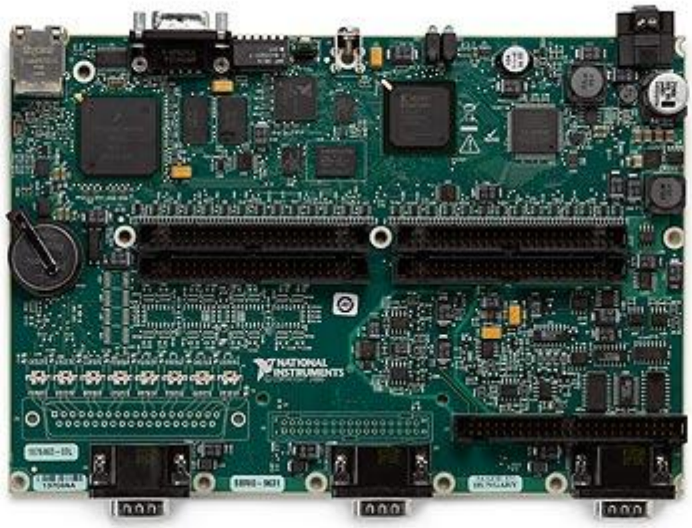

Figure 3.5: NI sbRIO-9632XT Front View

NI sbRIO-9632XT devices are designed to be easily embedded in high-volume applications that require flexibility, high performance, and reliability. (National Instruments, 2011) In the project, NI sbRIO-9632XT, is the communication medium between PC and all electronic devices. NI sbRIO-9632XT provides sufficient digital and analog I/O pins for the system. The electronic devices mentioned are listed in the Table 3.1:

Table 3.1: List of I/O Table for System

Devices	*Number of I/O pins needed*
Motors x2	10
LED	8
LCD display	6
Switches	8
Flexible holder	1
Laser Pointer	1

3.4 Electrical Motors

Electrical Motors are used to move the laser pointer in 2-D directions, x-axis and y-axis. Requirements needed for the motor are: 1) able to provide precise distance of movement, 2) excellent response to starting/stopping/reversing, 3) light and small in physical size and 4) have small step distance of movement. Among the various types of motors, stepper motors are chosen.

Figure 3.6: NEOCENE Stepper Motor

Table 3.2: Neocene 2T357247

Type	**NTC PM-type Stepper Motor**
Motor outer diameter	35mm
Step angle	3.75^o
Height	8.3mm
Number of wire	5

The motor provides a step angle of 3.75^o , which is relatively small that the movement can reach few millimetres only. The stepper motor contains five wires: four input wires from respective winding and one ground wire. The sequence of the inputs needs to be identified so the motor can rotate smoothly in either clockwise or anticlockwise direction.

3.5 Image Processing

The source of image can be obtained by two ways: from the existing template or from the camera. There are two major image processing steps in the system: image locating and image matching.

National Instruments provides a driver called NI_IMAQdx, as a part of the Vision Acquisition Software, which is suitable for USB and FireWire cameras (National Instruments, 2011). With NI-IMAQ for USB cameras, user can acquire images from any USB imaging device with DirectShow support. The user can also configure cameras programmatically, with graphical programming languages. The flowchart of image processing is shown in Figure 3.7:

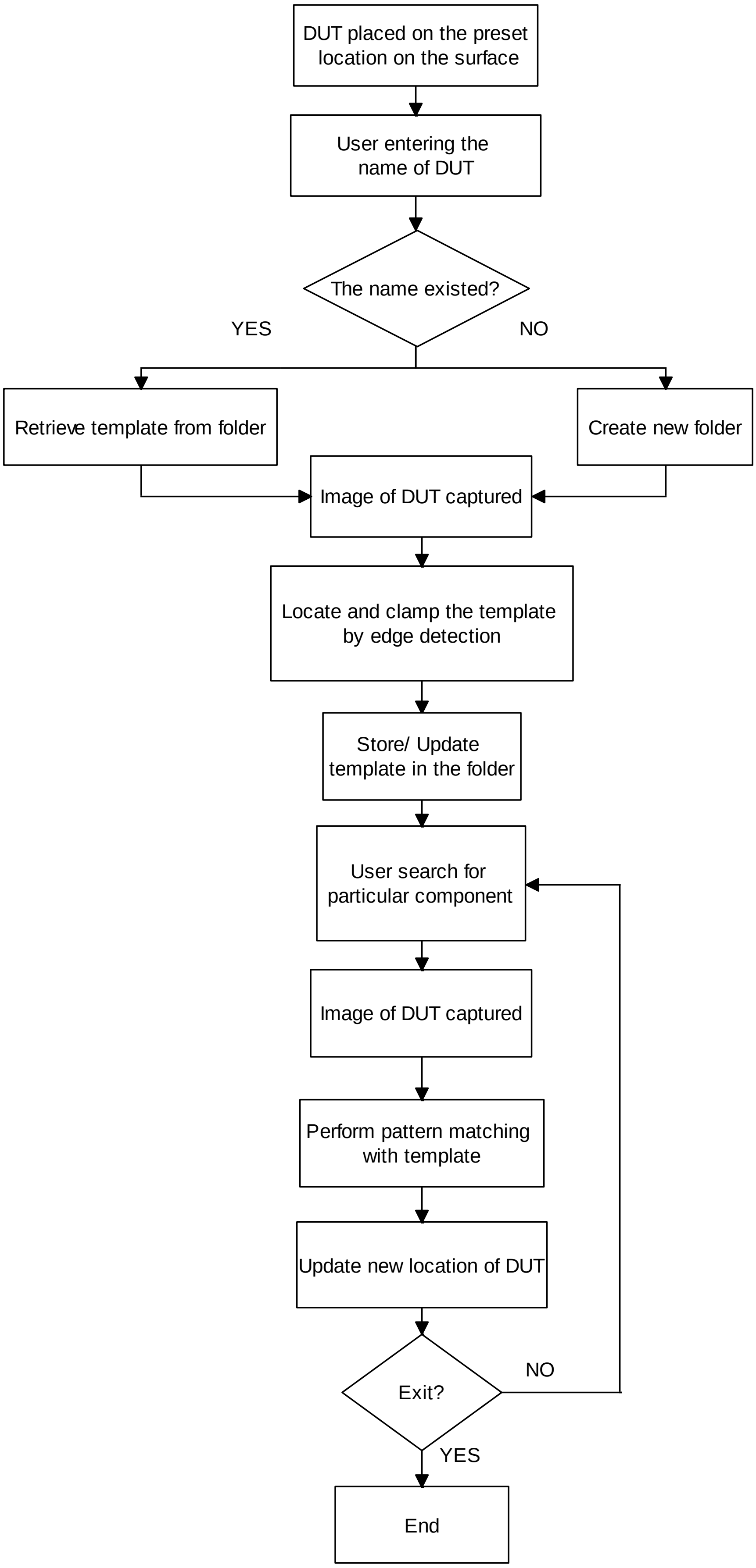

Figure 3.7: Procedure of Image Processing

3.5.1 Template Locate

In LabVIEW Vision Acquisition Software, functions that related to image locating are IMAQ Clamp Horizontal VI, IMAQ Clamp Vertical VI, IMAQ Edge Detection VI and IMAQ Edge Detection VI.

For the system, IMAQ Clamp Horizontal and Vertical are used. The reason is it provide the x-axis distance between two lines when hit-line to the object through the leftmost edge and another hit-line from rightmost edge, while y-axis distance when hit-line from uppermost and lowermost edge are calculated. In addition, edge coordinates are also provides after perform IMAQ clamp functions.

From the results of image clamping, it is able to identify what is the size of the DUT, the resultant image and the coordinates of four respective edges. If the user moves the DUT, the information of clamping functions can pass to next functions to perform relocation, which will be discussed in next subtopic.

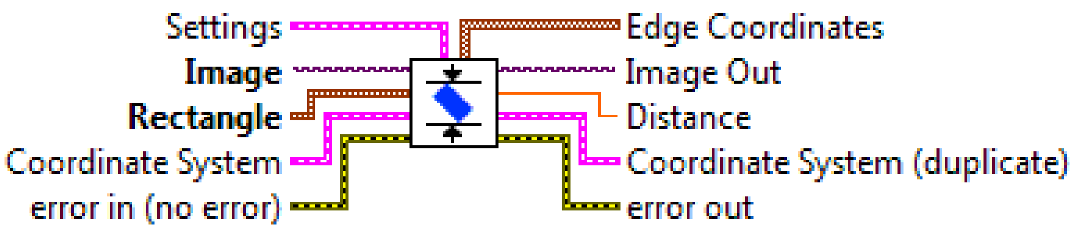

Figure 3.8: IMAQ Clamp Vertical Max VI (LabVIEW 2011)

3.5.2 Image Relocation

It is important to detect the location of the object in order to update the latest location’s coordinates. To detect new location, the parameters of the template have to be learned by the function in LabVIEW. This is the reason why template is obtained at earlier stage.

After create a quality template, the pattern matching algorithm has to learn the important features of the template. The learning process usually time intensive because the algorithm attempts to find unique features of the template that allow for fast, accurate matching. The parameters that influence the IMAQ Vision pattern matching algorithm are match mode, minimum contrast and rotation angle ranges.

LabVIEW does provide several types of searching and matching functions such as colour pattern matching, and geometric pattern matching. Pattern matching is chosen to locate object it is because DUT is not a symmetrical in shape and each components on the DUT has unique identity.

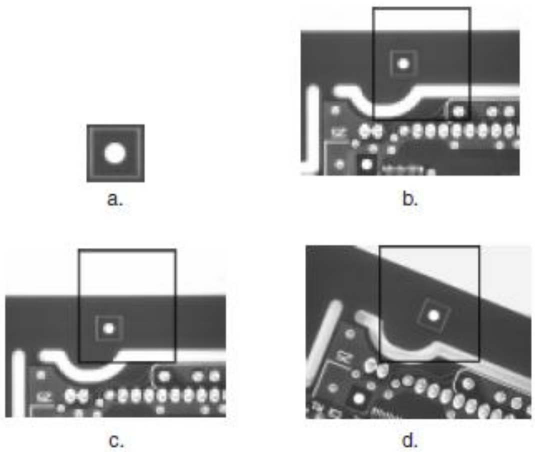

Figure 3.9: Example of Pattern Matching

3.6 Liquid Crystal Displays

Liquid Crystal Display (LCD) used for display the status of the system. This is to inform user what kind of status of the system currently so user can continue communicate with it. In this case, the LCD is interfaced with NI sbRIO-9632XT. Figure 3.10 shows the image of 2 X 16 LCD.

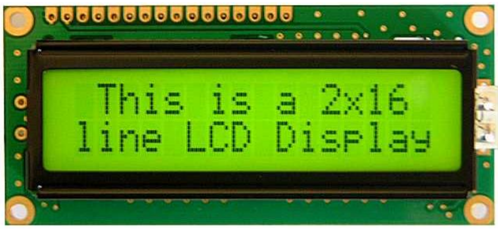

Figure 3.10: 2 x 16 LCD

CHAPTER 4

IMPLEMENTATION OF SYSTEM AND OUTCOMES

4.1 Overall Implementation

The physical design of the 2-D Location Pointing System is implemented as shown in Figure 4.1 and Figure 4.2. The labels of the figures are shown in Figure 4.3:

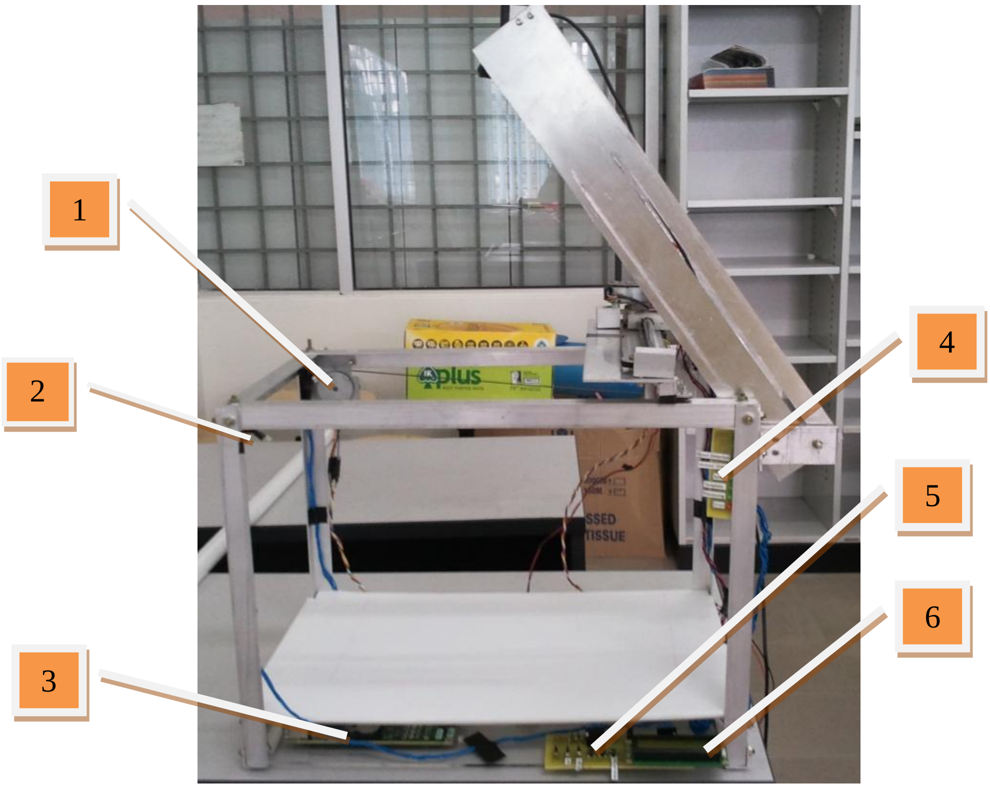

Figure 4.1: Side View of the System

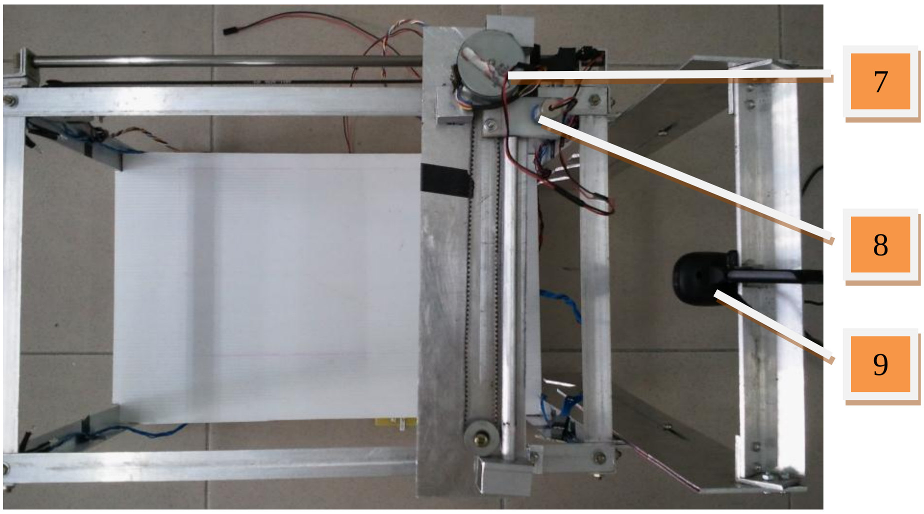

Figure 4.2: Plan View of the System

Table 4.1: List of Devices

Number	Device
1	Y-axis Stepper Motor
2	Super Bright White LED
3	NI sbRIO-9632XT
4	LED Indicators
5	Switches
6	2x16 LCD
7	X-axis Stepper Motor
8	Laser Pointer
9	C170 Logitech Webcam

The mechanical structure of this project is formed by L bars. In order to allow users having more space to perform their probing, two sides of the structure are designed to have least hardware components. The camera of system can be lifted for user convenience. The overall dimension of the 2-D Location Pointer System is summarized in Table 4.2:

Table 4.2: Overall Dimension of the System

Structure	***Distance***
Length (y-axis)	418mm
Width (x-axis)	260mm
Height (without camera)	300mm
Height (with camera, not lifted)	400mm
Height (with camera, lifted)	620mm
From base to platform	45mm
From platform to camera lens	510mm
From platform to laser pointer	280mm

The core of the system is NI sbRIO-9632XT board connected to a personal computer with RJ45 Ethernet cross cable. The model of power supply to the board is NES-100-24 from Mean Well Enterprises, which is a 100W Single Output Switching Power Supply with 24V.

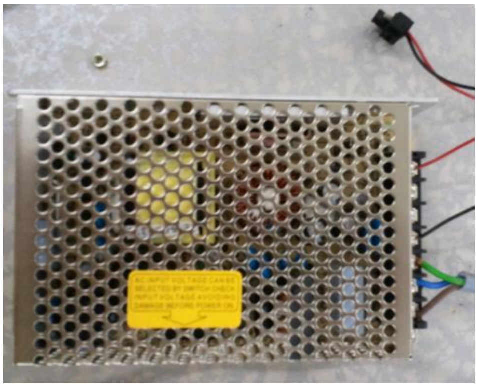

Figure 4.3: NES-100-24 Single Output Switching Power Supply

4.2 Hardware Design Architecture

All hardware except image capturing device, are controlled by LabVIEW FPGA. The details connections of NI sbRIO-9632XT shown in Table 4.3:

Table 4.3: Devices Input/Output Connections on NI sbRIO-9632XT

Port	Devices	Functions
Port 4/ DIO 3	2x16 LCD	R/S
Port 4/ DIO 4		EN
Port 4/ DIO 5		R4
Port 4/ DIO 6		R5
Port 4/ DIO 7		R6
Port 4/ DIO 8		R7
Port 7/DIO 0	LED	Indicates Error
Port 7/DIO 1	LED	Indicates System in Progress
Port 7/DIO 2	LED	Indicates Template Availability
Port 7/DIO 3	LED	Indicates User can Select Component
Port 3/DIO 9	LED	Indicates Motors Back to Origin
Port 3/DIO 0	LED	Indicates Object Detected
Port 3/DIO 1	LED	Reserved
Port 3/DIO 2	LED	Reserved

Port 9/DIO 1	Stepper Motor	Provide sequential output for y-axis movement
Port 9/DIO 2		
Port 9/DIO 3		
Port 9/DIO 4		
Port 9/DIO 5	Stepper Motor	Provide sequential output for x-axis movement
Port 9/DIO 6		
Port 9/DIO 7		
Port 9/DIO 8		
Port 8/DIO 7	Lever Switch	Stop motor movement at the x-axis edge
Port 8/DIO 8	Lever Switch	Stop motor movement at the y-axis edge
Port 9/DIO 0	Laser Pointer	Points to search result
Port 9/DIO 9	White LEDs	Provide lightings
Port 4/DIO 0	Push Button	Motor Back to Origin
Port 4/DIO 1	Push Button	Relocate Object
Port 4/DIO 2	Push Button	Control Laser on/off
Port 4/DIO 9	Toggle Switch	Control Lightings
Port 3/DIO 7	Toggle Switch	Reserved
Port 3/DIO 8	Toggle Switch	Reserved

4.2.1 Stepper Motors

Two Stepper Motors are used to move laser pointer in x and y direction respectively. The shafts of motors are embedded with gears in order to pull the rubber belts. Figure 4.4 shows the image of x-axis stepper motor and Figure 4.5 shows the image of y-axis stepper motor:

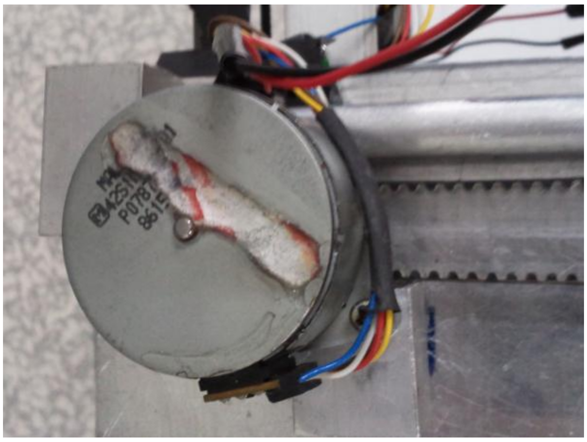

Figure 4.4: X-axis Stepper Motor

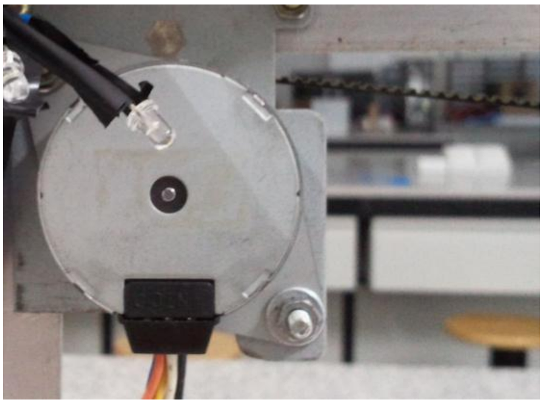

Figure 4.5: Y-axis Stepper Motor

The Input/Output ports from NI sbRIO-9632XT are not sufficient to provide current to both of the stepper motors. Hence, high current Darlington transistor array ULN2803 used to drive stepper motor with the input voltage 24V, with the ports connections showed in Figure 4.6:

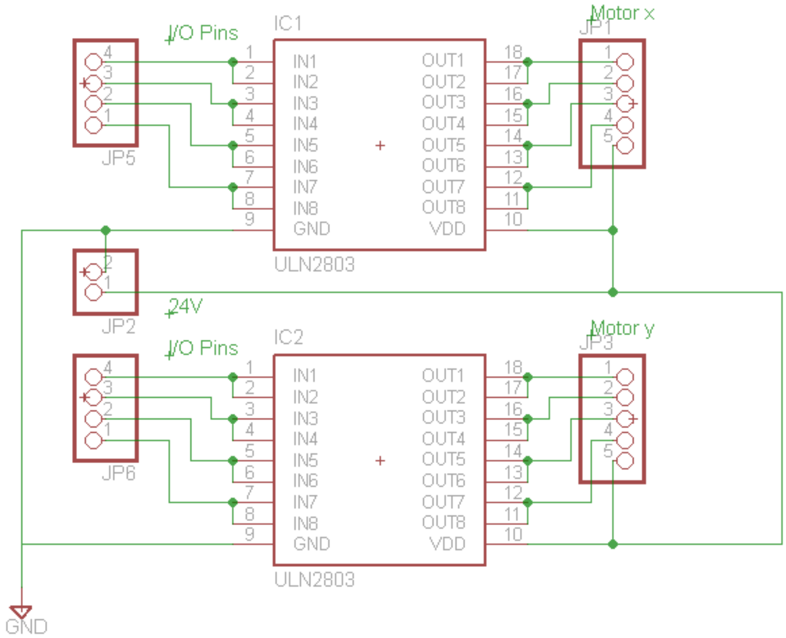

Figure 4.6: Stepper Motors and ULN2803

The way to rotate both of the stepper motors is to send sequence output to motor's pins. The stepper motors are driven in full step drive in order to move the loads with full rated torque. The sequence output from I/O pins to rotate the motors is stated in Table 4.4:

Table 4.4: Full Step Drive of Stepper Motors

X-axis Motor	Port 9/DIO 5	Port 9/DIO 6	Port 9/DIO 7	Port 9/DIO 8
Y-axis Motor	Port 9/DIO 1	Port 9/DIO 2	Port 9/DIO 3	Port 9/DIO 4
State 1	1	1	0	0
State 2	0	1	1	0
State 3	0	0	1	1
State 4	1	0	0	1

The direction of rotations are depends on the sequence of output whether is from State 1 to State 4, or vice versa.

In order to obtain required distance of rotation in x and y axis, the step number of motors have to be calibrated. Table 4.5 and 4.6 shows the reading between distance and number of steps, and their errors.

Table 4.5: Experiment on X-axis Stepper Motor

Steps	10	50	100	200
Distance(mm)	3	18	37	75
Steps/Distance(mm^{-1})	3.33	2.78	2.70	2.67
Error Percentage (%)	16.03	3.14	5.92	6.97

Average Steps/Distance =2.87mm^{-1}

Full movement length =180mm

Number of steps needed = 480 steps

Approximate steps per 10mm = 27steps

Table 4.6: Experiment on Y-axis Stepper Motor

Steps	100	200	500	1000
Distance(mm)	2	4	10	21
Steps/Distance(mm^{-1})	50.00	50.00	50.00	47.62
Error Percentage (%)	1.19	1.19	1.19	3.62

Average Steps/Distance =49.41mm^{-1}

Full movement length = 300mm

Number of steps needed = 14100 steps

Approximate steps per 10mm = 500 steps

From the experiments, the motors can be precisely stop at require distance in range of milimeter. In order to reduce the errors in range, two motors have to be returned to the initial position. Lever switches are act as an indicator to stop the motor at the initial position which is 0,0 in coordinate. The lever switches schematic is shown in Figure 4.7:

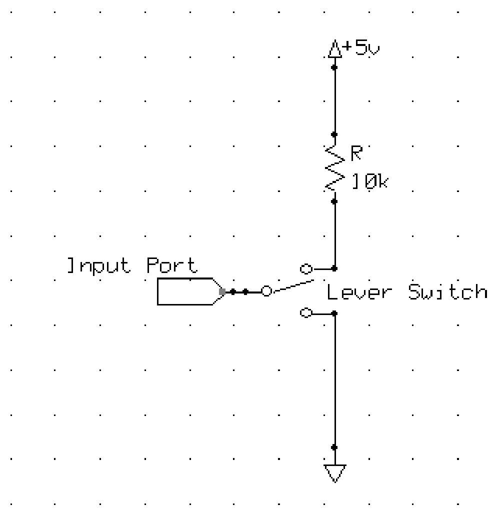

Figure 4.7: Lever Switch Circuit

The functions of stepper motors are coded into a module called "motor run.vi", which allow designer to determine three functions which are the mode (searching or back to origin point), x-axis motor steps and y-axis motor steps. The "motor_run.vi" module is shown in Figure 4.8:

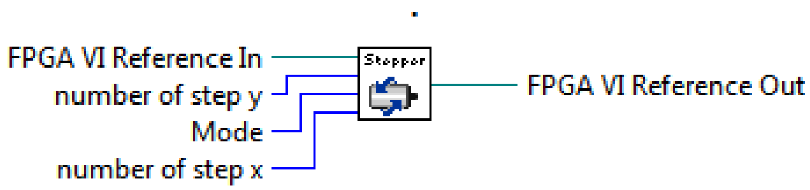

Figure 4.8: "motor run.vi" Module

The operation of stepper motors can be viewed in Figure 4.9:

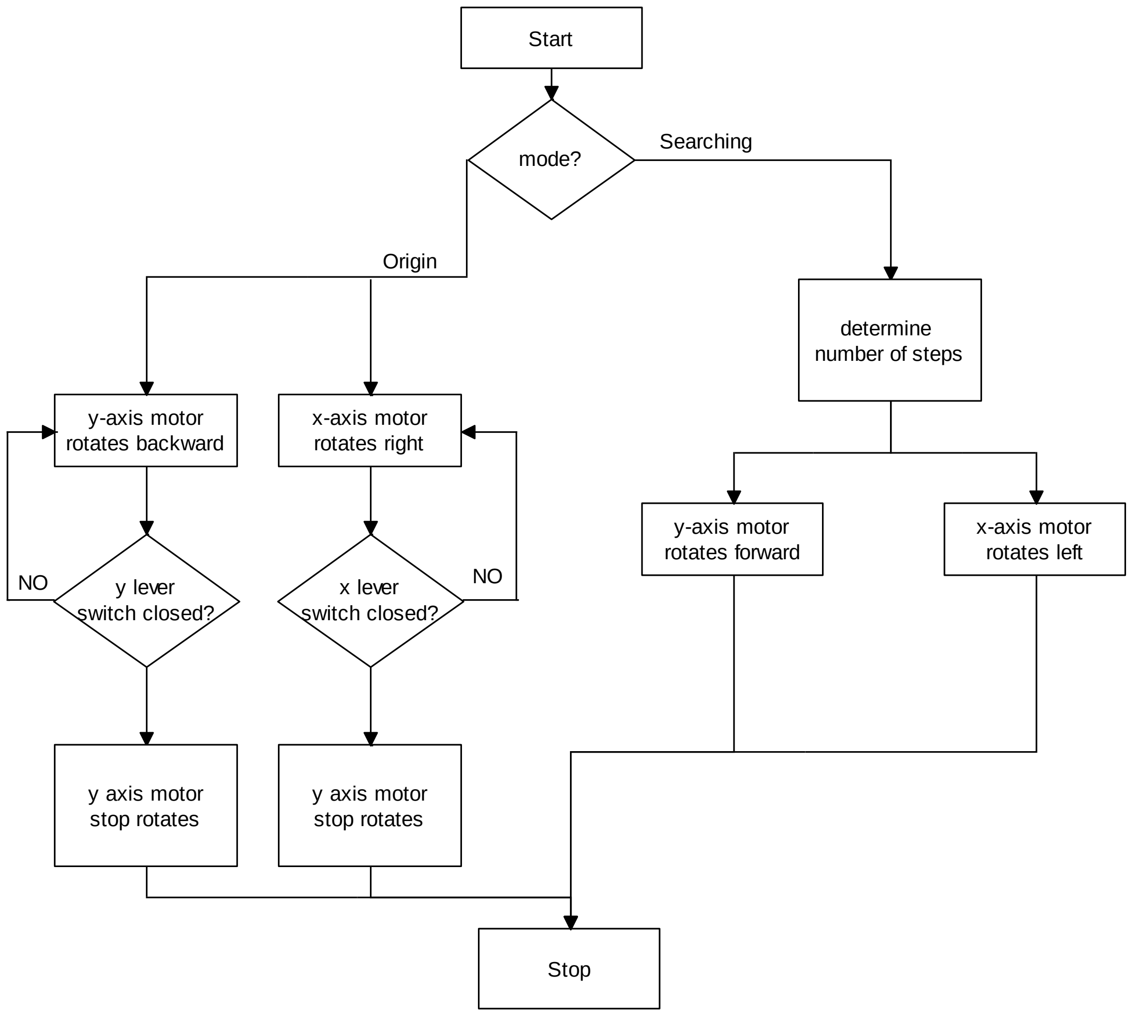

Figure 4.9: Flowchart of Stepper Motors

4.2.2 LCD Displays

2x16 LCD is used to display information about the system as in Table 4.7. From the display, user able to track on the process of the system, project name and the condition of the image captured.

Table 4.7: Display of LCD and Descriptions

Display	Descriptions
Start	First time access of the system
Define Path	Define path for EAGLE 6.1.0
Select File	Choose schematic
<project name>	Project name
No Result File Deleted	No cropping result from template captured, project file is deleted.
Template Taken	Template have been cropped
Coordinates…	User can select component from schematic
No Component	No component is selected from schematic
Object not found	System can't detect object from the platform
Exit File….	User exits project

Figure 4.10: LCD Display during Implementation

The LCD display module as shown in Figure 4.11 allows designer to determine whether the previous display need to be cleared, or whether the string displayed in first or second row.

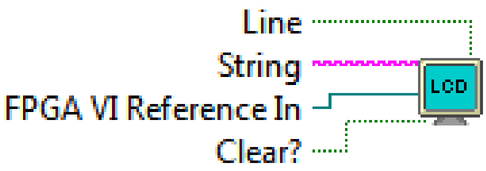

Figure 4.11: "LCD module.vi" Module

4.2.3 Hardware Controls and Indications

External controls are designed to provide user extra options in control lighting, laser and motors' movement. This is shown in Figure 4.12. RC circuits are designed in order to prevent contact bouncing of the switches. The value of resistor is 10k ohm while the value of capacitor is 0.1 µF:

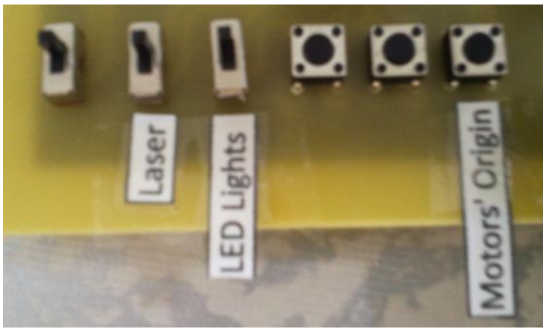

Figure 4.12: Physical Switches of the System

Indicators provide specific information on the situations of the system. Figure 4.13 shows available LED indicators in the system. Resistors 1k ohms are connected in series with LED to limit current flow from 3.3V output ports. Current drawn from each LED has to be less than 3mA from each digital port as stated in NI sbRIO-9632XT User Guide.

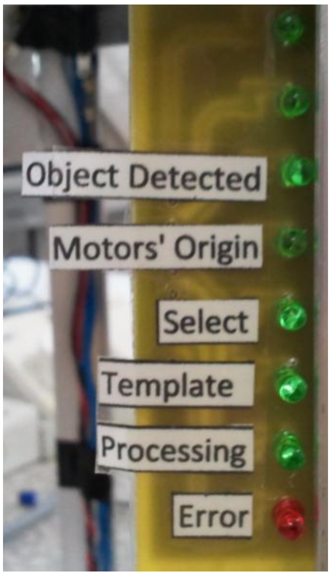

Figure 4.13: LED Indicators of the System

Eight super bright white LED are used to provide lighting to the system. High current Darlington transistors array ULN2803 is needed to provide larger power to LEDs, with the circuit design showed in Figure 4.14:

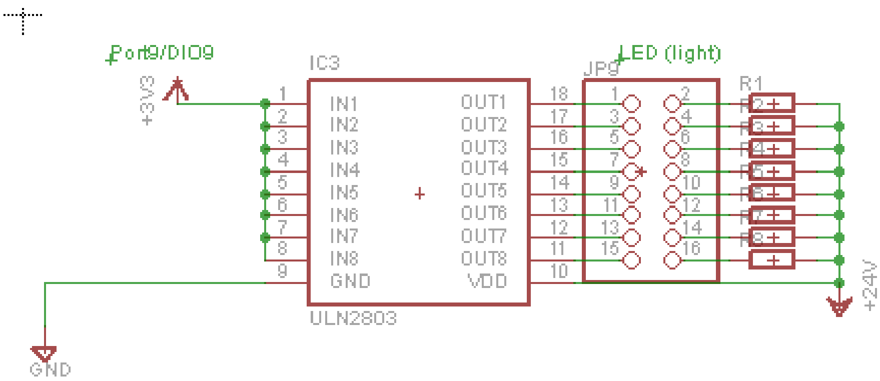

Figure 4.14: Circuit Design for LED Lighting System

4.2.4 Laser Pointer

Laser Pointer is controlled manually by user. It is embedded in the foam form of polyethylene, which on the track of x-axis. Table 4.8 shows the characteristics of the laser pointer and Figure 4.15 shows the image of laser pointer from the system:

Table 4.8: Characteristics of Laser Pointer

Characters	Unit
Model	HLM1230
Maximum Power	5mW
Input Voltage	3.5-4.5Vdc
Wavelength	650nm
Class	3A
Colour	Red

Figure 4.15: Laser Pointer Embedded in Polyethylene

4.2.5 Outcome

The circuits are placed under the platform of the system. Figure 4.16 shows the image of circuits using PCB:

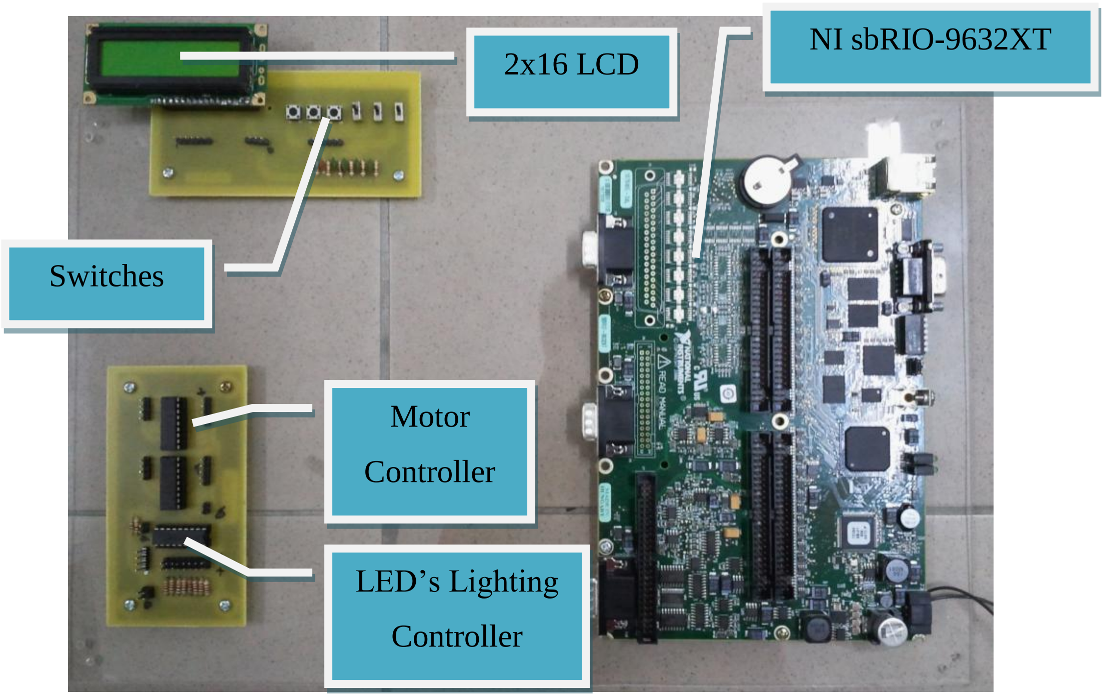

Figure 4.16: Outcome of Hardware Circuits

4.3 Image Processing

C170 Logitech Webcam is used as image capturing device for the system. The height of the webcam is important as it determines the area of image captured. A holder is constructed to hold the webcam with fixed distance from the platform. Holder can be lifted up and set it back down manually as shown in Figure 4.17:

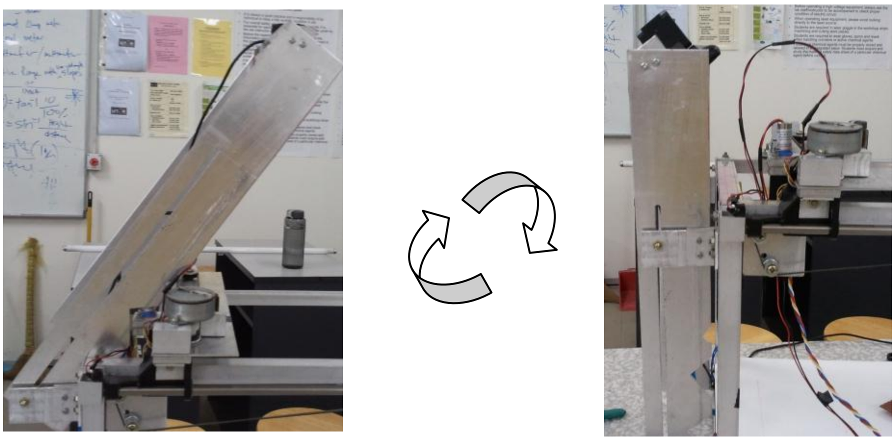

Figure 4.17: The Mechanism of Camera Holder

The working principle of image processing includes template processing and pattern matching is shown in Figure 4.18:

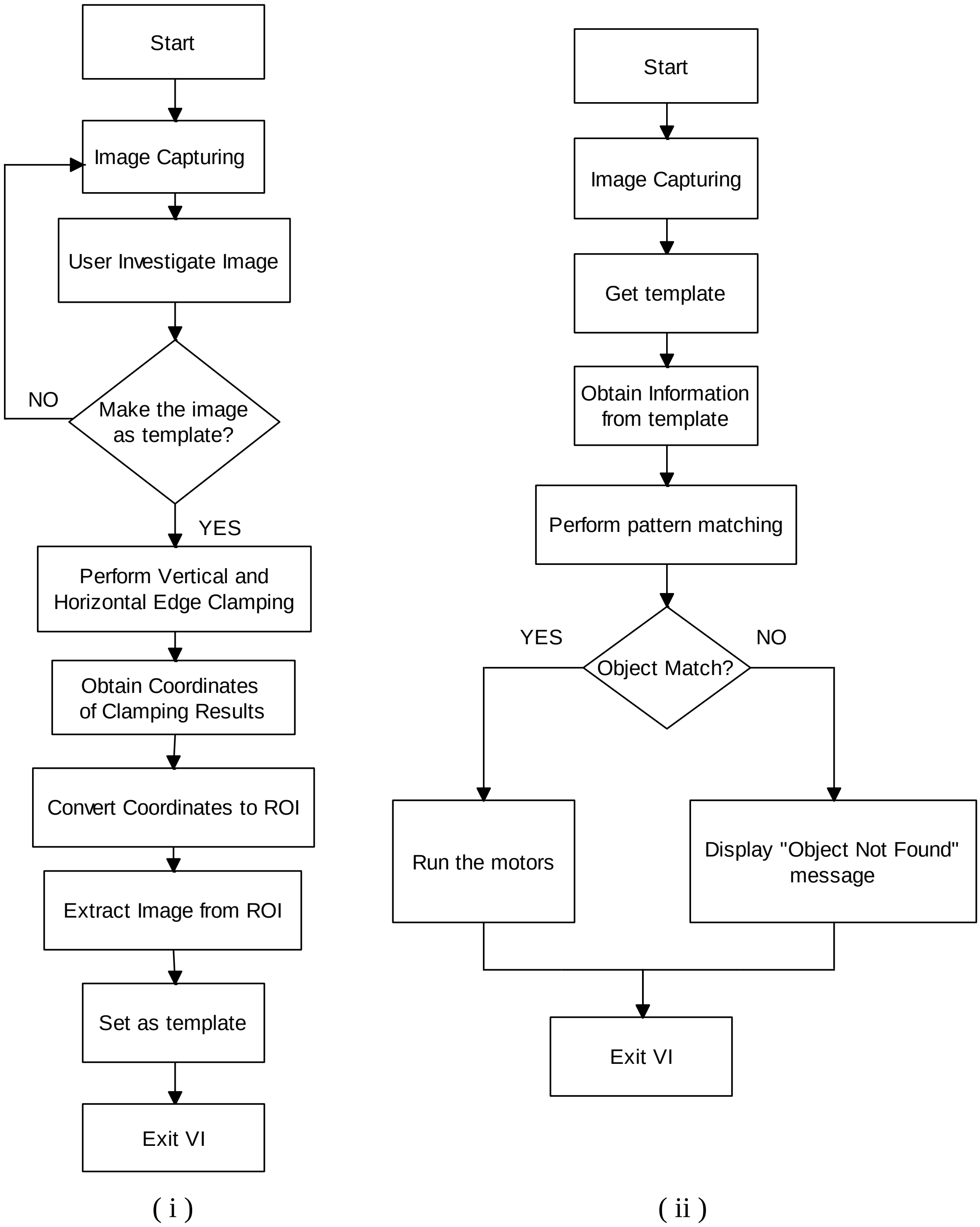

Figure 4.18: Working Principle of Image Processing, (i) Template Processing, (ii) Pattern Matching

4.3.1 Template Processing

A template is needed to locate the DUT. In order to get a good quality of template and increase accuracy of pointing system, DUT have to be placed in parallel with x and y axis of image captured by camera. Horizontal and Vertical Clamping functions are used to obtain the edges coordination of the object captured. The above process only repeated for every new DUT. Figure 4.19 shows a good quality template and Figure 4.20 shows a bad quality template:

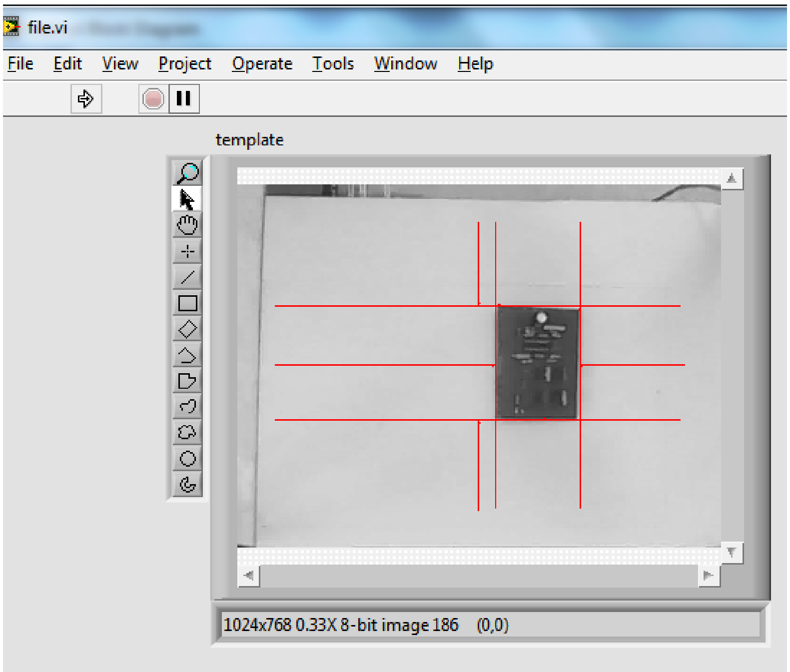

Figure 4.19: Good Quality Template

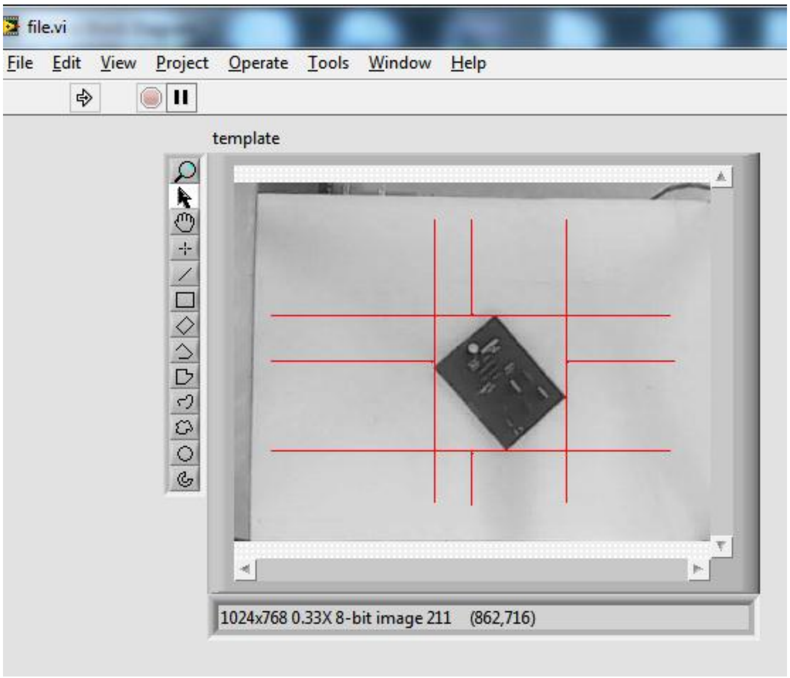

Figure 4.20: Bad Quality Template

There are few parameters that need to be set in order to clamp the object under captured. Those parameters are contrast of edge, slope of the edge and filter width. Contrast is defined as the difference between the average pixel intensity before the edge and the average pixel intensity after the edge. Figure 4.21 to figure 4.23 provide object image clamped under different contrast settings:

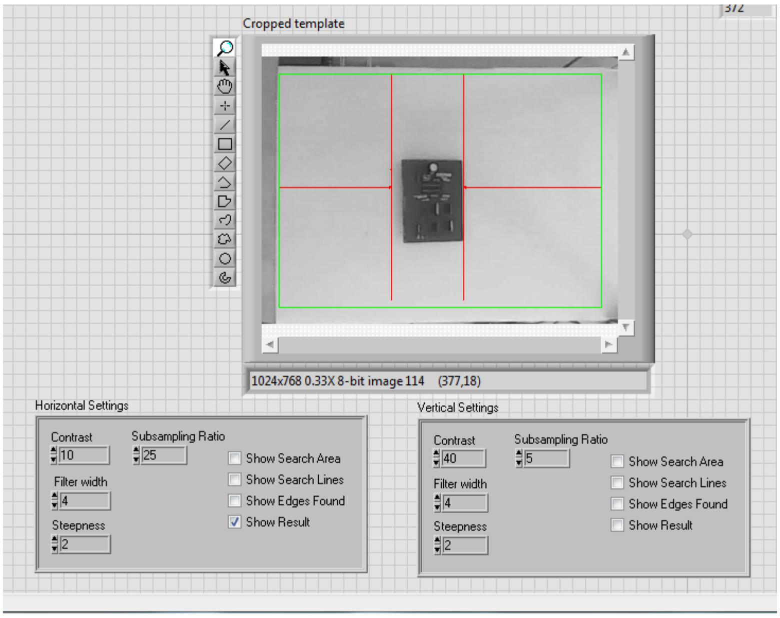

Figure 4.21: Image Clamping with Contrast=10

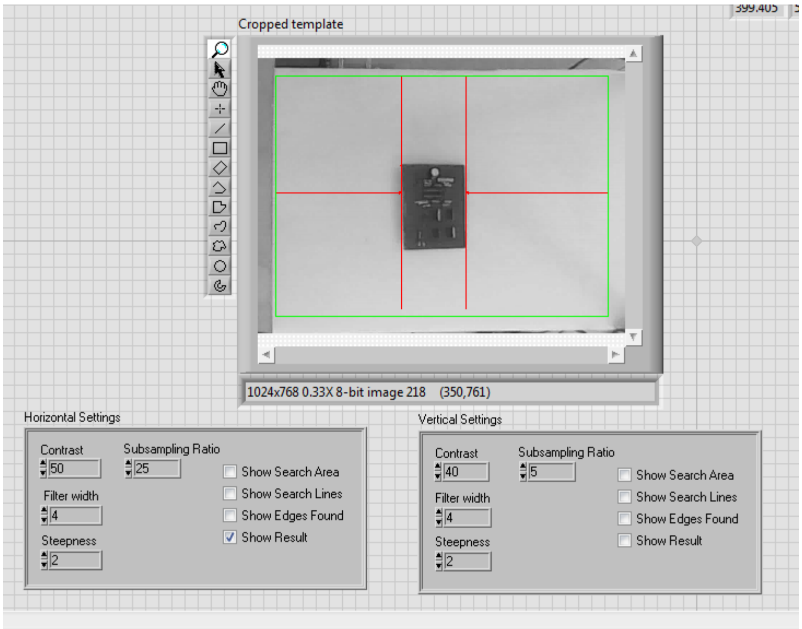

Figure 4.22: Image Clamping with Contrast=50

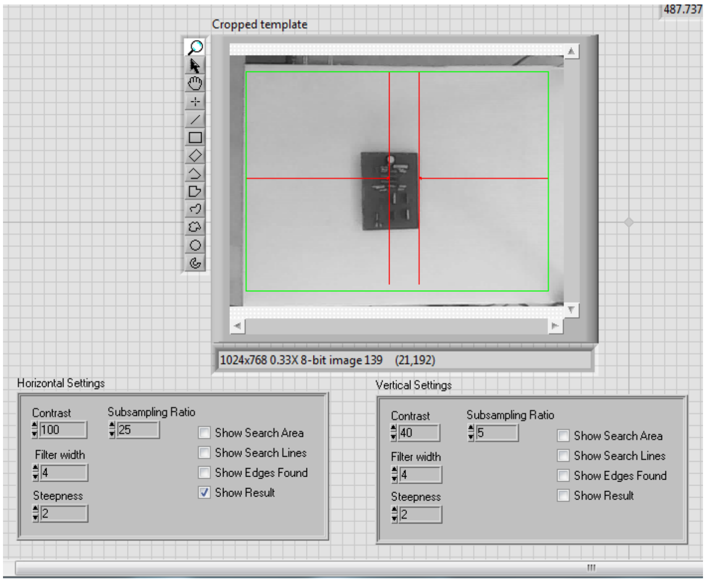

Figure 4.23: Image Clamping with Contrast=100

4.3.2 Pattern Matching Implementation

In order to locate an object regarding its edges within the active region of platform, pattern matching module is used in system implementation. Before perform pattern matching, the quality of template need to be good so the accuracy of matching is higher. Figure 4.24 shows pattern matching using good quality template from Figure 4.19 while Figure 4.25 shows pattern matching using bad quality template from Figure 4.20:

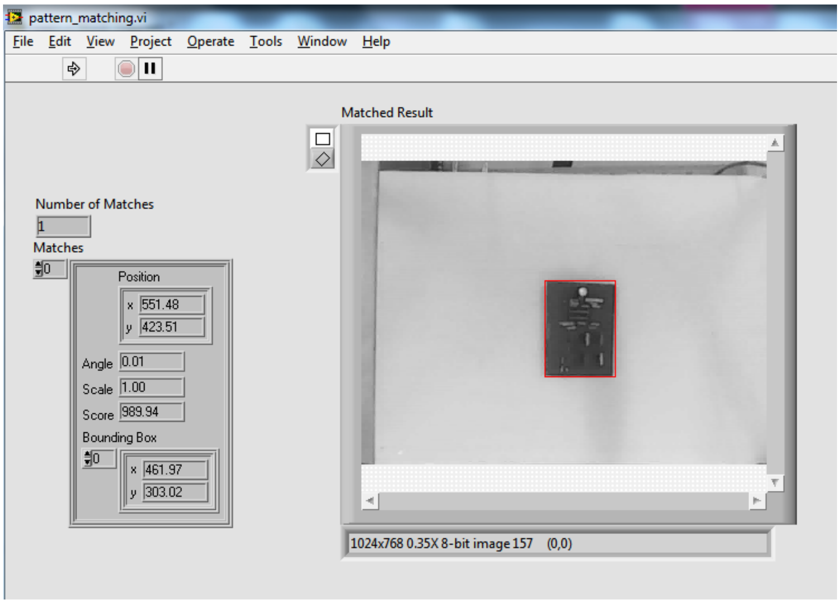

Figure 4.24: Pattern Matching with Good Quality Template

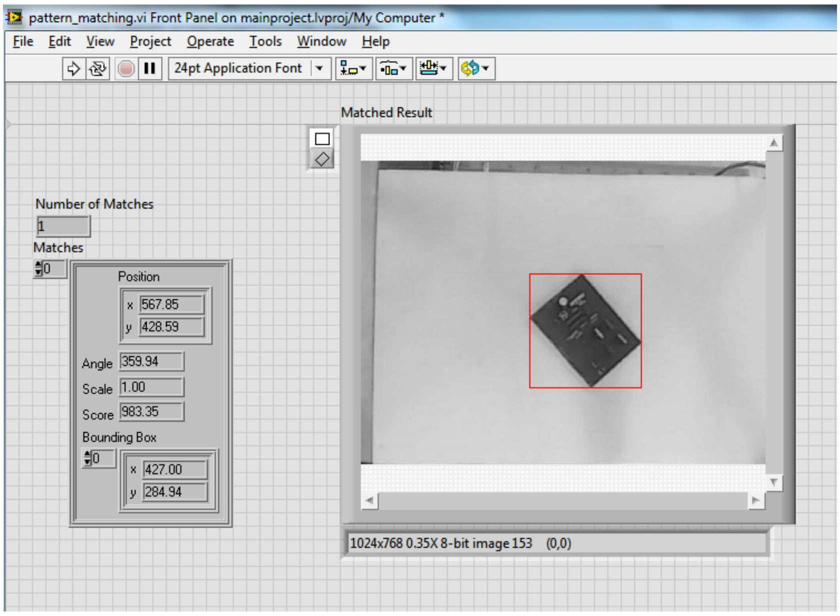

Figure 4.25: Pattern Matching with Bad Quality Template

The parameters need to setup the pattern matching module are templates, number of matches requested, minumum match score and match mode. Templates are the images that cropped from the clamping function, discussed in template processing. Next, number of matches requested is set to one and the match mode set to Rotation Invariant instead of Shift Invariant. Rotation Invariant allows the searches for the template in the image regardless of the rotation of the template.

Minimum Match Score is the smallest score a match can have to be considered valid. The data range for a match is between 0 and 1000. Figures 4.26 to Figure 4.29 shows the score of pattern matching in different situations.

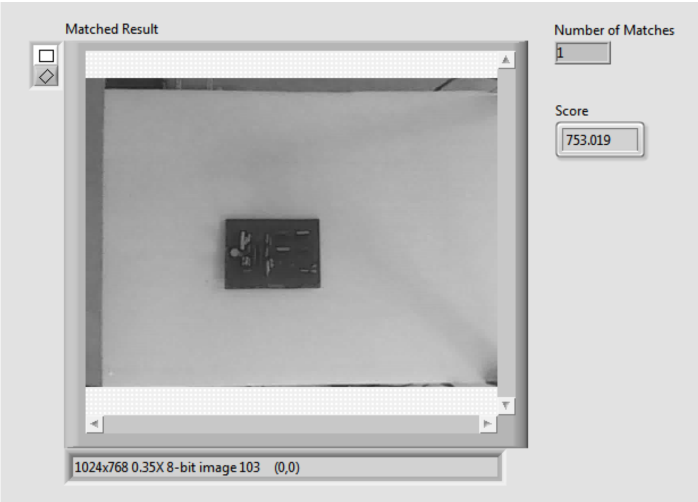

Figure 4.26: Image Captured at Indoor during Daylight

Figure 4.27: Image Captured with Lighting System Enabled

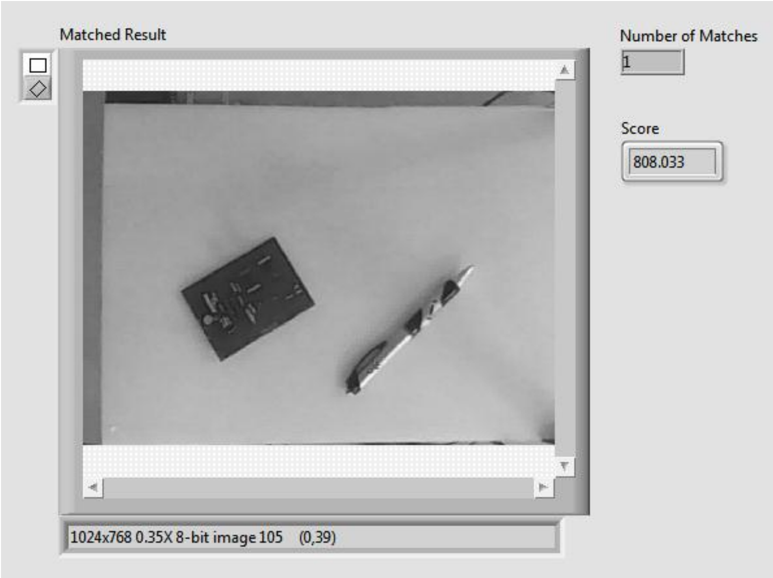

Figure 4.28: Image Captured with Interrupt of Extra Object

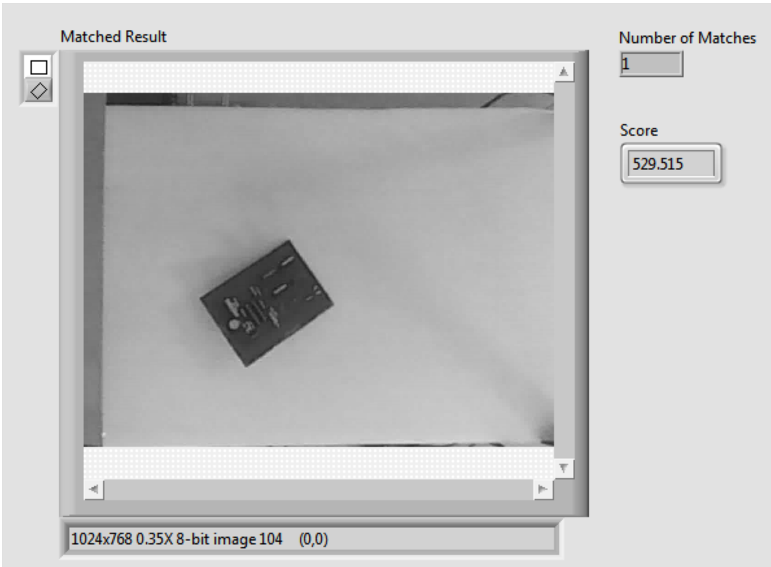

Figure 4.29: Image Captured with Objects Not Parallel with Platform

The experiments show that the score can at least reach 500 in different kind of situation. Therefore minimum match score can set to 500 so it can increase the accuracy of object searching and matching.

4.4 Program Flow Implementation

4.4.1 Implementation

The main program flow of the system basically can be summarized into a finite state machine as in Figure 4.30 while the descriptions listed in Table 4.9. The programs are running by using NI LabVIEW graphical programming language.

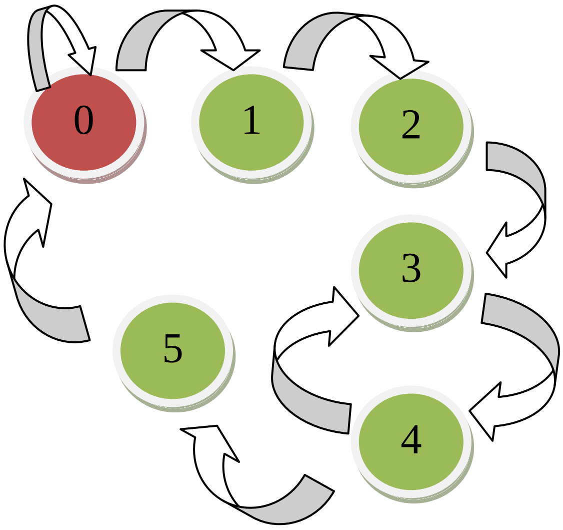

Figure 4.30: Finite State Machine of the System

Table 4.9: Description of Program States

State Number	Descriptions
0	Idle state and determine path for EAGLE
1	Select project and schematic
2	Determine folder to save and template processing
3	Select Component
4	Pattern matching and laser point to required position
5	Exit project and documentation

4.4.2 Outcome

The GUIs of the system are shown start from Figure 4.31 to Figure 4.36. The overall system is summarized in a flowchart, as shown in Figure 4.37.

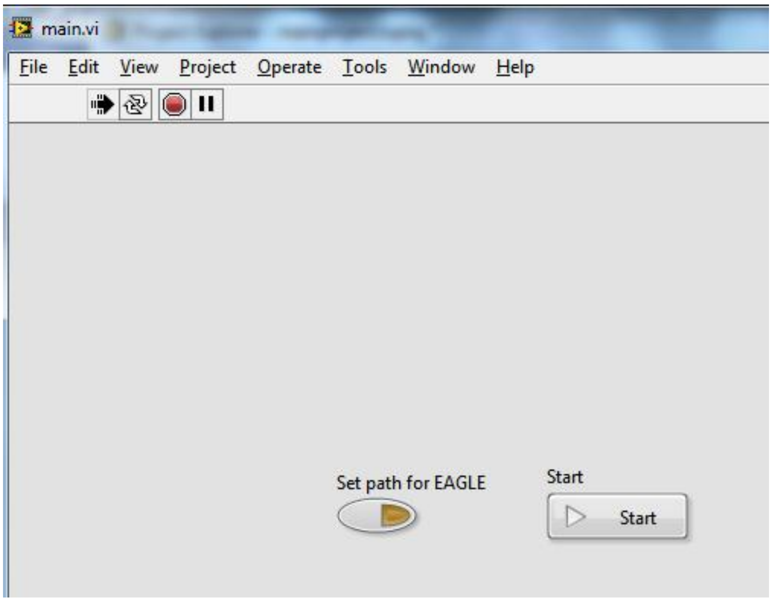

Figure 4.31: GUI on "Start"

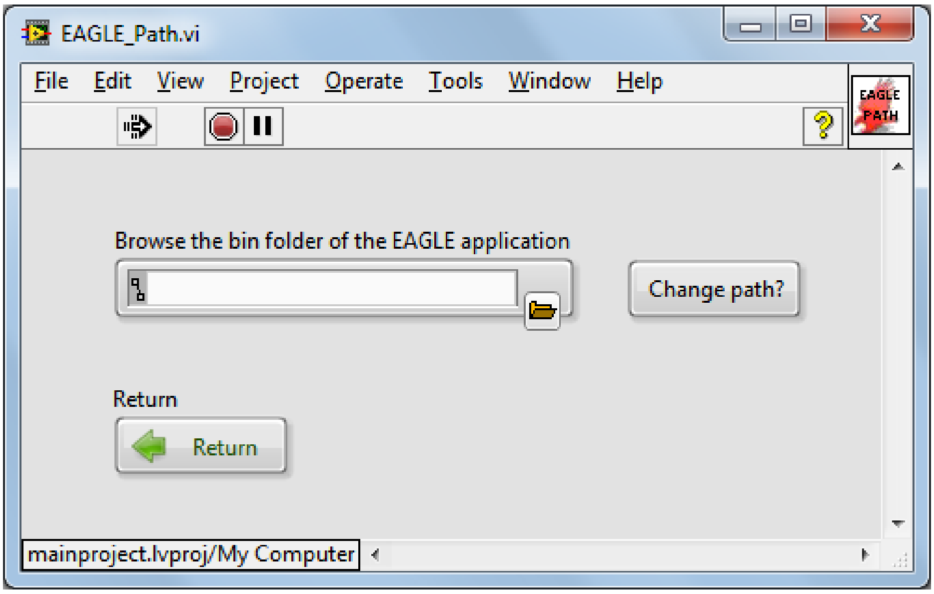

Figure 4.32: GUI on "Set Path for EAGLE"

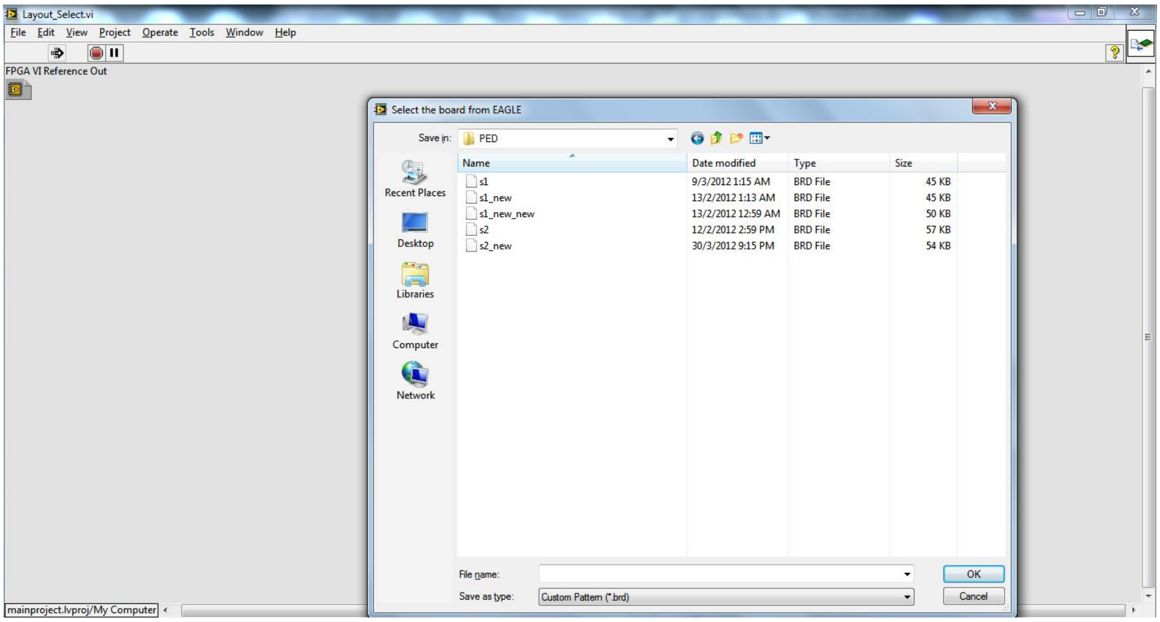

Figure 4.33: GUI on "Select Schematic"

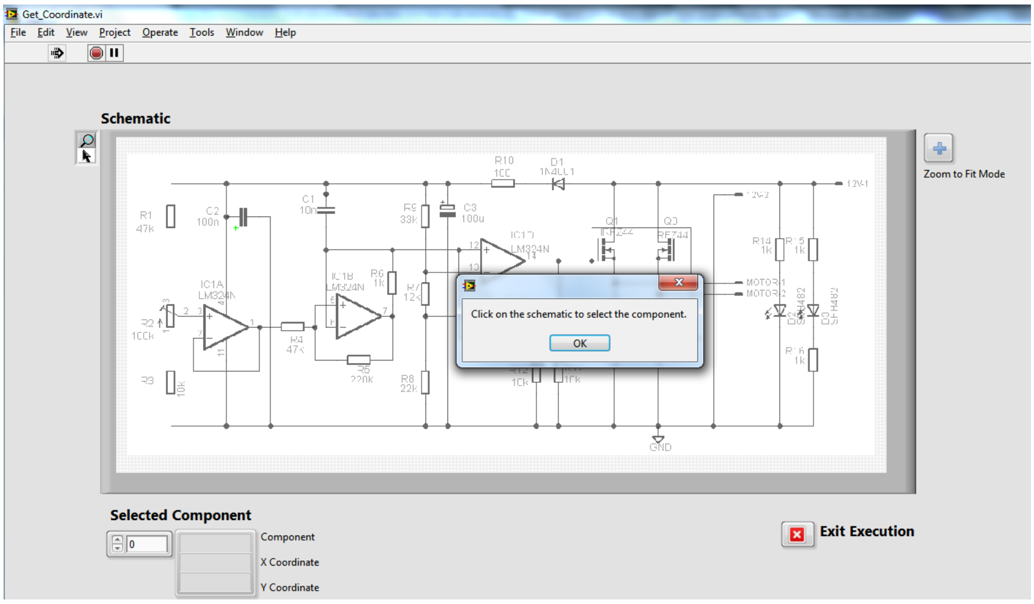

Figure 4.34: GUI on "Load Schematic to Front Page"

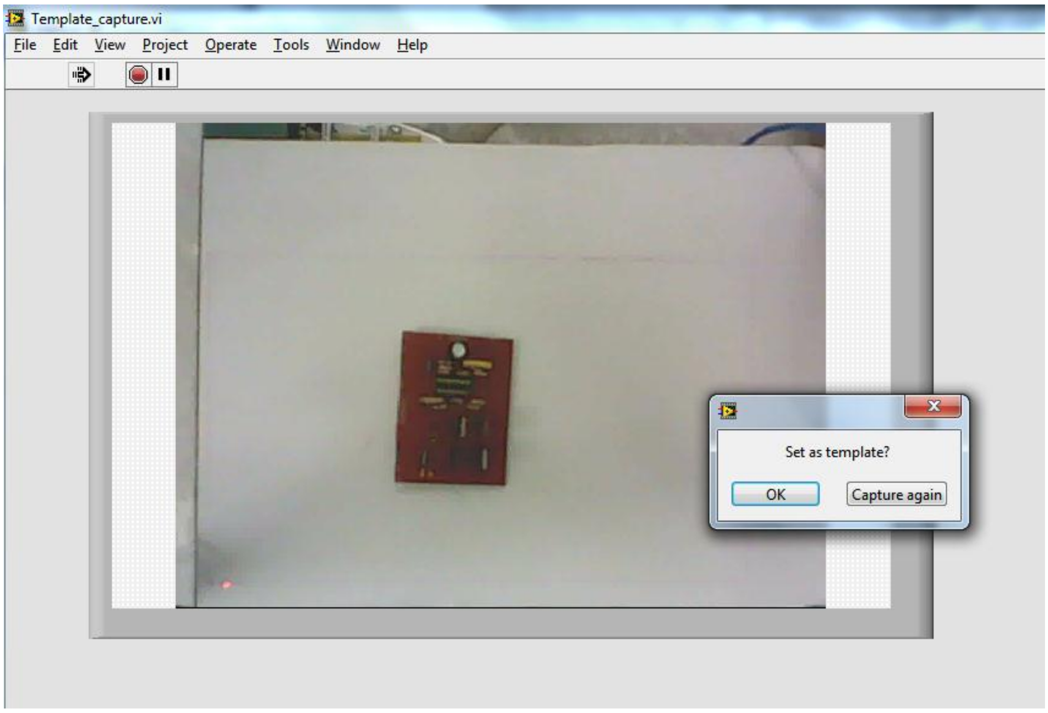

Figure 4.35: GUI on "Set as Template?"

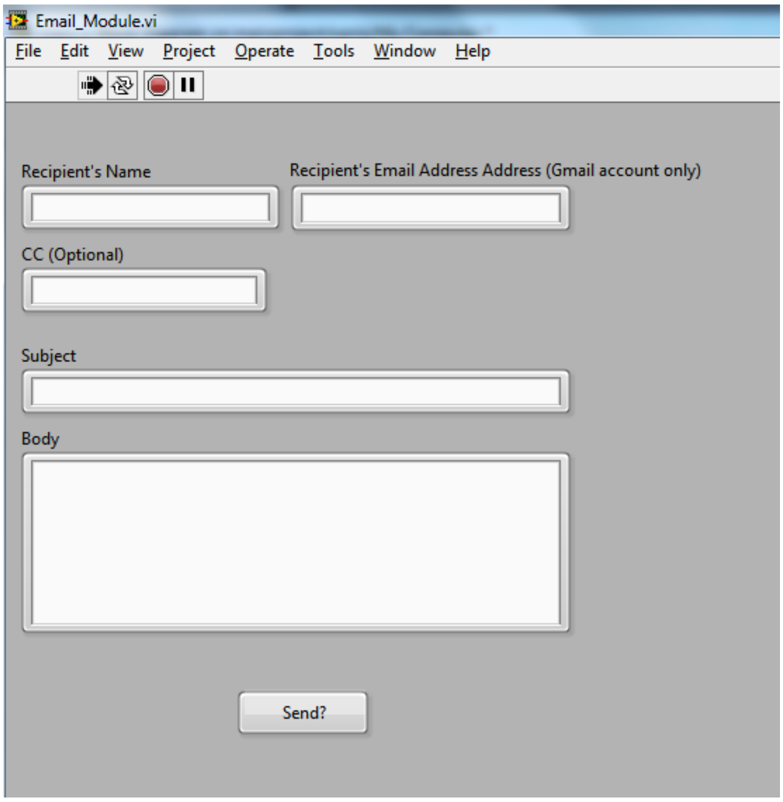

Figure 4.36: GUI on "Send Searched Components' Record to Email"

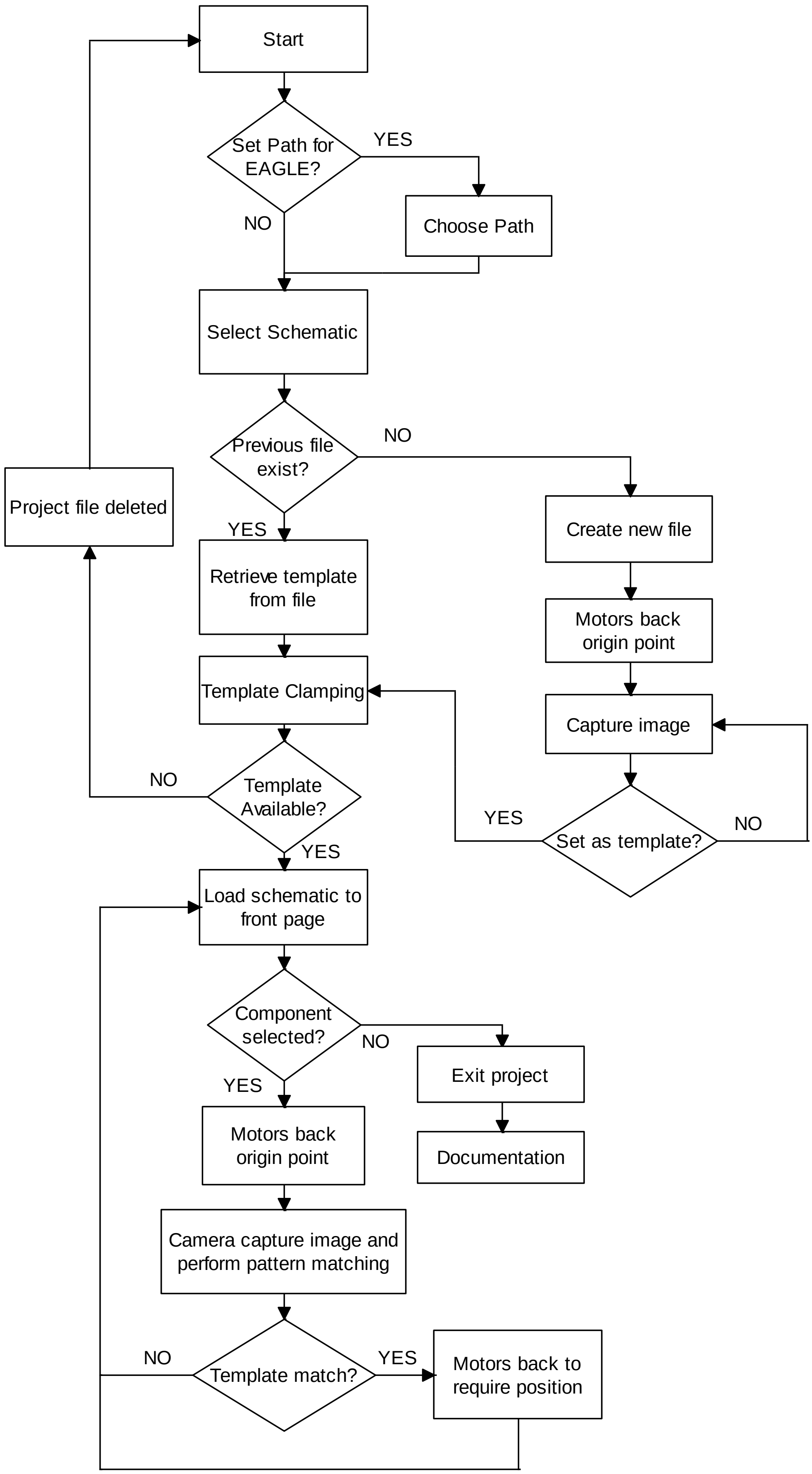

Figure 4.37: Program Flow of 2-D Location Pointer

CHAPTER 5

CONCLUSION AND FUTURE IMPLEMENTATION

As a conclusion, the objectives of the project are met, which is to design a 2-D Pointing System for individual component on device under test. The system is designed with the aim that the time consumption can be reduced for user to perform searching and probing on individual component.

There are few limitations found on the system which can be further improved. First of all, the current system can only function for DUT front side. The algorithms can be further improved so that searching for both side of the DUT can be included. Furthermore, the system can be further designed so that DUT can be turned to either one side automatically.

Besides that, size of the DUT that can perform under the system is limited due to the camera is set statically at the top of the system. Further implementation can be done by modify the camera in order to move in x and y axis. The camera needs to be able to locate object while moving along the axis. This objective of this improvement is not only increasing the area to perform, it can also further shrink the height of the overall physical structure, and useful for image processing since the image capture is clearer.

Next, the system can be improved so it becomes less dependent to the host which is computer. It can be modified so NI sbRIO-9632XT acts as host for the system. Various modifications like USB module, touch screen display and compatible smart camera can be added to the system. User can easily proceed to the usage of the system without connect to computer and install required software which is time consuming.

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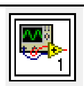
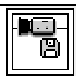
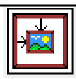
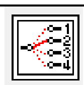
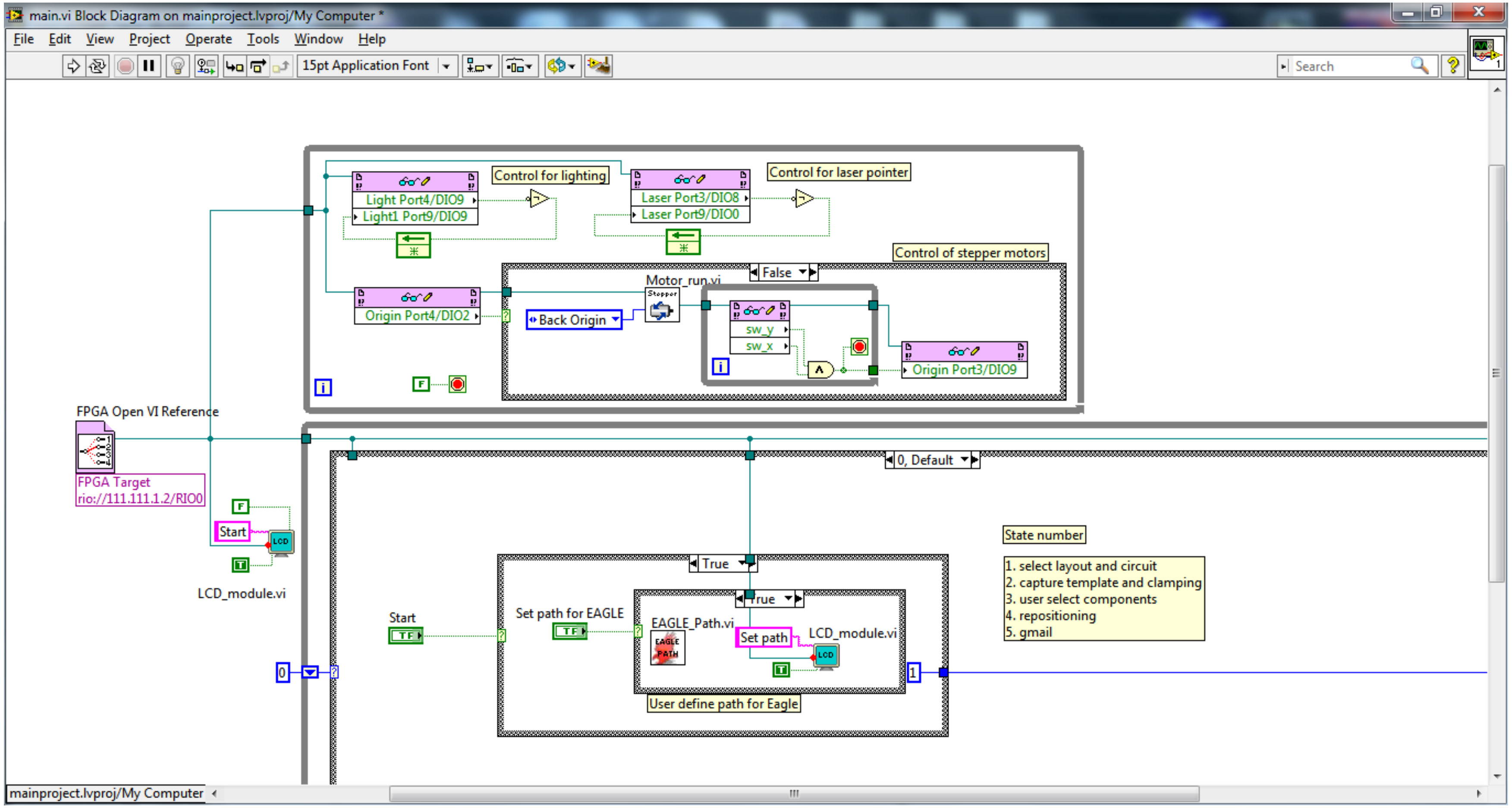
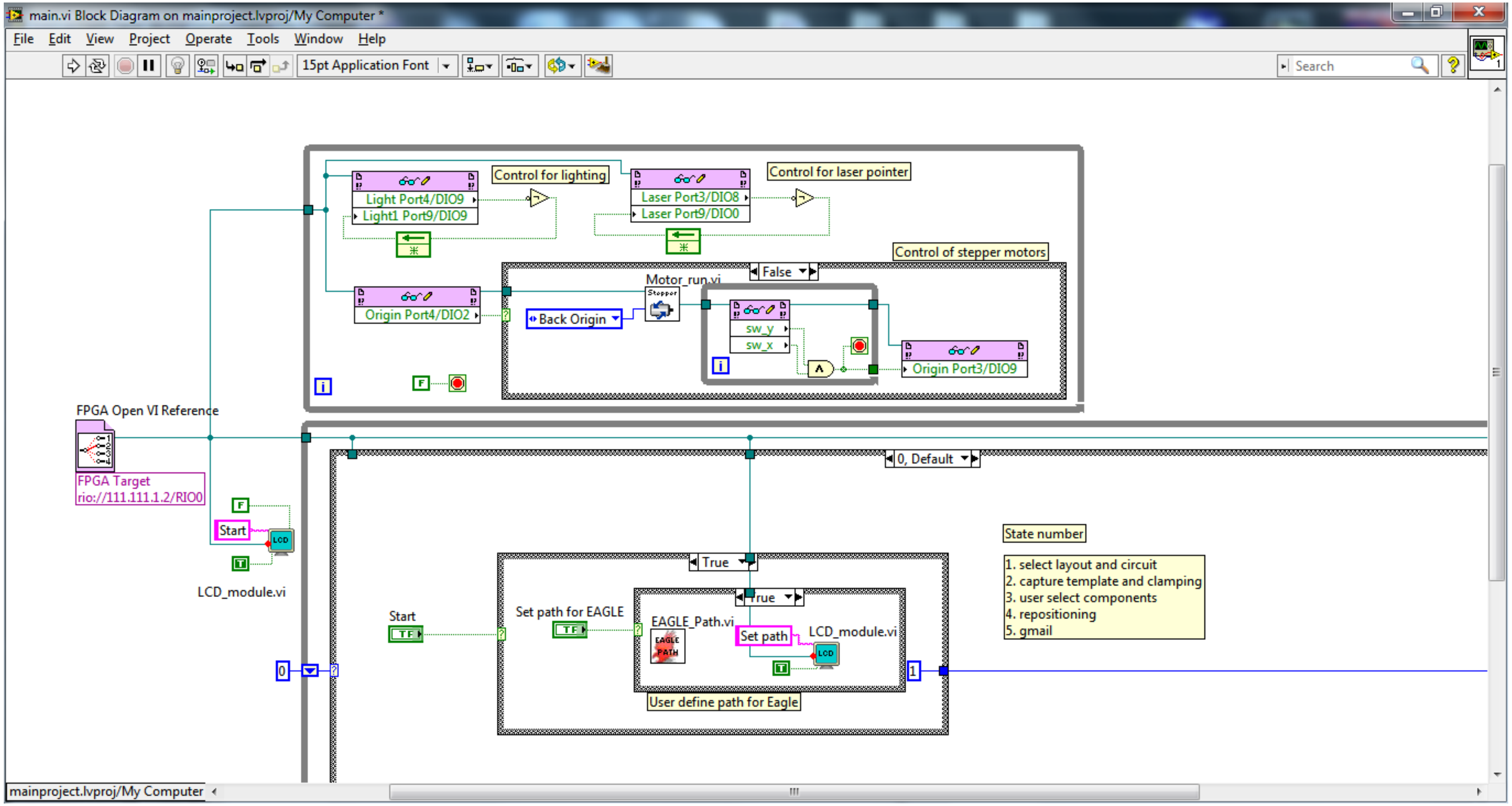
APPENDICES

APPENDIX A: LabVIEW Graphical Programming

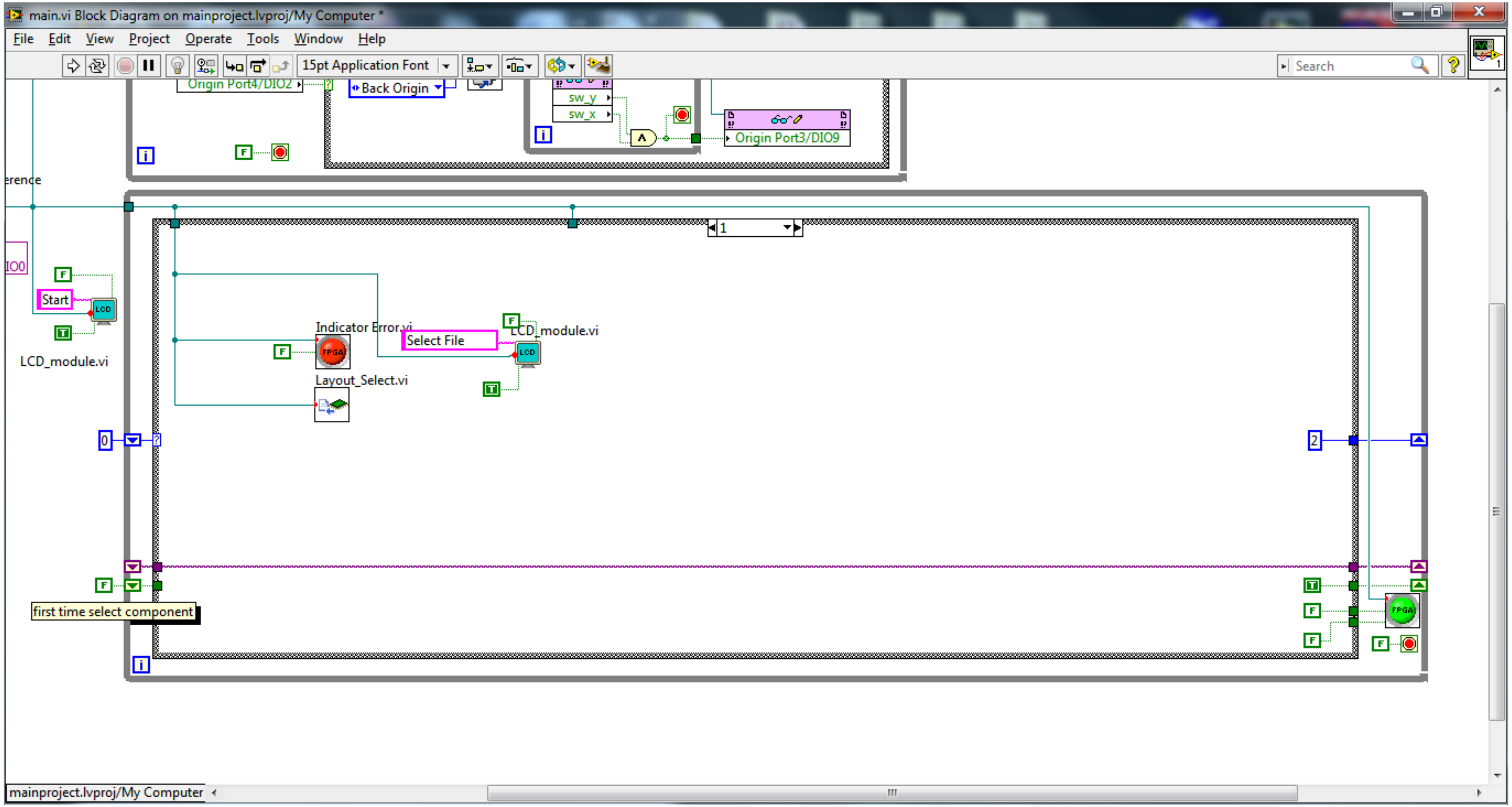
MODULE	VI ICONS	PAGES
Main.vi		67
LCD_module.vi		76
File.vi		80
Template_capture.vi		82
Get_template.vi		83
Pattern_matching.vi		84
Motor_run.vi		85
Final_FPGA.vi		86

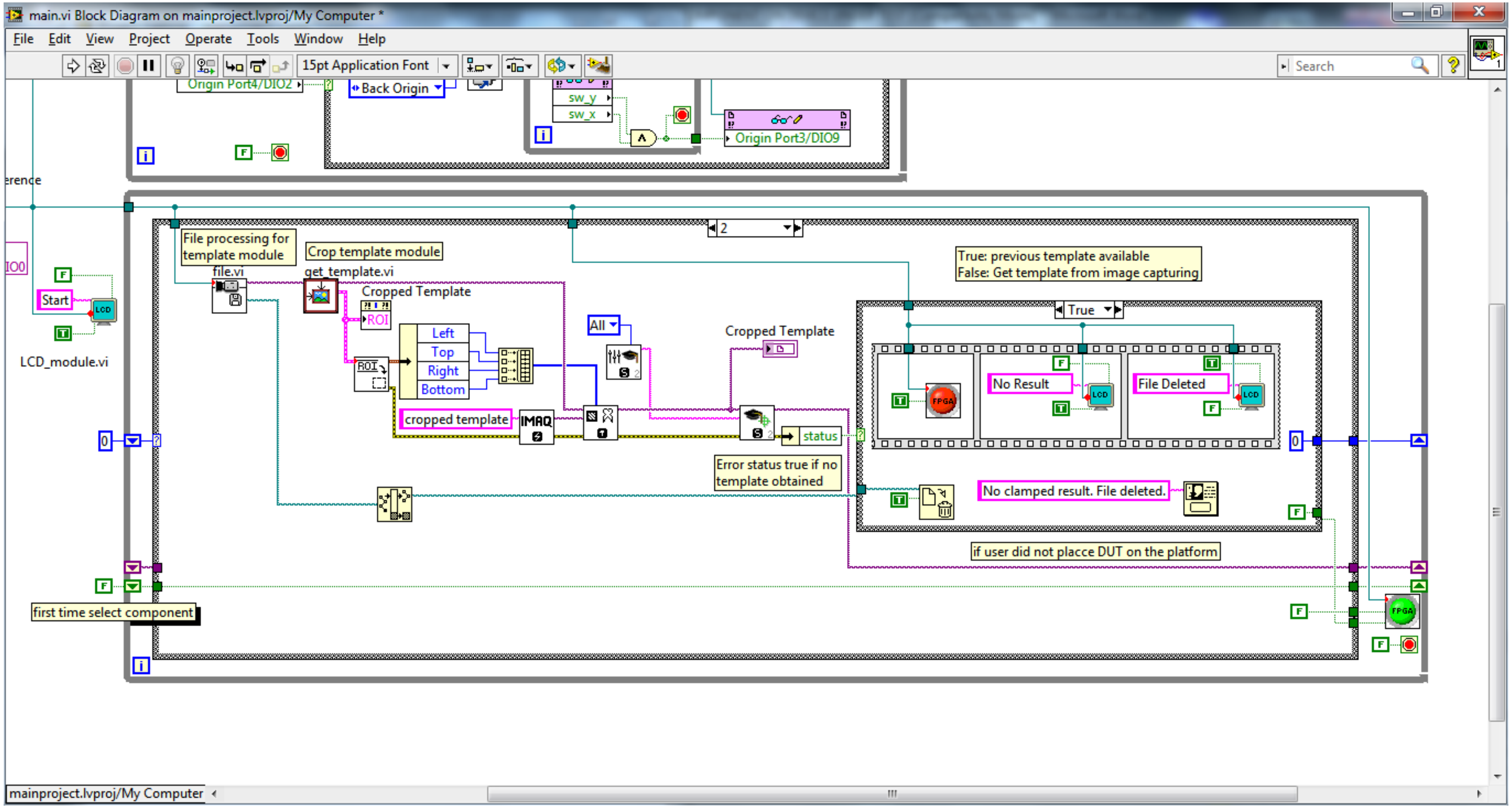


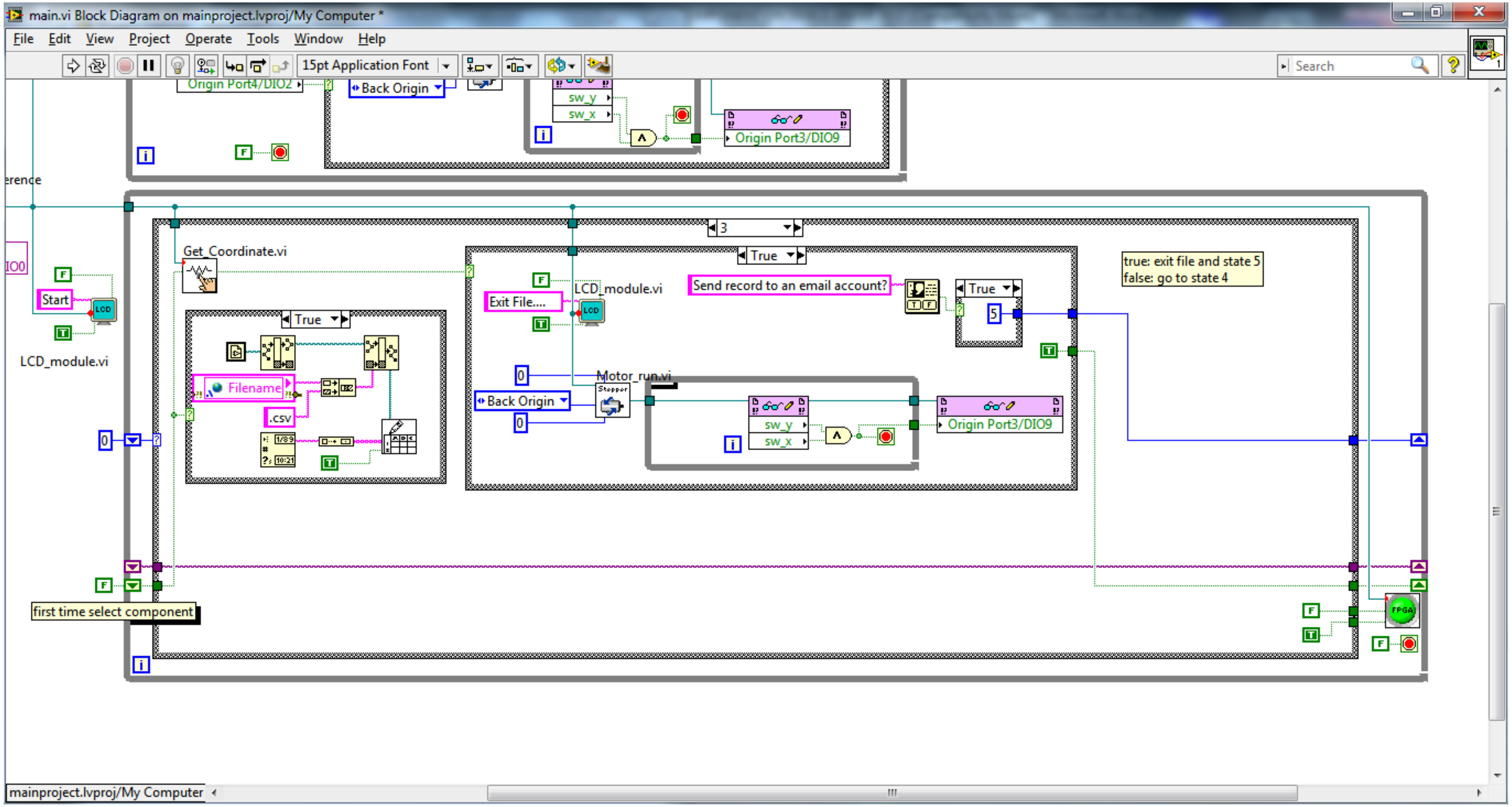
main.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
Control for lighting
Light Port4/DIO9
Light1 Port9/DIO9
Control for laser pointer
Laser Port3/DIO8
Laser Port9/DIO0
Control of stepper motors
False
Motor_run.vi
Origin Port4/DIO2
Back Origin
sw_y
sw_x
Origin Port3/DIO9
FPGA Open VI Reference
FPGA Target
rio://111.111.1.2/RIO0
Start
LCD_module.vi
0, Default
State number
1. select layout and circuit
2. capture template and clamping
3. user select components
4. repositioning
5. gmail
True
Start
Set path for EAGLE
EAGLE_Path.vi
Set path
LCD_module.vi
User define path for Eagle
mainproject.lvproj/My Computer

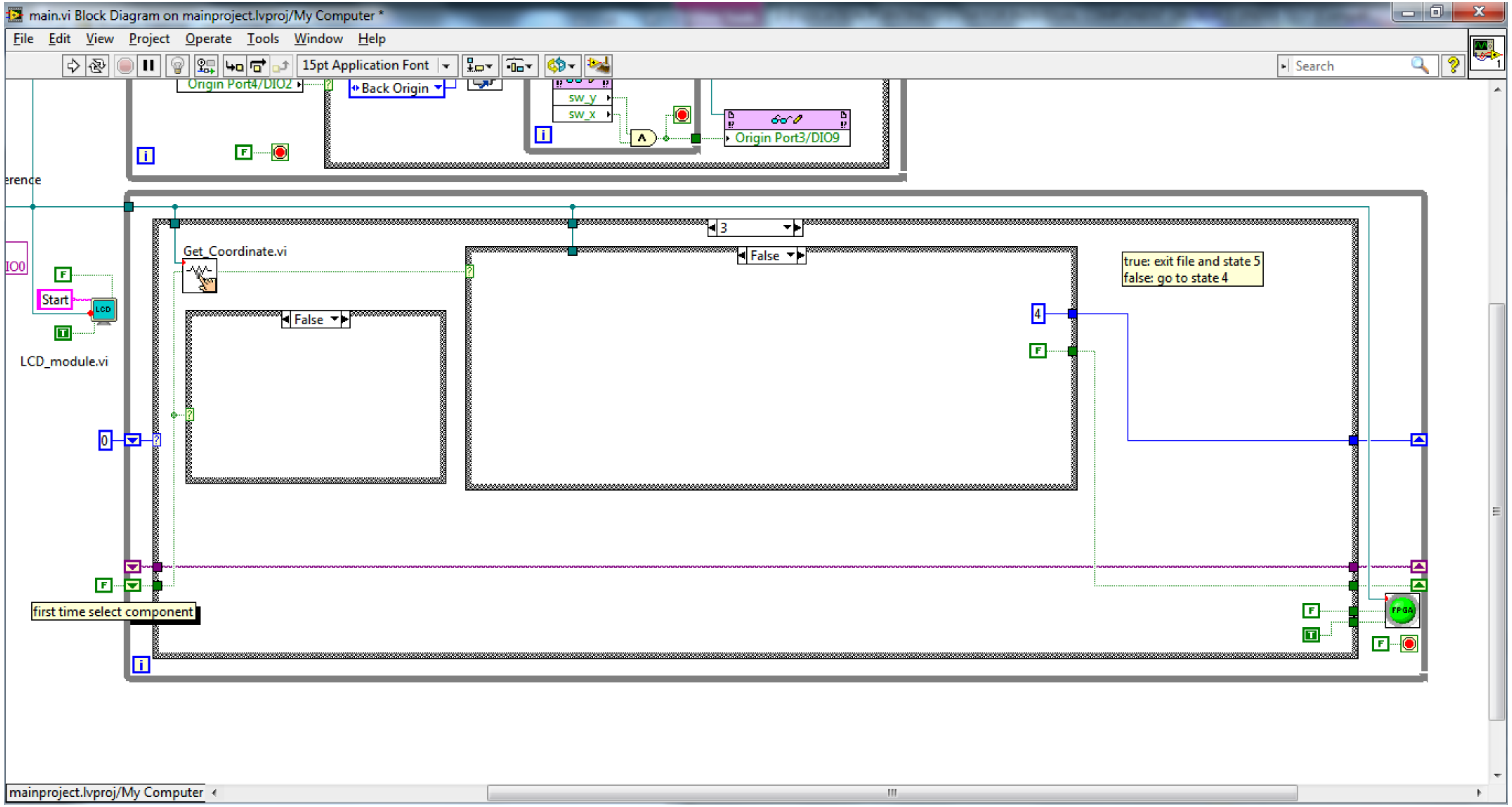


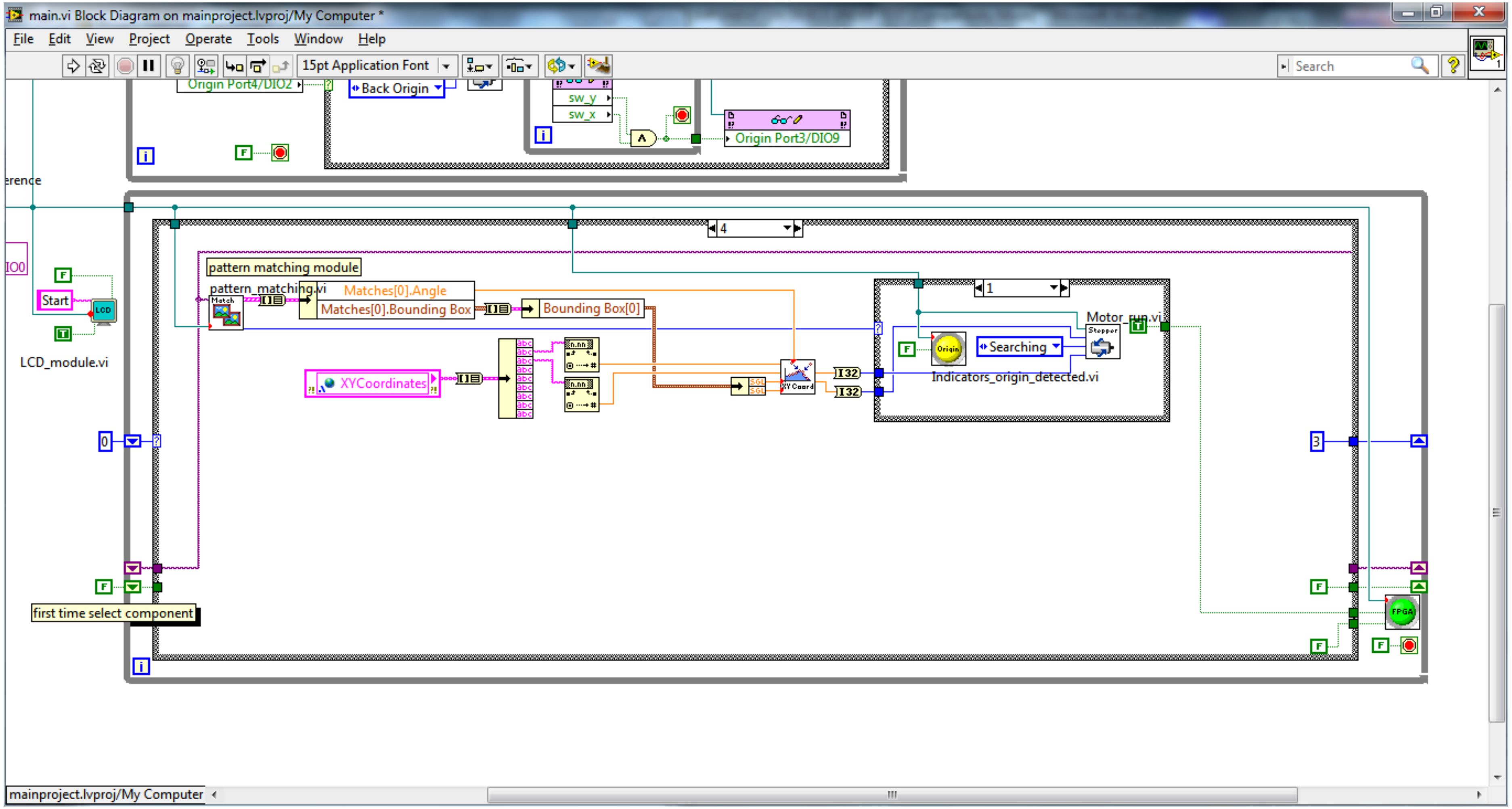
main.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
Control for lighting
Light Port4/DIO9
Light1 Port9/DIO9
Control for laser pointer
Laser Port3/DIO8
Laser Port9/DIO0
Control of stepper motors
False
Motor_run.vi
Origin Port4/DIO2
Back Origin
sw_y
sw_x
Origin Port3/DIO9
FPGA Open VI Reference
FPGA Target
rio://111.111.1.2/RIO0
Start
LCD_module.vi
0, Default
State number
1. select layout and circuit
2. capture template and clamping
3. user select components
4. repositioning
5. gmail
Start
Set path for EAGLE
True
EAGLE_Path.vi
Set path
LCD_module.vi
User define path for Eagle
mainproject.lvproj/My Computer

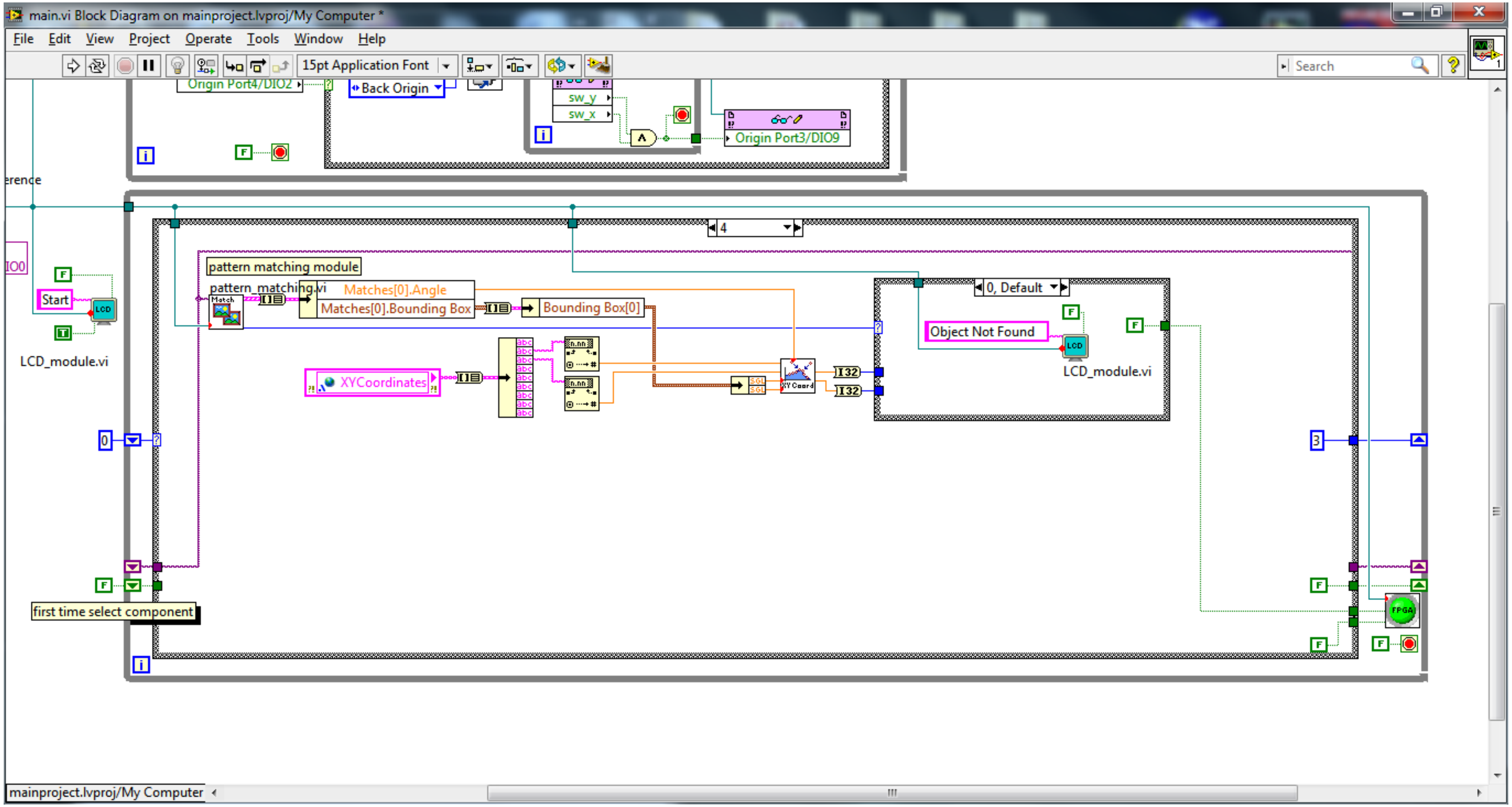

main.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
Origin Port4/DIO2
Back Origin
sw_y
sw_x
Origin Port3/DIO9
Start
LCD_module.vi
Indicator Error.vi
Select File
LCD_module.vi
Layout_Select.vi
first time select component
mainproject.lvproj/My Computer

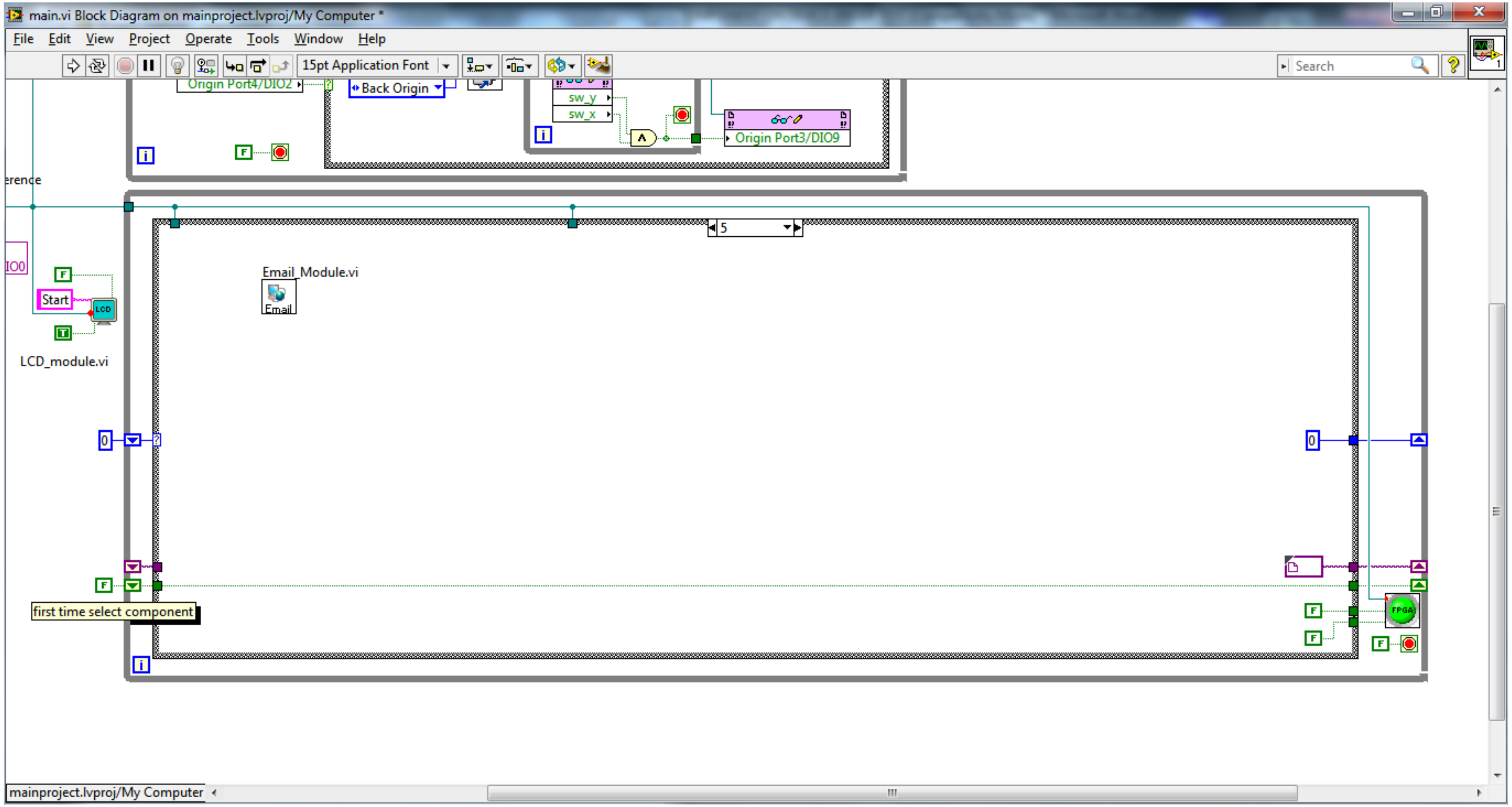

main.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
Origin Port4/DIO2
Back Origin
sw_y
sw_x
Origin Port3/DIO9
Start
LCD_module.vi
File processing for template module
file.vi
Crop template module
get_template.vi
Cropped Template
ROI
Left
Top
Right
Bottom
cropped template
All
Cropped Template
status
Error status true if no template obtained
True: previous template available
False: Get template from image capturing
True
No Result
File Deleted
No clamped result. File deleted.
if user did not placce DUT on the platform
first time select component
mainproject.lvproj/My Computer

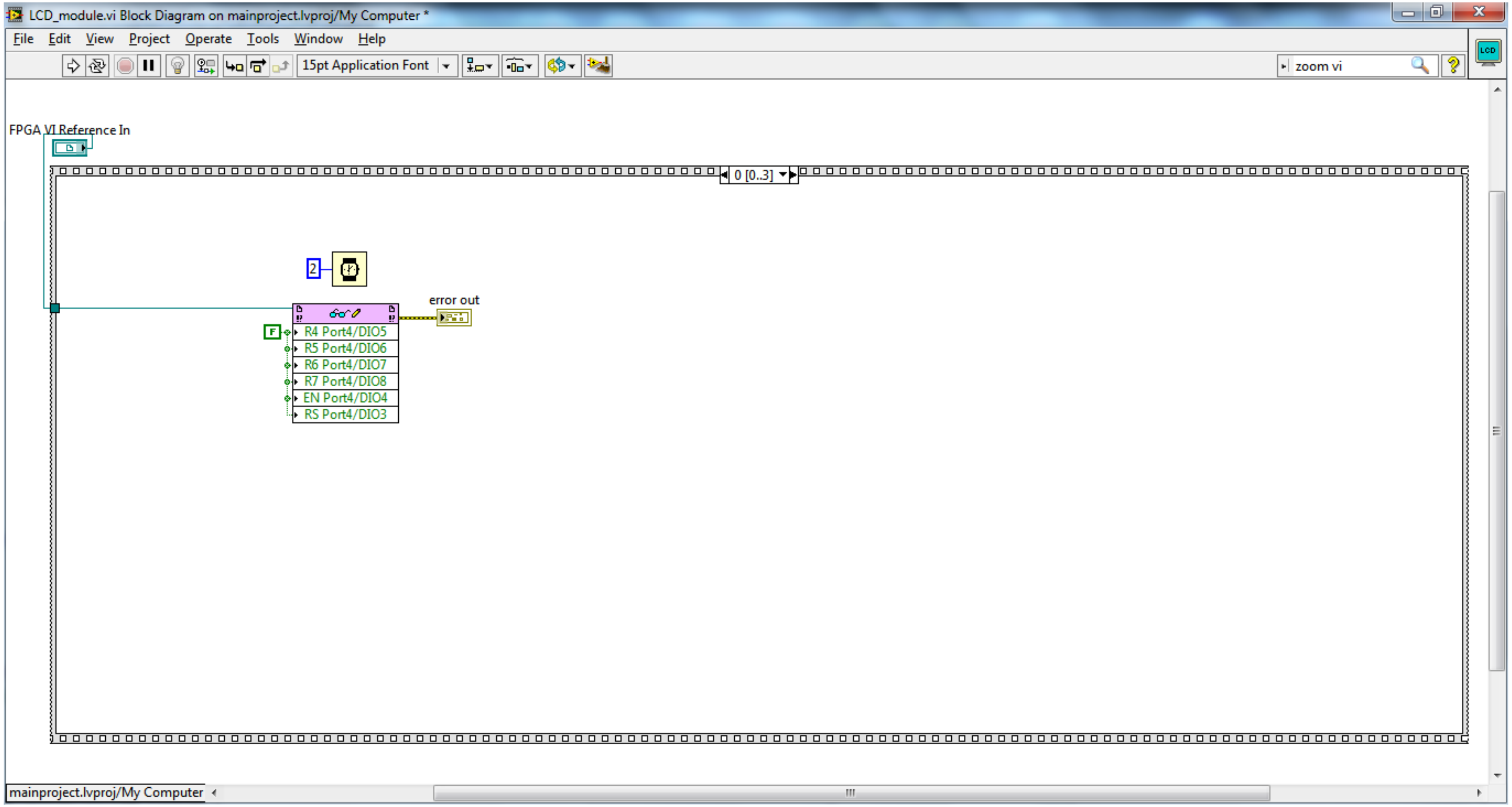

main.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
Origin Port4/DIO2
Back Origin
sw_y
sw_x
Origin Port3/DIO9
Start
LCD_module.vi
Get_Coordinate.vi
True
Filename
.csv
3
Exit File....
LCD_module.vi
Send record to an email account?
5
true: exit file and state 5
false: go to state 4
Motor_run.vi
Back Origin
first time select component
mainproject.lvproj/My Computer

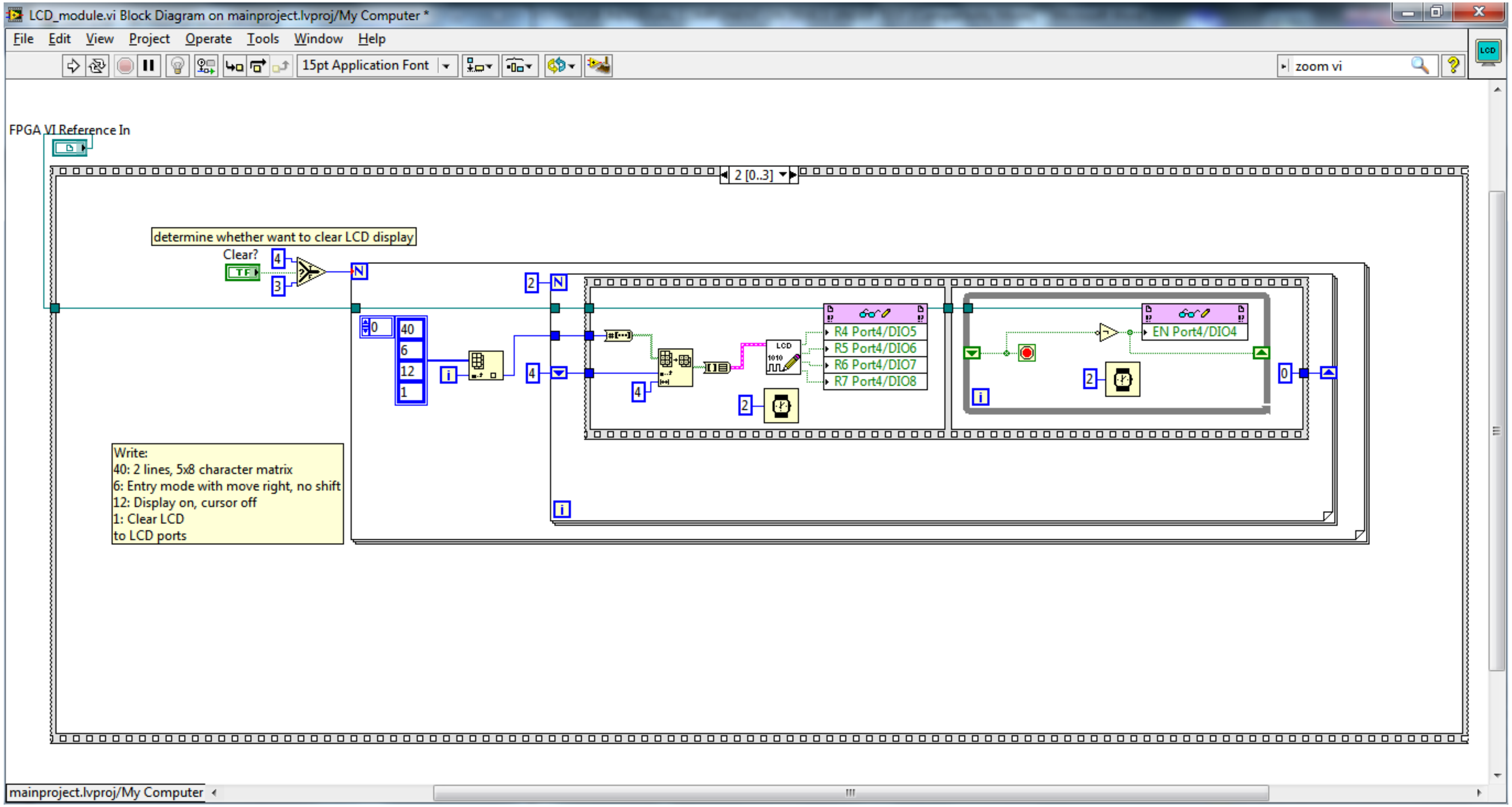

main.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
Origin Port4/DIO2
Back Origin
sw_y
sw_x
Origin Port3/DIO9
Start
LCD_module.vi
Get_Coordinate.vi
3
False
False
true: exit file and state 5
false: go to state 4
4
0
first time select component
mainproject.lvproj/My Computer

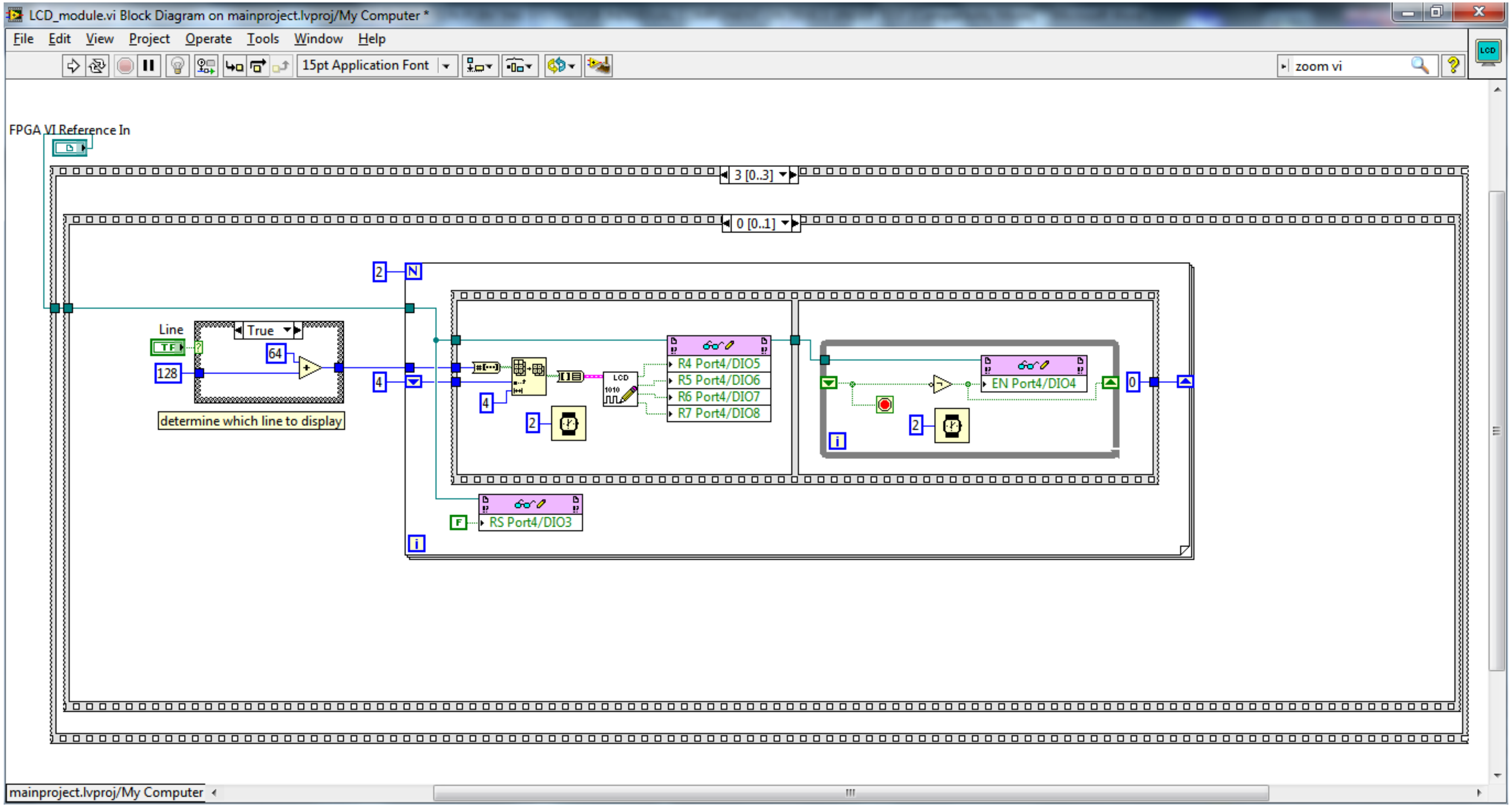

main.vi Block Diagram on mainproject.lvproj/My Computer *
File
Edit
View
Project
Operate
Tools
Window
Help
15pt Application Font
Search
Origin Port4/DIO2
Back Origin
sw_y
sw_x
Origin Port3/DIO9
erence
Start
LCD_module.vi
4
pattern matching module
pattern_matching.vi
Matches[0].Angle
Matches[0].Bounding Box
Bounding Box[0]
XYCoordinates
1
Motor_run.vi
Searching
Indicators_origin_detected.vi
0
3
first time select component
mainproject.lvproj/My Computer


main.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
Origin Port4/DIO2
Back Origin
sw_y
sw_x
Origin Port3/DIO9
Start
LCD_module.vi
pattern matching module
pattern_matching.vi
Matches[0].Angle
Matches[0].Bounding Box
Bounding Box[0]
XYCoordinates
0, Default
Object Not Found
LCD_module.vi
first time select component
mainproject.lvproj/My Computer

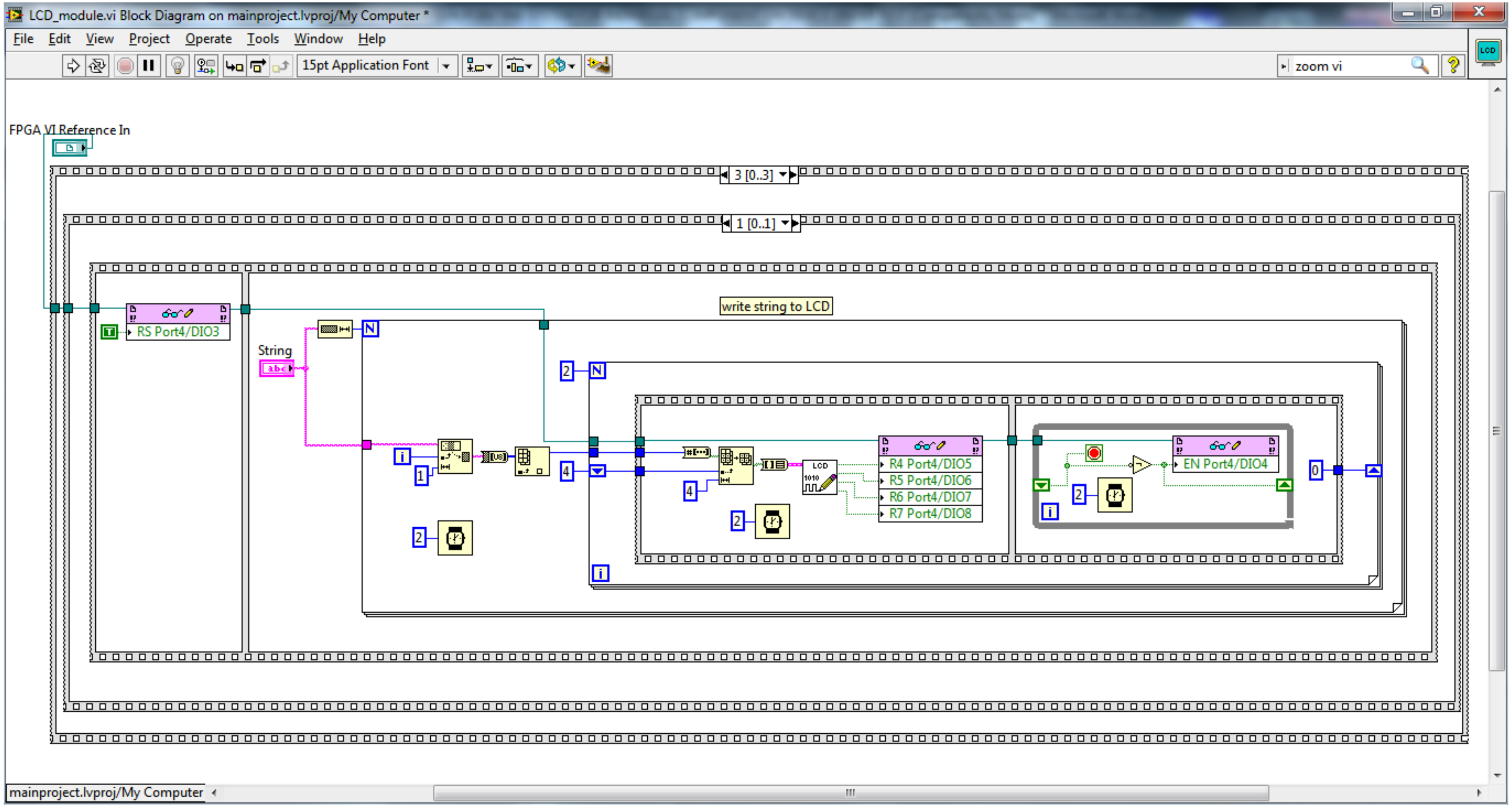

main.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
Origin Port4/DIO2
Back Origin
sw_y
sw_x
Origin Port3/DIO9
Email_Module.vi
Email
Start
LCD_module.vi
first time select component
mainproject.lvproj/My Computer


LCD_module.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
zoom vi
FPGA VI Reference In
0 [0..3]
2
error out
F
R4 Port4/DIO5
R5 Port4/DIO6
R6 Port4/DIO7
R7 Port4/DIO8
EN Port4/DIO4
RS Port4/DIO3
mainproject.lvproj/My Computer

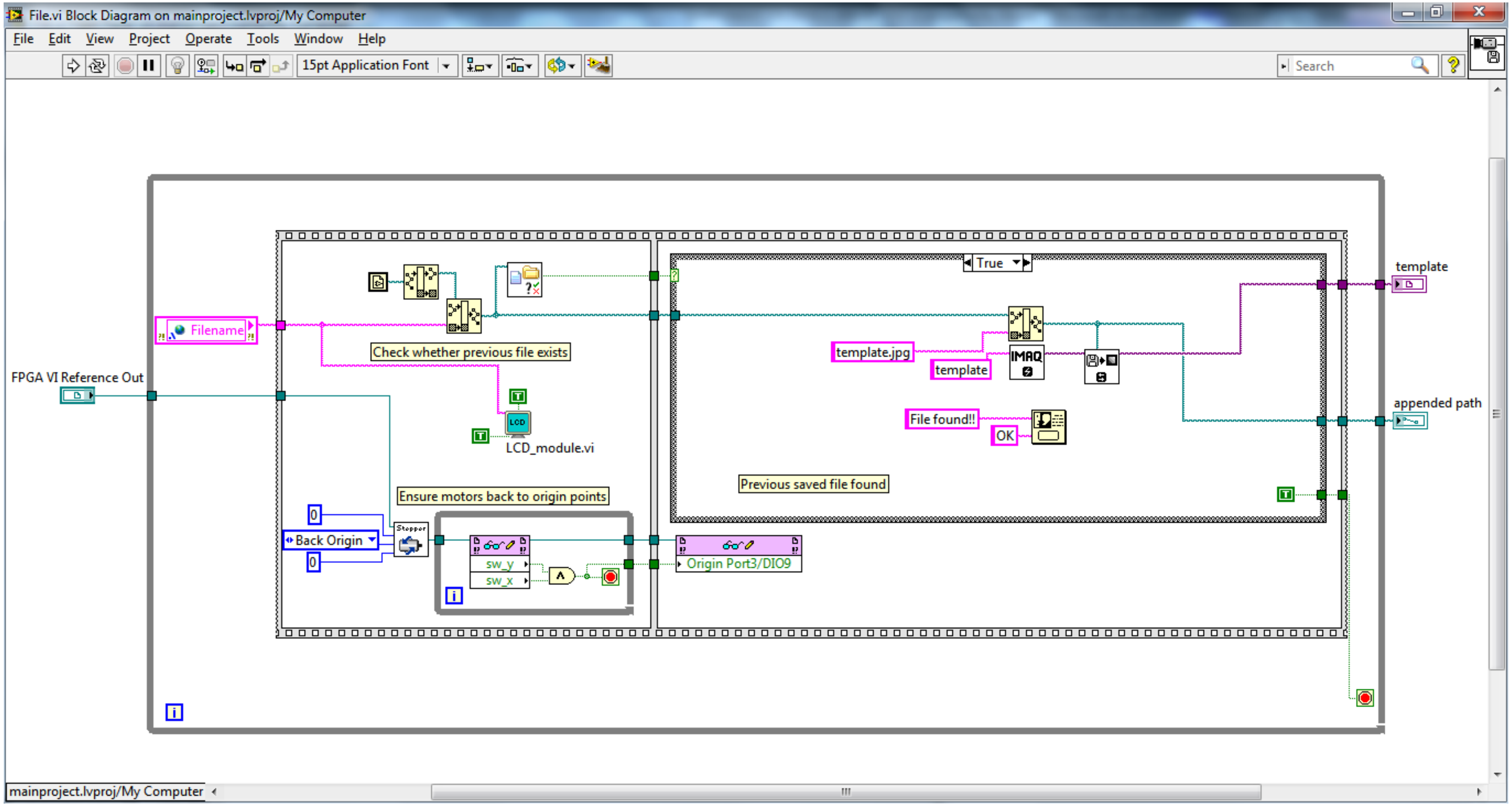

LCD_module.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
zoom vi
FPGA VI Reference In
2 [0..3]
determine whether want to clear LCD display
Clear?
R4 Port4/DIO5
R5 Port4/DIO6
R6 Port4/DIO7
R7 Port4/DIO8
EN Port4/DIO4
Write:
40: 2 lines, 5x8 character matrix
6: Entry mode with move right, no shift
12: Display on, cursor off
1: Clear LCD
to LCD ports
mainproject.lvproj/My Computer

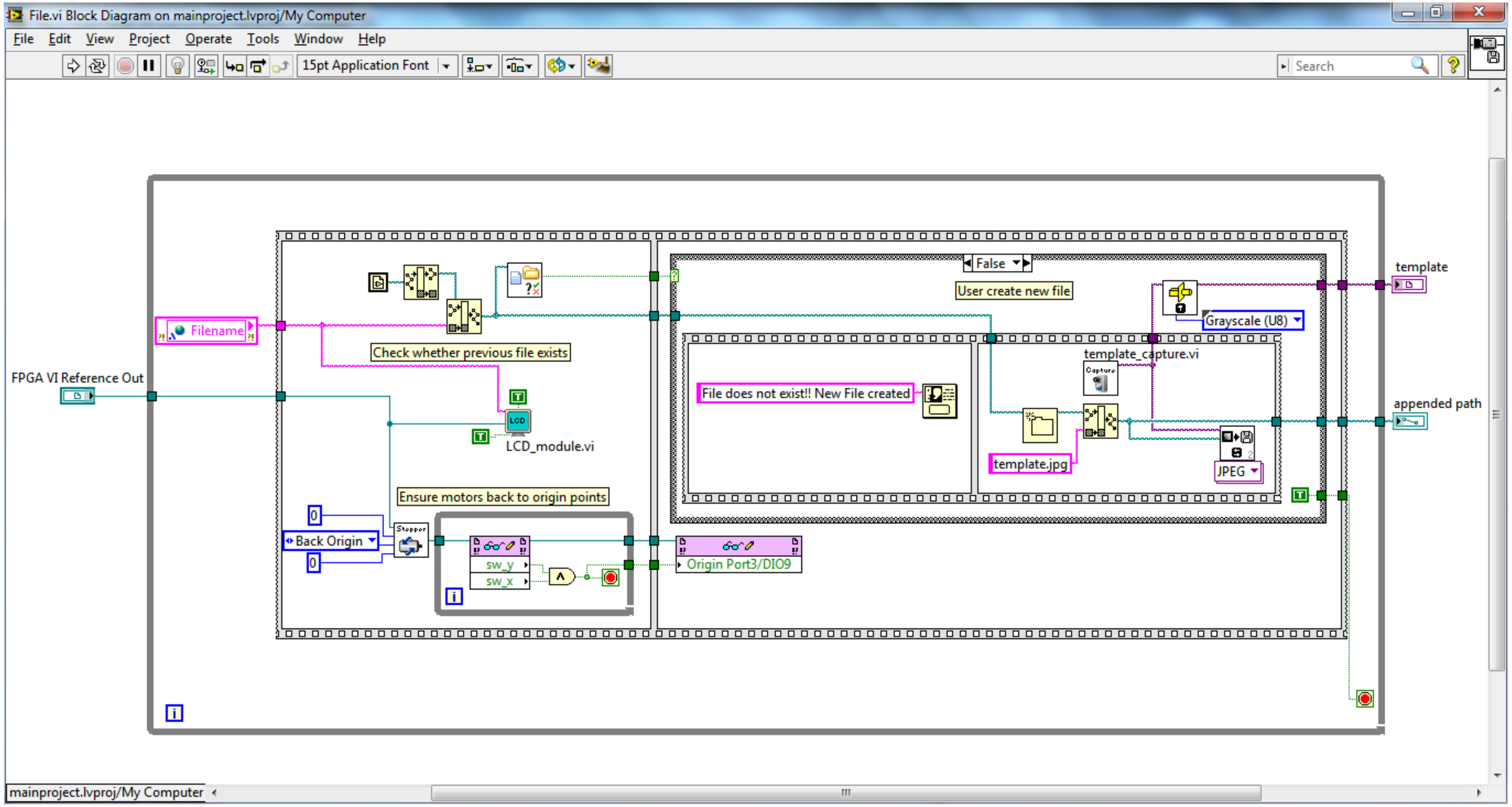


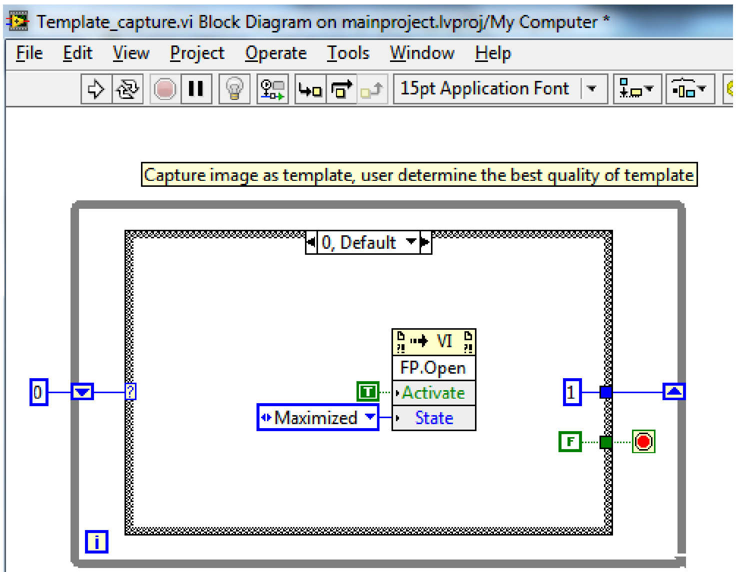
LCD_module.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
zoom vi
FPGA VI Reference In
3 [0..3]
0 [0..1]
Line
True
64
128
determine which line to display
2
N
4
R4 Port4/DIO5
R5 Port4/DIO6
R6 Port4/DIO7
R7 Port4/DIO8
EN Port4/DIO4
RS Port4/DIO3
mainproject.lvproj/My Computer

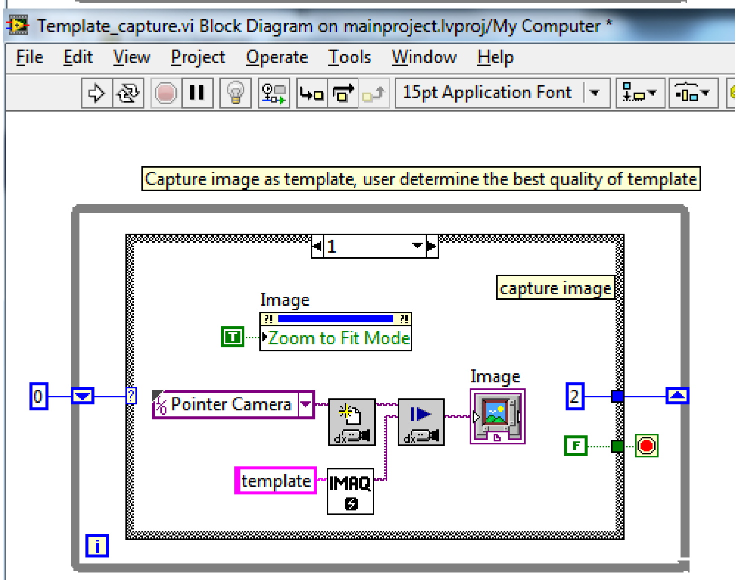


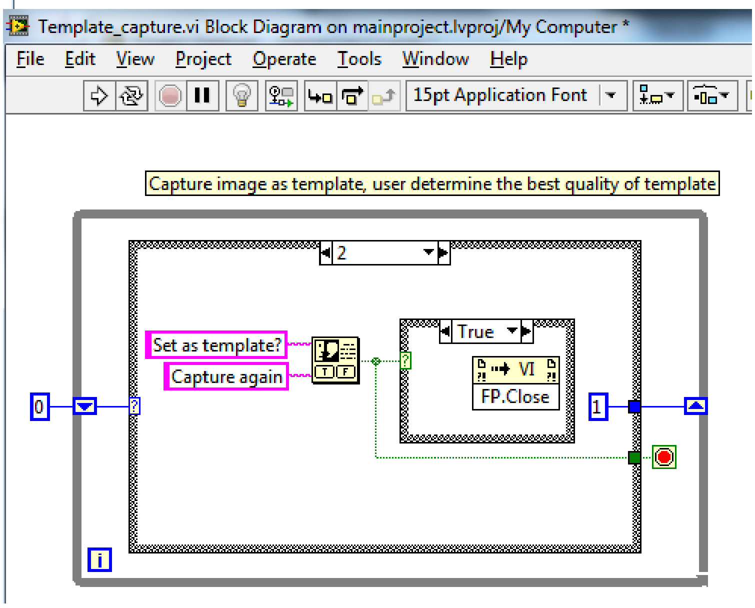
LCD_module.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
zoom vi
FPGA VI Reference In
3 [0..3]
1 [0..1]
write string to LCD
RS Port4/DIO3
String
R4 Port4/DIO5
R5 Port4/DIO6
R6 Port4/DIO7
R7 Port4/DIO8
EN Port4/DIO4
mainproject.lvproj/My Computer

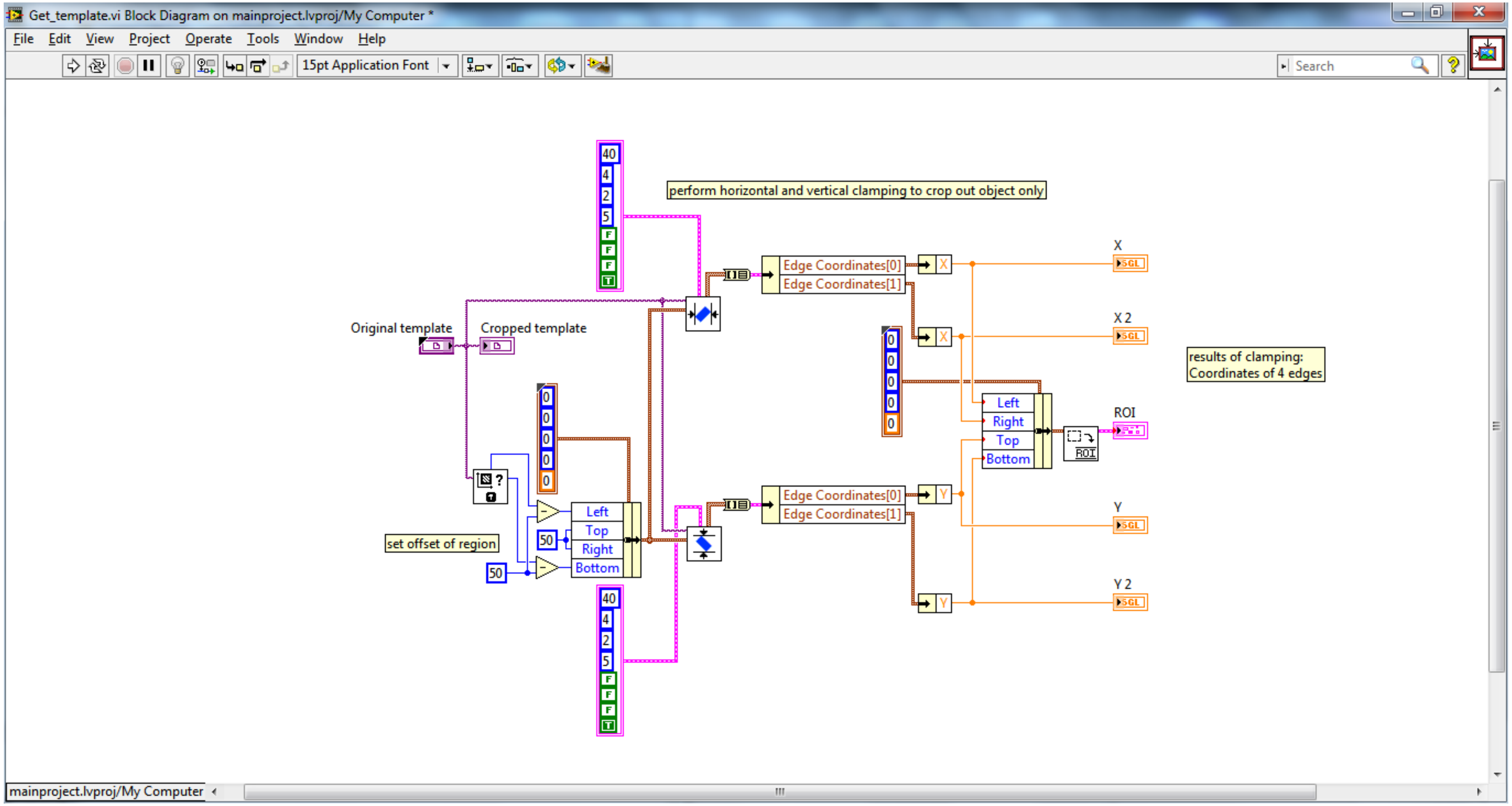

File.vi Block Diagram on mainproject.lvproj/My Computer
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
FPGA VI Reference Out
Filename
Check whether previous file exists
LCD_module.vi
Ensure motors back to origin points
Back Origin
Stepper
sw_y
sw_x
Origin Port3/DIO9
True
template.jpg
template
File found!!
OK
Previous saved file found
template
appended path
mainproject.lvproj/My Computer

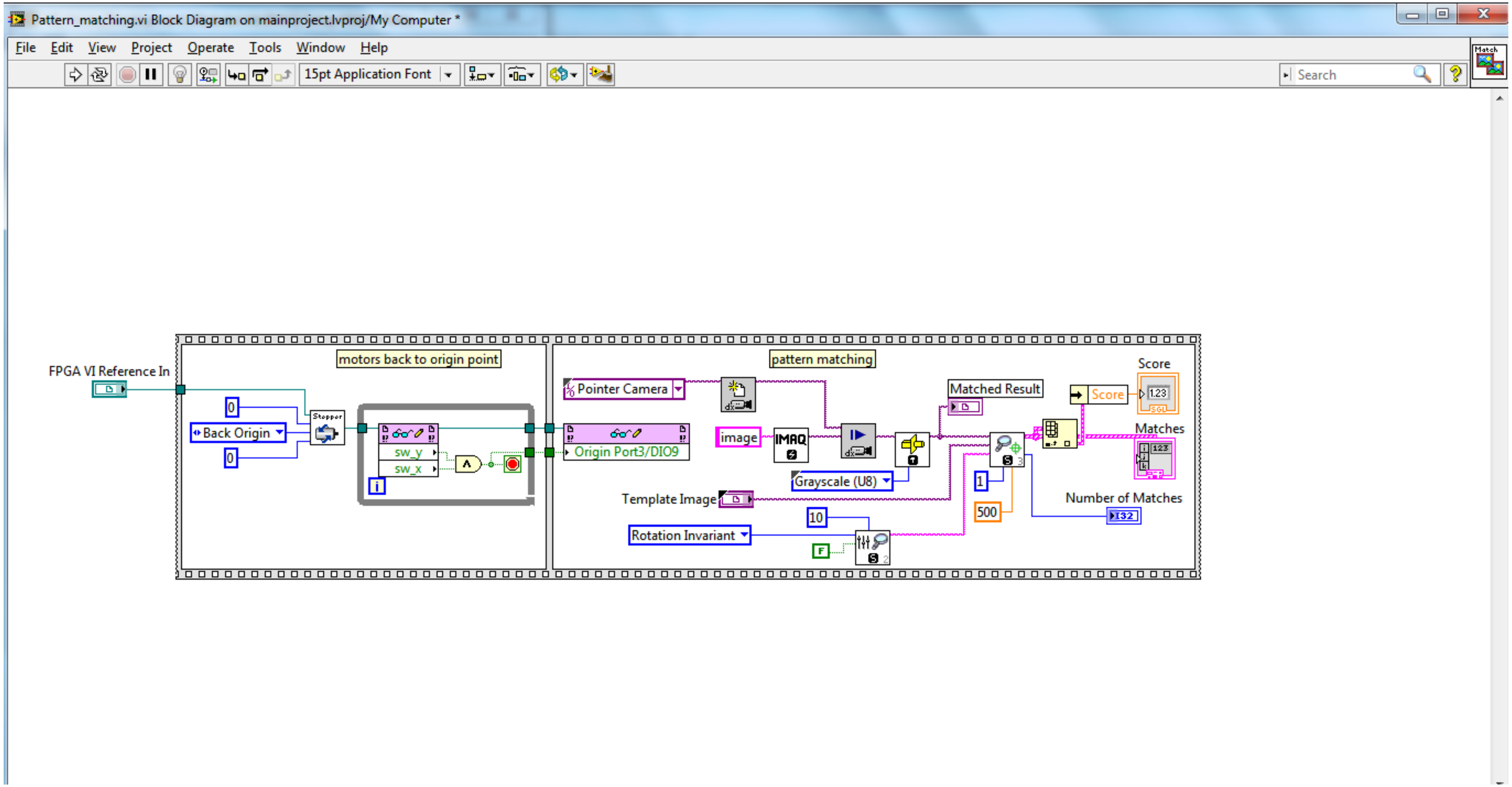

File.vi Block Diagram on mainproject.lvproj/My Computer
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
FPGA VI Reference Out
Filename
Check whether previous file exists
LCD_module.vi
Ensure motors back to origin points
Back Origin
sw_y
sw_x
False
User create new file
File does not exist!! New File created
template_capture.vi
Grayscale (U8)
template.jpg
JPEG
Origin Port3/DIO9
template
appended path
mainproject.lvproj/My Computer

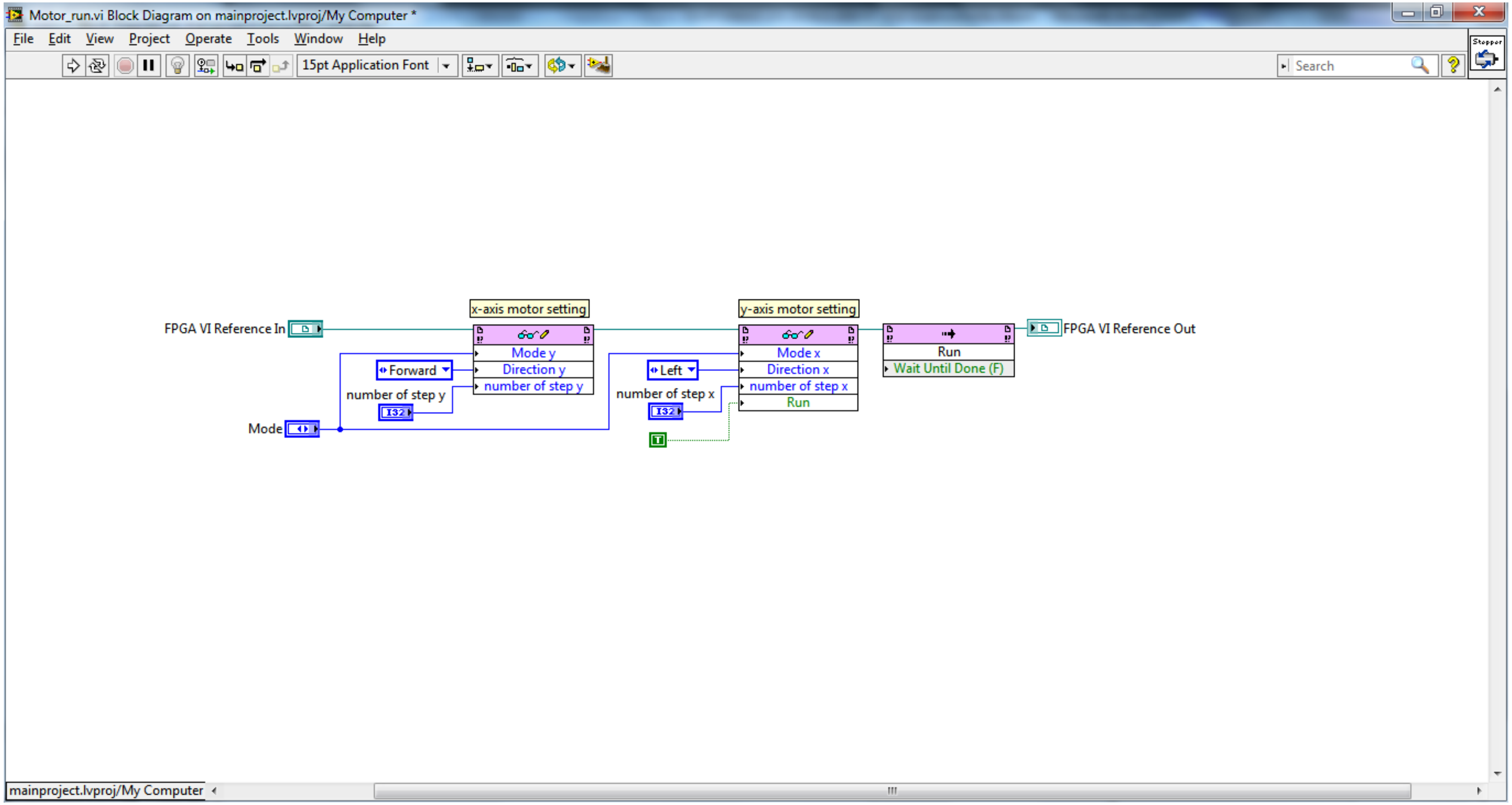

Template_capture.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
Capture image as template, user determine the best quality of template
0, Default
VI
FP.Open
Activate
State
Maximized
0
1

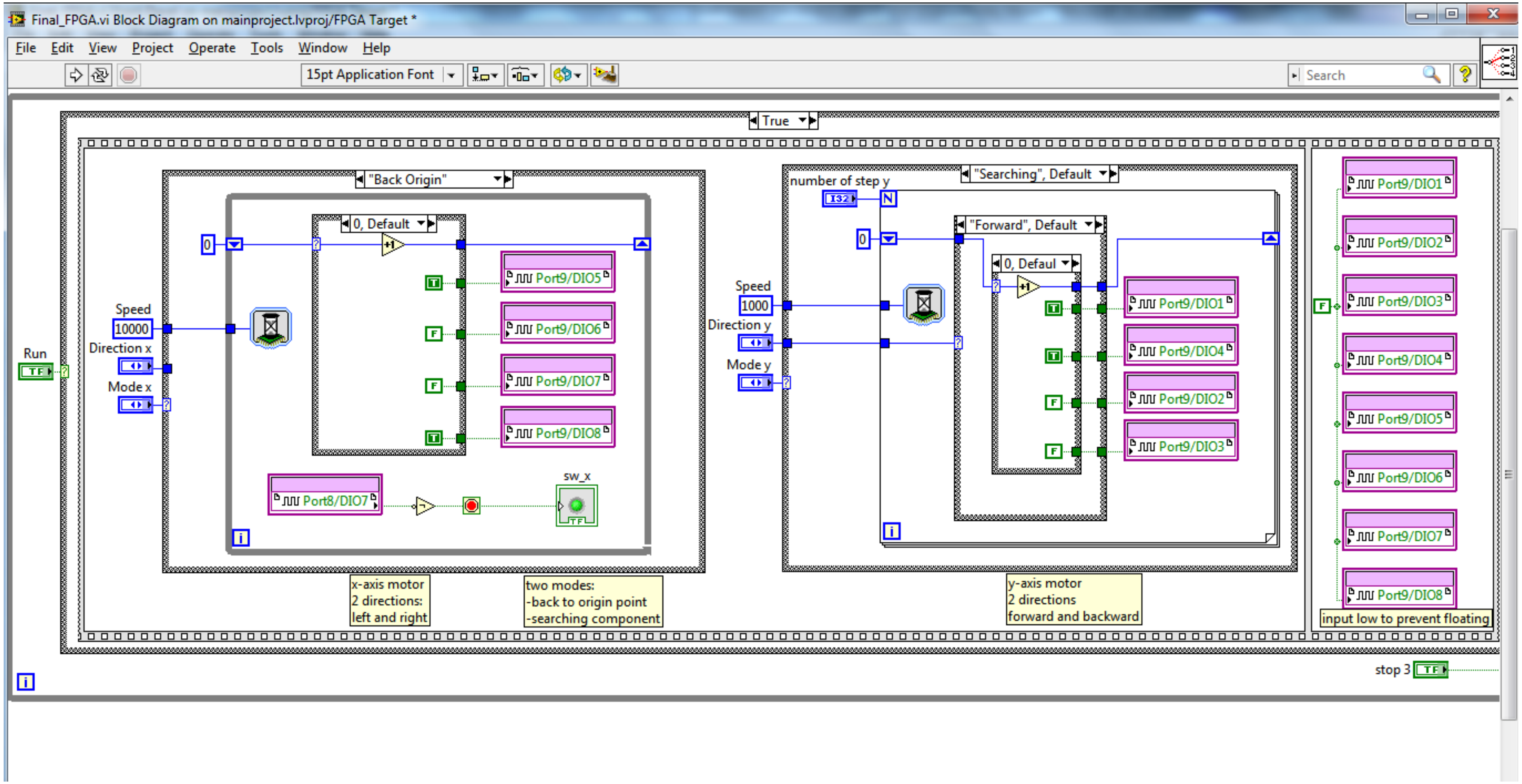

Template_capture.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
Capture image as template, user determine the best quality of template
1
capture image
Image
Zoom to Fit Mode
Pointer Camera
Image
template
IMAQ
0
2

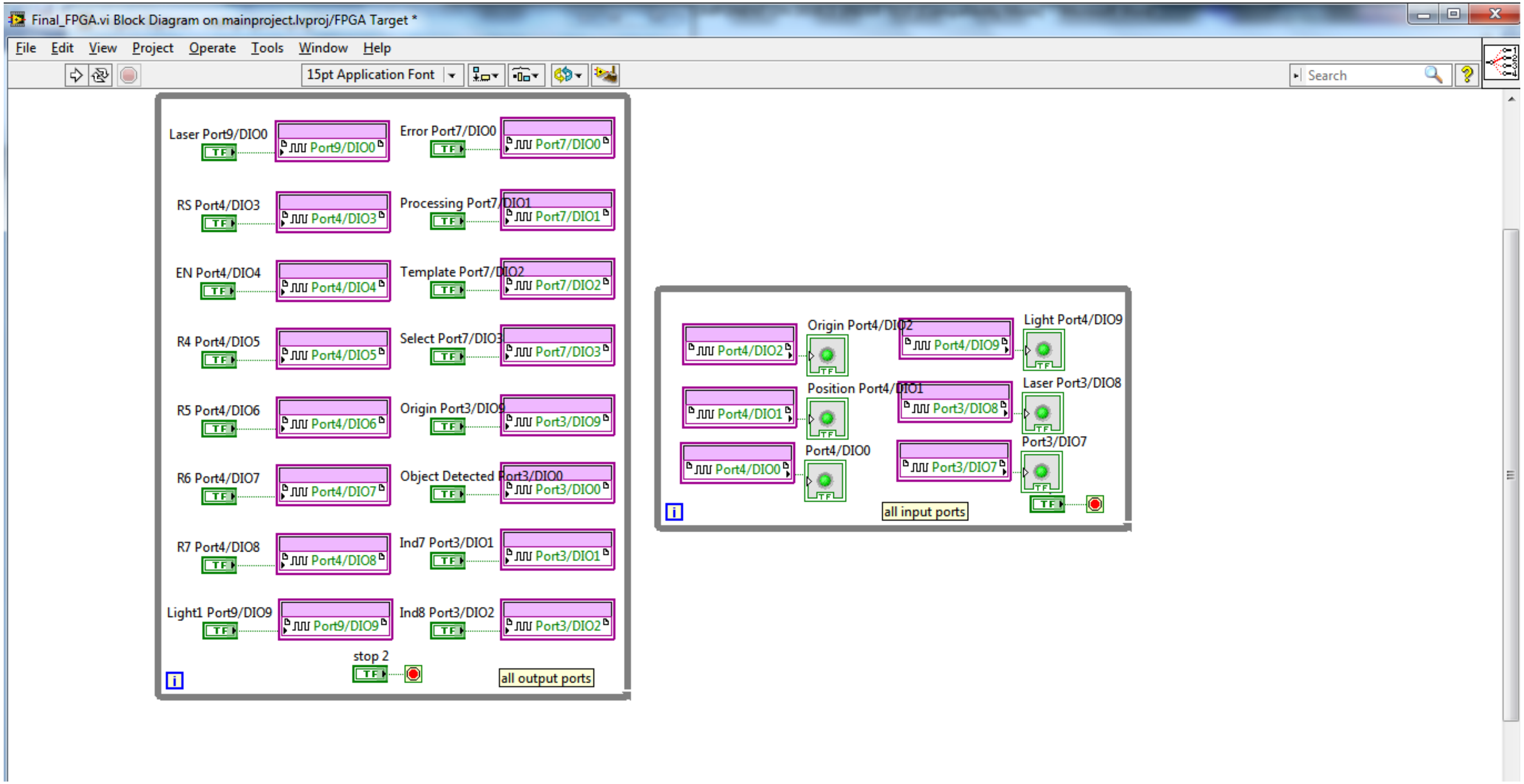

Template_capture.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
Capture image as template, user determine the best quality of template
2
True
Set as template?
Capture again
VI
FP.Close
0
1


Get_template.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
perform horizontal and vertical clamping to crop out object only
Original template
Cropped template
Edge Coordinates[0]
Edge Coordinates[1]
X
X 2
results of clamping:
Coordinates of 4 edges
ROI
Left
Right
Top
Bottom
set offset of region
Y
Y 2
mainproject.lvproj/My Computer

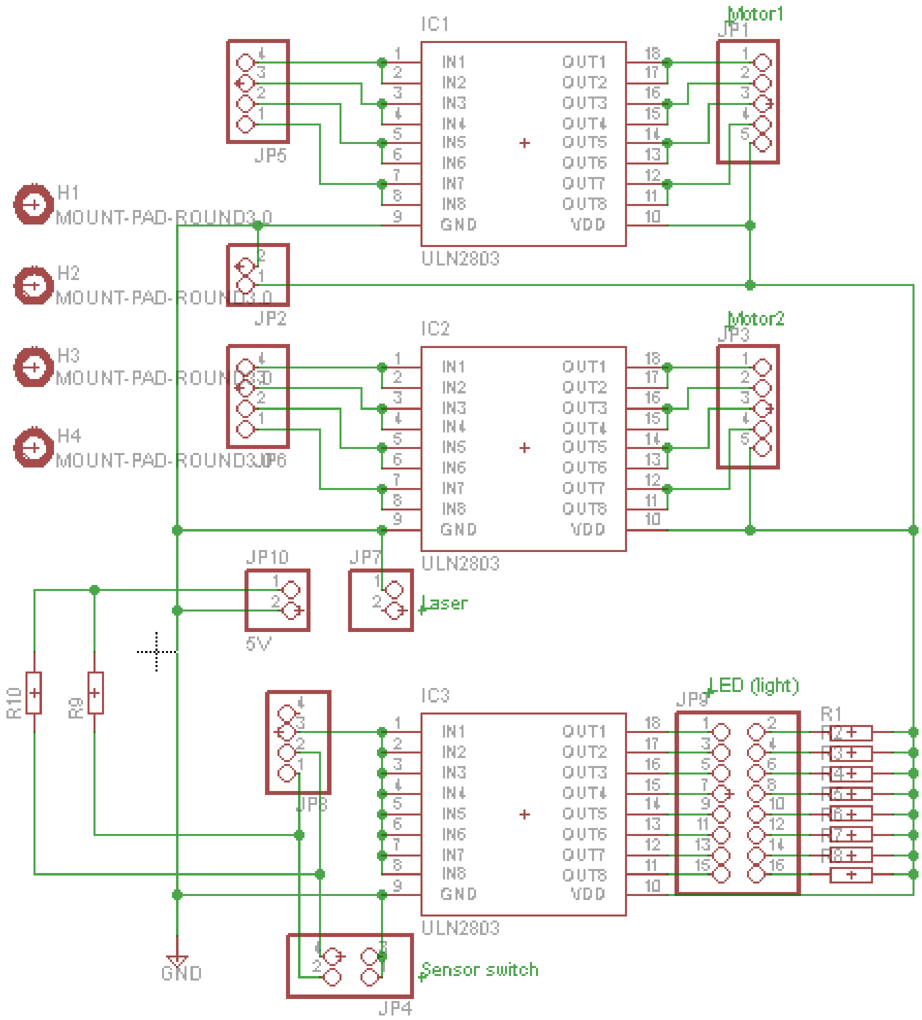

Pattern_matching.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
FPGA VI Reference In
motors back to origin point
Back Origin
Stopper
sw_y
sw_x
pattern matching
Pointer Camera
Origin Port3/DIO9
image
IMAQ
Grayscale (U8)
Template Image
Rotation Invariant
Matched Result
Score
Matches
Number of Matches
10
500


Motor_run.vi Block Diagram on mainproject.lvproj/My Computer *
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
x-axis motor setting
y-axis motor setting
FPGA VI Reference In
Mode y
Direction y
number of step y
Forward
number of step y
Mode
Mode x
Direction x
number of step x
Run
Left
number of step x
Run
Wait Until Done (F)
FPGA VI Reference Out
mainproject.lvproj/My Computer

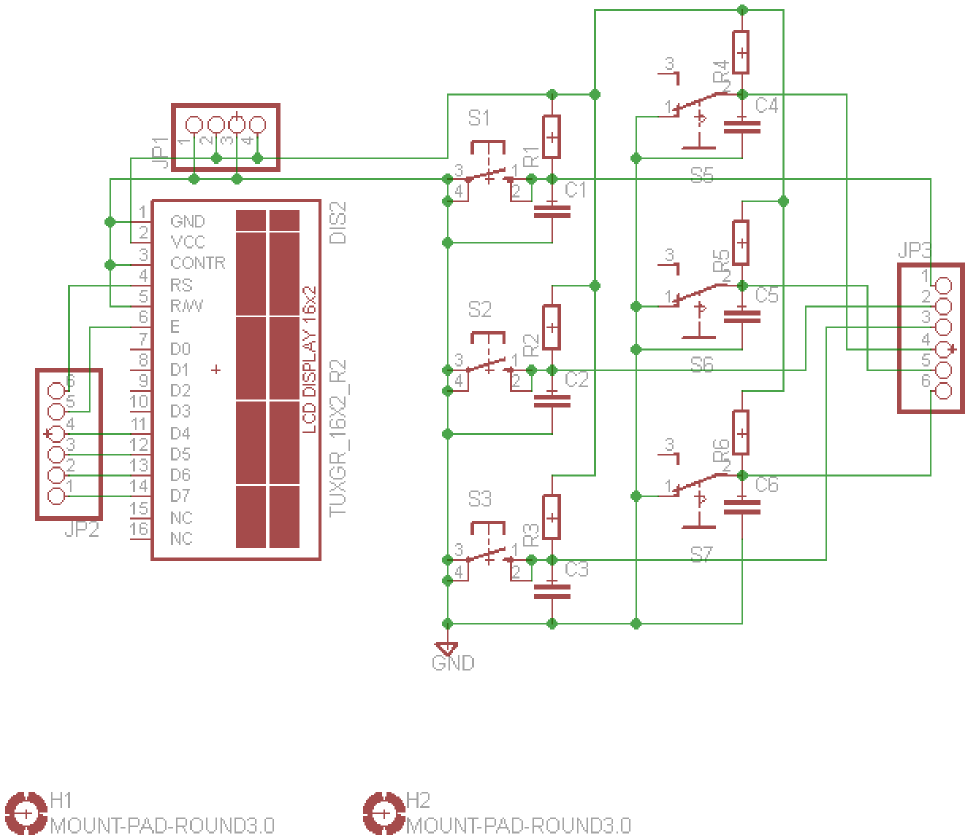

Final_FPGA.vi Block Diagram on mainproject.lvproj/FPGA Target *
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
True
"Back Origin"
0, Default
Speed
10000
Direction x
Mode x
Run
Port9/DIO5
Port9/DIO6
Port9/DIO7
Port9/DIO8
Port8/DIO7
sw_x
x-axis motor
2 directions:
left and right
two modes:
-back to origin point
-searching component
number of step y
"Searching", Default
"Forward", Default
0, Defaul
Speed
1000
Direction y
Mode y
Port9/DIO1
Port9/DIO4
Port9/DIO2
Port9/DIO3
y-axis motor
2 directions
forward and backward
Port9/DIO1
Port9/DIO2
Port9/DIO3
Port9/DIO4
Port9/DIO5
Port9/DIO6
Port9/DIO7
Port9/DIO8
input low to prevent floating
stop 3


Final_FPGA.vi Block Diagram on mainproject.lvproj/FPGA Target *
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
Laser Port9/DIO0
Port9/DIO0
Error Port7/DIO0
Port7/DIO0
RS Port4/DIO3
Port4/DIO3
Processing Port7/DIO1
Port7/DIO1
EN Port4/DIO4
Port4/DIO4
Template Port7/DIO2
Port7/DIO2
R4 Port4/DIO5
Port4/DIO5
Select Port7/DIO3
Port7/DIO3
R5 Port4/DIO6
Port4/DIO6
Origin Port3/DIO9
Port3/DIO9
R6 Port4/DIO7
Port4/DIO7
Object Detected Port3/DIO0
Port3/DIO0
R7 Port4/DIO8
Port4/DIO8
Ind7 Port3/DIO1
Port3/DIO1
Light1 Port9/DIO9
Port9/DIO9
Ind8 Port3/DIO2
Port3/DIO2
stop 2
all output ports
Port4/DIO2
Origin Port4/DIO2
Port4/DIO9
Light Port4/DIO9
Port4/DIO1
Position Port4/DIO1
Port3/DIO8
Laser Port3/DIO8
Port4/DIO0
Port4/DIO0
Port3/DIO7
Port3/DIO7
all input ports

APPENDIX B: Schematic of Motors and Lighting Controllers



APPENDIX C: Schematic of LCD and Switches Circuit Design



APPENDIX D: Schematic of LED Circuit Design