FABRICATION OF JIG FOR TEXTILE CONTROL PANELS

A Project Report

Submitted by

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in partial fulfillment for the award of the degree

of

BACHELOR OF ENGINEERING
in

ELECTRICAL & ELECTRONICS ENGINEERING

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

KUMARAGURU COLLEGE OF TECHNOLOGY, COIMBATORE – 641 006

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APRIL– 2009

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BONAFIDE CERTIFICATE

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COIMBATORE – 641 006.

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LECS/HR/PROJ 04-04-2009

TO WHOMSOEVER IT MAY CONCERN

This is to certify that **Mr.S.R.Alaga Raja (71205105004),** Final year BE - EEE Student of Kumaraguru College of Technology, Coimbatore, have done a Project Work titled **"Fabrication of Test Jig for Textile Control Panel"**, in our Organisation from 01.12.2008 to 02.04.2009.

During the Project, he was sincere and showed keen interest in data collection, and interpretations of testing Automation.

We wish success in all his future endeavors.

For LAKSHMI ELECTRICAL CONTROL SYSTEMS LIMITED

A.Murugesan
Manager – HRD

ISO 9001 BUREAU VERITAS Certification

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During the Project, he was sincere and showed keen interest in data collection, and interpretations of testing Automation.

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ABSTRACT

The control panel which is used to control the process of ring frame textile machine. It is the heart of the ring frame machine. So it is essential, to test the control panel before they are fixed to the machine. A series of test is conducted on the control panel and it requires more skilled man power. When it is done manually, the testing would create many human errors and would consume more time.

The testing of control panel is done with a panel called JIG, which is used normally in manual testing. In our project we design an automated JIG. The JIG consists of two programmable logical controllers (PLC's), switches and lamp simulators. The JIG operates on the principle of continuity test. The programmable logical controller in this JIG makes the conventional manual testing into an automated testing, so that efficiency of the testing is increased, by reducing time of testing, human involvement and human errors.

As this JIG is an automated one, a skilled labor can test many control panels using corresponding test JIG simultaneously, there increasing the mass production rapidly.

ACKNOWLEDGEMENT

We thank the KCT Management for providing us with all necessary infrastructure and other facilities, to successfully carry out this project.

At the outset, we wish to place on record our sincere thanks and gratitude to **Prof. K. Regupathy Subramanian,** Dean and HOD, Electrical and Electronics Engineering, who motivated us to embark on such a project and whose keen and sustained interest in this project had been a moral booster for us.

We express our sincere thanks to our guide **Ms. T.SHANTHI** M.Tech., Lecturer, Department of Electrical and Electronics Engineering for valuable suggestions and advice at all stages of our project.

We extend our thanks to our industrial guide **Mr. G.RAVICHANDRAN**, Senior Manager in control panel and **Mr. PRAVEEN** M.E., Engineer Lakshmi Electrical Control Systems, Arasur for their guidance and kind co-operation.

We also thank our teaching and non-teaching staff of Electrical and Electronics Engineering Department for their help and support in guiding us through out the project.

Finally, we thank our parents for the great support and encouragement in completing this project.

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SYMBOLS AND ABBREVIATIONS

NO.	SYMBOLS	ABBREVIATIONS
01	PLC	Programmable Logic Controller
02	NO	Normally Open
03	NC	Normally Closed
04	PBU	Push Button Up
05	I/O	Input/Output
06	PPI	Point to point interface
07	LAD	Ladder Logic
08	STL	Statement List
09	FBD	Function Block Diagram
10	C	Counter
11	AC	Accumulator
12	Ton	On-Delay Timer
13	CV	Current Value

1. INTRODUCTION

1. INTRODUCTION

1.1OBJECTIVE

The main objective of this project is to simplify the test bench for testing control panels which will give results with higher accuracy and faster rate when compared with a manual test bench. It will increase the production rate of control panels and reduce the involvement of the skilled operator.

1.2 LR 60 AX CONTROL PANEL

The LR60AX is a control panel used in ring frame machine which is used in textile companies. This panel is capable of performing cording for 1200 spindles at a time. This panel uses servo drive for its operation. The panel is divided in to head stock and tail stock. Both are placed at two ends of the machine, to get higher efficiency. Earlier the machine has only one panel. The supply to the machine is from this panel only, it serves as a brain for machine and it controls all the operations and parameters of the machine

1.3 TEST JIG

The test JIG is used to test the textile control panels for the correct circuitry .There is multiple numbers of functions in the control panel, it is very difficult to test all the functions manually. In manual test, the test consumes lot of time space and skilled labors. Thus increasing the cost of production and time of production.

Test JIG consists of indicator lamps which will indicates the operations (outputs) in the control panel. The JIG also has a PLC and rotary switches which is used to check the input circuits as well as the output of the control panel and the machine. Our JIG would operate in 24V DC which is supplied from control panel and is also used to operate the PLC and also used to activate contactors in the control panel. The JIG gives the control panel a real time environment and verifies the panel's response to that environment. It also checks weather the panel detects the change in the environmental parameters and acts accordingly.

By implementing the PLC the JIG is semi automated thus reducing the human error time and money. Even as the initial cost programming, fabrication of the test JIG consumes time and money in long term it increases production, reduces time for testing and also reduces the human error considerably. Because of this test JIG production of the panel will also increased. The panel's worth is understood very well in cases of mass production.

1.4 LITERATURE REVIEW

Now in the industries, the methods to check the control panel circuitry are manual test jig, ohmmeter testing and real time testing. All these methods have certain disadvantages and advantages.

1.4.1 Manual test jig

Here instead of using PLCs to give 24V DC supply, they have rotary switches to give the supply. This consumes a lot time, money and constant monitoring of the JIG by supervisors. Moreover the motors are not run really and problems encountered by them during running like overloading, heating of the coils are not tested. Thus the testing is not totally complete.

1.4.2 Ohmmeter testing

Here each and every terminal in panel is tested and checked manually by using ohmmeter which is very time consuming and needs more than one labor at a time which is costly. This type of testing is not advised in case of mass production of panels.

1.4.3 Real time testing

In this type of testing, a real environment is created to the panel and it is tested. Here all the motors are run really and real time problems encountered by them during running like overloading, heating of the coils are tested. Thus the testing is complete. This type of testing is done in places where the panel is to be perfectly correct and there should me no room for small error. Here all the possible scenarios are simulated to the panel and its reaction to that change is checked. The speed at which the panel responded is checked. In this method time consumption is very high and cost of testing the panel is also very high which includes the cost of labor. cost of testing machines. Moreover this type of testing is not economical.

2. CONSTRUCTION

2. CONSTRUCTION

The JIG is made of mild steel of thickness 2mm. it is of box like shape and also as a lid which houses illumination lamps and rotary switches. The inner potion of the box contains the circuit, PLCs, and transformers and terminal connectors. The PLC and connectors are placed on the end rail which is mounted on the wall and floor of the JIG.

Plastic channel of size 5cm * 5cm is used. The purpose of using plastic channel is to house the connecting wires so that they are invisible. Channel has vertical holes show that the wires are taken out from the channel. The channels and end rails are mounted to the JIG by using 0.33 mm screws.

The connectors are placed on the end rails so that the terminals frills placed on the connectors are visible to the user. End plate is used among the connectors so that we can differentiate between different batches of the terminals. Output terminals and input terminals are normally viewed different to avoid confusions.

The output and input to the control panel is taken from the JIG by using coaxial cables of various cores. The end of the coaxial cable are connected to different types of sockets like combian plug , 16 pole and 24 pole socket according to the requirements.

The ends of the connector wire used inside the JIG are crimped and respective frill number is placed and sealed using cable connector.

PLC is placed in the end rail and clamped by using end plate. The expansion module is connected to the main PLC by using RS443 which is provided with the expansion module. The input and output PLC and their expansion modules are kept in the different places and were given different names to avoid confusion.

The indicator lamp is placed at the lid of the JIG is used to indicate the power supply at the point to which it is attached. The other end of the indicator lamp is grounded. In our JIG we use both 230V and 24V lamps. The 230V lamps are used to indicate the power supply at the point at which motors may be connected. Thus simulating the motor is ON. The 24V lamps are used in the places where power supply to the contactor is to be known. If the lamp glows it indicates that the contactor is ON.

Rotary switch is used to perform manual actions like PLC sequence start, next machine ON, previous machine ON and other operations which are not usually done by PLC. This is normally a NO point.

Emergency switch used is press and rotate to off switch. Normally NC point is used for this switch .the 24V supply from the panel goes to the JIG through this switch.

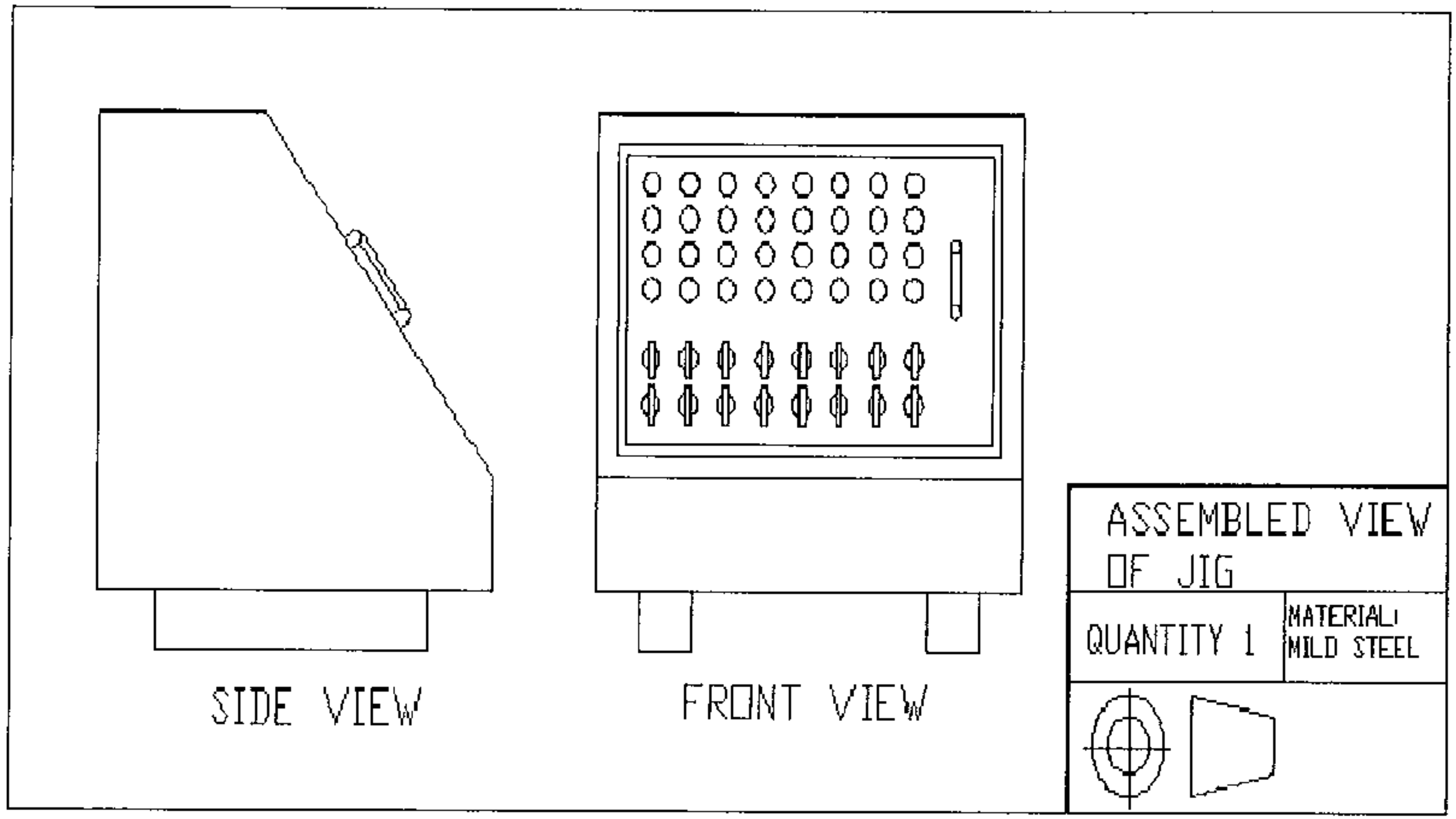

Fig 2.1 Jig View

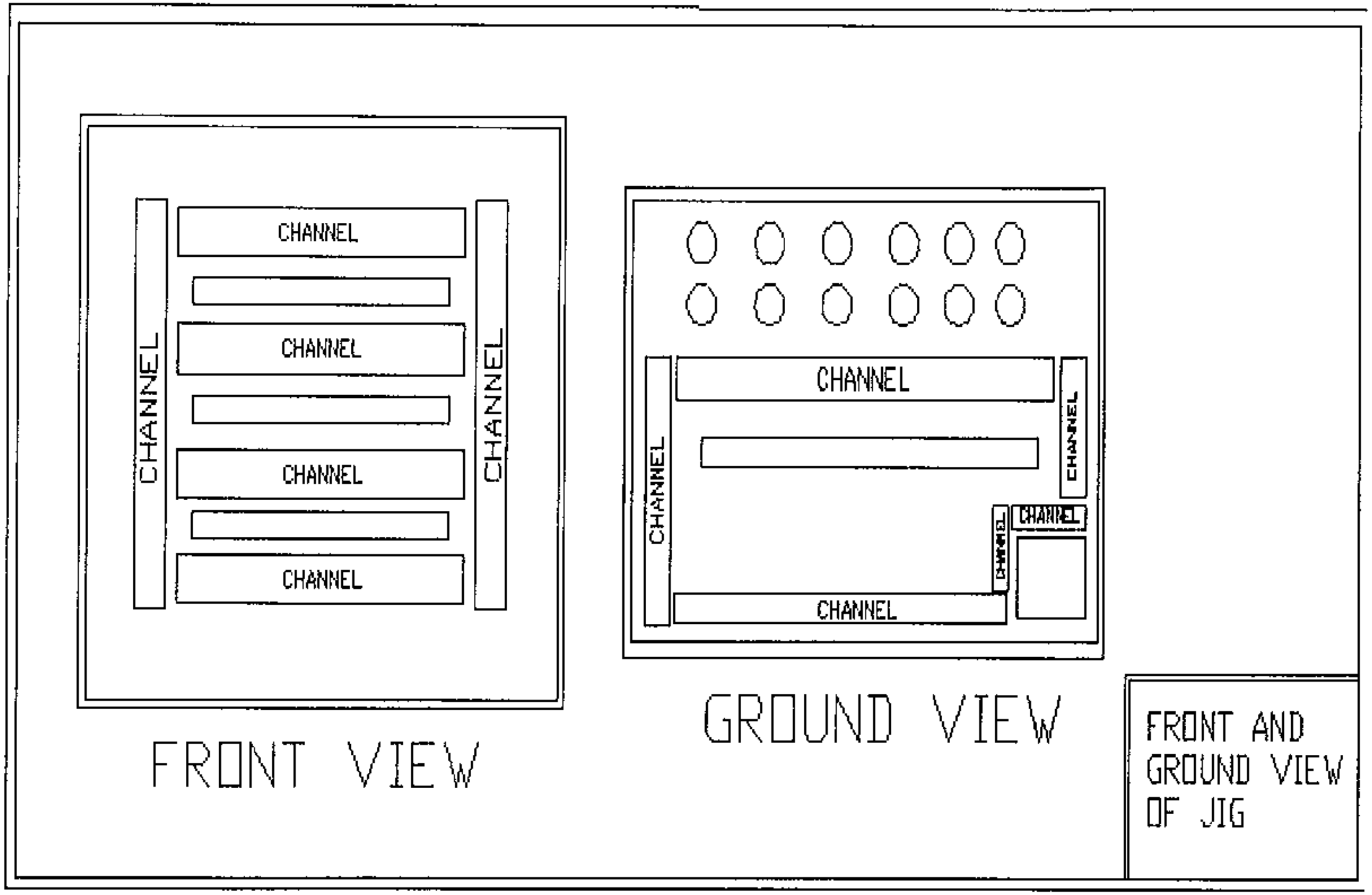

Fig 2.2 Jig Lay Out

3. WORKING

3. WORKING

3.1 WORKING PRINCIPLE:

The test JIG works on the principle of **continuity** test.

The continuity test is the checking of an electric circuit to see if current flows. It is performed by placing a small voltage wired in series with an LED or noise-producing component such as a piezoelectric speaker across the chosen path. If the chosen path is a complete circuit the electron flow and the LED glows or noise is produced by the piezoelectric speaker. If electron flow is inhibited by broken conductors, damaged components, or excessive resistance, then the circuit is said to be open.

This test should be done when current is NOT present. Always unplug the device or turn off the main circuit breaker before attempting a continuity test.

In our project the small voltage is applied by the PLC which gives 24V dc voltage and the indicator lamps are used to indicate that the chosen circuit is complete.

3.2 INPUT SEGMENT

First, let us take the input segment of the panel. The output of the JIG PLC is given to control terminals of the panel through socket like combian and 16 pole sockets. In the real environment these sockets are connected to the sensors, detector and signals, the signals from these sensors and detectors are given to the inputs to the panel PLC and the indicative lamps attached to the PLC's input glows. The panel PLC considers these inputs and according to the program in it gives output signal. Now, it is enough to check weather the circuit from the terminal and the panel PLC is complete. This is done by applying the JIG PLC's 24V output to the panel's sockets and verifying the lamps in the PLC's input. As the poles in the sockets are designated to the particular pins of PLC only when you apply a voltage at one pole, the corresponding input lamp to that pole should only glow. If other input lamp excluding that particular lamp glow it indicates that there is a cross connection and if that particular lamp does not glow it indicates that the connection is complete.

To know whether the glowing lamp is correct for the given input we should have a complete knowledge about the circuit of the panel. A semi skilled labor or an unskilled labor can not have a complete knowledge about the circuit all the time and in an industry which is manufacturing many varieties of control panels this is impossible. To solve this problem the circuit is studied and simplified by us and written pattern on how the lamps will glow and it's duration of the glow is given to the operator which is called the **CONTROL CORD**. The pattern in which the lamp glows is determined by program used in the JIG PLC. The duration for which the lamp glows is also given by the program. If the pattern of lamp glow is correctly according to the control cord the whole input circuitry is complete and correct. The inputs to the panel PLC which is not from the sensors and detectors like **interlock previous machine, interlock next machine and motor overload** are given by rotary switches in the JIG. By rotating the switch to NO point, a 24V DC supply is applied to the poles of the panel's socket and thus illuminating the PLC's input lamps. If the PLC input lamps respond to the given signal correctly then the circuit is correct and complete.

3.4 OUTPUT SEGMENT

Here the panel circuit consists of contractors, relays, motors and ohtc.
The panel PLC sent output to this segment only according to the program in it.

To switch the motor in forward, reverse mode and to run in slow and fast mode, the PLC uses contractors. These contractors are also used to prevent overload.

A contactor is an electrically controlled switch (relay) used for switching a power circuit. A contactor is activated by a control input which is a lower voltage / current than that which the contactor is switching. A contactor is composed of three different systems. The contact system is the current carrying part of the contactor. This includes Power Contacts, Auxiliary Contacts, and Contact Springs. The electromagnet system provides the driving force to close the contacts. The enclosure system is a frame housing the contact and the electromagnet. Enclosures are made of insulating materials like Bakelite, Nylon 6, and thermosetting plastics to protect and insulate the contacts and to provide some measure of protection against personnel touching the contacts.

In real case, the panel PLC gives 24V DC supply to its output according to the pattern of its input. This output activates motors and relays. To test this segment we need real motors and real machines which is not accordable because it consumes lot of money, power and skilled laborers. To avoid this constrain we use indicator lamps. These lamps are in the test JIG and we use both 230V and 24V lamps.

Here in testing we bypass the panel PLC itself by applying the JIG PLC's output parallel to the panel PLC's output. As we do not need PLC's input and our objective is only about output segment.

In our testing, we sequentially give 24V DC supply to the panel PLC's output by JIG PLC and according to the circuit either an contractor is activated and a motor is run or an relay is activated. Thus if a 24V supply is given at an point the relay or contractor attached to it responds. To know weather the glowing lamp is correct for the given input we should have a complete knowledge about the circuit of the panel. A semi skilled labor or an unskilled labor can not have a complete knowledge about the circuit all the time and in an industry which is manufacturing many verities of control panels this is impossible. To solve this problem the circuit is studied and simplified by us and written pattern on how the lamps will glow and it's duration of the glow is given to the operator which is called the **CONTROL CORD**. The pattern in which the lamp glows is determined by program used in the JIG PLC. The duration for which the lamp glows is also given by the program. If the pattern of lamp glow is correctly according to the control cord the whole input circuitry is complete and correct.

Thus by using PLC the whole panel circuit is checked automatically in very short time. In earlier version that is in manual version the 24V DC supply is given by rotary switches which is costly, time consuming and needs constant supervision by labors.

4. PROCESS ELEMENTS

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4.1 ROTARY SWITCHES

A **rotary switch** is a type of switch that is used on devices which have two or more different "states" or modes of operation, such as a three-speed fan or a CB radio with multiple frequencies of reception or "channels".

A rotary switch consists of a spindle or "rotor" that has a contact arm or "spoke" which projects from its surface like a cam. It has an array of terminals, arranged in a circle around the rotor, each of which serves as a contact for the "spoke" through which any one of a number of different electrical circuits can be connected to the rotor. The switch is layered to allow the use of multiple poles, each layer is equivalent to one pole. Usually such a switch has a detent mechanism so it "clicks" from one active position to another rather than stalls in an intermediate position. Thus a rotary swich provides greater pole and throw capabilities than simpler switches do.

4.2 INDICATOR LAMPS

An indicator lamp is LED lamp or a bulb. By connecting negative point to earth and by connecting input wire to positive line the lamp become an indicator. In our project we use lamp manufactered by TEKNIC. The output voltage from the panel is given to the JIG by sockets. For high voltage lamps like 230V lamps a serial resistance is used and by using it the voltage to lamp is reduced. Thus the lamps used here are of very low voltage, intensity and illumination. As the use of this lamp is only indication this illumination is enough.

5. PROGRAMMABLE LOGIC CONTROLLER

5. PROGRAMMABLE LOGIC CONTROLLER (PLC)

5.1 INTRODUCTION

Control engineering has evolved over time. More recently electricity has been used for control and early electrical control was based on relays. These relays allow power to be switched on and off without a mechanical switch. It is common to use relays to make simple logical control decisions. The development of low cost computer has brought the most recent revolution, the Programmable Logic Controller (PLC). The advent of the PLC began in the 1970s, and has become the most common choice for manufacturing controls. PLCs have been gaining popularity on the factory floor and will probably remain predominant for some time to come. Most of this is because of the advantages they offer.

- Cost effective for controlling complex systems.
- Flexible and can be reapplied to control other systems quickly and easily.
- Computational abilities allow more sophisticated control.
- Trouble shooting aids make programming easier and reduce downtime.
- Reliable components make these likely to operate for years before failure.

There is a constant need for process control systems in the manufacturing industries to produce a better quality product more efficiently and at a low cost. This has led to the evolution of the automated systems.

Since the mid 1975 advances in electronics and especially microelectronics have made a revolution in industry from small to large system. To ensure that the plant or machinery operates within the tolerances and the correct speed etc., It must be programmed and controlled.

The programmable logic controller (PLC) has become a standard for control. It now not only replaces the earlier relay controls but has also taken over any additional control functions. The development of the programmable logic controller resulted in a paradigm change in control engineering. The first PLC was an extremely high voltage oriented design be connected over the same wire and using the same tools as contactor controls. It main benefit was its hardwareindependent ability to permit changes. Now, it was possible to implement control tasks in the form of software programs.

During the further evolution of the PLC, the offering was extended with a number of controllers with scalable performance and configuration, along with appropriate signal converters for different input and output voltages and output currents, respectively. An associated development was that short response times required the use of fast processors.

Programmable Logic Controllers (PLCs), also referred to as programmable controllers, are in the computer family. They are used in commercial and industrial applications. A PLC monitors inputs, makes decisions based on its program, and controls outputs to automate a process or machine.

The PLC used to be a dedicated device communicating only with the machine it controlled. Today's PLC has the ability to control several machines at one time, has extensive man – machine interfaces and can communicate with other PLC's through its own data high way system to create a distributed control Network.

5.2 BASIC PLC OPERATIONS

PLCs consist of input modules or points, a Central Processing Unit (CPU), and Output modules or points. An input accepts a variety of digital or analog signals from various field devices (sensors) and converts them into a logic signals that can be used by the CPU. The CPU makes decisions and executes control instructions based on program instructions in memory. Output modules convert control instructions from the CPU into a digital or analog signal that can be used to control various field devices (actuators). A programming device is used to input the desired instructions. These instructions determine what the PLC will do for a specific input. An operator interface device allows process information to be displayed and new control parameters to be entered.

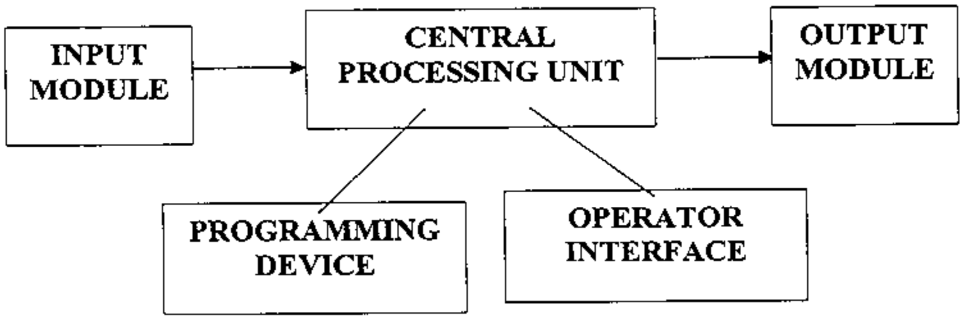


Fig 5.1 Basic PLC Unit

5.3 ELECTRONIC CONTROL WITH LOGIC GATES

In this contactor and relays together with timers and counters were replaced with logic gates and electronic timers in the control circuits.

Major benefits:

- Reduced space requirements
- Energy saving
- Less maintenance and hence greater reliability

Implementation of changes in the control logic as well as reducing the project lead time was not possible.

Hard Wired Control:

Prior to PLCs, many of these control tasks were solved with contactor or relay controls. This is often referred to as hard-wired control. Circuit diagrams had to be designed, electrical components specified and installed, and wiring lists created. Electricians would then wire the components necessary to perform a specific task. If an error was made the wires had to be reconnected correctly. A change in function or system expansion required extensive component changes and rewiring.

5.4 PLC

The same, as well as more complex tasks can be done with a PLC. Wiring between devices and relay contacts is done in the PLC program. Hard wiring, though still required to connect field devices, is less intensive. Modifying the application and correcting errors are easier to handle. It is easier to create and change a program in a PLC than it is to wire and rewire a circuit.

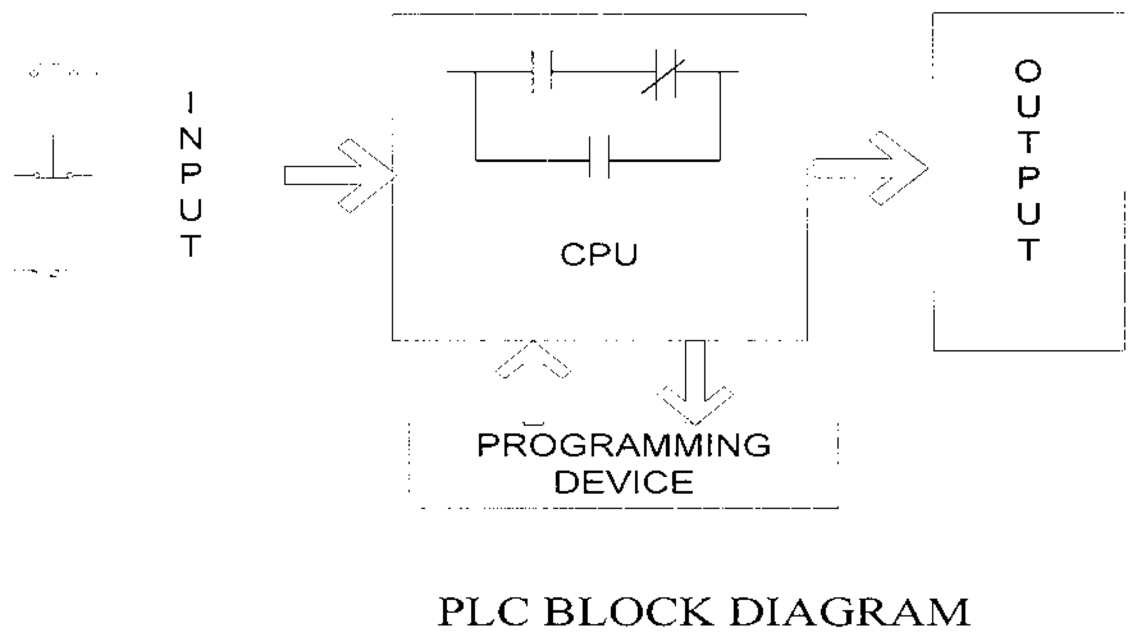


Fig 5.2 Basic PLC Block Diagram

Sensor

A sensor is device that converts a physical condition into an electrical signal for use by the PLC. Sensors are connected to the input of a PLC. A pushbutton is one example of a sensor that is connected to the PLC input. An electrical signal is sent from the pushbutton to the PLC indicating the condition (open/close) of the pushbutton contacts.

Actuators

Actuators convert an electrical signal from the PLC into a physical condition. Actuators are connected to the PLC output. A motor starter is one example of an actuator that is connected to the PLC output. Depending on the output PLC signal the motor starter will either start or stop the motor.

5.4.1 Discrete Input

A discrete input also referred to as a digital input, is an input that is either in an ON or OFF condition. Pushbuttons, toggle switches, limit switches, proximity switches, and contact closures are examples of discrete sensors, which are connected to the PLCs discrete or digital inputs. In the ON condition a discrete input may be referred to as logic 1 or logic high. In the OFF condition a discrete input may be referred to as logic O or logic low.

A normally open (NO) pushbutton is used in the following example. One side of the pushbutton is connected to the first PLC input. The other side of the pushbutton is connected to an internal 24 VDC power supply. Many PLCs require a separate power supply to power the inputs. In the open state, no voltage is present at the PLC input. This is OFF condition. When the pushbutton is depressed, 24 VDC is applied to the PLC input. This is the ON condition.

5.4.2 Analog Input

An analog input is an input signal that has a continuous signal. Typical analog inputs may vary from 0 to 20 milliamps, 4 to 20 milliams, or 0 to 10 volts. In the following example, a level transmitter monitors the level of liquid in a tank. Depending on the level transmitter, the signal to the PLC can either increase or decrease as the level increases or decreases.

5.4.3 Discrete Output

A discrete output is an output that is either in an On or Off condition. Solenoids, contactor coils, and lamps are examples of actuator devices connected to discrete outputs. Discrete outputs may also be referred to as digital outputs. In the following example, a lamp can be turned on or off by the PLC output it is connected to.

5.4.4 Analog Output

An analog output is an output signal that has a continuous signal. The output may be as simple as a 0-10 VDC level that drives an analog meter; Examples of analog meter outputs are speed, weight, and temperature. The output signal may also be used on more complex applications such as a current-to pneumatic transducer that controls an air-operated flow-control valve.

5.4.5 CPU

The central processor unit (CPU) is a microprocessor system that contains the system memory and is the PLC decision-making unit. The CPU monitors the inputs and makes decisions based on instructions held in the program memory. The CPU performs relay, counting, timing, data comparison, and sequential operations.

5.5 MAJOR BENEFITS

- Reduced Space
- Energy saving
- Ease of maintenance
- Economical
- Greater life and reliability
- Tremendous Flexibility

- Short project time
- Easier storage archiving and documentation
- Modular replacement, easy trouble shooting, error diagnostics programming.

Capabilities of PLCs

- Logic Control
- PID Control
- Co-ordination and communication
- Operator Control
- Signaling-and listing etc.,

5.6 GENERAL APPLICATION AREAS OF PLC

- Sequence control applications
- Individual machines
- Conveyors
- Packaging machineries
- Modern control applications
- Motion control applications
- Linear motion
- Rotary motion
- Single / multiple axes control
- Servo drives
- Steeper drives
- Hydraulic drives
- Metal cutting machineries
- Computer numerical control machines
- Process control applications
- Temperature/Pressure/Flow controls
- P, PI, PID controls

- Plastic injection Moulding machines
- Heat treatment furnace
- Data Management applications
- Data acquisition systems
- Data manipulation
- Unmanned FMS/FMC
- Large material handling

5.7 LADDER DIAGRAM CONSTRUCTION

Some of the steps in planning for a ladder diagram are:

1. Define the process to be controlled.
2. Make a sketch of the process operation.
3. Create a written step sequence listing for the process.
4. Add sensors on the sketch as needed to carry out the control sequence.
5. Add manual controls as needed for process setup or operational and checking.
6. Consider the safety of the operating personnel and make additions and adjustments as needed.
7. Add master stop switches as required for safe shutdown.
8. Create-the ladder logic diagram that will be used as a basis for the PLC program.
9. Consider the process sequence may go astray. Some other steps needed in program planning that we will not cover are troubleshooting of process malfunctions, parts list of sensors, relay, and so on, and wiring diagrams, including terminals, conduit runs, and so on.

We then go through the creative process to illustrate [each of the steps of the planning process].

Step 1

Define the problem?.

We wish to set up a system for spray-painting parts. A part is to be placed on a mandrel. (A mandrel is a shaft or bar whose end is inserted into a work piece to hold it during an operation.) When the parts are in place, two pushbuttons are pressed and the mandrel rises. After the part rises to the top and is in the hood, it is to have spray paint applied for a period of 6 seconds. At the end of the 6 seconds, the mandrel returns to the original position. The painted part is then removed from the mandrel by hand.

Step 2

List the sequence of operational steps in as much detail as possible. The sequence steps should be double or triple spaced so that any omitted steps discovered later may be added.

The following is a step sequence for this process.

1 Turn on the paint pump and pneumatic air supply.

2 Turn the system on. This requires pushbuttons other than the system buttons.

3 Put the part on the mandrel. A sensor indicates that the part is in place.

4 Flush the Master Start button and the two system start buttons. Having to push two system start buttons (with both hands) reduces the possibility of the operator's hands being injured by the rising mandrel.

5 A pneumatic cylinder energized by the opening of an electrically actuated air valve when the system start buttons are pressed raises the mandrel. (The mandrel will return by gravity and downward spring action when the valve is re- opened.) When the mandrel rises, the part-in-place sensor at the bottom becomes de-energized. (Note: The part-in-place sensor does not rise with the mandrel.)

6 When the part reaches the top and is under the hood, it is held against a stop by air pressure. A sensor has indicated that the part has reached the top.

7 During the timing period of 6 seconds, the sprayer applies paint.

8 At the end of 6 seconds, painting stops and the mandrel, with the part on it, lowers.
9 The up sensor is de-energized when the mandrel with the part on descends.
10 The part arrives at the bottom, reenergizing the part-in-place sensor.
11 The part is removed from the mandrel.
12 The system resets so that we may start at step 3 again.

Step 3

Add sensors as required. Once we list the sequence, we find that sensors are needed in the machine to indicate process status. We need a sensor (a limit switch placement) to show that the part has been placed on the mandrel initially. We also need a sensor (limit switch up) to indicate when the mandrel is fully extended upward. Among other possible sensors that a process such as this might need is one to make sure the paint sprayer has paint and one to make sure the inserter's hand is out of the way. Depending on the process and the detail of control, other sensors could be required as well.

Step 4

Add manual controls as needed. We may need a manual pushbutton to raise the mandrel to the top for setup purposes. The manual up position is needed when we set the spray-gun pressure for optimum paint coverage. We include pushbutton up (PBU) on our ladder diagram to accomplish this manual control.

Step 5

Consider the safety of the machine operator. One basic way to keep hands out of a process is to have two start buttons. Then both hands must be away from the work to depress both buttons (which works until the operator figures out how to use one knee and one hand).
Other considerations, which we do not cover in detail here, might be operating a fan to disperse fumes during spraying, or perhaps a photocell proximiity-personnel-system-stop device.

Step 6

Add emergency and master stop switches as needed for operator safety. This may seem to be part of step 6 because both steps deal with operator safety. It is a continuation of the safety issue, but emergency stop switches are so important that they need special consideration as an additional step.

Step 7

Create the ladder logic diagram. The diagram created is to include the steps and considerations of the first six steps.

Step 8

Determine the potential problem areas. After the ladder diagram is completed, all possible situations and emergencies should be listed. In this example, some of them might be:

- What if no part is in place when the start buttons are pushed?
- What if the power fails during the cycle when the part is rising, during painting or at any other time?
- What if the sprayer runs of paint?
- What if the same part is left in for a double coat?
- What if the master stop button is pushed? Does the stop button really stop the entire process, or can the mandrel move and create a safety problem after the stop button is depressed.

All of these types of questions should be considered in the final sequence and ladder diagram. Further modifications would be needed for a more complete consideration of contingencies.

6. SIMATIC S7 200 PLC'S

6.SIMATIC S7 200 PLC'S

6.1 S7 – 200 MICRO PLC'S

The S7-200 Micro PLC is the smallest member of the SIMATIC S7 family of programmable controllers. The central processing unit (CPU) is internal to the PLC. Inputs and outputs (I/O) are the system control points. Inputs monitor field devices, such as switches and sensors. Outputs control other devices, such as motors and pumps. The programming port is the connection to the programming device.

S7-200 MODELS

There are four S7-200 CPU types: S7-221, S7-222, S7-224, and S7-226 and three power supply configurations for each type.

Table 6.1 S7-200 Models

Model Description	Power Supply	Input Types	Output Types
221 DC/DC/DC 221 AC/DC/Relay	20.4-28.8 VDC 85-264 VAC 47-63 Hz	6 DC Inputs 6 DC Inputs	4 DC Outputs 4 Relay Outputs
222 DC/DC/DC 222AC/DC/Relay	20.4-28.8 VDC 85-264 VAC 47-63 Hz	8 DC Inputs 8 DC Inputs	6 DC Outputs 6 Relay Outputs
224 DC/DC/DC 224 AC/DC/Relay	20.4-28.8 VDC 85-264 VAC 47-63 Hz	14 DC Inputs 14 DC Inputs	10 DC Outputs 10 Relay Outputs
226 DC/DC/DC 226 AC/DC/Relay	20.4-28.8 VDC 85-264 VAC 47-63 Hz	24 DC Inputs 24 DC Inputs	16 DC Outputs 15 Relay Outputs

6.2 S7-200 FEATURES

The S7-200 family includes a wide variety of CPUs and features. This variety provides a range of features to aid in designing a cost-effective automation solution. The following table provides a summary of the major features. This variety provides a range of features to aid in designing a cost effective automation solution. The following table provides a summary of the major features.

Table 6.2(a) S7-200 Features

Features	CPU 221	CPU 222
Integrated Inputs/Outputs	6DE/4DA	8DE/6DA
Max Expansion Modules	-	2
Max.# of Dig. I/O Channels	10	78
Analogue Points In/Out/Max	-	8/4/10
Program/Data Memory	4KB/2KB	4KB/2KB
Boolean Execution Time	0.22	0.22
Bit Relays/Counters/Timers	256/2/56/256	256/2/56/256
High Speed Counters	4x30kHz	4x30kHz
Real Time Clock	Optional	Optional
Pulse Outputs	2x20 kHz	2x20kHz
Communication Interface	1xRs-485	1xRS-485
Analogue Potentiometers	1	1

Table 6.2(b) S7-200 Features

Features	CPU 224	CPU 224XP	CPU 226
Integrated Inputs/Outputs	14DE/10 DA	14DE/10 DA	24DE/16DA
Integrated Analogue In/Out	-	2AE/1AA	-
Max. Expansion	7	7	7
Max. # of Dig. I/O Channels	168	168	248
Analogue Points In/Out/Max	28/14/35	30/15/38	28/14/35
Program/	8/12 KB	12/16 KB	16/24 KB
Data Memory	8KB	10KB	10KB
Boolean Execution Time	0.22		
Bit Relays /counter/ timers	256/256/256	256/256/256	256/256/256
High Speed Counters	6 x 30 kHZ	4x30 kHz 2 x 200 KHz	6x30 kHz
Real time clock	Integrated	Integrated	Integrated
Pulse outputs	2 x 20 kHz	2 x 100 k Hz	2 x 100 k Hz
Communication interface	1x RS-485	2x RS-485	1x RS-485
Analogue potentiometers	2	2	2

6.3 MODE SWITCH AND ANALOG ADJUSTMENT

When the mode switch is in the RUN position the CPU is in the run mode and executing the program. When the mode switch is in the STOP position the CPU is stopped. When the mode switch is in the TERM position the programming device can select the operating mode.

The analog adjustment is used to increase or decrease values stored in special memory. These values can be used to update the value of a timer or counter, or can be used to set limits.

Installing The S7-200 can be installed in one of two ways. A DIN clip allows installation on a standard DIN rail. The DIN clip snaps open to allow installation and snaps closed to secure the unit c the rail, The S7-2OO can also be panel mounted using installation holes.

External Power Supply An S7-200 can be connected to either a 24 VDC or a 120/230 Sources VAC power supply depending on the CPU. An S7-2O0 DC/DC/ DC would be connected to a 24 VDC power supply. The power supply terminals are located on the far right side of the top terminal strip.

I/O Numbering S7-2OO Inputs and outputs are labeled at the wiring terminations and next to the status indicators. These alphanumeric symbols identify the I/O address to which a device is connected. The CPU to determine which input is present and which output needs to be turned on or off uses this address. It designates a discrete input and Q designates a discrete output. The first number Identifies the byte, the second number identifies the bit. Input 10.0, for example, is byte 0, bit 0.

The following table Identifies the Input and output designations.

Table 6.3 I/O designations

10.0	1^{st} Input	I1.0	9^{th} Input	Q0.0	1^{st} Output	Q1.0	9^{th} output
I 0.1	2^{nd} Input	I1.1	10^{th} Input	Q0.1	2^{nd} Output	Q1.1	10^{th} Output
I 0.2	3^{rd} Input	I1.2	11^{th} Input	Q0.2	3^{rd} Output		
I 0.3	4^{th} Input	I1.3	12^{th} Input	Q0.3	4^{th} Output		
I 0.4	5^{th} Input	I1.4	13^{th} Input	Q0.4	5^{th} Output		
I 0.5	6^{th} Input	I1.5	14^{th} Input	Q0.5	6^{th} Output		
I 0.6	7^{th} Input			Q0.6	7^{th} Output		
I 0.7	8^{th} Input			Q0.7	8^{th} Output		

Inputs

Input Devices, such as switches, pushbuttons, and other sensor devices are connected to the terminal strip under the bottom cover of the PLC.

Outputs	Output devices, such as relays, are connected to the ten strips under the top cover of the PLC. When testing a program it is not necessary to connect output devices. The LED stay indicators signal if an output is active.
Optional Connector	An optional fan-out connector allows for field wiring connections to remain fixed when removing or replacing an S7-221 or 222. The appropriate- connector slides into the Input, output, or expansion modulo terminals.
Removable Terminal Strip	The S7-224 and S7-226 do not have an optional fan-out connector. Instead, the terminal strips are removable. This allows the field wiring connections to remain fixed when removing or replacing the S7-224 and S7-226.
Super Capacitor	A super capacitor, so named because of its ability to maintain a charge for a long period of time, protects data stored in RAM In the event of a power loss. The RAM memory is typically backed up on the S7-221 and 222 for 50 hours, and on the S7-224 and 226 for 72 hours.

6.4 PROGRAMMING OF SIEMENS S7 200 PLC

In order to create or change a program, the following items are needed:

- PLC
- Programming Device
- Programming Software
- Connector Cable

The program is created in a programming device (PG) and then transferred to the PLC. The program for the S7-200 can be created using a dedicated Siemens SIMATIC S7 programming device, such as a PG 720 (not shown) or PG 740, if STEP 7 Micro/WIN software

is installed. A personal computer (PC), with STEP 7 Micro/WIN installed, can also be used as a programming device with the S7-200.

Software

A software program is required in order to tell the PLC what instructions it must follow. Programming software is typically PLC specific. A software package for one PLC, or one family of PLCs, such as the S7 family, would not be useful on other PLCs. The S7-200 uses a Windows based software program called STEP 7-Micro/WIN32. The PG 720 and PG 740 have STEP 7 software pre-installed. Micro/WIN32 is installed on a personal computer in a similar manner to any other computer software.

Connector Cables

PPI Connector cables are required to transfer data from the (Point-to-Point Interface) programming device to the PLC. Communication can only take place when the two devices speak the same language or protocol. Communication between a Siemens programming device and the S7-200 is referred to as PPI protocol (point-to point interface). An appropriate cable is required for a programming device such as a PG 720 or PG 740. The S7-200 uses a 9-pin, D-connector. This is a straight-through serial device that is compatible with Siemens programming devices (MPI port) and is a standard connector for other serial interfaces.

Programming Device Cable

A special cable, referred to as a PC/PPI cable, is needed when a personal computer is used as a programming device. This cable allows the serial interface of the PLC to communicate with the RS-232 serial interface of a personal computer. DIP switches on the PC/PPI cable are used to select an appropriate speed (baud rate) at which information is passed between the PLC and the computer.

Programming Methods

A program consists of one or more instructions that accomplish a task. Programming a PLC is simply constructing a set of instructions. There are several ways to look at a program such as ladder logic, statement lists, or function block diagrams.

Ladder Logic

Ladder logic (LAD) is one programming language used with PLCs. Ladder logic uses components that resemble elements used in a line diagram format to describe hard-wired control. Ladder Logic Diagram The left vertical line of a ladder logic diagram represents the power or energized conductor. The output element or instruction represents the neutral or return path of the circuit. The right vertical line, which represents the return path on a hard-wired control line diagram, is omitted. Ladder logic diagrams are read from left-to-right, top-to-bottom. Rungs are sometimes referred to as networks. A network may have several control elements, but only one output coil.

Statement list

A statement list (STL) provides another view of a set of instructions. The operation, what is to be done, is shown on the left. The operand, the item to be operated on by the operation, is shown on the right. A comparison between the statement list shown below, and the ladder logic shown on the previous page, reveals a similar structure.

Function Block Diagram

Function Block Diagrams (FBD) provide another view of a set of instructions. Each function has a name to designate its specific task. Functions are indicated by a rectangle. Inputs are shown on the left-hand side of the rectangle and outputs are shown on the right-hand side.

Using the Memory Address to Access Data

To access a bit in a memory area, you specify the address, which includes the memory area ldentifier. The byte address and the bit number. Figure 14.3 shows an example of addressing a bit (which is also called 'byte, bit1 addressing). In this example, the memory area and byte address (1=input, and 3=byte 3) are followed by a period (".") to separate the bit address. By using the byte address format, you can access data In many CPU memory areas (I.O. M, and SM) as bytes, words, or double words. To access B byte, word, or double word of data in the CPU memory, you must specify the address in a similar way to the address for a bit. This includes an area identifier, data size designation, and the starting byte address of the byte, word, or double word value, as shown in Figure 10-4. Data in other CPU memory areas (such as T, C, HC, and the accumulators) are accessed by using an address format that includes identifier and a device number.

Representation of Numbers

Table shows the range of integer values that can be represented by the different size of data. Real (or floating-point) numbers are represented as 32-bd, single-precision number, whose format is described in the ANSI/IEEE 754- 1995 standard. Real number values are accessed in double - word lengths.

Data Size and Associated integer ranges

Table 6.4 Data size and associated integer ranges

Data Size	**Unsigned Integer Range**		**Signed integer range**	
	Decimal	**Hexadecimal**	**Decimal**	**Hexadecimal**
B (Byte): 8-bit value	0 to 255	O to FF	- 128 to 127	80 to 7F
W(Word): 16-bil value	0 to 65,535	0 to FFFF	- 32, 768 to 32, 767 / '	8000 to 7FFF
D (Double word, Dword): 32-bil value	O to 4,294,967,295	0 to FFFF FFFF	-2,147,483,648 to 2,147,483,647	8000 0000 to 7FFF FFFF

Addressing the Variable (V) Memory Area

You can use V memory to store intermediate results of operations being performed by the control logic in your program. You can also use V memory to store other data pertaining to your process or task. You can access the V memory area in bits, bytes, words; or double word.

Format: Bit V (bytes address), [bit address) VIO.2

Byte, Word, Double Word V (Size) (starting byte address) VW100

Addressing the Bit Memory (M) Area

You can use the internal memory bits (M memory) as control relays to stored intermediate status of an operation or other control Information. While the name 'bit memory area" implies that this information is stored in bit-length units, you can access the bit memory area not only in bits, but also in bytes, words, or double words.

Format: Bit M (byte address), (bit address) M26.7

Byte, Word, Double Word M (size) [starting byte address] MD20

Addressing Sequence Control Relay (S) Memory Area

Sequence Control relay bits (S) are used to organize machine operations or stops into equivalent program segments. SCRs allow logical segmentation of the control program. You can access the S bits as bits, bytes, wards, or double words.

Format: Bit 5[byte address], [bit address] 53.1

Byte. Word, 1 Double Word 5(size) (starting byte address] 5B4

Addressing the Special Memory (SM) Bits

The SM bits provide a means for communicating information between the CPU and your program. You can use these bits to select and control some of the special functions of the S7-200 CPU, such as:

- A bit that turns on for the first scan
- Bits that toggle at fixed rates
- Bits that show the status of math or operational instructions

Format: Bit	SM [byte address), (bit address] SMO.1
Byte. Word, Double Word	SM [size)(starting byte address] SMB86

Addressing the Timer (T) Memory Area

In the S7-200 CPU, timers are devices that count Increments of time. The S7-200 timers have resolutions (time-base Increments) of 1 ms, 10 ms, or 100 ms. There are two variables that are associated with a timer:

Current value this 16 bit signed integer stores the amount of time counted by the timer. Liner bit this bit turns on (is set to 1) when the current value of the timer is greater than or equal to the preset value. (The preset value in entered a part of the timer instruction. You access both of these variables by using the timer address (T + timer number). Access to either the timer hit or the current value is dependent on the instruction used: instructions with operands access the timer bit, while instructions with word operands access the current value. The Normally Open Contact instruction accesses the timer bit, while the Move Word (MOV-M instruction accesses the current Value of the timer.

Addressing the Counter (C) Memory Area

In the S7-200 CPU, counters are devices that count each low-to-high transition event on the counter input(s). The CPU provides two types of counters: one type counts up only, and the other counts both up and down. There are two variables that are associated with a counter:

Current value: this 16-bit signed integer stores the accumulated Counter bit, this bit turns on (is sat to 1) when the current value of the counter is greater than or equal to the preset value. (The preset value is entered as part of the timer instruction.) You access

both of these variables by using the counter address (C + counter number). Access to either the counter bit or the current, value is dependent on the instruction used: instructions with bit operands access the
counter bit, while instructions with word operands access the current value. The normally open Contact instruction accesses the counter bit while the Move Word (MOV_W) instruction accesses the current value of the counter. For more information about the S7-200 instruction set

Format: C [counter number] C20

Addressing the Analog Inputs (A)

The S7-200 converts a real-world, analog value (such as temperature or voltage) into a word-length (16-bit) digital value. You access these values by the area identifier (AI), size of the data (W), and the starting byte address. Since analog inputs are words and always start on even-number bytes (such as 0, 2, or 4), you access them with even-number byte addresses (such as AIWO, AIW2, or AIW4. Analog input values are read only values.

Format: AIW[Starting by-to address) AIW4

Addressing the Analog Outputs (AQ)

The S7-200 converts a word-length (1 6-bd) digital value into a current or voltage, proportional to the digital value (such as for a current or voltage). You write these values by the area identifier (AO), size of the data (M, and the starting byte address. Since analog outputs are words and always start on even-number bytes (such as 0, 2, or 4), you write them with even-number byte addresses (such as ACWO, AOW2, or AOW4). Your program cannot read the values of the analog outputs.

Format AQW (Startling byte address] AQW4

Addressing the Accumulators (AC)

Accumulators are read / time devices that can be used like memory. For example, you can use accumulators to pass parameters to and from subroutines and to store intermediate values used in a calculation. The CPU provides four 32-bh accumulators (ACO, ACI, AC2, and AC3). You can access the data in the accumulators as bytes, words, or double words. Accessing the
accumulator as bytes, or words, uses the least significant L3 or 16 bits of the value that Is stored In the accumulator. Accessing the accumulator as a double word uses all 32 bits. The size of the data being accessed is determined by the instruction that is used to access the accumulator.

Symbols

In order to understand the instructions a PLC is to carry out, an understanding of the language is necessary. The language of PLC ladder logic consists of a commonly used set of symbols that represent control components and instructions. Contacts One of the most confusing aspects of PLC programming for first-time users is the relationship between the device that controls a status bit and the programming function that uses a status bit. Two of the most common programming functions are the normally open (NO) contact and the normally closed (NC) contact. Symbolically, power flows through these contacts when they are closed. The normally open contact (NO) is true (closed) when the input or output status bit controlling the contact is 1. The normally closed contact (NC) is true (closed) when the input or output status bit controlling the contact is 0.

Coils: Coils represent relays that are energized when power flows to them. When a coil is energized, it causes a corresponding output to turn on by changing the state of the status bit controlling that output to 1. That same output status bit may be used to control normally open and normally closed contacts elsewhere in the program.

Boxes: Boxes represent various instructions or functions that are executed when power flows to the box. Typical box functions are timers, counters, and math operations.

Entering Elements: Control elements are entered in the ladder diagram by positioning the cursor and selecting the element from lists. In the following example the cursor has been placed in the position to the right of 10.2. A coil was sheeted from a pull-down list and inserted in this position.

6.5 TIMERS AND COUNTERS

Timers are devices that count increments of time. Traffic light is one example where timers are used. In this example timers are used to control the length of time between signal changes. Boxes in ladder logic represent timers. When a timer receives an enable, the timer starts to time. The timer compares its current time with the preset time. The output of the timer is logic 0 as long as the current time is less than the preset time. When the current time is greater than the preset time the timer output is a logic 1. S7-200 uses three types of timers: On-Delay (TON), Retentive On-Delay (TONR), and Off-Delay (TOF).

S7-200 Timers are provided with resolutions of 1 millisecond, 10 milliseconds, and 100 milliseconds. The maximum value of these timers is 32.767 seconds, 327.67 seconds, and 3276.7 seconds, respectively. By adding program elements, logic can be programmed for much greater time intervals.

On-Delay (TON) When the On-Delay timer (TON) receives an enable (logic 1) at its input (IN), a predetermined amount of time (preset time - PT) passes before the timer bit (T-bit) turns on. The T-bit is a logic function internal to the timer and is not shown on the symbol. The timer resets to the starting time when the enabling input goes to logic 0.

Retentive On-Delay Timer (TONR) This timer (TONR) functions in a similar manner to the On-Delay timer (TON). There is one difference. The Retentive On-Delay timer times as long as the enabling input is on, but does not reset when the input goes off. The timer must be reset with a RESET (R) instruction.

Off-Delay (TOF) This timer is used to delay an output off for a fixed period of time after the input turns off. When the enabling bit turns on the timer bit turns on immediately and the value is set to 0. When the input turns off, the timer counts until the preset time has elapsed before the timer bit turns off.

Counters

Counters used in PLCs serve the same function as mechanical counters. Counters compare an accumulated value to a preset value to control circuit functions. Control applications that commonly use counters include the following:

- Count to a preset value and cause an event to occur
- Cause an event to occur until the count reaches a preset value

Counters used in PLCs serve the same function as mechanical counters. Counters compare an accumulated value to a preset value to control circuit functions.

There are 256 counters in the S7-200, numbered CO through C255. The same number cannot be assigned to more than one counter. For example, if an up counter is assigned number 45, a down counter cannot also be assigned number 45. The maximum count value of a counter is ±32,767.

The **up counter** counts up from a current value to a preset value (PV). Input CU is the count input. Each time CU transitions from logic 0 to logic 1 the counter increments by a count of 1. Input R is the reset. A preset count value is stored in PV input. If the current count is equal to or greater than the preset value stored in PV.

The **down counter** counts down from the preset value (PV) each time CD transitions from logic 0 to logic 1. When the current value is equal to zero the counter output bit (Q) turns on (not shown). The counter resets and loads the current value with the preset value (PV) when the load input (LD) is enabled.

The **up/down counter** counts up or down from the reset value each time either CD or CU transitions from logic 0 to logic 1. When the current value is equal to the preset value, the output QU turns on. When the current value (CV) is equal to zero, the output QD turns on. The counter loads the current value (CV) with the preset value (PV) when the load input (LD) is enabled. Similarly, the counter resets and loads the current value (CV) with zero when the reset (R) is enabled. The counter stops counting when it reaches preset or zero.

6.6 TESTING A PROGRAM

Once a program has been written it needs to be tested and debugged. One way this can be done is to simulate the field inputs with an input simulator, such as the one made for the S7-200. The program is first downloaded from the programming device to the CPU. The selector switch is placed in the RUN position. The simulator switches are operated and the resulting indication is observed on the output status indicator lamps.

Status Functions After a program has been loaded and is running in the PLC, the actual status of ladder elements can be monitored using STEP 7 Micro WIN32 software. The standard method of showing a ladder element is by indicating the circuit condition it produces when the device is in the reenergized or on operated state. In the following illustration input 1 (I0.0) is programmed as a normally open (NO) contact. In this condition, power will not flow through the contacts to the output (Q0.0). When viewing the ladder diagram in the status mode, control elements that are active, or true (logic 1), are highlighted. In the example shown the toggle switch connected to input 1 has been closed. Power can now flow through the control element associated with input 1 (I0.0) and activate the output (Q0.0).

Forcing: Forcing is another useful tool in the commissioning of an application. It can be used to temporarily override the input or output status of the application in order to test and debug the program. The force function can also be used to override discrete output points. The force function can be used to skip portions of a program by enabling a jump instruction with a forced memory bit. Under normal circumstances the toggle switch, shown in the illustration below, would have to be closed to enable input 1 (I0.0) and turn on the output light. Forcing enables input 1 even though the input toggle switch is open. With input 1 forced high the output light will illuminate. When a function is forced the control bit identifier is highlighted. The element is also highlighted because it is on.

7. CONCLUSION

7. CONCLUSION

The advantages of Semi Automated Test JIG using PLC are that it is semi automatic, economical, compact, accurate, efficient and more reliable in operation. By this test JIG machine, intervention of skilled labor is not required and production rate is also increased. In general, PLC's are more robust and require less maintenance, they work better independent of the environment. Generally PLC's appear to be a better solution for many problems. The panel testing devices used in this project are very sensitive and the percentage of error is negligible. The average testing time of 3hrs is achieved to test a panel in this advanced panel-testing JIG which has taken 8hrs in case of manual testing.

8. FUTURE ENHANCEMENT

8. FUTURE ENHANCEMENT

The use of indicator lamps can be eliminated by giving these output points to another JIG PLC as input. This PLC detects its inputs. By synchronizing both the input and output PLC and checking whether the output PLC gets the correct panel output to its corresponding input, the circuit can be checked in a very short time. Thus by making the TEST JIG a fully automated one, human intervention is reduced to near zero. By connecting an LCD display or memory or a computer, the process of testing can be monitored and recorded. Thus the testing time may be reduced considerably by modifying the design of the panel-testing JIG to a fully automated one.

REFERENCES

REFERENCES

1. Albert Paul Malvino, "Programmable logic devices and logic controllers", Tata McGraw Hill publications, 5th edition, 1995-1998.

2. Hans Berger, "Programmable controller book", Technical publication,3rd edition, 2005.

3. "PLCs Toshiba programmable logic controllers introduction" ,4th Edition,1994-2001,Transtronics

4. "Microcontrollers and Programmed Logic",2nd edition, by Kenneth L.Short, 2003.

5. "An Introduction to Siemens S7-200", 1995-2002,Siemens, Inc

6. Siemens Software: STEP7 micro/win32, Version 3.1

7. http://www.plc.com

8. http://www.logiccontrollers.com

9. http://www.automation.siemens.com/_en/s7-200/index.htm

10. http://www.automation.siemens.com/_en/s7-200/Products/01CPUs/cpu226.html

11. http://en.wikipedia.org/wiki/Continuity_test

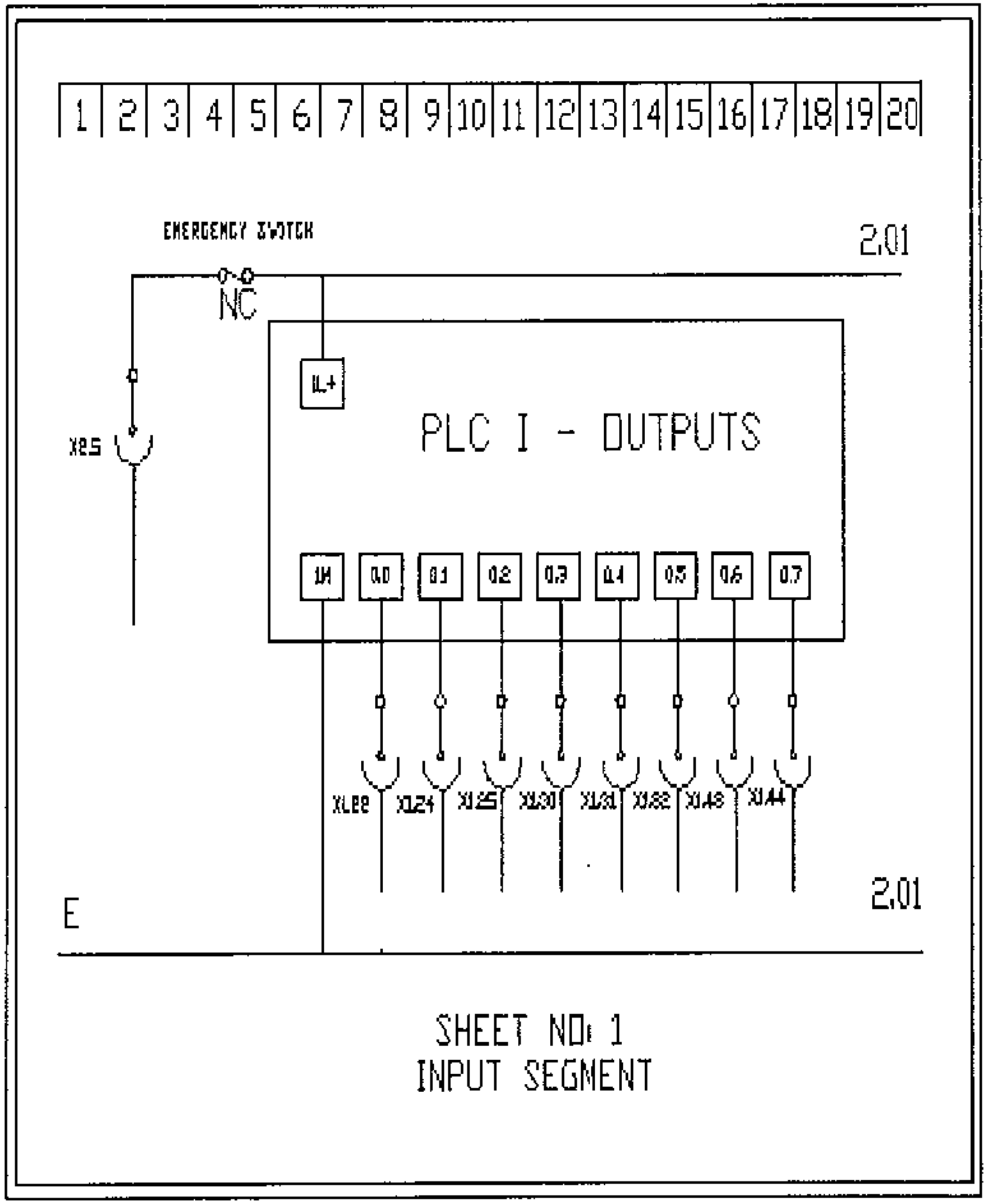
12. www.acmehowto.com/howto/homemaintenance/electrical/**continuitytest**.php

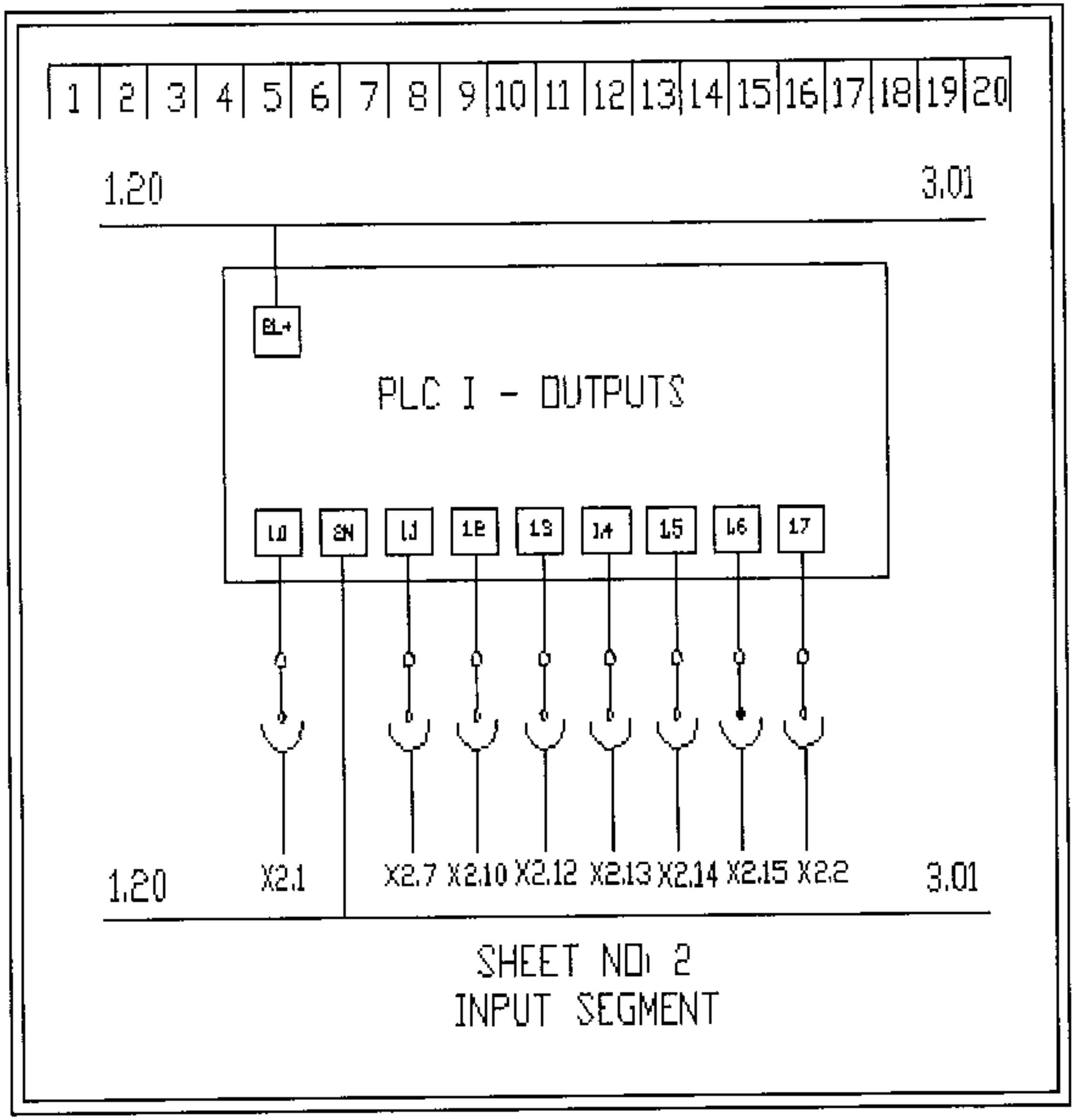
13. www.**teknic**.co.in

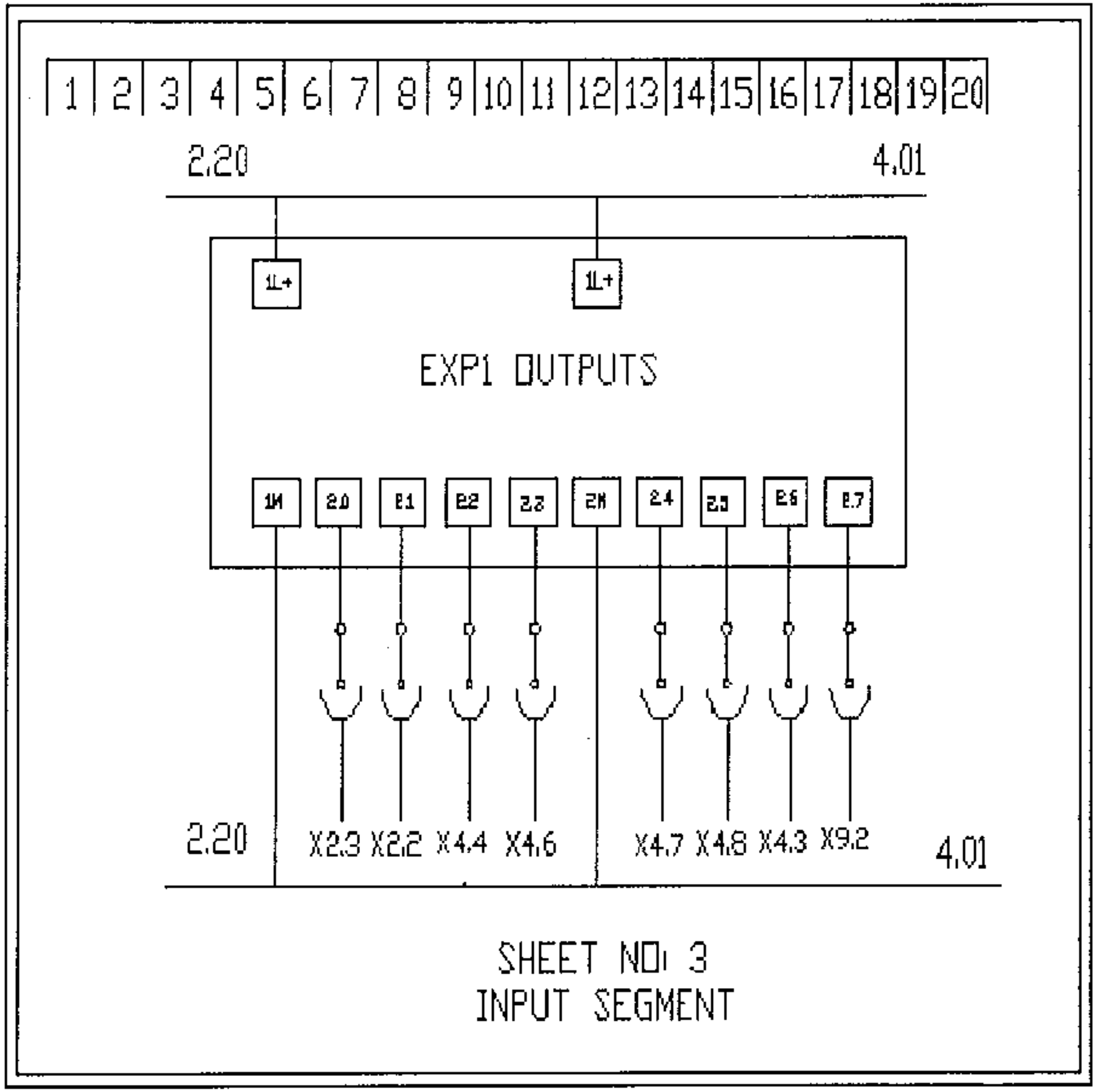
14. http://www.automation.siemens.com/_en/s7-200/Products/02Erweiterungsmodule/digital.html

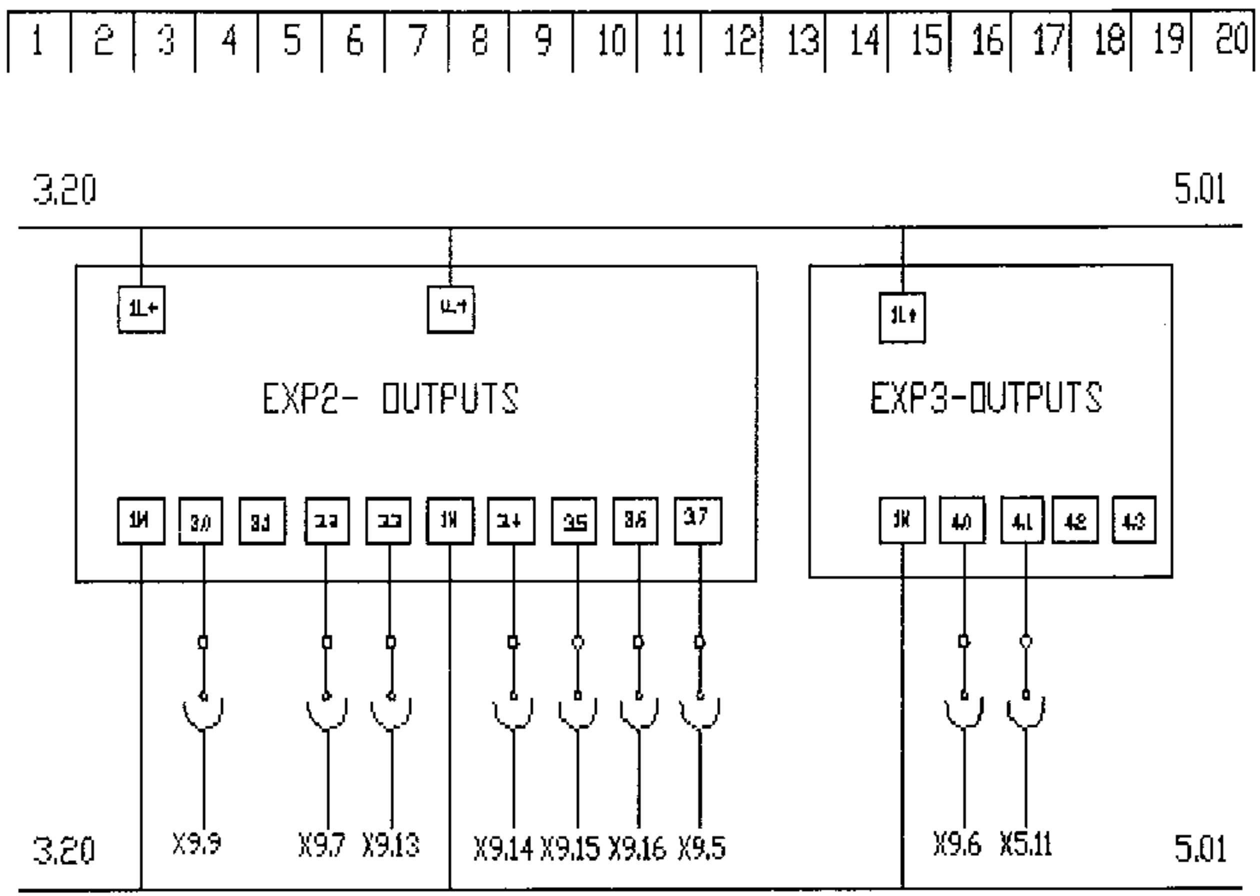
APPENDIX A

CIRCUIT DIAGRAM

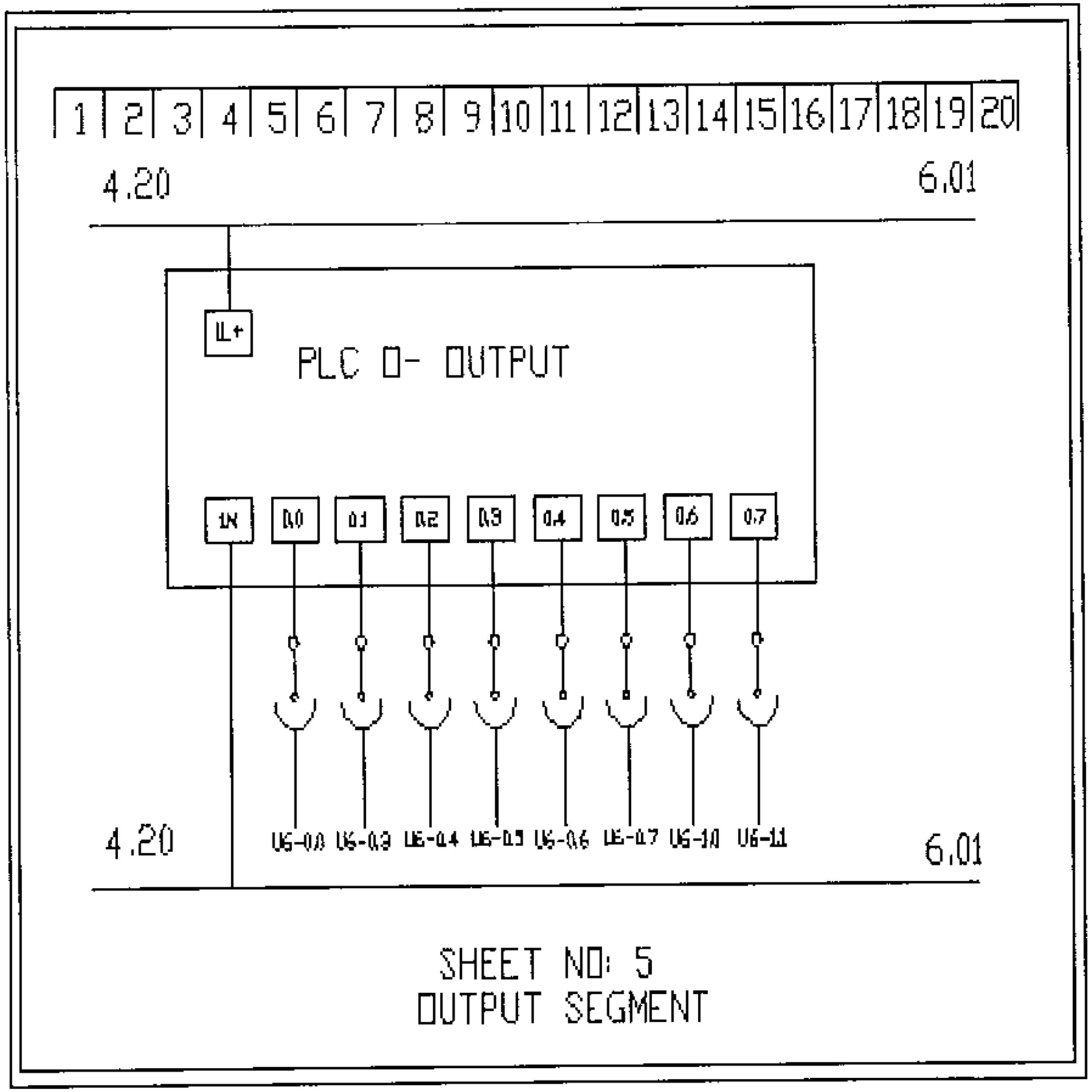

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
EMERGENCY SWITCH
NC
2.01
PLC I - OUTPUTS
2.01
E
SHEET NO: 1
INPUT SEGMENT

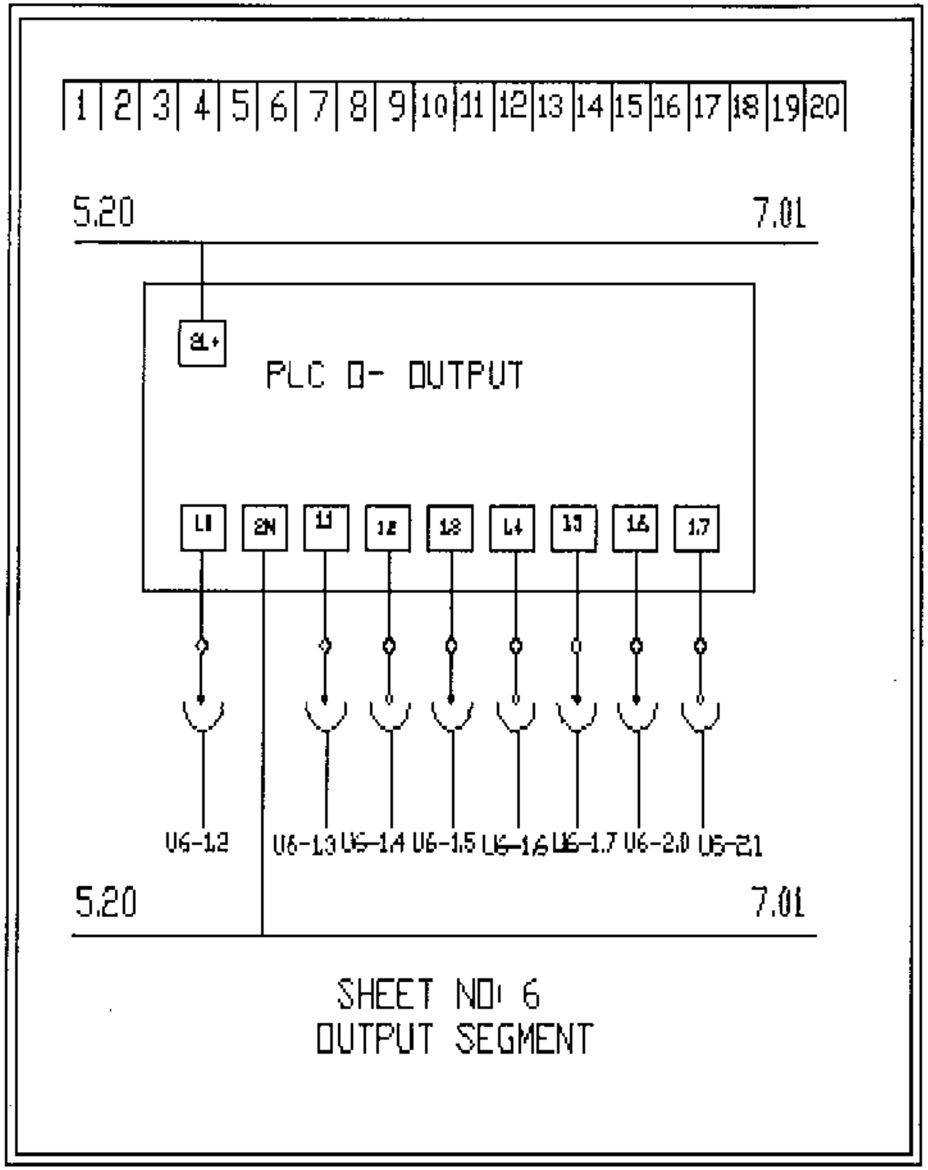

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
1.20
3.01
BL+
PLC I - OUTPUTS
2N
X2.1
X2.7 X2.10 X2.12 X2.13 X2.14 X2.15 X2.2
1.20
3.01
SHEET NO. 2
INPUT SEGMENT


1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
2.20
4.01
1L+
1L+
EXP1 OUTPUTS
1M
2.0
2.1
2.2
2.3
2M
2.4
2.5
2.6
2.7
2.20
X2.3
X2.2
X4.4
X4.6
X4.7
X4.8
X4.3
X9.2
4.01
SHEET NO: 3
INPUT SEGMENT

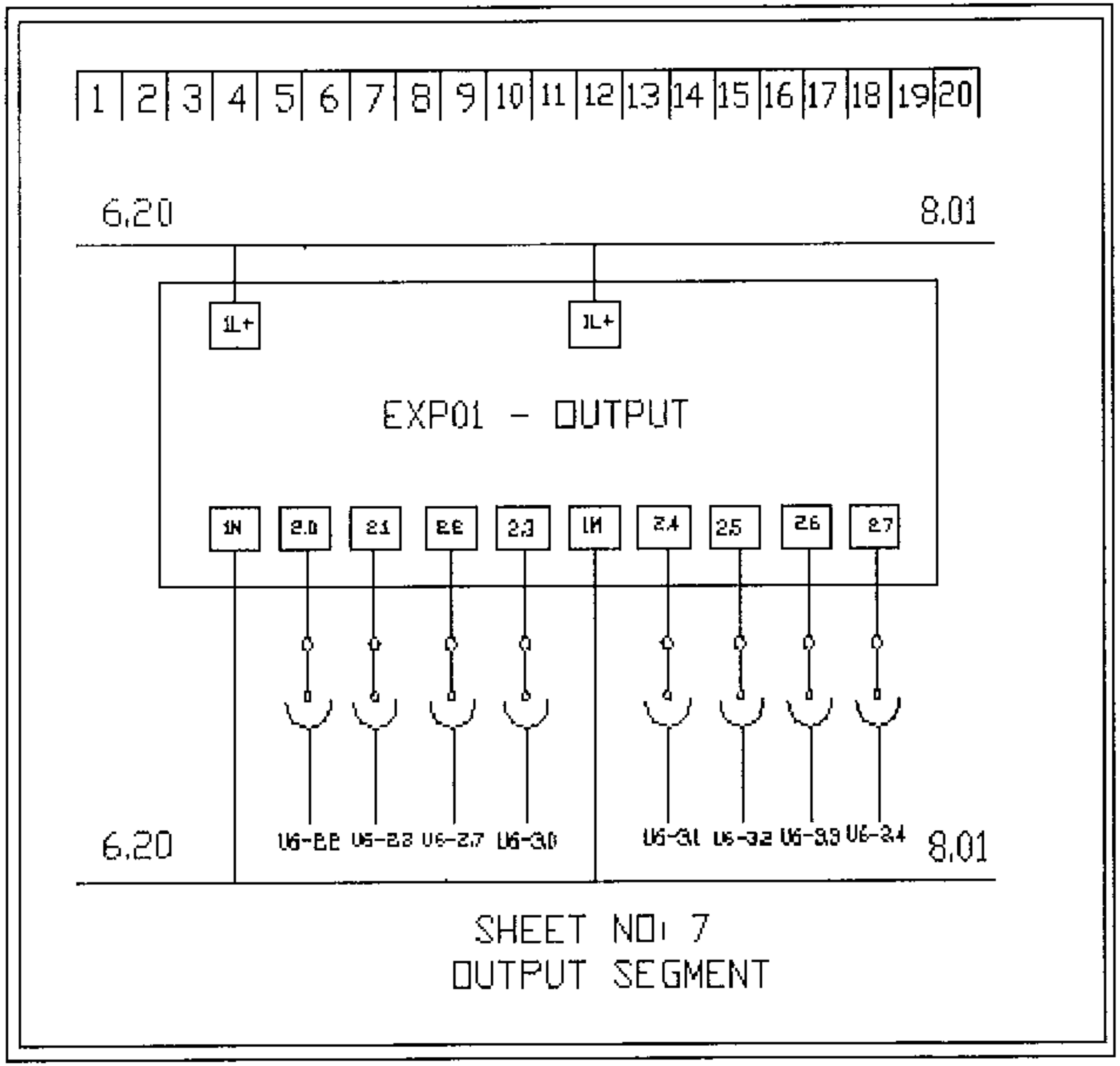


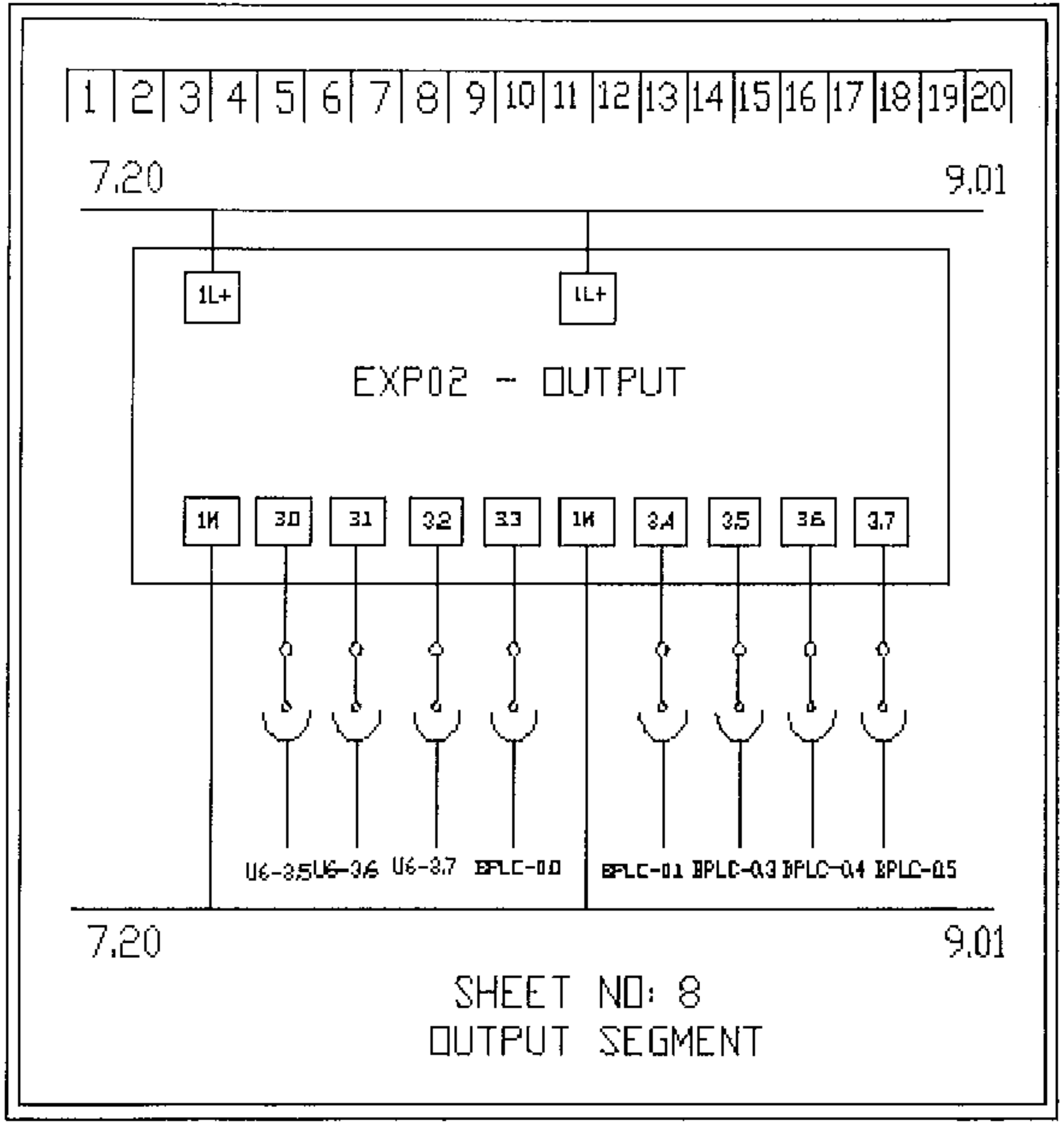
SHEET NO. 4
INPUT SEGMENT

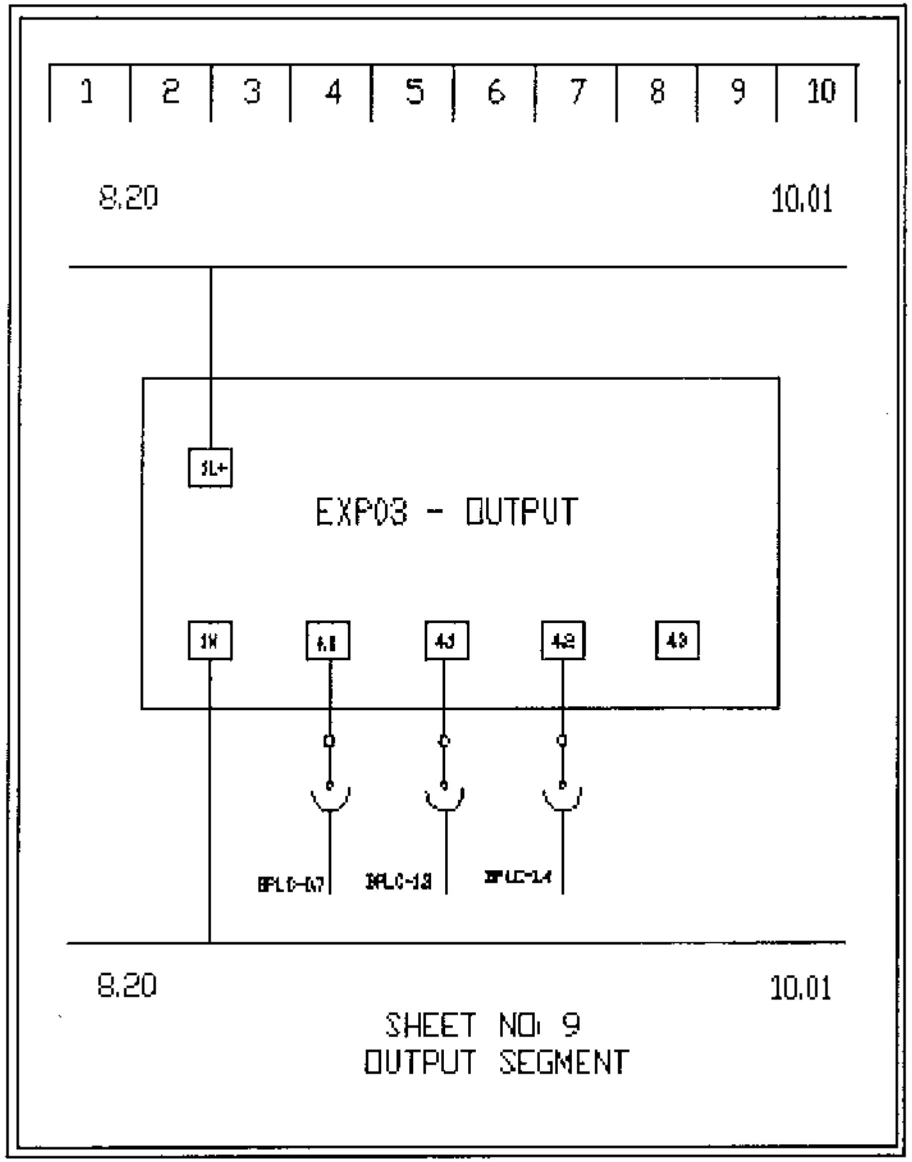

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
4.20
6.01
1L+
PLC O- OUTPUT
1N
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
U6-0.0
U6-0.3
U6-0.4
U6-0.5
U6-0.6
U6-0.7
U6-1.0
U6-1.1
4.20
6.01
SHEET NO: 5
OUTPUT SEGMENT

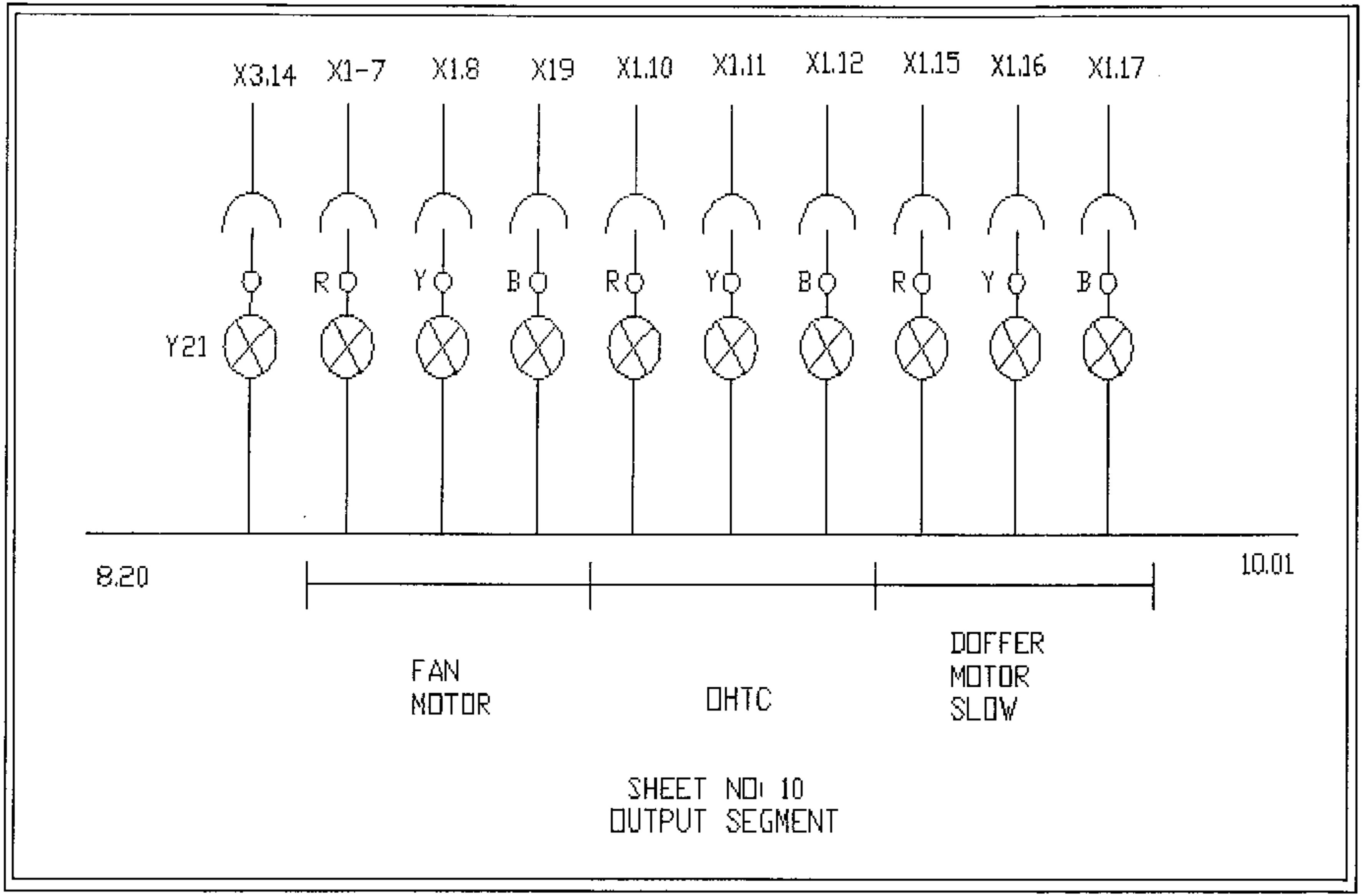


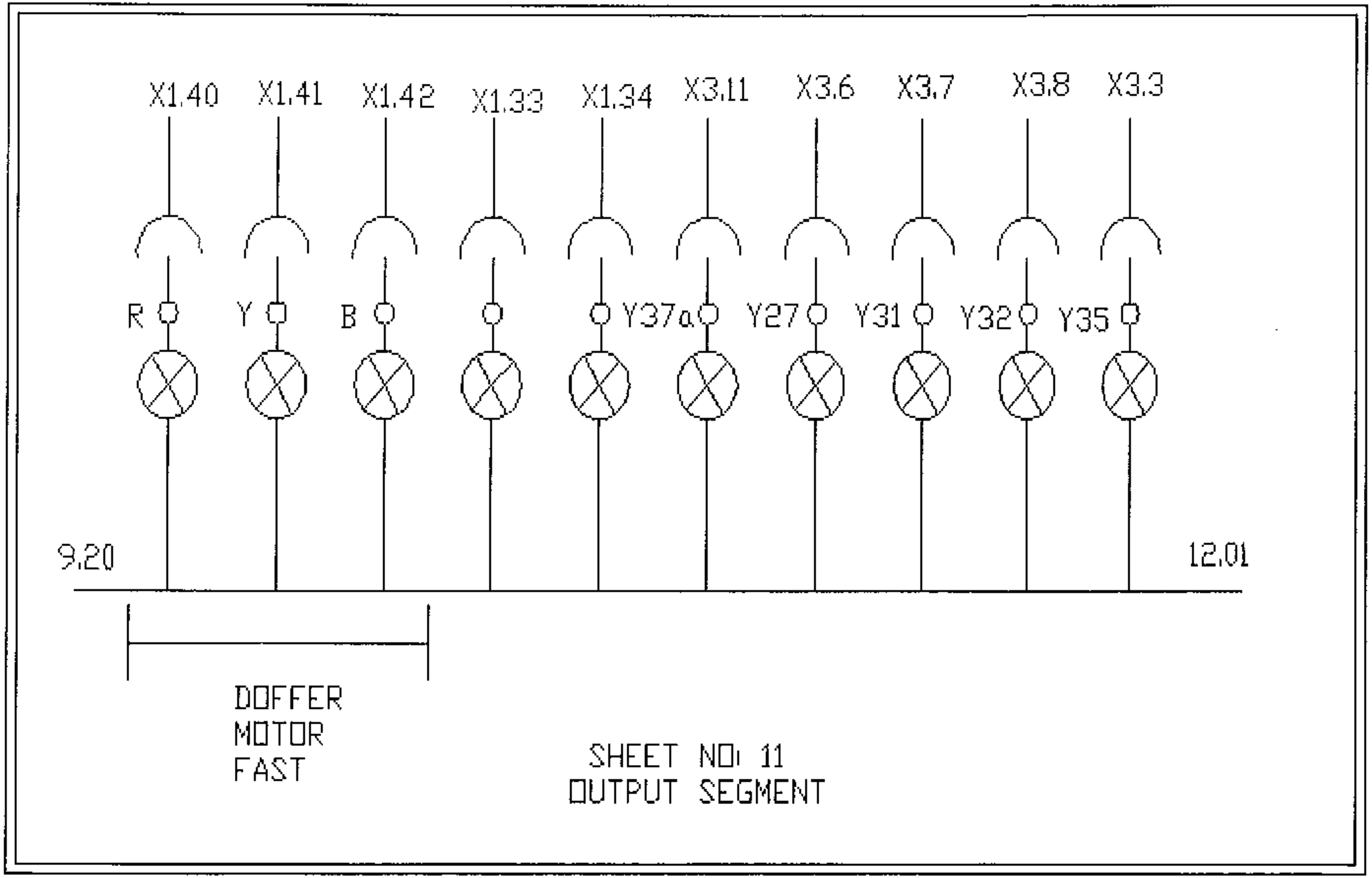
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
5.20
7.01
PLC O- OUTPUT
U6-1.2
U6-1.3
U6-1.4
U6-1.5
U6-1.6
U6-1.7
U6-2.0
U6-2.1
5.20
7.01
SHEET NO: 6
OUTPUT SEGMENT

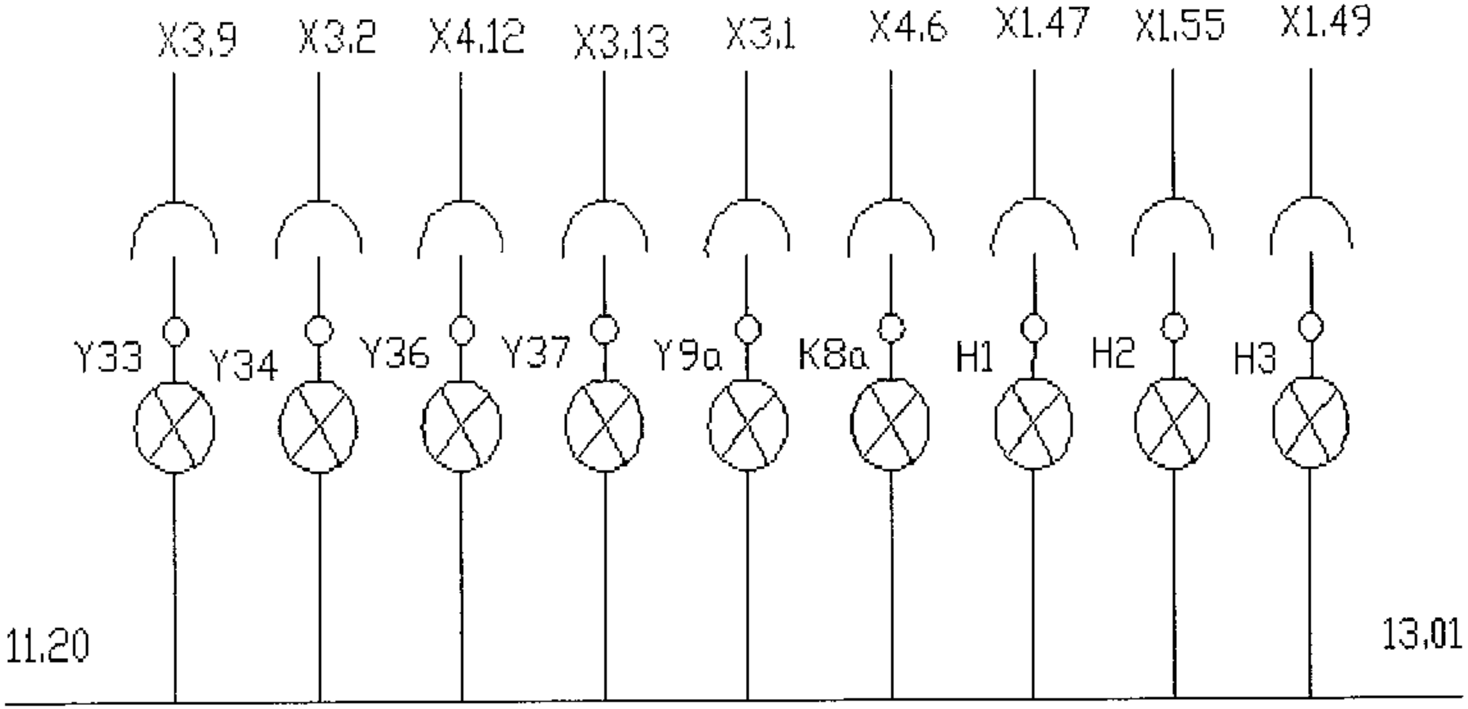

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
6.20
8.01
1L+
1L+
EXP01 - OUTPUT
1N
2.0
2.1
2.3
1M
2.4
2.5
2.6
2.7
6.20
8.01
SHEET NO: 7
OUTPUT SEGMENT


1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
7.20
9.01
1L+
1L+
EXP02 - OUTPUT
1M
3.0
3.1
3.2
3.3
1M
3.4
3.5
3.6
3.7
U6-3.5
U6-3.6
U6-3.7
BPLC-0.0
BPLC-0.1
BPLC-0.3
BPLC-0.4
BPLC-0.5
7.20
9.01
SHEET NO: 8
OUTPUT SEGMENT

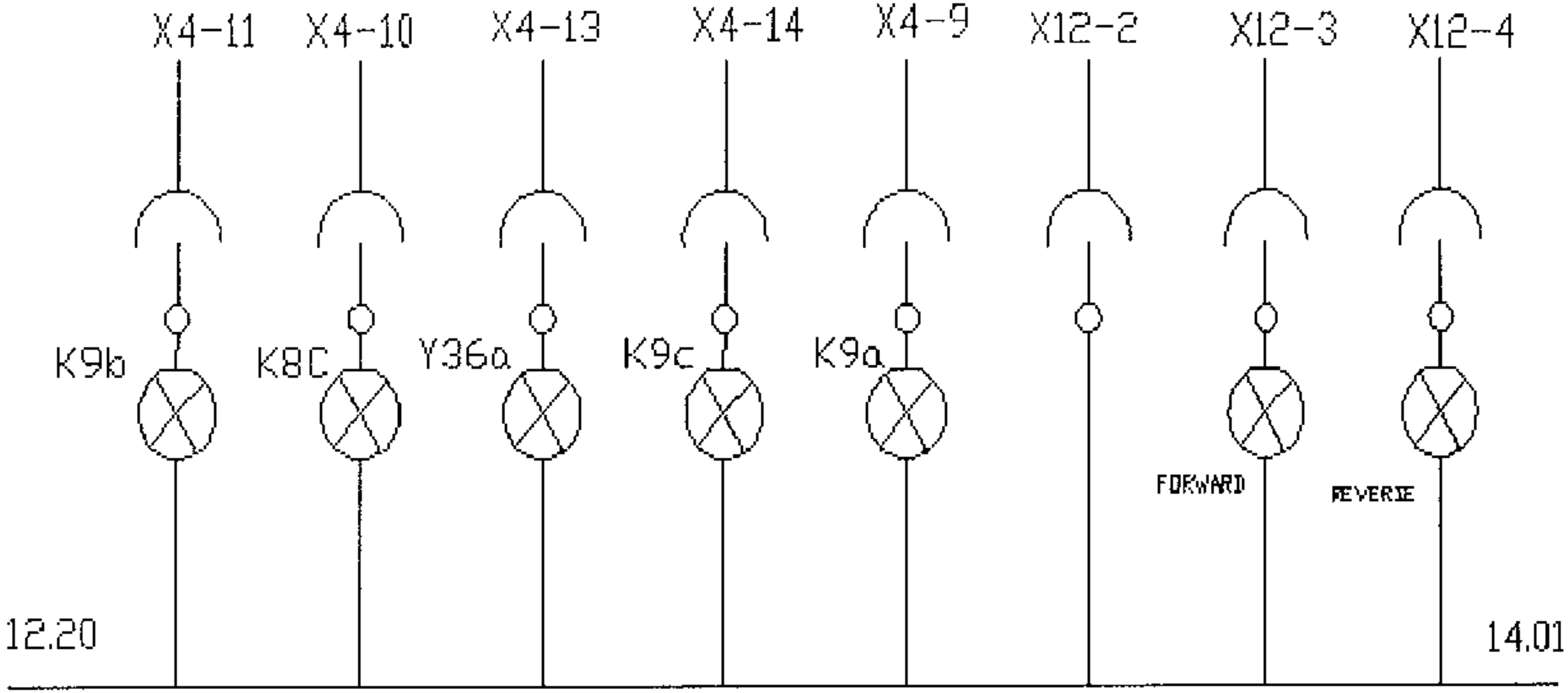

1 2 3 4 5 6 7 8 9 10
8.20
10.01
1L+
EXP03 - OUTPUT
1M
8.20
10.01
SHEET NO. 9
OUTPUT SEGMENT


X3.14
X1-7
X1.8
X19
X1.10
X1.11
X1.12
X1.15
X1.16
X1.17
Y21
R
Y
B
R
Y
B
R
Y
B
8.20
10.01
FAN MOTOR
OHTC
DOFFER MOTOR SLOW
SHEET NO: 10
OUTPUT SEGMENT

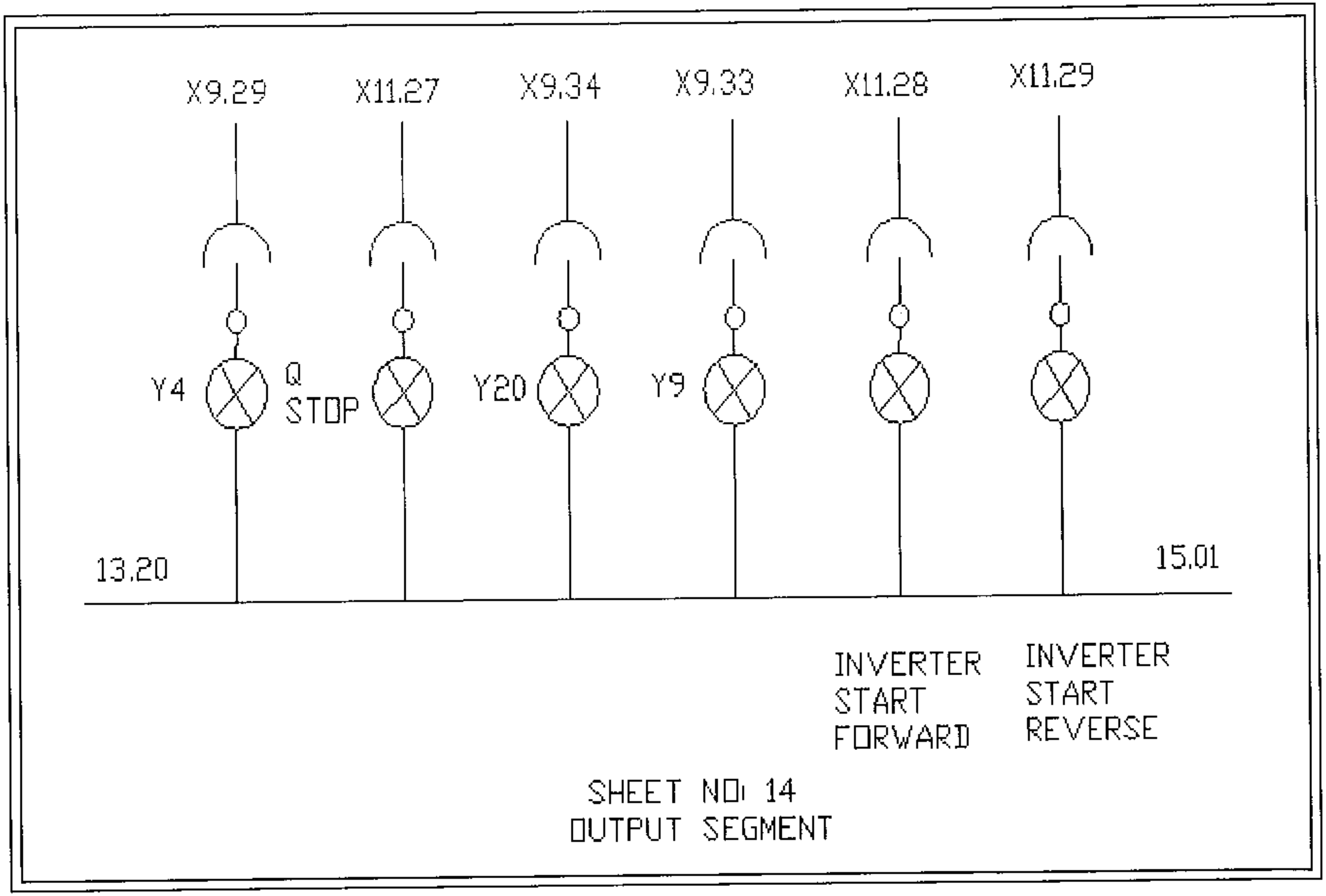

X1.40
X1.41
X1.42
X1.33
X1.34
X3.11
X3.6
X3.7
X3.8
X3.3
R
Y
B
Y37a
Y27
Y31
Y32
Y35
9.20
12.01
DOFFER
MOTOR
FAST
SHEET NO. 11
OUTPUT SEGMENT

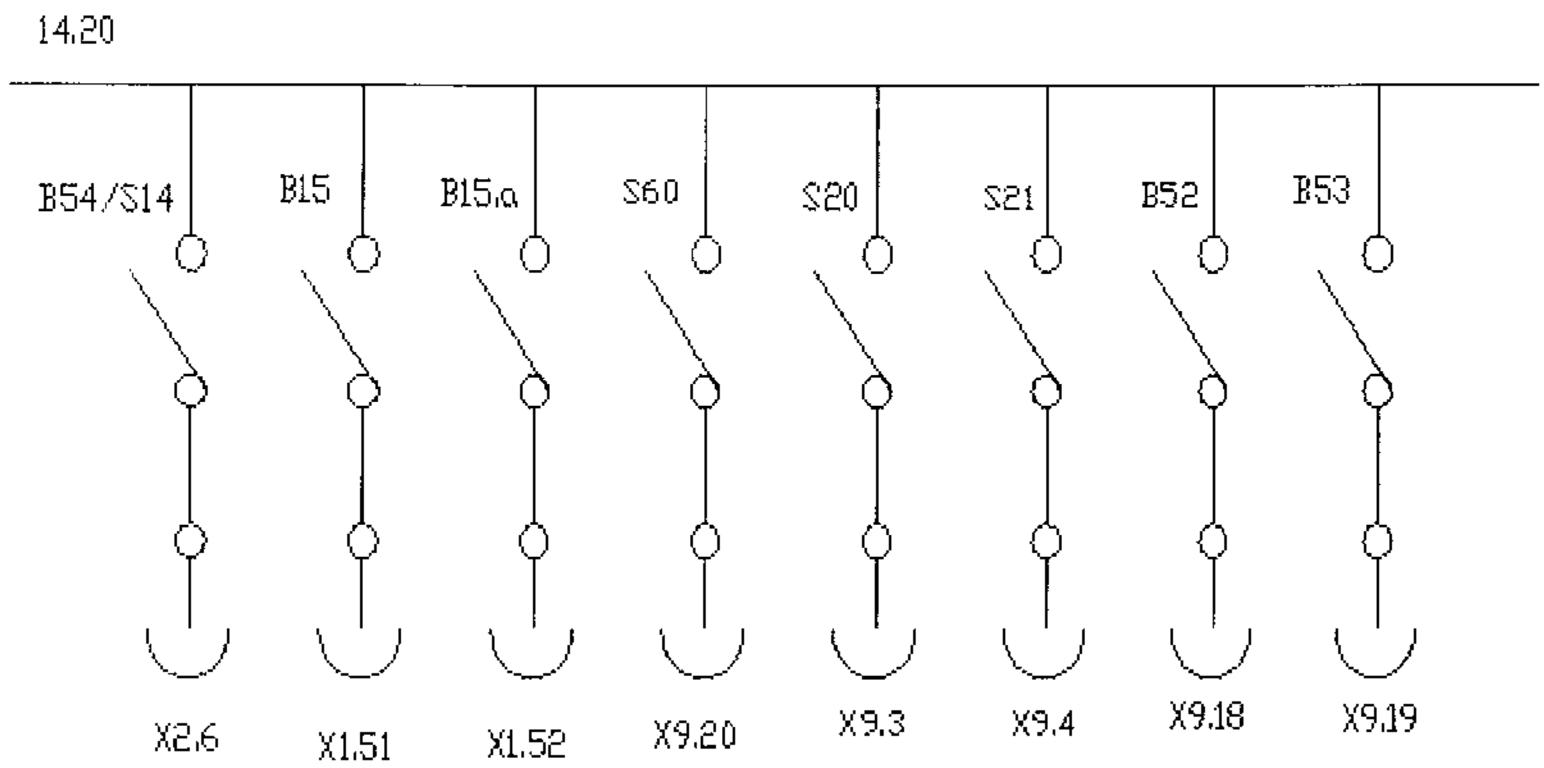


SHEET NO: 12
OUTPUT SEGMENT



SHEET NO: 13
OUTPUT SEGMENT


X9.29
X11.27
X9.34
X9.33
X11.28
X11.29
Y4
Q
STOP
Y20
Y9
13.20
15.01
INVERTER
START
FORWARD
INVERTER
START
REVERSE
SHEET NO: 14
OUTPUT SEGMENT



SHEET NO: 15
OUTPUT SEGMENT

APPENDIX B

CONTROL CORD

CONTROL CARD

DRAWING NUMBER :	DESCRIPTION	: Ring Frame LR60 / AX Panel	
CONTROL CARD NO :	DRG. ALT / ISSUE DATE	: 05.04.2009	Sample Size/
LOCATION : QACP - Final Inspection	INSPECTION LEVEL	: -	AQL = 100%

S.no	Test Functions	Inspection Instruments
1	**Panel Identification**	
	Serial Number Written on the Sticker and to be Affixed with the Panel Box.	Visual
1a	**Check List Verification**	
	Ensure the Component Details as per given Check List.	Visual
2	**Earth Looping**	
	Check Continuty between Starting Point and Finishing Point of Earthing Wires.	Multimeter
3	**Electrical Functions**	
	1.Test Jig Initial Condition - Tail Stock	
	1. Connect the Test Jig Wires and Cables to Corresponding Terminals / Socket.	-
	2. Connect the 3 Phase Cable to the F1 Terminal 2,4 and 6.	-
	3. Keep Q2,Q5,Q3 and Q6 MPCB's are in ON Position.	-
	4. Keep all the Switches are OFF and Emergency Switch is in Released Condition in Tail Stock Test Jig.	-
	5. Emergency Switch is in Released Condition in Tail Stock Panel.	-
	6. Connect the communication Cable Between Head and Tail Stock PLC in Port '0'.	-
	7. Keep PLC in STOP Mode in Haed Stock and Tail Stock Panels.	-
	8. Ensure L+ and M Wires are Connected to Corresponding Terminals in respective PLC's.	-
	9. Switch ON the 3 Phase AC Supply.	-
	10. Connect the 220V Test Lamp between Earth and Q0 Main Switch 2,4 and 6 Terminals.	-
	-- Test Lamp is glow	Visual
	11. Switch ON the Q0 Main Switch.	-
	11a. Energy Meter is Energised, If Energy Meter is Connected.	Visual
	12. Connect the 220V Test Lamp between Earth and K1 Contactor 1,3 and 5 Terminal.	-
	-- Test Lamp is glow	Visual
	13. Connect the 220V Test Lamp between Power Filter Z100,Z101,Z102 Input Output Terminal.	-
	-- Test Lamp is glow	Visual
	14. Connect the 220V Test Lamp between Earth and Q2 MCCB 1,3 and 5 Terminals.	-
	-- Test Lamp is glow	Visual
	15. Connect the 220V Test Lamp between Earth and K2 Contactor 1,3 and 5 Terminals.	-
	-- Test Lamp is glow	Visual
	16. Press Q2 MCCB Red button.	-
	-- Test Lamp is OFF	Visual
	17. Press Q2 MCCB Green button.	-
	-- Test Lamp is glow	Visual
	18. Connect the 220V Test Lamp between Earth and Q5 MCCB 1,3 and 5 Terminals.	-
	19. Connect the 220V Test Lamp between Earth and K5 Contactor 1,3 and 5 Terminals.	-
	-- Test Lamp is glow	Visual
	20. Press Q5 MCCB Red button.	-
	-- Test Lamp is OFF	Visual
	21. Press Q5 MCCB Green button.	-

-- Test Lamp is glow	Visual
22. Connect the 220V Test Lamp between Earth and Q3 MCCB 1,3 and 5 Terminals.	-
-- Test Lamp is glow	Visual
23. Connect the 220V Test Lamp between Earth and K3a,K3b Contactor 1,3 & 5 Terminals.	-
-- Test Lamp is glow	Visual
24. Press Q3 MCCB Red button.	-
-- Test Lamp is OFF	Visual
25. Press Q3 MCCB Green button.	-
-- Test Lamp is glow	Visual
26. Connect the 220V Test Lamp between Earth and Q6 MCCB 1,3 and 5 Terminals.	-
-- Test Lamp is glow	Visual
27. Connect the 220V Test Lamp between Earth and K6a,K6b Contactor 1,3 and 5 Terminals.	-
-- Test Lamp is glow	Visual
28. Press Q6 MCCB Red button.	-
-- Test Lamp is OFF	Visual
29. Press Q6 MCCB Green button.	-
-- Test Lamp is glow	Visual
30. Connect the 220V Test Lamp between Earth and F1(1) and F2(1) MCB's.	-
-- Test Lamp is glow	Visual
31. Switch ON F1,F2 MCB and Connect the 220 V Test Lamp between 0V and 220V in 320 VA and 220 VA Transformer T1.	-
-- Test Lamp is glow	Visual
31a. Switch ON F1,F2 MCB and Connect the 220 V Test Lamp between 0V and 220V in Transformer T2.	-
-- Test Lamp is glow	Visual
32. Connect the Test Lamp between Earth and Terminal X1(13) Earth and Terminal X1(14).	-
-- Test Lamp is glow	Visual
33. Connect the Test lamp between Earth & Terminal X11(13) Earth & Terminal X11(14) and Earth & MCB F1a(1),F2a(1) in Head Stock Panel.	-
-- Test Lamp is glow.	Visual
34. Switch ON F1a,F2a MCB and Connect the 220V Test Lamp between 0V and 220V in Transformer T1a and T2a in Head Stock Panel.	-
-- Test Lamp is glow	Visual
35. Set K4 Timer in 5 Seconds Tail Stock Panel.	-
36. Switch ON F3 MCB in Tail Stock Panel.	-
-- F4 Thermister Energised.	Visual
-- K4 Timer Energised and Tripping after 5 Seconds.	Visual
37. Switch ON F3b MCB in Tail Stock Panel.	-
<u>For Rittal Fan</u>	
-- M4 Exhaust Fan runs at Panel Door at Top Side.	Visual
-- M5 Cooling Fan Runs at Panel Door at Bottom Side.	Visual
<u>For Nadi Fan</u>	
-- M4 Exhaust Fan runs at Panel box at Top Side.	Visual
38. After K4 Timer Tripping	-
-- K3 Relay is ON.	Visual
-- K1 contactor is ON.	Visual
-- U1 Invertor is ON.	Visual
-- Orange Colour LED is glow in U6 PLC.	Visual
-- Green LED is glow in U8 Power Supply.	Visual
2. DC Voltage Setting.	
1. Set the DC Voltage between 7(-Ve) and 9(-Ve) Terminals in U8 Power supply Unit and Paste the Protection Sticker on Potentio Meter in Tail Stock Panel.	-
-- 24 Volts + 0.3 V	Multimeter

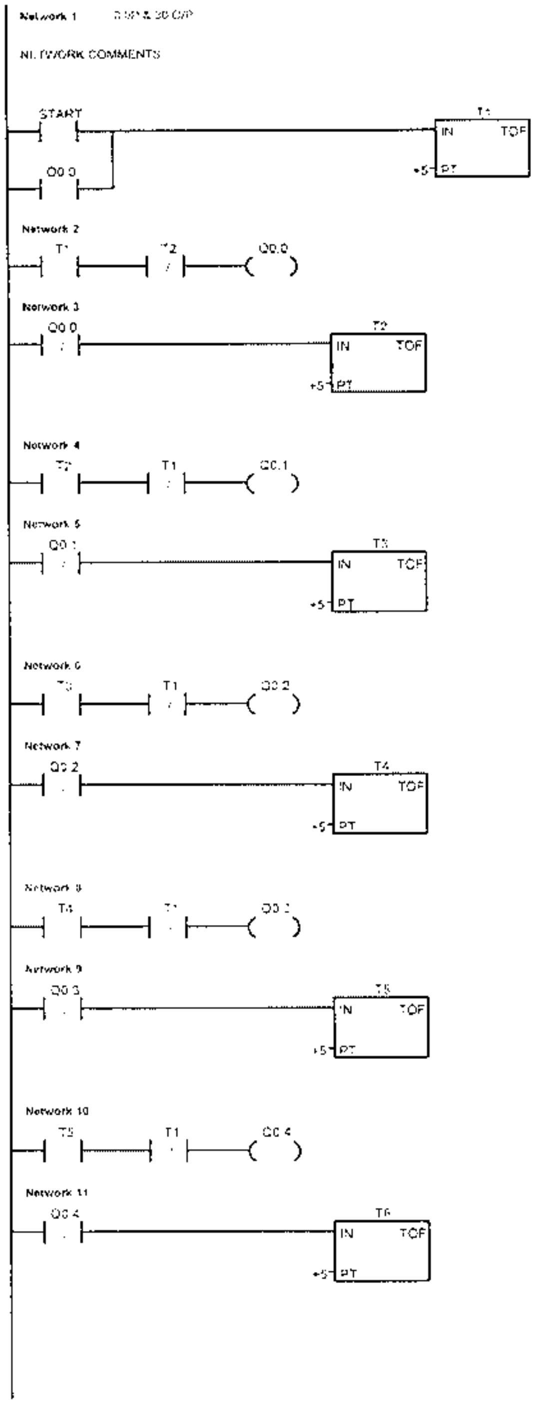
2. Switch ON the F5 MCB.	-
-- Inputs LED glow in U6 Base and Expansion PLC.	Visual
-- U7 Display Unit Displayed.	Visual
3. PLC Digital Input Signal Test - Tail Stock Panel	
1. Check All the PLC Digital Input Signal by Actuating Corresponding Switch - As Per Tail Stock Drawing.	-
-- Green Colour LED glow in PLC Digital Input Module for 10Sec.	Visual
2. 0.1 LED's are glow in Base PLC	Visual
3. Press S11 Push button Switch in Tail Stock Panel.	-
-- 0.2 LED is glow in Base PLC	Visual
4. Release S11 push button Switch in Tail Stock Panel.	-
-- 0.2 LED is OFF in Base PLC	Visual
5. -- 0.3 LED is glow in Base PLC	Visual
6. -- 0.6 LED is glow in Base PLC	Visual
7. -- 1.2 LED is glow in Base PLC	Visual
8. -- 1.3 LED is glow in Base PLC	Visual
9. -- 1.4 LED is glow in Base PLC	Visual
10. -- 1.5 LED is glow in Base PLC	Visual
11. -- 1.6 LED is glow in Base PLC	Visual
12. -- 1.7 LED is glow in Base PLC	Visual
13. -- 2.0 LED is glow in Base PLC	Visual
14. -- 2.1 LED is glow in Base PLC	Visual
15. -- 2.3 LED is glow in Base PLC	Visual
16. -- 2.4 LED is glow in Base PLC	Visual
17. -- 2.5 LED is glow in Base PLC	Visual
18. -- 2.6 LED is glow in Base PLC	Visual
19. Press S13 Push button Switch in Tail Stock Panel.	-
-- 2.7 LED is glow in Base PLC	Visual
20. Release S13 Push button Switch in Tail Stock Panel.	-
-- 2.7 LED is OFF in Base PLC	Visual
21. -- 3.0 LED glow in Expansion - 1 PLC.	Visual
22. -- 3.1 LED glow in Expansion - 1 PLC.	Visual
23. -- 3.2 LED glow in Expansion - 1 PLC.	Visual
24. -- 3.3 LED glow in Expansion - 1 PLC.	Visual
25. -- 3.4 LED glow in Expansion - 1 PLC.	Visual
26. -- 3.5 LED glow in Expansion - 1 PLC.	Visual
27. Switch ON B54/S14 Selector Switch in tail Stock Test Jig.	-
-- 3.7 LED is glow in Expansion -1 PLC	Visual
28. Switch OFF B54/S14 Selector Switch in Tail Stock Test Jig.	-
-- 3.7 LED is OFF in Expansion -1 PLC	Visual
29. Switch ON B15 Selector Switch in tail Stock Test Jig.	-
-- 4.0 LED is glow in Expansion -1 PLC	Visual
30. Switch OFF B15 Selector Switch in Tail Stock Test Jig.	-
-- 4.0 LED is OFF in Expansion -1 PLC	Visual
31. Switch ON B15A Selector Switch in tail Stock Test Jig.	-
-- 4.1 LED is glow in Expansion -1 PLC	Visual
32. Switch OFF B15A Selector Switch in Tail Stock Test Jig.	-
-- 4.1 LED is OFF in Expansion -1 PLC	Visual
33. -- 4.4 LED glow in Expansion - 1 PLC.	Visual
34. -- 4.5 LED glow in Expansion - 1 PLC.	Visual
35. -- 4.6 LED glow in Expansion - 1 PLC.	Visual

4. Test Jig Initial Condition - Head Stock	
1. Keep all the Switches are OFF and Emergency Switch is in Released Condition in Head Stock Test Jig.	-
2. Emergency Switch is in Released Condition in Head Stock Panel.	-
3. Switch ON F3a MCB in Head Stock Panel.	-
<u>For Rittal Fan</u>	
-- M5 Cooling Fan Runs at Panel at Bottom Side.	Visual
<u>For Nadi Fan</u>	
-- M5 Exhaust Fan Runs at Panel box at Top Side.	Visual
-- Y20 Lamp is glow in Head Stock Test Jig.	Visual
-- K4 Timer is Energised and Tripping after 5 Seconds.	Visual
4. After K4 Timer is Tripping,	-
-- K3 Relay is ON.	Visual
-- Orange Colour LED is glow in U5 PLC.	Visual
-- Green Colour LED is glow in U8 Power Supply.	Visual
-- Y2 Lamp is glow in Head Stock Test Jig.	Visual
6. DC Voltage Setting.	
1. Set the DC Voltage between 7(-Ve) and 9(-Ve) Terminals in U8 Power supply Unit and Stick the Protection Sticker on Potentio Meter in Head Stock Panel.	-
-- 24 Volts + 0.3 V	Multimeter
2. Switch ON the F5a MCB.	-
-- Inputs LED glow in U5 Base and Expansion PLC for 10 Secs.	Visual
7. PLC Digital Input Signal Test Head Stock Panel	
1. -- 0.0 LED glow in Base PLC.	Visual
2. -- 0.1 LED glow in Base PLC.	Visual
3. -- 0.2 LED glow in Base PLC.	Visual
4. Switch ON S21 Selector Switch in Head Stock Test Jig.	-
-- 0.3 LED is glow in Base PLC	Visual
5. Switch OFF S21 Selector Switch in Head Stock Test Jig.	-
-- 0.3 LED is OFF in Base PLC	Visual
6. -- 1.2 LED glow in Base PLC.	Visual
7. -- 1.4 LED glow in Base PLC.	Visual
8. -- 1.5 LED glow in Base PLC.	Visual
9. -- 1.6 LED glow in Base PLC.	Visual
10. -- 1.7 LED glow in Base PLC.	Visual
11. --2.1 LED glow in Base PLC.	Visual
12. -- 2.2 LED glow in Base PLC.	Visual
13. Switch ON B52 Selector Switch in Head Stock Test Jig.	-
-- 2.3 LED glow in Base PLC	Visual
14. Switch OFF B52 Selector Switch in Head Stock Test Jig.	-
-- 2.3 LED OFF in Base PLC	Visual
15. Switch ON B53 Selector Switch in Head Stock Test Jig.	-
-- 2.4 LED glow in Base PLC	Visual
16. Switch OFF B53 Selector Switch in Head Stock Test Jig.	-
-- 2.4 LED OFF in Base PLC	Visual
12. -- 2.0 LED glow in Base PLC.	Visual
8.PLC Digital Output Signal Test Tail Stock Panel	
Outputs LAMPS glow in Test JIG for 10 Secs.	Visual
1. Output LAMP --- Y21 glow in Test JIG	Visual
2. Output LAMPS --- FAN MOTOR glows in Test JIG	Visual
3. Output LAMPS --- OHTC glows in Test JIG	Visual

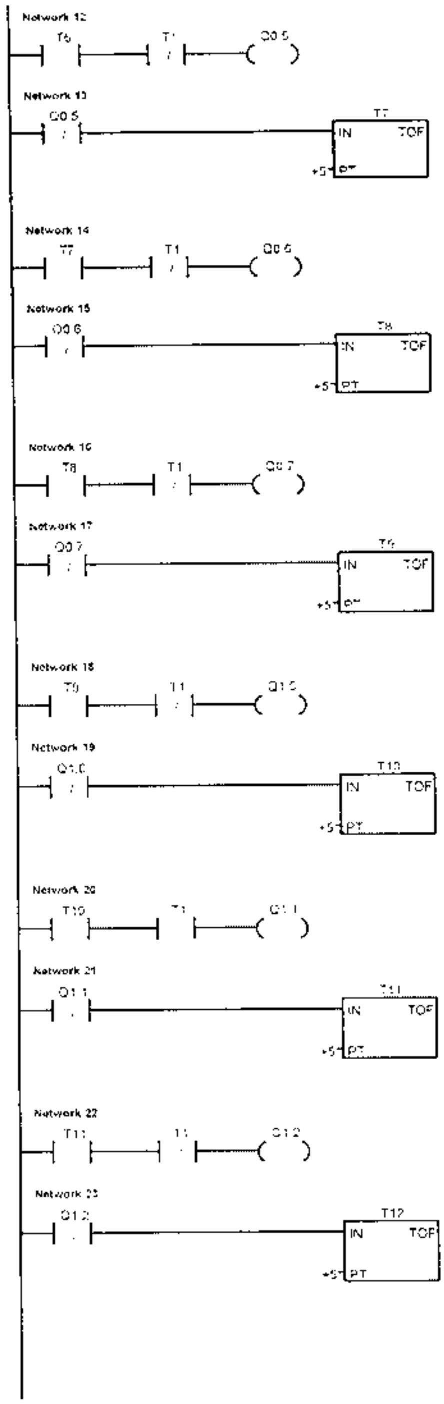
4. Output LAMPS --- DOFFER MOTOR SLOW SPEED glows in Test JIG	Visual
5. Output LAMPS --- DOFFER MOTOR FAST SPEED glows in Test JIG	Visual
6. Output LAMP --- K13 glow in Test JIG	Visual
7. Output LAMP --- Y37A glow in Test JIG	Visual
8. Output LAMP --- Y27 glow in Test JIG	Visual
9. Output LAMP --- Y31 glow in Test JIG	Visual
10. Output LAMP --- Y32 glow in Test JIG	Visual
11. Output LAMP --- Y35 glow in Test JIG	Visual
12. Output LAMP --- Y33 glow in Test JIG	Visual
13. Output LAMP --- Y34 glow in Test JIG	Visual
14. Output LAMP --- Y36 glow in Test JIG	Visual
15. Output LAMP --- Y37 glow in Test JIG	Visual
16. Output LAMP --- Y9A glow in Test JIG	Visual
17. Output LAMP --- K8A glow in Test JIG	Visual
18. Output LAMP --- H1 glow in Panel	Visual
19. Output LAMP --- H2 glow in Panel	Visual
20. Output LAMP --- H3 glow in Panel	Visual
21. Output LAMP --- K9B glow in Test JIG	Visual
22. Output LAMP --- K8C glow in Test JIG	Visual
23. Output LAMP --- Y36A glow in Test JIG	Visual
24. Output LAMP --- K9C glow in Test JIG	Visual
25. Output LAMP --- K9A glow in Test JIG	Visual
9.PLC Digital Output Signal Test Head Stock Panel	
1. Output LAMP --- LAPPET MOTOR FORWARD glow in Test JIG	Visual
2. Output LAMP --- LAPPET MOTOR REVERSE glow in Test JIG	Visual
3. Output LAMP --- Y4 glow in Test JIG	Visual
4. Output LAMP --- Q STOP glow in Test JIG	Visual
5. Output LAMP --- Y20 glow in Test JIG	Visual
6. Output LAMP --- Y9 glow in Test JIG	Visual
7. Output LAMP --- START FWD TO INVERTER glow in Test JIG	Visual
8. Output LAMP --- START REV TO INVERTER glow in Test JIG	Visual

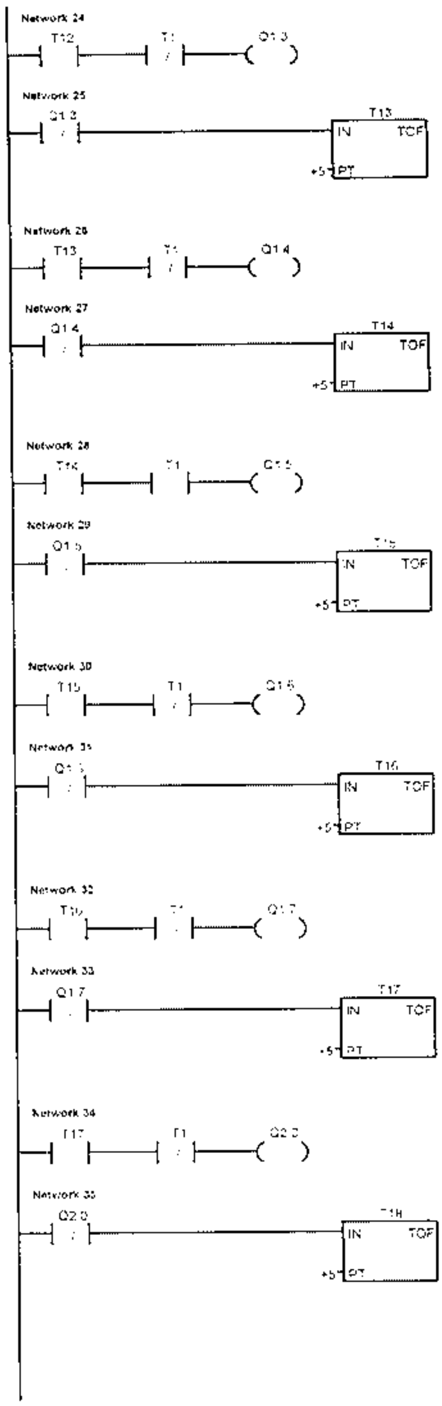
APPENDIX C

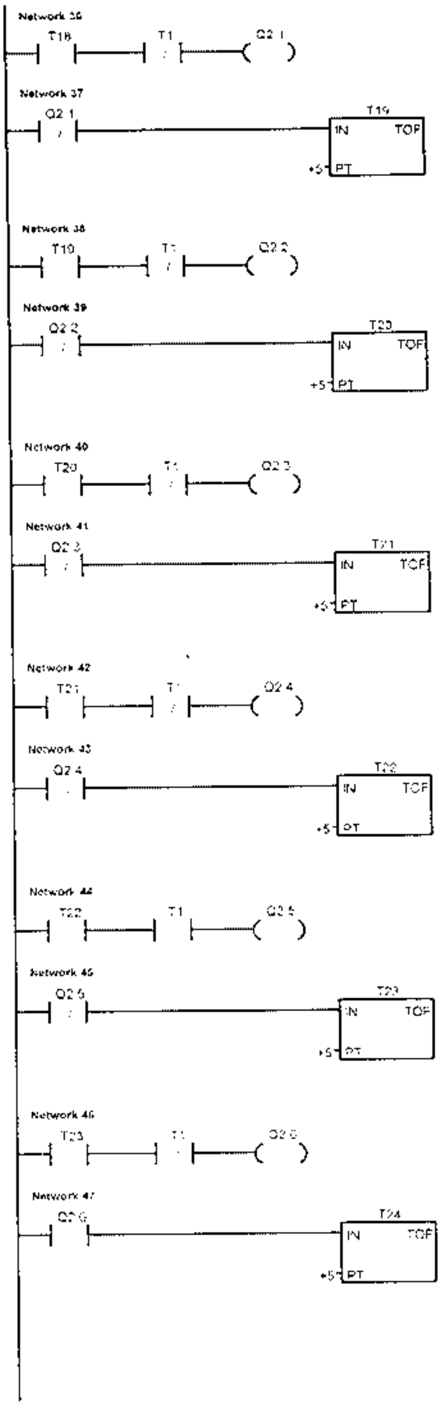
LADDER LOGIC

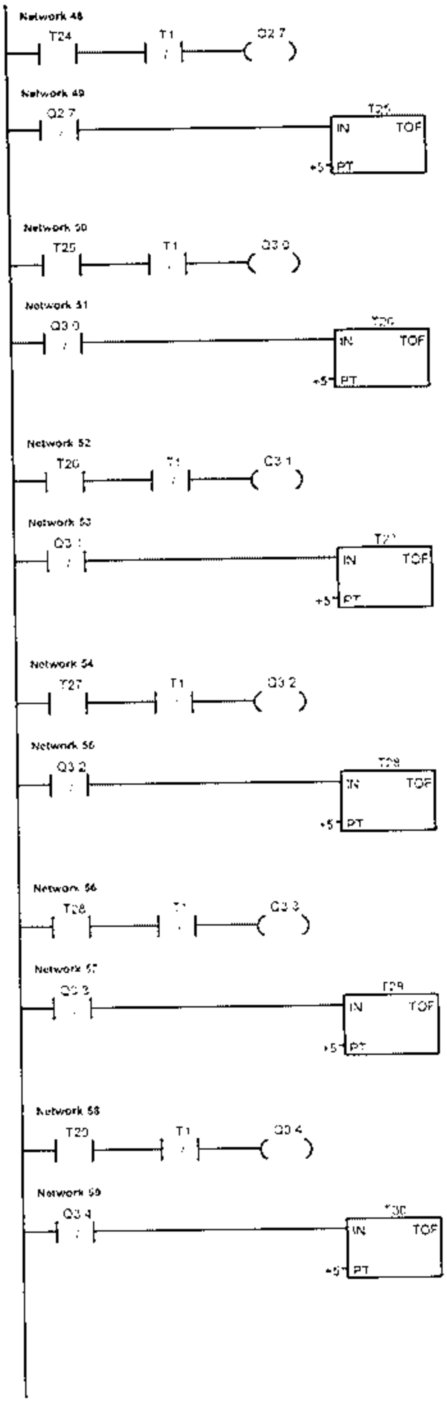


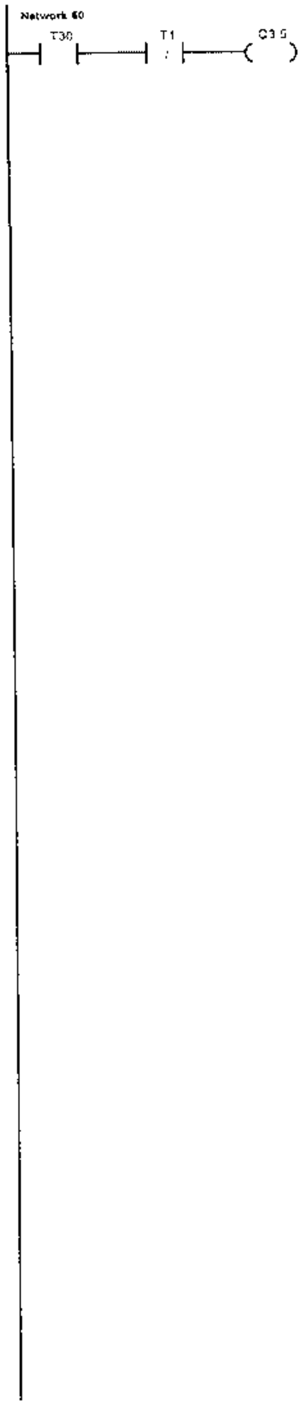
Network 1
NETWORK COMMENTS
START
Q0.0
T1
IN
TOF
+5
PT
Network 2
T1
T2
Q0.0
Network 3
Q0.0
T2
IN
TOF
+5
PT
Network 4
T2
T1
Q0.1
Network 5
Q0.1
T3
IN
TOF
+5
PT
Network 6
T3
T1
Q0.2
Network 7
Q0.2
T4
IN
TOF
+5
PT
Network 8
T4
Q0.3
Network 9
Q0.3
T5
IN
TOF
+5
PT
Network 10
T5
T1
Q0.4
Network 11
Q0.4
T6
IN
TOF
+5
PT




Network 24
T12
Network 25
T13
IN
TOF
+5
PT
Network 26
T13
Q1.4
Network 27
Q1.4
T14
IN
TOF
+5
PT
Network 28
Network 29
IN
TOF
+5
PT
Network 30
Network 31
T16
IN
TOF
+5
PT
Network 32
Network 33
Q1.7
T17
IN
TOF
+5
PT
Network 34
Network 35
Q2.0
IN
TOF
+5
PT


Network 36
T18
Q2.1
Network 37
Q2.1
T19
IN
TOF
+5
PT
Network 38
T19
Q2.2
Network 39
Q2.2
T20
IN
TOF
+5
PT
Network 40
T20
Q2.3
Network 41
Q2.3
T21
IN
TOF
+5
PT
Network 42
T21
Q2.4
Network 43
Q2.4
T22
IN
TOF
+5
PT
Network 44
T22
T1
Q2.5
Network 45
Q2.5
T23
IN
TOF
+5
PT
Network 46
T23
Q2.6
Network 47
Q2.6
T24
IN
TOF
+5
PT


Network 48
T24
T1
Q2.7
Network 49
Q2.7
IN
TOF
+5
PT
Network 50
T25
T1
Network 51
IN
TOF
+5
PT
Network 52
T26
C3.1
Network 53
IN
TOF
+5
PT
Network 54
T27
T1
Q3.2
Network 55
Q3.2
IN
TOF
+5
PT
Network 56
T28
Network 57
IN
TOF
+5
PT
Network 58
T29
T1
Network 59
Q3.4
IN
TOF
+5
PT


Network 60
T30
T1
/
Q3.5

APPENDIX D

PHOTOGRAPH