



TABLE OF CONTENTS

Chapter 1: Getting Started

Introduction	1-2
The Purpose of this Manual.....	1-2
Where to Begin	1-2
Technical Support.....	1-2
Key Topics for Each Chapter	1-3
DL405 System Components	1-4
CPUs.....	1-4
Bases.....	1-4
I/O Configuration.....	1-4
I/O Modules.....	1-4
Programming Methods	1-4
DirectSOFT Programming for Windows™	1-4
DL405 System Diagrams	1-5
Steps to Designing a Successful System	1-12
Frequently Asked Questions	1-14

Chapter 2: Installation, Wiring, and Specifications

Safety Guidelines	2-2
Emergency Power Disconnect.....	2-4
Orderly System Shutdown.....	2-4
Mounting Guidelines	2-5
Base Dimensions	2-5
Panel Layout and Clearances	2-6
Enclosures.....	2-7
Agency Approvals	2-8
Environmental Specifications.....	2-8
Power.....	2-8

Installing DL405 Bases	2-9
Three Sizes of Bases.....	2-9
Installing Components in the Base	2-10
CPU and Expansion Unit Wiring Guidelines.....	2-11
CPU Wiring	2-11
Expansion Unit Wiring	2-12
Connecting Program Devices	2-12
Connecting Operator Interfaces Devices.....	2-13
I/O Wiring Strategies	2-14
PLC Isolation Boundaries	2-14
Powering I/O Circuits with the Auxiliary Supply.....	2-15
Powering I/O Circuits Using Separate Supplies	2-16
Sinking / Sourcing Concepts	2-17
I/O "Common" Terminal Concepts.....	2-18
Connecting DC I/O to "Solid State" Field Devices.....	2-19
Solid State Input Sensors.....	2-19
Relay Output Guidelines.....	2-21
Transient Suppression for Inductive Loads in a Control System.....	2-21
I/O Modules Wiring, and Specification	2-26
Slot Numbering.....	2-26
Module Placement Restrictions.....	2-26
Module Placement.....	2-27
I/O Module Status Indicators	2-27
Color Coding of I/O Modules.....	2-27
Wiring the Different Module Connectors	2-28
Wiring 32 and 64 Point I/O Modules.....	2-29
I/O Wiring Checklist	2-30
DL405 Input Module Chart.....	2-31
DL405 Output Module Chart.....	2-31

Chapter 3: CPU Specifications and Operation

Overview.....	3-2
General CPU Features	3-2
CPU Electrical Specifications	3-2

CPU Specifications..... 3-3

 Toggle Switch Functions 3-4

 Status Indicators..... 3-5

 Communication Ports 3-6

 Port 0 Specifications..... 3-6

 Port 1 Specifications..... 3-7

 Port 2 Specifications..... 3-8

 Port 3 Specifications..... 3-9

Using Battery Backup 3-10

CPU Setup Information 3-11

 Setting the Clock and Calendar 3-11

 Variable/Fixed Scan Time Feature 3-11

 Password Protection..... 3-11

 Clearing an Existing Program..... 3-11

 Initializing System Memory 3-12

 Setting Retentive Memory Ranges 3-12

CPU Operation..... 3-13

 CPU Operating System 3-13

 Program Mode Operation..... 3-14

 Run Mode Operation 3-14

 Read Inputs 3-15

 Read Inputs from Specialty and Remote I/O..... 3-15

 Service Peripherals and Force I/O 3-15

 Update Special Relays and Special Registers..... 3-16

 CPU Bus Communication 3-16

 Update Clock, Special Relays and Special Registers 3-17

 Solve Application Program 3-17

 Solve PID Loop Equations..... 3-18

 Write Outputs 3-18

 Write Outputs to Specialty and Remote I/O..... 3-18

 Diagnostics 3-18

I/O Response Time 3-19

 Is Timing Important for Your Application 3-19

 Normal Minimum I/O Response..... 3-19



Normal Minimum I/O Response.....	3-19
Improving Response Time	3-20
CPU Scan Time Considerations.....	3-21
Initialization Process.....	3-22
Reading Inputs.....	3-22
Update Clock/Calendar, Special Relays, Special Registers.....	3-22
Reading Inputs from Specialty I/O	3-23
CPU Bus Communications	3-24
Writing Outputs	3-24
Writing Outputs to Specialty I/O	3-25
Diagnostics	3-25
Application Program Execution	3-26
Program Control Instructions	3-26
PLC Numbering Systems.....	3-27
PLC Resources	3-27
V-Memory.....	3-28
Binary-Coded Decimal Numbers.....	3-28
Hexadecimal Numbers	3-28
Memory Map.....	3-29
Octal Numbering Systems.....	3-29
Discrete and Word Locations.....	3-29
V-Memory Locations for Discrete Memory Areas	3-29
Input Points (X Data Type).....	3-30
Output Points (Y Data Type).....	3-30
Control Relays (C Data Type).....	3-30
Timers and Timer Status Bits (T Data Type).....	3-30
Timer Current Values (V Data Type).....	3-31
Counters and Counter Status Bits (CT Data type).....	3-31
Counter Current Values (V Data Type).....	3-31
Word Memory (V Data Type).....	3-31
Stages (S Data type).....	3-32
Special Relays (SP Data Type).....	3-32
Remote I/O Points (GX and GY Data Type)	3-32
System Parameters (V Data Type).....	3-33

DL405 Aliases	3-36
X Input / Y Output Bit Map.....	3-37
Control Relay Bit Map	3-39
Timer and Counter Status Bit Map.....	3-43
Remote I/O Bit Map	3-44
Stage Control / Status Bit Map	3-48

Chapter 4: System Design and Configuration

I/O System Configurations.....	4-2
Network Configurations.....	4-3
Module Placement and Configuration	4-4
Valid Module/Unit Locations	4-4
I/O Configuration Methods	4-5
Automatic Configuration.....	4-5
Manual Configuration.....	4-5
Power-On I/O Configuration Check.....	4-6
Calculating the Power Budget.....	4-7
Managing your Power Resource	4-7
CPU Power Specifications	4-7
Module Power Requirements.....	4-7
Power Budget Calculation Example	4-9
Power Budget Calculation Worksheet	4-10
Local I/O Expansion	4-11
Local Base and I/O.....	4-11
Local Expansion Base and I/O	4-11
Remote I/O Expansion.....	4-12
How to Add Remote I/O Channels	4-12
Configuring the CPU's Remote I/O Channel	4-13
Configure Remote I/O Slaves.....	4-15
Configuring the Remote I/O Table	4-15
Remote I/O Setup Program	4-16
Remote I/O Test Program	4-17
Network Connections to MODBUS[®] and DirectNet.....	4-18

Table of Contents

Configuring the CPU's Comm Ports.....	4-18
MODBUS Port Configuration.....	4-20
Network Slave Operation	4-22
Determining the MODBUS Address	4-23
If Your Host Software Requires the Data Type and Address.....	4-23
If Your MODBUS Host Software Requires an Address Only.....	4-25
Network Master Operation	4-28
Step 1: Identify Master Port # and Slave #.....	4-29
Step 2: Load Number of Bytes to Transfer.....	4-29
Step 3: Specify Master Memory Area.....	4-30
Step 4: Specify Slave Memory Area.....	4-31
Communications from a Ladder Program	4-31
Multiple Read and Write Interlocks.....	4-32
Chapter 5: Standard RLL Instructions	
Using Boolean Instructions.....	5-5
END Statement.....	5-5
Simple Rungs.....	5-5
Normally Closed Contact	5-6
Contacts in Series	5-6
Midline Outputs	5-6
Parallel Elements.....	5-7
Joining Series Branches in Parallel	5-7
Joining Parallel Branches in Series.....	5-7
Combination Networks.....	5-7
Comparative Boolean.....	5-8
Boolean Stack.....	5-8
Immediate Boolean	5-9
Boolean Instructions	5-10
Comparative Boolean	5-25
Immediate Instructions	5-31
Timer, Counter and Shift Register Instructions.....	5-38
Using Timers.....	5-38

Timer Example Using Discrete Status Bits	5-40
Timer Example Using Comparative Contacts.....	5-40
Accumulating Timer Example using Discrete Status Bits.....	5-42
Accumulator Timer Example Using Comparative Contacts	5-42
Using Counters.....	5-43
Counter Example Using Discrete Status Bits	5-45
Counter Example Using Comparative Contacts.....	5-45
Stage Counter Example Using Discrete Status Bits	5-47
Stage Counter Example Using Comparative Contacts	5-47
Up / Down Counter Example Using Discrete Status Bits	5-49
Up / Down Counter Example Using Comparative Contacts	5-49
Accumulator/Stack Load and Output Data Instructions.....	5-51
Using the Accumulator	5-51
Copying Data to the Accumulator.....	5-51
Changing the Accumulator Data	5-52
Using the Accumulator Stack	5-53
Accumulator and Accumulator Stack Memory Locations.....	5-54
Using Pointers.....	5-55
Logical Instructions (Accumulator)	5-69
Math Instructions.....	5-86
Transcendental Functions	5-118
Bit Operation Instructions.....	5-120
Number Conversion Instructions (Accumulator).....	5-127
Shuffle Digits Block Diagram.....	5-139
Table Instructions.....	5-141
Copy Data From a Data Label Area to V-memory	5-143
Clock/Calendar Instructions.....	5-173
CPU Control Instructions.....	5-175
Program Control Instructions	5-177
Interrupt Instructions	5-185

Message Instructions 5-187

Chapter 6: Drum Instruction Programming

Introduction 6-2

 Purpose..... 6-2

 Drum Terminology..... 6-2

 Drum Chart Representation..... 6-3

 Output Sequences..... 6-3

Step Transitions 6-4

 Drum Instruction Types..... 6-4

 Timer-Only Transitions..... 6-4

 Timer and Event Transitions..... 6-5

 Event-Only Transitions..... 6-6

 Counter Assignments..... 6-6

 Last Step Completion..... 6-7

Overview of Drum Operation..... 6-8

 Drum Instruction Block Diagram..... 6-8

 Power Up State of Drum Registers..... 6-9

Drum Control Techniques 6-10

 Drum Control Inputs 6-10

 Initializing Drum Outputs..... 6-11

 Using Complex Event Step Transitions 6-11

 Self-Resetting Drum 6-11

Drum Instructions 6-12

 Timed Drum with Discrete Outputs (DRUM)..... 6-12

 Event Drum (EDRUM)..... 6-14

 Masked Event Drum with Discrete Outputs (MDRMD)..... 6-16

 Masked Event Drum with Word Output (MDRMW) 6-18

Chapter 7: RLL^{PLUS} Stage Programming

Introduction to Stage Programming 7-2

 Overcoming “Stage Fright” 7-2

Learning to Draw State Transition Diagrams 7-3

 Introduction to Process States 7-3

The Need for State Diagrams	7-3
A 2-State Process.....	7-3
RLL Equivalent	7-4
Stage Equivalent	7-4
Let's Compare.....	7-5
Initial Stages	7-5
What Stage Bits Do	7-6
Stage Instruction Characteristics	7-6
Using the Stage Jump Instruction for State Transitions	7-7
Stage Jump, Set, and Reset Instructions.....	7-7
Stage Program Example: Toggle On/Off Lamp Controller	7-8
A 4-State Process.....	7-8
Four Steps to Writing a Stage Program	7-9
Stage Program Example: A Garage Door Opener	7-10
Garage Door Opener Example	7-10
Draw the Block Diagram.....	7-10
Draw the State Diagram.....	7-11
Add Safety Light Feature.....	7-12
Modify the Block Diagram and State Diagram	7-12
Using a Timer Inside a Stage.....	7-13
Add Obstruction Stop Feature	7-14
Exclusive Transitions.....	7-14
Stage Program Design Considerations.....	7-15
Stage Program Organization.....	7-15
How Instructions Work Inside Stages	7-16
Using a Stage as a Supervisory Process	7-17
Stage Counter.....	7-17
Power Flow Transition Technique.....	7-18
Parallel Processing Concepts	7-19
Parallel Processes.....	7-19
Converging Processes.....	7-19
Convergence Stages (CV).....	7-19
Convergence Jump (CVJMP)	7-20
Convergence Stage Guidelines	7-20

RLL^{PLUS} (Stage) Instructions	7-21
Stage (SG)	7-21
Initial Stage (ISG)	7-22
Jump (JMP)	7-22
Not Jump (N JMP)	7-22
Converge Stage (CV) and Converge Jump (CVJMP)	7-23
Block Call (BCALL)	7-25
Block End (BEND)	7-25
Block (BLK)	7-25
Chapter 8: PID Loop Operation...	8-1
D4-454 PID Control	8-2
D4-454 PID Control Features	8-2
Introduction to PID Control.....	8-4
What is PID Control?.....	8-4
Introducing D4-454 PID Control	8-6
Process Control Definitions	8-8
PID Loop Operation.....	8-9
Position Form of the PID Equation.....	8-9
Reset Windup Protection.....	8-10
Freeze Bias	8-11
Adjusting the Bias.....	8-11
Step Bias Proportional to Step Change in SP	8-12
Eliminating Proportional, Integral or Derivative Action.....	8-12
Velocity Form of the PID Equation.....	8-12
Bumpless Transfer	8-13
Loop Alarms.....	8-13
Loop Operating Modes	8-14
Special Loop Calculations.....	8-14
Ten Steps to Successful Process Control.....	8-16
PID Loop Setup.....	8-18
Some Things to Do and Know Before Starting.....	8-18
Establishing the Loop Table Size and Location.....	8-19
Loop Table Word Definitions	8-21
PID Mode Setting 1 Bit Descriptions (Addr + 00).....	8-22

PID Mode Setting 2 Bit Descriptions (Addr + 01)	8-23
Mode/Alarm Monitoring Word (Addr + 06).....	8-24
Ramp/Soak Table Flags (Addr + 33)	8-24
Ramp/Soak Table Location (Addr + 34)	8-25
Ramp/Soak Table Programming Error Flags (Addr + 35)	8-25
Configure the PID Loop.....	8-26
PID Loop Tuning	8-42
Open-Loop Test.....	8-42
Manual Tuning Procedure	8-43
Alternative Manual Tuning Procedures by Others.....	8-46
Tuning PID Controllers.....	8-46
Auto Tuning Procedure	8-47
Use DirectSOFT Data View with PID View.....	8-51
Open a New Data View Window	8-51
Open PID View	8-52
Using the Special PID Features	8-54
How to Change Loop Modes	8-54
Operator Panel Control of PID Modes.....	8-55
PLC Modes Effect on Loop Modes.....	8-55
Loop Mode Override	8-56
PV Analog Filter	8-57
Creating an Analog Filter in Ladder Logic.....	8-58
Use the DirectSOFT Filter Intelligent Box Instruction	8-59
Ramp/Soak Generator	8-60
Introduction.....	8-60
Ramp/Soak Table.....	8-61
Ramp/Soak Table Flags.....	8-63
Ramp/Soak Generator Enable	8-63
Ramp/Soak Controls	8-63
Testing Your Ramp/Soak Profile.....	8-64
Ramp/Soak Profile Monitoring.....	8-64
Ramp/Soak Programming Errors.....	8-64
DirectSOFT Ramp/Soak Example	8-65
Setup the Profile in PID Setup	8-65
Program the Ramp/Soak Control in Relay Ladder	8-65

Test the Profile	8-66
Cascade Control	8-67
Introduction.....	8-67
Cascaded Loops in the D4-454 CPU.....	8-68
Tuning Cascaded Loops.....	8-69
Time-Proportioning Control	8-70
On/Off Control Program Example	8-71
Feedforward Control.....	8-72
PID Example Program	8-74
Program Setup for the PID Loop	8-74
Troubleshooting Tips.....	8-77
Glossary of PID Loop Terminology	8-79
Bibliography	8-81
Chapter 9: Maintenance and Troubleshooting	
Hardware System Maintenance	9-2
Standard Maintenance	9-2
Battery Replacement.....	9-2
Diagnostics	9-3
Fatal Errors	9-3
Non-fatal Errors.....	9-3
V-memory Error Code Locations	9-4
Special Relays (SP) Corresponding to Error Codes.....	9-5
I/O Module Codes.....	9-6
Error Message Tables.....	9-6
Program Error Codes.....	9-7
CPU Status Indicators	9-8
PWR Indicator.....	9-9
RUN Indicator	9-10
CPU Indicator	9-11
BATT Indicator	9-11
DIAG Indicator	9-11
TXD and RXD Indicators.....	9-12
I/O Point Troubleshooting.....	9-13

Some Quick Steps.....	9-13
Testing Output Points	9-14
Noise Troubleshooting.....	9-15
Electrical Noise Problems	9-15
Reducing Electrical Noise.....	9-15
Machine Startup and Program Troubleshooting.....	9-16
Syntax Check	9-16
Special Debug Instructions	9-18
Run Time Edits	9-20
Forcing I/O Points.....	9-21
Bit Override Forcing.....	9-23
Appendix A: Error Codes.....
D4-454 Error Codes.....	A-2
Appendix B: Special Relays...
Startup and Real-Time Relays	B-2
CPU Status Relays.....	B-2
System Monitoring.....	B-3
Accumulator Status	B-3
Communication Monitoring Relay.....	B-4
Appendix C: Product Weights.....
Product Weight	C-2
Appendix D: ASCII Conversion Table	
ASCII Conversion Table	D-2
Appendix E: Numbering Systems	
Introduction.....	E-2
Binary Numbering System.....	E-2
Hexadecimal Numbering System.....	E-3
Octal Numbering System.....	E-4
Binary Coded Decimal (BCD) Numbering System	E-5
Real (Floating Point) Numbering System	E-5

Table of Contents

BCD/Binary/Decimal/Hex/Octal - What is the Difference?.....	E-6
Data Type Mismatch	E-7
Signed vs. Unsigned Integers.....	E-8
AutomationDirect.com Products and Data Types	E-9
DirectLOGIC PLCs.....	E-9
C-more/C-more Micro-Graphic Panels	E-9