ALLEN-BRADLEY

Distributed Diagnostics and Machine Control

(Cat. No. 6401-DDMC,-SDSC, 6402-DDMC, 6403-DDMC)

Application Notes

Important User Information

Because of the variety of uses for this product and because of the differences between solid state products and electromechanical products, those responsible for applying and using this product must satisfy themselves as to the acceptability of each application and use of this product. For more information, refer to publication SGI–1.1 (Safety Guidelines For The Application, Installation and Maintenance of Solid-State Control).

The illustrations, charts, and layout examples shown in this manual are intended solely to illustrate the text of this manual. Because of the many variables and requirements associated with any particular installation, Allen-Bradley Company cannot assume responsibility or liability for actual use based upon the illustrative uses and applications.

No patent liability is assumed by Allen-Bradley Company with respect to use of information, circuits, equipment or software described in this text.

Reproduction of the contents of this manual, in whole or in part, without written permission of the Allen-Bradley Company is prohibited.

Throughout this manual we make notes to alert you to possible injury to people or damage to equipment under specific circumstances.

ATTENTION: Tells readers where people may be hurt if procedures are not followed properly.

ATTENTION: Tells readers where machinery may be damaged or economic loss can occur if procedures are not followed properly.

Warnings and Cautions:

- Identify a possible trouble spot.
- Tell what causes the trouble.
- Give the result of improper action.
- Tell the reader how to avoid trouble.

Important: We recommend you frequently backup your application programs on appropriate storage medium to avoid possible data loss.

Summary of Changes

New Information in this Publication

This release of the publication contains the following new information:

In this release, a new 14 step detented value SDS instruction replaces the SDS shown in the previous version of this manual (see page 6-6 of "Applying the SDS Instruction to a Machine Clamp"). The new SDS instruction includes changes that have been made to eliminate processor scan dependencies. These changes include:

- swapping the request and memory I/O addresses in the input table
- other step transition changes throughout the SDS

New or changed information is noted with a revision bar, as shown in the margin.

Table of Contents

Using this Manual

Manual Objectives

This manual describes how to apply Distributed Diagnostics and Machine Control (DDMC), specifically the SDS instruction, to your application.

In this manual we provide:

- a tutorial for implementing state transition/conditional logic programming:
  - decomposing your machine or line into manageable segments
  - defining states, inputs and outputs, transitions and conditions
  - developing state diagrams and state tables
  - developing a program that uses ladder logic and DDMC instructions
- application examples for common mechanisms
- application examples for providing operator guidance
- a sample program for logging IMC faults sent as messages from the PLC-5 processor
- other sample programs

Audience

We assume that if you are using this manual, you have read the DDMC User's Manual (publication 6401–6.5.1). This means you are familiar with the following:

- the SDS instruction configuration utility
- the DFA instruction configuration utility
- PLC-5 hardware and programming software
- 1771 I/O
- Allen-Bradley operator interface and programming terminals
- the line or machine for which you are developing the program

Specific Sections of the Manual

This manual is divided into two sections. The first focuses on learning to build an application with the SDS and DFA instructions. This is demonstrated with a conceptual example of a drill machine and a real-world example of a transfer line. The second section of the manual provides several programming examples and techniques that you can use when building your own custom DDMC application.

Table P.A
Sections of the Manual

	If you want to read about:	Refer to chapter:	
Section 1 Application Concepts	SDS and DFA instruction basics	1	Understanding DDMC Instructions and Their Purpose
	Levels of DDMC implementation; using the DDMC instruction for operator guidance messages	2	Implementing DDMC to a Specific Level
	Decomposing your machine into manageable segments; understanding the basics of truth tables, state diagrams, and state tables	3	Getting Started with State Transition/Conditional Logic Programming
	Applying state transition/conditional logic to a drill machine example	4	Organizing a Drill Machine Application
	Applying state transition/conditional logic to a transfer line example	5	Organizing a Transfer Line Application
Section 2 Programming Techniques	Applying DDMC instructions to a hydraulic slide, machine clamp, part stamp, spindle, and a mechanical slide	6	Applying DDMC Instructions to Common Mechanisms
	Using DDMC Instructions to provide operators with guidance messages	7	Applying DDMC Instructions for Operator Guidance
	Applying a technique that uses the PLC-5 message instruction to simulate fault messages like those created with the SDS instruction.	8	Logging IMC Faults Sent as Messages by the PLC processor
	Using DDMC instructions for various applications such as scan dependencies, prioritizing messages, adding power loss detection and management logic, providing flashing push button guidance for operators	9	Other Application Examples
	Worksheets for building state tables to configure SDS instructions	Appendix A	SDS Instruction Worksheets

ATTENTION and Important Notes

Information that is especially important to note is identified with an ATTENTION or Important note:

ATTENTION: identifies informaton about practices or circumstances that can lead to personal injury or death, property damage or economic loss.

Important: provides you with information that is important for the successful application of DDMC.

Terms and Conventions

In this manual, we use the following terms:

This:	Is:
Combinatorial Equation	A chain of events or steady state conditions; a Boolean equation — in the SDS instruction this is limited to ANDed conditions. This type of equation doesn't care about the order or sequence in which inputs occur, it only cares that they all did occur.
DDMC (Distributed Diagnostics and Machine Control)	An industrial automation system containing hardware and software components that help you configure a control and diagnostics system for your equipment.
DFA (Diagnostic Fault Annunciator)	An instruction that resides in ladder logic, providing messaging capabilities when a fault occurs.
SDS (Smart Directed Sequencer).	An instruction that resides in ladder logic, providing state machine control and up-to-date diagnostics for your machine.
State/Step	The conditions of the outputs of a machine at a point in time.
State Transition	An input change from ON to OFF or OFF to ON associated with a single input.
Watchdog Timer	A diagnostic technique that incorporates a timer to monitor a sequencer event.
Interlock	A real or storage output used to coordinate sequences.

Related Publications

For more information about DDMC components, see the following publications:

Publication Title	Publication Number
DDMC User Manual	6401–6.5.1
PLC-5 Processors	
1785 PLC-5 Family Programmable Controllers Installation Manual	1785-6.6.1
1785 PLC-5 Programmable Controller Design Manual	1785-6.2.1
Pyramid Integrator™ Design Manual	5000-6.2.1
PLC-5 Programming Software Documentation Set	6200-N8.001
PLC-5 Programming Software Installation and Configuration	6200-6.4.6
PLC-5 Programming Software Programming User's Manual	6200-6.4.7
PLC-5 Programming Software Instruction Set Reference	6200-6.4.11
PLC-5 Programming Software: I/O Configuration Software	6200-6.4.12
PLC-5/250™ Programming Software Documentation Set	6200-N8.002
PLC-5/250 Programming Software Installation and Configuration	5000-6.4.7
PLC-5/250 Programming Software Programming Manual	5000-6.4.8
PLC-5/250 Programming Software Testing and Maintenance	5000-6.4.11
PLC-5/250 Programming Software Instruction Set Reference	5000-6.4.12
PLC-5/250 Programming Software I/O Configuration Software User Manual	5000-6.4.15
Operator Interface Terminal	
T35 Plant Floor Terminal User's Manual	1784-6.5.6
T60 Industrial Workstation User's Manual	6160-6.5.1
RealRAM™ Enhanced Memory Card (cat. no. 6174-DMB10) User's Manual	6171-6.5.15
RealRAM Enhanced Memory Card (cat. no. 6190-MB14) User's Manual	6190-6.5.15
Communications	
Data Highway/Data Highway Plus™ Protocol and Command Set User's Manual	1770-6.5.16
Peer Communication Link Interface Module (cat. no. 1784-KT) Product Data	1784-2.3
ControlView™	
ControlView Core User's Manual	6190-6.5.1
ControlView A-B Drivers User's Manual	6190-6.5.5
ControlView Mouse GRAFIX® Editor User's Manual	6190-6.5.3

Chapter 1

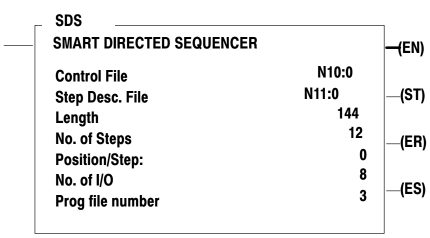
Understanding DDMC Instructions and their Purpose

Chapter Objectives

Read this chapter to get an overview of DDMC instructions that you will use as part of your ladder program to build an application. In this chapter we describe the:

- SDS instruction (Smart Directed Sequencer)
- DFA instruction (Diagnostic Fault Annunciator)

Understanding the SDS Instruction



You can use the Smart Directed Sequencer (SDS) instruction in many ways, such as providing fault diagnostic information about sensing devices like:

- limit switches
- pressure switches
- proximity switches

The SDS instruction allows two basic types of logic equations:

- Transitional (Logical OR)
- Combinatorial (Logical AND)

Transition equations provide traditional state-based control. In other words, a transition equation defines the destination step for the transition (either ON—>OFF or OFF—>ON) of a desired input.

Combinatorial equations define the destination step based on the steady state values and the relationship between a collection of inputs. Currently, the only valid relationship is the logical AND function. This allows you to accommodate complex combinations in the instruction while keeping the number of steps within a configuration to a minimum. You can define up to 4 logical AND combinations in an 8 input SDS instruction. You can define up to 8 ANDed conditions in a 16 or 32 input SDS instruction.

Using the combinatorial feature of the SDS instruction, you can:

- replace complex ladder logic required for permissives in a state transition SDS instruction
- obtain diagnostic information on logical conditions (use for operator guidance)
- develop "shadow mode" diagnostics — the instruction follows what the machine is doing without controlling any outputs.

Figure 1.1 shows an example of the SDS instruction's step table (Edit Step screen) using the combinatorial feature. Figure 1.2 shows a step table with transitional structure (each input transition sends the instruction to a unique state for those conditions. For more information about the SDS configuration utility and steps for configuring the instruction, refer to the DDMC User's Manual (publication 6401–6.5.1).

Figure 1.1
SDS Instruction showing combinatorial function (Edit Step Screen)

```
  STEP 1    -- untitled --         TIMER=5.00s          STEP  11     MSG:ON

No   Input ID          Equation    Destination     No   Output ID         State
 0 PART IN POSITION    ON-->OFF     ERSTEP 10       1   VALVE 4            OFF
 1 CLAMP LS1           EQ1          STEP 9          2   CLAMPS OPEN        ON
 2 CLAMP LS2           EQ1          STEP 9          3   CLAMPS CLOSED      OFF
 3 CLAMP LS3           EQ1          STEP 9          4   SOLENOID           LAST
 4 CLAMP LS4           EQ1          STEP 9          5   LIGHT              LAST
 5 HAND                EQ2          STEP 5          6   MOTOR 2            ON
 6 AUTO
 7 JOG PB              EQ2          STEP 5
 8 PERMISSIVE          ON-->OFF     STEP 2





Press a function key.
Enter destination step number or 'INIT' >
Prog        edit mode                                  5/25 Addr 5   SDSTEST
 Equatn Display  Step    Step    Edit    Step     Msg    Equatn Output  Marked
  List  Symbol   Name    Type    Step    Timer    Off    Editor  State   Exit
  F1      F2      F3      F4      F5      F6      F7      F8      F9      F10
```

Figure 1.2
SDS Instructions showing state transitional function (Edit Step Screen)

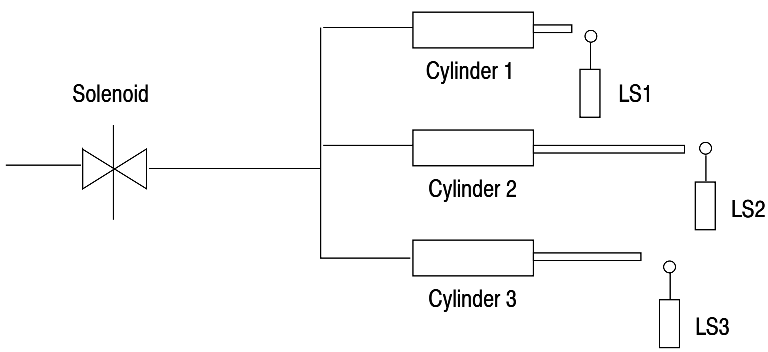
```
  STEP 1   READY                       TIMER=0.0s - DISABLED              MSG:OFF

No   Input ID          Equation    Destination     No   Output ID         State
 0 RET'D LS             OFF-->ON      STEP 4        0 FORWARD MOTOR 1      OFF
 1 ADV'D LS             OFF-->ON      STEP 10       1 REVERSE MOTOR 1      OFF
 2 FULL DEPTH LS        OFF-->ON      STEP 4        2 DRILL MOTOR          OFF
 3 ADVANCE COMMAND      OFF-->ON    **STEP 2
 4 RETURN COMMAND






Press a function key.

Program         edit mode                                   PLC-5/25 Addr 1
 Equatn Display  Step    Step    Edit    Step     Msg    Input  Output  Marked
 List   Symbol   Name    Type    Step    Timer    On    Transit  State   Exit
  F1      F2      F3      F4      F5      F6      F7      F8      F9      F10
```

To What Mechanisms Can You Apply the SDS Instruction?

As a rule, you may want to limit the use of an SDS instruction to a single sequence or motion like a rotary or linear axis. Refer to the following examples.

Suppose that you have an actuator, such as a solenoid, that actuates several mechanically independent cylinders (Figure 1.3). These cylinders move at different speeds.

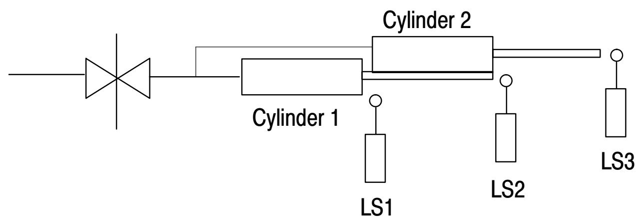
Figure 1.3
Independent cylinders actuated by one solenoid



To provide accurate diagnostics for the above mechanism, you would want to assign one SDS instruction to **each** cylinder to diagnose the reaction of the position sensor switches associated with that cylinder. If you included all of the cylinders in the above example in one SDS instruction, the diagnostics would be lost because the cylinders operate at different speeds (not sequential). In addition, any messages generated by a single SDS instruction would not be precise and indicate which cylinder had faulted.

On the other hand, say that you have two cylinders of equal length connected together to produce a three-position shuttle. The shuttle has three switches to indicate each of its three positions (Figure 1.4). In this case, the shuttle's movement is sequential — each movement depends on the movement that just occurred. In this situation, a single SDS instruction would work well to diagnose faults accurately and provide precise messages.

Figure 1.4
Three-position shuttle with two cylinders and three switches



For more information on applying the SDS instruction to a particular mechanism, refer to chapter 6, "Applying DDMC Instructions to Common Mechanisms."

What Information Should the SDS Instruction Include?

The SDS instruction works with ladder logic to provide control and diagnostics for your application. You can use the instruction to varying degrees to achieve your desired level of diagnostics and control. Some instructions can become quite complex if you try to include too much information. We provide the following recommendations for keeping your SDS instructions as simple as possible.

Limit inputs to:

- motion requests from sequencing logic
- position indicators
- a fault reset request, if applicable
- interlocks

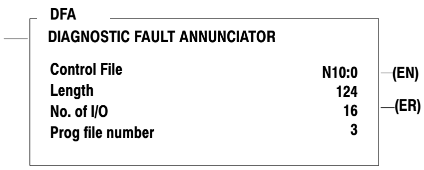
Limit outputs to:

- motion-actuator devices
- position indicating lights
- bits

Keep in mind that you want to use the SDS for a particular motion or mechanism. Any other information related to that motion— but not part of that motion — can be handled more easily with conventional ladder logic like full depth information (or in a separate SDS instruction if you want messages generated). This information could include:

Information:	Description:
Operating Mode	Including operating mode in your SDS only increases the number of steps required in the instruction, thus increasing the difficulty of the instruction. It is not necessary that the SDS instruction know why the axis it controls is being requested to move, only that it must behave a certain way when it is requested to do so.
Full Depth	When you configure an SDS instruction for a motion it is likely that you include the inputs and outputs required to generate a full depth condition. Even so, we recommend keeping full depth logic out of the SDS because canceling the full depth signal requires including additional inputs, complicating the configuration. Internal storage points or logical conditions are more easily suited for ladder logic. For example, a full depth condition usually includes latches and unlatches — both easily handled by ladder logic.
Motor Starter Overloads	When you program an SDS instruction to go to a fault step upon seeing an overload trip, the instruction stops all motion and reports a fault message. This is how the SDS instruction is supposed to react; however, while the SDS is in the fault step, it cannot detect other faults. If an input card or switch faults while the overload is tripped, the SDS cannot detect the fault and flag it. Rather than use the SDS in this case, we recommend that you use the Diagnostic Fault Annunciator (DFA) instruction. The DFA is described below.
Manual Inputs	Manual inputs include anything that does not control machine motion (such as pushbuttons, on/off switches, and dials).

Understanding the DFA Instruction



The Diagnostic Fault Annunciator (DFA) instruction is a monitoring only instruction; that is, it cannot control outputs. You must define the inputs in the instruction that you want monitored. Valid inputs can be:

- storage points such as binary bits
- counter/timer done bits
- outputs (real or logical)
- any valid bit address
- lube or level indicators
- alarms
- fault bits (set by another device — such as an IMC motion controller or ladder logic)

If you currently have diagnostics programmed in ladder logic, you can use the DFA instruction to generate messages when a fault occurs. In addition, you can create other types of operational and diagnostic messages with the DFA instruction, such as tool change messages and operating instructions.

Figure 1.5 shows an example of the DFA configuration template. For more information about the DFA configuration utility and steps for configuring the instruction, refer to the DDMC User's Manual (publication 6401–6.5.1).

Figure 1.5
DFA Instruction – Message Screen

```
                             DFA for DFA 1 AT N9:0
No     Input ID                 Input Message                             State
 0 C4:01/ON            TOOL CHANGE REQUIRED
 1 I:000/02            LUBE FAULT
 2 I:000/01            LUBE LEVEL LOW
 3 I:000/06            NO PARTS PRESENT
 4 I:B3/03             LOAD PARTS IN STA.5
 5 I:000/04            PLACE MACHINE IN AUTO MODE
 6 O:000/05            TIME TO CALL MAINTENANCE
 7 T5:1/ON             MACHINE OVER CYCLE







Press a function key or enter input number.
█
Rem Prog                                                 5/25 Addr 5   DB_TEST
Change  Display  Exit             Input           Edit    Input          Accept
 Mode   Symbol                   Monitor         Message  State           Edits
  F1      F2      F3               F5              F7      F8              F10
```

Summary

This chapter gave you an overview of DDMC instructions and what they are used for. Read chapter 2 to learn methods for implementing these instructions into your program.

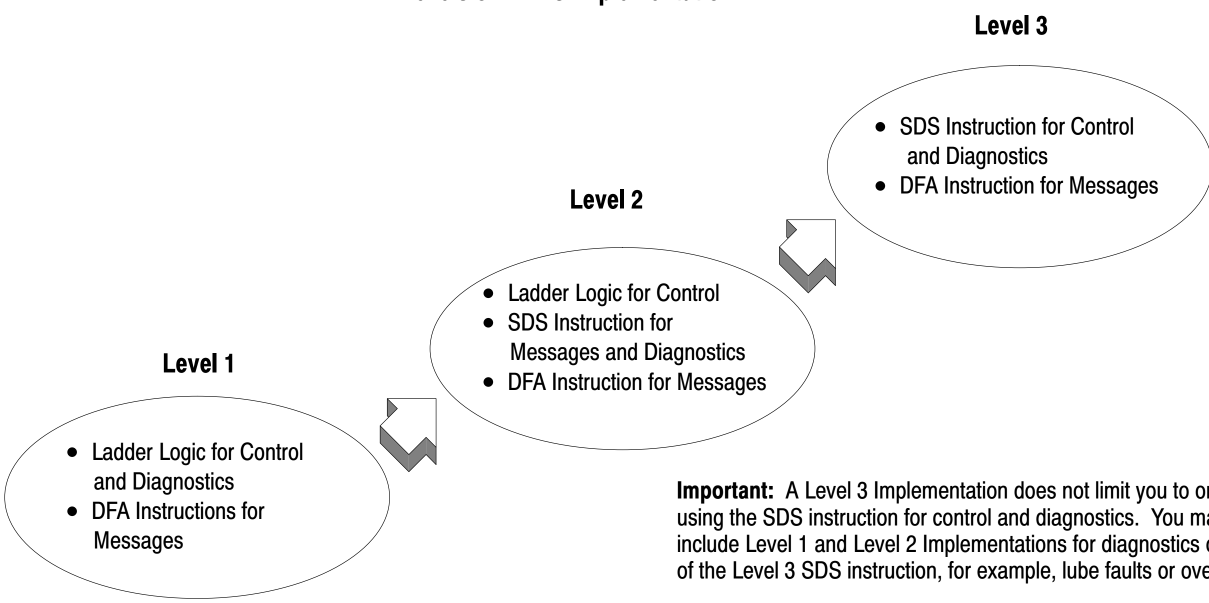
Chapter 2

Implementing DDMC to a Specific Level

Chapter Objectives

You can implement DDMC instructions at different operational levels, depending on the amount of diagnostics and control that you need for your application. Each level provides incremental increases in terms of diagnostic coupling with the control. Figure 2.1 shows levels of implementation. Table 2.A describes the levels.

Figure 2.1
Levels of DDMC Implementation



Important: A Level 3 Implementation does not limit you to only using the SDS instruction for control and diagnostics. You may also include Level 1 and Level 2 Implementations for diagnostics outside of the Level 3 SDS instruction, for example, lube faults or overloads.

Table 2.A
Description of DDMC Levels

This level:	Uses this DDMC instruction:	Control is handled by:	Diagnostics are handled by:	Message Generation is handled by:
1	DFA	ladder logic	ladder logic	DFA
2	SDS and DFA	ladder logic	SDS	SDS and DFA
3	SDS and DFA	SDS	SDS	SDS and DFA

In addition to operational levels, you can implement DDMC to be used for operator guidance messages. Read this chapter to learn more about the level of implementation that best suits your application.

Implementing DDMC for Messaging Only — Level 1

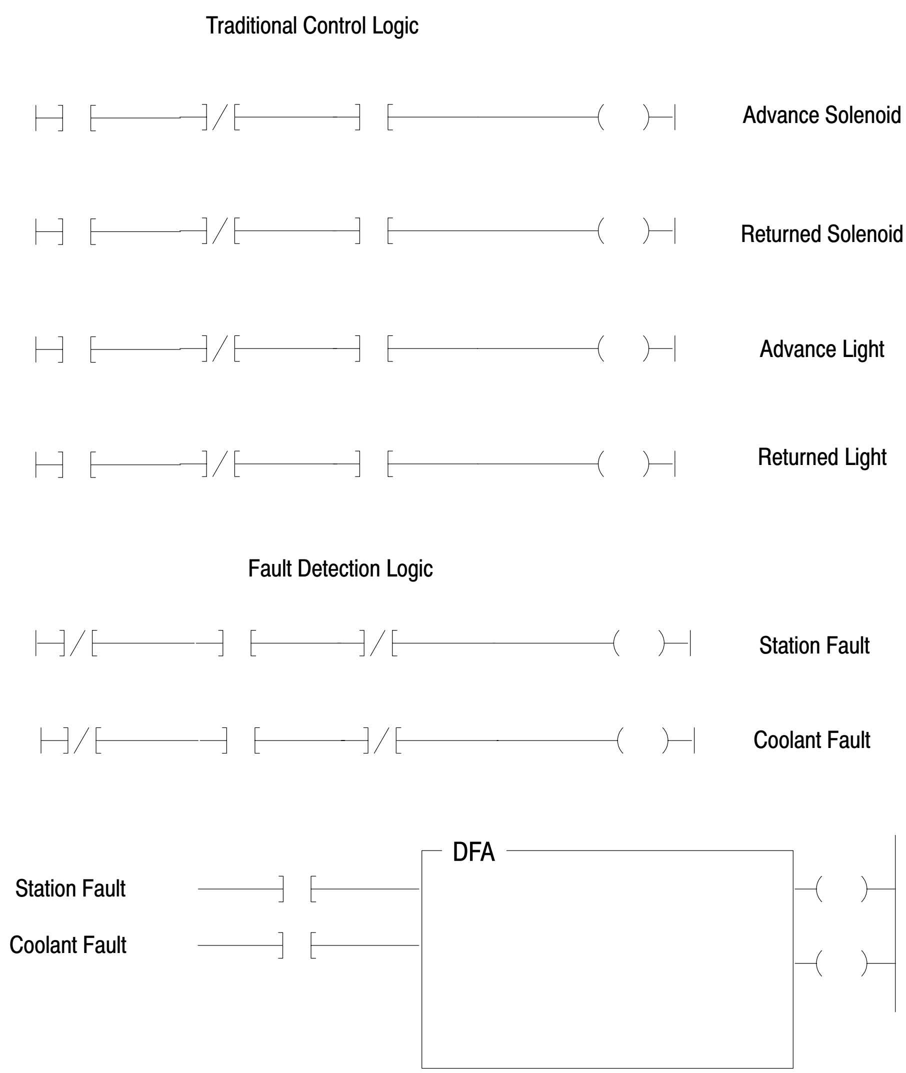
The Level 1 implementation of the DDMC uses the DFA instruction as a fault message generator. The PLC ladder logic is required to control the machine and to detect faults. You configure the instruction to monitor these fault bits for a transition to the faulted state. Upon that transition, the DFA instruction generates a fault message. Machine control logic, fault detection logic, and fault annunciation logic are *not* integrated. Using Level 1 the following is true:

- ladder logic controls the machine
- diagnostics are not updated with control logic changes
- diagnostic detection relies on ladder logic

Figure 2.2 shows an example of Level 1 implementation:

Figure 2.2
DDMC Implementation — Level 1

Level 1
Conventional ladder logic is used for both control and fault detection. The DFA monitors the ladder logic fault bits and generates messages



Implementing DDMC for Messaging and Diagnostics — Level 2

Level 2 implementation of the DDMC uses the SDS instruction to decompose a mechanism into individual states based on the inputs or conditions that relate to the given mechanism. Refer to chapter 6 for examples of applying DDMC instructions to common mechanisms.

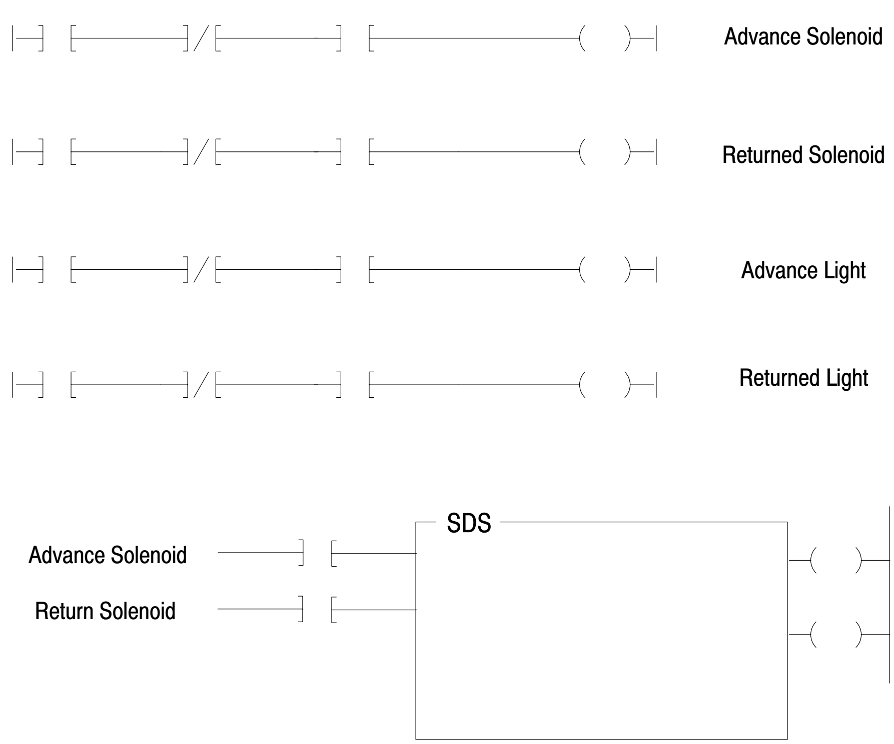
The SDS instruction monitors the mechanism as it cycles from state to state. Upon an invalid transition of an input, or when the SDS instruction exceeds a predefined time period for a given step, the instruction generates a fault message that details the mechanism's state and the input that had the invalid transition. The ladder logic is used to control the outputs of the machine. Both fault detection and fault message annunciation are performed by the SDS instruction. Using Level 2, the following is true:

- ladder logic controls the machine
- SDS instruction performs diagnostics
- PLC processor control and fault diagnostics are not integrated
- you should use the DFA instruction for discrete fault annunciation

Level 2

Conventional ladder logic is used to control outputs. The SDS instruction monitors inputs and conditions to detect faults and generate messages.

Figure 2.3
DDMC Implementation — Level 2



Implementing DDMC for Messaging, Diagnostics and Control — Level 3

The Level 3 implementation of the SDS instruction requires the instruction to perform the machine output control, fault detection and fault message annunciation. The control logic and the machine diagnostics are integrated.

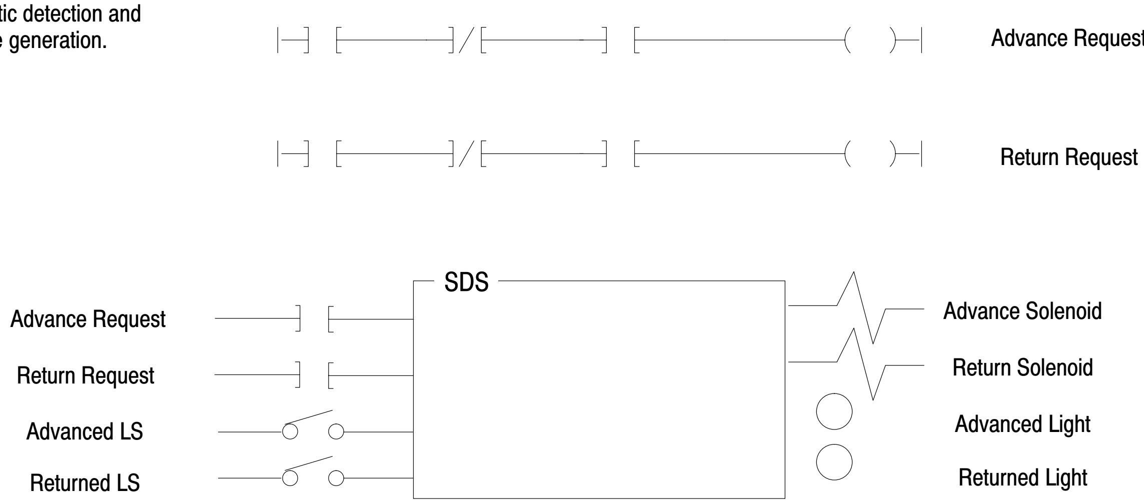
Similar to the Level 2 implementation, you must decompose the given mechanism into individual states. The SDS instruction monitors the mechanism's input for transition and uses the SDS instruction to control the mechanism's outputs while it is in a given step. Upon an invalid transition of a mechanism's input, the instruction generates a fault message. Changes that affect the control of a mechanism also update that mechanism's diagnostics. Using Level 3, the following is true:

- the SDS instruction is used to control the machine's outputs
- diagnostics and control are integrated
- you should use the DFA instruction for discrete fault annunciation

Figure 2.4
DDMC Implementation — Level 3

Level 3

The SDS controls outputs and monitors inputs for disagnostic detection and automatic message generation.



Implementing DDMC for Operator Guidance Messaging

In addition to implementing DDMC at various levels, you can implement the instructions to provide operators with messages that guide them to perform sequential steps. For example, when a machine faults in automatic mode, the operator may need to perform steps to get the machine back to home position so that it can be placed back in automatic mode. You can use the messages generated by the DDMC instructions to tell the operator what to do.

As stated on page 1-1, you can use the SDS instruction in two different ways:

- state-transitional mode (inputs are ORed) where individual input state transitions and changes are analyzed
- combinatorial mode (inputs or steady states are ANDed) to analyze logical conditions

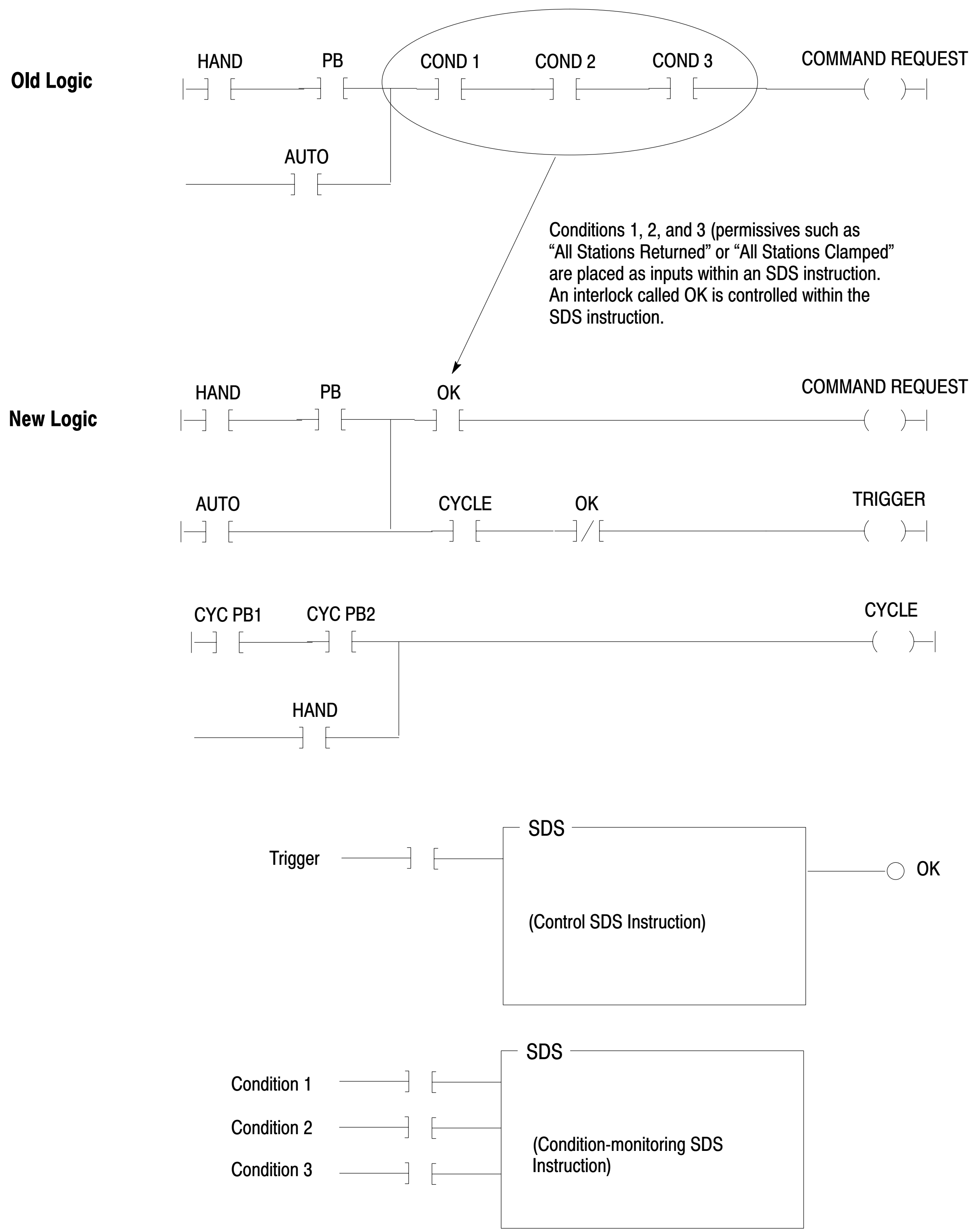
To achieve operator guidance, you still would want to keep those actions related to the motion of the mechanism in a separate SDS instruction. Information for analyzing expected conditions that are being monitored by the SDS instruction and allow the operator's request to be acted upon should be kept in another SDS instruction.

Important: You do this to reduce the complexity in the instruction and to display messages different than those used to indicate control faults. (You use the configuration utility differently to configure operator guidance messages than to configure warning messages.)

To configure operator guidance messages, you first analyze existing or standard request logic, relocate the permissive and interlocks from the ladder logic, and put them in their own SDS instruction as shown in Figure 2.5. The permissives in the request logic must not allow for parallel paths.

For sample programs that show DDMC implementations for operator guidance, refer to chapter 6, "Applying DDMC Instructions to Common Mechanisms".

Figure 2.5
DDMC Implementation — Operator Guidance



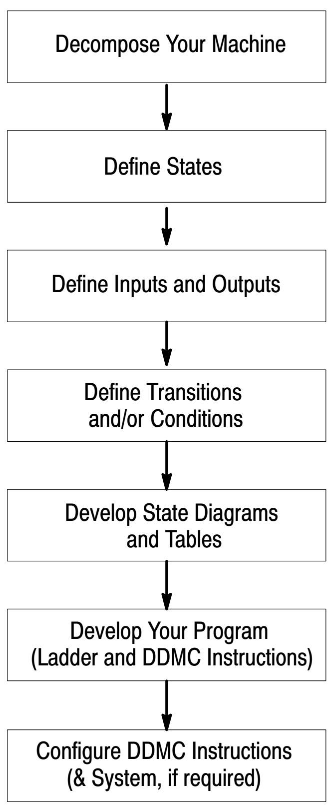
Preparing to Apply DDMC Instructions

Now that you have an understanding of the DDMC philosophy and the extent to which you can implement the DDMC instructions to provide diagnostics and messaging, you can begin building your application.

If you are building:

- **a messaging only application (Level 1)**, you can use the DFA instruction with your traditional ladder program.
- **an application that contains diagnostics, control, or operator guidance**, you will need to analyze your application a bit further. Figure 2.6 shows the basic mode of thinking you must go through to prepare a DDMC application of Level 2 or greater. (Much of this requires a good understanding of your machine or line and the motions it goes through to complete an operation.)

Figure 2.6
Requirements for applying DDMC



Summary

This chapter explained the various levels of DDMC implementation. Read chapters 3 – 5 for examples on performing the steps shown in Figure 2.6.

Chapter 3

Getting Started with State Transition/Conditional Logic Programming

Chapter Objectives

State transitional programming has several advantages. This approach lets you:

- represent machine functions in a step-by-step manner, parallel to the way the control system operates
- combine the machine control program and the diagnostic program

Read this chapter to learn techniques used to develop a state transition/conditional logic application. Some of the topics you must understand to develop your application include:

- decomposing your machine
- developing a truth table
- developing a state diagram
- developing a state table

Decomposing Your Machine

Decomposition is the act of breaking a line or machine into manageable segments so that you can define states, or steps, and transitions/conditions that determine which state or step the machine should be in.

A large machine or transfer line consists of many states — far too many to be considered manageable in one state instruction. When setting up a state application for a machine you need to first decompose the machine so that segments are manageable; In addition, decomposition with individual SDS instruction for each part of the machine provides more accurate and precise messages.

Levels of Decomposition

Decomposition is a logical process performed in levels. These levels vary for each machine, depending on its size and complexity. To determine levels for decomposition, it is imperative that you know how your machine operates.

In the decomposition process, your first level is the overall system, machine, or line. Subsequent levels are actions parallel to one another — all smaller portions of the system until you achieve segments that are manageable.

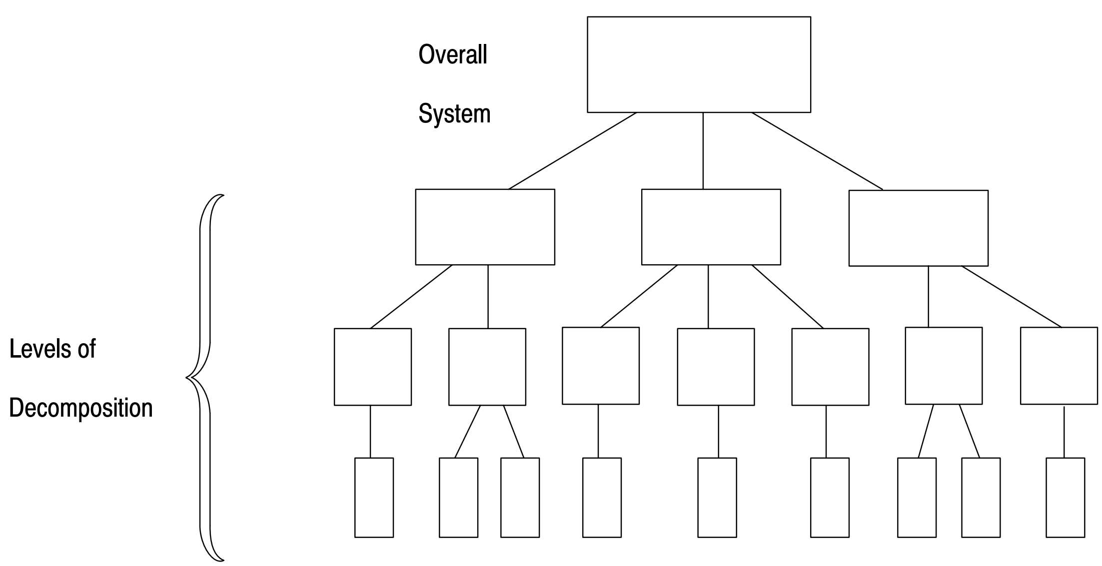
Logical decomposition levels could be:

- second level - decompose along physical lines of your system, for example:
  - stations of a transfer line
  - major operations of a machine or process
- third level - decompose along functional lines of your second level, for example:
  - operations of a station on a transfer line
  - suboperations of a machine or process
- fourth level - decompose according to the physical movements of third level components, for example:
  - movement of a component or a subassembly

Once you reach the level at which your segments become manageable, you can determine states for each segment.

Figure 3.1 shows the decomposition process. The top block or level represents the overall system. Other blocks in the pyramid show successive levels of decomposition.

Figure 3.1
Decomposition Process



Methods of Decomposition

To decompose a machine accurately, you must understand how the machine operates. You can use several methods to gain a better understanding of the relationships between the machine components at each level of decomposition. For example:

- sketch a block or physical diagram of the line, machine, or components
- refer to blueprints of the machine, if available
- describe the sequence of operation
- detail each operation
- refer to or develop a timing diagram for each operation

Apply these methods as needed to obtain the information you need to complete the decomposition process.

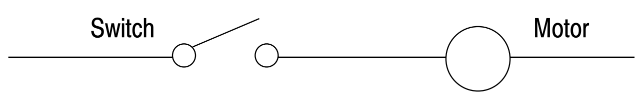
Defining States

A state corresponds to the physical status of a machine and its components, such as motor off or motor on.

States can be normal or in error. A state is normal when it follows the expected operation. A state is in error when it occurs outside normal operation.

In the following example we have a motor that is controlled by one input — an on/off switch. Figure 3.2 shows the relay logic diagram of the motor example.

Figure 3.2
Relay Logic Diagram of a Motor



We have two normal states in our motor example:

- motor on
- motor off

Figure 3.3 shows a schematic of our two normal states.

Figure 3.3
Normal States for Motor

Defining Transitions

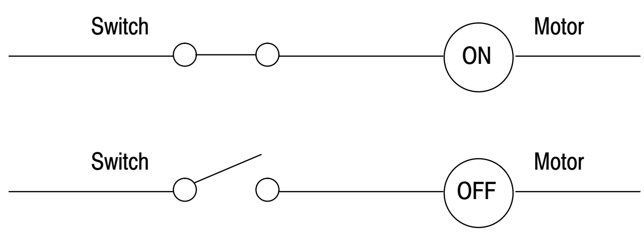
In this case, a single transition is the condition that provides direction to move from one state to another. Normally, we think of these conditions as inputs that change state or state transition. Transitions may be caused by actuators, sensors, or elapsed times. Conditions may be represented by an equation.

In our motor example we have two states, motor on and motor off. We also have two state transitions:

- Switch ON → OFF
- Switch OFF → ON

Figure 3.4 shows a schematic of input transitions between our two normal output states.

Figure 3.4
Transitions for Motor



Setting up a Truth Table

A truth table shows all possible states of a machine. The number of possible conditions in a truth table depends on the number of inputs.

When setting up a pure state transition application, you must be able to determine the state transitions you need to include when programming. You can determine the number of possible states using the following formula:

$\mathbf{P}=2^{\mathbf{I}}$

where:

- **P** = possible number of input state transitions
- **I** = number of inputs

For example, if you have two inputs, you have four possible state transitions, because $2^2 = 4$.

The number of possible states refers to physical or logical actions that could theoretically occur. The number of possible states does not always equal the number of states you use in a state application. Some will be impractical and can be ignored due to the nature of the machine. You can determine the number of practical states by setting up a truth table and analyzing the information.

To set up a truth table, list:

- all inputs and outputs in a row
- possible states of each input (use 1's and 0's to represent ON and OFF states) or equations that represent a set of conditions that must be met
- logical outputs based on the machine configuration

Table 3.A shows the truth table for our motor example:

Table 3.A
Truth Table for Motor

Inputs	Outputs
On/Off Switch	Motor
1	1
0	0

In this example the number of possible states equals the number of practical states.

Setting up a State Transition Diagram

A state diagram graphically represents the control or operation of a machine in a state transition format. A state diagram consists of states and transitions. States are often represented as bubbles. Transitions are often represented as arcs with arrows pointing in the appropriate direction between bubbles.

When defining states in a state diagram:

- label the state with the state number on the edge of the bubble
- put the name of the state inside the bubble

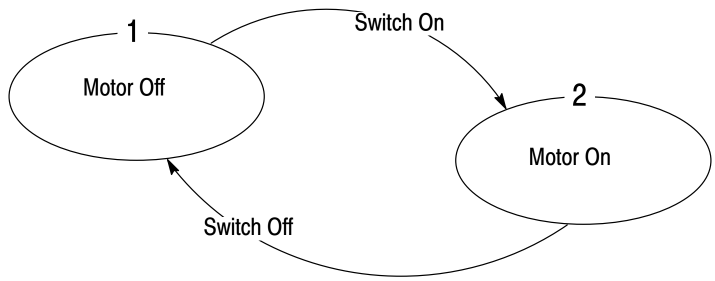
Important: When naming states, choose the name that most accurately describes what is happening at that particular state. When you begin using state names to diagnose machine faults it is imperative that the state name clearly identifies the state at which the fault is occurring.

When defining transitions in a state diagram label the:

- input causing the transition at the edge of the arc
- transition below or beside the input

Figure 3.5 shows a state diagram for the motor example.

Figure 3.5
State Diagram of Motor



Setting up a State Table

A state table combines information from the truth table with information from the state diagram.

A state table contains:

- output states
- input conditions
- input transitions
- actions to be taken

The state table is a helpful tool when you are ready to enter data into the SDS instruction. You can also take information directly from the state table and plug it into the fill-in-the-blank configuration templates at the programming terminal.

Table 3.B shows a state table for our simple motor.

Table 3.B
State Table for Motor

State	Input Description	Input Transition or Conditions	Next State	Output Description	Output Status
1	On/Off switch	OFF-->ON	State 2	Motor	OFF
2	On/Off switch	ON-->OFF	State 1	Motor	ON

A Drill Motor Example

The first motor example was helpful in showing how to use the tools in developing a state application. In the following example, we have a drill motor with one device — a motor starter — and four inputs. We use the same tools to develop a state transition application for the drill motor.

The following sequence of operation explains how the motor starter reacts to the different inputs:

1. When the **START PB** is pressed, the motor starter turns on

2. When the motor starter turns on, the **MOTOR STARTER AUXILIARY CONTACT** closes (turns on), sealing the circuit

3. If the motor starter has a current overload, the **MOTOR STARTER OVERLOAD CONTACT** opens (turns off). When the motor starter contact resets itself, then you can restart the motor by pressing the **START PB**.

4. When the **STOP PB** is pressed, the motor starter turns off

Figure 3.6 illustrates the above operation in a relay logic diagram. Figure 3.7 shows the PLC ladder logic for the same operation.

Figure 3.6
Relay Logic Diagram of Drill Motor Starter Operation

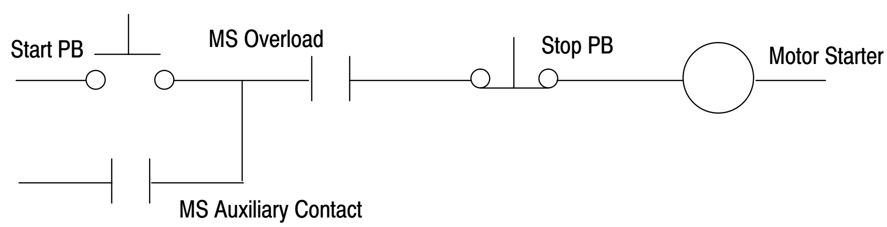
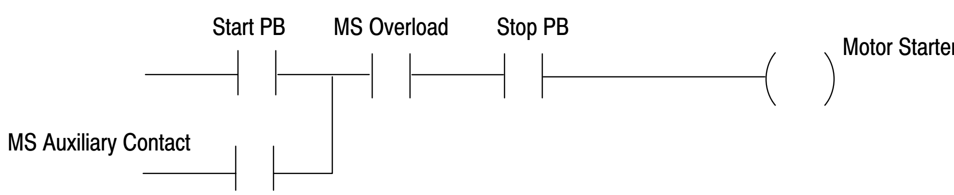


Figure 3.7
PLC Ladder Logic of Drill Motor Starter Operation



Decomposing the Drill Motor

Because the drill motor is a fairly simple operation with 4 inputs and 1 output, and one basic motion, we need not decompose it further.

Setting up a Truth Table

Using the formula 2^I we can determine that we have 16 possible states since we have four inputs.

Table 3.C shows the truth table which confirms this.

Table 3.C
Truth Table of Possible States for Drill Motor

Inputs				Outputs
Start PB	Auxiliary Contact	Stop PB	Motor Overload	Motor Starter
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	0
0	1	0	1	0
0	1	1	0	0
0	1	1	1	1
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	1
1	1	0	0	0
1	1	0	1	0
1	1	1	0	0
1	1	1	1	1

The truth table shows all of the possible states for the drill motor. Several of these states, though probable, are not practical for this application.

For example, it is unlikely that you will press the START PB and STOP PB at the same time or that all four inputs will be false at the same time. Likewise it makes little sense to worry about the START PB or the START AUXILIARY CONTACT when the motor overload is tripped, since it overrides both.

Once you have developed a truth table for possible states, you must evaluate each state for your application and narrow the truth table down to practical states. As you do this, think of the sequence of operation and try to put the states in order so you can develop your state diagram.

Table 3.D shows the truth table of practical states for the drill motor application.

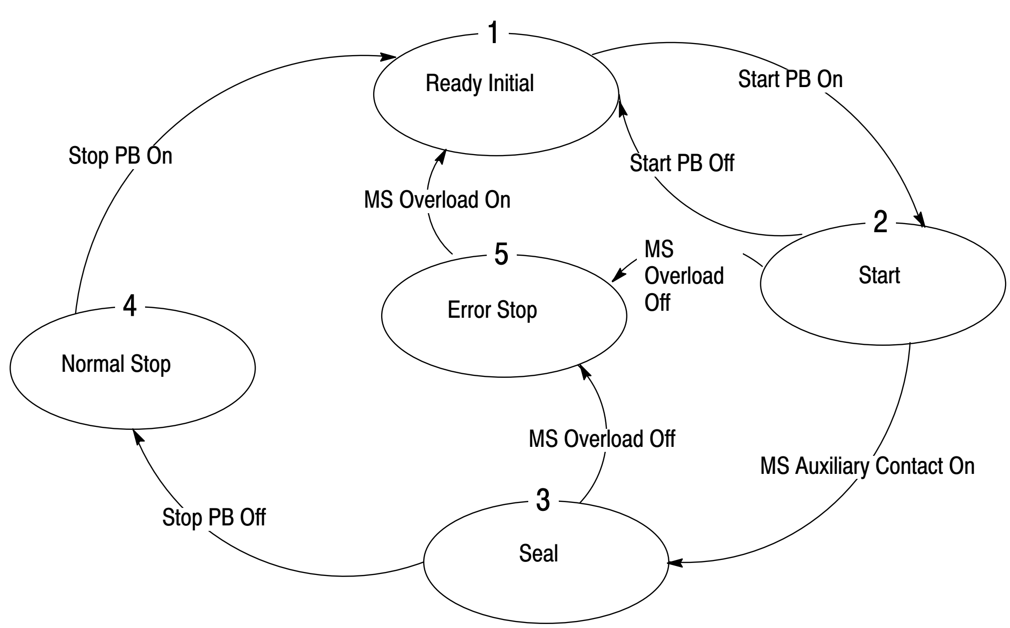
Table 3.D
Truth Table of Practical States for Drill Motor

Inputs				Outputs
Start PB	Auxiliary Contact	Stop PB	Motor Overload	Motor Starter
0	0	1	1	0
1	0	1	1	1
1	1	1	1	1
0	1	1	1	1
0	1	0	1	0
0	1	1	0	0
1	0	1	0	0

Setting up a State a Diagram

Figure 3.8 shows the state diagram for the drill motor example. Note that the diagram consists of only five states. (Our truth table of practical states contained seven.) In this case rows (or states) 3 and 4 and rows 6 and 7 in the table could be combined since the state of the START PB varied and did not change the operation.

Figure 3.8
State Diagram of Drill Motor (State Transition Logic)



Setting up a State Table

Table 3.E shows the state table for the drill motor. Blanks in the input transition column and next state column mean the state is ignored.

Table 3.E
State Table for Drill Motor

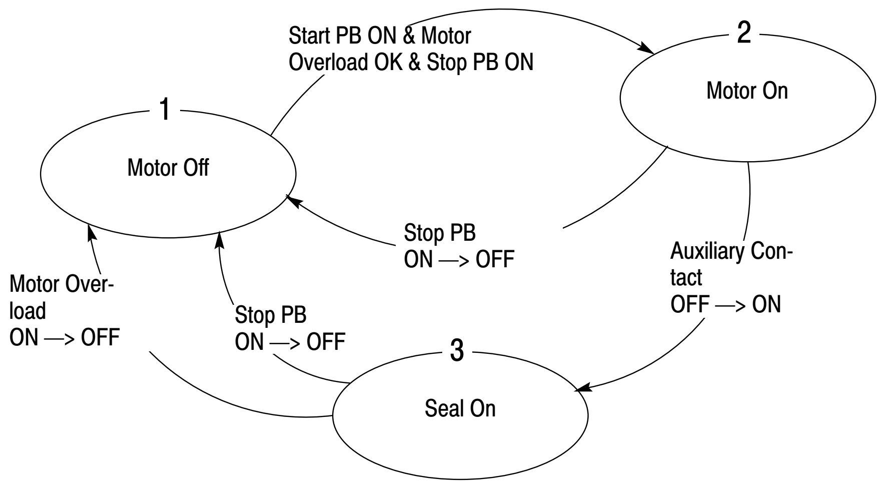
State	Input Description	Input Transition	Next State	Output Description	Output Status
1	Start PB Auxiliary Contact Stop PB Motor Overload	OFF-->ON	State 2	Motor Starter	OFF
2	Start PB Auxiliary Contact Stop PB Motor Overload	ON-->OFF OFF-->ON ON-->OFF	State 1 State 3 State 5	Motor Starter	ON
3	Start PB Auxiliary Contact Stop PB Motor Overload	 ON-->OFF ON-->OFF	 State 4 State 5	Motor Starter	ON
4	Start PB Auxiliary Contact Stop PB Motor Overload	 OFF-->ON	 State 1	Motor Starter	OFF
5	Start PB Auxiliary Contact Stop PB Motor Overload	 OFF-->ON	 State 1	Motor Starter	OFF

A Combinatorial Logic Approach

Another more practical approach to the drill motor example would be to utilize the combinatorial functionality available in the SDS to reduce complexity based on individual transitions.

Figure 3.9 shows the state diagram for the drill motor. Instead of five states using the state transition method, using the combinatorial approach we have only *three* states to be concerned with.

Figure 3.9
State Diagram of Drill Motor (Combinatorial Logic)



In Figure 3.9, we don't care about the order in which the Start PB, Motor Overload, and Stop PB transition to ON. We only care that they are all on at the same time for us to go to the Motor ON step. Table 3.F shows the conditional logic for the drill motor in a table form. The 1's and 0's represent the states that are applicable to the operation of the drill motor. The dashes represent "don't care" states. Compare this table to the truth table on page 3-9.

Table 3.F
Conditional Logic Table for Drill Motor

Inputs				Outputs
Start PB	Auxiliary Contact	Stop PB	Motor Overload	Motor Starter
1 and	—	1 and	1	1
—	—	—	1	1
—	—	0	—	0
—	0	—	—	0

Using the conditional approach, the sequence of input transitions is not considered or checked. The diagnostic accuracy desired may be a factor in when to use or when not use this approach. For the above example, the diagnostics should retain a high degree of accuracy since the probability of all three conditions failing at the same time is low. With the combinatorial SDS instruction functionality, you can configure messages to annunciate all missing conditions.

Summary

This chapter described the concepts of state transitional programming by developing a small state application for a motor and a drill motor.

We also showed you tools to help you identify states and transitions for your application, such as setting up a:

- truth table
- state diagram
- state table

Chapter 4 builds upon the concepts presented in this chapter by developing a state application for a larger example.

Chapter 4

Organizing a Drill Machine Application

Chapter Objectives

Read this chapter to get a better understanding of developing a Level 3 state transition application. The machine we describe in this chapter — a drill machine — is not technically a “real world” application; however, the procedure will help you better understand the concepts for implementing a Level 3 state transition application.

In this chapter we:

- describe the two-station drill machine
- decompose the two-station drill machine into manageable segments
- prepare a state diagram and state tables for one of the two-station drill machine segments

Becoming Familiar with the Drill Machine

Figure 4.1 shows a diagram of a two-station drill machine and all of its devices. We first decompose the drill machine into manageable segments; then, we set up a state application for one of the segments created by decomposition.

Figure 4.2 shows the operation of our drill machine in a relay logic diagram.

Figure 4.1
Diagram of Two-station Drill Machine

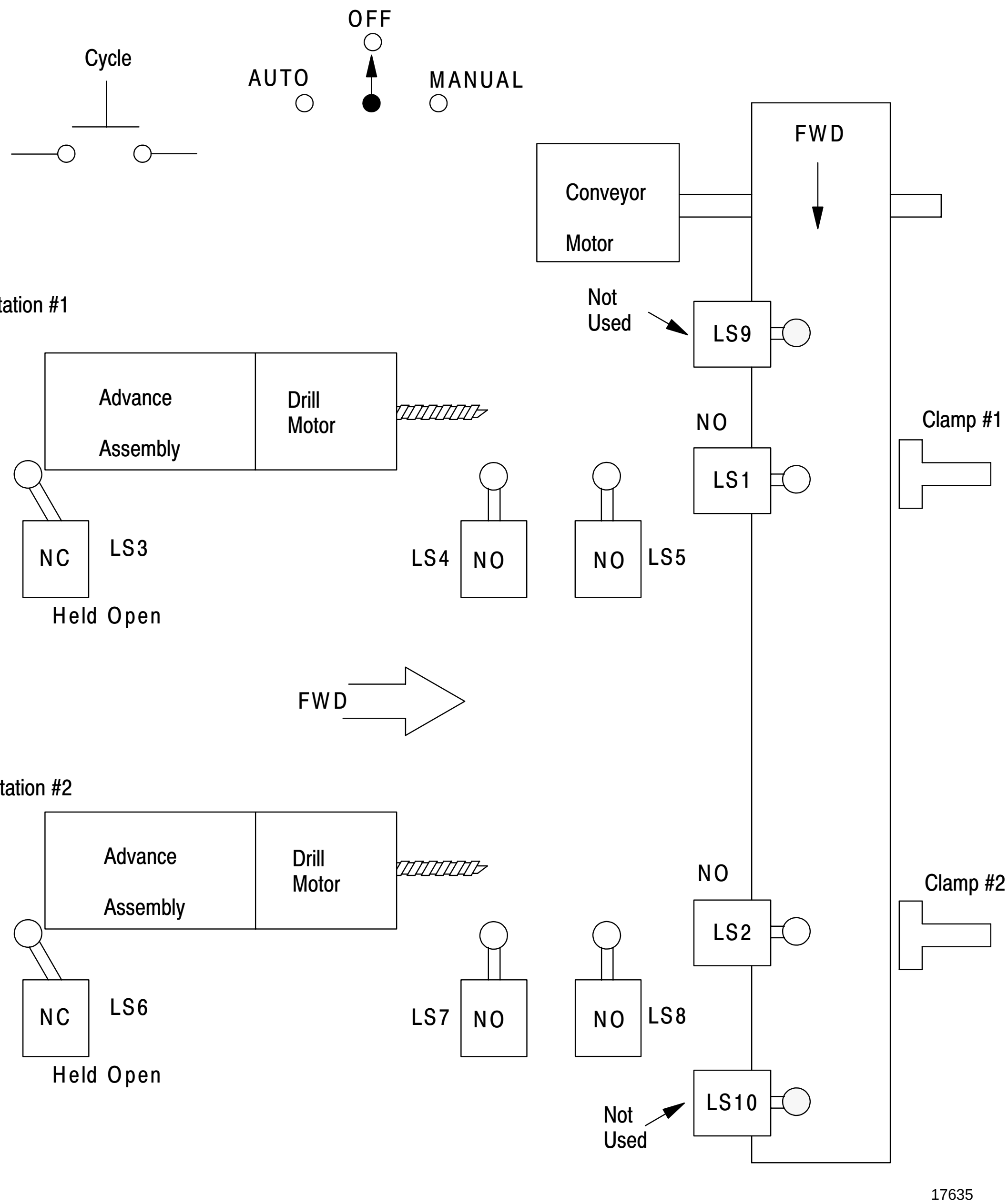
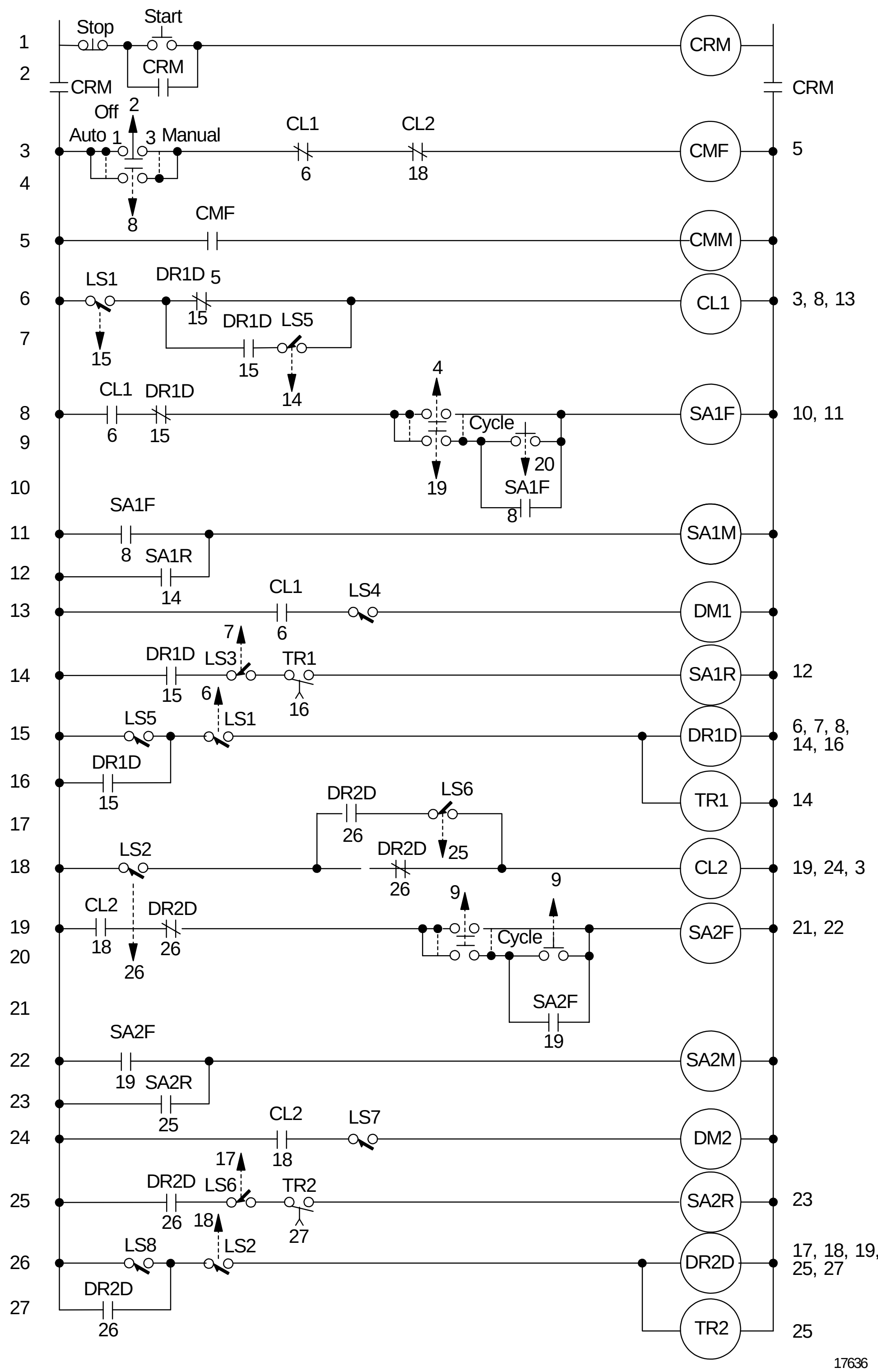


Figure 4.2
Relay Logic Diagram of Two-station Drill Machine



Decomposing the Drill Machine

To decompose our drill machine, we use some of the methods previously described for decomposition.

Our first level of decomposition is the two-station drill machine (see Figure 4.1 and Figure 4.2).

Decomposing to the Second Level

Using the diagram of the drill machine at Figure 4.1, we can see three basic operations — a conveyor operation and two drilling operations. Therefore, we decompose the drill machine into three second-level segments:

- drill station #1
- drill station #2
- indexing conveyor

Decomposing to the Third Level

To decompose to the next level we need to look at what happens at each operation. By referring back to Figure 4.1 and analyzing the sequence of operation for the drill machine, we can decompose each operation into suboperations.

Table 4.A gives us an overview of the drill machine operations.

Table 4.A
Overview of Drill Machine Operations

Type of Operation	Step	Description
System Initialization and Shutdown	1	Turn the SELECTOR SWITCH to Auto (position 1) or Manual (position 2).
	2	Press the START BUTTON to start the conveyor.
	3	Press the E-STOP BUTTON to shut the entire machine down.
Sequence of Operation	1	A part is placed on the start end of the indexing conveyor.
	2	The part actuates the part-in-place limit switch (LS1), indicating the part is at the drill station #1.
	3	Drill station #1 clamp solenoid (CL1) is energized and the conveyor motor is de-energized.
	4	AUTO — Drill station assembly #1 moves forward. MANUAL — Press cycle button, moving drill station assembly #1 forward.

Type of Operation	Step	Description
	5	Drill station assembly #1 actuates the advanced limit switch (LS4), energizing drill motor #1.
	6	Drill station assembly #1 actuates the full depth limit switch (LS5), stopping drill station assembly #1, and initiating a three-second dwell.
	7	After the three-second dwell delay, drill station assembly #1 begins to retract.
	8	Drill station assembly #1 retracts past LS4 (LS4 opens), de-energizing drill motor #1.
	9	Drill station assembly #1 actuates the returned limit switch (LS3), stopping the assemble, de-energizing CL1, and starting the indexing conveyor to move the part to drill station #2.
Steps 4 through 9 are repeated for drill station #2.		

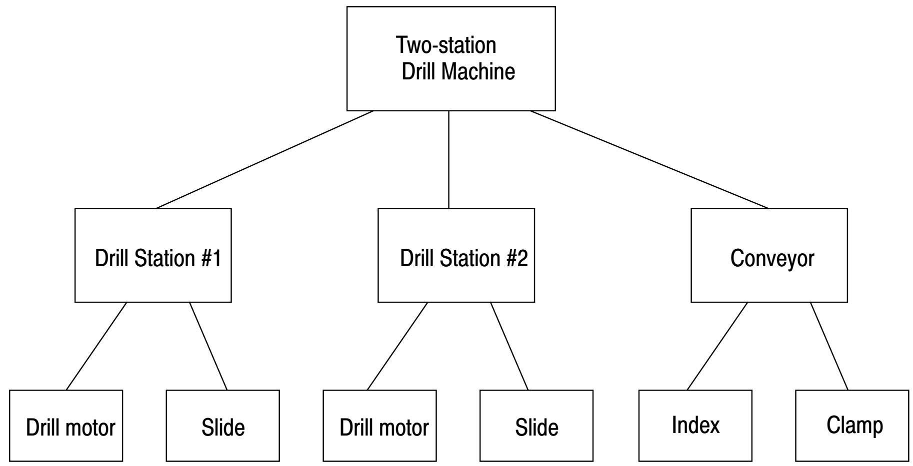
Now that we understand the working relationship of operations, we can decompose each operation into the following suboperations:

- **indexing conveyor**
  - conveyor index
  - clamp assembly
- **drill station #1**
  - drill motor assembly
  - slide assembly
- **drill station #2**
  - drill motor assembly
  - slide assembly

Based on the sequence of operation and sketch of the drill machine, we can establish that our suboperations for each operation are fairly simple. Therefore, we can determine states from the second level of decomposition without decomposing further.

Figure 4.3 graphically shows the decomposition process for the two-station drill machine.

Figure 4.3
Decomposition Process for Drill Machine



In the event that you decompose to a level and find that your number of states for each segment becomes unmanageable, we recommend that you decompose the segment to the next level.

Defining States for a Drill Machine Segment

After decomposing the drill machine into manageable segments, we can define states and transitions for each segment as described in chapter 3. We use the segment of drill station #1 as an example.

Figure 4.4 and Figure 4.5 shows drill station #1 and the relay logic diagram for its operation. Refer to Figure 4.1 to see how these segments fit into the overall machine process.

Figure 4.4
Drill Station #1

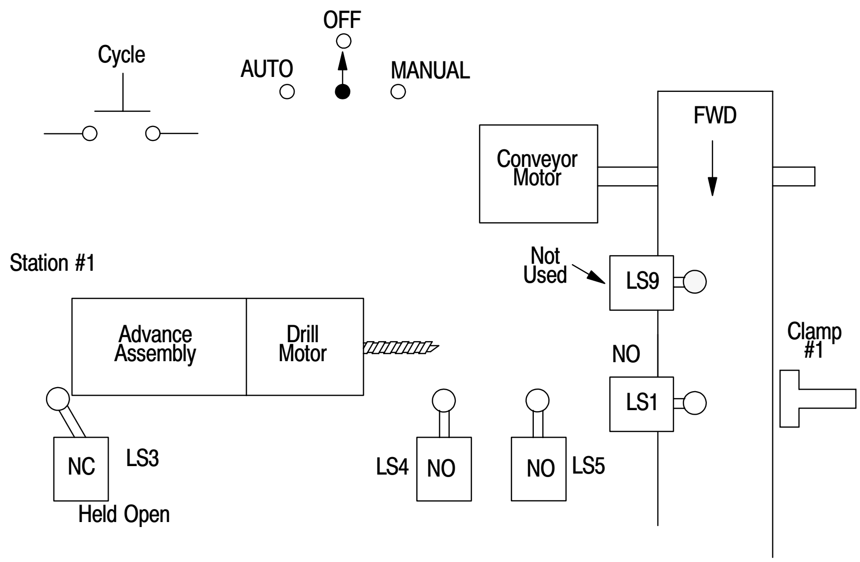
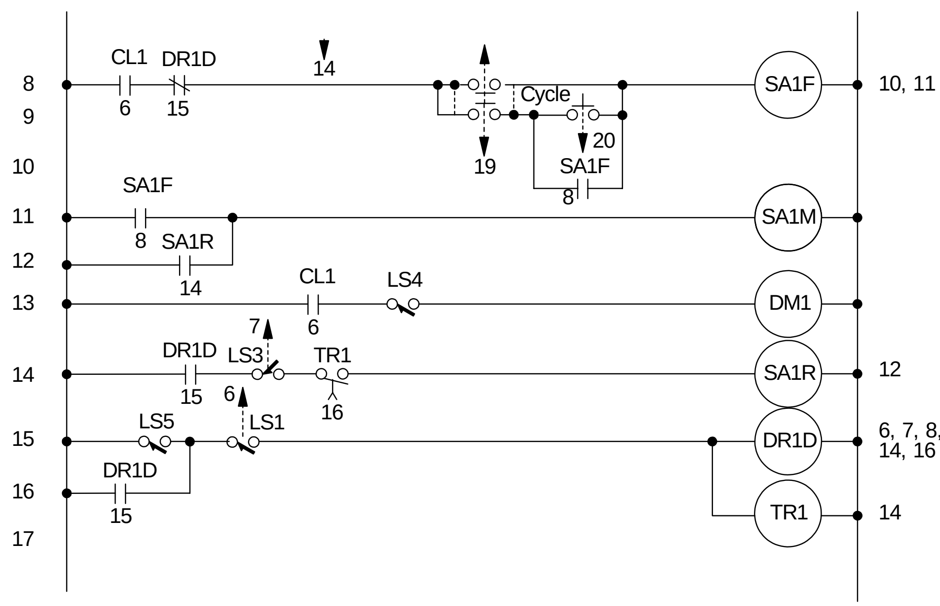


Figure 4.5
Relay Logic Diagram of Station #1



Defining Inputs and Outputs

To define the possible states in station #1, we need to know the inputs and outputs.

Inputs for station #1:

Physical:

- returned limit switch (LS3)
- advanced limit switch (LS4)
- full depth limit switch (LS5)

Logical:

- advance command
- return command

Outputs for station #1:

Physical:

- station #1 on/off (SAIM)
- station #1 forward motor (SAIF)
- station #1 reverse motor (SAIR)
- drill motor (DM1)

Using the formula 2^I, we can determine that we have 32 possible states for drill station #1 since we have five inputs ($2^5 = 32$). As with the drill motor example in chapter 3, several of the possible states are not practical for this application.

Analyzing the Sequence of Operation

By referring to steps 4 - 9 in the sequence of operation at Table 4.A ,we can logically define states for drill station #1. Table 4.B shows the analysis you must go through to turn steps of the sequence of operation into states. State names appear in all capital letters. Some steps may contain more than one state if more than one input transition changes within that step.

Table 4.B
Analysis of Steps in Sequence of Operation

Step (from Figure 4.4)	Corresponding States
4	When all motors are off and station #1 is looking for a command, the station is RETURNED AND READY. When station #1 receives the advance command, the station is READY TO ADVANCE. As station #1 moves forward, it de-activates LS3, meaning the station is ADVANCING.
5	Once station #1 actuates LS4, the station is ADVANCED. At this point the drill motor comes on.
6	Station #1 is still moving forward. When station #1 actuates LS5, it stops moving forward, meaning the station is AT FULL DEPTH. The drill motor is still turning. When station #1 receives a return command or has met full depth conditions, it remains in position for three seconds, that is, at FULL DEPTH DWELL, letting the drill clean out any chips remaining in the part.
7	When the timer for the three-second dwell goes off, station #1 is at FULL DEPTH AND RETURNING. When station #1 retracts past and de-activates LS5, the station is ADVANCED AND RETURNING.
8	When station #1 retracts past and deactivates LS4, the station is RETURNING.
9	Once station #1 actuates LS3, it is back to its original position at RETURNED AND READY.

After you have determined all of the normal states from the sequence of operation, you need to determine the error states. For example, once the returned limit switch (LS3) goes on, it should remain on until station #1 returns to its original position after cycling. If LS3 goes off when the advance limit switch (LS4) goes on, then we have an error state. Your state diagrams and state tables should account for all error states that could occur.

Setting up a State Diagram

Figure 4.6 shows the state diagram for drill station #1.

Figure 4.6
State Diagram for Drill Station #1

Important: In the state diagram, the error step has no transitions leading to or from it. This is because all states except state 11 lead to the error state. The error state in turn leads back to an INITIALIZATION state. The INITIALIZATION state is discussed in the DDMC User's Manual (publication 6401–6.5.1). We chose to eliminate the transition arcs to the error state to keep the state diagram readable. You may want to do this in similar cases also.

Setting up a State Table

Table 4.C shows the state table for drill station #1.

Table 4.C
State Table for Drill Station #1

State	Input Description	Input Transition	Next State	Output Description	Output Status
1	Returned LS Advanced LS Full Depth LS Advance Command Return Command	OFF-->ON OFF-->ON OFF-->ON OFF-->ON	State 10 State 10 State 10 State 2	Forward Motor Reverse Motor Drill Motor	OFF OFF OFF
2	Returned LS Advanced LS Full Depth LS Advance Command Return Command	OFF-->ON OFF-->ON OFF-->ON ON-->OFF	State 3 State 10 State 10 State 1	Forward Motor Reverse Motor Drill Motor	ON OFF OFF
3	Returned LS Advanced LS Full Depth LS Advance Command Return Command	ON-->OFF OFF-->ON OFF-->ON ON-->OFF	State 10 State 4 State 10 State 11	Forward Motor Reverse Motor Drill Motor	ON OFF OFF
4	Returned LS Advanced LS Full Depth LS Advance Command Return Command	ON-->OFF ON-->OFF OFF-->ON ON-->OFF	State 10 State 10 State 5 State 10	Forward Motor Reverse Motor Drill Motor	ON OFF ON
5	Returned LS Advanced LS Full Depth LS Advance Command Return Command	ON-->OFF ON-->OFF ON-->OFF OFF-->ON	State 10 State 10 State 10 State 6	Forward Motor Reverse Motor Drill Motor	OFF OFF ON

Table 4.C
State Table for Drill Station #1 (cont.)

State	Input Description	Input Transition	Next State	Output Description	Output Status
6	Returned LS	ON-->OFF	State 10	Forward Motor	OFF
	Advanced LS	ON-->OFF	State 10	Reverse Motor	OFF
	Full Depth LS	ON-->OFF	State 10	Drill Motor	ON
	Advance Command				
	Return Command	ON-->OFF	State 5		
	Timer	OFF-->ON	State 7		
7	Returned LS	ON-->OFF	State 10	Forward Motor	OFF
	Advanced LS	ON-->OFF	State 10	Reverse Motor	ON
	Full Depth LS	ON-->OFF	State 8	Drill Motor	ON
	Advance Command				
	Return Command	ON-->OFF	State 11		
8	Returned LS	ON-->OFF	State 10	Forward Motor	OFF
	Advanced LS	ON-->OFF	State 9	Reverse Motor	ON
	Full Depth LS	OFF-->ON	State 10	Drill Motor	OFF
	Advance Command				
	Return Command	ON-->OFF	State 11		
9	Returned LS	ON-->OFF	State 1	Forward Motor	OFF
	Advanced LS	OFF-->ON	State 10	Reverse Motor	ON
	Full Depth LS	OFF-->ON	State 10	Drill Motor	OFF
	Advance Command				
	Return Command				
10	Returned LS			Forward Motor	OFF
	Advanced LS			Reverse Motor	OFF
	Full Depth LS			Drill Motor	OFF
	Advance Command				
	Return Command				
11	Returned LS		State 3	Forward Motor	OFF
	Advanced LS		State 8	Reverse Motor	OFF
	Full Depth LS			Drill Motor	OFF
	Advance Command	OFF-->ON			
	Return Command	OFF-->ON			

Once you have defined states and transitions for one segment of your state application, you can do the same for each of the other segments you want to program with state logic.

Assigning I/O

Before you can develop your program, you must assign addresses to your inputs and outputs. I/O module assignments are the same regardless of the control method used. Addresses are entered onto rungs on the ladder program and into the I/O definition screen in the SDS instruction.

Addressing

The PLC-5 processor can address its I/O in 2-slot, 1-slot, and 1/2-slot groups. Refer to PLC-5 Family Programmable Controllers Installation Manual (publication 1785-6.6.1) for information on how to address your hardware.

Refer to PLC-5 Programming Software Documentation Set (publication 6200-N8.001) or PLC-5/250 Programming Software Documentation Set (publication 6200-N8.002) for information on formatting I/O addresses.

As you program, you will want to have addresses, descriptions, and symbolic names of I/O accessible. (Symbolic names can be up to 10 characters long in 6200 series software.) Figure 4.7 and Figure 4.8 shows Worksheet 1 and Worksheet 2 — I/O Data Worksheets for the two-station drill machine. Outputs are listed on the first worksheet; inputs are on the second worksheet.

Figure 4.7
I/O Data Worksheet for Two-station Drill Machine - Outputs

RACK ADDRESS GROUPING 0 **PAGE** 1 **OF** 2

DATE ____

PROJECT NAME Two-station drill machine **MODULE GROUP** 0

DESIGNER ____

Address	Symbolic Name	Description
00	CLAMP 2	CLAMP #2 (CL2)
01	SAIR CYC	STATION # ONE REVERSE (SAIR)
02	DRILLMTR1	DRILL MOTOR # ONE (DM1)
03	SAIM CYC	STATION # ONE ON (SAIM)
04	SAIF CYC	STATION # ONE FORWARD (SAIF)
05	CLAMP 1	CLAMP # ONE (CL1)
06	C FORWARD	CONVEYOR MOTOR FORWARD (CMF)
07	CONV MTR	CONVEYOR MOTOR ON (CMM)
10	SA2F CYC	STATION # TWO FORWARD (SA2F)
11	ADVCOMD2	STATION # TWO ON (SA2M)
12	DRILLMTR2	DRILL MOTOR # TWO (DM2)
13	REVMTR2	STATION # TWO REVERSE (SA2R)

Figure 4.8
I/O Data Worksheet for Two-station Drill Machine

RACK ADDRESS GROUPING 0 **PAGE** 2 **OF** 2
PROJECT NAME Two-station drill machine **MODULE GROUP** 1 **DATE**
DESIGNER

Address	Symbolic Name	Description
00		
01	LS2	LIMIT SWITCH # 2 N/O (LS2)
02		
03	RET LS6	LIMIT SWITCH # 6 N/C (LS6)
04	LS1	LIMIT SWITCH # 1 N/O
05	CYCLE	PUSH BUTTON
06	AUTO	POSITION # 1
07	MANUAL	POSITION # 3
10	ADV LS7	LIMIT SWITCH # 7 N/O (LS7)
11	FD2 LS8	LIMIT SWITCH # 8 N/O (LS6)
12		
13		
14	FD LS5	LIMIT SWITCH # 5 N/O (LS5)
15	ADV LS4	LIMIT SWITCH # 4 N/O (LS4)
16	RET LS3	LIMIT SWITCH # 3 N/C (LS3)

Combining the SDS Instruction with Ladder Logic

By combining the SDS instruction with ladder logic, you can develop an effective application program in less time while increasing your machine's diagnostic capabilities.

For example, suppose you have a machine that operates in two modes — automatic and manual. You would need two SDS instructions to account for the operation in each mode. By keeping the auto/manual permissive in the ladder program, you need only one SDS instruction.

You can optimize your programming, if you use the SDS instruction for:

- outputs to be controlled
- inputs or signals you want to diagnose
- devices that provide feedback
- “what” information

and use ladder logic for:

- serial permissives
- combinatorial logic
- “why” and “when” information

For example, in our drill machine example, we will not develop state logic for the clamp because we do not receive feedback from the clamp to determine if it closed properly. (In most “real-world” examples there would be an input to make this determination.)

Using the SDS Instruction

In DDMC, state logic resides in ladder logic in the form of an SDS instruction. Within this one instruction is all of the logic from the state diagram and state tables described earlier.

The SDS instruction is very powerful; in the PLC-5/250 processor it can contain up to 255 states (or steps). In the PLC-5 processor, the instruction can contain 76 steps with 8 inputs, 45 steps with 16 inputs, or 23 steps with 32 inputs. You determine the number of states per SDS instruction through the decomposition process. (In our two-station drill machine example, we defined 11 states.) Each diagnostic segment derived from the decomposition process has its own SDS instruction on a rung of ladder logic.

Each SDS instruction contains screens for entering the I/O, states, and transitions from the state diagram and state table. Refer to the DDMC User's Manual (publication 6401–6.5.1) for more information on the instruction's configuration screens.

Figure 4.9 shows the state configuration for station #1 of the two-station drill machine in a step description worksheet. The SDS instruction uses the term "step" to refer to states. For example, in our drill machine example we have 11 steps. We have provided blank worksheets in appendix B if you would like to use them when configuring your instructions.

Figure 4.9
Step DescriptionWorksheet for Station #1 of the Drill Machine

STEP Returned & Ready TIMER 0.00 sec. STEP ______ MESSAGES: ON / OFF

No	Input ID	Equation	Destination	No	Output ID	State
1	Returned LS	OFF-->ON	STEP 10	1	Forward Motor	OFF
2	Advanced LS	OFF-->ON	STEP 10	2	Reverse Motor	OFF
3	Full Depth LS	OFF-->ON	STEP 10	3	Drill Motor	OFF
4	Advance Command	OFF-->ON	STEP 2	4		
5	Return Command		STEP	5		
6			STEP	6		
7			STEP	7		
8			STEP	8		
9			STEP	9		
10			STEP	10		
11			STEP	11		
12			STEP	12		

STEP Ready to Advance TIMER 20.00 sec. STEP 10 MESSAGES: ON / OFF

No	Input ID	Equation	Destination	No	Output ID	State
1	Returned LS	OFF-->ON	STEP 3	1	Forward Motor	ON
2	Advanced LS	OFF-->ON	STEP 10	2	Reverse Motor	OFF
3	Full Depth LS	OFF-->ON	STEP 10	3	Drill Motor	OFF
4	Advance Command	ON-->OFF	STEP 1	4		
5	Return Command		STEP	5		
6			STEP	6		
7			STEP	7		
8			STEP	8		
9			STEP	9		
10			STEP	10		
11			STEP	11		
12			STEP	12		

Integrating the SDS Instruction with Ladder Logic

Figure 4.10 shows a ladder program for the two-station drill machine. We have incorporated the state logic we developed for drill station #1 in the SDS instruction at rung 2.7. As previously mentioned, the clamps have been kept in ladder logic only because they do not contain feedback sensors to say we are clamped, preventing us from diagnosing a fault.

As a contrast, we kept the entire control for drill station #2 in ladder logic, even though it and drill station #1 are identical. We did this so that you could see the manipulations made in the ladder program to accommodate the SDS instruction.

Figure 4.10
Ladder Program for Two-station Drill Machine

Figure 4.10
Ladder Program for Two-station Drill Machine (continued)

Figure 4.10
Ladder Program for Two-station Drill Machine (continued)

Summary

In this chapter we showed you how to decompose a machine into manageable segments so that you could set up a state application. We also took one segment created by decomposition and defined states and transitions with a state diagram and state table. Read chapter 5 to see how to apply DDMC, specifically the SDS instruction, to a larger application that uses state transition logic.

Chapter 5

Organizing a Transfer Line Application

Chapter Objectives

Read this chapter to see how state transitional logic is applied to a transfer line. In this chapter, we:

- decompose the transfer line into manageable segments
- implement state control with ladder logic
- show methods of determining the number of SDS instructions
- develop a state diagram and state table for each SDS instruction

Decomposing the Transfer Line

A transfer line is composed of several smaller assemblies. Seting up a state application for such a large system requires the decomposition process. When decomposing the transfer line, you want to break the line down into manageable segments. By using the methods previously described, you can decompose level by level until you achieve segments that are manageable.

Figure 5.1 shows a block diagram of the transfer line where each block represents a station. We use this block diagram to visualize the complexity of the transfer line so we can decompose it.

Figure 5.1
Transfer Line Block Diagram

R.H.	Station	L.H.
R.H. LOADING STATION	1	
	2	
	3	L.H. PRESS STATION
	4	L.H. PRESS STATION
	5	
R.H. PRESS STATION	6	
R.H. PRESS STATION	7	
	8	
	9	L.H. PROBE GAUGE
R.H. BORE & REAM	10	L.H. SLIDE
R.H PROBE/GAUGE	11	
R.H. EJECT STATION	12	
	13	
R.H. CNC STATION	14	L.H. CNC STATION
	15	
	16	L.H. EJECT STATION
R.H MILLING STATION	17	
	18	
	19	
	20	L.H. MILLING STATION
	21	
	22	
R.H. STAMPING STATION	23	
	24	
R.H. UNLOADING	25	

Decomposing to the Second Level (Stations)

In a transfer line application, decomposing to the second level requires dividing the system along physical lines. By looking at the block diagram (Figure 5.1), we see transfer and clamping mechanisms and a series of stations. Therefore, we can decompose the line into 27 separate stations — the 25 stations on the line, the transfer mechanism, and the clamping mechanism.

Decomposing to the Third Level (Operations)

Once you have determined the second level of decomposition (stations), you must decompose each of the stations to the next level (in this case, operations). We have selected station 10 (R.H. line bore and ream/L.H. slide station) to decompose to operations.

At this point we want to look at the subassemblies that make up station 10. If the subassemblies require further breakdown, we will continue the decomposition process.

Several operations are performed at station 10. The subassemblies performing these operations are:

- clamp/lower/lock
- line bore feed
- reamer feed
- slide index table
- slide feed

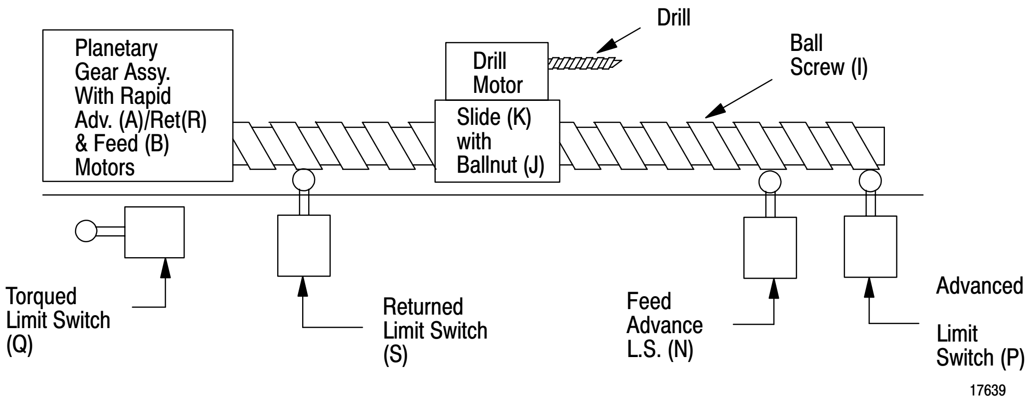
Because each subassembly contains several components, we want to continue decomposing to determine manageable segments.

Decomposing to the Fourth Level (Motions)

From station 10, we have selected the slide to decompose into motions. To decompose the slide, we must look very closely at the motions the slide components make through their sequence of operation.

Figure 5.2 shows the physical arrangement of the slide's devices.

Figure 5.2
Slide Representation



The slide's devices are fairly simple with the exception of the sun/planetary gearbox. Figure 5.3 shows mechanical drawings detailing slide's devices and their movement.

Figure 5.3
Slide Mechanical Drawings

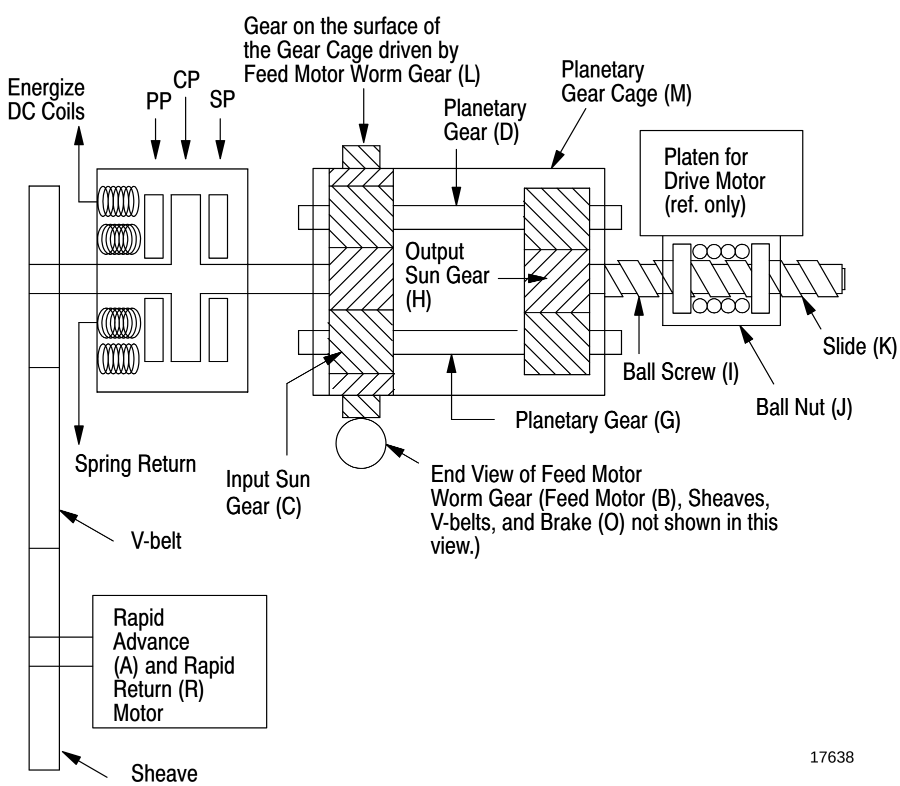
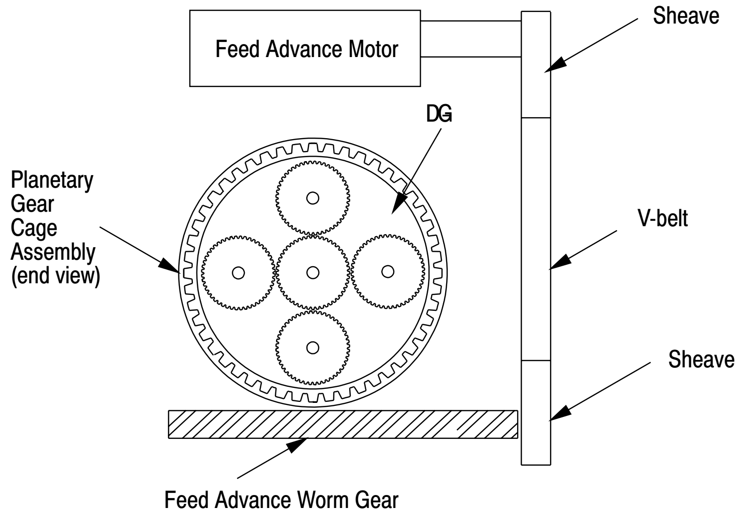


Figure 5.4
Slide Mechanical Drawings (continued)



To detail the slide further, we need to get an overview of its operation (Table 5.A). Reference letters from components in Figure 5.2 and Figure 5.3 are shown in parentheses.

Table 5.A
Overview of Slide Operations

Type of Operation	Step	Description
System Initialization	1	Turn on the rapid advance motor (A).
	2	Turn on the feed motor (B).
Sequence of Operation	1	When the rapid advance motor (A) is turned on, the input sun gear (C) turns the planetary gears (D-G).
	2	The planetary gears (D-G) turn the output sun gear (H).
	3	The output sun gear (H) turns the ball screw (I).
	4	The ball screw (I) moves the ball nut (J) forward.
	5	The slide (K) is then carried forward by the ball nut (J).
	6	When the feed motor (B) is turned on, the feed motor (B) drives the worm gear (L).
	7	The worm gear (L) then drives the surfaces of the gearbox cage (M). This affects the slide (K) speed.

Table 5.A
Overview of Slide Operations (continued)

Type of Operation	Step	Description
	8	In about 8 seconds, the feed limit switch (N) is activated, de-energizing the rapid motor (A) and engaging the brake (O).
	9	When the brake (O) is engaged, the input sun gear (C) locks up.
	10	The slide (K) speed is reduced to the feed rate as the feed motor (B) is still spinning the gearbox cage (M).
	11	This actuates the advanced limit switch (P) in about 8 seconds.
	12	When the slide (K) advances to a mechanical stop, a torque spring actuates a piston operated limit switch (Q) in about 1 second.
	13	When the feed motor (B) is turned off, there is a short dwell time of about one second to ensure that the drilling is complete.
	14	When the rapid return motor (R) is turned on, the effect of driving the gearbox cage (M) backward against the worm gear (L) locks up the cage.
	15	The rapid return then occurs at the rapid rate, actuating the returned limit switch (S), about 2 seconds later.
	16	This turns the rapid return motor (R) off.

Based on the methodology presented in chapter 3 and recalling examples, we can:

- associate states with different movements from the sequence of operation.
- decompose the slide into the following movements:
  - brake engage
  - brake disengage
  - rapid advance slide
  - rapid return slide
  - feed advance slide

We stop our decomposition at this point and set up our state application from this level.

Detailing the I/O

To determine states for our example, we need to know the physical and logical inputs and outputs controlling the operation of the slide. (Refer to Figure 5.3 for locations of devices.)

The **physical inputs** or **sensors** needed by the state logic (to sense the motion, position, states, or conditions of the devices) are:

- brake contactor energized
- feed motor started energized
- rapid advance motor started energized
- rapid return motor started energized
- returned position limit switch
- advanced position limit switch
- feed position limit switch
- torqued limit switch
- rapid advance/return motor overloads
- feed motor overloads

The **logical input requests** (internal ladder logic or other SDS instructions) to the state logic are:

- brake release request
- feed request
- rapid return request
- rapid advance request
- reset overloads request

The **physical outputs** used by the state logic to control the output devices are:

- brake release command
- feed advance command
- rapid advance command
- rapid return command

The **logical output indications** (internal ladder logic) needed by the state logic to synchronize with other state and ladder logic are:

- brake release indication
- advanced indication
- returned indication
- in feed area indication
- overloads okay indication

Organizing the Logic

To reduce complexity and programming time, evaluate which logic is handled best in ladder programming and which works best in state programming before setting up your SDS instructions.

Associating Motions with SDS Instructions

With larger applications that require decomposing to the motion level, you may want to associate the physical movements with SDS instructions. This lets you determine how many instructions you need to achieve a manageable number of states per instruction.

You can do this by:

1. sketching a sample SDS block of the operation
2. breaking the block into multiple SDS instructions
3. picking one view to develop into SDS instruction

Sketching a Sample SDS Block

Table 5.B shows the sample single SDS block with all physical and logical inputs and outputs. Using the large block as one SDS instruction, we have 2^{15} = 32,786 possible states.

Because this is too complex to handle as one SDS instruction, we want to decompose the large block into smaller blocks with fewer possible states.

Table 5.B
Sample SDS Block of the Operation - 15 Inputs and 9 Outputs

Inputs	Outputs
1. brake contactor energized	1. brake release indication
2. brake release request	2. brake release command
3. feed motor starter energized	3. feed advance command
4. rapid return motor starter energized	4. rapid return command
5. returned position limit switch	5. returned indication
6. advanced position limit switch	6. advanced indication
7. torqued limit switch	
8. feed request	
9. rapid return request	
10 rapid advance motor starter energized	7. rapid advance command
11. feed position limit switch	8. in feed area indication
12. rapid advance request	
13. rapid advance/return motor overloads	9. overload okay indication
14. feed motor overload	
15. reset overload request	

Table 5.C shows the SDS block decomposed into two motions:

- brake engage
- advance/return

By decreasing the number of inputs in each section of the block, we have simplified our SDS instructions.

Table 5.C
View # 1 of SDS Block - Brake Engage, Advance/Return

Inputs	Outputs
1. brake contactor energized	1. brake release indication
2. brake release request	2. brake release command
3. feed motor starter energized	3. feed advance command
4. rapid return motor starter energized	4. rapid return command
5. returned position limit switch	5. returned indication
6. advanced position limit switch	6. advanced indication
7. torqued limit switch	
8. feed request	
9. rapid return request	
10 rapid advance motor starter energized	7. rapid advance command
11. feed position limit switch	8. in feed area indication
12. rapid advance request	
13. rapid advance/return motor overloads	9. overload okay indication
14. feed motor overload	
15. reset overload request	

Table 5.D shows the SDS block decomposed into three motions:

- brake engage
- feed
- rapid advance/rapid return

By further reducing the inputs in each segment, we continue to simplify the SDS instructions.

Table 5.D
View # 2 of SDS Block - Brake Engage, Feed, Rapid Advance/Rapid Return

Inputs	Outputs
1. brake contactor energized	1. brake release indication
2. brake release request	2. brake release command
3. feed motor starter energized	3. feed advance command
5. returned position limit switch	5. returned indication
6. advanced position limit switch	6. advanced indication
7. torqued limit switch	
8. feed request	
14. feed motor overload	
15. reset overload request	9. overload okay indication
4. rapid return motor starter energized	4. rapid return command
5. returned position limit switch	5. returned indication
9. rapid return request	
10 rapid advance motor starter energized	7. rapid advance command
11. feed position limit switch	8. in feed area indication
12. rapid advance request	
13. rapid advance/return motor overloads	

Table 5.E shows the SDS block decomposed to three motions, different from those shown in view #2:

- brake engage
- feed advance/rapid return
- rapid advance

View #3 looks beyond the physical device at the optimum motion pair. (The order of inputs and outputs has been changed from view #2.)

Table 5.E
View # 3 of SDS Block - Brake Engage, Feed Advance/Rapid Return, Rapid Advance

Inputs	Outputs
1. brake contactor energized	1. brake release indication
2. brake release request	2. brake release command
3. feed motor starter energized	3. feed advance command
4. rapid return motor starter energized	4. rapid return command
5. returned position limit switch	5. returned indication
6. advanced position limit switch	6. advanced indication
7. torqued limit switch	
8. feed request	
13. rapid advance/return motor overloads	
9. rapid return request	
10 rapid advance motor starter energized	7. rapid advance command
11. feed position limit switch	8. in feed area indication
12. rapid advance request	
13. rapid advance/return motor overloads	9. overload okay indication
14. feed motor overload	
15. reset overload request	

Table 5.F decomposes the SDS block into four motions based on view #3:

- brake engage
- feed advance/rapid return
- rapid advance
- motor overload

This approach reduces the complexity of the SDS instruction in view #3.

Table 5.F
View # 4 of SDS Block - Brake Engage, Feed Advance/Rapid Return, Rapid Advance, and Motor Overloads

Inputs	Outputs
1. brake contactor energized	1. brake release indication
2. brake release request	2. brake release command
3. feed motor starter energized	3. feed advance command
4. rapid return motor starter energized	4. rapid return command
5. returned position limit switch	5. returned indication
6. advanced position limit switch	6. advanced indication
7. torqued limit switch	
8. feed request	
9. rapid return request	
10 rapid advance motor starter energized	7. rapid advance command
11. feed position limit switch	8. in feed area indication
12. rapid advance request	
13. rapid advance/return motor overloads	9. overload okay indication
14. feed motor overload	
15. reset overload request	

Important: When using the approach at #4, be certain that the desired coupling between the control and the diagnostics is not lost.

Table 5.G shows the estimated number of normal states for the views shown in Table 5.B through Table 5.F.

Table 5.H contrasts Table 5.G with the number of possible states for each view.

Table 5.G
Number of Normal States for Each View

View	SDS #1	SDS#2	SDS#3	SDS#4
Big block	50			
View #1	4	48		
View #2	4	20	25	
View #3	4	25	33	
View #4	4	25	8	1

Table 5.H
Number of Possible States for Each View

View	SDS #1	SDS#2	SDS#3	SDS#4
Big block	32,768			
View #1	4	8192		
View #2	4	128	128	
View #3	4	128	128	
View #4	4	128	8	2

After evaluating the complexity of each view, we pick the most feasible view, that is, the one with the fewest inputs per SDS, and develop state diagrams and state tables.

From Table 5.G, view #4 looks like the best choice since it has 38 total states (compared to 50, 52, 49, and 62 from the other views).

From Table 5.H, view #4 is the clear choice when considering the total number of states that we must investigate when setting up a state application. (View #4 has 142 possible states while the others have 32,768, 8196, 260, and 260.)

Developing State Diagrams and State Tables

View #4 provided us with the most manageable segments for setting up a state application. In this section, we set up a state diagram and state tables for each of the four segments that become our SDS instructions.

The four segments are:

- brake
- feed advance/rapid return
- rapid advance
- motor overload

SDS #1 (Brake)

The brake has two inputs and two outputs. They are:

- Inputs:
  - brake contactor energized
  - brake release request
- Outputs:
  - brake release indication
  - brake release command

Figure 5.5 shows the state diagram for the brake.

Table 5.I shows the state table for the brake.

Figure 5.5
State diagram for SDS #1 (Brake)

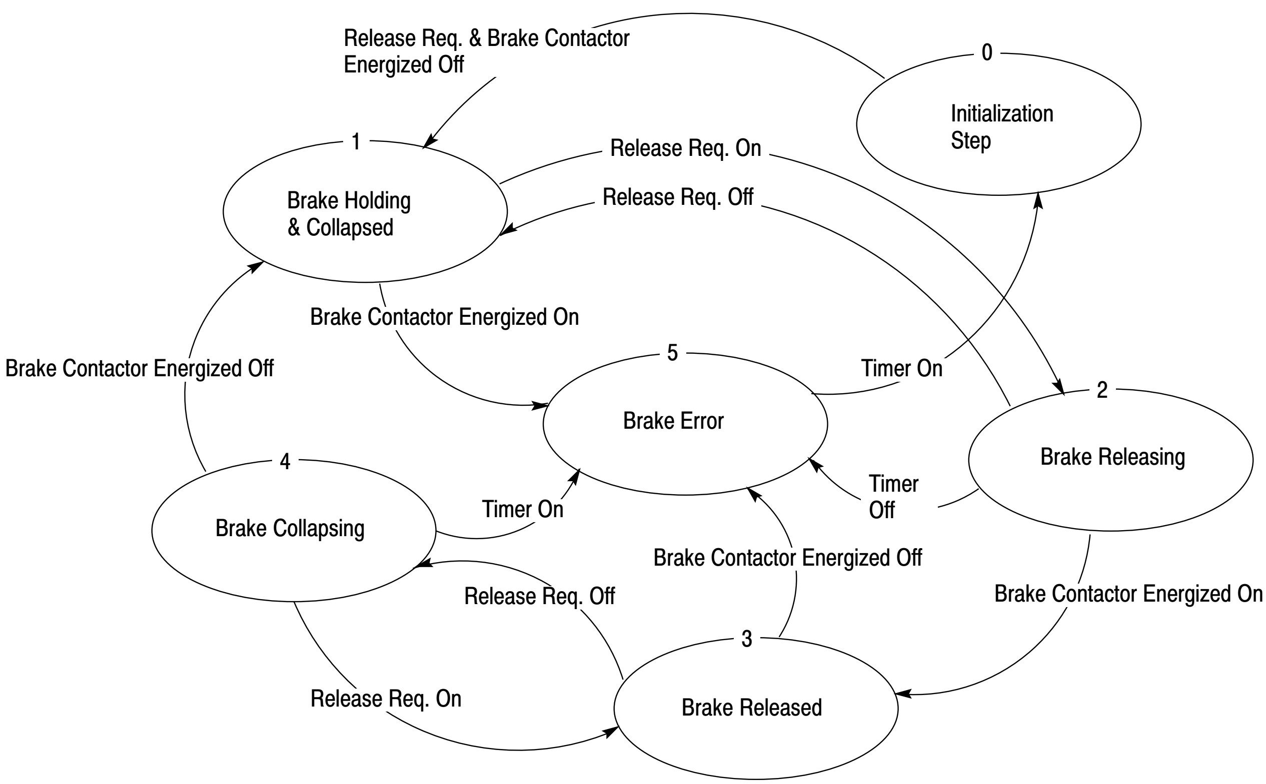


Table 5.I
State Table for SDS #1 (Brake)

State	Input Description	Input Transition	Next State	Output Description	Output Status
1	Release Request Brake Con. Energized	OFF-->ON OFF-->ON	State 2 State 5	Release Command Released Indication	OFF OFF
2	Release Request Brake Con. Energized Timer (2 seconds)	ON-->OFF OFF-->ON ON-->OFF	State 1 State 3 State 5	Release Command Released Indication	ON OFF
3	Release Request Brake Con. Energized	ON-->OFF ON-->OFF	State 4 State 5	Release Command Released Indication	ON ON
4	Release Request Brake Con. Energized Timer (2 seconds)	OFF-->ON ON-->OF OFF-->ON	State 3 State 1 State 5	Release Command Released Indication	OFF ON
5	Release Request Brake Con. Energized Timer (2 seconds)	 OFF-->ON	 State 0	Release Command Released Indication	OFF OFF

SDS #2 (Feed Advance/Rapid Return)

The feed advance/rapid return has seven inputs and four outputs. They are:

- Inputs:
  - feed motor starter confirmation
  - rapid return motor starter confirmation
  - returned position limit switch
  - advanced position limit switch
  - torqued limit switch
  - feed request
  - rapid return request
- Outputs:
  - advanced indication
  - returned indication
  - feed advance command
  - rapid return command

Figure 5.6 shows the state diagram for the feed advance/rapid return.

Table 5.J shows the state table for the feed advance/rapid return.

Figure 5.6
State Diagram for SDS #2 (Feed Advance/Rapid Return)

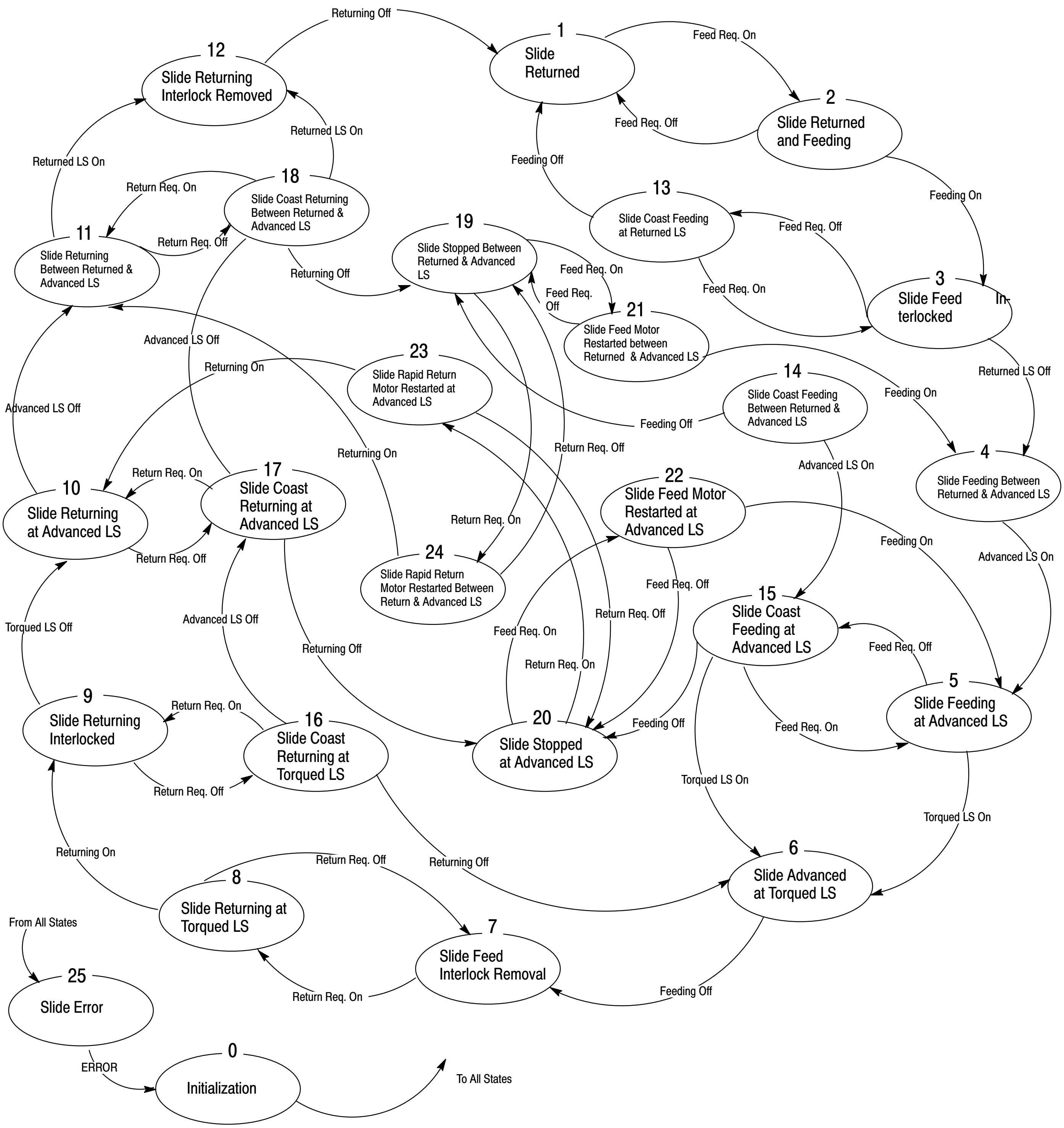


Table 5.J
State Table for SDS #2 (Feed Advance/Rapid Return)

State	Input Description	Input Transition	Next State	Output Description	Output Status
1	Feed Request	OFF-->ON	State 2	Feed Adv. Command	OFF
	Return Request			Rap. Ret. Command	OFF
	Returned LS	ON-->OFF	State 5	Advanced Indication	OFF
	Advanced LS	OFF-->ON	State 25	Returned Indication	ON
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	OFF-->ON	State 25		
	Return Motor Starter	OFF-->ON	State 25		
2	Feed Request	ON-->OFF	State 1	Feed Adv. Command	ON
	Return Request	OFF-->ON	State 25	Rap. Ret. Command	OFF
	Returned LS	ON-->OFF	State 25	Advanced Indication	OFF
	Advanced LS	OFF-->ON	State 25	Returned Indication	ON
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	OFF-->ON	State 3		
	Return Motor Starter	OFF-->ON	State 25		
3	Feed Request	ON-->OFF	State 13	Feed Adv. Command	ON
	Return Request	OFF-->ON	State 25	Rap. Ret. Command	OFF
	Returned LS	ON-->OFF	State 4	Advanced Indication	OFF
	Advanced LS	OFF-->ON	State 25	Returned Indication	ON
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	ON-->OFF	State 25		
	Return Motor Starter	OFF-->ON	State 25		
4	Feed Request	ON-->OFF	State 14	Feed Adv. Command	ON
	Return Request	OFF-->ON	State 25	Rap. Ret. Command	OFF
	Returned LS	OFF-->ON	State 25	Advanced Indication	OFF
	Advanced LS	OFF-->ON	State 5	Returned Indication	OFF
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	ON-->OFF	State 25		
	Return Motor Starter				
5	Feed Request	ON-->OFF	State 15	Feed Adv. Command	ON
	Return Request	OFF-->ON	State 25	Rap. Ret. Command	OFF
	Returned LS	OFF-->ON	State 25	Advanced Indication	OFF
	Advanced LS	ON-->OFF	State 25	Returned Indication	OFF
	Torqued LS	OFF-->ON	State 6		
	Feed Motor Starter	ON-->OFF	State 25		
	Return Motor Starter	OFF-->ON	State 25		
6	Feed Request			Feed Adv. Command	OFF
	Return Request	OFF-->ON	State 1	Rap. Ret. Command	OFF
	Returned LS	OFF-->ON	State 25	Advanced Indication	ON
	Advanced LS	ON-->OFF	State 25	Returned Indication	OFF
	Torqued LS	ON-->OFF	State 25		
	Feed Motor Starter	ON-->OFF	State 7		
	Return Motor Starter	OFF-->ON	State 25		

Table 5.J
State Table for SDS #2 (Feed Advance/Rapid Return) (cont.)

State	Input Description	Input Transition	Next State	Output Description	Output Status
7	Feed Request	OFF-->ON	State 25	Feed Adv. Command	OFF
	Return Request	OFF-->ON	State 8	Rap. Ret. Command	OFF
	Returned LS	OFF-->ON	State 25	Advanced Indication	ON
	Advanced LS	ON-->OFF	State 25	Returned Indication	OFF
	Torqued LS	ON-->OFF	State 25		
	Feed Motor Starter	OFF-->ON	State 25		
	Return Motor Starter	OFF-->ON	State 25		
8	Feed Request	OFF-->ON	State 25	Feed Adv. Command	OFF
	Return Request	ON-->OFF	State 7	Rap. Ret. Command	ON
	Returned LS	OFF-->ON	State 25	Advanced Indication	ON
	Advanced LS	ON-->OFF	State 25	Returned Indication	OFF
	Torqued LS	ON-->OFF	State 25		
	Feed Motor Starter	OFF-->ON	State 25		
	Return Motor Starter	OFF-->ON	State 9		
9	Feed Request	OFF-->ON	State 25	Feed Adv. Command	OFF
	Return Request	ON-->OFF	State 18	Rap. Ret. Command	ON
	Returned LS	OFF-->ON	State 25	Advanced Indication	ON
	Advanced LS	ON-->OFF	State 25	Returned Indication	OFF
	Torqued LS	ON-->OFF	State 10		
	Feed Motor Starter	OFF-->ON	State 25		
	Return Motor Starter	ON-->OFF	State 25		
10	Feed Request	OFF-->ON	State 25	Feed Adv. Command	OFF
	Return Request	ON-->OFF	State 17	Rap. Ret. Command	ON
	Returned LS	OFF-->ON	State 25	Advanced Indication	ON
	Advanced LS	ON-->OFF	State 11	Returned Indication	OFF
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	OFF-->ON	State 25		
	Return Motor Starter	ON-->OFF	State 25		
11	Feed Request	OFF-->ON	State 25	Feed Adv. Command	OFF
	Return Request	ON-->OFF	State 18	Rap. Ret. Command	ON
	Returned LS	OFF-->ON	State 12	Advanced Indication	OFF
	Advanced LS	OFF-->ON	State 25	Returned Indication	OFF
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	OFF-->ON	State 25		
	Return Motor Starter	ON-->OFF	State 25		
12	Feed Request	OFF-->ON	State 25	Feed Adv. Command	OFF
	Return Request			Rap. Ret. Command	OFF
	Returned LS	ON-->OFF	State 25	Advanced Indication	OFF
	Advanced LS	OFF-->ON	State 25	Returned Indication	ON
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	OFF-->ON	State 25		
	Return Motor Starter	ON-->OFF	State 1		

Table 5.J
State Table for SDS #2 (Feed Advance/Rapid Return) (cont.)

State	Input Description	Input Transition	Next State	Output Description	Output Status
13	Feed Request	OFF-->ON	State 3	Feed Adv. Command	OFF
	Return Request	OFF-->ON	State 25	Rap. Ret. Command	OFF
	Returned LS	ON-->OFF	State 14	Advanced Indication	OFF
	Advanced LS	OFF-->ON	State 25	Returned Indication	ON
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	ON-->OFF	State 1		
	Return Motor Starter	OFF-->ON	State 25		
14	Feed Request	OFF-->ON	State 4	Feed Adv. Command	OFF
	Return Request	OFF-->ON	State 25	Rap. Ret. Command	OFF
	Returned LS	OFF-->ON	State 25	Advanced Indication	OFF
	Advanced LS	OFF-->ON	State 15	Returned Indication	OFF
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	ON-->OFF	State 19		
	Return Motor Starter	OFF-->ON	State 25		
15	Feed Request	OFF-->ON	State 5	Feed Adv. Command	OFF
	Return Request	OFF-->ON	State 25	Rap. Ret. Command	OFF
	Returned LS	OFF-->ON	State 25	Advanced Indication	OFF
	Advanced LS	ON-->OFF	State 25	Returned Indication	ON
	Torqued LS	OFF-->ON	State 6		
	Feed Motor Starter	ON-->OFF	State 20		
	Return Motor Starter	OFF-->ON	State 25		
16	Feed Request	OFF-->ON	State 25	Feed Adv. Command	OFF
	Return Request	OFF-->ON	State 9	Rap. Ret. Command	OFF
	Returned LS	OFF-->ON	State 25	Advanced Indication	ON
	Advanced LS	OFF-->ON	State 25	Returned Indication	OFF
	Torqued LS	ON-->OFF	State 17		
	Feed Motor Starter				
	Return Motor Starter	ON-->OFF	State 6		
17	Feed Request	OFF-->ON	State 25	Feed Adv. Command	OFF
	Return Request	OFF-->ON	State 10	Rap. Ret. Command	OFF
	Returned LS	OFF-->ON	State 25	Advanced Indication	OFF
	Advanced LS	ON-->OFF	State 18	Returned Indication	OFF
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	OFF-->ON	State 25		
	Return Motor Starter	ON-->OFF	State 20		
18	Feed Request	OFF-->ON	State 25	Feed Adv. Command	OFF
	Return Request	OFF-->ON	State 11	Rap. Ret. Command	OFF
	Returned LS	OFF-->ON	State 12	Advanced Indication	OFF
	Advanced LS	OFF-->ON	State 25	Returned Indication	OFF
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	OFF-->ON	State 25		
	Return Motor Starter	ON-->OFF	State 19		

Table 5.J
State Table for SDS #2 (Feed Advance/Rapid Return) (cont.)

State	Input Description	Input Transition	Next State	Output Description	Output Status
19	Feed Request	OFF-->ON	State 21	Feed Adv. Command	OFF
	Return Request	OFF-->ON	State 24	Rap. Ret. Command	OFF
	Returned LS	OFF-->ON	State 25	Advanced Indication	OFF
	Advanced LS	OFF-->ON	State 25	Returned Indication	OFF
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	OFF-->ON	State 25		
	Return Motor Starter	OFF-->ON	State 25		
			State 25		
20	Feed Request	OFF-->ON	State 22	Feed Adv. Command	OFF
	Return Request	OFF-->ON	State 23	Rap. Ret. Command	OFF
	Returned LS	OFF-->ON	State 25	Advanced Indication	OFF
	Advanced LS	ON-->OFF	State 25	Returned Indication	OFF
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	OFF-->ON	State 25		
	Return Motor Starter	OFF-->ON	State 25		
21	Feed Request	ON-->OFF	State 19	Feed Adv. Command	ON
	Return Request	OFF-->ON	State 25	Rap. Ret. Command	OFF
	Returned LS	OFF-->ON	State 25	Advanced Indication	OFF
	Advanced LS	OFF-->ON	State 25	Returned Indication	OFF
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	OFF-->ON	State 4		
	Return Motor Starter	OFF-->ON	State 25		
22	Feed Request	ON-->OFF	State 20	Feed Adv. Command	ON
	Return Request	OFF-->ON	State 25	Rap. Ret. Command	OFF
	Returned LS	OFF-->ON	State 25	Advanced Indication	OFF
	Advanced LS	ON-->OFF	State 25	Returned Indication	OFF
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	OFF-->ON	State 5		
	Return Motor Starter	OFF-->ON	State 25		
23	Feed Request	OFF-->ON	State 25	Feed Adv. Command	OFF
	Return Request	ON-->OFF	State 20	Rap. Ret. Command	ON
	Returned LS	OFF-->ON	State 25	Advanced Indication	OFF
	Advanced LS	ON-->OFF	State 25	Returned Indication	OFF
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	OFF-->ON	State 25		
	Return Motor Starter	OFF-->ON	State 10		
24	Feed Request	OFF-->ON	State 25	Feed Adv. Command	OFF
	Return Request	ON-->OFF	State 19	Rap. Ret. Command	ON
	Returned LS	OFF-->ON	State 25	Advanced Indication	OFF
	Advanced LS	OFF-->ON	State 25	Returned Indication	OFF
	Torqued LS	OFF-->ON	State 25		
	Feed Motor Starter	OFF-->ON	State 25		
	Return Motor Starter	OFF-->ON	State 11		

Table 5.J
State Table for SDS #2 (Feed Advance/Rapid Return) (cont.)

State	Input Description	Input Transition	Next State	Output Description	Output Status
25	Feed Request Return Request Returned LS Advanced LS Torqued LS Feed Motor Starter Return Motor Starter	 OFF-->ON	 State 0	Feed Adv. Command Rap. Ret. Command Advanced Indication Returned Indication	OFF OFF OFF OFF

SDS #3 (Rapid Advance)

The rapid advance has four inputs and two outputs. They are:

- Inputs:
  - rapid advance motor starter confirmation
  - feed position limit switch
  - rapid return request
  - rapid advance request
- Outputs:
  - in feed area indication
  - rapid advance command

Figure 5.7 shows the state diagram for the rapid advance.

Table 5.K shows the state table for the rapid advance.

Figure 5.7
State Diagram for SDS #3 (Rapid Advance)

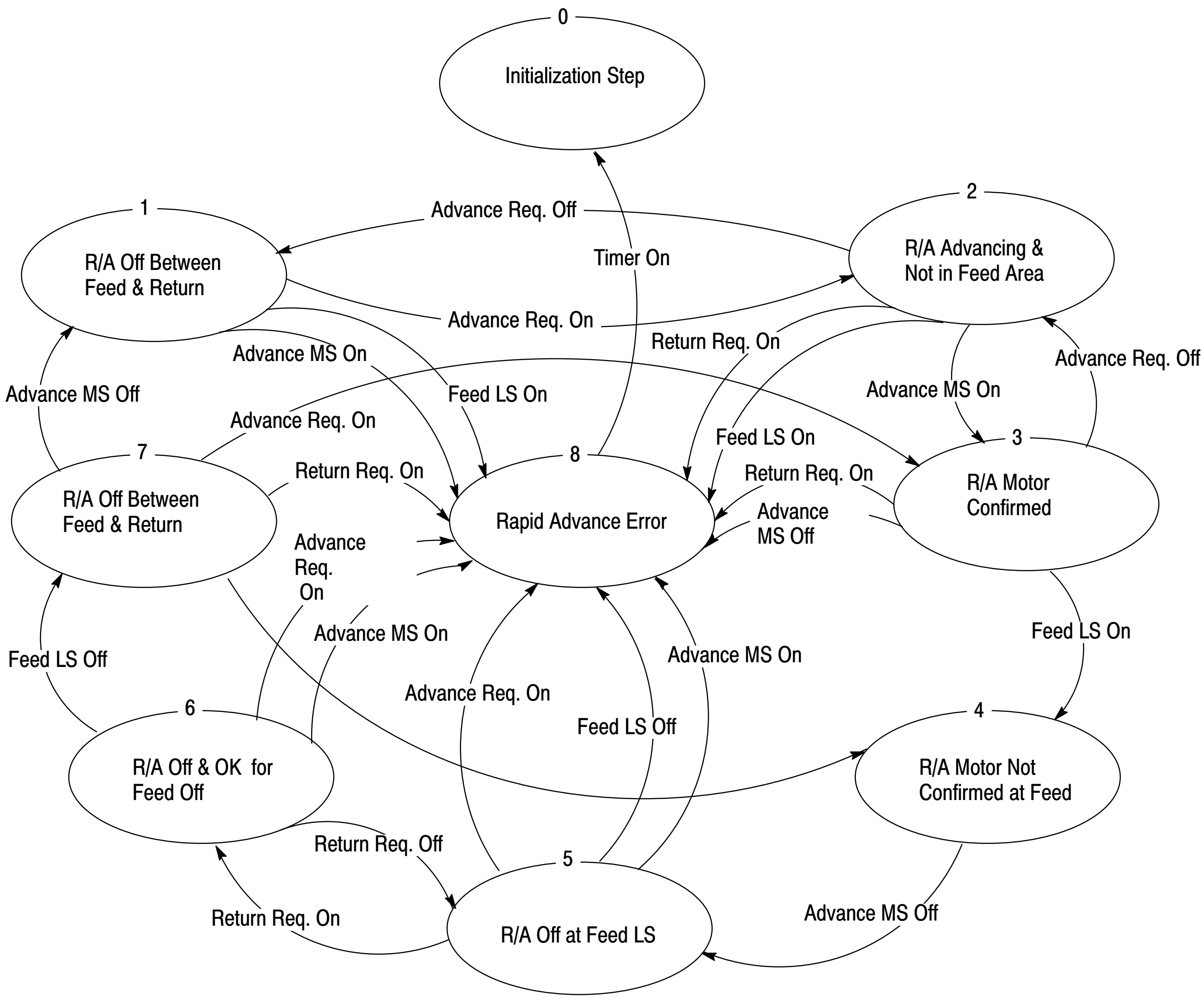


Table 5.K
State Table for SDS #3 (Rapid Advance)

State	Input Description	Input Transition	Next State	Output Description	Output Status
1	Advance Request Return Request Feed LS Advance Motor Starter	OFF-->ON OFF-->ON OFF-->ON OFF-->ON	State 2 State 8 State 8 State	Advance Command In Feed Area Ind.	OFF OFF
2	Advance Request Return Request Feed LS Advance Motor Starter	ON-->OFF OFF-->ON OFF-->ON OFF-->ON	State 1 State 8 State 8 State 3	Advance Command In Feed Area Ind.	ON OFF
3	Advance Request Return Request Feed LS Advance Motor Starter	ON-->OFF OFF-->ON OFF-->ON ON-->OFF		Advance Command In Feed Area Ind.	ON OFF
4	Advance Request Return Request Feed LS Advance Motor Starter	 OFF-->ON ON-->OFF	 State 8 State 5	Advance Command In Feed Area Ind.	OFF ON
5	Advance Request Return Request Feed LS Advance Motor Starter	OFF-->ON OFF-->ON ON-->OFF OFF-->ON	State 8 State 6 State 8 State 8	Advance Command In Feed Area Ind.	OFF ON
6	Advance Request Return Request Feed LS Advance Motor Starter	OFF-->ON ON-->OFF ON-->OFF OFF-->ON	State 8 State 5 State 7 State 8	Advance Command In Feed Area Ind.	OFF ON
7	Advance Request Return Request Feed LS Advance Motor Starter	OFF-->ON OFF-->ON OFF-->ON ON-->OFF	State 3 State 8 State 4 State 1	Advance Command In Feed Area Ind.	OFF OFF
8	Advance Request Return Request Feed LS Advance Motor Starter	 OFF-->ON	 State 0	Advance Command In Feed Area Ind.	OFF OFF

SDS #4 (Motor Overload Monitor)

The inputs and outputs for the motor overload monitor are:

- Inputs:
  - rapid advance/return motor overloads
  - feed motor overload
  - reset overload request
- Outputs:
  - overload okay indication

Figure 5.8 shows the state diagram of motor overload monitor.

Table 5.L shows the state table of motor overload monitor.

Figure 5.8
State Diagram for SDS #4 (Motor Overload Monitor)

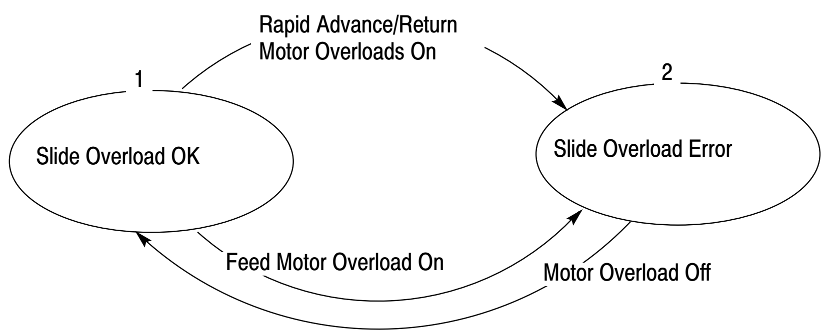


Table 5.L
State Table for SDS #4 (Motor Overload Monitor)

State	Input Description	Input Transition	Next State	Output Description	Output Status
1	Rapid Advance/Return Motor Overloads Feed Motor Overload Reset Overload Fault	 OFF-->ON OFF-->ON	 State 2 State 2	Overload OK Ind.	 ON
2	Rapid Advance/Return Motor Overloads Feed Motor Overload Reset Overload Fault	 OFF-->ON	 State 0	Overload OK Ind.	OFF

After you develop state diagrams and state tables for your SDS instructions, double-check your tables to see if there are any redundant states. If you find redundant states, eliminate them from your state table and diagram.

Summary

Chapters 3 and 4 showed you how to organize an application that uses the DDMC philosophy. From our transfer line example, you can see how complex a simple slide movement can be from a state programming point of view.

You can use the methods detailed in this chapter to setting up state transition applications for other machines or lines.

Read chapter 6 to see how to apply the SDS and DFA instructions to common mechanisms on your line or machine.

Chapter 6

Applying DDMC Instructions to Common Mechanisms

Chapter Objectives

This chapters shows how the SDS and DFA instructions can be used with common mechanisms on your line or machine to perform control and diagnostic functions. We show examples for the following mechanisms:

- hydraulic slide (3-position valve with 2 limit switches)
- machine clamp (detented valve)
- part stamp (spring-return valve)
- spindle
- mechanical slide

For each example above, we show:

- ladder logic
- the SDS or DFA step directory for the mechanism (number and names of steps)
- the inputs and outputs defined for the instructions
- step tables for each step

Applying the SDS Instruction to a Hydraulic Slide

The following three lines of logic are for a hydraulic slide. From a request logic standpoint there is no apparent difference between this logic and the request logic for other types of slides. The difference is in the SDS configuration. The configuration for the hydraulic slide is set up for a 3-position valve. Detented, spring return, or other types of valves would have a different configuration.

```
|  STA 7     |                                 |STA 7
|  ADVANCE   |STA 7     |CLAMP     |STA 7 RET |SLIDE                STA 7 ADV
|  SLIDE PB  |AUTO SS   |ADVANCED  |SLIDE REQ |FAULT                SLIDE REQ
|    I:066      I:066        B3         B3       N28:0                  B3
+-+---] [--------]/[----+---] [--------]/[--------]/[------------------( )-----
| |     10         07   |     54         41        12                    40
| |STA 7     |STA 7     |
| |CYCLE     |FULL      |
| |STATION   |DEPTH     |
| |    B3       O:066   |
| +---] [--------]/[----+
|       48         07
```

The SDS instruction in this line of logic is used to control the hydraulic slide for station 7.

```
| POWER ON  |POWER ON                                    HYDRAULIC
| DWELL     |CRM                                         SLIDE
|    T4:1      I:001                        +SDS-------------------------+
+----] [--------] [-------------------------+SMART DIRECTED SEQUENCER    +-(EN)-
|      DN         00                        |Control File           N28:0|
|                                           |Step Desc. File        N29:0+-(ST)
|                                           |Length                   143|
|                                           |No. of Steps              11+-(ER)
|                                           |Position/Step:             0|
|                                           |No. of I/O                 8+-(ES)
|                                           |Prog file number           3|
|                                           +----------------------------+
```

This rung of logic is used to request Station 7 slide to return.

```
|  STA 7     |          |STA 7     |STA 7     |STA 7
|  RETURN    |STA 7     |OVRLOADS  |SLIDE     |SLIDE     |STA 7 ADV  STA 7 RET
|  SLIDE PB  |AUTO SS   |OK        |RETURNED  |FAULT     |SLIDE REQ  SLIDE REQ
|    I:066      I:066        B3         B3       N28:0        B3        B3
+-+---] [--------]/[----+---] [--------]/[--------]/[--------]/[-------( )-----
| |     10         07   |     49         44         12         40        41
| |STA 7     |STA 7     |
| |CYCLE     |FULL      |
| |STATION   |DEPTH     |
| |    B3       O:066   |
| +---] [--------] [----+
|       48         07
```

Step Directory

```
      Control File: N28:0        Step Description File: N29:0

Step #      Step Name                  Step #      Step Name
   0    INITIALIZATION                    6    ADVD & RETURNING
   1    RETURNED                          7    RETURNING
   2    RETD & ADVANCING                  8    RETD & RETURNING
   3    ADVANCING                         9    STOP'D BTW ADV & RET
   4    ADVD & ADVANCING                 10    COASTING
   5    ADVANCED                         11    FAULT
```

Inputs and Outputs

I/O CROSS–REFERENCE

Input	Logical Address	Address Symbol	Address Comment
0	B3/40	B3/40	STA 7 ADV SLIDE REQ
1	B3/41	B3/41	STA 7 RET SLIDE REQ
2	I:066/01	I:066/01	ADVANCED LS
3	I:066/00	I:066/00	RETURNED LS
7	B3/42	B3/42	RESET SLIDE FAULT

Output	Logical Address	Address Symbol	Address Comment
0	O:066/00	O:066/00	ADVANCE SLIDE SOL
1	O:066/01	O:066/01	RETURN SLIDE SOL
2	B3/43	B3/43	SLIDE ADVANCED
3	B3/44	B3/44	SLIDE RETURNED

Step Tables

STEP 1 RETURNED   TIMER = 0.00 sec – DISABLED   MESSAGE:OFF

No	Input ID	Transition	Destination	No	Output ID	State
0	STA 7 ADV SLIDE REQ	OFF––>ON	**STEP 2	0	ADVANCE SLIDE SOL	OFF
1	STA 7 RET SLIDE REQ	OFF––>ON	STEP 8	1	RETURN SLIDE SOL	OFF
2	ADVANCED LS	OFF––>ON	ERSTEP 11	2	SLIDE ADVANCED	OFF
3	RETURNED LS	ON––>OFF	ERSTEP 11	3	SLIDE RETURNED	ON
7	RESET SLIDE FAULT					

STEP 2 RETD & ADVANCING   TIMER = 1.00 sec WARNING   MESSAGE:OFF

No	Input ID	Transition	Destination	No	Output ID	State
0	STA 7 ADV SLIDE REQ	ON––>OFF	STEP 1	0	ADVANCE SLIDE SOL	ON
1	STA 7 RET SLIDE REQ	OFF––>ON	INITIALIZE	1	RETURN SLIDE SOL	OFF
2	ADVANCED LS	OFF––>ON	ERSTEP 11	2	SLIDE ADVANCED	OFF
3	RETURNED LS	ON––>OFF	**STEP 3	3	SLIDE RETURNED	ON
7	RESET SLIDE FAULT					

STEP 3 ADVANCING   TIMER = 5.00 sec WARNING   MESSAGE:OFF

No	Input ID	Transition	Destination	No	Output ID	State
0	STA 7 ADV SLIDE REQ	ON––>OFF	STEP 10	0	ADVANCE SLIDE SOL	ON
1	STA 7 RET SLIDE REQ	OFF––>ON	INITIALIZE	1	RETURN SLIDE SOL	OFF
2	ADVANCED LS	OFF––>ON	**STEP 4	2	SLIDE ADVANCED	OFF
3	RETURNED LS	OFF––>ON	ERSTEP 11	3	SLIDE RETURNED	OFF
7	RESET SLIDE FAULT					

STEP 4 ADVD & ADVANCING   TIMER = 0.00 sec – DISABLED   MESSAGE:OFF

No	Input ID	Transition	Destination	No	Output ID	State
0	STA 7 ADV SLIDE REQ	ON––>OFF	INITIALIZE	0	ADVANCE SLIDE SOL	ON
1	STA 7 RET SLIDE REQ	OFF––>ON	INITIALIZE	1	RETURN SLIDE SOL	OFF
2	ADVANCED LS	ON––>OFF	ERSTEP 11	2	SLIDE ADVANCED	ON
3	RETURNED LS	OFF––>ON	ERSTEP 11	3	SLIDE RETURNED	OFF
7	RESET SLIDE FAULT					

```
  STEP   5 ADVANCED                  TIMER = 0.00 sec - DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 7 ADV SLIDE REQ   OFF-->ON     STEP 4       0 ADVANCE SLIDE SOL      OFF
 1 STA 7 RET SLIDE REQ   OFF-->ON   **STEP 6       1 RETURN SLIDE SOL       OFF
 2 ADVANCED LS           ON-->OFF   ERSTEP 11      2 SLIDE ADVANCED         ON
 3 RETURNED LS           OFF-->ON   ERSTEP 11      3 SLIDE RETURNED         OFF
 7 RESET SLIDE FAULT

  STEP   6 ADVD & RETURNING           TIMER = 1.00  sec WARNING     MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 7 ADV SLIDE REQ   OFF-->ON  INITIALIZE      0 ADVANCE SLIDE SOL      OFF
 1 STA 7 RET SLIDE REQ   ON-->OFF     STEP 5       1 RETURN SLIDE SOL       ON
 2 ADVANCED LS           ON-->OFF   **STEP 7       2 SLIDE ADVANCED         ON
 3 RETURNED LS           OFF-->ON   ERSTEP 11      3 SLIDE RETURNED         OFF
 7 RESET SLIDE FAULT


  STEP   7 RETURNING                  TIMER = 5.00  sec WARNING     MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 7 ADV SLIDE REQ   OFF-->ON  INITIALIZE      0 ADVANCE SLIDE SOL      OFF
 1 STA 7 RET SLIDE REQ   ON-->OFF     STEP 10      1 RETURN SLIDE SOL       ON
 2 ADVANCED LS           OFF-->ON   ERSTEP 11      2 SLIDE ADVANCED         OFF
 3 RETURNED LS           OFF-->ON   **STEP 8       3 SLIDE RETURNED         OFF
 7 RESET SLIDE FAULT

  STEP   8 RETD & RETURNING          TIMER = 0.00 sec - DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 7 ADV SLIDE REQ   OFF-->ON  INITIALIZE      0 ADVANCE SLIDE SOL      OFF
 1 STA 7 RET SLIDE REQ   ON-->OFF  INITIALIZE      1 RETURN SLIDE SOL       ON
 2 ADVANCED LS           OFF-->ON   ERSTEP 11      2 SLIDE ADVANCED         OFF
 3 RETURNED LS           ON-->OFF   ERSTEP 11      3 SLIDE RETURNED         ON
 7 RESET SLIDE FAULT

  STEP   9 STOP'D BTW ADV & RET      TIMER = 0.00 sec - DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 7 ADV SLIDE REQ   OFF-->ON   **STEP 3       0 ADVANCE SLIDE SOL      OFF
 1 STA 7 RET SLIDE REQ   OFF-->ON     STEP 7       1 RETURN SLIDE SOL       OFF
 2 ADVANCED LS           OFF-->ON   ERSTEP 11      2 SLIDE ADVANCED         OFF
 3 RETURNED LS           OFF-->ON   ERSTEP 11      3 SLIDE RETURNED         OFF
 7 RESET SLIDE FAULT

  STEP  10 COASTING                 TIMER = 0.50  sec INITIALIZE    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 7 ADV SLIDE REQ                             0 ADVANCE SLIDE SOL      OFF
 1 STA 7 RET SLIDE REQ                             1 RETURN SLIDE SOL       OFF
 2 ADVANCED LS                                     2 SLIDE ADVANCED         LAST
 3 RETURNED LS                                     3 SLIDE RETURNED         LAST
 7 RESET SLIDE FAULT

ERSTEP  11 FAULT                     TIMER = 0.00 sec - DISABLED    MESSAGE:ON

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 7 ADV SLIDE REQ                             0 ADVANCE SLIDE SOL      OFF
 1 STA 7 RET SLIDE REQ                             1 RETURN SLIDE SOL       OFF
 2 ADVANCED LS                                     2 SLIDE ADVANCED         OFF
 3 RETURNED LS                                     3 SLIDE RETURNED         OFF
 7 RESET SLIDE FAULT     OFF-->ON     STEP 0
```

Applying the SDS Instruction to a Machine Clamp (Detented Valve)

These three lines of ladder logic show an example of an SDS for a detented valve. This line is used to request the clamp to advance.

```
|  ADVANCE   |MACHINE   |TRANSFER  |RETURN    |CLAMP               ADVANCE
|  CLAMP PB  |HAND PL   |LOWERED   |CLAMP REQ |FAULT               CLAMP REQ
|    I:012      O:001        B3         B3       N32:0                 B3
+-+---] [--------] [----+---] [--------]/[--------]/[------------------( )-----
| |     10         07   |     15         51         12                   50
| |                     |
| |AUTO                 |
| |CYCLE ON             |
| |    B3               |
| +---] [---------------+
|       05
```

The SDS instruction in this line of logic is used to control the machine clamp.

```
| POWER ON  |POWER ON                                     MACHINE
| DWELL     |CRM                                          CLAMP
|    T4:1      I:001                        +SDS-----------------------------+
+----] [--------] [-------------------------+SMART DIRECTED SEQUENCER    +-(EN)-
|      DN         00                        |Control File           N32:0|
|                                           |Step Desc. File        N33:0+-(ST)
|                                           |Length                   286|
|                                           |No. of Steps              14+-(ER)
|                                           |Position/Step:             0|
|                                           |No. of I/O                 8+-(ES)
|                                           |Prog file number           3|
|                                           +----------------------------+
```

This rung of logic is used to request the clamp to return.

```
|  RETURN    |MACHINE   |TRANSFER  |ADVANCE   |CLAMP               RETURN
|  CLAMP PB  |HAND PL   |RETURNED  |CLAMP REQ |FAULT               CLAMP REQ
|    I:012      O:001        B3         B3       N32:0                 B3
+-+---] [--------] [----+---] [--------]/[--------]/[------------------( )-----
| |     11         07   |     14         50         12                   51
| |                     |
| |AUTO                 |
| |CYCLE ON             |
| |    B3               |
| +---] [---------------+
|       05
```

Step Directory

Control File: N116:0 Step Description File: N117:0

Step #	Step Name	Step #	Step Name
0	INITIALIZATION	8	RETD & RETURNING
1	RETURNED	9	RETD & WTG FOR REQ
2	ADVANCING	10	ADVD & WTF FOR REQ
3	SHIFTED ADVANCE	11	BTWN & WTG FOR REQ
4	ADVD & ADVANCING	12	REV TO RETURN
5	ADVANCED	13	REV TO ADVANCE
6	RETURNING	14	FAULT
7	SHIFTED RETURN		

Inputs and Outputs

I/O CROSS-REFERENCE

Input	Logical Address	Address Symbol	Address Comment
0	B3/1	B3/1	RETURN REQUEST
1	B3/0	B3/0	ADVANCE REQUEST
2	I:000/03	I:000/03	RETURNED LS
3	I:000/02	I:000/02	ADVANCED LS
4	B3/10	B3/10	RETURN MEMORY
5	B3/11	B3/11	ADVANCE MEMORY
7	I:000/07	I:000/07	RESET SDS FAULT

Output	Logical Address	Address Symbol	Address Comment
0	O:000/04	O:000/04	RETURN SOL
1	O:000/05	O:000/05	ADVANCE SOL
2	O:000/06	O:000/06	RETURNED PL
3	O:000/07	O:000/07	ADVANCE PL
4	B3/10	B3/10	RETURN MEMORY
5	B3/11	B3/11	ADVANCE MEMORY

Step Tables

STEP 1 RETURNED TIMER = 0.00 sec – DISABLED MESSAGE:OFF

No	Input ID	Equation	Destination	No	Output ID	State
0	RETURN REQUEST	OFF––>ON	STEP 8	0	RETURN SOL	OFF
1	ADVANCE REQUEST	OFF––>ON	**STEP 13	1	ADVANCE SOL	OFF
2	RETURNED LS	ON––>OFF	ERSTEP 14	2	RETURNED PL	ON
3	ADVANCED LS	OFF––>ON	ERSTEP 14	3	ADVANCED PL	OFF
4	RETURN MEMORY	ON––>OFF	ERSTEP 14	4	RETURN MEMORY	ON
5	ADVANCE MEMORY	OFF––>ON	ERSTEP 14	5	ADVANCE MEMORY	OFF
7	RESET SDS FAULT					

STEP 2 ADVANCING TIMER = 3.00 sec WARNING MESSAGE:OFF

No	Input ID	Equation	Destination	No	Output ID	State
0	RETURN REQUEST	OFF––>ON	INITIALIZE	0	RETURN SOL	OFF
1	ADVANCE REQUEST	ON––>OFF	INITIALIZE	1	ADVANCE SOL	ON
2	RETURNED LS	EQ4	**STEP 4	2	RETURNED PL	OFF
3	ADVANCED LS	EQ4	**STEP 4	3	ADVANCED PL	OFF
4	RETURN MEMORY	OFF––>ON	ERSTEP 14	4	RETURN MEMORY	OFF
5	ADVANCE MEMORY			5	ADVANCE MEMORY	ON
7	RESET SDS FAULT					

EQ4 NED LS=0 AND ADVANCED LS=1

STEP 3 SHIFTED ADVANCE TIMER = 3.00 sec WARNING MESSAGE:OFF

No	Input ID	Equation	Destination	No	Output ID	State
0	RETURN REQUEST	OFF––>ON	STEP 12	0	RETURN SOL	OFF
1	ADVANCE REQUEST	OFF––>ON	INITIALIZE	1	ADVANCE SOL	OFF
2	RETURNED LS	EQ5	**STEP 5	2	RETURNED PL	OFF
3	ADVANCED LS	EQ5	**STEP 5	3	ADVANCED PL	OFF
4	RETURN MEMORY	OFF––>ON	ERSTEP 14	4	RETURN MEMORY	OFF
5	ADVANCE MEMORY	ON––>OFF	ERSTEP 14	5	ADVANCE MEMORY	ON
7	RESET SDS FAULT					

EQ5 NED LS=0 AND ADVANCED LS=1

STEP 4 ADVD & ADVANCING TIMER = 0.00 sec – DISABLED MESSAGE:OFF

No	Input ID	Equation	Destination	No	Output ID	State
0	RETURN REQUEST	OFF––>ON	INITIALIZE	0	RETURN SOL	OFF
1	ADVANCE REQUEST	ON––>OFF	**STEP 5	1	ADVANCE SOL	ON
2	RETURNED LS	OFF––>ON	ERSTEP 14	2	RETURNED PL	OFF
3	ADVANCED LS	ON––>OFF	ERSTEP 14	3	ADVANCED PL	ON
4	RETURN MEMORY	OFF––>ON	ERSTEP 14	4	RETURN MEMORY	OFF
5	ADVANCE MEMORY			5	ADVANCE MEMORY	ON
7	RESET SDS FAULT					

STEP 5 ADVANCED TIMER = 0.00 sec – DISABLED MESSAGE:OFF

No	Input ID	Equation	Destination	No	Output ID	State
0	RETURN REQUEST	OFF––>ON	**STEP 12	0	RETURN SOL	OFF
1	ADVANCE REQUEST	OFF––>ON	STEP 4	1	ADVANCE SOL	OFF
2	RETURNED LS	OFF––>ON	ERSTEP 14	2	RETURNED PL	OFF
3	ADVANCED LS	ON––>OFF	ERSTEP 14	3	ADVANCED PL	ON
4	RETURN MEMORY	OFF––>ON	ERSTEP 14	4	RETURN MEMORY	OFF
5	ADVANCE MEMORY	ON––>OFF	ERSTEP 14	5	ADVANCE MEMORY	ON
7	RESET SDS FAULT					

```
STEP   6 RETURNING                  TIMER = 3.00  sec WARNING     MESSAGE:OFF

No   Input ID           Equation   Destination    No   Output ID         State
 0 RETURN REQUEST       ON-->OFF   INITIALIZE      0   RETURN SOL         ON
 1 ADVANCE REQUEST      OFF-->ON   INITIALIZE      1   ADVANCE SOL        OFF
 2 RETURNED LS          EQ4        **STEP 8        2   RETURNED PL        OFF
 3 ADVANCED LS          EQ4        **STEP 8        3   ADVANCED PL        OFF
 4 RETURN MEMORY                                   4   RETURN MEMORY      ON
 5 ADVANCE MEMORY       OFF-->ON   ERSTEP 14       5   ADVANCE MEMORY     OFF
 7 RESET SDS FAULT
EQ4  NED LS=1 AND ADVANCED LS=0

STEP   7 SHIFTED RETURN             TIMER = 3.00  sec WARNING     MESSAGE:OFF

No   Input ID           Equation   Destination    No   Output ID         State
 0 RETURN REQUEST       OFF-->ON   INITIALIZE      0   RETURN SOL          OFF
 1 ADVANCE REQUEST      OFF-->ON     STEP 13       1   ADVANCE SOL         OFF
 2 RETURNED LS          EQ5        **STEP 1        2   RETURNED PL         OFF
 3 ADVANCED LS          EQ5        **STEP 1        3   ADVANCED PL         OFF
 4 RETURN MEMORY        ON-->OFF   ERSTEP 14       4   RETURN MEMORY       ON
 5 ADVANCE MEMORY       OFF-->ON   ERSTEP 14       5   ADVANCE MEMORY      OFF
 7 RESET SDS FAULT
EQ5  NED LS=1 AND ADVANCED LS=0

STEP   8 RETD & RETURNING          TIMER = 0.00 sec - DISABLED    MESSAGE:OFF

 No   Input ID          Equation   Destination    No   Output ID         State
 0 RETURN REQUEST       ON-->OFF   INITIALIZE      0   RETURN SOL          ON
 1 ADVANCE REQUEST      OFF-->ON   **STEP 13       1   ADVANCE SOL         OFF
 2 RETURNED LS          ON-->OFF   ERSTEP 14       2   RETURNED PL         ON
 3 ADVANCED LS          OFF-->ON   ERSTEP 14       3   ADVANCED PL         OFF
 4 RETURN MEMORY                                   4   RETURN MEMORY       ON
 5 ADVANCE MEMORY       OFF-->ON   ERSTEP 14       5   ADVANCE MEMORY      OFF
 7 RESET SDS FAULT

STEP   9 RETD & WTG FOR REQ        TIMER = 0.00 sec - DISABLED    MESSAGE:OFF

No   Input ID           Equation   Destination    No   Output ID         State
 0 RETURN REQUEST       OFF-->ON   **STEP 12       0   RETURN SOL          OFF
 1 ADVANCE REQUEST      OFF-->ON     STEP 13       1   ADVANCE SOL         OFF
 2 RETURNED LS          ON-->OFF     STEP 11       2   RETURNED PL         ON
 3 ADVANCED LS          OFF-->ON   ERSTEP 14       3   ADVANCED PL         OFF
 4 RETURN MEMORY        OFF-->ON   ERSTEP 14       4   RETURN MEMORY       OFF
 5 ADVANCE MEMORY       OFF-->ON   ERSTEP 14       5   ADVANCE MEMORY      OFF
 7 RESET SDS FAULT

STEP  10 ADVD & WTG FOR REQ        TIMER = 0.00 sec - DISABLED    MESSAGE:OFF

No   Input ID           Equation   Destination    No   Output ID         State
 0 RETURN REQUEST       OFF-->ON   **STEP 12       0   RETURN SOL          OFF
 1 ADVANCE REQUEST      OFF-->ON     STEP 13       1   ADVANCE SOL         OFF
 2 RETURNED LS          OFF-->ON   ERSTEP 14       2   RETURNED PL         OFF
 3 ADVANCED LS          ON-->OFF     STEP 11       3   ADVANCED PL         ON
 4 RETURN MEMORY        OFF-->ON   ERSTEP 14       4   RETURN MEMORY       OFF
 5 ADVANCE MEMORY       OFF-->ON   ERSTEP 14       5   ADVANCE MEMORY      OFF
 7 RESET SDS FAULT
```

```
STEP  11 BTWN & WTG FOR REQ        TIMER = 0.00 sec – DISABLED    MESSAGE:OFF

No   Input ID            Equation   Destination    No   Output ID         State
 0 RETURN REQUEST       OFF––>ON   **STEP 12       0   RETURN SOL           OFF
 1 ADVANCE REQUEST      OFF––>ON     STEP 13       1   ADVANCE SOL          OFF
 2 RETURNED LS          OFF––>ON     STEP 9        2   RETURNED PL          OFF
 3 ADVANCED LS          OFF––>ON     STEP 10       3   ADVANCED PL          OFF
 4 RETURN MEMORY        OFF––>ON   ERSTEP 14       4   RETURN MEMORY        OFF
 5 ADVANCE MEMORY       OFF––>ON   ERSTEP 14       5   ADVANCE MEMORY       OFF
 7 RESET SDS FAULT

STEP  12 REV TO RETURN            TIMER = 0.10  sec INITIALIZE    MESSAGE:OFF

No   Input ID            Equation   Destination    No   Output ID         State
 0 RETURN REQUEST       ON––>OFF   INITIALIZE      0   RETURN SOL           ON
 1 ADVANCE REQUEST      OFF––>ON   INITIALIZE      1   ADVANCE SOL          OFF
 2 RETURNED LS                                     2   RETURNED PL          OFF
 3 ADVANCED LS                                     3   ADVANCED PL          OFF
 4 RETURN MEMORY                                   4   RETURN MEMORY        ON
 5 ADVANCE MEMORY                                  5   ADVANCE MEMORY       OFF
 7 RESET SDS FAULT

STEP  13 REV TO ADVANCE           TIMER = 0.10  sec INITIALIZE    MESSAGE:OFF

No   Input ID            Equation   Destination    No   Output ID         State
 0 RETURN REQUEST       OFF––>ON   INITIALIZE      0   RETURN SOL           OFF
 1 ADVANCE REQUEST      ON––>OFF   INITIALIZE      1   ADVANCE SOL          ON
 2 RETURNED LS                                     2   RETURNED PL          OFF
 3 ADVANCED LS                                     3   ADVANCED PL          OFF
 4 RETURN MEMORY                                   4   RETURN MEMORY        OFF
 5 ADVANCE MEMORY                                  5   ADVANCE MEMORY       ON
 7 RESET SDS FAULT

ERSTEP  14 FAULT                   TIMER = 0.00 sec – DISABLED    MESSAGE:ON

No   Input ID            Equation   Destination    No   Output ID         State
 0 RETURN REQUEST                                  0   RETURN SOL           OFF
 1 ADVANCE REQUEST                                 1   ADVANCE SOL          OFF
 2 RETURNED LS                                     2   RETURNED PL          OFF
 3 ADVANCED LS                                     3   ADVANCED PL          OFF
 4 RETURN MEMORY                                   4   RETURN MEMORY        OFF
 5 ADVANCE MEMORY                                  5   ADVANCE MEMORY       OFF
 7 RESET SDS FAULT      OFF––>ON   INITIALIZE
```

Applying the SDS Instruction to a Part Stamp (Spring-Return Valve)

These two lines of ladder logic show an example of an SDS for a spring return valve. This line is used to request the part stamp to advance.

```
|  STA 9     |                    |STA 9     |STA 9
|  ADVANCE   |STA 9     |CLAMP     |PART      |PART STAMP          STA 9 ADV
|  SLIDE PB  |AUTO SS   |ADVANCED  |PRESENT   |FAULT               STAMP REQ
|    I:066      I:066        B3         B3       N34:0                  B3
+-+---] [--------]/[----+---] [--------] [--------]/[------------------( )-----
| |     10         07   |     54         71        12                    60
| |STA 9     |STA 9     |
| |CYCLE     |FULL      |
| |STATION   |DEPTH     |
| |    B3       O:076   |
| +---] [--------]/[----+
|       68         07
```

The SDS instruction in this line of logic is used to control the part stamp.

```
| POWER ON  |POWER ON                                  PART
| DWELL     |CRM                                       STAMP
|    T4:1      I:001                       +SDS-------------------------+
+----] [--------] [------------------------+SMART DIRECTED SEQUENCER    +-(EN)-
|      DN         00                       |Control File           N34:0|
|                                          |Step Desc. File        N35:0+-(ST)
|                                          |Length                   104|
|                                          |No. of Steps               8+-(ER)
|                                          |Position/Step:             0|
|                                          |No. of I/O                 8+-(ES)
|                                          |Prog file number           3|
|                                          +----------------------------+
```

Step Directory

Control File: N34:0 Step Description File: N35:0

Step #	Step Name	Step #	Step Name
0	INITIALIZATION	5	RETURNING
1	RETD & ADVANCING	6	RETURNED
2	ADVANCING	7	FAULT
3	ADVANCED & ADVANCING	8	COASTING
4	ADVANCED & RETURNING		

Inputs and Outputs

I/O CROSS–REFERENCE

Input	Logical Address	Address Symbol	Address Comment
0	B3/60	B3/60	ADVANCE REQUEST
1	I:067/01	I:067/01	RETURNED LS
2	I:067/00	I:067/00	ADVANCED LS
7	B3/69	B3/69	RESET FAULT

Output	Logical Address	Address Symbol	Address Comment
0	O:067/00	O:067/00	ADVANCE SOL
1	B3/62	B3/62	RETURNED
2	B3/63	B3/63	BETWEEN ADVD & RETD
3	B3/64	B3/64	ADVANCED

Step Tables

STEP 1 RETD & ADVANCING TIMER = 0.00 sec – DISABLED MESSAGE:OFF

No	Input ID	Transition	Destination	No	Output ID	State
0	ADVANCE REQUEST	ON––>OFF	**STEP 8	0	ADVANCE SOL	ON
1	RETURNED LS	ON––>OFF	STEP 2	1	RETURNED	ON
2	ADVANCED LS	OFF––>ON	ERSTEP 7	2	BETWEEN ADVD & RETD	OFF
7	RESET FAULT			3	ADVANCED	OFF

STEP 2 ADVANCING TIMER = 2.00 sec WARNING MESSAGE:OFF

No	Input ID	Transition	Destination	No	Output ID	State
0	ADVANCE REQUEST	ON––>OFF	**STEP 8	0	ADVANCE SOL	ON
1	RETURNED LS	OFF––>ON	ERSTEP 7	1	RETURNED	OFF
2	ADVANCED LS	OFF––>ON	STEP 3	2	BETWEEN ADVD & RETD	ON
7	RESET FAULT			3	ADVANCED	OFF

STEP 3 ADVANCED & ADVANCING TIMER = 0.00 sec – DISABLED MESSAGE:OFF

No	Input ID	Transition	Destination	No	Output ID	State
0	ADVANCE REQUEST	ON––>OFF	**STEP 4	0	ADVANCE SOL	ON
1	RETURNED LS	OFF––>ON	ERSTEP 7	1	RETURNED	OFF
2	ADVANCED LS	ON––>OFF	ERSTEP 7	2	BETWEEN ADVD & RETD	OFF
7	RESET FAULT			3	ADVANCED	ON

```
  STEP   4 ADVANCED & RETURNING      TIMER = 0.00 sec – DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 ADVANCE REQUEST       OFF––>ON   **STEP 3       0 ADVANCE SOL            OFF
 1 RETURNED LS           OFF––>ON   ERSTEP 7       1 RETURNED               OFF
 2 ADVANCED LS           ON––>OFF     STEP 5       2 BETWEEN ADVD & RETD    OFF
 7 RESET FAULT                                     3 ADVANCED               ON

  STEP   5 RETURNING                  TIMER = 2.00  sec WARNING     MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 ADVANCE REQUEST       OFF––>ON   **STEP 2       0 ADVANCE SOL            OFF
 1 RETURNED LS           OFF––>ON     STEP 6       1 RETURNED               OFF
 2 ADVANCED LS           OFF––>ON   ERSTEP 7       2 BETWEEN ADVD & RETD    ON
 7 RESET FAULT                                     3 ADVANCED               OFF

  STEP   6 RETURNED                  TIMER = 0.00 sec – DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 ADVANCE REQUEST       OFF––>ON   **STEP 1       0 ADVANCE SOL            OFF
 1 RETURNED LS           ON––>OFF   ERSTEP 7       1 RETURNED               ON
 2 ADVANCED LS           OFF––>ON   ERSTEP 7       2 BETWEEN ADVD & RETD    OFF
 7 RESET FAULT                                     3 ADVANCED               OFF


ERSTEP   7 FAULT                     TIMER = 0.00 sec – DISABLED    MESSAGE:ON

No       Input ID       Transition Destination    No      Output ID        State
 0 ADVANCE REQUEST                                 0 ADVANCE SOL            OFF
 1 RETURNED LS                                     1 RETURNED               OFF
 2 ADVANCED LS                                     2 BETWEEN ADVD & RETD    OFF
 7 RESET FAULT           OFF––>ON     STEP 0       3 ADVANCED               OFF

  STEP   8 COASTING                 TIMER = 0.50  sec INITIALIZE    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 ADVANCE REQUEST                                 0 ADVANCE SOL            OFF
 1 RETURNED LS                                     1 RETURNED               LAST
 2 ADVANCED LS                                     2 BETWEEN ADVD & RETD    LAST
 7 RESET FAULT                                     3 ADVANCED               LAST
```

Applying the DFA Instruction to a Spindle

The next five lines of logic show how to implement diagnostics on a spindle. By using timers to check the reaction time on the starter contactor and the flow switch, we can verify that they are in the proper state. The timer done bit is then monitored in the DFA instruction to display a fault message whenever neccessary. The DFA would also be used to monitor any other static faults pertaining to the station (ex OVERLOADS OK).

```
|   STA 6     |
|   START     |STA 6     |HEAD LUBE |OVERLOADS |STOP      |SPINDLE
|   SPINDLE PB|AUTO SS   |FLOW OK   |OK        |SPINDLE   |CHECK OK  |SPINDLE
|     I:065      I:065      I:065        B3         B3         B3       O:065
+-++---] [--------]/[----+---]/[----+---] [--------] [--------] [--------( )----
| ||     13         07   |     06   |     35         29         28         05
| ||START     |STA 6     |          |
| ||SPINDLES  |AUTO SS   |          |
| ||    B3       I:065   |          |
| |+---] [--------] [----+          |
| |       6         07              |
| |          |SPINDLE               |
| |SPINDLE   |ON                    |
| |  O:065      I:065               |
| +---] [--------] [----------------+
|       05         05
|                                                          SPINDLE
|           |SPINDLE                                       CONTACTOR
|  SPINDLE  |ON                                            CHECK
|    O:065      I:065                               +TON---------------+
+-+---] [--------]/[----+---------------------------+TIMER ON DELAY    +-(EN)-
| |     05         05   |                           |Timer         T4:2|
| |          |SPINDLE   |                           |Time base     0.01+-(DN)
| |SPINDLE   |ON        |                           |Preset           5|
| |  O:065      I:065   |                           |Accum            0|
| +---]/[--------] [----+                           +------------------+
|       05         05
|                                                          SPINDLE
|           |HEAD LUBE                                     LUBE FLOW
|  SPINDLE  |FLOW OK                                       CHECK
|    O:065      I:065                               +TON---------------+
+-+---] [--------]/[----+---------------------------+TIMER ON DELAY    +-(EN)-
| |     05         06   |                           |Timer         T4:3|
| |          |HEAD LUBE |                           |Time base     0.01+-(DN)
| |SPINDLE   |FLOW OK   |                           |Preset          30|
| |  O:065      I:065   |                           |Accum            0|
| +---]/[--------] [----+                           +------------------+
|       05         06
```

```
| SPINDLE   |SPINDLE
| CONTACTOR |LUBE FLOW                                           SPINDLE
| FAULT     |FAULT                                               CHECK OK
|    T4:2      T4:3                                                  B3
+----]/[--------]/[---------------------------------------------------( )-----
|      DN        DN                                                  28
| POWER ON
| DWELL                                           STA #6
|    T4:1                                  +DFA------------------------+
+----] [-----------------------------------+DIAGNOSTIC FAULT ANNUNCIATOR+-(EN)
|      DN                                  |Control File          N30:0|(ST)
|                                          |No. of I/O                8+-(ER)
|                                          |Prog file number          4|(ES)
|                                          +----------------------------+
```

The following are examples of messages you could configure as part of the DFA instruction.

STA #6 SPINDLE CONTACTOR FAULT

STA #6 HEAD LUBE FLOW FAULT

STA #6 SPINDLE OVERLOAD TRIPPED

Inputs

Input	Logical Address	INPUT CROSS–REFERENCE Address Symbol	Address Comment
0	B3/28	B3/28	SPINDLE CHECK OK
1	I:065/06	I:065/06	HEAD LUBE FLOW OK
2	B3/35	B3/35	OVERLOADS OK

DFA Messages

No	Input ID	Message	State
0	SPINDLE CHECK OK	SPINDLE FAULT	ON
1	HEAD LUBE FLOW OK	HEAD LUBE FAULT	OFF
2	OVERLOADS OK	MOTOR OVERLOAD FAULT	OFF

Applying the SDS Instruction to a Mechanical Slide

The next four lines of logic show the request logic and the SDS instruction for a mechanical slide station. Note that all motions are initiated with a line of request logic. It is in this request logic that any sequence interlocks are handled. It should also be noted that whenever possible, the permissives used in the request line should be internal bits that are controlled from some other SDS instruction or ladder logic, (e.g., CLAMP ADVANCED).

```
|  STA 6     |                                          |STA 6
|  ADVANCE   |STA 6     |SPINDLE   |CLAMP     |STA 6 RET |SLIDE     |STA 6 ADV
|  SLIDE PB  |AUTO SS   |ON        |ADVANCED  |REQUEST   |FAULT     |REQUEST
|    I:065      I:065      I:065        B3         B3      N26:0        B3
+-+---] [--------]/[----+---] [--------] [--------]/[--------]/[--------( )----
| |     10         07   |     05         54         31         12         30
| |STA 6     |          |
| |CYCLE     |STA 6     |
| |STATION   |FULL DEPTH|
| |    B3       O:065   |
| +---] [--------]/[----+
|       38         07


| POWER ON  |POWER ON                                  MECHANICAL
| DWELL     |CRM                                        SLIDE
|    T4:1      I:001                       +SDS-------------------------+
+----] [--------] [------------------------+SMART DIRECTED SEQUENCER    +-(EN)-
|      DN         00                       |Control File          N26:0|
|                                          |Step Desc. File       N27:0+-(ST)
|                                          |Length                  234|
|                                          |No. of Steps             18+-(ER)
|                                          |Position/Step:            0|
|                                          |No. of I/O                8+-(ES)
|                                          |Prog file number          3|
|                                          +----------------------------+
|  STA 6     |                   |STA 6     |          |STA 6
|  RETURN    |STA 6     |OVERLOADS |RETURNED  |STA 6 ADV |SLIDE     |STA 6 RET
|  SLIDE PB  |AUTO SS   |OK        |LT        |REQUEST   |FAULT     |REQUEST
|    I:065      I:065        B3         B3         B3      N26:0        B3
+-+---] [--------]/[----+---] [--------]/[--------]/[--------]/[--------( )----
| |     11         07   |     35         36         30         12         31
| |STA 6     |          |
| |CYCLE     |STA 6     |
| |STATION   |FULL DEPTH|
| |    B3       O:065   |
| +---] [--------] [----+
|       38         07
| STA 6     |
| RETURN TO |                     |STA 6
| TOOL CHG  |STA 6     |STA 6 TOOL|SLIDE                            STA 6 RET
| POSN PB   |AUTO SS   | CHG POSN |FAULT                            TO TL CHG
|   I:065      I:065        B3       N26:0                               B3
+----] [--------]/[--------]/[--------]/[------------------------------( )-----
|      12         07         37         12                               32
```

Step Directory

Control File: N26:0 Step Description File: N27:0

Step #	Step Name	Step #	Step Name
0	INITIALIZATION	10	RETD & RETURNING
1	RETURNED	11	STPD BTW FEED & RETD
2	RETD & ADVANCING	12	STOPPED IN FEED AREA
3	RAPID ADVANCING	13	RETG TO TOOL CHG
4	ADVG IN FEED AREA	14	RETD TL CHG & RETG
5	ADVD & ADVANCING	15	RETD TO TOOL CHANGE
6	ADVANCED	16	RETD TL CHG & ADVG
7	ADVD & RETURNING	17	COASTING
8	RETG IN FEED AREA	18	FAULT
9	RETURNING		

Inputs and Outputs

I/O CROSS–REFERENCE

Input	Logical Address	Address Symbol	Address Comment
0	B3/30	B3/30	STA 6 ADV REQUEST
1	B3/31	B3/31	STA 6 RET REQUEST
2	B3/32	B3/32	STA 6 RET TO TL CHG
3	I:065/01	I:065/01	FEED POSITION LS
4	I:065/02	I:065/02	ADVANCED LS
5	I:065/00	I:065/00	RETURNED LS
6	I:065/03	I:065/03	TOOL CHG POSN LS
7	B3/39	B3/39	RESET STA 6 FLT

Output	Logical Address	Address Symbol	Address Comment
0	O:065/00	O:065/00	STA 6 ADV SLIDE MOTO
1	O:065/01	O:065/01	STA 6 RET SLIDE MOTO
2	O:065/02	O:065/02	STA 6 FEED MOTOR
3	B3/33	B3/33	STA 6 FEED AREA
4	B3/34	B3/34	STA 6 SLIDE ADVD
5	B3/36	B3/36	STA 6 RETURNED LT
6	B3/37	B3/37	STA 6 TOOL CHG POSN

Step Tables

STEP 1 RETURNED TIMER = 0.00 sec – DISABLED MESSAGE:OFF

No	Input ID	Transition	Destination	No	Output ID	State
0	STA 6 ADV REQUEST	OFF––>ON	**STEP 2	0	STA 6 ADV SLIDE MOTO	OFF
1	STA 6 RET REQUEST	OFF––>ON	ERSTEP 18	1	STA 6 RET SLIDE MOTO	OFF
2	STA 6 RET TO TL CHG	OFF––>ON	STEP 13	2	STA 6 FEED MOTOR	OFF
3	FEED POSITION LS	OFF––>ON	ERSTEP 18	3	STA 6 FEED AREA	OFF
4	ADVANCED LS	OFF––>ON	ERSTEP 18	4	STA 6 SLIDE ADVD	OFF
5	RETURNED LS	ON––>OFF	ERSTEP 18	5	STA 6 RETURNED LT	ON
6	TOOL CHG POSN LS	OFF––>ON	ERSTEP 18	6	STA 6 TOOL CHG POSN	OFF
7	RESET STA 6 FLT					

```
 STEP   2 RETD & ADVANCING          TIMER = 1.00  sec WARNING     MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST     ON-->OFF     STEP 1       0 STA 6 ADV SLIDE MOTO   ON
 1 STA 6 RET REQUEST     OFF-->ON  INITIALIZE      1 STA 6 RET SLIDE MOTO   OFF
 2 STA 6 RET TO TL CHG   OFF-->ON   ERSTEP 18      2 STA 6 FEED MOTOR       ON
 3 FEED POSITION LS      OFF-->ON   ERSTEP 18      3 STA 6 FEED AREA        OFF
 4 ADVANCED LS           OFF-->ON   ERSTEP 18      4 STA 6 SLIDE ADVD       OFF
 5 RETURNED LS           ON-->OFF   **STEP 3       5 STA 6 RETURNED LT      ON
 6 TOOL CHG POSN LS      OFF-->ON   ERSTEP 18      6 STA 6 TOOL CHG POSN    OFF
 7 RESET STA 6 FLT

 STEP   3 RAPID ADVANCING         TIMER = 5.00  sec ERSTEP  18    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST     ON-->OFF     STEP 17      0 STA 6 ADV SLIDE MOTO   ON
 1 STA 6 RET REQUEST     OFF-->ON  INITIALIZE      1 STA 6 RET SLIDE MOTO   OFF
 2 STA 6 RET TO TL CHG   OFF-->ON   ERSTEP 18      2 STA 6 FEED MOTOR       ON
 3 FEED POSITION LS      OFF-->ON   **STEP 4       3 STA 6 FEED AREA        OFF
 4 ADVANCED LS           OFF-->ON   ERSTEP 18      4 STA 6 SLIDE ADVD       OFF
 5 RETURNED LS           OFF-->ON     STEP 2       5 STA 6 RETURNED LT      OFF
 6 TOOL CHG POSN LS      OFF-->ON   ERSTEP 18      6 STA 6 TOOL CHG POSN    OFF
 7 RESET STA 6 FLT

 STEP   4 ADVG IN FEED AREA         TIMER = 2.50  sec WARNING     MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST     ON-->OFF     STEP 17      0 STA 6 ADV SLIDE MOTO   OFF
 1 STA 6 RET REQUEST     OFF-->ON  INITIALIZE      1 STA 6 RET SLIDE MOTO   OFF
 2 STA 6 RET TO TL CHG   OFF-->ON   ERSTEP 18      2 STA 6 FEED MOTOR       ON
 3 FEED POSITION LS      ON-->OFF   ERSTEP 18      3 STA 6 FEED AREA        ON
 4 ADVANCED LS           OFF-->ON   **STEP 5       4 STA 6 SLIDE ADVD       OFF
 5 RETURNED LS           OFF-->ON   ERSTEP 18      5 STA 6 RETURNED LT      OFF
 6 TOOL CHG POSN LS      OFF-->ON   ERSTEP 18      6 STA 6 TOOL CHG POSN    OFF
 7 RESET STA 6 FLT


 STEP   5 ADVD & ADVANCING         TIMER = 0.00 sec - DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST     ON-->OFF  INITIALIZE      0 STA 6 ADV SLIDE MOTO   OFF
 1 STA 6 RET REQUEST     OFF-->ON  INITIALIZE      1 STA 6 RET SLIDE MOTO   OFF
 2 STA 6 RET TO TL CHG   OFF-->ON   ERSTEP 18      2 STA 6 FEED MOTOR       OFF
 3 FEED POSITION LS      ON-->OFF   ERSTEP 18      3 STA 6 FEED AREA        ON
 4 ADVANCED LS           ON-->OFF   ERSTEP 18      4 STA 6 SLIDE ADVD       ON
 5 RETURNED LS           OFF-->ON   ERSTEP 18      5 STA 6 RETURNED LT      OFF
 6 TOOL CHG POSN LS      OFF-->ON   ERSTEP 18      6 STA 6 TOOL CHG POSN    OFF
 7 RESET STA 6 FLT

 STEP   6 ADVANCED                 TIMER = 0.00 sec - DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST     OFF-->ON   ERSTEP 18      0 STA 6 ADV SLIDE MOTO   OFF
 1 STA 6 RET REQUEST     OFF-->ON   **STEP 7       1 STA 6 RET SLIDE MOTO   OFF
 2 STA 6 RET TO TL CHG   OFF-->ON     STEP 13      2 STA 6 FEED MOTOR       OFF
 3 FEED POSITION LS      ON-->OFF   ERSTEP 18      3 STA 6 FEED AREA        ON
 4 ADVANCED LS           ON-->OFF   ERSTEP 18      4 STA 6 SLIDE ADVD       ON
 5 RETURNED LS           OFF-->ON   ERSTEP 18      5 STA 6 RETURNED LT      OFF
 6 TOOL CHG POSN LS      OFF-->ON   ERSTEP 18      6 STA 6 TOOL CHG POSN    OFF
 7 RESET STA 6 FLT

 STEP   7 ADVD & RETURNING         TIMER = 0.00 sec - DISABLED    MESSAGE:OFF
```

```
No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST     OFF-->ON   ERSTEP 18      0 STA 6 ADV SLIDE MOTO   OFF
 1 STA 6 RET REQUEST     ON-->OFF     STEP 17      1 STA 6 RET SLIDE MOTO   ON
 2 STA 6 RET TO TL CHG   OFF-->ON   ERSTEP 18      2 STA 6 FEED MOTOR       OFF
 3 FEED POSITION LS      ON-->OFF   ERSTEP 18      3 STA 6 FEED AREA        ON
 4 ADVANCED LS           ON-->OFF   **STEP 8       4 STA 6 SLIDE ADVD       ON
 5 RETURNED LS           OFF-->ON   ERSTEP 18      5 STA 6 RETURNED LT      OFF
 6 TOOL CHG POSN LS      OFF-->ON   ERSTEP 18      6 STA 6 TOOL CHG POSN    OFF
 7 RESET STA 6 FLT

  STEP   8 RETG IN FEED AREA         TIMER = 0.00 sec – DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST     OFF-->ON  INITIALIZE      0 STA 6 ADV SLIDE MOTO   OFF
 1 STA 6 RET REQUEST     ON-->OFF     STEP 17      1 STA 6 RET SLIDE MOTO   ON
 2 STA 6 RET TO TL CHG   OFF-->ON   ERSTEP 18      2 STA 6 FEED MOTOR       OFF
 3 FEED POSITION LS      ON-->OFF   **STEP 9       3 STA 6 FEED AREA        ON
 4 ADVANCED LS           OFF-->ON   ERSTEP 18      4 STA 6 SLIDE ADVD       OFF
 5 RETURNED LS           OFF-->ON   ERSTEP 18      5 STA 6 RETURNED LT      OFF
 6 TOOL CHG POSN LS      OFF-->ON   ERSTEP 18      6 STA 6 TOOL CHG POSN    OFF
 7 RESET STA 6 FLT


  STEP   9 RETURNING                 TIMER = 0.00 sec – DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST     OFF-->ON  INITIALIZE      0 STA 6 ADV SLIDE MOTO   OFF
 1 STA 6 RET REQUEST     ON-->OFF     STEP 17      1 STA 6 RET SLIDE MOTO   ON
 2 STA 6 RET TO TL CHG   OFF-->ON   ERSTEP 18      2 STA 6 FEED MOTOR       OFF
 3 FEED POSITION LS      OFF-->ON   ERSTEP 18      3 STA 6 FEED AREA        OFF
 4 ADVANCED LS           OFF-->ON   ERSTEP 18      4 STA 6 SLIDE ADVD       OFF
 5 RETURNED LS           OFF-->ON   **STEP 10      5 STA 6 RETURNED LT      OFF
 6 TOOL CHG POSN LS      OFF-->ON   ERSTEP 18      6 STA 6 TOOL CHG POSN    OFF
 7 RESET STA 6 FLT

  STEP  10 RETD & RETURNING          TIMER = 0.00 sec – DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST     OFF-->ON  INITIALIZE      0 STA 6 ADV SLIDE MOTO   OFF
 1 STA 6 RET REQUEST     ON-->OFF  INITIALIZE      1 STA 6 RET SLIDE MOTO   ON
 2 STA 6 RET TO TL CHG   OFF-->ON   ERSTEP 18      2 STA 6 FEED MOTOR       OFF
 3 FEED POSITION LS      OFF-->ON   ERSTEP 18      3 STA 6 FEED AREA        OFF
 4 ADVANCED LS           OFF-->ON   ERSTEP 18      4 STA 6 SLIDE ADVD       OFF
 5 RETURNED LS           ON-->OFF   ERSTEP 18      5 STA 6 RETURNED LT      ON
 6 TOOL CHG POSN LS      OFF-->ON   ERSTEP 18      6 STA 6 TOOL CHG POSN    OFF
 7 RESET STA 6 FLT

  STEP  11 STPD BTW FEED & RETD      TIMER = 0.00 sec – DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST     OFF-->ON   **STEP 3       0 STA 6 ADV SLIDE MOTO   OFF
 1 STA 6 RET REQUEST     OFF-->ON     STEP 9       1 STA 6 RET SLIDE MOTO   OFF
 2 STA 6 RET TO TL CHG   OFF-->ON     STEP 13      2 STA 6 FEED MOTOR       OFF
 3 FEED POSITION LS      OFF-->ON   ERSTEP 18      3 STA 6 FEED AREA        OFF
 4 ADVANCED LS           OFF-->ON   ERSTEP 18      4 STA 6 SLIDE ADVD       OFF
 5 RETURNED LS           OFF-->ON   ERSTEP 18      5 STA 6 RETURNED LT      OFF
 6 TOOL CHG POSN LS      OFF-->ON   ERSTEP 18      6 STA 6 TOOL CHG POSN    OFF
 7 RESET STA 6 FLT
```

```
  STEP  12 STOPPED IN FEED AREA      TIMER = 0.00 sec – DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST     OFF––>ON   **STEP 4       0 STA 6 ADV SLIDE MOTO   OFF
 1 STA 6 RET REQUEST     OFF––>ON     STEP 8       1 STA 6 RET SLIDE MOTO   OFF
 2 STA 6 RET TO TL CHG   OFF––>ON     STEP 13      2 STA 6 FEED MOTOR       OFF
 3 FEED POSITION LS      ON––>OFF   ERSTEP 18      3 STA 6 FEED AREA        ON
 4 ADVANCED LS           OFF––>ON   ERSTEP 18      4 STA 6 SLIDE ADVD       OFF
 5 RETURNED LS           OFF––>ON   ERSTEP 18      5 STA 6 RETURNED LT      OFF
 6 TOOL CHG POSN LS      OFF––>ON   ERSTEP 18      6 STA 6 TOOL CHG POSN    OFF
 7 RESET STA 6 FLT
```

```
  STEP  13 RETG TO TOOL CHG          TIMER = 0.00 sec – DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST     OFF––>ON   ERSTEP 18      0 STA 6 ADV SLIDE MOTO   OFF
 1 STA 6 RET REQUEST     OFF––>ON   ERSTEP 18      1 STA 6 RET SLIDE MOTO   ON
 2 STA 6 RET TO TL CHG   ON––>OFF   **STEP 17      2 STA 6 FEED MOTOR       OFF
 3 FEED POSITION LS                                3 STA 6 FEED AREA        OFF
 4 ADVANCED LS                                     4 STA 6 SLIDE ADVD       OFF
 5 RETURNED LS                                     5 STA 6 RETURNED LT      OFF
 6 TOOL CHG POSN LS      OFF––>ON     STEP 14      6 STA 6 TOOL CHG POSN    OFF
 7 RESET STA 6 FLT
```

```
  STEP  14 RETD TL CHG & RETG        TIMER = 0.00 sec – DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST     OFF––>ON   ERSTEP 18      0 STA 6 ADV SLIDE MOTO   OFF
 1 STA 6 RET REQUEST     OFF––>ON   ERSTEP 18      1 STA 6 RET SLIDE MOTO   ON
 2 STA 6 RET TO TL CHG   ON––>OFF   **STEP 17      2 STA 6 FEED MOTOR       OFF
 3 FEED POSITION LS      OFF––>ON   ERSTEP 18      3 STA 6 FEED AREA        OFF
 4 ADVANCED LS           OFF––>ON   ERSTEP 18      4 STA 6 SLIDE ADVD       OFF
 5 RETURNED LS           OFF––>ON   ERSTEP 18      5 STA 6 RETURNED LT      OFF
 6 TOOL CHG POSN LS      ON––>OFF   ERSTEP 18      6 STA 6 TOOL CHG POSN    ON
 7 RESET STA 6 FLT
```

```
  STEP  15 RETD TO TOOL CHANGE       TIMER = 0.00 sec – DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST     OFF––>ON   **STEP 16      0 STA 6 ADV SLIDE MOTO   OFF
 1 STA 6 RET REQUEST     OFF––>ON   ERSTEP 18      1 STA 6 RET SLIDE MOTO   OFF
 2 STA 6 RET TO TL CHG   OFF––>ON   ERSTEP 18      2 STA 6 FEED MOTOR       OFF
 3 FEED POSITION LS      OFF––>ON   ERSTEP 18      3 STA 6 FEED AREA        OFF
 4 ADVANCED LS           OFF––>ON   ERSTEP 18      4 STA 6 SLIDE ADVD       OFF
 5 RETURNED LS           OFF––>ON   ERSTEP 18      5 STA 6 RETURNED LT      OFF
 6 TOOL CHG POSN LS      ON––>OFF   ERSTEP 18      6 STA 6 TOOL CHG POSN    ON
 7 RESET STA 6 FLT
```

```
  STEP  16 RETD TL CHG & ADVG        TIMER = 0.00 sec – DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST     ON––>OFF     STEP 17      0 STA 6 ADV SLIDE MOTO   ON
 1 STA 6 RET REQUEST     OFF––>ON   ERSTEP 18      1 STA 6 RET SLIDE MOTO   OFF
 2 STA 6 RET TO TL CHG   OFF––>ON   ERSTEP 18      2 STA 6 FEED MOTOR       ON
 3 FEED POSITION LS      OFF––>ON   ERSTEP 18      3 STA 6 FEED AREA        OFF
 4 ADVANCED LS           OFF––>ON   ERSTEP 18      4 STA 6 SLIDE ADVD       OFF
 5 RETURNED LS           OFF––>ON   ERSTEP 18      5 STA 6 RETURNED LT      OFF
 6 TOOL CHG POSN LS      ON––>OFF   **STEP 3       6 STA 6 TOOL CHG POSN    ON
 7 RESET STA 6 FLT
```

```
  STEP  17 COASTING                  TIMER = 0.00 sec – DISABLED    MESSAGE:OFF

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST                               0 STA 6 ADV SLIDE MOTO   OFF
 1 STA 6 RET REQUEST                               1 STA 6 RET SLIDE MOTO   OFF
 2 STA 6 RET TO TL CHG                             2 STA 6 FEED MOTOR       OFF
 3 FEED POSITION LS                                3 STA 6 FEED AREA        OFF
 4 ADVANCED LS                                     4 STA 6 SLIDE ADVD       OFF
 5 RETURNED LS                                     5 STA 6 RETURNED LT      OFF
 6 TOOL CHG POSN LS                                6 STA 6 TOOL CHG POSN    OFF
 7 RESET STA 6 FLT

ERSTEP  18 FAULT                     TIMER = 0.00 sec – DISABLED    MESSAGE:ON

No       Input ID       Transition Destination    No      Output ID        State
 0 STA 6 ADV REQUEST                               0 STA 6 ADV SLIDE MOTO   OFF
 1 STA 6 RET REQUEST                               1 STA 6 RET SLIDE MOTO   OFF
 2 STA 6 RET TO TL CHG                             2 STA 6 FEED MOTOR       OFF
 3 FEED POSITION LS                                3 STA 6 FEED AREA        OFF
 4 ADVANCED LS                                     4 STA 6 SLIDE ADVD       OFF
 5 RETURNED LS                                     5 STA 6 RETURNED LT      OFF
 6 TOOL CHG POSN LS                                6 STA 6 TOOL CHG POSN    OFF
 7 RESET STA 6 FLT       OFF––>ON     STEP 0
```

Summary

This chapters showed you examples of logic that apply the DDMC instruction to common mechanisms. You can refer to these examples when you set up similar applications. Chapter 7 shows examples of using DDMC instruction in a DDMC implementation for operator guidance.

Chapter 7

Applying DDMC Instructions for Operator Guidance

Chapter Objectives

In addition to implementing DDMC at various levels, you can implement the instructions to provide operators with messages that guide them to perform sequential steps. For example, when a machine faults in automatic mode, the operator may need to perform steps to get the machine back to home position so that it can be placed back in automatic mode. You can use the messages generated by the DDMC instructions to tell the operator what to do.

Read this chapter to gain a basic understanding of providing operators with guidance messages and to better understand the terminology used in DDMC instructions for operator guidance.

Getting Started with Providing Operator Guidance

As stated on page 1-1, you can use the SDS instruction in two different ways:

- state-transitional mode (inputs are ORed) where individual input state transitions and changes are analyzed
- combinatorial mode (inputs or steady states are ANDed) to analyze logical conditions

To achieve operator guidance, we recommend that you keep those actions related to the motion of the mechanism in a separate SDS instruction. Information for analyzing expected conditions that are being monitored by the SDS instruction and allow the operator's request to be acted upon should be kept in another SDS instruction.

You do this to reduce the complexity in the instruction and to display messages different than those used to indicate control faults. (You use the configuration utility differently to configure operator guidance messages than to configure warning messages.)

To configure operator guidance messages, you first analyze existing or standard request logic and relocate the permissive and interlocks from the ladder logic and put them in their own SDS instruction as shown in Figure 7.1. The permissives in the request logic must not allow for parallel paths. Figure 7.2 shows the state diagram for the SDS instruction that monitors the conditions. The state (or step) tables follow the state diagram.

Figure 7.1
DDMC Implementation — Operator Guidance

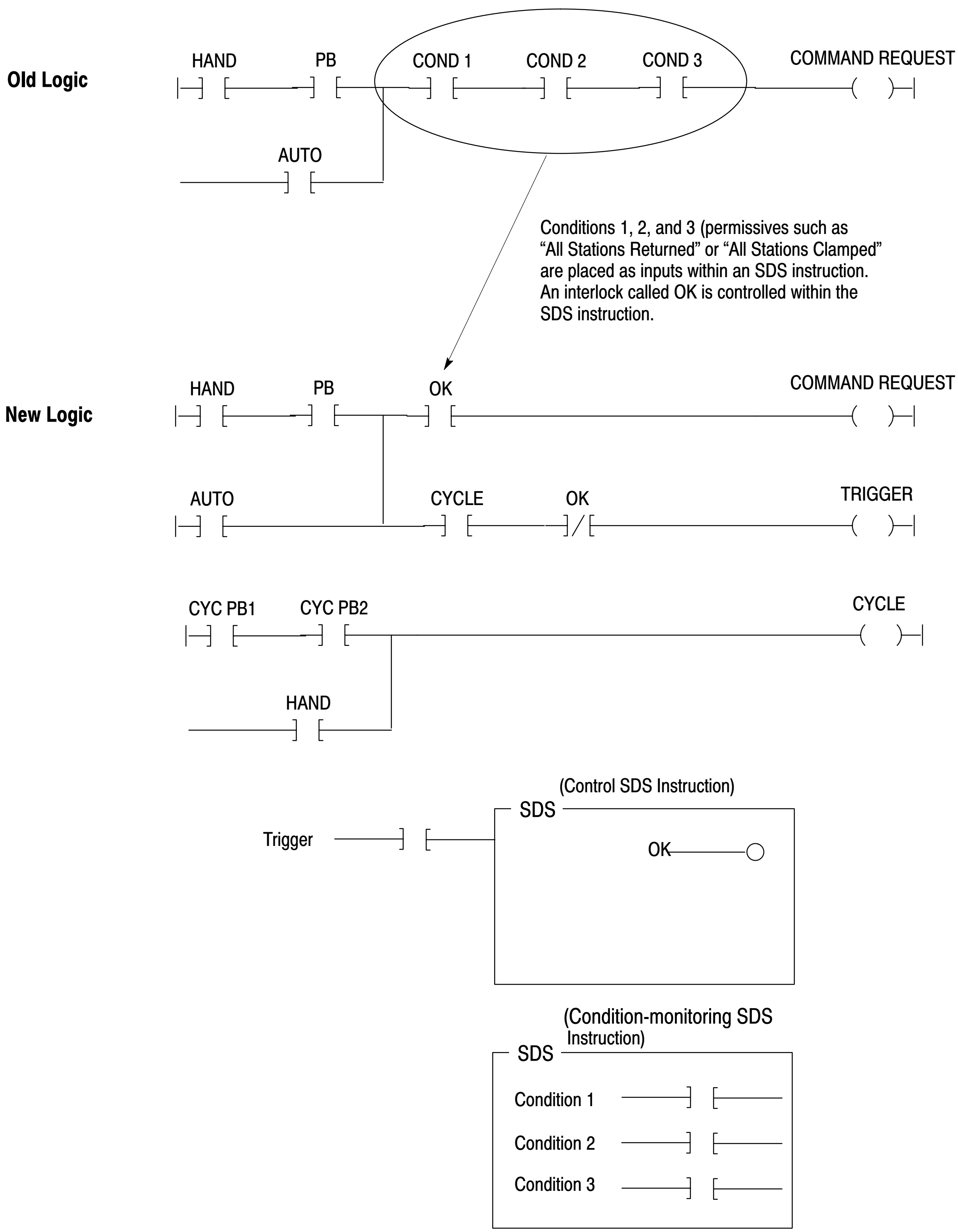


Figure 7.2
State Diagram for Condition-monitoring SDS Instruction

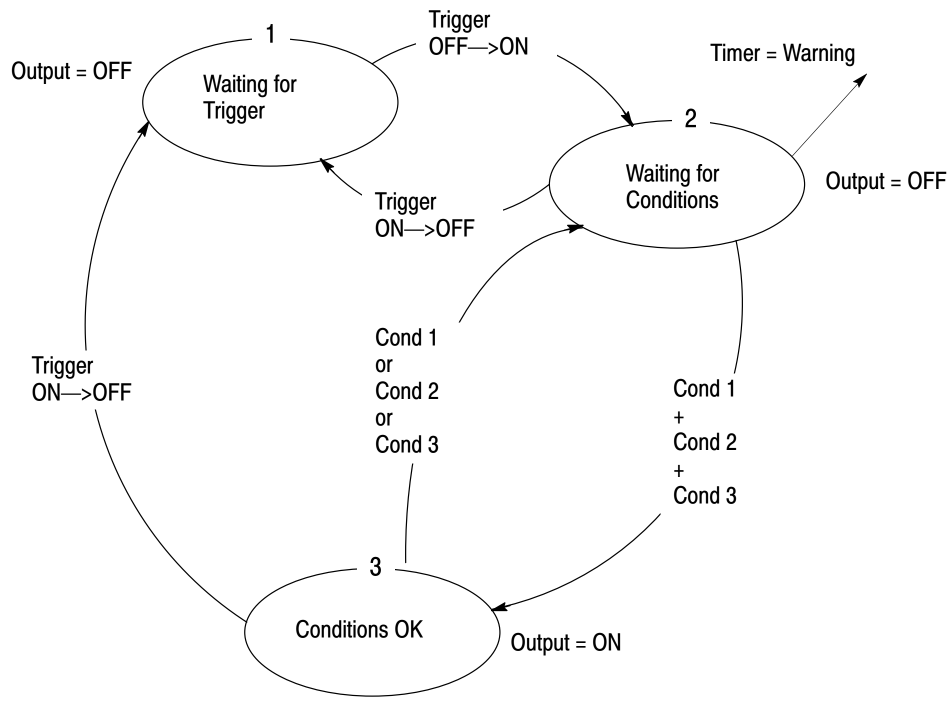


Table 1.A
Step Tables for Condition-monitoring SDS Instruction

STEP 1 WAITING FOR TRIGGER TIMER = 0.00 sec – DISABLED MESSAGE:OFF

No	Input ID	Transition	Destination	No	Output ID	State
0	TRIGGER	OFF-->ON	STEP 2	0	OK	OFF
1	COND 1					
2	COND 2					
3	COND 3					

STEP 1 WAITING FOR CONDITIONS TIMER = WARNING MESSAGE:OFF

No	Input ID	Transition	Destination	No	Output ID	State
0	TRIGGER	ON-->OFF	STEP 1	0	OK	OFF
1	COND 1	OFF-->ON	INPUT 2			
2	COND 2	OFF-->ON	INPUT 3			
3	COND 3	OFF-->ON	STEP 3			

STEP 1 WAITING FOR TRIGGER TIMER = 0.00 sec – DISABLED MESSAGE:OFF

No	Input ID	Transition	Destination	No	Output ID	State
0	TRIGGER	ON-->OFF	STEP 1	0	OK	ON
1	COND 1	ON-->OFF	STEP 2			
2	COND 2	ON-->OFF	STEP 2			
3	COND 3	ON-->OFF	STEP 2			

Understanding Interlock Terminology

In Figure 7.1, three conditions from the old logic were transferred to the SDS instruction. To make the transfer valid, an *interlock* called OK was included in the new ladder logic. An interlock refers to a condition that affects another motion. Interlocks are based on logical or mechanical safety considerations, usually related to multiple sequences. Below we define the terms relating to interlocks and describe their use.

Control Permissives

A control permissive is a command to allow or condition the next motion within a sequence.

In manual control, a control permissive may be the operation of a push-button; however, in automatic mode, it may be dependent on a number of states, for example, "left and right hand clamps open and pin retracted." Another example of a control permissive is "part in place" permissive.

Where multiple machine states are required to provide a control permissive, we recommend placing control permissives in ladder logic. Although the permissives can be placed in a separate SDS instruction, you gain little by doing this since the individual permissives have their own diagnostics associated with their SDS instruction and as part of their own logic program.

Critical Interlocks

Critical interlocks are conditions that are required regardless of the machine's mode of operation. These interlocks are provided to protect the machine from damage whether the machine is in automatic or manual mode.

For example, a critical interlock might be a spindle or lube OK condition required before a tool can advance into a piece of work. In most cases, these conditions must be satisfied regardless of the mode of operation; that is, don't close the door until all fingers are out of the way, or don't move the transfer mechanism until all heads are returned and all stations are unclamped.

You can include critical interlocks in the same SDS instruction used for controlling a mechanism, but the instruction could contain a large number of steps. We recommend including critical interlocks in a second SDS instruction to provide a permissive to the SDS that controls the mechanism.

Constantly-Monitored Interlocks

Constantly-monitored interlocks are commands that are required regardless of a machine's mode of operation or its position within a sequence. These interlocks are provided to protect the operator in case of machine failure.

Examples of constantly-monitored interlocks include:

- air pressure OK
- emergency stop
- guards closed

You can place these interlocks in ladder logic and monitor them with the DFA instruction to provide the operator with startup/manual operation and diagnostics information if the machine fails.

Process Interlocks

Process interlocks are commands or conditions required for a number of operations within a sequence.

You can include process interlocks in an SDS instruction, similar to the way you handle critical interlocks. However, if a process interlock fails, all of the instructions that were tied to it would each generate the same error messages for a single failure.

We instead recommend implementing process interlocks like constantly-monitored interlocks — actually performing the interlocking in ladder logic and generate diagnostics information with the DFA instruction.

Summary

In this chapter you read about using the SDS instruction to provide guidance to your operators. In addition, we described some of the terminology common to using DDMC instructions for operator guidance. Chapter 8 contains application information for logging IMC faults sent as messages by the PLC-5 processor.

Chapter 8

Logging IMC Faults Sent as Messages by the PLC-5 Processor

Chapter Objectives

A special message type has been defined for an IMC fault within the DDMC system. By using the message instruction (MSG) in PLC-5 software, you can log IMC faults and send them to an operator interface terminal. This procedure simulates the diagnostic messages sent by the SDS instruction.

In addition, you can use this same IMC message format as means of integrating other devices such as drives into the DDMC fault display and logging utilities.

Read this chapter to learn the techniques for logging this fault.

Important: This procedure assumes you are familiar with programming 6200 Series software, the message instruction function and structure, and IMC MML programming.

Configuring the IMC Fault Message Type

To configure the IMC message type, you must perform the following tasks:

- configure the message instruction
- edit the data table
- provide PLC logic

Configuring the Message Instruction

To configure the message instruction, do the following:

1. Create a message instruction in your program.

2. Configure the message instruction (within the Message Instruction Data Entry screen) as shown in Figure 8.1.

Figure 8.1
Message Instruction Data Entry screen

```
   MESSAGE INSTRUCTION DATA ENTRY FOR CONTROL BLOCK N12:20


               Communication Command:             PLC–5 TYPED WRITE
               PLC–5 Data Table Address:          N12:0
               Size in Elements:                  13
               Local/Remote:                      LOCAL
                  Remote Station:                 N/A
                  Link ID:                        N/A
                  Remote Link Type:               N/A
               Local Node Address:                77
               Destination Data Table Address:    ”IMC”


  BLOCK SIZE = 9 WORDS



Press a key to change a parameter or <ENTER> to accept parameters.
>
Program    Forces:None      Edits:None                  5/15 Addr 0  DDMCIMC
Command  PLC–5  Size in Local/  Remote   Link   Remote   Local  Destin
 Type   Address Elemnts Remote  Station   ID     Link    Node   Address
  F1      F2      F3      F4      F5      F6      F7      F8      F9
```

Editing the Data Table

You must edit the first 13 words of the local data table to contain the information which will be sent in your message. You may want to change the radix to ASCII to make editing simpler. To edit the data table, do the following:

1. Access the data table at the data file address for the message instruction.

2. Enter information into words 0 – 12 as shown below.

Note that you configure words 0 – 6 by editing the data table directly; words 7 – 12 need to be supplied by the ladder programming when an error is detected.

WORD 0

15	14	13	12	11	10	09	08	07	06	05	04	03	02	01	00
CLASS (Message class = C)				TYPE (fault = 0 clear =4)				PLCTYPE (PLC-5 = 1 PLC-5/250 =2)				UNUSED			

WORDS 1–4

PROCESSOR NAME entered in ASCII

WORD 5

15	14	13	12	11	10	09	08	07	06	05	04	03	02	01	00
RACK (Rack number of IMC device)								GROUP (Group number of IMC device)							

WORD 6

15	14	13	12	11	10	09	08	07	06	05	04	03	02	01	00
SLOT (Slot number of IMC device)								IMC TYPE (IMC 120 = 1 IMC 121 = 2 IMC 123 = 3)							

WORD 7

IMC Error Code from IMC program

WORDS 8–12

IMC to PLC Block Zero information words 2-6

Figure 8.2 shows the data table at the message instruction control file address configured with information.

Figure 8.2
Configured Data Table at Message Instruction Control File Address (Radix shown in ASCII)

```
  Address     0      1      2      3      4      5      6      7      8      9
N12:0      \C4\10  D  D   M  C   T  S   T \00 \00\03 \00\03 \00\00 \00\00 \00\00
N12:10     \00\00 \00\00 \00\00 \00\00









Press a function key or enter a value.
N12:1 =
Program    Forces:None      Data:ASCII      Addr:Decimal 5/15 Addr 0  DDMCIMC
Change                          Specify          Next    Prev
 Radix                          Address          File    File
  F1                              F5              F7      F8
```

Providing PLC Programming Logic

The PLC-5 ladder program must do the following:

- determine when an error is occurring
- load the proper data in words 7 through 12 of the message instruction
- send the message

Determining an Error Condition

Your PLC-5 ladder program must determine when an error condition has occurred. You can structure your program to do this by:

- monitoring the IMC data in block 0 (block 0 is the status block) word 5 and word 6. Any non-zero data in these words indicates an error or status condition.
- monitoring the fault bit (bit 4) in the IMC to PLC single status word.
- monitoring the detailed error code returned from the MML program through block 6.

You can also combine these methods to achieve the desired results.

Loading the Data in Words 7-12
Whenever a fault condition is detected, your PLC-5 ladder program must load the IMC fault log message into words 7 through 12 of the data table.

The error code found in word 7 must be passed back from the IMC program. (There is the variable $ERROR in the IMC program. Refer to next section for a sample MML program that passes this detailed error code number back to the PLC-5 processor.) If this code is not available, your program must place a zero (0) in word 7.

Your program should copy IMC to PLC block 0 words 2 through 6 into words 8 through 12 when a fault is detected. You can use copy or move instruction to do this. When the error code is not available in word 7, error information in block 0 is used to identify the error.

Sending the Error Message
After the error condition has been detected and the data loaded, your program should activate the message instruction to send the message.

Sample Motion Program Which Reports Errors

The following is an example of an IMC 123 program that demonstrates the techniques for passing error information. The information is passed back through the short integers which can then be passed to the PLC processor through block 6.

Important: In the following sample program, programmers comments will be indicated by the sections marked by dashed lines on the left hand side.

```
PROGRAM report
     CONST
          max_splcos = 20
     VAR
          abort_flag, ret_val : boolean
          i, err : integer

--
--           OUTPUT_ERRS
--           [This subroutine passes the errors back to the PLC program.]
--
--

ROUTINE output_errs
     VAR
          ir : integer
```

```
BEGIN
     FOR ir = 1 TO max_splocs DO
          $sploc[ir] = 0
     ENDFOR
     ir = 1
     WHILE ((dequeue(err) = true) and (ir <= max_splocs)) DO
          $sploc[ir] = err
          ir = ir + 1
     ENDWHILE
     put_plc(6)
     abort_flag = false
     enable condition [2]

END output_errs

--
--        START_OF_PROGRAM
--

BEGIN
     ouput_errs
     IF UNINIT (ABORT_FLAG) THEN
          ABORT_FLAG = FALSE
     ENDIF
     IF ABORT_FLAG THEN
          OUTPUT_ERRS
     ENDIF
```

```
--
--      CONDITIONS
--

     CONDITION [1] :
          WHEN ERROR [*] DO
               RET_VAL = ENQUEUE ($ERROR)
               SIGNAL EVENT [1]
               ENABLE CONDITION [1]
     ENDCONDITION

     CONDITION [2] :
          WHEN EVENT [1] DO
               OUTPUT_ERRS
     ENDCONDITION

     CONDITION [3] :
          WHEN ABORT DO
               ABORT_FLAG = TRUE
     ENDCONDITION
     ENABLE CONDITION [1]
     ENABLE CONDITION [2]
     ENABLE CONDITION [3]

--
--    [The actual motion program is placed here.  (This simple program
--    moves a single axis back and forth while toggling a single output
--    value to indicate direction.)]
--

     AXIS2.$SPEED = 200; AXIS2.$TERMTYPE = NOSETTLE
     WHILE ON DO
          FOUT[1] = ON
          MOVE AXIS2 BY 10
          FOUT[1] = OFF
          MOVE AXIS2 BY –10
     ENDWHILE

END report
```

Chapter 9

Other Application Examples

Chapter Objectives

This chapter provides guidelines to help you implement the Smart Directed Sequencer (SDS) instruction in various applications. In this chapter, we define guidelines for:

- accounting for scan dependencies
- prioritizing SDS messages
- adding power-loss detection and management logic
- providing flashing push buttons for operator guidance

Accounting for Scan Dependencies

Like the PLC-5 program, each SDS instruction is scanned and executed sequentially. You must account for this when interlocking SDS instructions or when monitoring or using interlocks or other signals from external logic.

If real I/O controlled from another SDS or external logic is being monitored within an SDS, you may need to use immediate input or output commands prior to the SDS to ensure it has the most accurate I/O image table data.

If situations exist where the transition of two inputs within an SDS “race” each other (for example, activating the ADVANCE COMMAND and the RETURN COMMAND at the same time), you should make sure they are exclusive and unique states by adding to or modifying the driving ladder logic.

Prioritizing SDS Messages

You can prioritize SDS messages generated by the SDS four ways. The first three methods are built into the DDMC system; the fourth method shows how you can add conditional logic for prioritizing messages. These methods are described below.

Method 1

The first or highest class of prioritization is provided by the MMS portion of the DDMC software. (Refer to the DDMC User's Manual (publication 6401–6.5.1) for details on the MMS software capabilities.) The software contains a utility that lets you assign on of 10 levels of message priority based on the following:

- PLC processor
- message type
- SDS/DFA control file

A message generated with a Level 1 priority will replace a message with a priority of Level 2 on the operator interface display.

Method 2

The second method of prioritizing messages is based on the position of an SDS instruction within a program scan. If two faults of the same priority (as configured in the MMS software) were to occur on the same program scan, then the first SDS to be scanned would provide the message displayed on the annunciator panel. The second message would remain in the fault queue until the first fault is cleared, thereby allowing the second message to be sent to the first panel.

Method 3

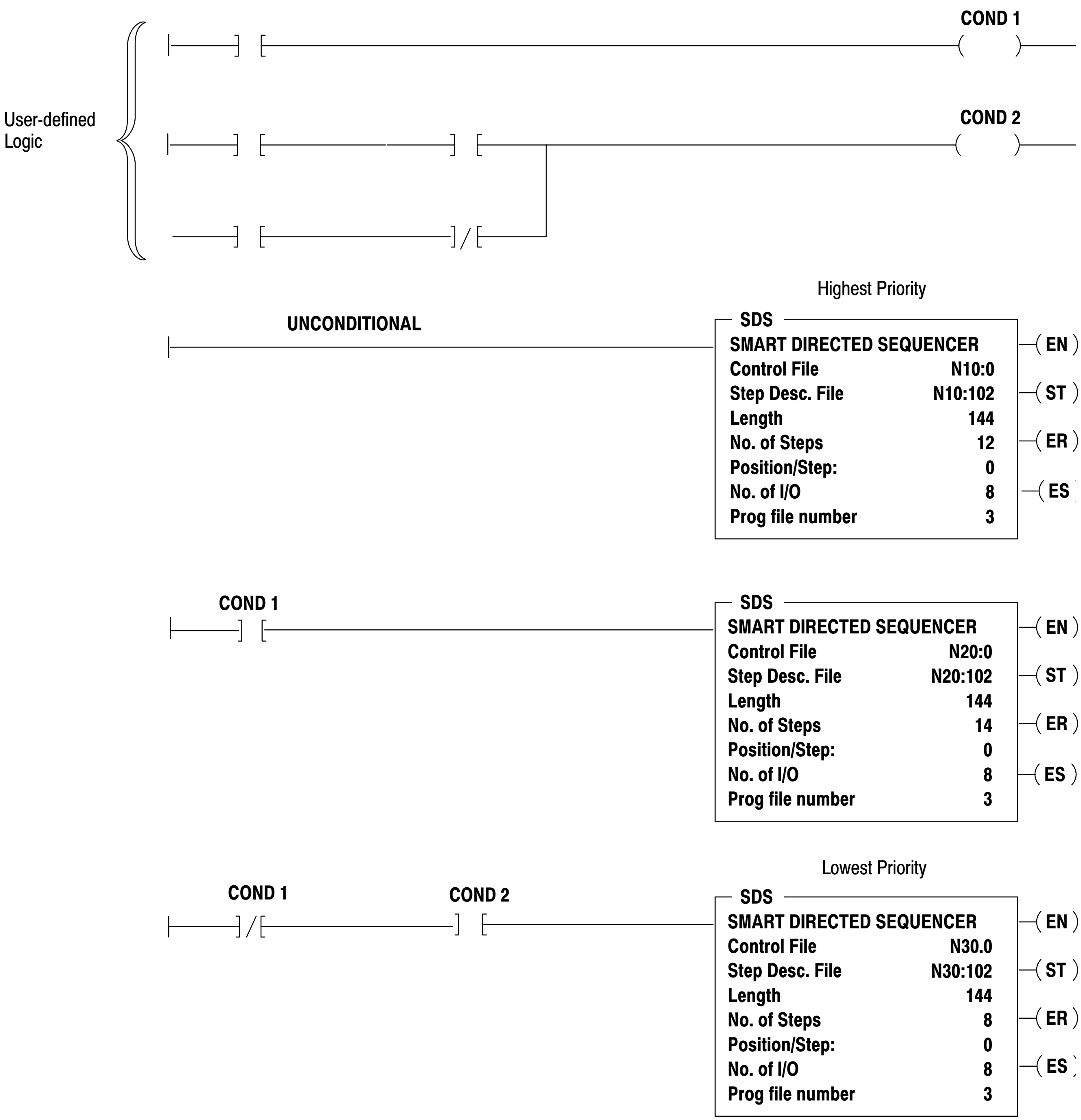
The third method of prioritization is based on the order of the inputs in the SDS instruction. For example, if 2 inputs monitored by the same SDS instruction changed state on the same program scan, the first input to appear in the SDS I/O configuration would be the one included in the fault message.

Method 4

Because SDS instructions are part of ladder logic, you can prioritize instruction by using conditional logic external to the instruction. You can also use sequential function charts to schedule when SDS instructions are activated.

Figure 9.1 shows an example of prioritizing SDS instructions by providing conditional logic.

Figure 9.1
Conditional Logic for Prioritizing SDS Instructions



Adding Power Loss Detection and Management Logic

The SDS instruction cannot differentiate between the loss of field power to an input and the transition of that same input from on to off. This loss of field power can create or trigger false error messages. Loss of field power can be caused by the following:

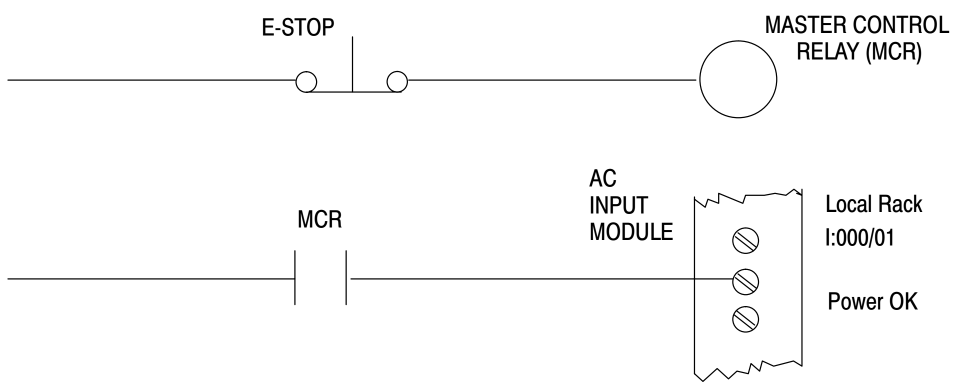
- hardwired normally-closed E-stops being activated
- power brown-outs
- remote rack or adapter faults
- breakers to remote control cabinets

To prevent false generation of messages, we recommend the following or similar approach to manage the loss of field power.

Hardwiring

Figure 9.2 shows an example of suggested hardwired ac power. An explanation follows.

Figure 9.2
Hardwired ac power



1. Reserve an input in the **local** rack to detect if power is available.

   A local rack is required since loss of power to a remote rack could result in the loss of power to the adapter and I/O modules and might otherwise go undetected. If power is lost to the local rack, the processor goes through an orderly shut down and automatically disables the SDS instructions. The instructions then reset to their “initialization” state at power-up. If power is lost to a remote rack, the SDS remains active (is not reset).

2. Bring into the local rack a contact from the master control relay that is:

   - hardwired and external to the PLC
   - has been designed to accommodate safety and other critical aspects of machine control, such as the E-stop circuit

Ladder Logic

Figure 9.3 shows an example of suggested ladder logic. Table 9.A, following the figure, explains each rung of the logic.

Figure 9.3
Ladder Logic for Power Loss Detection and Management

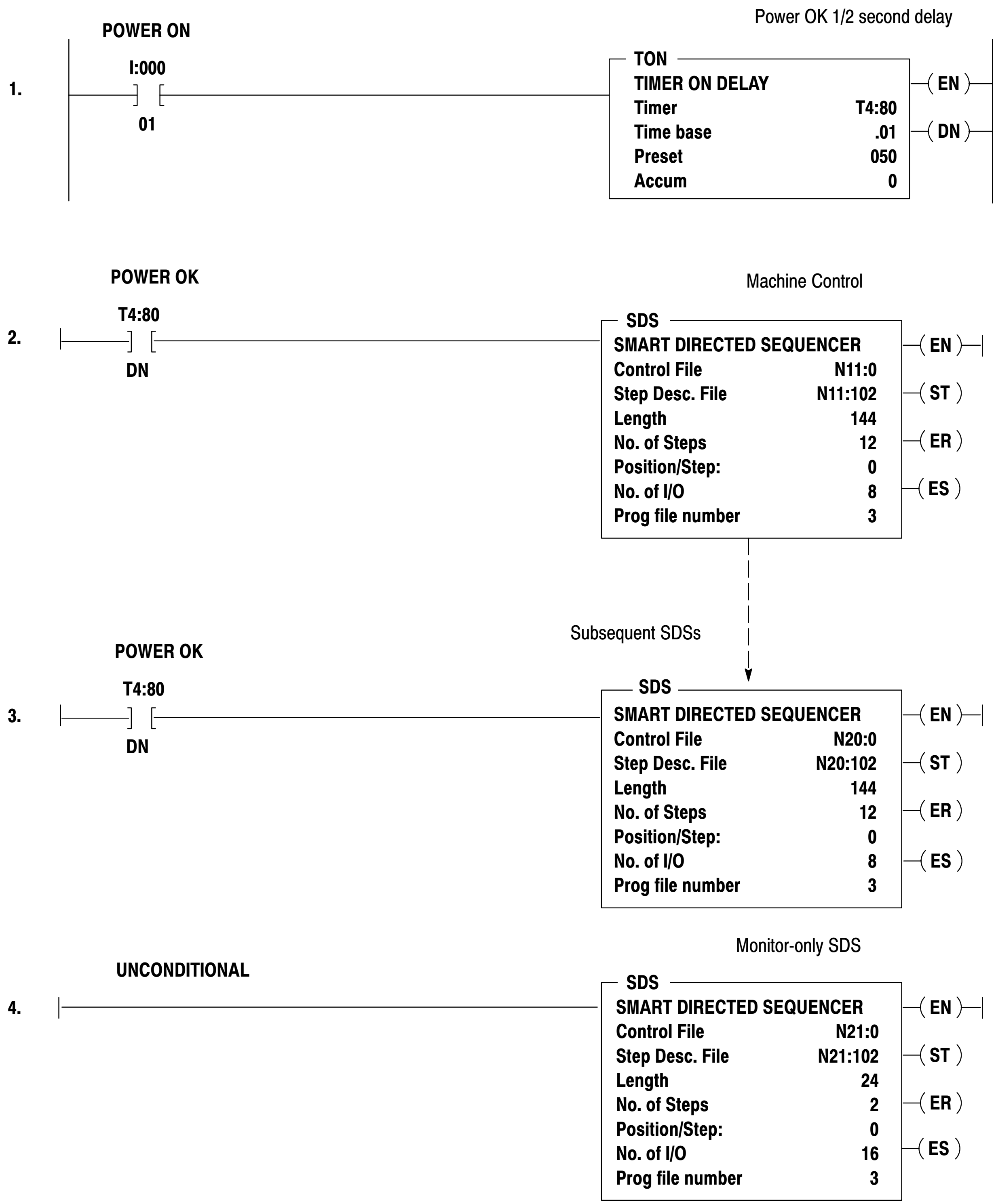


Table 9.A
Ladder Rung Explanations

Rung(s):	Explanation:
1	The timer conditions the power available signal, allows for system settling at power-up, and allows for a half-second delay.
2 and 3	The power-on done bit of the timer (Power OK) conditions the SDS instructions used for control and monitoring. Conditioning these instructions gives you the ability to disable them, preventing the instructions from detecting false errors.
4	The unconditional SDS monitors the Power OK signal and generates a message should power be lost.

Providing Flashing Push Buttons for Operator Guidance

On many machines, it is desirable to provide operators with guidance as to which operation he/she should perform next. This is especially important on machines which have a hand or manual mode of operation with multiple choices. In many cases, the operator needs to know exactly which manual command to initiate to satisfy logic/control requirements.

You can provide this guidance with lighted push buttons that flash to prompt the operator to perform a specific action.

For example, if the machine is stopped in mid-cycle, should the operator press the advance or return manual push button? A flashing push button could eliminate this decision, meaning operators could perform their jobs with less training on the machine.

Figure 9.4 shows an example of a circuit for providing flashing push buttons. Table 9.B, following the figure, explains each rung of the logic.

Figure 9.4
Ladder Logic for Flashing Lighted Push Buttons

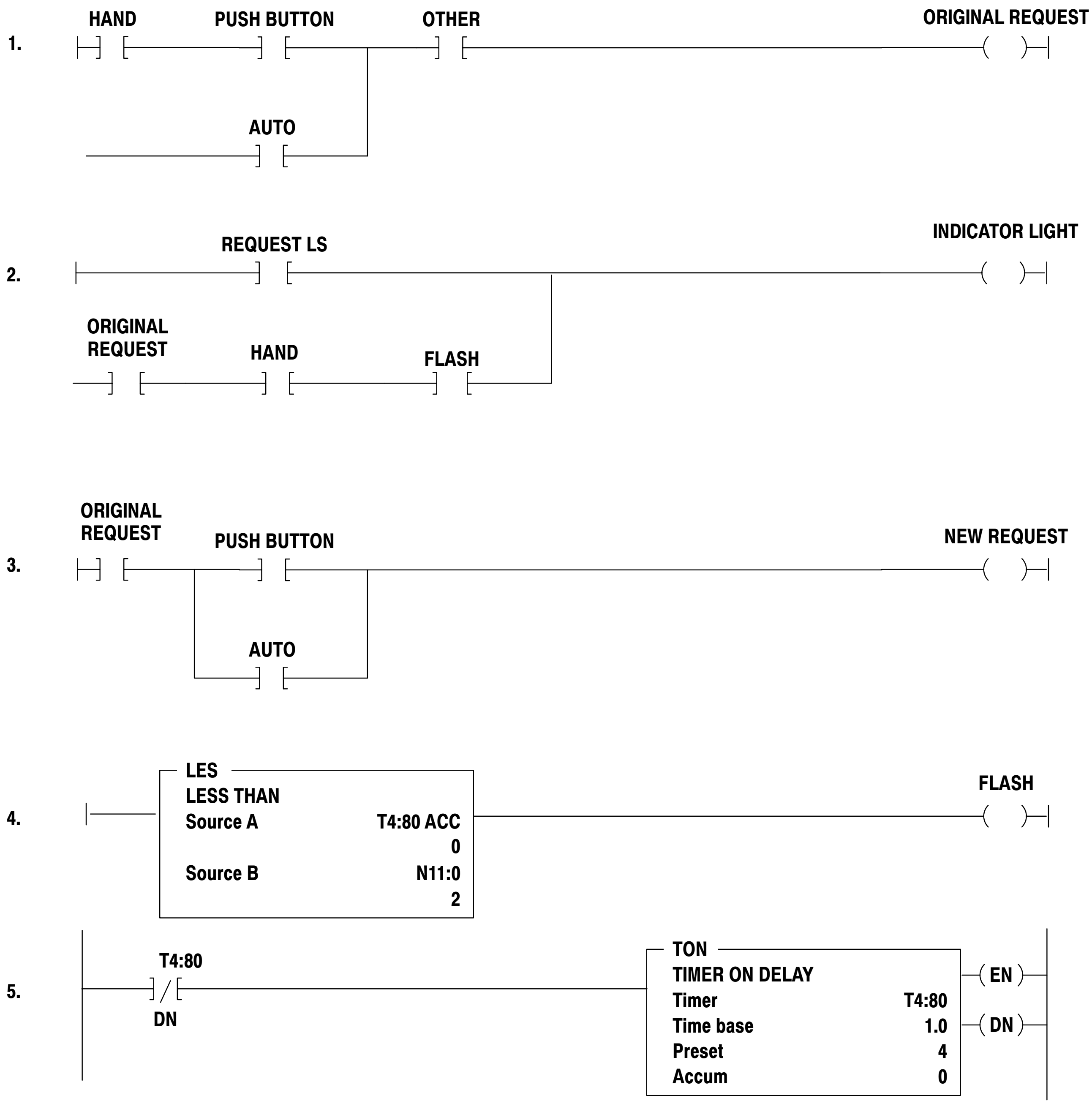


Table 9.B
Ladder Rung Explanations

Rung(s):	Explanation:
1	The original motion request is used as an input to the SDS instructions. Typical examples of this request are the advance and return command. The ladder circuit contains the elements that permit the motion.
2 (top portion)	This portion of the rung depicts the logic that is used to turn on an indicator light when a motion or command is complete. This indicator is usually driven by an input device such as a limit switch that trips when the motion or command is complete.
2 (bottom portion)	This portion of the rung shows how rung 2 can be modified to flash on and off when a motion is required in the hand mode, but is not yet complete. The limit switch that provides the feedback to turn on the indicator when a requested motion has been completed can be “ORed” with the request (e.g., hand and a flashing/pulsing contact to flash the indicator).
3	This rung is necessary to recondition the original requested signal to create a new one using a storage bit. This bit is then used to replace the original request as an input to the SDS instruction.
4 and 5	The circuit shown by these rungs is used to create a pulsing output called “flash” that toggles on and off. This output is used to drive all flashing instructions. A 4-second timer is used to turn the light off every 2 seconds. (You may choose other alternatives, such as flip flops, to achieve this flashing condition.
The logic in rungs 1 through 3 must be repeated for each request signal and indicator light pair.	

Appendix A

SDS Instruction Worksheets

Appendix Overview

This appendix provides the following worksheets:

- I/O Data Worksheet
- Step Description Worksheets (two versions)

Use the I/O Data Worksheet to help you address your I/O.

Use the Step Description Worksheets to help you program steps into the SDS instruction.

I/O Data Worksheet

RACK ADDRESS GROUPING________________ **PAGE**_____ **OF**_____

DATE ________________

PROJECT NAME ____________________ **MODULE GROUP** ________________ **DESIGNER**________________

Address	Symbolic Name	Description

Step Description Worksheet 1

STEP____________ TIMER________ sec. STEP ________ MESSAGES: ON / OFF

No	Input ID	Equation	Destination	No	Output ID	State
1			STEP	1		
2			STEP	2		
3			STEP	3		
4			STEP	4		
5			STEP	5		
6			STEP	6		
7			STEP	7		
8			STEP	8		

STEP____________ TIMER________ sec. STEP ________ MESSAGES: ON / OFF

No	Input ID	Equation	Destination	No	Output ID	State
1			STEP	1		
2			STEP	2		
3			STEP	3		
4			STEP	4		
5			STEP	5		
6			STEP	6		
7			STEP	7		
8			STEP	8		

STEP____________ TIMER________ sec. STEP ________ MESSAGES: ON / OFF

No	Input ID	Equation	Destination	No	Output ID	State
1			STEP	1		
2			STEP	2		
3			STEP	3		
4			STEP	4		
5			STEP	5		
6			STEP	6		
7			STEP	7		
8			STEP	8		

Step Description Worksheet 2

	STEP	STEP	STEP	STEP	STEP
STEP TIMER →	STEP	STEP	STEP	STEP	STEP
INPUTS/OUTPUTS ↓					
1.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
2.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
3.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
4.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
5.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
6.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
7.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
8.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					

	STEP	STEP	STEP	STEP	STEP
STEP TIMER →	STEP	STEP	STEP	STEP	STEP
INPUTS/OUTPUTS ↓					
1.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
2.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
3.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
4.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
5.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
6.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
7.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
8.	→ STEP	→ STEP	→ STEP	→ STEP	→ STEP
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					

Symbols

Numbers

A

C

D

F

G

H

I

L

M

O

ALLEN-BRADLEY
A ROCKWELL INTERNATIONAL COMPANY

As a subsidiary of Rockwell International, one of the world's largest technology companies — Allen-Bradley meets today's challenges of industrial automation with over 85 years of practical plant-floor experience. More than 11,000 employees throughout the world design, manufacture and apply a wide range of control and automation products and supporting services to help our customers continuously improve quality, productivity and time to market. These products and services not only control individual machines but integrate the manufacturing process, while providing access to vital plant floor data that can be used to support decision-making throughout the enterprise.

With offices in major cities worldwide

WORLD HEADQUARTERS
Allen-Bradley
1201 South Second Street
Milwaukee, WI 53204 USA
Tel: (1) 414 382-2000
Telex: 43 11 016
FAX: (1) 414 382-4444

EUROPE/MIDDLE EAST/AFRICA HEADQUARTERS
Allen-Bradley Europe B.V.
Amsterdamseweg 15
1422 AC Uithoorn
The Netherlands
Tel: (31) 2975/43500
Telex: (844) 18042
FAX: (31) 2975/60222

ASIA/PACIFIC HEADQUARTERS
Allen-Bradley (Hong Kong) Limited
Room 1006, Block B, Sea View Estate
28 Watson Road
Hong Kong
Tel: (852) 887-4788
Telex: (780) 64347
FAX: (852) 510-9436

CANADA HEADQUARTERS
Allen-Bradley Canada Limited
135 Dundas Street
Cambridge, Ontario N1R 5X1
Canada
Tel: (1) 519 623-1810
FAX: (1) 519 623-8930

LATIN AMERICA HEADQUARTERS
Allen-Bradley
1201 South Second Street
Milwaukee, WI 53204 USA
Tel: (1) 414 382-2000
Telex: 43 11 016
FAX: (1) 414 382-2400

Publication 6401-6.4.1 – November 1992 PN 95578101
Supersedes 6401-6.4.1 – October 1991