

# RLL<sup>PLUS</sup>

## Programming Basics

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**Handheld Programmer D3-HP & D3-HPP have been retired as of 03/2021 & 01/2018 respectively. Please consider Productivity, BRX, or CLICK series PLC systems as upgrades.**

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## Introduction

If you've ever been around some *really* accomplished RLL programmers you have probably been amazed at how easily they seem to be able to create programs of incredible complexity. Well, not everyone has years of experience in programming PLCs. Because of this the DL330P CPU has RLL<sup>PLUS</sup> instructions that make it considerably easier to design and create programming solutions. These instructions are especially useful to those of you who aren't that familiar with the interlocking concepts commonly used in RLL programs.

You can still use the normal instructions you've already seen, plus you only have to become familiar with a few new instructions that help you organize your program into manageable pieces.

This programming method is similar to Sequential Function Chart programming and literally allows you to design a flowchart of the program operation sequence and load it into the CPU! You can expect to see several benefits by using this method.

- Considerably reduced program design time. We've seen many, many cases where these few instructions have cut program design time by well over 50%.
- Shorter, more simple programs. Later in this chapter we'll show you why your programs sometimes end up being a lot larger than you first anticipated. The RLL<sup>PLUS</sup> instructions can help make your programs simple for everyone to understand.
- Easier program troubleshooting. How many times have you tried to troubleshoot or modify a program that was written by someone else? If you've done this very often you know it's not an easy task. This chapter will show you a few instructions that will also help with this problem as well.

The following paragraphs discuss several RLL<sup>PLUS</sup> programming concepts. We'll use a simple example to show you how to use the various types of instructions. Also, we'll show you the equivalent program without RLL<sup>PLUS</sup> instructions to give you an idea of the differences between the two approaches.



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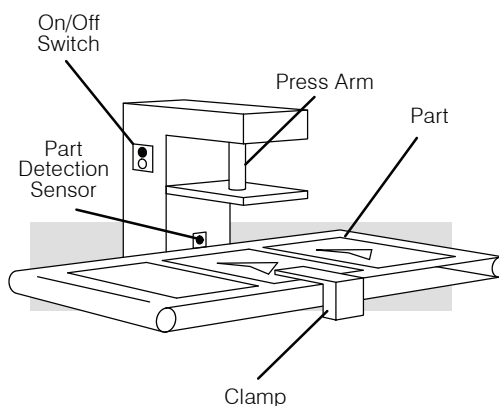
**NOTE:** The DL330P has several instructions that do not operate quite the same as the equivalent instructions in the DL330 or DL340. If you want to take advantage of the benefits associated with the RLL<sup>PLUS</sup> instructions, make sure you also take time to review Chapter 12. This chapter discusses the instructions that are unique or different with the DL330P CPU.

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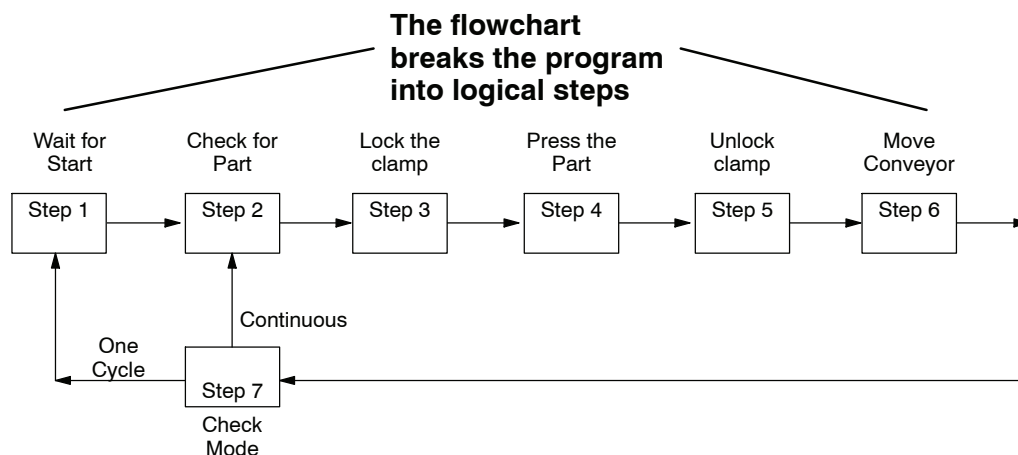
# An Example Machine

**Machine Operation** Most any application can be described as a sequence of events. The PLC program merely makes sure the events are completed in a specific order. Not only does the program control normal operation, but it also has to allow for machine failures and emergency conditions. Consider a simple example.

1. The operator presses the start switch.
2. The machine checks for a part. If the part is present, the process continues. If not, the conveyor moves until a part is present.
3. The part is locked in place with a clamp.
4. The press stamps the part.
5. The clamp is unlocked and the finished piece is moved out of the press.
6. The process stops if the machine is in one-cycle mode, or the process continues if automatic mode is selected.



**Machine Flowchart** The following diagram provides a flowchart of this operations sequence.



Inputs		Outputs	
Start Switch	000	Clamp	020
Part Present	001	Press	021
Part Locked	002	Conveyor	022
Part Unlocked	003		
Lower Limit	004		
Upper Limit	005		
Conveyor Indexed	006		
One-Cycle Switch	007		

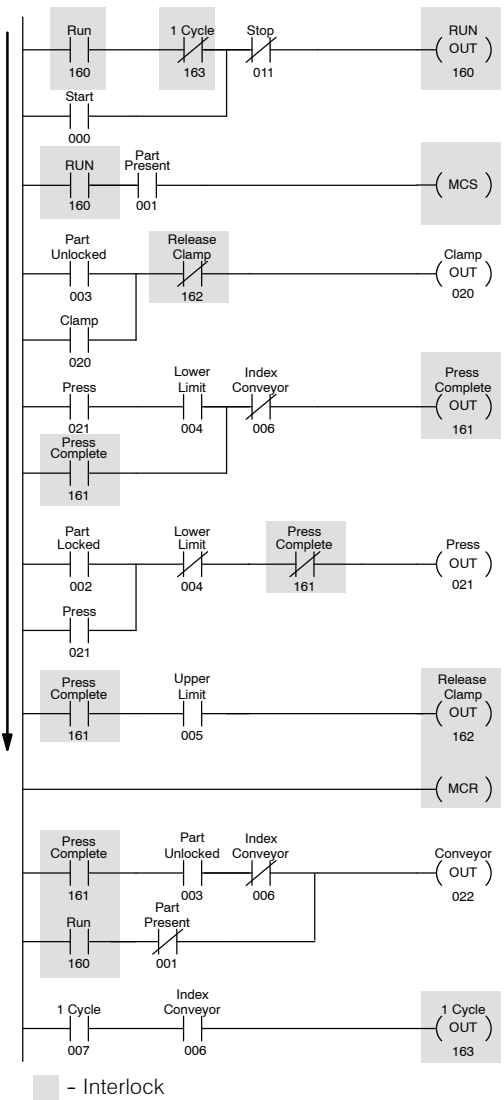
## An RLL Solution

Why is RLL so popular? Simple. Before the PLC arrived control problems were generally solved with hardwired relays and switches. About 30 years ago people started experimenting with a way to make quick and easy changes without changing the actual panel wiring. Thus, the PLC was born. Since the people developing and using this new technology were familiar with the relay and switch solution, it made sense to have this new technology emulate something that was familiar to them. That's why RLL programs emulate a relay panel solution.

When you supply power to a relay panel the combination of contact and coil status determines what actions take place. Since the RLL program emulates the relay panel solution, the entire program is scanned left-to-right, top-to-bottom. The program executes the operations sequence when a certain combination of contacts are activated. This process is known as interlocking.

Since many PLCs do not have instructions to help manage the operations sequence, the programmer has to make sure the program carries out the correct sequence by adding the required interlocks. One great thing about the RLL solution is the individual rungs are easy to understand. By examining the contacts you can easily determine if the output will be on or off.

**Executes all rungs Left to Right, Top to bottom**



Many accomplished RLL programmers use things such as Master Control Relays and Subroutines to reduce the amount of interlocking required. However, these instructions can sometimes make the program more difficult to understand. There are several things you should notice about our simple press program.

- Most all rungs use some amount of interlocking.
- The number of interlocks is usually proportional to the number of tasks in the operations sequence.
- Most of the instructions are devoted to processing the interlocks. (Plus, since the program is larger, it takes more time to process.)
- It usually requires several attempts until a program is designed that is not susceptible to inadvertent activation and deactivation.
- The program can be difficult to debug if you do not have a considerable amount of RLL programming experience.

## An RLL<sup>PLUS</sup> Solution

The RLL<sup>PLUS</sup> instructions keep the simplicity of the contacts and coils while removing some of the problems associated with the enormous amount of interlocks. There are several RLL<sup>PLUS</sup> instructions, but the most often used are the Initial Stage (ISG), Stage (SG), and Jump (JMP) instructions. Here's the example press program created using RLL<sup>PLUS</sup> instructions. There are two things you should notice.

- Control Relay interlocks are not required.
- The program directly follows the flowchart of the press operation.

How can this happen? Simple. The interlocks were added to the RLL program to keep the outputs from coming on at the improper time. This is because every rung of the RLL program was examined on every scan.

The Stage instructions (and the logic between the Stage instruction and the next stage instruction) are not necessarily examined on every scan. Only stages that are on are examined.

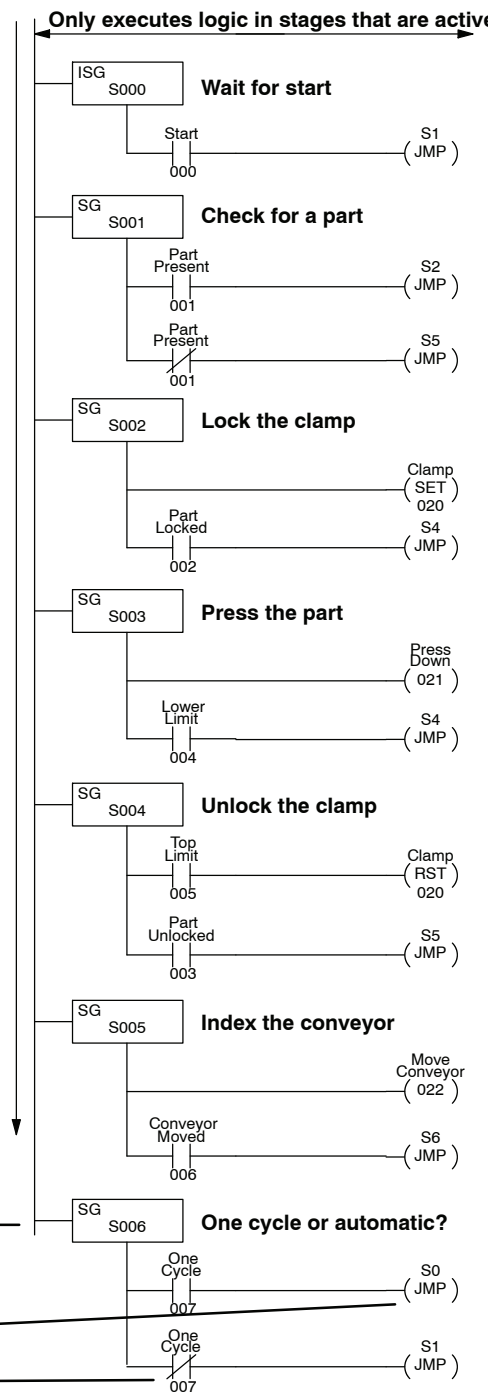
Each stage instruction has a status bit that is on when the stage is active, and off when the stage is inactive. On every scan the CPU examines which stage status bits are on and only examines the logic in those stages. If a stage is inactive, the CPU skips the logic between that stage and the next active stage.

The following pages will talk about several different aspects of the CPU execution for the Stage Instructions. It will help to understand the pieces of an individual stage.

### Stage Nomenclature

As we discuss the examples it will be necessary for you to understand the various pieces that can make up a program stage.

- Stages — a instruction that denotes a piece of the program
- Actions— an event in the program, such as an output, jump, or some other instruction.
- Transitions — the event that causes the program to move to the next stage.



## Stage Instruction Execution

### Stage Instruction Numbering

Stages are numbered in octal, so you can't have any stages with the numbers 8 or 9 in them. Notice the stages skipped from 7 to 10 since the numbers 8 and 9 are not used. There are 128 (decimal) stages available in the DL330P CPU, numbered 0 through 177.

Since each stage has a unique status bit, you cannot have stages with the same address number. For example, since the example program already has a Stage1, we wouldn't want to use that number again.

There's another advantage to having a status bit for each stage. This allows you to skip stage numbers as necessary. This is a good practice to follow because it makes it easier to insert stages later without affecting the appearance of the program flow.

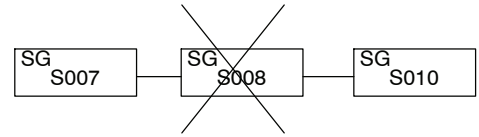
The stage numbers do not necessarily have to be numbered sequentially, but it can be *extremely* helpful to use sequential numbers if you are working with large programs.

Also, the stages do not have to be entered sequentially with the programming device. For example, you could have Stage 100 be the first entry in the program. This is not a good programming practice, but since the CPU looks at the active status bits to determine which stages to execute, it doesn't care where the stages are physically located in the program.

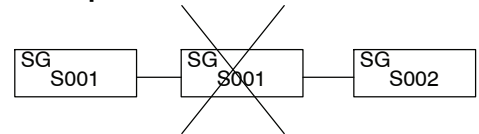
**NOTE:** Remember, machines do break. We recommend you use numbering that matches the machine flowchart. Also, we recommend you enter the program in the same order whenever possible. This will make troubleshooting much easier.

The section on Designing an RLL<sup>PLUS</sup> Program at the end of this chapter provides guidelines for assigning numbers to the stage instructions.

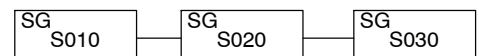
### Octal Numbering



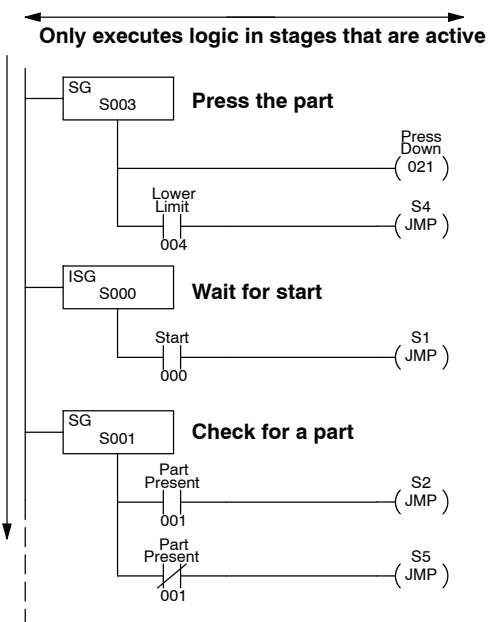
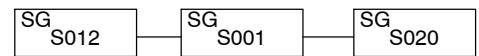
### No Duplicate Numbers



### Skip Numbers if Necessary



### Non-sequential Numbering



### A Few Simple Rules for Execution

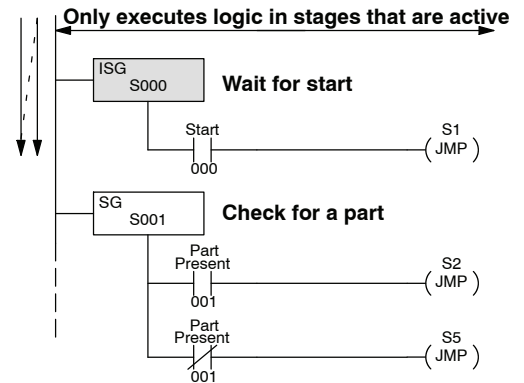
Since the CPU will only examine the logic in those stages that are active, it is important you understand how stages can be turned on and off. There are a few simple rules that dictate how this works. This may seem like quite a few things to remember, but it's really pretty simple. We'll show examples in the following pages that show how each of these rules apply to the program execution.

1. Only active stages are executed. If a stage is inactive, the CPU skips the logic between that stage and the next active stage.
2. You can turn stages on by the following methods.
  - 2.a Initial Stages are automatically turned on when the CPU transitions from Program Mode to Run Mode.
  - 2.b A stage can be turned on when the program "jumps" from stage to stage with the Jump (JMP) instruction.
  - 2.c You can use the SET instruction to set a stage status bit just like you would SET an output.
  - 2.d A stage can be turned on when the program has power flow between two stages that are tied together by a single transition element.
3. You can turn stages off by the following methods.
  - 3.a An active stage is automatically turned off if the program jumps from the active stage to another stage.
  - 3.b You can use the Reset (RST) instruction to turn off a stage just like you use Reset to turn off an output point.
  - 3.c The current stage is automatically turned off if the program has power flow between the current stage and the next stage.

## Activating Stages

**Using Initial Stages** Any initial stages (ISG instructions) are automatically turned on when the CPU goes from Program Mode to Run Mode. For example, when the CPU executing our example program enters Run Mode, the Initial Stage (ISG 000) will be turned on automatically. The other stages are off, so the CPU only scans the portion of the program associated with ISG 000.

Since there's only one rung in Stage 0, the CPU continually monitors the start switch. Nothing else will happen until the start switch is pressed.



Although it is unusual, there may be times when you need more than one initial stage. There is nothing at all wrong with this. If your application has a need for more than one starting point, you can use more than one initial stage. For example, if you had three initial stages, then those three stages would all be active when the CPU entered the Run Mode.



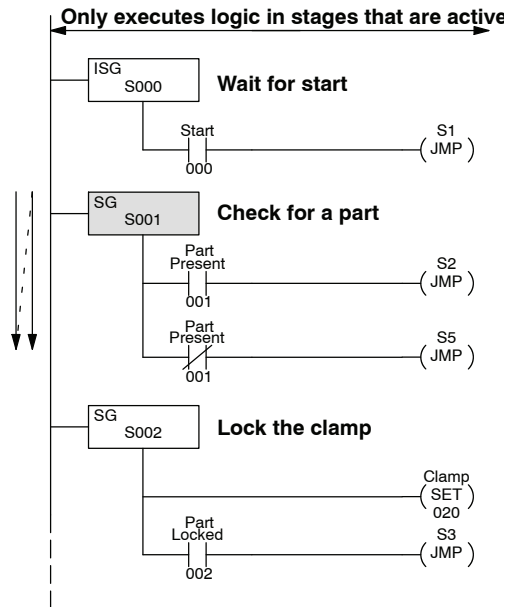
### Using Jump Instructions

When the operator presses the start switch input 000 comes on. When 000 comes on the CPU executes the Jump instruction and “jumps” to Stage 1.

Now the CPU only scans Stage 1. Stage 0 is no longer scanned after the program jumped to stage 1. This means the Jump instruction did two things.

- It activated the destination stage. In this case, it activated stage 1.
- It deactivated the stage it came from, which was stage 0 in this case.

So, you can *jump to* a stage to turn it on, and when you *jump from* a stage it turns off.

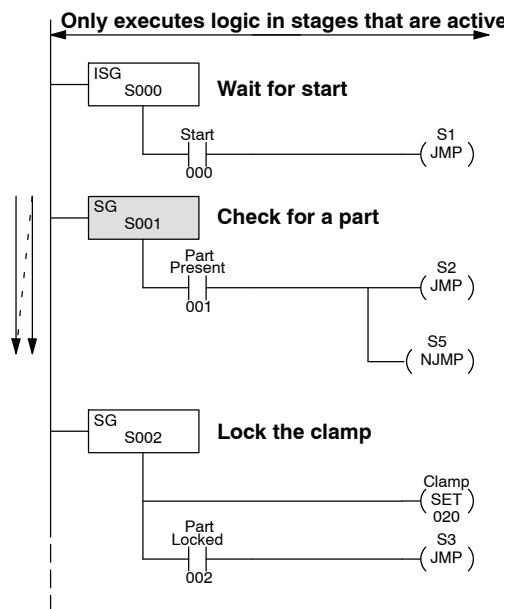


This example only shows an action that initiates a jump to one destination. You can use several jumps ORed together if necessary. Examples of this will be shown later.

There’s also another type of Jump instruction called a Not Jump. This instruction only works if the input conditions are *not true*, whereas the regular JMP instruction only works if the input conditions are *true*.

In the previous example we examined a single contact to determine which part of the program to jump to next. If the part is present (001 closed), the program jumps to Stage 2. If a part is not present (001 open), the program jumped to Stage 5. We could have used a single contact and the NJMP instruction.

The program example to the right shows how the NJMP instruction would be used in this situation. Notice there is one less instruction required in this example compared to the previous one.



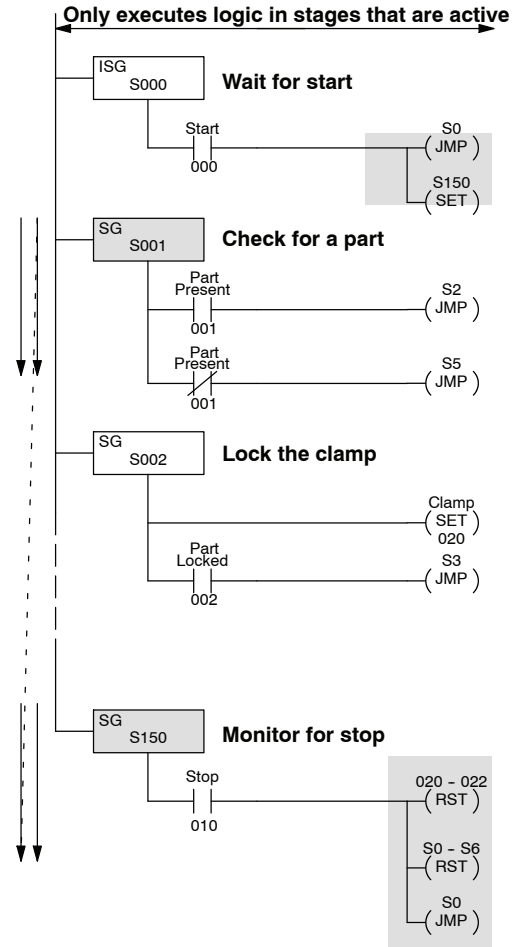
**NOTE:** We *strongly* recommend you *avoid* using the NJMP instruction. This is because program debugging can become more difficult, especially for those who are not so familiar with structured programming concepts.

## Using Set Instructions with Stages

When you examine the instruction set more carefully you'll notice the DL330P CPU offers a Set (SET) instruction that works similarly to a latching operation. For example, you could use a SET instruction to latch an output point. The output point can then be unlatched with the Reset (RST) instruction.

You can also use a SET instruction to turn on a stage. To show how this works, we're going to add a stage to the program. You may have noticed the original flowchart did not contain a stop switch. Well, we don't want to make these little widgets forever, so we're adding Stage 150, which monitors for a stop switch. (This is also a good example of how you can skip stage numbers.)

Notice we added a SET instruction in the first stage. Now when the start switch is pressed, two stages will be activated. The CPU examines Stage 1, which monitors for a part, and it also examines Stage 150, which monitors the stop switch.



We did not absolutely have to use a SET instruction in the example. We could have used a Jump, since you can jump to more than one stage. We just used a SET to show how it works.

If you examine Stage 150, you'll notice we do three things when the stop switch is pressed.

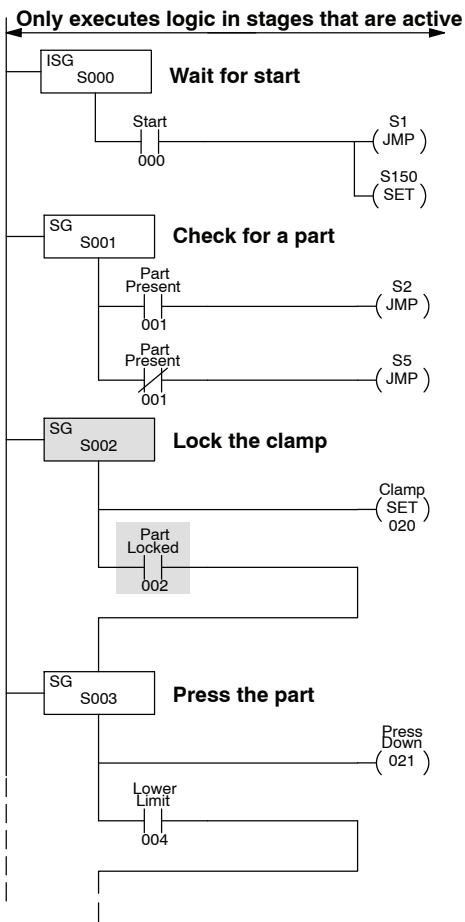
- The RST 020 - 022 instruction makes sure all the outputs are turned off. (We'll discuss this in more detail in the next section.)
- The RST S0-S6 instruction resets (turns off) stages 0 through 6. We reset the entire range so that we guarantee we can stop the press no matter which stage is currently executing. Notice we reset stages that were not necessarily turned on with the SET instruction. The Reset (RST) instruction can be used to turn off stages, no matter how they were turned on. This is especially handy in larger, more complex programs.
- The program jumps back to Stage 0 and starts over again. Note, just because Stage 0 is an initial stage does not mean it can *only* be active at a transition to Run Mode. You can return to an Initial Stage at any time. It's just the CPU *automatically* activates Initial Stages at the Run Mode transition.

**Power Flow Transitions**

You do not always have to use a Jump instruction to move from stage to stage. If you only move to one stage, instead of multiple stages, you can use what it is called a power flow transition. For example, we used Jump instructions in our sample program. For those stages that did not have multiple transition possibilities, we could have just used power flow transitions.

Look at Stage 2. Notice how the transition contact, 002 now is directly connected to the next stage, Stage 3. You can only do this if you are moving from one stage to one other stage.

If you examine Stage 1, you'll notice we have to use the Jump instructions because the program can transition to more than one stage.



**NOTE:** We suggest you use Jump Instructions instead of power flow transitions. This is because we've seen many cases where we had to come back and add things to the program. If you used Jumps from the beginning, you only have to add another Jump instruction. If you used power flow transitions, the program edits can take a little longer.

## Using Outputs in Stages

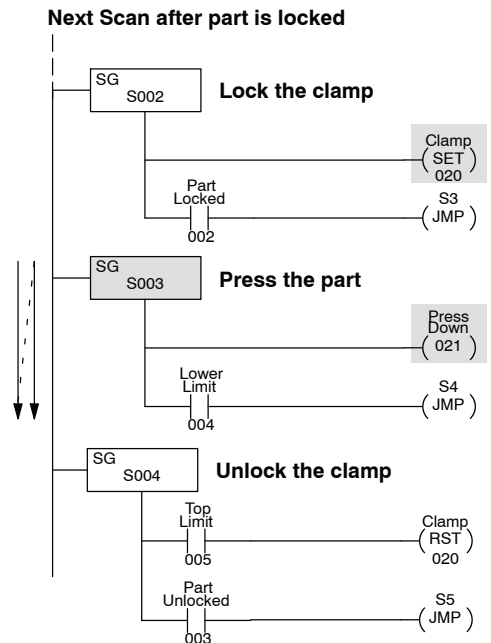
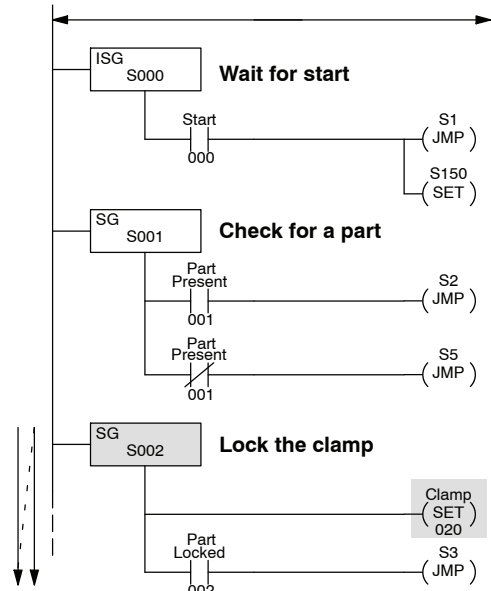
### Setting Outputs with the SET Instruction

Since the CPU only examines the logic in stages that are on, you have a lot more flexibility in how you use outputs with the RLL<sup>PLUS</sup> instructions. Also, you don't have to worry about adding several permissive contacts to keep the output from coming on at an inappropriate time. (If the stage is not on, the CPU doesn't even scan the stage, so the output can't possibly be turned on by the logic in that stage.)

If you examine Stage 2, you'll notice we use a SET instruction to clamp the part in place. Why a set? Simple. If we used a regular output the clamp will be deactivated when the program transitions to Stage 3. Remember, when you leave a stage the CPU no longer scans that stage until it is turned on again. So if we had used a regular OUT instruction, the CPU would have automatically turned off the output, which would have unclamped the part.

The first example shows the program execution in Stage 2. The second example shows what happens on the next scan after the part is locked. Notice the clamp output is still on even though the CPU is not scanning this portion of the program. This is why we use the SET instruction in this case. We want the clamp to stay on while the press completes the cycle.

The clamp will stay on until the program enters Stage 4. Stage 4 unlocks the part by resetting output 020 when the press returns to the top limit.



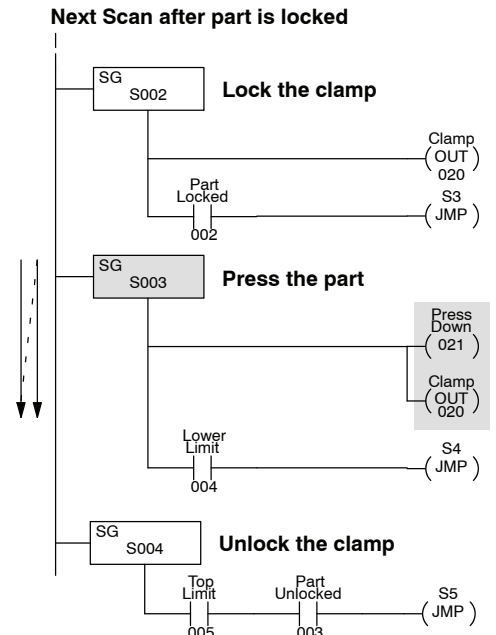
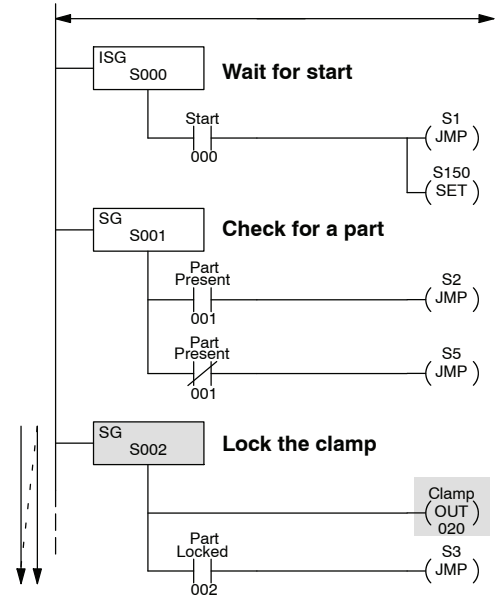
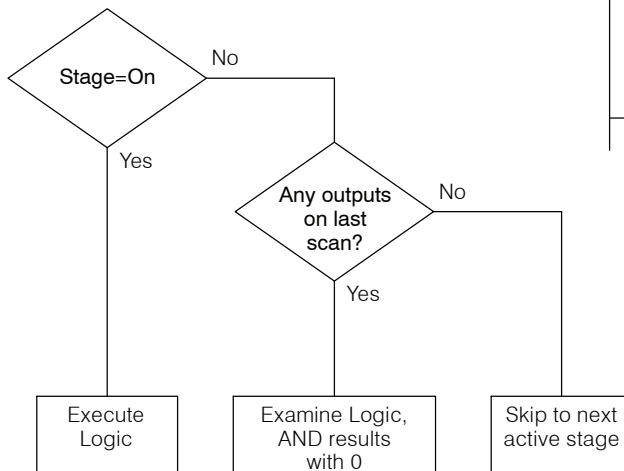
**Using the OUT Instruction**

One other benefit with RLL<sup>PLUS</sup> is the ability to use the same output in multiple places. Instead of using the SET instruction in Stage 2, we could have just put the clamp output, 020, in all the stages where we wanted the part to remain clamped.

If you examine Stage 2 you'll notice output 020 is on because the stage is active. The next example shows what happens after the part is locked in place. The program moves to Stage 3 from Stage 2. Notice output 020 is now off in Stage 2. However, since we included the same clamp output in Stage 3, the part remains clamped in place.

The clamp will automatically turn off when the program enters Stage 4. Notice Stage 4 does not have to have any kind of Reset instruction, since the output is automatically turned off when the program exits Stage 3.

The concept of automatically turning off the outputs sometimes confuses many people. However, the CPU just uses a very simple algorithm to determine if the output should be turned off. The following diagram shows how this algorithm works.



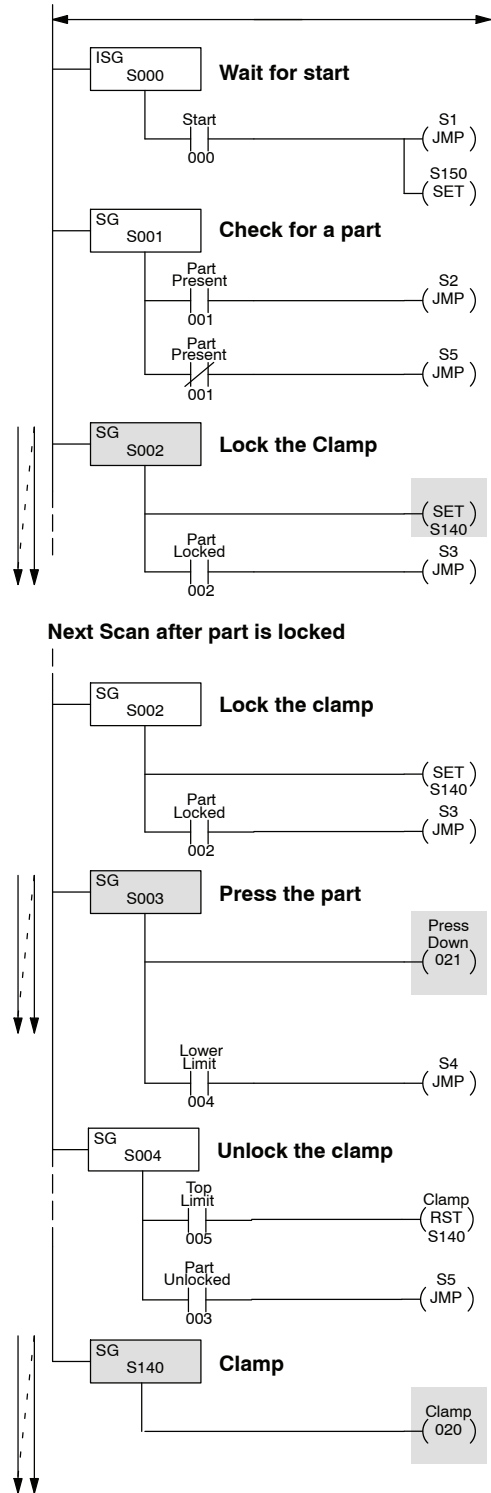
## Latching Outputs with Stages

There's one more way to control outputs with the Stage instructions. You may recall once a stage is turned on, you can only turn it off by resetting it, or by having a transition from it, either by a Jump or a power flow.

What happens if you have a stage that does not have any kind of transition? What if it doesn't have a Jump instruction or any other kind of transition contact leading to another stage? Simple. The stage will stay on until it is reset by some other part of the program that uses a Reset instruction.

This makes it easy to use a stage without a transition to latch an output. For example, if you examine Stage 2 you'll notice we've now changed this part of the program again. Now this stage sets Stage 140, which will be used to control the clamp.

Notice Stage 140 does not have any type of transition. The only way to turn off the clamp is to Reset Stage 140. This instruction has now been included in Stage 4. So, after the program transitions to Stage 4, the Reset instruction will turn off Stage 140.



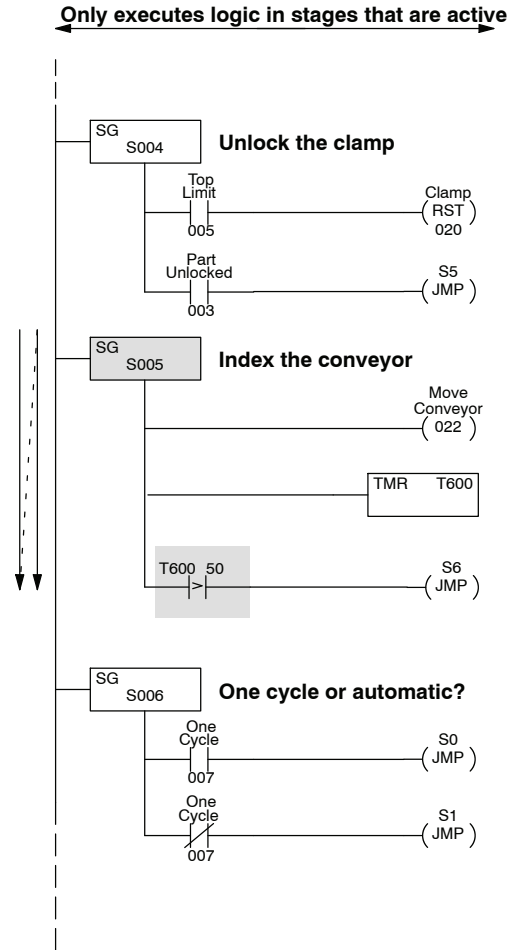
# Using Timers and Counters in Stages

## Time Based Transitions

Up to this point we've been using certain events that triggered the transition from stage to stage. There will probably be many cases where the transition should be related to a timer value. For example, if you know the speed of the conveyor you could use a timer to control the conveyor movement.

If we used this approach we would modify Stage 5 as shown. Notice the timer does not have a preset value. The timer begins incrementing as soon as it becomes active. Since the timer does not have a preset value, you do not have a timer contact, so you have to use a comparative instruction.

In the example shown, the conveyor will be turned on for 5 seconds and then the program will jump to the next stage.



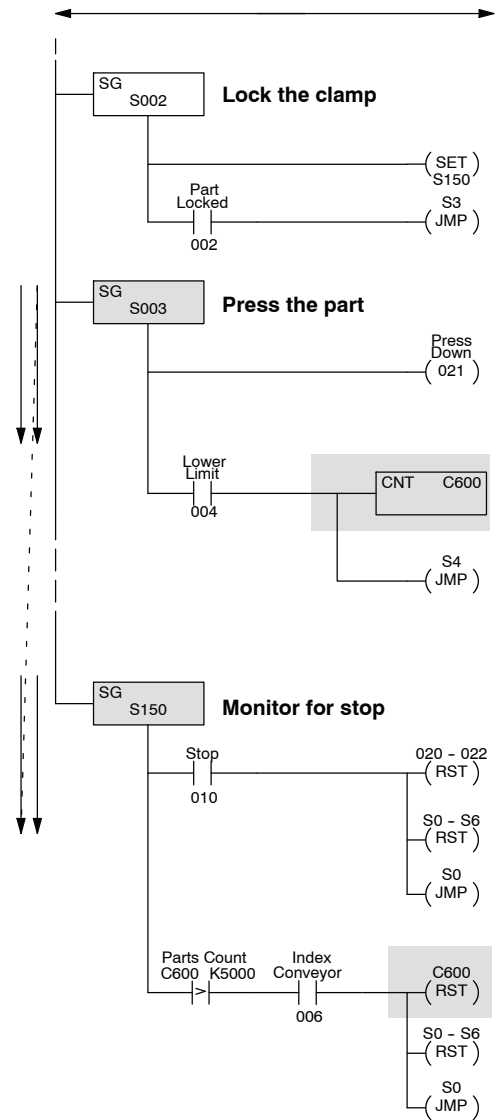
### Using Counters

There will also be times when you need to count things that happen throughout the process. For example, you may want to know the number of parts produced during any given shift, or you may know the presses generally require some type of maintenance after a certain number of cycles.

If we wanted to count the number of widgets made on our simple press, we could just add a counter to Stage 4 to monitor how many times the press is used. We're also going to use the counter as an automatic shutdown when the press has made 5000 parts so we've added a new rung in Stage 150 to perform the shutdown operation.

Notice the counter does not have a reset leg. This is true only when you use a counter with the DL330P. (The other CPUs have counters with reset legs.) Even though this counter does not have a reset leg, it can be reset with a Reset instruction. This works just like an output reset, so you could place this reset wherever it is appropriate. We've placed it in Stage 150 for this example.

When the parts count reaches 5000, the program will finish the current cycle, reset the part counter, and jump to Stage 0 to wait for another start cycle. You may notice we added an additional input, 006. This is what allows the program to finish the current cycle. (You may recall 006 only came on after the part was unlocked and the conveyor was indexed.)





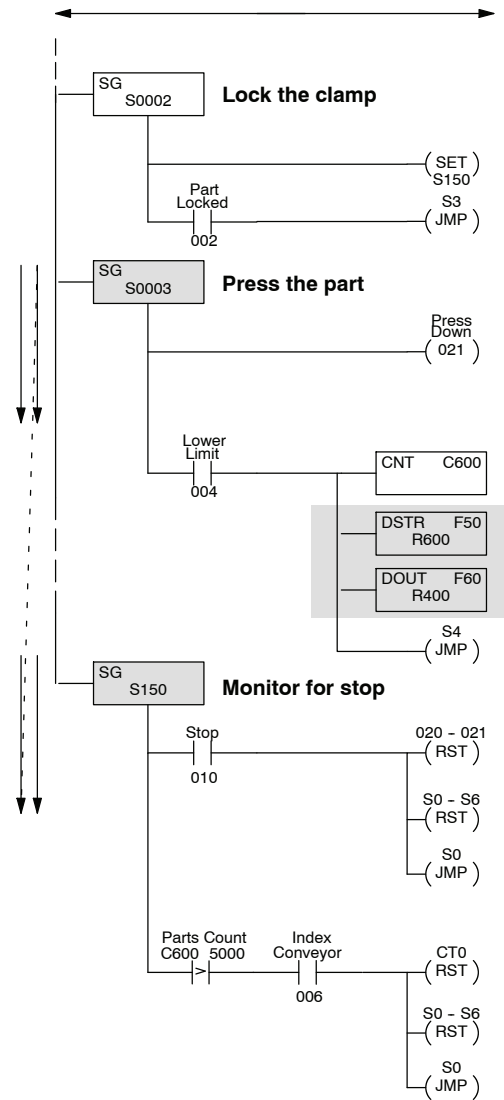
## Using Data Instructions in Stages

Even though there are a few differences in the way some of the instructions operate between the various CPUs, there are many of the normal instructions that can be used inside an individual stage. For example, you may need to load data into the accumulator to perform some type of math, or, you may need to store values into register locations.

If you examine Stage 3, you'll notice we've added a couple of instructions. These instructions store the current parts count in a register.

Now the CPU will take the current parts count, stored in R600, and load it into the accumulator with the DSTR instruction. Then this 4-digit BCD count will be moved to R400 with the DOUT instruction.

This is just one example of how you can use the various types of data instructions. There are many other possibilities. Just remember, if the stage is active, the instructions can be executed. If the stage isn't active, the instructions will not even be examined.



# Using Comparative Contacts in Stages

You may recall you had to use a comparative instruction with the timers and counters. The DL330P provides several comparative contacts that are very useful. You can use these contacts to examine the relationship between a counter or timer value and a constant or register value.

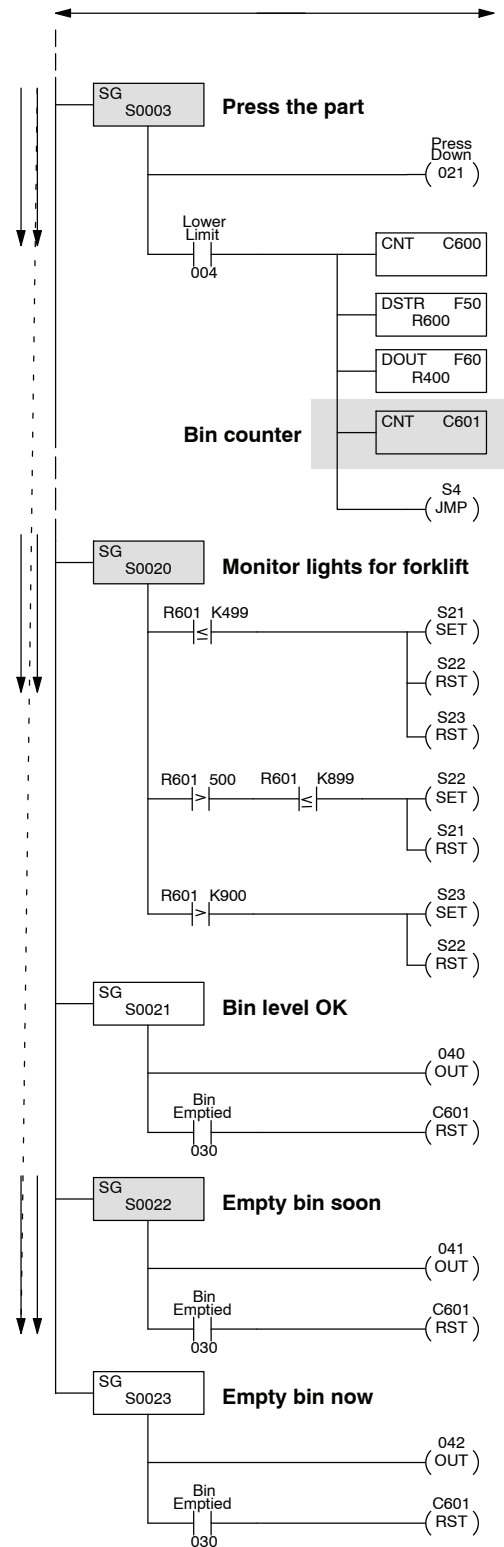
For example, let's assume the pressed widgets move off the conveyor into a holding bin. The bin can only hold 1000 widgets, so we'll add another counter, C601, to note how many widgets are in the bin. Also, we want to use different colored lights mounted on top of the press to alert a forklift driver the bin needs to be carried to the next operation. We'll use the following indicators.

Indicator	Meaning	Address	Stage
Green	OK	040	21
Yellow	Soon	041	22
Red	Urgent	042	23
Reset	Emptied	030	

Notice we've added a few more stages to monitor this condition. For this example, assume the press has made 750 widgets. This means the Yellow indicator (Stage 22) should be active.

We also need a way to reset the bin counter whenever the forklift driver empties the bin. If you examine Stage 21 through Stage 23, you'll notice we reset the bin counter whenever the bin reset (030) is active.

This example doesn't show it, but you would also have to make some changes to other parts of the program. For example, you'd need to modify the Stop Stage to shut off these stages when the machine was stopped.



# Parallel Branching Concepts

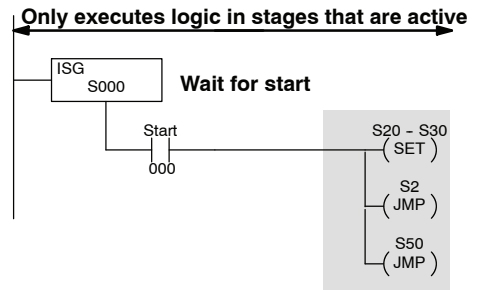
## Branching Methods

As you examined some of the previous examples you saw we could have more than one stage being processed on any given scan. The CPU scanned the first active stage and then moved on to the next active stage, skipping any inactive stages in between. For some complex applications, you can easily have as many parallel paths as necessary. This is often called branching or divergence.

There are a couple of approaches you can take when you want to turn on more than one stage. The diagrams shown don't necessarily apply to our press example, but instead show the various approaches.

In this example, you use one transition contact to activate several stages.

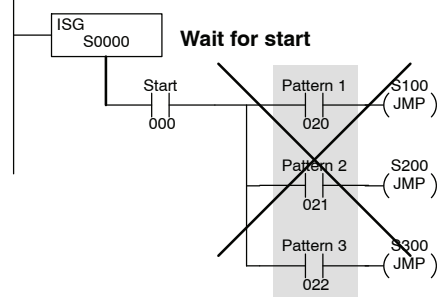
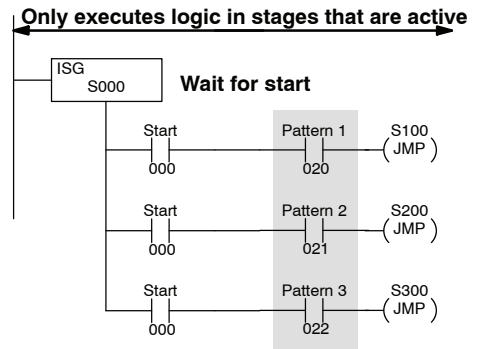
- The SET instruction sets a range of stages. These stages would remain on until they were reset, or, until any transition instructions contained within the stages were executed.
- There are two Jump instructions, both activating different stages.



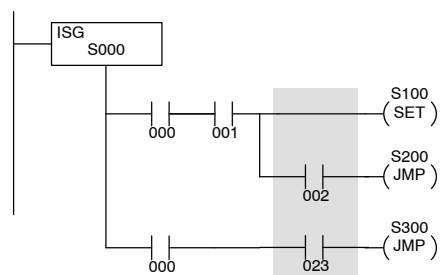
In this example, notice the stage that gets activated depends on an extra condition. For example, if the machine was capable of producing three different patterns, there may be a section of program for each pattern.

There are other types of contacts that can be used. For example, you may recall we used Comparative contacts in some earlier examples.

Notice we had to repeat the start switch in a separate rung each time. At first glance you would think you could simply have one Start switch contact and OR the remaining switches. The DL305 CPUs do support midline outputs (which is what this is called), but only in an AND situation.



You can also use midline outputs to control branching conditions. Here's an example of branching instructions that follow the guidelines for midline outputs. (This example is not for the press program, but merely shows how the midline outputs would appear.)

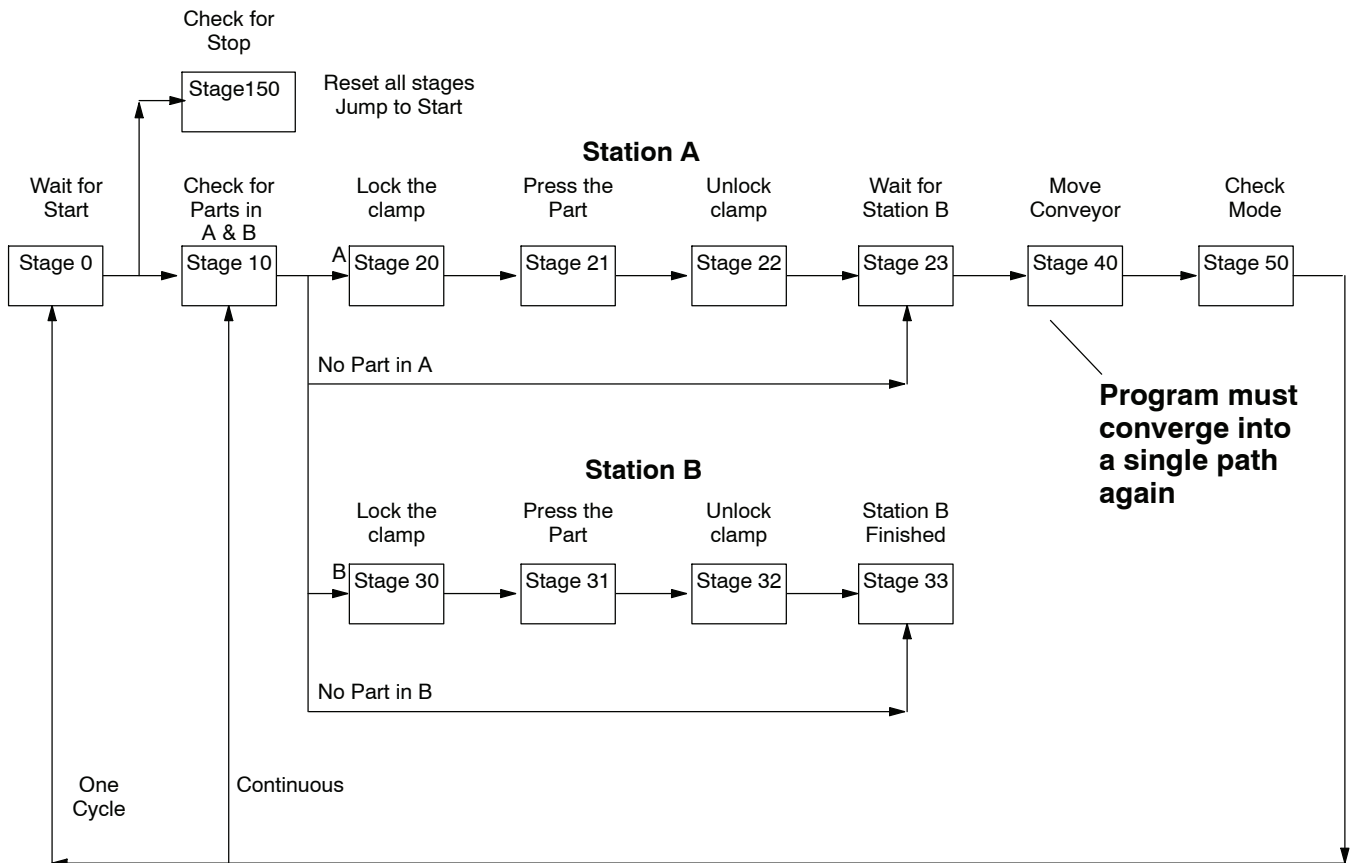


**Joining Parallel  
Branches**

There are many times you have to bring parallel branches back together at some point in the program. You may recall the stages have status bits associated with them. You can use this status bit as a contact to easily converge the parallel paths.

To illustrate this method, we're going to use a simple press with two stations. Now a widget must get pressed at each station before it is a finished product. Since there are two stations, we must make sure both operations are complete before we move the conveyor.

Here's a flowchart that describes the two-station press. Please note we've changed some of the stage numbers, input numbers, and output numbers, so they won't necessarily match the previous examples.



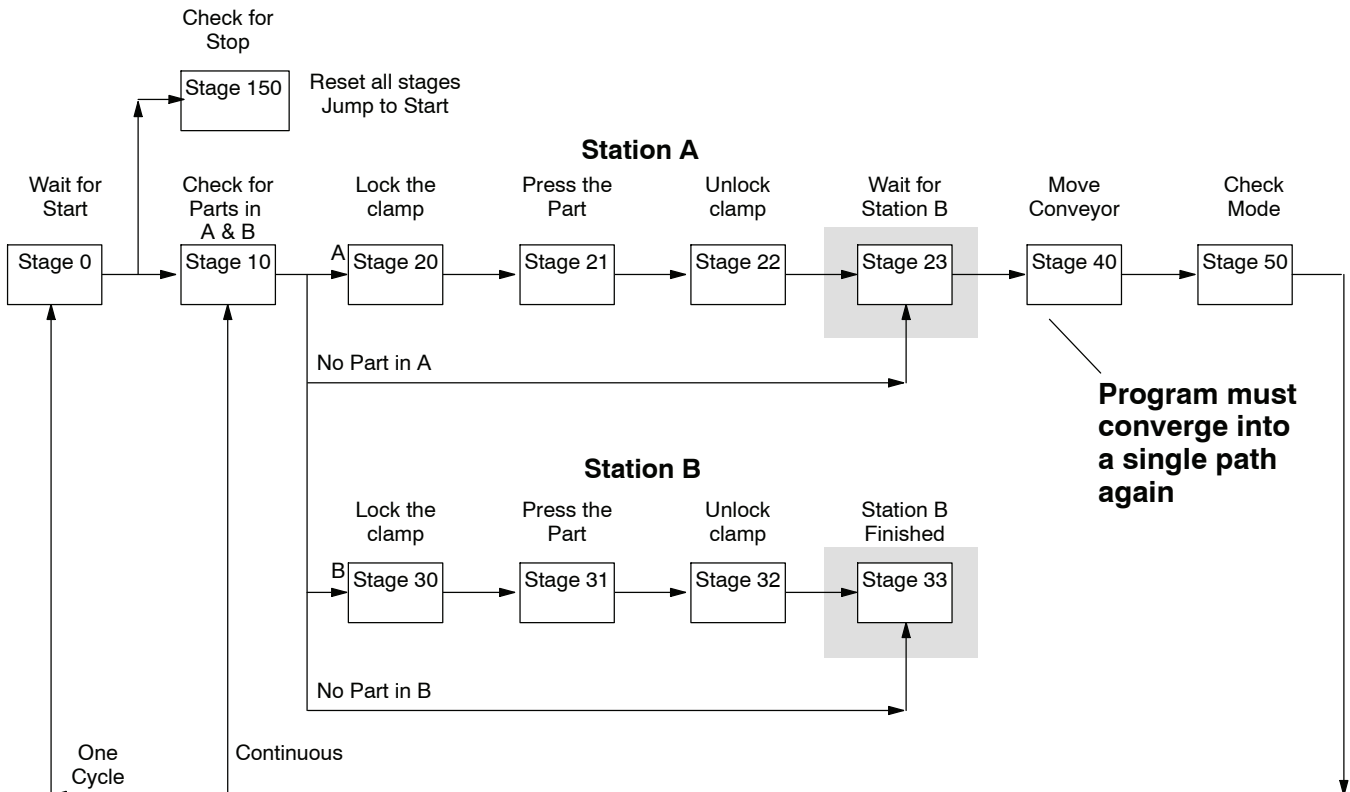
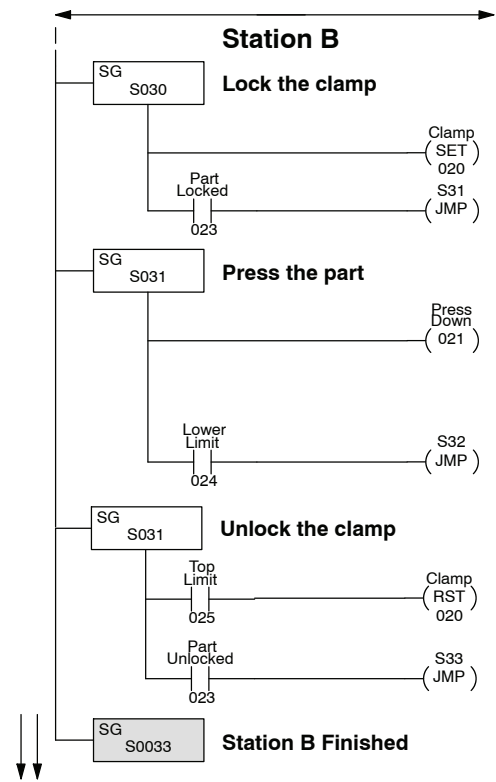
You've already seen how the basic sequence of operations was executed. so we're only going to show the portions of the program that describe how the branches are joined together.

### Using Stage Bits as Contacts

If you examine the flowchart you'll notice once the part is unclamped in station B, the program transitions to Stage 33 which indicates Station B is complete.

If you look at that portion of the program shown here, you'll notice there are no other instructions or actions that take place in this stage. This is why we call it a "dummy" stage. We're just going to use the status of the stage bit associated with this dummy stage as a contact elsewhere in the program to indicate station B is finished.

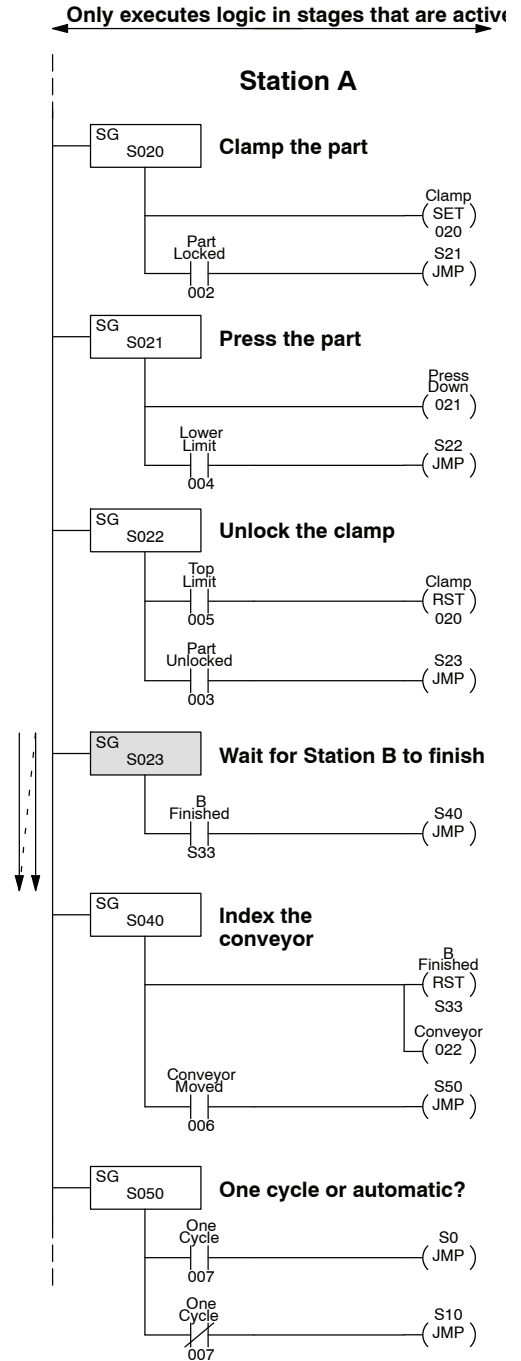
You may be wondering how we can turn off this stage. Since it does not have any type of jump or power flow transition, the only other option is to Reset the stage. We'll do this later in the program.



**Stage Contact Example**

Since each stage has a status bit that is either on or off, you can use this bit as a contact in the program. If you examine Stage 23 you'll notice we've used a contact labeled S33. This contact reflects the status of Stage 33, which indicated Station B was finished.

When S33 is on, the contact labeled S33 is also on and the program will transition to Stage 40. In Stage 40 we use a reset instruction to reset Stage 33 before we move the conveyor.



## Unusual Operations in Stages

### Using the Same Output Multiple Times

Over the last few pages you've learned how the CPU executes the Stage instructions. However, there are a few unusual circumstances that may not work exactly as they appear.

In the program shown it appears output 021 will be turned on at three separate times before the program jumps to the next stage. However, the only time the output actually comes on is when the final condition has been met.

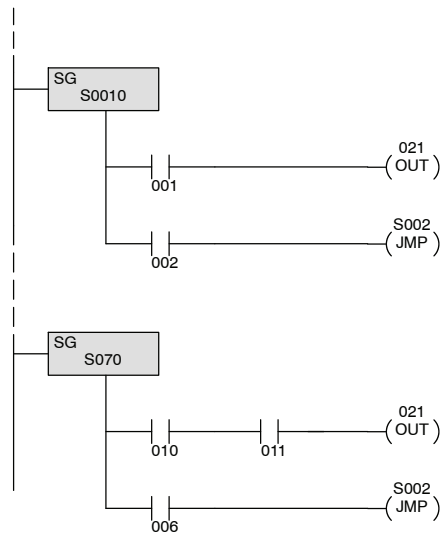
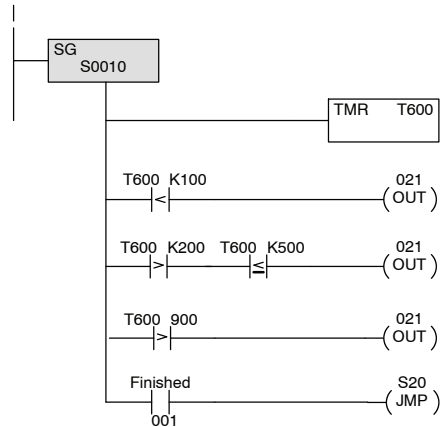
Why? Remember if you use multiple outputs in a program, the last rung containing the output controls the status that will be written to the module. This is no different in a program that uses RLL<sup>PLUS</sup> instructions.

In this example, the last comparison rung says the output should be off until the timer value reaches 90 seconds.

In the previous example the same output was used multiple times in the same stage. The last use of the output controlled the status of the output.

There may be occasions when you have the same output in different stages. Even though it's not advisable to do this in normal RLL programs, this is perfectly acceptable with a program that uses RLL<sup>PLUS</sup> instructions. However, if both stages are active at the same time, then the logic in the last stage will control the status of the output.

In the example shown, if both stages are active, then the logic in Stage 70 will control the output status.





## Using a Set Out Reset (SET OUT RST) Instruction

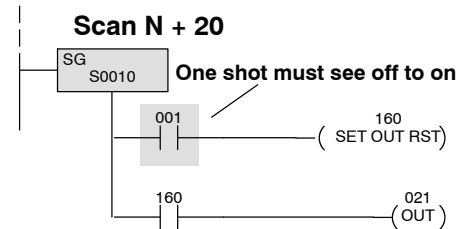
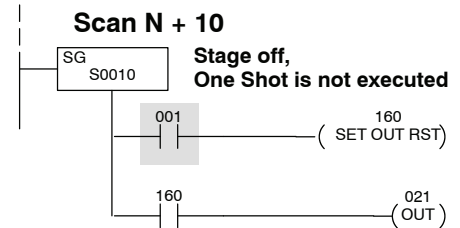
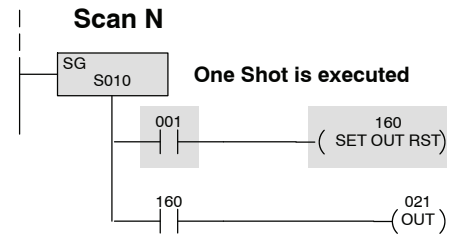
Many normal RLL programs use one-shot instructions. In the DL305 instruction set, this instruction is called a Set Out Reset (SET OUT RST).

In the program shown, input 001 will trigger the SET OUT RST 160 instruction, which will in turn activate output 021 for one scan.

However, what happens if 001 stays on and Stage 10 is activated, deactivated, and then activated again? At first glance it appears the one shot only gets executed one time since 001 stayed on while Stage 10 was turning on and off. It doesn't work this way.

The logic in an inactive stage is not executed. So even though the stage became active the SET OUT RST instruction did not see an off to on transition, so the instruction is not executed.

The SET OUT RST instruction will work in an active stage as long as the input transitions from off to on while the stage is active.



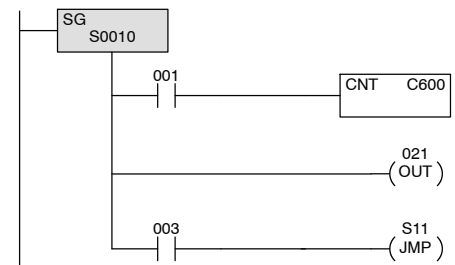
## Output Placement

As you've seen in some of the previous examples, we always place unconditional outputs immediately following the Stage Instructions. There's a reason for doing this.

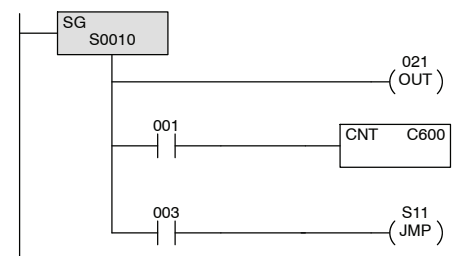
If you look at the example stage shown here, the output is placed after a counter box. The *DirectSOFT* software and the Handheld Programmer will allow you to enter this as shown. However, the CPU will only turn on output 021 when the counter input 001 is turned on. This is because the CPU interprets the output as being tied to the counter input leg instead of the Stage power rail.

You can easily avoid this problem by placing any unconditional actions at the very beginning of the stage. Then, the output will work the way you expect.

### Incorrect Placement



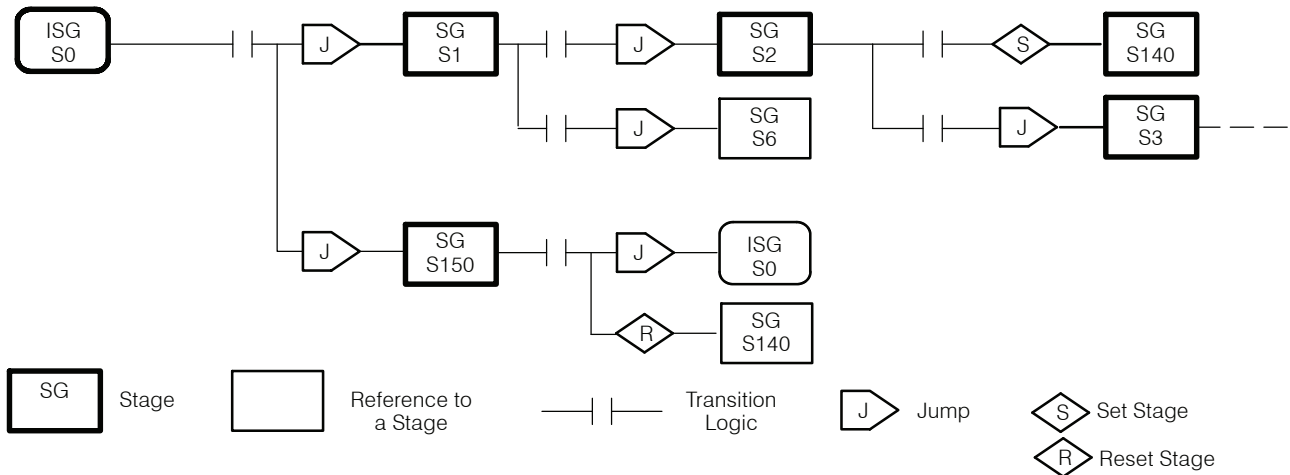
### Correct Placement



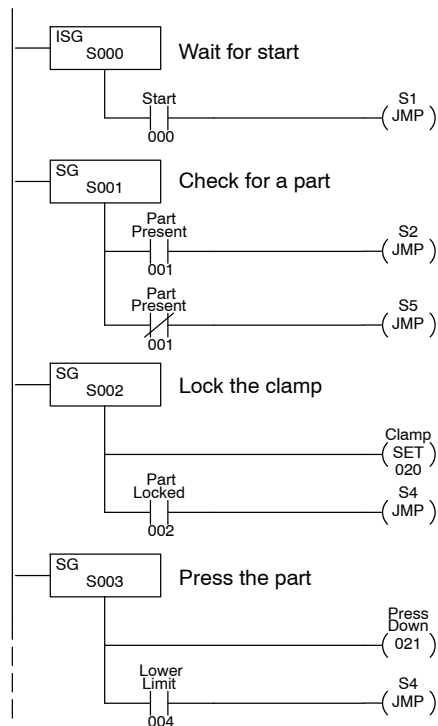
## Two Ways to View RLL<sup>PLUS</sup> Programs

Throughout the example programs, we've consistently shown how the instructions appear in when viewed as ladder instructions. However, with **DirectSOFT**, you also have the capability to view the program as a flowchart. You can even view the program flowchart (in Stage View) and view the ladder program at the same time with a split screen feature. The **DirectSOFT** manual provides detailed information on how to view the programs in this manner.

### DirectSOFT Stage View



### DirectSOFT Ladder View



## Designing a Program Using RLL<sup>PLUS</sup> Instructions

As with most any application problem, a thorough understanding of the tasks combined with a good plan of execution often results in success. The RLL<sup>PLUS</sup> instructions provide an easy way to load the plan of execution directly into the CPU. The easiest way to make sure you understand the tasks is to make a flowchart. This is often the most critical part of creating a program that uses RLL<sup>PLUS</sup> instructions. There are a few simple steps you can follow to create a detailed flowchart.

1. Create a top-level flowchart.
2. Expand the flowchart by adding things that cause the transitions from step to step.
3. Add any actions that must occur in each step.
4. Add any conditions that control the actions.
5. Add any special monitoring or alarm steps that must be performed.
6. Assign numbers to the stages (steps).
7. Add the I/O instructions and addresses (input contacts, output coils, jump instructions, etc.)
8. Enter the program.

### Use *DirectSOFT* to Save Time

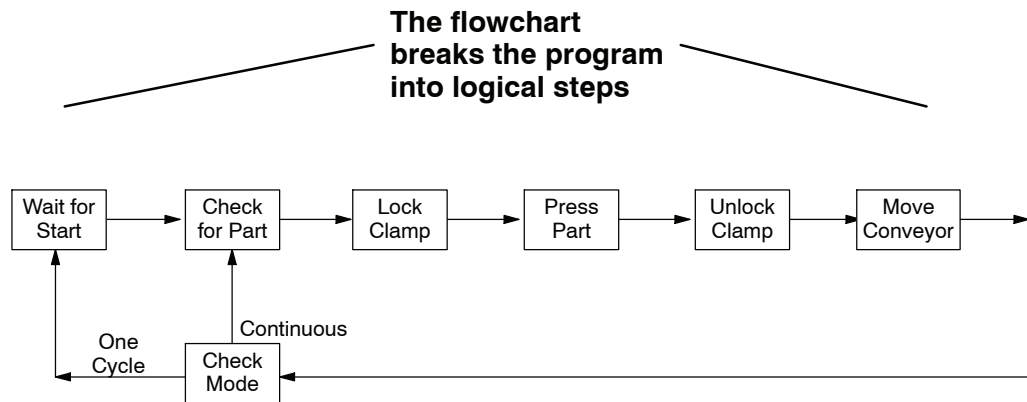
The *DirectSOFT* programming package allows you to quickly and easily create programs with RLL<sup>PLUS</sup> instructions. The software has special features that allow you to create the flowcharts, add the transitions, actions, etc. Even if your programs are fairly small, *DirectSOFT* can make the job much easier.

**Step 1:  
Design a Top-level  
Flowchart**

There are many different ways to design a flowchart of the application problem, but there are a few guidelines that will make the job easier.

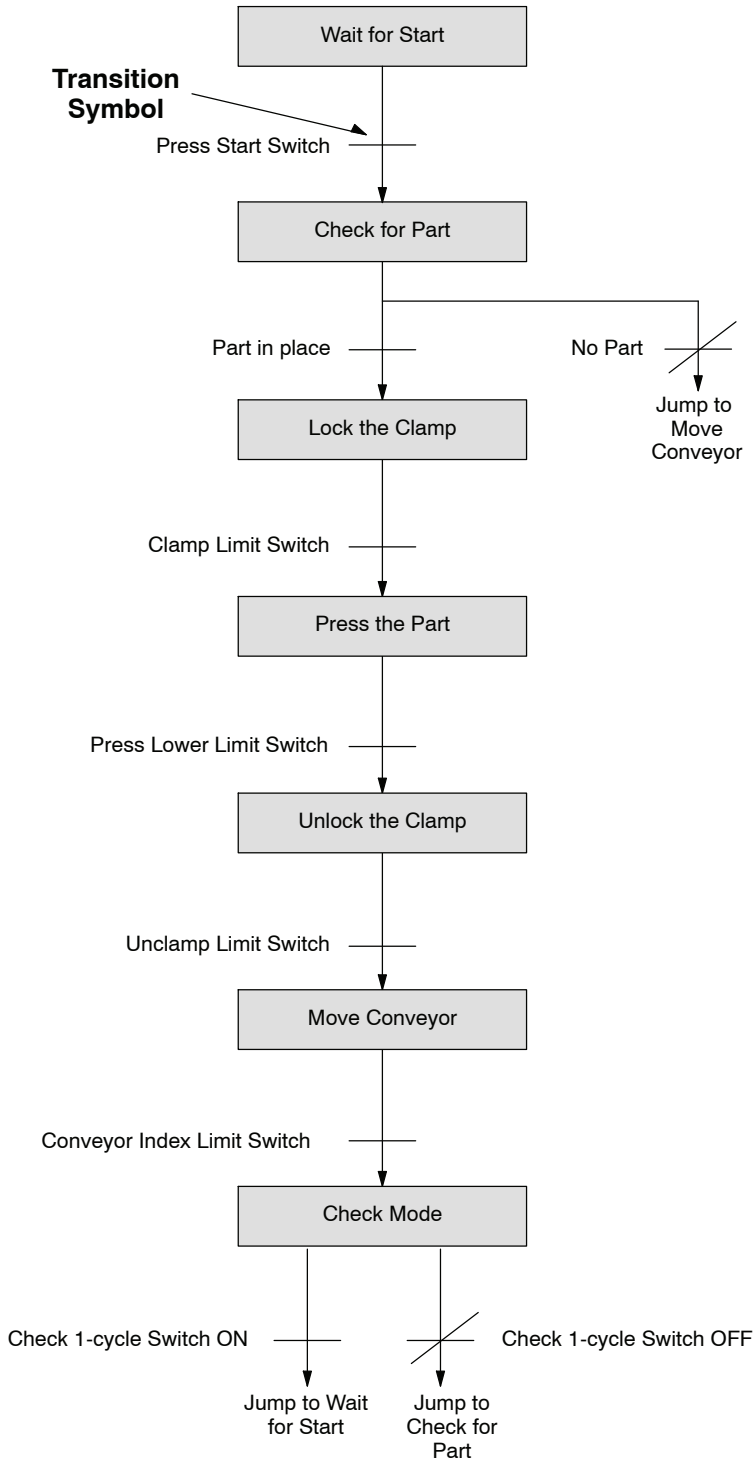
1. Start with a “top-level” flowchart that breaks the operation sequence into simple pieces.
2. Each piece of the top-level flowchart should only represent one action. Resist the temptation to group several operations into one part of the flowchart.
3. Don’t try to add input or output addresses to the flowchart. Only use words to describe the things that are taking place.
4. Don’t worry about special conditions, such as stop conditions, alarms, etc at this point. These will be added later when you fully understand how the main part of the operations sequence is organized.

You can draw the flowchart horizontally or vertically at any point in the design process, the choice is yours. Here’s an example top level flowchart for our simple one-station press.



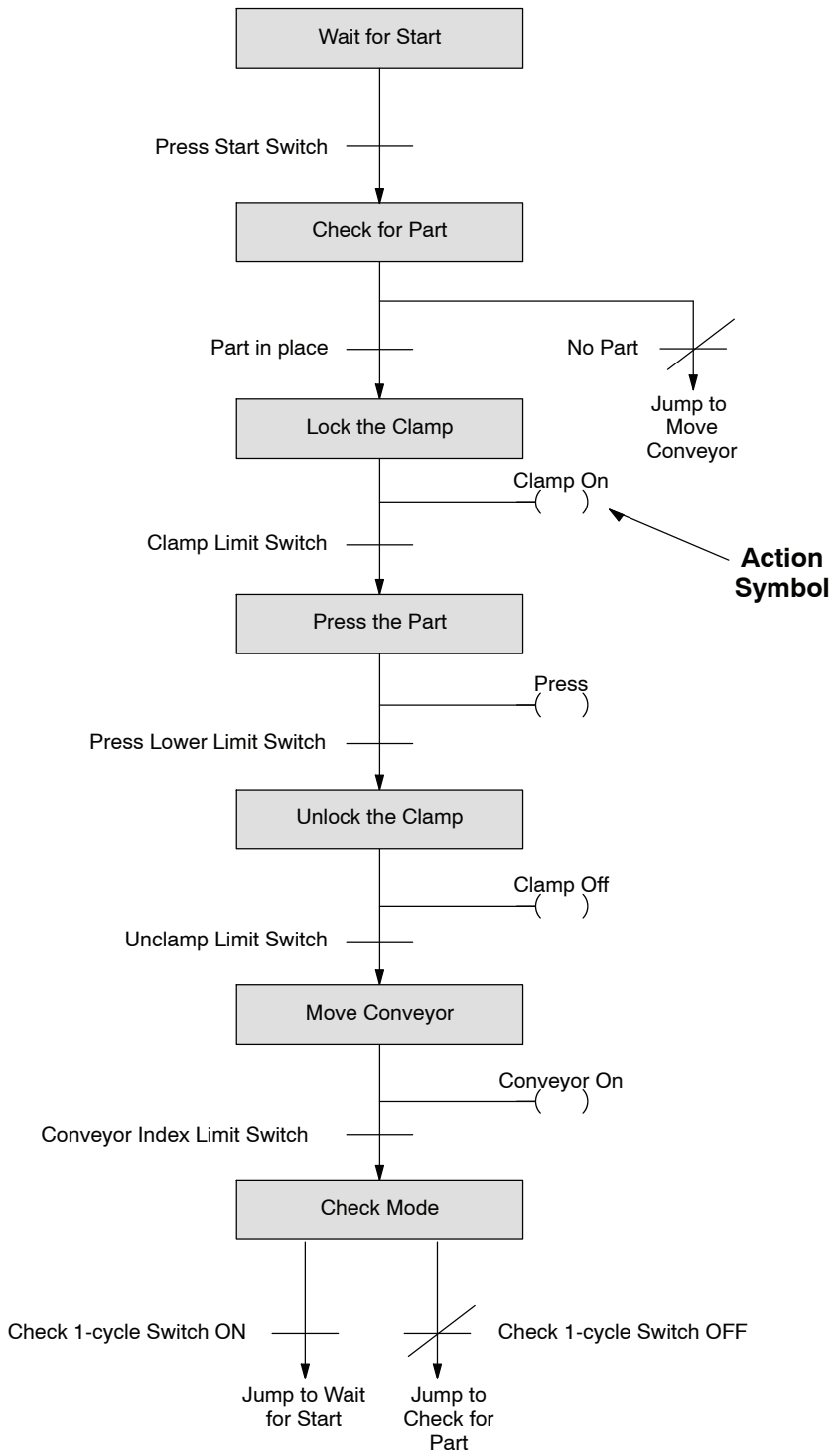
**Step 2:  
Add Flowchart  
Transitions**

Once you have designed the basic operating sequence you should determine the events that cause a transition from step to step. During this phase you may find things need to be added to the flowchart. All you're really doing is adding more detail to the top-level flowchart. Once again, don't try to use addresses yet. Concentrate on using words to describe the events taking place. The following flowchart adds the transition conditions for our one-station press.



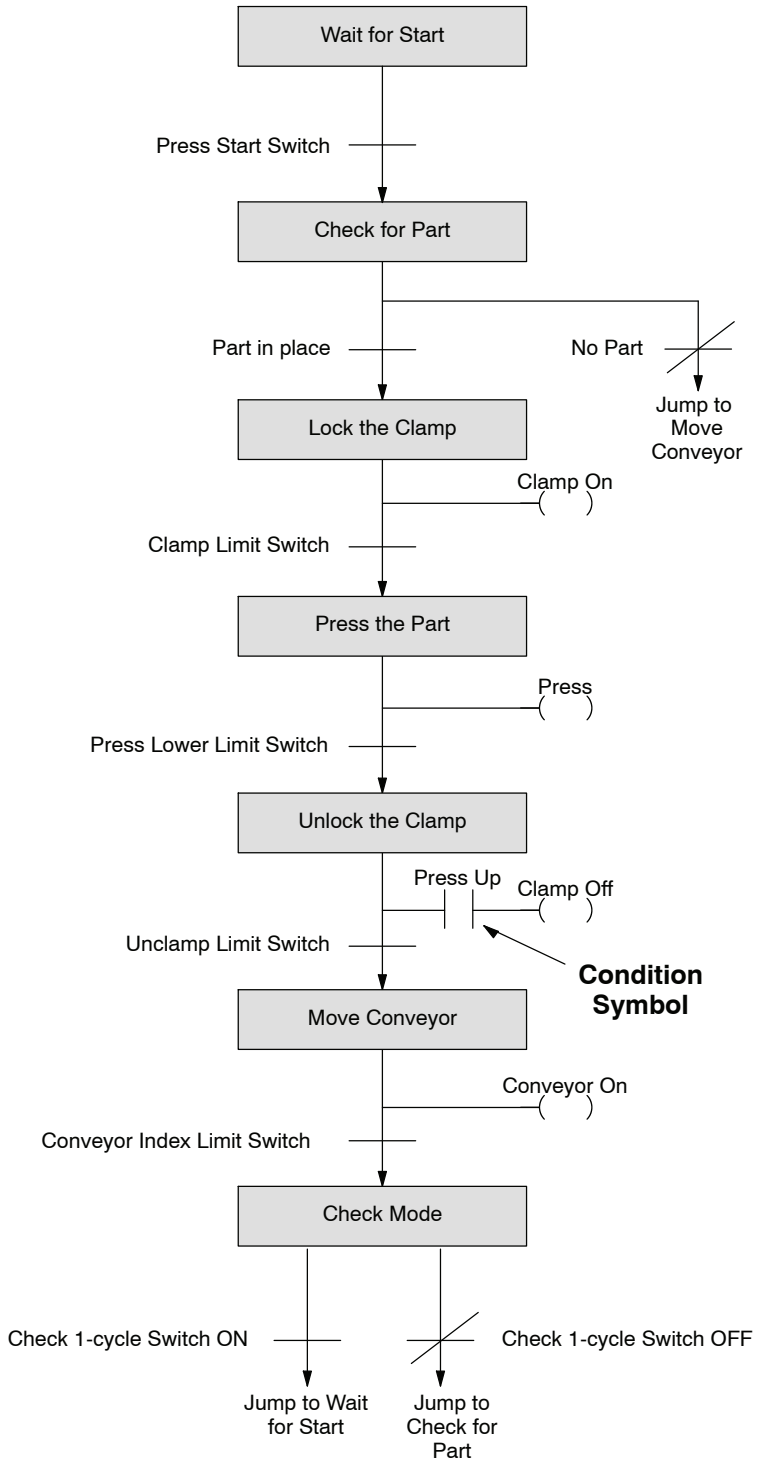
### Step 3: Add Actions

After you determine the events that cause a transition from step to step you should add any actions that need to take place during the sequence. Again, don't try to use addresses yet. Concentrate on using words to describe the actions taking place. The following flowchart adds the actions that take place during each part of the program.



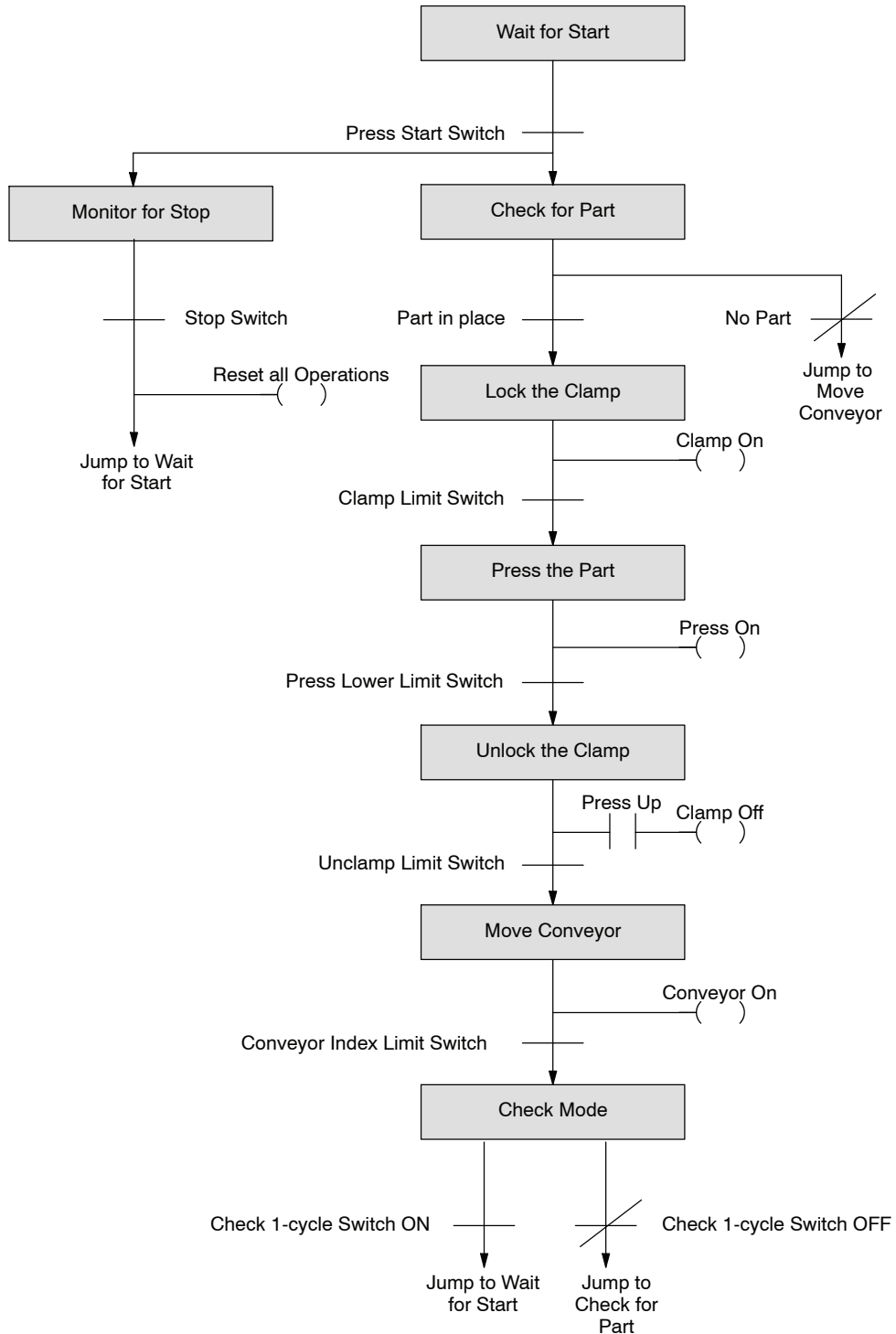
**Step 4:  
Add Conditions for  
Actions**

Some actions may only take place if certain conditions are met. Examine the program carefully to determine any conditions that should be added. The following flowchart adds any conditions for the actions that take place during each part of the program.



**Step 5:  
Add Alarm or  
Monitoring  
Operations**

Many people are tempted to add alarm or monitoring operations earlier in the flowchart design process. It is almost always easier to add them last because then you know how they should affect the main part of the program. The following flowchart adds an operation that monitors for the conditions that will stop the press.





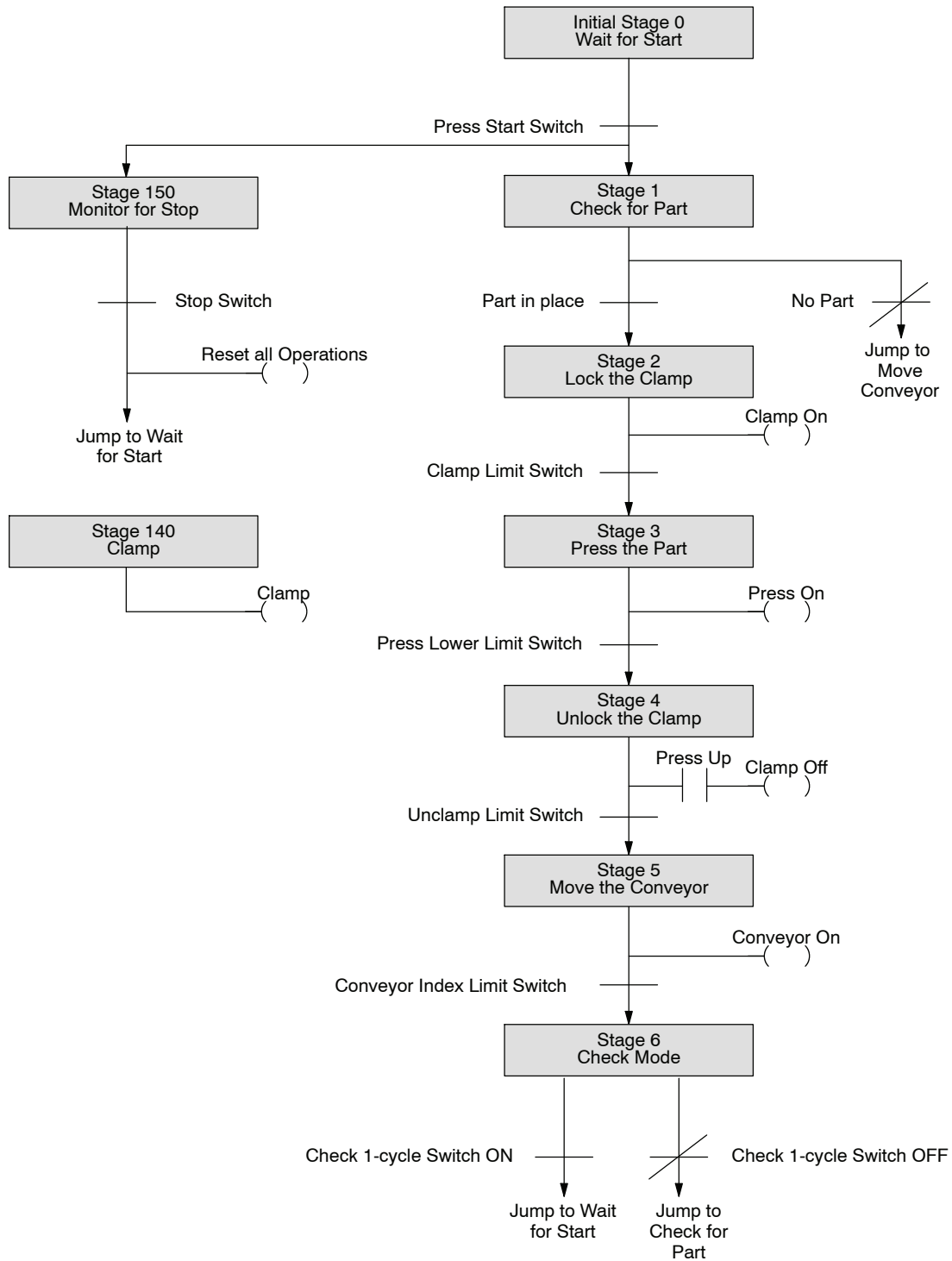
**Step 6:  
Determine Stage  
Numbering**

You can number the stages any way you would like, but it's usually best to follow some type of sequence that matches the flow of the program. This makes it much easier to understand. There are a few guidelines we have used to determine the best numbering sequence. You don't have to follow these guidelines, but they may help. You can typically find these types of operations in any program.

- **Sequential Operations** — a certain sequence of events, one after the other. This is usually the main part of the program. It's usually best to number these first. For example, you may want to always number these stages from 0 - 127 (octal).
- **Independent Operations** — these operations usually only perform one task, such as activating a motor or turning on a horn. For example, you may want to number all independent operations starting from 130 - 147 (octal).
- **Alarm and Monitoring Operations** — These operations usually monitor the main parts of the program. Since you may want to reset parts of the program during an alarm condition, it is usually best to number these last. This way you can use one Reset (RST) instruction to reset almost the entire program. Use stages 150 - 177 for alarming and monitoring stages.

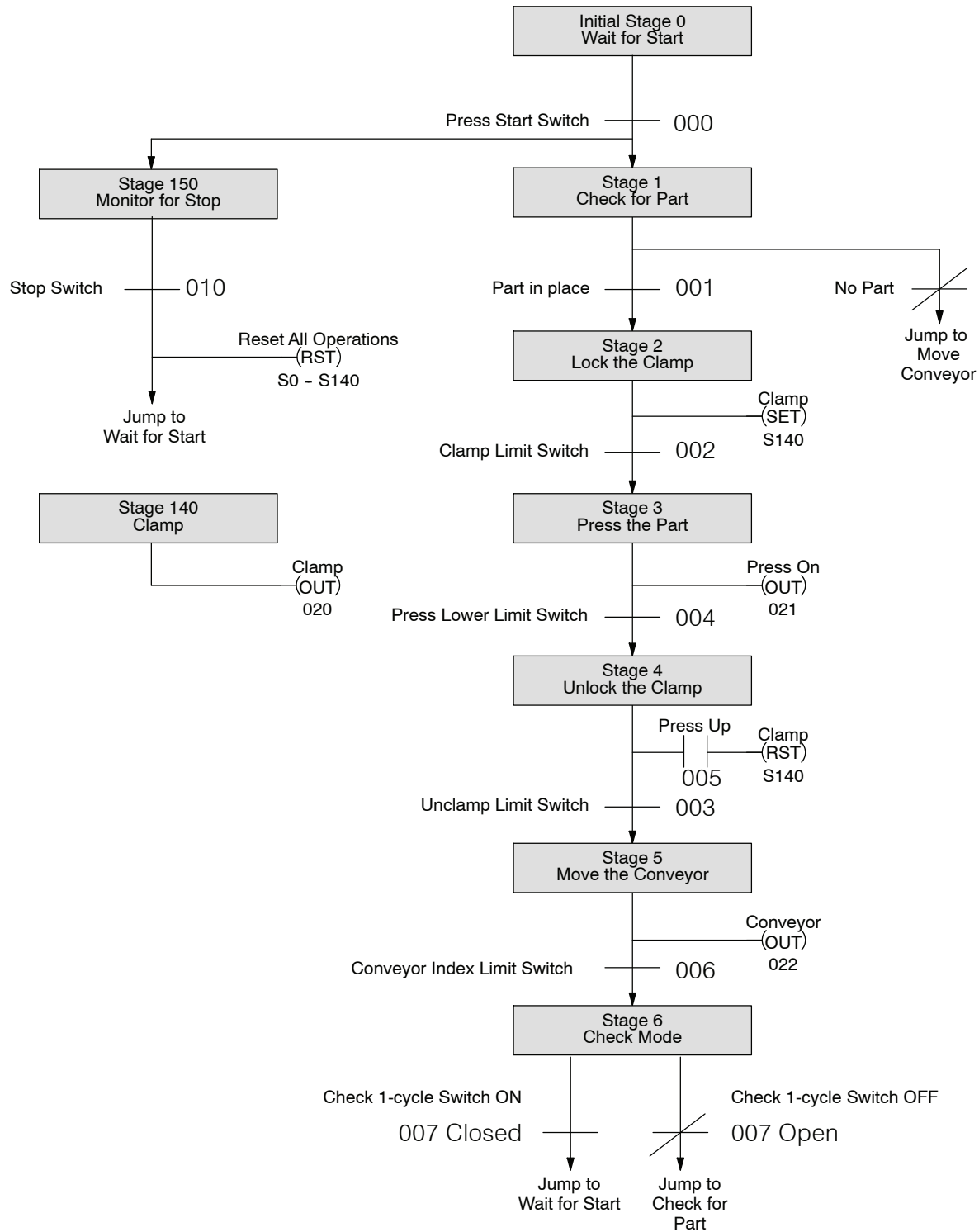
These guidelines are especially helpful if you have many different programs. By using a standard numbering scheme, you always know where to look for the various types of operations.

The example shows how we assigned numbers for the example press. Notice we've also made a separate stage for the clamp. This was not an absolute requirement because there are several ways you could have done this. We just did it to show you an example of an independent operation.



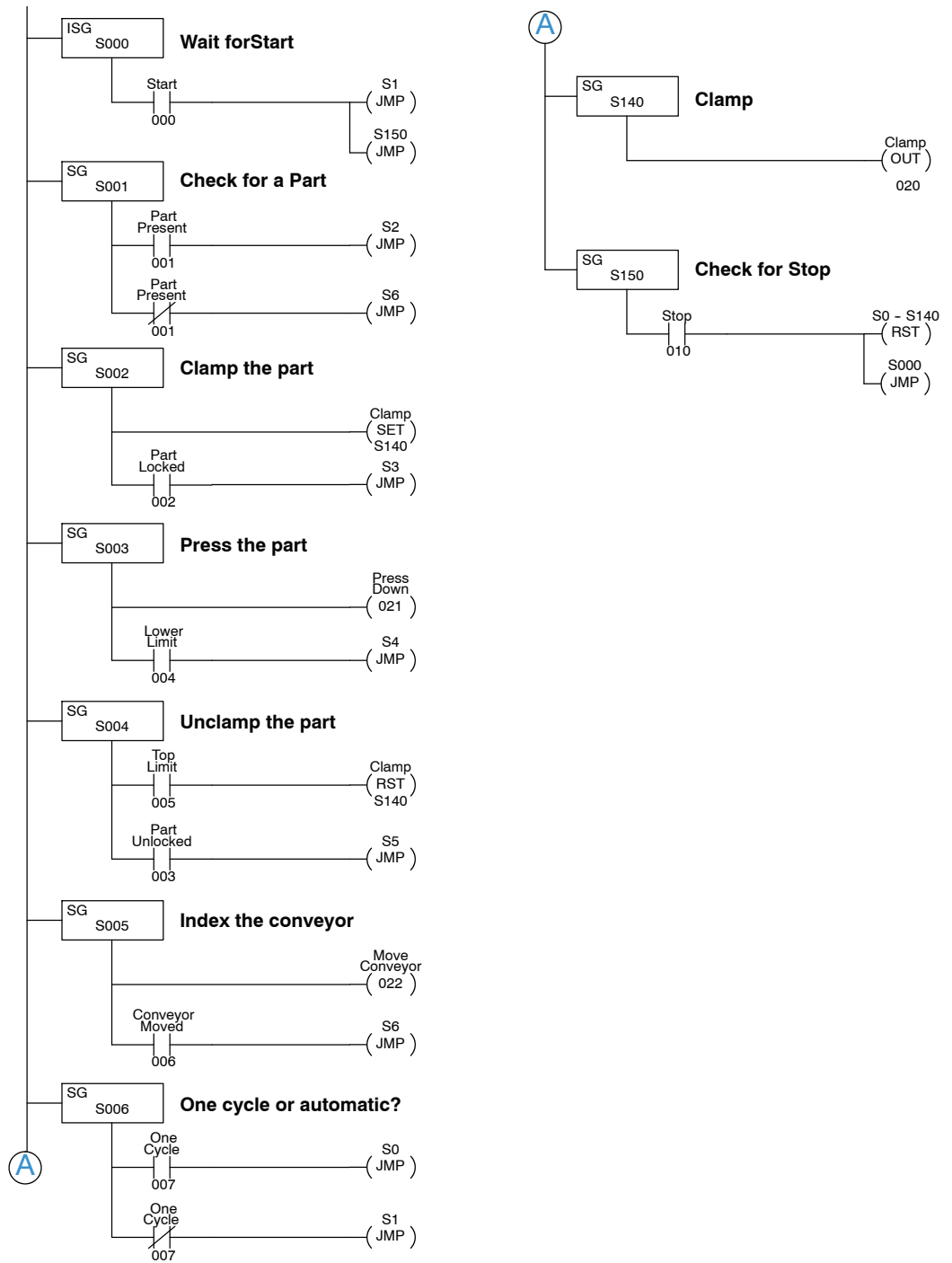
**Step 7:  
Assign I/O  
Addresses**

The final step before you enter the program is to assign the I/O addresses and the destinations for any Jump, Set, or Reset instructions.



### Step 8: Enter the Program

The following diagram shows how the program would look when viewed as a ladder program.



This diagram shows how a portion of the program would look when viewed as a Stage Diagram in *DirectSOFT*.

