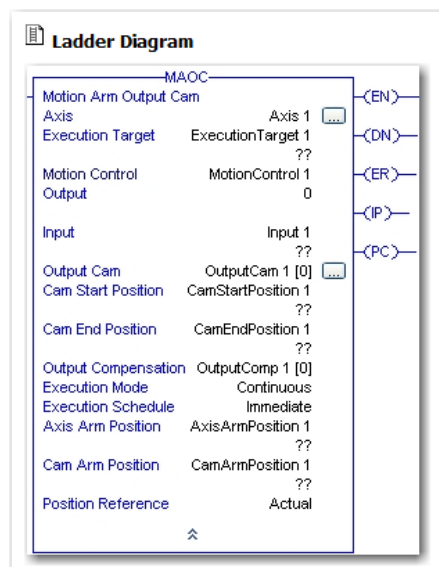


Position-based Output Control with the MAOC Instruction

Catalog Numbers 1756-OB16IS, 1756-OB16IEFS, 1732E-OB8M8SR

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This application technique describes applications that use the Motion Arm Output Cam (MAOC) instruction with and without the use of scheduled output modules.



Description

The MAOC instruction enables you to synchronize digital outputs with axis motion. At low speeds, you can use the instruction with a standard output module to ease the axis and output synchronization. As performance requirements increase, a scheduled output module is necessary to operate with tight time synchronization.

This document describes three application examples that benefit from an MAOC-based solution.

Strobe Trigger

A strobe trigger initiates systems, such as cameras, bar code scanners, or other self-contained processes, that detect a rising edge input.

In this application, use the instruction to follow the position of the conveyor axis:

- The instruction triggers the strobe each time the conveyor moves a preset distance.
- The instruction simplifies programming and the mechanical system. Because the instruction controls the monitoring and trigger, it eliminates the need to monitor limit switches or axis position in application code. This frees up scan time and logic to focus on other aspects of the machine. This also enables the strobe to have a very short and repeatable duration.

Applicator Control

The MAOC instruction is useful with glue applicators or other applications that turn an output On and Off as the master line shaft changes position and forces the output On if needed.

In this application, use the instruction to follow the master line shaft virtual axis:

- Program the compensation data to account for the mechanical delays of turning the solenoid valve On and Off.
- Use enable bits to allow operator-based manual control of the outputs.

When used with gluing applications, the instruction reduces complex compensation math. The Purge function is especially useful for glue applicators that need to clear the lines.

Product Diverting

In a product diverting application, product moves from one high-speed conveyor to another via pneumatic or electrical drivers.

In this application, use the instruction to trigger the output when the product is directly in front of the diverter.

This application is particularly useful for any kind of product quality rejection system and also works well for material handling.

Operation

By itself, the MAOC instruction enables position-based output control in these ways:

- Uses the position of any motion axis in a ControlLogix® system as the position reference
- Uses any output or DINT
- Updates outputs based on the motion axis position at the motion group coarse update rate, typically 1...32 ms

The instruction can update standard digital output modules at the coarse update rate. However, some high speed applications require a higher degree of accuracy.

The 1756-OB16IS, 1756-OB16IEFS, and 1732E-OB8M8SR scheduled output modules improve the accuracy of the MAOC instruction by supporting the ability to schedule output On and Off times. All of the scheduling configuration for an output's On and Off times is completed through the MAOC instruction. The instruction then updates values in the module's output tags that define the scheduled output behavior.

Table 1 - Scheduled Output Module Features

Feature	1756-OB16IS	1756-OB16IEFS	1732E-OB8M8SR
Number of schedules	16	32	16
Output points available for scheduling	8 (points 0...7)	16 (points 0...15)	8 (points 0...7)
Remote operation	None	Remote chassis	On-Machine™ over the EtherNet/IP network
Minimum schedule interval ⁽¹⁾	100 μs	5 μs	100 μs

(1) The MAOC limits the minimum schedule interval (minimum pulse width) to 1/16 of the coarse update period.

Factors that Impact Schedule Accuracy

The following sections describe factors that can contribute to a loss of accuracy on the scheduled output modules.

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Minimum Pulse Width

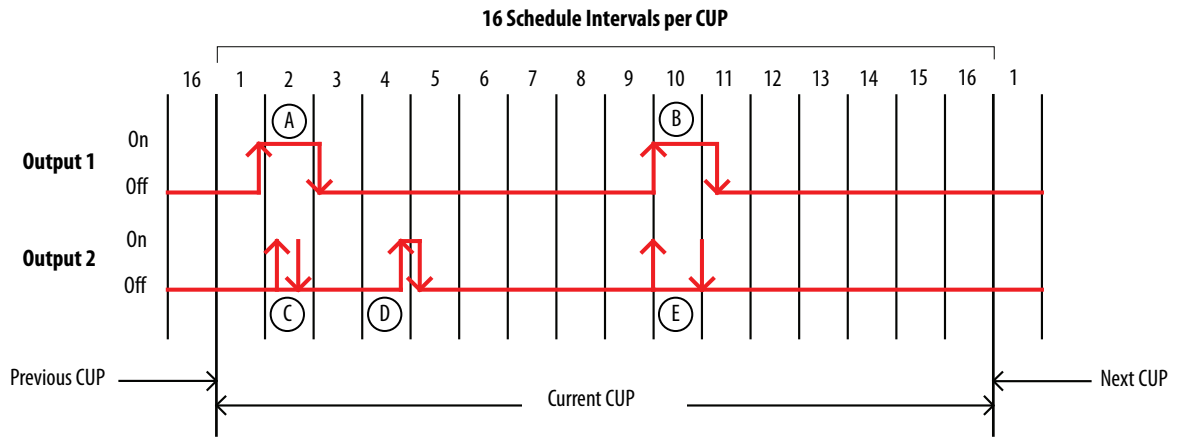
A schedule interval is the course update period (CUP) divided by 16. Each schedule interval can have only one scheduled event within it. If multiple schedules fall within a single schedule interval, only the last event is evaluated.

The width of a pulse must be longer than a schedule interval. If the pulse width is shorter than or equal to the schedule interval, it is less than the minimum pulse width, and a loss of accuracy can occur.

[Figure 1 on page 5](#) shows a minimum repeatable pulse width for a 1756-OB16IEFS module that supports as many as 16 schedules per CUP. The summary of events is as follows:

- **A**—The On and Off events are spaced far enough apart that they cannot fall within the same schedule interval. This meets the minimum pulse width criteria.
- **B**—Even though the On event occurs on the edge of the schedule interval, the Off event is longer than the minimum pulse width and falls into a different schedule interval.
- **C**—The On and Off events fall within the same schedule interval and cancel each other. The output is never energized.
- **D**—The pulse has the same width as example C, but the On and Off events fall into separate schedule intervals. In this case, the output is energized. Because it is not possible to predict where the schedule interval starts or ends, the output can turn On at times, but not at others—even on the same machine.
- **E**—The pulse width is exactly equal to the schedule interval, and the output is energized as scheduled in most cases. However, in some cases, output behavior can be unpredictable. Because it is not possible to predict where the schedule interval starts or ends, the output can turn On at times, but not at others—even on the same machine.

Figure 1 - Schedule Intervals



Refer to the table below to determine the minimum pulse width for your application.

Table 2 - Minimum Pulse Width

Discrete Output CUP (μs)	MAOC Time Slot (μs)	1756-OB16IS (μs)	1756-OB16IEFS (μs)	1732E-OB8M8SR (μs)
500	31	100	31	100
1000	63	100	63	100
1500	94	100	94	100
≥ 2000	CUP/16	CUP/16	CUP/16	CUP/16

Schedule Limitations

Each module has a limited number of total schedules it can process, and a limited number of schedules it can process per CUP, as shown below.

Table 3 - Schedule Limits by Module

Count	1756-OB16IS	1756-OB16IEFS	1732E-OB8M8SR
Total Schedule Count	16	32	16
Schedules per CUP	8	16	8

Schedules can be allocated to multiple points, or even a single point, as long as you maintain the minimum pulse width and maximum schedule count.

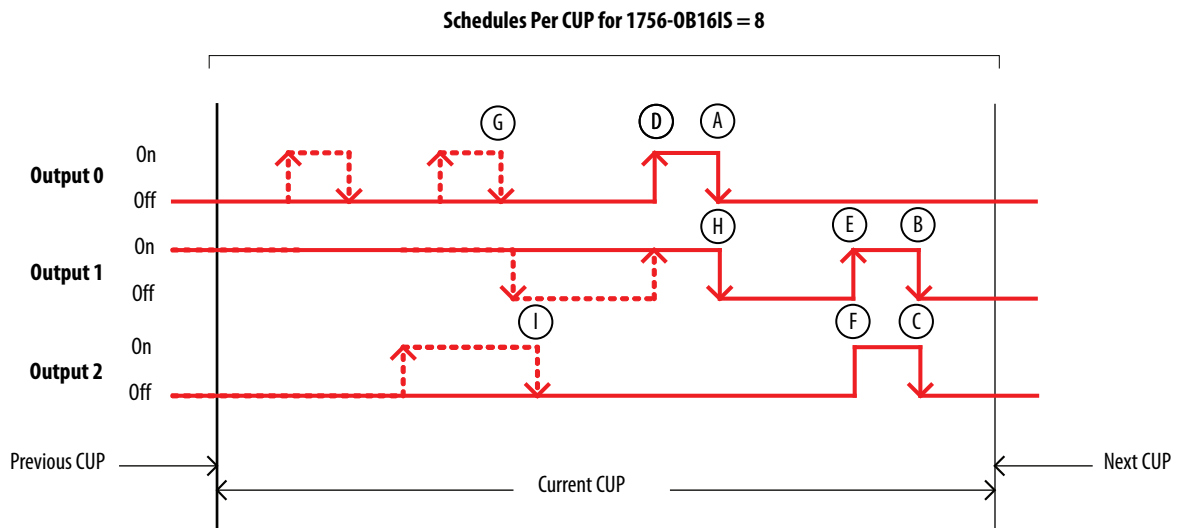
Figure 2 shows an example of the 1756-OB16IS module processing eight schedules in the normal order (illustrated alphabetically). The module processes the last schedule on output 0, then the last schedule on output 1, followed by the last schedule on output 2, and so on. The module then processes the second to last output for each output point. After the module processes the last schedule, the processing completes. Any unprocessed schedules are not acted upon.

In the figure, the dashed lines signify the intended behavior, and the solid lines show the actual behavior for these schedules:

- **G**—The schedule is processed; however, there is no change of state because of the previous state of the output.
- **H**—The schedule turns output 1 Off, but much later than expected.
- **I**—This transition and all of the unmarked transitions are never processed.

If the 1756-OB16IS module in this example is replaced with a 1756-OB16IEFS module with a higher schedule count, all of the schedules can be processed and executed. Slowing down the master axis can also help because fewer schedules are executed within each CUP.

Figure 2 - Schedule Limitations



Position Reference: Actual versus Command

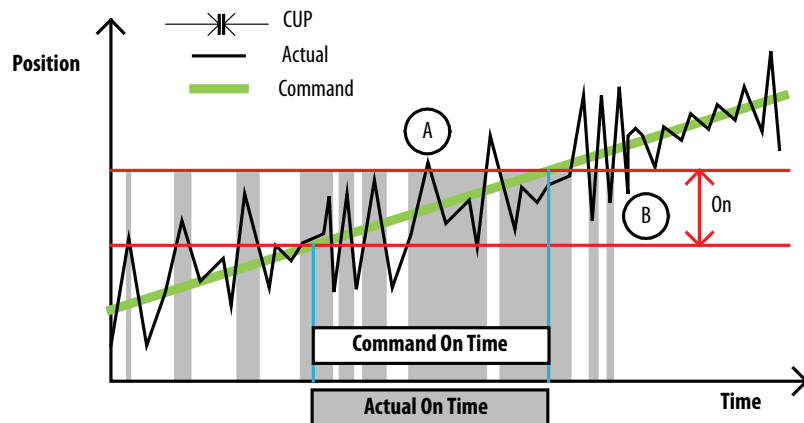
The MAOC instruction provides the option to use the actual feedback or the command position as the master reference for the output cam:

- For axes configured as Feedback Only, the command position is equal to the actual position.
- For axes configured as Virtual, the actual position is equal to the command position.

Typically, the actual position for an axis has more variability than the command position. For axes that have the option for either position, use the command position to reduce possible error.

[Figure 3](#) shows an extremely exaggerated case of actual position variability. Filtering occurs when the position reference uses the actual position. This increases the difficulty in determining when outputs change state, as shown by labels A and B. In the example below, the MAOC instruction is bi-directional. If the position reference is actual, the output energizes in a potentially troubling manner. Setting the position reference to the command position improves the output signal and the accuracy of the MAOC instruction.

Figure 3 - Command versus Actual Position



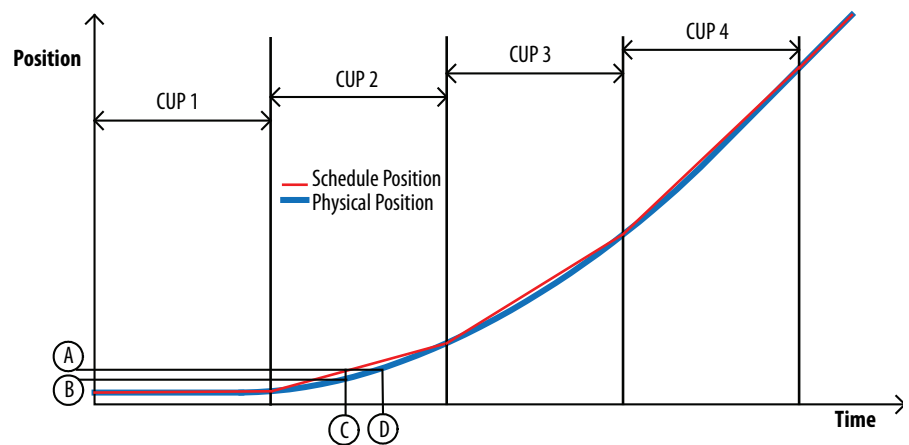
Constant versus Changing Velocity

The MAOC instruction calculates schedules without acceleration compensation. Between each CUP, the instruction assumes a linear velocity. However, physical systems behave in a non-linear fashion due to mechanics and physics. This can lead to slight deviations between the scheduled position and physical position of an event.

During times of high acceleration or deceleration, outputs can change state sooner or later than planned. For example, in [Figure 4](#), the intended result is to turn the output On where position A intersects the physical position graph at time D. The velocity compensation estimates that this will happen where position A crosses the schedule position graph at time C. Because the physical position lags behind the schedule position, the output turns On where position B crosses the physical position graph. This demonstrates an output changing state earlier than expected during acceleration.

This example is graphical only, and numerical difference is dependent on the acceleration profile, the mechanical system, the available dynamic response, and the duration of the coarse update period.

Figure 4 - Example of Constant versus Changing Velocity



Configure Output Modules

For use with the MAOC instruction, output modules require minimal configuration:

- When using a scheduled output module, the outputs associated with the MAOC instruction operate independently of the requested packet interval (RPI). Standard output modules are typically updated at the RPI, but can be updated faster in certain circumstances.
- To associate an output module with an MAOC instruction, assign the module's scheduled data tag to the output tag in the instruction. Using any tag other than the scheduled data tag can cause problems with the execution.
- For the 1756-OB16IS, 1756-OB16IEFS, and 1732E-OB8M8SR scheduled output modules, use the default settings shown in the figures below.

Figure 5 - 1756-OB16IS Communication Format

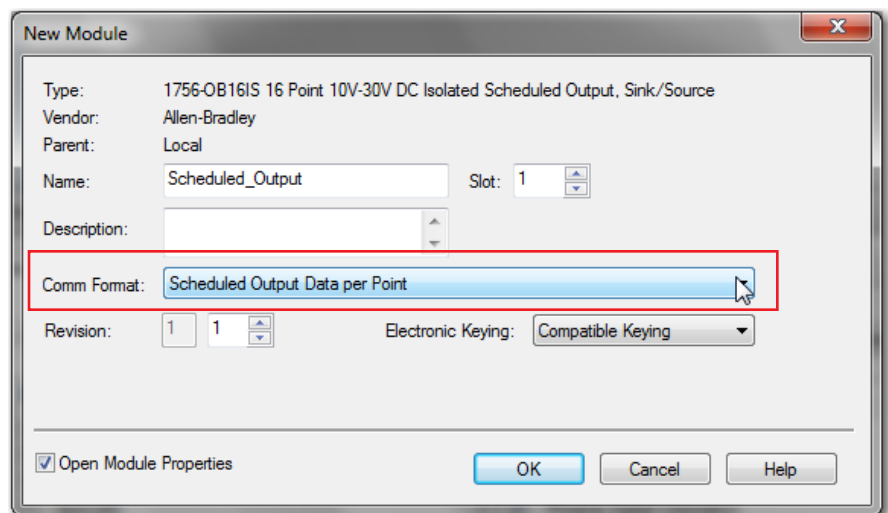


Figure 6 - 1756-OB16IEFS Output Data

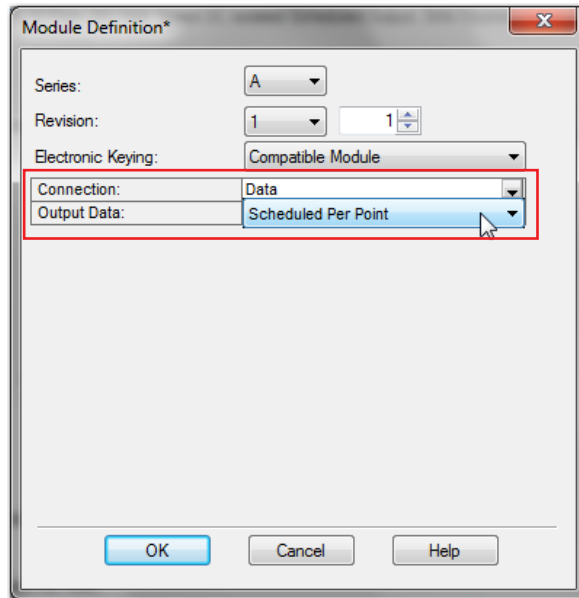
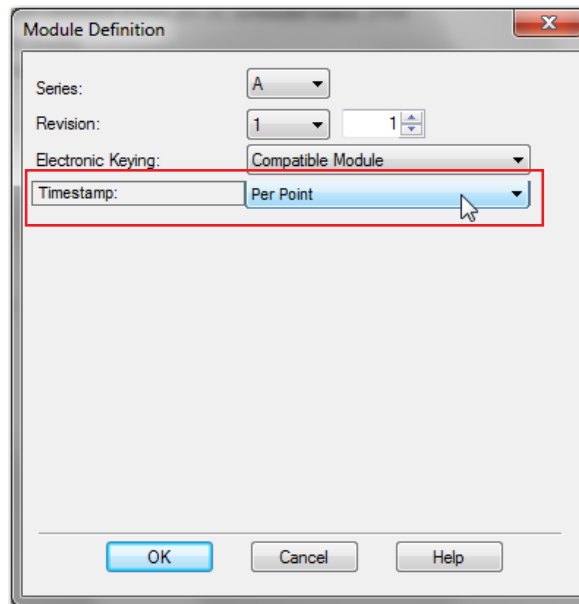


Figure 7 - 1732E-OB8M8SR Timestamp



Configure the Axis

The controller uses execution targets to provide a unique identifier for each output cam on an axis. This value enables the controller to reference the MAOC instruction internally. The execution target in the MAOC and MDOC instructions must match to stop the execution of the output cam.

You can configure as many as eight (0...7) output cam execution targets per axis. The default number of execution targets for each axis is zero, so you must change the default value to use the MAOC instruction. The location of the parameter in the hardware profile varies depending on the type of axis, as shown in the figures below.

Figure 8 - AXIS_SERVO_DRIVE

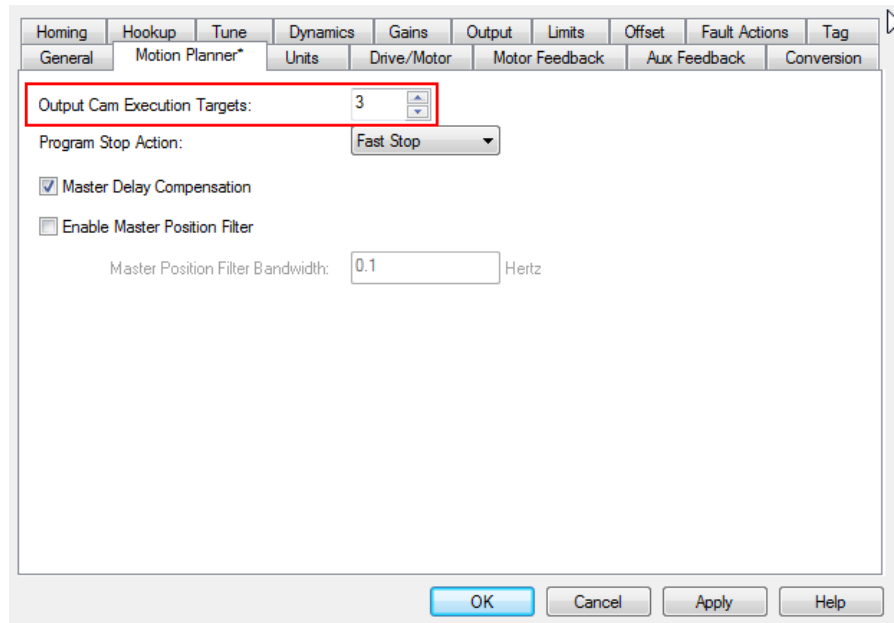


Figure 9 - AXIS_CIP_DRIVE

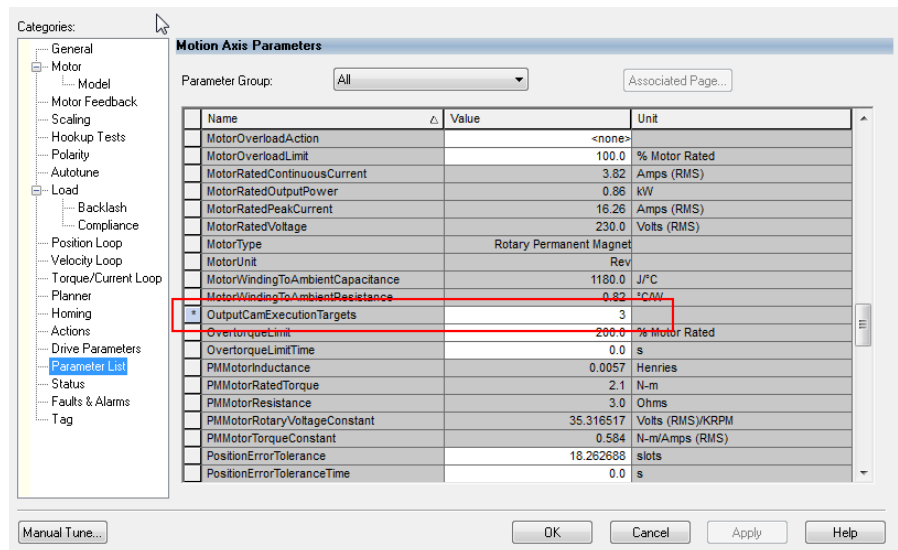
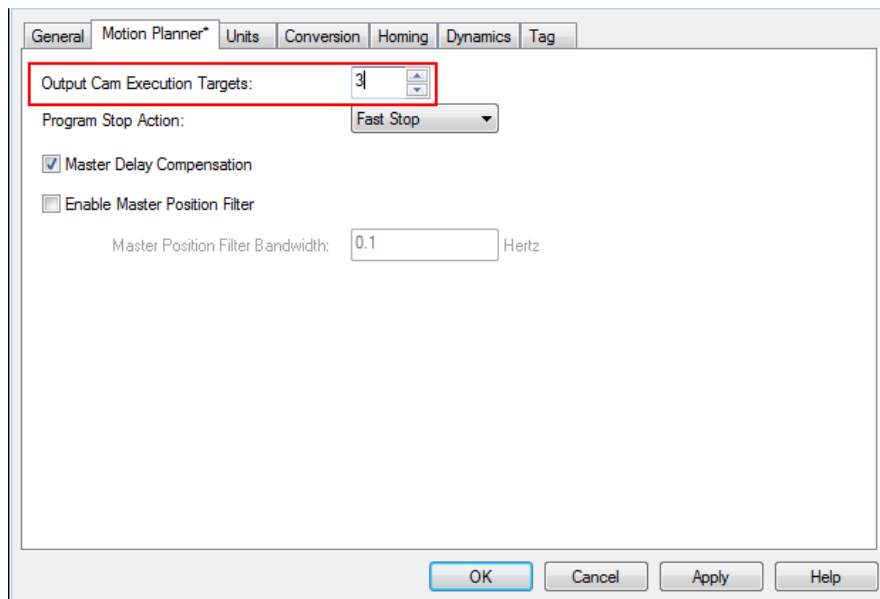


Figure 10 - AXIS_VIRTUAL



Program the Instruction

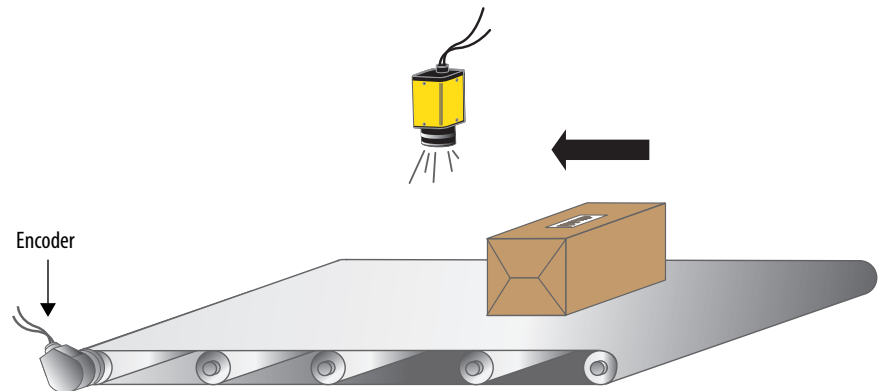
This section provides programming examples for three MAOC-based applications. For detailed information about the MAOC instruction, refer to the online Help within the Studio 5000™ Logix Designer application.

Once the MAOC instruction starts, you do not need to terminate the instruction when the axis motion stops. Once the axis motion resumes, the instruction continues to monitor the axis. To stop the MAOC instruction, use a Motion Disarm Output Cam (MDOC) instruction.

Strobe Trigger Example

In this strobe trigger example, a camera takes a picture of labels on boxes as they travel along a conveyor. The conveyor can be driven by any device, such as a servo drive, variable frequency drive, or soft starter. An encoder sends the speed of the conveyor to the controller.

Figure 11 - Strobe Trigger Example



The programming logic for this example must take into account the following:

- Boxes on the conveyor are 1000 mm apart.
- The strobe must trigger when a box is in the middle of its travel, nominally at 500 mm.
- The duration of the strobe light flash must be exactly 10 ms.
- To account for boxes that are out of place, the strobe must trigger multiple times: just before, at, and just after the center of the field of view.

[Figure 12](#) shows the configuration of the output cam for this example. As the axis travels through the 450 mm, 500 mm, and 550 mm points, the strobe output turns On for 10 ms, independent of the scan time of the controller. This is especially useful for applications with long scan times, or exact requirements for the On time duration.

Figure 12 - Output Cam for Strobe Trigger

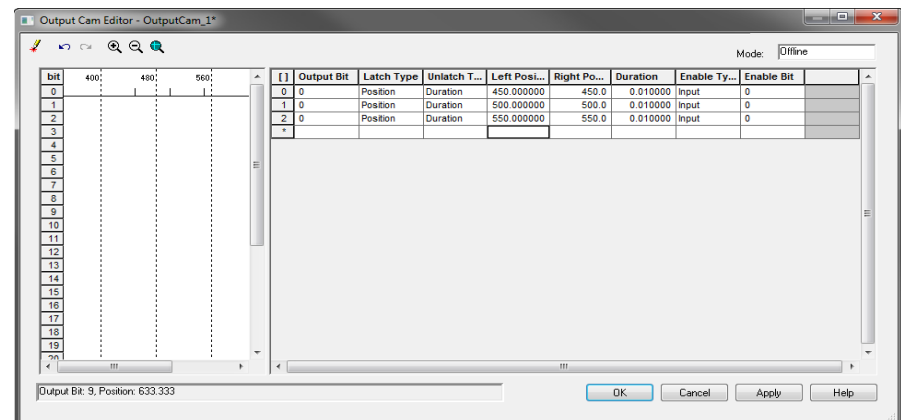


Figure 13 shows the configuration of the MAOC instruction for this example.

Figure 13 - MAOC Instruction for Strobe Trigger

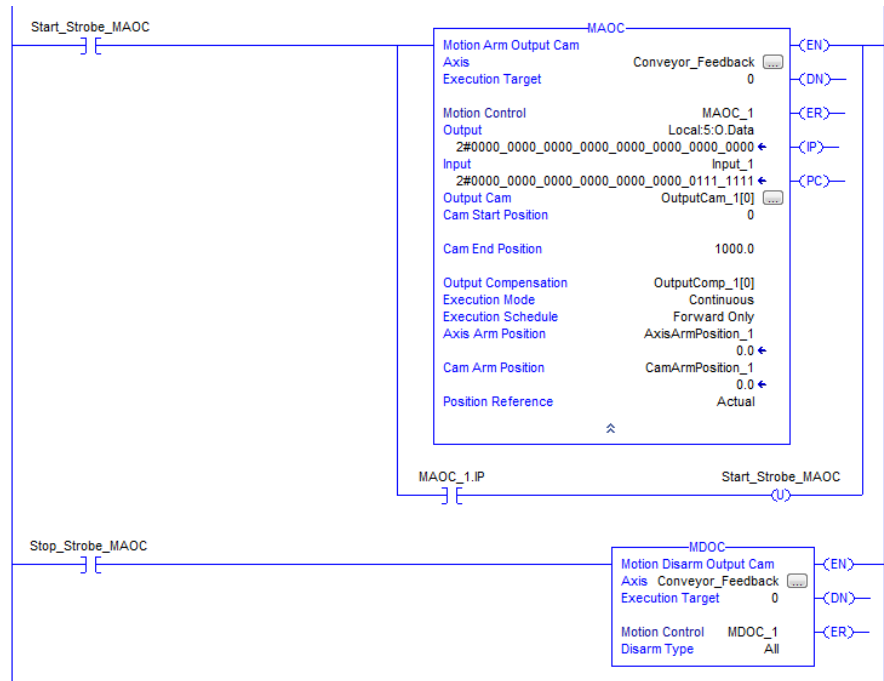


Table 4 - MAOC Operands for Strobe Trigger

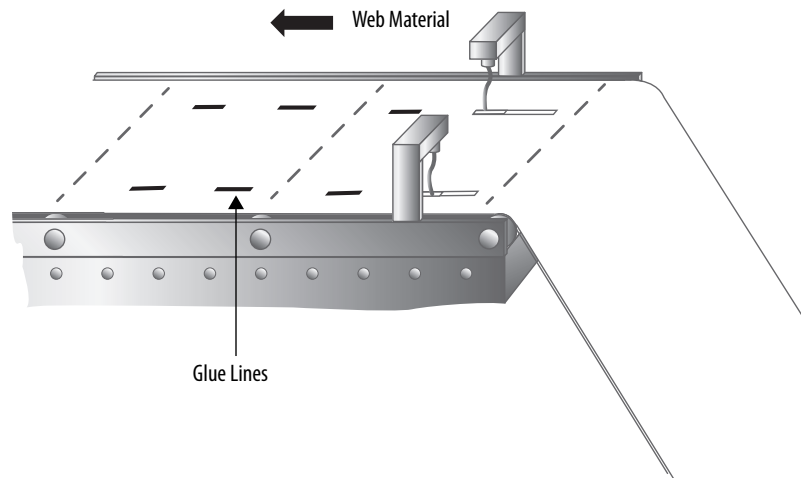
Operand	Configuration
Axis	Associate the axis with the Conveyor_Feedback tag.
Execution Target	Specify a value of 0 . . . 7. Each output cam on an axis requires a unique identifier.
Motion Control	Specify a unique tag to identify the motion instruction.
Output	Set the output to use the data structure of the output module that triggers the strobe.
Input	In this example, the input is ignored because none of the latch types include the Enable feature.
Output Cam	Select the output cam profile defined in the Output Cam Editor, as shown in Figure 12.
Cam Start Position	Set to 0. The output cam starts with a position of 0.0 when the axis moves forward and crosses 0.0 mm.
Cam End Position	Set to 1000.0. The output cam rolls over from 1000.0 to 0.0 when it is moving forward, based on the cam start and end positions.
Output Compensation	Use the default tag values for the Output Compensation operand because no compensation is required in this example.
Execution Mode	Set to Continuous. The instruction must run continuously so that each new box gets photographed without having to reset, but will start only when the conveyor is moving forward.
Execution Schedule	Set to Forward Only. The instruction starts as soon as the axis moves past the axis arm position in the forward direction.

Table 4 - MAOC Operands for Strobe Trigger (continued)

Operand	Configuration
Axis Arm Position	Set to 0.0 with the knowledge that the box is 0.5 m further on the conveyor belt.
Cam Arm Position	Set to 0.0. This operand determines the position in the output cam at the moment that the output cam is armed. In this application, no phase correction is required.
Position Reference	Set to Actual. The Conveyor_Feedback axis is a feedback-only axis, so the position reference must be the actual position of the axis.

Applicator Control Example

In this applicator control example, glue applicators apply four lines of glue in controlled patterns on moving web material.

Figure 14 - Applicator Control Example

[Figure 15](#) shows the configuration of the output cam for this example:

- The configuration includes a short and long pulse for each glue applicator.
- The pulses use the Position and Enable parameter. This lets the programmer disable the glue when running the system at very low speeds, which creates excess glue production, or when running tests without any product.
- The last two entries let the programmer set a purge cycle in which glue continues to run without following the master axis. When the enable bits are turned On, the glue heads continue to operate even if the axis is not moving.

Figure 15 - Output Cam for Applicator Control

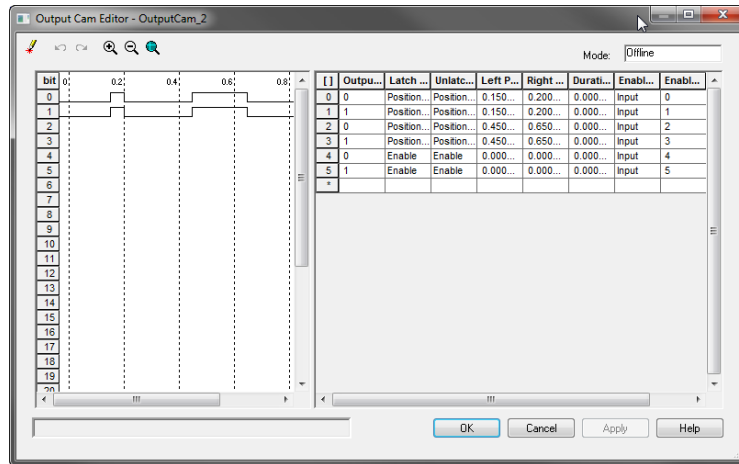


Figure 16 shows the configuration of the MAOC Instruction for this example.

Figure 16 - MAOC Instruction for Applicator Control

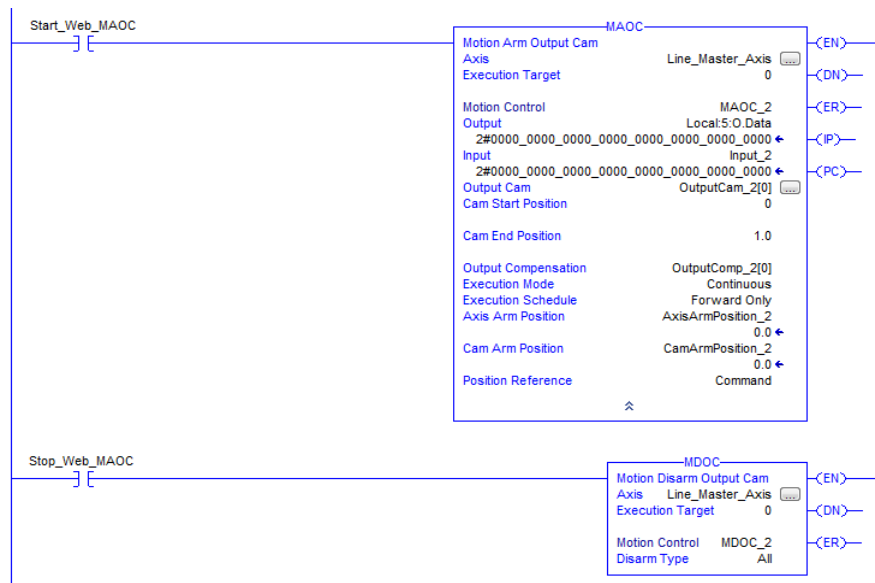


Table 5 - MAOC Operands for Applicator Control

Operand	Configuration
Axis	Coordinate the instruction with a virtual line master axis.
Execution Target	Specify a value of 0 . . . 7. Each output cam on an axis requires a unique identifier.
Motion Control	Specify a unique tag to identify the motion instruction.
Output	Set the output to use the data structure of the output module that triggers the strobe.
Input	Specify the input tag that controls the Enable bits for each member of the output cam. The Enable bits can be controlled from logic or from an operator terminal.
Output Cam	Select the output cam profile defined in the Output Cam Editor, as shown in Figure 15 .
Cam Start Position	Set to 0. Program the instruction to start only as the axis rolls over to zero in the forward direction, maintaining synchronization with the virtual master.

Table 5 - MAOC Operands for Applicator Control (continued)

Operand	Configuration
Cam End Position	Set equal to the unwind distance of the axis. In this example, the distance is 1.0.
Output Compensation	Specify the tag associated with the output compensation structure, as shown in Figure 17 .
Execution Mode	Set to Continuous. The instruction can run continuously because the virtual line master axis unwinds with each product.
Execution Schedule	Set to Forward Only. The instruction starts as soon as the axis moves past the axis arm position in the forward direction.
Axis Arm Position	Set to 0.0 to align the output cam with the virtual master axis.
Cam Arm Position	Set to 0.0. This operand determines the position in the output cam at the moment that the output cam is armed. In this application, no phase correction is required.
Position Reference	Set to Command because the target axis is controlled.

This application example also requires you to use output compensation with the MAOC instruction. Output compensation enables the motion planner to account for the delay in opening and closing valves, relays, or other delays inherent to the application. As shown in [Figure 17](#), the valve takes 10 ms to open and 15 ms to close.

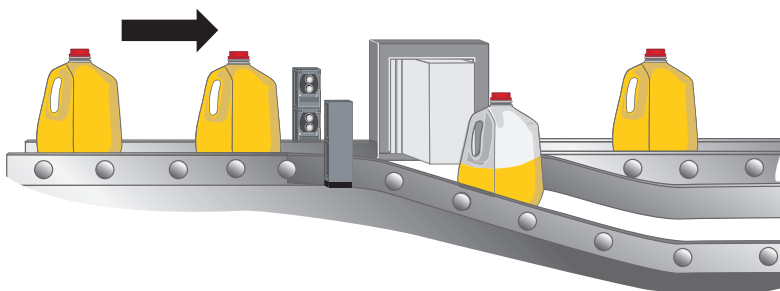
Figure 17 - Output Compensation for Applicator Control

[-] OutputComp_2		{...}	{...}		OUTPUT_COMP...
[-] OutputComp_2[0]		{...}	{...}		OUTPUT_COMP...
[-] OutputComp_2[0].Offset		0.0		Float	REAL
[-] OutputComp_2[0].LatchDelay		0.01		Float	REAL
[-] OutputComp_2[0].UnlatchDelay		0.015		Float	REAL
[+] OutputComp_2[0].Mode		0		Decimal	DINT
[-] OutputComp_2[0].CycleTime		0.0		Float	REAL
[-] OutputComp_2[0].DutyCycle		0.0		Float	REAL

Product Diverting Example

In this product diverting example, jugs of orange juice pass along the conveyor belt while sensors determine the fullness of each jug. If a jug is not full, it is deflected off of the conveyor belt, as shown below.

Figure 18 - Product Diverting Example



The programming logic for this example must take into account the following:

- The sensor and the center of the actuator are 9 in. apart.
- Each bottle is nominally 12 in. apart.
- The conveyor measures the position of the bottles in inches.

Typically, you can use timers to measure position with constant speed conveyors, but if the conveyors are starting and stopping regularly, use the position of the belt instead of timers.

Figure 19 shows the configuration of the output cam for this example. The configuration schedules the actuator to extend after 9 in. of travel and to stay extended until after an additional inch of travel.

Figure 19 - Output Cam for Product Diverting

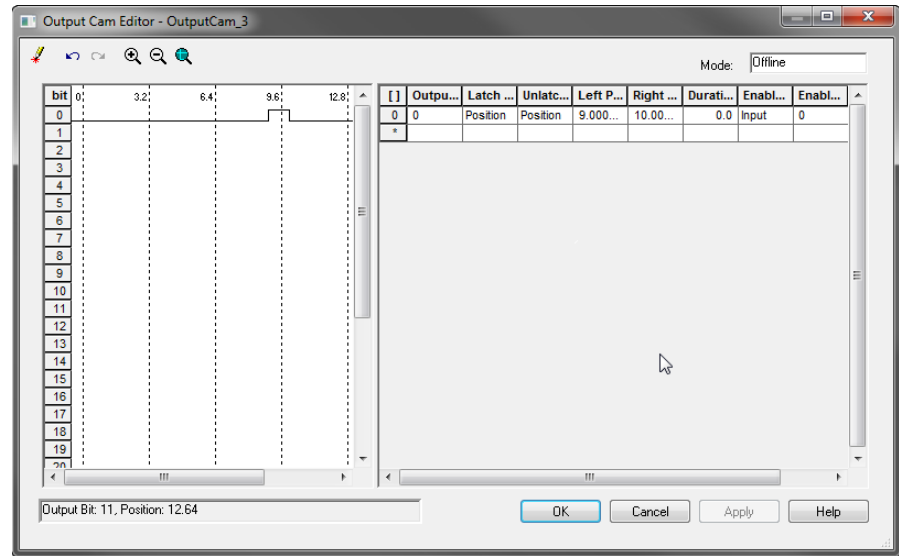
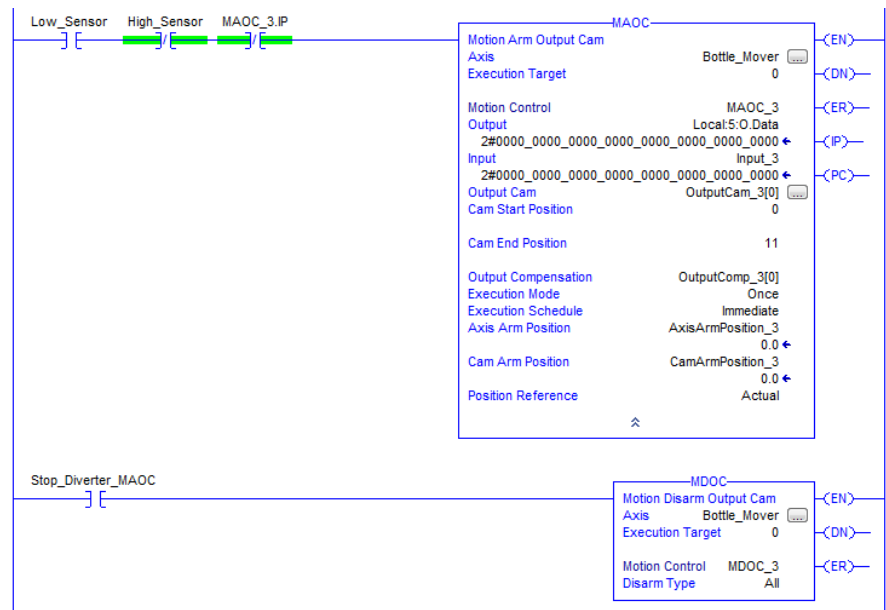


Figure 20 shows the configuration of the MAOC instruction for this example. The instruction starts if the low sensor detects liquid, but the top sensor does not. Triggering the instruction can be more complicated in an actual machine. The instruction starts immediately and ends after the bottle mover has traveled 11 in.

Figure 20 - MAOC Instruction for Product Diverting



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For an additional level of technical phone support for installation, configuration, and troubleshooting, we offer TechConnect™ support programs. For more information, contact your local distributor or Rockwell Automation representative, or visit <http://www.rockwellautomation.com/support/>.

Installation Assistance

If you experience a problem within the first 24 hours of installation, review the information that is contained in this manual. You can contact Customer Support for initial help in getting your product up and running.

United States or Canada	1.440.646.3434
Outside United States or Canada	Use the Worldwide Locator at http://www.rockwellautomation.com/support/americas/phone_en.html , or contact your local Rockwell Automation representative.

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Rockwell Automation tests all of its products to ensure that they are fully operational when shipped from the manufacturing facility. However, if your product is not functioning and needs to be returned, follow these procedures.

United States	Contact your distributor. You must provide a Customer Support case number (call the phone number above to obtain one) to your distributor to complete the return process.
Outside United States	Please contact your local Rockwell Automation representative for the return procedure.

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