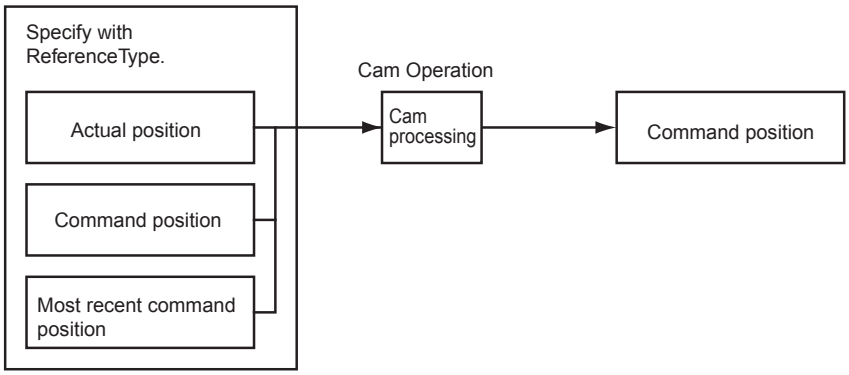
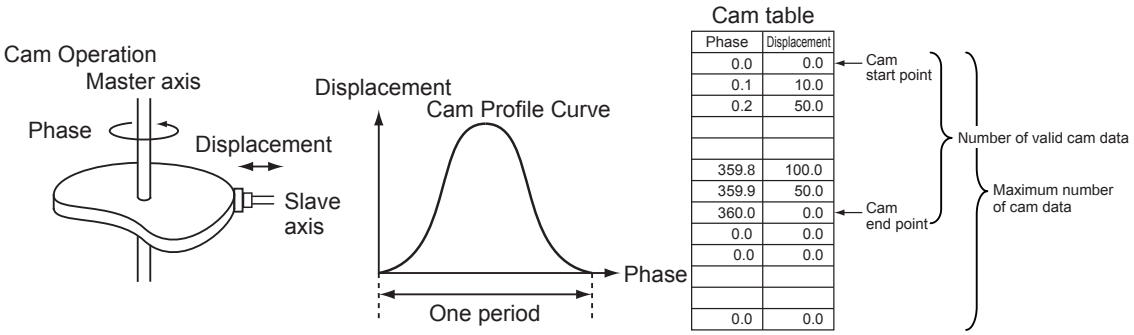
## 9-2-4 Cam Operation

Cam operation synchronizes the position of the slave axis with the master axis according to a cam table. Start cam operation with the MC_CamIn (Start Cam Operation) instruction. End cam operation with the MC_CamOut (End Cam Operation) instruction or the MC_Stop instruction. Create a cam table using the Cam Editor in the Sysmac Studio and download it to the CPU Unit. Use the Synchronization menu command of the Sysmac Studio to download the project to the CPU Unit.




In a combination of a CPU Unit with unit version 1.06 or later and Sysmac Studio version 1.07 or higher, the following operation is possible: if another MC_CamIn (Start Cam Operation) instruction is executed by using multi-execution with the Buffer Mode set for blending while the current MC_CamIn (Start Cam Operation) instruction is executed, the operation can continue using the switched cam table and the slave axis does not stop.

For details on cam operation, refer to the MC_CamIn (Start Cam Operation), MC_CamOut (End Cam Operation), and MC_Stop instructions in the *NJ-series Motion Control Instructions Reference Manual* (Cat. No. W508).

For details on the Cam Editor, refer to the *Sysmac Studio Version 1 Operation Manual* (Cat. No. W504).

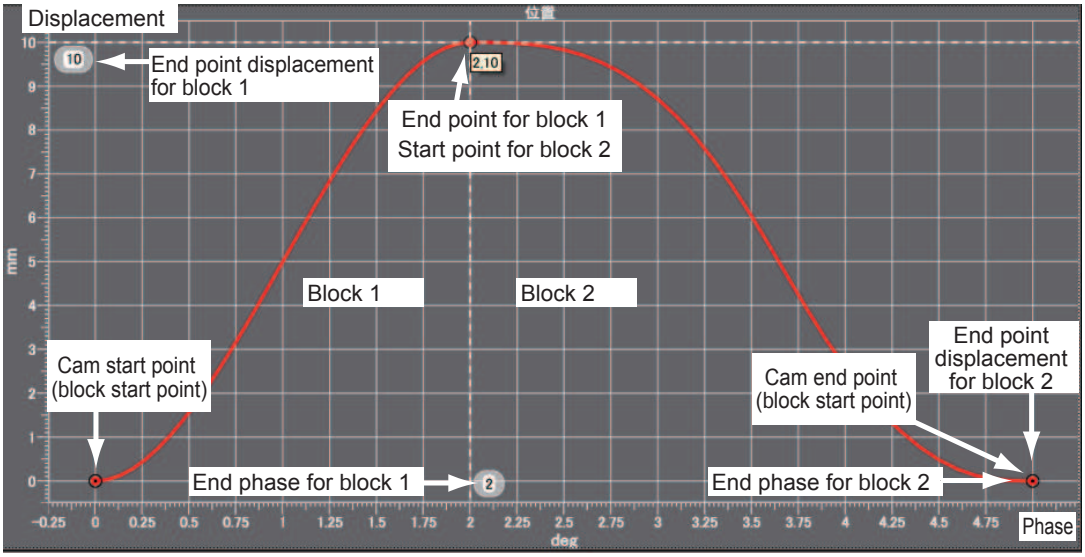
## 9-2-5 Cam Tables

This section describes the cam tables that are used for cam operation.

### Cam Table Terminology

| Term | Description |
|---|---|
| cam operation | An operation that takes one master axis and one slave axis and follows the cam profile curve to derive the displacement of the slave axis from the phase of the master axis. |
| cam profile curve | A curve that shows the relationship between phases and displacements in a cam operation. Cam profile curves are used in the Cam Editor.<br>The cam profile curve is created on the Sysmac Studio. You can use the cam profile curve with a cam data variable after the cam profile curve is downloaded to the CPU Unit. Use the Synchronization menu command of the Sysmac Studio to download the project to the CPU Unit. |
| cam block | You can select a cam curve in this block. It represents the area between the end point of the previous cam block and the end point of the current cam block. |
| cam curve | A curve that represents the cam characteristics. You can select a cam curve for each cam block. The Sysmac Studio calculates the phase widths and displacement widths from the specified points and creates the actual cam profile curve. You can choose from different curves, such as straight line, parabolic, and trapecloid. |
| cam data | Data made up of phases (master axis) and displacements (slave axis) for cam operation. |
| cam data variable | A variable that represents the cam data as a structure array. |
| cam table | A data table that contains cam data. If phase data is not in ascending order the cam table is treated as an illegal cam table. |
| cam start point | The first point in the cam data. |
| cam end point | The last point of valid cam data in the cam data. If the cam end point is less than the number of cam data, all phases and displacements after the cam end point will be 0. |
| cam block start point | The start point for a cam block. It is the same as the cam start point at the start of the cam operation. If the cam profile curve continues, this will be the same as the cam block end point. |
| cam block end point | The end point for a cam block. It is the same as the cam end point at the end of the cam operation. If the cam profile curve continues, this will be the same as the cam block start point. The cam block end point is defined as (horizontal axis, vertical axis) = (phase end point, displacement end point). |
| original cam data | Cam data that is created by dividing up the cam profile curve in the Cam Editor. |
| program-modified cam data | The cam data changed by the user program while the CPU Unit is in operation. |
| master axis | The axis that serves as the input to the cam operation. You can specify either Linear Mode or Rotary Mode. |
| slave axis | The axis that serves as the output from the cam operation. You can specify either Linear Mode or Rotary Mode. |
| phase | The relative distance on the master axis from the start point of the cam table. |
| displacement | The relative distance on the slave axis from the master following distance. |
| valid cam data | The cam data other than the cam start point and other than data where the phase is 0. |
| invalid cam data | The cam data other than the cam start point where the phase is 0. |
| number of valid cam data | The number of sets of cam data. |
| maximum number of cam data | The maximum number of sets of cam data that the cam table can contain. |
| cam data index | The number of the cam data that is executed. |

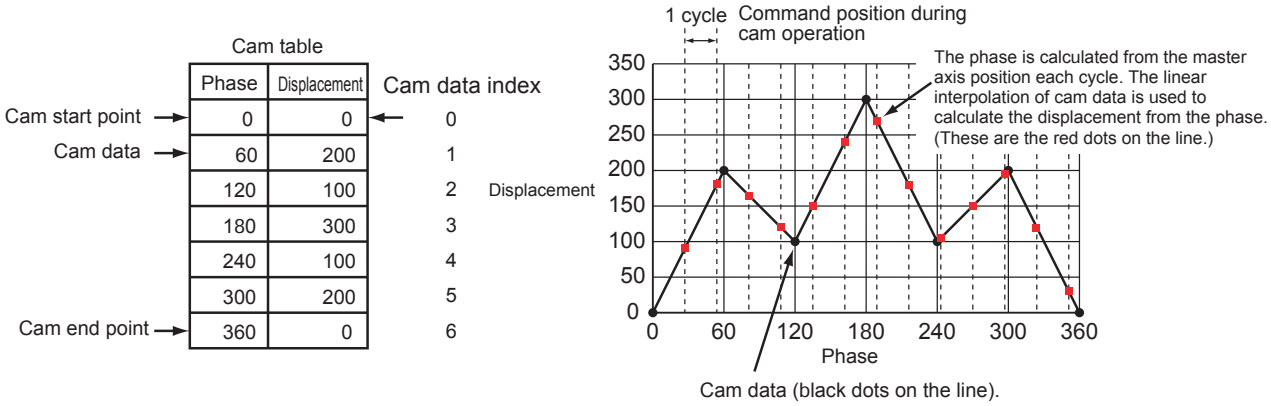
| Term | Description |
|---|---|
| cam table start position | The absolute position of the master axis that corresponds to the cam start point (phase = 0). |
| master following distance | The master start distance where the slave axis starts cam operation represented as either an absolute position or relative position. The relative position is based on the cam start point position. |
| start mode | A specification of whether to represent the master following distance as an absolute position or relative position. |
| null cam data | Cam data that can be set after the end point where the phase and displacement are 0. |
| connecting velocity | The connecting velocity that is used to connect cam profile curves. The connecting velocity cannot be specified for some curves. |
| connecting acceleration | The acceleration rate that is used to connect cam profile curves. The connecting acceleration cannot be specified for some curves. |
| phase pitch | The width when dividing the cam profile curve by phases (horizontal axis). The points after dividing the curve into the phase pitch correspond to the cam data in the cam table. You must specify the phase pitch for each cam block. |



## Cam Tables

The MC Function Module defines a single element of data consisting of the phase of the master axis and the displacement of the slave axis as one cam data. A cam table is defined as the combination of multiple sets of cam data. The cam table is created with the Cam Editor in the Sysmac Studio. You can modify cam data in the cam table from the user program.

The phases and displacements in the cam data that makes up the cam table are represented as relative distances from the start point 0.0. During cam operation, the command position sent to the slave axis is the displacement determined by interpolating linearly between the two cam data elements adjacent to the phase of the master axis. The more cam data there is in the cam table, the more accurate the trajectory and the smoother the cam profile curve will be.




### Precautions for Correct Use

- Make sure that the cam data is arranged in the cam table so that the phases are in ascending order. An instruction error occurs if a cam operation instruction is executed when the phases are not in ascending order.
- Cam data variables are global variables. You can therefore access or change the values of cam data variables from more than one task. If you change the values of cam data variables from more than one task, program the changes so that there is no competition in writing the value from more than one task.
- If you use exclusive control of global variables between tasks for a cam data variable, do not use the cam data variable for motion control instructions in a task that does not control the variable. An Incorrect Cam Table Specification error (error code: 5439 hex) will occur.

## Cam Table Specifications

| Item | Description |
|---|---|
| Maximum number of cam data per cam table | 65,535 points |
| Maximum size of all cam data | 1,048,560 points*1 |
| Maximum number of cam tables | 640 tables*2 |
| Switching cam operation | You can switch to a different cam operation by executing a motion control instruction |
| Changing cam data | Cam data can be edited from the user program.<br>Cam data can be overwritten with the Generate Cam Table instruction.*3 |
| Saving cam data | Cam data can be saved to non-volatile memory by using the Save Cam Table instruction. |
| Information attached to the cam data | Information can be downloaded or uploaded for display in the Cam Editor*4 |
| Timing to load cam data to main memory | • When the data is downloaded from the Sysmac Studio<br>• When power is turned ON |

*1 If 65,535 points are used for each cam table, there will be a maximum of 16 cams. A resolution of 0.1° allows for a maximum of 3,600 points per cam table for a maximum of 291 cams.

*2 The total size is 10 MB max.

*3 A CPU Unit with unit version 1.08 or later and Sysmac Studio version 1.09 or higher are required to use the Generate Cam Table instruction.

*4 Use the Synchronization menu command of the Sysmac Studio to upload and download the project.

## Data Type of Cam Tables

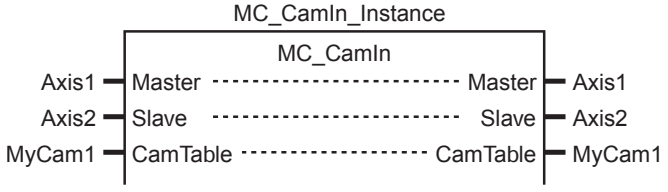
A cam table is declared as an array of cam data structures. The type declaration for the cam data structure is shown below.

```
TYPE
        (*Cam data structure*)
        _sMC_CAM_REF :
        STRUCT
                Phase       : REAL;       (*Phase*)
                Distance    : REAL;       (*Displacement*)
        END_STRUCT;
END_TYPE
```

You must create the cam data with the Cam Editor in the Sysmac Studio and then specify the name of the cam table and the number of cam data (i.e., the size of the array). For example, to make a cam table called *MyCam1* with 1,000 points use the following declaration.

```
VAR
        (*Cam table*)
        MyCam1          :       ARRAY [0..999] OF _sMC_CAM_REF;
END_VAR
```

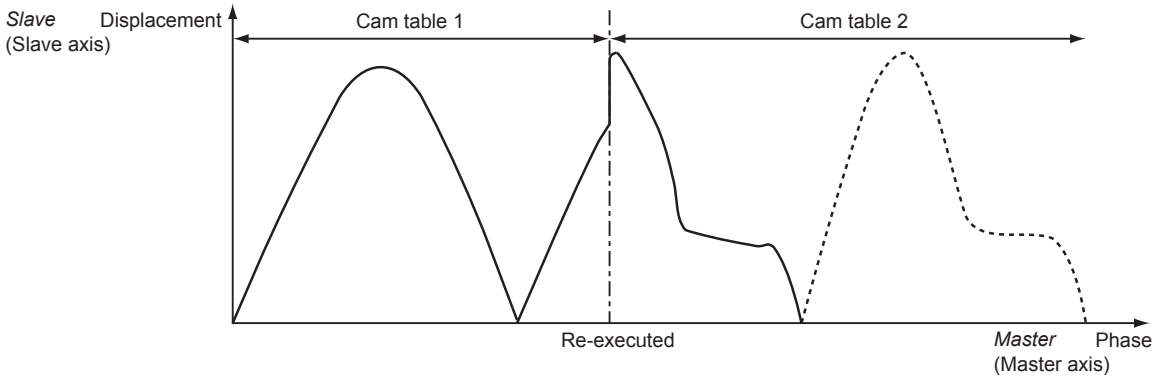
The following notation is used to specify *MyCam1* for a cam operation instruction. In this example, the master axis is *Axis1* and the slave axis is *Axis2*.



An error will occur if the specified cam table does not exist in the Controller. You can also specify the same cam table for more than one axis.

## Switching Cam Tables

You can switch cam tables by re-executing the cam operation instruction during cam operation. After switching, cam operation will be performed with the cam table you specified for re-execution of the instruction. The *EndOfProfile* and *Index* output variables from the MC_CamIn instruction are output according to the new cam table.




**Precautions for Correct Use**

- The cam table you want to switch to must be saved to non-volatile memory before it can be used.
- Switching cam tables during cam operation will cause discontinuous velocities. Adjust the timing for switching the cam table to avoid excessive velocity discontinuity.

## Loading/Saving Cam Data and Saving Cam Tables

Cam data can be loaded and saved from the user program just like any other variables. For example, you can use *MyCam1[0].Phase* to specify the phase and *MyCam1[0].Distance* to specify the displacement in the first array elements of a cam table named MyCam1. Cam data overwritten from the user program can be saved to the non-volatile memory in the CPU Unit as a cam table by executing the MC_SaveCamTable instruction.

**Precautions for Correct Use**

- Overwritten cam data will be lost if the CPU Unit is turned OFF or the cam data is downloaded from the Sysmac Studio before the Save Cam Table instruction is executed or if the instruction fails to save the data for any reason.
- Overwritten cam data will be lost if the CPU Unit is turned OFF before the Save Cam Table instruction is executed or if the instruction fails to save the data for any reason. Be careful not to lose the overwritten data when overwriting cam data from the user program in the CPU Unit.
- Cam data saved to non-volatile memory can be loaded by using the upload function of the Sysmac Studio.
- Use the Synchronization menu command of the Sysmac Studio to upload and download the project.

For details on arrays, refer to the *NJ-series CPU Unit Software User's Manual* (Cat. No. W501).

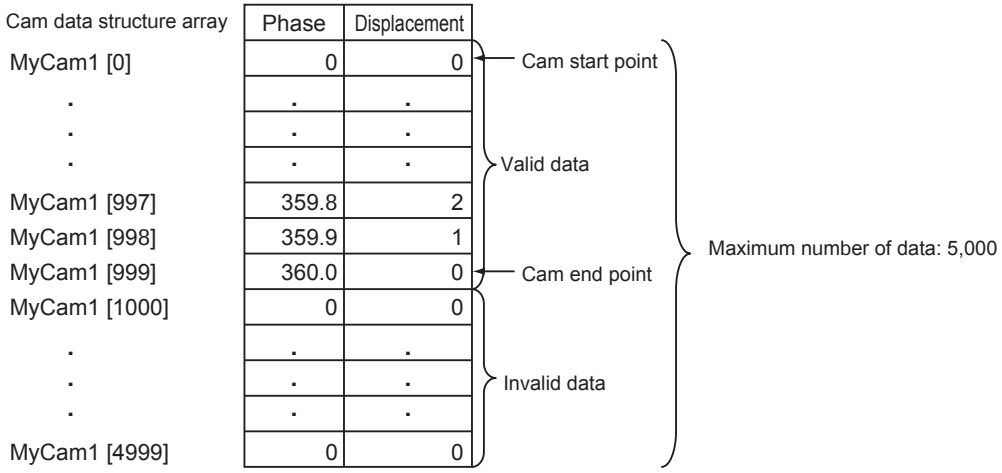
For details on the Save Cam Table instruction, refer to the MC_SaveCamTable instruction in the *NJ-series Motion Control Instructions Reference Manual* (Cat. No. W508).

## Updating Cam Table Properties

The MC Function Module must identify the cam end point of the cam table. If an overwrite is performed from the user program during cam operation and the number of valid cam data changes, you must update the number of valid cam data to the latest value. Use the MC_SetCamTableProperty instruction for this.

The cam end point is the data located one cam data before the first cam data with a phase of 0 after the start point in the cam table. All cam data after phase 0 is detected will be invalid.

For example, refer to the following cam table. The *EndPointIndex* (End Point Index) output variable is 999 and the *MaxDataNumber* (Maximum Number of Cam Data) output variable is 5,000 from the MC_SetCamTableProperty instruction.




**Precautions for Correct Use**

- You cannot change the maximum number of cam data from the user program.
- Execute this instruction after overwriting the cam data in any way that changes the number of valid cam data. If the number of valid cam data is not updated, the cam operation and the operation of the *EndOfProfile* (End of Cam Cycle) of the MC_CamIn instruction may not be as expected.

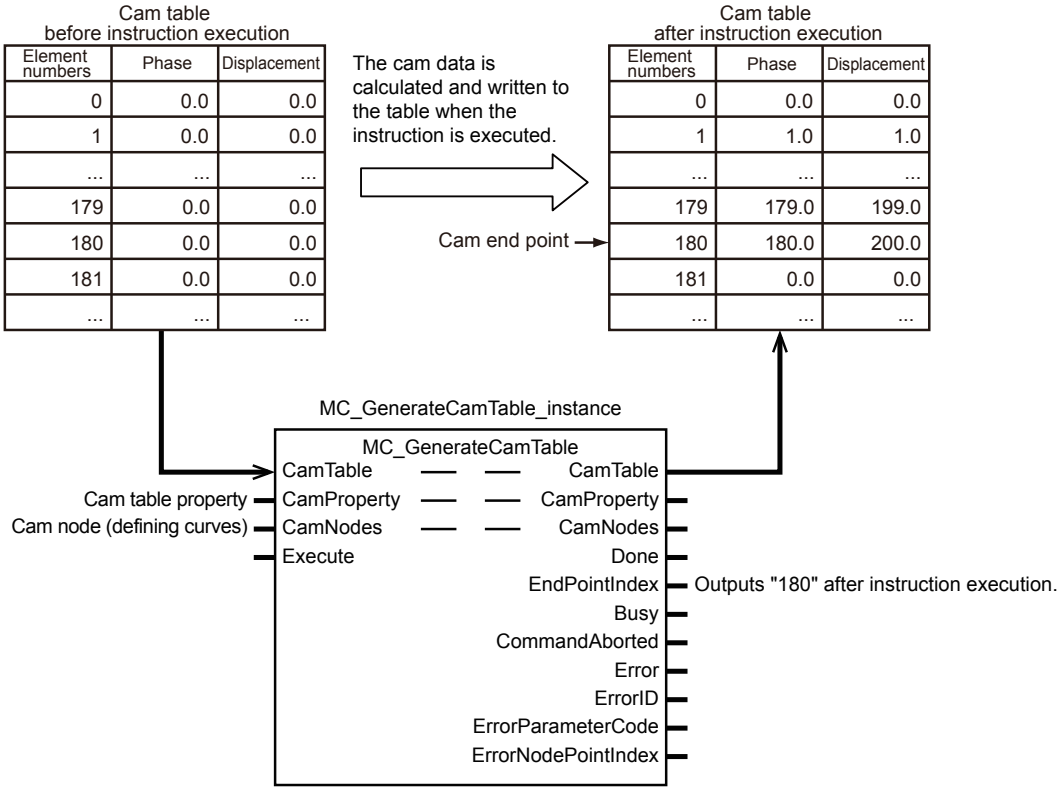
For details on the Set Cam Table Properties instruction, refer to the MC_SetCamTableProperty (Set Cam Table Properties) instruction in the *NJ-series Motion Control Instructions Reference Manual* (Cat. No. W508).

## Generate Cam Table

With a CPU Unit with unit version of 1.08 or later and the Sysmac Studio version 1.09 or higher, you can generate the cam table by executing the MC_GenerateCamTable (Generate Cam Table) instruction.

The MC_GenerateCamTable instruction calculates the cam data using the values specified for *CamProperty* (Cam Properties) and *CamNodes* (Cam Nodes), and rewrites the cam data variable specified for the *CamTable* (Cam Table) in-out variable.

When rewriting is completed, the MC_GenerateCamTable instruction updates the end point index of the cam table and outputs the element number of the cam end point to *EndPointIndex* (End Point Index).
It is not necessary to execute the MC_SetCamTableProperty (Set Cam Table Properties) instruction after the MC_GenerateCamTable instruction is completed.




The cam data variable is an array variable with the data type of cam data structure _sMC_CAM_REF. You create the cam data variable on the Cam Editor of the Sysmac Studio.
For *CamProperty*, specify the cam property variable. The cam property variable is an array variable with the data type of cam property structure _sMC_CAM_PROPERTY. You create the cam property variable as a user-defined variable on the global variable table of the Sysmac Studio. Or, you create the variable using the cam data settings on the Sysmac Studio.
For *CamNode*s, specify the cam node variable. The cam node variable is an array variable with the data type of cam node structure _sMC_CAM_NODE. You create the cam node variable as a user-defined variable on the global variable table of the Sysmac Studio. Or, you create the variable using the cam data settings on the Sysmac Studio.
The cam property variable and the cam node variable are collectively called “cam definition variable”.

If the cam definition variable is created as a user-defined variable, the default of its Retain attribute is Non-retain. You must set the Retain attribute of variable to Retain, if you want to reuse the variable after changing its value and switching the operating mode to PROGRAM mode or cycling the power supply. If you set the variable each time of use from the PT, etc., the attribute can be left Non-retain.
If the cam definition variable is created with the cam data settings on the Sysmac Studio, the Retain attribute of variable will be fixed to Retain.

By using the PT, etc. to set the values for the MC_GenerateCamTable instruction, you can create the cam data variable and adjust the cam operation without using the Sysmac Studio.
The following is the procedure used to adjust the cam operation.

1. Create a user program, in advance, that includes the following processing.
   - Assigning the value of the cam definition variable that is set from the PT to the Generate Cam Table instruction.
   - Displaying the cam variable that is created by the Generate Cam Table instruction graphically on the PT.
   - Displaying the value of *EndPointIndex* (End Point Index) on the PT.
2. Set the value of the cam definition variable from the PT.
3. Execute the Generate Cam Table instruction.
4. Verify the curve shape of the generated cam table and the value of the end point index displayed on the PT.
5. If there is no problem with the curve shape of the cam table and the number of the cam data, then execute the cam operation.
6. Verify the result of the cam operation and consider changing the value of the cam definition variable.
7. Repeat steps 2 to 6.

For details on the cam definition variable and the Generate Cam Table instruction, refer to the MC_GenerateCamTable instruction in the *NJ-series Motion Control Instructions Reference Manual* (Cat. No. W508-E1-08 or later).

Refer to the *Sysmac Studio Version 1 Operation Manual* (Cat. No. W504-E1-10 or higher) for information on creating and transferring the cam definition variables using the Sysmac Studio.