An MPiec Surface Compensation Solution for 3D Printers and CNC Applications

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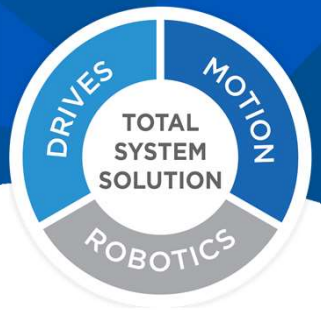


Surface Compensation Overview

- **Purpose**
  - Measure surface variations
  - Compensate for surface variations through displacement data
    - Distance from the tool to the surface

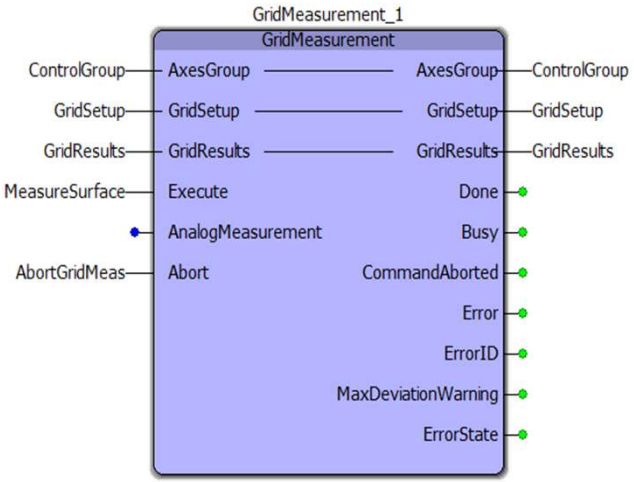
- **Function blocks**
  - GridMeasurement
  - GridControl
  - ReadGridFile
  - WriteGridFile

Example 1: Bumpy surface

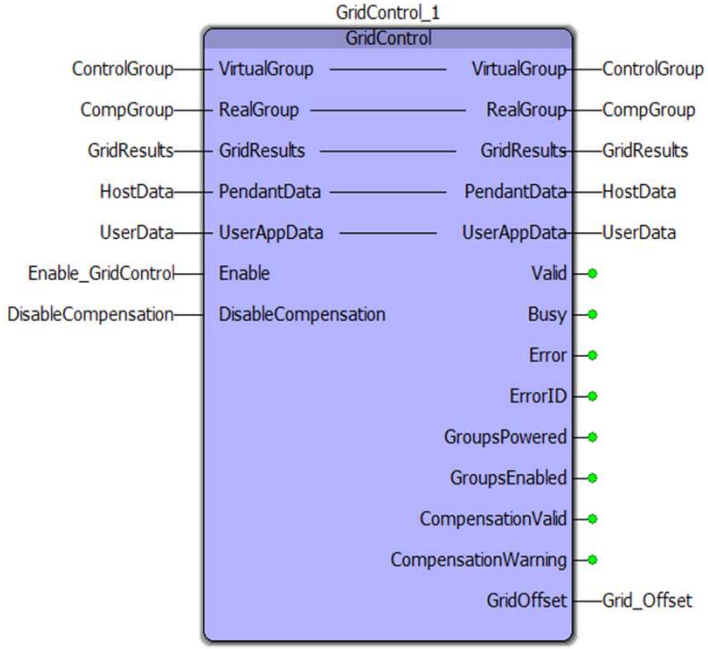
Example 2: Wavy surface

Core Function Blocks

- **GridMeasurement**
  - Measure the displacement from the tool to a surface

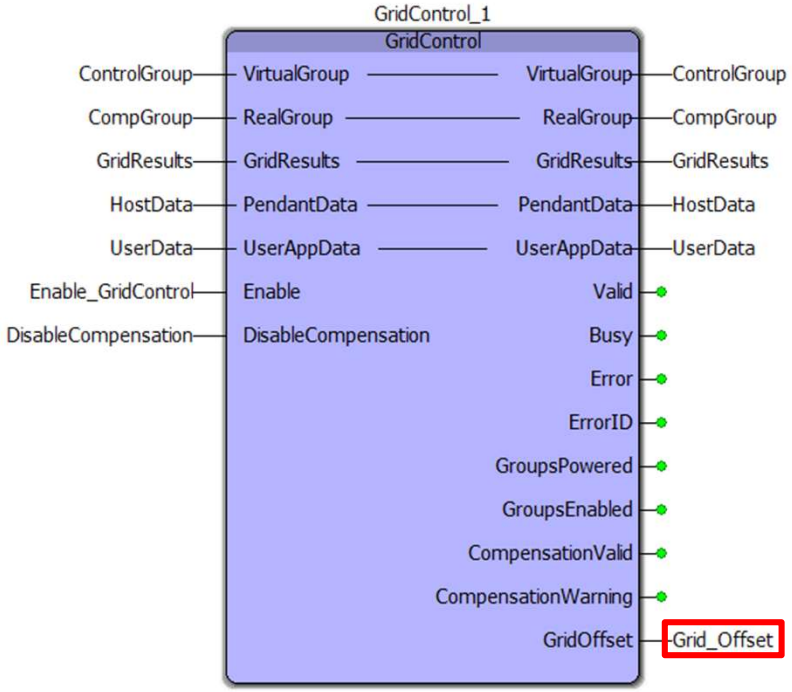


- **GridControl**
  - Controls the real group via Y_GroupDirectControl
  - Calculates position offset
  - Applies offset to the axis commanded position in real time



Core Function Blocks

- **GridControl**
  - Two Groups
    - Virtual Group (Control Group)
      - Does not need to be made up of all virtual axes
    - Real Group (Compensation Group)
      - Custom Group made up of real axis
      - Can have a prime axis
  - Function block controls CompGroup
  - Applies compensation offset to the axis commanded position
    - Applied in real-time



Control Group

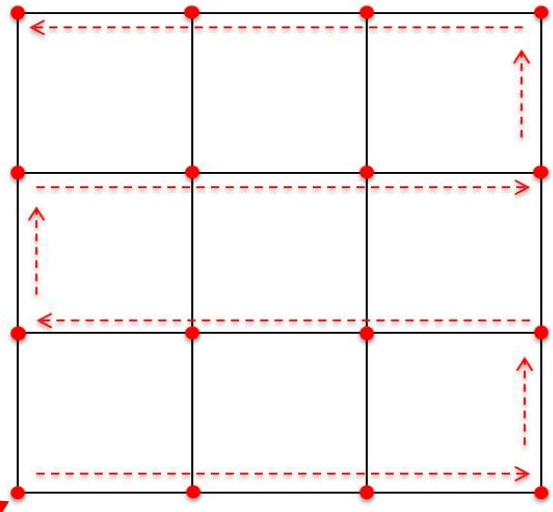
Label	Axis Name
X	X
Y	Y
Z	VirtualZ
FExt	FExt

Comp Group

Label	Axis Name
Z	Z
Z'	ZPrime

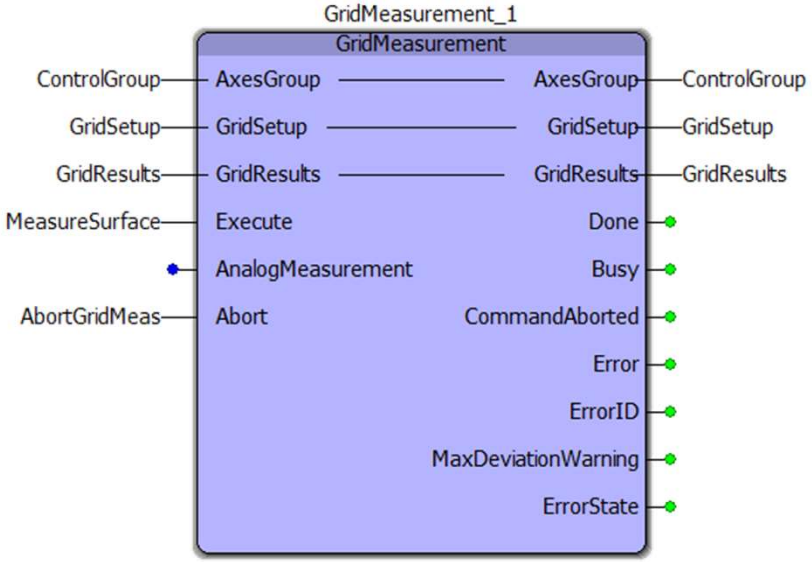
Core Function Blocks

- **GridMeasurement**
  - Measure the displacement from the tool to the surface



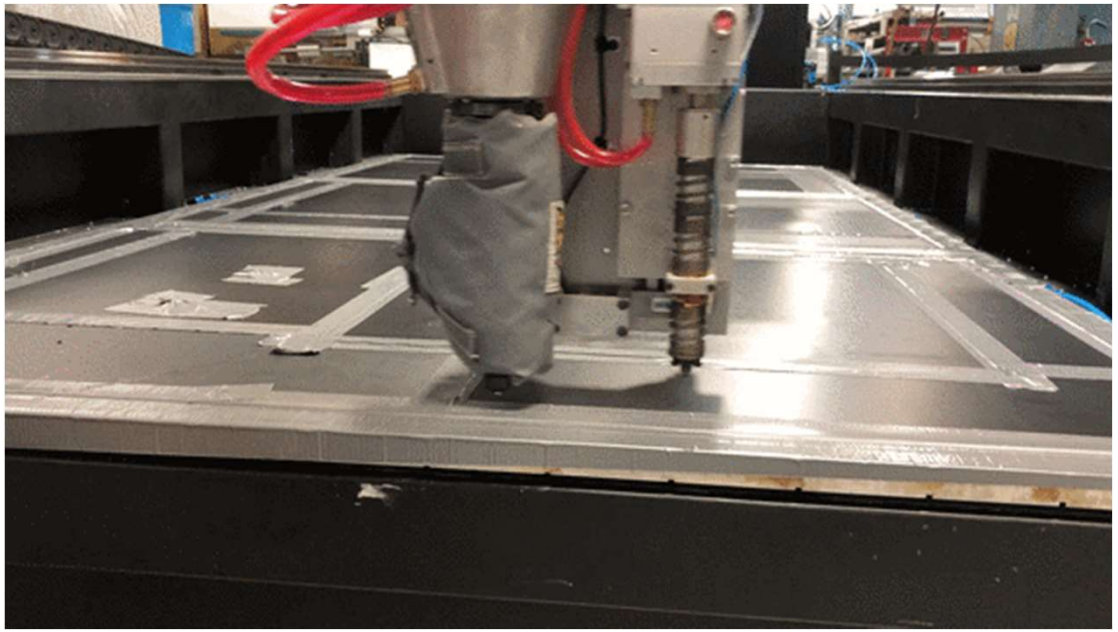
Example Grid

The real Z Axis must be zeroed at its first measurement point. (GridSetup.MinCorner)



GridMeasurement

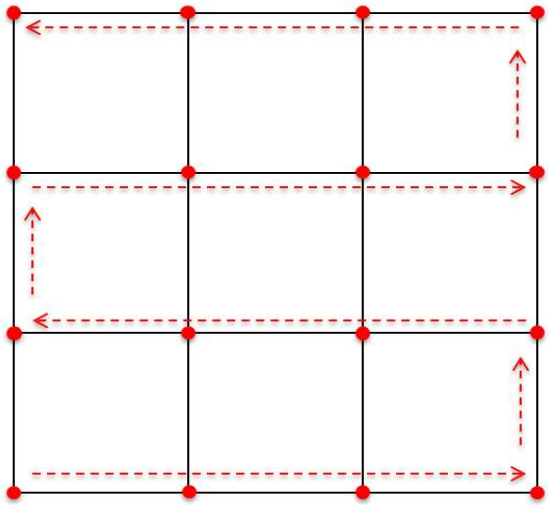
Recording the measured data



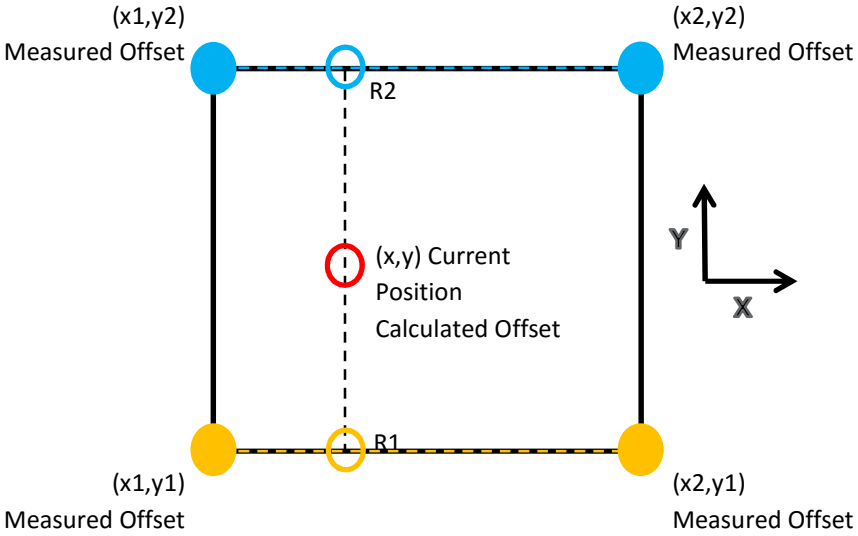
Example: Analog Measure Method

GridControl

Calculating the compensation value using Bilinear Interpolation

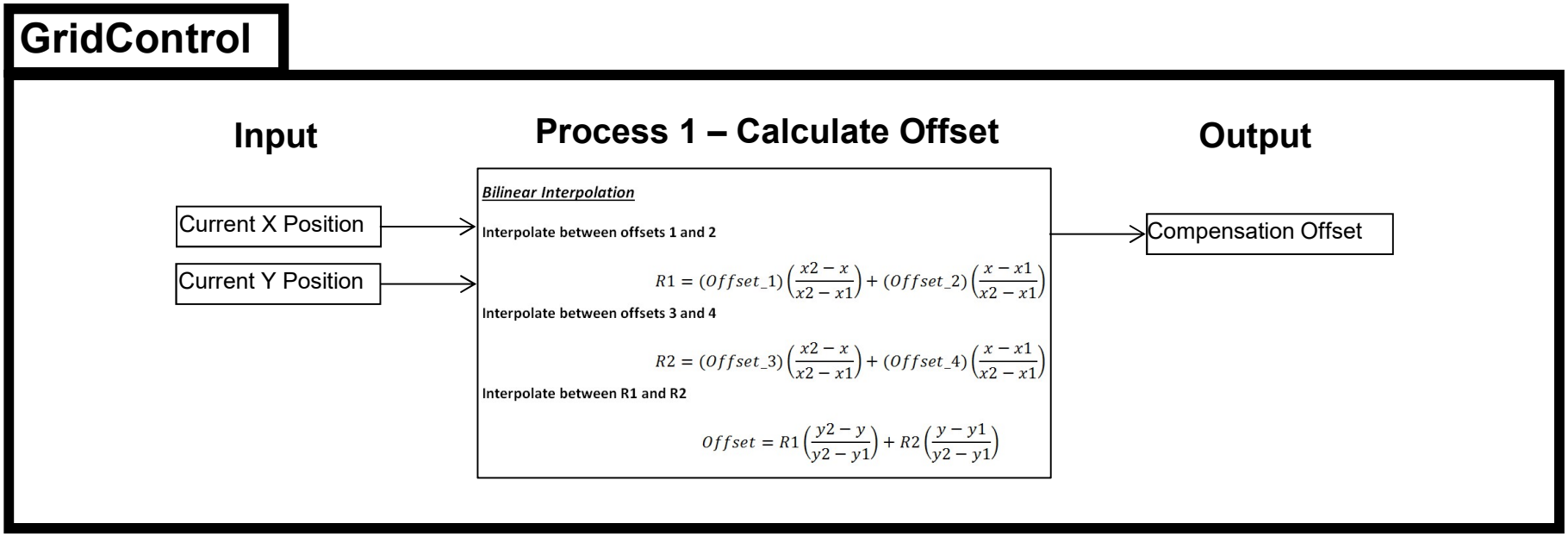


Example Grid



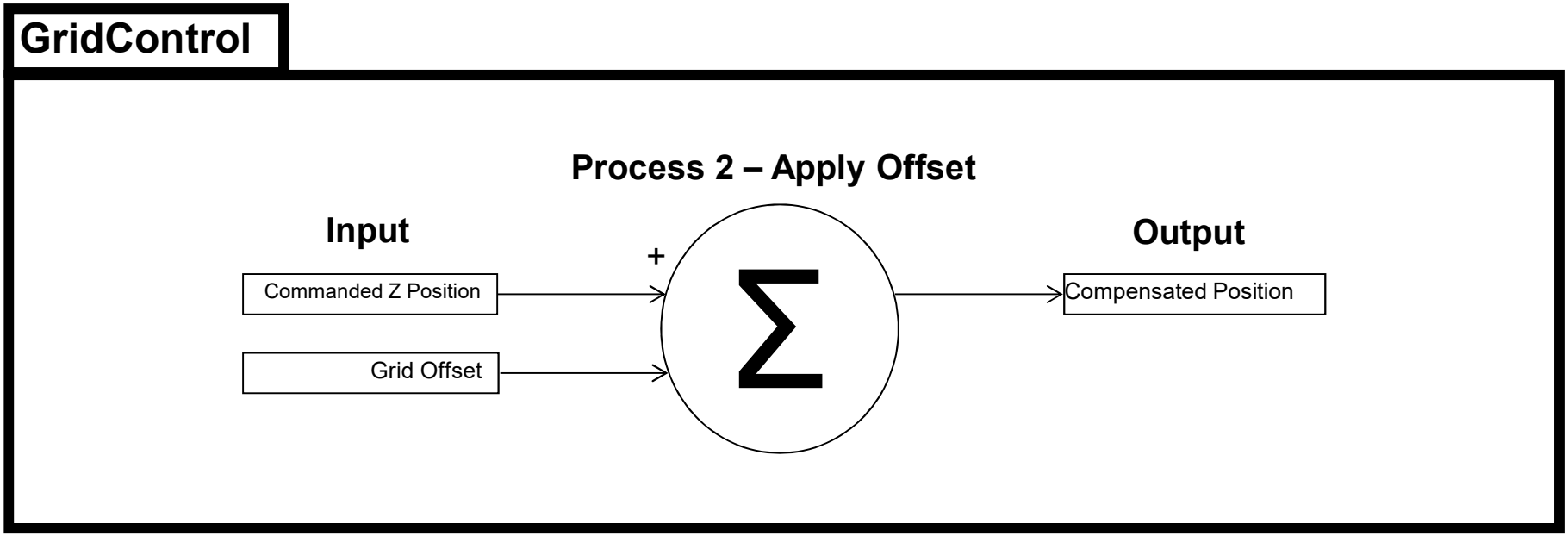
GridControl

Process 1: Calculating the Compensation offset



GridControl

Process 2: Calculating the Gridoffset



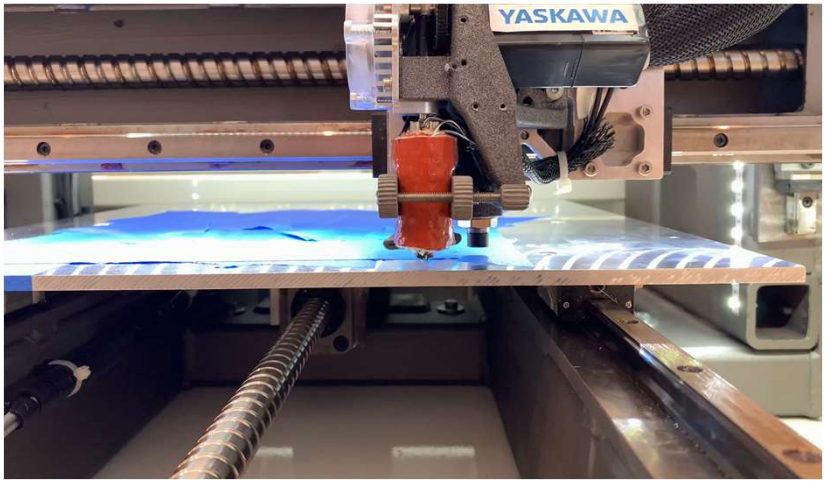
Methods of Measurement

GridSetup.MeasureMethod

- **Analog Input**
  - Laser / LVDT
  - Input to LIO option card or SLIO
    - Variable used as VAR_INPUT to GridMeasurement
    - Datatype: BOOL
  - GTB_MeasureMethod#Analog

- **Digital Input**
  - Proximity Sensor input to Servopack CN-1
  - MC_TouchProbe
    - GridSetup.DigitalTrigger
    - Datatype: Trigger_Ref
  - GTB_MeasureMethod#Digital

- **Torque Feedback (least recommended)**
  - Sets Servopack torque limit
    - Pn 402 (positive torque) or Pn 403 (negative torque)
  - Tool point surface contact
  - MC_ReadActualTorque
    - GridSetup.TorqueLimit
    - Datatype: DINT
  - GTB_MeasureMethod#Torque

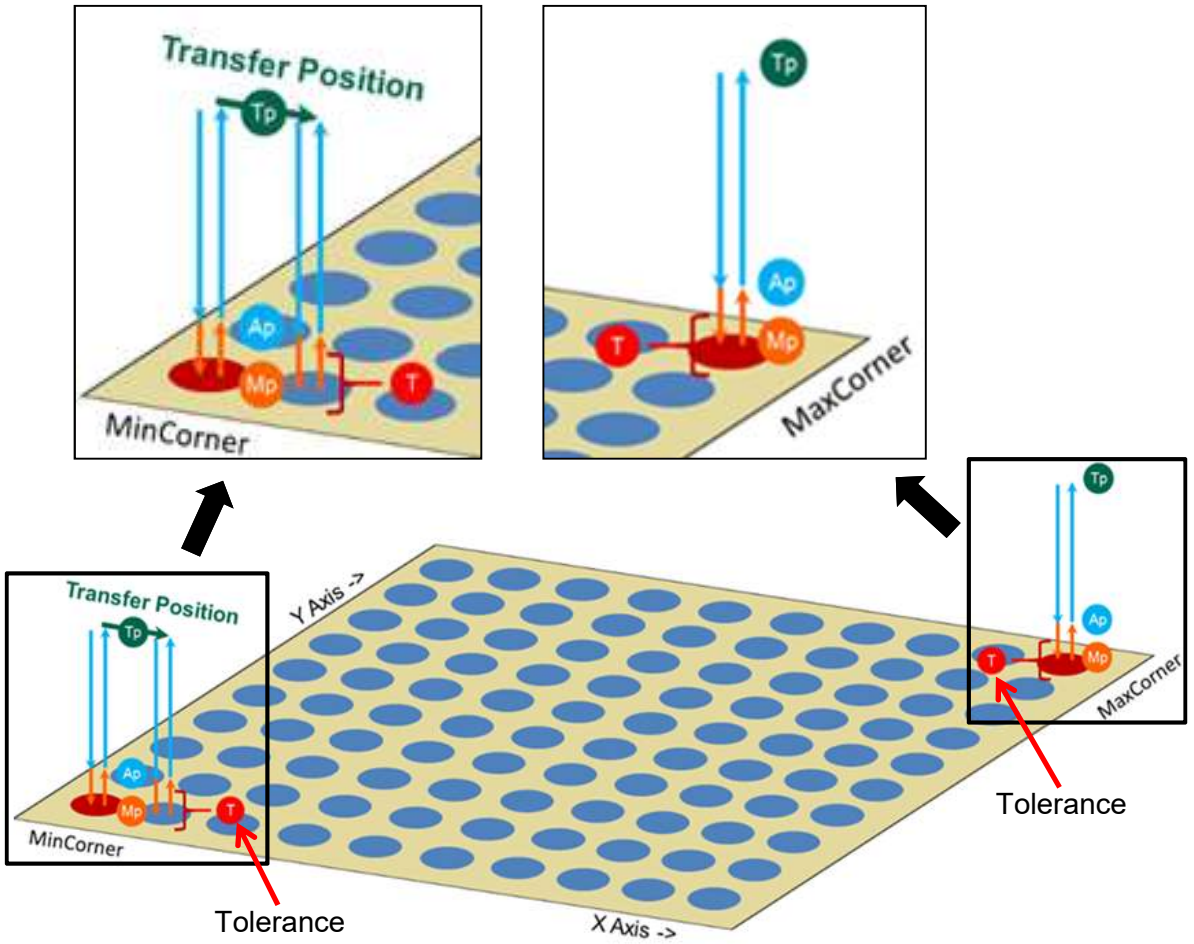


Example: Digital Measure Method

GridMeasurement

GridSetup Structure

Name	Type
GridSetup	GridSetupStruct
MeasureMethod	GTB_MeasureMethod
MeasuredPlane	YTB_STRING8
ExternalPlane	GTB_MotorArray
[0]	AXIS_REF
AxisNum	UINT
[1]	AXIS_REF
[2]	AXIS_REF
DigitalTrigger	TRIGGER_REF
Input	INPUT_REF
ID	UINT
Bit	UINT
Pattern	INT
ID	UINT
TorqueLimit	DINT
MinCorner	YTB_LrealArray2
[0]	LREAL
[1]	LREAL
MaxCorner	YTB_LrealArray2
[0]	LREAL
[1]	LREAL
ResolutionX	INT
ResolutionY	INT
Tolerance	LREAL
MaxDeviation	LREAL
Acceleration	LREAL
TransferVelocity	LREAL
ApproachVelocity	LREAL
MeasurementVelocity	LREAL
TransferPosition	LREAL
ApproachPosition	LREAL
MeasurementPosition	LREAL



GridMeasurement

Machine must have its zero position set at the location of the first measurement!

- **MinCorner[0] = X position**
- **MinCorner[1] = Y Position**

GridSetup Initialization (Digital Measure Method)

```
(* Position [mm], Velocity [mm/s], Acceleration [mm/s^2] in User Units defined in Hardware Configuration *)

(* GridSetup Digital Initialization *)
GridSetup.MeasureMethod := GTB_MeasureMethod#Digital;   (* Measuring using a digital proximity sensor connected to Servopack CN-1 *)
GridSetup.MeasuredPlane := '2';                         (* Measuring the Z plane *)

GridSetup.DigitalTrigger.ID  := UINT#0;                 (* Structure settings used for MC_TouchProbe trigger ref *)
GridSetup.DigitalTrigger.Bit := UINT#1;                 (* Bit 1 = Z_SI4_EXT1 *)

GridSetup.ExternalPlane[0].AxisNum := UINT#5;           (* Real Axis node number, this is controlled bythe virtual axis position in the main group *)
GridSetup.ExternalPlane[1].AxisNum := UINT#6;           (* Real Prime Axis node number *)

(* User units - mm *)
GridSetup.Tolerance    := LREAL#3.0;                    (* Acceptable tolerance of measurements away from Measurement Position *)
GridSetup.MaxDeviation := LREAL#2.5;                    (* Acceptable deviation between highest/lowest measurements before warning triggers *)

GridSetup.ResolutionX  := INT#4;                        (* Resolution squared defines the number of points measured across the surface *)
GridSetup.ResolutionY  := INT#4;                        (* Resolution squared defines the number of points measured across the surface *)

(* Min/Max XY Measurement positions *)
(* User units - mm *)
GridSetup.MinCorner[0] := LREAL#-10.0;                  (* First measurement position X *)
GridSetup.MinCorner[1] := LREAL#-55.0;                  (* First measurement position Y *)
GridSetup.MaxCorner[0] := LREAL#230.0;                  (* Last  measurement position X *)
GridSetup.MaxCorner[1] := LREAL#310.0;                  (* Last  measurement position Y *)

(* Group speed settings *)
(* User units - mm/s *)
GridSetup.Acceleration        := LREAL#9800.0;          (* Acceleration of moves while running GridMeasurement *)
GridSetup.TransferVelocity    := LREAL#50.0;            (* Velocity to while transferring to next measurement location *)
GridSetup.ApproachVelocity    := LREAL#15.0;            (* Approach Velocity while closer to Measurement position *)
GridSetup.MeasurementVelocity := LREAL#3.0;             (* Velocity while scanning for measurement position to be captured *)

(* Z Height Positions *)
GridSetup.TransferPosition    := LREAL#10.0;            (* Height at which machine moves to next measurement position *)
GridSetup.ApproachPosition    := LREAL#6.0;             (* Height at which machine moves to before scanning for trigger *)
GridSetup.MeasurementPosition := LREAL#2.5;             (* Height at which program begins scanning for trigger to record measurement *)
```

GridMeasurement

Machine must have its zero position set at the location of the first measurement!

- **MinCorner[0] = X position**
- **MinCorner[1] = Y Position**

GridSetup Initialization (Analog Measure Method)

```
(* Position [mm], Velocity [mm/s], Acceleration [mm/s^2] in User Units defined in Hardware Configuration *)

(* GridSetup Analog MeasureMethod Initialization *)
GridSetupAnalog.MeasureMethod:=GTB_MeasureMethod#Analog;(* Measuring using a Analog proximity sensor connected to Servopack CN-1 *)
GridSetupAnalog.MeasuredPlane:='Z';                     (* Measuring the Z plane - Label of joint in Hardware Configuration Group *)

GridSetupAnalog.Tolerance:=LREAL#3.0;                   (* Acceptable tolerance of measurements away from Measurement Position *)
GridSetupAnalog.MaxDeviation:= LREAL#2.5;               (* Acceptable deviation between highest/lowest measurements before warning triggers *)

GridSetupAnalog.ResolutionX:=INT#4;                     (* Resolution squrared defines the number of points measured across the surface *)
GridSetupAnalog.ResolutionY:=INT#4;                     (* Resolution squrared defines the number of points measured across the surface *)

(* Min/Max XY Measurement positions *)
GridSetupAnalog.MinCorner[0]:= LREAL#-10.0;             (* First measurement position X *)
GridSetupAnalog.MinCorner[1]:= LREAL#-55.0;             (* First measurement position Y *)
GridSetupAnalog.MaxCorner[0]:= LREAL#230.0;             (* Last  measurement position X *)
GridSetupAnalog.MaxCorner[1]:= LREAL#310.0;             (* Last  measurement position Y *)

(* Group speed settings *)
GridSetupAnalog.Acceleration:=LREAL#9800.0;             (* Acceleration of moves while running GridMeasurement (Default 5x TransferVelocity) *)
GridSetupAnalog.TransferVelocity:=LREAL#50.0;           (* Velocity to next measurement location *)

(* Z Height Position *)
GridSetupAnalog.TransferPosition:=LREAL#10.0;           (* Height at which machine moves to next measurement position *)
```

GridMeasurement

Machine must have its zero position set at the location of the first measurement!

- **MinCorner[0] = X position**
- **MinCorner[1] = Y Position**

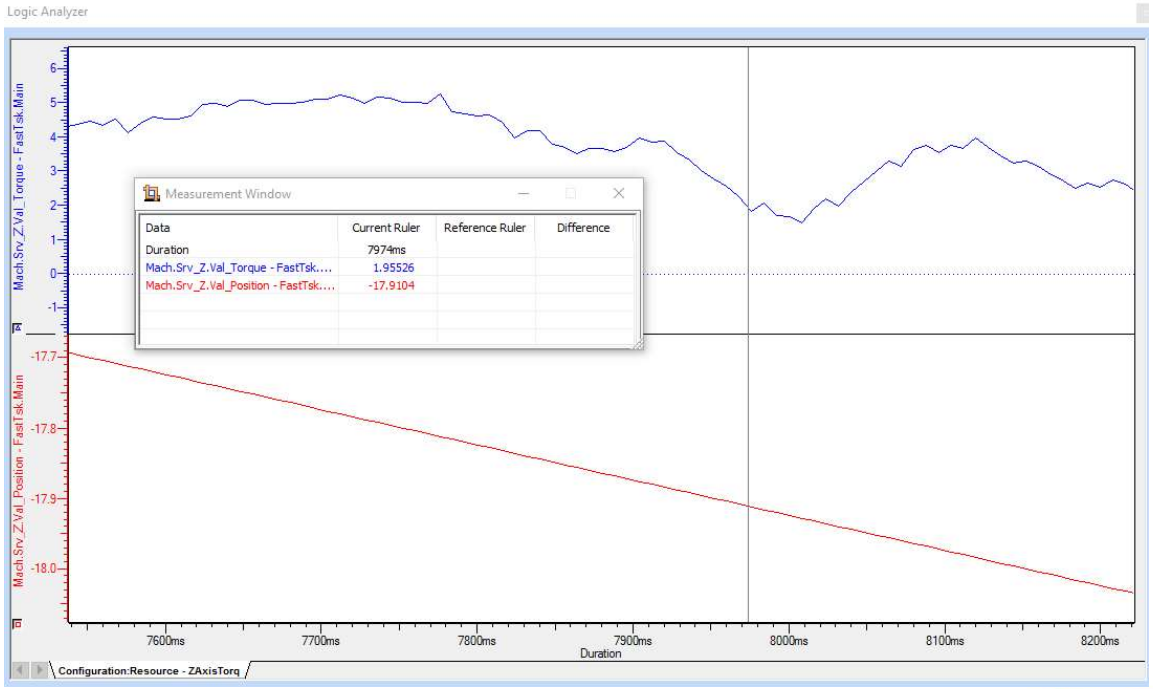
GridSetup Initialization (Torque Measure Method)

```
(* Position [mm], Velocity [mm/s], Acceleration [mm/s^2] in User Units defined in Hardware Configuration *)

(* GridSetup Torque MeasureMethod Initialization *)
GridSetupTorque.MeasureMethod:=GTB_MeasureMethod#Torque;     (* Measuring using a Torque proximity sensor connected to Servopack CN-1 *)
GridSetupTorque.MeasuredPlane:='Z';                          (* Measuring the Z plane - Label of joint in Hardware Configuration Group *)

GridSetupTorque.TorqueLimit:=DINT#1;                         (* Torque limit set on axis when taking measurements.  Measurement is recorded when this torque value is exceeded *)
GridSetupTorque.Tolerance:=LREAL#3.0;                        (* Acceptable tolerance of measurements away from Measurement Position *)
GridSetupTorque.MaxDeviation:= LREAL#2.5;                    (* Acceptable deviation between highest/lowest measurements before warning triggers *)

GridSetupTorque.ResolutionX:=INT#4;                          (* Resolution squrared defines the number of points measured across the surface *)

(* Min/Max XY Measurement positions *)
GridSetupTorque.MinCorner[0]:= LREAL#-10.0;                  (* First measurement position X *)
GridSetupTorque.MinCorner[1]:= LREAL#-55.0;                  (* First measurement position Y *)
GridSetupTorque.MaxCorner[0]:= LREAL#230.0;                  (* Last  measurement position X *)
GridSetupTorque.MaxCorner[1]:= LREAL#310.0;                  (* Last  measurement position Y *)

(* Group speed settings *)
GridSetupTorque.Acceleration:=LREAL#9800.0;                  (* Acceleration of moves while running GridMeasurement (Default 5x TransferVelocity) *)
GridSetupTorque.TransferVelocity:=LREAL#50.0;                (* Velocity to next measurement location *)
GridSetupTorque.ApproachVelocity:= LREAL#15.0;               (* Interim Velocity down to Measurement position *)
GridSetupTorque.MeasurementVelocity:=LREAL#3.0;              (* Velocity while scanning for measurement position to be captured *)

(* Z Height Positions *)
GridSetupTorque.TransferPosition:=LREAL#10.0;                (* Height at which machine moves to next measurement position *)
GridSetupTorque.ApproachPosition:= LREAL#6.0;                (* Height at which machine moves to before scanning for trigger *)
GridSetupTorque.MeasurementPosition:=LREAL#-0.5;             (* Height at which program scans for trigger to record measurement *)
```

GridMeasurement – Determining the Torque Limit

GridSetup Initialization (Torque Measure Method)

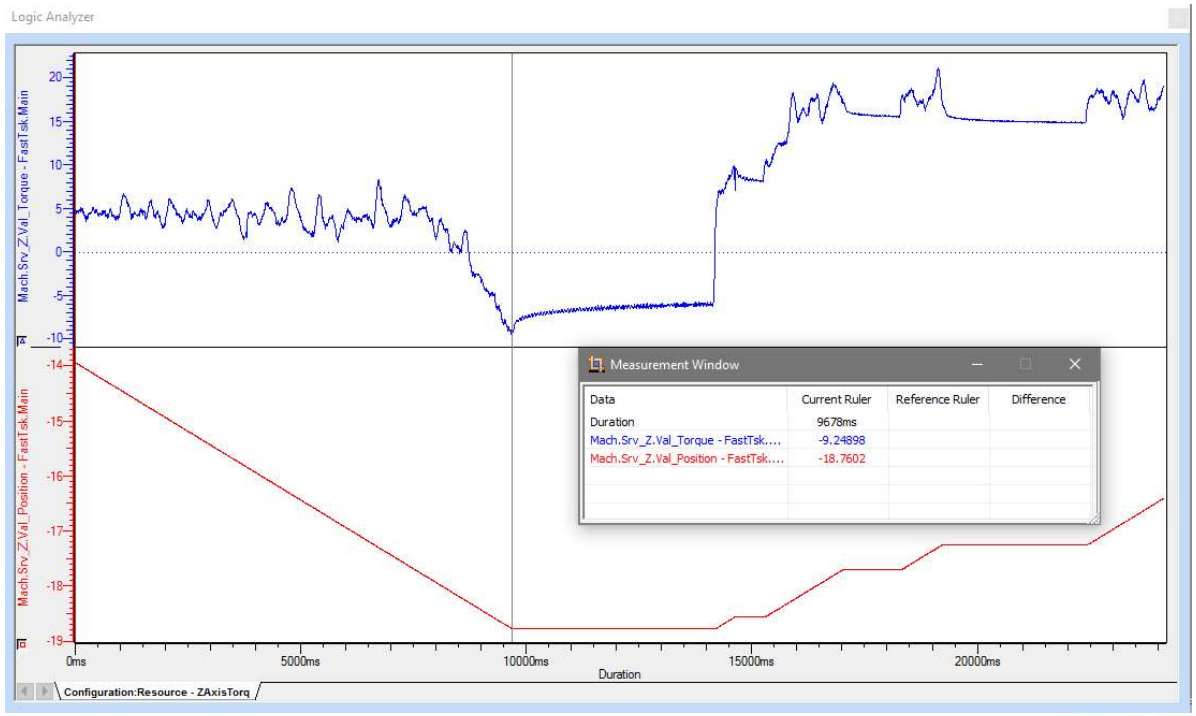
- **GridSetup.TorqueLimit = DINT#2**



GridMeasurement – Determining the Torque Limit

GridSetup Initialization (Torque Measure Method)

- **GridSetup.TorqueLimit = DINT#-9**



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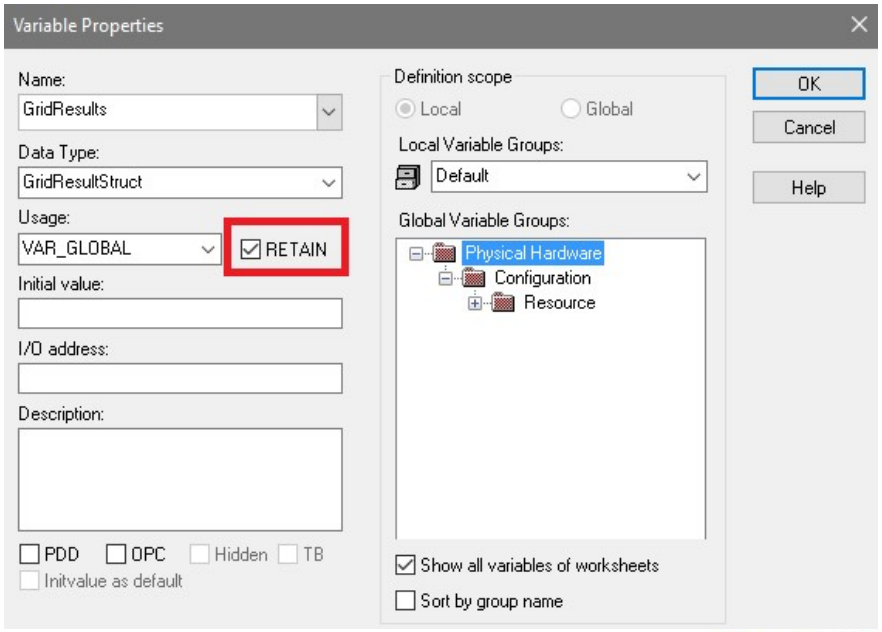
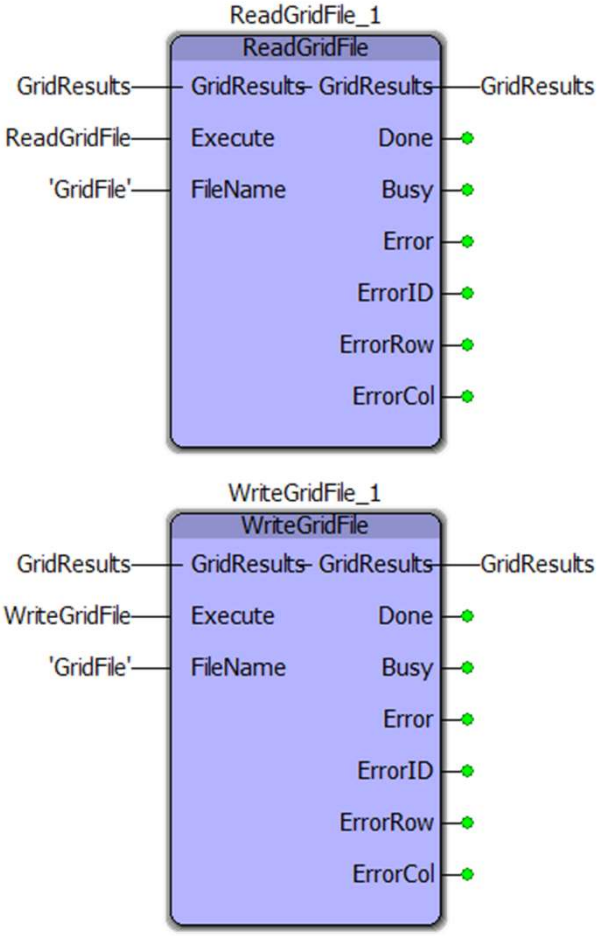
Retaining the Data

- **Data can be saved into a CSV file**
  - **File is stored on the controller's flash memory**
  - **Not required to read or write the files**
- **Recommended to set GridResults as a Retained variable**





Secondary Function Blocks

- **Data can be saved into a CSV file**
  - **File is stored on the controller's flash memory**

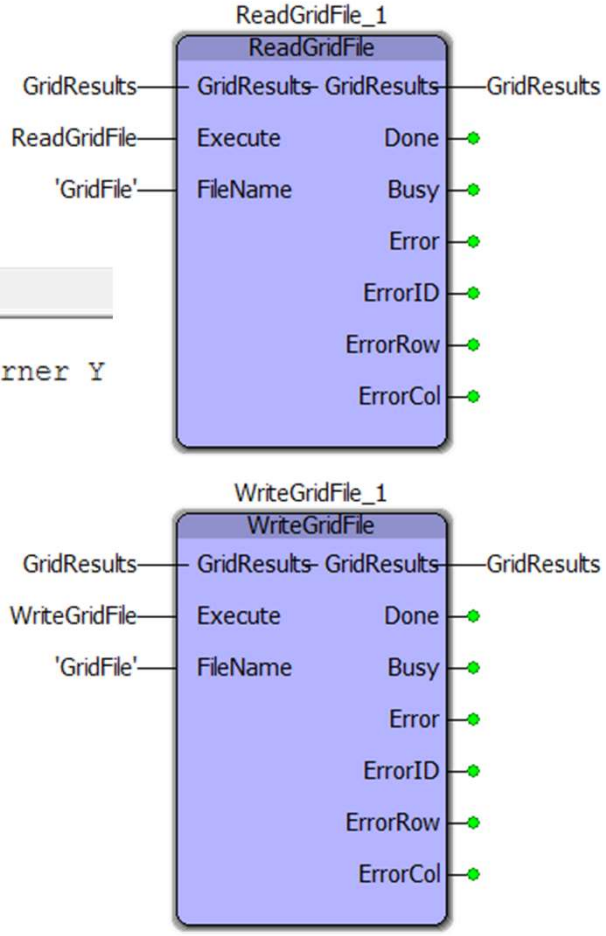
GridFile.GMD

```
1  20190906
2  ResolutionX,ResolutionY,MinCorner X,MinCorner Y,MaxCorner X,MaxCorner Y
3  04,04,-10.0,-10.0,230.0,230.0
4  0.000000000000000
5  0.059972000122059
6  0.167692184448242
7  0.378643989562988
8  -0.050804233550991
9  -0.022184371948242
10 0.102792072296154
11 0.330744934082020
12 -0.045460700988770
13 0.001834774017368
14 0.099196338653599
15 0.322431564331055
16 -0.014975452423073
17 0.049690914154041
18 0.148228740692161
19 0.327093887329113
```

All measurements are normalized to the first measurement taken at the GridSetup.MinCorner

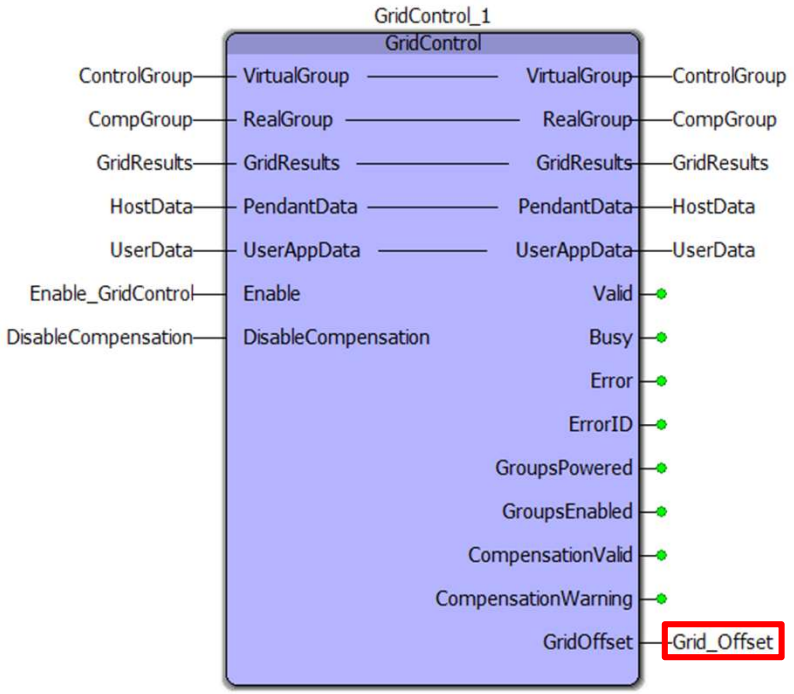
<u>Warning:</u> Z Axis on machine must have its zero position set at the location of the first measurement!

- **MinCorner[0] = X position**
- **MinCorner[1] = Y Position**



GridControl

- **GridControl**
  - Two Groups
    - Virtual Group (Control Group)
      - Does not need to be all virtual axes
    - Real Group (Compensation Group)
      - Custom Group made up of real axis
  - Function block controls CompGroup
  - Applies compensation offset to the axis commanded position
  - **Grid_Offset must be marked as a VAR_GLOBAL**



Control Group

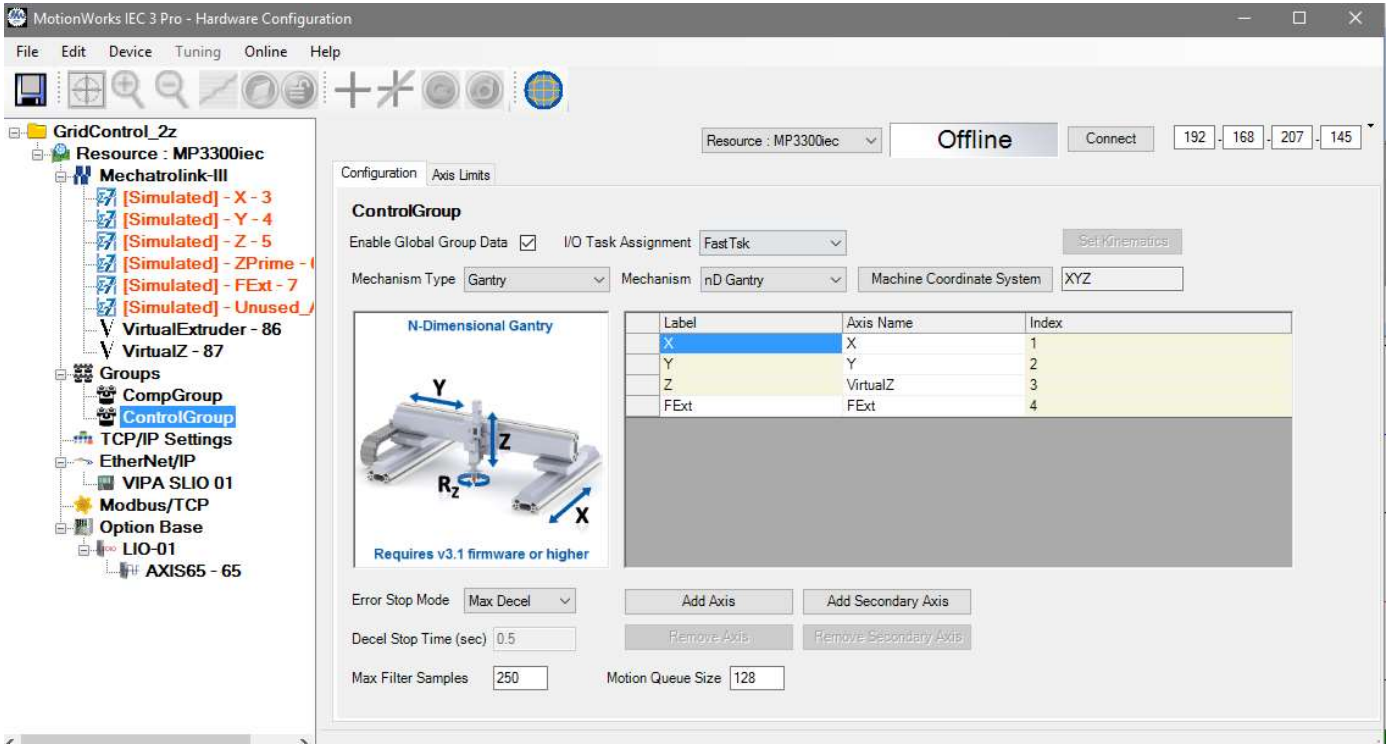
Label	Axis Name
X	X
Y	Y
Z	VirtualZ
FExt	FExt

Comp Group

Label	Axis Name
Z	Z
Z'	ZPrime

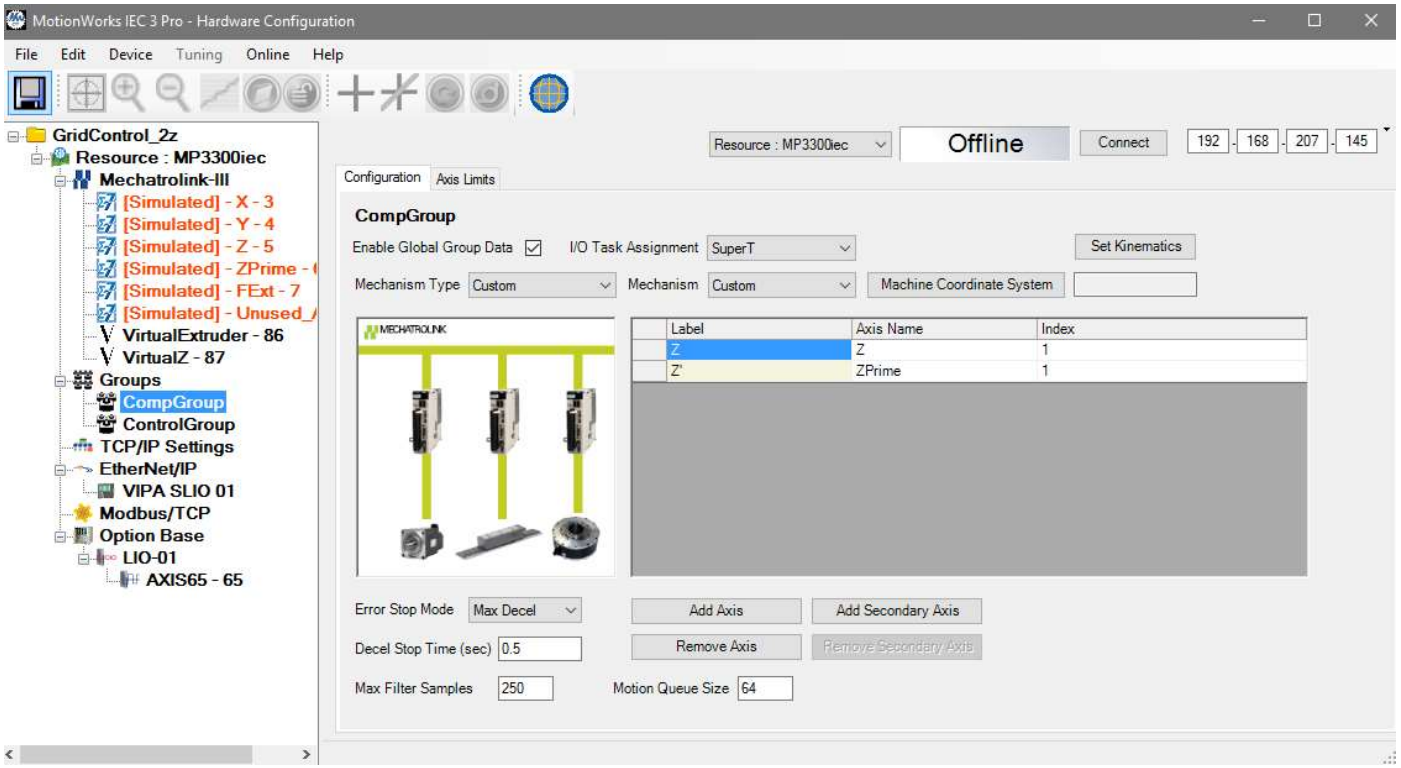
GridControl Group Configuration

- **Control Group (Virtual Group)**



GridControl Group Configuration

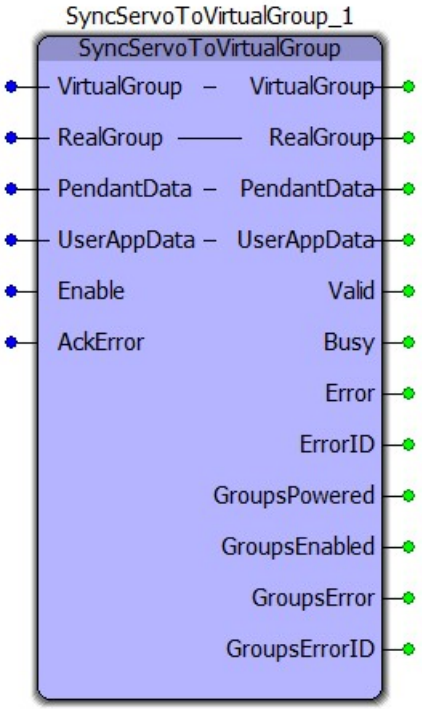
- **Compensation Group (RealGroup)**

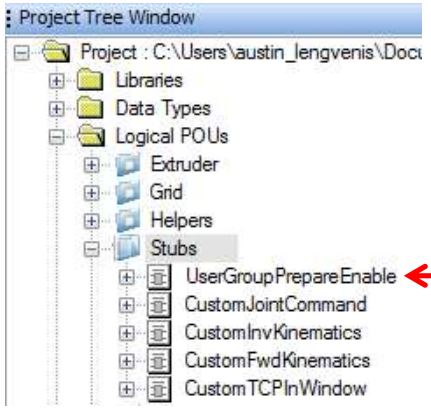


SyncServoToVirtualGroup

- Function block used inside of GridControl
  - Manages synchronization of a virtual group and real group
  - Stub function blocks required in User Project
    - Manages adding grid offset to the Virtual Axis position

- Future webinar on this topic is planned.





Required to power on real axes in custom group. Code is provided as a sample for one axis, but can be extended to a second prime axis

SyncServoToVirtualGroup

- CustomInvKinematics (MCS)

```
IF Enable THEN
    Joint_Coordinate[1]     := AxesGroup.Axis.CmdPos[3] + Grid_Offset;  (*   Read Virtual Z Axis Position in Printer Group   *)
END_IF;
Valid:= Enable;
```

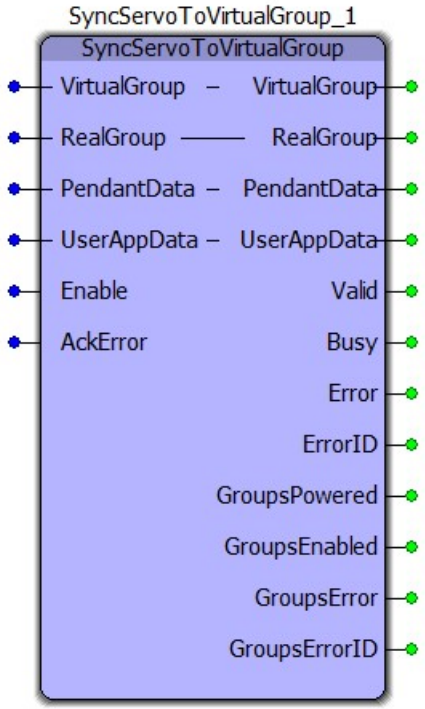
- CustomJointCommand (ACS)

```
IF Enable THEN
    realJointCmd[1] := VirtualGroup.Axis.CmdPos[3] + Grid_Offset;
END_IF;
Valid:=Enable;
```

VAR_GLOBAL

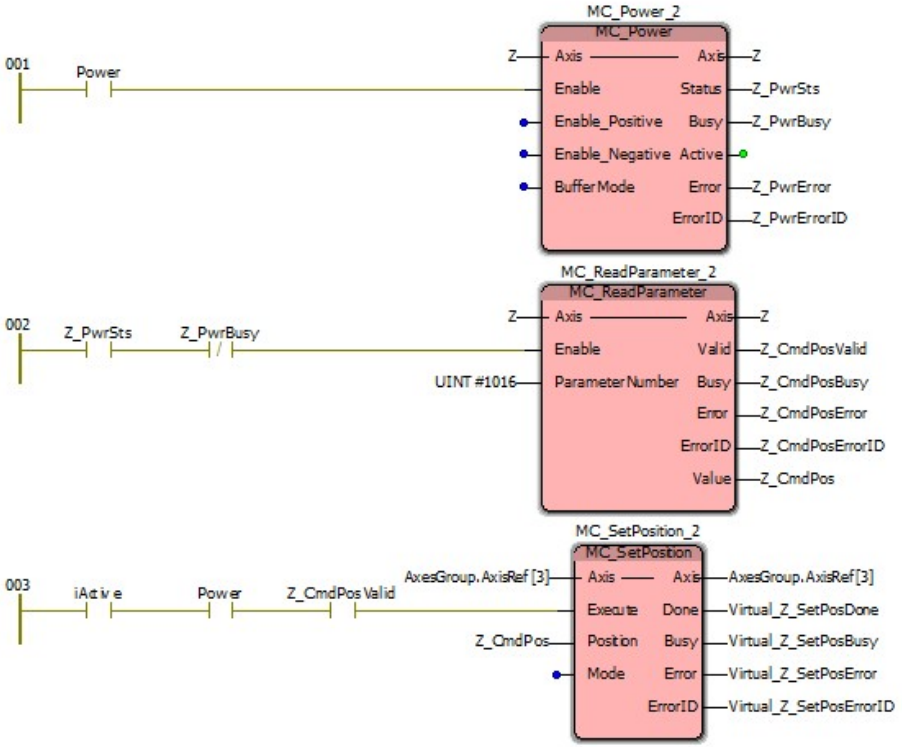
- CustomFwdKinematics (Syncing Virtual to Real)

```
IF Enable THEN
    TCP_Coordinate[3]    := AxesGroup.Axis.CmdPos[1] - Grid_Offset;  (*   Read Real Z Axis Position in GroupZ   *)
END_IF;
Valid:= Enable;
```



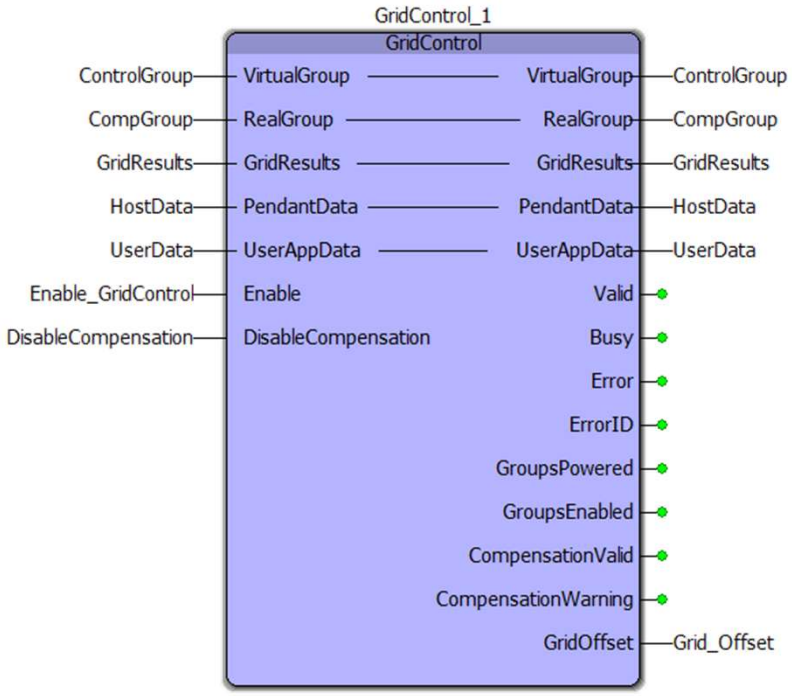
UserGroupPrepareEnable Stub Function Block

1. **Power Real Axis**
2. **Read Real Axis Commanded Position**
3. **Set Virtual Axis position**



GridControl

- **GridControl Demo**
  - Grid Offset applied in real-time
  - Real Axis Positions are changing based on Grid Offset
  - Offset does not change if machine goes outside the range that was measured
    - CompensationWarning will be set
- **Task settings**
  - **GridMeasurement**
    - Medium to Fast Task
    - ~ 8 ms
  - **GridControl**
    - Mechatrolink cycle rate
    - 2 – 4 ms
  - **ReadGridFile / WriteGridFile**
    - Slow Task

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