

## 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

#### Comp Group

Label	Axis Name		
Х	X	Label	Axis Name
Y	Y	Z	Z
Z	VirtualZ	Z'	ZPrime
FExt	FExt		



## **Core Function Blocks**

#### GridMeasurement

• Measure the displacement from the tool to the surface



#### Recording the measured data



Example: Analog Measure Method



#### Calculating the compensation value using Bilinear Interpolation



#### **Process 1: Calculating the Compensation offset**



#### **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	Туре
GridSetup	GridSetupStruct
MeasureMethod	GTB_MeasureMethod
MeasuredPlane	YTB_STRING8
ExternalPlane	GTB_MotorArray
	AXIS_REF
AxisNum	UINT
····· 🕀 ·· [1]	AXIS_REF
	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
	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



#### **GridSetup Initialization (Digital Measure Method)**

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

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

\*)

(\* 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 *)

(\* Height at which program begins scanning for trigger to record measurement \*)

#### **GridSetup Initialization (Analog Measure Method)**

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

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

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

#### (\* GridSetup Analog MeasureMethod Initialization \*)

GridSetupAnalog.MeasureMethod:=GTB MeasureMethod#Ana	alog; (* Measuring using a Analog proximity sensor connected to Servopack CN-1 *)
GridSetupAnalog.MeasuredPlane:='2';	(* 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 *)
<pre>GridSetupAnalog.MaxCorner[1]:= LREAL#310.0;</pre>	(* 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 \*)



#### **GridSetup Initialization (Torque Measure Method)**

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

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

(\* 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; GridSetupTorque.MeasuredPlane:='2';

GridSetupTorque.TorqueLimit:=DINT#1; GridSetupTorque.Tolerance:=LREAL#3.0; GridSetupTorque.MaxDeviation:= LREAL#2.5;

GridSetupTorque.ResolutionX:=INT#4;

#### (\* Min/Max XY Measurement positions \*)

GridSetupTorque.MinCorner[0]:= LREAL#-10.0; GridSetupTorque.MinCorner[1]:= LREAL#-55.0; GridSetupTorque.MaxCorner[0]:= LREAL#230.0; GridSetupTorque.MaxCorner[1]:= LREAL#310.0;

#### (\* Group speed settings \*)

GridSetupTorque.Acceleration:=LREAL\$9800.0; GridSetupTorque.TransferVelocity:=LREAL\$50.0; GridSetupTorque.ApproachVelocity:= LREAL\$15.0; GridSetupTorque.MeasurementVelocity:=LREAL\$3.0;

#### (\* Z Height Positions \*)

GridSetupTorque.TransferPosition:=LREAL#10.0; GridSetupTorque.ApproachPosition:= LREAL#6.0; GridSetupTorque.MeasurementPosition:=LREAL#-0.5;

- (\* Measuring using a Torque proximity sensor connected to Servopack CN-1 \*)
  (\* Measuring the Z plane Label of joint in Hardware Configuration Group \*)
  (\* Torque limit set on axis when taking measurements. Measurement is recorded when this torque value is exceeded \*)
  (\* Acceptable tolerance of measurements away from Measurement Position \*)
- (\* Acceptable deviation between highest/lowest measurements before warning triggers \*)
- (\* Resolution squrared defines the number of points measured across the surface \*)
- (\* First measurement position X \*)
  (\* First measurement position Y \*)
  (\* Last measurement position X \*)
  (\* Last measurement position Y \*)
- (\* Acceleration of moves while running GridMeasurement (Default 5x TransferVelocity) \*)
- (\* Velocity to next measurement location \*)
- (\* Interim Velocity down to Measurement position \*)
- (\* Velocity while scanning for measurement position to be captured \*)
- (\* Height at which machine moves to next measurement position \*)
- (\* Height at which machine moves to before scanning for trigger \*)
- (\* 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





- 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

Variable Properties		×
Name: GridResults	Definition scope     Global	ОК
Data Type:	Local Variable Groups:	Cancel
GridResultStruct ~	Default ~	Help
Usage:	Global Variable Groups:	
VAN_GLOBAL V RETAIN Initial value: I/O address:	Configuration	
Initvalue as default	Show all variables of worksheets	
	Sort by group name	





#### 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

#### Comp Group

Label	Axis Name		
Х	X	Label	Axis Name
Y	Y	Z	Z
Z	VirtualZ	Z'	ZPrime
FExt	FExt		





## **GridControl Group Configuration**

#### Control Group (Virtual Group)

MotionWorks IEC 3 Pro - Hardware Configura	tion				- 🗆 🗙
le <mark>Edit Device Tuning Online H</mark> e	lp				
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GridControl_2z	Configuration Axis Limits	Resource : M	°3300iec ∨ Offlir	Connect	192 - 168 - 207 - 145
	ControlGroup Enable Global Group Data 🗹 1/0 Task /	Assignment FastTsk	v	Set Kinematics	1
[Simulated] - FExt - 7	Mechanism Type Gantry 🗸	Mechanism nD Gantry	V Machine Coordinate	System XYZ	
V VirtualExtruder - 86 V VirtualZ - 87	N-Dimensional Gantry	Label X Y	Axis Name X Y	Index 1 2	
- 2 CompGroup - 2 CompGroup - 2 ControlGroup	Y	Z FExt	VirtualZ FExt	3 4	
	R2 X Requires v3.1 firmware or higher				
	Error Stop Mode Max Decel 🗸	Add Axis	Add Secondary Axis		
	Decel Stop Time (sec) 0.5	Remove Axis	Ferrove Secondary Axis		

## **GridControl Group Configuration**

#### Compensation Group (RealGroup)

File       Edit       Device       Tuning       Online       Hep         Image: Structure index index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index         Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index         Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index         Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index         Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index         Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index         Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Image: Structure index       Ima	File       Edit       Device       Tuning       Online       Help         Image: Strandard Processory Control 2z       Image: Strandard Processory Procesory Procesory Procesory Processory Procesory Processory Procesory	File       Edit       Device       Turing       Online       Help         Image: Strandstard	File       Edit       Device       Turning       Online       Help         Image: Structure of the chartonink-ill         Image: Structure of the chartonink-ill       Image: Structure of the chartonink-ill       Image: Structure of the chartonink-ill       Image: Structure of the chartonink-ill         Image: Structure of the chartonink-ill       Image: Structure of the chartonink-ill       Image: Structure of the chartonink-ill       Image: Structure of the chartonink-ill         Image: Structure of the chartonink-ill       Image: Structure of the chartonink-ill       Image: Structure of the chartonink-ill       Image: Structure of the chartonink-ill         Image: Structure of the chartonink-ill       Image: Structure of the chartonink of the chart	🚳 MotionWorks IEC 3 Pro - Hardware Configurat	ion				- 0	×
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## 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.





SyncServoToVirtualGroup		SyncServoToVir	tualGroup_1
<ul> <li>CustomInvKinematics (MCS)</li> </ul>	•	– VirtualGroup –	VirtualGroup
1 IF Enable THEN 2 Join_Coordinate[1] := AxesGroup.Axis.CmdPos[3] Grid_Offset; (* Read Virtual Z Axis Fosition in Frinter Group *)	•	– RealGroup ––––	– RealGroup
3 END_IF; 4 Valid:= Enable; 5	•	– PendantData –	PendantData 🔶
CustomInvK	•	– UserAppData –	UserAppData 🔶
	•	Enable	Valid 🛶
CustomJointCommand (ACS)	•	AckError	Busy 🛶
1 IF Enable THEN			Error•
3 END_IF; 4 Valid:=Enable;			ErrorID•
5		G	roupsPowered
E CustomJoint		C	GroupsEnabled
			GroupsError
• CustomFwdKinematics (Syncing Virtual to Real)		(	GroupsErrorID
<pre> 1 [F Enable THEN 2</pre>	*)		

## UserGroupPrepareEnable Stub Function Block

MC\_Power 001 Power -Z PwrSts Enable Status Enable Positive Z PwrBusy Busy 1. Power Real Axis Enable\_Negative Active Buffer Mode -Z\_PwrError Error ErrorID \_Z\_PwrErrorID MC\_ReadParameter\_2 2. Read Real Axis Commanded Position MC ReadParamete 002 Z\_PwrSts Z\_PwrBusy Enable -Z CmdPosValid Valio UINT #1016-Parameter Number Z CmdPosBusy Bus 3. Set Virtual Axis position Eno -Z CmdPosError ErrorID \_Z\_CmdPosErrorID -Z\_CmdPos Value MC\_SetPosition\_2 MC SetPosition AxesGroup, AxisRef [3] AxesGroup.AxisRef[3] Axi Axis 003 Z CmdPos Valid iAtive Power Done Execute Virtual\_Z\_SetPosDone Z\_OmdPos-Position Busy Virtual Z SetPosBusy Mode Erro Virtual\_Z\_SetPosError ErrorID -Virtual\_Z\_SetPosErrorID



MC Power 2

#### 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



