Dynamic access on variables Workspace/ protection space monitoring
Notes on the documentation

This description is only intended for the use of trained specialists in control and automation engineering who are familiar with the applicable national standards.

It is essential that the documentation and the following notes and explanations are followed when installing and commissioning the components.

It is the duty of the technical personnel to use the documentation published at the respective time of each installation and commissioning.

The responsible staff must ensure that the application or use of the products described satisfy all the requirements for safety, including all the relevant laws, regulations, guidelines and standards.

Disclaimer

The documentation has been prepared with care. The products described are, however, constantly under development.

We reserve the right to revise and change the documentation at any time and without prior announcement.

No claims for the modification of products that have already been supplied may be made on the basis of the data, diagrams and descriptions in this documentation.

Trademarks

Beckhoff®, TwinCAT®, TwinCAT/BSD®, TC/BS®, EtherCAT®, EtherCAT G®, EtherCAT G10®, EtherCAT P®, Safety over EtherCAT®, TwinSAFE®, XFC®, XTS® and XPlanar® are registered trademarks of and licensed by Beckhoff Automation GmbH.

Other designations used in this publication may be trademarks whose use by third parties for their own purposes could violate the rights of the owners.

Patent Pending

The EtherCAT technology is patent protected, in particular by the following applications and patents:


with corresponding applications or registrations in various other countries.

EtherCAT® is registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany

Copyright

© Beckhoff Automation GmbH & Co. KG, Germany.

The reproduction, distribution and utilisation of this document as well as the communication of its contents to others without express authorisation are prohibited.

Offenders will be held liable for the payment of damages. All rights reserved in the event of the grant of a patent, utility model or design.
General and safety instructions

Icons used and their meanings

This documentation uses the following icons next to the safety instruction and the associated text. Please read the (safety) instructions carefully and comply with them at all times.

Icons in explanatory text

1. Indicates an action.
   ⇒ Indicates an action statement.

---

**DANGER**

Acute danger to life!
If you fail to comply with the safety instruction next to this icon, there is immediate danger to human life and health.

---

**CAUTION**

Personal injury and damage to machines!
If you fail to comply with the safety instruction next to this icon, it may result in personal injury or damage to machines.

---

**NOTE**

Restriction or error
This icon describes restrictions or warns of errors.

---

Tips and other notes
This icon indicates information to assist in general understanding or to provide additional information.

---

General example
Example that clarifies the text.

---

NC programming example
Programming example (complete NC program or program sequence) of the described function or NC command.

---

Specific version information
Optional or restricted function. The availability of this function depends on the configuration and the scope of the version.
# Table of contents

Notes on the documentation ............................................................................................................. 3

General and safety instructions ........................................................................................................ 4

1 Overview ........................................................................................................................................ 8

2 Description .................................................................................................................................... 9
   2.1 Effectiveness ............................................................................................................................ 9
   2.2 Standard control for axes ......................................................................................................... 10
   2.3 Characteristics of workspace/protection area control ............................................................ 11

3 Programming ................................................................................................................................ 14
   3.1 Defining workspace and protection areas ................................................................................. 15
      3.1.1 Polygonal control areas “POLY” ...................................................................................... 16
      3.1.2 Cylindrical control areas “CIRC” .................................................................................... 18
   3.2 Activating workspace and protection areas .............................................................................. 19
   3.3 Deactivating workspace and protection areas .......................................................................... 19
   3.4 Clearing workspace and protection areas ................................................................................ 20

4 Support and Service .................................................................................................................... 21

Index .................................................................................................................................................. 22
List of figures

Figure 1  Software limit switches .................................................................................................................. 10
Figure 2  Definition of workspace/protection areas ...................................................................................... 11
Figure 3  Example of an incorrect and correct polygon contour .................................................................... 12
Figure 4  Definition of 3D control areas .......................................................................................................... 12
Figure 5  Example of cylindrical workspace areas in an application ............................................................ 12
Figure 6  Path check by area control .............................................................................................................. 13
Figure 7  State transitions caused by #CONTROL AREA commands ................................................................. 14
Figure 8  2D view of the programmed polygonal workspace .............................................................................. 16
Figure 9  3D view of the programmed polygonal workspace .............................................................................. 17
Figure 10  2D view of the programmed cylindrical workspace .......................................................................... 18
Figure 11  3D view of the programmed cylindrical workspace .......................................................................... 18
1 Overview

Task
Monitoring 3D bodies by defining workspace or protection areas in a cylindrical or polygonal form of a constant height.

Properties
Work space and protection space monitoring with tool centre point monitoring is possible with

- automatic mode in conjunction with:
  - Linear motion blocks
  - Circular motion blocks (regardless of orientation G17/G18/ G19)
  - Kinematic transformations
  - Polynomial contouring (monitoring interpolation points for the polynomial depending on dynamics and slope)
  - Helical motions
  - Reference point offsets with G92, G54
  - Cartesian transformations #(A)CS available as of CNC Build V2.11.2015:
  - Exclusive (G200) or inclusive mode (G201/G202)
  - Kinematic transformations

Parametrisation and programming
The parameters of workspaces/protection areas are defined for a specific channel directly in the NC program by means of # commands.

Links to other documents
For the sake of clarity, links to other documents and parameters are abbreviated, e.g. [PROG] for the Programming Manual or P-AXIS-00001 for an axis parameter.

For technical reasons, these links only function in the Online Help (HTML5, CHM) but not in pdf files since pdfs do not support cross-linking.
2 Description

2.1 Effectiveness

Workspace or protection areas are defined, activated or deactivated by means of the #CONTROL AREA command. After a reset all workspace/protection areas are deactivated. Control normally refers to the 3 current main axes of a channel.

- As of CNC Build V2.11.2015.00 workspace and protection area control can also be used for active Cartesian transformations #(A)CS.

- As of CNC Build V2.11.2025.00 polygonal protection areas can also be defined for tracking axes. Workspace or protection areas are each programmed and are effective for a specific channel.
2.2 Standard control for axes

Software limit switches

Their simplest application is as axis-specific software limit switches for work space monitoring. The minimum and maximum limits defined for each axis limit the motion range of each axis.

The position of software limit switches can be defined by:

- Parameterisation in the axis configuration list P-AXIS-00177 and P-AXIS-00138 or
- directly in the NC program

![Diagram of software limit switches](image-url)

Figure 1: Software limit switches
2.3 Characteristics of workspace/protection area control

Workspace/protection areas

A workspace is defined as a zone that the TCP (Tool Centre Point) is not permitted to exit.

On the other hand, a protection area must never be touched by the TCP.

Workspace and protection areas can be nested to any extent required. When areas are nested, the protection area control overrides the workspace monitor.

Figure 2: Definition of workspace/protection areas

Control areas as 3D objects

A workspace/protection area is defined by an object in space. Basically 2 different geometries are available. Circles or polygons can be defined by a third constant dimension.

Cylinders are defined by a full circle in the basic plane.

Polygons can be of any complexity in the basic plane. Only the convex form (self-contained chain without overlaps) is mandatory.

The X/Y/Z coordinates of the control areas are referred directly to the three main axes of the channel configuration.

Example of X/Y basic plane (G17):

X → 1. Main axis
Y → 2. Main axis
Z → 3. main axis (constant due to min/max values)
Control areas are always defined as viewed by the 3 main axes of the channel configuration (Cartesian). An active Cartesian transformation #(A)CS is not considered when control areas are defined. They are always defined in the MCS coordinate system, taking into consideration any active Cartesian offsets (e.g. G54, G92, etc.).

Figure 3: Example of an incorrect and correct polygon contour

Figure 4: Definition of 3D control areas

Schematic of 2 machining units with workspace areas that are limited by 2 cylindrical workspaces (green).

Figure 5: Example of cylindrical workspace areas in an application
Path check

In workspace/protection area control, the path between the starting and end points is checked for any violations.

With standard linear and circular motion blocks, equations search for intersections with the defined control areas.

When polynomial contouring is activated or with helical motions, the path is first segmented and the individual points are then checked. This results in the requirement for considerably more computation resources.

Figure 6: Path check by area control
3 Programming

Definition and activation

Workspace and protection areas are defined and activated directly in the NC program. Different # commands are available for this purpose. The #CONTROL AREA function initiates a workspace/protection area command. A number of different options are then expected depending on the # command issued.

All possible states for a single control area are shown in the diagram below. In the diagram, the term "nop" stands for 'No Operation' and thus for a direct state transition.

![Diagram showing state transitions caused by #CONTROL AREA commands](image)

Figure 7: State transitions caused by #CONTROL AREA commands

- **Program end**
  - Active workspace and protection areas are not automatically deactivated at the end of the NC program; i.e. they continue to be monitored at the next program start. The OFF command can be used to explicitly deactivate workspace and protection areas at the end of the CNC program.

- **Controller reset**
  - Stored workspace/protection areas are not deleted when the controller is reset. They are only deactivated and can be reactivated at any time by their IDs.
  - The clear command is used to explicitly clear workspace/protection areas.
3.1 Defining workspace and protection areas

Time of definition

No workspace/protection areas are predefined when the controller starts up. A definition in the configuration lists is not possible.

A work or protection space is defined directly in the NC program in a sequence of path motions embedded in plain text commands.

In this case, path motions must always be programmed in absolute dimensions. The contour of the control area in the plane is defined either by a closed polygon formed by linear blocks (target point and starting point of the block sequence must be identical) or by a full circle. The excursion in the third dimension and further characteristics of the control area are defined in the assigned plaintext command.

Start of control area definition:

```
#CONTROL AREA BEGIN [ ID<expr> WORK | PROT POLY | CIRC
               MIN_EXCUR<expr> MAX_EXCUR<expr>
               [EXCUR_AX<expr>|EXCUR_AXNR<expr>] ]
```

- **ID<expr>**: Identification number of the control area (ID). The definition is global valid after program end and RESET. Up to 20 different control areas can be defined.
- **WORK**: Control area is a workspace.
- **PROT**: Control area is a protection space.
- **POLY**: Contour of a control area is defined as a polygonal shape.
- **CIRC**: Contour of a control area is defined as a full circle.
- **MIN_EXCUR<expr>**: Limitation of the control area in the third dimension in negative direction in \([\text{mm, inch}]\).
- **MAX_EXCUR<expr>**: Limitation of the control area in the third dimension in positive direction in \([\text{mm, inch}]\).
- **EXCUR_AX<expr>**: Optional specification of an axis identifier for the third excursion direction of the workspace or protection area (as of CNC Build V2.11.2025.00). By default the third main axis is used.
- **EXCUR_AX<expr>**: Optional specification of a logical axis number for the third excursion direction of the workspace or protection area (as of CNC Build V2.11.2025.00). By default the third main axis is used.

End of control area definition:

```
#CONTROL AREA END
```

Each control area must be closed by the command #CONTROL AREA END. Only then can further control areas be defined.

Sequence of NC command to define a workspace/protection space

Every control area definition begins with #CONTROL AREA BEGIN and must be terminated with #CONTROL AREA END. Between these two commands, the basic geometric form of the workspace or protection area is programmed by means of DIN 66025 motion commands. A valid feedrate (F word) must be active.

Depending on the configured geometric shape, G02 or G03 is expected for cylindrical control areas and G01 for a polygonal area with corresponding motion blocks.

**NOTE**

When the control area is defined, all positions must be programmed in absolute dimensions (G90).
Overwrite control areas

A control area can be overwritten by programming the same ID again. However, the condition is that the control area with this ID is not activated at the same time.

3.1.1 Polygonal control areas “POLY”

A two-dimensional polygon is defined by a string of linear NC motion commands. The string of points is checked for a convex profile, i.e. connections between 2 adjacent points may not intersect. For the 3rd dimension (3rd main axis), the minimum and maximum limits are defined in the start command.

Normally, the surface area of the workspace or protection area is defined by the first two main axes of the active machining plane.

As of CNC Build V2.11.2025.00 polygonal protection areas can also be defined for tracking axes. The starting point of the two tracking axes must therefore be specified.

First and last points identical

When polygonal control areas are defined, note that the first and last points must be identical. This rule ensures that a closed contour is defined as a polygon.

Defining a polygonal work space

Polygonal workspace

```
N10 #CONTROL AREA BEGIN [ID3 WORK POLY MIN_EXCUR=-50 MAX_EXCUR=50]
N20 G01 F1000 G90 X-150 Y75 (Starting point)
N30 X-50 Y150
N40 X50 Y150
N50 X150 Y75
N60 X150 Y0
N70 X50 Y0
N80 X50 Y75
N90 X-50 Y75
N100 X-50 Y0
N120 X-150 Y0
N130 X-150 Y75 (End point identical with starting point)
N140 #CONTROL AREA END
```

Figure 8: 2D view of the programmed polygonal workspace
Figure 9: 3D view of the programmed polygonal workspace
### 3.1.2 Cylindrical control areas “CIRC”

When cylindrical control areas are defined, two NC motion commands according to DIN 66025 are required. The 1st motion command defines the starting point of the full circle and thus the absolute position of the control area.

A circular NC motion command (G02/G03) is expected as mandatory as the 2nd motion command. For the 3rd dimension (3rd main axis), the minimum and maximum limits are defined in the start command.

**Defining a cylindrical protection space:**

**Cylindrical protection area**

```plaintext
N10 #CONTROL AREA BEGIN [ID4 PROT CIRC MIN_EXCUR=-70 MAX_EXCUR=70]
N20 G01 X100 Y0 F10000 (Starting point for cylindrical protection areas)
N30 G02 G162 I50 J0
N40 #CONTROL AREA END
```

![Diagram of cylindrical workspace](image1)

**Figure 10:** 2D view of the programmed cylindrical workspace

**Figure 11:** 3D view of the programmed cylindrical workspace
3.2 Activating workspace and protection areas

Commands for selection

The TCP is checked for violations with all activated workspace and protection areas. Control areas can either be activated individually via their unique ID or they can all be activated at once.

When control areas are activated the TCP must already be in the valid work space. In the same way, when a protection area is activated, the TCP may not incur any violation at the current position.

The NC command to select a control area contains the following syntax elements:

```
#CONTROL AREA ON [ALL] | [ ID<expr> ] (modal, program global)
```

- ID<expr>: Unique identifier to identify the different workspace/protection areas.
- ALL: All currently defined workspace and protection areas are activated.

Activating workspace and protection areas

```
#CONTROL AREA ON [ID3] (Activate specific control area)
#CONTROL AREA ON ALL (Activate all defined control areas)
```

3.3 Deactivating workspace and protection areas

Commands for deselection

The monitoring function does not check deactivated control areas for violations. They are stored until they are cleared or until the controller is shut down and can be reactivated at any time.

The NC command to deselect a control area contains the following syntax elements:

```
#CONTROL AREA OFF [ALL] | [ ID<expr> ]
```

- ID<expr>: Unique identifier to identify the different workspace/protection areas.
- ALL: All currently defined workspace and protection areas are deactivated.

Deactivating workspace and protection areas

```
#CONTROL AREA OFF [ID3] (Deactivate specific control area)
#CONTROL AREA OFF (Deactivate control area last selected)
#CONTROL AREA OFF ALL (Deactivate all active control areas)
```
3.4 Clearing workspace and protection areas

Commands for clearing

Information on cleared control areas is irrevocably lost. The memory space occupied is then released in order to define new control areas. Only deactivated control areas can be cleared.

The NC command to clear a control area contains the following syntax elements:

```
#CONTROL AREA CLEAR [ALL] | [ ID<expr> ] (modal)
```

- **ID<expr>** Unique identifier to identify the different workspace/protection areas.
- **ALL** All currently defined workspace and protection areas are cleared and the memory space is released for new definitions.

Clearing workspace and protection areas

```
#CONTROL AREA CLEAR [ID3] (Clear specific control area)
#CONTROL AREA CLEAR ALL (Clear all defined control areas)
```
Support and Service

Beckhoff and their partners around the world offer comprehensive support and service, making available fast and competent assistance with all questions related to Beckhoff products and system solutions.

Beckhoff’s branch offices and representatives

Please contact your Beckhoff branch office or representative for local support and service on Beckhoff products!

The addresses of Beckhoff's branch offices and representatives round the world can be found on her internet pages: https://www.beckhoff.com

You will also find further documentation for Beckhoff components there.

Beckhoff Support

Support offers you comprehensive technical assistance, helping you not only with the application of individual Beckhoff products, but also with other, wide-ranging services:

• support
• design, programming and commissioning of complex automation systems
• and extensive training program for Beckhoff system components

Hotline: +49 5246 963 157
Fax: +49 5246 963 9157
e-mail: support@beckhoff.com

Beckhoff Service

The Beckhoff Service Center supports you in all matters of after-sales service:

• on-site service
• repair service
• spare parts service
• hotline service

Hotline: +49 5246 963 460
Fax: +49 5246 963 479
e-mail: service@beckhoff.com

Beckhoff Headquarters

Beckhoff Automation GmbH & Co. KG
Huelshorstweg 20
33415 Verl
Germany

Phone: +49 5246 963 0
Fax: +49 5246 963 198
e-mail: info@beckhoff.com
web: https://www.beckhoff.com
Index
More information:
www.beckhoff.com/TF5200