OPERATING HANDBOOK

KR C2

Machine Data

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PD Interleaf

Contents

1 Introduction

Incorrect modifications to the machine data can cause the robot to malfunction. Robot malfunctions constitute a risk of danger to life and limb.

1.1 Characteristics

The robot-specific file $machine.dat contains important configuration data that are required for operation of the robot hardware.

The drives, motors and axis kinematic systems are defined in the file $machine.dat.

All the machine data contained in the file $machine.dat are described in this documentation.

1.2 System requirements

1.2.1 Software

This description is valid from:
KR C2 system software release 5.2

1.2.2 Hardware

- Controller type KR C2

Special training is required for configuring machine data.
Advanced knowledge of KR C... robot controllers and their configuration and programming is required.

2 The file $MACHINE.DAT

The machine data dealt with in this documentation also include the necessary addresses for the configuration of external drive boxes. These additional data are always specially indicated in this documentation.

2.1 Description of the individual machine data

2.1.1 $V_R1MADA[ ]

Version identifier

Data type	char	Value min	--
Unit	--	Value max	--
Assignment	--		

Example

$V_R1MADA[]="V4.4.0/KUKA5.2"

(V4.4.0 is the machine data version;
KUKA 5.2 is the system software release)

2.1.2 $TECH_MAX

Number of function generators

Data type	int	Value min	--
Unit	--	Value max	--
Assignment	--		

Function generators define the number of technology packages.

Default=6

Example

The default value with six function generators is entered as follows:

$TECH_MAX=6

2.1.3 $NUM_AX

Number of axes in the robot system

Data type	int	Value	min	1
Unit	--		max	6
Assignment	[1] axis 1 ... [6] axis 6			

Example

The value for a robot system with six axes is entered as follows:

$NUM_AX=6

2.1.4 $AXIS_TYPE[ ]

Definition of the axis type

Data type	int	Value	min	1
Unit	[ ]		max	5
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

The axis type of each axis used must be defined.

1 = **LINEAR** (e.g. linear traversing units)
The axis value is converted to millimeters.
A check is carried out for software limit switches.

2 = **SPINDLE** (special kinematics and spindle drives)
The axis value is converted to millimeters.
A check is carried out for software limit switches.

3 = **ROTATIONAL** (standard case: rotational axes; turning range from -358° to 358°)
The axis value is converted to degrees.
A check is carried out for software limit switches.

4 = **Finitely rotating**
The axis value is converted to degrees.
A check is carried out for software limit switches.

Finitely rotating axes are not implemented and must not be used.

5 = **Infinitely rotating** (e.g. robot axis 4 or 6)
The axis value is converted to degrees.

Infinitely rotating axes are also limited, according to the gear ratio.

The software limit switches for rotational axes can only be set between [-358 degrees] and [+358 degrees].

Infinitely rotating axes turn modulo 360 degrees, i.e. PTP {A6 3610} results in a motion of A6 from 0 degrees to 10 degrees.

An infinitely rotating axis can move max. 180 degrees in a single motion block.

Example

In the example, external axis 7 is defined as a linear traversing unit, i.e. axis type 1:

$AXIS_TYPE[7]=1

The type of axis is not automatically defined by the definition of the main axis type. In the case of a SCARA (#CC), axis 1 must be explicitly identified as a linear axis.

2.1.5 $COUP_COMP[ ]

Compensation of the mechanical coupling between the wrist axes

Data type	frame	Value	min	--
Unit	--		max	--
Assignment	[A x, A y] = Nn, Dn			

An axis "m" is rotated through a defined angle and the angle change at axis "n" is measured.

$COUP_COMP= (reaction axis n)/(angle axis m)

2.1.6 $EXCOUP_COMP[ ]

Compensation of the mechanical coupling between the external axes

Data type	frame	Value	min	--
Unit	--		max	--
Assignment	[A x, A y] = Nn, Dn			

Axis "m" is rotated through a defined angle and the rotation of axis "n" is measured.

2.1.7 $MAMES[ ]

Zero point offset

Data type	--	Value min	--
Unit	mm, degrees	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

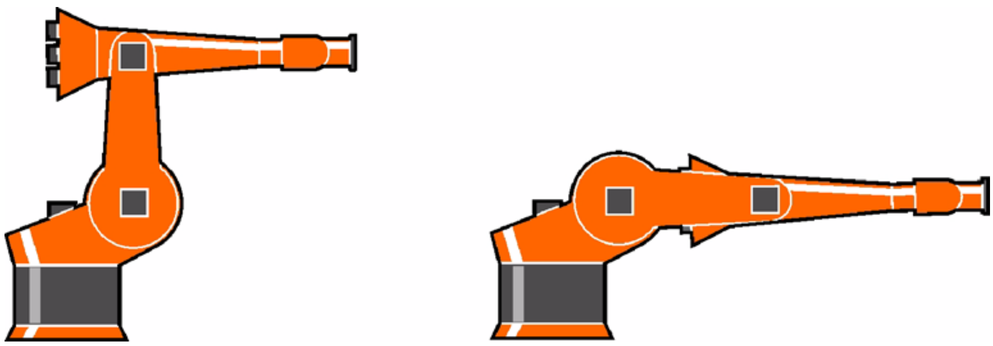
Offset between the mechanical zero point (mastering notch) and the mathematical zero point of the axes in mm (degrees). At the mechanical zero point, the value of $MAMES is assigned to the axis counter.

$MAMES should be in the range ±180 degrees for rotational axes.

For robot axes:

Mechanical zero position: **Cannon position** (see Fig. 1)

Mathematical zero position: **Extended position** (see Fig. 1)



Cannon position   Extended position

Fig. 1 Zero positions

$MAMES[i]=K

i = axis number

K = offset in mm or degrees

2.1.8 $ROBROOT

Offset and orientation

Data type	--	Value min	--
Unit	mm, degrees	Value max	--
Assignment	FRAME {X, Y, Z, A, B, C}		

Offset and orientation of the robot relative to the world coordinate system.

Ceiling-mounted robots: Angle C is 180 degrees

Wall-mounted robots: Angle B is 90 degrees

The frame chain or vector chain of the robot arm (axes 1 to 6) without external axes is illustrated in Fig. 2:

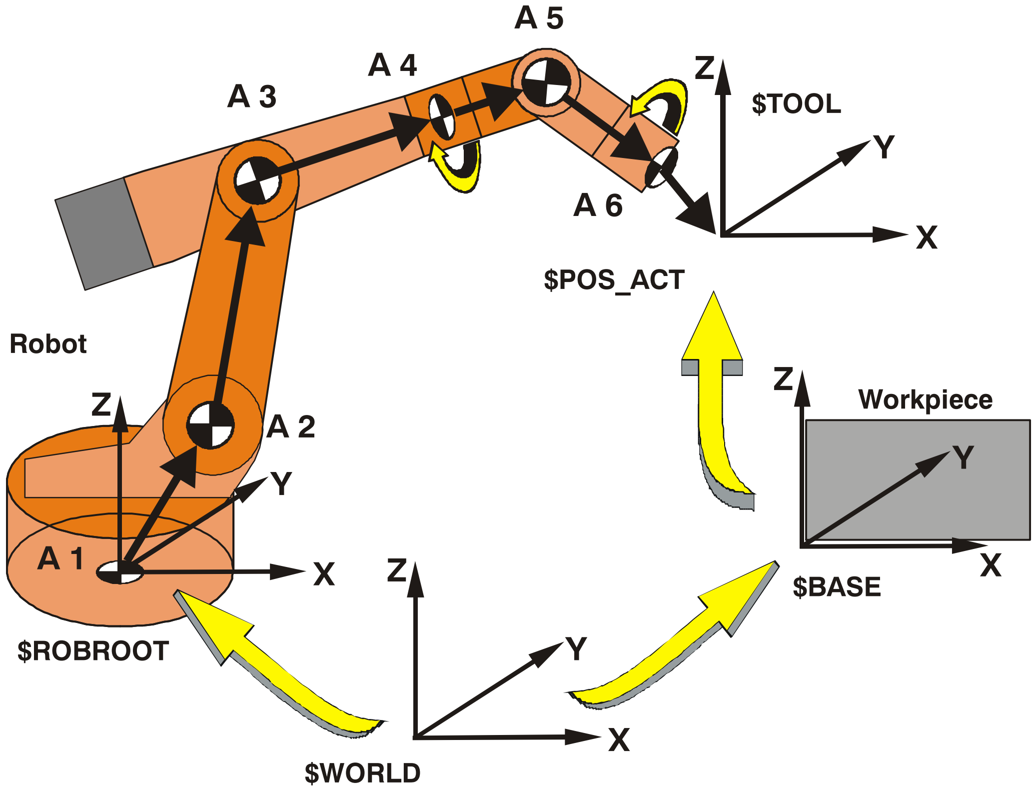


Fig. 2 Frame chain without external axes

The BASE coordinate system is used as the reference system to define the position of the workpiece. The programming of the robot is done in the BASE coordinate system, which has the WORLD coordinate system as its reference coordinate system.

When interpolating the motion path, the robot controller calculates, under normal circumstances (stationary workpiece, tool mounted on the robot flange), the current position ($POS_ACT) in relation to the $BASE coordinate system.

2.1.9 $ERSYSROOT

Offset and orientation with external axes

Data type	--	Value min	--
Unit	mm, degrees	Value max	--
Assignment	FRAME {X, Y, Z, A, B, C}		

Offset and orientation of the robot relative to the world coordinate system.

Defines the offset between the root point of the external axis and the robot base flange.

Only valid if external axes are present (e.g. robot is mounted on a linear unit).

If $ERSYSROOT is valid, $ROBROOT is ignored.

The frame chain of a robot arm and a linear unit (KL) with mathematical coupling is illustrated below (Fig. 3).

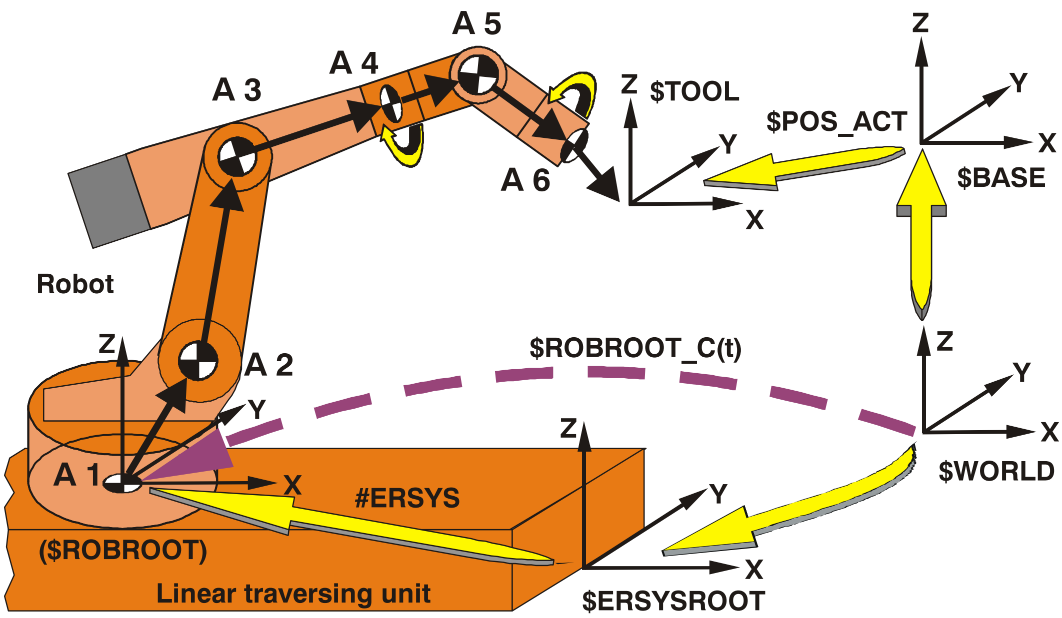


Fig. 3 Frame chain with linear unit

The external ROBROOT kinematic system lies in the offset from “$WORLD” to “$ROBROOT”. With every motion of the ROBROOT kinematic system, the position in space of the robot changes. As allowance must always be made for this external axis when calculating the position, this external kinematic system is always situated in the offset from “$WORLD” to “$ROBROOT”.

The external coupling is always switched on and cannot be switched off. As in the case of the external BASE kinematic system, there is no constant ROBROOT value. The contents of the machine datum “$ROBROOT” are ignored. The current value can be read from the main run variable “$ROBROOT_C”.

2.1.10 $RAT_MOT_AX[ ]

Motor/axis gear ratio

Data type	frame	Value min	15
Unit	[ ]	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

In order to calculate the resolution, the gear ratio of the motor to the axis must be specified for each axis. This information is entered as a fraction. The direction of rotation of the axis can be changed by means of a negative sign in the numerator N.

$RAT_MOT_AX[i]={N x,D y}

i = axis number

x = value of numerator N (i.e. motor)

y = value of denominator D (i.e. axis)

Unit for linear axes: [Number of motor revolutions per 1000 mm travel]

Example 1

Rotational axis with gear unit:

Every 10th motor revolution, the axis turns through 1 revolutions.

```
$RAT_MOT_AX[i]={N 100,D 1}
```

Example 2

Linear axis:

I_{compl} = complete reduction ratio of the gear unit
I_{box} = reduction ratio of the gear box
D = reference diameter of the gear [unit = m]

$$I_{compl} = \frac{1}{(\pi \cdot D)} \cdot i_{box}$$

The gear ration should be at least {N 15,D 1}.

2.1.11 $RAT_MOT_ENC[ ]

Motor/encoder ratio

Data type	frame	Value	min	--
Unit	[ ]		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

In order to calculate the resolution, the ratio of the motor to the encoder must be specified for each axis. For cyclical absolute encoders, the number of cyclical absolute periods per revolution is defined.

$RAT_MOT_ENC[i]={N x,D y}

i = axis number

x = value of numerator N (i.e. motor)

y = value of denominator D (i.e. axis)

Example 1

Robot with a 6-pole resolver: (3 absolute ranges, each 120 degrees)

$RAT_MOT_ENC[i]={N 1,D 3}

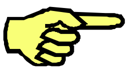
2.1.12 $DSECHANNEL[ ]

Axis assignment on the DSE

Data type	int	Value	min	0
Unit	[ ]		max	18
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

Until now, this variable has determined which of the 8 DSE channels is assigned to an axis (An) (and thus also which slot on the RDC). With the new definition of this variable, a control loop ("loop") on the DSE is now assigned to an axis (An). There are 8 control loops (corresponding to 8 channels) on the DSE.

In the case of master/slave configurations, the number of the master control loop is entered. With the default robot configuration, axes 1-6 are consecutively assigned to channels 1-6 (and thus control loops 1-6) respectively. With standard configurations the meaning of this variable thus remains unchanged.



The number of motor pole pairs should be the same as, or a multiple of, the number of resolver pole pairs.

Valid values for $DSECHANNEL are:

Loop

0	Channel not used
1–8 (1–9)	8 control loops on DSE no. 1 (+spare channel 9)
10–17 (10–18)	8 control loops on DSE no. 2 (+spare channel 18)

Each control loop number may be specified only once.

This entry defines which DSE channel is to be used by the axis.

There are eight channels available on the first DSE. With a standard robot, channels 7 and 8 can thus be used for external axes.

The RDC inputs are also defined using “$DSECHANNEL”.

For unused axes, $DSECHANNEL[ ] = 0 must be entered.

$DSECHANNEL[i]=K

i = robot axis

K = DSE channel and RDC channel

Example

Axes 1 and 2 occupy DSE channels 1 and 2 and slots X1 and X2 on the RDC card; axis 7 occupies DSE channel 3 and slot 3 on the RDC card:

```
$DSECHANNEL[1]=1
$DSECHANNEL[2]=2
$DSECHANNEL[3]=0
$DSECHANNEL[4]=0
$DSECHANNEL[5]=0
$DSECHANNEL[6]=0
$DSECHANNEL[7]=3
```

2.1.13 $PMCHANNEL[ ]

Selection of the KPS

Data type	int	Value	min	20
Unit	[ ]		max	34
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

$PMCHANNEL[An]

This variable defines which KPS is used to drive the axis (An). The meaning remains unchanged.

In the case of master/slave configurations with several KPSs for master and slave axes, only the assignment of the master axis is entered here. For slave axes, the KPS is defined using the variable $SLAVE_LOOP_PMCHANNEL (see below).

Assignment of the axes to the drive interfaces of a single KPS.

The following applies for robot axes 1 to 6:

$PMCHANNEL[1]=20

$PMCHANNEL[2]=20

$PMCHANNEL[3]=20

$PMCHANNEL[4]=20

$PMCHANNEL[5]=20

$PMCHANNEL[6]=20

The following applies for external axes 7 and 8:

$PMCHANNEL[7]=21

$PMCHANNEL[8]=21

Example

Axis 4 uses the first channel of the second KPS.

PMCHANNEL[4]=22

The following applies for the first DSE-IBS:

$PM_CHANNEL[]=20 1st KPS

$PM_CHANNEL[]=22 2nd KPS

$PM_CHANNEL[]=24 3rd KPS

$PM_CHANNEL[]=26 4th KPS

The following applies for the second DSE-IBS:

$PM_CHANNEL[]=28 1st KPS

$PM_CHANNEL[]=30 2nd KPS

$PM_CHANNEL[]=32 3rd KPS

$PM_CHANNEL[]=34 4th KPS

$PM_CHANNEL is also used to define the braking channel (2 per KPS) assigned to the axis brake. Odd numbers indicate that the second braking channel of the KPS is used.

Example

Axis 5 is assigned to the first braking channel of the first KPS of the first DSE.

$PM_CHANNEL[5]=20

Axis 7 is assigned to the second braking channel of the first KPS of the first DSE.

$PM_CHANNEL[7]=21

This machine datum has been expanded for external drive boxes. The meaning of the existing contents remains unchanged. A “1” before the entry signifies that the axis module concerned has an SBM (Single Brake Module).

2.1.14 $LOOP_LG_PTP[ ]

Position controller gain

Data type	real	Value	min	--
Unit	--		max	--
Assignment	--			

Defines the position controller gain of the control loop.

The value applies to PTP and CP motion.

It is only required for the control loop of a position-controlled slave (“Slave Pos”).

2.1.15 $LOOP_G_VEL_PTP[ ]

Speed controller gain

Data type	Real	Value	min	--
Unit	--		max	--
Assignment	--			

Defines the proportional gain of the speed controller.

The value applies to PTP and CP motion.

It is only required for the control loop of a position-controlled slave (“Slave Pos”).

2.1.16 $LOOP_I_VEL_PTP[ ]

Integral component of the speed controller

Data type	real	Value min	--
Unit	--	Value max	--
Assignment	--		

Defines the integral factor of the speed controller.

The value applies to PTP and CP motion.

It is only required for the control loop of a position-controlled slave ("Slave Pos").

2.1.17 $LOOP_DIRECTION[ ]

Direction specification for slave axes

Data type	int	Value min	--
Unit	--	Value max	--
Assignment	--		

Specifies the direction in which the slave moves relative to the master.

Description of the valid values:

Control loop of a position-controlled slave ("Slave Pos"):

1 = Same direction as master

-1 = Opposite direction to that of master

Control loop of a torque-controlled slave ("Slave Torq"):

1 = Same torque (or command current) as master

-1 = Opposite torque (or command current) to that of master

2.1.18 $SLAVE_LOOP_FOL_CRITICAL[ ]

Percentage value for configuration of a max. deviation limit

Data type	int	Value min	101
Unit	%	Value max	--
Assignment	--		

Shut-off threshold with loss of mastering

If the following error exceeds the threshold value, PATH-MAINTAINING BRAKING is triggered.

The percentage value refers to $SLAVE_LOOP_FOL_ALARM.

The value must be >100, otherwise it is automatically set to 120.

2.1.19 $SLAVE_LOOP_FOL_ALARM[ ]

Deviation limit between master and slave

Data type	real	Value	min	--
Unit	degrees, mm		max	--
Assignment	--			

Shut-off threshold

If the following error exceeds the threshold value, PATH-MAINTAINING BRAKING is triggered.

2.1.20 $SLAVE_LOOP_SPEED_ALARM[ ]

Max. speed deviation for torque-controlled slave drives

Data type	real	Value	min	--
Unit	rpm		max	--
Assignment	--			

Shut-off threshold

If the actual speed exceeds the threshold value, PATH-MAINTAINING BRAKING is triggered. The value is specified in rpm.

2.1.21 $SLAVE_LOOP_PMCHANNEL[Ln]

Definition of the KPS module for slave control loops

Data type	int	Value	min	-
Unit	[ ]		max	--
Assignment	--			

$SLAVE_LOOP_PMCHANNEL[Ln]=y defines the KPS module connected to a slave control loop. In the case of master loops, the value 0 must be entered as the assignment for these control loops is already defined using $PMCHANNEL[An] (see above) and must not be taken into consideration here.

2.1.22 $LOOP_TYPE[Ln]

Selection of the control loop type

Data type	int	Value	min	1
Unit	[ ]		max	4
Assignment	--			

$LOOP_TYPE[Ln]=y

This variable specifies the control loop type (Ln). Control loop type 4, for example, indicates a control loop with 2 KSDs connected in parallel to a single motor with a double winding. The main winding is commutated by a master (type 1), and the parallel winding by a slave (type 4).

The following values are possible:

y

1 Master control loop

2 Control loop of a position-controlled slave ("Slave Pos")

3 Control loop of a torque-controlled slave ("Slave Torq")

4 Control loop for parallel winding with 2 KSDs connected in parallel to a single motor

6 Force control, servo gun force control

In the case of 2 KSDs connected in parallel to a single motor, it is not possible to connect the resolver of the motor to a CAN bus.

2.1.23 $LOOP_TYPE_ATTRIBUTE[ ]

Additional characteristics of the control loop

Data type	int	Value	min	1
Unit	[ ]		max	18
Assignment	--			

Bit array!

Required for certain Loop_types (currently only $Loop_type[Ln]=5) for the detailed definition of linked characteristics.

Default value = 0

This machine datum is used exclusively for KUKA-internal development purposes.

2.1.24 $MASTER_LOOP[Ln]

Selection of the higher-level master control loop

Data type	int	Value	min	1
Unit	[ ]		max	18
Assignment	--			

$MASTER_LOOP[Ln]=y

In the case of slave control loops, this variable indicates the number of the higher-level master control loop. The permissible combinations are described in the documentation about the master/slave functions.

Valid values for $MASTER_LOOP are:

y		
1-8	(1-9)	Control loop number of the master (only DSE no. 1)
10-17	(10-18)	Control loop number of the master (only DSE no. 2)

Master and slave loops cannot be distributed over two DSEs.

2.1.25 $SLAVE_TORQUE_RATIO[ ]

Torque-controlled slave: ratio between command torque and slave/master

Data type	real	Value min	1
Unit	[ ]	Value max	5
Assignment	--		

This variable specifies the torque (or command current!) for the slave relative to the master.

It is only required for the control loop of a torque-controlled slave ("Slave Torq").

2.1.26 $NINPUT_SENSORTYPE[Ln]

Sensor type for the speed input

Data type	int	Value min	1
Unit	[ ]	Value max	5
Assignment	--		

$NINPUT_SENSORTYPE[Ln]=y defines the sensor type for the speed input of the DSE control loop (Ln). This describes the hardware connection.

Valid values for $NINPUT_SENSORTYPE are:

y	
1	Sensor (resolver) connected to RDC
2	Sensor with external resolver box connected via CAN-KSD and servo bus
3	Incremental encoder connected via CAN-KSD and servo bus
4	Servo bus encoder with IBS K3 protocol (multiple/single incremental encoder)
5	Servo bus encoder with IBS K2 protocol (multiple/single incremental encoder)

2.1.27 $NINPUT_SENSORCHANNEL[Ln]

Channel number of the speed input for the DSE loop

Data type	int	Value	min	--
Unit	[ ]		max	--
Assignment	--			

$NINPUT_SENSORCHANNEL[Ln]=y for RDC-commutated motors:
Defines the channel number (y) of the speed input for the DSE loop (Ln). Each channel number may be specified only once. The $NINPUT_SENSORCHANNEL channel number should be the same as the DSE channel number in order to avoid confusion during configuration. A different assignment would be technically possible, however.

For CAN-RDC-commutated motors:

Defines the KSD-SBM in the servo bus ring from which the NINPUT information is received. Other devices, such as the KPS, are not counted as KSD-SBMs.

This is necessary as the NINPUT and POSINPUT information of a control loop may come from different KSDs.

2.1.28 $NINPUT_SUBCHANNEL[Ln]

Sub-channel for speed channel of a DSE control loop

Data type	int	Value	min	1
Unit	[ ]		max	4
Assignment	--			

$NINPUT_SUBCHANNEL[Ln]=y This variable can be used to define a “sub-channel” for each speed channel of a DSE control loop (Ln). This can be used for a more detailed definition, for example, if an encoder supplies different values on a single channel. The value 0 must be entered if this variable is not required.

RDC-commutated motors:

The SUBCHANNEL is not required; the value 0 must be entered.

CAN-RDC-commutated motors:

If the encoder is connected via external resolver box, CAN and servo bus (“sensor type 2”), the resolver channel, i.e. the number of the slot on the external resolver box (“CAN-RDC”), is set here. Only the slot on the CAN-RDC need be specified here, as the specification of which CAN-RDC is connected to the motor is defined by the position in the servo bus. An additional CAN-RDC must be connected after each KPS (see example 3).

Valid values for $NINPUT_SUBCHANNEL with “sensor type 2” are:

y = 1 – 4

y: resolver channel; 1: CAN master*

* The “CAN master” is responsible for synchronization of the resolver box with the servo bus. A CAN master must be defined for each resolver box. It is not possible to connect more than one CAN master to a single resolver box. The sequence of the information from the resolver slots is by definition always identical to the sequence of the KSDs with CAN–RDC in the servo bus!

Each CAN channel may be specified only once.

2.1.29 $POSINPUT_SENSORTYPE[Ln]

Position input of the DSE control loop

Data type	int	Value	min	––
Unit	[ ]		max	––
Assignment	––			

$POSINPUT_SENSORTYPE[Ln]=y

Like $NINPUT_SENSORTYPE for the position input of the DSE control loop (Ln).

2.1.30 $POSINPUT_SENSORCHANNEL[Ln]

Position input of the DSE loop

Data type	int	Value	min	––
Unit	[ ]		max	––
Assignment	––			

$POSINPUT_SENSORCHANNEL[Ln]=y

Like $NINPUT_SENSORCHANNEL for the position input of the DSE control loop (Ln).

Additional laser sensor:

The SENSORCHANNEL defines the laser sensor in the servo bus ring from which the position information is received.

2.1.31 $POSINPUT_SUBCHANNEL[Ln]

Position input of the DSE control loop

Data type	int	Value	min	––
Unit	[ ]		max	––
Assignment	––			

$POSINPUT_SUBCHANNEL[Ln]=y

Like $NINPUT_SUBCHANNEL for the position input of the DSE control loop (Ln).

2.1.32 $TORQINPUT_SENSORTYPE[Ln]

Force/torque input of the DSE control loop

Data type	real	Value	min	--
Unit	[ ]		max	--
Assignment	--			

$TORQINPUT_SENSORTYPE[Ln]=y

Like $NINPUT_SENSORTYPE for the force/torque input of the DSE control loop (Ln).

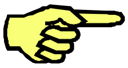
2.1.33 $LOOP_RAT_MOT_AX[ ]

Motor / drive gear ratio of the slave axis

Data type	frame	Value	min	--
Unit	[ ]		max	--
Assignment	--			

Gear ratio (motor:axis) of a slave control loop.

The ratio (motor : rotary encoder) of the slave must be the same as that of the master.



Only for slave drives.

Example

$LOOP_RAT_MOT_AX[2]={N 20,D 1}

2.1.34 $LOOP_RAT_EXTPOS_AX[ ]

Ratio of the sensor gear

Data type	frame	Value	min	--
Unit	[ ]		max	--
Assignment	--			

Gear ratio of the external position encoder of a control loop (possible for both master and slave).

Example

$LOOP_RAT_EXTPOS_AX[1]={N -3,D 1}

2.1.35 $MOTOR_POLE_NUMBER[ ]

Number of pole pairs of the motor

Data type	int	Value	min	--
Unit	[ ]		max	--
Assignment	--			

This machine datum is used exclusively for KUKA-internal development purposes.

Default value: 3

2.1.36 $SERVOFILE_CONFIG[ ]

Configuration file for motor/KSD combination

Data type	char	Value	min	--
Unit	[ ]		max	--
Assignment	--			

The servo file entered must be located in the R1/MADA directory.

For each permissible motor/KSD combination there is a special configuration file which must be entered in the machine data:

Example

Axis 1 is driven by a motor of type B (S=Siemens) and controlled using a KSD1-32:

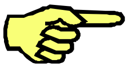
```
CHAR $SERVOFILE1[16]
$SERVOFILE1[]="KSD_32_MB_S"
```

2.1.37 $SERVOFILEKPS1[ ]

Servo file KPS1 DSE1

Data type	char	Value	min	--
Unit	[ ]		max	--
Assignment	--			

For each KPS there is a configuration file which must be entered in the machine data:



The servo file entered must be located in the R1/MADA directory.

Example

First KPS of type 600_20 on the first DSE:

$SERVOFILEKPS1[] = “KPS_600_20”

2.1.38 $CURR_MAX[ ]

Maximum KSD current

Data type	real	Value	min	8
Unit	A		max	64
Assignment	--			

Maximum effective current at the KSD output.

$CURR_MAX[i]=K

i = axis number

K = max. KSD current (A_{rms})

KSD type	KSD 1-64	KSD 1-48	KSD 1-32	KSD 1-16	KSD 1-08
$CURR_MAX[ ]	64	48	32	16	8

Example

Axis 7 is controlled using a KSD1-48:

$CURR_MAX[7] = 48

2.1.39 $CURR_CAL[ ]

KSD current calibration

Data type	real	Value	min	--
Unit	[ ]		max	--
Assignment	--			

In the KR C2, $CURR_CAL[i] always has the value 1.

$CURR_CAL[i]=K

i = axis number

K = current factor

2.1.40 $CURR_LIM[i]

Current setpoint limit

Data type	int	Value min	1
Unit	%	Value max	100
Assignment	Axis number		

The current setpoint defines the maximum permissible motor current and thus also defines the torque limit. This value is entered as a percentage of the maximum KSD current.

The following relationship exists between the machine data:

$CURR_LIM[i]= (max. motor current I_{max} / $CURR_MAX[i]) x 100

$CURR_LIM[i]=K

i = axis number

K = current limit

Example

For a motor of type E with a KSD1-08, the following applies:

$CURR_LIM[ ]= (7.3 / 8) x 100 = 91

If the motor current is set too high, this can result in damage to the gear unit or demagnetization of the permanent magnets in the motors.

2.1.41 $CURR_MON[i]

Permissible standstill current of the motor

Data type	real	Value min	--
Unit	A	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

Specification of the permissible standstill current of the motor for axis i.

If the value is set too high, this can cause the motor cable or the motor itself to overheat.

2.1.42 $KPS_CURR_MAX

Maximum current of the KPS over 1 s (KR C2)

Data type	real	Value	min	--
Unit	A		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

2.1.43 $KPS_CURR_RATED

Maximum rated current of a KPS over 60 s (KR C2)

Data type	real	Value	min	--
Unit	A		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

2.1.44 $CURR_COM_EX[ ]

Current limit of the external axes for jogging

Data type	real	Value	min	--
Unit	%		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

Definition of the max. limit for the torque and motor current for jogging the external axes. This value is entered as a percentage of the maximum KSD current.

It is used, for example, for machine protection when jogging a position-controlled electric motor-driven weld gun. On closing the gun, the current would go to the command current limit ($CURR_LIM) and destroy the gun.

The value of $CURR_COM_EX[1] is written to the variable for torque mode when jog key E1 is pressed.

Example

$CURR_COM_EX[1]=50

$CURR_RED[7.1]=50
$CURR_RED[7.2]=50

2.1.45 $KT_MOT[ ]

KT factor of the motors

Data type	real	Value min	--
Unit	--	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

This entry describes the motor characteristic in terms of the ratio between the torque and the rated current at the nominal velocity.

Default value dependent on motor type.

2.1.46 $KT0_MOT[ ]

KT0 factor of the motors

Data type	real	Value min	--
Unit	--	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

This entry describes the motor characteristic in terms of the ratio between the torque and the rated current at standstill.

Default value dependent on motor type.

2.1.47 $RAISE_TIME[ ]

Axis acceleration time

Data type	real	Value min	--
Unit	ms	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

$RAISE_TIME + $FILTER/2 is the time in ms in which the axis can be accelerated to its rated speed ($VEL_AXIS_MA). ($FILTER is usually $DEF_FLT_PTP)

If the value is set too low, a corresponding error message is generated. This means that the ramp is too steep and that the current limit is thus exceeded. This value can be determined exactly using the oscilloscope.

Only used with non-KUKA kinematic systems with deactivated acceleration adaptation ($ADAP_ACC=#NONE) and deactivated higher motion profile ($OPT_MOVE=#NONE).
With KUKA standard robots, the accelerations are calculated according to the reach, the specified load and the mass inertia. In this case, the times are only used for monitoring the command acceleration.

The corresponding axis must not be allowed to go into current limitation during measurement and should not exceed 90% of Imax.

Normal values = 300 to 1000 ms

Default value = 500 ms

2.1.48 $RAISE_T_MOT[ ]

Motor acceleration time

Data type	real	Value	min	--
Unit	ms		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

The entry "$RAISE_T_MOT[ ]" defines the time taken for the motor to accelerate to the rated speed without an axis. These data are incorporated in the calculation of the dynamic model and monitored.

Default value = 5.0

Example

```
$RAISE_T_MOT[7]=5.0
$RAISE_T_MOT[8]=5.0
```

The motor speed must be lower than the maximum frequency (266 Hz) of the RDC.

2.1.49 $VEL_AXIS_MA[ ]

Rated motor speed

Data type	real	Value	min	--
Unit	rpm		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

The rated speed of the axis motor is defined here. This maximum speed is reached with override set to 100%. It is possible to reduce the axis traversing velocity.

Example

The drive motor of axis 7 is to have a rated speed of 1500 rpm:

```
$VEL_AXIS_MA[7]=1500.0
```

2.1.50 $VEL_CPT1_MA

Reduction factor for CP motions in T1

Data type	int	Value min	--
Unit	--	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

2.1.51 $VEL_DSE_MA[ ]

Axis-specific velocity monitoring limits

Data type	int	Value min	--
Unit	--	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

Actual speed monitoring on the DSE.

v_ist_max = v_soll_max*$VEL_DSE_MA/100

v_soll_max is the currently valid command velocity limit

2.1.52 $AXIS_RESO[ ]

Resolution of the measuring system

Data type	int	Value min	--
Unit	increments	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

This entry defines the resolution (pulse count) of an encoder:

- **per encoder revolution** (for incremental and absolute encoders).
- **per absolute cyclic range** (e.g. for multi-pole resolvers).

Default value:

- 4096 for KR C2

Example

The default value 4096 is entered for axis 7:

```
$AXIS_RESO[7]=4096
```

2.1.53 $RED_VEL_AXC[ ]

Reduction factor for axial velocity (HOV)

Data type	int	Value	min	--
Unit	%		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

Reduction factor for axial velocities during axis-specific jogging and in command mode (PTP motion) relative to the rated motor speed “$VEL_AXIS_MA”. This means a reduction in velocity to the 250 mm/s predefined in HOV.

Default value = 10

Example

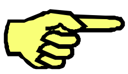
```
$RED_VEL_AXC[7]=10
$RED_VEL_AXC[8]=10
```

2.1.54 $RED_ACC_AXC[ ]

Reduction factor for axial acceleration (HOV)

Data type	int	Value	min	--
Unit	%		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

“$RED_ACC_AXC[ ]” is the reduction factor for axial acceleration during axis-specific jogging and in command mode (PTP motion) relative to the **maximum axial acceleration = $VEL_AXIS_MA[ ]/$RAISE_TIME[ ]**.



If the values are set too high, the axis will vibrate (jerky start to motions).

Default value = 20

Example

```
$RED_ACC_AXC[7]=20
$RED_ACC_AXC[8]=20
```

2.1.55 $RED_ACC_DYN

Reduzierfaktor für Beschleunigung

Data type	int	Value min	--
Unit	%	Value max	--
Assignment	--		

This factor can generally be used to reduce all accelerations to the specified value.

2.1.56 $RED_VEL_CPC

Reduction factor for CP and orientation velocity

Data type	int	Value min	--
Unit	%	Value max	--
Assignment	--		

Reduction factor for CP and orientation velocity in Cartesian jogging and command mode (CP).

2.1.57 $RED_ACC_CPC

Reduction factor for CP and orientation acceleration

Data type	int	Value min	--
Unit	%	Value max	--
Assignment	--		

Reduction factor for CP and orientation acceleration in Cartesian jogging and command mode (CP).

2.1.58 $VEL_CP_T1

Maximum CP velocity in Test1 mode

Data type	real	Value min	--
Unit	m/s	Value max	0,25
Assignment	--		

2.1.59 $VEL_CP_COM

Reduction factor for flange velocity

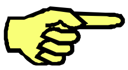
Data type	real	Value min	--
Unit	m/s	Value max	--
Assignment	--		

Reduction factor for the flange velocity in tool reorientation motions.

2.1.60 $RED_JUS_UEB

Reduction factor for sensor location run

Data type	real	Value	min	--
Unit	%		max	--
Assignment	--			



This machine datum is used exclusively for KUKA-internal development purposes.

2.1.61 $RED_ACC_OV[ ]

Axial reduction of acceleration for override

Data type	int	Value	min	100
Unit	%		max	100
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

This setting allows you to reduce the accelerations caused by changes to the override setting in axial motions.

This entry is fixed

Default value = 100

Example

```
$RED_ACC_OV[7]=100
$RED_ACC_OV[8]=100
```

2.1.62 $ACC_CAR_TOOL

Cartesian acceleration monitoring (relative to the flange)

Data type	frame	Value	min	--
Unit	--		max	--
Assignment	FRAME {X, Y, Z, A, B, C}			

If the effective accelerations at a specific point on a tool that is mounted on the flange are to be calculated cyclically and monitored against a maximum value, the machine datum defines this point.

2.1.63 $ACC_CAR_LIMIT

Cartesian acceleration monitoring

Data type	frame	Value	min	--
Unit	m/s^2		max	--
Assignment	FRAME {X, Y, Z, A, B, C}			

The frame variable $ACC_CAR_LIMIT can be used to set a value for the maximum permissible acceleration for the components X, Y and Z.

As soon as the current acceleration in one component exceeds one of these values the robot is stopped by means of ramp-down braking (as when the Stop key is pressed) and the error message “Maximum Cartesian acceleration exceeded” is displayed. This message is an acknowledgement message.

The default value for all components of $ACC_CAR_LIMIT is zero. At present, only the components ABS, X, Y and Z are used.

The components A, B and C are not evaluated.

The stop reaction is only triggered if the machine datum $ACC_CAR_STOP is set to TRUE. If the value is FALSE, no stop reaction takes place.

2.1.64 $ACC_CAR_ACT

For future expandability to rotational acceleration

Data type	frame	Value	min	--
Unit	--		max	--
Assignment	FRAME {X, Y, Z, A, B, C}			

This machine datum is used exclusively for KUKA-internal development purposes.

2.1.65 $ACC_CAR_STOP

Cartesian acceleration monitoring

Data type	bool	Value	min	--
Unit	--		max	--
Assignment	--			

This machine datum can be used to activate/deactivate the stop reaction triggered when the permissible limits specified in $ACC_CAR_LIMIT are exceeded.

The current acceleration is always calculated and $ACC_CAR_MAX is always updated irrespective of $ACC_CAR_STOP.

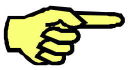
2.1.66 $RED_ACC_EMX[ ]

Reduction factor for path-maintaining Emergency Stop ramp

Data type	int	Value	min	--
Unit	%		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

In the case of a normal Emergency Stop, the maximum current should not be exceeded, otherwise the robot is no longer stopped on the path. The exact value can be determined using the oscilloscope.

Path-maintaining E-Stop ramp [ms] = $RAISE_TIME[ms]/$RED_ACC_EMX[%]*100[%]



The corresponding axis should not be allowed to go into current limitation.

Default value = 100

Example

```
$RED_ACC_EMX[7]=100
$RED_ACC_EMX[8]=100
```

2.1.67 $WARMUP_RED_VEL

Warm-up functionality

Data type	bool	Value	min	--
Unit	--		max	--
Assignment	--			

Example

Warm-up functionality activated:

$WARMUP_RED_VEL=TRUE

2.1.68 $WARMUP_TIME

Warm-up time of the gears

Data type	real	Value	min	--
Unit	min		max	--
Assignment	--			

If the gear units are very cold, the increased friction means that there is insufficient motor torque available for motion with high acceleration and speed.

This function makes it possible for the robot not to shut down on reaching the motor limits during the time defined in WARMUP_TIME, but merely to move more slowly.

As long as the robot is considered cold, the motor currents are monitored for all PTP motions. As soon as the current for one axis is greater than the maximum current specified in $WARMUP_CURR_LIMIT, an internal override is multiplied by the factor $WARMUP_MIN_FAC in order to reduce the motor currents.

This internal override is subsequently reset to 100% in several steps ($WARMUP_SLEW_RATE).

2.1.69 $COOLDOWN_TIME

Cool-down time

Data type	real	Value	min	--
Unit	min		max	--
Assignment	--			

2.1.70 $WARMUP_CURR_LIMIT

Monitoring value of the max. motor current

Data type	int	Value	min	--
Unit	%		max	--
Assignment	--			

2.1.71 $WARMUP_MIN_FAC

Min. factor applied to the den override

Data type	int	Value	min	--
Unit	%		max	--
Assignment	--			

2.1.72 $WARMUP_SLEW_RATE

Factor by which the internal override is increased

Data type	real	Value	min	--
Unit	%/s		max	--
Assignment	--			

2.1.73 $ST_TOL_VEL[ ]

Velocity tolerance for standstill detection

Data type	real	Value min	15.0
Unit	rpm	Value max	15.0
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

Velocity tolerance for standstill detection. This entry is fixed.

Default value = 15.0

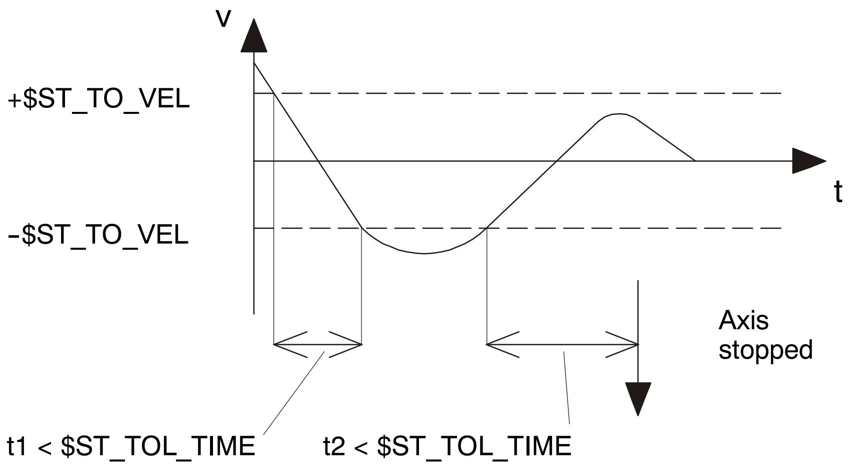


Fig. 4 Standstill detection

2.1.74 $ST_TOL_TIME

Detection time

Data type	int	Value min	15.0
Unit	ms	Value max	15.0
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

See Fig. 4.

2.1.75 $BOUNCE_TIME

Bounce time for EMT signals

Data type	int	Value min	--
Unit	ms	Value max	--
Assignment	--		

The signal is only accepted if it remains stable for the whole period defined in $BOUNCE_TIME.

2.1.76 $VEL_AX_JUS[ ]

Velocity for EMT mastering

Data type	real	Value min	--
Unit	mm/s, degrees/s	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

This entry defines the velocity at which a particular axis moves during EMT mastering. The user can thus set the velocity in such a way that the EMT can detect the reference notch reliably. The vertical velocity required by the EMT should be ±250 μm/s.

Default value = 0.1

2.1.77 $SEN_DEL[ ]

Distance traveled by EMT during signal propagation delay

Data type	int	Value min	--
Unit	increments	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

“$SEN_DEL[ ]” is the distance covered between detection of the mastering notch and output of the signal to the controller, i.e. the distance covered during the signal propagation delay.

Entry for the difference between EMT and dial mastering for the “same” mastering position.

Default value = 0

2.1.78 $L_EMT_MAX[ ]

Maximum length of EMT mastering travel

Data type	real	Value min	--
Unit	degrees, mm	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

This is the maximum length of the EMT mastering path. If this path is exceeded, a corresponding message is generated and the mastering process is aborted.

Formula:

$L_EMT_MAX = 8 / 5 * EMT_path

2.1.79 $G_VEL_CAL

Velocity factor for speed controller gain

Data type	real	Value min	--
Unit	--	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

This machine datum is used exclusively for KUKA-internal development purposes.

2.1.80 $LG_PTP[ ]

Loop gain PTP

Data type	real	Value min	--
Unit	1/ms	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

“$LG_PTP[ ]” is used to set the loop gain of the position control loop for PTP motions. This influences the motion characteristics of the axis.

If the control value is set too high, the command value is reached quickly resulting in “hard control”. This causes the axis to “pulse”.

Default value = 0.3

2.1.81 $LG_CP[ ]

Loop gain for CP motion

Data type	real	Value min	--
Unit	1/ms	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

"$LG_CP[ ]" is used to define the loop gain of the position controller for CP motion. In order to achieve optimal CP motion, the value of the robot motors should be entered here.

All axes have the same value.

2.1.82 $TC_SYM

Time-constant for symmetry of the axes

Data type	real	Value min	--
Unit	--	Value max	--
Assignment	--		

In order to achieve optimal CP motion, the value of the equivalent time constant of the slowest speed control loop should be entered here.

Default value = 0.1

2.1.83 $DECEL_MB[ ]

Braking ramp for dynamic braking

Data type	real	Value min	--
Unit	ms	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

In the event of dynamic braking being triggered by a fault situation, it is possible to set a ramp for the command speed using the entry "$DECEL_MB[ ]". This prevents the command value from falling too quickly and causing the current controller to go into limitation, which in turn would prevent the robot from being braked in a controlled manner.

$$\$DECEL\_MB[] = \frac{\$RAISE\_TIME[]}{\$RED\_ACC\_EMX[]} \cdot 100 \quad but\ \ min.\ 180\,ms$$

2.1.84 $G_COE_CUR

Proportional gain of the current controller

Data type	int	Value	min	--
Unit	--		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

This machine datum is only relevant for the KR C1 controller.

2.1.85 $G_VEL_PTP[ ]

Proportional gain of the speed controller for PTP motion

Data type	real	Value	min	--
Unit	[ ]		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

The setting of the proportional gain of the speed controller for PTP motion is made in "$G_VEL_PTP[ ]".

The P component can be used to set the strength of the reaction of the controller output to a deviation from the command value. Generally, the P component should be as high as possible. However, if the P component is too high, this can render the control loop unstable; this results in poor positioning or causes the drive to buzz loudly.

The value depends on the motor type.

2.1.86 $G_VEL_CP[ ]

Proportional gain of the speed controller for CP motion

Data type	real	Value	min	--
Unit	[ ]		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

The setting of the proportional gain of the speed controller for CP motion is made in "$G_VEL_CP[ ]".

The P component can be used to set the strength of the reaction of the controller output to a deviation from the command value. Generally, the P component should be as high as possible. However, if the P component is too high, this can render the control loop unstable; this results in poor positioning or causes the drive to buzz loudly.

The value depends on the motor type.

2.1.87 $I_VEL_PTP[ ]

I factor of the speed controller for PTP motions

Data type	real	Value min	--
Unit	[ ]	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

“$I_VEL_PTP[1]” is the integral-action factor of the speed controller for PTP motion.

The I component $I_VEL_PTP[ ] can be used to set the build-up speed of the controller output in the event of a deviation from the command value. Generally, the I component should be as small as possible, resulting in a fast rise. However, if the I component is too small, this can render the control loop unstable; this results in poor positioning or causes the drive to buzz loudly.

If the I factor of the controller is set too low, this cause vibrations.

Guide values: = 90 for small external motors

(types C0, C, CS, D, E)

= 200 .. 500 for large external motors

(types A01, A0, A, B, G1, I, I1, H, HS)

2.1.88 $I_VEL_CP[ ]

I factor of the speed controller for CP motion

Data type	real	Value min	--
Unit	[ ]	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

“$I_VEL_CP[ ]” is the integral-action factor of the speed controller for CP motion.

The I component $I_VEL_CP[ ] can be used to set the build-up speed of the controller output in the event of a deviation from the command value. Generally, the I component should be as small as possible, resulting in a fast rise. However, if the I component is too small, this can render the control loop unstable; this results in poor positioning or causes the drive to buzz loudly.

If the I factor of the controller is set too low, this cause vibrations.

Guide values: = 90 for small external motors (types C, D, E)

= 200 .. 500 for large external motors (types B, A, A0)

2.1.89 $VEL_FILT[ ]

Tacho filter

Data type	real	Value	min	2.5
Unit	ms		max	2.5
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

“$VEL_FILT[ ]” sets the time constant for the current speed filter.

This entry is fixed.

Default value = 2.5

2.1.90 $TM_CON_VEL

Minimum constant travel phase

Data type	int	Value	min	--
Unit	ms		max	--
Assignment	--			

The minimum constant travel phase is used to avoid sudden loading of the robot arm. Such loading is caused by abrupt changes between acceleration and braking with short distances between points.

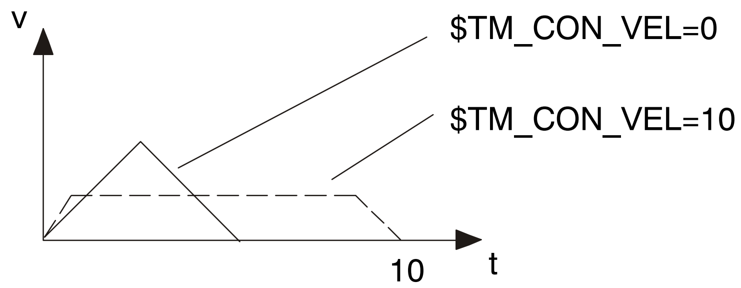


Fig. 5 Minimum constant travel phase

2.1.91 $APO_DIS_PTP[ ]

Maximum approximation distance for PTP motions

Data type	real	Value	min	--
Unit	degrees, mm		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

The maximum approximation distance is specified individually for each axis in “$APO_DIS_PTP[ ]”.

Default value = 90.0 degrees or 500.0 mm

2.1.92 $ACC_MA

Data for path acceleration of the TCP

Data type	real	Value	min	--
Unit	m/s^2, degrees/s^2		max	--
Assignment	--			

CP: Path in m/s^2:

Cartesian motions are carried out with the acceleration RED_ACC_CPC*ACC_MA.CP.

ORI1: Swivel in degrees/s^2

Swivel motions are carried out with the acceleration RED_ACC_CPC*ACC_MA.ORI1.

ORI2: Rotation in degrees/s^2

Rotational motions are carried out with the acceleration $RED_ACC_CPC*ACC_MA.ORI2.

Incorrect use can significantly shorten the service life of the gear units.

2.1.93 $VEL_MA

Data for path velocity of the TCP

Data type	real	Value	min	--
Unit	m/s, degrees/s		max	--
Assignment	--			

CP: Path in m/s

Cartesian motions are carried out with the velocity RED_VEL_CPC*VEL_MA.CP.

ORI1: Swivel in degrees/s

Swivel motions are carried out with the velocity RED_VEL_CPC*VEL_MA.ORI1.

ORI2: Rotation in degrees/s

Rotational motions are carried out with the velocity $RED_VEL_CPC*VEL_MA.ORI2.

Incorrect use can significantly shorten the service life of the gear units.

2.1.94 $ACC_OV

Data for path acceleration with changes of override

Data type	real	Value	min	--
Unit	m/s^2, $degrees/s^2$		max	--
Assignment	--			

CP: Path in m/s^2

ORI1: Swivel in $degrees/s^2$

ORI2: Rotation in $degrees/s^2$

2.1.95 $RED_T1

Reduction factor for Test 1 mode

Data type	int	Value	min	--
Unit	%		max	--
Assignment	--			

Linear change in velocity for PTP and CP motions:

V=($RED_T1/100)*$VEL.CP

Quadratic change in acceleration:

A=($RED_T1/100)²*$ACC.CP

2.1.96 $DEF_FLT_PTP

Default mean value filter for PTP motion

Data type	int	Value	min	--
Unit	ms		max	--
Assignment	--			

2.1.97 $DEF_FLT_CP

Default mean value filter for CP motion

Data type	int	Value	min	--
Unit	ms		max	--
Assignment	--			

2.1.98 $DEF_OV_JOG

Default value for override in jog mode

Data type	int	Value	min	1
Unit	--		max	100
Assignment	--			

2.1.99 $ANA_DEL_FLT

Filtering of the analog output

Data type	--	Value	min	--
Unit	--		max	--
Assignment	--			

2.1.100 $SEQ_CAL

Definition of the mastering sequence of the individual axes

Data type	bin	Value	min	--
Unit	--		max	--
Assignment	[1] Step 1 ... [12] Step 12			

Bit sequence:

LSB: Axis 1

MSB: Axis 12

2.1.101 $DIR_CAL

Definition of the mastering direction for each axis

Data type	bin	Value	min	--
Unit	--		max	--
Assignment	--			

Defines the mastering direction for each axis.

Bit (n)= 0 Reference point of axis n is approached in the positive direction

Bit (n)= 1 Reference point of axis n is approached in the negative direction

Bit	0	1	2	3	4	5	... 15
Axis	A1	A2	A3	A4	A5	A6	... A16

2.1.102 $RED_CAL_SD

Reduction factor for mastering velocity after reaching reference point cam

Data type	int	Value	min	--
Unit	%		max	--
Assignment	--			

Only required for incremental encoders; not relevant for resolvers.

2.1.103 $RED_CAL_SF

Reduction factor for mastering velocity before reaching reference point cam

Data type	int	Value	min	--
Unit	%		max	--
Assignment	--			

Only required for incremental encoders; not relevant for resolvers.

2.1.104 $BRK_MODE

This machine datum may only be modified if it is absolutely certain that the modification will not endanger persons.

Brake control mode

Data type	bin	Value	min	--
Unit	--		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

"$BRK_MODE" defines the brake control mode.

Bit no.	3	2	1	0
Meaning	External axes	Program mode	General	Command mode

Command mode:

Bit 0 = 0 Robot brakes do not close at end of command.

Bit 0 = 1 Robot brakes close at end of command in accordance with mode bit 1.

General:

For KR C2: robot brakes always open and close simultaneously!

Program mode:

Bit 2 = 0 Robot brakes do not close during motion pauses within programs.

Bit 2 = 1 Robot brakes close during motion pauses within programs in accordance with mode bit 1.

External axes:

Bit 3 = 0 The brakes of external axes respond in the same way as the robot brakes in accordance with mode bits 0 – 2.

Bit 3 = 1 Mathematically coupled external axes respond in the same way as the robot axes. External axes that are not mathematically coupled function independently of the robot axes if they are controlled separately.

Default settings of the brake mode:

- Robot brakes close at end of command
- Robot brakes close simultaneously
- Robot brakes close during motion pauses
- External axes do not brake individually during motion pauses

With asynchronous external axes and SBMs: $BRK_MODE=1101

Example

```
$BRK_MODE='B0101'
```

2.1.105 $BRK_OPENTM

This machine datum may only be modified if it is absolutely certain that the modification will not endanger persons.

Delay of command velocity output

Data type	int	Value	min	1
Unit	ms		max	--
Assignment	--			

Delay of command velocity output after the axis brakes have been opened (prevents motion “against the brakes”).

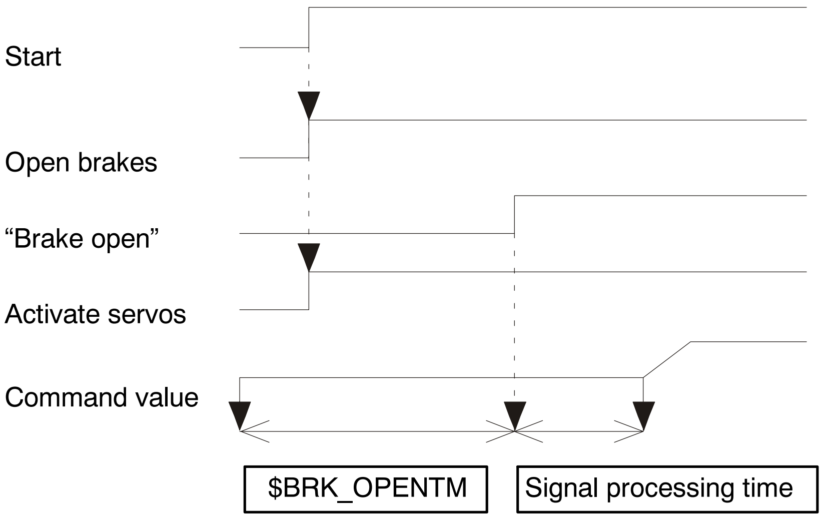


Fig. 6 Delay

2.1.106 $BRK_DEL_COM

Time after which the axis brakes are closed on completion of positioning in the command mode

Data type	int	Value	min	--
Unit	ms		max	--
Assignment	--			

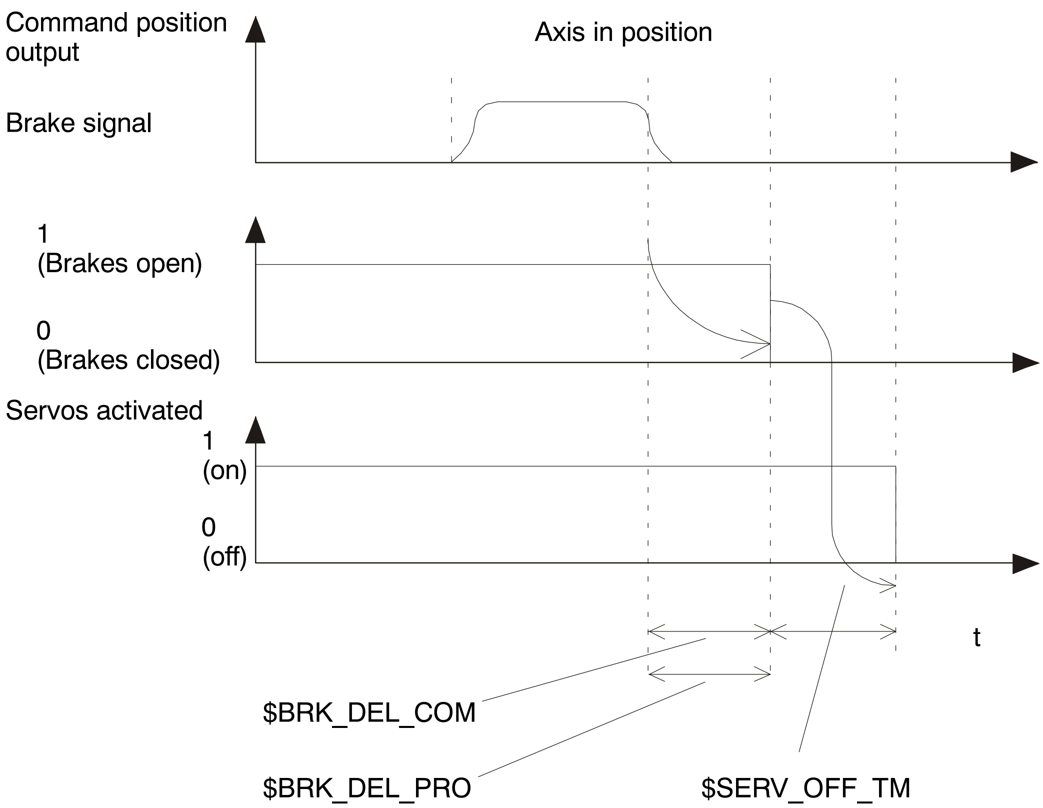


Fig. 7 Closing the axis brakes

2.1.107 $BRK_DEL_PRO

Time after which the axis brakes are closed on completion of positioning in program mode

Data type	int	Value min	--
Unit	ms	Value max	--
Assignment	--		

See Fig. 7.

2.1.108 $BRK_DEL_EX

Brake delay time for external axes

Data type	int	Value	min	--
Unit	ms		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

"$BRK_DEL_EX" defines the delay time after which the brakes of the external axes close.

This entry is only active if bit 3 is set in "$BRK_MODE" (see Section 2.1.104).

2.1.109 $SERV_OFF_TM

Axis servo and axis brake overlap time

Data type	int	Value	min	--
Unit	ms		max	--
Assignment	--			

Time during which axis servo and axis brake overlap in order to locate the axis securely.

See Fig. 7.

2.1.110 $MS_DA

Modification of this machine datum constitutes a major danger to persons and is thus not permitted.

This machine datum is used exclusively for KUKA-internal development purposes.

2.1.111 $FFC_VEL

Velocity feed forward control switching

Data type	bin	Value	min	--
Unit	--		max	--
Assignment	--			

Bit sequence

LSB: Axis 1

MSB: Axis 12

0 Off

1 On

2.1.112 $FFC_TORQ

Torque pre-control

Data type	bool	Value	min	--
Unit	--		max	--
Assignment	--			

Torque pre-control On/Off is only used in conjunction with higher motion profile. In the case of non-KUKA kinematic systems with deactivated acceleration adaptation ($ADAP_ACC=#NONE) and deactivated higher motion profile ($OPT_MOVE=#NONE), it must be switched off.

Description of the valid values:

TRUE = activated

FALSE = deactivated

2.1.113 $GEARTORQ_MON

Control of gear torque monitoring

Data type	bool	Value	min	--
Unit	--		max	--
Assignment	--			

Gear torque monitoring On/Off is only used in conjunction with higher motion profile. In the case of non-KUKA kinematic systems with deactivated acceleration adaptation ($ADAP_ACC=#NONE) and deactivated higher motion profile ($OPT_MOVE=#NONE), it must be switched off.

TRUE: Activated using the limits (% of the maximum accelerating torques) defined in the data $DYN_DAT[231]-$DYN_DAT[236] in $robcor.dat.

FALSE: Deactivated

2.1.114 $SERVOMODE

Controller functions

Data type	int	Value	min	--
Unit	--		max	--
Assignment	--			

This machine datum is used exclusively for KUKA-internal development purposes.

2.1.115 $ACC_ACT_MA

Limit value of axial command acceleration

Data type	int	Value	min	--
Unit	%		max	--
Assignment	--			

a_soll_max=$ACC_ACT_MA/100*"Maximum motor speed"/$raise_time

V_soll_max=$VEL_ACT_MA/100* "Maximum motor speed"*"Reduction factor"/100

"Maximum motor speed"=

- $VEL_AXIS_MA with deactivated energy monitoring ($energy_mon=false) and non-KUKA kinematic systems.
- With active energy monitoring ($energy_mon=true), a value is calculated from the dynamic model DYN_DAT[249-254].

2.1.116 $VEL_ACT_MA

Limit value of axial command velocity

Data type	real	Value	min	--
Unit	%		max	--
Assignment	--			

V_soll_max=$VEL_ACT_MA/100* "Maximum motor speed"*"Reduction factor"/100

"Maximum motor speed"=

- $VEL_AXIS_MA with deactivated energy monitoring ($energy_mon=false) and non-KUKA kinematic systems.
- With active energy monitoring ($energy_mon=true), a value is calculated from the dynamic model DYN_DAT[249-254].

“Reduction factor”=

- $RED_VEL_AXC in jog mode
- $RED_T1 for PTP/PTP-PTP in T1 mode
- $VEL_CPT1_MA for CP/CP-CP/CP-PTP/PTP-CP in T1 mode
- $RED_VEL_AXC for BCO run with PTP
- $VEL_CPT1_MA for BCO run with CP

In all other cases: 100%.

2.1.117 $IN_POS_CAR

Cartesian positioning window (translation section)

Data type	real	Value	min	--
Unit	mm		max	--
Assignment	--			

2.1.118 $IN_POS_ORI

Cartesian positioning window (orientation section)

Data type	real	Value	min	--
Unit	degrees		max	--
Assignment	--			

2.1.119 $IN_POS_MA[ ]

Positioning window

Data type	real	Value min	--
Unit	mm, degrees	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

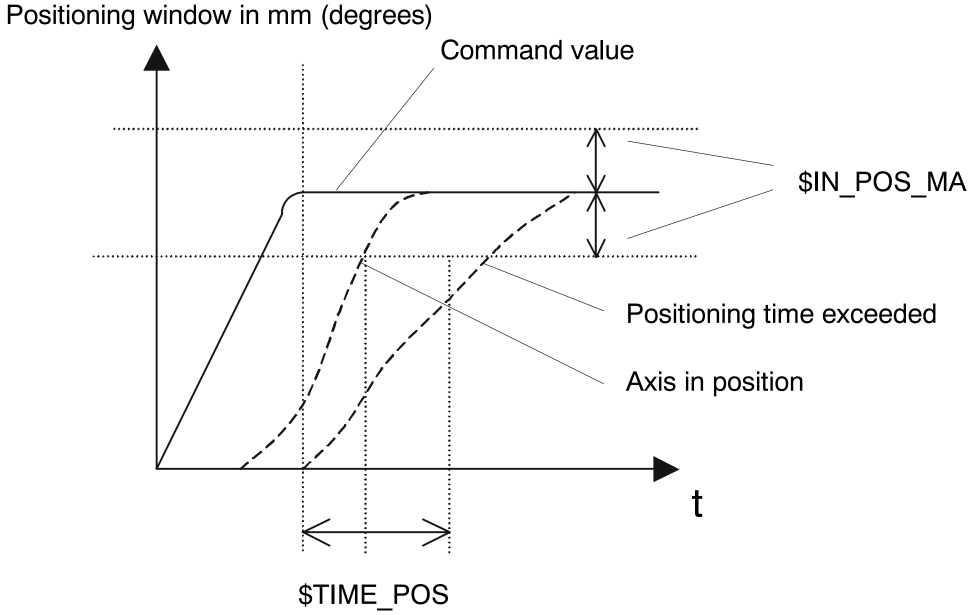


Fig. 8 Positioning window

During positioning, a check is made in the position controller for each axis to see whether the following error is inside the positioning window for [axis velocity = 0] within the time specified ($TIME_POS).

If the following error is larger after this time has elapsed, a corresponding error message is generated.

Default value = 0.1

For linear axes = 1.5 mm

For motor type E = 0.2

2.1.120 $TIME_POS[ ]

Positioning time

Data type	int	Value	min	512
Unit	ms		max	512
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

During positioning, a check is made in the position controller for each axis to see whether the following error is inside the positioning window for [axis velocity = 1] within the time specified ($TIME_POS).

This entry is fixed.

Default value = 512

See Fig. 8

2.1.121 $IN_STILL_MA

Factor for standstill window (see Fig. 9)

Data type	int	Value	min	--
Unit	--		max	--
Assignment	--			

The size of the window is defined by IN_STILL_MA*IN_POS_MA.

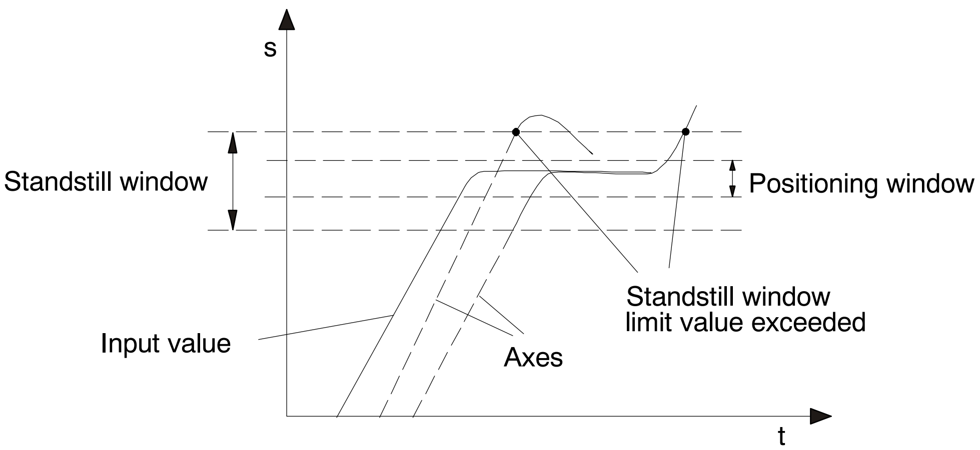


Fig. 9 Standstill window

2.1.122 $FOL_ERR_MA[ ]

Factor for following error monitoring on the DSE

Data type	real	Value	min	20.0
Unit	[ ]		max	20.0
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

The definition of the monitoring window for following error monitoring refers to $IN_POS_MA * $FOL_ERR_MA

If the value is exceeded, the error message “Regulator limit exceeded Ax” is generated and maximum braking is triggered.

This entry is fixed.

Default value = 20.0

2.1.123 $VEL_ENC_CO

Command speed threshold for encoder monitoring

Data type	int	Value	min	--
Unit	--		max	--
Assignment	--			

This machine datum is used exclusively for KUKA-internal development purposes.

2.1.124 $COM_VAL_MI[ ]

Command speed limitation

Data type	real	Value	min	150.0
Unit	%		max	150.0
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

Limitation of axis command speed.

The command speed value is limited to the value specified in $COM_VAL_MI.

This entry is fixed.

Default value = 150.0

2.1.125 $TL_COM_VAL

Tolerance time after exceeding the command speed limitation

Data type	int	Value	min	50
Unit	ms		max	50
Assignment	--			

If the command speed is still greater than the limit value defined in $COM_VAL_MI after the time defined in $TL_COM_VAL has elapsed, the error message “Command velocity exceeded” is generated.

This entry is fixed.

Default values = 50.0 and 50.0

2.1.126 $TOUCH_VEL

Maximum retract velocity for touch sensor

Data type	int	Value	min	--
Unit	%		max	--
Assignment	--			

2.1.127 $TOUCH_ACC

Retract acceleration for touch sensor

Data type	int	Value	min	--
Unit	%		max	--
Assignment	--			

2.1.128 $SOFTN_END[ ]

Software limit switches in the minus direction

Data type	real	Value	min	--
Unit	mm, degrees		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

In the mastered state, the range of motion of the axes can be restricted using software limit switches.

2.1.129 $SOFTP_END[ ]

Software limit switches in the plus direction

Data type	real	Value	min	--
Unit	mm, degrees		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

In the mastered state, the range of motion of the axes can be restricted using software limit switches.

Example

```
$SOFTP_END[7]=180.0
$SOFTP_END[8]=190.0
```

2.1.130 $AXWORKSPACE

Axis-specific workspaces

Data type	real	Value	min	--
Unit	--		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

“$AXWORKSPACE” is an axis-specific workspace monitoring function similar to the Cartesian workspace monitoring function.

A maximum of eight workspaces can be defined via KRL system variables.

2.1.131 $BRK_MAX_TM

Maximum braking time for path-maintaining EMERGENCY STOP

Data type	int	Value	min	--
Unit	ms		max	--
Assignment	--			

If the time is exceeded, the error message “Max. braking distance exceeded” is generated.

2.1.132 $EMSTOP_TIME

Time monitoring for path-maintaining EMERGENCY STOP

Data type	int	Value	min	--
Unit	ms		max	--
Assignment	--			

If the robot is not stationary after the time defined in "$EMSTOP_TIME", the drives contactor is switched off.

2.1.133 $ACT_VAL_DIF

Max. permissible difference of encoder actual values

Data type	int	Value	min	--
Unit	--		max	--
Assignment	--			

Maximum permissible difference of the encoder actual values, in increments, before and after the controller is booted.

2.1.134 $TRAFONAME

Name of coordinate transformation

Data type	char	Value	min	--
Unit	--		max	--
Assignment	--			

This makes it possible to assign the transformation a symbolic name. It is also compared with the robot names programmed on the RDC ($ROBTRAFO).

2.1.135 $KINCLASS

Kinematic classes

Data type	char	Value	min	--
Unit	--		max	--
Assignment	--			

The machine datum defines the "kinematic class".

Permissible values are:

- **#STANDARD**

This value activates a transformation that is configured using the following data.

- **#NONE**

This value is for kinematic systems for which no transformation exists. These can then nonetheless be moved in axis-specific mode.

Programs can only be taught in the KRL assistant (axis-specific) or at Expert level (axis-specific).

The machine datum also has the values #TEST and #SONDER. These are meaningless, however, and must not be used.

2.1.136 $AX_SIM_ON

This machine datum may only be modified if it is absolutely certain that the modification will not endanger persons.

Simulation of the closed speed control loop for axis ...

Data type	real	Value min	--
Unit	--	Value max	--
Assignment	--		

Bit array of the simulated axes. This allows the simulation of axes that may not actually be present. It is thus possible, for example, to implement main axis kinematic systems with fewer than three degrees of freedom.

The thing to remember here is that the position of the simulated axes when the system is run up is initialized either to 0 (configured DSE channel present, but no RDC channel) or to the value of the corresponding axes in $H_POS (no DSE channel available for this axis).

Bit sequence:

- LSB: Axis 1
- MSB: Axis 12

2.1.137 $SIMULATED_AXIS

Simulation of robot axes

Data type	bin	Value min	--
Unit	--	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

Axes are included in the planning, but are not moved.

2.1.138 $TRAFO_AXIS

Number of transformed axes

Data type	int	Value min	--
Unit	--	Value max	--
Assignment	--		

This machine datum specifies the number of transformed axes.

The value must be between 4 and 6, even if, for example, only three axes are physically present, and can differ from the value of $NUM_AX.

2.1.139 $MAIN_AXIS

Main axis identification

Data type	real	Value min	--
Unit	--	Value max	--
Assignment	--		

Main axes is the designation given to the first three robot axes. These can be designed as either rotating or linear joints. Two consecutive main axes are either parallel or perpendicular to one another.

This means that a maximum of 12 geometrically different arrangements are possible.

Eight of these arrangements can be configured using this machine datum.

Description of the permissible values:

- #SS = Gantry

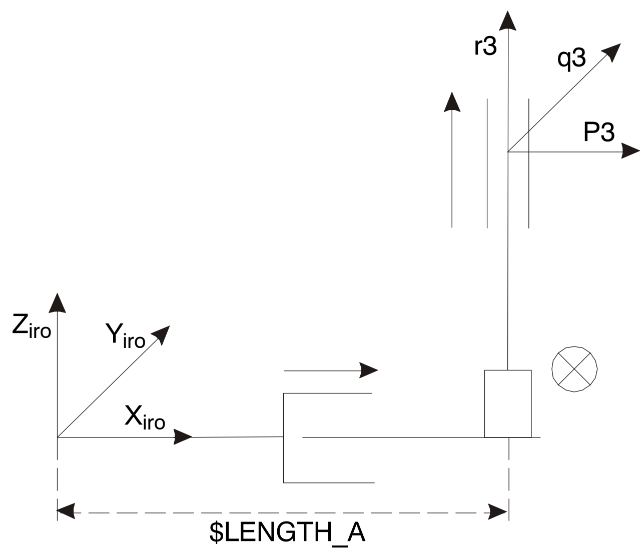


Fig. 10 #SS configuration

- #CC = SCARA

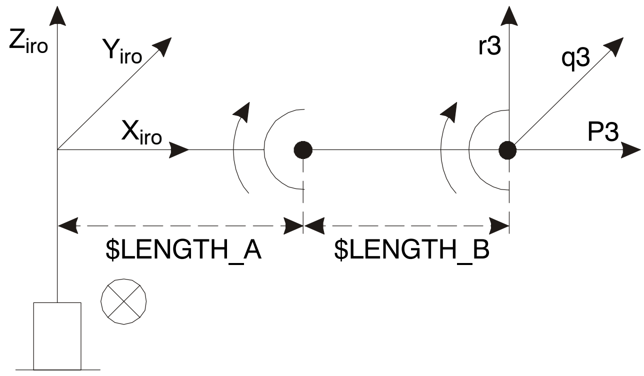


Fig. 11 #CC configuration

- #NR = Jointed-arm robot

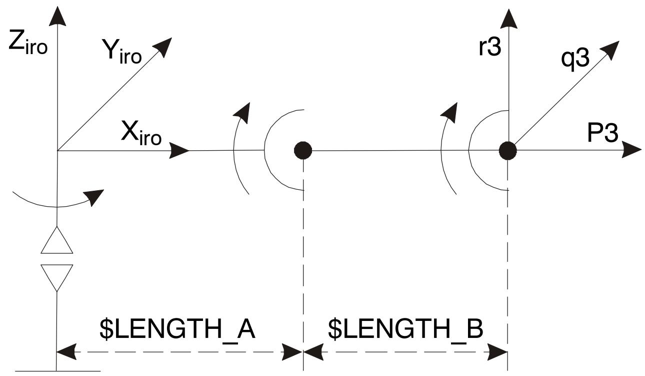


Fig. 12 #NR configuration

- #SC = Gantry/SCARA

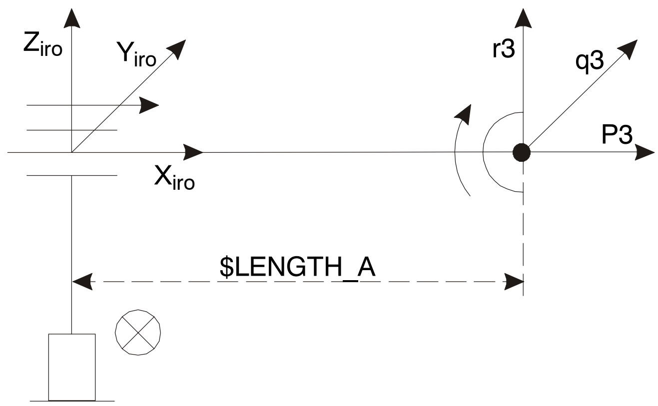


Fig. 13 #SC configuration

- #RR

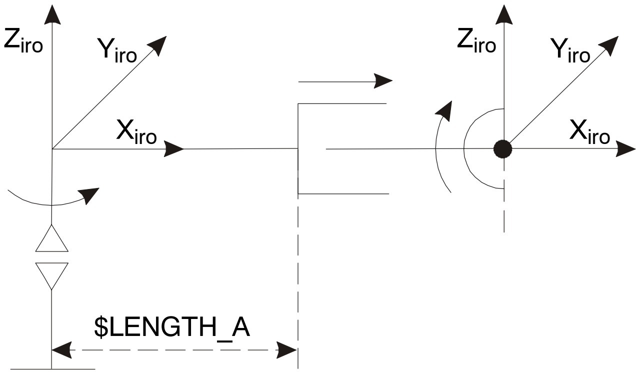


Fig. 14 #RR configuration

- #CS

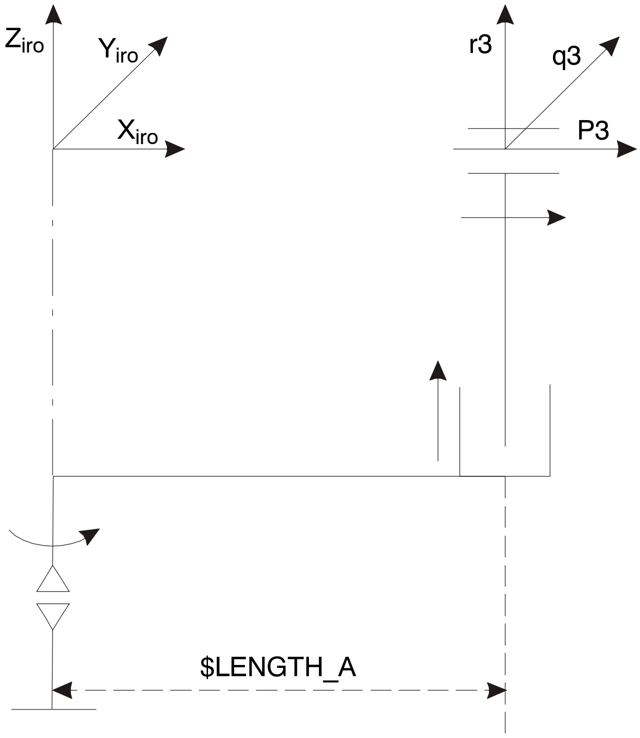


Fig. 15 #CS configuration

- #NN

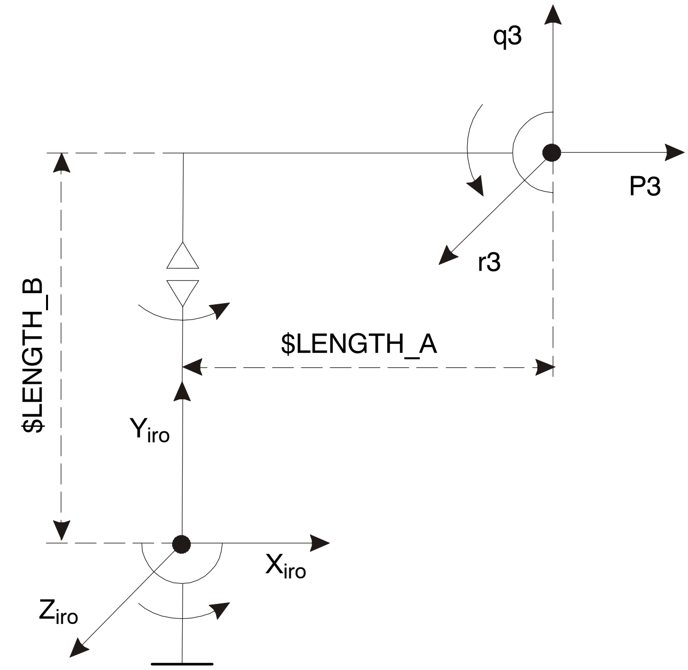


Fig. 16 #NN configuration

- #RN

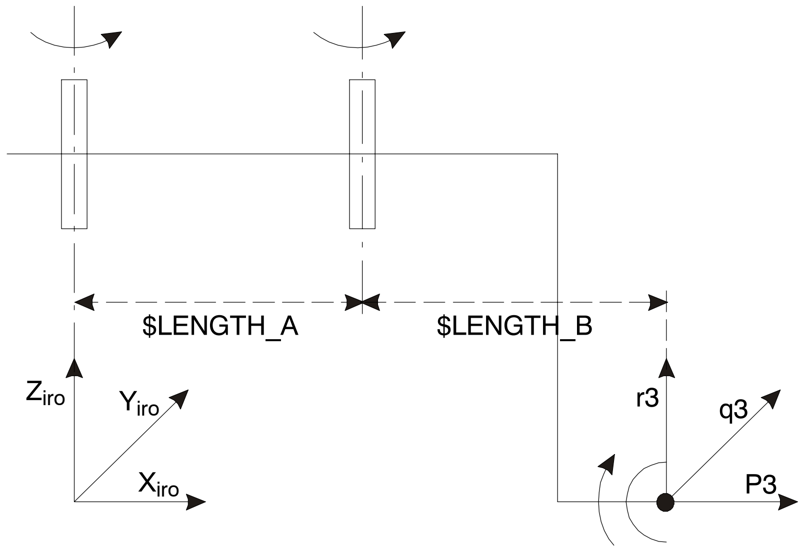


Fig. 17 #RN configuration

(The other four possible configurations #SN, #CR, #NS and #RC are not implemented.)

2.1.140 $WRIST_AXIS

Wrist axis identification

Data type	real	Value min	--
Unit	--	Value max	--
Assignment	--		

This configures the kinematic structure of the wrist.

Description of the permissible values:

- #NOH = no wrist transformation
- #ZEH = in-line wrist; the three wrist axes intersect and are perpendicular to one another, i.e. the Denavit-Hartenberg parameters are defined and must be a4=a5=d5=0, α4=±90 degrees, α5=±90 degrees.
- #SRH = oblique wrist; the three wrist axes intersect at a single point, i.e. the Denavit-Hartenberg parameters a4=a5=d5=0 are defined; any value (greater than 10 degrees) can be selected for α4 and α5.
- #DSH = triple-roll wrist; only the "oblique angle" α can be freely selected and is entered in $DH_4.ALPHA; the values for a4=a5=d5=0 and α5=-2α are fixed.
- #WIH offset wrist; the three wrist axes are perpendicular to one another, i.e. the Denavit-Hartenberg parameters α4=±90 degrees, α5=±90 degrees are fixed; a4, d5 and a5 can be freely selected.
- #WSH = oblique offset wrist; this is the "most general" wrist; all DH parameters (with the exception of d4 which is always 0!) can be freely selected.

2.1.141 $A4_PAR

Axis 4 parallel to the last rotational main axis

Data type	int	Value min	0
Unit	--	Value max	1
Assignment	--		

This specifies whether axis 4 is parallel to the last rotational main axis:
0 = not parallel; 1 = parallel.

2.1.142 $DEF_A4FIX

Fixed positioning of axis 4 and simultaneous control of axis 5 in palletizing mode

Data type	bool	Value	min	--
Unit	--		max	--
Assignment	--			

This machine datum must be set to TRUE for the 5-axis palletizing robot. In the case of Cartesian positions, the orientation is modified so that the flange is always parallel to the floor. The position remains identical.

In the case of axis-specific positions, the angle of axis 5 is adapted in such a way that the flange is parallel to the floor (this naturally causes the Cartesian position to change).

This setting is only permissible for type #NR and only for floor- or ceiling-mounting (can be seen from $ROBROOT and $TIRORO).

The value of $DEF_A4FIX also serves as a default setting for $PAL_MODE.

Description of the permissible values:

- TRUE = Palletizing mode on by default
- FALSE = Palletizing mode off by default

2.1.143 $DEF_A5LINK

4-axis palletizing mode control

Data type	bool	Value	min	--
Unit	--		max	--
Assignment	--			

This machine datum must be set to TRUE for the 4-axis palletizing robot. $DEF_A4FIX is then also implicitly set to TRUE. This setting is also only permissible for type #NR and is only meaningful if the robot is mounted on the floor.

$PAL_MODE must not be set to FALSE in this case!

Description of the permissible values:

- TRUE = 4-axis palletizing mode activated
- FALSE = 4-axis palletizing mode deactivated

If 4-axis palletizing mode is activated, axes 4 and 5 are automatically switched internally to axis simulation. The assignment of $DEF_A4FIX is ignored.

2.1.144 $SPINDLE

Spindles

Data type	int	Value	min	0
Unit	--		max	1
Assignment	--			

Description of the permissible values:

- 0 = No
- 1 = Yes

2.1.145 $AXIS_SEQ

Change in sequence from axis ... to axis ...

Data type	real	Value	min	--
Unit	--		max	--
Assignment	[1] axis 1 ... [6] axis 6			

Assignment of the axes.

With certain kinematic systems it is possible to interchange the axes without this resulting in a different kinematic behavior.

With main axes #SS and #CC, for example, the axes can be freely interchanged; with #CS and #SC it is possible to interchange axes 1 and 2 or 2 and 3. This interchange is carried out using $AXIS_SEQ[]. $AXIS_SEQ[i]=j thus means that axis j corresponds to the normal axis i.

In the case of a SCARA robot (#CC), for example, axis 1 is usually the linear axis. $AXIS_SEQ[1]=3 defines axis 3 as the linear axis.

A change to the axis sequence of other kinematic systems is not rejected. It is thus necessary to use this machine datum with extreme caution!

2.1.146 $AXIS_DIR[ ]

Direction of rotation of the axes for the transformation

Data type	int	Value	min	--
Unit	--		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

It is only the direction of rotation for the transformation that is defined by the machine datum.

The rotational axis and thus direction of rotation (for the transformation) of the main axes is defined by the definition of the coordinate systems IRO and X3. This machine datum is thus required for the free selection of any direction of rotation.

The actual direction of rotation of an axis is not affected by $AXIS_DIR. This can only be modified by means of the sign preceding the value for the gear ratio ($RAT_MOT_AX).

Mathematically positive = 1

Mathematically negative = -1

Definition of the direction of rotation is only meaningful once the external axes have been calibrated.

Example

In the example, the sign of the angle of axis 2 is inverted in the transformation. If the axis is at -10 degrees, for example, the transformation works on the basis of +10 degrees.

```
$AXIS_DIR[2]=-1
```

2.1.147 $INC_AXIS

Incremental dimension, axis-specific

Data type	real	Value	min	--
Unit	degrees, mm		max	--
Assignment	[1] axis 1 ... [6] axis 6			

2.1.148 $INC_EXTAX[ ]

Axis-specific increment of external axes

Data type	real	Value	min	--
Unit	increments		max	--
Assignment	[1] axis 1 ... [6] axis 6			

The increment for an axis is the distance moved by the robot each time a jog key is pressed.

Example

```
$INC_EXTAX[1]=10.0
$INC_EXTAX[2]=10.0
```

2.1.149 $INC_CAR[ ]

Increment, Cartesian, relative to the tool

Data type	real	Value	min	--
Unit	degrees, mm		max	--
Assignment	[1]... [6]			

2.1.150 $POS_SWB[ ]

Modification of Status for singularities

Data type	int	Value	min	--
Unit	--		max	--
Assignment	--			

For each of the max. three singularities, it is possible to specify here whether or not modification of the solution branch, i.e. the status, is permissible during a CP motion.

Modification can, however, lead to velocity-dependent axis positions and does not solve the underlying problem of the singularities. We therefore recommend leaving this value always set to 0.

Description of the permissible values:

0 = NO

1 = YES

Example

Singularity 1 – modification of Status is not to be possible:

$POS_SWB[1]=0

2.1.151 $SINGUL_POS

Treatment of an undefined joint positions

Data type	int	Value min	0
Unit	--	Value max	1
Assignment	[1] [2] [3]		

Configuration of the treatment of undefined joint positions on specification of a singular PTP end point.

Description of the permissible values:

The value 0 means that the corresponding axis is moved to 0 degrees, while the value 1 means that the axis value of the start point is used.

0 Use theta=0 degrees

1 Use old value of theta

Example

If the end point of a PTP motion results in the wrist singularity (Alpha 5), the angles of axes 4 and 6 cannot be determined unambiguously.

If $SINGUL_POS[3] is equal to 0, the angle of axis 4 will in any case be moved to 0 degrees, while the value 1 means that the value of the start point is retained for axis 4. The angle of axis 6 is then adapted accordingly.

2.1.152 $DIS_WRP1

Average distance of wrist point from singularity 1 (Alpha1 singularity)

Data type	real	Value min	--
Unit	--	Value max	--
Assignment	--		

2.1.153 $DIS_WRP2

Average distance of wrist point from singularity 2 (Alpha5 singularity)

Data type	real	Value min	--
Unit	--	Value max	--
Assignment	--		

2.1.154 $ORI_CHECK

Orientation check at CP end points (only with five-axis robots)

Data type	int	Value	min	--
Unit	--		max	--
Assignment	--			

In the case of 5-axis robots, one degree of freedom is missing. This means that it is not possible to set a default value for the orientation angle C.

There are two possibilities, however, for addressing a Cartesian position. The only difference here is a difference of 180 degrees for angle C.

If $ORI_CHECK is set to 1, a check is carried out to see whether or not the 5-axis robot reached the taught end point.

2.1.155 $TIRORO

Offset between internal and current robot coordinate system

Data type	real	Value	min	--
Unit	--		max	--
Assignment	FRAME {X, Y, Z, A, B, C}			

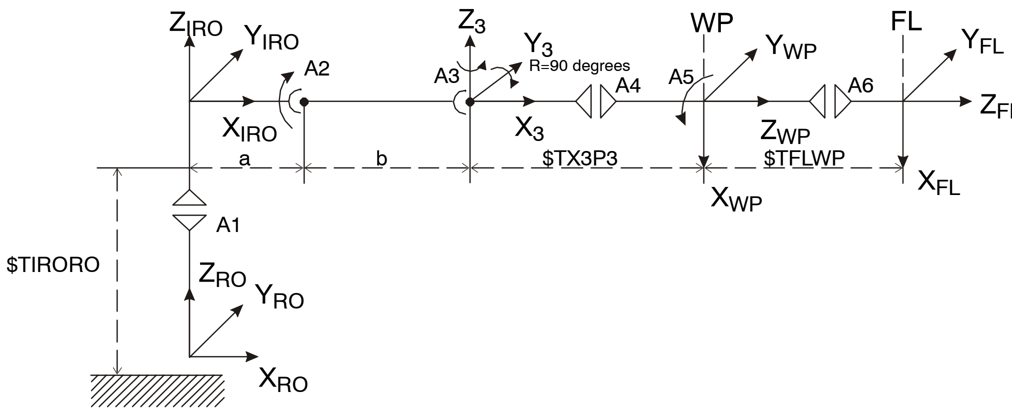


Fig. 18 TIRORO

This frame represents the position of the internal robot coordinate system (IRO) in the externally visible robot base system (RO).

2.1.156 $TFLWP

Offset between flange point and wrist point coordinate system

Data type	real	Value	min	--
Unit	--		max	--
Assignment	FRAME {X, Y, Z, A, B, C}			

(See Fig. 18.) Link frame between the last wrist coordinate system (WP) and the externally visible flange system (FL) (representation of FL system in the WP system).

2.1.157 $TX3P3

Offset of robot wrist, based on axis 3

Data type	real	Value	min	--
Unit	--		max	--
Assignment	FRAME {X, Y, Z, A, B, C}			

Link frame between the last main axis system (P3) and the first wrist coordinate system (X3) (representation of the X3 system in the P3 system).

Bear in mind that coordinate system P3 does not correspond to the DH convention as robot axis 3 in the standard robot (#NR), for example, rotates about the Y3 axis of the P3 system.

The Z axis of the first wrist axis system X3 must be parallel (or antiparallel) to rotational axis 4, as the wrist is described using DH parameters.

2.1.158 $LENGTH_A

Main axis length A, eccentricity of axis 2 relative to axis 1

Data type	real	Value	min	--
Unit	--		max	--
Assignment	--			

This is a geometrical length that depends on the specific main axis kinematic system that has been set.

2.1.159 $LENGTH_B

Main axis length B, link arm length

Data type	real	Value	min	--
Unit	--		max	--
Assignment	--			

This is a geometrical length that depends on the specific main axis kinematic system that has been set.

2.1.160 $DH_4

Denavit-Hartenberg parameters

Data type	real	Value	min	--
Unit	--		max	--
Assignment	--			

Length A	DHART_A
Length D	DHART_D
Angle α	DHART_ALPHA

Denavit-Hartenberg parameters a, d and α for frame between axis 4 and 5, or 5 and 6. $DH_4.D is always 0 and two consecutive wrist axes must not be "quasi-parallel", i.e. $|\alpha|$ must not be less than 10 degrees.

Caution: The initial system X3 in axis 4 is defined by $TX3P3. Only the Z axis is defined by X3. The position of the X axis can be "freely" selected, thus giving rise to a number of configuration options, each with a different zero position of the wrist axes.

2.1.161 $DH_5

Denavit-Hartenberg parameters

Data type	--	Value	min	--
Unit	--		max	--
Assignment	--			

Length A	DHART_A
Length D	DHART_D
Angle α	DHART_ALPHA

Denavit-Hartenberg parameters a, d and α for frame between axis 4 and 5, or 5 and 6. $DH_4.D is always 0 and two consecutive wrist axes must not be "quasi-parallel", i.e. $|\alpha|$ must not be less than 10 degrees.

Caution: The initial system X3 in axis 4 is defined by $TX3P3. Only the Z axis is defined by X3. The position of the X axis can be "freely" selected, thus giving rise to a number of configuration options, each with a different zero position of the wrist axes.

2.1.162 $SPIN_A

Data type	--	Value min	--
Unit	--	max	--
Assignment	--		

This machine datum is used exclusively for KUKA-internal development purposes.

2.1.163 $SPIN_B

Data type	--	Value min	--
Unit	--	max	--
Assignment	--		

This machine datum is used exclusively for KUKA-internal development purposes.

2.1.164 $SPIN_C

Data type	--	Value min	--
Unit	--	max	--
Assignment	--		

This machine datum is used exclusively for KUKA-internal development purposes.

2.1.165 $TRP_A

Axis driven by trapezoid

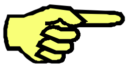
Data type	--	Value min	--
Unit	--	max	--
Assignment	--		

This machine datum is used exclusively for KUKA-internal development purposes.

2.1.166 $SPC_KIN

Data for special kinematics

Data type	real	Value	min	--
Unit	--		max	--
Assignment	[1] ... [30]			



This machine datum is used exclusively for KUKA-internal development purposes.

2.1.167 $ASR_ERROR

Permissible speed deviation (external position encoder/motor encoder)

Data type	real	Value	min	--
Unit	--		max	--
Assignment	[1] ... [30]			

If an external position encoder is used, "$ASR_ERROR" specifies the permissible deviation of the speed measured by the motor encoder from that measured by the external encoder.

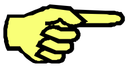
2.1.168 $RAT_EXT_ENC

Axis-specific encoder ratio of the external encoder

Data type	real	Value	min	--
Unit	--		max	--
Assignment	[1] ... [30]			

Example

$RAT_EXT_ENC[1]={N 1,D 4}



If the slave also has an external sensor, the encoder ratio of the slave must be the same as that of the master.

2.1.169 $AX_ENERGY_MAX[ ]

Maximum energy of the axis

Data type	real	Value min	--
Unit	--	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

The value must be calculated on a case-by-case basis.

The maximum energy $E_{\max}$ of the axis consists of the potential energy E_{pot} and the kinetic energy E_{kin}. It is the energy which must be taken up by the brake in the worst-case situation.

$$E_{\max} = E_{pot} + E_{kin}$$

2.1.169.1 Kinetic energy

The kinetic energy E_{kin} is the sum of translational E_{trans} and rotational energy E_{rot}:

$$E_{kin} = E_{trans} + E_{rot}$$

$$E_{trans} = \frac{m}{2} \cdot v_{\max}^2$$

$$E_{rot} = \frac{J_{motor}}{2} \cdot \omega_{motor}^2 + \frac{J_{gear}}{2} \cdot \omega_{gear}^2 + \frac{J_{structure}}{2} \cdot \omega_{structure}^2$$

$$\omega = n \cdot \frac{\pi}{30}$$

E: Energy [J]

m: Mass [kg]

v: Velocity [m/s]

J: Mass moment of inertia [kg m^2]

ω: Angular velocity [1/s]

n: Speed [rpm]

In the case of a cylindrical turntable of mass m and radius r, the following applies:

$$J_{structure} = \frac{m}{2} \cdot r^2$$

2.1.169.2 Potential energy

The formula for the potential energy E_{pot}:

$$E_{pot} = m \cdot g \cdot \Delta h$$

m: Mass [kg]

g: Gravitational acceleration 9.81 [m/s^2]

Δh: Height difference [m]

2.1.169.3 Maximum energy of the linear unit

For a linear unit in the plane, $\Delta h = 0$:

$$E_{\max} = \frac{m}{2} \cdot v_{\max}^2$$

2.1.169.4 Maximum energy of a turntable

For a turntable:

$$E_{\max} = \frac{J_{motor}}{2} \cdot \omega_{motor}^2 + \frac{J_{gear}}{2} \cdot \omega_{gear}^2 + \frac{m_{turntable}}{4} \cdot r_{turntable}^2 \cdot \omega_{turntable}^2$$

2.1.170 $BRK_ENERGY_MAX[ ]

Maximum permissible braking energy

Data type	real	Value min	--
Unit	J	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

The values here can be read from a table and are dependent on the motor.

2.1.171 $BRK_COOL_OFF_COEFF[ ]

Brake cooling factor

Data type	real	Value min	--
Unit	J/s	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

The brake cools down again when the system is at standstill. The energy dissipated depends on the cooling factor of the brake.

Example

The first external axis is driven by a motor of type D:

```
$BRK_COOL_OFF_COEFF[7]=33
```

2.1.172 $BRK_TORQUE[ ]

Dynamic braking torque

Data type	real	Value	min	--
Unit	Nm		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

The energy taken up by the brake depends on the dynamic braking torque.

Example

The first external axis is driven by a motor of type D:

```
$BRK_TORQUE[7]=5
```

2.2 Machine data for external axes

The last machine data in $Machine.dat are for the configuration of external axes.

The following sections contain descriptions of all the machine data for external axes.

More detailed information on external axes can be found in the documentation “Configuration (Machine Data)” / “External Axes”.

2.2.1 $EX_AX_NUM

Number of external axes

Data type	int	Value min	--
Unit	--	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

“$EX_AX_NUM” defines the number of external axes that are connected to the robot system.

Example

Three external axes are present:

```
$EX_AX_NUM=3
```

2.2.2 $EX_AX_ASYNC

Switching external axes to asynchronous motion

Data type	int	Value min	--
Unit	--	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

This option makes it possible to move the external axes independently of the robot axes.

Synchronous external axes: The robot axes and external axes start to move simultaneously and stop simultaneously.

Asynchronous external axes: Motion of the external axes starts and stops independently of the robot axes.

Bit no.	1	0
Meaning	E2	E1

- Bit = 1 --> corresponding axis is switched to asynchronous mode
- Bit = 0 --> corresponding axis is switched to synchronous mode

Example

All external axes are switched to synchronous mode:

```
$EX_AX_ASYNC='B0000'
```

2.2.3 $ASYNC_T1_FAST

Velocity reduction factor in T1 mode

Data type	int	Value	min	--
Unit	--		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

Deactivation of the T1 velocity reduction factor of asynchronous external axes.

Syntax:

$ASYNC_T1_FAST = Value

Argument	Type	Explanation
Value	INT	This bit-coded value specifies which external axis may be moved in the case of coordinated asynchronous motions without velocity reduction in T1 mode: - The bits correspond to the external axes in ascending order: Bit 0 = external axis 1, Bit 1 = external axis 2, etc. - If the bit is set, the external axis may be moved, in the case of coordinated asynchronous motions in T1 mode, at maximum velocity.

Description:

In the machine data, $ASYNC_T1_FAST specifies the external axes for which the velocity reduction in controller mode T1 can be canceled for ASYPTP motions.

Whether or not an ASYPTP motion is executed in T1 mode without velocity reduction, i.e. at program velocity, depends on the axes involved in the motion. An axis is involved in the motion if it is actually moved, i.e. it is part of the motion instruction and the start value and end value are not identical.

This means:

- If the corresponding bit is set in $ASYNC_T1_FAST for all the axes involved in the ASYPTP motion, the motion is executed in T1 mode at program velocity.
- If, for at least one of the axes involved in the ASYPTP motion, the corresponding bit is not set in $ASYNC_T1_FAST, the motion is executed in T1 mode at reduced velocity.

Remarks:

- Deactivation of the T1 velocity reduction may only be used for external axes of special applications which are not safety-sensitive (e.g. electric motor-driven spot welding gun).
- The value can only be altered in the machine data; other assignments are not possible.
- Bits may only be set for external axes that are actually present (configured via $EX_AX_NUM in the machine data). If, however, no external axes are present ($EX_AX_NUM = 0), the value is not checked.

Example

Velocity reduction activated for all external axes:

INT $ASYNC_T1_FAST='B0000'

Velocity reduction deactivated for E1:

INT $ASYNC_T1_FAST='B0001'

2.2.4 $ASYNC_EX_AX_DECOUPLE

Decoupled external axes

Data type	int	Value min	--
Unit	--	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

Decoupling of external axes with the position and DSE data saved for subsequent recoupling.

Decoupling an axis means that this axis is considered by the controller to be no longer present; in particular, the axis cannot be moved and all monitoring functions are deactivated.

In the case of coordinated synchronous motions (PTP, LIN, CIRC ...), a decoupled axis is not taken into consideration. This is because the axis is automatically switched to asynchronous mode.

In the case of coordinated asynchronous motions (ASYPTP), a decoupled axis is not taken into consideration.

Synchronous and asynchronous manual motions (MOVE, AJOG) of a decoupled external axis are rejected and an error message is generated.

A decoupled axis cannot be mastered using the normal mastering procedure in which the axis must be moved. An attempt to master such an axis in this way will be rejected and an error message will be generated.

The characteristics described above mean that this “functional” decoupling of an external axis in KRL makes it possible to change this axis electrically (and mechanically) while the robot system is in operation.

Decoupled external axes are automatically switched to asynchronous mode in $ASYNC_AXIS.

The flag $ASYNC_OPT for enabling the asynchronous functionality must be set to TRUE.

When $ASYNC_EX_AX_DECOUPLE is defined, an advance run stop is triggered if the value changes. Before a new value is saved, the system will wait until all synchronous motions (through advance run stop) and all asynchronous motions have been completed, and all axes are in position.

The axes to be decoupled may not be coupled mechanically or mathematically with other axes; most importantly, the axis may not be part of an external kinematic system.

$ASYNC_EX_AX_DECOUPLE can only be set in the brake control mode “Individual external axis brake control” (bit 3 of $BRK_MODE is set).

Invalid assignments will be rejected and a corresponding error message will be generated.

Bit no.	1	0
Meaning	E2	E1

1= axis decoupled

0= axis coupled

Example

All external axes are coupled:

```
ASYNC_EX_AX_DECOUPLE='B0000'
```

2.2.4.1 Interaction with system variables

$ASYNC_EX_AX_DECOUPLE changes or influences other KRL system variables:

$ASYNC_AXIS:

If a bit is set in $ASYNC_EX_AX_DECOUPLE, the corresponding bit is also set in $ASYNC_AXIS, i.e. the axis is switched to asynchronous mode. The status message for the asynchronous axis is not displayed.

If a bit is deleted in $ASYNC_EX_AX_DECOUPLE, $ASYNC_AXIS remains unchanged, i.e. the axis remains asynchronous. The status message for the asynchronous axis is displayed.

An attempt to switch a decoupled axis to synchronous mode by means of a direct value assignment to $ASYNC_AXIS will be rejected with an error message.

$AXIS_ACT:

In the case of a decoupled axis, it is possible to assign a value to the corresponding entry in the variable $AXIS_ACT which is otherwise write-protected. This allows the axis to be mastered in the KRL program.

$AXIS_JUS:

If a bit is set in $ASYNC_EX_AX_DECOUPLE, the mastering of the corresponding axis is deleted and the corresponding entry in $AXIS_JUS is set to FALSE.

2.2.5 $EX_KIN

External kinematic systems

Data type	real	Value	min	--
Unit	--		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

"$EX_KIN" establishes the link between the external transformation in $MACHINE.DAT and the external kinematic system in $CONFIG.DAT.

#E**A**SYS to #E**F**SYS = identifier for external base kinematic systems

#ERSYS = identifier for external ROBROOT kinematic system

Example

External transformations 1 and 2 are both base kinematic systems:

```
DECL EX_KIN $EX_KIN={ET1 #EASYS,ET2 #EBSYS,ET3 #NONE,ET4
#NONE,ET5 #NONE,ET6 #NONE}
```

2.2.6 $ET1_AX

External axes

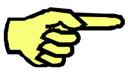
Data type	real	Value	min	--
Unit	--		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

"$ET1_AX" designates the aggregate containing a list of the external axes which are used in the 1st external transformation.

Example

The first transformed axis in the kinematic chain, **TR_A1**, is to be assigned the second external axis **#E2**:

```
DECL ET_AX $ET1_AX={TR_A1 #E2,TR_A2 #NONE,TR_A3 #NONE}
```



The aggregate must not contain any gaps; the assignments are made from left to right.

2.2.7 $ET1_NAME[ ]

Name of the transformation

Data type	char	Value	min	--
Unit	--		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

"$ET1_NAME[ ]" contains the name of the transformation.

Example

```
$ET1_NAME[ ]="REINHARD_1"
```

2.2.8 $ET1_TA1KR

Frame linkage between the root point and A1

Data type	real	Value	min	--
Unit	mm, degrees		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

"$ET1_TA1KR" defines the transformation between the kinematic root (root point of the external axis) and the pivot point of axis 1 (the first external axis used in this external transformation, ET1).

Example

```
FRAME $ET1_TA1KR={X 0.0,Y 0.0,Z 427.0,A 0.0,B 0.0,C 90.0}
```

2.2.9 $ET1_TA2A1

Frame linkage between A1 and A2

Data type	real	Value	min	--
Unit	[ ]		max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6			

"$ET1_TA2A1" defines the offset between transformation axis 1 (first external axis used) and the pivot point of axis 2 (second external axis used in this external transformation, ET1).

Example

```
FRAME $ET1_TA2A1={X 0.0,Y 0.0,Z 0.0,A 0.0,B 0.0,C 0.0}
```

2.2.10 $ET1_TA3A2

Frame linkage between A2 and A3

Data type	real	Value min	--
Unit	mm, degrees	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

"$ET1_TA3A2" defines the offset between transformation axis 2 (second external axis used) and the pivot point of axis 3 (third external axis used in this external transformation, ET1).

Example

```
FRAME $ET1_TA3A2={X 0.0,Y 0.0,Z 0.0,A 0.0,B 0.0,C 0.0}
```

2.2.11 $ET1_TFLA3

Frame linkage between A3 and the flange

Data type	real	Value min	--
Unit	mm, degrees	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

"$ET1_TFLA3" defines the offset between transformation axis 3 (third external axis used) and the flange coordinate system.

Example

```
FRAME $ET1_TFLA3={X 0.0,Y 0.0,Z 0.0,A 0.0,B 0.0,C 0.0}
```

2.2.12 $ET1_TPINFL

Frame linkage between the flange and the measuring point

Data type	real	Value min	--
Unit	mm, degrees	Value max	--
Assignment	[1] axis 1 ... [6] axis 6 [7] external axis 1 ... [12] external axis 6		

"$ET1_TPINFL" defines the offset between the origin of the kinematic coordinate system and the reference mark.

Example

```
FRAME $ET1_TPINFL={X 0.0,Y 0.0,Z 0.0,A 0.0,B 0.0,C 0.0}
```

A

B

C

D

E

F

G

I

J

K

L

M

N

O

P

R

S

T