NUM
1020/1040/1060

HIGH SPEED
MACHINING

0101938956/1

06-97

en-938956/1

Table of Contents

1 General Description			1 - 1
	1.1	Document Presentation	1 - 3
	1.2	General Information on the Tool Macros	1 - 3
	1.3	Functional Description of Total Anticipation	1 - 4
	1.4	List of Machine Parameters to Be Set	1 - 7
	1.5	Total Anticipation Enabling Conditions	1 - 8
	1.6	Order of Settings	1 - 9
2 Setting Procedure			2 - 1
	2.1	Searching for the Optimum Gain on the Different Axes and Measuring the Corresponding Time Constant	2 - 3
	2.2	Aligning All the Axes of the Group on the Longest Time Constant	2 - 3
	2.3	Setting the Maximum Radial Error (P52) and Minimum Block Execution Time (P51)	2 - 5
	2.4	Selecting the Filtering Time	2 - 5
	2.5	Setting the Acceleration Anticipation	2 - 6
	2.6	Setting the Maximum Permissible Acceleration for the Axes (P32) and the Minimum Acceleration Time (P53)	2 - 7
	2.7	Influence of the Reference Filtering Time on "Transients"	2 - 9
	2.8	Setting the Approach Speed	2 - 11
	2.9	Setting the "Anti-Pitch" Function	2 - 12
	2.10	Setting the Peripheral Parameters Concerning Machining by Small Segments	2 - 15
	2.11	Examining the Path Error Trace	2 - 16
	2.12	Displaying the Settings of the Coefficients	2 - 16
3 Description and Implentation of the Tool Macros			3 - 1
	3.1	Macro G254 - Cycle for Aligning the Position Gains on the Desired Time Constant	3 - 3
	3.2	Macro G255 - "Ball–Bar" Trace	3 - 6
	3.3	Macro G253 - Setting the Approach Speed - Examining the Position Loop Response	3 - 13
	3.4	Macro G252 - Path Error Trace	3 - 18
	3.5	Display Programme	3 - 25
4 Appendices			4 - 1
	4.1	Pitfalls to Be Avoided	4 - 3
	4.2	Tool Macros, Review of Call Possibilities	4 - 5

Record of Revisions

DOCUMENT REVISIONS		
Date	**Revision**	**Description**
01 - 96	0	Document creation
06 - 97	1	Conforming to software index K Manual upgrades: - Setting the speed transition time of sin^2 acceleration - Setting the minimum block execution time (P51) - Time constant per axis - Upgrading of macro G252 (window programming in machine dimensions)

Document History: Setting Procedures and Tool Macros

Unreferenced (Prospective Studies), 12 December 94

Software version G: First issue.

Unreferenced (Prospective Studies), 10 March 95

Software version G: Additional details.

DES.DMP95012/A, 8 September 95: Inclusion of Changes in Version J

Inclusion of the "maximum radial error" parameter (P52) on curves machined by small segments (TABCYLS):

Until version H, P52 was used only for circles (G02/G03) On curves machined by small segments, there was no possibility of speed control according to the curvature. This problem was solved by "special" use of the "block preparation time" parameter (P51) In version J, the use of P52 is extended to curves by small segments and P51 recovers its normal use. For High Speed Machining, P52 (maximum radial error) must be set to one or two micrometres.

Setting of the parameters related to curves machined by small segments:

Two peripheral parameters were created to be able to distinguish between the segments forming a curve and normal segments. A segment is considered as part of a curve if it is sufficiently small and is at a small angle to the adjacent segments.

E32004: Sagittal error:

This parameter is used in conjunction with the angle formed by two consecutive segments to distinguish between "short" and "normal" segments. This parameter is expressed in micrometres. It must be set to 1.25 times the value of the "sagittal error" used by the CAD/CAM to create the current programme. In case of doubt, it is recommended to specify a high sagittal error of 200 to 400 µm.

E32003: Maximum connection angle:

This parameter specifies the maximum angle above which two consecutive segments are no longer considered as part of the same curve. Their connection is then analysed as an angle. This parameter is expressed in degrees. The usual settings are from around 5 degrees to 10 degrees.

"On-line" setting of the reference filtering time and "anti-pitch" parameters:

These settings do not modify the machine parameters in the EEPROM but only their image in the memory.
- The two "Anti-Pitch" compensation parameters (initial amplitude and compensation signal time constant) are visible and can be edited on the "Ball–Bar" page (G255)
- The "reference filtering time parameter" is visible and can be edited on the "Ball–Bar" page provided this page is called in "Static Trace" mode (P1: stop after each revolution): G255 F8000 G17 P1. This parameter can be modified during a cycle stop but the modification is not taken into account until the next time the "CYCLE" button is pressed.

Inclusion of the "path error trace" macro (G252)

The speed versus the time is displayed using a new menu called "Scope".

1 General Description

1.1	**Document Presentation**		1 - 3
1.2	**General Information on the Tool Macros**		1 - 3
1.3	**Functional Description of Total Anticipation**		1 - 4
1.4	**List of Machine Parameters to Be Set**		1 - 7
	1.4.1	Parameters Concerning the Basic Control System Already Existing in Version F	1 - 7
	1.4.2	Parameters Concerning Total Anticipation and sin2 Acceleration	1 - 7
	1.4.3	Anti-Pitch Compensation Parameters	1 - 7
	1.4.4	Peripheral Parameters Concerning Machining by Small Segments	1 - 7
	1.4.5	Synchronised or Duplicated Axis Declaration in P9	1 - 7
1.5	**Total Anticipation Enabling Conditions**		1 - 8
1.6	**Order of Settings**		1 - 9
	1.6.1	Basic Control System Settings to Be Carried out with the Total Anticipation Option Inhibited	1 - 9
	1.6.2	Total Anticipation Settings to Be Carried out with This Option Enabled	1 - 9
	1.6.3	Setting The Default Values of the Parameters Concerning Machining by Small Segments	1 - 9
	1.6.4	Checking Machine Behaviour by "Dry Run" Machining of Qualification Parts	1 - 9

1.1 Document Presentation

In the context of this document, the term "High Speed Machining" refers to the automatic control technique using total speed anticipation and acceleration anticipation.

This document gives an axis setting methodology which is valid for total anticipation. However, the first steps in the procedure also apply to normal feedback, i.e. without anticipation. This methodology uses tool macros, developed to facilitate the settings. These tool macros are described in greater detail below.

This document also covers the settings relative to the "anti-pitch compensation function". From version J on, this function no longer depends on the High Speed Machining function and is now included in the basic functions.

This document includes the four following chapters:
- Chapter 1, General Description,
- Chapter 2, Setting Procedure,
- Chapter 3, Description and Use of the Tool Macros,
- Chapter 4, Appendices.

1.2 General Information on the Tool Macros

All the macros can be executed in a part programme and in MDI mode.

When axis coordinates are included in the call to a macro, the point defined by these coordinates in conjunction with the initial position determines an area of movement in which all the subsequent movements are carried out.

The "useful" movements are all carried out with the feed rate override potentiometer locked on 100 percent (M49) However, before each operation, a complete cycle is carried out in dry run mode with potentiometer enabled (M48) to make sure there is no collision on the machine.

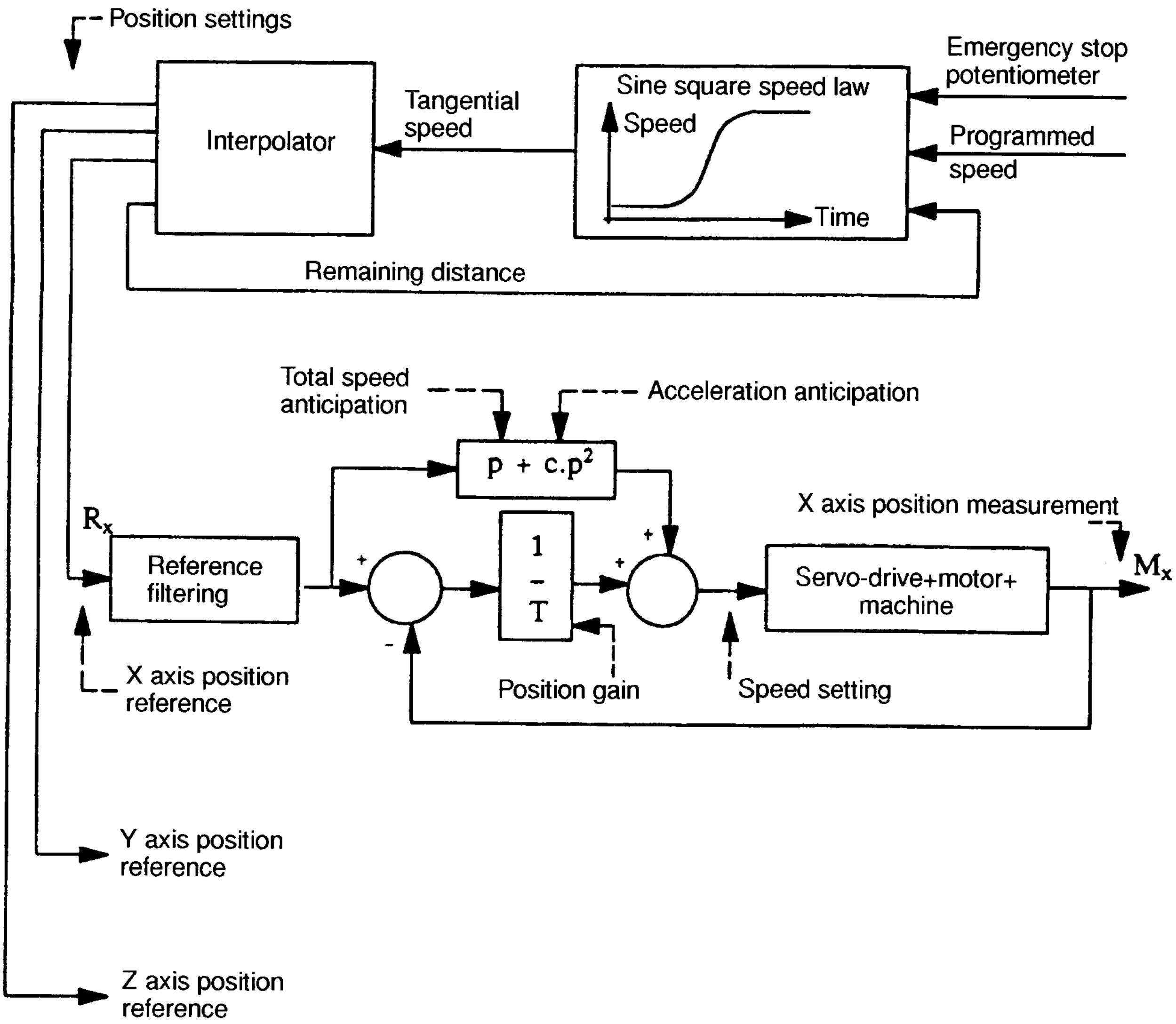
For the tests to be significant, the macros must always be executed at the maximum work rate. This speed must be programmed when the macro is called.

The macros provide a large number of functions. Not all the macros are needed for routine settings. The setting procedures described below specify the macros that are normally used. The others are provided as tools for additional diagnostics.

The use of these macros requires certain precautions, which are described in Chapter 4, Section 4.1.1, "Tool Macro Implementation Conditions". It is **absolutely essential to read this section** before attempting to use the macros.

1.3 Functional Description of Total Anticipation

Total anticipation is characterised by four functionalities:
- Total speed anticipation,
- Acceleration anticipation,
- Filtering of the "Position reference signal",
- Damping of movements by a "sine square" speed law.



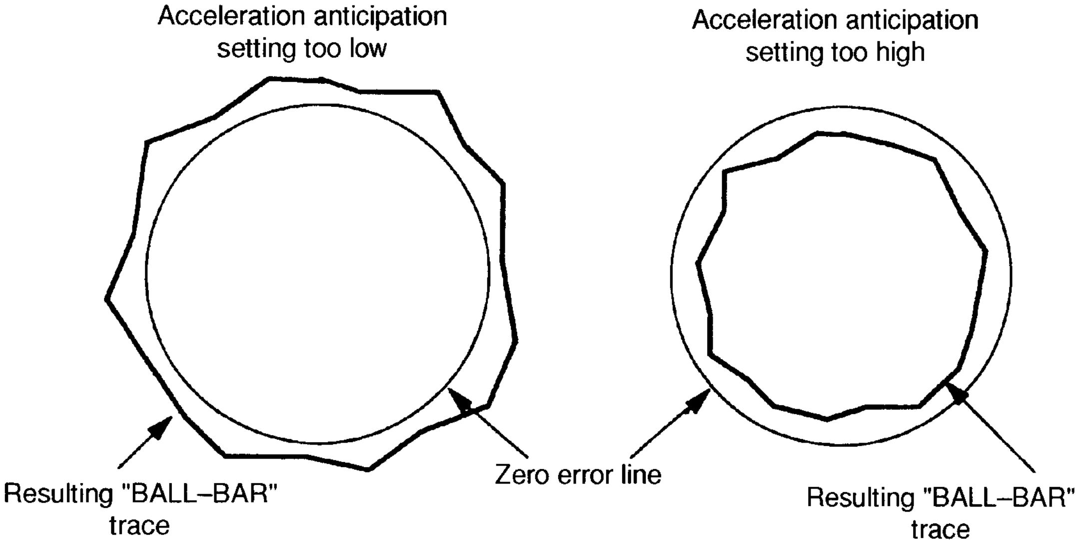
Functional block diagram of position feedback with total speed anticipation

Speed anticipation

Total speed anticipation cancels the following error during a steady linear movement. This action is controlled only by machine parameter P56 (Position time constant). Without accompanying measurements, this action would cause:
- Enlargement of circles by an extent related to the servo-drive response time,
- A tendency to overshoot the position when stopping.

Acceleration anticipation

Acceleration anticipation cancels the radial error on a circle travelled at constant speed. An increase in this parameter moves the real path toward the inside of the circle and a decrease toward the outside. This parameter also cancels the following error on a uniformly accelerated linear movement. It is set using tool macro G255 ("Ball–Bar" Trace).

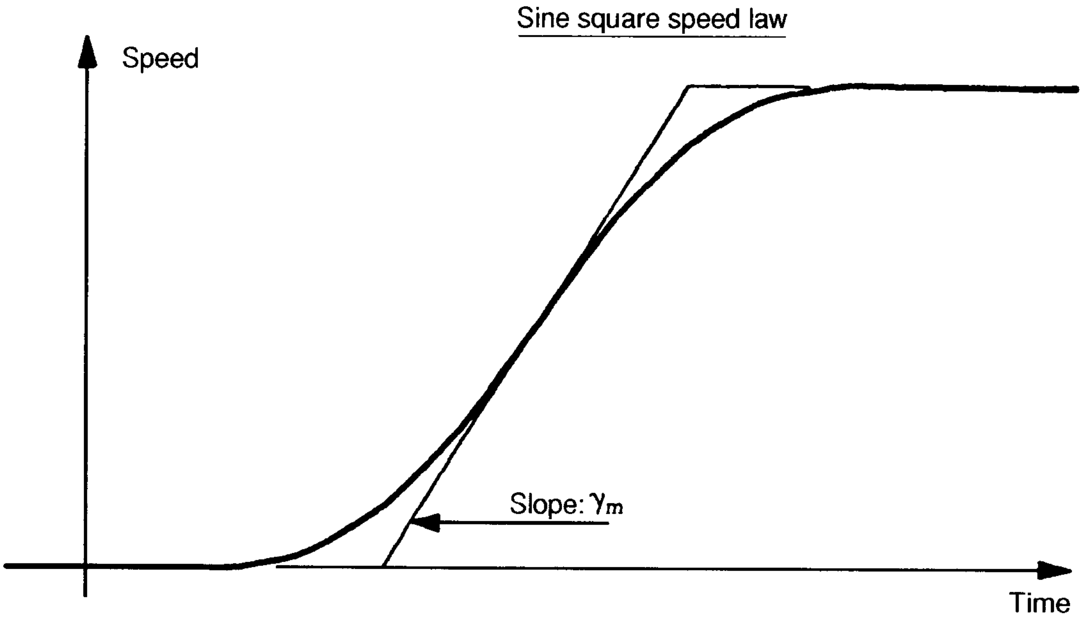


Position reference filtering

The "position reference filtering" function is necessary for machining curves by small segments (Tabcyls). The main purpose is to smooth the angles in the path as much as possible to allow the double derivative of the "position reference" signal to be calculated (i.e. so that it is different from zero). The use of reference filtering moves the circular path toward the inside of the circle and therefore tends to “underset” the action of acceleration anticipation. Underset the acceleration anticipation to compensate for this effect. To compensate for this effect, decrease the acceleration anticipation.

Sine square speed law

With total anticipation, the "trapezoidal" speed law generally used would cause position overshoots, especially when stopping. The sine square speed law prevents the position overshoots by damping the movements. The sine square law effectively used in the current versions damps the movements better for large speed errors than for small errors. It is planned to improve this law in forthcoming versions to optimise its behaviour.



1

1.4 List of Machine Parameters to Be Set

1.4.1 Parameters Concerning the Basic Control System Already Existing in Version F

P21 (E980xx):	Internal position gain per axis (KVAR).
P56 (E41006):	Position loop time constant per axis group (in ms). This is the ratio of the following error to the speed.
P32 (E971xx/E972xx):	Maximum permissible acceleration (in mm/s^2). There are two values per axis: work rate and traverse rate.
P52 (E32002):	Maximum permissible radial error on curves per group (in micrometres).
P51:	Minimum block execution time.

1.4.2 Parameters Concerning Total Anticipation and sin^2 Acceleration

P55/N8..N15 (E32005):	Position reference filtering time per axis group as a number of samples.
P19/N0..N31 (E981XX):	Acceleration anticipation coefficient per axis (in ms/1024).
P33/N0..N31 (E973XX):	Approach speed per axis (in mm/min). This parameter is used to adjust angle crossings. It represents the maximum speed level that can be tolerated on an axis without causing any undesirable overshoots.
P53 (E32006):	Minimum time for speed transition with sin^2 acceleration (expressed in ms).

1.4.3 Anti-Pitch Compensation Parameters

P19/N32..N63 (E982xx):	Anti-pitch signal amplitude at the initial time.
P19/N64..N95 (E983xx):	Anti-pitch compensation signal time constant (in hundredths of ms).

1.4.4 Peripheral Parameters Concerning Machining by Small Segments

E32004:	Sagittal error. This parameter must be equal to 1.25 times the sagittal error parameter used by the CAD/CAM. It is expressed in micrometres.
F32003:	Maximum angle between consecutive segments of a curve. It is expressed in degrees.

1.4.5 Synchronised or Duplicated Axis Declaration in P9

The first four bits (nibble) of each word should contain the group number, as for normal axes, instead of FF as before.

1.5 Total Anticipation Enabling Conditions

The Total Anticipation option must be enabled on three levels:

- Option bit level: The UGV (high speed machining) bit (bit 18) must be equal to 1.
- Machine parameter level: The option is conventionally enabled by specifying a nonzero reference filtering time in machine parameter P55/N8..N15. Each of the words of this parameter corresponds to an axis group.
- Peripheral parameter level: E11012 must be set to 1.

At initialisation, this parameter is forced to 1 or 0 according as the two above conditions are satisfied or not. This bit can of course be written by a programme.

> ⚠ **CAUTION**
>
> If total anticipation is enabled, the sin2 speed law must also be enabled. This law is enabled by programming, by setting peripheral parameter E11013 to 1. At initialisation, E11013 is initialised with the value of machine parameter P7 word 1 bit 5.

1.6 Order of Settings

1.6.1 Basic Control System Settings to Be Carried out with the Total Anticipation Option Inhibited

- Search for the optimum gain (P21) and measure the corresponding time constant to be carried out for each of axes. The time constant corresponds to the ratio: (Following error)/Speed.
- Align all the axes of a group on the longest time constant.

1.6.2 Total Anticipation Settings to Be Carried out with This Option Enabled

- Set the maximum radial error (P52) and the block execution time (P51).
- Select the approximate filtering time (P55/N8..N15).
- Set the acceleration anticipation coefficients for each axis (P19/N0..N31) using macro G255 ("Ball–Bar" trace).
- Set the maximum acceleration per axis (P32).
- Set the minimum speed transition time (P53) for software version K or above.
- Check the behaviour on the transients. If necessary, readjust the filtering time and acceleration anticipation. This is done using the "Ball–Bar" macro (G255 P1).
- Set the approach speed.
- Set the anti-pitch compensation.

1.6.3 Setting The Default Values of the Parameters Concerning Machining by Small Segments

These settings concern the peripheral parameters. The settings remain after a reset but can be reinitialised with the default values by programming in the reset subroutine (%11000).

1.6.4 Checking Machine Behaviour by "Dry Run" Machining of Qualification Parts

This check is carried out using the path error trace macro (G252).

2 Setting Procedure

2.1	**Searching for the Optimum Gain on the Different Axes and Measuring the Corresponding Time Constant**		2 - 3
2.2	**Aligning All the Axes of the Group on the Longest Time Constant**		2 - 3
	2.2.1	Digital Servo-Drives	2 - 3
	2.2.2	Analogue Servo-Drives	2 - 4
	2.2.3	Using Time Constants Adapted to Each Axis	2 - 5
2.3	**Setting the Maximum Radial Error (P52) and Minimum Block Execution Time (P51)**		2 - 5
2.4	**Selecting the Filtering Time**		2 - 5
2.5	**Setting the Acceleration Anticipation**		2 - 6
2.6	**Setting the Maximum Permissible Acceleration for the Axes (P32) and the Minimum Acceleration Time (P53)**		2 - 7
2.7	**Influence of the Reference Filtering Time on "Transients"**		2 - 9
2.8	**Setting the Approach Speed**		2 - 11
2.9	**Setting the "Anti-Pitch" Function**		2 - 12
	2.9.1	Functional Description	2 - 12
	2.9.2	Compensation Principle	2 - 12
	2.9.3	Parameters to Be Set	2 - 13
	2.9.4	Setting Technique	2 - 13
	2.9.4.1	Setting in Version G or H	2 - 13
	2.9.4.2	Setting in Version J (Using the "Ball–Bar" Trace Macro)	2 - 14
2.10	**Setting the Peripheral Parameters Concerning Machining by Small Segments**		2 - 15
	2.10.1	Sagittal Error (E32004)	2 - 15
	2.10.2	Maximum Connection Angle (E32003)	2 - 15
2.11	**Examining the Path Error Trace**		2 - 16
2.12	**Displaying the Settings of the Coefficients**		2 - 16

2.1 Searching for the Optimum Gain on the Different Axes and Measuring the Corresponding Time Constant

The time constant corresponds to the ratio of the following error to the speed without anticipation:

$$Tp = \frac{\text{(Following error)}}{\text{Speed}}$$

Two techniques are used for searching for the optimum gain:
- Use of SETTOOL (see Operator Manual),
- Use of macro G253 (Q3 call parameters). Macro "G253 Q3" traces the position response of an axis subjected to a speed level (constant speed/zero speed transition) The position loop is kept closed.

Example:

G0 X <dimension1> Y <dimension2>
E11012=1 E11013=1
G253 X <dimension3> Y <dimension4> I <axis number> Q3 F<max feed rate>

The procedure for use of this macro and its syntax are described in detail in Chapter 3, "Description and Use of the Tool Macros".

2.2 Aligning All the Axes of the Group on the Longest Time Constant

2.2.1 Digital Servo-Drives

With integrated digital servo-drives, equality of the gains (P21) ensures equality of the time constants (all other things being equal) It is suggested to set all the gain parameters (P21) of an axis group to the value found for the least performing axis. The axis time constant can then be accurately identified using macro G254. Considering the remark made above, it is sufficient to identify a single axis. The accurately identified value must be stored (in ms) in parameter P56 for the group considered.

Example:

G0 X <dimension1>
G254 F<m ax feed rate> X <dimension2>

⚠ CAUTION

The value of the time constant obtained by the above operation must be equal to an exact number of milliseconds (within a few microseconds). If not, adjust the setting of P21. This precaution is required because parameter P56 expresses the time constant as a whole number of milliseconds.

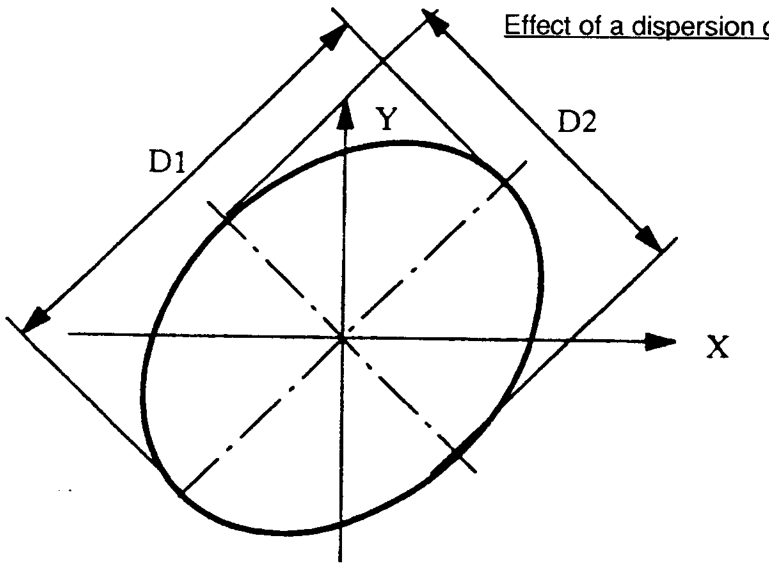
2.2.2 Analogue Servo-Drives

In the case of analogue servo-drives, the gain (P21) must be set individually for each axis to obtain the exact value of the time constant to be set in parameter P56 for the corresponding group. It is necessary to set each individual axis because of the dispersion in the characteristics of the axes. A dispersion of the time constant would result in "ovalisation" of the ""Ball–Bar"" trace according to the diagonals of the quadrants and therefore a deformation of the circle effectively machined. Such a deformation could not be compensated for by any other setting.

A dispersion in the time constant causes a difference between the two extreme dimensions of the path that is equal to four times the product of the speed multiplied by the difference in time constants:

lD1 – D2l = 4 * V * dT

Effect of a dispersion of the time constants on the path



|D1 - D2| = 4 * V * dT

The relative accuracy required on the axis time constants is around 1/1000

Suggested Procedure:
- Set the group time constant parameter (P56) to the value measured for the least performing axis (longest time constant measured),
- Align the gain of each axis (P21) on the time constant (P56) using the alignment cycle (G254):

G0 X<dimension1>
G254 F<max_machining_speed> X<dimension2> R

This cycle actually adjusts only the memory image of the gain (P21): E980xx.

The operator must therefore not forget to record the values obtained in the words of P21. Otherwise, these values will be lost the next time the system is reset. To facilitate read of the values set, programme %12000 displays the contents of all the peripheral parameters E980xx on the Graphic Parameters page (Plane 1+2). (In versions before J, the display programme number was %8081).

2.2.3 Using Time Constants Adapted to Each Axis

Starting with software version K, it is possible to set a different time constant for each axis. In this case, the time constants are declared in parameter P66, with one word per axis. When the contents of a word of P66 is different from 0, its value is substituted for the value declared in P56 for the corresponding axis. This is theoretically possible with high speed machining, but has not yet been tested in practice.

If the same time constant is set on all the axes (conventional setting), it must be made sure that all the words of P66 are set to 0.

2.3 Setting the Maximum Radial Error (P52) and Minimum Block Execution Time (P51)

With High Speed Machining (UGV), the maximum radial error parameter (P52/E32002) must absolutely be set, generally to a low value (one to a few micrometres). From version J on, this parameter is used not only for circles (as was the case in the previous versions) but also for curves programmed by small segments ("TABCYLS"). This parameter limits the speed according to the curvature of the path so as never to exceed the maximum error specified.

P52 is always enabled, whether or not High Speed Machining is used. However, for the same value of P52, the speed limiting is less penalising in UGV (E11012 = 1) than for normal machining (E11012 = 0) This behaviour is authorised by the gain in accuracy provided by High Speed Machining. This speed advantage justifies the use of UGV.

Starting with software version K, it is recommended to set parameter P51 to 0 (minimum block execution time). This change is due to the fact that it is now possible to interpolate several blocks during the same sample.

2.4 Selecting the Filtering Time

The position reference signal filtering time is set by machine parameter P55/N8..N15 with one word for each axis group expressed as a number of samples. The setting of this time therefore depends on parameter P50 (Sampling period).

There is no mathematical rule for defining its value. The filtering times that seem best suited by experience are between 75 percent and 100 percent of the position time constant.

It should be noted that the setting of this parameter affects the acceleration anticipation parameter. Too high a value of the filtering time can result in negative values for the acceleration anticipation coefficient.

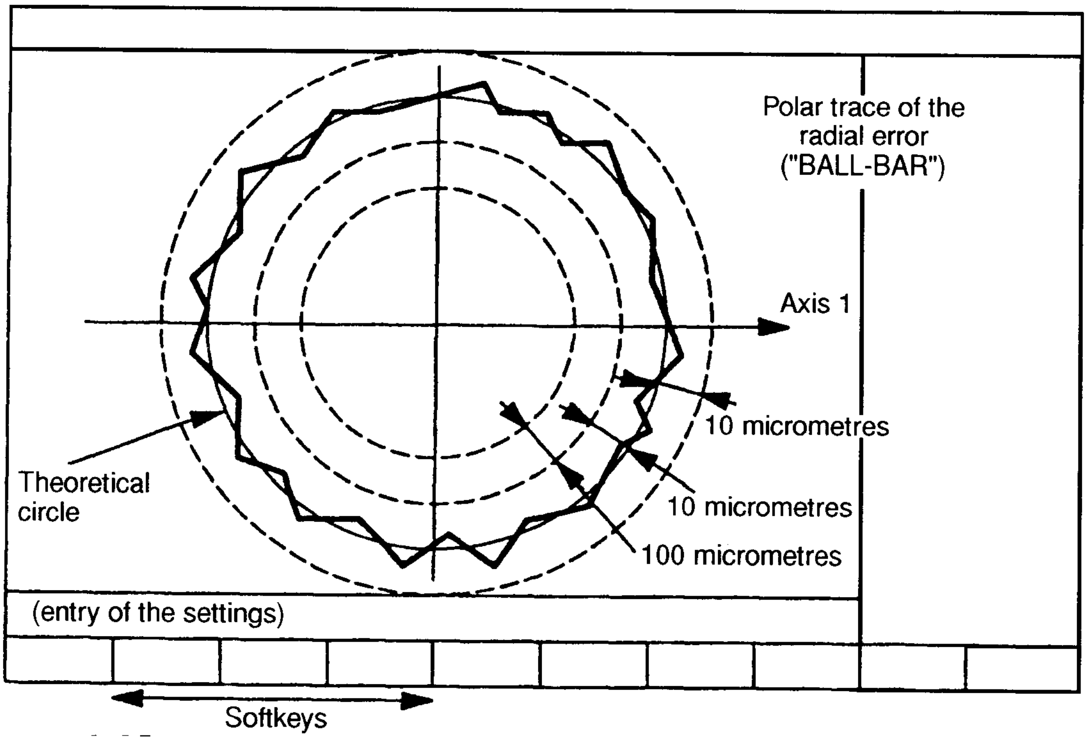
The filtering time parameter is available (version J) in parameter E32005.

The filtering time parameter also affects transient deformations in the path. For this reason, the first setting may need to be trimmed, but this should not be carried out until the acceleration anticipation has been set. This aspect is detailed below.

> ⚠ **CAUTION**
>
> The filtering time cannot exceed the value of 13 sampling periods as the servo-system behaviour is unpredictable above this value.

2.5 Setting the Acceleration Anticipation

Polar trace of the radial error: "Ball–Bar"



The acceleration anticipation is set for each axis while observing the "Ball–Bar" trace on the screen obtained by circular interpolation of two axes.

The trace is obtained by executing cycle G255 which animates the selected axis pair with a circular movement and by the trace on the graphic page ("Scale 1+2") of programme %9997.9.

If at least one of the two axes selected is not a main axis (X, Y or Z), circular interpolation is carried out by small line segments (Tabcyl)

The use and syntax of macro G255 are described in detail in Chapter 3. As an illustration, the following calls are possible:

E11012=1 E11013=1
G0 Y<dimension1> Z<dimension2> (centre position),
G255 [G02] [G18] [F<feed_rate>] [R<radius>] [P] (circular interpolation by G02),

or

E11012=1 E11013=1
G0 A<dimension1> B<dimension2> (centre position),
G255 [G02] A B Q<chordal_error> [F<feed_rate>] [R<radius>] [P] (Tabcyl).

Optional arguments are enclosed in square brackets [ ].

Once interpolation has started, the programme can only be stopped by pressing CYHLD and RESET.

Macro G255 does not force the total anticipation (E11012) or sine square (E11013) enable conditions, which must first be forced if necessary by programming E11012 = 1 and E11013 = 1.

The programmed feed rate (F) must be as high as possible. It is recommended to programme the maximum machining feed rate for this value. The choice of a lower feed rate would lead to an insufficiently accurate setting.

R is the radius. If it is not specified, the macro uses the radius causing an error equal to the resolution unit (micrometre) at the programmed feed rate. It is recommended not to set parameter R.

When the "Ball–Bar" trace display (%9997.9) is active on the "graphic" page, this page gives access to a keyboard dialogue to edit the acceleration anticipation coefficients. Increasing the coefficient associated with an axis contracts the trace in the direction of this axis and decreasing it expands the trace.

When G255 is called, parameter P specifies the type of trace. It is recommended not to programme parameter "P" when setting the acceleration anticipation. If "P" is not programmed, the dynamic trace displayed immediately shows the effect of any changes made.

2.6 Setting the Maximum Permissible Acceleration for the Axes (P32) and the Minimum Acceleration Time (P53)

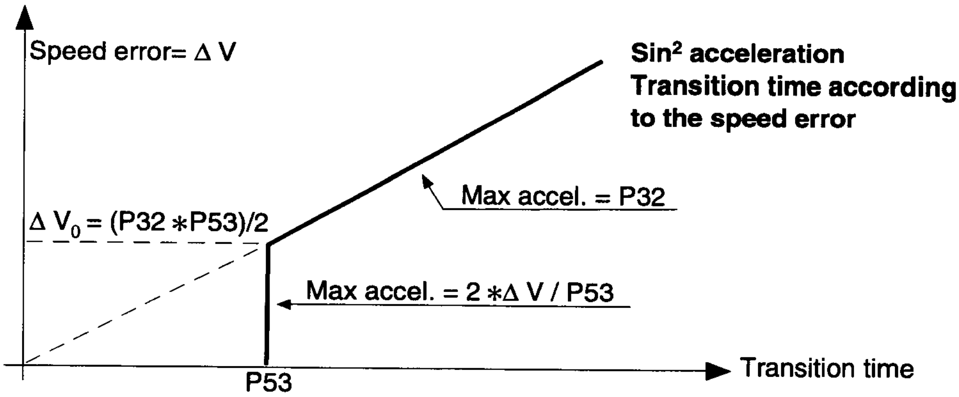
REMARK *In versions G, H and J, the technique used to implement the "sine square" speed law is such that the maximum permissible acceleration is always reached at the knee of the curve. This means that the lower the amplitude of the speed transition, the higher the derivative of the acceleration. With total speed anticipation, there is therefore a risk of overshooting the position when stopping, especially if the transition is made at low speed. The higher the maximum acceleration declared for the axes, the greater this risk.*

These considerations could lead to restricting the range of acceleration on certain machines. As an illustration, the table below shows the overshoots in micrometres measured on a real machine according to the speed difference and maximum acceleration declared:

Overshoot when stopping (micrometres)

Initial speed (mm/mn)	Maximum declared acceleration (P32)	
	1 m/s2	0.5 m/s2
2000	0	0
1600	4	0
800	11	1
400	10	5
200	5	5
100	2	2

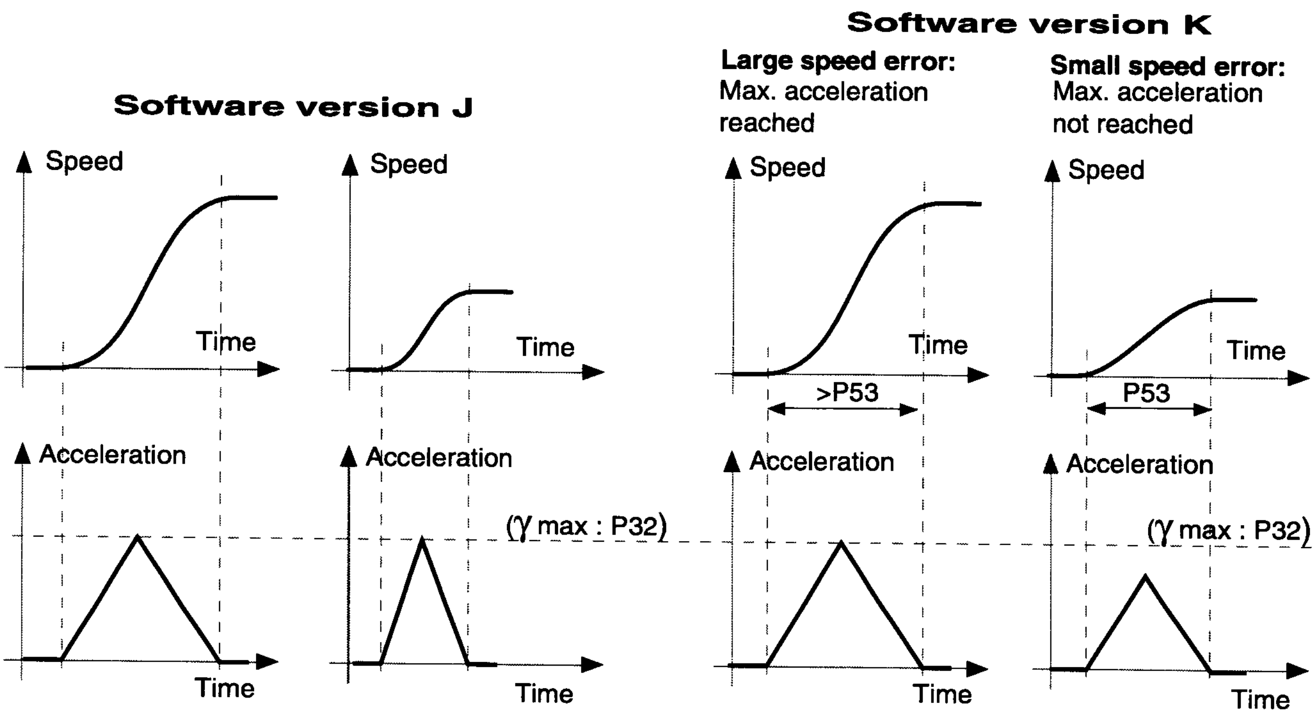
Starting with software version K, a parameter has been created to specify the minimum duration of the sin2 acceleration phase. This parameter, P53, is expressed in milliseconds. It is generally set to a value equal to two or three times the position loop time constant (P56). This parameter limits the derivative of the acceleration. By definition, it affects only low amplitude speed changes.



With sin² acceleration, the derivative of the acceleration is equal to the maximum acceleration reached, divided by half the transition time. The derivative of the acceleration is a maximum when the speed error to be corrected is equal to DV_0 show in the figure below. In this case, the maximum acceleration is equal to P32 and the transition time is equal to P53.

The maximum value of the derivative of the acceleration is then equal to:

$$\boxed{\gamma'_{max} = 2 * \frac{P32}{P53}}$$



2.7 Influence of the Reference Filtering Time on "Transients"

For high speeds and low curve radii, a transient error on the theoretical path can occur during acceleration or deceleration.

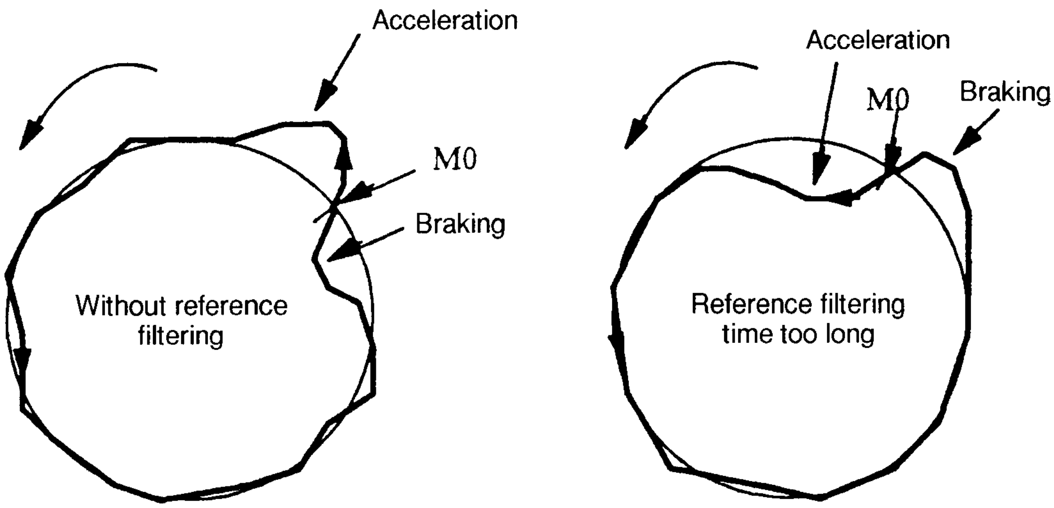
This error can be illustrated using the "Ball–Bar" trace with the "static trace" option (parameter P1).

Example of call:

G255 G18 F600 P1

The above macro call forces the CNC to draw a circle whose radius is calculated so that the radial error does not exceed the internal resolution (0.001 mm or 0.0001 degree). The path is travelled at the programmed feed rate (here F6000) When the circle is complete, the machine goes on wait on M0. It starts machining another circle when "Cycle" is pressed. For each circle, two path segments are shown on the screen (%9997.9). These two segments correspond to acceleration and stopping.

If an deviation from the theoretical path occurs, it can generally be compensated for by adjusting the filtering time. According as the deformation at startup is toward the outside or inside of the circle, a correction can be attempted by increasing or decreasing the filtering time respectively. (The path deformation during stopping is generally in the opposite direction from the deformation during startup).



Influence of the reference filtering time on transients
(Starting and stopping on a circle)

If a change is made to the "filtering time" machine parameter (P55/N8..N15), the acceleration anticipation coefficients must then also be modified. The change in these coefficients is calculated as follows, based on the change of the filtering parameter:

$$C2 - C1 = \frac{(n1^2 - n2^2)}{24} \cdot \frac{te^2}{Tp} \cdot 1024$$

C1 : is the old acceleration anticipation coefficient,
C2 : is the new acceleration anticipation coefficient,
n1 : is the old filtering time (as a number of samples),
n2 : is the new filtering time (as a number of samples),
te : is the sampling period (in ms),
Tp : is the position loop time constant (in ms).

Coefficient 1024 takes into account the fact that C1 and C2 are in ms/1024, i.e. approximately in microseconds.

It should be noted that starting with software index J, the filtering time can be modified using the "Ball–Bar" macro (G255). In this case, parameters E981xx - which are the images of the acceleration anticipation parameters for the axes of the group - are automatically readjusted by the macro.

Using the "Ball–Bar" trace macro (G255)

Start the "Ball–Bar" macro in static trace mode (M0 after each revolution):

G255 ... P1

and call the page: PROCAM Graphic Parameters - *programme 9997.9* - Scale 1+2.

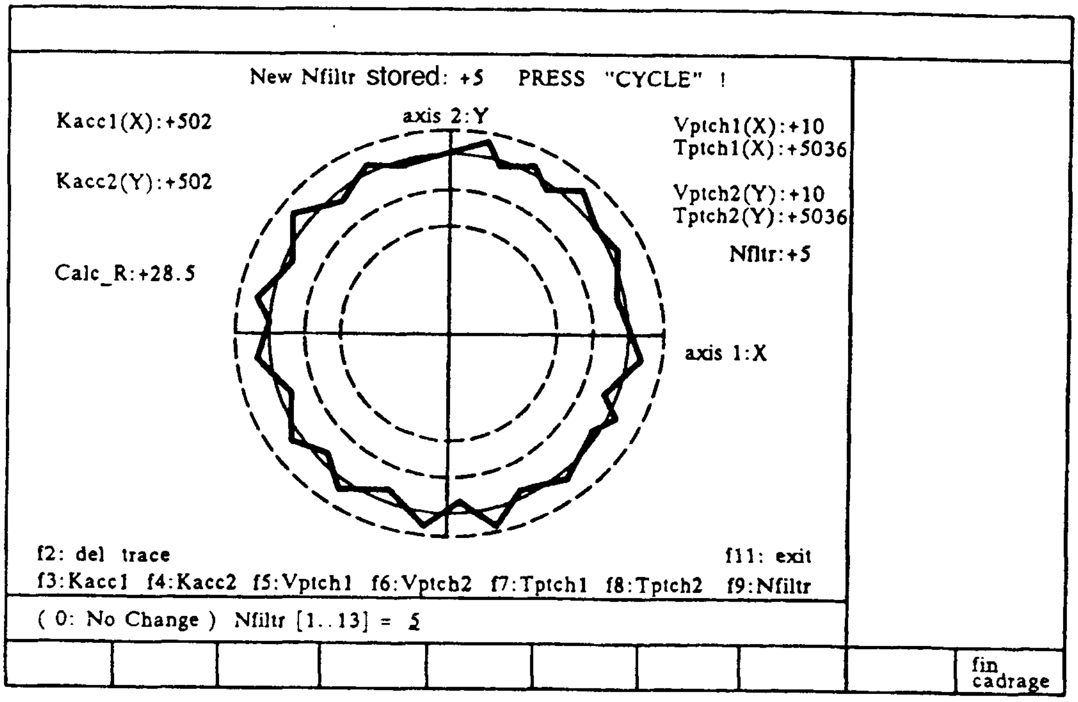
The filtering time is adjusted with the machine stopped by pressing a function key and entering a value from the keyboard.

The operator can enter a new filtering time (Nfiltr) between 1 and 13 sampling periods. The value entered is only stored. It is not applied until Cycle is pressed again to start a new revolution.

The new behaviour of the axes can be observed directly on the screen.

It is recommended to make the setting without setting parameter R (radius).

The "Ball–Bar" trace has the following shape:



It should be noted that a change in the filtering time causes automatic readjustment of the image of the acceleration anticipation parameters (E981xx) for all the axes in the group by application of the equation described above.

Too high a filtering time can result in negative acceleration anticipation coefficients. These values would be rejected with display of the following message:

"Nfiltr ignored ==> Kacc would be negative."

2.8 Setting the Approach Speed

With total anticipation, a speed level applied to an axis always causes a position overshoot. The overshoot is especially large if the speed level leads to stopping of the axis. The amplitude of the overshoot depends on the size of the level.

The "approach speed" machine parameter (P33) represents the maximum permissible speed level that can be used on an axis without excessive overshoot.

This parameter is used to set the maximum authorised speed at angle crossings. In effect, when an angle is crossed at a constant speed V, crossing causes a speed level DVi on axis i equal to:

$$DVi = V * (|Cos(Ai1) - Cos(Ai2)|)$$

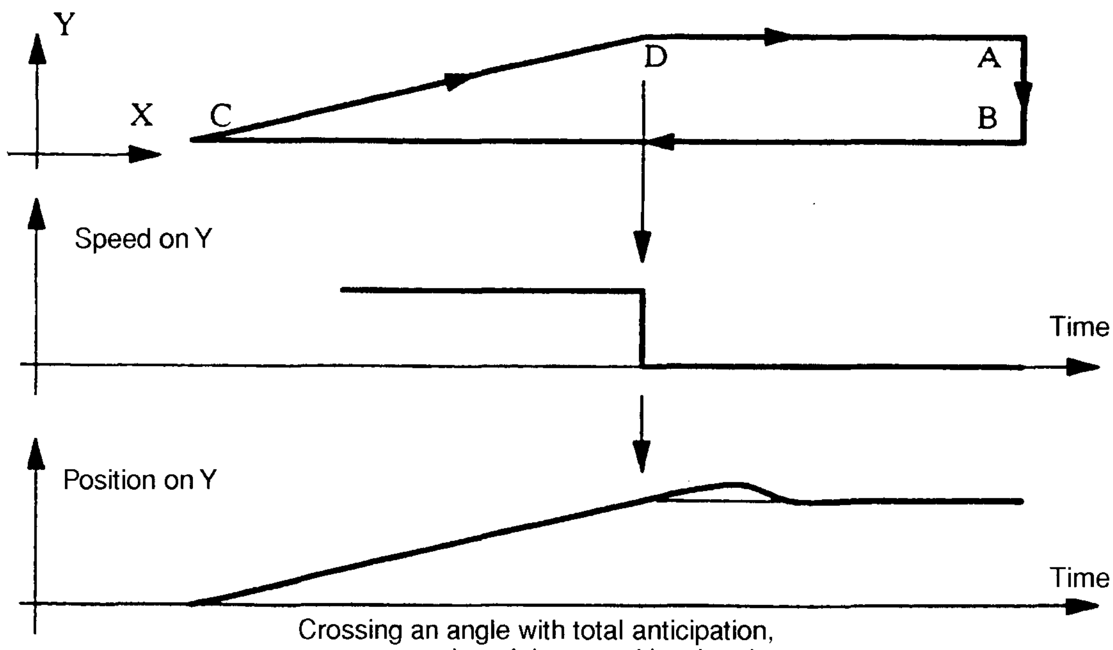
Ai1 and Ai2 are the angles formed with axis i by the two line segments before and after the angle.

It is recommended to set this parameter using macro G253 with calling argument Q3. Macro G253 determines the value of the "approach speed" according to the specified overshoot. Values commonly used are around 200 mm/min for a tolerated overshoot of 5 micrometres.

CAUTION

In versions G and H, the approach speed machine parameter (P33) must be forced to 0 before using macro G253. Otherwise, operation would be disturbed by processing the angle crossing and the result would be meaningless.

From software version J and above, this precaution is no longer necessary, since the macro temporarily inhibits processing of the angle crossing at the point of interest (use of E11015).

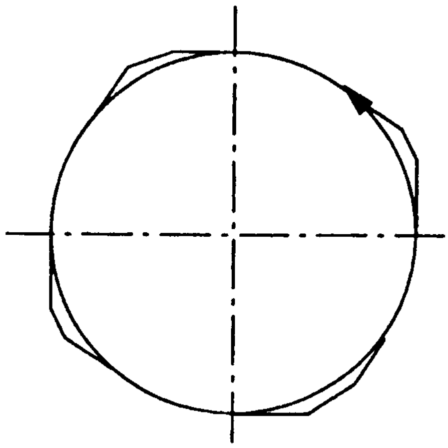


Crossing an angle with total anticipation, representation of the speed level and position overshoot

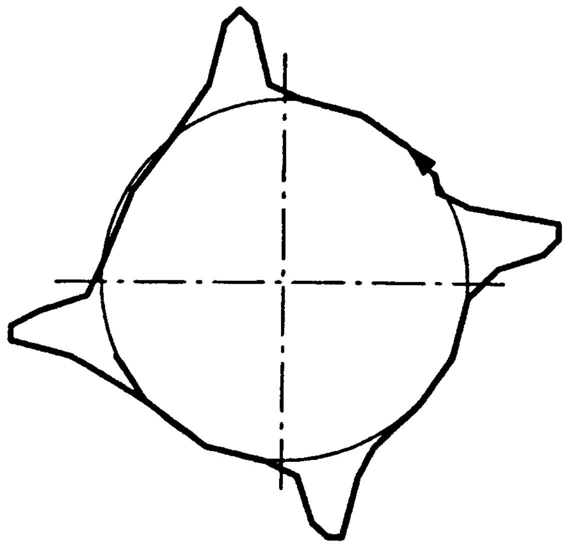
2.9 Setting the "Anti-Pitch" Function

2.9.1 Functional Description

"Pitch" is an error occurring on "Ball–Bar" type traces that results in spikes pointing outward from the circle just after changing quadrants.



Real path with enlargement of the straight section



Display of the straight section on the polar trace of the radial error (BALL-BAR)

These trace errors actually identify the presence of straight sections in the real path which occur after changing quadrants. These straight sections amplified by the "Ball–Bar" trace appear as spikes on the screen.

These deformations are generally explained by the fact that when the direction of movement on an axis is reversed, a discontinuity occurs in the inertia component due to drive friction.

This component changes at that time from a finite value in one direction to a finite value in the other. The spikes are a consequence of this discontinuity. It is as though the servo-drive did not correct the effects of the discontinuity fast enough (play take-up or pitch on the axis?, servo-drive reaction time?..)

REMARK *Starting with version J, the values of these parameters are displayed on the "Ball–Bar" page and can be edited by dialogue. See below.*

2.9.2 Compensation Principle

The principle used in version G to compensate for this error was to accelerate movement on the axis when reversal occurred by "injecting a disturbance" in the feed rate setting. This disturbance is called "compensation signal" below.

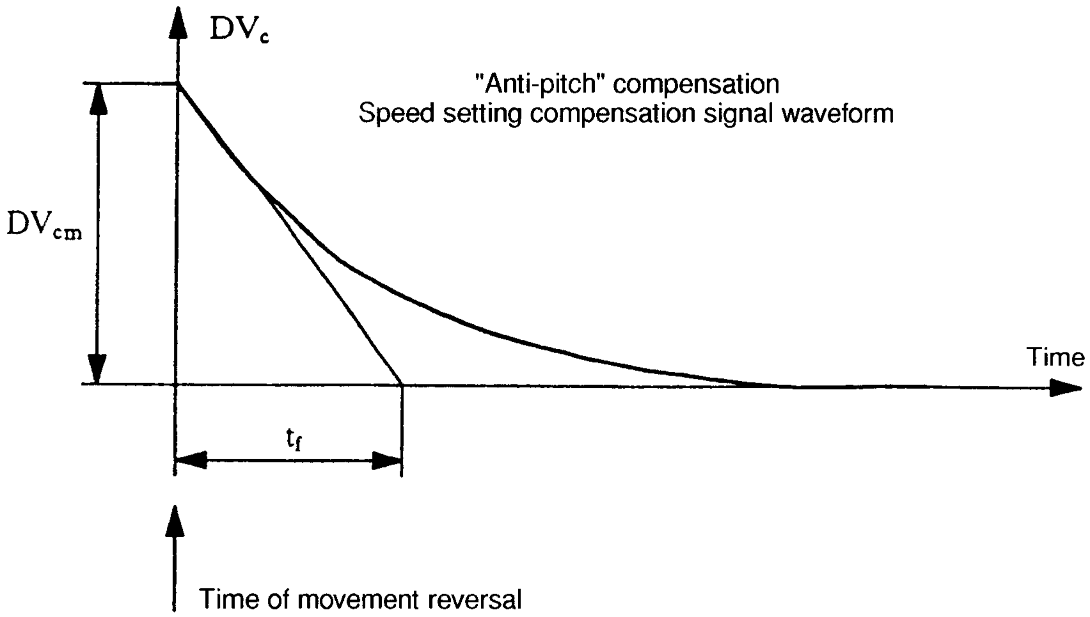
Although purely empirical, this technique considerably attenuates the pitch. It is however difficult or even impossible to eliminate pitch completely. In addition, this technique loses some of its efficiency when too far from the setting range (feed rate and radius)

2.9.3 Parameters to Be Set

The "compensation signal" level decreases exponentially with time. Its waveform is defined by two parameters:

DVcm : Signal amplitude at the "initial" time, i.e. the time when the position reference changes sign. This amplitude is set by machine parameter P19/N32..N63.

tf : Exponential time constant, set by machine parameter P19/N64..N95.



DVcm (initial amplitude) is in micrometres (or ten-thousandths of a degree). The actual compensation signal is a speed.

This speed is generated by dividing DVcm by the position time constant Tp. Physically, it is calculated in internal units by multiplying DVcm by the position gain.

tf (compensation time constant) is in hundredths of milliseconds (0.01 ms)

2.9.4 Setting Technique

Setting is carried out by trial and error, simultaneously adjusting both parameters (initial amplitude and time constant) relative to an axis.

The result is checked by observing the appearance of the "Ball–Bar" trace after each modification.

2.9.4.1 Setting in Version G or H

In version G or H, the only way to set these parameters is by Utility 5 and each new setting requires resetting the CNC and rehoming. Setting of each axis therefore requires repeating the trace, adjustment, CNC reset, homing cycle several times.

In versions G and H, the anti-pitch compensation setting procedure is therefore relatively long.

2.9.4.2 Setting in Version J (Using the "Ball–Bar" Trace Macro)

Starting with version J of the software, the values of these parameters are displayed on the Ball–Bar page and can be directly modified by dialogue using the following procedure:

Start the Ball–Bar macro preferably in dynamic trace mode without parameter P or in semi-static mode (P0):

G255 ...

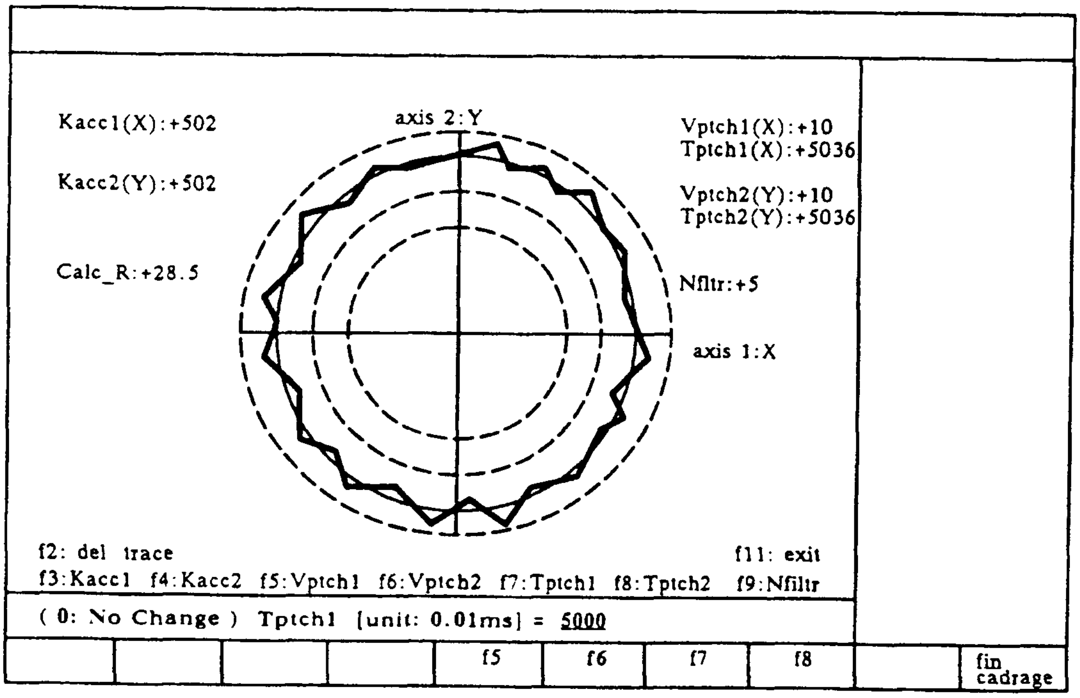
G255 ... [P0]

and call the page: PROCAM, Graphic Parameters - *programme 9997.9* - Scale 1+2.

The parameters are selected by the corresponding function key (F5 to F8)

The operator is prompted to enter a new value for the parameter selected.

Then he can see on the screen the new trace obtained by circular interpolation of two axes together. The Ball–Bar trace has the following appearance:



2.10 Setting the Peripheral Parameters Concerning Machining by Small Segments

Until version H, "small" segments were treated as "normal" line segments. Therefore, the angle crossing routine was always performed between two segments. Not only did that cause a loss of time, but it sometimes resulted in unjustified local decreases in speed along perfectly connected curves. This behaviour was due to the fact that angle crossing analysis affects the speed more adversely than curvature analysis.

In version J, the attempt was made to distinguish between the elementary segments of a curved path ("small" segments) and normal line segments ("normal" segments) A segment is considered "small" if the following relation is satisfied:

Length < (8 * Sagittal_error)/Angle.

Length:	Segment length.
Angle :	Angle formed with the previous segment.
Sagittal_error:	CAD/CAM parameter defining the accuracy of the path.
	This value is specified in parameter E32004.

In addition, in version J:
- Curvature analysis is performed only for "small" segments,
- Angle crossing analysis is performed between two segments if one of the following conditions is satisfied:
  . At least one of the segments is not a "small" segment,
  . The angle formed by the two segments is larger than the value specified by parameter E32003.

Parameters E32004 (Sagittal error) and E32003 (Maximum connection angle) preserve their value after a reset. E32004 is initialised with 0.010 mm and E32003 with 0 degrees. These default values are probably not suitable for all applications. It is therefore recommended to set these parameters to the values required for the routine type of application on each site in the reset subroutine (%11000).

2.10.1 Sagittal Error (E32004)

This parameter must be equal to 1.25 times the sagittal error specified for the active programme in the CAD/CAM. The margin of 25 percent corresponds to the variation in length observed at constant curvature on the real programmes produced by the CAD/CAM. In some cases, small segment programmes are not produced with a "constant sagittal error" (e.g. generation by macro). In this case, it is recommended to specify a high sagittal error value in parameter E32004 (200 µm or 400 µm). This parameter is expressed in micrometres.

2.10.2 Maximum Connection Angle (E32003)

Values of 5 to 15 degrees appear suitable. This angle must not be too small. Otherwise, angle crossing analysis could be activated along parts with a very pronounced curvature. It should be noted that the edges of flat dihedrals (with an angle less than the setting of E32003) are crossed at a speed and may therefore be somewhat blunted.

Example: A sagittal error of 0.010 mm on a circle with a radius of 3 mm gives segments forming an angle: α = ((8 * sagittal error)/R) ^ (1/2) = ((8 * 0.010)/3) ^ (1/2) = 0.16 rad = 9.4 degrees.

This parameter is in degrees.

2.11 Examining the Path Error Trace

When the settings are completed, it is advisable to examine the behaviour of the machine while machining one or more "qualification" parts. It is suggested to use the "Error trace" macro (G252) for this purpose. This macro displays the graph of the position error along a selected segment of the path. Certain parameters, in particular the maximum radial error parameter (P52/E32002), may need to be adjusted, depending on the results.

For instance, the path errors after angle crossings can generally be corrected by decreasing the "approach speed" parameter (P33/E973xx)

Macro G252 also displays the graph of the tangential speed versus the time along the segment of path examined. This allows any unjustified decelerations to be detected. Such decelerations can generally be corrected by increasing the sagittal error parameter (E32004) or the "maximum connection angle" parameter (E32003)

2.12 Displaying the Settings of the Coefficients

When the coefficients are set by macro G255, only the memory image of the coefficients (E980xx and E981xx) are modified but not the corresponding machine parameter (P19/N0..N31).

The machine parameters **must therefore be set using Utility 5**. In the event of an accidental CNC reset, parameters E980xx and E981xx are reinitialised with the values set in the corresponding machine parameters. To facilitate loading of these values, programme %12000 (in version J) or programme %8081 (in versions G and H) displays all the values contained in the images of parameters P21 (E980xx) and P19 (E981xx, E982xx, E983xx)

Procedure: Call the page:

<u>PROCAM</u>, Graphic Parameters - *programme %12000* - Scale 1+2.

This page has changed in version J of the software. It now has the following form:

Axis	P21/Kp	P19/Kacc	P19/Vpitch	P19/Tpitch
+0	+3000	+4000	+10	+5036
+1	+2700	+502	+10	+5036
+2	+3100	+2100	+10	+5036
+3	+3000	+4000	+10	+5036
+4	+3000	+4000	+10	+5036
+5	+3000	+4000	+10	+5036
+6				
+7				

f2 : Next f11 : Exit

Scaling in progress

f2 f11

3 Description and Implentation of the Tool Macros

3.1 **Macro G254 - Cycle for Aligning the Position Gains on the Desired Time Constant** 3 - 3

3.1.1 Purpose 3 - 3
3.1.2 Theory of Operation 3 - 3
3.1.2.1 Cycle Used to Evaluate the Real Time Constant 3 - 3
3.1.2.2 Cycle Used to Set the Internal Gain of the CNC (KVAR) 3 - 3
3.1.2.3 Remark 3 - 4
3.1.3 Programming 3 - 4
3.1.3.1 Basic Programming 3 - 4
3.1.3.2 Movement Specification 3 - 4
3.1.3.3 Programming of Additional Addresses 3 - 5
3.1.4 Display Specific to Cycle G254 3 - 5

3.2 **Macro G255 - "Ball–Bar" Trace** 3 - 6

3.2.1 Functionalities 3 - 6
3.2.2 Description of the Trace 3 - 7
3.2.3 Operating Modes 3 - 8
3.2.3.1 Trace Modes 3 - 8
3.2.3.2 Path Types 3 - 8
3.2.4 Programming 3 - 9
3.2.5 Remarks on Use 3 - 10
3.2.5.1 Modification of the Filtering Time 3 - 10
3.2.5.2 Modification of the "Anti-Pitch" Compensation Parameters 3 - 11
3.2.5.3 Elementary Block Processing Time (TABCYLS) 3 - 12
3.2.5.4 Initial Positioning on the "Modulo" Axes 3 - 12

3.3 **Macro G253 - Setting the Approach Speed - Examining the Position Loop Response** 3 - 13

3.3.1 Functionalities 3 - 13
3.3.1.1 Setting the Approach Speed 3 - 13
3.3.1.2 Examining the Position Loop Response 3 - 13
3.3.2 Operating Modes 3 - 14
3.3.3 Display 3 - 15
3.3.4 Description of the Cycle Performed on the Machine 3 - 15
3.3.5 Programming 3 - 16
3.3.5.1 General Call Format 3 - 16
3.3.5.2 Setting the Approach Speed 3 - 16
3.3.5.3 Examining the Position Loop Response 3 - 17

3.4	**Macro G252 - Path Error Trace**		3 - 18
	3.4.1	General	3 - 18
	3.4.2	Implementation	3 - 18
	3.4.3	Call Syntax	3 - 19
	3.4.4	Determining the Dimensions of the Starting Window Graphically	3 - 20
	3.4.4.1	Specifying the Window for Storing the First Record (Method 1)	3 - 20
	3.4.4.2	Specifying the Window for Storing the First Record (Method 2)	3 - 21
	3.4.4.3	Specifying the Window for Storing a Series of Records	3 - 21
	3.4.5	Procedure	3 - 22
	3.4.5.1	Main Menu	3 - 23
	3.4.5.2	Path Scanning Menu	3 - 23
	3.4.5.3	Zoom Select Menu	3 - 24
	3.4.5.4	Scope Menu (Graph of the Feed Rate Versus the Time)	3 - 24
3.5	**Display Programme**		3 - 25
	3.5.1	Setting Display Page	3 - 25
	3.5.2	"Ball–Bar" Trace Display Page	3 - 25
	3.5.3	Page Displaying the Response Curves Obtained with Cycle G253	3 - 26
	3.5.4	Path Error Display Pages (G252)	3 - 26

3.1 Macro G254 - Cycle for Aligning the Position Gains on the Desired Time Constant

3.1.1 Purpose

Accurate servo-control at high speed requires setting the gain on the axes very accurately. The ratio of the following error to the speed must be strictly equal to the value of the position time constant declared in P56 (relative accuracy of around 1 in 1000).

To facilitate this setting, a cycle programmed by a G function (G254) was developed to accurately measure the time constant and adjust the axis position gain if necessary. The adjustment is made by adjusting peripheral parameters E980xx (memory images of P21).

In addition, with analogue servo-drives, a drift, although slight, of the gain with time cannot be precluded. It is therefore advisable to provide a process on the machine for correcting any drifts (e.g. a Warm-Up programme). This cycle can be called in MDI mode during manual adjustments. It can also be programmed in a "Warm-Up" programme and run in Single Step or Automatic mode.

3.1.2 Theory of Operation

There are two ways of using cycle G254.

3.1.2.1 Cycle Used to Evaluate the Real Time Constant

A series of back-and-forth movements are carried out during which the tool speed and following error are measured. The measurement is not made until the position reference speed has stabilised. The time constant measured for the position loop is evaluated as follows:

$$Tp = \frac{\text{average following error}}{\text{average speed}}$$

The number of back-and-forth movements made depends on the programmed speed and amplitude of movement. The rule is to obtain a relative accuracy of 0.00025 on the measured time constant. Assuming an uncertainty of 0.3 ms on the time of detection of the RTC interrupt, the recording should last 0.3 ms/0.00025 = 1.2 sec.

The number of back-and-forth movements will therefore be that required to total 1.2 s of stabilised movement in each direction.

3.1.2.2 Cycle Used to Set the Internal Gain of the CNC (KVAR)

The two following operations are repeated a certain number of times:
- Evaluation of the real position time constant,
- Adjustment of the internal gain parameter (KVAR) or at least its image that can be modified by part programming (E980xx) to obtain the required position time constant.

The iteration stops when the required value is effectively obtained.

Each iteration, the new value of KVAR is calculated by the following equation:

$$KVAR(i) = KVAR(i-1) * \frac{\text{measured\_Tp}}{\text{required\_Tp}}$$

In the current versions, the cycle cannot be used for setting DISC servo-drives. It should be noted that on DISC servo-drives, identical gains yield identical time constants.

3.1.2.3 Remark

The complete cycle is carried out implicitly with the feed rate override potentiometer locked on 100 percent (M49) with the exception of the first back-and-forth movement. This first movement is carried out "off load" with the potentiometer enabled (M48) to allow the operator to check the movement. No measurements are made during this phase.

3.1.3 Programming

3.1.3.1 Basic Programming

The cycle is carried out by function G254. This function is not modal, i.e. it is always cancelled at the end of the cycle. There are three types of call:

<u>Accurate identification of the position time constant of an axis without making any adjustment</u>

G254 [F < feed rate >] X < dimension > [P]

<u>Alignment of the position gain of an axis (KVAR) on the "position time constant" parameter (P56)</u>

G254 [F < feed rate >] X < dimension > R0 [P]

<u>Alignment of the position gain of an axis (KVAR) on a given value of the time constant (Tp in ms)</u>

G254 [F < feed rate >] X < dimension > R < Tp > [P]

REMARKS *X denotes an axis address: X, Y, Z, U, V, W, A, B or C.*

Only one axis address must be included in a G254 block.

The back-and-forth travel is carried between the current position when the call to the cycle is made and the position indicated by the axis address.

With address "R", parameter E9800x (KVAR) is modified.

The presence of optional address "P" allows this macro to be used even without the High Speed Machining option.

G91 (incremental programming) is prohibited.

3.1.3.2 Movement Specification

Movement can be programmed by G90 (absolute workpiece dimensions) or G52 (absolute machine dimensions to be programmed on each call block). Programming by G52 is advantageous in a "warm-up" programme because it eliminates the problem of shifts. Programming by G91 (incremental) is prohibited since it could cause a misunderstanding of the "modality".

If the programmed movement is too small, the axis does not have the time to reach stabilised speed and the cycle then continues to oscillate indefinitely. However, the cycle is able to detect too small a movement, in which case it displays the value of the optimum movement while continuing to oscillate. The optimum movement displayed is the one which allows the gain to be evaluated by a single round trip (preceded by the "off load" round trip systematically conducted with M48 at the beginning of each cycle). A movement two or three times smallest than the optimum movement can be programmed but will cause more oscillations.

With modulo type axes, it is recommended not to programme movements above 180 degrees. If the programmed movement exceeds 180 degrees, the first movement is carried out as programmed, but the consecutive movements are carried out on the complementary angular path (excursion < 180 degrees).

3.1.3.3 Programming of Additional Addresses

<u>Function "G52":</u> Programming in machine dimensions.

<u>Address "P":</u>

Normally, the G254 cycle forces the accurate feedback enable parameter (E11012) and the gradual acceleration enable parameter (E11013) to zero. The first of these parameters must always be forced to zero. Forcing the second to zero allows faster accelerations. These parameters are returned to their initial state at the end of the cycle. However, there are cases when access to these parameters is prohibited and results in a programming error. These cases are as follows:

- "accurate feedback" option absent (bit 18 = 0),
- "accurate feedback" option not enabled by machine parameter (P55, N8 = 0). To avoid a programming error in the above cases, address "P" must be programmed in block G254. The presence of this address inhibits access to peripheral parameters E11012 and E11013.

3.1.4 Display Specific to Cycle G254

At the end of the cycle, the following messages are displayed on the "Axis page" and the "Info" page:

<u>Use for evaluation:</u>

IDEN <axis> Tp = <__> Uncer = <__>

<u>Use for adjustment:</u>

SET <axis> Tp = <__> Uncer = <   > Kp = <___>

Tp: Measured position loop time constant. During adjustment, Tp is the value obtained after adjustment.

Uncer: Uncertainty. The time constant is measured separately for each direction of movement. Tp is the mean value and Uncer is the difference between the two measurements.

Kp: Open loop position gain (KVAR) resulting from the adjustment.

3.2 Macro G255 - "Ball–Bar" Trace

3.2.1 Functionalities

Macro G255 is used to display a "Ball–Bar" type trace on the screen in order to adjust the "acceleration anticipation" parameter (E981xx) while checking the effect of this setting on the screen. The trace is actually a polar diagram of the radial error obtained when the tool travels a circular path. The error is shown on an enlarged scale around a circle symbolising the theoretical path. This is the type of trace supplied when using the "Ball–Bar" system to qualify servo-controls.

Cycle G255 causes execution of a circular path. Depending on the parameters selected, the tool travels either a single revolution or an uninterrupted sequence of revolutions.

This sequence can only be interrupted by CYHLD and RESET. The first case of operation (one revolution each cycle) is called "Static Mode" and the second is called "Dynamic Mode" or "Semi-Static Mode" depending on the type of display.

Part programme %9997.9 displays the trace associated with cycle G255 and supports the setting dialogue. The real-time trace is obtained by calling programme %9997.9 by the "Scale 1+2" function key on the "Graphic Parameters" page.

When the display is active:
- the "acceleration anticipation" parameters, and
- the "anti-pitch" compensation parameters (from version J on) relative to the two axes involved in the circle being executed can be modified by dialogue. It should be noted that this dialogue does not modify the parameters stored in EEPROM but only their active image in the memory. Accordingly, the settings must be re-entered at the end of the operation using Utility 5.

Starting with version J, the "filtering time" parameter of the current group can also be modified by macro G255, but this modification can only be made in "**Static Mode**". The modification can only be entered when the system is stopped between two revolutions and is not taken into account **until the next cycle**. When the filtering time is modified, macro G255 adjusts the acceleration anticipation coefficients of **all the axes of the current group** according to the new filtering value. In this case as well, only the memory images are modified.

Table summarising the parameters accessible by macro G255 (in version J):

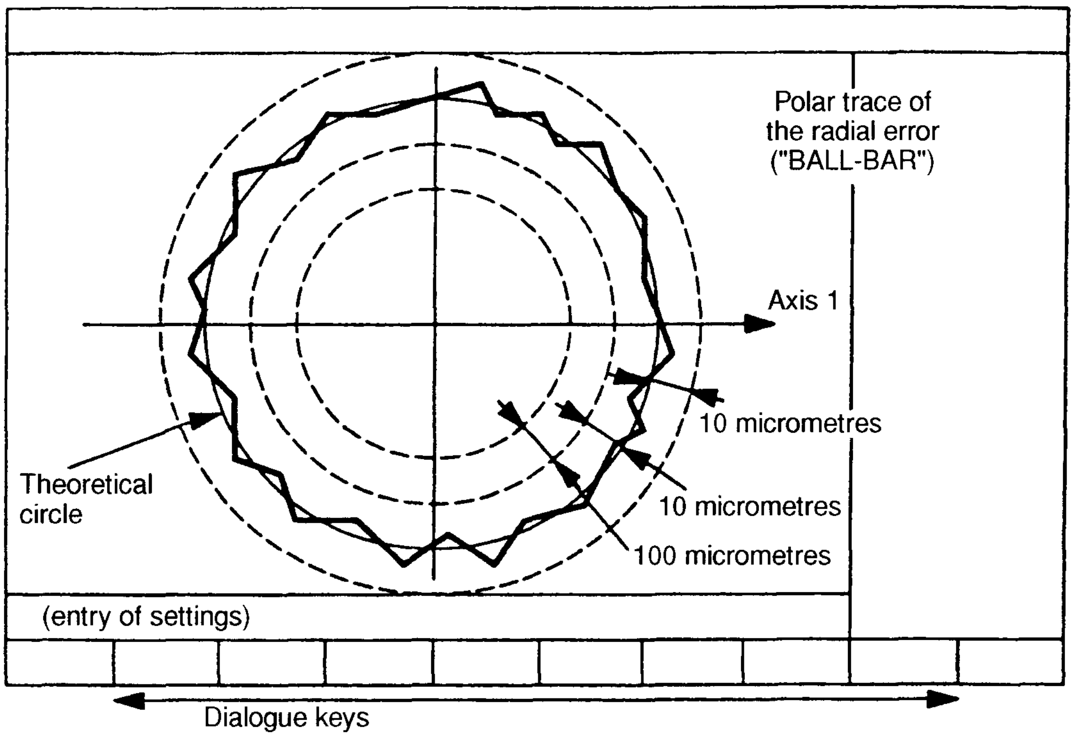
Name		Machine Parameter	Keys	E Parameter	Mode
- Acceleration anticipation	(G)	P19 N00..N31	F3 and F4	E981xx	all
- Anti-pitch compensation amplitude	(J)	P19 N32..N63	F5 and F6	E982xx	all
- Anti-pitch time constant	(J)	P19 N64..N95	F7 and F8	E983xx	all
- Filtering time	(J)	P55 N8..N15	F9	E32005	static

3.2.2 Description of the Trace

It should be noted that there are three areas with different scales within the theoretical circle:

- The first area to scale 1:1 corresponds to radial errors between 0 and -10 micrometres,
- The second area to scale 1:10 corresponds to radial errors between -11 and -100 micrometres,
- The third area to scale 1:100 corresponds to radial errors above -100 micrometres.

Accordingly, an "unanticipated" path (or a path overcompensated for acceleration) always is regular in appearance since it is located outside the "sensitive" area, whereas a correctly compensated path always has an irregular appearance, probably due to the nonlinearities inherent in all real systems.



The "micrometre" is used in the above lines for reasons of convenience. The "display unit" is actually as follows:

- Linear Axes: Micrometres or tenths of a micrometre depending on the choice made for internal units by machine parameter
- Circular Axes: The basic unit is ten-thousandths of a degree. However, if the axes are equipped with 0.001 degree sensors, the display unit can be modified using parameter "K" (resolution of circular axes). K1 means: "The circular axis sensors are in thousandths of a degree".

3.2.3 Operating Modes

3.2.3.1 Trace Modes

Three types of traces can be obtained depending on whether or not address "P" is used when the macro is called.

Dynamic trace ("P" absent):

The programme always displays the last point reached in machining. The display is synchronous with movement. It is therefore possible to display only one point out of n and the resulting trace is therefore "filtered". This is the type of trace that should be used for adjusting the acceleration anticipation parameters, since it is the only one that reacts immediately to modification of the parameters. An increase in an acceleration parameter contracts the trace on the axis concerned and a decrease expands it.

This trace should also be used for checking the setting of the "anti-pitch" parameters and modifying it as required (from J on).

Semi-static trace ("P0"):

This trace is an alternation of:
- a point recording phase (500 points), and
- a phase during which the points recorded are displayed.

The trace is therefore the real image of the error obtained, but it is not continuous. It consists of a sequence of disjoint curve segments each of which represents a series of recordings. This type of trace is used to see the exact shape of the "pitches" as well as the shape of the radial error oscillations around the circle.

Static trace ("P1"):

In this trace mode, the moving point is normally stopped in its path by a function "M0". Each time "CYCLE" is pressed, the tool travels a full circle. In a revolution, only the first 250 points and last 250 points are stored. The display therefore includes two segments representing the acceleration and deceleration phases respectively at the start and end of the revolution. This trace therefore gives an exact idea of the behaviour of the axes during the transient phases. It can be used to trim the setting of the filtering time parameter (P55/N8..N15) (see Chapter 2, "Settings")

3.2.3.2 Path Types

Two types of paths can be travelled according as address "Q" is present or not when the macro is called:
- If address "Q" is not present, the macro describes a clockwise (G02) or counterclockwise (G03) circle between the main axes of the modal plane (G17/G18/G19),
- If address "Q" is programmed, the macro describes a circle formed of small line segments (Tabcyl). Parameter "Q" then specifies either the sagittal error to be complied with (Q > 0) or the length of the segments (Q < 0).

In the case of circles formed by small segments, the interpolations can be made between any two linear or rotary axes. The interpolated axes must then be specified by supplying a pair of axis names when calling the macro, e.g.: G255 Z A Q0.005.

If these names are not specified, the small segment circle is drawn between the two main axes of the modal interpolation plane.

3.2.4 Programming

In all cases of use of macro G255, address "R" (radius) is optional. If it is not programmed, the path radius is calculated so that the feedback error does not exceed the resolution unit: 0.001 mm, 0.0001 degree (or 0.001 degree if programmed by K1)

Address P specifies the trace mode:

"P" absent: Dynamic trace (one point out of n at the rate of the display),

"P0": Semi-static trace (trace by series of stored points),

"P1": Static trace (path segments when starting and when arriving on an M0).

3

Circles traced by G02/G03:

G255	**G3**	**G17**	**[F < feed rate >] [R < radius >]**	**[P0]**
	G2	**G18**		**[P1]**
		G19		

Circles traced by small segments (Tabcyls) on the main axes only:

G255	**G3**	**G17**	**[F < feed rate >] [R < radius >]**	**[P0]**	**Q < +sagittal error >**
	G2	**G18**		**[P1]**	**Q < - step >**
		G19			

Circles traced by small segments (Tabcyls) on any pair of axes:

G255	**G3**	**X_1 X_2**	**[F < feed rate >] [R < radius>]**	**[P0]**	**Q < +sagittal error > [K < circ_resol >]**
	G2			**[P1]**	**Q < -step >**

X_1 and X_2 are the addresses of existing axes.

If at least one of these axes is linear:
- "F" (feed rate) is in mm/min,
- "R" and "Q" are in mm.

If both axes are circular:
- "F" is in degrees/min,
- "R" and "Q" are in degrees.

"K": Sensor resolution on rotary axes in 0.001 degrees ("K1" = 0.001 degree, "K0.1" = 0.0001 degree; default value "K0.1").

Remarks on trace by small segments:

The macro makes sure the blocks are sufficiently long to be covered at the programmed feed rate within a time greater than or equal to P51 (E32000) If this is not the case, it displays the limit value of Q <-step> (or "Q <+sagittal error>" and "R <radius>").

The execution of calculated tabcyls (sin/cos) is very time-consuming. If the setting of P51 is too small, the display is refreshed in bursts. The values of "Q" and/or "R" must then be increased accordingly. Q and/or R can be estimated as follows:

$Q_{-} = Tb * (F/60)$ or $R*Q_{+} = (1/8)*(Tb*(F/60))^2$; with the following values for Tb,

Tb = 0,025 s for "Series 1" with sampling period = 5 ms and Tb = 0.008 s for "Series 1 + coprocessor" with sampling period = 4 ms.

3.2.5 Remarks on Use

3.2.5.1 Modification of the Filtering Time

It should be noted that starting with software index J, the filtering time can be modified using the "Ball–Bar" macro.

In this case, parameters E981xx - image of the acceleration anticipation parameters for the axes of the group - are automatically readjusted by the macro. Refer to the section on selection of the filtering time.

Procedure:

Start the "Ball–Bar" macro in *static* trace mode:

G255 ... PI

and call the page: PROCAM, Graphic Parameters - *programme 9997.9* - Scale 1+2.

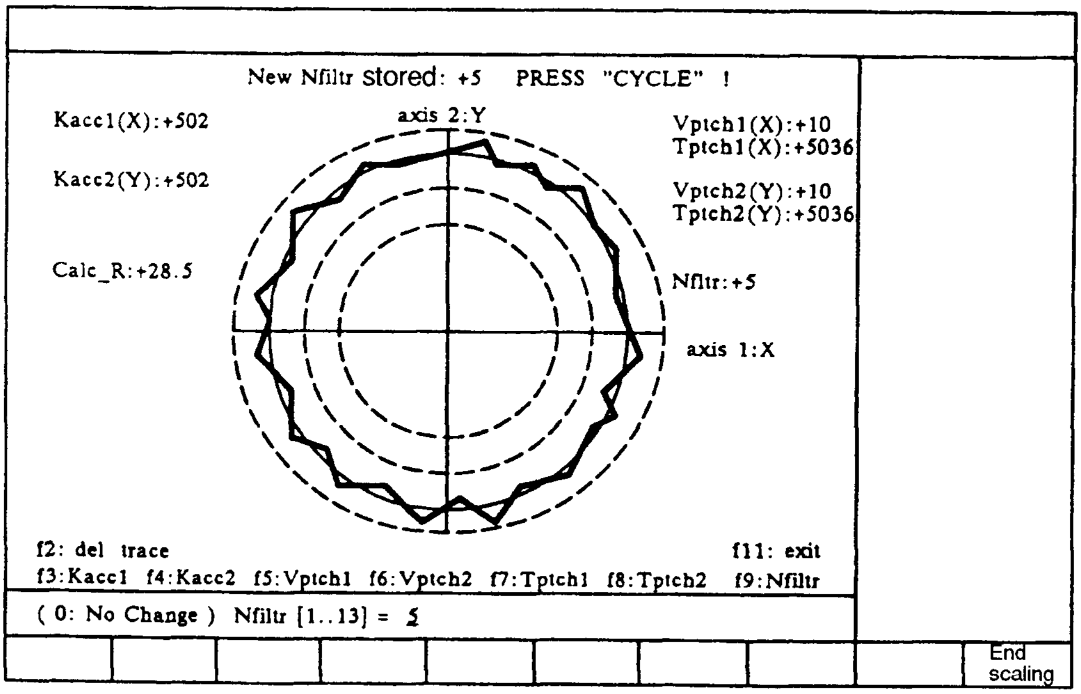
The new filtering time is entered by dialogue [*function key F9: Nfiltr:* **entry of the new time** (confirmed by pressing Cycle)].

The operator can enter a new filtering time (Nfiltr) between 1 and 13 sampling periods. The value entered is stored and is applied the next time Cycle is pressed.

The new trace obtained by circular interpolation of two axes can then be seen on the screen.

It is recommended to make the setting without programming parameter R.

The "Ball–Bar" trace has the following appearance:



It should be noted that a modification of the filtering time automatically readjusts the image of the acceleration anticipation parameters (E981xx) of all the axes of the group according to the following equation:

If E32005 is changed from: n1 ——> n2

E981xx for each axis group is changed from: C1 ——> C2

$$C2 = C1 + (n1^2 - n2^2) \frac{Te^2}{Tp} \times \frac{1024}{24}$$

n1 is the old filtering time (as a number of samples) - image de E32005

n2 is the new filtering time (as a number of samples)

C1 is the old acceleration anticipation coefficient,

C2 is the new acceleration anticipation coefficient,

Te is the sampling period (in ms),

Tp is the position loop time constant (in ms).

Coefficient 1024 takes into account the fact that C1 and C2 are in ms/1024, i.e. approximately in microseconds.

Too high a filtering time can result in negative acceleration anticipation coefficients. These values would be rejected with display of the following message:
Nfiltr ignored -> Kacc would be negative.

3.2.5.2 Modification of the "Anti-Pitch" Compensation Parameters

Starting with version J of the software, these values are displayed on the "Ball–Bar" page and can be directly modified by dialogue using the following procedure:

Start the "Ball–Bar" macro preferably in dynamic trace mode without parameter P or *in semi-static mode [P0]*:

G255 ...

G255 ... [P0]

and call the page: PROCAM, Graphic Parameters - *programme 9997.9* - Scale 1+2.

The parameters are selected by the corresponding *function key* [F5 to F8]

The operator is prompted to enter a new value for the parameter selected.

Then he can see on the screen the new trace obtained by circular interpolation of two axes together.

3.2.5.3 Elementary Block Processing Time (TABCYLS)

In the case of circles drawn by small segments, the macro checks that the execution time of an elementary block (length/feed rate) is at least equal to the block preparation time declared in P51. If not, a message is displayed proposing a set of values for parameters "Q" and "R".

If the elementary blocks are too small, the display is refreshed in bursts. If the CNC includes a coprocessor, the display is refreshed normally, but the trace exhibits "abnormal spikes". For coherent operation, parameters "Q" and "R" must satisfy the following relations:

Q->= Tb* (F/60) ou R*Q+ >= Tb* (F/60)) ^ 2

Tb is the time required to calculate an elementary block with evaluation of the sine and cosine values.

Approximate values for Tb are as follows:

"Series 1" with a sampling period of 5 ms —> Tb=0,025s

"Series 1 + coprocessor" with a sampling period of 4 ms —> Tb = 0,008s

To make these computations unnecessary, the "image" of P51 (E32000) can be initialised with the above durations expressed in ms.

Example:

E32000 = 25

G255 F6000 QO.005 X A

The macro then makes the required check and suggests corrections for these parameters if necessary.

3.2.5.4 Initial Positioning on the "Modulo" Axes

To avoid prohibitive computation times, the modulo evaluations are not made. This means that a "Ball–Bar" trace may not cross the machine zero point. The circle centre, which is also the "initial point" of the macro, must therefore be located beyond machine dimension R and inside machine dimension (360 - R). The macro makes this check and displays a message if an overlap occurs.

3.3 Macro G253 - Setting the Approach Speed - Examining the Position Loop Response

3.3.1 Functionalities

3.3.1.1 Setting the Approach Speed

Macro G253 was initially created to set the approach speed machine parameter P33. This parameter is only relevant with the "Total Anticipation" option. It is used to control the speed at angle crossings.

The approach speed of an axis represents the maximum speed level that this axis can support with "total anticipation" without any unacceptable position overshoots or accelerations above the limits accepted by the machine.

When an angle is crossed at a speed other than zero, a speed level is induced on one or more axes. With "total anticipation", the speed level causes an overshoot whose amplitude depends on the speed level. Machine parameter P33 was created to define the maximum permissible speed level on each axis. In this way, small angles are crossed without deceleration as long as the crossing does not cause a speed level above the setting of P33 on any of the axes.

For setting the "approach speed", the "position overshoot" criterion is more restrictive than the "acceleration" criterion. However, macro G253 allows settings based on both these criteria, although the second mainly has an experimental interest.

⚠ CAUTION

In versions G and H, when adjusting the Approach speed, P33 must be forced to 0.

In version J, this precaution is no longer necessary.

3.3.1.2 Examining the Position Loop Response

This functionality is completely unrelated to the above one. The two functionalities are included in the same macro since they both cause the same type of cycle on the machine and both produce the same type of diagnostic (position overshoot). This operation is carried out with the "Total Anticipation" function disabled.

3.3.2 Operating Modes

Macro G253 can operate:
- in "setting" mode, or,
- in "evaluation" mode.

The macro supports the following functions:
- Evaluation/setting of the approach speed according to the "position overshoot" criterion,
- Evaluation/setting of the approach speed according to the acceleration criterion,
- Examination of the position gain.

The "evaluation" mode forces the machine to perform a cycle using the setting specified by the operator.

The "setting" mode performs a series of cycles similar to the one mentioned above varying the parameter to be set in order to satisfy the selected criterion as well as possible. The iteration stops when the criterion is deemed satisfied.

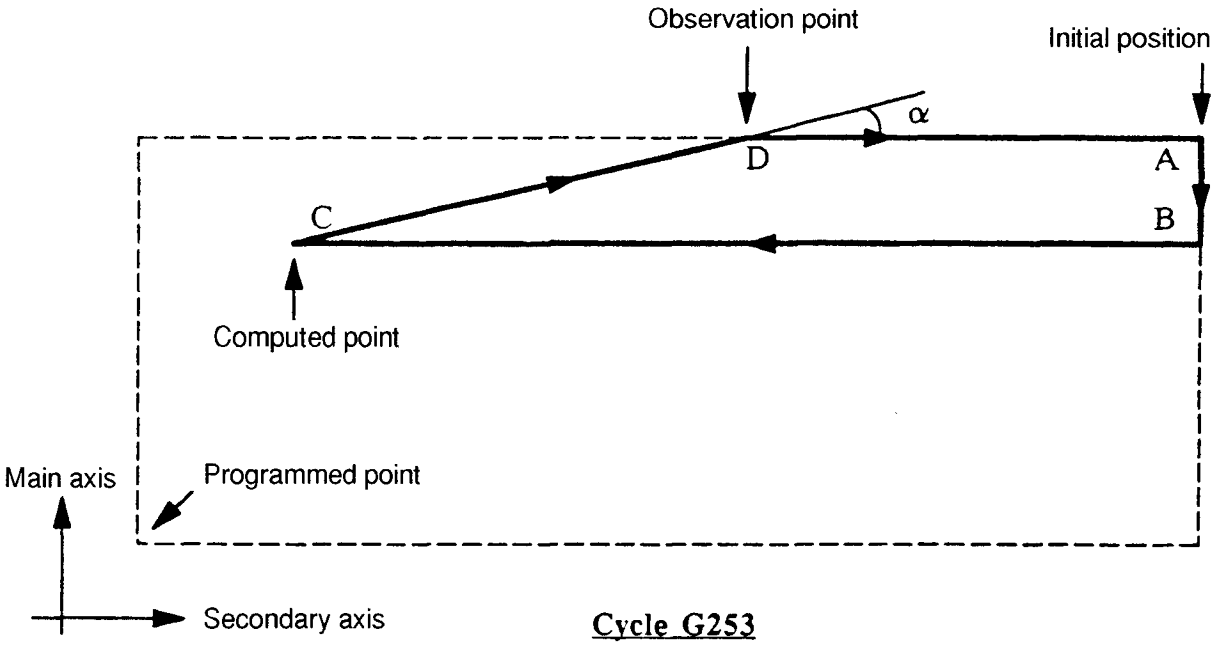
An optional parameter can be specified when calling the macro and a numerical result is generally displayed on the "Current Position" page at the end of execution. The meaning of the optional parameter and the result displayed is given in the table below.

Functionalities and modes of macro G253				
Parameter adjusted/ evaluated	Mode	Macro call code	Optional call parameter	Result displayed
Approach speed (overshoot criterion)	Evaluation	Q1	Approach speed	Overshoot
	Setting	Q2	Overshoot	Approach speed
Approach speed (acceleration criterion)	Evaluation	Q6	Approach speed	Max. accel.
	Setting	Q7	Max. accel.	Approach speed
Examination of position loop rsponse	Evaluation	Q3	Pos. gain (KVAR)	--

3.3.3 Display

At the end of execution, the appearance of the last response curve obtained can always be displayed on the Graphic page, "Plane 1". Programme %12253 (%8082 in versions G and H) called from the Graphic Parameters page draws the trace. To obtain the trace on the screen, "Plane 1" must be assigned on the "Graphic Parameters" page to the modal plane when macro G255 is called (plane G17 or G18 or G19). The default plane is G17 for milling and G18 for turning.

3.3.4 Description of the Cycle Performed on the Machine



Cycle G253

The cycle is performed by moving two axes, i.e. the axis being set or evaluated (main axis) and a service axis (secondary axis). The large movements are on the secondary axis and the small ones on the main axis.

The path travelled always includes a fairly flat angle to make sure it is crossed at a speed. The machine behaviour is then observed in the vicinity of the angle.

The length of the path is computed according to the programmed feed rate and the possible accelerations. In iterated cycles, this value remains unchanged.

The initial value of the angle a to be crossed is calculated as follows:
- Evaluation of the approach speed: α = arcsin (V_approach/F) where F is the programmed feed rate,
- Setting of the approach speed: The approach speed is set to 1/8th of the above value.

The initial cycle width is determined from the initial angle:

width = (length/2)*tan alpha

In approach speed setting modes ("Q2", "Q7"), the iteration concerns the aperture of angle alpha and therefore the cycle width. At the end of the iteration, the approach speed displayed is calculated as follows:

Speed_approach = F_programmed * sin a_final

The cycle is started on the start point. The logical number of the main axis is specified when calling the macro (address "I"). The direction of movement on each of the axes is specified by the position of the point programmed in the call to the macro: X1, X2 (Xi: addresses of axes X, Y, Z, etc.). The start point and programmed point define a rectangle in which they are the opposite angles. This rectangle is the outer boundary for all the movements. The macro makes sure that the complete cycle remains inside this rectangle.

3.3.5 Programming

3.3.5.1 General Call Format

G253 [F < feed rate >] X_1 < dimension > X_2 < dimension > I < main axis No. > Q < function > [R < param >]

I: Main axis number, (X=0, Y= 1, Z=2, U=3, V=4, W=5, A=6, B=7, C=8).

X_1, X_2: Axis names,

Q: Function code,

R: Specific to the function performed.

Programming in G91 is prohibited.

It is prohibited to combine a linear main axis with a rotary secondary axis.

In all cases, the trace of the behaviour observed during the last cycle is available.

It can be displayed in "Plane 1" programme %12000 (%8082 in versions G and H).

3.3.5.2 Setting the Approach Speed

Display of the position overshoot when crossing an angle (single cycle)

G253 [F < feed rate >] X_1 < dimension > X_2 < dimension > I < main axis No. > Q1 R < v_approach >

< v_approach >: in mm/min or deg/min depending on the type of main axis.

At the end of the cycle, the overshoot detected is displayed on the "Current Position" page. For the operation to be valid, P33 must mandatorily be forced to 0 when the macro is called (in versions G and H). This precautino is not required in version J.

Setting the approach speed according to the tolerated overshoot (iterated cycles)

G253 [F < feed rate >] X_1 < dimension > X_2 < dimension > I < main axis No. > Q2 [R < overshoot >]

< overshoot >: Tolerated overshoot in external units, mm or degrees (default 0.001 mm or 0.0001 degree).

At the end of iteration, the value found for the approach speed is displayed on the "Current Position" page. For the operation to be valid, P33 must mandatorily be forced to 0 when the macro is called. (in versions G and H). This precaution is not required in version J. Parameter E973xx corresponding to the image of P33 is not updated. It will be in releases after J1.

Display of the acceleration due to an angle crossing (single cycle)

G253 [F < feed rate >] X_1 < dimension > X_2 < dimension > I < main axis No. > Q6 R < v_approach >

< v_approach >: in mm/min or deg/min depending on the nature of the main axis.

At the end of the cycle, the maximum acceleration is displayed on the "Current Position" page.

Setting the approach speed according to a tolerated acceleration (iterated cycles)

G253 [F < feed rate >] X_1 < dimension > X_2 < dimension > I < main axis No. > Q7 [R < accel >]

< accel >: Tolerated acceleration in external units: mm/s² or deg/s² (the default value is the value set in P32).

At the end of iteration, the value found for the approach speed is displayed on the "Current Position" page. For the operation to be valid, P33 must mandatorily be forced to 0 when the macro is called. This precaution is not required in version J.

3.3.5.3 Examining the Position Loop Response

These functions can be used with or without the High Speed Machining option (address "P").

Display of the position measurement during an angle crossing (single cycle)

G253 [F < feed rate >] X_1 < dimension > X_2 < dimension > I < main axis No. > Q3 [R < kvar >] [P]

< kvar >: Value of the gain to be tested. The default gain is the value set in P21.

At the end of the cycle, the detected overshoot is displayed on the "Current Position" page.

The display is generated by tracing programme %12253 in the Plane 1 static trace page. The XY plane is used for milling machines and the ZX plane for lathes.

3.4 Macro G252 - Path Error Trace

3.4.1 General

This macro provides a graphic tool for examining the shape of the feedback error curve along a programmed path. The macro must be called at the beginning of the programme.

The macro stores a specific segment of the theoretical path (position reference) and the corresponding segment of the "real" path (position measurement). The start of the segment is defined in the call to the macro. The segment length generally corresponds to 450 stored points, keeping in mind that the points are stored at the sampling rate. The curvilinear length of the stored segment therefore depends on the average feed rate.

During the second phase, this macro displays the theoretical path segment on which it superimposes the "real" path segment, expanding the difference between the two paths to make the following error visible on the scale of the trace.

The macro provides a number of services for analysing the results:
- Change of the error expansion scale,
- Measurement of the path error,
- Zoom on part of the path,
- Measurement of the average feed rate,
- Display of the graph of the speed versus the time, etc.

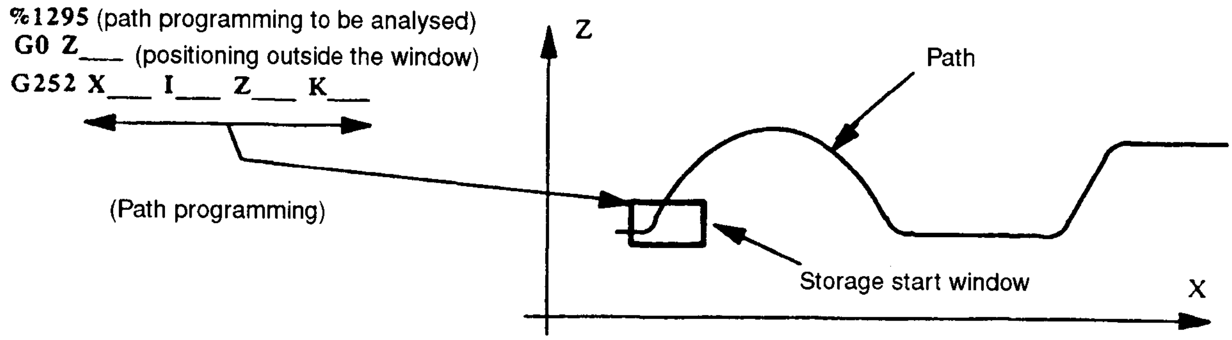
3.4.2 Implementation

The code of this macro is **G252**.

The storage start point is determined by a window defined by programming four dimensions. Storage starts when the theoretical current position enters the window.

It is possible to specify by programming whether storage starts the first time or only the nth time the current position enters the window.

The display is handled by programme **%12252 in version J** or programme **%8083** in versions **G** and **H**. This programme must be run from one of the Graphic pages: "Scale 1+2", "Plane 1 Trace" or "Plane 2 Trace".



3.4.3 Call Syntax

```
G252  X<x1>  I<x2>  Y<y1>  J<y2>    [P<oc>] [Q<esp>] [R<ech>] [S<nv>]
      Y<y1>  J<y2>  Z<z1>  K<z2>
      Z<z1>  K<z2>  X<x1>  I<x2>    [T1] [T4] [T5]
      └──────────────────────────┘ └──────────────────────────────────┘
        4 mandatory dimensions             Optional arguments
```


X, I, Y, J, etc.:

Definition of the "window" on which storage is started. This window is defined on two axes. Storage generally starts as soon as the current position enters the window. It is mandatory to programme the starting window. The dimensions are expressed in part coordinates. They can be determined from the graphic display on the "Plane 1" or "Plane 2" page by the procedure described below.

Optional arguments:

P: Storage occurrence. With the default value (P1), storage starts the first time the current position enters the window.
However, storage can be started the second or third time, etc., the current position enters the window. This is done by programming P2, P3, etc.
This possibility is used, for instance, when the window was positioned at the end of the path so that storage does not start until the tool is on the return path.

Q: Storage spacing. With the default value (Q1), the points are stored at a rate of one per sampling period. However, it is possible to store the points only every other or every three sampling periods by programming Q2 or Q3.
This possibility is used to increase the length of path traced each time.

> ⚠ **CAUTION**
>
> Spacing the stored points introduces a distortion which may become large in computation of the "expanded" error.
> It is preferable to use the default setting (Q1).
> Programming of values above Q3 is prohibited.

R: Error expansion scale. It is expressed as:
Number of pixels per micrometre of error.
The default value is 20 (R20). This value can be modified by a procedure when the scale is displayed.
The expansion scale does not change when zooming on the path.
With High Speed Machining, it is recommended to use scales from 20 to 40.
Without High Speed Machining, it is recommended to use a scale of 5.

S: Number of variables available in E81000 (and E82000).
The default number is 1000 (S1000) which represents the total space of variables E81000 and/or E82000 and which allows 450 points to be stored.
This parameter is used only to require the macro to allocate a number of E81000/E82000 variables at the beginning of an area (the macro always uses the same number of E81000 and E82000 variables).
If 200 variables must be allocated, e.g. from E81000 to E81199, programme S800. The macro then allocates 100 variables and uses the remaining space to store the points. The value S800 leads to storing only (800-100)/2 = 350 points.

T1: Window programming in machine dimensions (required for RTCP).

T4: Trace of the error made by the slave axis of a pair of synchronised axes.

T5: Combination of the two above modes.

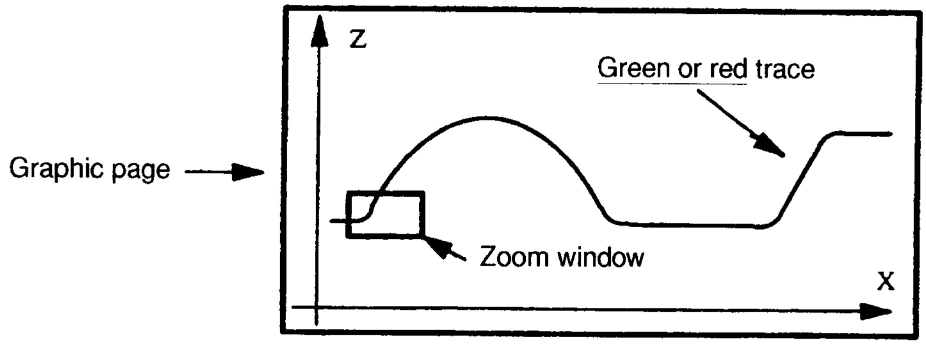
3.4.4 Determining the Dimensions of the Starting Window Graphically

Two cases can occur:
- Determination of the window for the first storage. In this case, it is suggested to use the trace of the programme to be tested in a standard Static Graphic page using the procedure described below,
- Determination of the window for a sequence of recordings on the path. In this case, it is suggested to directly use the macro display possibilities.

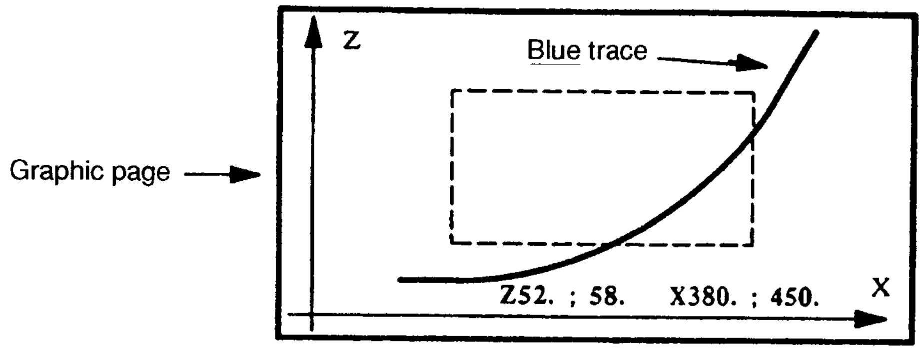
3.4.4.1 Specifying the Window for Storing the First Record (Method 1)

1 - Trace the programme whose path is to be analysed on a standard Graphic page: "Trace Plane 1" or "Trace Plane 2".

2 - Considering the zoom window as starting window, position it on the profile traced in the location where storage is to be started.



3 - Request zoom.



4 - When the zoom is displayed, measure the end dimensions displayed at the bottom of the page.

> ⚠ **CAUTION**
>
> The page is then enlarged (blue trace)

5 - Programme the call to G252 with the dimensions of the window as they were noted. To check, trace the part again. This time, the programmed window should appear on the screen in the desired location.

3.4.4.2 Specifying the Window for Storing the First Record (Method 2)

1 - Really run the programme and follow its progress on the graphic "Trace while machining" page.

2 - Stop with the potentiometer or Stop Cycle in the location where the window is to be placed.

3 - Measure the dimensions of the current position ("Current Position" page). The window dimensions are the dimensions just measurement plus a margin of 1 mm on either side. This method gives the dimensions in machine coordinates, which are the only ones that can be used with RTCP.

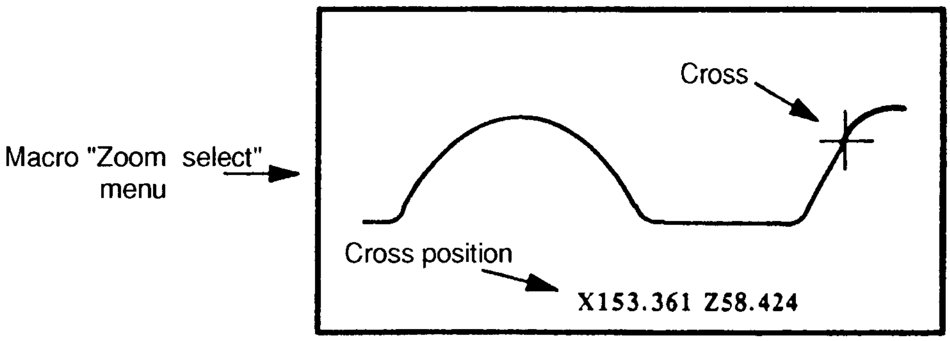
3.4.4.3 Specifying the Window for Storing a Series of Records

The trace of a record already stored is assumed to be displayed on the screen on the specific display page of the macro (programme %12252 in version J or %8083 in version G or H).

1 - Without exiting from the specific page of the macro, go into the "Zoom Select" menu (see below). On this menu, it is possible to move a cross along the theoretical path. The coordinates of the current cross position are permanently displayed at the bottom of the screen.

2 - Move the cross to the end of the path. Measure the current coordinates of the cross.

3 - Move the cross slightly back. Again measure the pair of current coordinates of the cross. The two points measured are the opposite points of the starting window for the sequence of records to be stored.

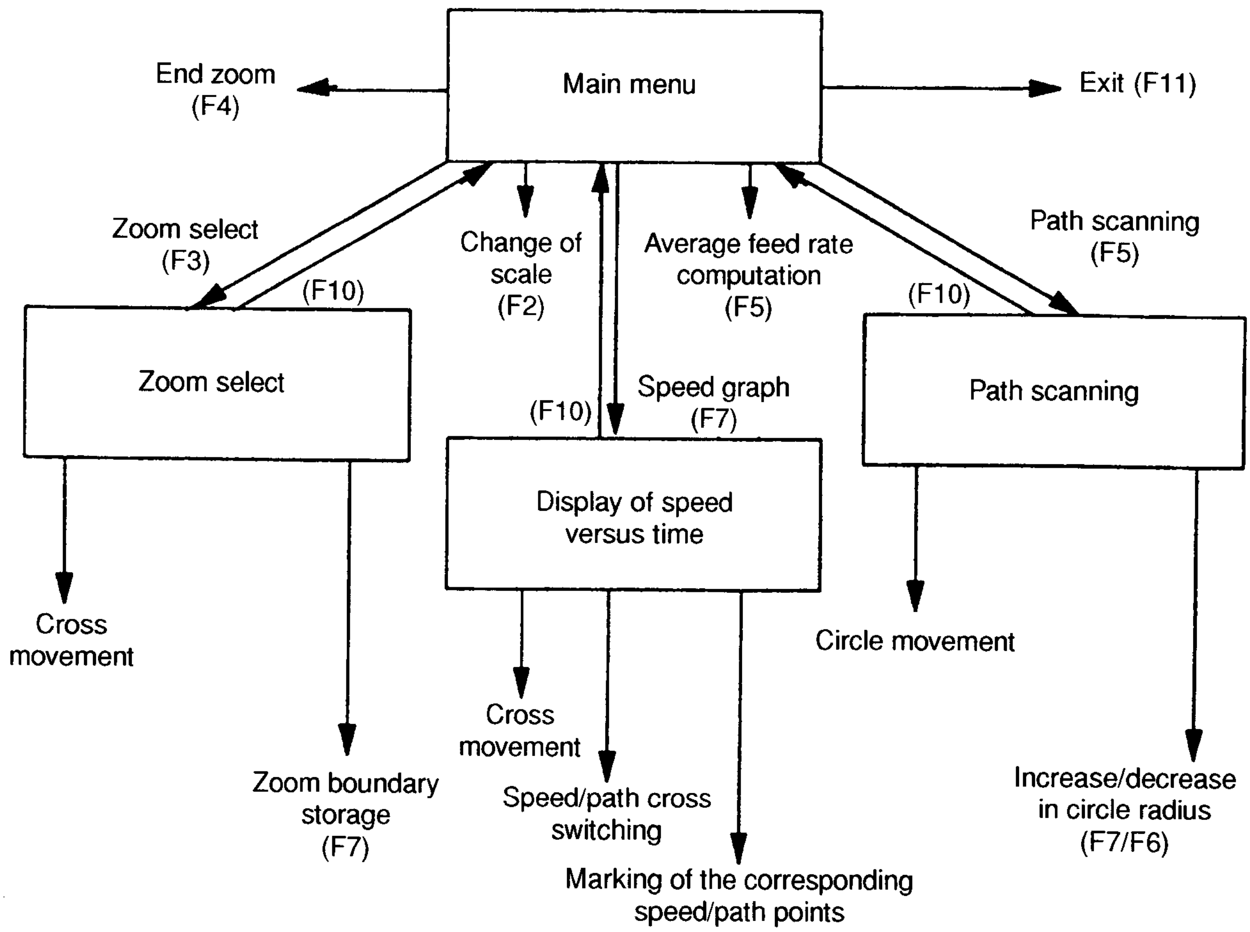


3.4.5 Procedure

Four menus were defined:
- Main menu,
- Zoom select,
- Path scanning,
- Scope,

To return from a secondary menu to the main menu, press key "F10".

General menu organisation

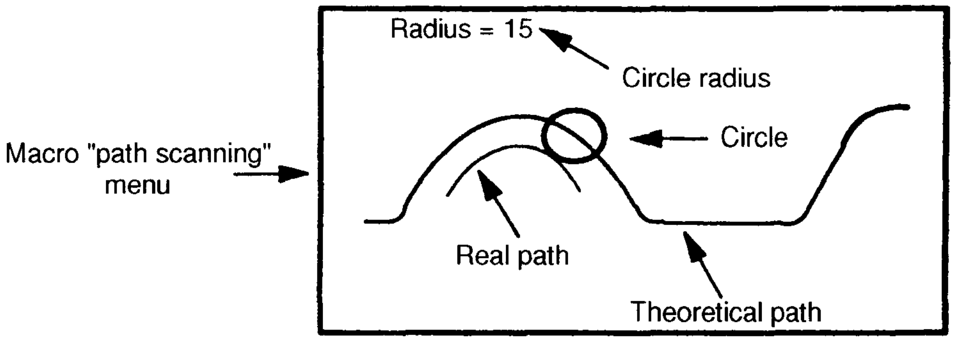


3.4.5.1 Main Menu

In the main menu:
- Key "F2" is used to modify the path error expansion scale:
  . with High Speed Machining, use scales from 20 to 40,
  . Without High Speed Machining, use a scale of 5,
- Key "F6" displays the average speed rate along the stored path segment,
- Key "F5" calls the Path scanning menu,
- Key "F3" calls the Zoom select menu,
- Key "F4" (End zoom) quits the zoom and returns to display of the entire stored path segment,
- Key "F7" displays the scope menu.

3.4.5.2 Path Scanning Menu

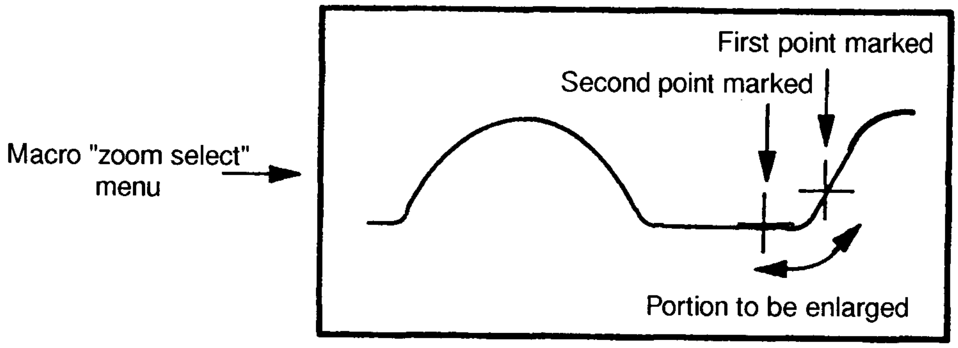
This menu is mainly used to evaluate the size of the error along the path.
- Keys "F2" to "F5" move a circle centred on the theoretical path,
- Keys "F6" and "F7" expand and contract the circle respectively so that its circumference is roughly tangent to the real path curve. The circle radius is displayed at the top of the screen. When the circle circumference is tangent to the real path, the radius displayed gives the order of magnitude of the path error in micrometres.



3.4.5.3 Zoom Select Menu

The "zoom" function enlarges part of the stored path to the full size of the screen. This function is especially useful for analysing the variation in the path error in sections with a high curvature. The enlargement changes the path display scale without changing the error expansion scale:

- In this menu, keys "F2" to "F5" are used to move a cross centred on the theoretical path. The coordinates of the cross centre are permanently displayed at the bottom of the screen,
- To select a zoom, move the cross with keys "F2" to "F5" successively onto the two ends of the portion of path to be enlarged. Mark each of the two ends by pressing key "F7". When the second end is marked, the zoom is activated and causes a return to the main menu.

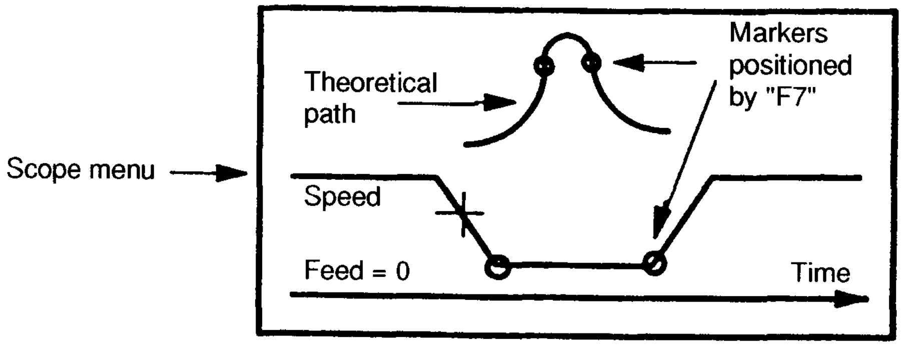


3.4.5.4 Scope Menu (Graph of the Feed Rate Versus the Time)

The "Scope" function displays the graph of the tangential feed rate controlled by the CNC versus the time in the bottom half of the screen.

The theoretical path is displayed in the top half of the screen. The display scale is half that used on the other pages:

- In this menu, keys "F2" to "F5" are used to move a cross centred either on the scope or the theoretical path. The coordinates of the point designated by the cross are permanently displayed at the bottom of the screen as is the tangential speed in this point and the current tangential acceleration,
- Key "F6" is used to switch the cross from one trace to the other (scope or path). The switch does not change the current position,
- Key "F7" is used to set markers corresponding to the current position designated by the cross on both the scope and the path. The markers are persistent once they are positioned,
- Key "F8" is used to superimpose the usual error trace on the theoretical path.



3.5 Display Programme

3.5.1 Setting Display Page

This page is displayed by a part programme (%12000 in version J, %8081 in versions G, H and J). It is used after making the settings to record the values to be entered in machine parameters P21 and P19. This page is displayed by running the above programme in Graphic mode ("Trace Plane 1"). This programme can only be run in Graphic mode. It displays the following information for the 32 machine axes:

- Open-loop position gain E980xx,
- Acceleration anticipation coefficient E981xx,
- Initial "Anti-pitch" compensation amplitude E982xx,
- "Anti-pitch" compensation time constant E983xx.

In version J of the software, this page now has the following format:

Axis	P21/Kp	P19/Kacc	P19/Vpitch	P19/Tpitch
+0	+3000	+4000	+10	+5036
+1	+2700	+502	+10	+5036
+2	+3100	+2100	+10	+5036
+3	+3000	+4000	+10	+5036
+4	+3000	+4000	+10	+5036
+5	+3000	+4000	+10	+5036
+6				
+7				

F2 : Next F11 : Exit

Scaling in progress

F2 F11

3.5.2 "Ball–Bar" Trace Display Page

This page is displayed by part programme %9997.9. It is used during execution of macro G255 to display the polar traces of the radial error. This page is displayed by running the above programme in Graphic mode ("Scale 1+2"). This programme can only be run in Graphic mode.

3.5.3 Page Displaying the Response Curves Obtained with Cycle G253

This page is displayed by part programme %12253 in version J (%8082 in versions G, H and J). It is used after executing macro G253 to trace the resulting response curves. These response curves represent a position or an acceleration, depending on the case. This page is displayed by running the above programme in Graphic mode (Trace "Plane 1"). This programme can only be run in Graphic mode.

To obtain a trace on the screen, "Plane 1" must be assigned to the modal plane (plane G17 or G18 or G19) on the "Graphic Parameters" page when macro G255 is called. The default plane is G17 for milling and G18 for turning.

3.5.4 Path Error Display Pages (G252)

These pages display the recording of the position reference and measurement made by macro G252. They are displayed by part programme %12252 in version J (%8083 in versions G, H and J). These pages are displayed by running the above programme in Graphic mode ("Scale 1+2"). The function keys are used to move around in the pages. In addition to the error trace, it is possible to display the curve of the speed along the path.

4 Appendices

4.1 Pitfalls to Be Avoided		4 - 3
4.1.1	Tool Macro Implementation Conditions	4 - 3
4.1.2	Operational Pitfalls	4 - 3
4.2 Tool Macros, Review of Call Possibilities		4 - 5
4.2.1	Macro Numbers	4 - 5
4.2.2	Accurate Identification and Alignment of the Position Time Constant (G254)	4 - 5
4.2.3	Integrated "Ball–Bar" Trace (G255)	4 - 6
4.2.4	Macro G253, General	4 - 8
4.2.4.1	Setting the Approach Speed	4 - 8
4.2.4.2	Display of Position Loop Response	4 - 9
4.2.5	Trace of the Path Error	4 - 10

4.1 Pitfalls to Be Avoided

4.1.1 Tool Macro Implementation Conditions

Conflicts with Other Macros

These macros cannot be used simultaneously with other macros. It is therefore necessary to watch out for the macros that could be called implicitly by the PLC...

Space of Variables E81000/E82000 (interaxis calibration table)

The length of this area must mandatorily be set to 1000 (machine parameter P58/N0 = 1000, which is actually the default value).

Programme Stack

The programme stack must have a sufficient size (machine parameter P58/N1 = 20000).

Programme Write in E81000 and E82000

This function must be enabled. Bit 0 of P7/N0 must be set to 0.

Programming Mandatory in Metric Units

The macros only function in metric units (G71).

4.1.2 Operational Pitfalls

Filtering Time

The filtering time must not exceed 13 sampling periods or the behaviour of the servo-control will become unpredictable.

Modification of the Sampling Period

Since the filtering time is expressed as a number of sampling periods, any change in the sampling period requires adjusting the contents of the "filtering time" parameter (P55/N8..N15) to preserve the same filtering time.

Modification of the "Filtering Time" or "Time Constant"

Changes in these parameters require readjusting the acceleration anticipation coefficients using the "Ball–Bar" trace. In version J, modification of the filtering time by macro G255 automatically readjusts the anticipation.

Writing of the Machine Parameters in EEPROM

The tool macros do not change the values of the parameters in EEPROM. They merely modify the memory images of these parameters. Accordingly, the new settings of these parameters should be noted when setting is finished and before resetting the CNC so that they can be stored in the EEPROM using Utility 5. If this is not done, it is necessary to repeat the entire setting procedure from the beginning. The parameters to be stored in the EEPROM are as follows:
- Gains (KVAR) supplied by macro G253 (E980xx/P21),
- Acceleration anticipations supplied by macro G255 (E981xx/P19),

- Filtering time (E32005/P55N8..N15),
- Anti-pitch compensation (3982xx/P19N32..N53 and E983xx/P19N64..N95),
- Time constants supplied by macro G254 (E41006/P56),
- Approach speeds supplied by macro G253 (E973xx/P33).

Approach Speed Settings

In version G or H, when this setting is made using macro G253, the corresponding machine parameter, P33, must mandatorily be forced to zero or the result is not significant. In version J, this precaution is no longer necessary.

Enabling the High Speed Machining Function

Contrary to the other macros, macro G255 does not implicitly enable the High Speed Machining function. It is necessary to check that this function is active or, if not, to force it (E11012 = 1, E11013 = 1) (also see "High Speed Machining enable conditions")

Reservations Relative to "QVN" Axes

The position gain is internal to QVN and is not accessible to the macros. This means that macros which modify the position gain cannot be used with QVN (search for maximum gain and alignment of gains. This last function is moreover irrelevant for digital axes)

Parameters Not to Be Omitted

- Parameter P52 (radial error) must absolutely be set. For High Speed Machining, the settings are necessarily low: one or a few micrometres.
- With High Speed Machining, it is recommended to initialise the "sagittal error" parameter (E32004) to a default value suited to the type of machining performed in the plant in the RESET subroutine (%11000). Normally, the sagittal error used by the CAD/CAM is known, and it is recommended to programme a value 25 percent higher in E32004. If the sagittal error is not known, it is probably preferable to programme a "high" value (0.200 or 0.400).
- With High Speed Machining, the "maximum connecting angle" parameter (E32003) must be set to a value between 5 and 15 degrees in the RESET programme (%11000).

4.2 Tool Macros, Review of Call Possibilities

4.2.1 Macro Numbers

Macro No.	Code	% Display	Function
%9997.9	G255	%9997.9	Ball–Bar,
%12254	G254		Gain balancing,
%12253	G253	%12253(%8082)	Approach speed and KVAR setting,
%12252	G252	%12252(%8083)	Path error trace,
%12000		%12000(%8081)	Display of settings (P21,P19).

4.2.2 Accurate Identification and Alignment of the Position Time Constant (G254)

Accurate Identification

G254 [F < feed rate >] X < dimension > [P]

Alignment of KVAR on P56 (inoperative for QVN axes)

G254 [F < feed rate >] X < dimension > R [P]

Alignment of KVAR on a Given Time Constant (inoperative for QVN axes)

G254 [F < feed rate >] X < dimension > R < Tp > [P] (Tp in ms)

REMARKS *With address "R", parameter E9800x (KVAR) is modified.*

The presence of optional address "P" allows this macro to be used even in the absence of the High Speed Machining option.

G91 (incremental programming) is prohibited.

4.2.3 Integrated "Ball–Bar" Trace (G255)

In all the cases of use of macro G255, address R (Radius) is optional. If it is not programmed, the path radius is calculated so that the feedback error does not exceed the resolution unit: 0.001 mm, 0.0001 degree (or 0.001 degree with K1).

Address P specifies the trace mode

"P" not specified: Dynamic trace (one point out of N at the display refresh rate),

"P0": Semi-static trace (trace by series of points),

"P1": Static trace (path segments at the start and when arriving on an M0).

Circles traced by G02/G03

G255	**G3**	**G17**	**[F < feed rate >] [R < radius >]**	**[P0]**
	G2	**G18**		**[P1]**
		G19		

Circles traced by small segments (Tabcyls) on the main axes only

G255	**G3**	**G17**	**[F < feed rate >] [R < radius >]**	**[P0]**	**Q < + sagittal error >**
	G2	**G18**		**[P1]**	**Q < -step >**
		G19			

Circles traced by small segments (Tabcyls) on any pair of axes

G255	**G3**	**X_1 X_2**	**[F < feed rate >] [R < radius >]**	**[P0]**	**Q < + sagittal error >**	**[K < circ_resol >]**
	G2			**[P1]**	**Q < -step >**	

X_1 and X_2 are the addresses of existing axes.

If at least one of these axes is linear:
- "F", (feed rate) is in mm/min,
- "R" and "Q", dimensions, are in mm..

If both axes are circular:
- "F", is in degrees/min,
- "R" and "Q", are in degrees.

"K": Sensor resolution on rotary axes in 0.001 degrees (K1 = 0.001 degree, K0.1 = 0.0001 degree; default value K0.1).

Remarks on circles traced by small segments

The macro makes sure the blocks are sufficiently long to be covered at the programmed feed rate within a time greater than or equal to P51 (E32000). If this is not the case, it displays the limit value of "Q <-step>" (or "Q <+sagittal error>" and "R <radius>").

The execution of calculated tabcyls (sin/cos) is very time-consuming. If the setting of P51 is too small, the display is refreshed in bursts. The values of "Q" and/or "R" must then be increased accordingly. Q and/or R can be estimated as follows:

$Q\_ = Tb^* (F/60)$ or $R^*Q+ = (1/8)^*(Tb^*(F/60))^2$; with the following values for Tb:

Tb = 0,025 s for "Series 1" with sampling period = 5 ms and Tb = 0.008 s for "Series 1 + coprocessor" with sampling period = 4 ms.

4.2.4 Macro G253, General

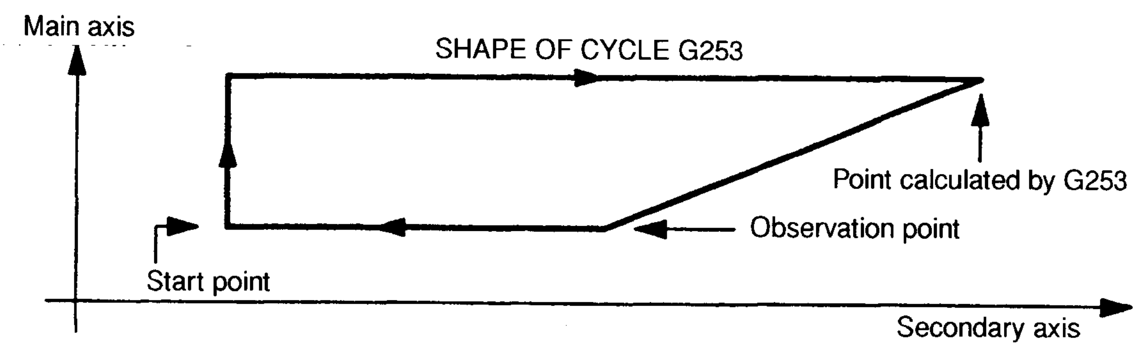
This macro serves two purposes:
- To set the approach speed,
- To display the position loop response.

The macro performs a cycle between two axes: one main axis (the one to be set) and one secondary axis.

Two types of operations are performed:
- Single cycle to examine the axis behaviour after making a setting,
- Reiterated cycles to find the required setting.

In all cases, the trace of the behaviour observed during the last cycle is available. It can be displayed in "Plane 1" by programme %12253 (%8082 in versions G and H).

Shape of the cycle executed by G253



General Call Format

G253 [F < feed rate >] X_1 < dimension > X_2 < dimension > I < main axis No. > Q < function > [R < param >]

I: Main axis number, (X=0, Y=1, Z=2, U=3, V=4, W=5, A=6, B=7, C=8).

X_1, X_2: Axis names,

Q: Function code,

R: Specific to the function performed,

Programming by G91 is prohibited.

It is prohibited to combine a linear main axis with a rotary secondary axis.

4.2.4.1 Setting the Approach Speed

Display of the position overshoot when crossing an angle (single cycle)

G253 [F < feed rate >] X_1 < dimension > X_2 < dimension > I < main axis No. > Q1 R < v_approach >

< v_approach >: in mm/min or deg/min depending on the type of main axis.

Setting the approach speed according to the tolerated overshoot (iterated cycles)

G253 [F < feed rate >] X_1 < dimension > X_2 < dimension > I < main axis No. > Q2 [R < overshoot >]

< overshoot >: Tolerated overshoot in external units, mm or degrees (default 0.001 mm or 0.0001 degree). For the operation to be valid in versions G and H, P33 must mandatorily be forced to 0 when the macro is called.

Display of the acceleration due to an angle crossing (single cycle)

G253 [F < feed rate >] X_1 < dimension > X_2 < dimension > I < main axis No. > Q6 R < v_approach >

< v_approach >: in mm/min or deg/min depending on the nature of the main axis.

Setting the approach speed according to a tolerated acceleration (iterated cycles)

G253 [F < feed rate >] X_1 < dimension > X_2 < dimension > I < main axis No. > Q7 [R < accel >]

< accel >: Tolerated acceleration in external units: mm/s2 or deg/s2 (the default value is the value set in P32). For the operation to be valid in versions G and H, P33 must mandatorily be forced to 0 when the macro is called.

4.2.4.2 Display of Position Loop Response

This function can be used with or without the High Speed Machining option (address "P").

Display of the position measurement during an angle crossing (single cycle)

G253 [F < feed rate >] X_1 < dimension > X_2 < dimension > I < main axis No. > Q3 [R < kvar >] [P]

< kvar >: Value of the gain to be tested. The default gain is the value set in P21.

4.2.5 Trace of the Path Error

This macro must be programmed at the beginning of the programme for which the path is to be analysed.

```
G252  X<x1>  I<x2>  Y<y1>  J<y2>   [P<oc>] [Q<esp>] [R<ech>] [S<nv>]
      Y<y1>  J<y2>  Z<z1>  K<z2>
      Z<z1>  K<z2>  X<x1>  I<x2>   [T1] [T4] [T5]
      |__________________________| |___________________________|
        4 mandatory dimensions          Optional arguments
```

X, I, Y, J, etc.:

Definition of the window on which storage is started. This window is defined on two axes. Storage generally starts as soon as the current position enters the window.

Optional arguments

P: Storage occurrence. With the default value (P1), storage starts the first time the current position enters the window.
However, storage can be started the second or third time, etc., the current position enters the window. This is done by programming P2, P3, etc.

Q: Storage spacing. With the default value (Q1), the points are stored at a rate of one per sampling period. However, it is possible to store the points only every other or every three sampling periods by programming Q2 or Q3.

> **⚠ CAUTION**
>
> Spacing the stored points introduces a distortion which may become large in computation of the expanded error. It is preferable to use the default setting (Q1).
> Programming of values above Q3 is prohibited.

R: Error expansion scale. It is expressed as:
Number of pixels per micrometre of error.
With High Speed Machining, it is recommended to use scales from 20 to 40.
Without High Speed Machining, it is recommended to use a scale of 5.

S: Number of variables available at the end of area E81000 (and E82000)
The default number is 1000 (S1000) which represents the total space of variables E81000 and/or E82000 and which allows 450 points to be stored.

T1: Window programming in machine dimensions (required for RTCP).

T4: Trace of the error made by the slave axis of a pair of synchronised axes.

T5: Combination of the two above modes.