Coupling machine modules via encoder signal output with TM41 (encoder simulation)
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AL: N

ECCN: N
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Coupling machine modules via encoder signal output with TM41

A position (a leading value) can be provided via incremental encoder emulation using the SINAMICS TM41 I/O module, for example, to provide a second control as encoder signal. The position that is output behaves just like the signal output from an incremental encoder.

It would also be possible to couple a machine via an encoder mounted on the machine or via field device TOs (cross-project synchronous operation with Simotion).

Note:
The following information should be considered as a supplement to the SIMOTION Function Manuals (03/2007 edition).

Information on the basic configuration of the TM41 is provided in the Manual Achse_Technologie_Funktionen.pdf [Axis_Technology_Functions.pdf] (on the SCOUT CD/DVD under Documentation\German\2_System_and_Description_of_Functions) in the Chapters "Setting as real axis with encoder signal emulation" and "Encoder signal output".

In addition, the following Manuals are also relevant:

- Ergaenzende_SINAMICS_Systemkomponenten_betreiben.pdf [Operate_Supplementary_SINAMICS_System_Components.pdf] (under Documentation\German\4_Supplementary_Documentation)
- SINAMICS_S_Listenhandbuch_LH1.pdf [SINAMICS_S_List Manual_LH1.pdf], includes function charts (under Documentation\German\5_SIMOTION_D\SINAMICS_integrated)

1 General information on TM41

TM41 can be used in two operating modes (these modes are set using TM41 parameters):

- SIMOTION (p4400=0)
  TM41 is considered just like an axis and its position setpoint is output via the incremental encoder emulation of the TM41 (refer to function chart 9474).
  This means that it is possible to operate the TM41 as following (slave) axis in synchronous operation. The incremental encoder emulation (mapping) is output in synchronism to the motion of a leading value.
  -> setpoint coupling (however with quantization effects of the incremental signal of the TM41)

- SINAMICS (p4400=1)
  The encoder position actual value of another drive is output as incremental encoder emulation (mapping) of the TM41 (refer to function chart 9476).
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FAQ TM41

-> actual value coupling (with the corresponding effects)
This mode is not taken into consideration in this FAQ.

Fig. 1: TM41 operating mode

SIMOTION mode of the TM41:

TM41 is configured in SIMOTION as a special type of a real axis (typeOfAxis:=REAL_AXIS_WITH_SIGNAL_OUTPUT).
This means that TM41 can be used just like an axis and interconnected with other TOs!

Fig. 2: TM41 axis configuration

The DO of the TM41 is connected to the TO axis via PROFIdrive, standard telegram 3 (refer to Fig. 3). This means that the DO (Drive Object) of the TM41 behaves - from the perspective of the TO axis - just like a real drive.
In order to eliminate remaining position deviations in the output signal as a result of numerical inaccuracies, a PV controller can be used at the axis at the actual position returned from the TM41 / DO41 (PV controller type for P position controllers with pre-control in the configuration data TypeOfAxis.NumberOfDataSets.DataSet_1.ControllerStruct.conType).

Corresponding to a real axis it is also possible to select a load gearbox. Although this does not correspond to the mechanical design, it can be used, e.g. to multiply pulses if the TM41 resolution is not adequate and the zero pulse is not required for synchronization (the zero pulses are also multiplied). It is not practical to set a measuring gearbox at the TM41.

A maximum of 8192 increments can be set for the TM41. The max. resolution should always be used.
TM41 supplies a TTL signal; HTL is not supported.
For TM41, the zero pulse is also simulated. -> position synchronization
Pulse multiplication is possible when using a load gearbox (in this case, the zero pulses are also multiplied).
The TM41 can output a maximum of 256000 pulses/s.

The maximum "virtual" speed $n_{\text{max}}$ is therefore obtained as follows:
$$n_{\text{max}} = f \times \left(\frac{\text{number of pulses}}{\text{number of pulses per revolution}}\right) \times 60 \times \text{rpm}$$
Example:
The pulse number is 8192 (maximum pulse number of the TM41)
\[ n_{\text{max}} = \frac{256,000}{8291} \times 60 = 1875 \text{ rpm} \]
This therefore defines the max. speed setpoint \( n_{\text{max}} \) of the speed interface to the drive.

The following formulas apply referred to the velocity of the TOs of the TM41.
- Linear axis: \( v_{\text{max}} = \frac{256,000}{(\text{number of pulses per revolution})} \times \text{spindle pitch} \times \frac{1}{\text{load gear factor}} \)
- Rotary axis: \( v_{\text{max}} = \frac{256,000}{(\text{number of pulses per revolution})} \times 360 \text{ degrees} \times \frac{1}{\text{load gear factor}} \)

with
- Configuration data, spindle pitch: \text{LeadScrew.pitchVal}
- Configuration data, load gearbox factor:
  \[ \frac{\text{TypOfAxis.NumberOfDataSet.DataSet}_x\_\text{Gear NumFactor}}{\text{TypOfAxis.NumberOfDataSet.DataSet}_x\_\text{Gear denFactor}} \]
  \( \text{(number of motor revolutions / number of load revolutions)} \)

If the maximum frequency is violated, the DO TM41 outputs fault F35220 and limits the frequency to 256.000.

2 Coupling machine modules using the TM41

When coupling machine modules it is important to extrapolate the output actual value (leading value) for synchronous operation. This is to compensate deadtimes that occur when acquiring actual values within the system, for example, as a result of bus communications and the processing times in the system.

Velocity-dependent position errors between two axes would otherwise occur as a result of these deadtimes.

With the extrapolation time, the system pre-calculates the actual value for the future position after this time has expired depending on the actual velocity.

The following describes how the extrapolation time is determined.

Two machine modules are shown in Fig. 4.
A real servo axis (A1) (operated with DSC) as well as an axis with only a signal output via TM41 module (A2) is addressed via a virtual leading axis (VA) on CPU1.

The axis position through TM41 (A2) is used in turn as leading value for the real servo axis A4 operated with DSC on CPU2.
Coupling machine modules via encoder signal output with TM41

**Fig. 4: Machine modules CPU1 and CPU2**

Legend (referred to Fig. 4 and the following calculations):
- Light gray: SIMOTION component
- Dark gray: SINAMICS component
- Ax: Axis x
- DSC: Dynamic Servo Control (the part of the position controller that is dynamically effective is implemented in the drive)
- ExtEnc: External encoder
- DOx: Drive Object X
- SMC: Sensor Module Cabinet SMC30
- LR: Position controller
- x: Position
- v: Velocity
- x1/4(t): Actual position of axis 1/4
- t1: Position delay, axis 1
- t2: Position delay, axis 2 (TM41)
- Tel: Runtime of the electronic I/O drivers (internal quantity with approx. 0.013ms)
- Tdp: DP cycle time (HW Config)
- Ti: Instant in time that the actual value is sensed (HW Config)
- To: Instant in time that the setpoint is accepted (HW Config)
- Tservo: Servo clock cycle (set the SCOUT system clock cycles)
- Tipo: Interpolator clock cycle (set the SCOUT system clock cycles)
- vTc: Time constant for the balancing filter (dynamicData.velocityTimeConstant), corresponds to the equivalent time of the speed control loop
The values for $T_i$ and $T_o$ can be determined in HW Config using the DP slave properties of the drive.

DO3 shown in Fig. 4 is configured as 2\textsuperscript{nd} encoder of a drive DO (there is still no separate DO just for an encoder). In this example this could also be the DO4. Telegram 106 should be used to transfer the additional encoder actual value.

The actual velocity $N_{act}$ of the DO3 should be used (sets `typeofAxis.numberOfEncoders.encoder_n.encoderValueType:=POSITION_AND_DIRECT_NIST`). To do this it is necessary to extend the telegram and to attach $N_{act}$ to the telegram via BiCo. The speed value that is transferred is converted into an actual velocity. The logical address of $N_{act}$ should be specified (`typeofAxis.numberOfEncoders.encoder_n.nistConfig.lodAddress`). TO normalizes $N_{act}$ (reference value is set in `typeofAxis.numberOfEncoders.encoder_n.nistConfig.referenceValue`). $N_{act}$ can be used for the velocity pre-control via the switch "`typeOfAxis.extrapolation.extrapolatedVelocitySwitch`".

The configuration data, specified in the FAQ, can be entered into the Expert list (configuration data have been completely specified) or in the axis dialog box "Closed-loop control" (static controller data and dynamic controller data with the Expert mode setting).
Depending on the required objective, different versions are possible:

1. The axis positions at TM41 should correspond to those from A1; the extrapolation time on the second control plays a secondary role (refer to Chapter, Consideration for each machine module).
   -> classic actual value coupling - as if the actual value from A1 would be the leading value for A4
   The distinguishing feature for version 1 is that the machine modules can be evaluated independently of one another. This especially plays a role if there is either no or little information about the complete machine (e.g. machine modules that have been generated by different manufacturers).

2. With the shortest possible extrapolation time at the external encoder, axes A1 and A4 should match one another (refer to Chapter
Consideration of the complete machine).

The distinguishing factor for version 2 is that a shorter extrapolation time can be achieved than for version 1. To achieve this, the complete system must be evaluated. A lower extrapolation time should be aimed for if an irregular following behavior of axis A4 is obtained due to an excessively low resolution of the incremental encoder emulation - or the leading value changes very quickly (via TM41).

3 Pre-conditions for the following evaluations

This FAQ is only referred to the following pre-settings:
- TM41 with PV controller;
  TypeOfAxis.NumberOfDataSets.DataSet_1.ControllerStruct.conType = PV (3)
  TypeOfAxis.NumberOfDataSets.DataSet_1.ControllerStruct.PV_Controller
  (Kv = 100, Kpc = 100)
- Pre-control active
  (TypeOfAxis.NumberOfDataSets.DataSet_1.ControllerStruct.PV_Controller.preCon = TRUE) for all real axes and TM41
- No balancing filter for axis 1 and axis 4
  (TypeOfAxis.NumberOfDataSets.DataSet_1.ControllerStruct.PV_Controller.balance
   FilterMode = OFF), i.e.
  vTc
  (TypeOfAxis.NumberOfDataSets.DataSet_1.DynamicData.velocityTimeConstant) is not taken into account.
- DSC
  (TypeOfAxis.NumberOfDataSets.DataSet_1.ControllerStruct.PV_Controller.enable
   DSC) active for servo axes, TM41 without DSC
- No dynamic compensation (dynamic filter) for all axes
  (TypeOfAxis.NumberOfDataSets.DataSet_1.DynamicComp.enable = NO)
- Fine interpolator (TypeOfAxis.FineInterpolator._type) should be set to cubic
  (CUBIC_MODE; interpolation with constant acceleration)
- The resolution and/or pulse number on SMC30 and TM41 should be set to the same values
4 Consideration for each machine module

Requirements:
- The axis positions of A1 and A4 should match one another \( x_1(t) = x_4(t) \)
- The axis positions of A1 and TM41 should match one another, i.e. TM41 should be aligned to A1

The TM41 operates with a delay. This means that the encoder signal that is output has no overshoot.

Calculation:

The actual value at TM41 must be delayed and as a result the leading value for axis 4 must be extrapolated on CPU2 with a longer time.

Delay through the TM41 balancing filter

\[ v_{Tc} = T_{servo_1} \]

Setting of the balancing filter for the axis configuration of the TM41:

- \( \text{dynamicData.velocityTimeConstant} = v_{Tc} \)
- \( \text{balanceFilterMode} = \text{Mode}_2 \)

Extrapolation of the leading value (external encoder) for axis 4 (index 2 corresponds to CPU2)

\[ \text{Text} = 2*\text{Tipo}_2 + T_{dp2} + T_{i2} + T_{o2} + T_{el} \]

Extrapolation time text setting for the external encoder in CPU2 (\( \text{TypeOfAxis.extrapolation.extrapolationTime} \)).

If a balancing filter is set at axis 1 (contrary to the pre-conditions), then the time must be taken into account as summed time constant in the dynamic adaptation for TM41.
Configuration example for the following Fig. 6:
Settings on CPU1: Tdp = 1ms, Tservo = 2ms, Ti = 0.125ms, To = 0.5ms
Settings for TM41:
Balancing filter (balanceFilterMode) = MODE 2,
vTc (dynamicData.velocityTimeConstant) = 2ms

The velocity characteristic of the TM41 signal output (blue) is shown in Fig. 6. The balancing time of the TM41 should be selected so that the axis controller of TM41 operates without any overshoot. This results in the signal output being delayed. The delay time corresponds to the delay time of a real axis (under the specified constraints) - whereby TM41 and the local real axis 1 are synchronized.

Note:
The extrapolation time can also be calculated using the tool provided on the Utilities&Applications CD/DVD (under Tools and Documentation > Extrapolation time calculation for PROFIBUS drives).
5 Consideration of the complete machine

Requirements:
- The axis positions of A1 and A4 should match one another \((x_1(t) = x_4(t))\)
- The extrapolation time should be as short as possible

TM41 operates to some degree "with extrapolation" (parts of the extrapolation are shifted to the TM41). As a consequence the encoder signal that is output overshoots. However, the coupling is more dynamic (faster response time).

Calculation:
\[
tcpu_1 = t_1 - t_2 \\
(\text{as a result of the setpoint delay due to DSC, the actual position } x_1(t) \text{ of A1 lags the position supplied from the TM41})
\]
\[
tcpu_1 = T_{dp1} + T_{servo1} + T_i1 + T_o1
\]
\[
tcpu_2 = 2^*T_{ipo2} + T_{dp2} + T_i2 + T_o2
\]
\[
\text{Text} = tcpu_2 - tcpu_1 + T_{el}
\]

If \(\text{text} > 0\):
Extrapolation time text setting for an external encoder in CPU2
\((\text{TypeOfAxis.extrapolation.extrapolationTime})\).
It is not permissible that the balancing filter is activated for all real axes and TM41
\((\text{balanceFilterMode} = \text{OFF, i.e. } vT_c (\text{dynamicData.velocityTimeConstant}) = 0)\)

If \(\text{text} < 0\):
The absolute value of the text should be set as deadtime \(T_t\)
\((\text{NumberOfDataSets.DataSet_1.DynamicComp.deadTime})\) in the dynamic adaptation of TM41.
Information regarding dynamic adaptation (dynamic filter):
There is a parameterizable PT2 filter in the setpoint branch in order to be able to adapt
the dynamic behavior of axes. This parameterizable PT2 filter has a deadtime with the
time constants T1, T2 and Tt.

The dynamic adaptation comprises the following
Tda = T1 + T2 + Tt

T1 additive time constant 1  (NumberOfDataSets.DataSet_1.DynamicComp.T1)
T2 additive time constant 2  (NumberOfDataSets.DataSet_1.DynamicComp.T2)
Tt  deadtime            (NumberOfDataSets.DataSet_1.DynamicComp.deadTime)

For reasons of simplicity we recommend that the dynamic adaptation is only carried out
using deadtime Tt.

Configuration example for the following Fig. 7:
Settings on CPU1;  Tdp = 1ms, Tservo = 2ms, Ti = 0.125ms, To = 0.5ms
Settings for TM41:
Balancing filter (balanceFilterMode) = OFF
vTc (dynamicData.velocityTimeConstant) = 0 ms

Fig. 7: TM41 signal output

The velocity characteristic of the TM41 signal output (blue) is shown in Fig. 7. The
balancing filter (balanceFilterMode = OFF) of the TM41 axis controller was de-
activated. As a result, the TM41 extrapolates and as a consequence the signal output
overshoots. As a result of the extrapolation behavior of TM41, for the external encoder
on CPU2, a shorter extrapolation time can be taken into consideration.
Appendix

6  Revisions

Table 6-1: Revisions

<table>
<thead>
<tr>
<th>Version</th>
<th>Date/revision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version 1.0</td>
<td>December 21, 2007</td>
</tr>
</tbody>
</table>

7  Contact partners

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