Isochrone mode –
Reliable control over high-speed events
Decentralization has become more and more important in recent years in the design of modern automation systems. This is driven, in particular, by cost considerations thanks to less cabling and easier installation.

Users today also demand distributed solutions for controlling high-speed machines. Production and machining processes are becoming faster and faster. Demands on precision in production are also becoming more and more stringent.

In this context, short, reproducible, defined process response times are required, also in the case of distributed I/O. This means that I/O signals must be read in and output at intervals in an equidistant time frame and synchronized with the user program.

The time from acquisition of a signal by the distributed I/O to the appropriate response from the actuator must be as short as possible and precisely reproducible.

Applications that are subject to requirements of this type include:
- Motion Control
- Synchronous operation
- Closed-loop controls
- Software-based cam controls
- Measuring at several measuring points
- Speed and flowrate measurement

This requirement is solved by establishing a direct interface between the equidistant DP cycle, the I/O modules and the user program.

**Synchronous coupling of a SIMATIC automation solution to the equidistant PROFIBUS is called "isochrone mode" and offers the following advantages:**
- High-speed, time-specific procedures in which reproducibility (strict real-time requirements) plays a decisive role can also be automated using distributed I/O
- Isochrone mode opens up a wide range of application possibilities that are not restricted to drive applications alone. Isochrone mode is well suited to applications whose sensors and actuators are distributed throughout the machine in a decentralized manner.

**Without isochrone mode:**

**Unsynchronized machining cycles**

In the distributed automation configurations implemented until now, many machining cycles execute in non-isochrone mode (see Figure below):
- Read in input signal (T1)
- Cycle for backplane bus of ET 200 (T2, T6)
- DP cycle time (T3 and T5)
- CPU program execution (T4)
- Output of output signal (T7)

The response time is the time that elapses between the occurrence of an event and the output of a response from an output module. This response time can lie between the sum of all single cycles and the double cycle.
Mode of operation **today** – with isochrone mode

**With isochrone mode:**

Synchronized execution cycles

The equidistant PROFIBUS was introduced several years ago. It guarantees that data is transmitted at consistently equidistant time intervals.

The system characteristic of isochrone mode allows a SIMATIC® automation solution to be coupled to the equidistant PROFIBUS. Isochrone mode has the following properties (see Figure on the right):

- The user program is **synchronized** with I/O processing. Synchronism means that all procedures are synchronized in time with each other; all input data are acquired at a defined point in time. Similarly, the output data are activated at a defined point in time. The input and output data are synchronized to the system clock right through to the terminal. The data from one cycle is always processed in the subsequent cycle.

- The input and output data are processed in **equidistant mode**. Equidistance means that input data are always read in at equal intervals and output data is always read out at equal intervals.

- All input data and output data are transferred **consistently**. Consistency means that all data of the process image are logically connected and valid for the same point in time.

**Technical background**

With clock synchronism, these sequences are embedded in a fixed time grid, the so-called **system cycle**. PROFIBUS marks time for the clock and generates the clock signal. All modules execute in accordance with this clock signal, from the CPU to the ET 200® head modules through to the signal or function module.

The point in time at which the inputs are acquired is configured by the user. This time $T_i$ is the same for all clock-synchronized modules.

The point in time at which the outputs are switched is called $T_o$. $T_o$ is also configured by the user.

At the configured point in time $T_i$ all the input signals are “frozen” simultaneously. The data are transferred to the slave (e.g. IM 153 interface module) and supplied to PROFIBUS (In).

With the clock signal, the data are transferred to the CPU. When the data are supplied to the CPU, a special organization block (OB6x) processes the data (OB).

The next clock signal starts the next system cycle and the calculated output data are transferred to the slaves via PROFIBUS. The data are then transferred to the output modules in the stations and are available on the outputs simultaneously at the time $T_o$ (Out).

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**Features**

<table>
<thead>
<tr>
<th>Application</th>
<th>Actual-value sensing and setpoint output are synchronous, i.e. concurrent for all inputs or all outputs, to generate data images consistently</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Synchronous applications are more precise</strong>, because the respective positions are measured simultaneously</td>
<td><strong>Signals closely synchronized in time</strong> can also be physically separated using distributed I/O, e.g. start signals on several equipment units for which the chronological order is relevant</td>
</tr>
<tr>
<td><strong>Time-synchronized acquisition and synchronous transfer ensures that the I/O image is internally consistent</strong>. This enables, for example, relationships to be established between several analog values (e.g. several printing variables in a press) or several linear scales in the “camshaft” application example (see Page 5)</td>
<td></td>
</tr>
</tbody>
</table>

| Actual value acquisition and setpoint output are performed equidistant, i.e. at constant time intervals | **Calculations from the difference of actual values**, e.g. in speed measurement or flowrate measurement |
| **Proportioning procedures** | **Control loops can also be closed via distributed I/O** |

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**Distributed automation structure with isochronous, deterministic dynamic response**
Configuration

Support provided in STEP 7

Configuration of the isochrone mode function is fully supported by STEP® 7.

In addition to simple activation of the isochrone mode function in STEP 7, the parameters for system clock (TDP), read in time (Ti) and output time (To) are configured. These parameters can either be set centrally for all bus stations or each slave can be configured individually. For this purpose, STEP 7 suggests suitable values that can then be optimized by the user as required. The parameters differ with regard to the actual configuration of connected modules and their properties (filter execution times, conversion times, cycle times).

Apart from the facility for activating the parameters in the respective screen forms for the individual modules, a configuration overview is also provided for the user (see Figure on the right). This overview is arranged hierarchically and shows the contributions of the individual modules and slaves to the time parameters. The time-consuming components can therefore be identified quickly for the purpose of optimizing the system clock (e.g. by reducing filter execution times). From this overview, the user can navigate to the corresponding position in the hardware configuration with a click of the mouse button.

The minimal system clock is determined by STEP 7 taking into account the relevant parameters and degree of expansion of the individual stations and lines as well as the OPs and PGs connected to the bus.

For each isochronous PROFIBUS line, a new organization block (OB61-64) is available. It is activated synchronously in each cycle and executes with an isochronous partial process image.

Notes on the Figure above

"Isochrone mode" window

The "isochrone mode" window is subdivided hierarchically to give the sub-windows Master - Slave - Module. This window provides an overview of the timing in the system clock and allows the user to jump directly to the relevant components for optimization purposes.

- Ti: Time of acquisition of input data.
- To: Time of output of output data.
- TDP: System clock.
- TWA: TWA and TWE are the conversion times of the inputs and outputs.

Configuration rules

- For configuring the isochrone mode system function, STEP 7 Version 5.2 upwards is required.
- Isochronous modules and non-isochronous modules can be used in mixed operation.
- Each PROFIBUS line forms a self-contained unit with regard to isochrone mode.
- Isochrone mode over several DP master systems cannot be configured.
- F components can be used with isochrone mode.
- H systems do not support isochrone mode.

- Full synchronism through to the terminal is only available when all components participating in the chain explicitly support this characteristic (see table on the final page).
- Isochrone mode is only available for electrical networks.
- The maximum configuration of a partial process image that can be transferred consistently depends on the type of CPU.
- Depending on the hardware expansion and program execution time, cycle times of ≥ 5 ms are achieved.
Application example
Speed measurement, camshaft

Example 1:
Speed measurement
A frequency generator outputs a signal at 80 Hz which simulates an incremental encoder with constant speed. This ensures that for all measurement sequences, identical constant initial conditions apply. For all measurement sequences, a count is read out every 32 ms.
The task is to determine the speed by means of a counter module. The count is acquired using a counter module. The speed is calculated from the difference between two counts.
The example indicates the time reproducibility in the acquisition of measured values. It shows the measurement deviation under otherwise identical initial conditions for different configurations (central/distributed configuration).
In the figure (top right), the differences measured in each instance (200 measured values) are plotted over time. Theoretically in this measurement configuration, the difference between two consecutive measured values is constant. The time reproducibility of the measurement can be read from the deviation of the curves from the optimum straight lines. Measured value acquisition is performed for the purposes of comparison in different configurations:

- ET 200S with 1 COUNT 24 V, decentralized. The count is read out via the I/O image into the 32 ms time interrupt OB
- FM 350-1, centralized configuration. The count is read out via I/O direct access into the 32 ms time interrupt OB
- ET 200S with 1 COUNT 24 V, decentralized isochrone mode. The count is read out every 32 ms (system clock = 32 ms)

Result:
In isochrone mode, the maximum deviation from the ideal theoretical value is 0.1% of the measured differences of the counts.

Example 2:
Measuring a camshaft
The task is to measure at each angular position of a camshaft, the displacement of the different cams using a linear scale. It is important that for each angular position the displacement is measured at the same moment in time. This simultaneity of measurement for all measurement points (angle and displacement) is guaranteed by means of isochrone mode.

With a single rotation of the camshaft, all positions of the camshaft and the associated measured values (red) are measured synchronously

Procedure without isochrone mode:
- Rotate camshaft one position
- Hold
- Read in position
- Measure all cams
- Rotate further, hold, measure, ...

Procedure with isochrone mode:
- Rotate the cam once
- During one continuous rotation, read positions and measured values synchronously
- Process next camshaft

Result:
Measurement tasks can be solved with much greater success by means of concurrent, synchronous measured value acquisition.

Reason:
Isochrone mode combines the equidistant scanning of the measured values with synchronous processing.
Technical specifications

The following components support the isochrone mode function:

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<th>Function</th>
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<th>Order No. group</th>
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<tr>
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<tr>
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<tr>
<td>Analog outputs</td>
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<tr>
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<td>1 SSI</td>
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Further information regarding SIMATIC controllers can be found in the Internet:
www.siemens.com/simatic-controller

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