DS5001 Digital Waveform Capture Board

# Features

Release 2021-A – May 2021

dSPACE

## How to Contact dSPACE


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## Software Updates and Patches

dSPACE strongly recommends that you download and install the most recent patches for your current dSPACE installation. Visit http://www.dspace.com/go/patches for software updates and patches.

## Important Notice

# Contents

# About This Document

**Contents**

This document provides feature-oriented access to the information you need to implement the functions of the DS5001.

**Symbols**

dSPACE user documentation uses the following symbols:

| Symbol | Description |
|---|---|
| DANGER | Indicates a hazardous situation that, if not avoided, will result in death or serious injury. |
| WARNING | Indicates a hazardous situation that, if not avoided, could result in death or serious injury. |
| CAUTION | Indicates a hazardous situation that, if not avoided, could result in minor or moderate injury. |
| NOTICE | Indicates a hazard that, if not avoided, could result in property damage. |
| Note | Indicates important information that you should take into account to avoid malfunctions. |
| Tip | Indicates tips that can make your work easier. |
|  | Indicates a link that refers to a definition in the glossary, which you can find at the end of the document unless stated otherwise. |
|  | Precedes the document title in a link that refers to another document. |

**Naming conventions**

dSPACE user documentation uses the following naming conventions:

**%name%** Names enclosed in percent signs refer to environment variables for file and path names.

**< >** Angle brackets contain wildcard characters or placeholders for variable file and path names, etc.

### Special folders

Some software products use the following special folders:

**Common Program Data folder** A standard folder for application-specific configuration data that is used by all users.

`%PROGRAMDATA%\dSPACE\<InstallationGUID>\<ProductName>`

or

`%PROGRAMDATA%\dSPACE\<ProductName>\<VersionNumber>`

**Documents folder** A standard folder for user-specific documents.

`%USERPROFILE%\Documents\dSPACE\<ProductName>\<VersionNumber>`

**Local Program Data folder** A standard folder for application-specific configuration data that is used by the current, non-roaming user.

`%USERPROFILE%\AppData\Local\dSPACE\<InstallationGUID>\<ProductName>`

### Accessing dSPACE Help and PDF Files

After you install and decrypt dSPACE software, the documentation for the installed products is available in dSPACE Help and as PDF files.

**dSPACE Help (local)** You can open your local installation of dSPACE Help:

- On its home page via Windows Start Menu
- On specific content using context-sensitive help via **F1**

**dSPACE Help (Web)** You can access the Web version of dSPACE Help at www.dspace.com.

To access the Web version, you must have a *mydSPACE* account.

**PDF files** You can access PDF files via the icon in dSPACE Help. The PDF opens on the first page.

# Introduction to the Features of the DS5001

**Where to go from here**

Information in this section

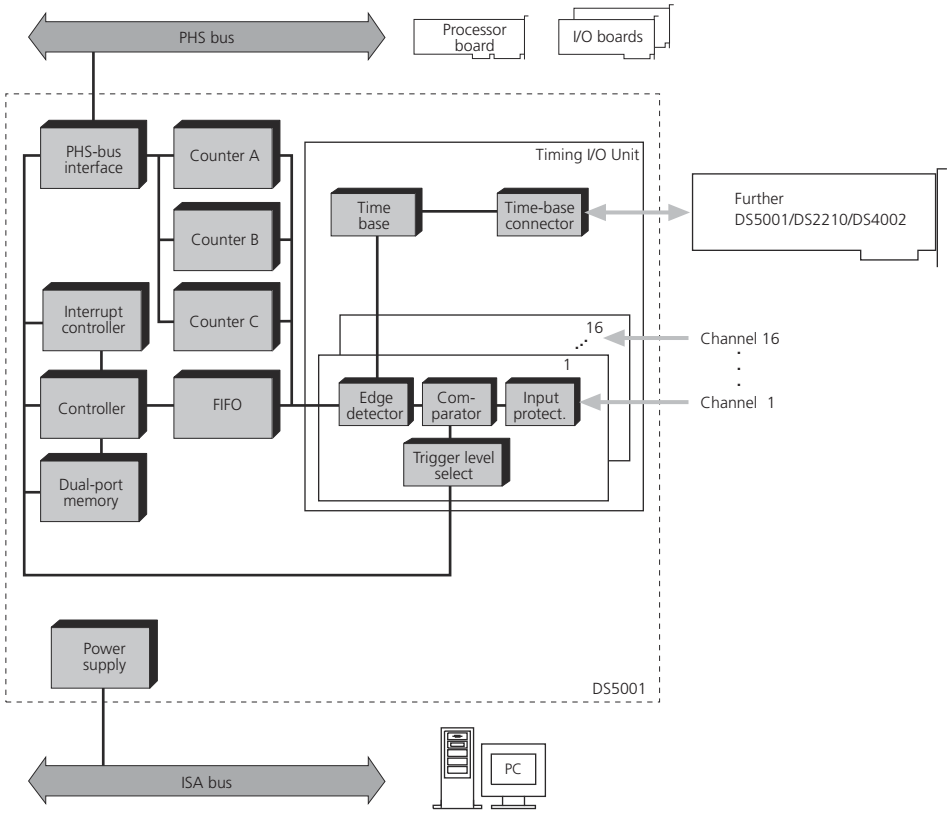


Information in other sections

# DS5001 Architecture

**Introduction**

The following illustration gives an overview of the functional units and architecture of the DS5001:




**Related topics**

References

DS5001 Interfaces....9
Feature Overview....8

# Feature Overview

**Introduction**

The DS5001 provides the several features.

**Feature overview**

The DS5001 Digital Waveform Capture Board has been designed to carry out acquisition of complex, high-speed digital signals, such as pulse-width

modulated waveforms or position signals from various sensors. It is capable of evaluating various signal parameters, including frequency, phase shifts or duty cycle.

**Timing I/O unit**

capturing digital signals on 16 channels. It converts the signals into events and stores these in a dual-port memory. The unit uses a time base with 25 ns resolution (see Timing I/O Unit on page 11).

**Note**

The time-base connector, which is part of the timing I/O unit, is supported only for specific board versions. For details, refer to DS5001 Board Revision on page 54.

**Interrupt control**

providing various hardware interrupts to the processor board (see Interrupts Provided by the DS5001 on page 51).

**Limitations**

There are some limitations when you work with the DS5001. For details, see Limitations of the DS5001 on page 53.

**Related topics**

References



# DS5001 Interfaces

**Introduction**

The DS5001 has interfaces for connection to a PHS-bus-based system and external devices.

**Integration into a PHS-bus-based system**

To be used, the DS5001 must be integrated into a PHS-bus-based system. While the DS5001 carries out acquisition of input signals, the processor board takes over the calculation of the real-time model. That is, applications using DS5001 I/O features are implemented on the processor board.

Communication between the processor board and I/O boards is performed via the peripheral high-speed bus: That is the PHS bus for a connection to a dSPACE processor board.

**Partitioning the PHS bus with the DS802** With the DS802 PHS Link Board you can spatially partition the PHS bus by arranging the I/O boards in several expansion boxes.

The DS802 can be used in combination with many types of available dSPACE I/O boards. However, some I/O boards and some functionalities of specific I/O boards are not supported.

The I/O board support depends on the dSPACE software release which you use. For a list of supported I/O boards, refer to DS802 Data Sheet (PHS Bus System Hardware Reference 🕮).

## Connection to external devices

There are two ways of connecting external devices to the DS5001. To access the I/O unit of the DS5001, connect external devices

- to the 37-pin, male Sub-D I/O connector P4 on the DS5001.
- to the BNC connectors on the optional connector panel CP5001.

## Related topics

References

DS5001 Architecture....8
Feature Overview....8

# Timing I/O Unit

**Introduction**

The DS5001 Digital Waveform Capture Board samples incoming signals on 16 channels and stores data on channels on which it detects input signal changes.

**Where to go from here**

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### Information in other sections

Introduction to the Features of the DS5001 ..... 7
Providing a diagram of the board's architecture, and an overview of the board's hardware and software features.

DS5001 Digital Waveform Capture Board (PHS Bus System Hardware Reference 🕮)

Limitations of the DS5001 ..... 53
You have to take into account certain limitations when working with the DS5001.

Interrupts Provided by the DS5001 ..... 51
The DS5001 generates an interrupt to the processor board from any one of its 16 channels when certain conditions are met.

# Signal Measurement and Event Capture

**Where to go from here**

Information in this section



Information in other sections

Timing I/O Unit (DS5001 RTI Reference 🕮)

Event Data Capture (DS5001 RTI Reference 🕮)

DS5001 Digital Waveform Capture Board (PHS Bus System Hardware Reference 🕮)

## Basics of Signal Measurement and Event Capture

**Introduction**

The DS5001 has a timing I/O unit featuring 16 input channels. For each channel there is a level comparator and an edge detector. These are followed by event storage circuitry consisting of dual-port memory and a controller.

**Time base**

The timing I/O unit contains a time-base circuit that provides the timing for all measurements. The circuit consists of a clock and a 31-bit counter. The timing I/O unit can operate in two modes:

- In the time-based mode, the counter is incremented by 1 every 25 ns, which is the time-base interval of the board. Standard applications such as PWM signal

measurement use this mode. After board initialization, it is the default operating mode of the DS5001.

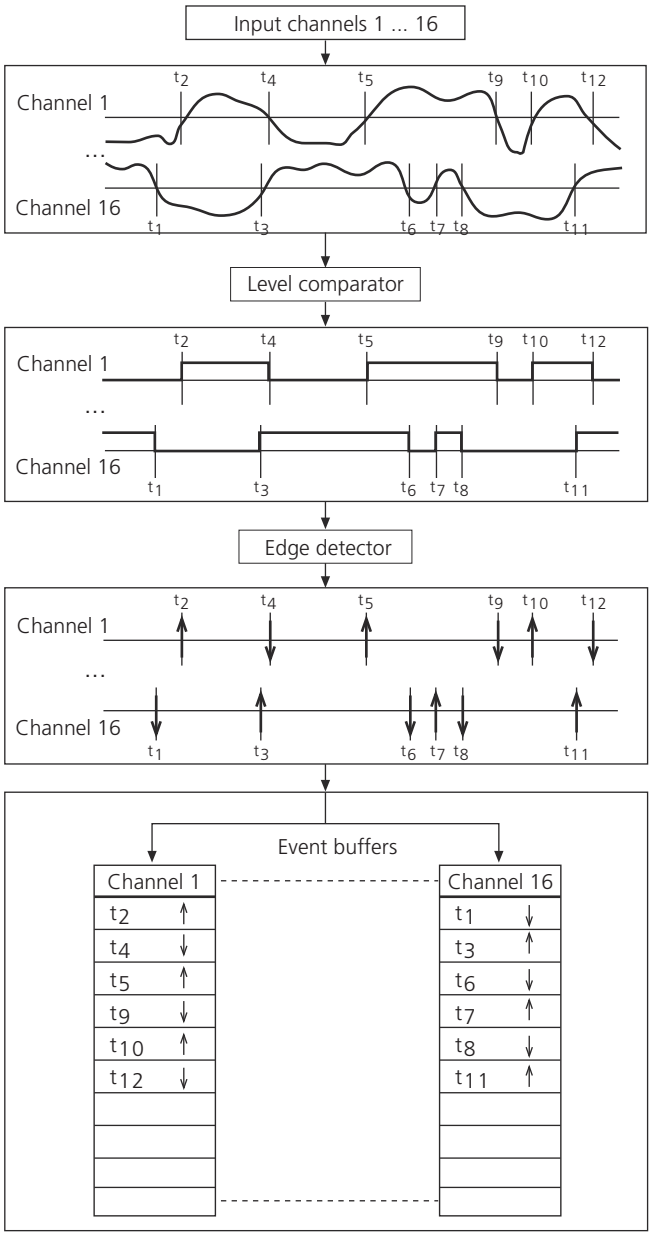
- In the angle-based mode, the time-base counter is also incremented every 25 ns, but the size of the increment is proportional to the speed of a rotating shaft. Refer to Angle-Based Mode (Board Revision DS5001-06 and Higher) on page 41.

**Event definition**

Each channel captures incoming signals and converts them into events. An event is the combination of edge polarity and the associated time stamp (the current time-base counter value when an edge was captured).

**Event capture sequence**

The following diagram shows the event capture sequence:




**Level compare**

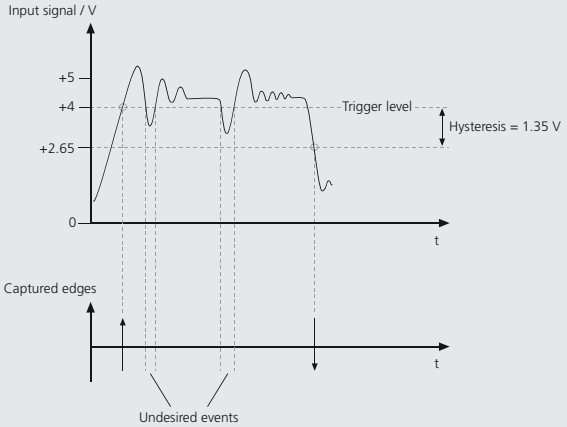
Each channel features a Schmitt Trigger input with an adjustable trigger level. The incoming signal on each channel is compared to the trigger level to obtain a digital waveform. You can specify the trigger level individually for each input channel. Refer to Trigger Level for Input Signals on page 17.

Each comparator has the following characteristics:

- 25 ns sample rate.
- ±10 V trigger level, individually programmable on each channel in 256 steps. Trigger resolution is thus 20 V / 256 steps = 78 mV.
- 80 mV fixed hysteresis on the input comparators to prevent ringing on slowly changing signals.

**Tip**

You can increase the hysteresis level up to 2.8 V for board revision DS5001-06 and higher, thereby eliminating erroneous detection of edges due to spikes on the input signals. The illustration shows the effect.




To increase the hysteresis level you have to insert an appropriate resistor array. Refer to Resistor Setting for Increasing Hysteresis Level (PHS Bus System Hardware Reference 🕮).

**Edge detection**

Rising and/or falling edges of the input signal can be detected. The edge detector also assigns a time stamp to each captured edge. The direction of each detected edge (rising or falling) is noted as the polarity.

**Event storage**

The DS5001 is equipped with a dual-port memory that is used to store captured events. For each of the 16 input channels, the dual-port memory provides one circular event buffer. Events are written to a buffer as they are captured, one after the other. When a buffer fills up, incoming data overwrites old data. There are two ways of reading the event buffer. Refer to Event Buffer Read Modes on page 18.

Event storage has the following characteristics:

- Up to 511 events can be stored in each event buffer.
- 31-bit time stamp with a resolution of 25 ns, the time base is common to all channels.
- The maximum time stamp period is $2^{31} \cdot 25$ ns = 53.687 s, when the counter overflows to zero and starts counting again.

**Related topics**

Basics

Angle-Based Mode (Board Revision DS5001-06 and Higher)....41
Event Buffer Read Modes....18
Introduction to the Features of the DS5001....7
Trigger Level for Input Signals....17

References

Resistor Setting for Increasing Hysteresis Level (PHS Bus System Hardware Reference 🕮)

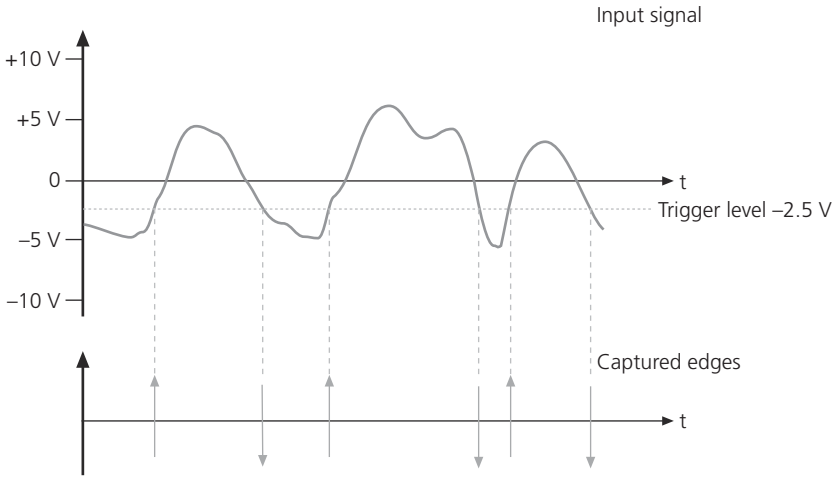
# Trigger Level for Input Signals

**Introduction**

You can set the trigger level on each input line individually in the range of ±10 V in 256 steps. This results in a trigger resolution of 20 V / 256 steps = 78 mV.

**Voltage offset compensation**

The adjustable trigger lets you compensate for any voltage offsets on the input signal. You should set the trigger level so as to capture all relevant edges of the waveform. The following figures show the effect of changing the trigger level on the position of the captured edges.



**Related topics**

Basics



References

DS5001 Digital Waveform Capture Board (PHS Bus System Hardware Reference 🕮)
Timing I/O Unit (DS5001 RTLib Reference 🕮)
Timing I/O Unit (DS5001 RTI Reference 🕮)

# Event Buffer Read Modes

**Introduction**

Events captured by the DS5001 must be evaluated by the processor board in order to determine the characteristics of the input signal.

**Reading event buffers**

To determine the characteristics of the input signal, the event buffer must be read and the events evaluated. For this purpose, you can specify the number of events to be read from the event buffer at the same time. There are two different modes for reading the event buffer. For details, see

- Overlapped Read Mode on page 19
- Contiguous Read Mode on page 21

**Value of count**

In either read mode you can specify the number of events to be read from the event buffer during each read operation. In RTLib, this number is referred to as `count`. It determines how many events are read by the processor board at a time to analyze data. The value of `count` can be changed with every execution of the RTLib function and indirectly with every execution of the RTI block.

**Interpretation of the count value**

The value of `count` is interpreted differently by various measurement functions. Event data capture measurement uses the value of `count` directly. PWM2D, F2D and phase-shift measurements interpret `count` as signal periods (for example, PWM2D measurement captures two events per period, F2D and phase-shift measurement capture only one event per period). This affects the number of edges that have to arrive at a channel.

The value of `count` is also interpreted differently by the two buffer read modes (see below).

**Related topics**

Basics



References

DS5001PWMTOD_Bx_Cy (DS5001 RTI Reference 🕮)
DS5001READ_Bx_Cy (DS5001 RTI Reference 🕮)
Event Data Capture (DS5001 RTLib Reference 🕮)
Timing I/O Unit (DS5001 RTLib Reference 🕮)

# Overlapped Read Mode

**Introduction**

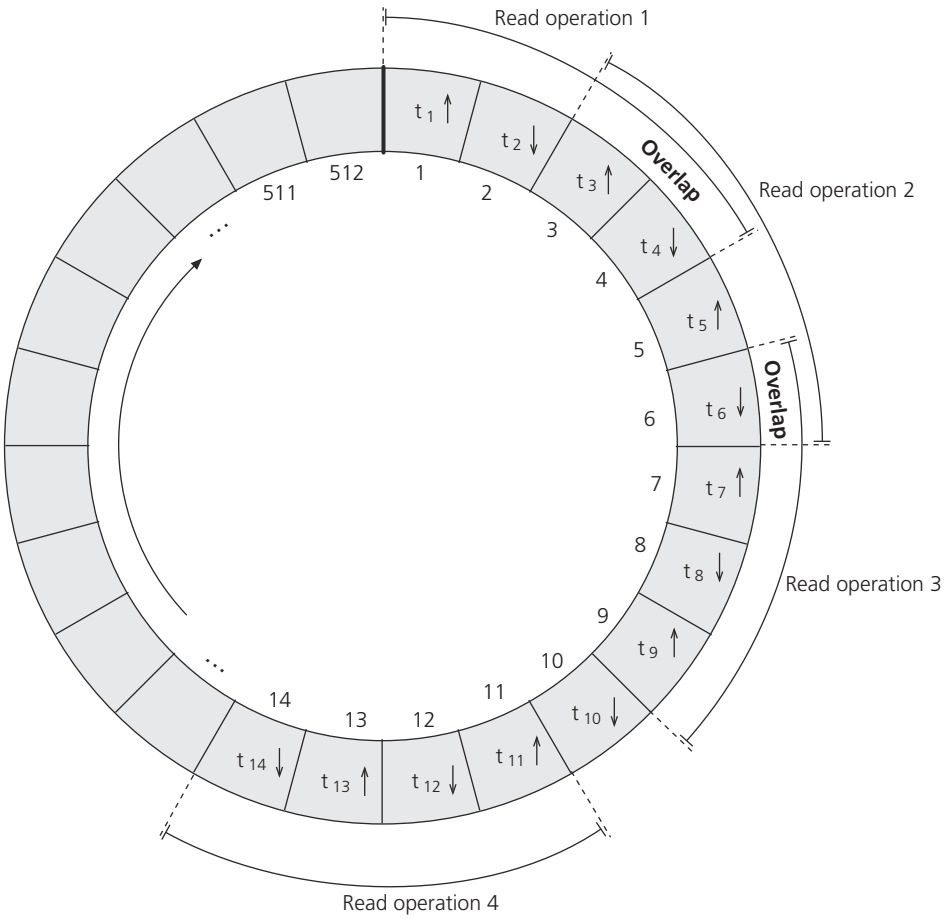
In the overlapped read mode, the processor board always reads the same number of events specified by `count` (except in the start-up phase, when the event buffer is not yet filled).

Event data is read out to the processor board in reverse order. The event captured last is read first. If more events have to be read than have been captured since the previous read operation, some events may be read again, thereby creating a read overlap. If the input signal stops, the existing events are read out over and over again.

If more events are captured than read, the unread events are ignored. Buffer overflow therefore cannot occur.

In the start-up phase, if the buffer contains no events, nothing is read and the function returns an error. If the buffer contains fewer events than have to be read, the existing events are read – provided the minimum number of events required for the measurement were captured (for example, at least four events are required to calculate PWM signals).

The following illustration serves as an example. It shows `count` as 4 events.




Each read operation always starts with the last event captured. This is illustrated in the above figure. For example, for read operation 2, $t_6$ is read first, $t_3$ is read last.

If the number of events captured between two read operations is less than the number of events read (i.e. `count`), an overlap occurs and the difference between the events read and the events captured may be read several times. This is shown in the figure: Only two events ($t_5$ and $t_6$) have been captured, but four are read. Therefore events $t_4$ and $t_3$ are read twice.

**Note**

- The events in an overlap region may be read several times if a low frequency signal is being captured and if at the same time the value of `count` and the read repeat rate are both high.
- If the number of events captured between two read operations is greater than the number of events read (i.e. `count`), the excess events are lost. In the figure, this applies to event $t_{10}$.

**Related topics**

Basics

Event Buffer Read Modes ..... 18
Event Data Capture ..... 36
Phase-Shift Measurement ..... 30
PWM Signal Measurement (PWM2D) ..... 24
Square-Wave Signal Measurement (F2D) ..... 27

References

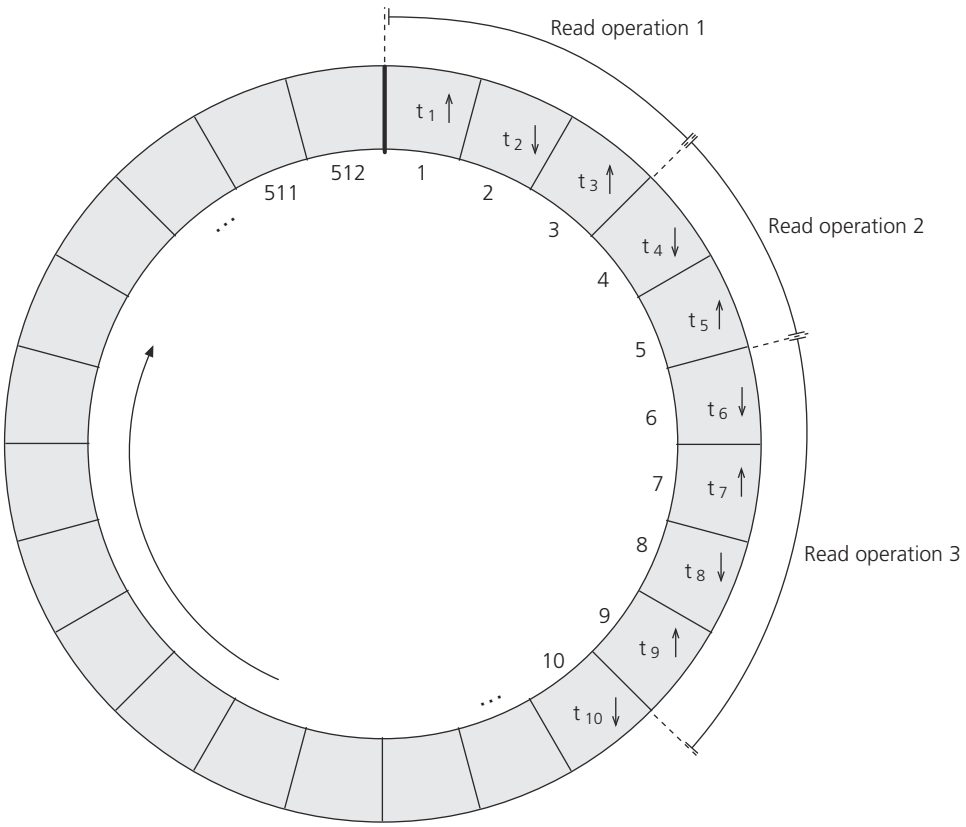
DS5001PWMTOD_Bx_Cy (DS5001 RTI Reference 🕮)
DS5001READ_Bx_Cy (DS5001 RTI Reference 🕮)
Event Data Capture (DS5001 RTLib Reference 🕮)
Timing I/O Unit (DS5001 RTLib Reference 🕮)

# Contiguous Read Mode

**Introduction**

In the contiguous read mode, event data is read out to the processor board in forward order, i.e. starting with the first unread event. Only events unread by the previous read operation are read from the event buffer. This allows reading of contiguous segments of event data without overlapping. The contiguous read mode thus reads a varying number of events, depending on how many have been captured. The value of `count` is therefore interpreted as the *highest* number of events that can be read. If more events keep arriving than can be read, the buffer eventually fills up or even overflows.

The following figure serves as an example. It shows `count` as 4 events.




Each read operation always starts with the first unread event. So for read operation 2 in the above figure, $t_4$ is read first because $t_3$ has already been read during read operation 1.

Read operation 2 reads only two events, because only $t_4$ and $t_5$ have been captured. Read operation 3 terminates with $t_9$ because `count` has been set to 4. Consequently, event $t_{10}$ is read in the subsequent read operation.

**Note**

If the number of events captured between two read operations is greater than 511, the oldest unread events are overwritten (buffer overflow). In this case, the event counter is set to 0 and the number of events specified by count is read.
If the buffer contains no new events, nothing is read and the function returns an error.

## Related topics

Basics



References

DS5001READ_Bx_Cy (DS5001 RTI Reference 🕮)
Event Data Capture (DS5001 RTLib Reference 🕮)
Timing I/O Unit (DS5001 RTLib Reference 🕮)

# Signal Measurement

**Where to go from here**

Information in this section



## PWM Signal Measurement (PWM2D)

**Introduction**

The DS5001 timing I/O unit allows the measurement of average frequency $f_p$ and the duty cycle d of pulse-width modulated (PWM) signals on up to 16 channels.

**Zero frequency detection**

The zero frequency detection feature uses channel 16. If zero frequency detection is active, channel 16 is not available for measurements.

**Note**

As of board revision DS5001-06 and dSPACE Release 3.5, RTLib does not use channel 16 for zero frequency detection. If you use RTLib functions for PWM2D or F2D, channel 16 is available for measurements while zero frequency detection is enabled.
This feature is not provided by RTI.
See also Enabling Zero Frequency Detection on page 58.

You can specify a minimum frequency `f_min` for each channel used in PWM signal measurement. Frequencies lower than `f_min` are regarded as 0 Hz. To disable zero frequency detection, specify a minimum frequency value `f_min` of 0 Hz.

**No input signal**

If the input signal stops while the measurement is in progress, the behavior of RTLib functions depends on the event buffer read mode used to make the PWM2D measurement:

**Overlapped mode** The behavior depends on the setting of `f_min`:

If `f_min` is zero or the time 1/`f_min` has not yet expired, the measurement returns the last measured frequency and duty cycle as the function keeps reading out the old events. RTLib returns the error code `DS5001_NO_ERROR`. If the buffer contains fewer than 4 events (as can occur in the start-up phase) the error code returned is `DS5001_EMPTY`.

If `f_min` is not zero and no event was captured for the time of 1/`f_min`, the measurement also returns a frequency of zero and the duty cycle corresponds to the input signal level (zero or one). RTLib returns the error code `DS5001_NO_ERROR`.

**Contiguous mode** The behavior depends on the setting of `f_min`:

If `f_min` is zero, the measurement returns a frequency of zero. The duty cycle corresponds to the signal level of the input signal (zero or one). The returned error code is `DS5001_EMPTY`.

If `f_min` is not zero, the measurement also returns a frequency of zero and the duty cycle corresponds to the input signal level (zero or one). The returned error code is `DS5001_EMPTY` for the time of 1/`f_min` after the last event has been read out, after that it changes to `DS5001_NO_ERROR`.

**Trigger level**

You have to set the trigger level for each channel separately. For details, refer to Trigger Level for Input Signals on page 17.

**Values for count**

The DS5001 captures rising as well as falling edges of the input signal during PWM2D. The measurement interprets `count` as half of the events captured, or in other words, as periods.

In RTI, you enter the value of count with the `Number of periods` parameter within the range 1 … 254.

**Note**

The DS5001PWMTOD_Bx_Cy block always uses the overlapped read mode. The contiguous read mode is not supported by RTI.

In RTLib, you have to specify a value of count with the `count` parameter. You also have to select the RTLib function to perform the PWM2D measurement. Your selection indirectly determines the mode that will be used to read the event buffer with.

In both read modes the values of count must remain within the range 1 … 254. For details of `count` and the read modes, see Event Buffer Read Modes on page 18.

**Measuring symmetric PWM signals**

The measurement algorithm used is accurate if the PWM period starts with the falling or rising edge of the corresponding PWM signal (asymmetric signal).

The DS5001 can also be used to measure PWM signals that are centered around the middle of the PWM period (symmetric signals). However, the measurement of the PWM frequency of symmetric PWM signals is faulty if the duty cycle of the PWM signal changes during measurement. For details, refer to Limitation for the Measurement of Symmetric PWM Signals on page 55.

**Read event interrupt**

With RTLib, you can specify the number of captured events after which the DS5001 issues an interrupt to the processor board. For details, refer to Interrupts Provided by the DS5001 on page 51.

**RTI/RTLib support**

To perform PWM signal measurement, use DS5001 Blockset or RTLib. Refer to

- RTI: DS5001PWMTOD_Bx_Cy (DS5001 RTI Reference 🕮).
- RTLib: PWM Signal Measurement (PWM2D) (DS5001 RTLib Reference 🕮).

**Execution times**

For the execution times of the RTLib functions, refer to Function Execution Times (DS5001 RTLib Reference 🕮).

**Connecting external devices**

For an I/O circuit and information on electrical characteristics and signal conditioning of the timing I/O unit, refer to Signal Connection to External Devices (PHS Bus System Hardware Reference 🕮).

### I/O mapping

The following table shows the mapping between the RTI block and the RTLib functions, and the corresponding pins used for PWM signal measurement.

| Related RTI Block | Ch (RTI) | Related RTLib Functions | Ch (RTLib) | Conn. Pin | Pin on CP | Signal |
|---|---|---|---|---|---|---|
| DS5001PWMTOD_Bx_Cy (DS5001 RTI Reference 🕮) | Ch 1 | See PWM Signal Measurement (PWM2D) (DS5001 RTLib Reference 🕮) | Ch 1 | P4 20 | CP1 | IN1 |
| | Ch 2 | | Ch 2 | P4 21 | CP2 | IN2 |
| | Ch 3 | | Ch 3 | P4 22 | CP3 | IN3 |
| | Ch 4 | | Ch 4 | P4 23 | CP4 | IN4 |
| | Ch 5 | | Ch 5 | P4 24 | CP5 | IN5 |
| | Ch 6 | | Ch 6 | P4 25 | CP6 | IN6 |
| | Ch 7 | | Ch 7 | P4 26 | CP7 | IN7 |
| | Ch 8 | | Ch 8 | P4 27 | CP8 | IN8 |
| | Ch 9 | | Ch 9 | P4 28 | CP9 | IN9 |
| | Ch 10 | | Ch 10 | P4 29 | CP10 | IN10 |
| | Ch 11 | | Ch 11 | P4 30 | CP11 | IN11 |
| | Ch 12 | | Ch 12 | P4 31 | CP12 | IN12 |
| | Ch 13 | | Ch 13 | P4 32 | CP13 | IN13 |
| | Ch 14 | | Ch 14 | P4 33 | CP14 | IN14 |
| | Ch 15 | | Ch 15 | P4 34 | CP15 | IN15 |
| | Ch 16 | | Ch 16 | P4 35 | CP16 | IN16 |

### Conflicting features

The I/O features of the DS5001 conflict with each other. For details, see Conflicting I/O Features on page 59.

### Related topics

Basics

Event Buffer Read Modes ..... 18
Signal Measurement and Event Capture ..... 13
Timing I/O Unit ..... 11
Trigger Level for Input Signals ..... 17

References

PWM Signal Measurement (PWM2D) (DS5001 RTLib Reference 🕮)

## Square-Wave Signal Measurement (F2D)

### Introduction

The DS5001 timing I/O unit allows the measurement of the average frequency $f_s$ of square-wave signals on up to 16 channels.

**Zero frequency detection**

The zero frequency detection feature uses channel 16. If zero frequency detection is active, channel 16 is not available for measurements.

**Note**

As of board revision DS5001-06 and dSPACE Release 3.5, RTLib does not use channel 16 for zero frequency detection. If you use RTLib functions for PWM2D or F2D, channel 16 is available for measurements while zero frequency detection is enabled.
This feature is not provided by RTI.
See also Enabling Zero Frequency Detection on page 58.

You can specify a minimum frequency `f_min` for each channel used in square-wave signal measurement. Frequencies lower than `f_min` are regarded by the DS5001RTLib functions as 0 Hz. To disable zero frequency detection, specify a minimum square-wave frequency value `f_min` of 0 Hz.

**No input signal**

If the input signal stops while the measurement is in progress, the behavior of the RTLib functions depends on the event buffer read mode used to make the F2D measurement:

**Overlapped Mode** If `f_min` is zero or the time 1/`f_min` has not yet expired, the measurement returns the last measured frequency as the function keeps reading out the old events. RTLib returns the error code `DS5001_NO_ERROR`. If the buffer contains fewer than 2 events (as can occur in the start-up phase) the returned error code is `DS5001_EMPTY`.

If `f_min` is not zero and no event was captured for the time of 1/`f_min`, the measurement also returns a frequency of zero. RTLib returns the error code `DS5001_NO_ERROR`.

**Contiguous Mode** If `f_min` is zero or the time 1/`f_min` has not yet expired, the measurement returns a frequency $f_s$ of zero. The returned error code is `DS5001_EMPTY`.

If `f_min` is not zero and no event was captured for the time of 1/`f_min`, the measurement also returns a frequency of zero. RTLib returns the error code `DS5001_NO_ERROR`.

**Trigger level**

You have to set the trigger level for each channel separately. For details, refer to Trigger Level for Input Signals on page 17.

**Values for count**

The DS5001 captures only the rising edges of the input signal during F2D. The measurement interprets `count` as periods.

In RTI you enter the value of count with the **Number of periods** parameter. In RTLib you have to specify a value of `count` which will be used to compute $f_s$. You also have to select the RTLib function to perform the F2D measurement.

Your selection indirectly determines the mode that will be used to read the event buffer with.

In both read modes the values of count must remain within the range 1 … 510. For details of `count` and the read modes, see Event Buffer Read Modes on page 18.

**Read event interrupt**

With RTLib you can specify the number of captured events after which the DS5001 issues an interrupt to the processor board. For details, refer to Interrupts Provided by the DS5001 on page 51.

**RTI/RTLib support**

To perform square-wave signal measurement, use DS5001 Blockset or RTLib. For details, see

- RTI: **DS5001FTOD_Bx_Cy** (DS5001 RTI Reference 🕮)
- RTLib: Square-Wave Signal Measurement (F2D) (DS5001 RTLib Reference 🕮)

**Execution times**

For the execution times of the RTLib functions, refer to Function Execution Times (DS5001 RTLib Reference 🕮).

**Connecting external devices**

For an I/O circuit and information on electrical characteristics and signal conditioning of the timing I/O unit, refer to Signal Connection to External Devices (PHS Bus System Hardware Reference 🕮).

**I/O mapping**

The following table shows the mapping between the RTI block and the RTLib functions, and the corresponding pins used for F2D signal measurement.

| Related RTI Block | Ch (RTI) | Related RTLib Functions | Ch (RTLib) | Conn. Pin | Pin on CP | Signal |
|---|---|---|---|---|---|---|
| DS5001FTOD_Bx_Cy | Ch 1 | See Square-Wave Signal Measurement (F2D) (DS5001 RTLib Reference 🕮) | Ch 1 | P4 20 | CP1 | IN1 |
| | Ch 2 | | Ch 2 | P4 21 | CP2 | IN2 |
| | Ch 3 | | Ch 3 | P4 22 | CP3 | IN3 |
| | Ch 4 | | Ch 4 | P4 23 | CP4 | IN4 |
| | Ch 5 | | Ch 5 | P4 24 | CP5 | IN5 |
| | Ch 6 | | Ch 6 | P4 25 | CP6 | IN6 |
| | Ch 7 | | Ch 7 | P4 26 | CP7 | IN7 |
| | Ch 8 | | Ch 8 | P4 27 | CP8 | IN8 |
| | Ch 9 | | Ch 9 | P4 28 | CP9 | IN9 |
| | Ch 10 | | Ch 10 | P4 29 | CP10 | IN10 |
| | Ch 11 | | Ch 11 | P4 30 | CP11 | IN11 |
| | Ch 12 | | Ch 12 | P4 31 | CP12 | IN12 |
| | Ch 13 | | Ch 13 | P4 32 | CP13 | IN13 |
| | Ch 14 | | Ch 14 | P4 33 | CP14 | IN14 |
| | Ch 15 | | Ch 15 | P4 34 | CP15 | IN15 |
| | Ch 16 | | Ch 16 | P4 35 | CP16 | IN16 |

**Conflicting features**

The I/O features of the DS5001 conflict with each other. For details, see Conflicting I/O Features on page 59.

**Related topics**

Basics



# Phase-Shift Measurement

**Introduction**

The DS5001 timing I/O unit allows the measurement of the average phase shift Δφ between two input signals. Up to eight such measurements can be made in parallel using eight pairs of channels. To make the measurement, you need to

specify one channel as the reference signal, the other in the pair as the compare signal. The result is scaled in radians and mapped to the interval -π … +π.

- $\Delta\varphi > 0$ indicates that the compare signal leads the reference signal.
- $\Delta\varphi < 0$ indicates that the compare signal lags the reference signal.

For example, if channel 1 is the reference channel, the phase shift becomes positive when the signal on channel 2 leads that on channel 1.

**Note**

For a phase-shift measurement the frequencies of the reference signal and the compare signal must be equal.

Phase shifts are measured in the overlapped read mode.

**No input signal**

If the input signal stops while the measurement is in progress, the measurement returns the last measured phase shift as the function keeps reading out the old events. The RTLib returns the error code `DS5001_NO_ERROR`.

**Trigger level**

You have to set the trigger level for each channel separately. For details, refer to Trigger Level for Input Signals on page 17.

**Values for count**

The measurement captures rising or falling edges only but not both. The number of events captured therefore corresponds to the number of measured periods. As a result, `count` is interpreted as periods. You have to specify a value of `count` which the DS5001 must use to compute $f_s$. The possible range of values for `count` is 1 … 509. For details of `count` and the read modes, see Event Buffer Read Modes on page 18.

**Read event interrupt**

With RTLib you can specify the number of captured events after which the DS5001 issues an interrupt to the processor board. For details, refer to Interrupts Provided by the DS5001 on page 51.

**RTI/RTLib support**

To perform phase-shift measurement, use RTLib. For details, see Phase-Shift Measurement (DS5001 RTLib Reference 🕮).

Using RTI, you have to program phase-shift measurement with RTLib functions, and incorporate your C code in a Simulink S-function. For details, refer to Implementing S-Functions (RTI and RTI-MP Implementation Guide 🕮).

**Execution times**

For the execution times of the RTLib functions, refer to Function Execution Times (DS5001 RTLib Reference 🕮).

### Connecting external devices

For an I/O circuit and information on electrical characteristics and signal conditioning of the timing I/O unit, refer to Signal Connection to External Devices (PHS Bus System Hardware Reference 🕮).

### I/O mapping

The following table shows the mapping between the RTLib functions and the corresponding pins used for phase-shift measurement.

| Related RTLib Functions | Ch (RTLib) | Conn. Pin | Pin on CP | Signal |
|---|---|---|---|---|
| See Phase-Shift Measurement (DS5001 RTLib Reference 🕮) | Ch 1 | P4 20 | CP1 | IN1 |
| | Ch 2 | P4 21 | CP2 | IN2 |
| | Ch 3 | P4 22 | CP3 | IN3 |
| | Ch 4 | P4 23 | CP4 | IN4 |
| | Ch 5 | P4 24 | CP5 | IN5 |
| | Ch 6 | P4 25 | CP6 | IN6 |
| | Ch 7 | P4 26 | CP7 | IN7 |
| | Ch 8 | P4 27 | CP8 | IN8 |
| | Ch 9 | P4 28 | CP9 | IN9 |
| | Ch 10 | P4 29 | CP10 | IN10 |
| | Ch 11 | P4 30 | CP11 | IN11 |
| | Ch 12 | P4 31 | CP12 | IN12 |
| | Ch 13 | P4 32 | CP13 | IN13 |
| | Ch 14 | P4 33 | CP14 | IN14 |
| | Ch 15 | P4 34 | CP15 | IN15 |
| | Ch 16 | P4 35 | CP16 | IN16 |

### Conflicting features

The I/O features of the DS5001 conflict with each other. For details, see Conflicting I/O Features on page 59.

### Related topics

Basics

Event Buffer Read Modes ..... 18
Signal Measurement and Event Capture ..... 13
Timing I/O Unit ..... 11

# Incremental Encoder Measurement

**Introduction**

The DS5001 timing I/O unit is able to capture digital phase signals from incremental encoder sensors on up to eight pairs of consecutive channels (1/2, 3/4, 5/6, 7/8, 9/10, 11/12, 13/14, 15/16).

**Note**

The board supports only rudimentary functionality of incremental encoder measurement – it accepts no differential signals and no index signal. It also provides no power supply for the encoder.

**Trigger level**

You have to set the trigger level for each channel separately. For details, refer to Trigger Level for Input Signals on page 17.

**Counting encoder lines**

The incremental encoder measurement simulates a 31-bit position counter and counts in a positive or negative direction, depending on the actual phase relationship.

**Note**

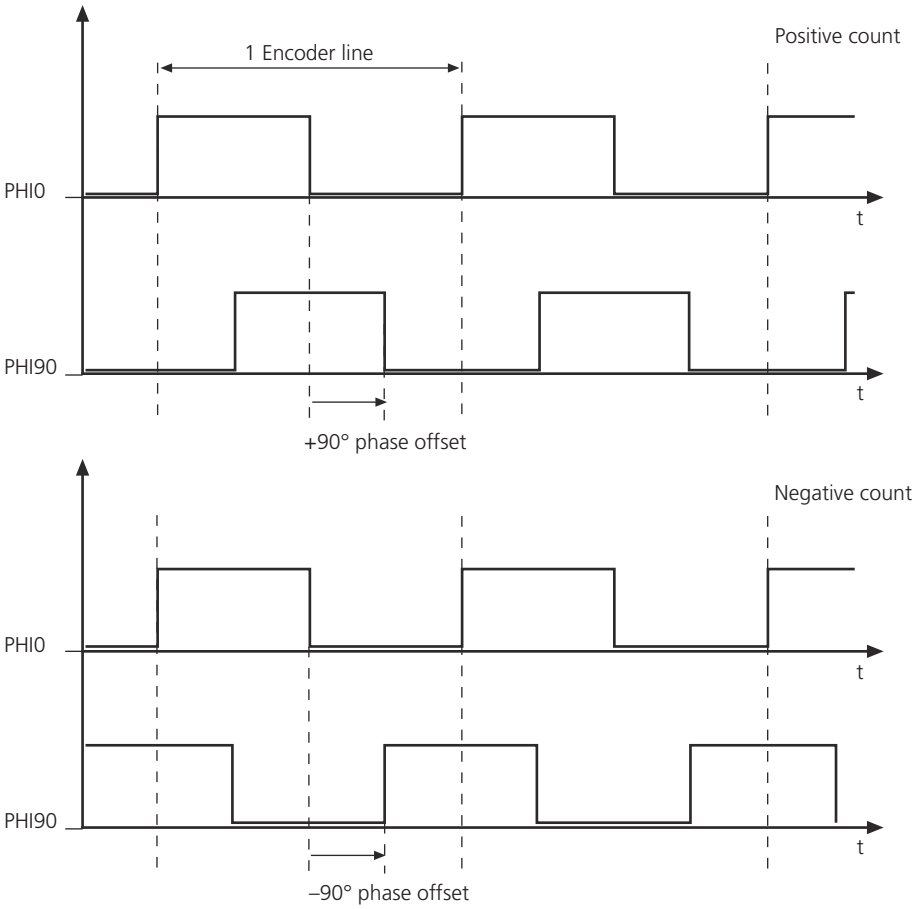
The RTLib function does a twofold subdivision (2 counter increments/decrements per encoder line).

**Detection of movement**

A digital incremental encoder outputs two square-wave signals (PHI0 and PHI90), which have a phase offset of +90° or –90° to one another, depending on the direction of movement.

The RTLib function counts in the positive direction if signal PHI90 lags signal PHI0. It counts in the negative direction if signal PHI90 leads signal PHI0.

The following figure illustrates this principle:




**RTI/RTLib support**

To perform incremental encoder measurement, use DS5001 Blockset and RTLib. Refer to

- RTI: Incremental Encoder Interface (DS5001 RTI Reference 🕮)
- RTLib: Incremental Encoder Measurement (DS5001 RTLib Reference 🕮)

**Execution times**

For the execution times of the RTLib functions, refer to Function Execution Times (DS5001 RTLib Reference 🕮).

**Connecting external devices**

For an I/O circuit and information on electrical characteristics and signal conditioning of the timing I/O unit, refer to Signal Connection to External Devices (PHS Bus System Hardware Reference 🕮).

## I/O mapping

The following table shows the mapping between the RTI block and the RTLib functions, and the corresponding pins used for incremental encoder measurement.

| Related RTI Blocks | Ch (RTI) | Related RTLib Functions | Ch (RTLib) | Conn. Pin | Pin on CP | Signal |
|---|---|---|---|---|---|---|
| DS5001POS_Bx_Cy / DS5001CLR_POS_Bx_Cy | Ch 1 | See Incremental Encoder Measurement (DS5001 RTLib Reference 🕮) | Ch 1 | P4 20 | CP1 | IN1 (PHI0) |
| | Ch 2 | | Ch 2 | P4 21 | CP2 | IN2 (PHI90) |
| | Ch 3 | | Ch 3 | P4 22 | CP3 | IN3 (PHI0) |
| | Ch 4 | | Ch 4 | P4 23 | CP4 | IN4 (PHI90) |
| | Ch 5 | | Ch 5 | P4 24 | CP5 | IN5 (PHI0) |
| | Ch 6 | | Ch 6 | P4 25 | CP6 | IN6 (PHI90) |
| | Ch 7 | | Ch 7 | P4 26 | CP7 | IN7 (PHI0) |
| | Ch 8 | | Ch 8 | P4 27 | CP8 | IN8 (PHI90) |
| | Ch 9 | | Ch 9 | P4 28 | CP9 | IN9 (PHI0) |
| | Ch 10 | | Ch 10 | P4 29 | CP10 | IN10 (PHI90) |
| | Ch 11 | | Ch 11 | P4 30 | CP11 | IN11 (PHI0) |
| | Ch 12 | | Ch 12 | P4 31 | CP12 | IN12 (PHI90) |
| | Ch 13 | | Ch 13 | P4 32 | CP13 | IN13 (PHI0) |
| | Ch 14 | | Ch 14 | P4 33 | CP14 | IN14 (PHI90) |
| | Ch 15 | | Ch 15 | P4 34 | CP15 | IN15 (PHI0) |
| | Ch 16 | | Ch 16 | P4 35 | CP16 | IN16 (PHI90) |

## Conflicting features

The I/O features of the DS5001 conflict with each other. For details, see Conflicting I/O Features on page 59.

## Related topics

Basics

Event Buffer Read Modes ..... 18
Signal Measurement and Event Capture ..... 13
Timing I/O Unit ..... 11
Trigger Level for Input Signals ..... 17

References

DS5001 Digital Waveform Capture Board (PHS Bus System Hardware Reference 🕮)

# Event Handling

**Where to go from here**

Information in this section



## Event Data Capture

**Introduction**

The timing I/O unit is able to capture aperiodic (arbitrary) signals on up to 16 channels and convert them into events. An event is the combination of edge polarity and the associated time stamp (the current time-base counter value when an edge was captured). Rising or falling edges, or both edges of the input signal, can be captured.

**Trigger level**

You have to set the trigger level for each channel separately. Refer to Trigger Level for Input Signals on page 17.

**Minimum distance between two edges**

The minimum distance between two edges to be measured is 50 ns.

**Values for count**

You have to specify a value for `count` which defines the number of events to be read from the event buffer.

In RTI, you enter the value of `count` with the `Number of events` parameter. When using RTLib, you also have to select the function to perform event capturing. Your selection indirectly determines the mode that will be used to read the event buffer with.

In both read modes the values of count must remain within the range 1 … 511. For details of `count` and the read modes, see Event Buffer Read Modes on page 18.

**Read event interrupt**

You can specify the number of captured events after which the DS5001 issues an interrupt to the processor board. For details, refer to Interrupts Provided by the DS5001 on page 51.

**RTI/RTLib support**

To perform event data capture, use DS5001 Blockset or RTLib. Refer to

- RTI: DS5001READ_Bx_Cy (DS5001 RTI Reference 🕮)
- RTLib: Event Data Capture (DS5001 RTLib Reference 🕮)

**Tip**

As of dSPACE Release 3.5, RTLib provides the `ds5001_timebase_read` function, which allows you to read the current time from the DS5001 time-base counter.

**Execution times**

For the execution times of the RTLib functions, refer to Function Execution Times (DS5001 RTLib Reference 🕮).

**Connecting external devices**

For an I/O circuit and information on electrical characteristics and signal conditioning of the timing I/O unit, refer to Signal Connection to External Devices (PHS Bus System Hardware Reference 🕮).

## I/O mapping

The following table shows the mapping between the RTI block and the RTLib functions, and the corresponding pins used for event data capture.

| Related RTI Block | Ch (RTI) | Related RTLib Functions | Ch (RTLib) | Conn. Pin | Pin on CP | Signal |
|---|---|---|---|---|---|---|
| DS5001READ_Bx_Cy | Ch 1 | See Event Data Capture (DS5001 RTLib Reference 🕮) | Ch 1 | P4 20 | CP1 | IN1 |
| | Ch 2 | | Ch 2 | P4 21 | CP2 | IN2 |
| | Ch 3 | | Ch 3 | P4 22 | CP3 | IN3 |
| | Ch 4 | | Ch 4 | P4 23 | CP4 | IN4 |
| | Ch 5 | | Ch 5 | P4 24 | CP5 | IN5 |
| | Ch 6 | | Ch 6 | P4 25 | CP6 | IN6 |
| | Ch 7 | | Ch 7 | P4 26 | CP7 | IN7 |
| | Ch 8 | | Ch 8 | P4 27 | CP8 | IN8 |
| | Ch 9 | | Ch 9 | P4 28 | CP9 | IN9 |
| | Ch 10 | | Ch 10 | P4 29 | CP10 | IN10 |
| | Ch 11 | | Ch 11 | P4 30 | CP11 | IN11 |
| | Ch 12 | | Ch 12 | P4 31 | CP12 | IN12 |
| | Ch 13 | | Ch 13 | P4 32 | CP13 | IN13 |
| | Ch 14 | | Ch 14 | P4 33 | CP14 | IN14 |
| | Ch 15 | | Ch 15 | P4 34 | CP15 | IN15 |
| | Ch 16 | | Ch 16 | P4 35 | CP16 | IN16 |

## Conflicting features

The I/O features of the DS5001 conflict with each other. For details, see Conflicting I/O Features on page 59.

## Related topics

Basics

Event Buffer Read Modes ..... 18
Signal Measurement and Event Capture ..... 13
Timing I/O Unit ..... 11
Trigger Level for Input Signals ..... 17

References

DS5001 Digital Waveform Capture Board (PHS Bus System Hardware Reference 🕮)
DS5001READ_Bx_Cy (DS5001 RTI Reference 🕮)
Event Data Capture (DS5001 RTI Reference 🕮)

# Counting Events

**Introduction**

The DS5001 provides three 32-bit counters that can be used to count rising and/or falling edges on up to three input channels.

> **Note**
>
> The counters only count the number of rising and/or falling edges that occur on an input channel. Unlike the event capture mechanism (see Event Data Capture on page 36), the related edge polarities are not saved and no time stamps are associated. The event buffers are not used.

In connection with the time base of the processor board, you can use the counters to determine fast frequencies lower than 20 MHz. However, the accuracy of this frequency measurement method is significantly smaller than the accuracy of the standard measurements using the event buffers.

**Trigger level**

You have to set the trigger level for each channel separately. For details, refer to Trigger Level for Input Signals on page 17.

**Maximum frequency**

For ideal symmetrical square-wave signals, a maximum frequency of lower than 20 MHz can be measured.

**Read mode**

The following read modes are available:

| Read Mode | Behavior |
|---|---|
| Continuous | The counter is continuously incremented. If the counter overflows, it continues with 0. |
| Reset | After the counter value is read, the counter is reset to 0. |

**RTI/RTLib support**

To count events, use DS5001 Blockset or RTLib. For details, see

- RTI: DS5001READ_CNT_Bx_Cy (DS5001 RTI Reference 🕮)
- RTLib: Counting Events (DS5001 RTLib Reference 🕮)

**Execution times**

For the execution times of the RTLib functions, refer to Function Execution Times (DS5001 RTLib Reference 🕮).

**Connecting external devices**

For an I/O circuit and information on electrical characteristics and signal conditioning of the timing I/O unit, refer to Signal Connection to External Devices (PHS Bus System Hardware Reference 🕮).

## I/O mapping

The following table shows the mapping between the RTI block and the RTLib functions, and the corresponding pins used for event data capture.

| Related RTI Block | Ch (RTI) | Related RTLib Functions | Ch (RTLib) | Conn. Pin | Pin on CP | Signal |
|---|---|---|---|---|---|---|
| DS5001READ_CNT_Bx_Cy | Ch 1 | See Counting Events | Ch 1 | P4 20 | CP1 | IN1 |
| | Ch 2 | | Ch 2 | P4 21 | CP2 | IN2 |
| | Ch 3 | | Ch 3 | P4 22 | CP3 | IN3 |
| | Ch 4 | | Ch 4 | P4 23 | CP4 | IN4 |
| | Ch 5 | | Ch 5 | P4 24 | CP5 | IN5 |
| | Ch 6 | | Ch 6 | P4 25 | CP6 | IN6 |
| | Ch 7 | | Ch 7 | P4 26 | CP7 | IN7 |
| | Ch 8 | | Ch 8 | P4 27 | CP8 | IN8 |
| | Ch 9 | | Ch 9 | P4 28 | CP9 | IN9 |
| | Ch 10 | | Ch 10 | P4 29 | CP10 | IN10 |
| | Ch 11 | | Ch 11 | P4 30 | CP11 | IN11 |
| | Ch 12 | | Ch 12 | P4 31 | CP12 | IN12 |
| | Ch 13 | | Ch 13 | P4 32 | CP13 | IN13 |
| | Ch 14 | | Ch 14 | P4 33 | CP14 | IN14 |
| | Ch 15 | | Ch 15 | P4 34 | CP15 | IN15 |
| | Ch 16 | | Ch 16 | P4 35 | CP16 | IN16 |

## Conflicting features

The I/O features of the DS5001 conflict with each other. For details, see Conflicting I/O Features on page 59.

## Related topics

Basics

Introduction to the Features of the DS5001 ..... 7
Trigger Level for Input Signals ..... 17

References

DS5001READ_CNT_Bx_Cy (DS5001 RTI Reference 🕮)

# Angle-Based Mode (Board Revision DS5001-06 and Higher)

**Introduction**

The DS5001 contains a time-base circuit that provides the timing for all measurements. The circuit consists of a clock and a 31-bit counter.

**Where to go from here**

Information in this section



Information in other sections



## Time-Based Mode and Angle-Based Mode

**Introduction**

The timing I/O unit of the DS5001 can operate in time-based mode or angle-based mode.

**Time-based mode**

In the time-based mode, the 31-bit time-base counter is incremented by 1 every 25 ns, which is the time-base interval of the board. The counter therefore overruns every 53.687 s ( = $2^{31}$ · 25 ns), restarting again from zero.

The time-based mode allows you to implement time-based applications such as PWM signal measurement. After board initialization, it is the default operating mode of the DS5001.

**Angle-based mode**

In contrast with the time-based mode, the increment added to the time-base counter every 25 ns is not constant in the angle-based mode. Instead, the increment is proportional to the current speed of a rotating shaft.

**Note**

The angle-based mode is only available for board revision DS5001-06 and higher.

**720° mode** In 720° mode, the increment is scaled so that one cycle of the 31-bit time-base counter represents two complete revolutions of a rotating shaft.

**360° mode** This mode is provided for compatibility reasons. In 360° mode, the increment is scaled so that one cycle of the 31-bit time-base counter represents one complete revolution of a rotating shaft.

To use the timing I/O unit in angle-based mode, the rotational speed is therefore required as an additional input parameter.

The angle-based mode allows you to implement angle-based applications such as crankshaft sensor signal generation, or injection pulse measurement.

**Note**

The mode setting applies to all channels of the timing I/O unit. You cannot use both modes at the same time. For example, it is not possible to implement an angle-based application on one channel, and perform PWM signal measurement on another channel simultaneously.

## Implementing the Angle-Based Mode and Time-Base Distribution

**Introduction**

DS5001 boards of revision DS5001-06 and higher allow you to operate in angle-based mode synchronously on one or more DS5001 boards.

**Angle-based mode on several dSPACE boards**

DS5001 boards of revision DS5001-06 and higher provide a time-base connector. Via the connector, you can set up a network and distribute the time base of one

DS5001 to other DS5001, DS2210, DS2211 and DS4002 boards. This allows you to implement the angle-based mode on several dSPACE boards. Do the following:

1. Connect the time-base connectors to set up the network. Refer to Connecting dSPACE Boards for Time-Base Distribution on page 43.
2. Configure one dSPACE board in the network as the time-base master, all the others as time-base slaves. Refer to Configuring Time-Base Master and Time-Base Slaves on page 44.
3. Specify the rotational speed on the time-base master. Refer to Specifying the Rotational Speed on page 45.

**Angle-based mode on a single DS5001**

To implement the angle-based mode on a single DS5001 without distributing its time base to other dSPACE boards, do the following:

1. Make sure that the time-base connector of the DS5001 is not connected to other DS5001, DS2210, DS2211 or DS4002 boards.
2. Configure the DS5001 on which you want to implement the angle-based mode as the time-base master. Refer to Configuring Time-Base Master and Time-Base Slaves on page 44.
3. Specify the rotational speed. Refer to Specifying the Rotational Speed on page 45.

**RTI/RTLib support**

You can implement the angle-based mode and time-base distribution via RTLib for the DS5001. For details, see Time Base Distribution (DS5001 RTLib Reference 🕮).

Using RTI, you have to implement the angle-based mode and time-base distribution with RTLib functions, and incorporate your C code in a Simulink S-function. For details, refer to Implementing S-Functions (RTI and RTI-MP Implementation Guide 🕮).

**Related topics**

Basics

Angle-Based Mode (Board Revision DS5001-06 and Higher)....41

# Connecting dSPACE Boards for Time-Base Distribution

**Introduction**

To setup the network, you have to connect DS5001, DS2210, DS2211 and DS4002 boards physically. For this purpose, these boards are equipped with a time-base connector. Use a standard 26-pin, ribbon cable to setup the network. A DS5001, DS2210, DS2211 or DS4002 can be connected to one or several other boards.

**Location of the time-base connector**

For the location of the time-base connector on a DS5001, DS2210, DS2211 or DS5001, refer to the corresponding *Board Overview* chapter in the PHS Bus System Hardware Reference 🕮.

**Note**

- The time-base connector of the DS5001 is available only for board revision DS5001-06 and higher.
- The time-base connector of the DS4002 is available only for board revision DS4002-04 and higher.

**Related topics**

Basics

Angle-Based Mode (Board Revision DS5001-06 and Higher)..... 41
Implementing the Angle-Based Mode and Time-Base Distribution..... 42

## Configuring Time-Base Master and Time-Base Slaves

**Introduction**

The *time-base master* distributes the time base to other boards – the *time-base slaves*.

**Time-base master, time-base slaves**

You have to configure one of the connected DS5001, DS2210, DS2211 or DS4002 boards as the *time-base master*. You have to configure all the other connected boards as time-base slaves. For this purpose, use the

- `ds4002_apu_mode_set` function for DS4002 boards,
- `ds2210_mode_set` function for DS2210 boards,
- `ds2211_mode_set` function for DS2211 boards,
- `ds5001_apu_mode_set` function for DS5001 boards.

All the other functions including initialization are not affected by the master/slave setting and must be performed for each board individually.

**Note**

- If you want to implement the angle-based mode on a single DS5001 without distributing its time base to other dSPACE boards, you have to configure your DS5001 as the time-base master.
- Do not configure a DS4002 as the time-base master if the network also contains one or more DS2210 or DS2211 boards. Otherwise, the DS2210 or DS2211 board(s) will not work correctly.

**Related topics**

Basics

Angle-Based Mode (Board Revision DS5001-06 and Higher)..... 41
Implementing the Angle-Based Mode and Time-Base Distribution..... 42

References

ds2210_mode_set (DS2210 RTLib Reference 🕮)
ds2211_mode_set (DS2211 RTLib Reference 🕮)
ds4002_apu_mode_set (DS4002 RTLib Reference 🕮)
ds5001_apu_mode_set (DS5001 RTLib Reference 🕮)

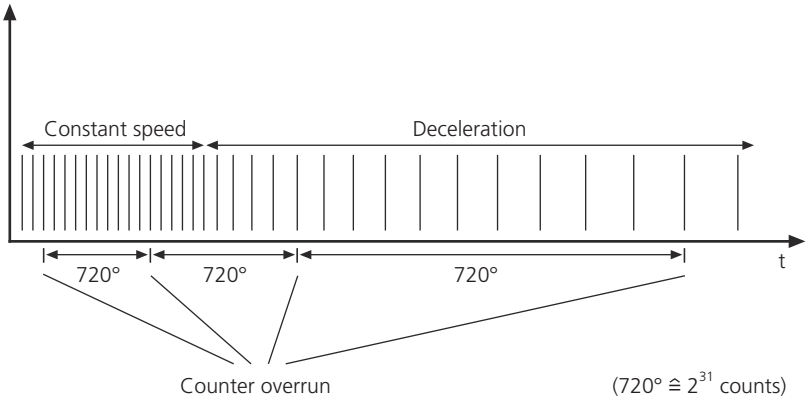
# Specifying the Rotational Speed

**Introduction**

To work with the DS5001 in angle-based mode, you have to specify the rotational speed on the time-base master.

**Rotational speed input parameter**

You can set the `vel` input parameter according to the current speed of a rotating shaft. If a DS5001 is the time-base master, the increment added to the 31-bit time-base counter of the DS5001 is scaled so that one cycle of the time-base counter represents two complete revolutions of the rotating shaft (720° mode). Run-time changes of the `vel` input parameter come into effect every 25 ns.




The following functions allow you to specify the `vel` input parameter:

- `ds5001_apu_velocity_write` function (time-base master is a DS5001)
- `ds4002_apu_velocity_write` function (time-base master is a DS4002)
- `ds2210_apu_velocity_write` function (time-base master is a DS2210)
- `ds2211_apu_velocity_write` function (time-base master is a DS2211)

### Returning to the time-based mode

If a DS5001 is the time-base master, specifying 0.234 [rad/s] as the `vel` input parameter for the `ds5001_apu_velocity_write` function results in a time-base counter increment of 1. This allows you to return to the time-based mode, which is the default mode after board initialization. For detailed information, refer to Time Base Distribution (DS5001 RTLib Reference 🕮).

### Resolution

One cycle of a four-stroke engine amounts to 0 … 720° (0 … 4π). The DS5001 uses a 31-bit counter to calculate the time base for internal use. The time-base master exports only the 13 most significant bits of the counter to generate the time base for the slaves. The resolution therefore is:

| Time-Base Type | Resolution (in bit) | Resolution (in °) |
|---|---|---|
| Master (DS5001) | $2^{31}$ | $3.35 \cdot 10^{-7}$ |
| Slave | $2^{13}$ | 0.088 |

### Using 360° mode

For compatibility reasons, the DS5001 can also work in the 360° mode (corresponding to one revolution of the rotating shaft). Use the `ds5001_set_rpm` function to set the angle-based mode with an angle width of 360°. Specifying 1.117587 rpm as the rotational speed input parameter results in a time-base counter increment of 1. This returns you to the time-based mode, which is the default mode after board initialization. For detailed information, refer to Angle-Based Mode (DS5001 RTLib Reference 🕮).

**Note**

The rotational speed input parameter used by the `ds5001_apu_velocity_write` function and the `ds5001_set_rpm` function have the same physical meaning. However, the `vel` parameter used by `ds5001_apu_velocity_write` must be stated in rad/s; the `rpm` parameter used by `ds5001_set_rpm` must be stated in rpm. Use the following conversion formula:
vel = 2π · rpm/60

**Related topics**

Basics

Angle-Based Mode (Board Revision DS5001-06 and Higher)..... 41
Implementing the Angle-Based Mode and Time-Base Distribution..... 42

References

ds2210_apu_velocity_write (DS2210 RTLib Reference 🕮)
ds2211_apu_velocity_write (DS2211 RTLib Reference 🕮)
ds4002_apu_velocity_write (DS4002 RTLib Reference 🕮)
ds5001_apu_velocity_write (DS5001 RTLib Reference 🕮)
ds5001_set_rpm (DS5001 RTLib Reference 🕮)

# Measuring Angle-Based Signals

**Introduction**

To measure angle-based signals, you first have to select the angle-based mode and provide the rotational speed as discussed in Specifying the Rotational Speed on page 45.

**Converting time stamps into angle values**

Having set the angle-based mode, you can implement angle-based signal measurement the normal way, that is by capturing events. The DS5001 stores every event as an edge direction and a corresponding time stamp. RTLib provides the `DS5001_TIME2ANGLE` and the `DS5001_TIME2ANGLE2` macros (360° and 720° mode) to convert the time stamps into angle values.

Apart from returning angle values instead of time stamps, angle-based signal measurement and event data capture do not differ from one another. For more information, see Event Data Capture on page 36.

**Example**

For an example of measuring ignition and injection signals, refer to Example of Using Angle-Based Functions (DS5001 RTLib Reference 🕮).

**Related topics**

Basics

Angle-Based Mode (Board Revision DS5001-06 and Higher)..... 41
Specifying the Rotational Speed..... 45

References

Angle-Based Mode (DS5001 RTLib Reference 🕮)
DS5001_TIME2ANGLE (DS5001 RTLib Reference 🕮)
DS5001_TIME2ANGLE2 (DS5001 RTLib Reference 🕮)

# Bit I/O

## Bit I/O

| | |
|---|---|
| **Introduction** | The timing I/O unit allows you to read the state of single input channels. If the current voltage on the input channel is above the trigger level, the value 1 is returned, otherwise 0. |
| **Trigger level** | You have to set the trigger level for each channel separately. For details, refer to Trigger Level for Input Signals on page 17. |
| **RTI/RTLib support** | To read the state of an input channel, use DS5001 Blockset or RTLib. Refer to<br>▪ RTI: DS5001IN_Bx_Cy (DS5001 RTI Reference 🕮)<br>▪ RTLib: Bit I/O (DS5001 RTLib Reference 🕮) |
| **Execution times** | For the execution times of the RTLib functions, refer to Function Execution Times (DS5001 RTLib Reference 🕮). |
| **Connecting external devices** | For an I/O circuit and information on electrical characteristics and signal conditioning of the timing I/O unit, refer to Signal Connection to External Devices (PHS Bus System Hardware Reference 🕮). |

## I/O mapping

The following table shows the mapping between the RTI block and the RTLib functions, and the corresponding pins used for digital input.

| Related RTI Block | Ch (RTI) | Related RTLib Functions | Ch (RTLib) | Conn. Pin | Pin on CP | Signal |
|---|---|---|---|---|---|---|
| DS5001IN_Bx_Cy | Ch 1 | See Bit I/O (DS5001 RTLib Reference 🕮) | Ch 1 | P4 20 | CP1 | IN1 |
| | Ch 2 | | Ch 2 | P4 21 | CP2 | IN2 |
| | Ch 3 | | Ch 3 | P4 22 | CP3 | IN3 |
| | Ch 4 | | Ch 4 | P4 23 | CP4 | IN4 |
| | Ch 5 | | Ch 5 | P4 24 | CP5 | IN5 |
| | Ch 6 | | Ch 6 | P4 25 | CP6 | IN6 |
| | Ch 7 | | Ch 7 | P4 26 | CP7 | IN7 |
| | Ch 8 | | Ch 8 | P4 27 | CP8 | IN8 |
| | Ch 9 | | Ch 9 | P4 28 | CP9 | IN9 |
| | Ch 10 | | Ch 10 | P4 29 | CP10 | IN10 |
| | Ch 11 | | Ch 11 | P4 30 | CP11 | IN11 |
| | Ch 12 | | Ch 12 | P4 31 | CP12 | IN12 |
| | Ch 13 | | Ch 13 | P4 32 | CP13 | IN13 |
| | Ch 14 | | Ch 14 | P4 33 | CP14 | IN14 |
| | Ch 15 | | Ch 15 | P4 34 | CP15 | IN15 |
| | Ch 16 | | Ch 16 | P4 35 | CP16 | IN16 |

## Conflicting features

The I/O features of the DS5001 conflict with each other. For details, see Conflicting I/O Features on page 59.

## Related topics

Basics

Introduction to the Features of the DS5001 ..... 7

# Interrupts

## Interrupts Provided by the DS5001

**Introduction**

The DS5001 generates an interrupt to the processor board from any one of its 16 channels when certain conditions are met.

**Interrupt types**

The DS5001 generates an interrupt to the processor board when the conditions described in the following table are met:

| Interrupt Type | Description |
|---|---|
| Read event INTLEN interrupt | An interrupt is issued when the preset number of events on any channel (1 … 16) has been captured. The range is 1 … *x*, where *x* is the maximum number of events that can be read from the buffer. Refer to Event Buffer Read Modes on page 18. |
| Read event FULL interrupt | An interrupt is issued when the event buffer on any one channel fills up, i.e. 511 events have been captured on a channel. |
| Input FIFO full | The input FIFO is full. Additional events captured are lost. |
| Arbitration error | The processor board was in the process of reading an event that was overwritten by a subsequent event from the edge detector before the reading operation could be completed. |

**Interrupt processing**

Interrupts from the event buffers are processed by the interrupt controller of the DS5001 and passed to the dSPACE processor board via the PHS-bus interrupt lines. Using RTI, interrupts from the DS5001 can be used to implement interrupt-driven tasks. Refer to Tasks Driven by Interrupt Blocks (RTI and RTI-MP Implementation Guide 🕮).

**Note**

Interrupt generation support by the DS5001 blockset is provided only via the event capture block **DS5001READ_Bx_Cy** (DS5001 RTI Reference 🕮). Interrupt generation for PWM2D or F2D is possible via RTLib only.

## RTI/RTLib support

You can access the read event interrupt via DS5001 Blockset and RTLib. For details, see

- RTI: DS5001_HWINT_Bx_Iy (DS5001 RTI Reference 🕮).
- RTLib: ds5001_read_init (DS5001 RTLib Reference 🕮), ds5001_f2d_init (DS5001 RTLib Reference 🕮), or ds5001_pwm2d_init (DS5001 RTLib Reference 🕮), depending on the kind of signal you are measuring.

**Note**

Read event interrupts can be generated on up to 16 channels. However, the PHS-bus connector of the DS5001 supports only one physical interrupt line. If you use RTLib, you have to use subinterrupt handling functions of the dSPACE processor board to identify the originating channel of the interrupts. Refer to Subinterrupt Handling (DS1006 RTLib Reference 🕮) or Subinterrupt Handling (DS1007 RTLib Reference 🕮).

## Related topics

Basics

Introduction to the Features of the DS5001 ..... 7
Timing I/O Unit ..... 11

References

Limitations of the DS5001 ..... 53

# Limitations of the DS5001

**Introduction**

**Note**

Knowledge of the basic principles is a prerequisite to understanding the limitations of the DS5001. Refer to Signal Measurement and Event Capture on page 13.

**Where to go from here**

Information in this section



Information in other sections

## DS5001 Board Revision

**Introduction**

The following features depend on the board revision.

**Time-base connector**

All features related to the time-base connector, which is part of the timing I/O unit, are supported only for board revision DS5001-06 and higher. The board revision is printed on the board.

For the location of the connector, refer to Board Overview (PHS Bus System Hardware Reference 🕮).

**Hysteresis level**

You can increase the hysteresis level up to 2.8 V for board revision DS5001-06 and higher, thereby eliminating erroneous detection of edges due to spikes on the input signals. See also Signal Measurement and Event Capture on page 13.

**Related topics**

Basics

Connecting dSPACE Boards for Time-Base Distribution ..... 43

References

DS5001 Digital Waveform Capture Board (PHS Bus System Hardware Reference 🕮)
Limitations of the DS5001 ..... 53

## Measuring Slowly Changing Signals

**Introduction**

The longest time between two edges amounts to 53.687 s. This is the maximum time-stamp period.

**⚠ WARNING**

Signals changing at a slower rate cause erroneous results! There is no error detection.

**PWM2D**

For PWM measurements, you need at least 4 events to determine the frequency and duty cycle. In this case, the longest time between the first and the fourth measured edge amounts to 53.687 s. See also PWM Signal Measurement (PWM2D) on page 24.

**Phase-shift measurement**

For phase-shift measurements, you need at least 3 events on each of the two channels to determine the phase shift between the compare signal and the reference signal. In this case, the longest time between the three edges amounts to 53.687 s. See also Phase-Shift Measurement on page 30.

**Related topics**

Basics

Signal Measurement and Event Capture ..... 13

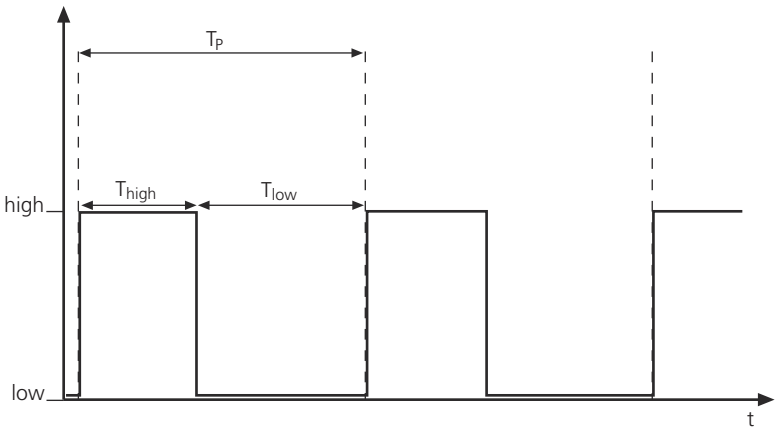
References

Limitations of the DS5001 ..... 53

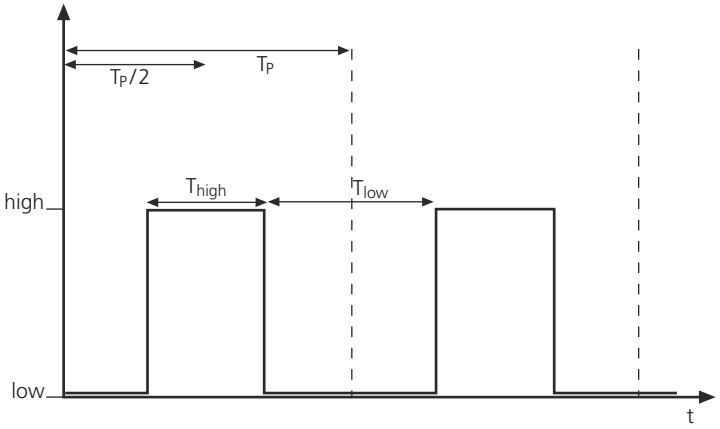
# Limitation for the Measurement of Symmetric PWM Signals

**Asymmetric and symmetric PWM signals**

PWM measurement is accurate if the PWM period starts with the falling or rising edge of the corresponding PWM signal (asymmetric signal). For example, in the illustration below, each PWM period starts with a rising edge of the asymmetric PWM signal:



The DS5001 can also measure PWM signals that are centered around the middle of the PWM period (symmetric signals):




However, the evaluation of the PWM frequency $f_p$ of symmetric PWM signals is faulty if the duty cycle of the PWM signal changes during measurement.

**PWM frequency evaluation algorithm**

The PWM frequency $f_p$ is evaluated according to the following equation:

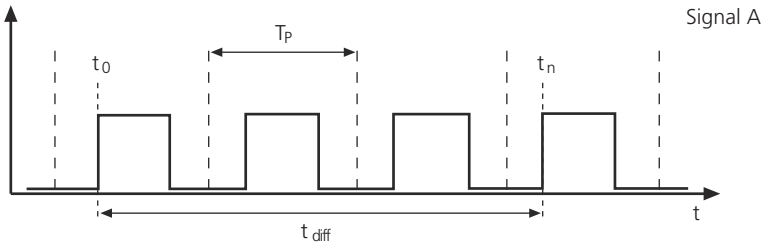
$$f_p = \frac{n}{t_{diff}}$$

Where

$t_{diff}$ is the interval between the first and the last detected rising edge

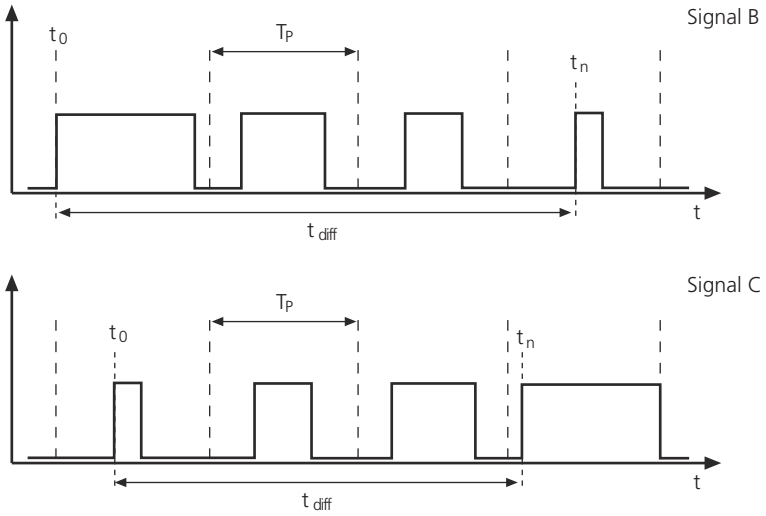
$n$ is the number of PWM periods used to evaluate $f_p$.

The following illustration shows how $f_p$ is evaluated for a symmetric PWM signal (signal A) without duty cycle changes during measurement; $n = 3$:




**Measurement error due to duty cycle changes**

PWM frequency measurement of a symmetric PWM signal is faulty if the duty cycle of the signal changes during measurement. The illustration below shows two PWM signals (signals B and C) with duty cycle changes: The duty cycle of signal B decreases whereas the duty cycle of signal C increases during measurement.




According to the illustration above, duty cycle changes during run time have an effect on the measured interval $t_{diff}$. As a result, the $f_p$ values evaluated for the signals B and C are faulty, since $t_{diff}$ is used to evaluate the PWM frequency $f_p$.

**Estimating the measurement error**

The difference between the correct frequency value and the one evaluated cannot be calculated exactly since it depends on the speed of the duty cycle change. However, the maximum deviation from the correct frequency value $f_p$ can be calculated according to the following equation:

$$f_{deviation} = \pm \frac{f_p}{(2 \cdot \pi - 1)}$$

The evaluated frequency value therefore is in the range

$$f_{p,\ evaluated} = f_p \pm \frac{f_p}{(2 \cdot \pi - 1)}$$

$$f_{p,\ evaluated} = f_p \cdot \left(1 \pm \frac{1}{(2 \cdot \pi - 1)}\right)$$

**Tip**

To decrease the measurement error, specify a large value for $n$, which is the number of PWM periods used to evaluate $f_p$.

**Related topics**

Basics

PWM Signal Measurement (PWM2D) ..... 24

References

Limitations of the DS5001 ..... 53

# Enabling Zero Frequency Detection

**Introduction**

Zero frequency detection is available for

- PWM Signal Measurement (PWM2D) on page 24
- Square-Wave Signal Measurement (F2D) on page 27

The frequency detection uses channel 16 (IN16). If zero frequency detection is enabled, channel 16 is *not* available for measurements. If you specify 0 Hz as the minimum frequency, zero frequency detection is disabled and channel 16 can be used for measurements.

**Note**

As of board revision DS5001-06 and dSPACE Release 3.5, RTLib does not use channel 16 for zero frequency detection. If you use RTLib functions for PWM2D or F2D, channel 16 is available for measurements while zero frequency detection is enabled.
This feature is not provided by RTI.

**Affected RTLib functions**

If zero frequency detection is enabled, the following RTLib functions (besides PWM2D and F2D) also cannot use channel 16 (refer to the *DS5001 RTLib Reference*):

- Phase-Shift Measurement
- Incremental Encoder Measurement
- Event Data Capture
- Counting Events
- Bit I/O

**Affected RTI blocks**

If automatic zero frequency detection is enabled, the following RTI blocks (besides PWM2D and F2D) also cannot use channel 16 (refer to the *DS5001 RTI Reference*):

- DS5001READ_Bx_Cy
- DS5001READ_CNT_Bx_Cy
- DS5001POS_Bx_Cy
- DS5001CLR_POS_Bx_Cy
- DS5001IN_Bx_Cy
- DS5001_HWINT_Bx_Iy

**Related topics**

References

Limitations of the DS5001 ..... 53

# Conflicting I/O Features

**Multiple channel use**

Each of the input channels IN1 … IN16 can be used for only one purpose at a time. For example, if you specify channel 2 via the DS5001PWMTOD_Bx_Cy block to perform PWM signal measurement, you cannot use this channel as incremental encoder interface at the same time.

**Zero frequency detection**

Zero frequency detection is available for F2D and PWM2D measurements. The DS5001 uses channel 16 to detect when a frequency on the PWM2D or F2D channels is zero (no changes occur within a certain time). If zero frequency detection is enabled, channel 16 is not available for measurements because it is used to read the elapsed time.

**Note**

As of board revision DS5001-06 and dSPACE Release 3.5, RTLib does not use channel 16 for zero frequency detection. In this case, if you use RTLib functions for PWM2D or F2D, channel 16 is available for measurements while zero frequency detection is enabled.
The availability of channel 16 is not provided by RTI.