



## Function Reference Manual - **HAL API**

HAL-API for software development with **m:explore** ultra-wideband sensors

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# Contents

<b>1</b>	<b>Function Reference Manual - HAL API</b>	<b>2</b>
1.1	Introduction . . . . .	2
1.2	Copyright and Disclaimer . . . . .	2
1.3	Further documentation . . . . .	2
1.4	Third party software . . . . .	3
1.5	Third party tools . . . . .	3
1.6	Contact Ilmsens . . . . .	4
<b>2</b>	<b>Measurement Data Format</b>	<b>5</b>
2.1	Data format of raw measured data . . . . .	5
2.2	Calculating the output-buffer size . . . . .	5
2.3	Layout example of output buffer . . . . .	5
<b>3</b>	<b>Module Index</b>	<b>6</b>
3.1	Modules . . . . .	6
<b>4</b>	<b>Data Structure Index</b>	<b>7</b>
4.1	Data Structures . . . . .	7
<b>5</b>	<b>File Index</b>	<b>8</b>
5.1	File List . . . . .	8
<b>6</b>	<b>Module Documentation</b>	<b>9</b>
6.1	Ilmsens Error Codes . . . . .	9
6.2	Library initialization/deinitialization . . . . .	10
6.3	Library version and revision . . . . .	11
6.4	Diagnostic interface . . . . .	12
6.5	Device handling . . . . .	13
6.6	Device ID & properties . . . . .	14
6.7	Device configuration . . . . .	16
6.8	Measurement configuration . . . . .	18
6.9	Measurement run . . . . .	21
6.10	Raw measured data retrieval . . . . .	23
6.11	Low-level access to sensor registers & memory . . . . .	26

<b>7</b>	<b>Data Structure Documentation</b>	<b>29</b>
7.1	ilmsens_hal_ModConfig Struct Reference . . . . .	29
7.2	ilmsens_hal_ModInfo Struct Reference . . . . .	29
7.3	ilmsens_hal_Version Struct Reference . . . . .	30
<b>8</b>	<b>File Documentation</b>	<b>31</b>
8.1	ilmsens_error.h File Reference . . . . .	31
8.2	ilmsens_hal.h File Reference . . . . .	31
8.3	ilmsens_hal_defn.h File Reference . . . . .	32
8.4	ilmsens_hal_types.h File Reference . . . . .	33
8.5	ilmsens_hal_version.h File Reference . . . . .	34
	<b>Index</b>	<b>35</b>

# 1 Function Reference Manual - HAL API

HAL-API for software development with **m:explore** ultra-wideband sensors

## 1.1 Introduction

As a service to our customers who want to integrate Imsens UWB sensors into their software environment, Imsens offers a hardware abstraction layer (**HAL**) application programming interface (**API**) for the **m:explore** ultra-wideband (UWB) sensors ("the software"). The HAL API comes in form of a dynamic library working on top of the device drivers with corresponding C header files. This is the function reference for the API.

The HAL API is available for different operating systems and allows device management, sensor configuration, acquisition configuration, and performing measurements. It abstracts from device- or digital interface-specific details as much as possible to enable portability of the application software. Future generations of the HAL API and Imsens UWB sensors will be developed with backward compatibility in mind. Product-specific extensions will extend the API rather than changing existing functions.

By default, the HAL API is provided as software in binary (compiled) form for many popular operating systems. Should the provided functionality be insufficient for the customer's purposes, please contact Imsens for other options (see below). We provide limited software support for the HAL API. To report problems, ask for help, or suggest improvements, contact Imsens (see below).

## 1.2 Copyright and Disclaimer

### Copyright

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All product and company names in this document may be the trademarks and tradenames of their respective owners and are hereby acknowledged.

## 1.3 Further documentation

This is a function reference only. Imsens provides additional documentation in various guides.

- **HAL API Programming Guide**

A software developer can find design and basic background information in the programming guide to ease application development. Data format, buffer layout, and typical data processing steps are explained as well.

- **HAL API Setup Guide**

The setup guide explains how to install the HAL library, the dependencies, and how to test successful installation.

## 1.4 Third party software

The HAL library makes use of great software developed by open source communities. These modules and libraries allow us to make the HAL library available on many platforms and operating systems. We appreciate this work very much and would like to thank the contributors of the following projects:

### 1.4.1 The libusb project

#### Copyright

Copyright © 2012-2015 libusb

We are using libusb-1.0 for communication with our sensors. The library is available on many Linux flavours and most modern Windows platforms (where it makes use of the built-in WinUSB drivers thus avoiding the need for proprietary driver development).

Check out these resources:

- Project website: <http://libusb.info>
- License: check the latest link on the project website. Currently the license is the [GNU Lesser General Public License, version 2.1](#)

### 1.4.2 The POCO project

#### Copyright

Copyright © 2006-2017 by Applied Informatics Software Engineering GmbH

POCO provides a very powerful multi-threaded framework for logging messages, errors, etc. It can be setup in a hierarchical manner and allows fine grain control of what gets logged to where. We are using libpocofoundation-1.7 for logs from the HAL library.

Check out these resources:

- Project website: [pocoproject.org](http://pocoproject.org)
- License: [The Boost Software License 1.0](#)

## 1.5 Third party tools

The development of the HAL library is done with the following great and free tools. They help a lot in keeping the library consistent, easy to build, and the documentation up to date. We appreciate these tools very much and would like to thank their contributors.

Check out these tools:

- Version control system: [Git](#)
- Building and Packaging: [CMake](#)
- Code documentation: [Doxygen](#)

## 1.6 Contact Ilmsens

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## 2 Measurement Data Format

This section briefly explains the format and buffer layout for measured data returned by the HAL API.

More detailed information can be found in the **HAL API Programming Guide**.

### 2.1 Data format of raw measured data

The data retrieved from the sensors is returned as 32 bit integers (**int**) to avoid any loss of precision while keeping the amount of data as small as possible. Besides the actual signal samples, additional status information is contained in the output buffer. How to convert raw integers into physical units is explained in detail in the **HAL API Programming Guide**.

### 2.2 Calculating the output-buffer size

This section describes how to calculate the minimum size of the output buffer for retrieving measured data for a given sensor configuration.

- In case of sensors with different configurations included in the measurement run

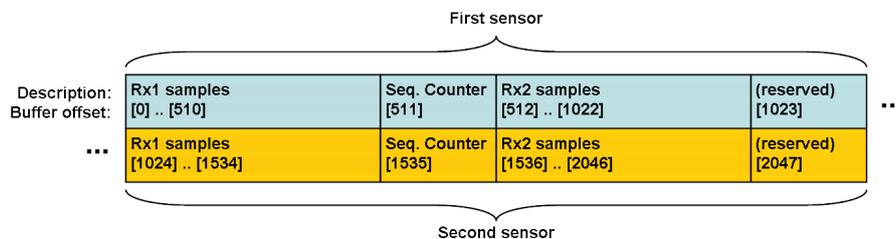
$$\begin{aligned}
 BufferSize_{min} &= \sum_i ChannelSize(i) \times NumberOfRx(i) \\
 &= \sum_i 2^{MLBS-order(i)} \times NumberOfOversampling(i) \times NumberOfRx(i)
 \end{aligned}$$

- In case of common configuration for all sensors included in the measurement run

$$\begin{aligned}
 BufferSize_{min} &= NumberOfSensors \times ChannelSize \times NumberOfRx \\
 &= NumberOfSensors \times 2^{MLBS-order} \times NumberOfOversampling \times NumberOfRx
 \end{aligned}$$

### 2.3 Layout example of output buffer

The following layout assumes a measurement with two indentially configures 9th order **m:explore** sensors.



**Figure 1 Buffer layout of example setup with two measuring 9th order m:explore sensors**

## 3 Module Index

### 3.1 Modules

Here is a list of all modules:

<b>Imsens Error Codes</b>	<b>9</b>
<b>Library initialization/deinitialization</b>	<b>10</b>
<b>Library version and revision</b>	<b>11</b>
<b>Diagnostic interface</b>	<b>12</b>
<b>Device handling</b>	<b>13</b>
<b>Device ID &amp; properties</b>	<b>14</b>
<b>Device configuration</b>	<b>16</b>
<b>Measurement configuration</b>	<b>18</b>
<b>Measurement run</b>	<b>21</b>
<b>Raw measured data retrieval</b>	<b>23</b>
<b>Low-level access to sensor registers &amp; memory</b>	<b>26</b>

## 4 Data Structure Index

### 4.1 Data Structures

Here are the data structures with brief descriptions:

<a href="#">ilmsens_hal_ModConfig</a>	Represents the basic device configuration	29
<a href="#">ilmsens_hal_ModInfo</a>	Represents the device configuration & runtime parameters and limits	29
<a href="#">ilmsens_hal_Version</a>	Represents the version identifier	30

## 5 File Index

### 5.1 File List

Here is a list of all documented files with brief descriptions:

<a href="#">ilmsens_error.h</a>	<b>Ilmsens error code definitions</b>	<b>31</b>
<a href="#">ilmsens_hal.h</a>	<b>Function definitions for Ilmsens HAL API</b>	<b>31</b>
<a href="#">ilmsens_hal_defn.h</a>	<b>Macro definitions for Ilmsens HAL</b>	<b>32</b>
<a href="#">ilmsens_hal_types.h</a>	<b>Type definitions for Ilmsens HAL</b>	<b>33</b>
<a href="#">ilmsens_hal_version.h</a>	<b>Version definitions</b>	<b>34</b>

## 6 Module Documentation

### 6.1 Ilmsens Error Codes

Ilmsens error codes provided as return values.

#### Enumerations

#### 6.1.1 Detailed Description

Ilmsens error codes provided as return values.

#### 6.1.2 Enumeration Type Documentation

##### 6.1.2.1 enum ilmsens\_error

Common error codes.

#### Enumerator

***ILMSENS\_SUCCESS*** No error.

***ILMSENS\_ERROR\_INVALID\_PARAM*** Invalid parameter.

***ILMSENS\_ERROR\_STATE*** Invalid state (e.g. on reading data, when no measurement is running).

***ILMSENS\_ERROR\_BUSY*** Ressource is busy.

***ILMSENS\_ERROR\_ACCESS*** Access denied.

***ILMSENS\_ERROR\_IO*** Input/Output error (e.g. transmission error or device disconnected).

***ILMSENS\_ERROR\_NO\_MEMORY*** Ressource allocation failed.

***ILMSENS\_ERROR\_AGAIN*** Not enough data, try again later (e.g. when a non-blocking operation would need to block the caller).

***ILMSENS\_ERROR\_TIMEOUT*** Timeout expired.

***ILMSENS\_ERROR\_NOT\_SUPPORTED*** Operation not supported.

***ILMSENS\_ERROR\_UNKNOWN*** Unspecified error.

## 6.2 Library initialization/deinitialization

### Modules

- [Library version and revision](#)
- [Diagnostic interface](#)

### Functions

- `int ilmsens_hal_initHAL (void)`  
*Initializes the library.*
- `void ilmsens_hal_deinitHAL (void)`  
*Deinitializes the library.*

#### 6.2.1 Detailed Description

#### 6.2.2 Function Documentation

##### 6.2.2.1 `int ilmsens_hal_initHAL ( void )`

Initializes the library.

This function must be called before calling any other library function.

#### Returns

number of connected devices  
negative [error-code](#)

##### 6.2.2.2 `void ilmsens_hal_deinitHAL ( void )`

Deinitializes the library.

Should be called after closing all open devices and before your application terminates. This function always succeeds. Errors that appeared, will only be visible when calling `ilmsens_hal_initHAL()` again (i.e. if the library is not unloaded but a new session is started).

## 6.3 Library version and revision

### Data Structures

- struct [ilmsens\\_hal\\_Version](#)  
*Represents the version identifier.*

### Macros

- #define [ILMSENS\\_HAL\\_API\\_VER\\_MAJOR](#) 1  
*major version number of HAL API*
- #define [ILMSENS\\_HAL\\_API\\_VER\\_MINOR](#) 1  
*minor version number of HAL API*
- #define [ILMSENS\\_HAL\\_API\\_VER\\_BUILD](#) 1  
*build number of HAL API*
- #define [ILMSENS\\_HAL\\_API\\_VER](#) ([ILMSENS\\_HAL\\_API\\_VER\\_MAJOR](#) \* 100000 + [ILMSENS\\_HAL\\_API\\_VER\\_MINOR](#) \* 1000 + [ILMSENS\\_HAL\\_API\\_VER\\_BUILD](#))  
*single version number for preprocessors*

### Functions

- int [ilmsens\\_hal\\_getVersion](#) (struct [ilmsens\\_hal\\_Version](#) \*pVersion)  
*Return the HAL version.*

#### 6.3.1 Detailed Description

#### 6.3.2 Function Documentation

##### 6.3.2.1 int [ilmsens\\_hal\\_getVersion](#) ( struct [ilmsens\\_hal\\_Version](#) \* *pVersion* )

Return the HAL version.

#### Parameters

<i>pVersion</i>	pointer to version information structure
-----------------	--

#### Returns

ILMSENS\_SUCCESS on success  
negative [error-code](#)

## 6.4 Diagnostic interface

### Macros

- #define [ILMSENS\\_DEB\\_NO](#) 0U  
*do not output debug/info messages*
- #define [ILMSENS\\_DEB\\_INFO](#) 1U  
*only output errors and very important information*
- #define [ILMSENS\\_DEB\\_MORE](#) 2U  
*output errors, warnings, and important information*
- #define [ILMSENS\\_DEB\\_MOST](#) 3U  
*output errors, warnings, and debug information*
- #define [ILMSENS\\_DEB\\_ALL](#) 4U  
*output errors, warnings, and trace information*

### Functions

- int [ilmsens\\_hal\\_setDEBLevel](#) (unsigned int pLevel)  
*Sets the verbosity of the diagnostics output Diagnostics are sent to std.*

#### 6.4.1 Detailed Description

#### 6.4.2 Function Documentation

##### 6.4.2.1 int [ilmsens\\_hal\\_setDEBLevel](#) ( unsigned int *pLevel* )

Sets the verbosity of the diagnostics output Diagnostics are sent to std.

error output by default. In case of an error, the current level is not changed.

#### Parameters

<i>pLevel</i>	verbosity level from <a href="#">ILMSENS_DEB_NO</a> to <a href="#">ILMSENS_DEB_ALL</a>
---------------	--

#### Returns

current debug level (on success and error)

## 6.5 Device handling

### Modules

- [Device ID & properties](#)

*Functions for identification and access to hardware-parameters of connected devices.*

### Functions

- [ilmsens\\_hal\\_openSensors](#) (unsigned int \*pDevNums, unsigned int pNum)  
*Allocates specified devices for a measurement session.*
- [ilmsens\\_hal\\_closeSensors](#) (unsigned int \*pDevNums, unsigned int pNum)  
*Releases specified devices.*

#### 6.5.1 Detailed Description

#### 6.5.2 Function Documentation

##### 6.5.2.1 `int ilmsens_hal_openSensors ( unsigned int * pDevNums, unsigned int pNum )`

Allocates specified devices for a measurement session.

This function must be called before doing the configuration or starting a measurement session.

#### Parameters

<i>pDevNums</i>	pointer to a first element or an array of device-indexes
<i>pNum</i>	number of array-elements

#### Returns

ILMSENS\_SUCCESS on success  
negative [error-code](#)

##### 6.5.2.2 `void ilmsens_hal_closeSensors ( unsigned int * pDevNums, unsigned int pNum )`

Releases specified devices.

Should be called after the last function call to any of the specified devices.

#### Parameters

<i>pDevNums</i>	pointer to a first element or an array of device-indexes
<i>pNum</i>	number of array-elements

## 6.6 Device ID & properties

Functions for identification and access to hardware-parameters of connected devices.

### Data Structures

- struct [ilmsens\\_hal\\_ModInfo](#)

*Represents the device configuration & runtime parameters and limits.*

### Macros

- #define [ILMSENS\\_HAL\\_MOD\\_ID\\_BUF\\_SIZE](#) 1024

*maximum length buffer size for retrieving the unique ID string.*

### Functions

- int [ilmsens\\_hal\\_getModId](#) (unsigned int pDevNum, char \*pID, size\_t pBufferSize)  
*Gets unique device-identifier.*
- int [ilmsens\\_hal\\_getModInfo](#) (unsigned int pDevNum, struct [ilmsens\\_hal\\_ModInfo](#) \*pInfo)  
*Gets device hardware-configuration.*

#### 6.6.1 Detailed Description

Functions for identification and access to hardware-parameters of connected devices.

#### 6.6.2 Function Documentation

##### 6.6.2.1 int [ilmsens\\_hal\\_getModId](#) ( unsigned int pDevNum, char \* pID, size\_t pBufferSize )

Gets unique device-identifier.

#### Parameters

<i>pDevNum</i>	device-index
<i>pID</i>	pointer to an output buffer
<i>pBufferSize</i>	Size of buffer pointed to by pID in bytes. Maximum ID length is given via <a href="#">ILMSENS_HAL_MOD_ID_BUF_SIZE</a> .

#### Returns

number of characters written to the buffer  
negative [error-code](#)

##### 6.6.2.2 int [ilmsens\\_hal\\_getModInfo](#) ( unsigned int pDevNum, struct [ilmsens\\_hal\\_ModInfo](#) \* pInfo )

Gets device hardware-configuration.

#### Parameters

<i>pDevNum</i>	device-index
<i>pInfo</i>	pointer to the <a href="#">ilmsens_hal_ModInfo</a> structure

#### Returns

ILMSENS\_SUCCESS on success (and populates pInfo)  
negative [error-code](#)

## 6.7 Device configuration

Functions for configuring specified devices.

### Data Structures

- struct [ilmsens\\_hal\\_ModConfig](#)  
*Represents the basic device configuration.*

### Macros

- #define [ILMSENS\\_HAL\\_SLAVE\\_SENSOR](#) 0  
*setup the sensor(s) to be slave devices*
- #define [ILMSENS\\_HAL\\_MASTER\\_SENSOR](#) 1  
*setup the sensor(s) to be master devices*

### Functions

- int [ilmsens\\_hal\\_setupSensors](#) (unsigned int \*pDevNums, unsigned int pNum, const struct [ilmsens\\_hal\\_ModConfig](#) \*pConfig)  
*Performs the initial setup of specified devices.*
- int [ilmsens\\_hal\\_setMaster](#) (unsigned int \*pDevNums, unsigned int pNum, int pMode)  
*Sets master/slave operational mode.*

#### 6.7.1 Detailed Description

Functions for configuring specified devices.

#### 6.7.2 Function Documentation

6.7.2.1 int [ilmsens\\_hal\\_setupSensors](#) ( unsigned int \* *pDevNums*, unsigned int *pNum*, const struct [ilmsens\\_hal\\_ModConfig](#) \* *pConfig* )

Performs the initial setup of specified devices.

This function must be called before starting a measurement session.

#### Parameters

<i>pDevNums</i>	pointer to a first element or an array of device-indexes
<i>pNum</i>	number of array-elements
<i>pConfig</i>	pointer to configuration parameters in a <a href="#">ilmsens_hal_ModConfig</a> structure

#### Returns

ILMSENS\_SUCCESS on success  
negative [error-code](#)

6.7.2.2 int ilmsens\_hal\_setMaster ( unsigned int \* *pDevNums*, unsigned int *pNum*, int *pMode* )

Sets master/slave operational mode.

Application needs to make sure, that any independent sensor is set to master mode.

For hardware-synchronized operation of multiple sensors, exactly one sensor of a connected group has to be master the others in teh group must be configured as slaves.

#### Parameters

<i>pDevNums</i>	pointer to a first element or an array of device-indexes
<i>pNum</i>	number of array-elements
<i>pMode</i>	<a href="#">ILMSENS_HAL_SLAVE_SENSOR</a> = slave   <a href="#">ILMSENS_HAL_MASTER_SENSOR</a> = master

#### Returns

ILMSENS\_SUCCESS on success  
negative [error-code](#)

## 6.8 Measurement configuration

### Macros

- #define `ILMSENS_HAL_SYNCH_OFF` 0  
*retract digital synchronisation, i.e. sensors will be unsynch'ed*
- #define `ILMSENS_HAL_SYNCH_ON` 1  
*perform digital synchronisation, i.e. sensors will be synch'ed*
- #define `ILMSENS_HAL_TX_OFF` 1  
*transmitter is in power down mode, i.e. output amplifier is switch off*
- #define `ILMSENS_HAL_TX_ON` 0  
*transmitter is working, i.e. output amplifier is switched on*

### Functions

- int `ilmsens_hal_setAvg` (unsigned int \*pDevNums, unsigned int pNum, unsigned int pAvg, unsigned int pWaitCyc)  
*Sets software averages and wait cycles.*
- int `ilmsens_hal_setMLBS` (unsigned int \*pDevNums, unsigned int pNum)  
*Resets the M-sequence generator (transmitter) of each device.*
- int `ilmsens_hal_setPD` (unsigned int \*pDevNums, unsigned int pNum, int pPD)  
*Controls the power-status of the transmitter.*
- int `ilmsens_hal_synchMS` (unsigned int \*pDevNums, unsigned int pNum, int pMode)  
*Performs digital synchronisation.*

#### 6.8.1 Detailed Description

#### 6.8.2 Function Documentation

##### 6.8.2.1 int `ilmsens_hal_setAvg` ( unsigned int \* *pDevNums*, unsigned int *pNum*, unsigned int *pAvg*, unsigned int *pWaitCyc* )

Sets software averages and wait cycles.

Software averages define the acquisition aperture duration. If wait cycles are set to 0, devices measure in continuous mode. If wait cycles are non-zero, devices measure in snapshot mode.

Note: May only be called when no measurement is running!

#### Parameters

<i>pDevNums</i>	pointer to a first element or an array of device-indexes
<i>pNum</i>	number of array-elements
<i>pAvg</i>	number of Sw averages
<i>pWaitCyc</i>	number of wait cycles

#### Returns

`ILMSENS_SUCCESS` on success  
negative [error-code](#)

### 6.8.2.2 int ilmsens\_hal\_setMLBS ( unsigned int \* pDevNums, unsigned int pNum )

Resets the M-sequence generator (transmitter) of each device.

After digital synchronisation, the M-sequence generator (transmitter) of each device should be reset to ensure repeatable alignment of the transmitters and receivers. The reset typically takes a few ms to complete and cannot be used to mute the transmitter(s).

Note: May only be called when no measurement is running!

#### Parameters

<i>pDevNums</i>	pointer to a first element or an array of device-indexes
<i>pNum</i>	number of array-elements

#### Returns

ILMSENS\_SUCCESS on success  
negative [error-code](#)

### 6.8.2.3 int ilmsens\_hal\_setPD ( unsigned int \* pDevNums, unsigned int pNum, int pPD )

Controls the power-status of the transmitter.

Note: May only be called when no measurement is running!

#### Parameters

<i>pDevNums</i>	pointer to a first element or an array of device-indexes
<i>pNum</i>	number of array-elements
<i>pPD</i>	<a href="#">ILMSENS_HAL_TX_ON</a> = power-up the transmitter   <a href="#">ILMSENS_HAL_TX_OFF</a> = power-down (mute) the transmitter

#### Returns

ILMSENS\_SUCCESS on success  
negative [error-code](#)

### 6.8.2.4 int ilmsens\_hal\_synchMS ( unsigned int \* pDevNums, unsigned int pNum, int pMode )

Performs digital synchronisation.

Must be used at least once before a measurement is started.

#### Parameters

<i>pDevNums</i>	pointer to a first element or an array of device-indexes
<i>pNum</i>	number of array-elements
<i>pMode</i>	<a href="#">ILMSENS_HAL_SYNCH_OFF</a> = de-synchronise sensors (revoke)   <a href="#">ILMSENS_HAL_SYNCH_ON</a> = trigger digital synchronisation

## Returns

ILMSENS\_SUCCESS on success  
negative [error-code](#)

## 6.9 Measurement run

Functions to start/stop measurements with one or more devices.

### Macros

- #define `ILMSENS_HAL_RUN_OFF` 0  
*sensor is currently not measuring*
- #define `ILMSENS_HAL_RUN_RAW` 1  
*sensor is measuring and data is not buffered by API*
- #define `ILMSENS_HAL_RUN_BUF` 2  
*sensor is measuring and data is buffered by API in separate thread*

### Functions

- int `ilmsens_hal_measRun` (unsigned int \*pDevNums, unsigned int pNum, int pMode)  
*Starts a measurement run with specified devices.*
- int `ilmsens_hal_measStop` (unsigned int \*pDevNums, unsigned int pNum)  
*Stops running measurement.*

### 6.9.1 Detailed Description

Functions to start/stop measurements with one or more devices.

The library supports two modes of operation for transferring measured data from the device-buffer memory to the host-system memory (HAL or application).

- In case the measurement session was started in the **raw mode**, measured data is transferred from the device to the host-system memory whenever a complete measurement is available and the function `ilmsens_hal_measRdy()` is called by the user application. This way the data transfer is performed synchronously with the user application's thread. However, the user application must ensure fast enough polling of the sensor to prevent ring buffer overflow by itself
- In case the measurement session is started in **buffered mode**, a separate thread is created by the library. This thread implements periodic **polling** of the devices' ring-buffer status and transfer of measured data to the host". Therefore, the data transfer is performed asynchronously with respect to the progress of the user application thread. This way high jitter in processing latency will not cause a discontinuity in the measurement progress and prevent potential overflow of the devices' ring-buffer memory.

Note: The **buffered mode** is the preferred mode of operation of the library.

### 6.9.2 Function Documentation

#### 6.9.2.1 int `ilmsens_hal_measRun` ( unsigned int \* *pDevNums*, unsigned int *pNum*, int *pMode* )

Starts a measurement run with specified devices.

One measurement run may be pending at a time.

#### Parameters

<i>pDevNums</i>	pointer to a first element or an array of device-indexes
<i>pNum</i>	number of array-elements
<i>pMode</i>	specifies the mode of operation ( <a href="#">ILMSENS_HAL_RUN_RAW</a> for <b>raw mode</b> of operation, <a href="#">ILMSENS_HAL_RUN_BUF</a> for <b>buffered mode</b> of operation)

#### Returns

ILMSENS\_SUCCESS on success  
negative [error-code](#)

#### See also

[ilmsens\\_hal\\_measStop\(\)](#)

6.9.2.2 int ilmsens\_hal\_measStop ( unsigned int \* *pDevNums*, unsigned int *pNum* )

Stops running measurement.

#### Parameters

<i>pDevNums</i>	pointer to a first element or an array of device-indexes
<i>pNum</i>	number of array-elements

#### Returns

ILMSENS\_SUCCESS on success  
negative [error-code](#)

## 6.10 Raw measured data retrieval

Functions to read measured data out of internal ring-buffer.

### Typedefs

- typedef int32\_t [ilmsens\\_hal\\_SampleType](#)  
*Represents the data type of raw measured data.*

### Functions

- int [ilmsens\\_hal\\_measRdy](#) (unsigned int \*pDevNums, unsigned int pNum)  
*Reads the fill-level of the internal ring-buffer for all specified devices.*
- int [ilmsens\\_hal\\_measRead](#) (unsigned int \*pDevNums, unsigned int pNum, [ilmsens\\_hal\\_SampleType](#) \*p↔ Buffer, size\_t pBufSizeBytes)  
*Reads the measurement data for all specified devices in non-blocking way.*
- int [ilmsens\\_hal\\_measGet](#) (unsigned int \*pDevNums, unsigned int pNum, [ilmsens\\_hal\\_SampleType](#) \*pBuffer, size\_t pBufSizeBytes, unsigned int pTimeoutMillis)  
*Blocks and reads the measurement data for all specified devices when it becomes available.*

### 6.10.1 Detailed Description

Functions to read measured data out of internal ring-buffer.

- There is a simple blocking interface implemented by [ilmsens\\_hal\\_measGet\(\)](#).
- Furthermore there is a non-blocking interface, implemented by [ilmsens\\_hal\\_measRdy\(\)](#) for polling buffer-level of the ring-buffer(s) and [ilmsens\\_hal\\_measRead\(\)](#) for actually reading the next measurement to the user application's memory.

### 6.10.2 Function Documentation

#### 6.10.2.1 int [ilmsens\\_hal\\_measRdy](#) ( unsigned int \* *pDevNums*, unsigned int *pNum* )

Reads the fill-level of the internal ring-buffer for all specified devices.

This functions is not blocking and returns immediately. However, in [raw mode](#), it will transfer data from a device to the libraries' ring-buffer on the host, if it discovers that a complete dataset is available.

#### Parameters

<i>pDevNums</i>	pointer to a first element or an array of device-indexes
<i>pNum</i>	number of array-elements

## Returns

minimum number of complete datasets available for all specified devices  
0 if at least one device has no new data available  
negative [error-code](#)

6.10.2.2 `int ilmsens_hal_measRead ( unsigned int * pDevNums, unsigned int pNum, ilmsens_hal_SampleType * pBuffer, size_t pBufSizeBytes )`

Reads the measurement data for all specified devices in non-blocking way.

This functions is not blocking and returns immediately with the next measurement data or an error-code if no data are available.

## Parameters

<i>pDevNums</i>	pointer to a first element or an array of device-indexes
<i>pNum</i>	number of array-elements
<i>pBuffer</i>	pointer to output buffer for measured data
<i>pBufSizeBytes</i>	Size of buffer pointed to by <i>pBuffer</i> in bytes

## Returns

number of elements (samples) copied to the buffer  
ILMSSENS\_ERROR\_AGAIN if a completed dataset is not available for every device  
negative [error-code](#)

## See also

[Measurement Data Format](#)  
[Calculating the output-buffer size](#)

6.10.2.3 `int ilmsens_hal_measGet ( unsigned int * pDevNums, unsigned int pNum, ilmsens_hal_SampleType * pBuffer, size_t pBufSizeBytes, unsigned int pTimeoutMillis )`

Blocks and reads the measurement data for all specified devices when it becomes available.

This functions blocks the caller until at least one complete measurement is available for every device or a specified timeout expired. The buffer *pBuffer* must be large enough to hold one complete dataset for each device, i.e. it must be able to hold at least *pNum* complete datasets.

Note: if *pTimeoutMillis* is 0, this function will block forever...

## Parameters

<i>pDevNums</i>	pointer to a first element or an array of device-indexes
<i>pNum</i>	number of array-elements
<i>pBuffer</i>	pointer to output buffer for measured data
<i>pBufSizeBytes</i>	Size of buffer pointed to by <i>pBuffer</i> in bytes
<i>pTimeoutMillis</i>	timeout [ms] (0 = forever)

**Returns**

number of elements (samples) copied to the buffer  
ILMSENS\_ERROR\_TIMEOUT when the timeout expired before enough data was received  
negative [error-code](#)

**See also**

[Measurement Data Format](#)  
[Calculating the output-buffer size](#)

## 6.11 Low-level access to sensor registers & memory

### Typedefs

- typedef uint32\_t [ilmsens\\_hal\\_MemoryType](#)  
*Represents data type for register and memory access.*

### Functions

- int [ilmsens\\_hal\\_readReg](#) (unsigned int \*pDevNums, unsigned int pNum, unsigned int pReg, [ilmsens\\_hal\\_MemoryType](#) \*pVal, size\_t pBufSizeBytes)  
*Reads value from register at pReg address from all specified devices to buffer.*
- int [ilmsens\\_hal\\_writeReg](#) (unsigned int \*pDevNums, unsigned int pNum, unsigned int pReg, [ilmsens\\_hal\\_MemoryType](#) pVal)  
*Writes pVal value to register at pReg address to all specified devices.*
- int [ilmsens\\_hal\\_readBlk](#) (unsigned int \*pDevNums, unsigned int pNum, unsigned int pAdr, unsigned int pNumEl, [ilmsens\\_hal\\_MemoryType](#) \*pVal, size\_t pBufSizeBytes)  
*Reads pNumEl elements (32-bit words) starting at address pAdr from the internal memory of specified devices into a buffer pVal.*
- int [ilmsens\\_hal\\_writeBlk](#) (unsigned int \*pDevNums, unsigned int pNum, unsigned int pAdr, unsigned int pNumEl, [ilmsens\\_hal\\_MemoryType](#) \*pVal, size\_t pBufSizeBytes)  
*Writes pNumEl elements (32-bit words) from buffer pVal to internal memory starting at address pAdr of specified devices.*

### 6.11.1 Detailed Description

### 6.11.2 Function Documentation

#### 6.11.2.1 int [ilmsens\\_hal\\_readReg](#) ( unsigned int \* pDevNums, unsigned int pNum, unsigned int pReg, [ilmsens\\_hal\\_MemoryType](#) \* pVal, size\_t pBufSizeBytes )

Reads value from register at pReg address from all specified devices to buffer.

The buffer pVal must be large enough to hold one word for each device, i.e. it must be at least pNum words in size.

#### Parameters

<i>pDevNums</i>	pointer to a first element or an array of device-indexes
<i>pNum</i>	number of array-elements
<i>pReg</i>	register address
<i>pVal</i>	pointer to buffer for register value(s)
<i>pBufSizeBytes</i>	Size of buffer pointed to by pVal in bytes

#### Returns

number of words (elements) copied to the buffer  
negative [error-code](#)

**6.11.2.2** `int ilmsens_hal_writeReg ( unsigned int * pDevNums, unsigned int pNum, unsigned int pReg, ilmsens_hal_MemoryType pVal )`

Writes `pVal` value to register at `pReg` address to all specified devices.

The same value is written to each device.

**Parameters**

<code>pDevNums</code>	pointer to a first element or an array of device-indexes
<code>pNum</code>	number of array-elements
<code>pReg</code>	register address
<code>pVal</code>	new register value

**Returns**

ILMSENS\_SUCCESS on success  
negative [error-code](#)

**6.11.2.3** `int ilmsens_hal_readBlk ( unsigned int * pDevNums, unsigned int pNum, unsigned int pAdr, unsigned int pNumEl, ilmsens_hal_MemoryType * pVal, size_t pBufSizeBytes )`

Reads `pNumEl` elements (32-bit words) starting at address `pAdr` from the internal memory of specified devices into a buffer `pVal`.

The buffer must be large enough to hold `pNumEl` words for all specified devices, i.e. it provide space for at least `pNumEl` x `pNum` words.

**Parameters**

<code>pDevNums</code>	pointer to a first element or an array of device-indexes
<code>pNum</code>	number of array-elements
<code>pAdr</code>	word-aligned start memory address
<code>pNumEl</code>	number of words (elements) to read
<code>pVal</code>	pointer to buffer for the transferred memory content
<code>pBufSizeBytes</code>	Size of buffer pointed to by <code>pVal</code> in bytes

**Returns**

number of words (elements) copied to the buffer  
negative [error-code](#)

**6.11.2.4** `int ilmsens_hal_writeBlk ( unsigned int * pDevNums, unsigned int pNum, unsigned int pAdr, unsigned int pNumEl, ilmsens_hal_MemoryType * pVal, size_t pBufSizeBytes )`

Writes `pNumEl` elements (32-bit words) from buffer `pVal` to internal memory starting at address `pAdr` of specified devices.

The same content is written to each device, i.e. the buffer `pVal` must hold `pNumEl` words regardless of `pNum`.

#### Parameters

<i>pDevNums</i>	pointer to a first element or an array of device-indexes
<i>pNum</i>	number of array-elements
<i>pAdr</i>	word-aligned start memory address
<i>pNumEl</i>	number of words (elements) to write
<i>pVal</i>	pointer to buffer with data to write
<i>pBufSizeBytes</i>	Size of buffer pointed to by <i>pVal</i> in bytes

#### Returns

ILMSENS\_SUCCESS on success  
negative [error-code](#)

## 7 Data Structure Documentation

### 7.1 ilmsens\_hal\_ModConfig Struct Reference

Represents the basic device configuration.

#### Data Fields

- unsigned int [mOrder](#)  
*MLBS order.*
- unsigned int [mSub](#)  
*subsampling factor*
- double [mClk](#)  
*master clock*
- unsigned int [mOV](#)  
*number of oversampling*
- unsigned int [mTx](#)  
*number of transmitters*
- unsigned int [mRx](#)  
*number of receivers*

#### 7.1.1 Detailed Description

Represents the basic device configuration.

Hint: In case useless data is returned or memory access exceptions occur, make sure your compiler does not use wrong memory alignment for structure members.

### 7.2 ilmsens\_hal\_ModInfo Struct Reference

Represents the device configuration & runtime parameters and limits.

#### Data Fields

- [ilmsens\\_hal\\_ModConfig mConfig](#)  
*basic configuration of sensor*
- double [mTB\\_Fc](#)  
*corner frequency for timebase calibration*
- double [mTemp](#)  
*device temperature*
- double [mLSB\\_Volt](#)  
*ADC LSB voltage (for calculating physical values out of raw data)*
- double [mFSR](#) [2]  
*ADC full scale range (minimum and maximum value)*
- unsigned int [mHWAvg](#)  
*number of hardware averages (FPGA)*
- unsigned int [mAvg](#)

- number of averages*
- unsigned int [mAvgLim](#) [2]
  - limits for averages (minimum and maximum value)*
- unsigned int [mWait](#)
  - number of wait cycles*
- unsigned int [mWaitLim](#) [2]
  - limits for wait cycles (minimum and maximum value)*
- unsigned int [mNumSamp](#)
  - number of samples per channel*

### 7.2.1 Detailed Description

Represents the device configuration & runtime parameters and limits.

Hint: In case useless data is returned or memory access exceptions occur, make sure your compiler does not use wrong memory alignment for structure members.

## 7.3 ilmsens\_hal\_Version Struct Reference

Represents the version identifier.

### Data Fields

- unsigned int [mMajor](#)
  - major version number*
- unsigned int [mMinor](#)
  - minor version number*
- unsigned int [mBuild](#)
  - build number*

### 7.3.1 Detailed Description

Represents the version identifier.

Hint: In case useless data is returned or memory access exceptions occur, make sure your compiler does not use wrong memory alignment for structure members.

## 8 File Documentation

### 8.1 ilmsens\_error.h File Reference

Ilmsens error code definitions.

#### Enumerations

#### 8.1.1 Detailed Description

Ilmsens error code definitions.

The error codes defined in this file are used in various Ilmsens APIs as return values.

#### Author

Ralf Herrmann [ralf.herrmann@ilmsens.com](mailto:ralf.herrmann@ilmsens.com)

### 8.2 ilmsens\_hal.h File Reference

Function definitions for Ilmsens HAL API.

#### Functions

- int [ilmsens\\_hal\\_getVersion](#) (struct [ilmsens\\_hal\\_Version](#) \*pVersion)  
*Return the HAL version.*
- int [ilmsens\\_hal\\_setDEBLevel](#) (unsigned int pLevel)  
*Sets the verbosity of the diagnostics output Diagnostics are sent to std.*
- int [ilmsens\\_hal\\_initHAL](#) (void)  
*Initializes the library.*
- void [ilmsens\\_hal\\_deinitHAL](#) (void)  
*Deinitializes the library.*
- int [ilmsens\\_hal\\_openSensors](#) (unsigned int \*pDevNums, unsigned int pNum)  
*Allocates specified devices for a measurement session.*
- void [ilmsens\\_hal\\_closeSensors](#) (unsigned int \*pDevNums, unsigned int pNum)  
*Releases specified devices.*
- int [ilmsens\\_hal\\_getModId](#) (unsigned int pDevNum, char \*pID, size\_t pBufferSize)  
*Gets unique device-identifier.*
- int [ilmsens\\_hal\\_getModInfo](#) (unsigned int pDevNum, struct [ilmsens\\_hal\\_ModInfo](#) \*pInfo)  
*Gets device hardware-configuration.*
- int [ilmsens\\_hal\\_setupSensors](#) (unsigned int \*pDevNums, unsigned int pNum, const struct [ilmsens\\_hal\\_ModConfig](#) \*pConfig)  
*Performs the initial setup of specified devices.*
- int [ilmsens\\_hal\\_setMaster](#) (unsigned int \*pDevNums, unsigned int pNum, int pMode)  
*Sets master/slave operational mode.*
- int [ilmsens\\_hal\\_setAvg](#) (unsigned int \*pDevNums, unsigned int pNum, unsigned int pAvg, unsigned int pWaitCyc)  
*Sets software averages and wait cycles.*

- int `ilmsens_hal_setMLBS` (unsigned int \*pDevNums, unsigned int pNum)  
*Resets the M-sequence generator (transmitter) of each device.*
- int `ilmsens_hal_setPD` (unsigned int \*pDevNums, unsigned int pNum, int pPD)  
*Controls the power-status of the transmitter.*
- int `ilmsens_hal_synchMS` (unsigned int \*pDevNums, unsigned int pNum, int pMode)  
*Performs digital synchronisation.*
- int `ilmsens_hal_measRun` (unsigned int \*pDevNums, unsigned int pNum, int pMode)  
*Starts a measurement run with specified devices.*
- int `ilmsens_hal_measStop` (unsigned int \*pDevNums, unsigned int pNum)  
*Stops running measurement.*
- int `ilmsens_hal_measRdy` (unsigned int \*pDevNums, unsigned int pNum)  
*Reads the fill-level of the internal ring-buffer for all specified devices.*
- int `ilmsens_hal_measRead` (unsigned int \*pDevNums, unsigned int pNum, `ilmsens_hal_SampleType` \*p↔ Buffer, size\_t pBufSizeBytes)  
*Reads the measurement data for all specified devices in non-blocking way.*
- int `ilmsens_hal_measGet` (unsigned int \*pDevNums, unsigned int pNum, `ilmsens_hal_SampleType` \*pBuffer, size\_t pBufSizeBytes, unsigned int pTimeoutMillis)  
*Blocks and reads the measurement data for all specified devices when it becomes available.*
- int `ilmsens_hal_readReg` (unsigned int \*pDevNums, unsigned int pNum, unsigned int pReg, `ilmsens_hal_↔ MemoryType` \*pVal, size\_t pBufSizeBytes)  
*Reads value from register at pReg address from all specified devices to buffer.*
- int `ilmsens_hal_writeReg` (unsigned int \*pDevNums, unsigned int pNum, unsigned int pReg, `ilmsens_hal_↔ MemoryType` pVal)  
*Writes pVal value to register at pReg address to all specified devices.*
- int `ilmsens_hal_readBlk` (unsigned int \*pDevNums, unsigned int pNum, unsigned int pAdr, unsigned int p↔ NumEl, `ilmsens_hal_MemoryType` \*pVal, size\_t pBufSizeBytes)  
*Reads pNumEl elements (32-bit words) starting at address pAdr from the internal memory of specified devices into a buffer pVal.*
- int `ilmsens_hal_writeBlk` (unsigned int \*pDevNums, unsigned int pNum, unsigned int pAdr, unsigned int p↔ NumEl, `ilmsens_hal_MemoryType` \*pVal, size\_t pBufSizeBytes)  
*Writes pNumEl elements (32-bit words) from buffer pVal to internal memory starting at address pAdr of specified devices.*

### 8.2.1 Detailed Description

Function definitions for `ilmsens` HAL API.

This header contains prototypes for the exported functions of the HAL library.

Author

Ralf Herrmann [ralf.herrmann@ilmsens.com](mailto:ralf.herrmann@ilmsens.com)

### 8.3 `ilmsens_hal_defn.h` File Reference

Macro definitions for `ilmsens` HAL.

## Macros

- #define `ILMSENS_HAL_RUN_OFF` 0  
*sensor is currently not measuring*
- #define `ILMSENS_HAL_RUN_RAW` 1  
*sensor is measuring and data is not buffered by API*
- #define `ILMSENS_HAL_RUN_BUF` 2  
*sensor is measuring and data is buffered by API in separate thread*
- #define `ILMSENS_HAL_MOD_ID_BUF_SIZE` 1024  
*maximum length buffer size for retrieving the unique ID string.*
- #define `ILMSENS_HAL_SLAVE_SENSOR` 0  
*setup the sensor(s) to be slave devices*
- #define `ILMSENS_HAL_MASTER_SENSOR` 1  
*setup the sensor(s) to be master devices*
- #define `ILMSENS_HAL_SYNCH_OFF` 0  
*retract digital synchronisation, i.e. sensors will be unsynch'ed*
- #define `ILMSENS_HAL_SYNCH_ON` 1  
*perform digital synchronisation, i.e. sensors will be synch'ed*
- #define `ILMSENS_HAL_TX_OFF` 1  
*transmitter is in power down mode, i.e. output amplifier is switch off*
- #define `ILMSENS_HAL_TX_ON` 0  
*transmitter is working, i.e. output amplifier is switched on*
- #define `ILMSENS_DEB_NO` 0U  
*do not output debug/info messages*
- #define `ILMSENS_DEB_INFO` 1U  
*only output errors and very important information*
- #define `ILMSENS_DEB_MORE` 2U  
*output errors, warnings, and important information*
- #define `ILMSENS_DEB_MOST` 3U  
*output errors, warnings, and debug information*
- #define `ILMSENS_DEB_ALL` 4U  
*output errors, warnings, and trace information*

### 8.3.1 Detailed Description

Macro definitions for `ilmsens HAL`.

This header contains definitions for various values used in different `HAL` functions.

#### Author

Ralf Herrmann [ralf.herrmann@ilmsens.com](mailto:ralf.herrmann@ilmsens.com)

### 8.4 `ilmsens_hal_types.h` File Reference

Type definitions for `ilmsens HAL`.

## Data Structures

- struct [ilmsens\\_hal\\_Version](#)  
*Represents the version identifier.*
- struct [ilmsens\\_hal\\_ModConfig](#)  
*Represents the basic device configuration.*
- struct [ilmsens\\_hal\\_ModInfo](#)  
*Represents the device configuration & runtime parameters and limits.*

## Typedefs

- typedef int32\_t [ilmsens\\_hal\\_SampleType](#)  
*Represents the data type of raw measured data.*
- typedef uint32\_t [ilmsens\\_hal\\_MemoryType](#)  
*Represents data type for register and memory access.*

### 8.4.1 Detailed Description

Type definitions for Ilmsens HAL.

This header defines structure types used by the various setup and information retrieval HAL functions. Furthermore, it defines the data types for measured samples and register/memory access.

#### Author

Ralf Herrmann [ralf.herrmann@ilmsens.com](mailto:ralf.herrmann@ilmsens.com)

## 8.5 ilmsens\_hal\_version.h File Reference

Version definitions.

### Macros

- #define [ILMSENS\\_HAL\\_API\\_VER\\_MAJOR](#) 1  
*major version number of HAL API*
- #define [ILMSENS\\_HAL\\_API\\_VER\\_MINOR](#) 1  
*minor version number of HAL API*
- #define [ILMSENS\\_HAL\\_API\\_VER\\_BUILD](#) 1  
*build number of HAL API*
- #define [ILMSENS\\_HAL\\_API\\_VER](#) (ILMSENS\_HAL\_API\_VER\_MAJOR \* 100000 + ILMSENS\_HAL\_API\_↔  
[VER\\_MINOR](#) \* 1000 + ILMSENS\_HAL\_API\_VER\_BUILD)  
*single version number for preprocessors*

### 8.5.1 Detailed Description

Version definitions.

#### Author

Ralf Herrmann [ralf.herrmann@ilmsens.com](mailto:ralf.herrmann@ilmsens.com)

## Index

- Device configuration, 16
  - ilmsens\_hal\_setMaster, 17
  - ilmsens\_hal\_setupSensors, 16
- Device handling, 13
  - ilmsens\_hal\_closeSensors, 13
  - ilmsens\_hal\_openSensors, 13
- Device ID & properties, 14
  - ilmsens\_hal\_getModId, 14
  - ilmsens\_hal\_getModInfo, 14
- Diagnostic interface, 12
  - ilmsens\_hal\_setDEBLevel, 12
- ILMSSENS\_ERROR\_ACCESS
  - Ilmsens Error Codes, 9
- ILMSSENS\_ERROR\_AGAIN
  - Ilmsens Error Codes, 9
- ILMSSENS\_ERROR\_BUSY
  - Ilmsens Error Codes, 9
- ILMSSENS\_ERROR\_INVALID\_PARAM
  - Ilmsens Error Codes, 9
- ILMSSENS\_ERROR\_IO
  - Ilmsens Error Codes, 9
- ILMSSENS\_ERROR\_NO\_MEMORY
  - Ilmsens Error Codes, 9
- ILMSSENS\_ERROR\_NOT\_SUPPORTED
  - Ilmsens Error Codes, 9
- ILMSSENS\_ERROR\_STATE
  - Ilmsens Error Codes, 9
- ILMSSENS\_ERROR\_TIMEOUT
  - Ilmsens Error Codes, 9
- ILMSSENS\_ERROR\_UNKNOWN
  - Ilmsens Error Codes, 9
- ILMSSENS\_SUCCESS
  - Ilmsens Error Codes, 9
- Ilmsens Error Codes, 9
  - ILMSSENS\_ERROR\_ACCESS, 9
  - ILMSSENS\_ERROR\_AGAIN, 9
  - ILMSSENS\_ERROR\_BUSY, 9
  - ILMSSENS\_ERROR\_INVALID\_PARAM, 9
  - ILMSSENS\_ERROR\_IO, 9
  - ILMSSENS\_ERROR\_NO\_MEMORY, 9
  - ILMSSENS\_ERROR\_NOT\_SUPPORTED, 9
  - ILMSSENS\_ERROR\_STATE, 9
  - ILMSSENS\_ERROR\_TIMEOUT, 9
  - ILMSSENS\_ERROR\_UNKNOWN, 9
  - ILMSSENS\_SUCCESS, 9
  - ilmsens\_error, 9
    - Ilmsens Error Codes, 9
- ilmsens\_error.h, 31
- ilmsens\_hal.h, 31
- ilmsens\_hal\_ModConfig, 29
- ilmsens\_hal\_ModInfo, 29
- ilmsens\_hal\_Version, 30
- ilmsens\_hal\_closeSensors
  - Device handling, 13
- ilmsens\_hal\_defn.h, 32
- ilmsens\_hal\_deinitHAL
  - Library initialization/deinitialization, 10
- ilmsens\_hal\_getModId
  - Device ID & properties, 14
- ilmsens\_hal\_getModInfo
  - Device ID & properties, 14
- ilmsens\_hal\_getVersion
  - Library version and revision, 11
- ilmsens\_hal\_initHAL
  - Library initialization/deinitialization, 10
- ilmsens\_hal\_measGet
  - Raw measured data retrieval, 24
- ilmsens\_hal\_measRdy
  - Raw measured data retrieval, 23
- ilmsens\_hal\_measRead
  - Raw measured data retrieval, 24
- ilmsens\_hal\_measRun
  - Measurement run, 21
- ilmsens\_hal\_measStop
  - Measurement run, 22
- ilmsens\_hal\_openSensors
  - Device handling, 13
- ilmsens\_hal\_readBlk
  - Low-level access to sensor registers & memory, 27
- ilmsens\_hal\_readReg
  - Low-level access to sensor registers & memory, 26
- ilmsens\_hal\_setAvg
  - Measurement configuration, 18
- ilmsens\_hal\_setDEBLevel
  - Diagnostic interface, 12
- ilmsens\_hal\_setMLBS
  - Measurement configuration, 18
- ilmsens\_hal\_setMaster
  - Device configuration, 17
- ilmsens\_hal\_setPD
  - Measurement configuration, 19
- ilmsens\_hal\_setupSensors
  - Device configuration, 16
- ilmsens\_hal\_synchMS
  - Measurement configuration, 19
- ilmsens\_hal\_types.h, 33
- ilmsens\_hal\_version.h, 34
- ilmsens\_hal\_writeBlk
  - Low-level access to sensor registers & memory, 27
- ilmsens\_hal\_writeReg
  - Low-level access to sensor registers & memory, 26
- Library initialization/deinitialization, 10
  - ilmsens\_hal\_deinitHAL, 10
  - ilmsens\_hal\_initHAL, 10
- Library version and revision, 11
  - ilmsens\_hal\_getVersion, 11
- Low-level access to sensor registers & memory, 26

- ilmsens\_hal\_readBlk, [27](#)
- ilmsens\_hal\_readReg, [26](#)
- ilmsens\_hal\_writeBlk, [27](#)
- ilmsens\_hal\_writeReg, [26](#)

Measurement configuration, [18](#)

- ilmsens\_hal\_setAvg, [18](#)
- ilmsens\_hal\_setMLBS, [18](#)
- ilmsens\_hal\_setPD, [19](#)
- ilmsens\_hal\_synchMS, [19](#)

Measurement run, [21](#)

- ilmsens\_hal\_measRun, [21](#)
- ilmsens\_hal\_measStop, [22](#)

Raw measured data retrieval, [23](#)

- ilmsens\_hal\_measGet, [24](#)
- ilmsens\_hal\_measRdy, [23](#)
- ilmsens\_hal\_measRead, [24](#)