

MCS2

Programmer's Guide



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SmarAct GmbH, Schuette-Lanz-Strasse 9, D-26135 Oldenburg
Phone: +49 (0) 441 - 800879-0, Telefax: +49 (0) 441 - 800879-21
Internet: www.smaract.com, E-Mail: info@smaract.com

Document Version: 1.2.0

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1 INTRODUCTION

This document describes the application programming interface (API) of the SmarAct MCS2. It may be used to control one or more MCS2 devices by software.

1.1 About this Programmers Guide

While this document mainly serves as a reference when programming your own software it also supplies some background information for a better understanding of the overall system. The General Concepts chapter covers all main features and explains the general concepts of the MCS2 controller. The Function Reference, Property Reference and Event Reference chapters give detailed information about all available functions, properties and events. The ASCII Interface chapter describes how to control the MCS2 using the SCPI based ASCII protocol.

This programmers guide focuses on the C application programming interface (API). The C syntax is used for programming examples and when functions, error codes, events or properties are referenced. Nonetheless, all information also applies for non-C APIs, like Python or LabVIEW™.

When programming in Python please refer to the "Using SmarAct Python SDKs" document for a description of the differences between the C and the Python API. Since the relationship between a Python function or constant and the C counterpart is very simple, you can search for Python function and constant names in this guide.

The MCS2 system supports different command interfaces (e.g. USB or ethernet) and driver modules to control actuators with different driving principles (e.g. stick-slip piezo actuators or electromagnetic driven positioners). Note that different modules have different features and properties. Furthermore, default settings and available options may differ between modules. Detailed information about the differences is given throughout the document.

Note that this document provides interactive cross-references for easy navigation. Clicking on a section reference, function- or property-name refers the reader to the corresponding detailed description.

1.2 Signal Words and Symbols

This document uses signal words and symbols to inform you about situations that require special attention.

**NOTICE**

Boxes of this style inform you about situations that might lead to equipment being damaged. It is important to understand that, depending on your machine setup, as a consequence this also might lead to personal injury!

Colored boxes like this one indicate facts that are non-critical but nevertheless noteworthy of pointing out, e.g. to avoid standard pit falls or to make explaining text less ambiguous.

1.3 Safety Note

SmarAct equipment has a wide range of applications. Therefore, control systems offer a variety of software controllable features and functionalities to achieve your goals.

However, these vast possibilities may lead to complex situations, not all of which can be verified by the control system to be harmless to equipment or personal safety. Therefore, always make sure to test your software thoroughly under safe circumstances.

Please also make sure to read and understand the information given in the *MCS2 User Manual*.

1.4 Terminologies

This section defines general terminologies that are used throughout this document. This section only gives a brief summary and the terminologies are explained in more detail later in this document.

Closed-Loop Movements are movements where sensor data is used as feedback to control the position, velocity and/or acceleration of a positioner. To be able to perform closed-loop movements the targeted positioner obviously must be equipped with an integrated position sensor. Furthermore, the sensor must not be disabled. See section 2.7.4 Closed-Loop Movements.

Open-Loop Movements are movements that do not use sensor data as feedback. The positioner simply moves according to the given parameters and the exact distance traveled is undefined. Especially, movements in different directions, but otherwise identical parameters, will typically result in slightly varying traveling distances. See section 2.7.3 Open-Loop Movements.

Calibrating is a process where the controller analyzes the individual characteristics of a positioner in order to optimize closed-loop behavior. The calibration data is saved to non-volatile memory. Therefore, the calibration only needs to be performed when the system setup changes, but not necessarily on each system start-up. See section 2.7.1 Calibrating.

Referencing is a process where the controller moves a positioner to detect its absolute physical position. After the referencing, points of interest identified in previous sessions may easily be recalled. See section 2.7.2 Referencing.

Trajectory Streaming allows to move several positioners synchronously along a defined trajectory. See section 2.18 Trajectory Streaming.

Stopped State means the state where the control-loop is disabled and the channel can not actively hold the current position. The output of the driver does not change when the channel is in *stopped* state.

Holding State means the closed-loop state where the control-loop is enabled but the positioner is not actively moving. The channel actively holds the current position by continuously updating the driving signals.

Hold Time The hold time of a closed-loop movement specifies how long the positioner will actively hold its position after reaching the target. This may be useful to compensate drift effects.

Max Closed-Loop Frequency When performing closed-loop movements with piezo driven positioners, the control-loop uses the current position and the commanded target position to generate a driving signal for the piezo actuator taking the control-loop parameters (PID) into account. The maximum allowed frequency that is generated by the control-loop depends on the actual positioner as well as the environment. (E.g. HV and UHV requires lower allowed frequencies.) The max closed-loop frequency defines the upper limit for the generated driving signal and must be configured with the corresponding property.

Phasing For electromagnetic driven positioners the controller must know the absolute position of the slider within a magnetic period. The sequence of establishing a phase reference is known as "phasing". See section 2.22 Phasing of Electro-Magnetic Driven Positioners.

2 GENERAL CONCEPTS

2.1 Connecting and Disconnecting

Before being able to communicate with a device a connection must be established via a call to `SA_CTL_Open`. This function connects to the device specified in the locator parameter (see section 2.1.1) and returns a handle to the device, if the call was successful. The returned device handle must be saved within the application and passed as a parameter to the other API functions. Once the connection is established you can use the other functions to interact with the connected device. If an application requires to connect to more than one device it must open each device separately. The API processes all communication independently for each device handle.

A device that has been acquired by an application cannot be acquired by a second application at the same time. You must close the connection to the device by calling `SA_CTL_Close` before it is free to be used by other applications. Not closing a device will cause a resource leak.

If you have threads blocking on functions like `SA_CTL_WaitForEvent` you may unblock them for a clean shutdown by calling `SA_CTL_Cancel`. The `SA_CTL_WaitForEvent` function will then return with the error code `SA_CTL_ERROR_CANCELED`.

Connecting to a device via the ASCII interface uses a different mechanism. Please refer to section 6.1 "Connection Setup" for more information.

2.1.1 Locators for Device Identification

Devices are identified with *locator* strings, similar to URLs used to locate web pages. The following sections describe the syntax of these locator strings.

USB Device Locator Syntax

Devices with a USB interface can be addressed with the following locator syntax:

- `usb:sn:<serial>`
where `<serial>` is the device serial which is printed on the housing of the device.
Example: `usb:sn:MCS2-00000412`
- `usb:ix:<n>` (deprecated)
where the number `<n>` selects the *n*th device in the list of all currently attached devices with a USB interface.
Example: `usb:ix:0`
The drawback of identifying a device with this method is that the number and the order of

connected devices may change between sessions, so the index *n* may not always refer to the same device. It is only safe to do this if you have exactly one device connected to the PC.

It is recommended to use the first format for USB devices, since the second one may accidentally connect to a device you are not intending to connect to.

Network Device Locator Syntax

Devices with a network interface are addressed with one of the following locator syntaxes:

- `network:sn:<serial>`
where `<serial>` is the device serial which is printed on the housing of the device.
Example: `network:sn:MCS2-00000412`
- `network:<ip>`
where `<ip>` is an IPv4 address which consists of four integer numbers between 0 and 255 separated by a dot.
Example: `network:192.168.1.200`

Data transmission bandwidth and latencies over networks can vary much more than over e.g. USB. A program should not rely on low transmission latencies.

2.1.2 Finding Devices

Devices may be connected to by using a specific locator as outlined above. To find devices automatically the function `SA_CTL_FindDevices` may be used. It will scan the USB ports as well as the network interfaces and return a list with the locator strings of the found devices.

Note that the Network Discover Mode property (see section 4.3.10) must be configured to active or passive mode to make it possible to list devices with ethernet interface. Note further that in case the DHCP mode is enabled a device cannot be found while the DHCP IP address allocation is running. If no DHCP server is available the interface will fall-back to the static IP settings after the configured DHCP timeout has expired. (See Network DHCP Timeout property, section 4.3.11). After that the device can be found again by the discovering but nevertheless a connection may probably not be established if the static IP settings do not match the users network settings.

2.1.3 Device Enumeration Options

By specifying the `options` parameter of the `SA_CTL_FindDevices` function, the default behavior of the function can be changed. The configuration consists of a number of parameters with default values, which will be used if they are not specified by the user. Parameters are organized in multiple lines separated by a newline character (`\n`). Each parameter line must contain a parameter with an optional value separated by a space character. Available parameters and their default values are:

Parameter	Default Value	Description
<code>iface-type</code>	<code>usb, network</code>	Select interface types for device discovery. Multiple values must be specified in separate lines. Setting this parameter once disables the default value. Possible values are <code>usb</code> and <code>network</code> .
<code>find-only-available</code>	<code>true</code>	List only devices which are currently not in use. Only network devices support discovery while already in use.
<code>only-locator</code>	<code>true</code>	Output format is one locator per line. See section on extended output format below.
<code>strict</code>	<code>true</code>	Report unknown parameters as error. When disabled unknown parameters will be ignored.

Extended output format

When disabling the `only-locator` parameter, the output format switches to an extended format which contains additional properties for each found device. Each line still contains one device, but consists of multiple key-value pairs. To enable output of a specific property add the line `include-<property>` in the `options` string, with `<property>` replaced by the actual property name. By specifying the special option `include-all` all available properties for a device are returned. Possible properties are:

Parameter	Description
<code>locator</code>	Device locator
<code>iface-type</code>	Interface type
<code>device-sn</code>	Device serial number
<code>device-info</code>	Device info string
<code>available</code>	Device is available
<code>network-host</code>	Device IP address

The property key and value are separated by an equal sign (=) and the key-value pairs are separated by a pipe character (|). Note that you cannot rely on a specific property order when parsing the output. Also the list of available properties depends on the interface type. To encode values with special characters percent-encoding with the following substitutions is used:

Character	Replacement
	%7C
\n	%0A
=	%3D
%	%25

Example option settings

Find only USB devices (specifying `iface-type` once disables the default behavior):

```
iface-type usb
```

Possible Output:

```
usb:sn:MCS2-00000088
```

Find devices on all interfaces (parameter must be specified multiple times):

```
iface-type usb
```

```
iface-type network
```

Possible Output:

```
usb:sn:MCS2-00000088
```

```
network:sn:MCS2-00000952
```

Find all network devices including unavailable ones with extended format output:

```
iface-type network
```

```
find-only-available false
```

```
only-locator false
```

```
include-locator
```

```
include-available
```

Possible Output:

```
available=0|locator=network:sn:MCS2-00000685
```

```
available=1|locator=network:sn:MCS2-00000952
```

2.1.4 Network Interface Configuration

While devices with USB interface do not need any interface configuration, the ethernet interface must be configured with the network parameters: DHCP mode, IP address, subnet mask and gateway IP address. The MCS2 is delivered with a default IP configuration which may be adjusted to match the users network settings.

The following table lists the default configuration:

Parameter	Default Value
DHCP Mode	disabled
IP Address	192.168.1.200
Subnet Mask	255.255.0.0
Gateway IP	192.168.1.1
Pass-Key	smaract

The interface may be configured to use DHCP to obtain an IP address from a DHCP-server or to use a static IP configuration. The configuration may be changed by connecting to the integrated

web server, by using the configuration menu of an MCS2 hand control module or by using the SmarActNetConfig tool for the PC.

See the *MCS2 User Manual* document for more details on the configuration.

2.2 Properties

Properties are configuration values that define the behavior of the device. Each property has a data type and an access mode. Some properties may be read and written, while others are read only or (in rare cases) write only. See chapter 4 "Property Reference" for a list of available properties and their descriptions.

Depending on the data type a property has you must use the corresponding function variant to access it. For example, the Number of Channels property is of type I32. Therefore, you must use the `SA_CTL_GetProperty_i32` function to read the property. In contrast the Device Serial Number property is of type string. Therefore, you must use the `SA_CTL_GetProperty_s` function to read the property.

Properties are identified by a *property key* that must be passed to the function call when accessing a property. Properties are categorized into device, module and channel properties. Module and channel properties require an additional *index* parameter to address a specific module or channel. Read the Number of Channels and Number of Bus Modules properties to determine the valid range for the channel and module index parameters. Note that the index parameter is zero-based. In case of device properties the controller is already addressed by the device handle. Therefore, the index parameter is unused and must be set to zero. For API properties the index parameter is unused too and must be set to zero.

Most properties are non-persistent which means that modifications do not outlive a power cycle. At device start-up they have the default value that is specified in the detailed property description. Other properties are kept persistent in the internal non-volatile memory. Therefore, their values are preserved and loaded at device start-up.

Note that not all properties are applicable for all interface and driver modules. Refer to the Property Reference to determine if a property is valid for a specific module. Reading or writing a property which is not available returns a `SA_CTL_ERROR_INVALID_KEY` error. Read the Interface Type, Module Type or Channel Type properties to determine the type of the interface, module or channel.

2.3 Accessing Properties

Modifying or retrieving property values takes a major role in controlling a device by software. Therefore, the API offers a variety of functions to get and set property values in order to meet all requirements an application might have. A straight forward method, though easy to use, is somewhat inefficient, while more complicated methods may greatly improve efficiency. The application may decide on a per-call basis which method to use, thus being very flexible depending on the applications context.

The different methods of accessing properties may be categorized by their use case and are described in the following sections. The figures illustrate the sequence of actions for getting two property values. Green boxes indicate non-blocking API calls while red boxes indicate blocking calls. Setting properties is very similar and is not explicitly discussed.

2.3.1 Synchronous Access

This is the easiest method for accessing properties since it consists of one simple function call for getting one property value (e.g. `SA_CTL_GetProperty_i32`). When the function returns the result is available (see figure 2.1).

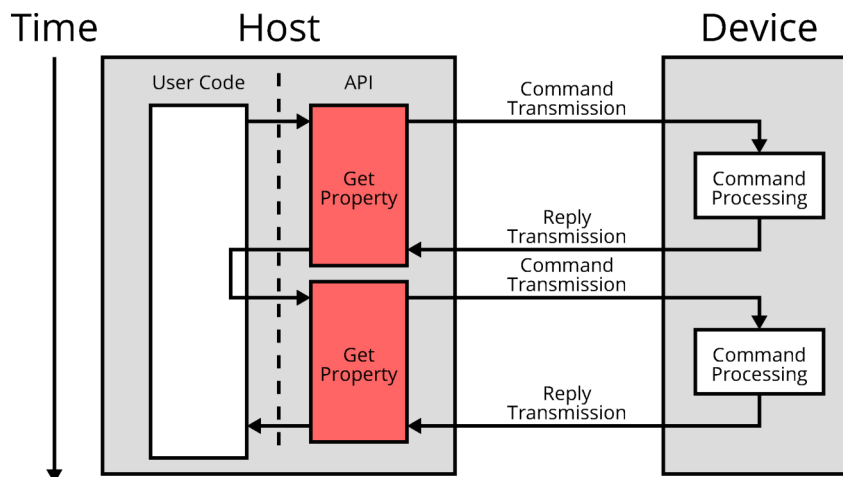


Figure 2.1: Synchronous Property Access

When the API function is called a command is sent to the device and the function waits for a reply from the device before it returns. From the view of the application, the function has a blocking behavior. Depending on the transmission delays the blocking time may be in the range of several milli seconds. During this time the user application cannot perform any other tasks. Therefore, this access method is the slowest of all.

Functions Used

`SA_CTL_GetProperty_i32`, `SA_CTL_SetProperty_i32`

Example Read

```

int32_t value[2];
int8_t channel;
for (channel = 0; channel < 2; channel++) {
    SA_CTL_Result_t result = SA_CTL_GetProperty_i32(
        dHandle, channel, SA_CTL_PKEY_CHANNEL_STATE, &(value[channel]), 0)
    );
    if (result) {
        // handle error
    }
}
// value[0] and value[1] hold the channel state

```

Example Write

```

int32_t value[2] = {SA_CTL_MOVE_MODE_CL_ABSOLUTE,
                    SA_CTL_MOVE_MODE_CL_RELATIVE};
int8_t channel;
for (channel = 0; channel < 2; channel++) {
    SA_CTL_Result_t result = SA_CTL_SetProperty_i32(
        dHandle, channel, SA_CTL_PKEY_MOVE_MODE, value[channel]
    );
    if (result) {
        // handle error
    }
}

```

2.3.2 Asynchronous Access

This method requires two function calls for getting one property value. One for requesting the property value and one for retrieving the answer (see figure 2.2).

When the API function is called a command is sent to the device and the function returns immediately, allowing the application to issue another request (or perform other tasks). When the application has finished performing other tasks (or cannot proceed until the property values are available) it may call the API function to receive the result.

The advantage of this method is that the application may request several property values in fast succession and then perform other tasks before blocking on the reception of the results.

Functions Used

SA_CTL_RequestReadProperty, SA_CTL_ReadProperty_i64,
SA_CTL_RequestWriteProperty_i64, SA_CTL_WaitForWrite

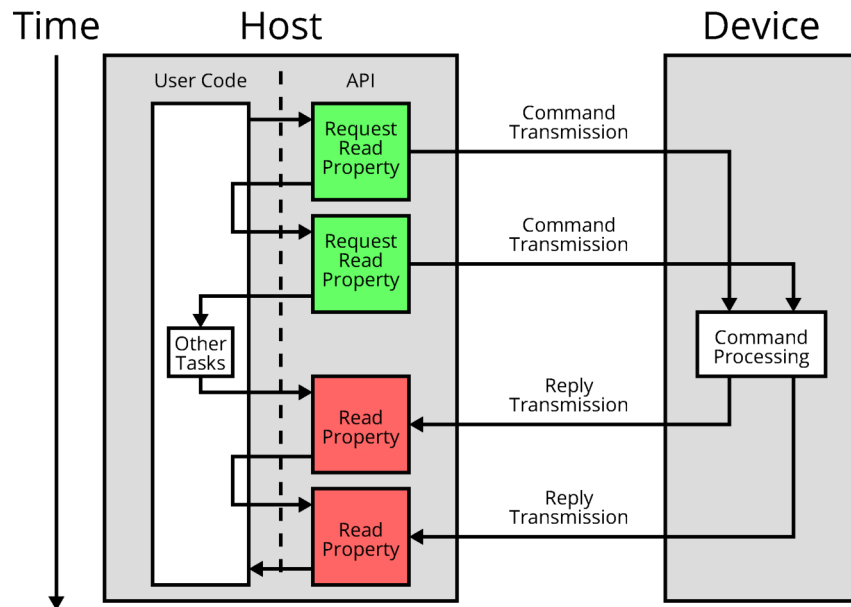


Figure 2.2: Asynchronous Property Access

Example Read

```
SA_CTL_Result_t result;
int64_t value[2];           // buffer for values to read
SA_CTL_RequestID_t rID[2];  // buffer for request IDs
int8_t channel;
// issue requests for two channels
for (channel = 0; channel < 2; channel++) {
    result = SA_CTL_RequestReadProperty(
        dHandle, channel, SA_CTL_PKEY_POSITION, &(rID[channel]), 0
    );
    if (result) {
        // handle error
    }
}
// process other tasks
// ...
// retrieve results
for (channel = 0; channel < 2; channel++) {
    result = SA_CTL_ReadProperty_i64(
        dHandle, rID[channel], &(value[channel]), 0
    );
    if (result) {
        // handle error
    }
}
}
```

Example Write

```

SA_CTL_Result_t result;
SA_CTL_RequestID_t rID[2];    // buffer for request IDs
int8_t channel;
// issue requests for two channels (set position to zero)
for (channel = 0; channel < 2; channel++) {
    result = SA_CTL_RequestWriteProperty_i64(
        dHandle, channel, SA_CTL_PKEY_POSITION, 0, &(rID[channel]), 0
    );
    if (result) {
        // handle error
    }
}
// process other tasks
// ...
// retrieve results
for (channel = 0; channel < 2; channel++) {
    result = SA_CTL_WaitForWrite(
        dHandle, rID[channel]
    );
    if (result) {
        // handle error
    }
}

```

2.3.3 High-Throughput Asynchronous Access

This method is similar to the asynchronous access with the difference that request commands are bundled (see figure 2.3).

When the API function is called the request is buffered. The function returns immediately and the command transmission is held back until the buffer is flushed. Again, the application may request several property values in fast succession and then perform other tasks before blocking on the reception of the results. In addition, the underlying media is able to combine several requests into one packet, thus further optimizing communication delays.

Functions Used

SA_CTL_CreateOutputBuffer, SA_CTL_FlushOutputBuffer,
SA_CTL_RequestReadProperty, SA_CTL_ReadProperty_i64

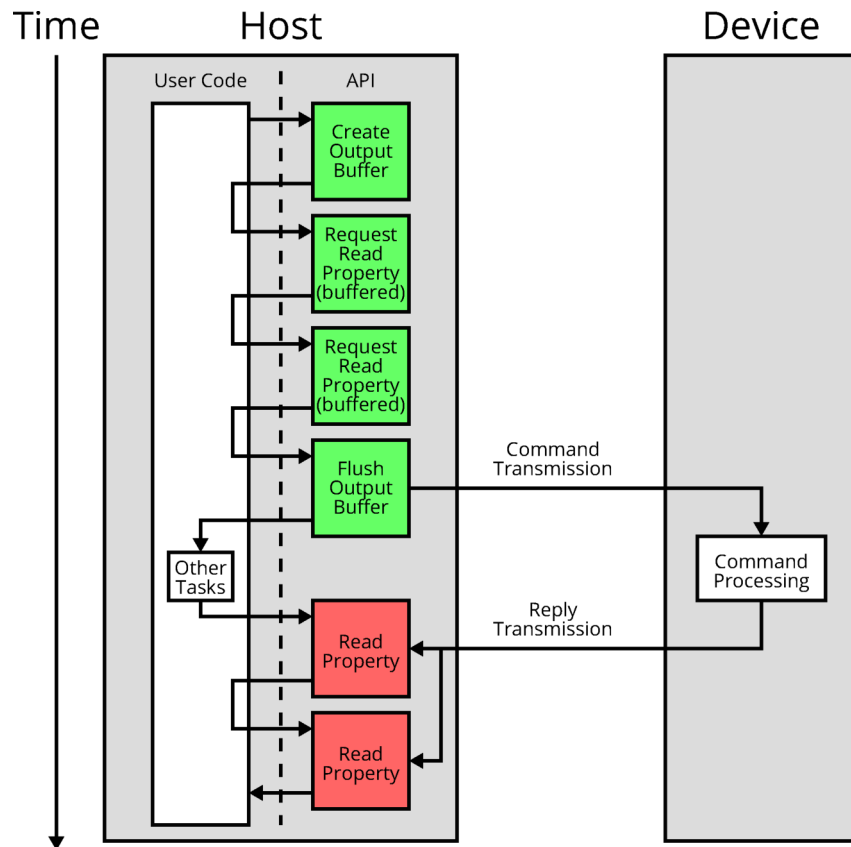


Figure 2.3: High-Throughput Asynchronous Property Access

Example Read

```
SA_CTL_Result_t result;
int32_t value[2];           // buffer for values to read
SA_CTL_RequestID_t rID[2];  // buffer for request IDs
int8_t channel;
// create output buffer
SA_CTL_TransmitHandle_t tHandle;
result = SA_CTL_CreateOutputBuffer(dHandle, &tHandle);
if (result) {
    // handle error
}
// issue requests for two channels
for (channel = 0; channel < 2; channel++) {
    // by passing the transmit handle (instead of zero)
    // the request is associated with the output buffer and
    // therefore only sent when the buffer is flushed (see below)
    result = SA_CTL_RequestReadProperty(
        dHandle, channel, SA_CTL_PKEY_POSITION, &(rID[channel]), tHandle
    );
    if (result) {
        // handle error
    }
}
```



```

    }
}
// flush output buffer
SA_CTL_FlushOutputBuffer(dHandle, tHandle);
// process other tasks
// ...
// retrieve results
for (channel = 0; channel < 2; channel++) {
    result = SA_CTL_ReadProperty_i64(
        dHandle, rID[channel], &(value[channel]), 0
    );
    if (result) {
        // handle error
    }
}
}

```

2.3.4 Call-and-Forget Mechanism

For property writes the result is only used to report errors. With the call-and-forget mechanism the device does not generate a result for writes and the application can continue processing other tasks immediately. Compared to asynchronous accesses, the application doesn't need to keep track of open requests and collect the results at some point. This mode should be used with care so that written values are within the valid range.

The call-and-forget mechanism is used by passing a null pointer for the request ID pointer to the `SA_CTL_RequestWriteProperty_x` functions.

Functions Used

`SA_CTL_RequestWriteProperty_i64`

Example Write

```

SA_CTL_Result_t result;
int8_t channel;
// issue requests for two channels (set position to zero)
for (channel = 0; channel < 2; channel++) {
    result = SA_CTL_RequestWriteProperty_i64(
        dHandle, channel, SA_CTL_PKEY_POSITION, 0, NULL, 0
    );
    if (result) {
        // handle error
    }
}
}

```

2.3.5 Request Ready Notification

Instead of using the blocking `SA_CTL_ReadProperty_x/SA_CTL_WaitForWrite` functions to retrieve the result of an asynchronous request, the event system (see section 2.4 "Event Notifications") can be used to get a notification once the answer has been received from the device. After receiving a Request Ready event (see there) the result of the asynchronous operation can be retrieved without blocking using the functions mentioned above.

Note that the request ready event needs to be enabled using the Event Notification Options property.

Example Request

```
// enable request ready events
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_API_EVENT_NOTIFICATION_OPTIONS,
    SA_CTL_EVT_OPT_BIT_REQUEST_READY_ENABLED
);
if (result) { /* handle error */ }

// send asynchronous request
SA_CTL_RequestID_t rID;
result = SA_CTL_RequestReadProperty(
    dHandle, 0, SA_CTL_PKEY_CHANNEL_STATE, &rID, 0
);
if (result) { /* handle error */ }
```

Example Event Processing

```
SA_CTL_Event_t evnt;
result = SA_CTL_WaitForEvent(dHandle, &evnt, SA_CTL_INFINITE);
if (result) { /* handle error */ }

if (evnt.type == SA_CTL_EVENT_REQUEST_READY) {
    // extract event data
    SA_CTL_RequestID_t rID = SA_CTL_EVENT_REQ_READY_ID(evnt.i64);
    int requestType = SA_CTL_EVENT_REQ_READY_TYPE(evnt.i64);
    int dataType = SA_CTL_EVENT_REQ_READY_DATA_TYPE(evnt.i64);

    // process read results
    if (requestType == SA_CTL_EVENT_REQ_READY_TYPE_READ) {
        size_t arraySize = SA_CTL_EVENT_REQ_READY_ARRAY_SIZE(evnt.i64);
        switch (dataType) {
            case SA_CTL_DTYPE_INT32:
            {
                std::vector<int32_t> values(arraySize);
                result = SA_CTL_ReadProperty_i32(
```

```
        dHandle, rID, values.data(), &arraySize
    );
    if (result) { /* handle error */ }

    values.resize(arraySize);
    // property data is now stored in values
    break;
}
// handle other data types
}
}
```

2.4 Event Notifications

In some situations events might occur that require further attention or reactions by the user. To avoid that the application has to poll the occurrence of such events the MCS2 offers a notification system. If an event occurs the MCS2 generates a notification event informing about the situation.

The application may receive events using the `SA_CTL_WaitForEvent` function. It returns events in form of a pointer to the struct:

```
typedef struct {
    uint32_t idx;
    uint32_t type;
    union {
        int32_t i32;
        int64_t i64;
        uint8_t unused[24];
    };
} SA_CTL_Event_t;
```

The fields of the struct have the following meaning:

- `idx` holds the source index that the event originated from. This may be a device, module or channel index, depending on the event type.
- `type` holds the type of the event. See chapter 5 "Event Reference" for a detailed description of the events and their parameters.
- `i32` / `i64` / `unused` are parameter fields that further describe the event. The meaning depends on the event type.

While the event type indicates "what happened" the event parameter from most events gives a more detailed hint why the event occurred. Note that the event queue is cleared when connecting to a device. This means that events which occurred *before* the connection was established are silently dropped.

The `SA_CTL_Cancel` function can be used to abort a waiting `SA_CTL_WaitForEvent` call. An event can also be translated into a human readable string by using the `SA_CTL_GetEventInfo` function.

Note that all **controller events** are enabled by default. There is no property to explicitly enable or disable any specific controller events. Only **API events** are disabled by default and need to be enabled explicitly by configuring the Event Notification Options property.

2.5 Module Overview

Each MCS2 controller consists of one *interface module* to provide a communication interface (e.g. USB or ethernet interface) and one or more *driver modules* to control actuators with different driving principles (e.g. stick-slip piezo actuators or electromagnetic driven positioners). Each driver module has a specific number of *channels* and optionally may carry an I/O module for auxiliary inputs and outputs. One sensor module per driver is required to connect the positioners to the controller. An optional hand control module may be integrated in the main controller or placed inside a separate housing to be connected to the main controller. Figure 2.4 shows the device structure on the example of a controller with two driver modules. Please refer to the *MCS2 User Manual* for more information about the hardware components of the MCS2 system.

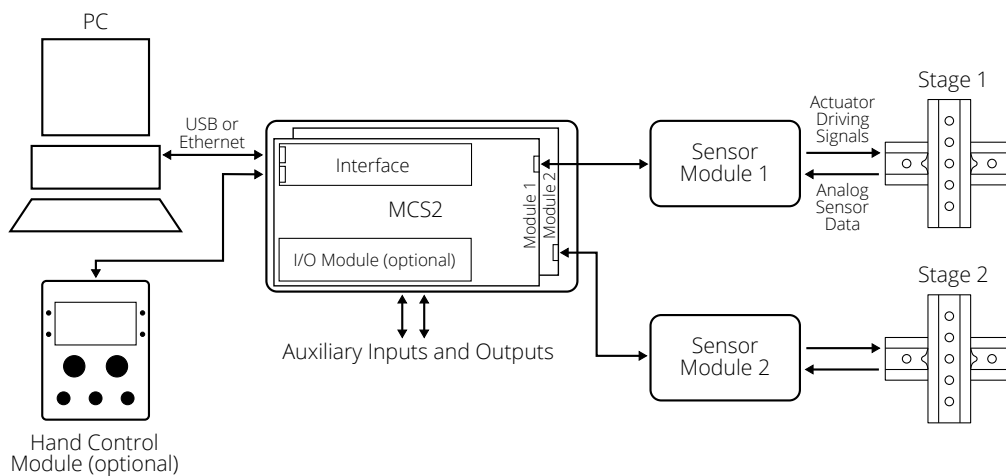


Figure 2.4: MCS2 Device Structure

It may be useful for an application to know the type of the channel or module e.g. to decide if a specific feature may be used. The Module Type and Channel Type properties return the type code of the module and channel. Although the type of the interface is usually well known when connecting to a device (the device locator reflects the type of interface) it may be read with the Interface Type property.

The following modules are of interest for the programming of the MCS2:

2.5.1 USB Interface

MCS2 devices with USB interface (`SA_CTL_INTERFACE_USB`) support the binary SmarActCTL protocol. The USB interface does not need any interface configuration.

2.5.2 Ethernet Interface

MCS2 devices with ethernet interface (`SA_CTL_INTERFACE_ETHERNET`) support the binary SmarActCTL protocol as well as a SCPI oriented ASCII protocol. See section 6 "ASCII Interface" for more information. The ethernet interface must be configured with an IP configuration to match the users network settings. See section 2.1.4 "Network Interface Configuration" for more information.

2.5.3 Stick-Slip Piezo Driver

The Stick-Slip Piezo Driver module (`SA_CTL_STICK_SLIP_PIEZO_DRIVER`) allows to drive three piezo driven stick-slip positioners. These positioners have the following features and requirements:

- The positioners may be commanded to perform open-loop movements (Scanning and Stepping) and closed-loop movements. (The positioners must be equipped with integrated sensors to perform closed-loop movements).
- Stick-Slip piezo actuators are self-locking. This means that they hold their position roughly without applying any driving signals to the actuator.
- The positioner type must be configured manually to the channel according to the connected positioner. See section 2.6 "Positioner Types" for more information.
- The amplifier of the driver channel is enabled and the channel is in the *stopped* state at startup. Commanding a closed-loop movement enables the control-loop. See section 2.7 "Moving Positioners" for more information.
- The channel may be instructed to actively hold the target position after it has been reached. (See Hold Time property.) After the hold time elapsed the channel is stopped.
- Closed-loop movements may be commanded without and with velocity control (and additionally acceleration control). If no velocity is defined the maximum positioner speed is limited only by the max closed-loop frequency (See Max Closed Loop Frequency property.)
- The sensor power-save mode may be used to reduce the generated thermal load of the positioner while resting for the operation in temperature critical environments. See section 2.11 "Sensor Power Modes" for more information.

2.5.4 Electromagnetic Driver

The Electromagnetic Driver module (`SA_CTL_MAGNETIC_DRIVER`) allows to drive three brushless permanent magnet positioners. These positioners have the following features and requirements:

- Integrated sensors are required for the operation of these positioners. The sensor feedback is used for the electronic commutation (phasing) as well as to perform closed-loop movements. Open-loop movements are not available.
- Electromagnetic positioners are *not* self-locking. This means that they require the control-loop to be enabled to continuously update the driving signals and to actively hold their position.
- SmarAct positioners are equipped with the SmarAct Positioner ID System. The positioner type is automatically detected and configured when the positioner is attached to a channel. See section 2.6 "Positioner Types" for more information.

- In general the amplifier is disabled at startup and must be explicitly enabled before being able to perform closed-loop movements. This also implicitly starts the phasing sequence of the positioner. See section 2.22 "Phasing of Electro-Magnetic Driven Positioners" for more information. Alternatively the channel may be configured to automatically enable the amplifier on startup. (See Startup Options property.)
- All movements require the velocity and acceleration control to be active to define the velocity resp. the acceleration with which the closed-loop movement is performed. See section 2.7.4 "Closed-Loop Movements" for more information.

2.5.5 I/O Module

One or more optional I/O modules may be integrated in the main controller to provide auxiliary inputs and outputs. The characteristics as well as the number of inputs and outputs vary depending on the specific type of I/O module. If no I/O module is available the related properties generate an `SA_CTL_ERROR_NO_IOM_PRESENT` error. See section 2.19 "Auxiliary Inputs and Outputs" for the programming of I/O module features and refer to the *MCS2 User Manual* for more details and electrical specifications.

2.5.6 Sensor Module

A sensor module is required to connect the positioners to the controller. The sensor signals of the connected positioners are digitalized by the sensor module and the preprocessed data is sent to the controller to provide position feedback and closed-loop operation. Note that different sensor modules support different sensor types. An `SA_CTL_ERROR_SENSOR_TYPE_NOT_SUPPORTED` error is generated when setting the Positioner Type to a type with a sensor which is not supported by the sensor module.

2.5.7 Hand Control Module

The hand control module offers easy and ready-to-go control of a positioning system without the need of a computer and additional software. It may be integrated in the main controller or placed inside a separate housing to be connected to the main controller. The external module is hot-pluggable, it is automatically detected and initialized even if attached to an already powered up controller.

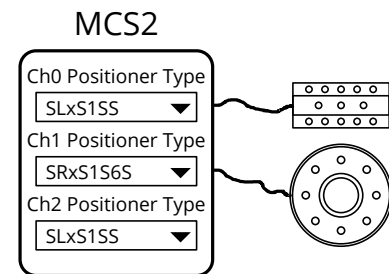
Special care must be taken when using a hand control module and a software running on a PC at the same time. The hand control module sets several movement relevant properties (like move velocity, move acceleration, hold time, step frequency, step amplitude, etc.) prior to commanding a movement command. Thus user software must not rely on previously configured parameters since they may have been modified in the meantime by the hand control module. To be on the safe side, user software may set the Hand Control Module Lock Options property to disable the control inputs of the hand control module during its operation.

2.6 Positioner Types

The positioner type gives the controller information about how to calculate positions, handle the referencing, configure the control-loop, etc.

The MCS2 controller provides sets of standard configuration parameters for all kinds of SmarAct positioners. For the majority of applications these predefined types are sufficient.

Note that the positioner type is represented by a generic *type code* instead of the descriptive name string. The descriptive name may be read with the Positioner Type Name property. Furthermore, the Tuning and Customizing Properties may be used to read additional information of the configured positioner type.



When the positioner type of a channel is changed (by manual configuration or by automatic detection), the channel must be calibrated to ensure proper operation of the positioner. See section 2.7.1 "Calibrating" for more information.

The sensor module provides the appropriate supply voltage for the integrated sensors of the positioners according to the configured positioner types. Note that this supply voltage configuration is global for *all* channels of a sensor module.

When using positioners with **M- or L-sensor** on *at least one* channel of a specific driver module *all* positioner types of *this* module must be set to a **M- or L-sensor** type too to configure the correct sensor supply voltage. This rule applies even if the other channels of the driver module are unused, respectively no positioners are connected.

Please refer to the *MCS2 Positioner Types* document for a list of available positioner types.

2.6.1 Manual Positioner Type Configuration

For positioners that are not equipped with the SmarAct positioner ID system the channel must be configured with the type of positioner that is connected. To configure a positioner type to a channel simply set the Positioner Type property.

Each channel stores the positioner type setting to non-volatile memory. Consequently, there is no need to configure the positioner type for each session. Only when changing the physical setup (switching positioners etc.) the channel must be reconfigured (and calibrated) again.

2.6.2 Automatic Positioner Type Configuration

The MCS2 automatically configures the Positioner Type for positioners that are equipped with the SmarAct Positioner ID System when attaching it to the channel. Additionally, the controller will generate a corresponding Positioner Type Changed event. The event parameter or the Positioner Type property provide the type that was automatically configured. The Positioner Type property

can also be used to select custom positioner types. (See next section for more details on custom positioner types.)

Note that the channel must be calibrated once again after the positioner type was changed by the automatic detection.

2.6.3 Custom Positioner Types

In special cases it might be necessary to modify tuning parameters of a positioner type to adapt to an application perfectly. The MCS2 controller offers this possibility by giving access to the tuning parameters. Once the tuning is finished the set of parameters may be saved to a *custom positioner type* slot. As a safety feature, all tuning properties are write protected by default. This prevents accidental modification of any parameters. A special key must be written to the Positioner Write Protection property to unlock the write access to the tuning properties. As long as the write protection is active, writing to a tuning property will return a `SA_CTL_ERROR_PERMISSION_DENIED` error.

Custom positioner type slots are also used to define the control-loop parameters in case an auxiliary input is used as feedback signal for the control-loop. Refer to section 2.19.5 "Using Analog Inputs as Control-Loop Feedback" for more information.

Creating Custom Positioner Types

When tuning a positioner type the first step should be to select one of the predefined positioner types to act as a template. Note that this step is important to define several internal parameters which are not user accessible. The predefined positioner type defines e.g. the sensor type (S, L, M, etc.) and sensor supply voltage as well as the position calculation parameters. (Positioners that support the SmarAct Positioner ID System automatically set the appropriate type when attaching it to the channel.) After this, tuning parameters may be modified. As long as the modified positioner type was not saved to a custom slot, the positioner type is read as 0 to indicate that the modifications are volatile. (The Positioner Type Name property returns 'modified' in that case.) Powering down the device in this state will discard the changes made. To save the modified set of parameters use the Save Positioner Type property. This will save the settings to one of four custom positioner type slots and set the Positioner Type to the new custom type implicitly.



NOTICE

Configuring inappropriate values may result in unstable or unexpected behavior of the positioners and potential damage of the stage. Custom tuning must be used with caution!

The available properties for customizing a positioner type are described in section 4.9 "Tuning and Customizing Properties".

Automatic Positioner Type Configuration

If the Positioner Type is automatically detected and configured when attaching the positioner to the channel (e.g. for electromagnetic driven positioners) the appropriate template type for the custom tuning is set automatically too. After tuning the parameters the positioner configuration may be saved to one of the four custom positioner type as described above. This implicitly sets the Positioner Type to the new custom type.

To return to the predefined (and automatically detected) type the Positioner Type property must be set to the special value `SA_CTL_POSITIONER_TYPE_AUTOMATIC` (299). This configures the predefined type and sets the Positioner Type to this type implicitly. Note that the channel must be calibrated again after changing the positioner type to ensure proper operation of the positioner. See section 2.7.1 "Calibrating" for more information.

Note that the write access to the Positioner Type property is restricted to *custom positioner types* and to the special *automatic positioner type* value.

2.7 Moving Positioners

There are several commands available that induce a movement of a positioner (**movement commands**). Mainly these are:

- Calibrating (`SA_CTL_Calibrate`).
- Referencing (`SA_CTL_Reference`).
- Moving (`SA_CTL_Move`). Depending on the configured Move Mode this command covers:
 - Open-loop movements (Scanning and Stepping for piezo-driven positioners)
 - Closed-loop movements
- Stopping (`SA_CTL_Stop`).

These commands are described in the following sections.

Generally, the base unit for position values is pico meters (pm) for linear positioners and nano degrees (n°) for rotary positioners.

API functions that involve movement of positioners (such as `SA_CTL_Move`, `SA_CTL_Calibrate` and `SA_CTL_Reference`) are always sent to the device asynchronously. Therefore, these functions do not return an acknowledge or error directly. Instead, the movement commands will always generate a `SA_CTL_EVENT_MOVEMENT_FINISHED` event where the event parameter indicates success or failure. For example, if a closed-loop movement could not be started due to a missing sensor, the event parameter will be `SA_CTL_ERROR_NO_SENSOR_PRESENT`. See See section 2.7.7 "Movement Feedback" for more information.

2.7.1 Calibrating

Even though every positioner is categorized by its type (which is configured to the channel via the Positioner Type property, see also section 2.6 "Positioner Types") each individual positioner may have slightly different characteristics that require the tuning of some internal parameters for correct operation and optimal results.

The `SA_CTL_Calibrate` function is used to adapt to these characteristics and automatically detects parameters for an individual positioner. It must be called once for each channel if the mechanical setup changes (different positioners connected to different channels). The calibration data will be saved to non-volatile memory. If the mechanical setup is unchanged, it is not necessary to run the calibration on each initialization, but newly connected positioners have to be calibrated in order to ensure proper operation.

The calibration routine is only executable by a positioner that has a sensor attached to it. The sensor must also be enabled or in power save mode (see the Sensor Power Mode property). Otherwise the `SA_CTL_EVENT_MOVEMENT_FINISHED` event that is generated by the channel will hold an error code as parameter. The calibration takes a few seconds to complete. During this time the Channel State bit `SA_CTL_CH_STATE_BIT_CALIBRATING` is set.

**NOTICE**

As a safety precaution, make sure that the positioner has enough freedom to move without damaging other equipment.

Before calling the `SA_CTL_Calibrate` function the Calibration Options property should be configured to define the behavior of the calibration sequence. This property holds a bit mask which is outlined in the following table.

Bit	Name	Short Description
0	Direction	Defines the direction in which the positioner will move for calibration purposes. The movement is started in <i>backward</i> direction if this flag is set.
1	Detect Distance Code Inversion	Activates a special mode that detects the individual setup of positioners with multiple reference marks. For normal calibration this bit should be set to 0.
2	Advanced Sensor Correction ¹	Activates a calibration routine to compensate periodic sensor errors.
8	Limited Travel Range ¹	Allows more than one endstop while calibrating. Should be used for positioners with limited travel range, e.g. micro grippers.

Undefined flags are reserved for future use. These flags should be set to zero.

Signal Correction Calibration (calibration options 0x00 or 0x01)

During this calibration routine the positioner will perform a movement of up to several mm in the configured direction to optimize the position calculation for the sensor signals of the positioner. Also the direction sense between sensor and actuator is determined (and automatically adjusted) by this routine. This is required for a proper operation of the control-loop. The signal correction calibration should not be started near a mechanical end stop. Nonetheless the calibration sequence automatically detects an endstop and reverts the movement direction to continue the calibration in the opposite direction. If more than one endstop is detected the calibration sequence is aborted with an error.

Some positioners (e.g. micro grippers) have a very **limited travel range**. For these positioners the movement distance may be too small to successfully finish the calibration.

The `SA_CTL_CALIB_OPT_BIT_LIMITED_TRAVEL_RANGE` calibration options flag may be used to increase the number of allowed endstops while calibrating.¹ The calibration sequence then moves back and forth between the two endstops to perform the signal corrections.

Positioners that are referenced via a **mechanical end stop** (see section 2.8.4 "Positioners With Endstop Reference") are moved to the end stop as part of the calibration routine. For this movement the configured Move Velocity and Move Acceleration are used.

¹This option is only applicable for Stick-Slip Piezo Driver.

Which end stop is used for referencing is defined by the configured Safe Direction instead of the direction bit of the Calibration Options property. Note that when changing the Safe Direction the end stop must be calibrated again for proper operation.

As a safety precaution, make sure that the positioner has enough freedom to move without damaging other equipment.

Once the calibration has finished successfully the `SA_CTL_CH_STATE_BIT_IS_CALIBRATED` bit of the Channel State property is set.

Note that Electromagnetic Driver channels **must** be calibrated in order to perform movements. Calling the `SA_CTL_Move` or `SA_CTL_Reference` function will otherwise generate a "movement finished" event with its parameter set to `SA_CTL_ERROR_NOT_CALIBRATED`.

Distance Code Inversion Detection (calibration options 0x02 or 0x03)

This calibration routine may be used to correct the absolute position calculation when referencing positioners with multiple reference marks. In rare cases the reference algorithm may produce faulty results due to a reference coding mismatch. These situations may be resolved by executing this calibration routine.

Advanced Sensor Correction Calibration (calibration options 0x04 or 0x05)¹

This calibration routine is used to improve the absolute sensor accuracy by compensating the periodic sensor error. A calibration sequence is needed to generate a compensation table which is stored in the controller. This calibration must be performed for every channel that should use the advanced sensor correction. During this calibration routine the positioner will perform a movement of up to several mm in the configured direction. The compensation may then be activated by setting the `SA_CTL_SIGNAL_CORR_OPT_BIT_ASC` bit of the Signal Correction Options property.

The advanced sensor correction needs a feature permission to be activated on the controller. See section 2.24 "Feature Permissions" for more information.

2.7.2 Referencing

The `SA_CTL_Reference` function may be used to instruct a positioner to determine its physical position. It will start to move in the configured search direction and look for a reference. The positioner must have a sensor attached to it and the sensor must be enabled or in power save mode in order to perform the referencing sequence (see the Sensor Power Mode property).

Depending on the reference strategy (which is partly predefined by the positioner type and partly configurable) as well as the individual positioner, the referencing takes some time to complete. During this time the Channel State bit `SA_CTL_CH_STATE_BIT_REFERENCING` is set. In case the reference could not be found the `SA_CTL_EVENT_MOVEMENT_FINISHED` event that is generated by the channel will hold an error code as parameter.

Before calling the `SA_CTL_Reference` function the Referencing Options property can be configured to define the behavior of the reference sequence. This property holds a bit mask with several options that influence the strategy of how to find the reference. Please refer to section 2.8.1 "Reference Marks" for more information.

The velocity and acceleration for the referencing movement may be specified with the Move Velocity and Move Acceleration properties. To guarantee that the reference mark can be found securely the maximum allowed velocity is limited and may be lower than for regular closed-loop movements. Since the limit is quite high this is usually not a restriction. The actual maximum value depends on the positioner type. (E.g. 125 mm s^{-1} for a linear positioner with S-sensor.) However, if a higher move velocity is configured when starting the referencing the value is temporary limited by the controller.

Calling the `SA_CTL_Reference` function starts the actual movement with the configured parameters. If the positioner will encounter a physical end stop *before* finding the mark, it will automatically reverse its search direction at the end stop and continue to look for the reference mark. (Except for end stop referenced positioners.) If the positioner encounters a second end stop then the reference algorithm will be aborted. The positioner is stopped and an "end stop reached" error is generated. Reasons for this situation may be a mechanical or electrical defect (the controller does not register the reference signal for some reason) or the reference mark is outside the physical movement range of the positioner (e.g. the positioner has bumped against an obstacle).

If a physical end stop is reached while decelerating to zero velocity *after* finding the mark, this is also indicated by an "end stop reached" error. Note that in general the physical position is known as soon as the reference mark was found and *not* after the positioner returned to the exact position of the mark. Nonetheless, to prevent errors the velocity and acceleration parameters should be configured to reasonable values which allow to decelerate the positioner to zero velocity *after* the reference mark was found and *before* an end stop is reached.

Note that reference movements (when successful) generate two events. One when the reference position has been determined and one after the positioner has come to a stop. The first event is mainly useful when using the *Continue On Reference Found* feature (see section 2.8.1 "Reference Marks").

Once the channel "knows" its physical position the `SA_CTL_CH_STATE_BIT_IS_REFERENCED` bit of the Channel State property is set.

2.7.3 Open-Loop Movements

There are two types of open-loop movement:*

- *Scan movements* allow to control the deflection of the piezo element of the positioner directly. To perform scan movements the Move Mode property must be set to one of the values `SA_CTL_MOVE_MODE_SCAN_ABSOLUTE` or `SA_CTL_MOVE_MODE_SCAN_RELATIVE`.

The scan velocity may be specified with the Scan Velocity property. The `SA_CTL_Move` function must be called to start the actual scan movement. The *move value* parameter of the

*Note that open-loop movements are not available for Electromagnetic Driver.

*Also note that open-loop step movements behave differently for dual-piezo hybrid positioners (see section 2.23).

`SA_CTL_Move` function is then interpreted as target scan position to which to scan to, respectively scan target increment in case of relative scan movement. The valid range for the scan position is 0 ... 65 535 for absolute scan positions and -65 535 ... 65 535 for relative scan increments. Note that for relative scan movements the movement will stop at the boundary if the resulting absolute scan target exceeds the valid range.

- *Step movements* allow to perform a burst of steps with the given frequency and amplitude. To perform step movements the Move Mode must be set to `SA_CTL_MOVE_MODE_STEP`.

Frequency and amplitude of the generated output signal may be specified with the properties Step Frequency and Step Amplitude. The `SA_CTL_Move` function must be called to start the actual step movement. The *move value* parameter of the `SA_CTL_Move` function is then interpreted as number of steps. The sign of the value codes the movement direction. The valid range for the step parameter is -100 000 ... -1 and 1 ... 100 000. Note that the quiescent voltage for step movements is half the piezo driver voltage (which is usually 100 V). If the amplitude is reduced this happens symmetrically related to half the driver voltage.

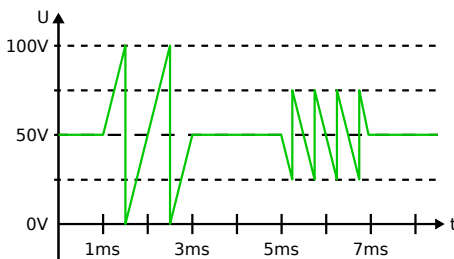


Figure 2.5 shows the generated output for two open-loop steps in forward direction with a frequency of 1 kHz and maximum amplitude followed by four steps in backward direction with a frequency of 2 kHz and half the amplitude.

Figure 2.5: Step Movement

The Channel State bit `SA_CTL_CH_STATE_BIT_ACTIVELY_MOVING` is set while performing scan or step movements.

2.7.4 Closed-Loop Movements

In order to perform a closed-loop movement the positioner must have a sensor attached to it. The sensor must also be enabled or in power save mode (see the Sensor Power Mode property). If this is not the case the `SA_CTL_EVENT_MOVEMENT_FINISHED` event that is generated by the channel will hold an error code as parameter. Furthermore the amplifier must be enabled (see the Amplifier Enabled property).

Before calling the `SA_CTL_Move` function the Move Mode property must be set to one of the following values:

- `SA_CTL_MOVE_MODE_CL_ABSOLUTE` In this mode the *move value* that is passed to the `SA_CTL_Move` function is interpreted as the new absolute target position the positioner should move to.
- `SA_CTL_MOVE_MODE_CL_RELATIVE` In this mode the *move value* that is passed to the `SA_CTL_Move` function is added to the current (target) position. The *move value* of 0 has a special meaning in this mode: the channel aborts an ongoing movement and actively holds the current position.

The valid range for the position is $-100 \times 10^{12} \dots 100 \times 10^{12}$ pm or n°.

Additionally, the following properties may be configured to modify the behavior of the closed-loop movement (see also the detailed property descriptions in chapter 4):

- Move Velocity and Move Acceleration

These properties define the velocity resp. the acceleration with which the closed-loop movement is performed.

If the move velocity is set to zero (only for Stick-Slip Piezo Driver) then the velocity control is disabled and the positioner moves to the target position as fast as possible, more precisely, only limited by the *maximum closed-loop frequency* (see Max Closed Loop Frequency).

Likewise, if the acceleration is set to zero (only for Stick-Slip Piezo Driver) then the acceleration control is disabled and the positioner accelerates and decelerates as fast as possible (only limited by mechanical factors).

- Control Loop Input

This property defines the feedback signal for the control-loop.

- SA_CTL_CONTROL_LOOP_INPUT_DISABLED The closed-loop operation is disabled. A SA_CTL_ERROR_CONTROL_LOOP_INPUT_DISABLED error will be generated when trying to command a closed-loop movement.
- SA_CTL_CONTROL_LOOP_INPUT_SENSOR The channel uses the integrated sensor of a positioner to calculate the current position. This position is used as input signal for the control-loop to allow closed-loop position control.
- SA_CTL_CONTROL_LOOP_INPUT_AUX_IN The input signal of an auxiliary input (e.g. an analog input of an MCS2 IO module) is used as control-loop input.

- Positioner Control Options

This property defines several options that apply to closed-loop movements. The property value is a bit field containing the following independent flags:

Table 2.1 – Positioner Control Options

Bit	Name	Short Description
0	Accumulate Relative Position Disabled	Disables the relative position accumulation.
1	No Slip ¹	Forbid the execution of actuator slips (steps).
2	No Slip While Holding ¹	Forbid the execution of actuator slips (steps) only while holding the target position.
3	Forced Slip Disabled ^{1,3}	Disables the forced slip feature.
4	Stop On Following Error	Stop positioner if a following error was detected.
5	Target To Zero Voltage ^{1,3}	The driver output voltage is forced to zero while retaining the target position after a closed-loop movement.

Continued on next page

Table 2.1 – Continued from previous page

Bit	Name	Short Description
6	CL Disable On Following Error ²	Disable control-loop if a following error was detected.
7	CL Disable On Emergency Stop ²	Disable control-loop if an emergency stop was triggered.
8	In Position	Configures the "in position" Channel State flag to be used as "movement finished" condition for closed-loop movements.

Undefined flags are reserved for future use. These flags should be set to zero.

The flags have the following meaning:

Accumulate Relative Positions Disabled (Bit 0) This flag affects the behavior of a positioner if a relative position command is issued before a previous one has finished. If relative position commands are to be accumulated (bit cleared, default) then all new relative position commands are added to the previous target position. Otherwise (bit set) the movement is executed relative to the position of the positioner at the time of command arrival.

Example: Say the positioner is currently at its zero position. Two relative movement commands are issued in fast succession both with +1 mm as relative target. With accumulation enabled (default) the final position will be 2 mm. With accumulation disabled the final position will vary (e.g. 1.12 mm) depending on when the second command arrives at the controller.

No Slip (Bit 1)¹ If this flag is set the actuator driving signal generation will never generate slips (steps). This means that only scan movement in the range of the piezo is performed for targeting. It might be useful for applications where the vibration of the piezo slip is unwanted, e.g. while approaching to a probe in the sub micrometer range.

No Slip While Holding (Bit 2)¹ This flag affects the behavior of a positioner if it is instructed to hold the target position after reaching it (see the Hold Time property). The piezo deflection will be adjusted automatically to hold the position. Additionally it may become necessary to do further steps to hold the position if the deflection of the piezo reaches a boundary. However, if this is not desired, this flag may be used to forbid the execution of steps even if this means that the position can not be held. Note that this flag has no effect if the **No Slip** flag (Bit 1) or the **Target To Zero Voltage** flag (Bit 5) is active.

Forced Slip Disabled (Bit 3)^{1,3} When reaching a target position the channel will try to stop at approx. 50% of its step size, thus improving the holding feature. This is achieved by forcing a slip, just before reaching the target position. If this behavior is unwanted it can be disabled with this flag.

¹This option is only applicable for Stick-Slip Piezo Driver.

²This option is only applicable for Electromagnetic Driver.

³This option has no effect for dual-piezo hybrid positioners.

Stop On Following Error (Bit 4) This flag defines if a closed-loop movement should be stopped as soon as the configured following error is exceeded. Electromagnetic driven positioners enter the holding state to stop the ongoing movement in this case. Note that this flag has no effect for movements without velocity control, if the Following Error Limit is set to zero or if the **CL Disable On Following Error** flag (Bit 6)² is active.

Target To Zero Voltage (Bit 5)^{1,3} If this flag is set a special holding sequence is started after a target position was reached. The controller will then perform several piezo scan operations to force the output voltage to zero while retaining the target position. This feature is e.g. useful for applications where the positioner should be moved to a specific target position and then should be disconnected from the controller without additional movement of the positioner carriage. (Which usually happens due to the contraction of the piezo element while discharging from the holding voltage.) Note that the hold threshold for this feature may be configured with the Target To Zero Voltage Hold Threshold property. If a Hold Time is specified the sequence is repeated whenever the difference between current position and target position exceeds the configured hold threshold.

CL Disable On Following Error (Bit 6)² This flag defines if the control-loop should be disabled instead of just stopping the movement as soon as the configured following error is exceeded while performing a movement or while actively holding the position. Note that disabling the control-loop removes any holding force from the positioner and thus must be used with caution.

CL Disable On Emergency Stop (Bit 7)² This flag defines if the control-loop should be disabled instead of just stopping the movement as soon as an emergency stop was triggered. See section 2.20.2 "Emergency Stop Mode" for more information. Note that disabling the control-loop removes any holding force from the positioner and thus must be used with caution.

In Position (Bit 8) This flag configures the "in position" Channel State flag to be used as additional "movement finished" condition for closed-loop movements.

If this flag is *not* set the "actively moving" Channel State flag is used to terminate a closed loop movement. A movement is reported as finished as soon as the positioner reaches the target position of a commanded movement (\pm Positioner Target Reached Threshold) for the first time. This guarantees fast feedback to the controlling application. Any potential overshoot or settling is not considered in this case. (However, with enabled Hold Time the control-loop corrects the overshoot, but *after* the movement has been reported as finished.) In some situations it may be useful to define an additional delay which must expire before the movement is reported as finished. Furthermore, an independent position threshold for the "in position" condition may be necessary. E.g. if it must be guaranteed that the positioner has settled at the target position before proceeding. In this case, this flag can be set to one. The "actively moving" Channel State flag then remains active and the `SA_CTL_EVENT_MOVEMENT_FINISHED` event is delayed after reaching the target until the "in position" condition is fulfilled too. Note that the In Position Threshold and In Position Delay properties must be configured to specify the "in position" condition. Refer to the "in position" Channel State flag description for more information. Note further that the Positioner Target Reached Threshold still applies to define the movement finished condition in the first place.

- Max Closed Loop Frequency*

Generally, the channel will not drive the positioner with frequencies above the maximum allowed frequency. If the maximum frequency is set too low for a certain move velocity, then the move velocity might not be reached or held. In this case the maximum frequency must be increased. Be aware that different positioners reach different velocities. If a positioner is not able to move as fast as the configured move velocity, then the driver will cap at the maximum driving frequency.

- Hold Time*

The channel may be instructed to hold the target position after it has been reached. This may be useful to compensate for drift effects and the like. The positioner will implicitly adjust the deflection of the piezo to hold the position if needed. When the piezo element of the positioner reaches a boundary a single step is performed. While holding the position the Channel State bit `SA_CTL_CH_STATE_BIT_CLOSED_LOOP_ACTIVE` is set and the bit `SA_CTL_CH_STATE_BIT_ACTIVELY_MOVING` is cleared. After the hold time elapsed the channel is stopped.

Note that the closed-loop movement is considered finished as soon as the target position is reached and *not* when the optional hold time has elapsed.

The channel's behavior in holding state when an endstop is detected depends on the type of the driver. Please refer to section 2.13 "Endstop Detection" for more information on the endstop detection while holding the position.

- Actuator Mode*

This mode defines the type of actuator driving signal generation.

- `SA_CTL_ACTUATOR_MODE_NORMAL` The normal mode is the default mode. It offers open-loop step movement as well as closed-loop movement.
- `SA_CTL_ACTUATOR_MODE_QUIET` The quiet mode only allows to perform closed-loop movement and reduces the noise that is emitted from the positioners while moving. It is useful in applications where the noise emission is disturbing. The trade-off between the quiet and the normal mode is the higher (generated) thermal load of the controller in quiet mode. For this reason the quiet mode is not recommended for continuous operation.
- `SA_CTL_ACTUATOR_MODE_LOW_VIBRATION` The low vibration mode allows to perform closed-loop movements which produce as little vibrations as possible. It is useful for applications where the high-frequent vibrations of the stick-slip driving principle cause troubles. Note that the low vibration mode requires the velocity and acceleration control to be active.

The low vibration mode needs a feature permission to be activated on the controller. See section 2.24 "Feature Permissions" for more information.

Once configured, call the `SA_CTL_Move` function to start the actual movement. While executing a closed-loop movement the Channel State bits `SA_CTL_CH_STATE_BIT_ACTIVELY_MOVING`

*This property is only available for Stick-Slip Piezo Driver.

and `SA_CTL_CH_STATE_BIT_CLOSED_LOOP_ACTIVE` are set. Refer to the sections 2.7.7 "Movement Feedback" and 2.7.8 "Movement States and Signals" for more details on the different Channel State bits and graphical examples of closed-loop movements.

2.7.5 Stopping Movements

The `SA_CTL_Stop` function stops any ongoing movement. The exact behavior of the different channel types is described in the following sections.

A digital input of an I/O module may be used to issue an emergency stop of all channels. See section 2.20.2 "Emergency Stop Mode" for more information.

Stick-Slip Piezo Driver

For closed-loop movements with *enabled* acceleration control (see Move Acceleration property) the "stop" command instructs the positioner to come to a halt by decelerating to zero velocity before stopping and disabling the control-loop. A second "stop" command triggers a hard stop.

For closed-loop movements with *disabled* acceleration control (Move Acceleration set to zero) the "stop" command immediately stops the movement and disables the control-loop. It also stops the hold position feature of a closed-loop command.

To command the channel to abort an ongoing movement and actively hold the current position ("enter holding"), set the Move Mode property to `SA_CTL_MOVE_MODE_CL_RELATIVE` and issue a `SA_CTL_Move` command with its move value parameter set to zero. The Hold Time property must be set to a non-zero value, otherwise the channel is stopped without actively holding the position. This command sequence may also be used to bring the channel from the *stopped* into the *holding* state to actively hold the current position without effectively commanding a movement.

For open-loop movements (Scanning and Stepping) the "stop" command immediately stops the movement.

Electromagnetic Driver

The `SA_CTL_Stop` function instructs the positioner to come to a halt by decelerating to zero velocity according to the configured Move Acceleration before entering the *holding* state. A second "stop" command triggers a hard stop by immediately entering the *holding* state at the current position. The `SA_CTL_Move` command with its move value parameter set to zero (and the Move Mode property set to `SA_CTL_MOVE_MODE_CL_RELATIVE`) also leads to a hard stop by entering the *holding* state at the current position.

To disable the control-loop (and to remove the holding force from the positioner) set the Amplifier Enabled property to `SA_CTL_DISABLED (0x00)`.

2.7.6 Overwriting Movement Commands

Generally, the function calls for movement commands (`SA_CTL_Move`, `SA_CTL_Calibrate`, `SA_CTL_Reference`) return as soon as the command has been transmitted to the hardware; the calls do not block as long as the command is in execution. Therefore, the software is free to issue new commands to the hardware (potentially to other channels) while the movement is being performed. In particular, new movement commands may also be sent to the same channel at any time. This will cause the previous movement command to be implicitly aborted. Note that there is no need to explicitly stop a channel before sending a new movement command. The new command will simply overwrite the current one.

Note on working with events: Overwriting movement commands (sending movement commands before the command finished event of the previous command has arrived) leads to a race condition. The second command might arrive just before the first has completed, thus, only one command complete event is generated (when the second command completes). However, if the second command arrives just after the first has completed, two command complete events are generated (one for each command).

Note on working with a Hand Control Module: Special care must be taken when using a hand control module and a software running on a PC at the same time. The hand control module sets several movement relevant properties (like move velocity, move acceleration, hold time, step frequency, step amplitude, etc.) prior to commanding a movement command. Thus user software must not rely on previously configured parameters since they may have been modified in the meantime by the hand control module. To be on the safe side, user software may set the Hand Control Module Lock Options property to disable the control inputs of the hand control module during its operation.

2.7.7 Movement Feedback

Movement commands are generally executed asynchronously by the device. Particularly, the API functions do not block for the duration of the execution of the movement. Instead, the functions simply trigger the start of the movement and the software may perform other tasks while the positioner is in motion (e.g. tracking the movement and continuously display the current position).

When issuing movement commands it is usually desirable to know if the movement could successfully be started and especially when the controller has finished the movement (e.g. found the reference mark, reached the target position, etc.). Generally, there are two methods of acquiring this information:

- Polling the Channel State property
- Listening to events

Polling

The Channel State property always indicates the current state of the channel. It may be used to check whether the positioner is moving, holding, stopped etc. The four lower state bits are of interest in this context. The following table summarizes the valid combinations and their meanings:

Bit 3 Referencing	Bit 2 Calibrating	Bit 1 Closed Loop Active	Bit 0 Actively Moving	Activity
0	0	0	0	Stopped / Control-loop disabled
0	0	0	1	Performing an open-loop movement (stepping or scanning) or phasing sequence
0	0	1	0	Holding the current target position (after a closed-loop movement)
0	0	1	1	Performing a closed-loop movement (moving to target position)
0	1	0	1	Performing a calibration sequence
1	0	1	1	Performing a reference sequence

Note that it is guaranteed that the channel state flags are updated at the time at which a movement command arrives. The next channel state request reflects the started movement. (Assuming the movement can actually be started and no error is generated.) An application can count on this behavior and thus there is no need to poll the Channel State until the corresponding flags become one indicating the start of the movements *before* waiting for the finish of the movement.

Since movement commands are always sent asynchronously to the device, they do not return an acknowledge or error directly. Instead, events are generated. (See next section.)

If event notifications are not used, the success or failure of a movement command may be determined by monitoring the `SA_CTL_CH_STATE_BIT_MOVEMENT_FAILED` bit of the Channel State property. The flag is set to zero if the movement could successfully be started. If the flag is read as one an error occurred. The movement could not be started or the execution failed. The reason for the failure may then be determined by reading the Channel Error property. Note that the channel error is reset to `SA_CTL_ERROR_NONE` by reading the property.

Further state flags may be monitored to indicate if the execution of a movement could not finish. (E.g. if an endstop was detected while executing the movement). Their meaning is described in section 2.10.3 "Channel State Flags".

Events

Generally, every movement command (including calibrating and referencing) generates an event of type `SA_CTL_EVENT_MOVEMENT_FINISHED` when the execution has finished. Note that a movement is also considered as "finished" if it could not be started due to an error, e.g. an invalid

parameter or a closed-loop movement could not be executed, because the sensor is offline. In any case the event parameter will indicate the result of the movement execution. The following table lists the most common event parameters:

Table 2.2 – Movement Finished Event Parameters

Parameter	Meaning
SA_CTL_ERROR_NONE	The movement finished with no error. In this case the event occurs at the time when the movement has finished, e.g. when reaching the target position.
SA_CTL_ERROR_INVALID_PARAMETER	The movement could not be executed because a parameter was invalid.
SA_CTL_ERROR_ABORTED	The movement was started, but then aborted by a stop command. In this case the event occurs at the time the controller received the stop command.
SA_CTL_ERROR_NO_SENSOR_PRESENT, SA_CTL_ERROR_SENSOR_DISABLED	The closed-loop movement could not be started, because no sensor is (currently) available.
SA_CTL_ERROR_POWER_SUPPLY_DISABLED, SA_CTL_ERROR_AMPLIFIER_DISABLED	The movement could not be started, because the power supply / amplifier is disabled.
SA_CTL_ERROR_END_STOP_REACHED	The closed-loop movement was started, but could not be finished normally, because an end stop was encountered.
SA_CTL_ERROR_FOLLOWING_ERR_LIMIT	The closed-loop movement was started, but could not be finished normally, because an following error limit was exceeded.
SA_CTL_ERROR_RANGE_LIMIT_REACHED	The closed-loop movement was started, but could not be finished normally, because a range limit was reached.
SA_CTL_ERROR_BUSY_STREAMING	The movement could not be started, because the channel is currently participating in a trajectory stream.
SA_CTL_ERROR_NOT_PHASED	The movement could not be started, because the channel is not phased.
SA_CTL_ERROR_NOT_CALIBRATED	The movement could not be started, because the channel is not calibrated.
SA_CTL_ERROR_POSITIONER_FAULT	The movement could not be started, because the channel has detected a positioner fault and the amplifier was disabled.

Continued on next page

Table 2.2 – Continued from previous page

Parameter	Meaning
SA_CTL_ERROR_POSITIONER_OVERLOAD	The movement could not be started, because the channel detected a thermal overload of the positioner and the closed-loop operation was disabled.

The full list of error codes may be found in the appendix A.1 "Error Codes".

2.7.8 Movement States and Signals

This section describes the different Channel State flags, events and signals of a closed-loop movement by two graphical examples. This may help to understand their interaction.

Figure 2.6 and 2.7 show the position over time of a closed-loop movement. The current position is displayed with a decent amount of over shoot to illustrate the influence of the position thresholds on the state signals. For both movements the Hold Time¹ property is configured to a non zero value and a velocity is set. The In Position Threshold x_2 is configured to be twice the value of the Positioner Target Reached Threshold x_1 . The movements differ in the settings of the Positioner Control Options and In Position Delay properties. The resulting behavior is described in the following sections.

Note that the "actively moving", "target reached" and "in position" signals are also available as electrical output signals of an I/O module. For this, the output trigger component must be configured to output the desired signal. See section 2.21 "Output Trigger" for more information.

Movement with *disabled* "In Position" Control Option and In Position Delay = 0

For the movement in figure 2.6 the "In Position" Positioner Control Options flag is disabled and the In Position Delay is set to zero.

Initially the channel is in the holding state actively holding the current position. For this, the control-loop must be active which is indicated by the "closed-loop active" Channel State flag.

At time t_1 the closed-loop movement is started with a SA_CTL_Move command. The channel is now actively moving towards the target position with the configured velocity. The "actively moving" Channel State flag goes high and the "in position" Channel State flag goes low to indicate that the channel is no longer "in position".

At time t_3 the positioner's current position reaches the commanded target (\pm the Positioner Target Reached Threshold x_1) for the first time. At this time the "actively moving" Channel State flag goes low and the movement is reported as "finished" with a SA_CTL_EVENT_MOVEMENT_FINISHED event. Since there is a Hold Time¹ specified for the movement the channel enters the holding state and the control-loop continues to compensate the overshoot for the time of d_2 .

¹This property is only available for Stick-Slip Piezo Driver.

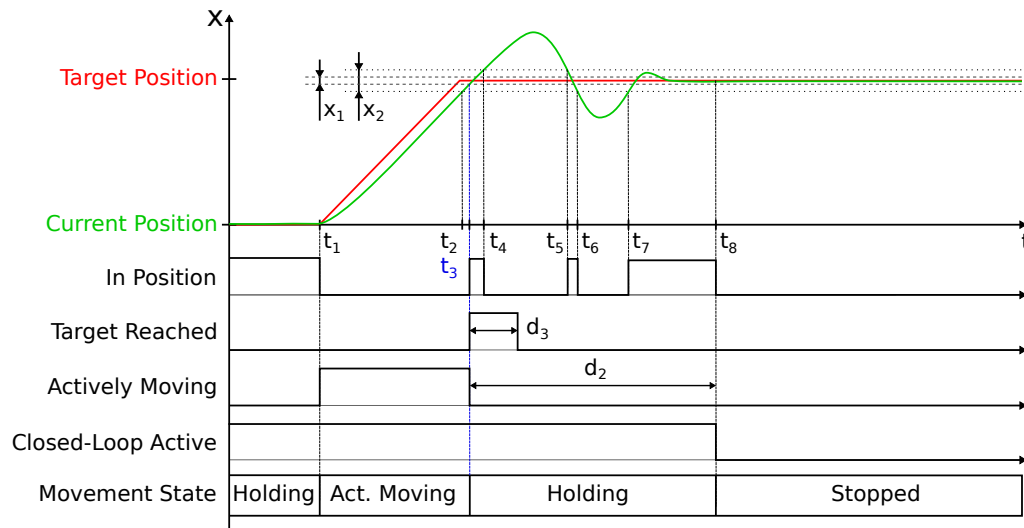


Figure 2.6: Movement States and Signals 1

Also at time t_3 the "target reached" signal of a digital output of an I/O module is generated with the Channel Output Trigger Pulse Width of d_3 .

As soon as the current position is within the configured In Position Threshold near the target and the channel is holding the position (t_3 to t_4 , t_5 to t_6 and t_7 to t_8), the "in position" Channel State flag goes high. Since the In Position Delay is set to zero only the In Position Threshold defines when the signal is high, which results in the flickering of the signal. Note that the target must have been reached *before* the channel can be "in position". (The "in position" signal goes high at time t_3 and *not* at time t_2 .)

At time t_8 the Hold Time d_2 has elapsed and the channel enters the stopped state. The control-loop is disabled and the channel no longer actively holds the current position. Therefore, the channel can no longer be "in position". The "closed-loop active" Channel State flag goes low. Electromagnetic Driver channels remain in the holding state at time t_8 .

Movement with *enabled* "In Position" Control Option and In Position Delay > 0

For the movement in figure 2.7 the "In Position" Positioner Control Options flag is enabled and an In Position Delay of d_1 is specified. With this configuration the channel must be "in position" before the movement is reported as "finished".

At time t_1 the closed-loop movement is started with a `SA_CTL_Move` command. The channel is now actively moving towards the target position with the configured velocity. The "actively moving" Channel State flag goes high and the "in position" Channel State flag goes low to indicate that the channel is no longer "in position".

At time t_2 the positioner's current position reaches the commanded target (\pm the Positioner Target Reached Threshold x_1) for the first time. This is a precondition for the "in position" Channel State flag to become high. Because the "In Position" Positioner Control Options flag is enabled, the movement is *not* yet reported as "finished" since the channel is not yet "in position" (i.e. has not yet settled). The "actively moving" Channel State flag remains active.

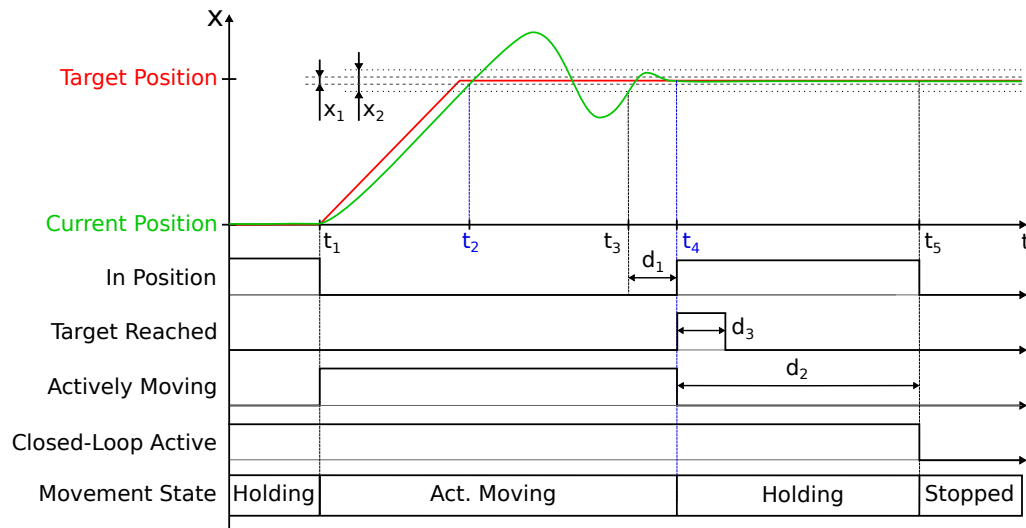


Figure 2.7: Movement States and Signals 2

As soon as the current position stays within the configured In Position Threshold near the target (t_3) for longer than the In Position Delay of d_1 , the "in position" Channel State flag goes high (t_4).

Now the "actively moving" Channel State flag goes low and the movement is reported as "finished" with a `SA_CTL_EVENT_MOVEMENT_FINISHED` event. Since there is a Hold Time¹ specified for the movement the channel enters the holding state and the control-loop continues to compensate any drift for the time of d_2 .

Also at time t_4 the "target reached" signal of a digital output of an I/O module is generated with the Channel Output Trigger Pulse Width of d_3 .

At time t_5 the Hold Time d_2 has elapsed and the channel enters the stopped state. The control-loop is disabled and the channel no longer actively holds the current position. Therefore, the channel can no longer be "in position". The "closed-loop active" Channel State flag goes low. Electromagnetic Driver channels remain in the holding state at time t_5 .

2.8 Defining Positions

Since position calculation is done on an incremental basis, the MCS2 controller has no way of knowing the physical position of a positioner after a system power-up. It simply assumes its starting position as the zero position.

However, in many applications it is convenient to define a certain physical position as the zero position. The Position property may be set for this purpose. It defines the current position to have an arbitrary value. This can be the zero position or any other position (it is possible to have the zero position outside the complete travel range of the positioner).

Figure 2.8 shows an example of a linear positioner. (a) shows the situation after a system power-up. The positioner assumes its current position as zero. (b) shows the situation after the Position property was set. The current position has been defined to +3 mm and the measuring scale is shifted accordingly.

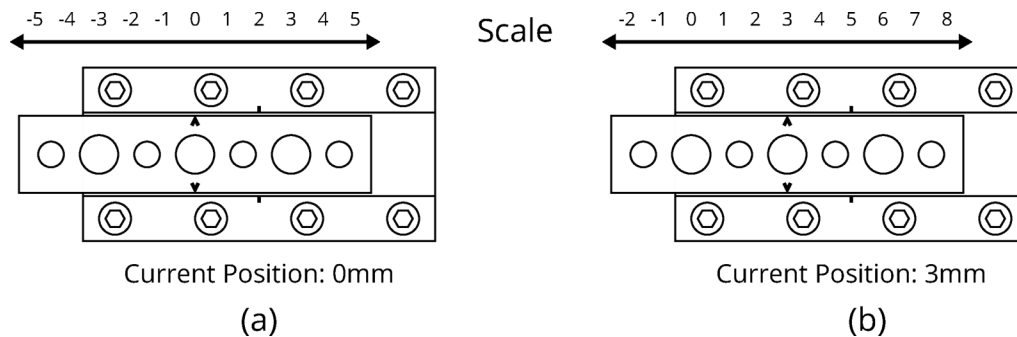


Figure 2.8: Scale Shift

2.8.1 Reference Marks

In the example above the physical position of a positioner must be determined by some external method and then configured to the system. Moreover, this procedure must be done on every system power-up.

To overcome this inconvenience the `SA_CTL_Reference` function may be used to determine the physical position in an automated fashion. After this the controller will return position values according to the positioners physical measuring scale (but see section 2.8.5 "Shifting the Measuring Scale").

Regarding the referencing, positioner types fall into one of three possible categories:

- **Single Reference Marks** The reference mark of positioners with a single mark is usually located near the middle of the travel range. The positioner will have to move to this mark in order to know its physical position.
- **Multiple Reference Marks** Positioners of this type may calculate their physical position by measuring the distance between two adjacent marks. This has the advantage that the positioner typically only has to move a few milli meters before knowing its physical position which is exceptionally useful when using positioners with very long travel ranges.

- **Endstop Reference Type** Positioners without any reference marks may use the mechanical endstop at the end of their travel range as a known physical position.

The behavior of the positioner while referencing depends on the *positioner type* that is attached to the channel (see Positioner Type property) as well as the configured *referencing options* (see Referencing Options property). The referencing options modify the behavior of the referencing algorithm. Currently, the following bits are available:

Table 2.3 – Referencing Options Bits

Bit	Name	Short Description
0	Start Direction	Defines the direction in which the positioner will start to look for a reference. The movement starts in <i>backward</i> direction if this flag is set.
1	Reverse Direction	Only relevant for positioners that have multiple reference marks. Will reverse the search direction as soon as the first reference mark is found.
2	Auto Zero	The current position is set to zero upon finding the reference position.
3	Abort On End Stop	Will abort the referencing on the first end stop that is encountered.
4	Continue On Reference Found	Will not stop the movement of the positioner once the reference is found. The positioner must be stopped manually.
5	Stop On Reference Found	Will stop the movement of the positioner immediately after finding the reference.
24	Invalidate	Invalidates the "is referenced" Channel State flag.

Undefined flags are reserved for future use. These flags should be set to zero.

Basically, the different mode flags may be combined to obtain a flexible behavior when referencing positioners. However, bits 4 and 5 cannot be combined. If both bits are set then the Stop On Reference Found (bit 5) has priority over Continue On Reference Found (bit 4). Furthermore, not all bits are valid for all positioner types. E.g. for endstop referenced positioners all option flags except the auto-zero flag are ignored. See the detailed description of the mode flags below.

When the `SA_CTL_Reference` command has completed successfully, the system knows the physical position of the positioner (see `SA_CTL_CH_STATE_BIT_IS_REFERENCED` of the Channel State property).

2.8.2 Positioners With Single Reference Marks

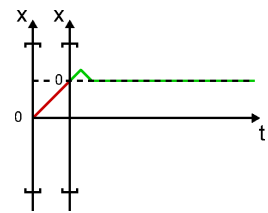
This section describes the behavior while referencing positioners with only one reference mark in more detail. The images on the right side illustrate the behavior of an example positioner that

is being referenced. The vertical x-axis represents the travel range of the positioner. The square brackets indicate mechanical end stops. The dashed line indicates the position of the reference mark.

In the examples the positioner always starts at position 0 and the physical position is unknown (red line). Once the reference mark has been found the physical position will become known (green line). It is assumed that the physical zero position is on the reference mark.

Default Behavior (referencing options 0b00000000)

By default the positioner will start to move in forward (positive) direction and look for a reference mark. As soon as the positioner has passed over the reference mark the internal position will be updated. This is indicated by the second x-axis having a different scale shift.



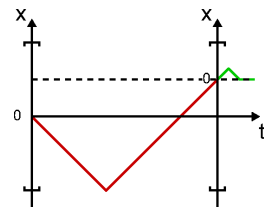
The small overshoot represents the reaction time of the positioner stopping. The amount of the overshoot depends on factors like the velocity with which the referencing is performed, the mass that is mounted on the positioner or a possibly configured acceleration control (in which case it takes some time to decelerate the positioner).

The positioner will turn around and move to the exact location of the reference mark. After this the referencing is complete.

Inverted Start Direction (referencing options 0b00000001)

Same as the default referencing, with the difference that the positioner will start to move in backward direction and look for a reference mark.

In this example the positioner will encounter a physical end stop before finding the mark. The positioner will automatically reverse its search direction at the end stop and continue to look for the reference mark.

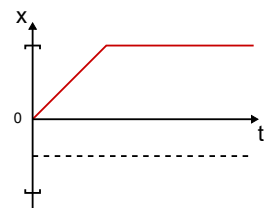


Abort On End Stop (referencing options 0b00001000)

As described above, by default the positioner will start to look for a reference mark in the start direction and reverse the search direction if a physical end stop is detected.

If the abort on end stop flag is set then the positioner will *not* reverse the search direction on detecting a physical end stop. Instead it will stop and generate an error which means that the referencing is aborted and considered as failed.

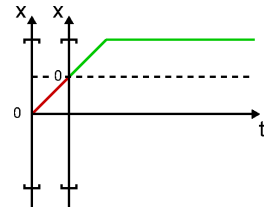
This setting may be useful when it is necessary to forbid the movement of the positioner in a direction other than the initial search direction.



Continue On Reference Found (referencing options 0b00010000)

Compared to the default referencing behavior this flag causes the positioner to continue to move in the current search direction after the reference has been found. The positioner does *not* stop or even turn around to return to the exact location of the reference mark. Instead the positioner must be stopped manually (or it is implicitly stopped by a physical end stop). Once the reference mark has been found a `SA_CTL_EVENT_REFERENCE_FOUND` event is generated and the `SA_CTL_CH_STATE_BIT_REFERENCING` Channel State bit is cleared.

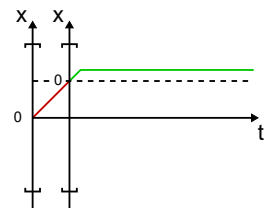
This setting may be useful e.g. when referencing several positioners synchronously that are mechanically connected in a parallel kinematic. A setup like this could cause one positioner to block and therefore fail to reference if another positioner has stopped because it has already found its reference mark.



Stop On Reference Found (referencing options 0b00100000)

Compared to the default referencing behavior this flag causes the positioner to stop moving as soon as the reference has been found. The positioner does *not* turn around and return to the exact location of the reference mark. Instead the positioner simply stops where it is.

This implies that due to the small overshoot described above the positioner will not come to stop exactly on the reference mark. Since in these examples the zero position is on the reference mark, the position will not be zero after the referencing has completed.



2.8.3 Positioners With Multiple Reference Marks

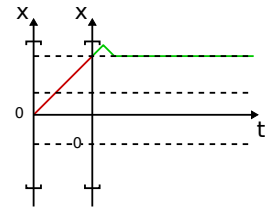
This section describes the behavior while referencing positioners with multiple reference marks in more detail. The general principle is that the positioner must pass over two adjacent reference marks. The physical position may then be determined by measuring the distance between these two marks. This method reduces the distance a positioner has to travel to determine its physical position compared to single reference marks, especially when operating with positioners with very long travel ranges.

As in the previous section the images on the right side illustrate the behavior of an example positioner that is being referenced. The vertical x -axis represents the travel range of the positioner. The square brackets indicate mechanical end stops. The dashed line indicates the positions of the reference marks.

In the examples the positioner always starts at position 0 and the physical position is unknown (red line). Once the reference mark has been found the physical position will become known (green line).

Default Behavior (without auto-zero, referencing options 0b00000000)

By default the positioner will start to move in forward (positive) direction and look for a reference mark. When the positioner has found the first reference mark it will continue to move in forward direction and look for a second mark. As soon as the positioner has passed over the second reference mark the internal position will be updated according to the physical scale of the positioner. This is indicated by the second x-axis having a different scale shift. At this point the logical scale offset will also be considered, which restores a previously set scale (e.g. referenced with auto-zero in the previous session). Note that this also applies if the controller is power cycled between sessions since the logical scale offset is held in non-volatile memory. The distance-coded reference marks make it possible to use *any* two reference marks of the positioner to restore the same absolute scale.

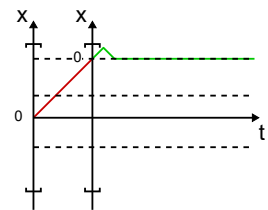


As in the previous examples the small overshoot in the image represents the reaction time of the positioner stopping. The amount of the overshoot depends on factors like the velocity with which the referencing is performed, the mass that is mounted on the positioner or a possibly configured acceleration control (in which case it takes some time to decelerate the positioner).

The positioner will turn around and move to the exact location of the second reference mark. After this the referencing is complete.

Auto-Zero Behavior (with auto-zero, referencing options 0b00000100)

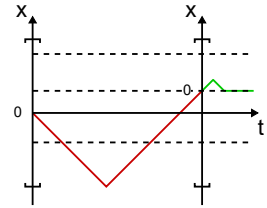
Just like the default behavior, the positioner will move in forward (positive) direction and look for two reference marks. The main difference to the default behavior is, that as soon as the positioner has passed over the second reference mark the internal position will be set to 0 and the logical scale offset will be updated accordingly. This is indicated by the second x-axis having a different scale shift with the positioner stopping at 0. This mode may be used for the initial setup of a system to define the absolute scale (respectively to define the zero position of the scale). Once defined, the default referencing mode may be used in later sessions to restore the same scale.



Inverted Start Direction (with auto-zero, referencing options 0b00000101)

Same as the default referencing, with the difference that the positioner will start to move in backward direction and look for two reference marks.

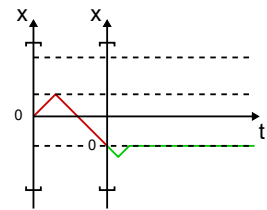
In this example the positioner passes over the first reference mark, but encounters a physical end stop before finding the second mark. The positioner will automatically reverse its search direction at the end stop and restart looking for a first reference mark.



As in the previous section please note that if the positioner should encounter a second end stop then the reference algorithm will be aborted. The positioner is stopped and an error event is generated. Reasons for this situation may be a mechanical or electrical defect (the controller does not register the reference signal for some reason) or the available travel range does not cover two reference marks (e.g. the positioner has bumped against an obstacle).

Reverse Direction (with auto-zero, referencing options 0b00000110)

In this mode the positioner will start to move in forward (positive) direction and look for a reference mark. When the positioner has found the first reference mark it will *reverse* the movement direction and look for a second mark. As soon as the positioner has passed over the second reference mark the internal position will be updated (in this case set to 0 due to the auto-zero flag). This is indicated by the second x-axis having a different scale shift.



As in the previous examples the small overshoot represents the reaction time of the positioner stopping. The amount of the overshoot depends on factors like the velocity with which the referencing is performed, the mass that is mounted on the positioner or a possibly configured acceleration control (in which case it takes some time to decelerate the positioner).

The positioner will turn around and move to the exact location of the second reference mark. After this the referencing is complete.

This mode may further reduce the distance traveled by the positioner to determine its physical position.

2.8.4 Positioners With Endstop Reference

This section describes the behavior while referencing positioners with an endstop reference type in more detail. The general principle is to move the positioner towards one end of the travel range until a mechanical endstop is detected. The sensor signals are then used to align the position to the reference position with high repeat accuracy.

For these types of positioners the physical measuring scale is defined such that the zero position lies near the mechanical end stop that is used for referencing. Note that the scale therefore depends on the Safe Direction as well as the Logical Scale Inversion setting.

Positioners with an endstop reference type use the additional Safe Direction property to define the direction of the referencing movement instead of the start direction bit of the Referencing Options property.

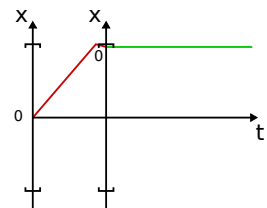
All Referencing Options flags except the auto-zero flag are ignored when referencing towards an endstop.

Note that the end stop must be calibrated with `SA_CTL_Calibrate` before it can be properly used as a reference point.

Default Behavior (with auto-zero, referencing options 0b0000100)

In this mode the positioner will start moving towards the configured Safe Direction and look for a mechanical end stop. In this example the Safe Direction is assumed to be set to forward (positive) direction.

Once the positioner has found the mechanical end stop it will move a short distance away from the end stop to find the exact reference using the position that was determined while calibrating the endstop.



As in the previous section the images on the right side illustrate the behavior of an example positioner that is being referenced. The vertical x-axis represents the travel range of the positioner. The square brackets indicate mechanical end stops.

In the examples the positioner starts at position 0 and the physical position is unknown (red line). Once the positioner is referenced the physical position will become known (green line). The auto-zero flag is assumed to be set so the position will be set to zero once the physical position has been determined.

2.8.5 Shifting the Measuring Scale

The *physical* measuring scale of a positioner is fix and cannot be changed. However, the MCS2 controller uses a *logical* measuring scale when calculating positions. The logical measuring scale may be shifted and/or inverted by the user so that the controller returns a desired position value at a certain physical position.

The relation between the physical and the logical scale is defined by two parameters. The *offset* value (which represents the shift) and the *inversion* value (which inverts the count direction) of the logical scale relative to the physical scale. The default value of the offset and the inversion is zero which makes the physical and the logical scale identical.

There are two methods to modify the offset value:

- Writing the Position property sets the offset implicitly by shifting the logical scale so that the current position equals the desired value.
- Writing the Logical Scale Offset property sets the offset explicitly and the current position will have a value that reflects the new scale shift.

The inversion value may be set by writing the Logical Scale Inversion property.

The offset and inversion values are stored in non-volatile memory. Once it is configured you only need to call the `SA_CTL_Reference` function to restore your settings on future power-ups.

Note: The behavior of the system when writing the Position property differs slightly depending on whether the physical position is known or not. When the physical position is unknown then writing the Position property will not update the scale offset value in the non-volatile memory. Likewise, writing the Logical Scale Offset property will have no immediate effect on the values read from the Position property. The following table summarizes the behavior.

	Physical position is known		Physical position is unknown	
	Set Position	Set Logical Scale	Set Position	Set Logical Scale
Offset value is written to non-volatile memory	yes	yes	no	yes
Function call has immediate effect on position values	yes	yes	yes	no

2.9 Device Monitoring

The MCS2 has several features to monitor the state of the device. Monitoring can be done by polling specific properties or by listening to events the device generates.

The Device State, Module State and Channel State properties hold state flags which can be checked to detect a failure of a movement command or a malfunction of the device. See section 2.10 "State Flags" for the meaning of the flags.

2.9.1 Movement Monitoring

Section 2.7.7 "Movement Feedback" describes the possibilities to obtain **movement feedback** by either polling the Channel State property, reading the Channel Error property to determine the reason for a movement failure or listening to the `SA_CTL_EVENT_MOVEMENT_FINISHED` event.

The **following error** of a positioner for closed-loop movements can be monitored by reading the Following Error property. An additional limit property may be set. In case the following error exceeds the configured limit a `SA_CTL_EVENT_FOLLOWING_ERR_LIMIT` event is generated and the movement may be stopped automatically. See section 2.14 "Following Error Detection" for the configuration of this feature.

2.9.2 Overload Protection

The MCS2 driver modules monitor the output energy of each channel to detect an overload condition of positioners. This prevents thermal overheating and potential damage to the positioners (e.g. piezo elements, coils, isolation and permanent magnets) and therefore does not require additional temperature sensors in the positioners.

The present load level may be read with the Motor Load property, given as a percentage. This may be useful to estimate the motor load while performing movements *before* the overload protection triggers and aborts a movement. In case the motor load reaches a critical level it should be reduced, e.g. by limiting velocities, accelerations and/or the mechanical load attached to the positioner.

If the load level exceeds a specified limit (see below) the overload protection triggers and the movement is aborted to protect the positioner. This is indicated by the `SA_CTL_CH_STATE_BIT_POSITIONER_OVERLOAD` Channel State bit. A currently executed movement is aborted and a `SA_CTL_EVENT_MOVEMENT_FINISHED` event with its parameter set to `SA_CTL_ERROR_POSITIONER_OVERLOAD` is generated. The overload flag is cleared automatically after the load level has dropped under a defined level again. After this a new movement may be commanded. Alternatively for electromagnetic positioners, the `SA_CTL_Stop` command may be used to enter the *holding* state.

Stick-Slip Piezo Driver Load Level

For stick-slip positioners the following factors mainly influence a thermal build up:

- the number of performed steps per time interval (i.e. the step frequency)
- the voltage amplitude of the performed steps
- the electrical capacity of the piezo-element.

Whenever a movement is performed the channel continuously estimates the energy that is dissipated in the positioner and calculates the load level. Note that the correct Positioner Type for the corresponding channel must be configured to ensure the proper drive capacitance is used for the calculations.

For these positioners the threshold at which the overload is triggered is defined by the Motor Overload Protection Threshold property. In this case it is optional and disabled by default.



NOTICE

For applications or environments with a low thermal conductivity it is highly recommended to configure the overload threshold to a level appropriate to the application. Otherwise the life time of the positioners may be reduced drastically. For more information see User Guide PT-UG00003.

Electromagnetic Driver Load Level

For electromagnetic positioners the following limiting parameters are defined for every positioner type:

- the continuous current limit
- the maximum (intermittent) current limit
- the permitted time constant

The **continuous current limit** specifies the highest current level the driver can apply continuously without overheating the positioner.

The **maximum (intermittent) current limit** specifies the highest current level the driver can apply for a specified **permitted time**. (Typically in the range of a few seconds.) This higher limit makes it possible to improve the performance of a movement by using a higher current for a short time, e.g. to accelerate and decelerate the positioner.

Whenever the control-loop is enabled the channel continuously integrates the square of the current. Because resistive heat generation is proportional to the square of the current this method gives a reasonable representation of the generated thermal load of the positioner. The difference between the squared present current and the squared continuous current is accumulated which makes up the load level.

For these positioners the threshold at which the overload is triggered is defined by the controller and cannot be changed or disabled. Furthermore, when the overload triggers the control-loop is disabled which may have further consequences:

**NOTICE**

Electromagnetic driven positioners are not self-locking. Disabling the control-loop removes any holding force from the positioner. Make sure not to damage any equipment when the positioner changes its position unintentionally!

2.9.3 Hardware Monitoring

The MCS2 offers limited hardware monitoring of critical components. This includes the temperature of the internal amplifiers and the voltage of the power supply.

Temperature

If an **over-temperature** condition is detected on a channel then the corresponding amplifier is shut down automatically to protect it from being damaged. This is indicated by the Channel State bit `SA_CTL_CH_STATE_BIT_OVER_TEMPERATURE`.

Additionally, the `SA_CTL_MOD_STATE_BIT_OVER_TEMPERATURE` flag of the Module State is set if *any* channel of the module shows the over-temperature flag (logical OR of the channel flags) and a `SA_CTL_EVENT_OVER_TEMPERATURE` event is generated to inform the user. Positioner movements in this state are not permitted. Once the amplifier has cooled down to a safe temperature the over-temperature flags are cleared and the channel may then be used again normally.

The diagnostic properties Channel Temperature and Bus Module Temperature may be used to read the current temperatures. (See there for more information.)

Cooling Fan

The `SA_CTL_MOD_STATE_BIT_FAN_FAILURE` flag of the Module State property indicates a **fan failure** for MCS2 devices which are equipped with a cooling fan.¹ This may be a blockage or damage of the fan. A `SA_CTL_EVENT_FAN_FAILURE_STATE_CHANGED` event is generated to inform the user. Note that the fan is temperature-controlled and thus disabled most of the time as long as the device temperature is within the normal range.

For some special applications it may be useful to override the automatic fan control. See the Min Fan Level property for more information.

Power Supply

The `SA_CTL_MOD_STATE_BIT_POWER_SUPPLY_OVERLOAD` flag of the Module State property indicates a **power supply overload**. A `SA_CTL_EVENT_POWER_SUPPLY_OVERLOAD` event is generated to inform the user. Note that an overload may be caused by a defective positioner or wiring. Remove the positioners and check for any damages. Once the failure is eliminated, the overload flag is cleared automatically.

¹The fan failure detection is currently only available for Electromagnetic Driver.

The `SA_CTL_MOD_STATE_BIT_POWER_SUPPLY_FAILURE` flag of the Module State property indicates a **power supply failure**. A `SA_CTL_EVENT_POWER_SUPPLY_FAILURE` event is generated to inform the user. Note that this failure points to a hardware damage. The controller should be powered down and checked by SmarAct in this case.

Positioner Faults

The Electromagnetic Driver may detect a defective positioner. A positioner fault is indicated by the Channel State bit `SA_CTL_CH_STATE_BIT_POSITIONER_FAULT`. In case of a fault the control-loop is disabled immediately and the channel enters the *stopped* state. The Positioner Fault Reason property may then be read to determine the fault reason. The positioner must be disconnected from the controller and should be checked by SmarAct in this case.

2.10 State Flags

The Device State, Module State and Channel State properties are used to obtain the current state of the controller. While the Device State and Module State mainly give information about global hardware states and available modules, the most prominent state property, the Channel State, may be used to get feedback for the current movement of a channel. As an alternative to using events, the Channel State may be polled continuously by an application to control the movement sequence. See section 2.7.7 "Movement Feedback" for more information.

The meaning of the different state flags is described in the following sections.

2.10.1 Device State Flags

The device state may be read from the Device State property. The value is a bit field containing independent flags. Undefined flags are reserved for future use. Therefore, the user software should not rely on a static value of undefined flags. The following flags are defined:

Bit	C-Definition	Mask
0	SA_CTL_DEV_STATE_BIT_HM_PRESENT	0x00000001
1	SA_CTL_DEV_STATE_BIT_MOVEMENT_LOCKED	0x00000002
2	SA_CTL_DEV_STATE_BIT_AMPLIFIER_LOCKED	0x00000004
3	SA_CTL_DEV_STATE_BIT_IO_MODULE_INPUT	0x00000008
4	SA_CTL_DEV_STATE_BIT_GLOBAL_INPUT	0x00000010
8	SA_CTL_DEV_STATE_BIT_INTERNAL_COMM_FAILURE	0x00000100
12	SA_CTL_DEV_STATE_BIT_IS_STREAMING	0x00001000

HM Present (bit 0)

This flag indicates that a hand control module is attached to the device.

Movement Locked (bit 1)

This flag indicates that the device is locked due to an emergency stop condition. (See section 2.20.2 "Emergency Stop Mode".)

Amplifier Locked (bit 2)

This flag indicates that the driver amplifiers are locked by an external electrical input signal. (See section 2.20.6 "Amplifier Lock Mode".)

I/O Module Input (bit 3)

This flag reflects the electrical level of the digital device input of an I/O module. Note that this flag shows the electrical level of the input independently from the configured polarity and mode of the input trigger component. Since the idle level of the I/O module input is low, the flag is cleared if no voltage is applied to the input (or no I/O module is available). (See section 2.20 "Device Input Trigger".)

Global Input (bit 4)

This flag reflects the electrical level of the digital global input of an MCS2 rack housing. Note that this flag shows the electrical level of the input independently from the configured polarity and mode of the input trigger component. Since the idle level of the global input is high, the flag is set if the input is not tied to ground level (or the input is not available). (See section 2.20 "Device Input Trigger".)

Internal Communication Failure (bit 8)

This flag indicates that an internal communication failure has occurred. This suggests a hardware defect. Please contact SmarAct.

Is Streaming (bit 12)

This flag indicates that the device is currently performing a trajectory stream (see section 2.18 "Trajectory Streaming").

2.10.2 Module State Flags

The module state may be read from the Module State property. The value is a bit field containing independent flags. Undefined flags are reserved for future use. Therefore, the user software should not rely on a static value of undefined flags. The following flags are defined:

Bit	C-Definition	Mask
0	SA_CTL_MOD_STATE_BIT_SM_PRESENT	0x00000001
1	SA_CTL_MOD_STATE_BIT_BOOSTER_PRESENT	0x00000002
2	SA_CTL_MOD_STATE_BIT_ADJUSTMENT_ACTIVE	0x00000004
3	SA_CTL_MOD_STATE_BIT_IOM_PRESENT	0x00000008
8	SA_CTL_MOD_STATE_BIT_INTERNAL_COMM_FAILURE	0x00000100
11	SA_CTL_MOD_STATE_BIT_FAN_FAILURE [*]	0x00000800
12	SA_CTL_MOD_STATE_BIT_POWER_SUPPLY_FAILURE	0x00001000
12	SA_CTL_MOD_STATE_BIT_HIGH_VOLTAGE_FAILURE ¹	0x00001000
13	SA_CTL_MOD_STATE_BIT_POWER_SUPPLY_OVERLOAD	0x00002000
13	SA_CTL_MOD_STATE_BIT_HIGH_VOLTAGE_OVERLOAD ¹	0x00002000
14	SA_CTL_MOD_STATE_BIT_OVER_TEMPERATURE	0x00004000

SM Present (bit 0)

This flag indicates whether a Sensor Module is currently attached to the Driver Module.

Booster Present (bit 1)

This flag indicates whether the Driver Module is equipped with a booster for high current signal output.

Adjustment Active (bit 2)

This flag indicates whether the module is performing an adjustment for the SmarAct PicoScale Laserinterferometer.

I/O Module Present (bit 3)

This flag indicates whether the Driver Module is equipped with an I/O Module.

Internal Communication Failure (bit 8)

This flag indicates that an internal communication error has occurred. This suggests a hardware defect. Please contact SmarAct.

^{*}This module state bit is only valid for Electromagnetic Driver.

¹This definition is deprecated and may be removed in future releases.

Fan Failure (bit 11)

This flag indicates that the module detected a failure of the cooling fan. Check for a blockage of the fan and make sure that it can spin freely.

High Voltage / Power Supply Failure (bit 12)

This flag indicates that the module detected a power supply failure. This suggests a hardware defect. Please contact SmarAct.

High Voltage / Power Supply Overload (bit 13)

This flag indicates that the module detected a power supply overload condition. For Stick-Slip Piezo Driver this can have two main reasons:

- A short circuit between one of the HV+ signals with HV- (or shield). Removing the short circuit will automatically clear the flag again.
- Driving a positioner continuously at high frequencies for too long may overload the power amplifier. Stopping positioners and letting the amplifier cool down will reset the flag.

Over Temperature (bit 14)

This flag indicates that the module detected an over temperature condition. This will shut down the power amplifier to prevent thermal damage. As soon as the temperature drops to a non-critical level the amplifier is enabled again and the flag is cleared.

Note that this flag is rarely raised under normal conditions and may indicate improper cooling, such as a fan failure.

2.10.3 Channel State Flags

The channel state may be read from the Channel State property. The value is a bit field containing independent flags. Undefined flags are reserved for future use. Therefore, the user software should not rely on a static value of undefined flags. The following flags are defined:

Bit	C-Definition	Mask
0	SA_CTL_CH_STATE_BIT_ACTIVELY_MOVING	0x00000001
1	SA_CTL_CH_STATE_BIT_CLOSED_LOOP_ACTIVE	0x00000002
2	SA_CTL_CH_STATE_BIT_CALIBRATING	0x00000004
3	SA_CTL_CH_STATE_BIT_REFERENCING	0x00000008
4	SA_CTL_CH_STATE_BIT_MOVE_DELAYED	0x00000010
5	SA_CTL_CH_STATE_BIT_SENSOR_PRESENT	0x00000020
6	SA_CTL_CH_STATE_BIT_IS_CALIBRATED	0x00000040
7	SA_CTL_CH_STATE_BIT_IS_REFERENCED	0x00000080
8	SA_CTL_CH_STATE_BIT_END_STOP_REACHED	0x00000100
9	SA_CTL_CH_STATE_BIT_RANGE_LIMIT_REACHED	0x00000200
10	SA_CTL_CH_STATE_BIT_FOLLOWING_LIMIT_REACHED	0x00000400
11	SA_CTL_CH_STATE_BIT_MOVEMENT_FAILED	0x00000800
12	SA_CTL_CH_STATE_BIT_IS_STREAMING	0x00001000
13	SA_CTL_CH_STATE_BIT_POSITIONER_OVERLOAD	0x00002000
14	SA_CTL_CH_STATE_BIT_OVER_TEMPERATURE	0x00004000
15	SA_CTL_CH_STATE_BIT_REFERENCE_MARK	0x00008000
16	SA_CTL_CH_STATE_BIT_IS_PHASED*	0x00010000
17	SA_CTL_CH_STATE_BIT_POSITIONER_FAULT*	0x00020000
18	SA_CTL_CH_STATE_BIT_AMPLIFIER_ENABLED	0x00040000
19	SA_CTL_CH_STATE_BIT_IN_POSITION	0x00080000

Actively Moving (bit 0)

The channel is actively moving the positioner (open-loop or closed-loop) which means that a commanded movement is currently executed. Note that a repositioning movement to hold the current position while the channel is in the holding state is *not* reported as "actively moving".

Closed Loop Active (bit 1)

The channel is in closed-loop operation using sensor feedback (moving or holding the position).

Calibrating (bit 2)

The channel is busy performing a calibration sequence. (See section 2.7.1 "Calibrating".)

*This channel state bit is only valid for Electromagnetic Driver.

Referencing (bit 3)

The channel is busy performing a find reference sequence. (See section 2.7.2 "Referencing".)

Move Delayed (bit 4)

The channel is waiting for the sensor to power-up before executing the movement command. This flag may be active if the sensor is operated in power save mode.

Sensor Present (bit 5)

A positioner with integrated sensor is attached to the channel. This indicates whether closed-loop movements may be performed.

Is Calibrated (bit 6)

The channel has valid signal correction calibration data for the configured positioner type. This flag is cleared when the positioner type is changed. It is set after a signal correction calibration sequence finished successfully. Note that physically different positioners of the same type require distinct calibration data. For positioners without SmarAct Positioner ID System the channel is *not* able to detect the change of the positioner. Consequently this flag will remain. Nonetheless the calibration sequence must be repeated once for the channel. (See section 2.7.1 "Calibrating".)

Is Referenced (bit 7)

The channel "knows" its physical (absolute) position. After a power-up the physical position is unknown. After the reference mark has been found by calling `SA_CTL_Reference` the physical position becomes known. (See section 2.7.2 "Referencing".) Detaching the positioner clears the flag.

Note that starting the referencing does *not* clear this flag if the absolute position is already known (from a previous referencing sequence). To invalidate the "is referenced" flag programmatically the Referencing Options property may be set to `SA_CTL_REF_OPT_BIT_INVALIDATE (0x01000000)`.

End Stop Reached (bit 8)

The target position of a closed-loop movement command could not be reached because a mechanical end stop was detected. The positioner was stopped. The flag is cleared when a new movement command respectively stop command is issued. (See section 2.13 "Endstop Detection".)

Range Limit Reached (bit 9)

The positioner left the software configured range limit. The positioner was stopped. The flag is cleared when a new movement command respectively stop command is issued. (See section 2.15 "Software Range Limit".)

Following Limit Reached (bit 10)

The positioners following error exceeded the configured limit. The flag is cleared when a new movement command respectively stop command is issued. (See section 2.14 "Following Error Detection".)

Movement Failed (bit 11)

The last movement command failed. The Channel Error property may be read to determine the reason for the error.

Is Streaming (bit 12)

The channel is currently participating in a trajectory stream. As long as this flag is set the channel is unavailable for movement or configuration commands. (See section 2.18 "Trajectory Streaming".)

Positioner Overload (bit 13)

The channel detected an overload condition of the positioner. This will disable the control-loop to prevent the positioner from overheating. As soon as the internal detection level drops to a non-critical value the flag is cleared. (See section 2.9.2 "Overload Protection" for Magnetic Drivers and Property reference 4.5.38 "Motor Overload Protection Threshold" for SlickSlip Drivers.)

Over Temperature (bit 14)

The channel detected an over temperature condition. This will shut down the power amplifier to prevent thermal damage. As soon as the temperature drops to a non-critical level the amplifier is enabled again and the flag is cleared.

Note that this flag is rarely raised under normal conditions and may indicate improper cooling, such as a fan failure.

Reference Mark (bit 15)

This flag reflects the state of the electrical reference mark signal of the sensor. It may be used for diagnostic purposes. Note that the controller uses the reference mark signal and the position signal to determine the reference position. Therefore, this signal does *not* reflect the exact reference position.

Is Phased (bit 16)*

The channel has valid data for the commutation of an electromagnetic driven positioner. A channel must be phased in order to be able to move a positioner. (See section 2.22 "Phasing of Electromagnetic Driven Positioners".)

Positioner Fault (bit 17)*

The channel detected a positioner fault. (See section 2.9.3 "Hardware Monitoring".)

Amplifier Enabled (bit 18)

This flag reflects the state of the amplifier. (See Amplifier Enabled property.)

In Position (bit 19)

This flag is active when the positioner has been within the configured In Position Threshold near the target for minimum or longer than the configured In Position Delay and no commanded movement is currently executed. While the "actively moving" flag reflects the state of the commanded movement, the "in position" flag is generated continuously based on the current and the commanded target position. If the positioner leaves the defined "in position" range the flag is cleared and the delay is restarted. For the flag to be set again the channel must be within the position threshold near the target for the specified delay again.

The channel must be in the holding state actively holding the current position for the flag to be active. This means that the flag is cleared if the Hold Time for the movement expires. If the hold time is configured to zero the flag will never be active.²

This flag may be used to terminate a commanded movement instead of the "actively moving" flag by enabling the `SA_CTL_POS_CTRL_OPT_BIT_IN_POSITION` flag of the Positioner Control Options property. (See section 2.7.4 "Closed-Loop Movements" for more information.)

*This channel state bit is only valid for Electromagnetic Driver.

²The Hold Time property is only available for Stick-Slip Piezo Driver.

2.11 Sensor Power Modes

In order for a positioner to track its position, its sensor needs to be supplied with power. However, since this generates heat (causing drift effects), it might be desirable to disable the sensors in some situations (especially in temperature critical environments). For this, there are three different modes of operation for the sensor, which may be configured individually for each channel with the Sensor Power Mode property. The following modes are available:

- **Disabled** In this mode the power supply of the sensor is turned off. This avoids the generation of heat by the sensor. Movement commands that require sensor feed back (such as closed-loop movements, referencing or calibrating) will not be executed. Instead, the generated `SA_CTL_EVENT_MOVEMENT_FINISHED` event holds an error code informing about the sensor state.
Besides avoiding heat generation this mode may also be useful if the light that is emitted by the sensor interferes with other components of your setup (e.g. detectors inside an SEM chamber).
- **Enabled** In this mode the sensor is supplied with power continuously. All movement commands are executed normally.
- **PowerSave**¹ If set to this mode the power supply of the sensor will be handled by the channel automatically. If the positioner is not actively moving (*stopped* or *holding* the position) the sensor will be offline most of the time, avoiding unnecessary heat generation. A movement command (open-loop or closed-loop) will cause the channel to activate the sensor before the movement is started. Since it takes a few milliseconds to power-up the sensor, the movement will be delayed. The Channel State bit `SA_CTL_CH_STATE_BIT_MOVE_DELAYED` is set during this time.

Figure 2.9 illustrates the different sensor modes and shows when the sensor is supplied with power.

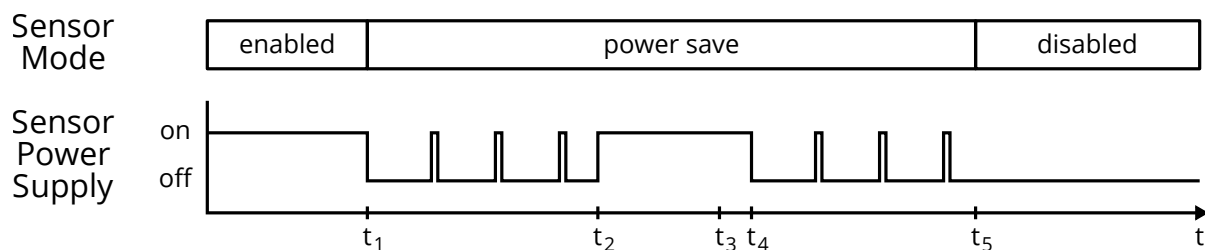


Figure 2.9: Sensor Modes

In this example the sensor mode is initially set to enabled. The sensor is continuously supplied with power. At time t_1 the sensor mode is switched to power save. In this mode the channel starts to pulse the power supply of the sensor to keep the heat generation low. At time t_2 a movement command is issued, which requires the sensor to be online in order to keep track of the current position. Note that the sensor mode stays unchanged during this time. After the movement has finished (t_3) an additional delay is started. While this delay the sensor stays online. (See the Sensor Power Save Delay property.) As soon as the delay time has elapsed (t_4) the channel will start to

¹The power save mode is only available for Stick-Slip Piezo Driver.

pulse the power supply again. At time t_5 the sensor mode is switched to disabled, in which the power supply is turned off continuously.

When in *PowerSave* or *Disabled* mode the positioner should not be moved by external means (e.g. by hand)! Since in these modes the power supply of the sensor is off most of the time or even continuously, the controller is not able to detect such movements. As a consequence the position data will become invalid. Furthermore, no error can be generated.

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Note that the sensor must be in *Enabled* or *PowerSave* mode for the sensor-present detection to be active. Accordingly, the Channel State bit `SA_CTL_CH_STATE_BIT_SENSOR_PRESENT` is not updated as long as the sensor is *Disabled*.

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The sensor-present detection is active in *Disabled* mode too. When setting the Sensor Power Mode to *Disabled* the control-loop and the amplifier is disabled and the phasing becomes invalid. See section 2.22 "Phasing of Electro-Magnetic Driven Positioners" for more information.



NOTICE

Electromagnetic driven positioners are not self-locking. Disabling the control-loop removes any holding force from the positioner. Make sure not to damage any equipment when the positioner changes its position unintentionally!

2.12 PicoScale Sensor Module

The MCS2 supports the SmarAct PicoScale laser interferometer as a high precision sensor module. This section explains the differences when using a PicoScale instead of the MCS2 sensor module. For a detailed description and setup of the PicoScale refer to the *PicoScale User Manual*.

For connecting the PicoScale to the MCS2 a special adapter cable (MCS2-A-PS-CABLE-1.5M-1.5M) is required. The adapter cable connects to the MCS2 and splits the high voltage output to three connections for positioners and forwards the data connection to the PicoScale.

When the PicoScale is connected to the MCS2, it is reported as a connected sensor module in the Module State Flags. Since the MCS2 only knows the sensor present flag in the Channel State Flags, but the PicoScale uses a number of different flags to indicate the system state, these flags are merged in the MCS2 context. For the sensor present flag to become active the following conditions must be met:

- System stable
- Channel enabled
- Channel data valid
- Beam not interrupted

For most of these flags to become active the channel needs to be adjusted. The adjustment can be performed using the PicoScale GUI or the MCS2 hand control module.

By default the MCS2 will use the PicoScale position data source as input for the control-loop. Alternatively, the calculation system can be selected as the input using the Sensor Input Select property. Note that the mapping between PicoScale calculation systems and MCS2 channels is static. The output of calculation system 0 of the PicoScale is used as input for channel 0 of the MCS2. Accordingly, calcSys 1 is used for channel 1 and calcSys 2 is used for channel 2.

When using the calculation system as input the conditions for the sensor present flag are as follows:

- System stable
- Calculation system data not interrupted

2.13 Endstop Detection

SmarAct positioners do not require any physical limit switches to detect the end of the travel range while moving. The MCS2 features a software-driven endstop detection. If a mechanical blockage is detected while performing a closed-loop movement the channel is stopped.

A `SA_CTL_EVENT_MOVEMENT_FINISHED` event with its parameter set to `SA_CTL_ERROR_END_STOP_REACHED` is generated and the Channel State bits:

- `SA_CTL_CH_STATE_BIT_END_STOP_REACHED` and
- `SA_CTL_CH_STATE_BIT_MOVEMENT_FAILED`

will be set to one. The flags remain set until a new movement (or a `SA_CTL_Stop`) is commanded.

Note that when using auxiliary inputs as control-loop feedback it may be necessary to disable the endstop detection by setting the Positioner ESD Distance Threshold property to zero. See section 2.19.5 "Using Analog Inputs as Control-Loop Feedback" for more information.

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The endstop detection is active while performing a closed-loop movement *and* while holding the position. If an endstop is detected the channel enters the *stopped* state and the control-loop is disabled. If a positioner is moved away from the target position by external means and the channel is not able to hold the target position for a longer time an endstop is triggered. To notify about this, a `SA_CTL_EVENT_HOLDING_ABORTED` event is generated and the channel is stopped.

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The endstop detection is active while performing a movement but *not* while holding the position. If an endstop is detected the channel enters the *holding* state to stop the movement. Furthermore the maximum output current is reduced to the permitted continuous current value. This means that the holding force of the positioner is reduced from then on but with the benefit that an ongoing blockage will *not* trigger the overload detection. This would otherwise disable the control-loop and subsequently remove the holding force from the positioner. A new movement command reverts the maximum current to its intermittent value.

If it is desired to abort the control-loop on a position deviation in the *holding* state the following error detection may be used. See section 2.14 "Following Error Detection" for more information.

2.14 Following Error Detection

The following error detection feature may be used to inform the application if a commanded trajectory cannot be followed by a positioner precisely enough. The following error is, at a given time, the difference between the target position and the actual position while performing closed-loop movements. The positioner will always have a non-zero following error but the control-loop is tuned to reduce this error to its minimum. To enable the detection:

- The Following Error Limit property must be set to a non-zero value.
- The velocity control must be enabled (see Move Velocity).

The limit value is given in pm for linear positioners and in n° for rotary positioners. By default an exceeded limit is reported only without taking any further actions. As soon as the configured limit is exceeded during a closed-loop movement a `SA_CTL_EVENT_FOLLOWING_ERR_LIMIT` event is generated and the `SA_CTL_CH_STATE_BIT_FOLLOWING_LIMIT_REACHED` Channel State bit will be set to one. The flag remains set until a new movement (or a `SA_CTL_Stop`) is commanded.

Optionally the movement may be stopped automatically if the limit is exceeded.

The `SA_CTL_POS_CTRL_OPT_BIT_STOP_ON_FOLLOWING_ERR` bit of the Positioner Control Options property must be set to one to stop the movement. In this case two events are generated. Firstly, the above mentioned `SA_CTL_EVENT_FOLLOWING_ERR_LIMIT`, secondly a `SA_CTL_EVENT_MOVEMENT_FINISHED` event. The latter will have its parameter set to `SA_CTL_ERROR_FOLLOWING_ERR_LIMIT`. Additionally the Channel State bits:

- `SA_CTL_CH_STATE_BIT_FOLLOWING_LIMIT_REACHED` and
- `SA_CTL_CH_STATE_BIT_MOVEMENT_FAILED`

will be set to one. The flags remain set until a new movement (or a `SA_CTL_Stop`) is commanded.

Note that the detection is not active during referencing movements.

The Following Error and Following Error Max properties may be read to monitor the *current* value and the *maximum* magnitude of the following error while moving.

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The following error detection is active while performing a movement *and* while holding the position. If the detection triggers (and the 'stop on following error' positioner control option is enabled) the channel enters the *stopped* state and the control-loop is disabled.

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The following error detection is active while performing a movement *and* while holding the position. Assuming that the 'stop on following error' positioner control option is enabled, the behavior is slightly different depending on the current state: While moving the channel enters the *holding* state to stop the movement if the detection triggers. If it triggers while holding the position (e.g. if the positioner is moved by external means) the channel tries to hold the position but the maximum output current is reduced to the permitted continuous current value. This means that the holding force of the positioner is reduced from then on but with the benefit that an ongoing

blockage will *not* trigger the overload detection. This would otherwise disable the control-loop and subsequently remove the holding force from the positioner. A new movement command reverts the maximum current to its intermittent value.

The additional `SA_CTL_POS_CTRL_OPT_BIT_CL_DIS_ON_FOLLOWING_ERR` bit of the Positioner Control Options property may be used to **disable** the control-loop instead of just stopping the movement. This option has a higher priority than the *stop* option if both options are enabled. Note that the amplifier is *not* disabled in this case. This means that any new movement or stop command will automatically re-enable the control-loop.

**NOTICE**

Electromagnetic driven positioners are not self-locking. Disabling the control-loop removes any holding force from the positioner. Make sure not to damage any equipment when the positioner changes its position unintentionally!

2.15 Software Range Limit

While linear positioners have a limited physical travel range it might be useful to further limit this range if the positioner must not be allowed to move beyond a certain point. Rotary positioners usually have no physical end stops, but e.g. wiring may require to limit the rotation here as well. For these situations the MCS2 controller offers to limit the travel range of a positioner by software.

By default no range limit is set. To enable the range checks, the Range Limit Max property must be set to a higher value than the Range Limit Min property. Once the limits are set the positioner will not move beyond the boundaries of the range limit. This affects all movements *except* scan movements. If a movement command is issued that move the positioner beyond the defined limit then the positioner is stopped. A `SA_CTL_EVENT_MOVEMENT_FINISHED` event with its parameter set to `SA_CTL_ERROR_RANGE_LIMIT_REACHED` is generated and the Channel State bits:

- `SA_CTL_CH_STATE_BIT_RANGE_LIMIT_REACHED` and
- `SA_CTL_CH_STATE_BIT_MOVEMENT_FAILED`

will be set to one. The flags remain set until a new movement (or a `SA_CTL_Stop`) is commanded. Further movements are only allowed if they move the positioner in the direction pointing back inside the range limit. This also applies if the positioner has been moved outside the defined range limit by external means.

Note that when commanding the positioner towards a limit with enabled acceleration control (see Move Acceleration property) the positioner is decelerated to zero velocity in a way that it comes to a halt on the specified limit position.

Both the minimum and maximum position of the range limit behave similarly to a physical end stop. For example, the `SA_CTL_Reference` command will reverse its movement direction while looking for the reference mark if a range limit boundary is reached. If the reference mark is located outside the range limit then it will not be found.

It is possible to define the default values for the range limits at device startup, e.g. for applications where no dedicated control software is used. This may be useful e.g. for stand-alone operation with the hand control module. Set the Default Range Limit Min and Default Range Limit Max properties to specify the startup defaults.

Please note the following restrictions:

- The Range Limit Min and Range Limit Max properties are **not** saved to non-volatile memory and must be configured in each session. (The default values at device startup may be configured with the Default Range Limit Min and Default Range Limit Max properties.)
- The range limits are **not** checked while performing the `SA_CTL_Calibrate` function for the signal correction calibration.
- The range limit has a limited accuracy. The positioner may pass over the boundary by a few micro meters resp. milli degrees if no acceleration control is used for the movement. Therefore, the range should be defined with sufficient tolerance in this case.

Setting the Position (as well as the Logical Scale Offset and Logical Scale Inversion properties) does **not** automatically adjust the software range limit accordingly. This means that shifting the measurement scale of the positioner with these commands will also shift the

physical position of the software range limit. Therefore, care should be taken when working with these commands.

2.16 Stop Broadcasting

This feature can be used to broadcast a stop command to all channels on the MCS2 controller when a channel

- detects a mechanical end stop (see section 2.13 Endstop Detection),
- reaches a software range limit (see section 2.15 Software Range Limit),
- exceeds a following error limit (see section 2.14 Following Error Detection) or
- triggers a motor overload (see section 2.9.2 Overload Protection).

It is typically useful when multiple channels are moving simultaneously and one of the above conditions on one channel should cause a halt on all other channels. The channel that caused the broadcast stop generates a `SA_CTL_EVENT_MOVEMENT_FINISHED` event with its parameter holding the reason for the stop. (`SA_CTL_ERROR_END_STOP_REACHED`, `SA_CTL_ERROR_RANGE_LIMIT_REACHED` or `SA_CTL_ERROR_FOLLOWING_ERR_LIMIT`)

All other (currently moving) channels will be stopped and generate a `SA_CTL_EVENT_MOVEMENT_FINISHED` event with its parameter set to `SA_CTL_ERROR_ABORTED`.

A channel's behavior for a broadcast stop is the same as when executing a single `SA_CTL_Stop` command. Thus channels moving with acceleration control active may not come to halt immediately.

Note that the broadcast stop function is not active during referencing or calibrating movements.

2.16.1 Stop Broadcast Configuration

The Broadcast Stop Options property defines the behavior of the broadcast stop feature. It holds a bit mask with the following mode bits:

Bit	Name	Short Description
0	End Stop Reached	Broadcast stop command if a mechanical end stop was detected.
1	Range Limit Reached	Broadcast stop command if a range limit was reached.
2	Following Error Limit Reached*	Broadcast stop command if a following error limit was exceeded.
3	Motor Load Threshold Reached**	Broadcast stop command if a motor load limit was exceeded.

Undefined flags are reserved for future use. These flags should be set to zero.

*Note that the `SA_CTL_POS_CTRL_OPT_BIT_STOP_ON_FOLLOWING_ERR` bit of the Positioner Control Options property must be set to one to stop the movement and subsequently generate a broadcast stop on a following error limit.

****For stick-slip positioners the SA_CTL_PKEY_MOTOR_LOAD_PROTECTION_THRESHOLD property must be configured to stop the movement and subsequently generate a broadcast stop on an overload event (see section 2.9.2 Overload Protection).**

Example

The example code below configures the device to issue a broadcast stop if channel 0 reaches an end stop or a Software Range Limit ($\pm 2\text{mm}$).

```
SA_CTL_Result_t result;
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_RANGE_LIMIT_MIN, -2e9);
if (result) { /* handle error, abort */ }
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_RANGE_LIMIT_MAX, 2e9);
if (result) { /* handle error, abort */ }
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_BROADCAST_STOP_OPTIONS,
    (SA_CTL_STOP_OPT_BIT_END_STOP_REACHED |
     SA_CTL_STOP_OPT_BIT_RANGE_LIMIT_REACHED)
);
if (result) { /* handle error, abort */ }
```


2.17 Command Groups

When issuing movement or configuration commands they usually target a single channel of the device. However, when trying to move several channels synchronously communication delays induce a time offset of the resulting movements.

Command groups offer the possibility to define an atomic group of commands that is executed synchronously. In addition, a command group may not only be triggered via software, but alternatively via an external trigger.

To define a command group simply surround the commands that should be grouped with calls to the `SA_CTL_OpenCommandGroup` and `SA_CTL_CloseCommandGroup` functions and pass the transmit handle received from the `SA_CTL_OpenCommandGroup` function to all commands to be grouped.

For example, consider the code sequence below that configures two channels with the closed-loop absolute move mode and then moves both channels to some target position. (For simplicity the function return values are not handled in this example.)

```
SA_CTL_RequestWriteProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_MOVE_MODE,
    SA_CTL_MOVE_MODE_CL_ABSOLUTE,
    &rID0,
    0
);
SA_CTL_RequestWriteProperty_i32(
    dHandle, 1,
    SA_CTL_PKEY_MOVE_MODE,
    SA_CTL_MOVE_MODE_CL_ABSOLUTE,
    &rID1,
    0
);
SA_CTL_Move(dHandle, 0, 1000000, 0);
SA_CTL_Move(dHandle, 1, 2000000, 0);
SA_CTL_WaitForWrite(dHandle, rID0);
SA_CTL_WaitForWrite(dHandle, rID1);
```

The next code snippet shows the same example, but the commands are put into a command group (changes are colored).

```
SA_CTL_TransmitHandle_t tHandle;
SA_CTL_OpenCommandGroup(dHandle, &tHandle
, SA_CTL_CMD_GROUP_TRIGGER_MODE_DIRECT);
SA_CTL_RequestWriteProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_MOVE_MODE,
    SA_CTL_MOVE_MODE_CL_ABSOLUTE,
    &rID0,
    tHandle
);
```

```

SA_CTL_RequestWriteProperty_i32(
    dHandle, 1,
    SA_CTL_PKEY_MOVE_MODE,
    SA_CTL_MOVE_MODE_CL_ABSOLUTE,
    &rID1,
    tHandle
);
SA_CTL_Move(dHandle, 0, 1000000, tHandle);
SA_CTL_Move(dHandle, 1, 2000000, tHandle);
SA_CTL_CloseCommandGroup(dHandle, tHandle);
SA_CTL_WaitForWrite(dHandle, rID0);
SA_CTL_WaitForWrite(dHandle, rID1);

```

As a result the commands are treated as one command and the movements of both channels start synchronously (in this case as soon as the command group is closed, since the direct trigger mode is used). A `SA_CTL_EVENT_CMD_GROUP_TRIGGERED` event is generated once the group was triggered.

One important thing to notice is that the `SA_CTL_WaitForWrite` function calls must be issued *after* the command group was closed. Otherwise the function calls will block. The same applies to commands that read properties from the device: put the `SA_CTL_RequestReadProperty` calls into the command group, but issue e.g. `SA_CTL_ReadProperty_i32` calls *after* the group close.

Note that synchronous property accesses cannot be put into a command group. Only the following *commands* may be added to command groups by passing the transmit handle to the function call:

- `SA_CTL_RequestReadProperty`
- `SA_CTL_RequestWriteProperty_i32`
- `SA_CTL_RequestWriteProperty_i64`
- `SA_CTL_RequestWriteProperty_s`
- `SA_CTL_Calibrate`
- `SA_CTL_Reference`
- `SA_CTL_Move`
- `SA_CTL_Stop`

In addition note that not all *properties* may be added to command groups. (E.g. device properties can never be used.) If a property is group-able or not is indicated in the detailed property description (See chapter 4 "Property Reference").

A maximum of 32 command groups may be opened *simultaneously*. If the limit is reached the `SA_CTL_OpenCommandGroup` function will return a `SA_CTL_ERROR_BUFFER_LIMIT_REACHED` error.

The maximum number of commands *per group* depends on the number of opened groups and the distribution of commands to the modules. Each module has *one* queue with 32 command slots for *all* commands to this module and its channels. If this limit is reached on one of the modules the execution of the group is aborted and a `SA_CTL_ERROR_BUFFER_OVERFLOW` error is reported

with the `SA_CTL_EVENT_CMD_GROUP_TRIGGERED` event which is generated after closing resp. triggering the command group.

2.17.1 Command Groups vs. Output Buffer

Output buffer (as described in the High-Throughput Asynchronous Access for properties) are quite similar to command groups. However, there are still some differences which are outlined in the following.

- **Triggering** While output buffer are executed as soon as they are flushed, command groups may alternatively be triggered via an external trigger.
- **Size Limit** Command groups are somewhat limited in size regarding the number of commands that may be put into them. Output buffer are (theoretically) unlimited in size.
- **Atomicity** Output buffer simply try to optimize communication, but still treat the commands independently from each other. Output buffer are flushed on library level. In contrast, command groups optimize both communication and synchronized execution. They are flushed on controller level.

2.18 Trajectory Streaming

Trajectory streaming allows a multi DoF manipulator to follow specific trajectories using the MCS2 controller. All participating positioners are moved synchronously along the defined trajectory.¹ This section describes the concepts of trajectory streaming and how an application program must use the API to perform a trajectory movement.

A trajectory movement requires special (user) software to pre-calculate support points of the trajectory (although the support points might also be calculated "on the fly"). These support points are then streamed to the controller which takes care of executing a synchronized movement of all participating channels.

2.18.1 General Streaming Concept

A trajectory stream is defined as a sequence of support points (*frames*). Each frame is a tuple of target positions for all channels that participate in the trajectory. Each target position in turn is a tuple of a channel index and a position value. Position values are given as a 64-bit integer value in little-endian format, representing pico meters for linear positioners and nano degrees for rotary positioners. All values are given as absolute (not relative) position values. Figure 2.10 shows the general format of a trajectory stream and figure 2.11 shows an example trajectory with the according binary stream data.

The timing with which the frames are executed can be defined by the *stream rate* that is configurable by the user. This rate is constant for the duration of the stream. Furthermore, the timing can be synchronized or even fully controlled by using an external trigger.

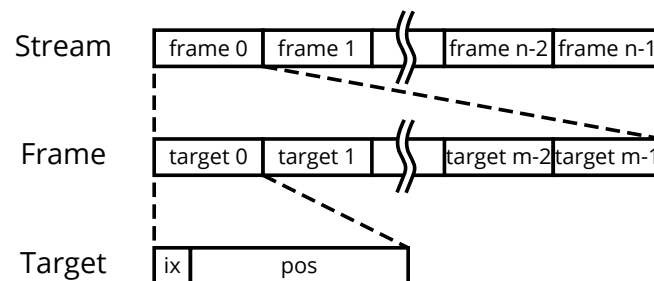


Figure 2.10: Trajectory Stream Format

Streaming Rules

When using trajectory streaming some rules must be heeded that are described in the following:

- Only one trajectory may be performed at a time. Suppose you have six channels available that are divided into two XYZ manipulators (A and B). Then you could start a trajectory with manipulator A. During this time it is not allowed to start a stream for manipulator B. If both manipulators are to be synchronized then the stream must contain all six channels from the beginning.

¹Note that the trajectory streaming is not available for dual-piezo hybrid positioners.

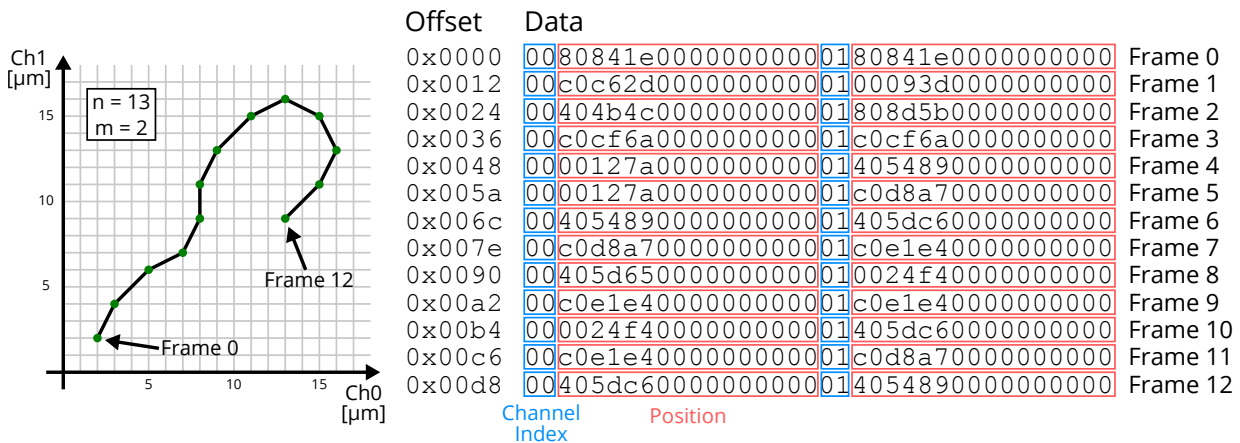


Figure 2.11: Trajectory Stream Example

- The first frame of a stream defines which channels participate in the stream. All further frames must contain the same channels (in the same order). Otherwise a stream error is generated.
- A trajectory stream must consist of at least two frames (start frame and end frame).
- The movement between the support points is linearly interpolated by the controller (this is the default setting, see section 2.18.3 "Options"). If a manipulator is supposed to perform an accelerated movement along the trajectory then the support points must be calculated accordingly. This implicitly means that the configured Move Velocity and Move Acceleration for channels that participate in the streaming have no meaning.
- Channels that are not participating in the stream can still be fully controlled, while channels that are currently streamed may answer with a `SA_CTL_ERROR_BUSY_STREAMING` error code (see A.1) when sending certain configuration or movement commands.
- Open-loop movements are not supported by the trajectory streaming. The configured Move Mode of the channels has no meaning while performing the trajectory streaming.
- The sensors of all participating positioners must be enabled (in particular, the power save mode is not allowed, see section 2.11 "Sensor Power Modes").
- Note that the trajectory stream defines the *target* position movement profile for all participating positioners. The control-loop does "its best" to move all positioners as close as possible along the defined trajectory. Nonetheless the actual *current* positions will deviate a little bit from the *target* positions. To optimize the closed-loop performance and to reduce the following error it may be necessary to modify the tuning parameters for the positioners. See section 2.6.3 "Custom Positioner Types" for more information. The Following Error may be polled to determine the difference while performing the movement. Furthermore, the "Following Error Detection" may be used to monitor (and potentially abort) the trajectory on a defined deviation.

Flow Control

When the host transmits stream frames to the controller they are stored in a (FIFO) stream buffer in the controller. The controller then executes the buffered frames synchronously. While the frames are executed at a constant rate (the stream rate that the user has configured), the rate at which the controller receives frames from the host may vary. Typically the rate is considerably higher or frames arrive in bursts with intermissions (or both), e.g. due to USB / Ethernet latency or application interruption by the operating system (see figure 2.12).

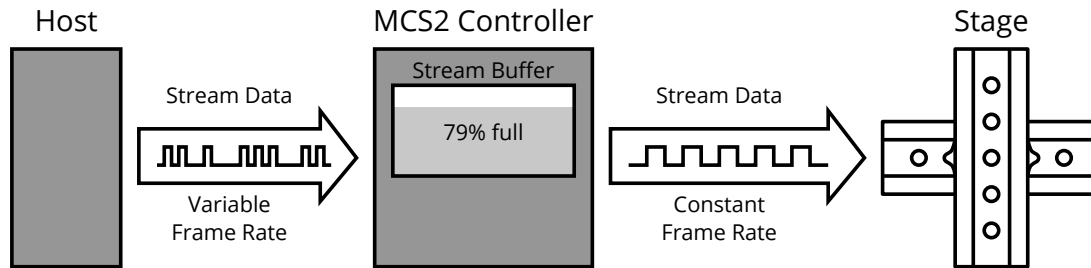


Figure 2.12: Flow Control

The library implements a flow control mechanism to prevent a buffer overflow on the controller:

- If the `SA_CTL_StreamFrame` function is called faster than the configured stream rate then the function may block from time to time, therefore implementing the flow control.
- If the `SA_CTL_StreamFrame` function is called slower than the configured stream rate then the streaming will eventually fail with a buffer underflow error.

The controller's stream buffer can hold up to 1024 tuples³ and while it allows a synchronized and consistent stream, it also induces a delay to the incoming frames. This delay depends on the controller's buffer size, the number of channels that participate in the stream as well as the configured stream rate and can be determined by the following formula:

$$\text{execution delay [s]} = \frac{\text{buffer size}}{\text{stream rate [Hz]} * \text{number of stream channels}}$$

E.g. a stream with a frame containing three tuples (position data for three channels) and a configured stream rate of 1000 Hz would induce a constant buffer delay of $\frac{1024}{1000 \text{ Hz} * 3} = 0.341 \text{ s}$.

2.18.2 Basic Approach

To execute a trajectory stream the following steps must be performed:

1. Configure the stream rate by writing the Stream Base Rate property (see section 4.10). This defines the rate (in Hz) with which the frames of the trajectory are executed.

³A tuple consists of a target position and its corresponding channel, see 2.18.1 (General Streaming Concept).

2. Move all positioners that participate in the trajectory to their starting position (first frame of the stream). Otherwise starting the stream will likely cause unexpected behavior, since stream frames hold absolute position values and therefore the first frame could cause very high velocities that cannot be performed mechanically.
3. Open a stream by calling the `SA_CTL_OpenStream` function. It returns a stream handle that must be passed to the following function calls to associate them with the opened stream.
4. Supply the stream data by calling the `SA_CTL_StreamFrame` function once per frame that should be executed. Note: This function may block if the flow control needs to throttle the data rate. The function returns as soon as the frame was transmitted to the controller.
5. Close the stream by calling the `SA_CTL_CloseStream` function. To the controller this marks the end of the stream. If the stream is not closed properly with this function call (or aborted by calling `SA_CTL_AbortStream`) then the controller will generate a buffer underflow error after the last frame has been executed.

Behavioral differences when closing or aborting a stream:

As already described, all incoming frames are stored in an intermediate buffer by the device (see Flow Control). The basic approach, after having sent all frames to the device, is to call `SA_CTL_CloseStream`. This leads to execution of all pending frames and thus finishing the stream at the given position(s). If a stream is to be stopped immediately, the `SA_CTL_AbortStream` function can be used. This leads to a trajectory stop, while remaining frames already sent to the device are discarded.

2.18.3 Options

Before calling the `SA_CTL_OpenStream` function the Stream Options property can be configured to define the stream's behavior. This property holds a bit mask which is outlined in the following table.

Bit	Name	Short Description
0	Disable Linear Interpolation	Disable the linear interpolation between consecutive stream target positions.

Undefined flags are reserved for future use. These flags should be set to zero.

Disable Linear Interpolation (streaming options 0x00 or 0x01)

By default, the path between consecutive stream target positions is linearly interpolated. In some applications this behavior might be unwanted. The interpolation can therefore be disabled using this option, resulting in a point-to-point movement with the configured stream rate.

2.18.4 Trigger Modes

A trajectory stream may be configured to be triggered (started) by various events. For example, in some situations it can be useful to synchronize the stream rate of a trajectory with an external clock. A camera could then take snap shots with a frequency of 10 Hz while the stage moves along a trajectory with a time resolution of 200 Hz.

The desired trigger mode is passed to the `SA_CTL_OpenStream` function. The following trigger modes are available:

- `SA_CTL_STREAM_TRIGGER_MODE_DIRECT` (0)
- `SA_CTL_STREAM_TRIGGER_MODE_EXTERNAL_ONCE` (1)
- `SA_CTL_STREAM_TRIGGER_MODE_EXTERNAL_SYNC` (2)
- `SA_CTL_STREAM_TRIGGER_MODE_EXTERNAL` (3)

Please note that in order to use the external trigger modes, the Input Trigger must be configured accordingly. Refer to section 2.20 "Input Trigger" on how to configure the device for triggered streaming.

Direct Mode

In this mode the stream is started as soon as the stream buffer on the controller contains enough data or has been closed (at which point a `SA_CTL_EVENT_STREAM_READY` event is generated).

External Once Mode

In this mode the stream is started by an external trigger that is fed into the device. Once the stream buffer on the controller contains enough data or has been closed a `SA_CTL_EVENT_STREAM_READY` event is generated to indicate that the stream is ready to be triggered by the external trigger. In this armed state the device waits for the trigger to occur and then generates a `SA_CTL_EVENT_STREAM_TRIGGERED` event. Further triggers are ignored in this mode.

External Synchronization Mode

This mode is used to synchronize the stream rate with an external clock which may be fed into the MCS2 controller. When the Stream External Sync Rate property is configured with the external clock rate then the trajectory stream will be synchronized with the external clock.

Figure 2.13 shows an example where the base stream rate is (should be) three times faster than the external sync rate (e.g. external 100 Hz, internal 300 Hz). The upper clock trace shows the external clock which makes 3 cycles within a given time window (Δt). The middle clock trace shows the internal clock while not being synchronized, being a speck too fast and making 10 cycles within the same time window. In the lower clock trace the internal clock is synchronized, making 9 clock

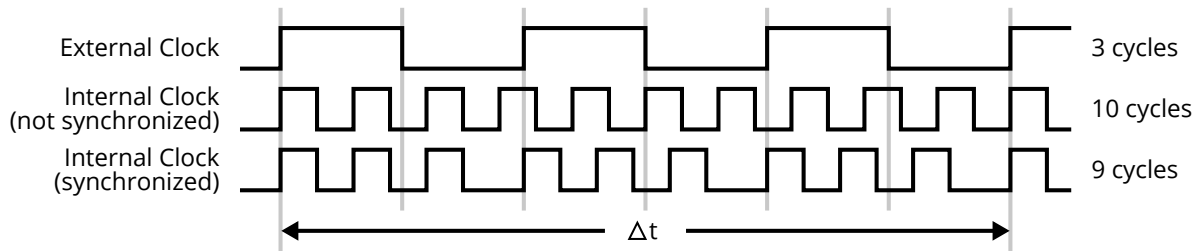


Figure 2.13: External synchronization with a 3:1 clock ratio

cycles within the time window as desired. As a result the synchronization prevents the clocks from drifting apart.

The external synchronization feature has some restrictions that should be noted:

- In order to use the external synchronization feature the MCS2 controller must be equipped with an appropriate I/O Module.
- The Stream Base Rate must be a whole-number multiple of the external clock rate.
- The external clock rate may not be higher than the Stream Base Rate.

External

In this mode, the external clock defines the streamrate and fully controls the trajectory's start and further execution. With each incoming trigger, the next support point of the given trajectory is targeted. Note that the maximum stable frequency for the input signal is limited e.g. depending on the number of involved channels (see Maximum Stream Rates).

Further implications when using the external trigger mode are:

- the configured Stream Base Rate is ignored
- the configured Stream External Sync Rate is ignored
- the internal linear interpolation is disabled (see Options)

2.18.5 Stream Events

A trajectory stream that is started always generates the following events (in the order given):

1. `SA_CTL_EVENT_STREAM_READY` This event is generated as soon as the internal stream buffer of the device contains enough frames to start the stream without risking an immediate buffer underflow. The default buffer threshold is 50%. In case the stream is very short this event is generated as soon as the stream is closed.
2. `SA_CTL_EVENT_STREAM_TRIGGERED` This event is generated as soon as the device has started to execute the stream. In case of direct streaming the Stream Ready and the Stream Triggered events are generated at the same time. In case of externally triggered streaming the Stream Triggered event is delayed until the external trigger is detected which effectively starts the stream execution.

3. `SA_CTL_EVENT_STREAM_FINISHED` This event is generated when the stream has stopped executing. The event parameter indicates the result of the streaming. This could be a normal termination (`SA_CTL_ERROR_NONE` when executed to the last frame) or an error code specifying the reason for the abnormal termination.

2.18.6 Maximum Stream Rates

The maximum stable *stream rate* to be configured depends on the general communication load as well as the number of involved channels. The more channels are included in the trajectory stream, the higher the device's stream load. Table 2.4 shows possible stream rates for different number of streaming channels.

Channels	Stream Rate [Hz]	Channels	Stream Rate [Hz]	Channels	Stream Rate [Hz]
1	1000	7	480	13	260
2	1000	8	420	14	240
3	1000	9	370	15	220
4	840	10	340	16	210
5	670	11	300	17	200
6	560	12	280	18	190

Table 2.4: Stream Rate examples

For a more accurate determination of the maximum stream rate for the current setup the Stream Load Maximum property can be monitored while streaming. The property acts like a peak detector. The highest load level generated by the currently running stream is stored and may be read in percent with the Stream Load Maximum property. When starting the stream the load value is reset to zero.

It is recommended to configure the trajectory stream (e.g. the Stream Base Rate) with some head-room to the maximum load to guarantee a stable operation. If an overload is detected the trajectory stream aborts with an `SA_CTL_ERROR_SYNC_FAILED` error.

Note that channels which are not part of the current stream can be fully controlled while a stream is running. However, doing so always generates some peak load which must be considered. Note further that streaming to multiple channels with high stream rates may also affect the performance for operations concerning other channels.

2.19 Auxiliary Inputs and Outputs

The MCS2 device offers auxiliary inputs and outputs to interface to external equipment.

The device must be equipped with an additional I/O module to use auxiliary inputs and outputs. The characteristics as well as the number of inputs and outputs vary depending on the specific type of I/O module. Please refer to the *MCS2 User Manual* for detailed electrical specifications.

2.19.1 Digital Device Inputs

Digital device inputs allow to synchronize movements to external events. Synchronizing the trajectory streaming or triggering command groups, aborting movements by triggering an emergency stop (global-stop) as well as disabling the driver amplifiers is possible. This feature is called "Input Trigger". See section 2.20 "Input Trigger" for the configuration of the input trigger.

2.19.2 Fast Digital Outputs

Fast digital outputs may be used to trigger external equipment like detectors or cameras depending on the current position of a positioner. This feature is called "Output Trigger". See section 2.21 "Output Trigger" for the configuration of the output trigger.

2.19.3 General Purpose Digital Inputs/Outputs

General purpose digital inputs and outputs may be used to control lights, relays, dispensers, etc. or to read the state of safety switches, light barriers, etc.

Digital Inputs

The Aux Digital Input Value property may be used to read the digital inputs of an I/O module. The first bit (bit 0) of the input value corresponds to the first digital input (GP-DIN-1), the second bit (bit 1) corresponds to the second input (GP-DIN-2) and so on.

The digital inputs may also be used as emergency stop input to stop the movement of a single channel with an external electrical signal. See section 2.20 "Channel Input Trigger" for more information.

It is possible to enable an event notification for the digital inputs to be notified if an input changes. Thus, continuous polling of the Aux Digital Input Value property can be avoided. To enable the event set the `SA_CTL_IO_MODULE_OPT_BIT_EVENTS_ENABLED` bit of the I/O Module Options property to one. Whenever a change of one or more of the general purpose digital inputs happens the device generates a `SA_CTL_EVENT_DIGITAL_INPUT_CHANGED` event with its parameter holding the new state of the inputs. Note that the input state capture frequency for the event

generation is limited to approx. 100 Hz. See section 2.4 "Event Notifications" for more information on receiving events.

The following code shows how to read the digital inputs of an I/O module:

```
SA_CTL_Result_t result;
// read the digital inputs
int32_t input;
result = SA_CTL_GetProperty_i32(dHandle, 0,
    SA_CTL_PKEY_AUX_DIGITAL_INPUT_VALUE, &input, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'input' holds the value of the digital inputs
}
// enable the digital input changed event
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_IO_MODULE_OPTIONS,
    SA_CTL_IO_MODULE_OPT_BIT_EVENTS_ENABLED
);
// -> receive event using the SA_CTL_WaitForEvent() function
```

Digital Outputs

The digital output driver circuit is disabled by default and must be enabled by setting the `SA_CTL_IO_MODULE_OPT_BIT_DIGITAL_OUTPUT_ENABLED` bit of the I/O Module Options property.

The following properties may be used to modify the digital outputs:

- The **Aux Digital Output Value** property sets all outputs at once to a defined value.
- The **Aux Digital Output Set** property sets all specified outputs to one without modifying the other ones.
- The **Aux Digital Output Clear** property clears all specified outputs without modifying the other ones.

The first bit (bit 0) of the output value corresponds to the first digital output (GP-DOUT-1), the second bit (bit 1) corresponds to the second output (GP-DOUT-2) and so on. Note that the general purpose outputs are designed as open-collector outputs. This means that the output logic is inverted. Writing a one to an output switches the output transistor on which leads to a low signal level at the output pin. The following code shows how to modify digital outputs of an I/O module:

```
SA_CTL_Result_t result;
// set the output driver voltage level to 5V
result = SA_CTL_SetProperty_i32(dHandle, 0,
    SA_CTL_PKEY_IO_MODULE_VOLTAGE, SA_CTL_IO_MODULE_VOLTAGE_5V
);
if (result) { /* handle error, abort */ }
```

```

// enable the digital output driver circuit of the I/O module
result = SA_CTL_SetProperty_i32(dHandle, 0,
    SA_CTL_PKEY_IO_MODULE_OPTIONS,
    SA_CTL_IO_MODULE_OPT_BIT_DIGITAL_OUTPUTS_ENABLED
);
if (result) { /* handle error, abort */ }
// first set all digital outputs of the I/O module to a specific value
// note: electrical levels are inverted due to the open-collector outputs
// DOUT-4 | DOUT-3 | DOUT-2 | DOUT-1 |
// H(1)   | L(0)   | H(1)   | L(0)   |
result = SA_CTL_SetProperty_i32(dHandle, 0,
    SA_CTL_PKEY_AUX_DIGITAL_OUTPUT_VALUE, 0x00000005
);
if (result) { /* handle error, abort */ }
// next set output 2 (DOUT-2) without modifying the other outputs
// DOUT-4 | DOUT-3 | DOUT-2 | DOUT-1 |
// H(1)   | L(0)   | L(0)   | L(0)   |
result = SA_CTL_SetProperty_i32(dHandle, 0,
    SA_CTL_PKEY_AUX_DIGITAL_OUTPUT_SET, 0x00000002
);
if (result) { /* handle error, abort */ }
// last clear output 1 (DOUT-1) without modifying the other outputs
// DOUT-4 | DOUT-3 | DOUT-2 | DOUT-1 |
// H(1)   | L(0)   | L(0)   | H(1)   |
result = SA_CTL_SetProperty_i32(dHandle, 0,
    SA_CTL_PKEY_AUX_DIGITAL_OUTPUT_CLEAR, 0x00000001
);

```

2.19.4 Fast Analog Inputs

Fast analog inputs may be used to read analog voltage signals. An application can poll the Aux I/O Module Input0 / Input1 Value properties and use the data for further processing. The I/O module has a total number of six analog inputs which are mapped in groups of two to the channels of the corresponding driver module. The following table shows the combinations of channel index and property which must be used to read the input values of the six analog inputs:

Analog Input	Channel Index	Property
AIN-1	0	SA_CTL_PKEY_AUX_IO_MODULE_INPUT0_VALUE
AIN-2	1	SA_CTL_PKEY_AUX_IO_MODULE_INPUT0_VALUE
AIN-3	2	SA_CTL_PKEY_AUX_IO_MODULE_INPUT0_VALUE
AIN-4	0	SA_CTL_PKEY_AUX_IO_MODULE_INPUT1_VALUE
AIN-5	1	SA_CTL_PKEY_AUX_IO_MODULE_INPUT1_VALUE
AIN-6	2	SA_CTL_PKEY_AUX_IO_MODULE_INPUT1_VALUE

The following code shows how to read the first analog input assigned to the second channel (channel index 1) of a device (AIN-2):

```

SA_CTL_Result_t result;
int64_t input;
result = SA_CTL_GetProperty_i64(dHandle,1,
    SA_CTL_PKEY_AUX_IO_MODULE_INPUT0_VALUE, &input, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'input' holds the value of the analog input AIN-2
}

```

2.19.5 Using Analog Inputs as Control-Loop Feedback

The MCS2 supports to feed external analog signals into the control-loop of a channel. This allows to implement applications like aligning a sample depending on the light intensity of an external light detector or force feedback for a gripper, etc. These tasks require a more complex configuration which is described in the following.

Note that the total number of six analog inputs of the I/O module are mapped in groups of two to the channels of the corresponding driver module. This means that per channel only two of the analog inputs may be used as control-loop feedback. (See Aux I/O Module Input Index property).



NOTICE

It is the user's responsibility to guarantee that a valid signal is fed into the input and that all properties (input ranges, PID parameters, etc.) are configured to reasonable values before enabling the closed-loop operation. Configuring inappropriate values may result in unstable or unexpected behavior of the positioners and potential damage of the stage.

To use an auxiliary input as control-loop feedback the following properties must be configured:

- The actual analog input must be selected with the **Aux Input Select** and **Aux I/O Module Input Index** properties.
- The analog input range must be selected with the **I/O Module Analog Input Range** property.
- The **Aux Positioner Type** must be set to a custom positioner type slot. This slot must be configured with a set of PID parameters with the Tuning and Customizing Properties. Note that not all positioner type properties have a meaning when used as auxiliary positioner type. The following properties are of interest to configure the PID loop: Positioner P Gain, Positioner I Gain, Positioner D Gain, Positioner Anti Windup, Positioner PID Shift, Positioner Target Hold Threshold. A dead band or dead zone for the input signal may be configured with the **Positioner Target Hold Threshold** property.
- Depending on the specific application and the type of feedback signal it may be necessary to disable the endstop detection by setting the **Positioner ESD Distance Threshold** property to zero. Whenever the auxiliary input value represents a set-point for the control-loop instead of a current position of the positioner the endstop detection must be disabled. (E.g. a force

signal in a force-feedback-gripper application defines the set-point and does not follow the actual position.)

- The modifications should be saved to a custom positioner type slot with the **Save Positioner Type** property.
- The direction sense of the feedback must be defined with the **Aux Direction Inversion** property. It must match the direction sense of the control-loop output. Otherwise a runaway condition may occur when commanding a closed-loop movement.
- The **Control Loop Input** property must be set to `SA_CTL_CONTROL_LOOP_INPUT_AUX_IN` to feed the auxiliary input signal into the PID controller.

Using an auxiliary input as control-loop feedback has some special characteristics which need to be considered:

- The `SA_CTL_CH_STATE_BIT_SENSOR_PRESENT` flag of the Channel State refers to the position control-loop input. The auxiliary input signal is always treated as 'present' for the control-loop.
- The auxiliary input value is reflected in the 'current position' of a channel, even if the representation of the input signal has a physical unit different from 'position'. Commanding the channels 'target position' with the `SA_CTL_Move` function always refers to the absolute value and range of the input signal.
- The auxiliary input signal is defined as absolute value, thus it is not possible to define a logical scale offset, e.g. by setting the position with the Position property. Doing so affects the position calculation of an integrated sensor of a positioner (if there is one). Several properties give access to the position of an integrated sensor as well as the auxiliary input values regardless of the actual signal currently used as feedback signal. Refer to figure 2.14 for the different signal paths and properties in this context.
- Two positioner type slots are used to define the tuning parameters of the control-loop:
 - The Aux Positioner Type property defines a set of tuning parameters which is used if an auxiliary input provides the control-loop feedback.
 - The Positioner Type property defines the parameters for all other configurations.

The corresponding set of parameters is configured implicitly when changing the control-loop input. This allows to switch between two operation modes without manually reconfiguring the control-loop tuning.

The following figure shows the auxiliary input configuration for each channel:

2.19.6 Using Analog Inputs for External Sensor Correction

Build-in sensors of SmarAct positioners offer nanometer resolution and allow high precision closed-loop position control. However, in some applications it may be required to correct the sensor position of a channel with an external signal, e.g. for location correction of a probe or live compensation of position errors with an additional external sensor, etc.

For this applications the MCS2 offers the possibility to apply an offset value to the current sensor position, which is derived from the auxiliary analog input of an I/O module.

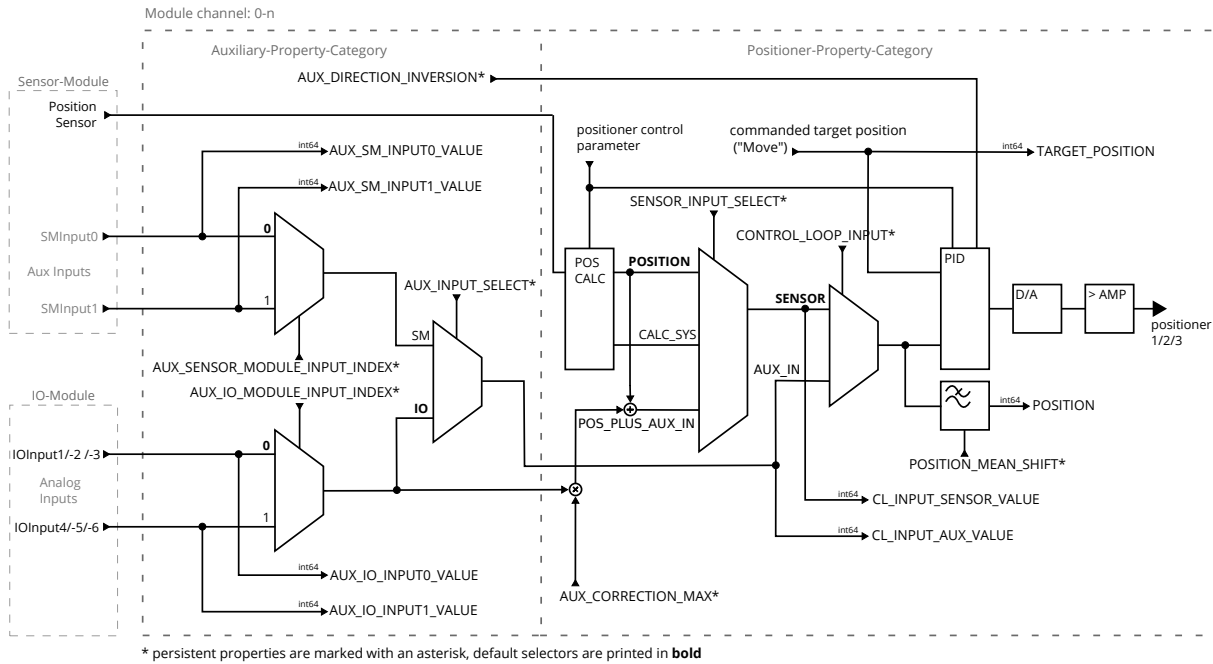


Figure 2.14: Auxiliary Input Configuration (per channel)

The following properties must be configured to use the external sensor correction feature:

- The **Aux Correction Max** property must be configured to define the scaling of analog input voltage to position offset. Furthermore the sign of this setting specifies if the resulting offset value is added or subtracted to the current position.
- The **Control Loop Input** property must be set to `SA_CTL_CONTROL_LOOP_INPUT_SENSOR` (1) to feed the sensor position (plus correction offset) into the PID controller.
- The **Aux I/O Module Input Index** must be configured to select which auxiliary input should be used to generate the position offset value.
- The **I/O Module Analog Input Range** property must be configured to specify the desired analog range for the input signal.
- The **Sensor Input Select** property must be set to `SA_CTL_SENSOR_INPUT_SELECT_POS_PLUS_AUX_IN` (2) to enable the correction.

After that the analog input signal, scaled to a corresponding position, is continuously added to the current position. Refer to figure 2.14 for an overview of the signal paths and used properties.

To actively hold the target while correcting the physical position according to the applied correction value issue a closed-loop movement with the desired target. The **Hold Time*** property must be set to `SA_CTL_HOLD_TIME_INFINITE` (-1) to keep the control-loop active after the commanded target has been reached.

Note that the **Sensor Power Mode** property must be set to `SA_CTL_SENSOR_MODE_ENABLED` (1) when using the sensor correction feature.

*The Hold Time property is only available for Stick-Slip Piezo Driver. For the Electromagnetic Driver the hold time is always infinite.

Note further that the correction offset is added *after* the logical position offset is applied to the current position and therefore is *not* included when setting the **Position** property. This means, that e.g. setting the position to zero while an external analog signal is applied to the input (and the correction is enabled) the current position will reflect the resulting correction offset value and *not* the zero position. Also the **referencing sequence** will finish its movement at the offset position and *not* at the position of the reference mark. (Nevertheless the scale will be set correctly, only the movement will end at the offset position.) To overcome this, it is recommended to disable the offset correction before starting the referencing.

The following code shows how to configure the sensor correction for the second channel of a device to use the first analog input assigned to this channel. The full range input voltage of $\pm 10.24\text{V}$ applied to the input then generates a position offset of $\pm 10\text{ }\mu\text{m}$.

```
SA_CTL_Result_t result;
// set the auxiliary range to 10um for the full range input of 10.24V
result = SA_CTL_SetProperty_i32(dHandle, 1,
    SA_CTL_PKEY_AUX_CORRECTION_MAX, 10e6);
if (result) { /* handle error, abort */ }
// route sensor input signal into PID controller
result = SA_CTL_SetProperty_i32(
    dHandle, 1, SA_CTL_PKEY_CONTROL_LOOP_INPUT,
    SA_CTL_CONTROL_LOOP_INPUT_SENSOR);
if (result) { /* handle error, abort */ }
// specify auxiliary input 0
result = SA_CTL_SetProperty_i32(
    dHandle, 1, SA_CTL_PKEY_AUX_IO_MODULE_INPUT_INDEX, 0);
if (result) { /* handle error, abort */ }
// set the analog input range to +/-10V
result = SA_CTL_SetProperty_i32(
    dHandle, 1, SA_CTL_PKEY_IO_MODULE_ANALOG_INPUT_RANGE,
    SA_CTL_IO_MODULE_ANALOG_INPUT_RANGE_BI_10V);
if (result) { /* handle error, abort */ }
// enable sensor correction
result = SA_CTL_SetProperty_i32(
    dHandle, 1, SA_CTL_PKEY_SENSOR_INPUT_SELECT,
    SA_CTL_SENSOR_INPUT_SELECT_POS_PLUS_AUX_IN);
if (result) { /* handle error, abort */ }
```

2.19.7 Analog Outputs

Analog outputs generate analog voltage control signals for external amplifiers, dispensers etc.

The analog output driver circuit is in a high-impedance state by default. Therefore, the `SA_CTL_IO_MODULE_OPT_BIT_ANALOG_OUTPUT_ENABLED` bit of the I/O Module Options property must be set to enable the output driver.

The Aux Analog Output Value0 / Value1 properties may be used to output an analog voltage on the I/O module analog outputs (AOUT-1 and AOUT-2).

The following code shows how to set both analog outputs of an I/O module:

```
SA_CTL_Result_t result;
// set the output value of analog output0 (AOUT-1) to zero
// which corresponds to 0V
result = SA_CTL_SetProperty_i32(dHandle, 0,
    SA_CTL_PKEY_AUX_ANALOG_OUTPUT_VALUE0, 0);
if (result) { /* handle error, abort */ }
// set the output value of analog output1 (AOUT-2) to max
// which corresponds to +10V
result = SA_CTL_SetProperty_i32(dHandle, 0,
    SA_CTL_PKEY_AUX_ANALOG_OUTPUT_VALUE1, 32768);
if (result) { /* handle error, abort */ }
```

2.20 Input Trigger

Digital input triggers allow to synchronize the device to external clock signals or events. Input triggers are available for the *device* and for individual *channels*.

In order to use the input trigger the device must be equipped with an additional I/O module. Nevertheless, MCS2 rack housings may be equipped with a global device trigger input.

Device Input Trigger

The device input trigger may be used as an emergency stop (global-stop) input, to synchronize the trajectory streaming, to trigger command groups (e.g. a group of movement commands) or to enable and disable the amplifiers of all channels. For this, the trigger signal must be fed into the *digital device input* (DIN-1) of an I/O module or the *global device input* of an MCS2 rack housing.

The following properties must be used to configure the device input trigger:

- The **Device Input Trigger Select** property defines which physical input is used.
- The **Device Input Trigger Condition** property defines whether to react to rising or falling edges.
- The **Device Input Trigger Mode** property defines how the device reacts to incoming trigger signals. The available trigger modes are described in more detail in the following sections.

The current level of the device inputs may be read at any time with the Device State property. The I/O module input and global input flags of the Device State reflect the current electrical level of the inputs independently of the configuration of the input trigger component.

Channel Input Trigger

The channel input trigger may be used as an emergency stop input to stop the movement of a single channel without influencing other channels. For this, the trigger signal must be fed into a *general-purpose digital input* of an I/O module. Note that the mapping between input line of the I/O module and channel is fix according to the following table:

Digital Input	Channel Index
GP-DIN-1	0 (3) (6)
GP-DIN-2	1 (4) (7)
GP-DIN-3	2 (5) (8)

Channel indexes in brackets refer to a second respectively third module of the device.

The following properties must be used to configure the channel input trigger:

- The **Channel Input Trigger Condition** property defines whether to react to rising or falling edges.

- The **Channel Input Trigger Mode** property defines how a channel reacts to incoming trigger signals. The available trigger modes are described in more detail in the following sections.

2.20.1 Disabled Mode

This is the default Device Input Trigger Mode in which all activities on the input line are ignored. (Nonetheless, the current level of the input(s) may be read with the Device State property.)

2.20.2 Emergency Stop Mode

The "emergency stop" Device Input Trigger Mode mode allows to use the input trigger to issue an emergency stop. In terms of the MCS2 an emergency stop stops all active movements. Depending on the used input line, an emergency stop condition may hard-stop *all* channels (and abort active streams and command groups) or stop only a *single* channel of a driver module.

In this mode the input reacts edge-based. The active trigger edge must be defined with the Device Input Trigger Condition resp. Channel Input Trigger Condition property. Note that channels moving with acceleration control active will also be stopped immediately. For Electromagnetic Driver the behavior on an emergency stop is configurable. (See Positioner Control Options property.) The desired behavior how to handle the emergency stop situations can further be configured by setting the Emergency Stop Mode or Channel Emergency Stop Mode property to one of the following modes:

SA_CTL_EMERGENCY_STOP_MODE_NORMAL In this mode the configured input trigger condition issues an emergency stop. After such an event the device or channel continues to behave normally.

SA_CTL_EMERGENCY_STOP_MODE_RESTRICTED In this mode the configured input trigger condition will issue an emergency stop and make the device or channel enter a locked state. In this state you may communicate with the device normally, but all movement commands will respond with a `SA_CTL_EVENT_MOVEMENT_FINISHED` event with its parameter set to `SA_CTL_ERROR_MOVEMENT_LOCKED`. Additionally, the movement locked bit of the Device State property is set. The locked state may be reset by setting the emergency stop mode to any valid value, thereby unlocking the movement again. The I/O module input or global input flag of the Device State property may then be polled to determine when the external emergency stop signal clears before proceeding.

SA_CTL_EMERGENCY_STOP_MODE_AUTO_RELEASE In this mode the configured input trigger condition will issue an emergency stop and make the device or channel enter a locked state. In this state you may communicate with the device normally, but all movement commands will respond with a `SA_CTL_EVENT_MOVEMENT_FINISHED` event with its parameter set to `SA_CTL_ERROR_MOVEMENT_LOCKED`. Additionally, the movement locked bit of the Device State property is set. This state remains until either the emergency stop mode is set to any valid value or the input trigger line is released (inverse edge is detected).

Note that the Emergency Stop Mode (and Channel Emergency Stop Mode) properties are not held in non-volatile memory, but the default value at device startup for the Emergency Stop Mode is configurable with the Default Emergency Stop Mode property.

A `SA_CTL_EVENT_EMERGENCY_STOP_TRIGGERED` event is generated if a *device* emergency stop condition is detected. Note that the *channel* emergency stop does not generate a specific event but the "input change" event of the I/O module may be used to inform the software on a change of a digital input. See section 2.19.3 "Digital Inputs" for more information..

The following code gives an example for the configuration of the *device* input trigger when used as emergency stop. After a successful configuration a falling edge on the **device input trigger** will issue an emergency stop, meaning that *all* channels of the device are stopped. The following behavior is defined by the configured Emergency Stop Mode (in this case the device continues normally).

```
SA_CTL_Result_t result;
// configure emergency stop mode
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_EMERGENCY_STOP_MODE,
    SA_CTL_EMERGENCY_STOP_MODE_NORMAL
);
if (result) { /* handle error, abort */ }
// set input trigger condition to falling edge
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_DEV_INPUT_TRIG_CONDITION,
    SA_CTL_TRIGGER_CONDITION_FALLING
);
if (result) { /* handle error, abort */ }
// set device input trigger mode to emergency stop
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_DEV_INPUT_TRIG_MODE,
    SA_CTL_DEV_INPUT_TRIG_MODE_EMERGENCY_STOP
);
if (result) { /* handle error, abort */ }
```

The following code gives an example for the configuration of the *channel* input trigger of channel one when used as emergency stop. After a successful configuration a falling edge on the **channel input trigger** will issue an emergency stop for *this* channel. The following behavior is defined by the configured Channel Emergency Stop Mode (in this case the channel enters the *locked* state).

```
SA_CTL_Result_t result;
// configure emergency stop mode
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_CH_EMERGENCY_STOP_MODE,
    SA_CTL_EMERGENCY_STOP_MODE_RESTRICTED
);
if (result) { /* handle error, abort */ }
// set input trigger condition to falling edge
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_CH_INPUT_TRIG_CONDITION,
```

```

    SA_CTL_TRIGGER_CONDITION_FALLING
);
if (result) { /* handle error, abort */ }
// set channel input trigger mode to emergency stop
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_CH_INPUT_TRIG_MODE,
    SA_CTL_CH_INPUT_TRIG_MODE_EMERGENCY_STOP
);
if (result) { /* handle error, abort */ }

```

2.20.3 Stream Sync Mode

The "stream sync" Device Input Trigger Mode allows to use the streaming's external trigger modes. Calling `SA_CTL_OpenStream` with one of the following modes will start resp. synchronize the stream to the input trigger.

- `SA_CTL_STREAM_TRIGGER_MODE_EXTERNAL_ONCE`
- `SA_CTL_STREAM_TRIGGER_MODE_EXTERNAL_SYNC`
- `SA_CTL_STREAM_TRIGGER_MODE_EXTERNAL`

See section 2.18 "Trajectory Streaming" for more information.

The following code gives an example for the configuration of the input trigger when used to start the stream. After a successful configuration a stream is opened with trigger mode *external once* parameter. If the stream is ready (stream ready event received), a rising edge on the input trigger will start the trajectory's execution.

```

SA_CTL_StreamHandle_t sHandle;
SA_CTL_Result_t result;
// set input trigger mode to stream sync
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_DEV_INPUT_TRIG_MODE,
    SA_CTL_DEV_INPUT_TRIG_MODE_STREAM
);
if (result) { /* handle error, abort */ }
// set input trigger condition to rising edge
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_DEV_INPUT_TRIG_CONDITION,
    SA_CTL_TRIGGER_CONDITION_RISING
);
if (result) { /* handle error, abort */ }
// open stream with trigger mode external once
result = SA_CTL_OpenStream(
    dHandle,
    &sHandle,
    SA_CTL_STREAM_TRIGGER_MODE_EXTERNAL_ONCE

```

```

);
if (result) { /* handle error, abort */ }
// ...
// start streaming frames to the device
// ...
// >> stream ready event <<
// device is now waiting for the external trigger condition to start
// the stream

```

2.20.4 Command Group Sync Mode

The "command group sync" Device Input Trigger Mode allows to use the command groups external trigger mode. Calling `SA_CTL_OpenCommandGroup` with the trigger mode `SA_CTL_CMD_GROUP_TRIGGER_MODE_EXTERNAL` will then delay the groups execution until the external input trigger occurs. See section 2.17 "Command Groups" for more information.

The following code gives an example for the configuration of the input trigger when used for starting command groups. After a successful configuration of the input trigger a command group is opened with the external trigger mode parameter, filled (e.g. with `SA_CTL_Move` commands) and then closed. The groups execution though is delayed until the device detects a rising edge on the input trigger.

```

SA_CTL_TransmitHandle_t tHandle;
SA_CTL_Result_t result;
// set input trigger mode to cmd group sync
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_DEV_INPUT_TRIG_MODE,
    SA_CTL_DEV_INPUT_TRIG_MODE_CMD_GROUP
);
if (result) { /* handle error, abort */ }
// set input trigger condition to rising edge
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_DEV_INPUT_TRIG_CONDITION,
    SA_CTL_TRIGGER_CONDITION_RISING
);
if (result) { /* handle error, abort */ }
// open command group with trigger mode external
result = SA_CTL_OpenCommandGroup(
    dHandle,
    &tHandle,
    SA_CTL_CMD_GROUP_TRIGGER_MODE_EXTERNAL
);
if (result) { /* handle error, abort */ }
// ...
// fill command group
// ...
// close command group

```

```
result = SA_CTL_CloseCommandGroup(dHandle, tHandle);
if (result) { /* handle error, abort */ }
// command group is now waiting for the external trigger condition
```

2.20.5 Event Trigger Mode

The "event" Device Input Trigger Mode allows to get a notification whenever an electrical trigger signal was detected on the trigger input. This mode is useful to simply inform the software about the occurrence of an external trigger signal without any further actions on the controller.

Note that the maximum frequency of the input signal should be limited to 500 Hz in this mode.

The following code gives an example for the configuration of the input trigger when used to get event notifications. After a successful configuration a rising edge on the input trigger will generate a `SA_CTL_EVENT_EXT_INPUT_TRIGGERED` event.

```
SA_CTL_Result_t result;
// set input trigger mode to event trigger
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_DEV_INPUT_TRIG_MODE,
    SA_CTL_DEV_INPUT_TRIG_MODE_EVENT
);
if (result) { /* handle error, abort */ }
// set input trigger condition to rising edge
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_DEV_INPUT_TRIG_CONDITION,
    SA_CTL_TRIGGER_CONDITION_RISING
);
if (result) { /* handle error, abort */ }
// wait for events
SA_CTL_Event_t event;
result = SA_CTL_WaitForEvent(dHandle, &event, SA_CTL_INFINITE);
if (result) { /* handle error, abort */ }
// ...
```

2.20.6 Amplifier Lock Mode

The "amplifier lock" Device Input Trigger Mode allows to enable and disable the amplifiers of *all* channels of the device with an external electrical signal.

In this mode the input reacts level-based. The active level must be defined with the Device Input Trigger Condition property. The following settings are possible:

SA_CTL_TRIGGER_CONDITION_RISING In this setting the amplifiers will be *enabled* with a *high* level on the device input and *disabled* with a *low* level.

SA_CTL_TRIGGER_CONDITION_FALLING In this setting the amplifiers will be *enabled* with a *low* level and *disabled* with a *high* level.

Disabling the amplifiers removes any driving voltage from the outputs of the drivers and implicitly disables the control-loops. All channels enter the *stopped* state and the amplifiers will be *locked*. In this state you may communicate with the device normally, but trying to enable the amplifier with the Amplifier Enabled property will return a SA_CTL_ERROR_AMPLIFIER_LOCKED error. Commanding any movement will respond with a SA_CTL_EVENT_MOVEMENT_FINISHED event with its parameter set to SA_CTL_ERROR_AMPLIFIER_LOCKED. Additionally, the Device State bit SA_CTL_DEV_STATE_BIT_AMPLIFIER_LOCKED will be set.

The SA_CTL_CH_STATE_BIT_AMPLIFIER_ENABLED bit of the Channel State reflects the current state of the channel's amplifiers.

Stick-Slip Piezo Driver

A level change on the input will automatically *disable* or *enable* the amplifiers according to the current level of the input signal and the configured trigger condition.

Electromagnetic Driver

A level change to the *disabled* condition will automatically *disable* the amplifiers and therefore remove any holding force from the positioners. Since the default amplifier mode is SA_CTL_DISABLED a level change to the *enabled* condition will **not** automatically enable the amplifier but will unlock the Amplifier Enabled property. As a safety measure the user must enable the amplifier manually by writing to this property.

Example

The following code gives an example for the configuration of the input trigger when used to enable and disable resp. lock the driver amplifiers. After a successful configuration a low level on the input will disable and lock the amplifiers and a high level will unlock the amplifiers.

```
SA_CTL_Result_t result;
// set input trigger mode to amplifier lock
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_DEV_INPUT_TRIG_MODE,
    SA_CTL_DEV_INPUT_TRIG_MODE_AMPLIFIER_LOCK
);
if (result) { /* handle error, abort */ }
// set input trigger condition to high active (rising)
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_DEV_INPUT_TRIG_CONDITION,
    SA_CTL_TRIGGER_CONDITION_RISING
);
```

```
if (result) { /* handle error, abort */ }
```

2.21 Output Trigger

In some applications it is useful to have the controller output a trigger signal each time the position of a channel has made a certain increment or the target position has been reached. The trigger signals may then be used by external logic (e.g. to trigger a camera).

In order to use the output trigger signals the device must be equipped with an additional I/O module. Since each I/O module is connected to a specific driver module the output trigger signals are assigned to the channels of the corresponding driver module.

In general the following properties must be used to configure the output trigger:

- The **Channel Output Trigger Mode** property defines what is output to the corresponding output pin. The available trigger modes are described in more detail in the following sections.
- The **Channel Output Trigger Polarity** property defines the polarity of the output trigger signal.
- The **Channel Output Trigger Pulse Width** property specifies the pulse width of a trigger output pulse for non level-based modes.
- The **I/O Module Options** property bit
SA_CTL_IO_MODULE_OPT_BIT_DIGITAL_OUTPUT_ENABLED must be set to enable the output driver circuit.
- The **I/O Module Voltage** selects the output voltage of the pin.

Additional properties must be configured for some modes as described in the following sections. Note that the I/O module settings are global for all output channels of the I/O module. The following example code enables the output trigger and configures the output voltage to 5V.

```
SA_CTL_Result_t result;
// set the output driver voltage level to 5V
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_IO_MODULE_VOLTAGE,
    SA_CTL_IO_MODULE_VOLTAGE_5V
);
if (result) { /* handle error, abort */ }
// enable the output driver circuit of the I/O module
result = SA_CTL_SetProperty_i32(
    dHandle, 0,
    SA_CTL_PKEY_IO_MODULE_OPTIONS,
    SA_CTL_IO_MODULE_OPT_BIT_DIGITAL_OUTPUT_ENABLED
);
if (result) { /* handle error, abort */ }
```

2.21.1 Constant Mode

This is the default mode in which a constant level is output. The level corresponds to the inactive state of the configured Channel Output Trigger Polarity.

The following example shows how user defined levels can be output in this mode.

```
SA_CTL_Result_t result;
result = SA_CTL_SetProperty_i32(
    dHandle, 2,
    SA_CTL_PKEY_CH_OUTPUT_TRIG_POLARITY,
    SA_CTL_TRIGGER_POLARITY_ACTIVE_HIGH
);
if (result) { /* handle error, abort */ }
result = SA_CTL_SetProperty_i32(
    dHandle, 2,
    SA_CTL_PKEY_CH_OUTPUT_TRIG_MODE,
    SA_CTL_CH_OUTPUT_TRIG_MODE_CONSTANT
);
if (result) { /* handle error, abort */ }
// output of channel 2 level is now low
// perform some tasks...
result = SA_CTL_SetProperty_i32(
    dHandle, 2,
    SA_CTL_PKEY_CH_OUTPUT_TRIG_POLARITY,
    SA_CTL_TRIGGER_POLARITY_ACTIVE_LOW
);
if (result) { /* handle error, abort */ }
// output of channel 2 level is now high
```

2.21.2 Position Compare Mode

The "position compare" mode allows to generate trigger signals according to the current position of a positioner. One independent trigger per channel is available.

The following additional properties must be used to configure the position compare component:

- Channel Position Compare Start Threshold
- Channel Position Compare Increment
- Channel Position Compare Direction
- Channel Position Compare Limit Min
- Channel Position Compare Limit Max

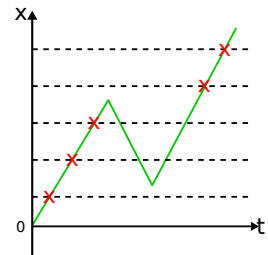
These properties must be configured differently according to the required operation. The start threshold and the increment span a raster of trigger positions over the positioners travel range. A dynamic threshold value is used internally to define a trigger position. The current position is compared against this threshold and the trigger is generated once the threshold has been passed. The threshold value is then shifted according to the configured parameters to define the next trigger position. The compare direction and a minimum and maximum position compare limit may be configured additionally to limit the active range and to define the trigger behavior.

Note that the maximum trigger rate of the outputs is defined by the update rate of the internal position calculation resp. the frame rate of the sensor module. The frame rate is 50 kHz for MCS2 sensor modules and 39.062 kHz for PicoScale interferometers. This is in general no limitation but must be considered for high-speed applications.

The following sections describe the different configurations.

Direction SA_CTL_FORWARD_DIRECTION or SA_CTL_BACKWARD_DIRECTION without limits

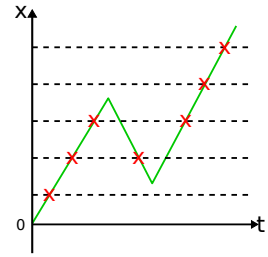
In this configuration the Channel Position Compare Direction is set to `SA_CTL_FORWARD_DIRECTION` or `SA_CTL_BACKWARD_DIRECTION` and the Channel Position Compare Limit Min and Channel Position Compare Limit Max are not active. (Set to the same value to disable the limit checks.) The position compare component will then only trigger on the next threshold in the configured direction without ever being reset again. This means that on the same position there will never be more than one trigger. To reset the component the Channel Position Compare Start Threshold must be set again.



In the image the thresholds are marked with dotted lines with the green solid line being the movement of the positioner. Every red X marks a trigger position.

Direction `SA_CTL_EITHER_DIRECTION` without limits

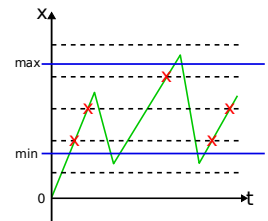
In this configuration the Channel Position Compare Direction is set to `SA_CTL_EITHER_DIRECTION` and the Channel Position Compare Limit Min and Channel Position Compare Limit Max are not active. (Set to the same value to disable the limit checks.) The position compare component will trigger in both directions, ignoring the most recent threshold, especially not triggering indefinitely when stopping right on a threshold position. This means that specific positions may trigger the output more than once but only if a different trigger position has been reached in the meantime.



The image shows equal behavior to the previous example except that the same physical position triggers the output more than once.

Direction `SA_CTL_FORWARD_DIRECTION` or `SA_CTL_BACKWARD_DIRECTION` with limits

In this configuration the Channel Position Compare Direction is set to `SA_CTL_FORWARD_DIRECTION` or `SA_CTL_BACKWARD_DIRECTION` and the Channel Position Compare Limit Min and Channel Position Compare Limit Max are active. This configuration is also called "line scanning" mode. Line scanning means that positions in one moving direction trigger the output but not in the other direction. The configured limits define a window between a min and a max position. Outside this window no pulses will be generated.



The advantage of the limit configuration is that no manual reset of the start threshold by writing the corresponding property is necessary. The threshold will be reset automatically once a limit position has been passed. Note that the limit positions should be defined with sufficient tolerance to reliably pass the last threshold while moving.

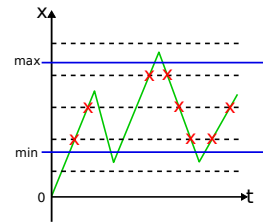
This configuration is especially useful to implement raster scanning applications where e.g. an X/Y stage moves a sample along a specific trajectory and a detector must be triggered according to the current position of a sample. With the X-positioner being moved while inside the window and the Y-positioner at the turning points of the X-positioner.

The image depicts the limits with a blue solid line, each threshold with a black dotted line and the current position with a green solid line. Every red X marks a trigger position. Once the max limit position has been passed the threshold is reset so that after passing the min limit position the output trigger pulses will be generated again.

Direction `SA_CTL_EITHER_DIRECTION` with limits

In this configuration the Channel Position Compare Direction is set to `SA_CTL_EITHER_DIRECTION` and the Channel Position Compare Limit Min and Channel Position Compare Limit Max are active. This configuration is also called "snake scanning" mode.

The snake scanning mode acts as if there were two "line scanning" modes active, one for each direction. This means that positions within a window will trigger the output in one direction and as soon as the limit has been passed trigger the output in the opposite direction again. In other words, the active trigger direction is flipped every time the corresponding limit position has been passed. Note that the limit positions should be defined with sufficient tolerance to reliably pass the last threshold while moving. This mode allows automatic operation without any further configuration while performing the movements.



The image depicts the limits with a blue solid line, each threshold with a black dotted line and the current position with a green solid line. Every red X marks a trigger position.

Line Scanning Programming Example

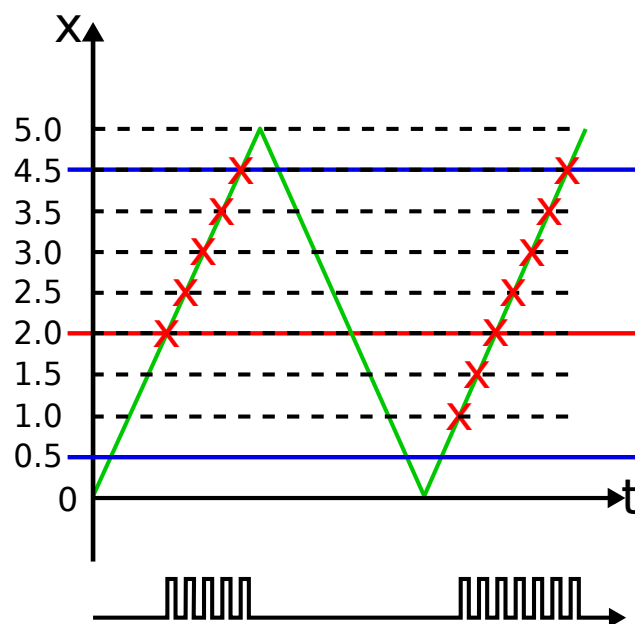


Figure 2.15: Visualization of the example for using the output trigger mode

The following code gives an example for the configuration of the output trigger for channel 1. The movement is commanded with its reversal points defined to 0 and 5 mm. After enabling the trigger the channel will generate a 1 μ s pulse (0.5 μ s high, 0.5 μ s low) once the position of channel 1 passed 2 mm in forward direction (horizontal red line). Furthermore every 500 μ m consecutive pulses are output (displayed below the graph) until the max limit of 4.5 mm was passed. This is repeated for every movement starting from zero position.

```
SA_CTL_Result_t result;
result = SA_CTL_SetProperty_i64(
    dHandle, 1,
    SA_CTL_PKEY_CH_POS_COMP_START_THRESHOLD, 2e9
);
if (result) { /* handle error, abort */ }
result = SA_CTL_SetProperty_i64(
```

```

    dHandle, 1,
    SA_CTL_PKEY_CH_POS_COMP_INCREMENT, 500e6
);
if (result) { /* handle error, abort */ }
result = SA_CTL_SetProperty_i32(
    dHandle, 1,
    SA_CTL_PKEY_CH_POS_COMP_DIRECTION,
    SA_CTL_FORWARD_DIRECTION
);
if (result) { /* handle error, abort */ }

result = SA_CTL_SetProperty_i64(
    dHandle, 1,
    SA_CTL_PKEY_CH_POS_COMP_LIMIT_MIN, 500e6
);
if (result) { /* handle error, abort */ }
result = SA_CTL_SetProperty_i64(
    dHandle, 1,
    SA_CTL_PKEY_CH_POS_COMP_LIMIT_MAX, 4500e6
);
if (result) { /* handle error, abort */ }
result = SA_CTL_SetProperty_i32(
    dHandle, 1,
    SA_CTL_PKEY_CH_OUTPUT_TRIG_POLARITY,
    SA_CTL_TRIGGER_POLARITY_ACTIVE_HIGH
);
if (result) { /* handle error, abort */ }
result = SA_CTL_SetProperty_i32(
    dHandle, 1,
    SA_CTL_PKEY_CH_OUTPUT_TRIG_PULSE_WIDTH, 1000
);
if (result) { /* handle error, abort */ }
result = SA_CTL_SetProperty_i32(
    dHandle, 1,
    SA_CTL_PKEY_CH_OUTPUT_TRIG_MODE,
    SA_CTL_CH_OUTPUT_TRIG_MODE_POSITION_COMPARE
);
if (result) { /* handle error, abort */ }
// start movement between position 0 and 5mm

```

2.21.3 Target Reached Mode

The "target reached" mode allows to generate a pulse once a closed-loop movement command finished and the positioner reached its target position. The pulse is only generated for successfully finished movement commands. Note for trajectory streaming that the pulse is only generated at the end of a stream and not on every stream target update.

The following code gives an example for the configuration of the target reached output trigger for channel 1. After enabling the trigger the output of the channel will generate a pulse of defined length once the target position of a movement has been reached. Note that the configured pulse

width includes the duration of the pulse as well as the duration of the pause. When setting the pulse width to 1000 ns pulses with 500 ns high level and 500 ns low level will be generated.

```
SA_CTL_Result_t result;
result = SA_CTL_SetProperty_i32(
    dHandle, 1,
    SA_CTL_PKEY_CH_OUTPUT_TRIG_POLARITY,
    SA_CTL_TRIGGER_POLARITY_ACTIVE_HIGH
);
if (result) { /* handle error, abort */ }
result = SA_CTL_SetProperty_i32(
    dHandle, 1,
    SA_CTL_PKEY_CH_OUTPUT_TRIG_PULSE_WIDTH,
    1000
);
if (result) { /* handle error, abort */ }
result = SA_CTL_SetProperty_i32(
    dHandle, 1,
    SA_CTL_PKEY_CH_OUTPUT_TRIG_MODE,
    SA_CTL_CH_OUTPUT_TRIG_MODE_TARGET_REACHED
);
if (result) { /* handle error, abort */ }
```

2.21.4 Actively Moving Mode

The "actively moving" mode generates an output level similar to the actively moving Channel State bit. The output level is in the active state while the positioner is moving (open-loop or closed-loop) and inactive otherwise. For the trajectory streaming the output is active as long as the stream is executed. Which output level (high or low) represents the active state must be defined with the Channel Output Trigger Polarity property. Since the output is level-based in this mode the Channel Output Trigger Pulse Width setting is ignored.

The following example code configures channel 2 to output a high level while the positioner is moving.

```
SA_CTL_Result_t result;
result = SA_CTL_SetProperty_i32(
    dHandle, 2,
    SA_CTL_PKEY_CH_OUTPUT_TRIG_POLARITY,
    SA_CTL_TRIGGER_POLARITY_ACTIVE_HIGH
);
if (result) { /* handle error, abort */ }
result = SA_CTL_SetProperty_i32(
    dHandle, 2,
    SA_CTL_PKEY_CH_OUTPUT_TRIG_MODE,
    SA_CTL_CH_OUTPUT_TRIG_MODE_ACTIVELY_MOVING
);
if (result) { /* handle error, abort */ }
```

2.21.5 In Position Mode

The "in position" mode generates an output level similar to the "in position" Channel State bit.

The output is active when the positioner has been within the configured In Position Threshold near the target for minimum or longer than the configured In Position Delay and no commanded movement (or trajectory streaming) is executed. The "in position" output signal is generated continuously based on the current and the commanded target position. The channel must be in the holding state actively holding the current position for the output to be active. If the positioner leaves the defined "in position" range the output becomes inactive and the delay is restarted. Which output level (high or low) represents the active state must be defined with the Channel Output Trigger Polarity property. Since the output is level-based in this mode the Channel Output Trigger Pulse Width setting is ignored.

The following example code configures channel 2 to output a high level when the channel is "in position" (for min. 200 ms max. 100 nm or 100 m° away from the target).

```
SA_CTL_Result_t result;
result = SA_CTL_SetProperty_i32(
    dHandle, 2,
    SA_CTL_PKEY_IN_POSITION_THRESHOLD,
    100000
);
if (result) { /* handle error, abort */ }
result = SA_CTL_SetProperty_i32(
    dHandle, 2,
    SA_CTL_PKEY_IN_POSITION_DELAY,
    200
);
if (result) { /* handle error, abort */ }
result = SA_CTL_SetProperty_i32(
    dHandle, 2,
    SA_CTL_PKEY_CH_OUTPUT_TRIG_POLARITY,
    SA_CTL_TRIGGER_POLARITY_ACTIVE_HIGH
);
if (result) { /* handle error, abort */ }
result = SA_CTL_SetProperty_i32(
    dHandle, 2,
    SA_CTL_PKEY_CH_OUTPUT_TRIG_MODE,
    SA_CTL_CH_OUTPUT_TRIG_MODE_IN_POSITION
);
if (result) { /* handle error, abort */ }
```

2.22 Phasing of Electro-Magnetic Driven Positioners

To drive brushless permanent magnet positioners the controller must know the absolute position of the slider within a magnetic period. Since the position sensor works on an incremental basis the absolute position is unknown at startup. The controller performs a special routine to establish the phasing reference. For this, the coils are driven in a defined pattern while monitoring the reaction of the positioner. This sequence is known as "phasing".

The phasing is started automatically when the amplifier is enabled by setting the Amplifier Enabled property to `SA_CTL_ENABLED` (0x01). Note that external force or displacement must not be applied to the positioner while the sequence is running. The phasing takes some time to complete. During this time the `SA_CTL_CH_STATE_BIT_ACTIVELY_MOVING` Channel State bit is set.

Once the sequence has finished a `SA_CTL_EVENT_PHASING_FINISHED` event is generated. The parameter of the event holds a `SA_CTL_ERROR_TIMEOUT` error in case the phasing could not determine the phase offset. Note that in this case the amplifier will also be disabled again.

If the phasing was successful the `SA_CTL_CH_STATE_BIT_IS_PHASED` Channel State bit is set and the channel enters the closed-loop *holding* state.

**NOTICE**

Note that the phasing routine induces some motion of the positioner while running. As a safety precaution, make sure that the positioner has enough freedom to move without damaging other equipment.

The phasing is invalidated in the following cases:

- The positioner is detached from the channel
- The Logical Scale Inversion property is modified
- The Positioner Type property is modified
- The sensor is disabled with the Sensor Power Mode property

Subsequently the control-loop and the amplifier are disabled.

**NOTICE**

Electromagnetic driven positioners are not self-locking. Disabling the control-loop removes any holding force from the positioner. Make sure not to damage any equipment when the positioner changes its position unintentionally!

2.23 Operation of Dual-Piezo Hybrid Positioners

SmarAct's dual-piezo hybrid positioners combine the advantages of stick-slip piezo positioners and piezo scanners in a single device by stacking two dedicated stages on top of each other. This brings the advantage that both, stick-slip actuator and scanner, use the same feedback-signal for closed-loop positioning. Dual-piezo hybrid positioners can be connected to Stick-Slip Piezo Driver channels. By configuring the appropriate positioner type the channel activates a special control signal generation to move either the stick-slip actuator or the piezo scanner actuator. Which actuator is driven depends on the distance to the commanded target. As both stick-slip actuator and piezo scanner use the same output signal for movements, it has to be shaped accordingly. The faster the change on the output signal, the less the piezo scanner moves. To ensure proper open-loop step movements, a minimal steepness of the output signal has to be enforced. That is why the signal for low open-loop frequencies will consist of fast pulses with pauses.

Note that configuring the correct positioner type as well as performing the calibration sequence is essential for the operation of dual-piezo hybrid positioners.



NOTICE

A positioner type mismatch may result in unstable closed-loop operation and oscillation of the stage. Be aware that these effects may be significantly more distinct than for regular stick-slip positioners.

After powering up the controller each positioner is scanned to the middle of its scan range. The resulting movement of dual-piezo hybrid positioners is in the range of up to 20 µm and therefore much higher than the movement of regular stick-slip positioners.



NOTICE

As a safety precaution, make sure that the positioner has enough freedom to move without damaging other equipment when powering up the controller.

Due to the different signal generation dual-piezo hybrid positioners have the following restrictions:

- The *quiet* and *low-vibration* actuator modes are not available. Setting the Actuator Mode to `SA_CTL_ACTUATOR_MODE_QUIET` or `SA_CTL_ACTUATOR_MODE_LOW_VIBRATION` has no effect on the actuator driving signal generation.
- The Positioner Control Options `SA_CTL_POS_CTRL_OPT_BIT_FORCED_SLIP_DIS` and `SA_CTL_POS_CTRL_OPT_BIT_TARGET_TO_ZERO_VOLTAGE` have no effect and are ignored.
- The Trajectory Streaming is not available. Starting a trajectory stream will generate a `SA_CTL_ERROR_INVALID_ACTUATOR_TYPE` error.

2.24 Feature Permissions

The MCS2 has a feature permission system which allows to activate special features via an software activation process without physically returning the controller to SmarAct. New features may be unlocked by upgrading the controller with an upgrade file. The MCS2 Service Tool is used to perform this upgrade. Please contact SmarAct for the details on purchasing a feature upgrade.

Currently the following features are available:

- Low Vibration Actuator Mode (Actuator Mode property)^{1,2}
- Advanced Sensor Correction (Signal Correction Options property)¹

In case that a feature is not activated on a controller, trying to enable it will generate a `SA_CTL_ERROR_PERMISSION_DENIED` error.

¹This feature is only available for Stick-Slip Piezo Driver.

²This option has no effect for dual-piezo hybrid positioners.

3 FUNCTION REFERENCE

All functions of the library use the `cdecl` calling convention. Some development environments, such as Delphi, use `stdcall` by default. This must be taken into account when importing the library functions.

3.1 Function Summary

Table 3.1 – Function Summary

Function Name	Short Description	Page
SA_CTL_GetFullVersionString	Returns the version of the library as a human readable string.	121
SA_CTL_GetResultInfo	Returns a human readable error string for the given error code.	122
SA_CTL_GetEventInfo	Returns a human readable info string for the given event.	123
SA_CTL_FindDevices	Returns a list of locator strings of available devices.	124
SA_CTL_Open	Opens a connection to a device.	126
SA_CTL_Close	Closes a connection to a device.	128
SA_CTL_Cancel	Unblocks all blocking API calls.	129
SA_CTL_GetProperty_i32	Directly returns the value of a 32-bit integer property.	130
SA_CTL_SetProperty_i32	Directly sets the value of a 32-bit integer property.	132
SA_CTL_SetPropertyArray_i32	Directly sets the value of a 32-bit integer array property.	133
SA_CTL_GetProperty_i64	Directly returns the value of a 64-bit integer property.	134
SA_CTL_SetProperty_i64	Directly sets the value of a 64-bit integer property.	135

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Table 3.1 – Continued from previous page

Function Name	Short Description	Page
SA_CTL_SetPropertyArray_i64	Directly sets the value of a 64-bit integer array property.	136
SA_CTL_GetProperty_s	Directly returns the value of a string property.	137
SA_CTL_SetProperty_s	Directly sets the value of a string property.	139
SA_CTL_RequestReadProperty	Requests the value of a property (non-blocking).	140
SA_CTL_ReadProperty_i32	Reads the value of a requested 32-bit integer property.	142
SA_CTL_ReadProperty_i64	Reads the value of a requested 64-bit integer property.	143
SA_CTL_ReadProperty_s	Reads the value of a requested string property.	144
SA_CTL_RequestWriteProperty_i32	Requests to write the value of a 32-bit integer property (non-blocking).	146
SA_CTL_RequestWriteProperty_i64	Requests to write the value of a 64-bit integer property (non-blocking).	148
SA_CTL_RequestWriteProperty_s	Requests to write the value of a string property (non-blocking).	149
SA_CTL_RequestWritePropertyArray_i32	Requests to write the value of a 32-bit integer array property (non-blocking).	150
SA_CTL_RequestWritePropertyArray_i64	Requests to write the value of a 64-bit integer array property (non-blocking).	151
SA_CTL_WaitForWrite	Waits until a write operation has finished.	152
SA_CTL_CancelRequest	Cancels a non-blocking read or write request.	153
SA_CTL_CreateOutputBuffer	Opens up an output buffer for delayed transmission of several commands.	154
SA_CTL_FlushOutputBuffer	Flushes an output buffer and triggers the transmission to the device.	155
SA_CTL_CancelOutputBuffer	Cancels an output buffer and discards all buffered commands.	156
SA_CTL_OpenCommandGroup	Opens up an atomic command group.	157

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Table 3.1 – Continued from previous page

Function Name	Short Description	Page
SA_CTL_CloseCommandGroup	Flushes a command group and makes all commands of the group take effect.	158
SA_CTL_CancelCommandGroup	Cancels a command group and discards all buffered commands.	159
SA_CTL_WaitForEvent	Listens to events from the device.	160
SA_CTL_Calibrate	Performs a calibration.	162
SA_CTL_Reference	Performs a finding of a reference mark.	164
SA_CTL_Move	Performs a movement.	166
SA_CTL_Stop	Aborts all ongoing movements.	168
SA_CTL_OpenStream	Opens a stream.	169
SA_CTL_StreamFrame	Sends a previously assembled frame to the device.	171
SA_CTL_CloseStream	Closes a stream.	173
SA_CTL_AbortStream	Aborts a stream.	174

3.2 Detailed Function Description

3.2.1 SA_CTL_GetFullVersionString

Interface:

```
const char* SA_CTL_GetFullVersionString();
```

Description:

This function returns the version of the library as a null terminated string.

Parameters:

none

Example:

```
cout << "version is: " << SA_CTL_GetFullVersionString() << endl;
```

3.2.2 SA_CTL_GetResultInfo

Interface:

```
const char* SA_CTL_GetResultInfo(  
    SA_CTL_Result_t result  
);
```

Description:

All functions of the library return a result code that indicates success or failure of execution. This function may be used to translate a result code into a human readable text string, e.g. to be output on a console or a GUI element.

Parameters:

- *result* (SA_CTL_Result_t), **input**: The error code.

Example:

```
SA_CTL_Result_t result;  
SA_CTL_DeviceHandle_t dHandle;  
result = SA_CTL_Open(&dHandle, "usb:sn:MCS2-00000001", "");  
if (result != SA_CTL_ERROR_NONE) {  
    cout << "Error occurred: " << SA_CTL_GetResultInfo(result) << endl;  
}
```

3.2.3 SA_CTL_GetEventInfo

Interface:

```
const char* SA_CTL_GetEventInfo(
    const SA_CTL_Event_t *event
);
```

Description:

On successful return of a call to `SA_CTL_WaitForEvent` this function may be used to translate an event into a human readable text string, e.g. to be output on a console or a GUI element.

The string returned by this function resides in thread-local storage and remains valid only until the next call of this function.

Parameters:

- *event* (const `SA_CTL_Event_t *`), **input:** Pointer to a buffer which holds an event returned from `SA_CTL_WaitForEvent`

Example:

```
SA_CTL_Event_t event;
SA_CTL_Result_t result = SA_CTL_WaitForEvent(
    dHandle,
    &event,
    SA_CTL_INFINITE
);
if (result == SA_CTL_ERROR_NONE) {
    cout << "Received Event: " << SA_CTL_GetEventInfo(&event);
    cout << endl;
}
```

See also:

`SA_CTL_WaitForEvent`

3.2.4 SA_CTL_FindDevices

Interface:

```
SA_CTL_Result_t SA_CTL_FindDevices(
    const char *options,
    char *deviceList,
    size_t *deviceListLen
);
```

Description:

This function writes a list of locator strings of devices that are connected to the PC into *deviceList*. The function lists devices with a USB or ethernet interface. The *options* parameter contains a list of configuration options for the find procedure. The caller must pass a pointer to a `char` buffer in *deviceList* and set *deviceListLen* to the size of the buffer. On success the function writes a list of device locators into *deviceList* and the number of characters written into *deviceListLen*. If the supplied buffer is too small to contain the generated list, the buffer will contain no valid content but *deviceListLen* contains the required buffer size (in characters).

For devices with ethernet interface the Network Discover Mode must be set to passive or active mode to enable the find procedure.

Parameters:

- *options* (const char *), **input**: Options for the find procedure (see section 2.1.3).
- *deviceList* (char *), **output**: Pointer to a buffer which holds the device locators after the function has returned. The locator strings are separated by a newline character.
- *deviceListLen* (size_t *), **input/output**: Specifies the size (in bytes) of *deviceList* before the function call. After the function call it holds the number of characters written to *deviceList*.

Example:

```
char buffer[4096];
size_t bufferSize = sizeof(buffer);
SA_CTL_Result_t result = SA_CTL_FindDevices("",buffer,&bufferSize);
if (result == SA_CTL_ERROR_NONE) {
    // buffer holds the locator strings, separated by '\n'
    // bufferSize holds the number of characters written to the buffer
}
```

See also:

4.3.10 Network Discover Mode

3.2.5 SA_CTL_Open

Interface:

```
SA_CTL_Result_t SA_CTL_Open(
    SA_CTL_DeviceHandle_t *dHandle,
    const char *locator,
    const char *config
);
```

Description:

Establishes a connection to a device for communication. Note that the overall device state is not changed. For example, settings made in previous sessions are preserved. Even ongoing movements are not interrupted by connecting to or disconnecting from the device.

The *locator* parameter specifies the device to connect to. See section 2.1.1 "Locators for Device Identification" for more information.

The *config* string parameter may be used to set configuration options for the initialization. The following options are available:

Config String	Description
device-reset	The device is reset on open. A reset has the same effect as a power-down / power-up cycle.
factory-reset	All properties are reset to their factory default values and the device is restarted on open. Warning: The current device configuration will be lost after the reset and can not be restored. Therefore this option must be used with caution.

The function returns with an `SA_CTL_ERROR_INVALID_PARAMETER` error if an invalid or unknown option is given.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t *`), **output**: Handle to the device. Must be passed to following function calls.
- *locator* (`const char *`), **input**: Specifies the device (see section 2.1.1).
- *config* (`const char *`), **input**: Configuration options for the initialization.

Example:

```
SA_CTL_Result_t result;
SA_CTL_DeviceHandle_t dHandle;
result = SA_CTL_Open(&dHandle, "usb:sn:MCS2-00000001", "");
if (result == SA_CTL_ERROR_NONE) {
    // success
}
```

See also:

SA_CTL_Close

3.2.6 SA_CTL_Close

Interface:

```
SA_CTL_Result_t SA_CTL_Close(  
    SA_CTL_DeviceHandle_t dHandle  
);
```

Description:

Closes a previously established connection to a device.

It is safe to call this function while other threads are still using the device, e.g., waiting for an event with `SA_CTL_WaitForEvent`. All blocking functions will be unblocked and will return with an `SA_CTL_ERROR_CANCELED` error.

After calling this function the device handle becomes invalid.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.

Example:

```
SA_CTL_Result_t result;  
SA_CTL_DeviceHandle_t dHandle;  
result = SA_CTL_Open(&dHandle, "usb:sn:MCS2-00000001", "");  
if (result == SA_CTL_ERROR_NONE) {  
    // success  
    result = SA_CTL_Close(dHandle);  
}
```

See also:

`SA_CTL_Open`

3.2.7 SA_CTL_Cancel

Interface:

```
SA_CTL_Result_t SA_CTL_Cancel(  
    SA_CTL_DeviceHandle_t dHandle  
);
```

Description:

This function unblocks a waiting `SA_CTL_WaitForEvent` call. If no thread is currently waiting, the next call to `SA_CTL_WaitForEvent` will be canceled. The unblocked function will return with an `SA_CTL_ERROR_CANCELED` error.

Calling this function before `SA_CTL_Close` is not required for proper cleanup.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.

See also:

`SA_CTL_WaitForEvent`, `SA_CTL_Close`

3.2.8 SA_CTL_GetProperty_i32

Interface:

```
SA_CTL_Result_t SA_CTL_GetProperty_i32(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_PropertyKey_t pkey,
    int32_t *value,
    size_t *ioArraySize
);
```

Description:

This function retrieves a 32-bit integer property value (array) from the device. The caller must supply a pointer to a buffer where the result should be written to as well as a size information which indicates how many values may be written into the buffer. The function then writes the resulting value(s) into the buffer and sets the size information to the number of values written.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *idx* (int8_t), **input**: Index of the addressed device, module or channel (see section 2.2).
- *pkey* (SA_CTL_PropertyKey_t), **input**: Key that identifies the property.
- *value* (int32_t *), **output**: Pointer to a buffer where the result should be written to.
- *ioArraySize* (size_t *), **input/output**: Pointer to a size value that must contain the size of the value buffer (in number of elements, not number of bytes) when the function is called. On function return it contains the number of values written to the buffer. A null pointer is allowed which implicitly indicates an array size of 1.

Example:

```
// get single value (number of bus modules)
int32_t numModules;
SA_CTL_Result_t result;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_NUMBER_OF_BUS_MODULES, &numModules, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // numModules holds the number of modules
}
// get value array
// firmware version properties are arrays of four int32 values
```

```
int32_t fwVersion[4];
size_t ioArraySize = 4;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_FIRMWARE_VERSION, fwVersion, &ioArraySize
);
if (result == SA_CTL_ERROR_NONE) {
    // ioArraySize holds the number of elements
    // fwVersion holds the firmware version (rev., update, minor, major)
}
```

See also:

SA_CTL_SetProperty_i32, SA_CTL_GetProperty_i64,
SA_CTL_GetProperty_s

3.2.9 SA_CTL_SetProperty_i32

Interface:

```
SA_CTL_Result_t SA_CTL_SetProperty_i32(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_PropertyKey_t pkey,
    int32_t value
);
```

Description:

This function writes a 32-bit integer property value to the device.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *idx* (int8_t), **input**: Index of the addressed device, module or channel (see section 2.2).
- *pkey* (SA_CTL_PropertyKey_t), **input**: Key that identifies the property.
- *value* (int32_t), **input**: Value that should be written.

Example:

```
// set move mode
SA_CTL_Result_t result;
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_MOVE_MODE, SA_CTL_MOVE_MODE_STEP
);
if (result == SA_CTL_ERROR_NONE) {
    // move mode for channel 0 is set to step mode (open-loop)
}
```

See also:

SA_CTL_GetProperty_i32, SA_CTL_SetProperty_i64,
SA_CTL_SetProperty_s

3.2.10 SA_CTL_SetPropertyArray_i32

Interface:

```
SA_CTL_Result_t SA_CTL_SetPropertyArray_i32(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_PropertyKey_t pkey,
    const int32_t *values
    size_t arraySize
);
```

Description:

This function writes multiple 32-bit integer values to the device and is used for setting array type properties. The caller must supply a pointer to a buffer containing the values as well as a size information which indicates how many values reside in the buffer.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *idx* (int8_t), **input**: Index of the addressed device, module or channel (see section 2.2).
- *pkey* (SA_CTL_PropertyKey_t), **input**: Key that identifies the property.
- *values* (const int32_t *), **input**: Pointer to a buffer that must contain the values to be written.
- *arraySize* (size_t), **input**: Size value that must contain the size of the value buffer (in number of elements, not number of bytes) when the function is called.

See also:

SA_CTL_GetProperty_i32, SA_CTL_SetPropertyArray_i64

3.2.11 SA_CTL_GetProperty_i64

Interface:

```
SA_CTL_Result_t SA_CTL_GetProperty_i64(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_PropertyKey_t pkey,
    int64_t *value,
    size_t *ioArraySize
);
```

Description:

This function retrieves a 64-bit integer property value (array) from the device. The caller must supply a pointer to a buffer where the result should be written to as well as a size information which indicates how many values may be written into the buffer. The function then writes the resulting value(s) into the buffer and sets the size information to the number of values written.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *idx* (int8_t), **input**: Index of the addressed device, module or channel (see section 2.2).
- *pkey* (SA_CTL_PropertyKey_t), **input**: Key that identifies the property.
- *value* (int64_t *), **output**: Pointer to a buffer where the result should be written to.
- *ioArraySize* (size_t *), **input/output**: Pointer to a size value that must contain the size of the value buffer (in number of elements, not number of bytes) when the function is called. On function return it contains the number of values written to the buffer. A null pointer is allowed which implicitly indicates an array size of 1.

Example:

See example on page 130.

See also:

SA_CTL_SetProperty_i64, SA_CTL_GetProperty_i32,
SA_CTL_GetProperty_s

3.2.12 SA_CTL_SetProperty_i64

Interface:

```
SA_CTL_Result_t SA_CTL_SetProperty_i64(  
    SA_CTL_DeviceHandle_t dHandle,  
    int8_t idx,  
    SA_CTL_PropertyKey_t pkey,  
    int64_t value  
);
```

Description:

This function writes a 64-bit integer property value to the device.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *idx* (int8_t), **input**: Index of the addressed device, module or channel (see section 2.2).
- *pkey* (SA_CTL_PropertyKey_t), **input**: Key that identifies the property.
- *value* (int64_t), **input**: Value that should be written.

Example:

See example on page 132.

See also:

SA_CTL_GetProperty_i64, SA_CTL_SetProperty_i32,
SA_CTL_SetProperty_s

3.2.13 SA_CTL_SetPropertyArray_i64

Interface:

```
SA_CTL_Result_t SA_CTL_SetPropertyArray_i64(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_PropertyKey_t pkey,
    const int64_t *values
    size_t arraySize
);
```

Description:

This function writes multiple 64-bit integer values to the device and is used for setting array type properties. The caller must supply a pointer to a buffer containing the values as well as a size information which indicates how many values reside in the buffer.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *idx* (int8_t), **input**: Index of the addressed device, module or channel (see section 2.2).
- *pkey* (SA_CTL_PropertyKey_t), **input**: Key that identifies the property.
- *values* (const int64_t *), **input**: Pointer to a buffer that must contain the values to be written.
- *arraySize* (size_t), **input**: Size value that must contain the size of the value buffer (in number of elements, not number of bytes) when the function is called.

See also:

SA_CTL_GetProperty_i64, SA_CTL_SetPropertyArray_i32

3.2.14 SA_CTL_GetProperty_s

Interface:

```
SA_CTL_Result_t SA_CTL_GetProperty_s(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_PropertyKey_t pkey,
    char *value,
    size_t *ioArraySize
);
```

Description:

This function retrieves a string property value (array) from the device. The caller must supply a pointer to a buffer where the result should be written to as well as a size information which indicates how many bytes may be written into the buffer. The function then writes the resulting string(s) into the buffer and sets the size information to the number of characters written. The null termination of a string implicitly serves as a separator in case multiple strings are returned.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *idx* (int8_t), **input**: Index of the addressed device, module or channel (see section 2.2).
- *pkey* (SA_CTL_PropertyKey_t), **input**: Key that identifies the property.
- *value* (char *), **output**: Pointer to a buffer where the result should be written to.
- *ioArraySize* (size_t *), **input/output**: Pointer to a size value that must contain size of the value buffer (in bytes) when the function is called. On function return it contains the number of characters written to the buffer.

Example:

```
char deviceSerial[128];
size_t len = sizeof(deviceSerial);
SA_CTL_Result_t result;
result = SA_CTL_GetProperty_s(
    dHandle, 0, SA_CTL_PKEY_DEVICE_SERIAL_NUMBER, deviceSerial, &len
);
if (result == SA_CTL_ERROR_NONE) {
    // deviceSerial holds the unique serial number of the device
    // len holds the length of the string
}
```

See also:

SA_CTL_SetProperty_s, SA_CTL_GetProperty_i32,
SA_CTL_GetProperty_i64

3.2.15 SA_CTL_SetProperty_s

Interface:

```
SA_CTL_Result_t SA_CTL_SetProperty_i32(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_PropertyKey_t pkey,
    const char *value
);
```

Description:

This function writes a string property value to the device. Note that the length of strings may never exceed 63 characters (plus a null terminator).

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *idx* (int8_t), **input**: Index of the addressed device, module or channel (see section 2.2).
- *pkey* (SA_CTL_PropertyKey_t), **input**: Key that identifies the property.
- *value* (const char *), **input**: String that should be written.

Example:

```
SA_CTL_Result_t result;
result = SA_CTL_SetProperty_s(
    dHandle, 0, SA_CTL_PKEY_DEVICE_NAME, "MyFavoriteController"
);
if (result == SA_CTL_ERROR_NONE) {
    // success
}
```

See also:

SA_CTL_GetProperty_s, SA_CTL_SetProperty_i32,
SA_CTL_SetProperty_i64

3.2.16 SA_CTL_RequestReadProperty

Interface:

```
SA_CTL_Result_t SA_CTL_RequestReadProperty(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_PropertyKey_t pkey,
    SA_CTL_RequestID_t *rID,
    SA_CTL_TransmitHandle_t tHandle
);
```

Description:

This function requests to read a property value (array) from the device and can be used for asynchronous (non-blocking) access. The caller must supply a pointer to a buffer where the request ID should be written to. Received values can be accessed later via the obtained request ID and the corresponding `SA_CTL_ReadProperty_x` functions.

The advantage of this method is that the application may request several property values in fast succession and then perform other tasks before blocking on the reception of the results.

The correct `SA_CTL_ReadProperty_x` function must be used depending on the data type of the requested property. Otherwise the read will fail with a `SA_CTL_ERROR_INVALID_DATA_TYPE` error.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.
- *idx* (`int8_t`), **input**: Index of the addressed channel or module (see section 2.2).
- *pkey* (`SA_CTL_PropertyKey_t`), **input**: Key of the property that is requested.
- *rID* (`SA_CTL_RequestID_t *`), **output**: Pointer to a request ID.
- *tHandle* (`SA_CTL_TransmitHandle_t`), **input**: Optional ID to a transmit buffer. If unused set to zero.

Example:

```
// Note: to keep the example clear, we omit processing the result codes
SA_CTL_Request_t rID[2];
int64_t position;
int32_t state;
// Issue requests for the two properties "position" and "channel state"
```

```
SA_CTL_RequestReadProperty(  
    dHandle, 0, SA_CTL_PKEY_POSITION, &rID[0], 0  
);  
SA_CTL_RequestReadProperty(  
    dHandle, 0, SA_CTL_PKEY_CHANNEL_STATE, &rID[1], 0  
);  
// process other tasks  
// ...  
// Receive the results  
SA_CTL_ReadProperty_i64(dHandle, rID[0], &position, 0);  
SA_CTL_ReadProperty_i32(dHandle, rID[1], &state, 0);
```

See also:

SA_CTL_ReadProperty_i32, SA_CTL_ReadProperty_i64,
SA_CTL_ReadProperty_s

3.2.17 SA_CTL_ReadProperty_i32

Interface:

```
SA_CTL_Result_t SA_CTL_ReadProperty_i32(
    SA_CTL_DeviceHandle_t dHandle,
    SA_CTL_RequestID_t rID,
    int32_t *value,
    size_t *ioArraySize
);
```

Description:

This function reads a 32-bit integer property value (array) that has previously been requested using `SA_CTL_RequestReadProperty`.

While the request-function is non-blocking the read-functions block until the desired data has arrived.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.
- *rID* (`SA_CTL_RequestID_t`), **input**: ID of the addressed request.
- *value* (`int32_t *`), **output**: Pointer to a buffer where the result should be written to.
- *ioArraySize* (`size_t *`), **input/output**: Pointer to a size value that must contain the size of the value buffer (in number of elements, not number of bytes) when the function is called. On function return it contains the number of values written to the buffer. A null pointer is allowed which implicitly indicates an array size of 1.

Example:

See example on page 140.

See also:

`SA_CTL_RequestReadProperty`, `SA_CTL_ReadProperty_i64`,
`SA_CTL_ReadProperty_s`

3.2.18 SA_CTL_ReadProperty_i64

Interface:

```
SA_CTL_Result_t SA_CTL_ReadProperty_i64(
    SA_CTL_DeviceHandle_t dHandle,
    SA_CTL_RequestID_t rID,
    int64_t *value,
    size_t *ioArraySize
);
```

Description:

This function reads a 64-bit integer property value (array) that has previously been requested using `SA_CTL_RequestReadProperty`.

While the request-function is non-blocking the read-functions block until the desired data has arrived.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.
- *rID* (`SA_CTL_RequestID_t`), **input**: ID of the addressed request.
- *value* (`int64_t *`), **output**: Pointer to a buffer where the result should be written to.
- *ioArraySize* (`size_t *`), **input/output**: Pointer to a size value that must contain the size of the value buffer (in number of elements, not number of bytes) when the function is called. On function return it contains the number of values written to the buffer. A null pointer is allowed which implicitly indicates an array size of 1.

Example:

See example on page 140.

See also:

`SA_CTL_RequestReadProperty`, `SA_CTL_ReadProperty_i32`,
`SA_CTL_ReadProperty_s`

3.2.19 SA_CTL_ReadProperty_s

Interface:

```
SA_CTL_Result_t SA_CTL_ReadProperty_s(
    SA_CTL_DeviceHandle_t dHandle,
    SA_CTL_RequestID_t rID,
    char *value,
    size_t *ioStringSize
);
```

Description:

This function reads a string property value (array) that has previously been requested using `SA_CTL_RequestReadProperty`.

While the request-function is non-blocking the read-functions block until the desired data has arrived.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.
- *rID* (`SA_CTL_RequestID_t`), **input**: ID of the addressed request.
- *value* (`char *`), **output**: Pointer to a buffer where the result should be written to.
- *ioStringSize* (`size_t *`), **input/output**: Pointer to a size value that must contain size of the value buffer (in bytes) when the function is called. On function return it contains the number of characters written to the buffer.

Example:

```
// Note: to keep the example simple, we omit processing the result codes
SA_CTL_Request_t rID;
char deviceSerial[128];
size_t len = sizeof(deviceSerial);
// Issue request for the "device serial number" property
SA_CTL_RequestReadProperty(
    dHandle, 0, SA_CTL_PKEY_DEVICE_SERIAL_NUMBER, &rID, 0
);
// process other tasks
// ...
// Receive the result
SA_CTL_ReadProperty_s(dHandle, rID, deviceSerial, &len);
```


See also:

SA_CTL_RequestReadProperty, SA_CTL_ReadProperty_i32,
SA_CTL_ReadProperty_i64

3.2.20 SA_CTL_RequestWriteProperty_i32

Interface:

```
SA_CTL_Result_t SA_CTL_RequestWriteProperty_i32(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_PropertyKey_t pkey,
    int32_t value,
    SA_CTL_RequestID_t *rID,
    SA_CTL_TransmitHandle_t tHandle
);
```

Description:

This function writes a 32-bit integer value to the device and can be used for asynchronous (non-blocking) access. The caller can supply a pointer to a buffer where the request ID should be written to. The result (whether the write was successful or not) can be accessed later by passing the obtained request ID to the `SA_CTL_WaitForWrite` function.

The advantage of this method is that the application may write several property values in fast succession and then perform other tasks before blocking on the reception of the results.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.
- *idx* (`int8_t`), **input**: Index of the addressed channel or module (see section 2.2).
- *pkey* (`SA_CTL_PropertyKey_t`), **input**: Key of the property that should be accessed.
- *value* (`int32_t`), **input**: Value that should be written.
- *rID* (`SA_CTL_RequestID_t *`), **output**: Pointer to a request ID. Can be null pointer for call-and-forget mechanism (see section 2.3.4).
- *tHandle* (`SA_CTL_TransmitHandle_t`), **input**: Optional ID to a transmit buffer. If unused set to zero.

Example:

```
SA_CTL_Result_t result;
SA_CTL_RequestID_t rID;
int8_t channel;
int64_t holdTime = 5000;
// Request to set hold time to 5 seconds
result = SA_CTL_RequestWriteProperty_i32(
    dHandle, channel, SA_CTL_PKEY_HOLD_TIME, holdTime, &rID, 0
```

```
);  
// process other tasks  
// ...  
// Wait for the result to arrive  
result = SA_CTL_WaitForWrite(dHandle, rID);
```

See also:

SA_CTL_WaitForWrite, SA_CTL_RequestWriteProperty_i64,
SA_CTL_RequestWriteProperty_s

3.2.21 SA_CTL_RequestWriteProperty_i64

Interface:

```
SA_CTL_Result_t SA_CTL_RequestWriteProperty_i64(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_PropertyKey_t pkey,
    int64_t value,
    SA_CTL_RequestID_t *rID,
    SA_CTL_TransmitHandle_t tHandle
);
```

Description:

This function writes a 64-bit integer value to the device and can be used for asynchronous (non-blocking) access. The caller can supply a pointer to a buffer where the request ID should be written to. The result (whether the write was successful or not) can be accessed later by passing the obtained request ID to the `SA_CTL_WaitForWrite` function.

The advantage of this method is that the application may write several property values in fast succession and then perform other tasks before blocking on the reception of the results.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.
- *idx* (`int8_t`), **input**: Index of the addressed channel or module (see section 2.2).
- *pkey* (`SA_CTL_PropertyKey_t`), **input**: Key of the property that should be accessed.
- *value* (`int64_t`), **input**: Value that should be written.
- *rID* (`SA_CTL_RequestID_t *`), **output**: Pointer to a request ID. Can be null pointer for call-and-forget mechanism (see section 2.3.4).
- *tHandle* (`SA_CTL_TransmitHandle_t`), **input**: Optional ID to a transmit buffer. If unused set to zero.

Example:

See example on page 146.

See also:

`SA_CTL_WaitForWrite`, `SA_CTL_RequestWriteProperty_i32`,
`SA_CTL_RequestWriteProperty_s`

3.2.22 SA_CTL_RequestWriteProperty_s

Interface:

```
SA_CTL_Result_t SA_CTL_RequestWriteProperty_s(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_PropertyKey_t pkey,
    const char *value,
    SA_CTL_RequestID_t *rID,
    SA_CTL_TransmitHandle_t tHandle
);
```

Description:

This function writes a string value to the device and can be used for asynchronous (non-blocking) access. The caller can supply a pointer to a buffer where the request ID should be written to. The result (whether the write was successful or not) can be accessed later by passing the obtained request ID to the `SA_CTL_WaitForWrite` function.

The advantage of this method is that the application may write several property values in fast succession and then perform other tasks before blocking on the reception of the results.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.
- *idx* (`int8_t`), **input**: Index of the addressed channel or module (see section 2.2).
- *pkey* (`SA_CTL_PropertyKey_t`), **input**: Key of the property that should be accessed.
- *value* (`const char *`), **input**: Value that should be written.
- *rID* (`SA_CTL_RequestID_t *`), **output**: Pointer to a request ID. Can be null pointer for call-and-forget mechanism (see section 2.3.4).
- *tHandle* (`SA_CTL_TransmitHandle_t`), **input**: Optional ID to a transmit buffer. If unused set to zero.

Example:

See example on page 146.

See also:

`SA_CTL_WaitForWrite`, `SA_CTL_RequestWriteProperty_i32`,
`SA_CTL_RequestWriteProperty_i64`

3.2.23 SA_CTL_RequestWritePropertyArray_i32

Interface:

```
SA_CTL_Result_t SA_CTL_RequestWritePropertyArray_i32(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_PropertyKey_t pkey,
    int32_t *values,
    size_t arraySize,
    SA_CTL_RequestID_t *rID,
    SA_CTL_TransmitHandle_t tHandle
);
```

Description:

This function writes multiple 32-bit integer values to the device and can be used for asynchronous (non-blocking) access of array type properties. The caller must supply a pointer to a buffer containing the values as well as a size information which indicates how many values reside in the buffer. Furthermore a pointer to a buffer where the request ID should be written to can be provided. The result (whether the write was successful or not) can be accessed later by passing the obtained request ID to the `SA_CTL_WaitForWrite` function.

The advantage of this method is that the application may write several property values in fast succession and then perform other tasks before blocking on the reception of the results.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *idx* (int8_t), **input**: Index of the addressed channel or module (see section 2.2).
- *pkey* (SA_CTL_PropertyKey_t), **input**: Key of the property that should be accessed.
- *values* (int32_t *), **input**: Pointer to a buffer that must contain the values to be written.
- *arraySize* (size_t), **input**: Size value that must contain the size of the value buffer (in number of elements, not number of bytes) when the function is called.
- *rID* (SA_CTL_RequestID_t *), **output**: Pointer to a request ID. Can be null pointer for call-and-forget mechanism (see section 2.3.4).
- *tHandle* (SA_CTL_TransmitHandle_t), **input**: Optional ID to a transmit buffer. If unused set to zero.

See also:

`SA_CTL_WaitForWrite`, `SA_CTL_RequestWritePropertyArray_i64`

3.2.24 SA_CTL_RequestWritePropertyArray_i64

Interface:

```
SA_CTL_Result_t SA_CTL_RequestWritePropertyArray_i64(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_PropertyKey_t pkey,
    int64_t *values,
    size_t arraySize,
    SA_CTL_RequestID_t *rID,
    SA_CTL_TransmitHandle_t tHandle
);
```

Description:

This function writes multiple 64-bit integer values to the device and can be used for asynchronous (non-blocking) access of array type properties. The caller must supply a pointer to a buffer containing the values as well as a size information which indicates how many values reside in the buffer. Furthermore a pointer to a buffer where the request ID should be written to can be provided. The result (whether the write was successful or not) can be accessed later by passing the obtained request ID to the `SA_CTL_WaitForWrite` function.

The advantage of this method is that the application may write several property values in fast succession and then perform other tasks before blocking on the reception of the results.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *idx* (int8_t), **input**: Index of the addressed channel or module (see section 2.2).
- *pkey* (SA_CTL_PropertyKey_t), **input**: Key of the property that should be accessed.
- *values* (int64_t *), **input**: Pointer to a buffer that must contain the values to be written.
- *arraySize* (size_t), **input**: Size value that must contain the size of the value buffer (in number of elements, not number of bytes) when the function is called.
- *rID* (SA_CTL_RequestID_t *), **output**: Pointer to a request ID. Can be null pointer for call-and-forget mechanism (see section 2.3.4).
- *tHandle* (SA_CTL_TransmitHandle_t), **input**: Optional ID to a transmit buffer. If unused set to zero.

See also:

`SA_CTL_WaitForWrite`, `SA_CTL_RequestWritePropertyArray_i32`

3.2.25 SA_CTL_WaitForWrite

Interface:

```
SA_CTL_Result_t SA_CTL_WaitForWrite(  
    SA_CTL_DeviceHandle_t dHandle,  
    SA_CTL_RequestID_t rID  
);
```

Description:

This function returns the result of a property write access that has previously been requested using the data type specific `SA_CTL_RequestWriteProperty_x` function.

While the request-function is non-blocking the `SA_CTL_WaitForWrite` function blocks until the desired result has arrived.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.
- *rID* (`SA_CTL_RequestID_t`), **input**: ID of the addressed request.

Example:

See example on page 146.

See also:

`SA_CTL_RequestWriteProperty_i32`, `SA_CTL_RequestWriteProperty_i64`,
`SA_CTL_RequestWriteProperty_s`

3.2.26 SA_CTL_CancelRequest

Interface:

```
SA_CTL_Result_t SA_CTL_CancelRequest(
    SA_CTL_DeviceHandle_t dHandle,
    SA_CTL_RequestID_t rID
);
```

Description:

This function cancels a non-blocking read or write request.

Without output buffering the request has already been sent. In this case only the answer/result will be discarded but property writes will still be executed.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *rID* (SA_CTL_RequestID_t), **input**: ID of the addressed request.

Example:

```
SA_CTL_Result_t result;
SA_CTL_RequestID_t rID;
// Request to set hold time to 5 seconds
result = SA_CTL_RequestWriteProperty_i32(
    dHandle, 0, SA_CTL_PKEY_HOLD_TIME, 5000, &rID, 0
);
// process other tasks
// ...
// We are not interested in the result anymore and discard the request
result = SA_CTL_CancelRequest(dHandle, rID);
```

See also:

SA_CTL_RequestWriteProperty_i32, SA_CTL_RequestWriteProperty_i64,
SA_CTL_RequestWriteProperty_s, SA_CTL_RequestReadProperty

3.2.27 SA_CTL_CreateOutputBuffer

Interface:

```
SA_CTL_Result_t SA_CTL_CreateOutputBuffer(
    SA_CTL_DeviceHandle_t dHandle,
    SA_CTL_TransmitHandle_t *tHandle
);
```

Description:

Creates an output buffer for optimizing communication throughput with the device using the asynchronous command set. After creation the retrieved transmit handle can be used to choose whether a command is to be buffered or sent directly. A buffered command is not sent to the device immediately. Instead, the data is held back and stored in the internal buffer. You may accumulate several commands and then call `SA_CTL_FlushOutputBuffer` to initiate the transmission or `SA_CTL_CancelOutputBuffer` to cancel the output buffer.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.
- *tHandle* (`SA_CTL_TransmitHandle_t *`), **output**: Pointer to a transmit handle.

Example:

```
// Note: to keep the example simple, we omit processing the result codes
SA_CTL_TransmitHandle_t tHandle;
SA_CTL_CreateOutputBuffer(dHandle, &tHandle);
SA_CTL_Move(dHandle, 0, 1000000, tHandle);
SA_CTL_Move(dHandle, 1, -1000000, tHandle);
// move commands have not been transmitted yet.
SA_CTL_FlushOutputBuffer(dHandle, tHandle);
// move commands have been transmitted and will be executed.
```

See also:

`SA_CTL_FlushOutputBuffer`, `SA_CTL_CancelOutputBuffer`

3.2.28 SA_CTL_FlushOutputBuffer

Interface:

```
SA_CTL_Result_t SA_CTL_FlushOutputBuffer(
    SA_CTL_DeviceHandle_t dHandle,
    SA_CTL_TransmitHandle_t tHandle
);
```

Description:

Initiates the transmission of all commands stored in the output buffer that is associated with the given transmit handle.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *tHandle* (SA_CTL_TransmitHandle_t), **input**: Handle of the addressed transmit buffer.

Example:

```
SA_CTL_Result_t result;
SA_CTL_TransmitHandle_t tHandle;
result = SA_CTL_CreateOutputBuffer(dHandle, &tHandle);
if (result == SA_CTL_ERROR_NONE) {
    // tHandle now holds a valid transmit handle
}
// append commands to buffer here
result = SA_CTL_FlushBuffer(dHandle, tHandle);
if (result == SA_CTL_ERROR_NONE) {
    // buffer is now flushed and the transmit handle released
}
// process generated answers/events
```

See also:

SA_CTL_CreateOutputBuffer, SA_CTL_CancelOutputBuffer

3.2.29 SA_CTL_CancelOutputBuffer

Interface:

```
SA_CTL_Result_t SA_CTL_CancelOutputBuffer(
    SA_CTL_DeviceHandle_t dHandle,
    SA_CTL_TransmitHandle_t tHandle
);
```

Description:

Discards all buffered commands and releases the associated transmit handle.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *tHandle* (SA_CTL_TransmitHandle_t), **input**: Handle of the addressed transmit buffer.

Example:

```
SA_CTL_Result_t result;
SA_CTL_TransmitHandle_t tHandle;
result = SA_CTL_CreateOutputBuffer(dHandle, &tHandle);
if (result == SA_CTL_ERROR_NONE) {
    // tHandle now holds a valid transmit handle
}
// append commands to buffer here
result = SA_CTL_CancelBuffer(dHandle, tHandle);
if (result == SA_CTL_ERROR_NONE) {
    // all buffered commands are discarded and the transmit handle released
}
```

See also:

SA_CTL_CreateOutputBuffer, SA_CTL_FlushOutputBuffer

3.2.30 SA_CTL_OpenCommandGroup

Interface:

```
SA_CTL_Result_t SA_CTL_OpenCommandGroup(
    SA_CTL_DeviceHandle_t dHandle,
    SA_CTL_TransmitHandle_t *tHandle,
    uint32_t triggerMode
);
```

Description:

Opens a command group that can be used to combine multiple asynchronous commands into an atomic group. A trigger mode can be set to select between different modes to start the groups execution. After creation the retrieved transmit handle can be used to choose whether a command is to be grouped or sent directly. You may accumulate several commands and then call `SA_CTL_CloseCommandGroup` to activate or `SA_CTL_CancelCommandGroup` to cancel the command group.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.
- *tHandle* (`SA_CTL_TransmitHandle_t *`), **output**: Pointer to a transmit handle.
- *triggerMode* (`uint32_t`), **input**: Desired trigger mode for this command group. Must be either `SA_CTL_CMD_GROUP_TRIGGER_MODE_DIRECT (0)` or `SA_CTL_CMD_GROUP_TRIGGER_MODE_EXTERNAL (1)`.

Example:

```
SA_CTL_Result_t result;
SA_CTL_TransmitHandle_t tHandle;
result = SA_CTL_OpenCommandGroup(
    dHandle, &tHandle, SA_CTL_CMD_GROUP_TRIGGER_MODE_DIRECT
);
if (result == SA_CTL_ERROR_NONE) {
    // tHandle now holds a valid transmit handle
}
```

See also:

`SA_CTL_CloseCommandGroup`, `SA_CTL_CancelCommandGroup`

3.2.31 SA_CTL_CloseCommandGroup

Interface:

```
SA_CTL_Result_t SA_CTL_CloseCommandGroup(
    SA_CTL_DeviceHandle_t dHandle,
    SA_CTL_TransmitHandle_t tHandle
);
```

Description:

Closes and eventually executes the assembled command group depending on the configured trigger mode.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *tHandle* (SA_CTL_TransmitHandle_t), **input**: Handle of the addressed transmit buffer.

Example:

```
SA_CTL_Result_t result;
SA_CTL_TransmitHandle_t tHandle;
result = SA_CTL_OpenCommandGroup(
    dHandle, &tHandle, SA_CTL_CMD_GROUP_TRIGGER_MODE_DIRECT
);
if (result == SA_CTL_ERROR_NONE) {
    // tHandle now holds a valid transmit handle
}
// append commands to buffer here
result = SA_CTL_CloseCommandGroup(dHandle, tHandle);
if (result == SA_CTL_ERROR_NONE) {
    // command group is now activated. since the command group is
    // triggered directly, it is executed right away.
}
// process other tasks
// ...
// optional: wait for the SA_CTL_EVENT_CMD_GROUP_TRIGGERED event
// process answers/events to commands
```

See also:

SA_CTL_OpenCommandGroup, SA_CTL_CancelCommandGroup

3.2.32 SA_CTL_CancelCommandGroup

Interface:

```
SA_CTL_Result_t SA_CTL_CancelCommandGroup(
    SA_CTL_DeviceHandle_t dHandle,
    SA_CTL_TransmitHandle_t tHandle
);
```

Description:

Discards all buffered commands and releases the associated transmit handle.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *tHandle* (SA_CTL_TransmitHandle_t), **input**: Handle of the addressed transmit buffer.

Example:

```
SA_CTL_Result_t result;
SA_CTL_TransmitHandle_t tHandle;
result = SA_CTL_OpenCommandGroup(
    dHandle, &tHandle, SA_CTL_CMD_GROUP_TRIGGER_MODE_DIRECT
);
if (result == SA_CTL_ERROR_NONE) {
    // tHandle now holds a valid transmit handle
}
// append commands to buffer here
result = SA_CTL_CancelCommandGroup(dHandle, tHandle);
if (result == SA_CTL_ERROR_NONE) {
    // all buffered commands are discarded and the transmit handle released
}
```

See also:

SA_CTL_OpenCommandGroup, SA_CTL_CloseCommandGroup

3.2.33 SA_CTL_WaitForEvent

Interface:

```
SA_CTL_Result_t SA_CTL_WaitForEvent(
    SA_CTL_DeviceHandle_t dHandle,
    SA_CTL_Event_t *event,
    uint32_t timeout
);
```

Description:

This function blocks until the device reports an event. Usually this function is used in a separate thread. The function returns when:

- An event has occurred within the given timeout. In this case the return value of the function will be `SA_CTL_ERROR_NONE` and the output parameter *event* will hold the event that occurred. See section 2.4 "Event Notifications" for the structure of events.
- No event occurred within the given timeout. In this case the return value of the function will be `SA_CTL_ERROR_TIMEOUT` and the *event* parameter is undefined.
- The call is canceled with a call of `SA_CTL_Cancel` from another application thread. In this case the return value of the function will be `SA_CTL_ERROR_CANCELED` and the *event* parameter is undefined. This is typically useful when the application is to be terminated and the event handling thread must be unblocked for a proper cleanup.

This function cannot be called simultaneously using multiple threads (for the same device handle). If a second thread tries to call this function, then a `SA_CTL_ERROR_THREAD_LIMIT_REACHED` error will be returned.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.
- *event* (`SA_CTL_Event_t *`), **output**: Event that occurred.
- *timeout* (`uint32_t`), **input**: Maximum time to wait for an event to occur. The timeout is given in milliseconds. The special value `SA_CTL_INFINITE` is also valid. Setting the timeout to zero will check for already queued events, but does not block if no event is available.

Example:

```
// thread 1:
SA_CTL_Event_t event;
SA_CTL_Result_t result;
```



```
result = SA_CTL_WaitForEvent(dHandle,&event,SA_CTL_INFINITE);  
if (result == SA_CTL_ERROR_CANCELED) {  
    // SA_CTL_WaitForEvent was canceled before an event occurred  
}
```

```
// thread 2:  
// wake up waiting thread 1  
SA_CTL_Result_t result = SA_CTL_Cancel(dHandle);
```

See also:

SA_CTL_Cancel

3.2.34 SA_CTL_Calibrate

Interface:

```
SA_CTL_Result_t SA_CTL_Calibrate(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_TransmitHandle_t tHandle
);
```

Description:

This movement function starts a calibration routine for a channel. Before calling this function the Calibration Options property must be configured to define the behavior of the calibration sequence. See section 2.7.1 "Calibrating" for more information.

The function call returns immediately, without waiting for the movement to complete. The calibration may however take a few seconds to complete. Therefore the `SA_CTL_CH_STATE_BIT_CALIBRATING` in the Channel State can be monitored to determine the end of the calibration sequence.



NOTICE

As a safety precaution, make sure that the positioner has enough freedom to move without damaging other equipment.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.
- *idx* (`int8_t`), **input**: Index of the addressed channel.
- *tHandle* (`SA_CTL_TransmitHandle_t`), **input**: Handle of the addressed transmit buffer. If unused set to zero.

Example:

```
SA_CTL_Result_t result;
// Set calibration mode for channel 0 (start direction: forward)
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_CALIBRATION_OPTIONS, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // calibration mode is now set
```

```
}  
// Start calibration sequence  
result = SA_CTL_Calibrate(dHandle, 0, 0);  
if (result == SA_CTL_ERROR_NONE) {  
    // calibration is now started (function call returns immediately)  
}
```

3.2.35 SA_CTL_Reference

Interface:

```
SA_CTL_Result_t SA_CTL_Reference(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_TransmitHandle_t tHandle
);
```

Description:

This movement function may be used to move the positioner to a known physical position. Before calling this function the Referencing Options property must be configured to define the referencing behavior. Since referencing movements are executed as closed-loop movements also the Move Velocity and Move Acceleration should be configured. See section 2.7.2 "Referencing" for more information.

The function call returns immediately, without waiting for the movement to complete. The `SA_CTL_CH_STATE_BIT_REFERENCING` in the Channel State can be monitored to determine the end of the referencing sequence. If the command was successful the `SA_CTL_CH_STATE_BIT_IS_REFERENCED` in the Channel State will be set. This bit can also be checked to determine whether it is necessary to perform the referencing sequence.



NOTICE

As a safety precaution, make sure that the positioner has enough freedom to move without damaging other equipment.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.
- *idx* (`int8_t`), **input**: Index of the addressed channel.
- *tHandle* (`SA_CTL_TransmitHandle_t`), **input**: Handle of the addressed transmit buffer. If unused set to zero.

Example:

```
SA_CTL_Result_t result;
// Set find reference mode for channel 0 (default is 0)
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_REFERENCING_OPTIONS, 0
```

```
);  
if (result == SA_CTL_ERROR_NONE) {  
    // desired reference mode is now set  
}  
// Start referencing sequence  
result = SA_CTL_Reference(dHandle, 0, 0);  
if (result == SA_CTL_ERROR_NONE) {  
    // referencing sequence has started (function call returns immediately)  
}
```

3.2.36 SA_CTL_Move

Interface:

```
SA_CTL_Result_t SA_CTL_Move(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    int64_t moveValue,
    SA_CTL_TransmitHandle_t tHandle
);
```

Description:

This function instructs a positioner to move according to the current move configuration. The Move Mode as well as corresponding parameters (e.g. Frequency, Velocity, HoldTime, etc.) have to be configured beforehand using the `SA_CTL_SetProperty_x` functions. See section 2.7 "Moving Positioners" for more information.

The function call returns immediately, without waiting for the movement to complete. The Channel State bits `SA_CTL_CH_STATE_BIT_ACTIVELY_MOVING` and `SA_CTL_CH_STATE_BIT_CLOSED_LOOP_ACTIVE` can be monitored to determine the end of the movement.

Parameters:

- *dHandle* (`SA_CTL_DeviceHandle_t`), **input**: Handle of the addressed device.
- *idx* (`int8_t`), **input**: Index of the addressed channel.
- *moveValue* (`int64_t`), **input**: Specifies the move value, which may be an absolute or relative target position, an open-loop scan value or a number of open-loop steps. The interpretation depends on the configured Move Mode.
- *tHandle* (`SA_CTL_TransmitHandle_t`), **input**: Handle of the addressed transmit buffer. If unused set to zero.

Example:

```
// Note: to keep the example simple, we omit processing the result codes
// Set move mode
SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_MOVE_MODE, SA_CTL_MOVE_MODE_CL_RELATIVE
);
// Set move velocity [in pm/s]
SA_CTL_SetProperty_i64(
    dHandle, 0, SA_CTL_PKEY_MOVE_VELOCITY, 500000000
```

```
);  
// Set move acceleration [in pm/s2],  
// a value of 0 disables the acceleration control  
SA_CTL_SetProperty_i64(  
    dHandle, 0, SA_CTL_PKEY_MOVE_ACCELERATION, 0  
);  
// Start actual movement, moveValue holds relative position (in pm)  
SA_CTL_Move(dhandle, 0, 500000000, 0);
```

3.2.37 SA_CTL_Stop

Interface:

```
SA_CTL_Result_t SA_CTL_Stop(
    SA_CTL_DeviceHandle_t dHandle,
    int8_t idx,
    SA_CTL_TransmitHandle_t tHandle
);
```

Description:

This function stops any ongoing movement of a positioner. The exact behavior depends on the specific channel's type. See section 2.7.5 "Stopping Movements" for more information.

Note for closed-loop movements with acceleration control enabled: The first `stop` command sent while moving triggers the positioner to come to a halt by decelerating to zero. A second `stop` command triggers a hard stop (*emergency stop*).

The function call returns immediately, without waiting for the stop to complete. The `SA_CTL_CH_STATE_BIT_ACTIVELY_MOVING` in the Channel State can be monitored to determine the end of the movement.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *idx* (int8_t), **input**: Index of the addressed channel.
- *tHandle* (SA_CTL_TransmitHandle_t), **input**: Handle of the addressed transmit buffer. If unused set to zero.

Example:

```
int8_t channel = 0;
SA_CTL_Result_t result;
result = SA_CTL_Stop(dHandle, channel, 0);
if (result == SA_CTL_ERROR_NONE) {
    // stop command is now being executed
}
```


3.2.38 SA_CTL_OpenStream

Interface:

```
SA_CTL_Result_t SA_CTL_OpenStream(
    SA_CTL_DeviceHandle_t dHandle,
    SA_CTL_StreamHandle_t *sHandle,
    uint32_t triggerMode
);
```

Description:

This function opens a stream to the device. It is used for trajectory streaming (see section 2.18). The caller must supply a pointer to a buffer where the stream handle should be written to. A trigger mode can be set to select between different modes to start and synchronize the streaming process.

For most of the supported trigger modes, the desired stream base rate has to be configured before calling this function (see section Trigger Modes).

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *sHandle* (SA_CTL_StreamHandle_t *), **output**: Pointer to a stream handle.
- *triggerMode* (uint32_t), **input**: Desired trigger mode. May be one of
 SA_CTL_STREAM_TRIGGER_MODE_DIRECT (0),
 SA_CTL_STREAM_TRIGGER_MODE_EXTERNAL_ONCE (1),
 SA_CTL_STREAM_TRIGGER_MODE_EXTERNAL_SYNC (2),
 SA_CTL_STREAM_TRIGGER_MODE_EXTERNAL (3).

Example:

```
SA_CTL_Result_t result;
SA_CTL_StreamHandle_t sHandle;
result = SA_CTL_OpenStream(
    dHandle,
    &sHandle,
    SA_CTL_STREAM_TRIGGER_MODE_DIRECT
);
if (result == SA_CTL_ERROR_NONE) {
    // stream is now opened
}
```

See also:

SA_CTL_StreamFrame, SA_CTL_CloseStream, SA_CTL_AbortStream

3.2.39 SA_CTL_StreamFrame

Interface:

```
SA_CTL_Result_t SA_CTL_StreamFrame(
    SA_CTL_DeviceHandle_t dHandle,
    SA_CTL_StreamHandle_t sHandle,
    uint8_t *frameData,
    uint32_t frameSize
);
```

Description:

This function supplies the device with stream data by sending one frame per function call. A frame contains the data for one interpolation point which must be assembled by concatenating elements of the following tuple:

- *Channel Index* (1 byte): The channel that receives the following position.
- *Position* (8 byte): A position that belongs to the current interpolation point.

See section 2.18 "Trajectory Streaming" for more information.

This function may block if the flow control needs to throttle the data rate. The function returns as soon as the frame was transmitted to the controller.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *sHandle* (SA_CTL_StreamHandle_t), **input**: Handle of the addressed stream.
- *frameData* (uint8_t *), **input**: Pointer to the frame data buffer.
- *frameSize* (uint32_t), **input**: Size of the given frame (in bytes).

Example:

```
SA_CTL_Result_t result;
// create frame data array for 2 channel/position tuples
uint8_t frameData[2*(1+8)];
// fill frame with data
// ...
// send frame
result = SA_CTL_StreamFrame(
    dHandle, sHandle, frameData, sizeof(frameData)
);
```

```
if (result == SA_CTL_ERROR_NONE) {  
    // frame successfully sent to the device  
}
```

See also:

SA_CTL_OpenStream, SA_CTL_CloseStream, SA_CTL_AbortStream

3.2.40 SA_CTL_CloseStream

Interface:

```
SA_CTL_Result_t SA_CTL_CloseStream(
    SA_CTL_DeviceHandle_t dHandle,
    SA_CTL_StreamHandle_t sHandle
);
```

Description:

This function closes a stream. For the device this marks the end of the stream. After having processed the remaining buffered interpolation points the stream is finished. See section 2.18 "Trajectory Streaming" for more information.

If the stream is not closed properly, the device will generate a buffer underflow error after the last frame has been processed.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *sHandle* (SA_CTL_StreamHandle_t), **input**: Handle of the addressed stream.

Example:

```
SA_CTL_StreamHandle_t sHandle;
SA_CTL_Result_t result;
result = SA_CTL_OpenStream(
    dHandle,
    &sHandle,
    SA_CTL_STREAM_TRIGGER_MODE_DIRECT
);
if (result != SA_CTL_ERROR_NONE) {
    // handle error
}
// stream frames
// ...
result = SA_CTL_CloseStream(dHandle, sHandle);
// remaining interpolation points are now processed
```

See also:

SA_CTL_OpenStream, SA_CTL_StreamFrame, SA_CTL_AbortStream

3.2.41 SA_CTL_AbortStream

Interface:

```
SA_CTL_Result_t SA_CTL_AbortStream(
    SA_CTL_DeviceHandle_t dHandle,
    SA_CTL_StreamHandle_t sHandle
);
```

Description:

This function aborts a stream. Thus all movements are stopped immediately and remaining buffered interpolation points are discarded.

Parameters:

- *dHandle* (SA_CTL_DeviceHandle_t), **input**: Handle of the addressed device.
- *sHandle* (SA_CTL_StreamHandle_t), **input**: Handle of the addressed stream.

Example:

```
SA_CTL_StreamHandle_t sHandle;
SA_CTL_Result_t result;
result = SA_CTL_OpenStream(
    dHandle,
    &sHandle,
    SA_CTL_STREAM_TRIGGER_MODE_DIRECT
);
if (result != SA_CTL_ERROR_NONE) {
    // handle error
}
// stream frames
// ...
result = SA_CTL_AbortStream(dHandle, sHandle);
// stream is aborted immediately
```

See also:

SA_CTL_OpenStream, SA_CTL_StreamFrame, SA_CTL_CloseStream

4 PROPERTY REFERENCE

4.1 Property Introduction

The property reference describes all available configuration values of the device. See section 2.2 "Properties" for general information about how to access properties.

The head section of each property lists:

- the *property key* in the form of a **C-Definition** as defined in the *SmarActControlConstants.h*
- the **Code** of the *property key* in the form of a hexadecimal code
- the **ASCII-Command** of the property (only available for devices with ethernet interface)
- and the following attributes:

Attribute	Values	Meaning
Type	I32, I64 or String	The data type of the property. Depending on the data type the corresponding function variant must be used to access the property.
Index	Device, Module, Channel, API	The index parameter which must be passed to the property function. "Device" or "API": the index parameter is unused and must be set to zero. "Module" or "Channel": the index parameter addresses a specific module or channel.
Access	R, RW, W, R(W)	The access-mode of the property. "R": the property is readable, "W": the property is writable, "(W)": the property is writable but the write protection must be removed before being able to write to this property.
Volatility	V, NV, (NV), NV-P, -	The volatility of the property. "V": the property is volatile, it is set to its default value on power-up of the device. "NV": the property is stored to nonvolatile memory and need not be configured on every power-up of the device. "(NV)": same as "NV" but the write protection must be removed before this property is stored to nonvolatile memory after writing. "NV-P": same as "NV" but additionally the property is <i>not</i> reset to its default when performing a factory-reset or a firmware update.
Cmd-Group	X, -	Indicates if the property may be added to a command group ("X") or not ("-"). See section 2.17 "Command Groups" for more information.

Properties may be applicable only for certain interface or driver types. The type code of a channel or module can be read using the corresponding Module Type and Channel Type properties. See section 2.5 "Module Overview" for more information.

4.2 Property Summary

Table 4.1 – Property Summary

Property	Code	Type	Idx	Access	V ¹	CG ²	Page
<i>Device Properties</i>							
Number of Channels	0x020F0017	I32	Dev	R	-	-	182
Number of Bus Modules	0x020F0016	I32	Dev	R	-	-	183
Interface Type	0x020F0066	I32	Dev	R	-	-	184
Device State	0x020F000F	I32	Dev	R	-	-	185
Device Serial Number	0x020F005E	String	Dev	R	-	-	186
Device Name	0x020F003D	String	Dev	RW	NV-P	-	187
Emergency Stop Mode	0x020F0088	I32	Dev	RW	V	-	188
Default Emergency Stop Mode	0x020F0116	I32	Dev	RW	NV	-	189
Min Fan Level	0x020F00DB	I32	Dev	RW	V	-	190
Network Discover Mode	0x020F0159	I32	Dev	RW	NV-P	-	192
Network DHCP Timeout	0x020F015C	I32	Dev	RW	NV-P	-	194
<i>Module Properties</i>							
Power Supply Enabled	0x02030010	I32	Mod	RW	V	X	196
Number of Bus Module Channels	0x02030017	I32	Mod	R	-	X	197
Module Type	0x02030066	I32	Mod	R	-	-	198
Module State	0x0203000F	I32	Mod	R	-	X	199
<i>Positioner Properties</i>							
Amplifier Enabled	0x0302000D	I32	Ch	RW	V	X	202
Amplifier Mode	0x030200BF	I32	Ch	RW	NV	X	204
Positioner Control Options	0x0302005D	I32	Ch	RW	NV	X	206
Actuator Mode	0x03020019	I32	Ch	RW	V	-	208
Control Loop Input	0x03020018	I32	Ch	RW	NV	X	210
Sensor Input Select	0x03020018	I32	Ch	RW	NV	X	210
Positioner Type	0x0302003C	I32	Ch	RW	NV	X	214

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Property	Code	Type	Idx	Access	V ¹	CG ²	Page
Positioner Type Name	0x0302003D	String	Ch	R	-	-	216
Move Mode	0x03050087	I32	Ch	RW	V	X	217
Channel Type	0x02020066	I32	Ch	R	-	-	219
Channel State	0x0305000F	I32	Ch	R	-	X	220
Position	0x0305001D	I64	Ch	RW	V	X	221
Target Position	0x0305001E	I64	Ch	R	-	X	223
Scan Position	0x0305001F	I64	Ch	R	-	X	224
Scan Velocity	0x0305002A	I64	Ch	RW	V	X	225
Hold Time	0x03050028	I32	Ch	RW	V	X	226
Move Velocity	0x03050029	I64	Ch	RW	V	X	228
Move Acceleration	0x0305002B	I64	Ch	RW	V	X	230
Max Closed Loop Frequency	0x0305002F	I32	Ch	RW	V	X	232
Default Max Closed Loop Frequency	0x03050057	I32	Ch	RW	NV	X	233
Step Frequency	0x0305002E	I32	Ch	RW	V	X	234
Step Amplitude	0x03050030	I32	Ch	RW	V	X	235
Following Error	0x03020055	I64	Ch	R	-	X	236
Following Error Max	0x05020055	I64	Ch	R	-	X	237
Following Error Limit	0x03050055	I64	Ch	RW	NV	X	238
Broadcast Stop Options	0x0305005D	I32	Ch	RW	NV	X	239
Sensor Power Mode	0x03080019	I32	Ch	RW	NV	X	240
Sensor Power Save Delay	0x03080054	I32	Ch	RW	NV	X	242
Position Mean Shift	0x03090022	I32	Ch	RW	NV	X	244
Safe Direction	0x03090027	I32	Ch	RW	NV	X	245
Control Loop Input Sensor Value	0x0302001D	I64	Ch	R	-	X	247
Control Loop Input Aux Value	0x030200B2	I64	Ch	R	-	X	248
Target To Zero Voltage Hold Threshold	0x030200B9	I32	Ch	RW	NV	X	249
Channel Emergency Stop Mode	0x02020088	I32	Ch	RW	V	X	251
In Position Threshold	0x03050058	I32	Ch	RW	NV	X	252
In Position Delay	0x03050054	I32	Ch	RW	NV	X	254

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Property	Code	Type	Idx	Access	V ¹	CG ²	Page
Motor Overload Protection Threshold	0x03020115	I32	Ch	RW	NV	X	255
<i>Scale Properties</i>							
Logical Scale Offset	0x02040024	I64	Ch	RW	NV	X	256
Logical Scale Inversion	0x02040025	I32	Ch	RW	NV	X	257
Range Limit Min	0x02040020	I64	Ch	RW	V	X	259
Range Limit Max	0x02040021	I64	Ch	RW	V	X	260
Default Range Limit Min	0x020400C0	I64	Ch	RW	NV	X	261
Default Range Limit Max	0x020400C1	I64	Ch	RW	NV	X	262
<i>Calibration Properties</i>							
Calibration Options	0x0306005D	I32	Ch	RW	V	X	263
Signal Correction Options	0x0306001C	I32	Ch	RW	NV	X	265
<i>Referencing Properties</i>							
Referencing Options	0x0307005D	I32	Ch	RW	V	X	267
Distance To Reference Mark	0x030700A2	I64	Ch	R	-	X	269
Distance Code Inverted	0x0307000E	I32	Ch	RW	NV	X	270
<i>Positioner Tuning and Customizing Properties</i>							
Positioner Movement Type	0x0309003F	I32	Ch	R(W)	(NV)	X	271
Positioner Is Custom Type	0x03090041	I32	Ch	R	-	X	273
Positioner Base Unit	0x03090042	I32	Ch	R(W)	(NV)	X	274
Positioner Base Resolution	0x03090043	I32	Ch	R(W)	(NV)	X	276
Positioner Sensor Head Type	0x0309008E	I32	Ch	R(W)	(NV)	X	278
Positioner Reference Type	0x03090048	I32	Ch	R(W)	(NV)	X	279
Positioner P Gain	0x0309004B	I32	Ch	R(W)	(NV)	X	281
Positioner I Gain	0x0309004C	I32	Ch	R(W)	(NV)	X	282
Positioner D Gain	0x0309004D	I32	Ch	R(W)	(NV)	X	283
Positioner PID Shift	0x0309004E	I32	Ch	R(W)	(NV)	X	284
Positioner Anti Windup	0x0309004F	I32	Ch	R(W)	(NV)	X	286
Positioner ESD Distance Threshold	0x03090050	I32	Ch	R(W)	(NV)	X	288
Positioner ESD Counter Threshold	0x03090051	I32	Ch	R(W)	(NV)	X	290

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Property	Code	Type	Idx	Access	V ¹	CG ²	Page
Positioner Target Reached Threshold	0x03090052	I32	Ch	R(W)	(NV)	X	291
Positioner Target Hold Threshold	0x03090053	I32	Ch	R(W)	(NV)	X	292
Save Positioner Type	0x0309000A	I32	Ch	W	V	X	294
Positioner Write Protection	0x0309000D	I32	Ch	RW	V	X	295
<i>Streaming Properties</i>							
Stream Base Rate	0x040F002C	I32	Dev	RW	V	-	296
Stream External Sync Rate	0x040F002D	I32	Dev	RW	V	-	297
Stream Options	0x040F005D	I32	Dev	RW	V	-	298
Stream Load Maximum	0x040F0301	I32	Dev	R	-	-	299
<i>Diagnostic Properties</i>							
Channel Error	0x0502007A	I32	Ch	R	-	X	300
Channel Temperature	0x05020034	I32	Ch	R	-	X	302
Bus Module Temperature	0x05030034	I32	Mod	R	-	X	303
Positioner Fault Reason	0x05020113	I32	Ch	R	-	X	304
Diag Closed Loop Frequency Max	0x0502002f	I32	Ch	R	-	X	308
Diag Closed Loop Frequency Avg	0x0502002e	I32	Ch	R	-	X	309
Diag Closed Loop Frequency Measure Time Base	0x050200c6	I32	Ch	RW	-	X	310
<i>Auxiliary Properties</i>							
Aux Positioner Type	0x0802003C	I32	Ch	RW	NV	X	311
Aux Positioner Type Name	0x0802003D	String	Ch	R	-	-	313
Aux Input Select	0x08020018	I32	Ch	RW	NV	X	314
Aux I/O Module Input Index	0x081100AA	I32	Ch	RW	NV	X	315
Aux Direction Inversion	0x0809000E	I32	Ch	RW	NV	X	317
Aux I/O Module Input0 / Input1 Value	0x08110000	I64	Ch	R	-	X	319
Aux I/O Module Input0 / Input1 Value	0x08110001	I64	Ch	R	-	X	319
Aux Correction Max	0x080200D8	I32	Ch	RW	NV	X	321
Aux Digital Input Value	0x080300AD	I32	Mod	R	-	X	323

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Property	Code	Type	Idx	Access	V ¹	CG ²	Page
Aux Digital Output Value / Set / Clear	0x080300AE	I32	Mod	RW	V	X	324
Aux Digital Output Value / Set / Clear	0x080300B0	I32	Mod	W	V	X	324
Aux Digital Output Value / Set / Clear	0x080300B1	I32	Mod	W	V	X	324
Aux Analog Output Value0 / Value1	0x08030000	I32	Mod	RW	V	X	326
Aux Analog Output Value0 / Value1	0x08030001	I32	Mod	RW	V	X	326
<i>I/O Module Properties</i>							
I/O Module Options	0x0603005D	I32	Mod	RW	V	X	328
I/O Module Voltage	0x06030031	I32	Mod	RW	V	X	330
I/O Module Analog Input Range	0x060300A0	I32	Mod	RW	NV	X	331
<i>Input Trigger Properties</i>							
Device Input Trigger Select	0x060D009D	I32	Dev	RW	NV	-	333
Device Input Trigger Mode	0x060D0087	I32	Dev	RW	NV	-	335
Device Input Trigger Condition	0x060D005A	I32	Dev	RW	NV	-	337
Channel Input Trigger Mode	0x06150087	I32	Ch	RW	V	-	338
Channel Input Trigger Condition	0x0615005A	I32	Ch	RW	V	-	340
<i>Output Trigger Properties</i>							
Channel Output Trigger Mode	0x060E0087	I32	Ch	RW	V	X	341
Channel Output Trigger Polarity	0x060E005B	I32	Ch	RW	V	X	343
Channel Output Trigger Pulse Width	0x060E005C	I32	Ch	RW	V	X	344
Channel Position Compare Start Threshold	0x060E0058	I64	Ch	RW	V	X	345
Channel Position Compare Increment	0x060E0059	I64	Ch	RW	V	X	346
Channel Position Compare Direction	0x060E0026	I32	Ch	RW	V	X	347
Channel Position Compare Limit Min	0x060E0020	I64	Ch	RW	V	X	349

Continued on next page

Table 4.1 – Continued from previous page

Property	Code	Type	Idx	Access	V ¹	CG ²	Page
Channel Position Compare Limit Max	0x060E0021	I64	Ch	RW	V	X	351
<i>Hand Control Module Properties</i>							
Hand Control Module Lock Options	0x020C0083	I32	Dev	RW	V	-	353
Hand Control Module Default Lock Options	0x020C0084	I32	Dev	RW	NV	-	355
<i>API Properties</i>							
Event Notification Options	0xF010005D	I32	API	RW	-	-	356
Auto Reconnect	0xF01000A1	I32	API	RW	-	-	358

¹Volatility: This column defines if a property is stored in non-volatile memory. Non-Volatile properties need not be configured on every power-up.

²Command Group: This column defines if a property may be used in command groups. See section 2.17 "Command Groups" for more information.

4.3 Device Properties

4.3.1 Number of Channels

Definition	Value				
C-Definition	SA_CTL_PKEY_NUMBER_OF_CHANNELS				
Code	0x020F0017				
ASCII-Command	[:PROPerTy]:DEvIce:NOCHannels				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	R	-	-
Applicable for					
USB Interface	SA_CTL_INTERFACE_USB			(0x0001)	
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET			(0x0002)	

Description

This property holds the total number of channels the connected device has. It defines the valid range for channel index parameters. The channel index is zero based. Therefore, the maximum index is *number of channels* - 1.

Note that the number of channels does not represent the number of positioners that are currently connected to the device.

Example

```
SA_CTL_Result_t result;
int32_t channels;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_NUMBER_OF_CHANNELS, &channels, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'channels' holds the number of available channels of the device
}
```

See Also

4.3.2 Number of Bus Modules, 4.4.2 Number of Bus Module Channels

4.3.2 Number of Bus Modules

Definition	Value				
C-Definition	SA_CTL_PKEY_NUMBER_OF_BUS_MODULES				
Code	0x020F0016				
ASCII-Command	[:PROPerTy]:DEViCe:NOBModules				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	R	-	-

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property holds the number of modules the connected device has. It defines the valid range for module index parameters. The module index is zero based. Therefore, the maximum index is *number of modules - 1*.

Example

```
SA_CTL_Result_t result;
int32_t modules;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_NUMBER_OF_BUS_MODULES, &modules, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'modules' holds the number of available modules of the device
}
```

See Also

4.4.2 Number of Bus Module Channels

4.3.3 Interface Type

Definition	Value				
C-Definition	SA_CTL_PKEY_INTERFACE_TYPE				
Code	0x020F0066				
ASCII-Command	[:PROPerTy]:DEViCe:ITYPE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	R	-	-

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property holds the type of the interface. The following types are defined:

Interface Type	C-Definition	Code
USB Interface	SA_CTL_INTERFACE_USB	0x0001
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	0x0002

See section 2.5 "Module Overview" for more information.

Example

```
SA_CTL_Result_t result;
int32_t type;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_INTERFACE_TYPE, &type, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'type' holds the type of the interface
}
```

See Also

4.5.11 Channel Type, 4.4.3 Module Type

4.3.4 Device State

Definition	Value				
C-Definition	SA_CTL_PKEY_DEVICE_STATE				
Code	0x020F000F				
ASCII-Command	[:PROPerTy]:DEvIce:StAtE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	R	-	-

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property holds the device state. The value is a bit field containing independent flags. Their meanings are described in section 2.10.1 "Device State Flags".

Undefined flags are reserved for future use. Therefore, the user software should not rely on a static value of undefined flags.

Example

```
SA_CTL_Result_t result;
int32_t state;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_DEVICE_STATE, &state, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // use bit masking to extract the needed information from the state
    if (state & SA_CTL_DEV_STATE_BIT_HM_PRESENT) {
        // a hand controller is connected to the device
    }
}
```

See Also

4.4.4 Module State, 4.5.12 Channel State

4.3.5 Device Serial Number

Definition	Value				
C-Definition	SA_CTL_PKEY_DEVICE_SERIAL_NUMBER				
Code	0x020F005E				
ASCII-Command	[:PROPerTy]:DEvIce:SNUMber				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	String	Device	R	-	-

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property may be used to identify a device connected to the PC. Each device has a unique serial number which makes it possible to distinguish one from another. The device serial number consists of the global device name ('MCS2') and an individual number.

Example

```
SA_CTL_Result_t result;
char deviceSn[SA_CTL_STRING_MAX_LENGTH];
size_t ioStrSize = sizeof(deviceSn);
result = SA_CTL_GetProperty_s(
    dHandle, 0, SA_CTL_PKEY_DEVICE_SERIAL_NUMBER, deviceSn, &ioStrSize
);
if (result == SA_CTL_ERROR_NONE) {
    // 'deviceSn' holds the serial number string, e.g. 'MCS2-00000001'
}
```

See Also

4.3.6 Device Name

4.3.6 Device Name

Definition	Value				
C-Definition	SA_CTL_PKEY_DEVICE_NAME				
Code	0x020F003D				
ASCII-Command	[:PROPerTy]:DEvIce:NAME				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	String	Device	RW	NV-P	-

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property may be used to identify a device connected to the PC. In contrast to the device serial number, the device name is writable by the user. The name is stored to non-volatile memory. By default, the device name is set to the device serial number string. Note that the device name is *not* reset to its default when performing a factory-reset or a firmware update.

Example

```
SA_CTL_Result_t result;
char deviceName[SA_CTL_STRING_MAX_LENGTH];
size_t ioStringSize = sizeof(deviceName);
result = SA_CTL_GetProperty_s(
    dHandle, 0, SA_CTL_PKEY_DEVICE_NAME, deviceName, &ioStringSize
);
if (result == SA_CTL_ERROR_NONE) {
    // 'deviceName' holds the user defined name of the device
}
```

See Also

4.3.5 Device Serial Number

4.3.7 Emergency Stop Mode

Definition	Value				
C-Definition	SA_CTL_PKEY_EMERGENCY_STOP_MODE				
Code	0x020F0088				
ASCII-Command	[:PROPerTy]:DEvIce:EStop:MODE[:CURRent]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	RW	V	-

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property specifies the emergency stop mode of the device. See section 2.20.2 "Emergency Stop Mode" for more information.

This property is not held in non-volatile memory but the default value at device startup is configurable with the Default Emergency Stop Mode property.

Valid Range

SA_CTL_EMERGENCY_STOP_MODE_NORMAL (0),
 SA_CTL_EMERGENCY_STOP_MODE_RESTRICTED (1),
 SA_CTL_EMERGENCY_STOP_MODE_AUTO_RELEASE (2)

Example

```
// set emergency stop mode to normal mode
result = SA_CTL_SetProperty_i32(
    dHandle,
    0,
    SA_CTL_PKEY_EMERGENCY_STOP_MODE,
    SA_CTL_EMERGENCY_STOP_MODE_NORMAL
);
```

See Also

4.3.8 Default Emergency Stop Mode, 4.14.2 Device Input Trigger Mode

4.3.8 Default Emergency Stop Mode

Definition	Value				
C-Definition	SA_CTL_PKEY_DEFAULT_EMERGENCY_STOP_MODE				
Code	0x020F0116				
ASCII-Command	[:PROPerTy]:DEvIce:EStop:MODE:DEFault				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	RW	NV	-
Applicable for					
USB Interface	SA_CTL_INTERFACE_USB			(0x0001)	
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET			(0x0002)	

Description

This property specifies the default value at device startup for the Emergency Stop Mode.

This property is stored to non-volatile memory and need not be configured on every power-up. The default mode is SA_CTL_EMERGENCY_STOP_MODE_NORMAL (0).

Valid Range

SA_CTL_EMERGENCY_STOP_MODE_NORMAL (0),
 SA_CTL_EMERGENCY_STOP_MODE_RESTRICTED (1),
 SA_CTL_EMERGENCY_STOP_MODE_AUTO_RELEASE (2)

Example

```
// set default emergency stop mode to restricted mode
result = SA_CTL_SetProperty_i32(
    dHandle,
    0,
    SA_CTL_PKEY_EMERGENCY_STOP_MODE,
    SA_CTL_EMERGENCY_STOP_MODE_RESTRICTED
);
```

See Also

4.3.7 Emergency Stop Mode, 4.14.2 Device Input Trigger Mode

4.3.9 Min Fan Level

Definition	Value				
C-Definition	SA_CTL_PKEY_MIN_FAN_LEVEL				
Code	0x020F00DB				
ASCII-Command	[:PROPerTy]:DEVIce:FAN:MINimum				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	RW	V	-

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property specifies the minimum spin level of the build-in cooling fan. It has no meaning for devices without cooling fan.

In general, the fan is temperature-controlled and thus disabled most of the time under normal operating conditions. If the internal temperature rises the fan starts up to prevent overheating.

For some special applications (e.g. when using open-loop movements with specific demands regarding position stability) it may be useful to keep the internal temperature (almost) constant. This may prevent drift effects of the positioners caused by a changing temperature of the amplifiers if active holding of the position is not desirable or possible. This property may be used to override the automatic fan control. A constant cooling of the controller may then result in a more stable position.

The fan speed is specified in 10 generic levels from lowest fan speed (1) to highest fan speed (10). Note that the fan may still spin with a higher speed than configured if the controller requires more cooling, only the speed never falls below the configured minimum level. Setting the property to 0 configures the automatic, temperature dependent fan control.

Note further that the life span of the fan is shortened if it runs continuously. It is therefore recommended to only enable the override while really needed.

The default value is 0 (automatic fan control).

Valid Range

0 ... 10

Example

```
// enable fan override (with highest fan speed)
result = SA_CTL_SetProperty_i32(
    dHandle,
    0,
    SA_CTL_PKEY_MIN_FAN_LEVEL,
    10
);
```

See Also

4.11.2 Channel Temperature, 4.11.3 Bus Module Temperature

4.3.10 Network Discover Mode

Definition	Value				
C-Definition	SA_CTL_PKEY_NETWORK_DISCOVER_MODE				
Code	0x020F0159				
ASCII-Command	[:PROPerTy]:DEVIce:NETWork:DISCover:MODE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	RW	NV-P	-
Applicable for					
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET				(0x0002)

Description

This property specifies the discover mode for devices with ethernet interface. The discover feature allows to use the `SA_CTL_FindDevices` function to list devices with ethernet interface without knowing the actual IP address. The MCS2 devices use broadcast packets to inform about their presence in the network and for the discovery mechanism. This technique is quite common for network devices like switches, routers, etc. However, some users might wish to limit the traffic in a restricted network. Therefore, the behavior of the discovery mechanism is configurable.

The following modes are available:

Mode	Name	Short Description
0	SA_CTL_NETWORK_DISCOVER_MODE_DISABLED	The discover feature is disabled. No broadcast packets will be generated. Devices will not be found by the <code>SA_CTL_FindDevices</code> function.
1	SA_CTL_NETWORK_DISCOVER_MODE_PASSIVE	The device will not generate packets to inform about its presence but still reacts to direct discover requests.
2	SA_CTL_NETWORK_DISCOVER_MODE_ACTIVE	The device informs about its presence and reacts to all discover requests.

See section 2.1 "Connecting and Disconnecting" for more information.

This property is stored to non-volatile memory and need not be configured on every power-up. Note that the discover mode is *not* reset to its default when performing a factory-reset or a firmware update. The default value is `SA_CTL_NETWORK_DISCOVER_MODE_ACTIVE` (2).

Example

```
// disable the network discover feature
result = SA_CTL_SetProperty_i32(
    dHandle,
    0,
    SA_CTL_PKEY_NETWORK_DISCOVER_MODE,
    SA_CTL_NETWORK_DISCOVER_MODE_DISABLED
);
```

See Also

3.2.4 SA_CTL_FindDevices

4.3.11 Network DHCP Timeout

Definition	Value				
C-Definition	SA_CTL_PKEY_NETWORK_DHCP_TIMEOUT				
Code	0x020F015C				
ASCII-Command	[:PROPerTy]:DEVice:NETWork:DHCP:TIMEout				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	RW	NV-P	-
Applicable for					
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET				(0x0002)

Description

This property specifies the timeout in s for the DHCP client of the ethernet interface.

If the DHCP mode is enabled the controller will try to get an IP address automatically from a DHCP server. If no server is available the interface will fall-back to the static IP settings after the configured timeout has expired. If the maximum value of 3600 is configured the DHCP client will never time out.

This setting has no meaning if the interface is configured with a static IP (DHCP mode disabled). See section 2.1 "Connecting and Disconnecting" for more information.

This property is stored to non-volatile memory and need not be configured on every power-up. Note that the DHCP timeout is *not* reset to its default when performing a factory-reset or a firmware update. The default value is 4 s.

Valid Range

4 ... 3600 s

Example

```
// set the dhcp timeout to 1 min
result = SA_CTL_SetProperty_i32(
    dHandle,
    0,
    SA_CTL_PKEY_NETWORK_DHCP_TIMEOUT,
    60
);
```

See Also

3.2.4 SA_CTL_FindDevices

4.4 Module Properties

4.4.1 Power Supply Enabled

Definition	Value				
C-Definition	SA_CTL_PKEY_POWER_SUPPLY_ENABLED				
Code	0x02030010				
ASCII-Command	[:PROPerTy]:MODule#:PSUPply[:ENABled]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Module	RW	V	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER				(0x0001)

Description

This property enables or disables the positioner driver power supply of the module. Of course the power supply must be enabled to perform positioner movements. Otherwise, if a movement is commanded, the SA_CTL_EVENT_MOVEMENT_FINISHED event that is generated by the channel will hold a SA_CTL_ERROR_POWER_SUPPLY_DISABLED error as parameter.

The default value is SA_CTL_TRUE (0x01).

Valid Range

SA_CTL_FALSE (0x00), SA_CTL_TRUE (0x01)

Example

```
// switch off the driver power supply of the first module
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POWER_SUPPLY_ENABLED, SA_CTL_FALSE
);
```

See Also

4.5.2 Amplifier Enabled

4.4.2 Number of Bus Module Channels

Definition	Value				
C-Definition	SA_CTL_PKEY_NUMBER_OF_BUS_MODULE_CHANNELS				
Code	0x02030017				
ASCII-Command	[:PROPerTy]:MODule#:NOMChannels				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Module	R	-	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property holds the number of channels the addressed module has.

Example

```
SA_CTL_Result_t result;
int32_t modChannels;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_NUMBER_OF_BUS_MODULE_CHANNELS, &modChannels, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'modChannels' holds the number of channel of the module 0
}
```

See Also

4.3.2 Number of Bus Modules, 4.3.1 Number of Channels

4.4.3 Module Type

Definition	Value				
C-Definition	SA_CTL_PKEY_MODULE_TYPE				
Code	0x02030066				
ASCII-Command	[:PROPerTy]:MODUle#:TYPE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Module	R	-	-

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property holds the type of the module. The following types are defined:

Module / Channel Type	C-Definition	Code
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	0x0001
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	0x0002

Note that the Channel Type and Module Type properties share the same list of types.

See section 2.5 "Module Overview" for more information.

Example

```
SA_CTL_Result_t result;
int32_t type;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_MODULE_TYPE, &type, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'type' holds the type of the first driver module of the device
}
```

See Also

4.3.3 Interface Type, 4.5.11 Channel Type

4.4.4 Module State

Definition	Value				
C-Definition	SA_CTL_PKEY_MODULE_STATE				
Code	0x0203000F				
ASCII-Command	[:PROPerTy]:MODUle#:STATe				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Module	R	-	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property holds the module state. The value is a bit field containing independent flags. Their meanings are described in section 2.10.2 "Module State Flags".

Undefined flags are reserved for future use. Therefore, the user software should not rely on a static value of undefined flags.

Example

```
SA_CTL_Result_t result;
int32_t state;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_MODULE_STATE, &state, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // use bit masking to extract the needed information from the state
    if (state & SA_CTL_MOD_STATE_BIT_SM_PRESENT) {
        // a sensor module is connected to the module
    }
}
```

See Also

4.3.4 Device State, 4.5.12 Channel State

4.5 Positioner Properties

4.5.1 Startup Options

Definition	Value				
C-Definition	SA_CTL_PKEY_STARTUP_OPTIONS				
Code	0x0A02005D				
ASCII-Command	[:PROPerTy]:CHANnel#:STARtup:OPTions				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X
Applicable for					
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER				(0x0002)

Description

This property defines the behavior of the channel after the startup of the device. The following flags are available:

Bit	C-Definition	Code
0	SA_CTL_STARTUP_OPT_BIT_AMPLIFIER_ENABLE	0x00000001

Undefined flags are reserved for future use. These flags should be set to zero.

Amplifier Enable (Bit 0) The amplifier is enabled automatically on startup. This also starts the phasing sequence and forces the channel into the *holding* state afterwards. Note that the Sensor Power Mode must be configured to `SA_CTL_SENSOR_MODE_ENABLED` (1) for this option to be operative.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is 0 (all flags cleared).

Example

```
// enable the amplifier for channel 0 directly after startup
result = SA_CTL_SetProperty_i32(
    dHandle,
    0,
    SA_CTL_PKEY_STARTUP_OPTIONS,
    SA_CTL_STARTUP_OPT_BIT_AMPLIFIER_ENABLE
);
```


See Also

4.5.2 Amplifier Enabled, 4.5.28 Sensor Power Mode

4.5.2 Amplifier Enabled

Definition	Value				
C-Definition	SA_CTL_PKEY_AMPLIFIER_ENABLED				
Code	0x0302000D				
ASCII-Command	[:PROPerTy]:CHANnel#:AMPLifier[:ENABled]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property enables or disables the positioner driver amplifier of the channel. Of course the amplifier must be enabled to perform positioner movements. Otherwise, if a movement is commanded, the SA_CTL_EVENT_MOVEMENT_FINISHED event that is generated by the channel will hold a SA_CTL_ERROR_AMPLIFIER_DISABLED error as parameter. Disabling the amplifier implicitly disables the control-loop and the channel enters the *stopped* state.

The Channel State bit SA_CTL_CH_STATE_BIT_AMPLIFIER_ENABLED reflects the state of the amplifier.

Stick-Slip Piezo Driver

The default value is SA_CTL_TRUE (0x01). The channel remains stopped after the amplifier is enabled until a closed-loop movement is commanded.

Electromagnetic Driver

The default value is SA_CTL_FALSE (0x00). If the channel is not phased when enabling the amplifier the phasing sequence is automatically started and the positioner enters the closed-loop *holding* state after the phasing has finished. See section 2.22 "Phasing of Electro-Magnetic Driven Positioners" for more information.

The channel may be configured to automatically enable the amplifier at startup. (See Startup Options property.)



NOTICE

Electromagnetic driven positioners are not self-locking. Disabling the control-loop removes any holding force from the positioner. Make sure not to damage any equipment when the positioner changes its position unintentionally!

Valid Range

SA_CTL_FALSE (0x00), SA_CTL_TRUE (0x01)

Example

```
// switch off the driver power amplifier of the first channel  
result = SA_CTL_SetProperty_i32(  
    dHandle, 0, SA_CTL_PKEY_AMPLIFIER_ENABLED, SA_CTL_FALSE  
);
```

See Also

4.5.3 Amplifier Mode, 4.4.1 Power Supply Enabled, 4.5.1 Startup Options

4.5.3 Amplifier Mode

Definition	Value				
C-Definition	SA_CTL_PKEY_AMPLIFIER_MODE				
Code	0x030200BF				
ASCII-Command	[:PROPerTy]:CHANnel#:AMPLifier:MODE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER				(0x0001)

Description

This property controls the behavior of the positioner driver amplifier.

In `SA_CTL_AMP_MODE_DEFAULT` mode the amplifier is automatically enabled on power-up of the device. It remains enabled regardless of whether a positioner is connected to the channel or not.

In `SA_CTL_AMP_MODE_POSITIONER_INTERLOCK` mode the amplifier is automatically disabled when the positioner is detached from the channel and enabled when a positioner is attached to the channel. Note that the interlock is triggered by the sensor presence detection which only works for positioners with integrated sensors.

At any time the amplifier may be enabled or disabled manually by setting the Amplifier Enabled property.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is `SA_CTL_AMP_MODE_DEFAULT` (0).

Valid Range

`SA_CTL_AMP_MODE_DEFAULT` (0),
`SA_CTL_AMP_MODE_POSITIONER_INTERLOCK` (1)

Example

```
// configure 'positioner interlock' amplifier mode for the first channel
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_AMPLIFIER_MODE,
    SA_CTL_AMP_MODE_POSITIONER_INTERLOCK
);
```

See Also

4.5.2 Amplifier Enabled, 4.4.1 Power Supply Enabled

4.5.4 Positioner Control Options

Definition	Value				
C-Definition	SA_CTL_PKEY_POSITIONER_CONTROL_OPTIONS				
Code	0x0302005D				
ASCII-Command	[:PROPerTy]:CHANnel#:PCONtrol:OPTions				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property defines several positioner control related options. The value is a bit field containing independent flags. The following flags are available:

Bit	C-Definition	Code
0	SA_CTL_POS_CTRL_OPT_BIT_ACC_REL_POS_DIS	0x00000001
1	SA_CTL_POS_CTRL_OPT_BIT_NO_SLIP ¹	0x00000002
2	SA_CTL_POS_CTRL_OPT_BIT_NO_SLIP_WHILE_HOLDING ¹	0x00000004
3	SA_CTL_POS_CTRL_OPT_BIT_FORCED_SLIP_DIS ^{1,3}	0x00000008
4	SA_CTL_POS_CTRL_OPT_BIT_STOP_ON_FOLLOWING_ERR	0x00000010
5	SA_CTL_POS_CTRL_OPT_BIT_TARGET_TO_ZERO_VOLTAGE ^{1,3}	0x00000020
6	SA_CTL_POS_CTRL_OPT_BIT_CL_DIS_ON_FOLLOWING_ERR ²	0x00000040
7	SA_CTL_POS_CTRL_OPT_BIT_CL_DIS_ON_EMERGENCY_STOP ²	0x00000080
8	SA_CTL_POS_CTRL_OPT_BIT_IN_POSITION	0x00000100

Undefined flags are reserved for future use. These flags should be set to zero.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is 0 (all flags cleared).

See section 2.7.4 "Closed-Loop Movements" for a more detailed description of the positioner control options flags.

¹This option is only applicable for Stick-Slip Piezo Driver.

²This option is only applicable for Electromagnetic Driver.

³This option has no effect for dual-piezo hybrid positioners.

Example

```
// enable the "no-slip-while-holding" feature for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle,
    0,
    SA_CTL_PKEY_POSITIONER_CONTROL_OPTIONS,
    SA_CTL_POS_CTRL_OPT_BIT_NO_SLIP_WHILE_HOLDING
);
```

See Also

4.5.10 Move Mode, 4.5.5 Actuator Mode, 4.5.36 In Position Threshold, 4.5.37 In Position Delay

4.5.5 Actuator Mode

Definition	Value				
C-Definition	SA_CTL_PKEY_ACTUATOR_MODE				
Code	0x03020019				
ASCII-Command	[:PROPerTy]:CHANnel#:ACTuator:MODE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	-
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	

Description

This property specifies the type of driving signal generation. See section 2.7.4 "Closed-Loop Movements" for a more detailed description of the actuator modes. It is not allowed to change the actuator mode during an ongoing movement. In that case a `SA_CTL_ERROR_BUSY_MOVING` error is returned.

Note that the *low vibration* mode requires the velocity and acceleration control to be active. If the velocity control is not already enabled (move velocity $\neq 0$), the move velocity is set implicitly to a default velocity of 10×10^9 . If the acceleration control is not already enabled (move acceleration $\neq 0$), the move acceleration is set implicitly to a default acceleration of 100×10^9 .

Note that all referencing movements are performed with the normal mode even if this property is configured to `SA_CTL_ACTUATOR_MODE_LOW_VIBRATION`.

The default mode is `SA_CTL_ACTUATOR_MODE_NORMAL` (0).

Valid Range

`SA_CTL_ACTUATOR_MODE_NORMAL` (0),
`SA_CTL_ACTUATOR_MODE_QUIET` (1),
`SA_CTL_ACTUATOR_MODE_LOW_VIBRATION` (2)

The low vibration actuator mode needs a feature permission to be activated on the controller. See section 2.24 "Feature Permissions" for more information.

Example

```
SA_CTL_Result_t result;
int8_t channelId = 0;
// configure the 'quiet' actuator mode for channel 0
```



```
result = SA_CTL_SetProperty_i32(  
    dHandle,  
    channelIdX,  
    SA_CTL_PKEY_ACTUATOR_MODE,  
    SA_CTL_ACTUATOR_MODE_QUIET  
);
```

See Also

4.5.18 Move Velocity, 4.5.19 Move Acceleration, 4.5.10 Move Mode, 4.5.4 Positioner Control Options

4.5.6 Control Loop Input

Definition	Value				
C-Definition	SA_CTL_PKEY_CONTROL_LOOP_INPUT				
Code	0x03020018				
ASCII-Command	[:PROPerTy]:CHANnel#:CLINput[:SElect]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies which signal is used as input for the control-loop. For the majority of applications this property will be set to `SA_CTL_CONTROL_LOOP_INPUT_SENSOR`, meaning the integrated sensor of the positioner is used as feedback signal for the control-loop.

Nonetheless it is also possible to use external signals. E.g. an analog voltage derived from a force sensor can be feed into an analog input of the MCS2 I/O module to implement a force feedback control for a gripper. Set this property to `SA_CTL_CONTROL_LOOP_INPUT_AUX_IN` to use one of the auxiliary inputs as control-loop feedback. Please refer to section 2.19.5 "Using Analog Inputs as Control-Loop Feedback" for more information on the auxiliary configuration.

In some cases it may be useful to prohibit the closed-loop operation of a channel. This can be achieved by setting this property to `SA_CTL_CONTROL_LOOP_INPUT_DISABLED`.

A `SA_CTL_ERROR_CONTROL_LOOP_INPUT_DISABLED` error will be generated when trying to command a closed-loop movement in this case.

This property is stored to non-volatile memory and need not be configured on every power-up. The default input is `SA_CTL_CONTROL_LOOP_INPUT_SENSOR` (1).

Note that setting this property implicitly stops the channel and disables the control-loop.



NOTICE

Electromagnetic driven positioners are not self-locking. Disabling the control-loop removes any holding force from the positioner. Make sure not to damage any equipment when the positioner changes its position unintentionally!

Valid Range

`SA_CTL_CONTROL_LOOP_INPUT_DISABLED` (0),
`SA_CTL_CONTROL_LOOP_INPUT_SENSOR` (1),
`SA_CTL_CONTROL_LOOP_INPUT_AUX_IN` (2)

Example

```
SA_CTL_Result_t result;
int8_t channelId = 0;
// configure the sensor as input for the control-loop for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle,
    channelId,
    SA_CTL_PKEY_CONTROL_LOOP_INPUT,
    SA_CTL_CONTROL_LOOP_INPUT_SENSOR
);
```

See Also

4.5.7 Sensor Input Select

4.5.7 Sensor Input Select

Definition	Value				
C-Definition	SA_CTL_PKEY_SENSOR_INPUT_SELECT				
Code	0x0302009D				
ASCII-Command	[:PROPerTy]:CHANnel#:CLINput:SENSor:SElect				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies which sensor signal is used for the 'sensor' input of the control-loop input mux. (See Control Loop Input property.) The property is only relevant if a SmarAct PicoScale laser interferometer is connected as sensor module or if the external sensor correction feature should be used.

The PicoScale calculation system can perform various calculations with different values of the device, in particular even from different channels. The calculation system may then be used to generate a control-loop input signal for the MCS2 channel.

Set this property to `SA_CTL_SENSOR_INPUT_SELECT_CALC_SYS` to configure the calculation system. Please refer to section 2.12 "PicoScale Sensor Module" and figure 2.14 "Auxiliary Input Configuration (per channel)" for more information.

Set this property to `SA_CTL_SENSOR_INPUT_SELECT_POS_PLUS_AUX_IN` to enable the external sensor correction feature. After that the analog input signal of an I/O module (scaled by the Aux Correction Max property) is continuously added to the current position. Please refer to section 2.19.6 "Using Analog Inputs for External Sensor Correction" and figure 2.14 "Auxiliary Input Configuration (per channel)" for more information.

This property is stored to non-volatile memory and need not be configured on every power-up. The default input is `SA_CTL_SENSOR_INPUT_SELECT_POSITION` (0).

Valid Range

`SA_CTL_SENSOR_INPUT_SELECT_POSITION` (0),
`SA_CTL_SENSOR_INPUT_SELECT_CALC_SYS` (1),
`SA_CTL_SENSOR_INPUT_SELECT_POS_PLUS_AUX_IN` (2)

Example

```
SA_CTL_Result_t result;
// configure the PSC calculation system as input
// for the control-loop for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle,
    0,
    SA_CTL_PKEY_SENSOR_INPUT_SELECT,
    SA_CTL_SENSOR_INPUT_SELECT_CALC_SYS
);
```

See Also

4.5.6 Control Loop Input, 4.12.7 Aux Correction Max

4.5.8 Positioner Type

Definition	Value				
C-Definition	SA_CTL_PKEY_POSITIONER_TYPE				
Code	0x0302003C				
ASCII-Command	[:PROPerTy]:CHANnel#:PTYPe[:CODE]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

The positioner type tells the channel what type of positioner is connected. The type implicitly gives the controller information about how to calculate positions, handle the referencing and configure the control-loop.

The positioner type configuration differs depending on whether the positioner and driver supports the SmarAct Positioner ID System. See section 2.5 "Module Overview" for more information about the supported features of the different driver modules.

If the positioner type of a channel is changed, the positioner is stopped implicitly. (For Electromagnetic Driver channels the amplifier is disabled.) Furthermore the calibration (and phasing) becomes invalid and the physical position becomes unknown. The Channel State bits:

- SA_CTL_CH_STATE_BIT_IS_CALIBRATED,
- SA_CTL_CH_STATE_BIT_IS_REFERENCED and
- SA_CTL_CH_STATE_BIT_IS_PHASED*

are reset to zero to indicate this.

The positioner type is read as SA_CTL_POSITIONER_TYPE_MODIFIED (0) if tuning parameters of a channel are modified and as long as the modified positioner type was not saved to a custom slot. See section 2.6 "Positioner Types" for more information.

Note that SA_CTL_Calibrate must be called to ensure proper operation of the positioner if the positioner type was changed.

Manual Positioner Type Configuration

The positioner type must be configured with this property to match the connected positioner. Each channel stores the type setting to non-volatile memory. Consequently, there is no need to set this property on every initialization.

*This channel state bit is only valid for Electromagnetic Driver.

Valid Range

Please refer to the *MCS2 Positioner Types* document for a list of valid positioner type codes.

Automatic Positioner Type Configuration

In case the positioner type is automatically detected and configured when the positioner is attached to the channel, the write access to this property is restricted to *custom positioner types* and to the special *automatic positioner type* value. Writing a different positioner type returns a `SA_CTL_ERROR_POSITIONER_TYPE_NOT_WRITEABLE` error.

Valid Range

`SA_CTL_POSITIONER_TYPE_AUTOMATIC (299),`
`SA_CTL_POSITIONER_TYPE_CUSTOM0 (250),`
`SA_CTL_POSITIONER_TYPE_CUSTOM1 (251),`
`SA_CTL_POSITIONER_TYPE_CUSTOM2 (252),`
`SA_CTL_POSITIONER_TYPE_CUSTOM3 (253)`

Example

```
// set the 'custom0' positioner type for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POSITIONER_TYPE,
    SA_CTL_POSITIONER_TYPE_CUSTOM0
);
```

4.5.9 Positioner Type Name

Definition	Value				
C-Definition	SA_CTL_PKEY_POSITIONER_TYPE_NAME				
Code	0x0302003D				
ASCII-Command	[:PROPerTy]:CHANnel#:PTYPE:NAME				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	String	Channel	R	-	-

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property holds a descriptive name of the configured positioner type. The positioner type name is a null terminated string. Note that the name is read-only.

Example

```
SA_CTL_Result_t result;
char name[SA_CTL_STRING_MAX_LENGTH];
size_t ioStringSize = sizeof(name);
result = SA_CTL_GetProperty_s(
    dHandle, 0, SA_CTL_PKEY_POSITIONER_TYPE_NAME, name, &ioStringSize
);
if (result == SA_CTL_ERROR_NONE) {
    // 'name' holds the name of the configured positioner type
}
```

See Also

4.5.8 Positioner Type

4.5.10 Move Mode

Definition	Value				
C-Definition	SA_CTL_PKEY_MOVE_MODE				
Code	0x03050087				
ASCII-Command	[:PROPerTy]:CHANnel#:MMODE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property specifies which movement mode is used when commanding a positioner movement using `SA_CTL_Move`. Depending on the configured move mode the *move value* parameter of the `SA_CTL_Move` function is interpreted differently. See section 2.7.3 "Open-Loop Movements" and 2.7.4 "Closed-Loop Movements" for a description of all related properties for the different move modes.

The default mode is `SA_CTL_MOVE_MODE_CL_ABSOLUTE (0)`.

Valid Range

`SA_CTL_MOVE_MODE_CL_ABSOLUTE (0)`,
`SA_CTL_MOVE_MODE_CL_RELATIVE (1)`,
`SA_CTL_MOVE_MODE_SCAN_ABSOLUTE (2)*`,
`SA_CTL_MOVE_MODE_SCAN_RELATIVE (3)*`,
`SA_CTL_MOVE_MODE_STEP (4)*`

Example

```
SA_CTL_Result_t result;
int8_t channelIdX = 0;
// configure an open-loop step movement with full amplitude at 2kHz
result = SA_CTL_SetProperty_i32(
    dHandle, channelIdX, SA_CTL_PKEY_MOVE_MODE, SA_CTL_MOVE_MODE_STEP
);
if (result) { // handle error, abort }
result = SA_CTL_SetProperty_i32(
    dHandle, channelIdX, SA_CTL_PKEY_STEP_AMPLITUDE, 65535
);
```

*This mode is only applicable for Stick-Slip Piezo Driver.

```
);  
if (result) {// handle error, abort}  
result = SA_CTL_SetProperty_i32(  
    dHandle, channelId, SA_CTL_PKEY_STEP_FREQUENCY, 2000  
);  
if (result == SA_CTL_ERROR_NONE) {  
    // perform 100 steps  
    result = SA_CTL_Move(  
        dHandle, channelId, 100  
    );  
}
```

See Also

4.5.22 Step Frequency, 4.5.23 Step Amplitude

4.5.11 Channel Type

Definition	Value				
C-Definition	SA_CTL_PKEY_CHANNEL_TYPE				
Code	0x02020066				
ASCII-Command	[:PROPerTy]:CHANnel#:TYPE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R	-	-

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property holds the type of the channel. The following types are defined:

Module / Channel Type	C-Definition	Code
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	0x0001
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	0x0002

Note that the Channel Type and Module Type properties share the same list of types.

See section 2.5 "Module Overview" for more information.

Example

```
SA_CTL_Result_t result;
int32_t type;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_CHANNEL_TYPE, &type, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'type' holds the type of the first channel
}
```

See Also

4.3.3 Interface Type, 4.4.3 Module Type

4.5.12 Channel State

Definition	Value				
C-Definition	SA_CTL_PKEY_CHANNEL_STATE				
Code	0x0305000F				
ASCII-Command	[:PROPerTy]:CHANnel#:STATe				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R	-	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property holds the channel state. The value is a bit field containing independent flags. Their meaning is described in section 2.10.3 "Channel State Flags".

Undefined flags are reserved for future use. Therefore, the user software should not rely on a static value of undefined flags.

Example

```
SA_CTL_Result_t result;
int8_t channelId = 0;
int32_t state;
result = SA_CTL_GetProperty_i32(
    dHandle, channelId, SA_CTL_PKEY_CHANNEL_STATE, &state, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // use bit masking to determine the channels movement state
    if ((state & (SA_CTL_CH_STATE_BIT_ACTIVELY_MOVING |
        SA_CTL_CH_STATE_BIT_CLOSED_LOOP_ACTIVE)) == 0) {
        // positioner is stopped
    }
}
```

See Also

4.3.4 Device State, 4.4.4 Module State

4.5.13 Position

Definition	Value				
C-Definition	SA_CTL_PKEY_POSITION				
Code	0x0305001D				
ASCII-Command	[:PROPerTy]:CHANnel#:POSition[:CURRent]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property holds the current position of a positioner. Note that it can only be used for positioners that have a sensor attached to it. A `SA_CTL_ERROR_NO_SENSOR_PRESENT` error is returned if no sensor is present. The Channel State bit `SA_CTL_CH_STATE_BIT_SENSOR_PRESENT` may be polled to determine if a sensor is present.

The interpretation of the read position value depends on the configured positioner type. The unit is pico meter (pm) for linear positioners and nano degree (n°) for rotatory positioners.

Read the Positioner Base Unit property to distinguish between linear and rotatory positioner type.

The position may be set to define the logical scale. See section 2.8.5 "Shifting the Measuring Scale" for more information. Note that it is not allowed to set the position while a calibration or referencing sequence or a trajectory stream is running. A `SA_CTL_ERROR_BUSY_CALIBRATING`, `SA_CTL_ERROR_BUSY_REFERENCING` or `SA_CTL_ERROR_BUSY_STREAMING` error is returned in that case.

Valid Range

$-100 \times 10^{12} \dots 100 \times 10^{12}$ pm or n°

Example

```
SA_CTL_Result_t result;
int64_t position;
result = SA_CTL_GetProperty_i64(
    dHandle, 0, SA_CTL_PKEY_POSITION, &position, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'position' holds the current position of channel 0
}
```

```
}
```

See Also

4.9.3 Positioner Base Unit, 4.9.4 Positioner Base Resolution

4.5.14 Target Position

Definition	Value				
C-Definition	SA_CTL_PKEY_TARGET_POSITION				
Code	0x0305001E				
ASCII-Command	[:PROPerTy]:CHANnel#:POSition:TARGet				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	R	-	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property holds the target position of a channel for the current closed-loop movement.

See Also

4.5.13 Position

4.5.15 Scan Position

Definition	Value				
C-Definition	SA_CTL_PKEY_SCAN_POSITION				
Code	0x0305001F				
ASCII-Command	[:PROPerTy]:CHANnel#:POSition:SCAN				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	R	-	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	

Description

This property holds the current scan position of a positioner. The scan position represents the voltage level that is currently applied to the piezo element of a positioner.

This property is mainly of interest when using the `SA_CTL_MOVE_MODE_SCAN_ABSOLUTE` and `SA_CTL_MOVE_MODE_SCAN_RELATIVE` Move Modes, since these modes are used to control the scan position.

The scan position is given in 16-bit increments from 0 ... 65 535, where 0 corresponds to 0V and 65 535 to 100V.

Example

```
SA_CTL_Result_t result;
int64_t position;
result = SA_CTL_GetProperty_i64(
    dHandle, 0, SA_CTL_PKEY_SCAN_POSITION, &position, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'position' holds the current scan position of channel 0
}
```

See Also

4.5.16 Scan Velocity, 4.5.10 Move Mode

4.5.16 Scan Velocity

Definition	Value				
C-Definition	SA_CTL_PKEY_SCAN_VELOCITY				
Code	0x0305002A				
ASCII-Command	[:PROPerTy]:CHANnel#:SCAN:VELOcity				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	RW	V	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER				(0x0001)

Description

This property specifies the scan velocity of a positioner. The scan velocity is given in 16-bit increments per second. With a value of 1 a scan over the full range from 0 to 65 535 takes 65 535 seconds while at maximum velocity the scan is performed in one micro second.

To perform a scan movement via the `SA_CTL_Move` function, the Move Mode property must be set to `SA_CTL_MOVE_MODE_SCAN_ABSOLUTE` or `SA_CTL_MOVE_MODE_SCAN_RELATIVE` first.

The default value is 65 535.

Valid Range

1 ... 65 535 000 000

Example

```
// set the scan velocity for channel 0
// (full range scan in 1 second)
result = SA_CTL_SetProperty_i64(
    dHandle, 0, SA_CTL_PKEY_SCAN_VELOCITY, 65535
);
```

See Also

4.5.15 Scan Position, 4.5.10 Move Mode

4.5.17 Hold Time

Definition	Value				
C-Definition	SA_CTL_PKEY_HOLD_TIME				
Code	0x03050028				
ASCII-Command	[:PROPerTy]:CHANnel#:HOLDtime				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	

Description

This property specifies how long (in ms) the position is actively held after reaching the target position. After the hold time elapsed the channel is stopped and the control-loop is disabled.

The Channel State bit `SA_CTL_CH_STATE_BIT_CLOSED_LOOP_ACTIVE` will be read as one as long as the the position is actively held.

A value of 0 deactivates this feature, a value of `SA_CTL_HOLD_TIME_INFINITE` (-1) sets the channel to infinite holding. (until manually stopped with `SA_CTL_Stop`).

Note that the end stop detection is still active in holding state. If a positioner is moved away from the target position by external forces and the channel is not able to hold the target position for a longer time an end stop is triggered. A `SA_CTL_EVENT_HOLDING_ABORTED` event is generated to notify about this and the channel is stopped.

The default hold time is `SA_CTL_HOLD_TIME_INFINITE`.

Valid Range

0 ... `INT32_MAX`, `SA_CTL_HOLD_TIME_INFINITE` (-1)

Example

```
// set hold time for channel 0 to infinite holding
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_HOLD_TIME, SA_CTL_HOLD_TIME_INFINITE
);
```

See Also

4.5.10 Move Mode

4.5.18 Move Velocity

Definition	Value				
C-Definition	SA_CTL_PKEY_MOVE_VELOCITY				
Code	0x03050029				
ASCII-Command	[:PROPerTy]:CHANnel#:VELocity				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the velocity of a positioner for closed-loop movement commands. The value is given in pm/s for linear positioners and in n°/s for rotary positioners.

Note that the move velocity also applies to movements executed during the find reference sequence (see SA_CTL_Reference).

Stick-Slip Piezo Driver

If a velocity > 0 is configured, all following closed-loop movement commands will be executed with velocity control.

Note that the channel will not drive the positioner with frequencies above the maximum allowed frequency (see Max Closed Loop Frequency). If the maximum frequency is set too low for a certain velocity, then the velocity might not be reached or held since the driver will cap at the maximum driving frequency. In this case increase the maximum frequency.

The default value is 0, meaning that the velocity control is inactive. In this state the behavior of closed-loop commands is influenced by the maximum driving frequency (see Max Closed Loop Frequency).

It is not allowed to *enable* or *disable* the velocity control during an ongoing movement. In that case a SA_CTL_ERROR_BUSY_MOVING error is returned. Anyway, *modifying* the velocity of an ongoing movement is possible.

Valid Range (Stick-Slip Piezo Driver)

0 ... 100×10^9 pm/s (linear) | 0 ... 1×10^{12} n°/s (rotatory, goniometer)

Electromagnetic Driver

The velocity and acceleration control must be used for all movements to define the move velocity resp. the acceleration, since there is no additional limiting parameter for magnetic driven positioners (like the Max Closed Loop Frequency for piezo driven positioners). The default value is 1×10^9 .

Valid Range (Electromagnetic Driver)

$1 \dots 10 \times 10^{12}$ pm/s (linear) | $1 \dots 100 \times 10^{12}$ n°/s (rotatory)

Example

```
// enable velocity control by configuring 1mm/s for channel 0  
result = SA_CTL_SetProperty_i64(  
    dHandle, 0, SA_CTL_PKEY_MOVE_VELOCITY, 1e9  
);
```

See Also

4.5.19 Move Acceleration, 4.5.10 Move Mode, 4.5.20 Max Closed Loop Frequency

4.5.19 Move Acceleration

Definition	Value				
C-Definition	SA_CTL_PKEY_MOVE_ACCELERATION				
Code	0x0305002B				
ASCII-Command	[:PROPerTy]:CHANnel#:ACCeleration				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	RW	V	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property specifies the acceleration of a positioner for closed-loop movement commands. The value is given in pm/s² for linear positioner and in n°/s² for rotary positioners.

Note that the move acceleration also applies to movements executed during the find reference sequence (see SA_CTL_Reference).

For closed-loop movements with enabled acceleration control a SA_CTL_Stop command instructs the positioner to come to a halt by decelerating to zero velocity. A second "stop" command triggers a hard stop.

Stick-Slip Piezo Driver

If an acceleration > 0 is configured, all following closed-loop movement commands will be executed with acceleration control. The acceleration control requires the velocity control to be enabled too (Move Velocity > 0).

The default value is 0, meaning that the acceleration control is inactive.

It is not allowed to *enable* or *disable* the acceleration control during an ongoing movement. In that case a SA_CTL_ERROR_BUSY_MOVING error is returned. Anyway, *modifying* the acceleration of an ongoing movement is possible.

Valid Range (Stick-Slip Piezo Driver)

0 ... 10×10^{12}

Electromagnetic Driver

The velocity and acceleration control must be used for all movements to define the move velocity resp. the acceleration, since there is no additional limiting parameter for magnetic driven positioners (like the Max Closed Loop Frequency for piezo driven positioners). The default value is 100×10^9 .

Valid Range (Electromagnetic Driver)

1 ... 100×10^{12}

Example

```
// enable acceleration control by configuring 1mm/s2 for channel 0  
result = SA_CTL_SetProperty_i64(  
    dHandle, 0, SA_CTL_PKEY_MOVE_ACCELERATION, 1e9  
);
```

See Also

4.5.18 Move Velocity, 4.5.10 Move Mode

4.5.20 Max Closed Loop Frequency

Definition	Value				
C-Definition	SA_CTL_PKEY_MAX_CL_FREQUENCY				
Code	0x0305002F				
ASCII-Command	[:PROPerTy]:CHANnel#:MCLFrequency[:CURRent]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	

Description

This property specifies the maximum frequency that a stick-slip piezo positioner is driven with when issuing closed-loop movement commands.

The maximum allowed frequency depends on the actual positioner as well as the environment. (E.g. HV and UHV environment requires lower allowed frequencies.)

This property is not held in non-volatile memory but the default value at device startup is configurable (see Default Max Closed Loop Frequency).

Valid Range

50 ... 20 000 Hz

Example

```
// set maximum closed-loop frequency to 3kHz for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_MAX_CL_FREQUENCY, 3000
);
```

See Also

4.5.21 Default Max Closed Loop Frequency

4.5.21 Default Max Closed Loop Frequency

Definition	Value				
C-Definition	SA_CTL_PKEY_DEFAULT_MAX_CL_FREQUENCY				
Code	0x03050057				
ASCII-Command	[:PROPerTy]:CHANnel#:MCLFrequency:DEFault				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)			

Description

This property specifies the default value at device startup for the maximum closed-loop frequency. The default frequency is 5000 Hz.

Valid Range

50 ... 20 000 Hz

Example

```
// set default maximum closed-loop frequency
// at start up to 6kHz for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_DEFAULT_MAX_CL_FREQUENCY, 6000
);
```

See Also

4.5.20 Max Closed Loop Frequency

4.5.22 Step Frequency

Definition	Value				
C-Definition	SA_CTL_PKEY_STEP_FREQUENCY				
Code	0x0305002E				
ASCII-Command	[:PROPerTy]:CHANnel#:STEP:FREQuency				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)			

Description

This property specifies the frequency in Hz that open-loop steps are performed with. To perform open-loop steps by using the `SA_CTL_Move` function, the Move Mode property must be set to `SA_CTL_MOVE_MODE_STEP` first. See section 2.7.3 "Open-Loop Movements" for more information.

The default frequency is 1000 Hz.

Valid Range

1 ... 20 000 Hz

Example

```
// set the step frequency to 1kHz for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_STEP_FREQUENCY, 1000
);
```

See Also

4.5.23 Step Amplitude, 4.5.10 Move Mode

4.5.23 Step Amplitude

Definition	Value				
C-Definition	SA_CTL_PKEY_STEP_AMPLITUDE				
Code	0x03050030				
ASCII-Command	[:PROPerTy]:CHANnel#:STEP:AMPLitude				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)			

Description

This property specifies the amplitude that open-loop steps are performed with. The Move Mode property must be set to `SA_CTL_MOVE_MODE_STEP` first, before open-loop steps may be performed with the `SA_CTL_Move` function. See section 2.7.3 "Open-Loop Movements" for more information.

Lower amplitude values result in a smaller step width. The step amplitude is a 16bit value from 1 ... 65 535, where 65 535 corresponds to 100 V.

The default amplitude is 65 535 (100 V).

Valid Range

1 ... 65 535

Example

```
// set the step amplitude to maximum (100V) for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_STEP_AMPLITUDE, 65535
);
```

See Also

4.5.22 Step Frequency, 4.5.10 Move Mode

4.5.24 Following Error

Definition	Value				
C-Definition	SA_CTL_PKEY_FOLLOWING_ERROR				
Code	0x03020055				
ASCII-Command	[:PROPerTy]:CHANnel#:FERRor				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	R	-	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property holds the *current* following error in pm for linear positioners and in n° for rotary positioners. The following error is, at a given time, the difference between the target position and the actual position while performing closed-loop movements.

Note that the following error is only available for movements with velocity control enabled (Move Velocity > 0) and while performing Trajectory Streaming.

See section 2.14 "Following Error Detection" for more information.

Example

```
SA_CTL_Result_t result;
int64_t error;
result = SA_CTL_GetProperty_i64(
    dHandle, 0, SA_CTL_PKEY_FOLLOWING_ERROR, &error, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'error' holds the current following error of channel 0
}
```

See Also

4.5.26 Following Error Limit, 4.5.25 Following Error Max, 4.5.18 Move Velocity

4.5.25 Following Error Max

Definition	Value				
C-Definition	SA_CTL_PKEY_FOLLOWING_ERROR_MAX				
Code	0x05020055				
ASCII-Command	[:PROPerTy]:CHANnel#:FEMax				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	R	-	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property holds the *maximum* following error in pm for linear positioners and in n° for rotary positioners while performing a closed-loop movement. It is the maximum unsigned magnitude of the Following Error of the last, resp. currently running movement. The value is reset to zero when starting a movement or trajectory stream.

Note that the following error is only available for movements with velocity control enabled (Move Velocity > 0) and while performing Trajectory Streaming.

See section 2.14 "Following Error Detection" for more information.

Example

```
SA_CTL_Result_t result;
int64_t error;
result = SA_CTL_GetProperty_i64(
    dHandle, 0, SA_CTL_PKEY_FOLLOWING_ERROR_MAX, &error, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'error' holds the maximum following error of channel 0
}
```

See Also

4.5.24 Following Error, 4.5.26 Following Error Limit, 4.5.18 Move Velocity

4.5.26 Following Error Limit

Definition	Value				
C-Definition	SA_CTL_PKEY_FOLLOWING_ERROR_LIMIT				
Code	0x03050055				
ASCII-Command	[:PROPerTy]:CHANnel#:FELimit				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	RW	NV	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the limit for the following error detection. The value is given in pm for linear positioners and in n° for rotary positioners. Setting the following error limit to zero disables the detection. See section 2.14 "Following Error Detection" for more information.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is 0 (disabled).

Valid Range

0 ... 100×10^{12}

Example

```
// set following error limit to 100um for channel 0
result = SA_CTL_SetProperty_i64(
    dHandle, 0, SA_CTL_PKEY_FOLLOWING_ERROR_LIMIT, 100000000
);
```

See Also

4.5.24 Following Error, 4.5.25 Following Error Max, 4.5.4 Positioner Control Options, 4.5.18 Move Velocity

4.5.27 Broadcast Stop Options

Definition	Value				
C-Definition	SA_CTL_PKEY_BROADCAST_STOP_OPTIONS				
Code	0x0305005D				
ASCII-Command	[:PROPerTy]:CHANnel#:BSOPtions				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the behavior of a broadcast stop of a channel. It is typically useful when multiple channels are moving simultaneously and an end stop (or range limit) on one channel should cause a halt on all other channels. See section 2.16 "Stop Broadcasting" for more information.

The value is a bit field containing independent flags with the following meaning:

Bit	C-Definition	Code
0	SA_CTL_STOP_OPT_BIT_END_STOP_REACHED	0x00000001
1	SA_CTL_STOP_OPT_BIT_RANGE_LIMIT_REACHED	0x00000002
2	SA_CTL_STOP_OPT_BIT_FOLLOWING_LIMIT_REACHED	0x00000004
3	SA_CTL_STOP_OPT_BIT_POSITIONER_OVERLOAD	0x00000008

Undefined flags are reserved for future use. These flags should be set to zero.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is 0 (all flags cleared).

Example

```
// enable stop broadcasting of channel 0 for end stops and range limits
result = SA_CTL_SetProperty_i32(
    dHandle,
    0,
    SA_CTL_PKEY_BROADCAST_STOP_OPTIONS,
    (SA_CTL_STOP_OPT_BIT_END_STOP_REACHED |
     SA_CTL_STOP_OPT_BIT_RANGE_LIMIT_REACHED)
);
```

4.5.28 Sensor Power Mode

Definition	Value				
C-Definition	SA_CTL_PKEY_SENSOR_POWER_MODE				
Code	0x03080019				
ASCII-Command	[:PROPerTy]:CHANnel#:SENSor:MODE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the sensor power mode. It may be used to activate or deactivate the sensor that is attached to the positioner. It effectively turns the power supply of the sensor on or off.

Please refer to section 2.11 "Sensor Power Modes" for more information on the sensor power modes.

Note that setting this property implicitly stops the channel and disables the control-loop.

The following sensor power modes are available:

Mode	Name	Short Description
0	SA_CTL_SENSOR_MODE_DISABLED	The sensor power supply is turned off continuously.
1	SA_CTL_SENSOR_MODE_ENABLED	The sensor is continuously supplied with power.
2	SA_CTL_SENSOR_MODE_POWER_SAVE*	The sensor power supply is pulsed to keep the heat generation low.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is SA_CTL_SENSOR_MODE_POWER_SAVE (2).

Electromagnetic Driver

Changing the sensor power mode for Electromagnetic Driver channels also disables the amplifier and invalidates the phasing. See section 2.22 "Phasing of Electro-Magnetic Driven Positioners" for more information.

*The power save mode is only available for Stick-Slip Piezo Driver.

**NOTICE**

Electromagnetic driven positioners are not self-locking. Disabling the control-loop removes any holding force from the positioner. Make sure not to damage any equipment when the positioner changes its position unintentionally!

Example

```
// set power save mode for the sensor of channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_SENSOR_POWER_MODE, SA_CTL_SENSOR_MODE_POWER_SAVE
);
```

See Also

4.5.29 Sensor Power Save Delay

4.5.29 Sensor Power Save Delay

Definition	Value				
C-Definition	SA_CTL_PKEY_SENSOR_POWER_SAVE_DELAY				
Code	0x03080054				
ASCII-Command	[:PROPerTy]:CHANnel#:SENSor:DELaY				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)			

Description

This property specifies the time in ms before the channel disables the sensor after a movement has finished. It has no meaning if the Sensor Power Mode is not configured to power save mode. In power save mode the sensor is disabled most of the time. Before a movement can be started it must be enabled by the channel to keep track of the current position. Once the movement has finished the sensor can be disabled again. The sensor power save delay configures an additional delay before the sensor power is disabled. If a new movement is started while this delay is running, the sensor is still enabled and the movement can be started directly. Since it takes a few milliseconds to enable the sensor, this setting may be used to optimize the timing of a movement sequence.

Please refer to section 2.11 "Sensor Power Modes" for more information on the sensor power save mode.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is 100 ms.

Valid Range

0 ... 5000

Example

```
// set power save delay for the sensor of channel 0 to 200 ms
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_SENSOR_POWER_SAVE_DELAY, 200
);
```

See Also

4.5.28 Sensor Power Mode

4.5.30 Position Mean Shift

Definition	Value				
C-Definition	SA_CTL_PKEY_POSITION_MEAN_SHIFT				
Code	0x03090022				
ASCII-Command	[:PROPerTy]:CHANnel#:POSition:MSHift				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property specifies the filter averaging factor for the position mean filter. The averaging factor must be set as a left-shift value by a power of two. Thus the resulting averaging factor may be calculated by the formula: $\text{factor} = 2^{\text{meanShift}}$.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is 5 (32-fold position averaging).

Valid Range

0 ... 7

Example

```
// set position mean filter to 0 (disabled) for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POSITION_MEAN_SHIFT, 0
);
```

4.5.31 Safe Direction

Definition	Value				
C-Definition	SA_CTL_PKEY_SAFE_DIRECTION				
Code	0x03090027				
ASCII-Command	[:PROPerTy]:CHANnel#:SDIRectiOn				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property specifies the safe direction used for calibration and referencing of positioner types that are referenced via a mechanical end stop.

Some positioners are not equipped with a physical reference mark. For these positioners a mechanical end stop is used as a reference point when calling `SA_CTL_Reference`. Which end stop is used is configured by the safe direction as well as the current Logical Scale Inversion. This should be the direction in which the positioner may safely move without endangering the physical setup of your manipulator system. Since the end stop must be calibrated before it can be properly used as a reference point, the direction settings also affect the behavior of `SA_CTL_Calibrate`. Positioners that are referenced via an end stop also move to the configured end stop as part of the calibration routine. This movement will use the configured Move Velocity and Move Acceleration.

Please note that the `SA_CTL_Reference` and `SA_CTL_Calibrate` functions will ignore their configured start directions for positioners that are referenced via a mechanical end stop and will implicitly use the direction configured by the safe direction and Logical Scale Inversion instead. Please refer to the *MCS2 Positioner Types* document for a list of available positioner types and their reference marks.

Note that when changing the safe direction the positioner must be calibrated again for proper operation.

This property is stored to non-volatile memory and need not be configured on every power-up.

Valid Range

`SA_CTL_FORWARD_DIRECTION` (0x00), `SA_CTL_BACKWARD_DIRECTION` (0x01)

Example

```
// set safe direction to forward for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_SAFE_DIRECTION, SA_CTL_FORWARD_DIRECTION
);
```

See Also

4.8.1 Referencing Options

4.5.32 Control Loop Input Sensor Value

Definition	Value				
C-Definition	SA_CTL_PKEY_CL_INPUT_SENSOR_VALUE				
Code	0x0302001D				
ASCII-Command	[:PROPerTy]:CHANnel#:CLINput:SENSor[:VALue]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	R	-	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property always returns the 'sensor' value regardless of the configured control-loop input. Note that an error is returned if no sensor module or no sensor is present. Please refer to section 2.19.5 "Using Analog Inputs as Control-Loop Feedback" for more information.

Example

```
SA_CTL_Result_t result;
int64_t val;
result = SA_CTL_GetProperty_i64(
    dHandle, 0, SA_CTL_PKEY_CL_INPUT_SENSOR_VALUE, &val, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'val' holds the current sensor position of channel 0
}
```

See Also

4.5.33 Control Loop Input Aux Value

4.5.33 Control Loop Input Aux Value

Definition	Value				
C-Definition	SA_CTL_PKEY_CL_INPUT_AUX_VALUE				
Code	0x030200B2				
ASCII-Command	[:PROPerTy]:CHANnel#:CLINput:AUXiliary[:VALue]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	R	-	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property always returns the 'auxiliary input' value regardless of the configured control-loop input. Note that an error is returned if no sensor module or no I/O module is available (depending on the configured Aux Input Select property). Please refer to section 2.19.5 "Using Analog Inputs as Control-Loop Feedback" for more information on using auxiliary inputs.

Example

```
SA_CTL_Result_t result;
int64_t val;
result = SA_CTL_GetProperty_i64(
    dHandle, 0, SA_CTL_PKEY_CL_INPUT_AUX_VALUE, &val, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'val' holds the auxiliary input value of channel 0
}
```

See Also

4.5.32 Control Loop Input Sensor Value

4.5.34 Target To Zero Voltage Hold Threshold

Definition	Value				
C-Definition	SA_CTL_PKEY_TARGET_TO_ZERO_VOLTAGE_HOLD_TH				
Code	0x030200B9				
ASCII-Command	[:PROPerTy]:CHANnel#:TTZVoltage:THReshold[:HOLD]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER				(0x0001)

Description

This property specifies the hold threshold in pm or n° for the target-to-zero-voltage feature. The threshold defines the maximum allowed remaining position error (distance to the target position) for the sequence to terminate. As a guiding value the threshold should be in the range of about ten times the target reached threshold of the configured positioner type but could be also much lower in the particular case. If the threshold is too low the sequence will not terminate.

If a Hold Time is specified the sequence is repeated whenever the difference between current position and target position exceeds the configured threshold. After the hold time elapsed the last sequence is still finished and the channel is stopped.

Note that the target-to-zero-voltage feature must be enabled by setting the `SA_CTL_POS_CTRL_OPT_BIT_TARGET_TO_ZERO_VOLTAGE` flag of the Positioner Control Options property. It has no meaning if the target-to-zero-voltage feature is disabled. If this property is set to 0 the hold threshold value is derived from the Positioner Target Reached Threshold parameter of the configured positioner type.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is 0.

Please refer to section 2.7.4 "Closed-Loop Movements" for more information on the target-to-zero-voltage feature.

Valid Range

0 ... 10×10^6 .

Example

```
// set the target to zero voltage hold threshold to 25nm for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_TARGET_TO_ZERO_VOLTAGE_HOLD_TH, 25000
);
```

See Also

4.5.4 Positioner Control Options

4.5.35 Channel Emergency Stop Mode

Definition	Value				
C-Definition	SA_CTL_PKEY_CH_EMERGENCY_STOP_MODE				
Code	0x02020088				
ASCII-Command	[:PROPerTy]:CHANnel#:ESTop:MODE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the emergency stop mode of a channel. See section 2.20.2 "Emergency Stop Mode" for more information.

The default value is SA_CTL_EMERGENCY_STOP_MODE_NORMAL (0).

Valid Range

SA_CTL_EMERGENCY_STOP_MODE_NORMAL (0),
 SA_CTL_EMERGENCY_STOP_MODE_RESTRICTED (1),
 SA_CTL_EMERGENCY_STOP_MODE_AUTO_RELEASE (2)

Example

```
// set emergency stop mode to normal mode for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle,
    0,
    SA_CTL_PKEY_CH_EMERGENCY_STOP_MODE,
    SA_CTL_EMERGENCY_STOP_MODE_NORMAL
);
```

See Also

4.14.4 Channel Input Trigger Mode

4.5.36 In Position Threshold

Definition	Value				
C-Definition	SA_CTL_PKEY_IN_POSITION_THRESHOLD				
Code	0x03050058				
ASCII-Command	[:PROPerTy]:CHANnel#:INPositiOn:THReshold				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the position threshold in pm or n° for the "in position" Channel State flag. This property as well as the In Position Delay property must be specified to configure the "in position" feature.

A channel is "in position" when the positioner has been within the configured position threshold near the target for minimum or longer than the configured In Position Delay and no commanded movement is currently executed. Furthermore, the channel must be in the holding state actively holding the current position. As soon as the positioner leaves the defined range it is no longer "in position" and the delay is restarted. Please refer to the Positioner Control Options description in section 2.7.4 "Closed-Loop Movements" for more information.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is 10 000.

Valid Range

$0 \dots 1 \times 10^9$.

Example

```
// set the in position threshold to 25nm for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_IN_POSITION_THRESHOLD, 25000
);
```

See Also

4.5.37 In Position Delay, 4.5.4 Positioner Control Options

4.5.37 In Position Delay

Definition	Value				
C-Definition	SA_CTL_PKEY_IN_POSITION_DELAY				
Code	0x03050054				
ASCII-Command	[:PROPerTy]:CHANnel#:INPosition:DElay				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the delay in ms for the "in position" Channel State flag. This property as well as the In Position Threshold property must be specified to configure the "in position" feature.

A channel is "in position" when the positioner has been within the configured In Position Threshold near the target for minimum or longer than the configured delay and no commanded movement is currently executed. Furthermore, the channel must be in the holding state actively holding the current position. As soon as the positioner leaves the defined range it is no longer "in position" and the delay is restarted. Please refer to the Positioner Control Options description in section 2.7.4 "Closed-Loop Movements" for more information.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is 10 ms.

Valid Range

0 ... 10 000 ms

Example

```
// set the in position delay to 200ms for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_IN_POSITION_DELAY, 200
);
```

See Also

4.5.36 In Position Threshold, 4.5.4 Positioner Control Options

4.5.38 Motor Overload Protection Threshold

Definition	Value				
C-Definition	SA_CTL_PKEY_MOTOR_LOAD_PROTECTION_THRESHOLD				
Code	0x03020115				
ASCII-Command	[:PROPerTy]:CHANnel#:MOTor:LOAD:PTHReshold				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER				(0x0001)

Description

This property specifies the overload threshold in percent for the "Positioner Overload" Channel State flag for a Stick-Slip Piezo Driver.

When the configured Threshold has been reached, a Positioner is considered to be overloaded. A `SA_CTL_EVENT_MOVEMENT_FINISHED` event with its parameter set to `SA_CTL_ERROR_POSITIONER_OVERLOAD` is generated and the movement will be stopped. The channel state flag `SA_CTL_CH_STATE_BIT_POSITIONER_OVERLOAD` remains set until the motor load is considered safe again.

Additionally the Broadcast Stop Option `SA_CTL_STOP_OPT_BIT_POSITIONER_OVERLOAD` may be configured to stop all other channels. Please refer to section 4.5.27 Broadcast Stop Options for more information.

The default value is 0 %, meaning that the threshold is disabled.

Valid Range

0 ... 200 %

Example

```
// set the motor load protection to 80% for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_MOTOR_LOAD_PROTECTION_THRESHOLD, 80
);
```

See Also

4.5.27 Broadcast Stop Options, 4.11.5 Motor Load

4.6 Scale Properties

4.6.1 Logical Scale Offset

Definition	Value				
C-Definition	SA_CTL_PKEY_LOGICAL_SCALE_OFFSET				
Code	0x02040024				
ASCII-Command	[:PROPerTy]:CHANnel#:LSCale:OFFSet				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	RW	NV	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property specifies the logical scale offset. The value is given in pm for linear positioners and in n° for rotary positioners. It is used to define the relation between the physical and the logical scale. The logical scale offset can be set directly with this property but is also updated by setting the Position property. Please refer to section 2.8.5 "Shifting the Measuring Scale" for more information on defining positions.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is 0.

Valid Range

$-100 \times 10^{12} \dots 100 \times 10^{12}$

Example

```
// set the scale shift of channel 0 to +1mm relative
// to the physical scale
result = SA_CTL_SetProperty_i64(
    dHandle, 0, SA_CTL_PKEY_LOGICAL_SCALE_OFFSET, 1e9
);
```

See Also

4.6.2 Logical Scale Inversion

4.6.2 Logical Scale Inversion

Definition	Value				
C-Definition	SA_CTL_PKEY_LOGICAL_SCALE_INVERSION				
Code	0x02040025				
ASCII-Command	[:PROPerTy]:CHANnel#:LScale:INVersion				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the logical scale inversion. It is used to define the count direction of the logical scale relative to the physical scale. Note that the scale inversion should be defined before the absolute position is determined with the `SA_CTL_Reference` function.

Further note that only the logical scale will be inverted. The Safe Direction setting will not be changed. Thus Positioners With Endstop Reference will move in the opposite direction when executing `SA_CTL_Calibrate` or `SA_CTL_Reference`.

Please refer to section 2.8.5 "Shifting the Measuring Scale" for more information on defining positions.

Note that setting this property implicitly stops the channel and disables the control-loop.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is `SA_CTL_NON_INVERTED` (0x00).

Electromagnetic Driver

Changing the scale inversion for Electromagnetic Driver channels also disables the amplifier and invalidates the phasing. See section 2.22 "Phasing of Electro-Magnetic Driven Positioners" for more information.



NOTICE

Electromagnetic driven positioners are not self-locking. Disabling the control-loop removes any holding force from the positioner. Make sure not to damage any equipment when the positioner changes its position unintentionally!

Valid Range

SA_CTL_NON_INVERTED (0x00), SA_CTL_INVERTED (0x01)

Example

```
// enable the scale inversion for channel 0  
result = SA_CTL_SetProperty_i32(  
    dHandle, 0, SA_CTL_PKEY_LOGICAL_SCALE_INVERSION, SA_CTL_INVERTED  
);
```

See Also

4.6.1 Logical Scale Offset

4.6.3 Range Limit Min

Definition	Value				
C-Definition	SA_CTL_PKEY_RANGE_LIMIT_MIN				
Code	0x02040020				
ASCII-Command	[:PROPerTy]:CHANnel#:RLIMit:MIN[:CURRent]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the software range limit minimum position. Note that the Range Limit Max must be set to a higher value than the Range Limit Min to enable the limit check. This property is not held in non-volatile memory but the default value at device startup is configurable (see Default Range Limit Min).

Please refer to section 2.15 "Software Range Limit" for more information on software range limits. The default value is 0.

Valid Range

$-100 \times 10^{12} \dots 100 \times 10^{12}$

Example

```
// set the min range limit to -10mm for channel 0
result = SA_CTL_SetProperty_i64(
    dHandle, 0, SA_CTL_PKEY_RANGE_LIMIT_MIN, -100000000000
);
```

See Also

4.6.4 Range Limit Max, 4.6.5 Default Range Limit Min, 4.6.6 Default Range Limit Max

4.6.4 Range Limit Max

Definition	Value				
C-Definition	SA_CTL_PKEY_RANGE_LIMIT_MAX				
Code	0x02040021				
ASCII-Command	[:PROPerTy]:CHANnel#:RLIMit:MAX[:CURRent]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the software range limit maximum position. Note that the Range Limit Max must be set to a higher value than the Range Limit Min to enable the limit check. This property is not held in non-volatile memory but the default value at device startup is configurable (see Default Range Limit Max).

Please refer to section 2.15 "Software Range Limit" for more information on software range limits. The default value is 0.

Valid Range

$-100 \times 10^{12} \dots 100 \times 10^{12}$

Example

```
// set the max range limit to +10mm for channel 0
result = SA_CTL_SetProperty_i64(
    dHandle, 0, SA_CTL_PKEY_RANGE_LIMIT_MAX, 10000000000
);
```

See Also

4.6.3 Range Limit Min, 4.6.5 Default Range Limit Min, 4.6.6 Default Range Limit Max

4.6.5 Default Range Limit Min

Definition	Value				
C-Definition	SA_CTL_PKEY_DEFAULT_RANGE_LIMIT_MIN				
Code	0x020400C0				
ASCII-Command	[:PROPerTy]:CHANnel#:RLIMit:MIN:DEFault				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	RW	NV	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the default value at device startup for the software range limit minimum position.

Please refer to section 2.15 "Software Range Limit" for more information on software range limits. The default value is 0.

Valid Range

$-100 \times 10^{12} \dots 100 \times 10^{12}$

Example

```
// set the (persistent) startup min range limit to -10mm for channel 0
result = SA_CTL_SetProperty_i64(
    dHandle, 0, SA_CTL_PKEY_DEFAULT_RANGE_LIMIT_MIN, -10000000000
);
```

See Also

4.6.6 Default Range Limit Max, 4.6.3 Range Limit Min, 4.6.4 Range Limit Max

4.6.6 Default Range Limit Max

Definition	Value				
C-Definition	SA_CTL_PKEY_DEFAULT_RANGE_LIMIT_MAX				
Code	0x020400C1				
ASCII-Command	[:PROPerTy]:CHANnel#:RLIMit:MAX:DEFault				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	RW	NV	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)			
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)			

Description

This property specifies the default value at device startup for the software range limit maximum position.

Please refer to section 2.15 "Software Range Limit" for more information on software range limits. The default value is 0.

Valid Range

$-100 \times 10^{12} \dots 100 \times 10^{12}$

Example

```
// set the (persistent) startup max range limit to +10mm for channel 0
result = SA_CTL_SetProperty_i64(
    dHandle, 0, SA_CTL_PKEY_DEFAULT_RANGE_LIMIT_MAX, 10000000000
);
```

See Also

4.6.6 Default Range Limit Max, 4.6.3 Range Limit Min, 4.6.4 Range Limit Max

4.7 Calibration Properties

4.7.1 Calibration Options

Definition	Value				
C-Definition	SA_CTL_PKEY_CALIBRATION_OPTIONS				
Code	0x0306005D				
ASCII-Command	[:PROPerTy]:CHANnel#:CALibration:OPTions				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property specifies the calibration options. It is used to define the behavior of the calibration routine when calling the `SA_CTL_Calibrate` function.

The value is a bit field containing independent flags. The following flags are available:

Bit	C-Definition	Code
0	SA_CTL_CALIB_OPT_BIT_DIRECTION	0x00000001
1	SA_CTL_CALIB_OPT_BIT_DIST_CODE_INV_DETECT	0x00000002
2	SA_CTL_CALIB_OPT_BIT_ASC_CALIBRATION*	0x00000004
8	SA_CTL_CALIB_OPT_BIT_LIMITED_TRAVEL_RANGE*	0x00000100

Undefined flags are reserved for future use. These flags should be set to zero.

Please refer to section 2.7.1 "Calibrating" for more information on the calibration sequence.

The default value is 0 (all flags cleared).

Example

```
SA_CTL_Result_t result;
int8_t channelId = 1;
// set calibration options of channel 1 (signal correction sequence)
result = SA_CTL_SetProperty_i32(
    dHandle, channelId, SA_CTL_PKEY_CALIBRATION_OPTIONS, 0
);
```

*This option is only applicable for Stick-Slip Piezo Driver.

```
if (result == SA_CTL_ERROR_NONE) {  
    // start signal correction calibration sequence  
    result = SA_CTL_Calibrate(dHandle, channelId, 0);  
}
```

See Also

4.7.2 Signal Correction Options

4.7.2 Signal Correction Options

Definition	Value				
C-Definition	SA_CTL_PKEY_SIGNAL_CORRECTION_OPTIONS				
Code	0x0306001C				
ASCII-Command	[:PROPerTy]:CHANnel#:SCORrection:OPTions				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the sensor signal correction options. The value is a bit field containing independent flags with the following meaning:

Bit	C-Definition	Code
0	Reserved	0x00000001
1	SA_CTL_SIGNAL_CORR_OPT_BIT_DAC	0x00000002
2	Reserved	0x00000004
3	SA_CTL_SIGNAL_CORR_OPT_BIT_DPEC	0x00000008
4	SA_CTL_SIGNAL_CORR_OPT_BIT_ASC*	0x00000010

Undefined flags are reserved for future use. These flags should be set to zero. Bit 0 and bit 2 are reserved and always read as one.

Dynamic Amplitude / Phase Error Correction (Bit 1 and Bit 3) Enables the dynamic sensor amplitude / phase error correction. The calibration routine corrects amplitude and phase errors of the sensor signals. See section 2.7.1 "Calibrating" for more information. Additionally, the controller automatically compensates the sensor signals while moving if these flags are set to one. Disabling the dynamic amplitude and phase error correction might be useful for some special applications to achieve a higher position repeatability with the trade-off off a lower absolute position accuracy.

Advanced Sensor Correction*(Bit 4) The Advanced Sensor Correction allows to compensate periodic sensor errors. The correction requires an additional calibration routine which must be performed once for every channel. This routine generates a compensation table for the sensor data which is applied to the position calculation if this flag is set to one. See section 2.7.1 "Advanced Sensor Correction Calibration (calibration options 0x04 or 0x05)¹" for the details on the calibration routine.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is 0x0f (15) which means that the amplitude and phase error corrections are active.

The advanced sensor correction needs a feature permission to be activated on the controller. See section 2.24 "Feature Permissions" for more information.

Example

```
// disable the dynamic amplitude and phase error correction for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_SIGNAL_CORRECTION_OPTIONS, 0
);
```

See Also

4.7.1 Calibration Options

*This option is only applicable for Stick-Slip Piezo Driver.

4.8 Referencing Properties

4.8.1 Referencing Options

Definition	Value				
C-Definition	SA_CTL_PKEY_REFERENCING_OPTIONS				
Code	0x0307005D				
ASCII-Command	[:PROPerTy]:CHANnel#:REFerencing:OPTions				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property specifies the find reference mode. It is used to define the behavior of the find reference routine when calling the `SA_CTL_Reference` function.

Note that the find reference sequence is also influenced by the Move Velocity and Move Acceleration properties (see there).

The value is a bit field containing independent flags. The following flags are available:

Bit	C-Definition	Code
0	SA_CTL_REF_OPT_BIT_START_DIR	0x00000001
1	SA_CTL_REF_OPT_BIT_REVERSE_DIR	0x00000002
2	SA_CTL_REF_OPT_BIT_AUTO_ZERO	0x00000004
3	SA_CTL_REF_OPT_BIT_ABORT_ON_ENDSTOP	0x00000008
4	SA_CTL_REF_OPT_BIT_CONTINUE_ON_REF_FOUND	0x00000010
5	SA_CTL_REF_OPT_BIT_STOP_ON_REF_FOUND	0x00000020
24	SA_CTL_REF_OPT_BIT_INVALIDATE	0x01000000

Undefined flags are reserved for future use. These flags should be set to zero.

Please refer to section 2.8.1 "Reference Marks" for more information on the find reference sequence.

Note that starting the referencing does *not* clear the "is referenced" Channel State flag if the absolute position is already known (from a previous referencing sequence). To invalidate the "is referenced" flag programmatically this property may be set to `SA_CTL_REF_OPT_BIT_INVALIDATE` (0x01000000). No other options flags must be active beside the invalidate flag for this to be executed. This may be useful e.g. for test purposes of the referencing algorithm.

The default value is 0 (all flags cleared).

Example

```
SA_CTL_Result_t result;
int8_t channelId = 2;
// set find reference mode of channel 2 (start direction: backwards)
result = SA_CTL_SetProperty_i32(
    dHandle,
    channelId,
    SA_CTL_PKEY_REFERENCING_OPTIONS,
    SA_CTL_REF_OPT_BIT_START_DIR
);
if (result) { // handle error, abort }
// set velocity to 1mm/s
result = SA_CTL_SetProperty_i64(
    dHandle, channelId, SA_CTL_PKEY_MOVE_VELOCITY, 1e9
);
if (result) { // handle error, abort }
// disable acceleration control
result = SA_CTL_SetProperty_i64(
    dHandle, channelId, SA_CTL_PKEY_MOVE_ACCELERATION, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // start searching for the reference with the previously
    // set parameters
    result = SA_CTL_Reference(dHandle, channelId, 0);
}
```

See Also

4.5.18 Move Velocity, 4.5.19 Move Acceleration, 4.5.31 Safe Direction

4.8.2 Distance To Reference Mark

Definition	Value				
C-Definition	SA_CTL_PKEY_DISTANCE_TO_REF_MARK				
Code	0x030700A2				
ASCII-Command	[:PROPerTy]:CHANnel#:REFeREncing:DTRMark				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	R	-	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property holds the distance between the start of a referencing movement and the reference mark. Note that the position of the reference mark is not necessarily the position where the positioner comes to halt. The behavior depends on the Referencing Options. See section 2.7.2 "Referencing" for more information. The value is updated whenever a referencing sequence finished. The unit is pico meter (pm) for linear positioners and nano degree (n°) for rotatory positioners.

See Also

4.8.1 Referencing Options

4.8.3 Distance Code Inverted

Definition	Value				
C-Definition	SA_CTL_PKEY_DIST_CODE_INVERTED				
Code	0x0307000E				
ASCII-Command	[:PROPerTy]:CHANnel#:REFerencing:DCINverted				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property is used to correct the absolute position calculation when referencing positioners with multiple reference marks. In rare cases the reference algorithm may produce faulty results due to a reference coding mismatch. The correct setting is determined by an automatic calibration routine, thus it is usually not necessary to manually modify this property. See section 2.7.1 "Calibrating" for more information.

This property is stored to non-volatile memory and need not be configured on every power-up.

Valid Range

SA_CTL_NON_INVERTED (0x00), SA_CTL_INVERTED (0x01)

See Also

4.8.1 Referencing Options

4.9 Tuning and Customizing Properties

4.9.1 Positioner Movement Type

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_MOVEMENT_TYPE				
Code	0x0309003F				
ASCII-Command	[:PROPeRty]:CHANnel#:TUNing:MTYPE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R(W)	(NV)	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property holds the positioner movement type. It may be used to determine the type of positioner (*linear*, *rotatory*, *goniometer* or *tip-tilt*) that is configured for the channel. This property has informational character only.

Note that you must remove the write protection with the Positioner Write Protection property (see there) before being able to write this property.

This is a setting of the positioner type configuration. To make it persistent save the positioner type configuration to a custom slot. See section 2.6.3 "Custom Positioner Types" for more information.

Valid Range

```
SA_CTL_POS_MOVEMENT_TYPE_LINEAR(0),
SA_CTL_POS_MOVEMENT_TYPE_ROTATORY(1),
SA_CTL_POS_MOVEMENT_TYPE_GONIOMETER(2),
SA_CTL_POS_MOVEMENT_TYPE_TIP_TILT(3)
```

Example

```
SA_CTL_Result_t result;
int32_t type;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POS_MOVEMENT_TYPE, &type, 0
);
if (result == SA_CTL_ERROR_NONE) {
    if (type == SA_CTL_POS_MOVEMENT_TYPE_GONIOMETER) {
```

```
    // goniometer type configured  
    }  
}
```

See Also

4.9.3 Positioner Base Unit, 4.9.4 Positioner Base Resolution

4.9.2 Positioner Is Custom Type

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_IS_CUSTOM_TYPE				
Code	0x03090041				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:CUSTom				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R	-	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property may be used to determine if the currently configured positioner type is a custom type. Custom positioner types are fully configurable. See section 2.6.3 "Custom Positioner Types" for more information.

Example

```
SA_CTL_Result_t result;
int32_t custom;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POS_IS_CUSTOM_TYPE, &custom, 0
);
if (result == SA_CTL_ERROR_NONE) {
    if (custom) // custom positioner type configured
    else // predefined positioner type configured
}
```

See Also

4.5.8 Positioner Type

4.9.3 Positioner Base Unit

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_BASE_UNIT				
Code	0x03090042				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:BASE:UNIT				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R(W)	(NV)	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property holds the basic unit of the position values a channel uses. (e.g. meter, degree). Note that this property has informational character only. Setting it to a different value won't influence the position calculation.

The hand control module reads this setting to display the appropriate unit on the screen.

Note that you must remove the write protection with the Positioner Write Protection property (see there) before being able to write this property.

This is a setting of the positioner type configuration. To make it persistent save the positioner type configuration to a custom slot. See section 2.6.3 "Custom Positioner Types" for more information.

Valid Range

SA_CTL_UNIT_NONE (0x00000000),
 SA_CTL_UNIT_METER (0x00000002),
 SA_CTL_UNIT_DEGREE (0x00000003)

Example

```
SA_CTL_Result_t result;
int32_t unit;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POS_BASE_UNIT, &unit, 0
);
if (result == SA_CTL_ERROR_NONE) {
    if (unit == SA_CTL_UNIT_METER) // linear positioner type configured
    else // rotatory/goniometer positioner type configured
}
```

See Also

4.9.4 Positioner Base Resolution

4.9.4 Positioner Base Resolution

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_BASE_RESOLUTION				
Code	0x03090043				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:BASE:RESolution				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R(W)	(NV)	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property holds the basic resolution of the position value in powers of 10. It may be used to programmatically determine the interpretation of the position value of a channel. The resolution depends on the configured positioner type. (see Positioner Type) For example, a channel configured as linear positioner type has a base unit of *Meter* and a base resolution of -12 . So a position value of 100 000 000 would correspond to 100 μm . Note that this property has informational character only. Setting it to a different value won't influence the position calculation. The resolution must be an integer multiple of 3.

The hand control module reads this setting to display the appropriate unit on the screen.

Note that you must remove the write protection with the Positioner Write Protection property (see there) before being able to write this property.

This is a setting of the positioner type configuration. To make it persistent save the positioner type configuration to a custom slot. See section 2.6.3 "Custom Positioner Types" for more information.

Valid Range

$-12, -9, -6, -3, 0$.

Example

```
SA_CTL_Result_t result;
int32_t resolution;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POS_BASE_RESOLUTION, &resolution, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'resolution' holds the base resolution of channel 0
}
```

```
}
```

See Also

4.9.3 Positioner Base Unit

4.9.5 Positioner Sensor Head Type

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_HEAD_TYPE				
Code	0x0309008E				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:HTYPE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R(W)	(NV)	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the sensor head type. This property is only relevant if a SmarAct PicoScale interferometer is used as sensor module. The head type is set to the PicoScale when an adjustment sequence is started with the MCS2 hand control module.

For more information on head types refer to the *PicoScale User Manual*.

Note that you must remove the write protection with the Positioner Write Protection property (see there) before being able to write this property.

This is a setting of the positioner type configuration. To make it persistent save the positioner type configuration to a custom slot. See section 2.6.3 "Custom Positioner Types" for more information.

Valid Range

C01, C02, C03, F01

See Also

4.9.17 Positioner Write Protection, 4.9.16 Save Positioner Type

4.9.6 Positioner Reference Type

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_REF_TYPE				
Code	0x03090048				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:RTYPE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R(W)	(NV)	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the reference type of the positioner. The reference type is used by the `SA_CTL_Reference` function to determine the physical position. See section 2.8.1 "Reference Marks" for more information.

Note that you must remove the write protection with the Positioner Write Protection property (see there) before being able to write this property.

This is a setting of the positioner type configuration. To make it persistent save the positioner type configuration to a custom slot. See section 2.6.3 "Custom Positioner Types" for more information.

Valid Range

SA_CTL_REF_TYPE_NONE (0),
 SA_CTL_REF_TYPE_END_STOP (1),
 SA_CTL_REF_TYPE_SINGLE_CODED (2),
 SA_CTL_REF_TYPE_DISTANCE_CODED (3)

Example

```
SA_CTL_Result_t result;
int32_t type;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POS_REF_TYPE, &type, 0
);
if (result == SA_CTL_ERROR_NONE) {
    if (type == SA_CTL_REF_TYPE_SINGLE_CODED) {
        // single coded reference type configured
    }
}
```

```
}
```

See Also

4.9.17 Positioner Write Protection, 4.9.16 Save Positioner Type

4.9.7 Positioner P Gain

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_P_GAIN				
Code	0x0309004B				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:GAIN:P				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R(W)	(NV)	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property specifies the proportional gain of the control-loop. Note that the resulting gain is also influenced by the Positioner PID Shift property.

Note that you must remove the write protection with the Positioner Write Protection property (see there) before being able to write this property.

This is a setting of the positioner type configuration. To make it persistent save the positioner type configuration to a custom slot. See section 2.6.3 "Custom Positioner Types" for more information.

Valid Range

$0 \dots 2 \times 10^9$.

Example

```
// set the P gain to 100 for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POS_P_GAIN, 100
);
```

See Also

4.9.8 Positioner I Gain, 4.9.9 Positioner D Gain, 4.9.10 Positioner PID Shift

4.9.8 Positioner I Gain

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_I_GAIN				
Code	0x0309004C				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:GAIN:I				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R(W)	(NV)	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the integral gain of the control-loop. The Positioner Anti Windup must be set to a non-zero value to activate the I gain of the control-loop. Note that the resulting gain is also influenced by the Positioner PID Shift property.

Note that you must remove the write protection with the Positioner Write Protection property (see there) before being able to write this property.

This is a setting of the positioner type configuration. To make it persistent save the positioner type configuration to a custom slot. See section 2.6.3 "Custom Positioner Types" for more information.

Valid Range

$0 \dots 2 \times 10^9$.

Example

```
// set the I gain to 0 for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POS_I_GAIN, 0
);
```

See Also

4.9.7 Positioner P Gain, 4.9.9 Positioner D Gain, 4.9.10 Positioner PID Shift, 4.9.11 Positioner Anti Windup

4.9.9 Positioner D Gain

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_D_GAIN				
Code	0x0309004D				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:GAIN:D				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R(W)	(NV)	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property specifies the differential gain of the control-loop. Note that the resulting gain is also influenced by the Positioner PID Shift property.

Note that you must remove the write protection with the Positioner Write Protection property (see there) before being able to write this property.

This is a setting of the positioner type configuration. To make it persistent save the positioner type configuration to a custom slot. See section 2.6.3 "Custom Positioner Types" for more information.

Valid Range

$0 \dots 2 \times 10^9$.

Example

```
// set the D gain to 10 for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POS_P_GAIN, 10
);
```

See Also

4.9.7 Positioner P Gain, 4.9.8 Positioner I Gain, 4.9.10 Positioner PID Shift

4.9.10 Positioner PID Shift

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_PID_SHIFT				
Code	0x0309004E				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:GAIN:SHIFt				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R(W)	(NV)	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies a divisor for the PID controller output. The resulting divisor is calculated as 2^{PIDshift} . Since the divisor is applied at the output of the PID controller it influences the P, I and D-term results.

PID gains are set as integer values. The result of the respective control term is divided by internally right-shifting it by the configured PID shift value. This way effective gains lower than one may be defined using only integer numbers. The effective gain is determined by the combination of the gain value and the PID shift.

$$\text{gain}_{\text{eff}} = \text{gain} / 2^{\text{PIDshift}}$$

E.g. an effective gain of 0.25 may be achieved by the settings:

gain = 8, shift = 5 or gain = 1, shift = 2, both settings result in the same effective gain.

$$\text{gain}_{\text{eff}} = 8 / 2^5 = 1 / 2^2 = 0.25$$

Note that you must remove the write protection with the Positioner Write Protection property (see there) before being able to write this property.

This is a setting of the positioner type configuration. To make it persistent save the positioner type configuration to a custom slot. See section 2.6.3 "Custom Positioner Types" for more information.

The default value is 10.

Valid Range (Stick-Slip Piezo Driver)

0 ... 16.

Valid Range (Electromagnetic Driver)

0 ... 31.

Example

```
// set the PID shift to 10 (default) for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POS_PID_SHIFT, 10
);
```

See Also

4.9.7 Positioner P Gain, 4.9.8 Positioner I Gain, 4.9.9 Positioner D Gain

4.9.11 Positioner Anti Windup

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_ANTI_WINDUP				
Code	0x0309004F				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:AWINDup				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R(W)	(NV)	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER				(0x0001)

Description

This property specifies the anti windup limit for the integral gain of the control-loop. It has no meaning if the Positioner I Gain property is set to zero. The value range refers to the range of the PID-controller's output which depends on the type of driver module.

Note that you must remove the write protection with the Positioner Write Protection property (see there) before being able to write this property.

This is a setting of the positioner type configuration. To make it persistent save the positioner type configuration to a custom slot. See section 2.6.3 "Custom Positioner Types" for more information.

The default value is 0.

Stick-Slip Piezo Driver

In general the integral gain must not be used for stick-slip piezo positioners since the plant model already has integrating behavior. The maximum output value of Stick-Slip Piezo Drivers is 2×10^6 mHz so that the maximum windup limit would also be this value.

Electromagnetic Driver

The windup limit is set internally so that this property has no effect for this type of driver channels.

Valid Range

$0 \dots 2 \times 10^9$.

Example

```
// set the anti windup to default for channel 0  
result = SA_CTL_SetProperty_i32(  
    dHandle, 0, SA_CTL_PKEY_POS_ANTI_WINDUP, 0  
);
```

See Also

4.9.7 Positioner P Gain, 4.9.8 Positioner I Gain, 4.9.9 Positioner D Gain, 4.9.10 Positioner PID Shift

4.9.12 Positioner ESD Distance Threshold

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_ESD_DIST_TH				
Code	0x03090050				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:ESDeTection:DISTanCe				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R(W)	(NV)	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the end stop detection distance threshold in pm or n°. This property in conjunction with the Positioner ESD Counter Threshold configure the end stop detection responsible to detect a physical end stop as well as a mechanical blockage of a positioner for closed-loop movements. An end stop condition leads to a stop of the channel.

Note that you must remove the write protection with the Positioner Write Protection property (see there) before being able to write this property.

This is a setting of the positioner type configuration. To make it persistent save the positioner type configuration to a custom slot. See section 2.6.3 "Custom Positioner Types" for more information.

Generally, there is no need to modify the end stop detection configuration. The configured Positioner Type defines appropriate values for all kinds of SmarAct positioners. Nonetheless it may be necessary to disable the end stop detection in some special cases. E.g. if an auxiliary input is used as feedback for the control-loop and the actual input value represents a set-point for the control-loop instead of a current position of the positioner.

The default value depends on the configured positioner type. The special value 0 disables the end stop detection.



NOTICE

Configuring inappropriate values or disabling the end stop detection prevents the channel from stopping the positioner in case of a mechanical blockage. The end stop detection configuration properties must be used with caution!

Valid Range

0 ... 1×10^9 .

Example

```
// set the end stop detection distance threshold to 1000000 for channel 0  
result = SA_CTL_SetProperty_i32(  
    dHandle, 0, SA_CTL_PKEY_POS_ESD_DIST_TH, 1000000  
);
```

See Also

4.9.13 Positioner ESD Counter Threshold

4.9.13 Positioner ESD Counter Threshold

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_ESD_COUNTER_TH				
Code	0x03090051				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:ESDection:COUNter				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R(W)	(NV)	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the end stop detection counter threshold.

Note that you must remove the write protection with the Positioner Write Protection property (see there) before being able to write this property.

This is a setting of the positioner type configuration. To make it persistent save the positioner type configuration to a custom slot. See section 2.6.3 "Custom Positioner Types" for more information.

Valid Range

$1 \dots 2 \times 10^9$.

Example

```
// set the end stop detection counter value to 100000 for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POS_ESD_COUNTER_TH, 100000
);
```

See Also

4.9.12 Positioner ESD Distance Threshold

4.9.14 Positioner Target Reached Threshold

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_TARGET_REACHED_TH				
Code	0x03090052				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:THReshold:TREached				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R(W)	(NV)	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the target reached threshold in pm or n°. A closed-loop movement is considered to be finished once the target position \pm the target reached threshold is reached.

Note that you must remove the write protection with the Positioner Write Protection property (see there) before being able to write this property.

This is a setting of the positioner type configuration. To make it persistent save the positioner type configuration to a custom slot. See section 2.6.3 "Custom Positioner Types" for more information.

Valid Range

$0 \dots 1 \times 10^9$.

Example

```
// set the target reached threshold to 5nm for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POS_TARGET_REACHED_TH, 5000
);
```

See Also

4.9.15 Positioner Target Hold Threshold

4.9.15 Positioner Target Hold Threshold

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_TARGET_HOLD_TH				
Code	0x03090053				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:THReshold:THOLd				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R(W)	(NV)	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the target hold threshold in pm or n°. The hold threshold defines a dead zone around the control-loop input signal where the output does not change (target \pm target hold threshold). This parameter is typically used in a system where the resolution of the sensor is significantly lower than the resolution of the actuator. The dead zone then prevents oscillation around the target or "hunting" of the control-loop.

If an auxiliary analog input is used as control-loop feedback this property defines the dead zone for the analog input signal. Since the digital representation of the analog input value is defined by the ADC of the IO-module (see I/O Module Analog Input Range property) the dead zone must be configured in counts of ADC bits in this case. Refer to section 2.19.5 "Using Analog Inputs as Control-Loop Feedback" for more information on the configuration.

Note that you must remove the write protection with the Positioner Write Protection property (see there) before being able to write this property.

This is a setting of the positioner type configuration. To make it persistent save the positioner type configuration to a custom slot. See section 2.6.3 "Custom Positioner Types" for more information.

The default value is 0.

Valid Range

0 ... 1×10^9 .

Example

```
// set the target hold threshold to 100nm for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POS_TARGET_HOLD_TH, 100000
```

```
);
```

See Also

4.9.14 Positioner Target Reached Threshold

4.9.16 Save Positioner Type

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_SAVE				
Code	0x0309000A				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:SAVE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	W	-	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property is used to save a modified positioner type to a custom slot of a channel. Currently four custom slots per channel are available. Saving the positioner type makes the parameters persistent and implicitly sets the Positioner Type to the given custom type.

Valid Range

SA_CTL_POSITIONER_TYPE_CUSTOM0 (250), SA_CTL_POSITIONER_TYPE_CUSTOM1 (251), SA_CTL_POSITIONER_TYPE_CUSTOM2 (252), SA_CTL_POSITIONER_TYPE_CUSTOM3 (253)

Example

```
// save a modified positioner type of channel 0 to custom slot 1
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POS_SAVE, SA_CTL_POSITIONER_TYPE_CUSTOM0
);
```

See Also

4.9.17 Positioner Write Protection

4.9.17 Positioner Write Protection

Definition	Value				
C-Definition	SA_CTL_PKEY_POS_WRITE_PROTECTION				
Code	0x0309000D				
ASCII-Command	[:PROPerTy]:CHANnel#:TUNing:WPRotectiOn				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property is used to unlock the write access to the tuning parameters. A special key must be written to this property to unlock the write access to the tuning properties. Write any other value to this property to enable the protection again. Otherwise the write protection remains unlocked for the channel until the device is restarted. The write protection key is:

SA_CTL_POS_WRITE_PROTECTION_KEY (0x534D4152)

Example

```
// disable tuning parameter write protection of channel 0
result = SA_CTL_SetProperty_i32(
    dHandle,
    0,
    SA_CTL_PKEY_POS_WRITE_PROTECTION,
    SA_CTL_POS_WRITE_PROTECTION_KEY
);
// set tuning parameters like P gain, etc.
```

See Also

4.9.16 Save Positioner Type

4.10 Streaming Properties

4.10.1 Stream Base Rate

Definition	Value				
C-Definition	SA_CTL_PKEY_STREAM_BASE_RATE				
Code	0x040F002C				
ASCII-Command	[:PROPerTy]:DEvIce:STReaming:BASerate				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	RW	V	-
Applicable for					
USB Interface	SA_CTL_INTERFACE_USB			(0x0001)	
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET			(0x0002)	

Description

This property specifies the stream base rate in Hz for the trajectory streaming. See section 2.18 "Trajectory Streaming" for more information.

The default stream base rate is 1000 Hz.

Valid Range

10 ... 1000 Hz

Example

```
// set the stream rate to 1 kHz
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_STREAM_BASE_RATE, 1000
);
```

See Also

4.10.2 Stream External Sync Rate, 4.14.2 Device Input Trigger Mode

4.10.2 Stream External Sync Rate

Definition	Value				
C-Definition	SA_CTL_PKEY_STREAM_EXT_SYNC_RATE				
Code	0x040F002D				
ASCII-Command	[:PROPerTy]:DEvIce:STReaming:SYNCrate				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	RW	V	-

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property specifies the external stream synchronization rate in Hz for the trajectory streaming. It may be used to synchronize the internal position streaming clock to an external clock signal. Note that the configured Stream Base Rate must be a whole-number multiple of the external sync rate.

The default value is 1.

Valid Range

1 ... 1000 Hz

In order to use the external stream synchronization the device must be equipped with an Input Trigger connector.

Example

```
// configure external stream synchronization rate to 100Hz
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_STREAM_EXT_SYNC_RATE, 100
);
```

See Also

4.10.1 Stream Base Rate, 4.14.2 Device Input Trigger Mode

4.10.3 Stream Options

Definition	Value				
C-Definition	SA_CTL_PKEY_STREAM_OPTIONS				
Code	0x040F005D				
ASCII-Command	[:PROPerTy]:DEvIce:STReaming:OPTions				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	RW	V	-

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property specifies the stream's options. It is used to define the behavior of the stream before calling the `SA_CTL_OpenStream` function.

The value is a bit field containing independent flags. The following flags are available:

Bit	C-Definition	Code
0	SA_CTL_STREAM_OPT_BIT_INTERPOLATION_DIS	0x00000001

Undefined flags are reserved for future use. These flags should be set to zero.

The default value is 0 (all flags cleared).

Please refer to section 2.18.3 "Options" for more information.

Example

```
// disable the target position interpolation for the trajectory streaming
result = SA_CTL_SetProperty_i32(
    dHandle,
    0,
    SA_CTL_PKEY_STREAM_OPTIONS,
    SA_CTL_STREAM_OPT_BIT_INTERPOLATION_DIS
);
```

See Also

4.10.1 Stream Base Rate

4.10.4 Stream Load Maximum

Definition	Value				
C-Definition	SA_CTL_PKEY_STREAM_LOAD_MAX				
Code	0x040F0301				
ASCII-Command	[:PROPerTy]:DEvIce:STReaming:LOAD:MAXimum				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	R	-	-

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property reports the maximum load generated by the current stream in percent. The property acts like a peak detector. The highest load level generated by the currently running stream is stored. When starting the stream the load value is reset to zero. Please refer to section 2.18 "Trajectory Streaming" for more information.

Valid Range

0 ... 100 %

Example

```
SA_CTL_Result_t result;
int32_t maximumLoad;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_STREAM_LOAD_MAX, &maximumLoad, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'maximumLoad' holds the maximum load of channel 0 in percent
}
```

See Also

4.10.1 Stream Base Rate

4.11 Diagnostic Properties

4.11.1 Channel Error

Definition	Value				
C-Definition	SA_CTL_PKEY_CHANNEL_ERROR				
Code	0x0502007A				
ASCII-Command	[:PROPerTy]:CHANnel#:ERRor				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R	-	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)			
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)			

Description

This property holds the last movement error of a channel. Generally, event notifications are used to inform about channel errors. (See section 2.7.7 "Movement Feedback" for more information.) However, if event notifications are not used in an application the Channel State bit `SA_CTL_CH_STATE_BIT_MOVEMENT_FAILED` can be monitored to detect channel errors. This property may be read then to determine the reason of the error.

Note that this property only holds errors caused by an asynchronous movement command (such as `SA_CTL_Move`, `SA_CTL_Calibrate` and `SA_CTL_Reference`). An error occurred while reading or writing a property is *not* captured. More precisely, the property returns the result parameter of the last `SA_CTL_EVENT_MOVEMENT_FINISHED` or `SA_CTL_EVENT_HOLDING_ABORTED` event.

Note that the channel error is reset to `SA_CTL_ERROR_NONE` after reading this property.

Example

```
SA_CTL_Result_t result;
int32_t chError;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_CHANNEL_ERROR, &chError, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'chError' holds the last error code of channel 0
}
```

See Also

4.5.12 Channel State, 5.2.2 Movement Finished, 5.2.3 Holding Aborted

4.11.2 Channel Temperature

Definition	Value				
C-Definition	SA_CTL_PKEY_CHANNEL_TEMPERATURE				
Code	0x05020034				
ASCII-Command	[:PROPerTy]:CHANnel#:TEMPerature				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R	-	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property holds the amplifier temperature in °C. The temperature is measured near the channels driver amplifier. See section 2.9.3 "Hardware Monitoring" for more information on temperature monitoring.

Example

```
SA_CTL_Result_t result;
int32_t chTemp;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_CHANNEL_TEMPERATURE, &chTemp, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'chTemp' holds the temperature of the amplifier of channel 0
}
```

See Also

4.11.3 Bus Module Temperature

4.11.3 Bus Module Temperature

Definition	Value				
C-Definition	SA_CTL_PKEY_BUS_MODULE_TEMPERATURE				
Code	0x05030034				
ASCII-Command	[:PROPerTy]:MODUle#:TEMPerature				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Module	R	-	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property holds the temperature of a bus module in °C. See section 2.9.3 "Hardware Monitoring" for more information on temperature monitoring.

Example

```
SA_CTL_Result_t result;
int32_t modTemp;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_BUS_MODULE_TEMPERATURE, &modTemp, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'modTemp' holds the temperature of the driver module 0
}
```

See Also

4.11.2 Channel Temperature

4.11.4 Positioner Fault Reason

Definition	Value				
C-Definition	SA_CTL_PKEY_POSITIONER_FAULT_REASON				
Code	0x05020113				
ASCII-Command	[:PROPerTy]:CHANnel#:PFReason				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R	-	X
Applicable for					
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER				(0x0002)

Description

This property holds a bit field of positioner faults. A positioner fault is indicated by the `SA_CTL_CH_STATE_BIT_POSITIONER_FAULT` bit of the Channel State property. This property may then be read to determine the exact fault situation. The reason of a positioner fault may be a bad wiring of the connector or a defective cable. The fault bits give a hint which wire is affected by a short or interruption. The *current deviation* flag indicates that the controller detected an unbalance of the phase currents which also may be an indicator for a positioner damage. The *driver fault* flag will be set in case of a fault or damage of the driver amplifier of the controller.

In any case the positioner must be disconnected from the controller and checked for damages.

The value is a bit field containing independent flags with the following meaning:

Bit	C-Definition	Code
0	SA_CTL_POS_FAULT_REASON_BIT_U_PHASE_SHORT	0x00000001
1	SA_CTL_POS_FAULT_REASON_BIT_V_PHASE_SHORT	0x00000002
2	SA_CTL_POS_FAULT_REASON_BIT_W_PHASE_SHORT	0x00000004
3	SA_CTL_POS_FAULT_REASON_BIT_U_PHASE_OPEN	0x00000008
4	SA_CTL_POS_FAULT_REASON_BIT_V_PHASE_OPEN	0x00000010
5	SA_CTL_POS_FAULT_REASON_BIT_W_PHASE_OPEN	0x00000020
6	SA_CTL_POS_FAULT_REASON_BIT_CURRENT_DEVIATION	0x00000040
15	SA_CTL_POS_FAULT_REASON_BIT_DRIVER_FAULT	0x00008000

Example

```
SA_CTL_Result_t result;
int32_t fault;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_POSITIONER_FAULT_REASON, &fault, 0
```



```
);  
if (result == SA_CTL_ERROR_NONE) {  
    // 'fault' holds the positioner fault reason of channel 0  
}
```

See Also

4.5.2 Amplifier Enabled

4.11.5 Motor Load

Definition	Value				
C-Definition	SA_CTL_PKEY_MOTOR_LOAD				
Code	0x05020115				
ASCII-Command	[:PROPerTy]:CHANnel#:MOTor:LOAD				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R	-	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property reports the current motor load in percent.

Stick-Slip Piezo Driver

The motor load is continuously calculated from the output driving frequency over time. (For open-loop and closed-loop movements.) The load value represents an equivalent to the heat generation of the piezo stage for a time interval of two seconds. The higher the output frequency, the higher the resulting motor load. Some positioners may not be driven constantly with the highest possible output frequency. In this case the effective movement time or the output frequency must be reduced. (See Max Closed Loop Frequency and Step Frequency properties.) Note that the reported load value may exceed 100 % to indicate an overload situation. Monitoring this property while performing movements may be useful to estimate the motor load to prevent the positioner from over-heating. The Motor Overload Protection Threshold property may be configured to trigger an abort of a movement should the motor load become too high.

Electromagnetic Driver

The motor load is calculated by the I2T protection algorithm from the motor current over time. See section 2.9.2 "Overload Protection" for more information. Note that only the amount of current which exceeds the continuous current value leads to an increasing load level. This means, that if the positioner is operated only with its nominal load the motor load remains at 0 %. Monitoring this property while performing movements may be useful to estimate the motor load *before* the overload protection trips and disables the control-loop to protect the positioner from over-heating.

Valid Range

0 ... 100 %

Example

```
SA_CTL_Result_t result;
int32_t motorLoad;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_MOTOR_LOAD, &motorLoad, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'motorLoad' holds the load of channel 0 in percent
}
```

See Also

4.11.4 Positioner Fault Reason, 4.5.20 Max Closed Loop Frequency, 4.5.22 Step Frequency,
4.5.38 Motor Overload Protection Threshold

4.11.6 Diag Closed Loop Frequency Max

Definition	Value				
C-Definition	SA_CTL_PKEY_DIAG_CLOSED_LOOP_FREQUENCY_MAX				
Code	0x0502002f				
ASCII-Command	[:PROPerTy]:CHANnel#:DIAG:CLFrequency:MAXimum				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R	-	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER				(0x0001)

Description

This property reports the maximum frequency in Hz that has been generated by the output driver of a Stick-Slip Piezo Driver channel while performing a closed-loop movement. The maximum closed-loop frequency detection may be used for diagnostic purposes of the positioner.

For the detection the channel performs a frequency measurement of the stick-slip driving signal while moving. The time base for this frequency measurement is set to 100 ms by default but may be configured with the Diag Closed Loop Frequency Measure Time Base property. The maximum value of the measured frequency is captured while moving and the result may then be read with this property after the movement has finished (or has been aborted by a `SA_CTL_Stop` command).

Note that the duration of a movement must be longer than the configured time base. Otherwise the frequency value will be read as zero to indicate that no valid frequency could be determined. Note further that the detection is only available for closed-loop movements.

Example

```
SA_CTL_Result_t result;
int32_t max;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_DIAG_CLOSED_LOOP_FREQUENCY_MAX, &max, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'max' holds the maximum output frequency of channel 0 in Hz
}
```

See Also

4.5.20 Max Closed Loop Frequency, 4.11.7 Diag Closed Loop Frequency Avg, 4.11.8 Diag Closed Loop Frequency Measure Time Base

4.11.7 Diag Closed Loop Frequency Avg

Definition	Value				
C-Definition	SA_CTL_PKEY_DIAG_CLOSED_LOOP_FREQUENCY_AVG				
Code	0x0502002e				
ASCII-Command	[:PROPerTy]:CHANnel#:DIAG:CLFrequency:AVERage				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	R	-	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)

Description

This property reports the average frequency in Hz that has been generated by the output driver of a Stick-Slip Piezo Driver channel while performing a closed-loop movement. Refer to the Diag Closed Loop Frequency Max property for more information on this feature.

Example

```
SA_CTL_Result_t result;
int32_t avg;
result = SA_CTL_GetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_DIAG_CLOSED_LOOP_FREQUENCY_AVG, &avg, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'avg' holds the average output frequency of channel 0 in Hz
}
```

See Also

4.5.20 Max Closed Loop Frequency, 4.11.6 Diag Closed Loop Frequency Max, 4.11.8 Diag Closed Loop Frequency Measure Time Base

4.11.8 Diag Closed Loop Frequency Measure Time Base

Definition	Value				
C-Definition	SA_CTL_PKEY_DIAG_CLF_MEASURE_TIME_BASE				
Code	0x050200c6				
ASCII-Command	[:PROPerTy]:CHANnel#:DIAG:CLFrequency:MTBase				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	-	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER				(0x0001)

Description

This property configures the time base for the maximum closed-loop frequency detection. Refer to the Diag Closed Loop Frequency Max property for more information on this feature. The default time base is 100 ms.

Valid Range

10 ... 1000 ms

Example

```
// set time base for the max CLF detection to 200 ms for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_DIAG_CLF_MEASURE_TIME_BASE, 200
);
```

See Also

4.11.6 Diag Closed Loop Frequency Max, 4.5.20 Max Closed Loop Frequency

4.12 Auxiliary Properties

4.12.1 Aux Positioner Type

Definition	Value				
C-Definition	SA_CTL_PKEY_AUX_POSITIONER_TYPE				
Code	0x0802003C				
ASCII-Command	[:PROPerTy]:CHANnel#:AUXiliary:PTYPe				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property is used to tell the channel which set of control-loop parameters (PID gains, etc.) is used when an auxiliary input is configured as input for the control-loop. More precisely, if the Control Loop Input property is set to `SA_CTL_CONTROL_LOOP_INPUT_AUX_IN` the auxiliary positioner type parameters are implicitly configured, otherwise the regular positioner type parameters are used. This way it is possible to switch between two control modes without manually changing all individual parameters. Typically a custom positioner type slot will be used here to define the necessary parameters.

Please refer to section 2.19.5 "Using Analog Inputs as Control-Loop Feedback" for more information on using auxiliary inputs.

This property is stored to non-volatile memory and need not be configured on every power-up.

Valid Range

SA_CTL_POSITIONER_TYPE_CUSTOM0 (250),
 SA_CTL_POSITIONER_TYPE_CUSTOM1 (251),
 SA_CTL_POSITIONER_TYPE_CUSTOM2 (252),
 SA_CTL_POSITIONER_TYPE_CUSTOM3 (253)

Example

```
// select the 'CUSTOM0' positioner type (type code 250) for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_AUX_POSITIONER_TYPE, 250
```

```
);
```

See Also

4.5.8 Positioner Type

4.12.2 Aux Positioner Type Name

Definition	Value				
C-Definition	SA_CTL_PKEY_AUX_POSITIONER_TYPE_NAME				
Code	0x0802003D				
ASCII-Command	[:PROPerTy]:CHANnel#:AUXiliary:PTName				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	String	Channel	R	-	-

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property holds a descriptive name of the configured auxiliary positioner type. The positioner type name is a null terminated string. Note that the name is read-only.

Example

```
SA_CTL_Result_t result;
char name[SA_CTL_STRING_MAX_LENGTH];
size_t ioStringSize = sizeof(name);
result = SA_CTL_GetProperty_s(
    dHandle, 0, SA_CTL_PKEY_AUX_POSITIONER_TYPE_NAME, name, &ioStringSize
);
if (result == SA_CTL_ERROR_NONE) {
    // 'name' holds the name of the configured auxiliary positioner type
}
```

See Also

4.12.1 Aux Positioner Type, 4.5.8 Positioner Type

4.12.3 Aux Input Select

Definition	Value				
C-Definition	SA_CTL_PKEY_AUX_INPUT_SELECT				
Code	0x08020018				
ASCII-Command	[:PROPerTy]:CHANnel#:AUXiliary:ISElect				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property selects the auxiliary input component. Note that the Aux I/O Module Input Index property must be configured too to select a specific analog input.

Note that the additional sensor module inputs are not available on all sensor module types. Please refer to section 2.19 "Auxiliary Inputs and Outputs" for more information on using auxiliary inputs.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is SA_CTL_AUX_INPUT_SELECT_IO_MODULE (0).

Valid Range

SA_CTL_AUX_INPUT_SELECT_IO_MODULE (0),
SA_CTL_AUX_INPUT_SELECT_SENSOR_MODULE (1)

Example

```
// set the auxiliary input selection to 'I/O module' for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_AUX_INPUT_SELECT,
    SA_CTL_AUX_INPUT_SELECT_IO_MODULE
);
```

See Also

4.12.4 Aux I/O Module Input Index, 4.12.5 Aux Direction Inversion, 4.5.33 Control Loop Input Aux Value, 4.5.6 Control Loop Input

4.12.4 Aux I/O Module Input Index

Definition	Value				
C-Definition	SA_CTL_PKEY_AUX_IO_MODULE_INPUT_INDEX				
Code	0x081100AA				
ASCII-Command	[:PROPerTy]:CHANnel#:AUXiliary:IOModule:INPut:INDeX				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies which input of an analog I/O module is used as input for the auxiliary control-loop input.

The I/O module has a total number of six analog inputs which are mapped in groups of two to the channels of the corresponding driver module. The input index refers to the analog inputs assigned to a specific channel as follows:

Input Index	Channel Index	Analog Input
0	0 (3) (6)	AIN-1
0	1 (4) (7)	AIN-2
0	2 (5) (8)	AIN-3
1	0 (3) (6)	AIN-4
1	1 (4) (7)	AIN-5
1	2 (5) (8)	AIN-6

Note that input indexes refer to a module (start with zero for each module) while the channel indexes refer to the entire device. Channel indexes in brackets refer to a second respectively third module of the device.

Please refer to section 2.19 "Auxiliary Inputs and Outputs" for more information on using auxiliary inputs. See the *MCS2 User Manual* for the pin assignment of the I/O module connector.

This property is stored to non-volatile memory and need not be configured on every power-up. The default input index is 0.

Valid Range

0 ... 1

Example

```
// set the auxiliary I/O module input index to 0 for channel 0  
result = SA_CTL_SetProperty_i32(  
    dHandle, 0, SA_CTL_PKEY_AUX_IO_MODULE_INPUT_INDEX, 0  
);
```

See Also

4.12.3 Aux Input Select, 4.12.5 Aux Direction Inversion, 4.12.6 Aux I/O Module Input0 / Input1 Value

4.12.5 Aux Direction Inversion

Definition	Value				
C-Definition	SA_CTL_PKEY_AUX_DIRECTION_INVERSION				
Code	0x0809000E				
ASCII-Command	[:PROPerTy]:CHANnel#:AUXiliary:DINVersion				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property specifies the feedback direction sense for the control-loop in case an auxiliary input is used as input for the control-loop. The direction sense of the feedback must match the direction sense of the control-loop output. Otherwise a runaway condition may occur when commanding a closed-loop movement. The end stop detection (if not disabled) will typically abort the movement in that case. While the direction sense is determined automatically by the calibration routine when using the position as feedback signal, this setting must be defined manually using this property when using an auxiliary input. This property has no meaning if the Control Loop Input is not configured to auxiliary input.

Please refer to section 2.19.5 "Using Analog Inputs as Control-Loop Feedback" for more information on using auxiliary inputs.

This property is stored to non-volatile memory and need not be configured on every power-up. The default is SA_CTL_NON_INVERTED (0x00).

Valid Range

SA_CTL_NON_INVERTED (0x00), SA_CTL_INVERTED (0x01)

Example

```
// set the auxiliary direction inversion to 'inverted' for channel 0
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_AUX_DIRECTION_INVERSION, SA_CTL_INVERTED
);
```

See Also

4.12.3 Aux Input Select, 4.12.6 Aux I/O Module Input0 / Input1 Value, 4.5.6 Control Loop Input

4.12.6 Aux I/O Module Input0 / Input1 Value

Definition	Value				
C-Definition	SA_CTL_PKEY_AUX_IO_MODULE_INPUT0_VALUE				
Code	0x08110000				
ASCII-Command	[:PROPerTy]:CHANnel#:AUXiliary:IOModule:INPut:VALue#				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	R	-	X

Definition	Value				
C-Definition	SA_CTL_PKEY_AUX_IO_MODULE_INPUT1_VALUE				
Code	0x08110001				
ASCII-Command	[:PROPerTy]:CHANnel#:AUXiliary:IOModule:INPut:VALue#				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	R	-	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

These properties hold the input values of the analog inputs of an analog I/O module. Note that an error is returned if no I/O module is available.

Note further that the interpretation of the value depends on the configured I/O Module Analog Input Range of the I/O module. Please refer to section 2.19 "Auxiliary Inputs and Outputs" for more information on using auxiliary inputs.

Example

```
SA_CTL_Result_t result;
int64_t inputVal;
result = SA_CTL_GetProperty_i64(
    dHandle, 0, SA_CTL_PKEY_AUX_IO_MODULE_INPUT0_VALUE, &inputVal, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'inputVal' holds the current input value of the first
    // I/O module input of channel 0
}
```

See Also

4.12.3 Aux Input Select, 4.5.33 Control Loop Input Aux Value, 4.5.32 Control Loop Input Sensor Value, 4.12.6 Aux I/O Module Input0 / Input1 Value, 4.5.6 Control Loop Input

4.12.7 Aux Correction Max

Definition	Value				
C-Definition	SA_CTL_PKEY_AUX_CORRECTION_MAX				
Code	0x080200D8				
ASCII-Command	[:PROPerTy]:CHANnel#:AUXiliary:CORRection:MAXimum				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	NV	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property is used to scale the analog input voltage of an I/O module auxiliary input to a corresponding offset position for the external sensor correction feature.

The value is given in pm or n° and specifies the resulting position offset for the maximum or minimum input voltage of the analog input. ($\pm 10.24V$ or 131071/-131072 in its digital representation, see I/O Module Analog Input Range property).

The value is interpreted as signed integer and therefore allows to specify if the resulting offset value is added to or subtracted from the current position. If a positive value is configured the offset value is added, if a negative value is configured the value is subtracted from the current position.

Which auxiliary input is used must be defined with the Aux I/O Module Input Index property. Note that the I/O Module Analog Input Range setting of the I/O module does *not* affect the scaling.

To enable the correction, the Sensor Input Select property must be configured to SA_CTL_SENSOR_INPUT_SELECT_POS_PLUS_AUX_IN (2). After that, the analog input signal, scaled to a corresponding position, is continuously added to the current position.

Please refer to section 2.19.6 "Using Analog Inputs for External Sensor Correction" for more information on using auxiliary inputs to correct the sensor position.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is 1 000 000.

Valid Range

$-2 \times 10^9 \dots 2 \times 10^9$.

Example

```
SA_CTL_Result_t result;  
// set the auxiliary range to 1mm for the full range input of 10.24V  
result = SA_CTL_SetProperty_i32(dHandle, 0,  
    SA_CTL_PKEY_AUX_CORRECTION_MAX, 1e9  
);
```

See Also

4.13.3 I/O Module Analog Input Range, 4.12.4 Aux I/O Module Input Index, 4.5.7 Sensor Input Select

4.12.8 Aux Digital Input Value

Definition	Value				
C-Definition	SA_CTL_PKEY_AUX_DIGITAL_INPUT_VALUE				
Code	0x080300AD				
ASCII-Command	[:PROPerTy]:MODule#:AUXiliary:DINPut[:VALue]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Module	R	-	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property holds a bit mask that represents the input levels of the general purpose digital inputs of an I/O module.

Please refer to section 2.19 "Auxiliary Inputs and Outputs" for more information.

Example

```
SA_CTL_Result_t result;
// read the digital inputs
int32_t input;
result = SA_CTL_GetProperty_i32(dHandle, 0,
    SA_CTL_PKEY_AUX_DIGITAL_INPUT_VALUE, &input, 0
);
if (result == SA_CTL_ERROR_NONE) {
    // 'input' holds the value of the digital inputs
}
```

See Also

4.12.9 Aux Digital Output Value / Set / Clear

4.12.9 Aux Digital Output Value / Set / Clear

Definition	Value				
C-Definition	SA_CTL_PKEY_AUX_DIGITAL_OUTPUT_VALUE				
Code	0x080300AE				
ASCII-Command	[:PROPerTy]:MODule#:AUXiliary:DOUTput[:VALue]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Module	RW	V	X

Definition	Value				
C-Definition	SA_CTL_PKEY_AUX_DIGITAL_OUTPUT_SET				
Code	0x080300B0				
ASCII-Command	[:PROPerTy]:MODule#:AUXiliary:DOUTput:SET				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Module	W	V	X

Definition	Value				
C-Definition	SA_CTL_PKEY_AUX_DIGITAL_OUTPUT_CLEAR				
Code	0x080300B1				
ASCII-Command	[:PROPerTy]:MODule#:AUXiliary:DOUTput:CLEar				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Module	W	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

These properties hold bit masks that may be used to modify the general purpose digital outputs of an I/O module. Note that the digital output driver circuit is disabled by default and must be enabled by setting the SA_CTL_IO_MODULE_OPT_BIT_DIGITAL_OUTPUT_ENABLED bit of the I/O Module Options property.

Please refer to section 2.19 "Auxiliary Inputs and Outputs" for more information.

Example

```
SA_CTL_Result_t result;  
// set all digital output of the I/O module to a specific value  
// DOUT-4 | DOUT-3 | DOUT-2 | DOUT-1 |  
// L(0)   | H(1)   | L(0)   | H(1)   |  
result = SA_CTL_SetProperty_i32(dHandle, 0,  
    SA_CTL_PKEY_AUX_DIGITAL_OUTPUT_VALUE, 0x00000005  
);
```

See Also

4.12.8 Aux Digital Input Value, 4.13.1 I/O Module Options

4.12.10 Aux Analog Output Value0 / Value1

Definition	Value				
C-Definition	SA_CTL_PKEY_AUX_ANALOG_OUTPUT_VALUE0				
Code	0x08030000				
ASCII-Command	[:PROPerTy]:MODUle#:AUXiliary:AOUTput:VALue#				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Module	RW	V	X

Definition	Value				
C-Definition	SA_CTL_PKEY_AUX_ANALOG_OUTPUT_VALUE1				
Code	0x08030001				
ASCII-Command	[:PROPerTy]:MODUle#:AUXiliary:AOUTput:VALue#				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Module	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

These properties specify the output values of the analog outputs of an I/O module. Note that the analog output driver circuit is in a high-impedance state by default and must be enabled by setting the `SA_CTL_IO_MODULE_OPT_BIT_ANALOG_OUTPUT_ENABLED` bit of the I/O Module Options property.

The output values are given as signed 16-bit values from $-32\,768$ to $32\,767$, where $-32\,768$ corresponds to -10 V and $32\,767$ to 10 V output voltage.

The default value is 0 which corresponds to an output voltage of 0 V.

Valid Range

$-32\,768 \dots 32\,767$

Example

```
SA_CTL_Result_t result;
// set the output value of analog output0 (AOUT-1) to zero
// which corresponds to 0V
```

```
result = SA_CTL_SetProperty_i32(dHandle, 0,  
    SA_CTL_PKEY_AUX_ANALOG_OUTPUT_VALUE0, 0  
);
```

See Also

4.12.6 Aux I/O Module Input0 / Input1 Value, 4.13.1 I/O Module Options

4.13 I/O Module Properties

4.13.1 I/O Module Options

Definition	Value				
C-Definition	SA_CTL_PKEY_IO_MODULE_OPTIONS				
Code	0x0603005D				
ASCII-Command	[:PROPerTy]:MODule#:IOModule:OPTions				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Module	RW	V	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property specifies the I/O module options. The value is a bit field containing independent flags with the following meaning:

Bit	C-Definition	Short Description
0	SA_CTL_IO_MODULE_OPT_BIT_DIGITAL_OUTPUT_ENABLED	Enables or disables the digital output driver circuit on the I/O module.
1	SA_CTL_IO_MODULE_OPT_BIT_EVENTS_ENABLED	Enables or disables the event notification for the digital inputs of an I/O module.
2	SA_CTL_IO_MODULE_OPT_BIT_ANALOG_OUTPUT_ENABLED	Enables or disables the analog output driver circuit on the I/O module.
3 .. 31	Reserved	These bits are reserved for future use.

All options are disabled by default, which means that all digital and analog outputs are in a high-impedance state and the digital input events are disabled.

Note that the *events enabled* bit refers to the general purpose digital inputs of the I/O module and **not** to the digital device trigger input. See section 2.20 "Input Trigger" for the event notification configuration of the device input trigger.

Note that the I/O Module Voltage property should be set first to define the voltage level of the digital outputs.

Example

```
// enable the digital and analog output driver circuit of the I/O module
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_IO_MODULE_OPTIONS,
    (SA_CTL_IO_MODULE_OPT_BIT_DIGITAL_OUTPUT_ENABLED |
     SA_CTL_IO_MODULE_OPT_BIT_ANALOG_OUTPUT_ENABLED)
);
```

See Also

4.13.2 I/O Module Voltage

4.13.2 I/O Module Voltage

Definition	Value				
C-Definition	SA_CTL_PKEY_IO_MODULE_VOLTAGE				
Code	0x06030031				
ASCII-Command	[:PROPerTy]:MODule#:IOModule:VOLTag				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Module	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the I/O module output voltage for the digital outputs. The output voltage should be set before enabling the outputs of the I/O module. Note that the voltage setting is global for all digital output channels of the I/O module.

The default value is SA_CTL_IO_MODULE_VOLTAGE_3V3 (0).

Valid Range

SA_CTL_IO_MODULE_VOLTAGE_3V3 (0),
SA_CTL_IO_MODULE_VOLTAGE_5V (1)

Example

```
// set the output driver voltage level to 5V
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_IO_MODULE_VOLTAGE,
    SA_CTL_IO_MODULE_VOLTAGE_5V
);
```

See Also

4.13.1 I/O Module Options

4.13.3 I/O Module Analog Input Range

Definition	Value				
C-Definition	SA_CTL_PKEY_IO_MODULE_ANALOG_INPUT_RANGE				
Code	0x060300A0				
ASCII-Command	[:PROPerTy]:MODUle#:IOModule:AINPut:RANGe				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Module	RW	NV	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the I/O module analog input range. This setting configures the analog gain settings of the ADCs of the I/O module. The inputs allow bipolar as well as unipolar operation. To achieve the best performance of the ADC it is recommended to always use the lowest full range setting that fits the desired analog input range.

Note that the range setting does not influence the digital representation of the input value. The signed value of 2^{17} corresponds to a bipolar full range input of 10.24V. This means that e.g. an analog voltage of 2.56V always returns a digital value of 32767 regardless of the actual range setting. The advantage of this representation is that e.g. configured PID gains or threshold limits must not be adjusted after changing the input range while the best matching analog gain is used for the analog to digital conversion. The following table summarizes the digital representations of the analog input voltage and their maximum values for the different gain settings:

Analog Voltage	Bipol. $\pm 10V$	Bipol. $\pm 5V$	Bipol. $\pm 2.5V$	Unipol. 10V	Unipol. 5V
+10.24V	131071	65535	32767	131071	65535
+5.12V	65535	65535	32767	65535	65535
+2.56V	32767	32767	32767	32767	32767
0V	0	0	0	0	0
-2.56V	-32768	-32768	-32768	0	0
-5.12V	-65536	-65536	-32768	0	0
-10.24V	-131072	-65536	-32768	0	0

Note that the input range setting is global for all analog inputs of the I/O module.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is SA_CTL_IO_MODULE_ANALOG_INPUT_RANGE_BI_10V (0).

Note that setting this property implicitly stops the channel and disables the control-loop.

**NOTICE**

Electromagnetic driven positioners are not self-locking. Disabling the control-loop removes any holding force from the positioner. Make sure not to damage any equipment when the positioner changes its position unintentionally!

Valid Range

SA_CTL_IO_MODULE_ANALOG_INPUT_RANGE_BI_10V (0),
SA_CTL_IO_MODULE_ANALOG_INPUT_RANGE_BI_5V (1),
SA_CTL_IO_MODULE_ANALOG_INPUT_RANGE_BI_2_5V (2),
SA_CTL_IO_MODULE_ANALOG_INPUT_RANGE_UNI_10V (3),
SA_CTL_IO_MODULE_ANALOG_INPUT_RANGE_UNI_5V (4)

Example

```
// set the analog input range to +/-5V
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_IO_MODULE_ANALOG_INPUT_RANGE,
    SA_CTL_IO_MODULE_ANALOG_INPUT_RANGE_BI_5V
);
```

See Also

4.13.1 I/O Module Options, 4.12.6 Aux I/O Module Input0 / Input1 Value

4.14 Input Trigger Properties

4.14.1 Device Input Trigger Select

Definition	Value				
C-Definition	SA_CTL_PKEY_DEV_INPUT_TRIG_SELECT				
Code	0x060D009D				
ASCII-Command	[:PROPerTy]:DEVIce:TRIGger:INPut:SElect				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	RW	NV	-
Applicable for					
USB Interface	SA_CTL_INTERFACE_USB			(0x0001)	
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET			(0x0002)	

Description

This property specifies which physical input is used for the device trigger functions. Currently two inputs are available: the device input of an I/O module and the global input of an MCS2 rack housing. Note that only one input can be used at the same time.

While this property defines the active input, the behavior on the occurrence of a trigger signal must be configured with the Device Input Trigger Condition and Device Input Trigger Mode properties.

Please refer to sections 2.20 "Input Trigger" and 2.19.1 "Digital Device Inputs" for more information.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is SA_CTL_DEV_INPUT_TRIG_SELECT_IO_MODULE (0).

Valid Range

SA_CTL_DEV_INPUT_TRIG_SELECT_IO_MODULE (0),
SA_CTL_DEV_INPUT_TRIG_SELECT_GLOBAL_INPUT (1)

Example

```
// define the device input of an MCS2 rack to be the active trigger input
result = SA_CTL_SetProperty_i32(
    dHandle,
    0,
    SA_CTL_PKEY_DEV_INPUT_TRIG_SELECT,
    SA_CTL_DEV_INPUT_TRIG_SELECT_RACK_INPUT
```

```
);
```

See Also

4.14.3 Device Input Trigger Condition, 4.14.2 Device Input Trigger Mode, 4.10.1 Stream Base Rate, 4.10.2 Stream External Sync Rate

4.14.2 Device Input Trigger Mode

Definition	Value				
C-Definition	SA_CTL_PKEY_DEV_INPUT_TRIG_MODE				
Code	0x060D0087				
ASCII-Command	[:PROPerTy]:DEvIce:TRIGger:INPut:MODE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	RW	NV	-

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property specifies the input trigger mode of the device. The input trigger may be used to synchronize the device to external events.

Please refer to sections 2.20 "Input Trigger" and 2.19.1 "Digital Device Inputs" for more information.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is SA_CTL_DEV_INPUT_TRIG_MODE_DISABLED (0).

Valid Range

SA_CTL_DEV_INPUT_TRIG_MODE_DISABLED (0),
 SA_CTL_DEV_INPUT_TRIG_MODE_EMERGENCY_STOP (1),
 SA_CTL_DEV_INPUT_TRIG_MODE_STREAM (2),
 SA_CTL_DEV_INPUT_TRIG_MODE_CMD_GROUP (3),
 SA_CTL_DEV_INPUT_TRIG_MODE_EVENT (4),
 SA_CTL_DEV_INPUT_TRIG_MODE_AMPLIFIER_LOCK (5)

Example

```
// set input trigger mode to external stream sync
result = SA_CTL_SetProperty_i32(
    dHandle,
    0,
    SA_CTL_PKEY_DEV_INPUT_TRIG_MODE,
    SA_CTL_DEV_INPUT_TRIG_MODE_STREAM
);
```

See Also

4.14.1 Device Input Trigger Select, 4.14.3 Device Input Trigger Condition, 4.3.7 Emergency Stop Mode, 4.10.1 Stream Base Rate, 4.10.2 Stream External Sync Rate

4.14.3 Device Input Trigger Condition

Definition	Value				
C-Definition	SA_CTL_PKEY_DEV_INPUT_TRIG_CONDITION				
Code	0x060D005A				
ASCII-Command	[:PROPerTy]:DEViCe:TRIGger:INPut:CONDition				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	RW	NV	-

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property defines the active edge for the device input trigger signal.

This property is stored to non-volatile memory and need not be configured on every power-up. The default value is SA_CTL_TRIGGER_CONDITION_RISING (0).

Valid Range

SA_CTL_TRIGGER_CONDITION_RISING (0), SA_CTL_TRIGGER_CONDITION_FALLING (1)

Example

```
// set input trigger condition to "rising"
result = SA_CTL_SetProperty_i32(
    dHandle,
    0,
    SA_CTL_PKEY_DEV_INPUT_TRIG_CONDITION,
    SA_CTL_TRIGGER_CONDITION_RISING
);
```

See Also

4.14.1 Device Input Trigger Select, 4.14.2 Device Input Trigger Mode, 4.10.1 Stream Base Rate, 4.10.2 Stream External Sync Rate

4.14.4 Channel Input Trigger Mode

Definition	Value				
C-Definition	SA_CTL_PKEY_CH_INPUT_TRIG_MODE				
Code	0x06150087				
ASCII-Command	[:PROPerTy]:CHANnel#:TRIGger:INPut:MODE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property specifies the channel input trigger mode. This input trigger may be used to trigger an emergency stop of the channel. The trigger signal must be fed into a *general-purpose digital input* of an I/O module. If no I/O module is available this property returns a SA_CTL_ERROR_NO_IOM_PRESENT error.

Please refer to sections 2.20 "Input Trigger" and 2.19.3 "Digital Inputs" for more information.

The default value is SA_CTL_CH_INPUT_TRIG_MODE_DISABLED (0).

Valid Range

SA_CTL_CH_INPUT_TRIG_MODE_DISABLED (0),
SA_CTL_CH_INPUT_TRIG_MODE_EMERGENCY_STOP (1)

Example

```
// set input trigger mode to emergency stop mode for channel 1
result = SA_CTL_SetProperty_i32(
    dHandle,
    1,
    SA_CTL_PKEY_CH_INPUT_TRIG_MODE,
    SA_CTL_CH_INPUT_TRIG_MODE_EMERGENCY_STOP
);
```

See Also

4.14.5 Channel Input Trigger Condition, 4.14.2 Device Input Trigger Mode, 4.14.3 Device Input Trigger Condition

4.14.5 Channel Input Trigger Condition

Definition	Value				
C-Definition	SA_CTL_PKEY_CH_INPUT_TRIG_CONDITION				
Code	0x0615005A				
ASCII-Command	[:PROPerTy]:CHANnel#:TRIGger:INPut:CONDition				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property defines the active edge for the channel input trigger signal.

The default value is SA_CTL_TRIGGER_CONDITION_RISING (0).

Valid Range

SA_CTL_TRIGGER_CONDITION_RISING (0), SA_CTL_TRIGGER_CONDITION_FALLING (1)

Example

```
// set input trigger condition to "rising" for channel 1
result = SA_CTL_SetProperty_i32(
    dHandle,
    1,
    SA_CTL_PKEY_CH_INPUT_TRIG_CONDITION,
    SA_CTL_TRIGGER_CONDITION_RISING
);
```

See Also

4.14.4 Channel Input Trigger Mode, 4.14.2 Device Input Trigger Mode, 4.14.3 Device Input Trigger Condition

4.15 Output Trigger Properties

4.15.1 Channel Output Trigger Mode

Definition	Value				
C-Definition	SA_CTL_PKEY_CH_OUTPUT_TRIG_MODE				
Code	0x060E0087				
ASCII-Command	[:PROPerTy]:CHANnel#:TRIGger:OUTPut:MODE				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X
Applicable for					
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER			(0x0001)	
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER			(0x0002)	

Description

This property specifies the output trigger mode of a channel. Note that further configuration of the output trigger should be done before it is enabled. If no I/O module is available this property returns a `SA_CTL_ERROR_NO_IOM_PRESENT` error.

Note for the position compare mode: if the Channel Position Compare Limit Max is set to a lower value than the Channel Position Compare Limit Min then this misconfiguration is indicated by a returned `SA_CTL_ERROR_INVALID_CONFIGURATION` error.

Please refer to section 2.21 "Output Trigger" for more information.

The default value is `SA_CTL_CH_OUTPUT_TRIG_MODE_CONSTANT (0)`.

Valid Range

`SA_CTL_CH_OUTPUT_TRIG_MODE_CONSTANT (0)`,
`SA_CTL_CH_OUTPUT_TRIG_MODE_POSITION_COMPARE (1)`,
`SA_CTL_CH_OUTPUT_TRIG_MODE_TARGET_REACHED (2)`,
`SA_CTL_CH_OUTPUT_TRIG_MODE_ACTIVELY_MOVING (3)`,
`SA_CTL_CH_OUTPUT_TRIG_MODE_IN_POSITION (4)`

Example

```
// set output trigger mode for channel 1
result = SA_CTL_SetProperty_i32(
    dHandle,
    1,
```

```
SA_CTL_PKEY_CH_OUTPUT_TRIG_MODE,  
SA_CTL_CH_OUTPUT_TRIG_MODE_POSITION_COMPARE  
);
```

See Also

4.15.4 Channel Position Compare Start Threshold, 4.15.5 Channel Position Compare Increment, 4.15.6 Channel Position Compare Direction, 4.15.2 Channel Output Trigger Polarity, 4.15.3 Channel Output Trigger Pulse Width, 4.5.36 In Position Threshold, 4.5.37 In Position Delay

4.15.2 Channel Output Trigger Polarity

Definition	Value				
C-Definition	SA_CTL_PKEY_CH_OUTPUT_TRIG_POLARITY				
Code	0x060E005B				
ASCII-Command	[:PROPerTy]:CHANnel#:TRIGger:OUTPut:POLarity				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property defines the polarity of the output trigger signal. If set to *active high* then the idle level is low and a high pulse is generated when the trigger occurs. If set to *active low* then the idle level is high and a low pulse is generated when the trigger occurs.

The default polarity is SA_CTL_TRIGGER_POLARITY_ACTIVE_HIGH (1).

Valid Range

SA_CTL_TRIGGER_POLARITY_ACTIVE_LOW (0),
SA_CTL_TRIGGER_POLARITY_ACTIVE_HIGH (1)

Example

```
// set output trigger polarity for channel 1 to 'active high'
result = SA_CTL_SetProperty_i32(
    dHandle,
    1,
    SA_CTL_PKEY_CH_OUTPUT_TRIG_POLARITY,
    SA_CTL_TRIGGER_POLARITY_ACTIVE_HIGH
);
```

See Also

4.15.1 Channel Output Trigger Mode, 4.15.4 Channel Position Compare Start Threshold, 4.15.5 Channel Position Compare Increment, 4.15.6 Channel Position Compare Direction, 4.15.3 Channel Output Trigger Pulse Width

4.15.3 Channel Output Trigger Pulse Width

Definition	Value				
C-Definition	SA_CTL_PKEY_CH_OUTPUT_TRIG_PULSE_WIDTH				
Code	0x060E005C				
ASCII-Command	[:PROPerTy]:CHANnel#:TRIGger:OUTPut:PWIDth				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property specifies the pulse width of the trigger output pulse in ns.

Note that the configured pulse width includes the duration of the pulse as well as the duration of the pause. E.g. when setting the Channel Output Trigger Pulse Width to 1000 ns pulses with 500 ns high level and 500 ns low level will be generated.

This property is only relevant for the non level-based output trigger modes ("position compare" and "target reached"), for all other modes this setting is ignored.

The default pulse width is 1000 ns.

Valid Range

100 ns ... 4×10^9 ns

Example

```
// set output trigger pulse width for channel 1 to 1us
result = SA_CTL_SetProperty_i32(
    dHandle, 1, SA_CTL_PKEY_CH_OUTPUT_TRIG_PULSE_WIDTH, 1000
);
```

See Also

4.15.1 Channel Output Trigger Mode, 4.15.4 Channel Position Compare Start Threshold, 4.15.5 Channel Position Compare Increment, 4.15.6 Channel Position Compare Direction, 4.15.2 Channel Output Trigger Polarity

4.15.4 Channel Position Compare Start Threshold

Definition	Value				
C-Definition	SA_CTL_PKEY_CH_POS_COMP_START_THRESHOLD				
Code	0x060E0058				
ASCII-Command	[:PROPerTy]:CHANnel#:TRIGger:PCOMpare:THReshold[:STARt]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property defines the start threshold value in pm or n° for the position compare output trigger. As soon as the position passes this threshold in the configured direction (see Channel Position Compare Direction) an output pulse is generated. Additionally the threshold is incremented by the value of the Channel Position Compare Increment to define the next trigger threshold. Please refer to section 2.21 "Output Trigger" for more information.

The default value is 1×10^9 .

Valid Range

$-100 \times 10^{12} \dots 100 \times 10^{12}$ pm or n°.

Example

```
// set output trigger start threshold for channel 1 to 1mm
result = SA_CTL_SetProperty_i64(
    dHandle, 1, SA_CTL_PKEY_CH_POS_COMP_START_THRESHOLD, 1e9
);
```

See Also

4.15.1 Channel Output Trigger Mode, 4.15.5 Channel Position Compare Increment, 4.15.6 Channel Position Compare Direction, 4.15.2 Channel Output Trigger Polarity, 4.15.3 Channel Output Trigger Pulse Width

4.15.5 Channel Position Compare Increment

Definition	Value				
C-Definition	SA_CTL_PKEY_CH_POS_COMP_INCREMENT				
Code	0x060E0059				
ASCII-Command	[:PROPerTy]:CHANnel#:TRIGger:PCOMpare:INCRement				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property defines the position compare output trigger increment in pm or n°. Please refer to section 2.21 "Output Trigger" for more information.

The default value is 1×10^9 .

Valid Range

$1 \dots 1 \times 10^{12}$ pm or n°.

Example

```
// set position compare increment for channel 1 to 100um
result = SA_CTL_SetProperty_i64(
    dHandle, 1, SA_CTL_PKEY_CH_POS_COMP_INCREMENT, 100e6
);
```

See Also

4.15.1 Channel Output Trigger Mode, 4.15.4 Channel Position Compare Start Threshold, 4.15.6 Channel Position Compare Direction, 4.15.2 Channel Output Trigger Polarity, 4.15.3 Channel Output Trigger Pulse Width

4.15.6 Channel Position Compare Direction

Definition	Value				
C-Definition	SA_CTL_PKEY_CH_POS_COMP_DIRECTION				
Code	0x060E0026				
ASCII-Command	[:PROPerTy]:CHANnel#:TRIGger:PCOMpare:DIREction				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Channel	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property defines how the position value and the configured trigger threshold are compared against each other.

The following trigger conditions are available:

Condition	Name	Short Description
0x00	SA_CTL_FORWARD_DIRECTION	The trigger pulse is output when the position value passes the threshold from below.
0x01	SA_CTL_BACKWARD_DIRECTION	The trigger pulse is output when the position value passes the threshold from above.
0x02	SA_CTL_EITHER_DIRECTION	The trigger pulse is output when the position value passes the threshold from below or above.

Please refer to section 2.21 "Output Trigger" for more information.

The default direction is SA_CTL_FORWARD_DIRECTION (0x00).

Example

```
// set output trigger condition for channel 1 to forward
result = SA_CTL_SetProperty_i32(
    dHandle,
    1,
    SA_CTL_PKEY_CH_POS_COMP_DIRECTION,
    SA_CTL_FORWARD_DIRECTION
);
```

See Also

4.15.1 Channel Output Trigger Mode, 4.15.4 Channel Position Compare Start Threshold, 4.15.5 Channel Position Compare Increment, 4.15.2 Channel Output Trigger Polarity, 4.15.3 Channel Output Trigger Pulse Width 4.15.7 Channel Position Compare Limit Min, 4.15.8 Channel Position Compare Limit Max

4.15.7 Channel Position Compare Limit Min

Definition	Value				
C-Definition	SA_CTL_PKEY_CH_POS_COMP_LIMIT_MIN				
Code	0x060E0020				
ASCII-Command	[:PROPerTy]:CHANnel#:TRIGger:PCOMpare:LMIN				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property defines the lower limit for the position compare output trigger in pm or n°. The limits act as an additional gate for the generation of output pulses. Output pulses are only generated when the current position lies between the configured minimum and maximum limits. Note that the maximum limit must be configured to a higher value than the minimum limit for the limit checks to be active. If both limits are set to the same value the checks are disabled and output pulses are generated according to the configured start threshold, increment and direction. Please refer to section 2.21 "Output Trigger" for more information.

The default value is 0.

Valid Range

$-100 \times 10^{12} \dots 100 \times 10^{12}$ pm or n°.

Example

```
// set position compare lower limit for channel 1 to 1mm
result = SA_CTL_SetProperty_i64(
    dHandle, 1, SA_CTL_PKEY_CH_POS_COMP_LIMIT_MIN, 1e9
);
```

See Also

4.15.1 Channel Output Trigger Mode, 4.15.4 Channel Position Compare Start Threshold, 4.15.5 Channel Position Compare Increment, 4.15.6 Channel Position Compare Direction, 4.15.2 Channel Output Trigger Polarity, 4.15.3 Channel Output Trigger Pulse Width, 4.15.8 Channel Position Compare Limit Max

4.15.8 Channel Position Compare Limit Max

Definition	Value				
C-Definition	SA_CTL_PKEY_CH_POS_COMP_LIMIT_MAX				
Code	0x060E0021				
ASCII-Command	[:PROPerTy]:CHANnel#:TRIGger:PCOMpare:LMAX				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I64	Channel	RW	V	X

Applicable for		
Stick-Slip Piezo Driver	SA_CTL_STICK_SLIP_PIEZO_DRIVER	(0x0001)
Electromagnetic Driver	SA_CTL_MAGNETIC_DRIVER	(0x0002)

Description

This property defines the upper limit for the position compare output trigger in pm or n°. The limits act as an additional gate for the generation of output pulses. Output pulses are only generated when the current position lies between the configured minimum and maximum limits. Note that the maximum limit must be configured to a higher value than the minimum limit for the limit checks to be active. If both limits are set to the same value the checks are disabled and output pulses are generated according to the configured start threshold, increment and direction. Please refer to section 2.21 "Output Trigger" for more information.

The default value is 0.

Valid Range

$-100 \times 10^{12} \dots 100 \times 10^{12}$ pm or n°.

Example

```
// set position compare upper limit for channel 1 to 2mm
result = SA_CTL_SetProperty_i64(
    dHandle, 1, SA_CTL_PKEY_CH_POS_COMP_LIMIT_MAX, 2e9
);
```

See Also

4.15.1 Channel Output Trigger Mode, 4.15.4 Channel Position Compare Start Threshold, 4.15.5 Channel Position Compare Increment, 4.15.6 Channel Position Compare Direction, 4.15.2 Channel Output Trigger Polarity, 4.15.3 Channel Output Trigger Pulse Width, 4.15.7 Channel Position Compare Limit Min

4.16 Hand Control Module Properties

4.16.1 Hand Control Module Lock Options

Definition	Value				
C-Definition	SA_CTL_PKEY_HM_LOCK_OPTIONS				
Code	0x020C0083				
ASCII-Command	[:PROPerTy]:DEvIce:HMODule:LOPTions[:CURRent]				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	RW	V	-

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property defines the different possible lock states of an attached hand control module. The value is a bit field containing independent flags with the following meaning:

Table 4.2 – Hand Control Module Lock Options Bits

Bit	C-Definition	Short Description
0	SA_CTL_HM1_LOCK_OPT_BIT_GLOBAL	Fully disables control over the hand controller.
1	SA_CTL_HM1_LOCK_OPT_BIT_CONTROL	Disables the control inputs (Encoder, Joystick, etc.).
4	SA_CTL_HM1_LOCK_OPT_BIT_CHANNEL_MENU	Hides the <i>Channel Settings</i> menu.
5	SA_CTL_HM1_LOCK_OPT_BIT_GROUP_MENU	Hides the <i>Group Settings</i> menu.
6	SA_CTL_HM1_LOCK_OPT_BIT_SETTINGS_MENU	Hides the <i>General Settings</i> menu.
7	SA_CTL_HM1_LOCK_OPT_BIT_LOAD_CFG_MENU	Hides the <i>Load Config</i> menu.
8	SA_CTL_HM1_LOCK_OPT_BIT_SAVE_CFG_MENU	Hides the <i>Save Config</i> menu.
9	SA_CTL_HM1_LOCK_OPT_BIT_CTRL_MODE_PARAM_MENU	Hides the generic control mode parameter menu.
12	SA_CTL_HM1_LOCK_OPT_BIT_CHANNEL_NAME	Hides the <i>Set Channel Name</i> menu entry.
13	SA_CTL_HM1_LOCK_OPT_BIT_POS_TYPE	Hides the <i>Positioner Type</i> menu entry.
14	SA_CTL_HM1_LOCK_OPT_BIT_SAFE_DIR	Hides the <i>Safe Direction</i> menu entry.

Continued on next page

Table 4.2 – Continued from previous page

Bit	C-Definition	Short Description
15	SA_CTL_HM1_LOCK_OPT_BIT_CALIBRATE	Hides the <i>Sensor Calibration</i> menu.
16	SA_CTL_HM1_LOCK_OPT_BIT_REFERENCE	Hides the <i>Find Reference</i> menu entry.
17	SA_CTL_HM1_LOCK_OPT_BIT_SET_POSITION	Hides the <i>Set Zero Position</i> menu entry.
18	SA_CTL_HM1_LOCK_OPT_BIT_MAX_CLF	Hides the <i>Max Closed-Loop Frequency</i> menu entry.
19	SA_CTL_HM1_LOCK_OPT_BIT_POWER_MODE	Hides the <i>Sensor Power Mode</i> menu entry.
20	SA_CTL_HM1_LOCK_OPT_BIT_ACTUATOR_MODE	Hides the <i>Actuator Mode</i> menu entry.

Undefined flags are reserved for future use. These flags should be set to zero.

Note that this property is volatile. In order to alter the lock bits across sessions the Hand Control Module Default Lock Options property must be used.

Example

```
// disable control inputs for the hand control module
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_HM_LOCK_OPTIONS, SA_CTL_HM1_LOCK_OPT_BIT_CONTROL
);
```

See Also

4.16.2 Hand Control Module Default Lock Options

4.16.2 Hand Control Module Default Lock Options

Definition	Value				
C-Definition	SA_CTL_PKEY_HM_DEFAULT_LOCK_OPTIONS				
Code	0x020C0084				
ASCII-Command	[:PROPerTy]:DEvIce:HMODule:LOPTions:DEFault				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	Device	RW	NV	-

Applicable for		
USB Interface	SA_CTL_INTERFACE_USB	(0x0001)
Ethernet Interface	SA_CTL_INTERFACE_ETHERNET	(0x0002)

Description

This property specifies the default lock state of the hand control module at startup. It is the non-volatile version of the Hand Control Module Lock Options property. See table 4.2 for a description of the bit field.

Example

```
// hide channel and group menu by default
int32_t defaultLockState = (SA_CTL_HM1_LOCK_OPT_BIT_CHANNEL_MENU |
                           SA_CTL_HM1_LOCK_OPT_BIT_GROUP_MENU);
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_HM_DEFAULT_LOCK_OPTIONS, defaultLockState
);
```

See Also

4.16.1 Hand Control Module Lock Options

4.17 API Properties

4.17.1 Event Notification Options

Definition	Value					
C-Definition	SA_CTL_PKEY_API_EVENT_NOTIFICATION_OPTIONS					
Code	0xF010005D					
ASCII-Command	N/A					
Attributes	Type	Index	Access	Volatility	Cmd-Group	
	I32	API	RW	V	-	

Description

This property may be used to configure the event notifications of the API. The value is a bit field containing independent flags.

Bit	C-Definition	Code
0	SA_CTL_EVT_OPT_BIT_REQUEST_READY_ENABLED	0x00000001

Undefined flags are reserved for future use. These flags should be set to zero.

Request Ready Enabled (Bit 0) Enables the generation of request ready events. See section 2.3.5 "Request Ready Notification" for more information.

The default value is 0 (all API events disabled).

Note that changing this property affects only new requests sent out after changing this property, not requests that were sent out before but have not received an answer yet.

Although this property is a setting of the API, an active connection to a device is still required. The setting applies to every individual device connection independently. Closing the connection to a device resets the setting to its default.

Example

```
// enable the request ready events of the API
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_API_EVENT_NOTIFICATION_OPTIONS,
    SA_CTL_EVT_OPT_BIT_REQUEST_READY_ENABLED
);
```

See Also

2.4 Event Notifications, 2.3.5 Request Ready Notification, 5.2.27 Request Ready

4.17.2 Auto Reconnect

Definition	Value				
C-Definition	SA_CTL_PKEY_API_AUTO_RECONNECT				
Code	0xF01000A1				
ASCII-Command	N/A				
Attributes	Type	Index	Access	Volatility	Cmd-Group
	I32	API	RW	V	-

Description

This property configures the automatic reconnect feature of the API. In the default configuration the reconnect feature is disabled. When enabled the API detects lost connections and tries to reconnect to the device. Note that during the reconnect all device requests functions block until the reconnect is finished.

Although this property is a setting of the API, an active connection to a device is still required. The setting applies to every individual device connection independently. Closing the connection to a device resets the setting to its default.

Valid Range

SA_CTL_ENABLED (0x01), SA_CTL_DISABLED (0x00)

Example

```
// enable automatic reconnect
result = SA_CTL_SetProperty_i32(
    dHandle, 0, SA_CTL_PKEY_API_AUTO_RECONNECT, SA_CTL_ENABLED);
```

5 EVENT REFERENCE

5.1 Event Summary

An event always carries a 32-bit parameter. The meaning of this parameter depends on the event. The "Parameter" column in the following table indicates the usage of the parameter. Some events don't use the parameter. This is indicated with "N/A" in the table.

Table 5.1 – Event Summary

Event	Code	Index	Parameter	Page
None	0x0000	N/A	N/A	361
Movement Finished	0x0001	Ch	Result Code	361
Sensor State Changed	0x0002	Ch	New State	363
Reference Found	0x0003	Ch	N/A	363
Following Error Limit	0x0004	Ch	N/A	364
Holding Aborted	0x0005	Ch	Error Code	361
Positioner Type Changed	0x0006	Ch	New Positioner Type Code	362
Phasing Finished	0x0007	Ch	Error Code	362
Sensor Module State Changed	0x4000	Mod	New State	364
Over Temperature	0x4001	Mod	Temperature	364
Power Supply Overload	0x4002	Mod	N/A	365
Power Supply Failure	0x4003	Mod	N/A	365
Fan Failure State Changed	0x4004	Mod	New State	366
Adjustment Finished	0x4010	Mod	Error Code	366
Adjustment State Changed	0x4011	Mod	New State	366
Adjustment Update	0x4012	Mod	Error Code	367
Digital Input Changed	0x4040	Mod	Input Value	367
Stream Finished	0x8000	Dev	Stream Handle, Index, Error Code	368
Stream Ready	0x8001	Dev	Stream Handle	368
Stream Triggered	0x8002	Dev	Stream Handle	369

Continued on next page

Table 5.1 – Continued from previous page

Event	Code	Index	Parameter	Page
Command Group Triggered	0x8010	Dev	Transmit Handle, Res. Code	369
Hand Control Module State Changed	0x8020	Dev	New State	370
Emergency Stop Triggered	0x8030	Dev	Input Index	370
External Input Triggered	0x8040	Dev	Input Index	370
Bus Resynchronization Triggered	0x8050	Dev	N/A	371
Unknown Command Received	0x8051	Dev	Packet Data	371
Request Ready	0xf000	Any	Request ID, Request Type, Data Type, Array Size, Property Key	372
Connection Lost	0xf001	N/A	N/A	373

5.2 Detailed Event Description

5.2.1 None

Definition

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_NONE	0x0000	N/A	N/A			

Description

This event type is a place holder indicating that no event occurred. The index and parameter fields are undefined.

5.2.2 Movement Finished

Definition

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_MOVEMENT_FINISHED	0x0001	Ch	Error Code			

Description

This event is generated when a channel has finished a movement command (either successful or unsuccessful). See also section 2.7.7 "Movement Feedback".

Parameter

The event parameter holds the error code. If the movement command finished successfully then the result is SA_CTL_ERROR_NONE. Otherwise the error code indicates what caused the failure. See table A.1 for a list of error codes.

5.2.3 Holding Aborted

Definition

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_HOLDING_ABORTED	0x0005	Ch	Error Code			

Description

This event is generated when a channel detects an endstop (or a configured following error limit is exceeded) while in holding state. Note that setting some specific properties may also abort the holding. E.g. disabling the power supply or amplifier as well as setting the sensor power mode aborts the holding. Subsequently this event is generated.

Parameter

The event parameter holds the error code: `SA_CTL_ERROR_END_STOP_REACHED` in case the holding was aborted due to an endstop or `SA_CTL_ERROR_FOLLOWING_ERR_LIMIT` in case the holding was aborted due to exceeding a following error limit. See table A.1 for a list of error codes.

5.2.4 Positioner Type Changed

Definition

C Definition	Code	Index	31-24	23-16	15-8	7-0
<code>SA_CTL_EVENT_POSITIONER_TYPE_CHANGED</code>	<code>0x0006</code>	Ch	Positioner Type Code			

Description

This event is generated when a positioner type of a channel changes to a new type. Note that this event is *not* sent to the interface which actually changed the type. This means that the event is sent to the host PC if the positioner type was changed on the hand-control-module and vice versa. In case of automatic configuration, the event will be sent to all available interfaces. See section 2.6 "Positioner Types" for more information.

Parameter

The event parameter holds the new positioner type code for the channel. Please refer to the *MCS2 Positioner Types* document for a list of possible positioner types.

5.2.5 Phasing Finished

Definition

C Definition	Code	Index	31-24	23-16	15-8	7-0
<code>SA_CTL_EVENT_PHASING_FINISHED</code>	<code>0x0007</code>	Ch	Error Code			

Description

This event is generated when a channel of a Electromagnetic Driver has finished a phasing sequence. See section 2.22 "Phasing of Electro-Magnetic Driven Positioners" for more information.

Parameter

The event parameter holds the error code. If the phasing sequence finished successfully then the result is `SA_CTL_ERROR_NONE`. Otherwise the error code indicates what caused the failure. See table A.1 for a list of error codes.

5.2.6 Sensor State Changed**Definition**

C Definition	Code	Index	31-24	23-16	15-8	7-0
<code>SA_CTL_EVENT_SENSOR_STATE_CHANGED</code>	0x0002	Ch	New State			

Description

A sensor was attached to or detached from a sensor module.

Parameter

The parameter value will be one of:

`SA_CTL_EVENT_PARAM_ATTACHED` (0x00000001),

`SA_CTL_EVENT_PARAM_DETACHED` (0x00000000)

5.2.7 Reference Found**Definition**

C Definition	Code	Index	31-24	23-16	15-8	7-0
<code>SA_CTL_EVENT_REFERENCE_FOUND</code>	0x0003	Ch	N/A			

Description

This event is generated during a reference movement. It is generated at the moment the physical position has been determined. Depending on the configuration of the referencing the movement might be continued and stopped at a later time. See section 2.7.2 "Referencing" for more information.

5.2.8 Following Error Limit

Definition

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_FOLLOWING_ERR_LIMIT	0x0004	Ch	N/A			

Description

This event is generated if the configured following error limit is exceeded during a closed-loop movement. See section 2.14 "Following Error Detection" for more information.

5.2.9 Sensor Module State Changed

Definition

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_SM_STATE_CHANGED	0x4000	Mod	New State			

Description

A sensor module was attached to or detached from a driver module.

Parameter

The parameter value will be one of:

SA_CTL_EVENT_PARAM_ATTACHED (0x00000001),
SA_CTL_EVENT_PARAM_DETACHED (0x00000000)

5.2.10 Over Temperature

Definition

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_OVER_TEMPERATURE	0x4001	Mod	Temperature			

Description

The module detected an over-temperature condition of a driver amplifier. Note that the amplifier circuit is automatically disabled at the occurrence of an over-temperature condition. The device must be cooled down before being able to continue to use the device. The Module State property (SA_CTL_MOD_STATE_BIT_OVER_TEMPERATURE) may be polled to know when the over temperature condition has passed by.

Parameter

The parameter holds the measured temperature in °C.

5.2.11 Power Supply Overload**Definition**

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_POWER_SUPPLY_OVERLOAD	0x4002	Mod			N/A	
SA_CTL_EVENT_HIGH_VOLTAGE_OVERLOAD ¹	0x4002	Mod			N/A	

Description

The module detected an overload condition of the power supply. See section 2.9.3 "Hardware Monitoring" for more information.

5.2.12 Power Supply Failure**Definition**

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_POWER_SUPPLY_FAILURE	0x4003	Mod			N/A	

Description

The module detected a failure condition or under-voltage of the power supply. See section 2.9.3 "Hardware Monitoring" for more information.

¹This definition is deprecated and may be removed in future releases.

5.2.13 Fan Failure State Changed

Definition

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_FAN_FAILURE_STATE_CHANGED	0x4004	Mod	New State			

Description

The module detected a change of the state of the cooling fan failure detection.

Parameter

If a blockage was detected the parameter value will be one, if the blockage ended and the fan spins freely again the parameter value will be zero.

5.2.14 Adjustment Finished

Definition

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_ADJUSTMENT_FINISHED	0x4010	Mod	Error Code			

Description

This event is generated when a module adjustment process has finished (either successful or unsuccessful).

Parameter

The event parameter holds the error code. If the adjustment finished successfully then the result is SA_CTL_ERROR_NONE. Otherwise the error code indicates what caused the failure. See table A.1 for a list of error codes.

5.2.15 Adjustment State Changed

Definition

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_ADJUSTMENT_STATE_CHANGED	0x4011	Mod	New State			

Description

This event is generated when a module adjustment state changes.

Parameter

The event parameter holds the new state of the adjustment process.

5.2.16 Adjustment Update**Definition**

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_ADJUSTMENT_UPDATE	0x4012	Mod	Error Code			

Description

This event is generated when a module adjustment update occurs.

Parameter

The event parameter holds the error code. If the adjustment update finished successfully then the result is `SA_CTL_ERROR_NONE`. Otherwise the error code indicates what caused the failure. See table A.1 for a list of error codes.

5.2.17 Digital Input Changed**Definition**

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_DIGITAL_INPUT_CHANGED	0x4040	Mod	Input Value			

Description

This event is generated whenever a level change of one or more of the general purpose digital inputs of an I/O module is detected. Note that this event must be explicitly enabled by configuring the I/O Module Options. See section 2.19.3 "Digital Inputs" for more information.

Parameter

The event parameter holds the new input value. The first bit (bit 0) of the input value corresponds to the first digital input (GP-DIN-1), the second bit (bit 1) corresponds to the second input (GP-DIN-2) and so on.

5.2.18 Stream Finished**Definition**

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_STREAM_FINISHED	0x8000	Dev	Handle	Index	Error Code	

Description

This event indicates that a trajectory stream has come to an end. See section 2.18 "Trajectory Streaming" for more information.

Parameter

The parameter holds information to further specify the event.

- **Stream Handle** The corresponding stream handle.
- **Index** The device/channel index that caused the given error code.
- **Error Code** The result of the trajectory streaming. If it finished successfully then the result is `SA_CTL_ERROR_NONE`. Otherwise the error code indicates what caused the failure. See table A.1 for a list of error codes.

5.2.19 Stream Ready**Definition**

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_STREAM_READY	0x8001	Dev	Handle	Reserved		

Description

This event indicates that the internal trajectory stream buffer contains enough data to start the stream. In case of direct streaming the stream will start automatically. Otherwise the device is ready to receive a start trigger for the stream. See section 2.18 "Trajectory Streaming" for more information.

Parameter

The parameter holds the corresponding stream handle.

5.2.20 Stream Triggered**Definition**

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_STREAM_TRIGGERED	0x8002	Dev	Handle	Reserved		

Description

This event indicates that the controller has started to execute the trajectory stream. See section 2.18 "Trajectory Streaming" for more information.

Parameter

The parameter holds the corresponding stream handle.

5.2.21 Command Group Triggered**Definition**

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_CMD_GROUP_TRIGGERED	0x8010	Dev	Handle	Reserved	Error Code	

Description

This event notifies that a command group has been executed (either directly or via a configured external trigger). See section 2.17 "Command Groups" for more information.

Parameter

The parameter holds the corresponding transmit handle and error code.

5.2.22 Hand Control Module State Changed

Definition

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_SM_STATE_CHANGED	0x4000	Dev	New State			

Description

A hand control module was attached to or detached from the device.

Parameter

The parameter value will be one of:

SA_CTL_EVENT_PARAM_ATTACHED (0x00000001),

SA_CTL_EVENT_PARAM_DETACHED (0x00000000)

5.2.23 Emergency Stop Triggered

Definition

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_EMERGENCY_STOP_TRIGGERED	0x8030	Dev	Input Index			

Description

This event notifies that an emergency stop condition has been detected. See section 2.20.2 "Emergency Stop Mode" for more information.

Parameter

The parameter holds the index of the input that triggered the emergency stop. Index 0 if the digital device input of an I/O module triggered the event, index 1 if the global device input of a rack housing triggered the event.

5.2.24 External Input Triggered

Definition

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_EXT_INPUT_TRIGGERED	0x8040	Dev	Input Index			

Description

This event notifies that a falling or rising edge was detected on the external trigger input. See section 2.20.5 "Event Trigger Mode" for more information.

Parameter

The parameter holds the index of the input trigger. Index 0 if the digital device input of an I/O module triggered the event, index 1 if the global device input of a rack housing triggered the event.

5.2.25 Bus Resynchronization Triggered**Definition**

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_BUS_RESYNC_TRIGGERED	0x8050	Dev	N/A			

Description

This event notifies that the internal system bus synchronization has been triggered. Note that this event points to a hardware malfunction.

5.2.26 Unknown Command Received**Definition**

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_UNKNOWN_COMMAND_RECEIVED	0x8051	Dev	Packet Data			

Description

This event notifies that a command was received that is not known by the device. This may indicate that an API feature was used that is not supported.

Parameter

The parameter contains four bytes of the received packet starting from the command byte.

5.2.27 Request Ready

Definition

C Definition	Code	Index	63-32			
SA_CTL_EVENT_REQUEST_READY	0xf000	Any	Property Key			
			31-24	23-16	15-8	7-0
			Size	Data Type	Rq. Type	Rq. ID

Description

The request ready event is generated by the API when the result of an asynchronous request is received. The event is also generated in case of a request timeout or any other error. After the event has been received the result of the asynchronous operation can be retrieved using the `SA_CTL_ReadProperty_x`, `SA_CTL_WaitForWrite` functions. By waiting for this event, it is guaranteed that these functions won't block and return a result immediately. This event is not generated if the retrieve function for this request has already been called.

This event needs to be enabled using the Event Notification Options property.

Parameter

The parameters store information needed to retrieve the result of the asynchronous request. The index parameter is same index as passed to the request function. Depending on the property key this is either a device, module or channel index.

- **Rq. ID** The request ID is identical to the one returned by the asynchronous request function and can be used to associate this event with open requests.
- **Rq. Type** The request type allows to differentiate between read and write requests. Possible values are `SA_CTL_EVENT_REQ_READY_TYPE_READ` (0x00) or `SA_CTL_EVENT_REQ_READY_TYPE_WRITE` (0x01)
- **Data Type** Indicates the type of the requested property. This information is needed to call the correct `SA_CTL_ReadProperty_x` function. If the property read failed, the data type is unknown and has a value of `SA_CTL_DTYPE_NONE` (0xff). In this case any of the `SA_CTL_ReadProperty_x` functions can be used to retrieve the error code.
- **Size** The array size stores the size of the received value. For integer properties this is the number of elements and for string properties the number of characters. Note that for strings the required buffer size is one byte larger because of the null terminator. This field is only set for successful property read requests.
- **Property Key** Key of the requested property.

Parameters can be extracted using the following macros:

```
SA_CTL_EVENT_REQ_READY_ID(),
SA_CTL_EVENT_REQ_READY_TYPE(),
SA_CTL_EVENT_REQ_READY_DATA_TYPE(),
SA_CTL_EVENT_REQ_READY_ARRAY_SIZE(),
SA_CTL_EVENT_REQ_READY_PROPERTY_KEY()
```

5.2.28 Connection Lost

Definition

C Definition	Code	Index	31-24	23-16	15-8	7-0
SA_CTL_EVENT_CONNECTION_LOST	0xf001	N/A	N/A			

Description

The connection to the device has been lost. All functions requiring communication with the device will fail with `SA_CTL_ERROR_COMMUNICATION_FAILED`. After receiving this event the device should be closed using `SA_CTL_Close`.

6 ASCII INTERFACE

As an alternative to control the MCS2 using the SmarActCTL library, the device also supports control using an ASCII protocol. To simplify the entry and overall operation this protocol is (with some exceptions) strongly orientated towards the well established SCPI¹ standard.

The ASCII Interface is only available for devices with an ethernet port. For general information on how to configure the ethernet interface please refer to the *MCS2 User Manual* document.

6.1 Connection Setup

A connection to the device can be established via raw TCP/IP or by using a telnet client. The settings needed to access the ASCII Interface include:

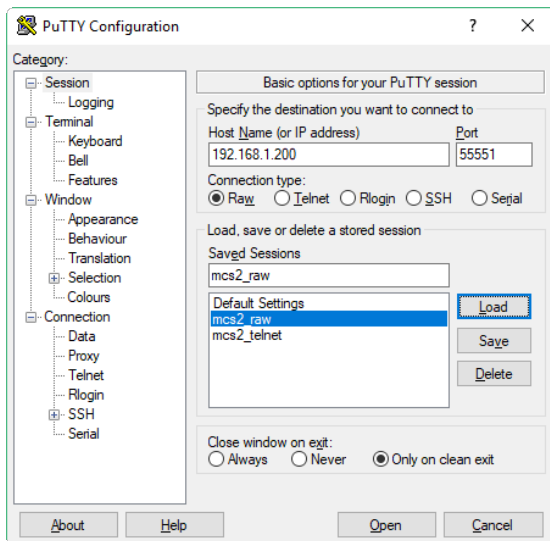
- the current IP address (default is 192.168.1.200).
- the fixed port number 55551.

One way to connect and communicate with the device through the ASCII Interface is by using a telnet client. In the following steps we will use the multipurpose client PuTTY² to read the serial number of an attached MCS2 controller.

1. Download and start PuTTY (www.putty.org)
2. In the tree view to the left select the **session** category
3. Select **raw** as connection type (see figure 6.1a)
4. Fill in the device's **IP** address and the correct **port** (55551)
5. Name and **save** the session options (optional)
6. A click on **open** will start the session (see figure 6.1b)
7. You are now ready to communicate with the device (e.g. to query the serial number).

¹Standard Commands for Programmable Instruments (www.ivifoundation.org/scpi)

²Open source SSH and telnet client PuTTY (www.putty.org)



(a) PuTTY Configuration Window



(b) PuTTY Terminal Window

Figure 6.1: Communicating with the MCS2 using PuTTY

6.1.1 Note On Message Termination

When communicating with the device via raw TCP/IP make sure to use the correct message termination for commands sent to and answers received from the device. The message termination characters used by the MCS2 are <CR><LF> (carriage return [0x0D] + line feed [0x0A]).

6.2 SCPI Basics

Initially developed due to the need of a common interface language between computers and instruments, SCPI is nowadays a well established open standard to communicate with all kinds of devices. Due to its easy to learn and mostly self-explanatory ASCII syntax it is usable with any computer language or application environment.

The following sections will give an overview on how to get started using SCPI with the MCS2. More information on the SCPI specification can be found on the IVI Foundation websites ³.

6.2.1 SCPI Conformance Information

Although being strongly orientated towards the SCPI standard (especially concerning the command syntax rules) we do not claim to be fully conform. Due to its rich set of functions and flexibility, the MCS2 does not fit in a predefined instrument class, but uses the well defined SCPI syntax and communication mechanisms for a convenient operation experience.

³www.ivifoundation.org/specifications/

6.2.2 Command Structure

SCPI differentiates between common and instrument commands. **Common commands** always start with an asterisk (*) and only consist of one keyword.

Common Command *IDN?

The behavior of these commands is mostly predefined by the standard and incorporates some general mechanisms like issuing a reset or reading global status bytes. Section 6.6.1 holds a table describing the common commands supported by the MCS2.

To access all the different properties and functions the MCS2 provides, **instrument commands** are used. These commands are device-dependent and follow a hierarchical tree system approach. Associated properties are therefore grouped into different subsystems (branches) creating a command tree like the one below.

```
[ :PROPerTy]      // "root"
  :DEVice         // "branch"
    :SNUMber      // "leaf"
    :STATe        // "leaf"
  :CHANnel#       // "branch"
    :VELocity     // "leaf"
```

As an example we now want to read the device's serial number. The assembling of a command always starts at the root of the tree. To obtain the value of a particular leaf the full path to it must be specified. This is achieved by traversing the command tree from root (:PROPerTy) to leaf (:SNUMber) and concatenate the different keywords on the way from left to right. When assembling commands, **colons** (:) are used to separate the different keywords. As result we get the full command string:

Instrument Command :PROPerTy:DEVice:SNUMber?

Square brackets ([]) enclose a keyword that is optional (default) and may be omitted. E.g. a command starting with the root may prepend or skip the optional [:PROPerTy] keyword:

- :PROPerTy:DEVice:SNUMber?
- :DEVice:SNUMber?

Each command has both a **long** and a **short form**. Only the exact long or the exact short form will be accepted with lower- and uppercase letters being ignored (case-insensitive).

The following commands would all be accepted by the MCS2:

```
Long Form (mixed case)      :PROPerTy:DEVice:SNUMber?
Long Form (all lower-case)  :property:device:snumber?
Short Form (all upper-case) :PROP:DEV:SNUM?
Short Form (all lower-case) :prop:dev:snum?
```

To keep track of long and short command forms, all of the following examples will use upper case letters for short commands and lower case letters for the remaining part of the corresponding long form.

An MCS2 may have a different number of channels and/or modules. To **address a particular module or channel**, the corresponding index has to be added when assembling the command. In general, if a command tree keyword contains a hash symbol (#), that symbol must be replaced by the desired module or channel index. Thus a `:CHANnel#` keyword becomes `:CHANnel2` when addressing the channel with index 2. Note that indexes are zero-based.

Many commands take an additional **command parameter**. Command and parameter must be separated by at least one space character. Command parameters can be of type 'numeric' (int32/64) and must then be given as integer value (e.g. 1000) or type 'string' and must then be surrounded with double quotes (e.g. "value").

For position-dependent properties the value must be given in the appropriate base unit (e.g. pm or n°). The following command requires the channel's move velocity as a parameter given in pm/s.

```
Set velocity for channel 0 to 1 mm/s :PROPerTy:CHANnel0:VELocity 1000000000
```

Note that *set* commands (as well as movement commands) do not generate a direct response. If an error is encountered it is stored in the error queue. (See section 6.3.8 "Error Handling".)

6.2.3 Compound Commands

Multiple commands may be sent in one message to the device (compound command). These commands have to be separated by **semicolons** (;). The first command must always be referenced to the root node (e.g. `:CHANnel0`). Subsequent commands however, are referenced to the same tree level as the previous command in a message:

```
Set channel 0 move mode      :CHANnel0:MMODE 1
Set channel 0 velocity      :CHANnel0:VELocity 10000
Set channel 0 acceleration  :CHANnel0:ACCeleration 0
Set all in one compound message :CHANnel0:MMODE 1;VELocity 10000;ACCeleration 0
```

Note that the maximum length of compound messages is limited to 256 characters and the required execution time may be higher compared to sending the same commands separated by the termination characters <CR><LF>. Sending a compound command message may also complicate error handling if one of the containing commands fails and its response value is omitted in the returned answer string.

It is therefore recommended to send each command as a single message to ensure a deterministic and performant program sequence.

6.2.4 Queries

To read the value of a specific device, module or channel property a **query command** has to be sent to the MCS2. Queries are generated by traversing the command tree and appending the final command with a question mark (?). The query form may be used for all properties which are readable. (See "Access" column in table 6.4 "Property Command Tree".) When the device receives a valid query form of a command, a response is generated containing the current setting or value associated with the property, e.g.:

```
Query velocity for channel 0 :PROPerTy:CHANnel0:VELocity?
Response (in pm/s)          1000000000
```

Note the following rules:

- Query responses do not include the command header or a unit but only the requested value.
- For numeric properties, the result is returned as an int32/64 type (see Property Summary).
- For string properties, the result is returned as string surrounded with double quotes ("value").
- Responses to compound query messages are separated by a semicolon (;).

Single Query	:CHANnel0:PTYPE?
Single Response	300
Single Query	:CHANnel0:MMODE?
Single Response	2
Compound Query	:CHANnel0:PTYPE?;MMODE?
Compound Response	300; 2
- If the query message is invalid no response is generated at all, but instead an error is stored in the error queue. (See section 6.3.8 "Error Handling".)

6.3 Basic Programming Examples

This section gives some examples how communication with the device may look like. All examples use the short command forms and omit the optional (default) :PROPerTy command tree keyword. For more info on long and short command forms, see 6.2.2 "Command Structure". Note that commands are only executed after the device receives the termination characters, see section 6.1.1 "Note On Message Termination".

6.3.1 Get Property

```
// get total number of channels from the from device
>> :DEV:NOCH?
// response
<< 3
```

6.3.2 Set Property

```
// set move mode to closed-loop relative (1) for channel 0
>> :CHAN0:MMOD 1
// no response is generated
```

6.3.3 Calibrate

```
// set calibration options for channel 0 (start direction: forward)
>> :CHAN0:CAL:OPT 0
// start calibration sequence
>> :CAL0
```

6.3.4 Reference

```
// set referencing options for channel 0 (default is 0)
>> :CHAN0:REF:OPT 0
// set move velocity [in pm/s or ndeg/s]
>> :CHAN0:VEL 1000000000
// set move acceleration [in pm/s2 or ndeg/s2]
>> :CHAN0:ACC 100000000000
// start referencing sequence
>> :REF0
```

6.3.5 Move

```
// set move mode to closed-loop relative (1) for channel 0
>> :CHAN0:MMOD 1
// set move velocity [in pm/s or ndeg/s]
>> :CHAN0:VEL 1000000000
// set move acceleration [in pm/s2 or ndeg/s2]
>> :CHAN0:ACC 100000000000
// start actual movement, value is interpreted as
// relative position (in pm)
>> :MOVE0 500000000
```

6.3.6 Stop

```
// send stop command to channel 0
>> :STOP0
```

6.3.7 Movement State

```
// get current state for channel 0
>> :CHAN0:STAT?
// response holds the state bitmask as int32 value
<< 37
// decoding the value leads to the following active state bits:
// - channel 0 is actively moving    (bit 0 is set)
// - channel 0 is calibrating        (bit 2 is set)
// - channel 0 has a sensor present (bit 5 is set)
```

6.3.8 Error Handling

Function calls or property queries do not return errors directly, instead errors are stored in an error queue.

This queue is implemented as FIFO⁴ and can be accessed by the :SYSTem:ERRor subsystem. If more than 32 errors have occurred, the last error stored in the queue (the most recent error) is replaced with -350, "Error queue overflow". No additional errors are stored until errors are removed from the queue.

Errors that occur during run-time can be detected by executing the following queries:

```
:SYSTem:ERRor:COUNT? Returns the number of errors the queue contains.
:SYSTem:ERRor[:NEXT]? Returns the next error in the form:
                        <error code>, "<Error string>" and removes it from
                        the queue. 0, "No Error" is returned if the queue is empty.
```

Error codes are signed integer values. Depending on the sign of an error code, it must be interpreted differently:

- A value of zero equals to "No Error",
- A negative value indicates a SCPI error which is usually caused by an incorrect assembling of a command message, see table 6.5 "SCPI Error Codes",
- A positive value indicates a SmarActControl error, see appendix A.1 "Error Codes".

A program sequence with error checking might look like the following:

```
// try to get the current state for channel 0
>> :CHAN0:STAT?!
// due to an invalid character in this command (!), there is no response
// by checking the error count
>> :SYST:ERR:COUN?
// we see that there is one error inside the error queue
<< 1
// to get more information we retrieve this error
>> :SYST:ERR:NEXT?
```

⁴First error In will be the First error Out

```
// and get the following response
<< -101,"Invalid character"
```

Note that when working with the error queue, it might already hold errors generated by previous commands. An incorrect command can even result in multiple errors being added to the queue. It is therefore good practice to query all possible errors before sending the next command.

6.4 Using Command Groups

Command groups offer the possibility to define an atomic group of commands that is executed synchronously. In addition, a command group may not only be triggered via software, but alternatively via an external trigger. For more general information on Command Groups please refer to section 2.17.

This section describes how to take advantage of Command Groups when using the ASCII interface.

6.4.1 Command Set

The following commands and queries are used to control a Command Group.

<code>:CGROUP:OPEN <triggerMode></code>	Opens a Command Group using the given trigger mode.
<code>:CGROUP:CLOSE</code>	Closes a previously opened Command Group.
<code>:CGROUP:ABORT</code>	Aborts a previously opened Command Group.
<code>:CGROUP:FINISHED?</code>	Indicates whether the Command Group is finished.
<code>:CGROUP:VALUES?</code>	Requests the values that were queried inside a Command Group.

Note that, when using the ASCII interface, the number of concurrently active Command Groups is limited to one. Figure 6.2 show the general process for either writing or reading multiple properties using a Command Group.

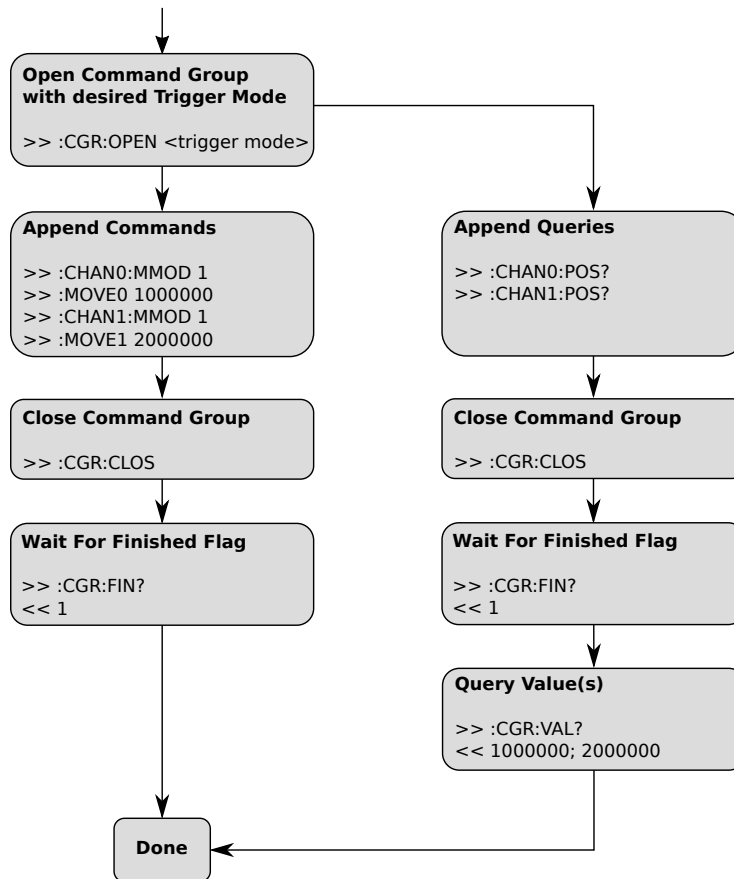


Figure 6.2: Command Group procedure(s)

The `CGR:OPEN` command is used to activate a Command Group using the given trigger mode. All of the following commands and queries will be appended to this Command Group. Note that properties missing the *Groupable* flag will lead to an error when put into a Command Group. Sending the `CGR:CLOS` command either starts the Command Group's execution immediately (trigger mode direct) or defers the execution until an external event occurs (trigger mode external).

The `CGR:FIN` query is used to check if execution of all grouped commands has been started or if the requested values are available (return code 1). It furthermore indicates if a Command Group has been aborted either by the user or the device itself (return code 2).

For finished Command Groups that contained at least one query, the `CGR:VAL` query is used to read the resulting values from the device.

6.4.2 Examples

This section contains some examples to further demonstrate the different use cases of Command Groups.

Synchronized movement using direct trigger

The following sequence uses a Command Group to synchronize the closed-loop movement of two channels. By using the Direct Trigger mode, the commands execution starts right after closing the Command Group.

```
// open command group in direct trigger mode (0)
// (every following command is not executed but put into the group)
>> :CGR:OPEN 0
// set move modes of channel 0 and 1 to closed-loop relative (1)
>> :CHAN0:MMOD 1
>> :CHAN1:MMOD 1
// move channel 0 to +1mm
>> :MOVE0 1000000000
// move channel 1 to +0.5mm
>> :MOVE1 500000000
// close command group
// (execution of grouped commands starts now)
>> :CGR:CLOS
// the command group's finished value signalizes
// that the command group has been processed
>> :CGR:FIN?
<< 1
```

Synchronized position query using direct trigger

The following sequence uses a Command Group to synchronize the position sampling of two channels. By using the Direct Trigger mode, the queries' execution starts right after closing the Command Group.

```
// open command group in direct trigger mode (0)
// (every following query is not executed but put into the group)
>> :CGR:OPEN 0
// query positions of channel 0 and 1
>> :CHAN0:POS?
>> :CHAN1:POS?
// close command group
// (execution of grouped commands starts now)
>> :CGR:CLOS
// the command group's finished value signalizes
// that the command group has been processed
>> :CGR:FIN?
<< 1
// we can now query the resulting value(s)
>> :CGR:VAL?
<< 1000000000; 500000000
```

Synchronized movement using external trigger

The following sequence uses a Command Group to synchronize the closed-loop movement of two channels. By using the External Trigger mode, the commands execution is deferred until the external event occurs. Note that the Input Trigger has to be configured accordingly in advance. See section 2.20 "Input Trigger" for more information.

```
// open command group in external trigger mode (1)
// (every following command is not executed but put into the group)
>> :CGR:OPEN 1
// set move modes of channel 0 and 1 to closed-loop relative (1)
>> :CHAN0:MMOD 1
>> :CHAN1:MMOD 1
// move channel 0 to +1mm
>> :MOVE0 1000000000
// move channel 1 to +0.5mm
>> :MOVE1 500000000
// close command group
// (execution of grouped commands is deferred)
>> :CGR:CLOS
// the command group's finished value signalizes
// that the command group has NOT been processed yet
>> :CGR:FIN?
<< 0
// ...
// process some other commands/queries
// ...
-> external event occurs
// the command group's finished value signalizes
// that the command group has now been processed
>> :CGR:FIN?
<< 1
```

6.5 Streaming Trajectories

Trajectory streaming allows a multi DoF manipulator to follow specific trajectories using the MCS2 controller. All participating positioners are moved synchronously along the defined trajectory. For more general information please refer to section 2.18 "Trajectory Streaming".

This section describes how to take advantage of Trajectory Streaming when using the ASCII interface.

6.5.1 Command Set

The following commands and queries are used to control a trajectory stream:

<code>:STReam:OPEN <triggerMode></code>	Opens a stream using the given trigger mode.
<code>:STReam:BFREe?</code>	Returns the number of free buffer slots.
<code>:STReam:FRAMe <frameData></code>	Transmits the desired frame.
<code>:STReam:CLOSe</code>	Closes a running stream.
<code>:STReam:ABORt</code>	Aborts a running stream.

Before starting a stream make sure to configure the following properties as desired:

Stream Base Rate Configures the stream base rate in Hz (See page 296).

Stream External Sync Rate Configures the external synchronization rate in Hz (See page 297).

Stream Options Configures the stream behavior (See page 298).

When using the ASCII interface, the maximum reachable streaming frequency is reduced, depending on the number of involved channels and the programming sequence. To prevent buffer under-/overruns, make sure to always supply enough stream frames according to the remaining free buffer slots.

Figure 6.3 shows the general procedure for a complete streaming sequence.

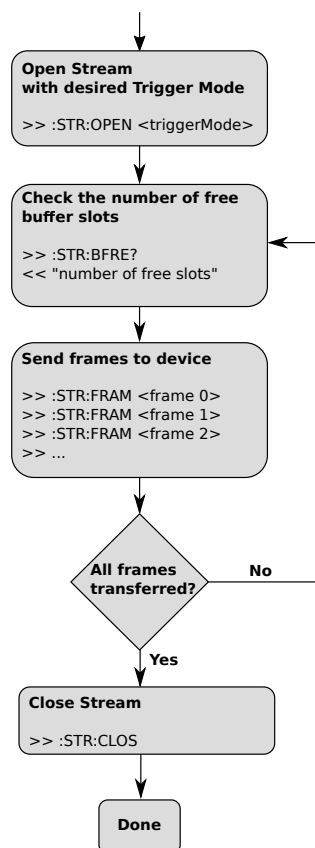


Figure 6.3: Streaming sequence

The `STR:OPEN` command is used to open a stream using the given trigger mode.

By reading the number of available buffer slots using the `STR:BFRE` query, the number of frames that can currently be transferred to the device can be calculated. The number of free buffer slots is given in positions, thus a stream containing two channels would take up two buffer slots. Using the `STR:FRAM` command, the device is now provided with the desired positions for each channel. A frame is assembled using a channel index following the corresponding absolute position, separated by comma. This mechanism is used until all frames have been sent to the device.

The `STR:CLOS` command is used to close the stream.

6.5.2 Example

The following example configures and sends a stream to the device containing positions for channel 0 and 1.

```
// configure the streaming base rate to 100Hz
>> :DEV:STR:BAS 100
// configure the streaming options to default (0)
>> :DEV:STR:OPT 0
// open stream in direct trigger mode (0)
>> :STR:OPEN 0
// check the current buffer level
>> :STR:BFRE?
<< 1024
// We have 1024 position buffer slots available.
// (This effectively results in 1024/numberOfChannels=512 frame slots)
// Now we transmit our frames containing positions for channel 0 and 1.
>> :STR:FRAM 0,1000000,1,100000
>> :STR:FRAM 0,2000000,1,150000
>> :STR:FRAM 0,3000000,1,200000
>> ...
// Streaming starts as soon as enough data has been received by the
// device. Repeat this process until all desired frames have been
// sent to the device.
// If all frames have been transferred, close the stream.
>> :STR:CLOS
// The remaining frames are processed until the stream is completed.
```

6.6 Command Summary

Section 6.6.1 contains an overview of the supported set of SCPI common commands and their behavior in the context of the MCS2. The following tables in section 6.3 and 6.4 show the command hierarchy as well as the necessary information to assemble all instrument commands available through the ASCII Interface.

6.6.1 Common Commands

In general, the ASCII Interface supports all mandatory common commands required by the SCPI standard. Nevertheless most of them are not needed for controlling the device. Table 6.1 gives an overview of the implemented common commands and their utilization.

Table 6.1 – Common Commands

Mnemonic	Name	Description
*CLS	Clear Status Command	This command clears all status data structures.
*ESE	Standard Event Status Enable Command	This command has no effect.
*ESE?	Standard Event Status Enable Query	This command has no effect.
*ESR	Standard Event Status Register Query	This command has no effect.
*IDN?	Identification Query	This command returns information about the device such as manufacturer and serial number.
*OPC	Operation Complete Command	This command has no effect.
*OPC?	Operation Complete Query	This command has no effect (will always return 1).
*RST	Reset Command	Resets the device. (A reconnect is necessary after this command!)
*SRE	Service Request Enable Command	This command has no effect.
*SRE?	Service Request Enable Query	This command has no effect.
*STB?	Read Status Byte Query	Returns the status byte.
*TST?	Self-Test Query	This command has no effect (will always return 0).
*WAI	Wait-to-Continue Command	This command has no effect.

6.6.2 System Commands

System commands are used to access the error queue and to perform a factory reset of the controller. Table 6.2 gives an overview of the implemented system commands.

Table 6.2 – System Commands

Mnemonic	Name	Description
:SYSTem:ERRor[:NEXT]?	Next Error	Returns the next error from the error queue. (See section 6.3.8 "Error Handling".)
:SYSTem:ERRor:COUNT?	Number of Errors	Returns the number of errors in the error queue. (See section 6.3.8 "Error Handling".)
:SYSTem:DEFault	Factory Reset	All properties are reset to their factory default values and the device is restarted. (A reconnect is necessary after this command!) Warning: The current device configuration will be lost after the reset and can not be restored. Therefore this command must be used with caution.

6.6.3 Movement Commands

Table 6.3 shows the commands that generate or stop movement. For detailed information on a movement command please follow the corresponding page to the Function Reference chapter.

Table 6.3 – Movement Summary

SCPI Command Tree	Type	Idx	Access	Page
:MOVE#	I64	Ch	W	166
:STOP#	-	Ch	W	168
:CALibrate#	-	Ch	W	162
:REFerence#	-	Ch	W	164

6.6.4 Property Command Tree

Table 6.4 shows the command hierarchy to access all the properties available for a proper device configuration. For detailed information on a property please follow the corresponding page to the Property Reference chapter.

Table 6.4 – Property Summary

SCPI Command Tree	Type	Idx	Access	Property	Page
[:PROPerTy]					
:DEvice					
:NOCHannels	I32	Dev	R	Number of Channels	182

Continued on next page

Table 6.4 – Continued from previous page

SCPI Command Tree	Type	Idx	Access	Property	Page
:NOBModules	I32	Dev	R	Number of Bus Modules	183
:ITYPE	I32	Dev	R	Interface Type	184
:STATe	I32	Dev	R	Device State	185
:SNUMber	String	Dev	R	Device Serial Number	186
:NAME	String	Dev	RW	Device Name	187
:ESTop					
:MODE					
[:CURRent]	I32	Dev	RW	Emergency Stop Mode	188
:DEFault	I32	Dev	RW	Default Emergency Stop Mode	189
:FAN:MINimum	I32	Dev	RW	Min Fan Level	190
:NETWork					
:DISCover					
:MODE	I32	Dev	RW	Network Discover Mode	192
:DHCP					
:TIMEout	I32	Dev	RW	Network DHCP Timeout	194
:STReaming					
:BASerate	I32	Dev	RW	Stream Base Rate	296
:SYNCrate	I32	Dev	RW	Stream External Sync Rate	297
:OPTions	I32	Dev	RW	Stream Options	298
:LOAD:MAXimum	I32	Dev	R	Stream Load Maximum	299
:HMODULE					
:LOPTIONs					
[:CURRent]	I32	Dev	RW	Hand Control Module Lock Options	353
:DEFault	I32	Dev	RW	Hand Control Module Default Lock Options	355
:TRIGger					
:INPut					
:SELeCt	I32	Dev	RW	Device Input Trigger Select	333
:MODE	I32	Dev	RW	Device Input Trigger Mode	335
:CONDition	I32	Dev	RW	Device Input Trigger Condition	337

Continued on next page

Table 6.4 – Continued from previous page

SCPI Command Tree	Type	Idx	Access	Property	Page
:MODUle#					
:PSUPply					
[:ENABled]	I32	Mod	RW	Power Supply Enabled	196
:TYPE	I32	Mod	R	Module Type	198
:STATe	I32	Mod	R	Module State	199
:NOMChannels	I32	Mod	R	Number of Bus Module Channels	197
:TEMPerature	I32	Mod	R	Bus Module Temperature	303
:IOModule					
:OPTions	I32	Mod	RW	I/O Module Options	328
:VOLTage	I32	Mod	RW	I/O Module Voltage	330
:AINPut					
:RANGe	I32	Mod	RW	I/O Module Analog Input Range	331
:AUXiliary					
:DINPut					
[:VALue]	I32	Mod	R	Aux Digital Input Value	323
:DOUtput					
[:VALue]	I32	Mod	RW	Aux Digital Output Value / Set / Clear	324
:SET	I32	Mod	W	Aux Digital Output Value / Set / Clear	324
:CLEar	I32	Mod	W	Aux Digital Output Value / Set / Clear	324
:AOUtput					
[:VALue] #	I32	Mod	RW	Aux Analog Output Value0 / Value1	326
:CHANnel#					
:AMPLifier					
[:ENABled]	I32	Ch	RW	Amplifier Enabled	202
:MODE	I32	Ch	RW	Amplifier Mode	204
:STARtup					
:OPTions	I32	Ch	RW	Startup Options	200
:PCONtrol					

Continued on next page

Table 6.4 – Continued from previous page

SCPI Command Tree	Type	Idx	Access	Property	Page
:OPTions	I32	Ch	RW	Positioner Control Options	206
:ACTuator					
:MODE	I32	Ch	RW	Actuator Mode	208
:CLINput					
[:SElect]	I32	Ch	RW	Control Loop Input	210
:SENSor					
:SElect	I32	Ch	RW	Sensor Input Select	212
[:VALue]	I64	Ch	R	Control Loop Input Sensor Value	247
:AUXiliary					
[:VALue]	I64	Ch	R	Control Loop Input Aux Value	248
:PTYPE					
[:CODE]	I32	Ch	RW	Positioner Type	214
:NAME	String	Ch	R	Positioner Type Name	216
:MMODE	I32	Ch	RW	Move Mode	217
:TYPE	I32	Ch	R	Channel Type	219
:STATE	I32	Ch	R	Channel State	220
:ERRor	I32	Ch	R	Channel Error	300
:POSition					
[:CURRent]	I64	Ch	RW	Position	221
:TARGet	I64	Ch	R	Target Position	223
:SCAN	I64	Ch	R	Scan Position	224
:MSHift	I32	Ch	RW	Position Mean Shift	244
:SCAN					
:VELocity	I64	Ch	RW	Scan Velocity	225
:HOLDtime	I32	Ch	RW	Hold Time	226
:VELocity	I64	Ch	RW	Move Velocity	228
:ACCEleration	I64	Ch	RW	Move Acceleration	230
:MCLFrequency					
[:CURRent]	I32	Ch	RW	Max Closed Loop Frequency	232

Continued on next page

Table 6.4 – Continued from previous page

SCPI Command Tree	Type	Idx	Access	Property	Page
:DEFault	I32	Ch	RW	Default Max Closed Loop Frequency	233
:STEP					
:FREQuency	I32	Ch	RW	Step Frequency	234
:AMPLitude	I32	Ch	RW	Step Amplitude	235
:FELimit	I64	Ch	RW	Following Error Limit	238
:FERRor	I64	Ch	R	Following Error	236
:FEMax	I64	Ch	R	Following Error Max	237
:BSOPTions	I32	Ch	RW	Broadcast Stop Options	239
:SENSor					
:MODE	I32	Ch	RW	Sensor Power Mode	240
:DELay	I32	Ch	RW	Sensor Power Save Delay	242
:SDIRection	I32	Ch	RW	Safe Direction	245
:LSCale					
:OFFSet	I64	Ch	RW	Logical Scale Offset	256
:INVersion	I32	Ch	RW	Logical Scale Inversion	257
:RLIMit					
:MIN[:CURRent]	I64	Ch	RW	Range Limit Min	259
:MAX[:CURRent]	I64	Ch	RW	Range Limit Max	260
:MIN:DEFault	I64	Ch	RW	Default Range Limit Min	261
:MAX:DEFault	I64	Ch	RW	Default Range Limit Max	262
:CALibration					
:OPTions	I32	Ch	RW	Calibration Options	263
:SCORrection					
:OPTions	I32	Ch	RW	Signal Correction Options	265
:REFerencing					
:OPTions	I32	Ch	RW	Referencing Options	267
:DTRMark	I32	Ch	R	Distance To Reference Mark	269
:DCINverted	I32	Ch	RW	Distance Code Inverted	270
:TEMPerature	I32	Ch	R	Channel Temperature	302

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Table 6.4 – Continued from previous page

SCPI Command Tree	Type	Idx	Access	Property	Page
:PFReason	I32	Ch	R	Positioner Fault Reason	304
:MOTor:LOAD	I32	Ch	R	Motor Load	306
:TTZVoltage					
:THReshold					
[:HOLD]	I32	Ch	RW	Target To Zero Voltage Hold Threshold	249
:ESTop					
:MODE	I32	Ch	RW	Channel Emergency Stop Mode	251
:INPosition					
:THReshold	I32	Ch	RW	In Position Threshold	252
:DElay	I32	Ch	RW	In Position Delay	254
:DIAG					
:CLFrequency:MAXimum	I32	Ch	R	Diag Closed Loop Frequency Max	308
:CLFrequency:AVERage	I32	Ch	R	Diag Closed Loop Frequency Avg	309
:CLFrequency:MTBase	I32	Ch	RW	Diag Closed Loop Frequency Measure Time Base	310
:AUXiliary					
:PTYPE	I32	Ch	RW	Aux Positioner Type	311
:PTName	String	Ch	R	Aux Positioner Type Name	313
:ISElect	I32	Ch	RW	Aux Input Select	314
:IOModule					
:INPut					
:INdex	I32	Ch	RW	Aux I/O Module Input Index	315
[:VALue] #	I32	Ch	R	Aux I/O Module Input0 / Input1 Value	319
:DINversion	I32	Ch	RW	Aux Direction Inversion	317
:CORRection:MAXimum	I32	Ch	RW	Aux Correction Max	321
:TRIGger					
:INPut					

Continued on next page

Table 6.4 – Continued from previous page

SCPI Command Tree	Type	Idx	Access	Property	Page
:MODE	I32	Ch	RW	Channel Input Trigger Mode	338
:CONDition	I32	Ch	RW	Channel Input Trigger Condition	340
:OUTPut					
:MODE	I32	Ch	RW	Channel Output Trigger Mode	341
:POLarity	I32	Ch	RW	Channel Output Trigger Polarity	343
:PWIDth	I32	Ch	RW	Channel Output Trigger Pulse Width	344
:PCOMpare					
:THReshold					
[:START]	I32	Ch	RW	Channel Position Compare Start Threshold	345
:INCRement	I32	Ch	RW	Channel Position Compare Increment	346
:DIRection	I32	Ch	RW	Channel Position Compare Direction	347
:LMIN	I64	Ch	RW	Channel Position Compare Limit Min	349
:LMAX	I64	Ch	RW	Channel Position Compare Limit Max	351
:TUNing					
:MTYPe	I32	Ch	R(W)	Positioner Movement Type	271
:CUSTom	I32	Ch	R(W)	Positioner Is Custom Type	273
:BASE					
:UNIT	I32	Ch	R(W)	Positioner Base Unit	274
:RESolution	I32	Ch	R(W)	Positioner Base Resolution	276
:HTYPe	I32	Ch	R(W)	Positioner Sensor Head Type	278
:RTYPe	I32	Ch	R(W)	Positioner Reference Type	279

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Table 6.4 – Continued from previous page

SCPI Command Tree	Type	Idx	Access	Property	Page
:GAIN					
:P	I32	Ch	R(W)	Positioner P Gain	281
:I	I32	Ch	R(W)	Positioner I Gain	282
:D	I32	Ch	R(W)	Positioner D Gain	283
:SHIFT	I32	Ch	R(W)	Positioner PID Shift	284
:AWINDup	I32	Ch	R(W)	Positioner Anti Windup	286
:ESDetection					
:DISTance	I32	Ch	R(W)	Positioner ESD Distance Threshold	288
:COUNter	I32	Ch	R(W)	Positioner ESD Counter Threshold	290
:THReshold					
:TREached	I32	Ch	R(W)	Positioner Target Reached Threshold	291
:THOLd	I32	Ch	R(W)	Positioner Target Hold Threshold	292
:WPRotectiOn	I32	Ch	RW	Positioner Write Protection	295
:SAVE	I32	Ch	W	Save Positioner Type	294

6.7 SCPI Error Codes

Table 6.5 – SCPI Error Codes

Code	Response	Definition / Description
0	0,"No error"	SCPI_ERROR_NO_ERROR No error occurred. Corresponds to an acknowledge.
-101	-101,"Invalid character"	SCPI_ERROR_INVALID_CHARACTER The command message contained an invalid character.
-103	-103,"Invalid separator"	SCPI_ERROR_INVALID_SEPARATOR The command message contained an invalid separator.
-104	-104,"Data type error"	SCPI_ERROR_DATA_TYPE_ERROR The command message contained an invalid data type.
-108	-108,"Parameter not allowed"	SCPI_ERROR_PARAMETER_NOT_ALLOWED The command message contained invalid parameter.
-109	-109,"Missing parameter"	SCPI_ERROR_MISSING_PARAMETER The command message is missing a parameter.
-113	-113,"Undefined header"	SCPI_ERROR_UNDEFINED_HEADER The command message does not exist for this device.
-151	-151,"Invalid string data"	SCPI_ERROR_INVALID_STRING_DATA The given string data is invalid.
-350	-350,"Queue overflow"	SCPI_ERROR_QUEUE_OVERFLOW An internal error queue overflow occurred. (See section 6.3.8 "Error Handling".)
-363	-363,"Input buffer overrun"	SCPI_ERROR_INPUT_BUFFER_OVERRUN An input buffer overrun occurred.

A CODE DEFINITION REFERENCE

A.1 Error Codes

Table A.1 – Error Codes

Code	C-Definition / Description
0x0000	SA_CTL_ERROR_NONE No error occurred. Corresponds to an acknowledge.
0x0001	SA_CTL_ERROR_UNKNOWN_COMMAND An unknown command opcode was received and the packet was dropped.
0x0002	SA_CTL_ERROR_INVALID_PACKET_SIZE Indicates that the size field of a packet does not match the packet structure.
0x0004	SA_CTL_ERROR_TIMEOUT A timeout occurred while receiving a complete packet.
0x0005	SA_CTL_ERROR_INVALID_PROTOCOL A packet was received that does not comply to a supported protocol.
0x000c	SA_CTL_ERROR_BUFFER_UNDERFLOW The targeted buffer is empty.
0x000d	SA_CTL_ERROR_BUFFER_OVERFLOW The targeted buffer is filled and has no more space for further data.
0x000e	SA_CTL_ERROR_INVALID_FRAME_SIZE The frame size of the packet is invalid.
0x0010	SA_CTL_ERROR_INVALID_PACKET A packet with an inconsistent structure was received.
0x0012	SA_CTL_ERROR_INVALID_KEY The given property key could not be resolved.
0x0013	SA_CTL_ERROR_INVALID_PARAMETER The passed parameter is not in the valid range.
0x0016	SA_CTL_ERROR_INVALID_DATA_TYPE Indicates that the data type of a parameter is invalid.
0x0017	SA_CTL_ERROR_INVALID_DATA The command could not be processed due to invalid data. (E.g. a calibration routine finished but could not generate valid data.)

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Table A.1 – Continued from previous page

Code	C-Definition / Description
0x0018	SA_CTL_ERROR_HANDLE_LIMIT_REACHED The command could not be processed because all available handles are currently in use.
0x0019	SA_CTL_ERROR_ABORTED The command has been aborted.
0x0020	SA_CTL_ERROR_INVALID_DEVICE_INDEX An invalid device index has been passed.
0x0021	SA_CTL_ERROR_INVALID_MODULE_INDEX An invalid module index has been passed.
0x0022	SA_CTL_ERROR_INVALID_CHANNEL_INDEX An invalid channel index has been passed.
0x0023	SA_CTL_ERROR_PERMISSION_DENIED The request cannot be processed due to an access violation.
0x0024	SA_CTL_ERROR_COMMAND_NOT_GROUPABLE The given command cannot be part of a command group.
0x0025	SA_CTL_ERROR_MOVEMENT_LOCKED The given command cannot be processed due to movements being locked.
0x0123	SA_CTL_ERROR_AMPLIFIER_LOCKED The given command cannot be processed because the amplifier is disabled and in the locked state.
0x0026	SA_CTL_ERROR_SYNC_FAILED A synchronization requirement could not be met. (E.g. the trajectory streaming was aborted due to a stream overload.)
0x0027	SA_CTL_ERROR_INVALID_ARRAY_SIZE The number of array elements is invalid for a given write array property command.
0x0028	SA_CTL_ERROR_OVERRANGE An over-range condition occurred.
0x0029	SA_CTL_ERROR_INVALID_CONFIGURATION The operation could not be started due to an invalid configuration of the component. (E.g. some other properties are not configured properly for the configured operation mode.)
0x0100	SA_CTL_ERROR_NO_HM_PRESENT The command could not be processed because no Hand-Control-Module is present.
0x0101	SA_CTL_ERROR_NO_IOM_PRESENT The command could not be processed because no I/O-Module is present.
0x0102	SA_CTL_ERROR_NO_SM_PRESENT The command could not be processed because no Sensor-Module is present.

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Table A.1 – Continued from previous page

Code	C-Definition / Description
0x0103	SA_CTL_ERROR_NO_SENSOR_PRESENT The command could not be processed because no sensor is present.
0x0104	SA_CTL_ERROR_SENSOR_DISABLED The command could not be processed because the sensor is disabled.
0x0105	SA_CTL_ERROR_POWER_SUPPLY_DISABLED The command could not be processed because the power supply is disabled.
0x0106	SA_CTL_ERROR_AMPLIFIER_DISABLED The command could not be processed because the amplifier is disabled.
0x0107	SA_CTL_ERROR_INVALID_SENSOR_MODE The command could not be processed with the current sensor mode setting. (E.g. the power save mode is not allowed while trajectory streaming.)
0x0108	SA_CTL_ERROR_INVALID_ACTUATOR_MODE The command could not be processed with the current Actuator Mode setting.
0x0109	SA_CTL_ERROR_INVALID_INPUT_TRIG_MODE The command could not be processed with the current Device Input Trigger Mode setting.
0x010a	SA_CTL_ERROR_INVALID_CONTROL_OPTIONS The command could not be processed with the current control options setting.
0x010b	SA_CTL_ERROR_INVALID_REFERENCE_TYPE The command could not be processed with the current reference type of the positioner.
0x010c	SA_CTL_ERROR_INVALID_ADJUSTMENT_STATE The command could not be processed with the current adjustment state.
0x010e	SA_CTL_ERROR_NO_FULL_ACCESS The command could not be processed because the MCS2 has not full access connection to a connected Picoscale sensor.
0x010f	SA_CTL_ERROR_ADJUSTMENT_FAILED An adjustment sequence failed.
0x0110	SA_CTL_ERROR_MOVEMENT_OVERRIDDEN A software commands a movement which is then interrupted by the Hand Control Module before it finished or vice versa.
0x0111	SA_CTL_ERROR_NOT_CALIBRATED The command could not be processed because the channel is not calibrated. See section 2.7.1 "Calibrating" for more information.
0x0112	SA_CTL_ERROR_NOT_REFERENCED The command could not be processed because the channel is not referenced.
0x0113	SA_CTL_ERROR_NOT_ADJUSTED The command could not be processed because the channel is not adjusted.

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Table A.1 – Continued from previous page

Code	C-Definition / Description
0x0114	SA_CTL_ERROR_SENSOR_TYPE_NOT_SUPPORTED The command could not be processed because the sensor type of the configured positioner is not supported from the hardware (e.g. from the sensor module).
0x0115	SA_CTL_ERROR_CONTROL_LOOP_INPUT_DISABLED The command could not be processed because the control-loop input is disabled. (See Control Loop Input property.)
0x0116	SA_CTL_ERROR_INVALID_CONTROL_LOOP_INPUT The command could not be processed because the control-loop input is invalid for the command. (E.g. the calibration and referencing movements cannot be started when the control-loop input is configured to 'aux in'.)
0x0117	SA_CTL_ERROR_UNEXPECTED_SENSOR_DATA The calibration routine could not be processed due to unexpected data from the position sensor. Check that the correct positioner type is configured and that the positioner has enough room to move freely before starting the calibration.
0x0118	SA_CTL_ERROR_NOT_PHASED The command could not be processed because the channel is not phased. See section 2.22 "Phasing of Electro-Magnetic Driven Positioners" for more information.
0x0119	SA_CTL_ERROR_POSITIONER_FAULT The command could not be processed because the channel detected a positioner fault.
0x011b	SA_CTL_ERROR_POSITIONER_TYPE_NOT_SUPPORTED The command could not be processed because the connected positioner type is not supported by the channel. Contact SmarAct to get a firmware update for your controller.
0x011c	SA_CTL_ERROR_POSITIONER_TYPE_NOT_IDENTIFIED The command could not be processed because the type of the connected positioner could not be identified.
0x011e	SA_CTL_ERROR_POSITIONER_TYPE_NOT_WRITEABLE The positioner type can not be set manually but is automatically configured by the positioner ID system. See section 2.6 "Positioner Types" for more information.
0x0121	SA_CTL_ERROR_INVALID_ACTUATOR_TYPE The command could not be processed with the current actuator type. (E.g. the trajectory streaming is not supported for dual-piezo hybrid positioners.)
0x0150	SA_CTL_ERROR_BUSY_MOVING The command could not be processed because the channel is currently busy performing a movement command. (E.g. disabling the velocity control while moving is not permitted.)
0x0151	SA_CTL_ERROR_BUSY_CALIBRATING The command could not be processed because the channel is currently busy performing a calibration sequence.

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Table A.1 – Continued from previous page

Code	C-Definition / Description
0x0152	SA_CTL_ERROR_BUSY_REFERENCING The command could not be processed because the channel is currently busy performing a referencing sequence.
0x0153	SA_CTL_ERROR_BUSY_ADJUSTING The command could not be processed because the channel is currently busy performing an adjustment sequence.
0x0200	SA_CTL_ERROR_END_STOP_REACHED An endstop was detected.
0x0201	SA_CTL_ERROR_FOLLOWING_ERR_LIMIT The following error exceeded the configured limit.
0x0202	SA_CTL_ERROR_RANGE_LIMIT_REACHED A configured position limit was hit.
0x0203	SA_CTL_ERROR_POSITIONER_OVERLOAD The command could not be processed because the channel detected an overload condition of the positioner. See section 2.9.1 "Movement Monitoring" for more information.
0x0205	SA_CTL_ERROR_POWER_SUPPLY_FAILURE A failure or under-voltage condition of the power supply was detected. See section 2.9.3 "Hardware Monitoring" for more information.
0x0206	SA_CTL_ERROR_OVER_TEMPERATURE The command could not be processed because a an over-temperature condition of a driver amplifier was detected.
0x0208	SA_CTL_ERROR_POWER_SUPPLY_OVERLOAD An overload condition of the power supply was detected. See section 2.9.3 "Hardware Monitoring" for more information.
0x0300	SA_CTL_ERROR_INVALID_STREAM_HANDLE The given stream handle is invalid.
0x0301	SA_CTL_ERROR_INVALID_STREAM_CONFIGURATION The configured streaming parameters are not supported by all modules.
0x0302	SA_CTL_ERROR_INSUFFICIENT_FRAMES This error is generated if the trajectory streaming was started without providing the minimum required number of frames. (A trajectory stream must consist of at least two frames.)
0x0303	SA_CTL_ERROR_BUSY_STREAMING The command could not be processed because the channel is currently participating in a trajectory stream.
0x0400	SA_CTL_ERROR_HM_INVALID_SLOT_INDEX An invalid slot index has been passed to the hand control module.

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Table A.1 – Continued from previous page

Code	C-Definition / Description
0x0401	SA_CTL_ERROR_HM_INVALID_CHANNEL_INDEX An invalid channel index has been passed to the hand control module.
0x0402	SA_CTL_ERROR_HM_INVALID_GROUP_INDEX An invalid group index has been passed to the hand control module.
0x0403	SA_CTL_ERROR_HM_INVALID_CH_GRP_INDEX An invalid channel group index has been passed to the hand control module.
0x0500	SA_CTL_ERROR_INTERNAL_COMMUNICATION An internal communication error occurred. This error usually indicates a hardware malfunction.
0x0501	SA_CTL_ERROR_EEPROM_BUFFER_OVERFLOW A property value could not be stored to the internal persistent memory due to an overflow of its write buffer.
0x7ffd	SA_CTL_ERROR_FEATURE_NOT_SUPPORTED Indicates that a requested feature is not available on the connected device.
0x7ffe	SA_CTL_ERROR_FEATURE_NOT_IMPLEMENTED Indicates that a feature is not yet implemented. The device may have to be update to a newer version.
0xf000	SA_CTL_ERROR_DEVICE_LIMIT_REACHED The maximum number of devices has been opened.
0xf001	SA_CTL_ERROR_INVALID_LOCATOR An invalid locator string has been passed.
0xf002	SA_CTL_ERROR_INITIALIZATION_FAILED Initialization of the specified device failed.
0xf003	SA_CTL_ERROR_NOT_INITIALIZED The device has not been initialized yet.
0xf004	SA_CTL_ERROR_COMMUNICATION_FAILED Communication with the device failed.
0xf006	SA_CTL_ERROR_INVALID_QUERYBUFFER_SIZE The given array size does not match the required size, e.g. the provided buffer is too small.
0xf007	SA_CTL_ERROR_INVALID_DEVICE_HANDLE An invalid device handle has been passed.
0xf008	SA_CTL_ERROR_INVALID_TRANSMIT_HANDLE An invalid transmit handle has been passed.
0xf00f	SA_CTL_ERROR_UNEXPECTED_PACKET_RECEIVED An unexpected packet has been received.
0xf010	SA_CTL_ERROR_CANCELED The function call has been canceled.

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Table A.1 – Continued from previous page

Code	C-Definition / Description
0xf013	SA_CTL_ERROR_DRIVER_FAILED The device could not be found due to a driver failure.
0xf016	SA_CTL_ERROR_BUFFER_LIMIT_REACHED The limit of available buffers has been reached.
0xf017	SA_CTL_ERROR_INVALID_PROTOCOL_VERSION A protocol version mismatch has been detected.
0xf018	SA_CTL_ERROR_DEVICE_RESET_FAILED The device software reset failed.
0xf019	SA_CTL_ERROR_BUFFER_EMPTY Action is not allowed with empty buffers (e.g. empty command group buffer).
0xf01a	SA_CTL_ERROR_DEVICE_NOT_FOUND The device specified in the locator could not be found.
0xf01b	SA_CTL_ERROR_THREAD_LIMIT_REACHED The maximum number of simultaneous calls for this function was reached.
0xf01c	SA_CTL_ERROR_NO_APPLICATION The device specified in the locator is not in the application state.

Sales partner / Contacts

Germany

SmarAct GmbH

Schuetten-Lanz-Strasse 9
26135 Oldenburg
Germany

T: +49 441 - 800 879 0
Email: info-de@smaract.com
www.smaract.com

France

SmarAct GmbH

Schuetten-Lanz-Strasse 9
26135 Oldenburg
Germany

T: +49 441 - 800 879 956
Email: info-fr@smaract.com
www.smaract.com

USA

SmarAct Inc.

2140 Shattuck Ave. Suite 302
Berkeley, CA 94704
United States of America

T: +1 415 - 766 9006
Email: info-us@smaract.com
www.smaract.com

China

Dynasense Photonics

6 Taiping Street
Xi Cheng District,
Beijing, China

T: +86 10 - 835 038 53
Email: info@dyna-sense.com
www.dyna-sense.com

Natsu Precision Tech

Room 515, Floor 5, Building 7,
No.18 East Qinghe Anning
Zhuang Road,
Haidian District
Beijing, China

T: +86 18 - 616 715 058
Email: chenye@nano-stage.com
www.nano-stage.com

Shanghai Kingway Optech Co.Ltd

Room 1212, T1 Building
Zhonggong Global Creative Center
Lane 166, Yuhong Road
Minhang District
Shanghai, China

Tel: +86 21 - 548 469 66
Email: sales@kingway-optech.com
www.kingway-optech.com

Japan

Physix Technology Inc.

Ichikawa-Business-Plaza
4-2-5 Minami-yawata,
Ichikawa-shi
272-0023 Chiba
Japan

T/F: +81 47 - 370 86 00
Email: info-jp@smaract.com
www.physix-tech.com

South Korea

SEUM Tronics

1109, 1, Gasan digital 1-ro
Geumcheon-gu
Seoul, 08594,
Korea

T: +82 2 - 868 10 02
Email: info-kr@smaract.com
www.seumtronics.com

Israel

Trico Israel Ltd.

P.O.Box 6172
46150 Herzeliya
Israel

T: +972 9 - 950 60 74
Email: info-il@smaract.com
www.trico.co.il