RM0005
Reference manual

QST standard communication protocol

Introduction

This manual provides details on the three possible communication interfaces which are offered by QST devices:

- Inter-Integrated Circuit (I^2C)
- Serial Peripheral Interface (SPI)
- Input/Output lines (I/O)

In addition, it describes the QST Standard Communication Protocol used to communicate between a QST (Slave) device and its Master device. This protocol ensures correct data transmission between both devices. It is built around a specific command set to offer more flexibility and system configurability.

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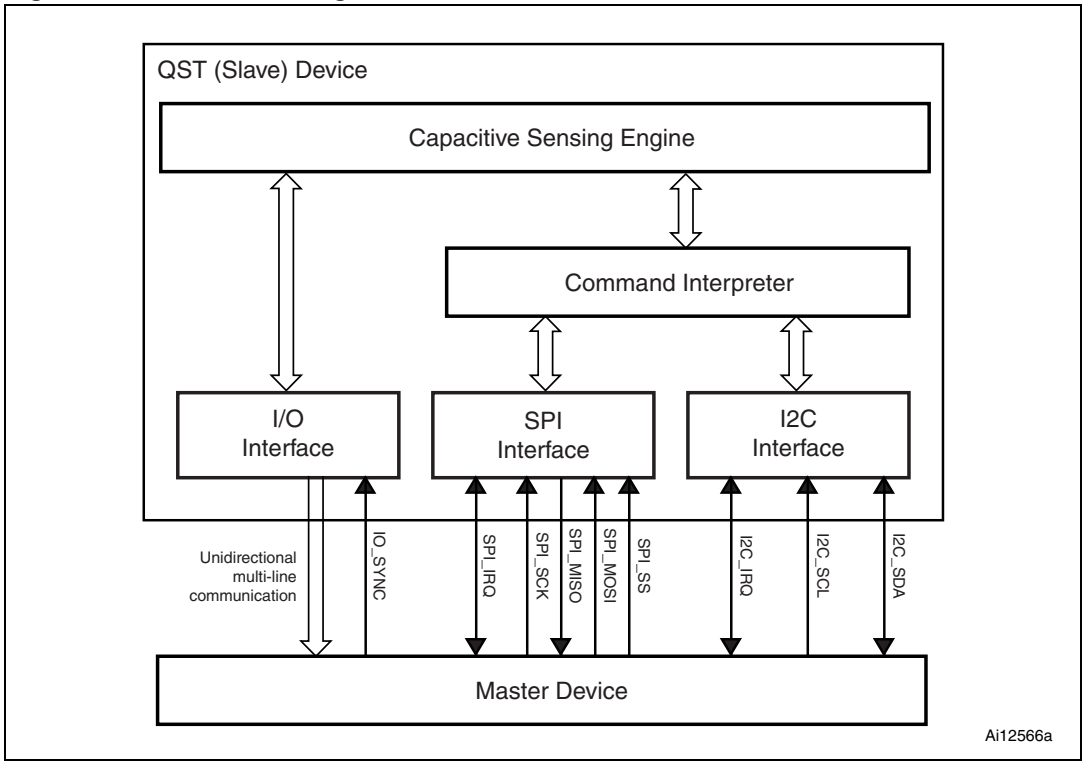
1 QST device architecture overview

The *Table 1* provides an overview of a QST (Slave) device:

- Capacitive Sensing Engine: this handles the management of the keys.
- Command Interpreter: it interprets the commands received from the Master device. It posts the corresponding requests to the Capacitive Sensing Engine and transmits the responses to the Master device through the dedicated interface.
- I/O Interface: it simply manages specific I/Os in output mode to report the state of the different keys.
- SPI Interface: it implements a basic protocol to format the Serial Peripheral Interface (SPI) bus communication in QST command format.
- I^2C Interface: it implements a basic protocol to format the Inter-Integrated Circuit (I^2C) bus communication in QST command format.

Figure 1. QST block diagram



2 I/O interface

2.1 Overview

The I/O interface is the most basic interface offered by a QST device. As a result, no command mechanism is allowed.

The QST device reports the system state via dedicated outputs (KOUTx). Depending on the device, several possible formats are available: Direct I/O or Encoded I/O (binary-coded for example).

An optional extra line (IO_SYNC) from the Master device to the QST (Slave) device may be added. This line acts as a synchronization signal forcing the QST (Slave) device to acquire sensing channels.

2.2 Optional signal

The IO_SYNC line allows a basic communication signal to synchronize the acquisition of the sensing channels with the Master device. The Master device must generate a pulse at logical level 0 for more than 2 µs and less than 4 µs. The falling edge of the IO_SYNC signal results in Slave acquisition.

3 SPI interface

3.1 Overview

The SPI interface is bidirectional and supports the complete command set described in *Section 6: Command description*.

This interface consists of the following hardware signals:

- SPI_SCK: clock used to synchronize data.
- SPI_MISO: data transfer line from QST (Slave) device to Master device.
- SPI_MOSI: data transfer line from Master device to QST (Slave) device.
- SPI_SS: Slave Select line (optional). It can be tied low to permanently select the QST device on the SPI bus.
- SPI_IRQ: bidirectional interrupt line (optional). This is an open drain output with a weak pull-up.

The SPI interface supports a clock frequency up to 100 kHz. This frequency is called 'Low Speed'. Phase and Polarity signals are respectively CPHA = 1 and CPOL = 1.

3.2 Packet encapsulation

As described in *Section 5: Protocol description*, the Master initiates communications at any time which are completed by the QST (Slave) device.

During Idle state, SPI_SCK is low and data lines are high.

As soon as SPI_SCK toggles, the Master sends Command packet bytes. After transmission of the complete Command packet, the SPI_MOSI continues to remain high continuously and the SPI_SCK can continue to clock the system or not.

When the Master wants to receive the Response packet, it must generate the SPI_SCK.

Within 16 bytes after receiving a Command packet, the QST (Slave) device must return a valid Response packet. While waiting to send the Response packet, the QST device continuously returns a dummy response (data bytes containing 0xFF) to the Master. If the Master receives 16 or more dummy response bytes, it should consider the QST (Slave) device as defective.

3.3 Optional signals

3.3.1 SPI_SS signal

When available on the QST (Slave) device, the Slave Select (SPI_SS) signal must be enabled (tied low) before any communication and must be kept low during the entire transaction process: from the beginning of the Command packet to the end of the Response packet.

3.3.2 SPI_IRQ signal

This is a bidirectional signal with two different significations:

- From the Master device to the QST (Slave) device: this is the SYNC signal. It synchronizes the acquisition of the sensing channels with the Master device
- From QST (Slave) device to the Master device: this is the IRQ signal. It informs the Master that a change has occurred in the QST (Slave) device state.

In Idle mode, the line is a logical level 1.

Master signal considerations

The Master device must generate a pulse at logical level 0 for more than 2 µs and less than 4 µs. Before and after this pulse generation, the Master must verify that the line is in Idle state. If it is not the case, it must wait for the Idle state to generate a valid SYNC signal.

During the Idle state, the Master device monitors the line for an IRQ signal from QST (Slave) device.

The falling edge of the SYNC signal results in Slave acquisition.

Slave signal considerations

The QST (Slave) device must generate a pulse at logical level 0 for more than 10 µs and less than 15 µs. It does not need to verify the line state before or after the pulse.

During the Idle state, the QST (Slave) device monitors the line for the SYNC signal from the Master device.

The falling edge or the signal level verification before or after the SYNC signal must be used to detect an IRQ signal.

4 I²C interface

4.1 Overview

The Inter-Integrated Circuit (I²C) interface is bidirectional and supports the complete command set described in *Section 6: Command description*.

This interface consists of the following hardware signals:

- I2C_SCL: I²C clock to synchronize data (from Master to Slave).
- I2C_SDA: bidirectional data transfer line.
- I2C_IRQ: bidirectional interrupt line (optional). This is an open drain output with a weak pull-up.

The I²C interface supports up two different I²C clock frequencies:

- 100 kHz: 'Low Speed' frequency (Default setting, must always be supported.)
- 400 kHz: 'High Speed' frequency

4.2 Packet encapsulation

As described in *Section 5: Protocol description*, the Master initiates communications at any time which are completed by the QST (Slave) device.

During Idle state, I2C_SCL and I2C_SDA are high in compliance with standard I²C communications. As a consequence, each byte is transmitted in 9 clock cycles (8 bits + acknowledge).

In case of a Non-Acknowledge signal on the bus, the complete transaction is discarded (Command and Response). As a consequence, a stop bit is generated by the Master and the system returns to the Idle state. The command is then ignored. The Master device can initiate a new communication.

The I²C Address is generated on the I²C bus as an extra byte (7-bit address) at the beginning of a Command and a Response packet.

After the complete Command packet has been sent, the I2C_SCL can continue to clock the system or not.

When the Master wants to receive the Response packet, it must activate the I2C_SCL. Waiting for the Response packet, the Master receives from the Slave a dummy response (data bytes containing 0xFF).

The Slave must send a valid Response packet within 16 bytes after the end of the Command packet. If the Master receives 16 or more dummy response bytes, it must consider the Slave as defective.

4.3 Optional signals

4.3.1 I2C_IRQ signal

This is the same signal as SPI_IRQ (see *Section 3.3.2: SPI_IRQ signal*).

5 Protocol description

5.1 Introduction

To ensure correct data transmission between Master and Slave devices, a standard communication protocol has been defined. This protocol formats the content of Master and Slave packets.

The Master device initiates all communications by sending a Command packet.

The Slave answers with a Response packet containing an ACK token if the data is ready or a STALL token if the command generates an error.

After a reset of the QST (Slave) device, all commands are stalled except GET_DEVICE_INFO.

5.2 Command packet format

Two types of Master Command packets are supported:

- Short Command packet used to send a basic and fast command to the QST (Slave) device with an optional short argument.
- Extended Command packet used to send complex commands to the QST (Slave) device with longer arguments.

The QST device identifies a short Command when Bit 7 of Command Byte 0 is set to '1'. This usually means a 1-byte command (no argument). In this case, the Argument bit is set to '0' and both the argument and the checksum fields are not sent (*Table 1*).

Table 1. Short Command packet format without argument

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	Command ID					Argument bit = 0	Parity bit

If the Argument bit is set to '1', the short Command packet contains 3 bytes which includes an argument and a checksum fields (*Table 2*).

Table 2. Short Command packet format with argument

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	Command ID					Argument bit = 1	Parity bit
1	Command argument							
2	8-bit checksum							

The QST device identifies an extended Command when Bit 7 of Command Byte 0 is set to '0'. The minimum length of this Command is 4 bytes. Argument and checksum fields are mandatory (*Table 3*).

Table 3. Extended Command packet format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	Command ID						
1	Length of 'Command arguments' field							
2	Command arguments							
Length +2	8-bit checksum							

5.3 Response packet format

The QST device (Slave) replies to a Command packet with a Response packet. The Response packet begins with either:

- ACK token (Bit 7 of Byte 0 is set to '0') if the data are ready to be sent.
- STALL token (Bit 7 of Byte 0 is set to '1') if the command generates an error.

The ACK token length depends on the command. Its minimum length is 1 byte (*Table 4*). The STALL token consists of one byte which includes an error code (*Table 6*).

Table 4. ACK short response packet format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	ACK token = 0	000000b						1

Or:

Table 5. ACK extended response packet format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	ACK token = 0	Length of 'Response data' field						Parity bit
1	Response data							
Length +1	8-bit checksum							

Or:

Table 6. STALL response packet format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	STALL token = 1	Error Code						Parity bit

5.4 Specific Command and Response fields

5.4.1 8-bit checksum

The 8-bit checksum used in Command and Response packets is the 8 least significant bits of the addition of all the packet bytes (except the checksum itself).

5.4.2 Parity bit

The parity bit embedded in the first byte of the packet causes the number of bits set to ‘1’ in this byte to be odd.

Example: 0x83 (STALL token = ‘1’, error code 0x01, Parity bit set to ‘1’).

5.4.3 Error code

This is the code associated with the STALL token. *Table 7* lists the legal values and significations for this field. All other values must be interpreted as an unknown error.

Table 7. Error codes associated with STALL token

Signification	v1.0	Error Code (6 bits)	STALL packet value (8 bits)
COMMAND_NOT_SUPPORTED	x	0x01	0x83
PARAMETER_NOT_SUPPORTED	x	0x02	0x85
PARITY_ERROR	x	0x10	0xA1
CHECKSUM_ERROR	x	0x11	0xA3
INITIALIZATION_PROCESS	x	0x30	0xE0

6 Command description

6.1 Command summary

These command sets are supported when using both I^2C and SPI communication interfaces. In I/O mode, the QST device is automatically configured and the settings cannot be dynamically changed.

6.1.1 Short Command set

Table 8. Short Command set

Command	v1.0 (1)	Command ID (5 bits)	Argument bit	Command byte
GET_PROTOCOL_VERSION	O	0x00	0	0x80
GET_DEVICE_INFO	M	0x01	0	0x85
SET_MAX_ON_DURATION	O	0x02	1	0x8A
SET_LOW_POWER_MODE	O	0x04	1	0x92
SET_KEY_ACTIVATION	O	0x05	1	0x97
CALIBRATE_KEY	M	0x06	0	0x98
	O	0x06	1	0x9B
SET_GPIO_MODE	O	0x07	1	0x9E
GET_KEY_STATE	M	0x10	0	0xC1
GET_KEY_ERROR	M	0x11	0	0xC4
	O	0x11	1	0xC7
GET_GPIO_STATE	O	0x12	0	0xC8
GET_DEBUG_INFO	O	0x1D	0	0xF4
			1	0xF7
RESET_DEVICE	O	0x1F	0	0xFD

1. M: Mandatory and O: Optional

6.1.2 Extended Command set

Table 9. Extended Command set

Command	v1.0 (1)	Command ID (7 bits)
SET_KEY_GROUP	O	0x00
SET_SCKEY_PARAMETERS	O	0x01
SET_MCKEY_PARAMETERS	O	0x02
SET_DETECT_INTEGRATORS	O	0x03
SET_DRIFT_COMPENSATION	O	0x04
SET_GPIO_STATE	O	0x08
SET_PWM_MODE	O	0x09

1. M: Mandatory and O: Optional

6.2 Short Command set description

6.2.1 GET_PROTOCOL_VERSION command

Command role

This is a Short Command without an argument.

This command returns the QST standard communication protocol version supported by the QST (Slave) device.

Master to Slave request

Table 10. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	00000b					0	0

Slave to Master ACK response

In case of success, the Slave returns the packet described in *Table 11*.

Table 11. Slave to Master ACK response format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	000011b						1
1	Main version of protocol							
2	Sub version of protocol							
3	Serial bus speed							
4	8-bit checksum							

Protocol version

Main and Sub version of the QST communication protocol implemented in the current device. These numbers are BCD-coded.

Serial bus speed

Defines the maximum speed frequency supported by the QST device:

0x00: 100 kHz 'Low Speed' frequency (Default setting, always supported.)

0x01: 400 kHz 'Full Speed'

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parity error

6.2.2 GET_DEVICE_INFO command

Command role

This is a Short Command without an argument.

This command returns the QST (Slave) device information: version, number of SCkey and MCkey, etc.

Master to Slave request

Table 12. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	00001b					0	1

Slave to Master ACK response

In case of success, the Slave returns the packet described in *Table 13*. The Slave must report at least the 4 first data bytes (minimum packet size is 6 bytes).

Table 13. Slave to Master ACK response format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	Length = N						Parity bit
1	Device main version							
2	Device sub-version							
3	Number of single-channel keys							
4	Number of multi-channel keys							
5	String info for system recognition (optional)							
N+1	8-bit checksum							

Device version

Main and sub- version of the current device. These numbers are BCD-coded.

Number of Single- or Multi-channel keys

The number of single-channel or multi-channel (slider/wheel) keys, in hexadecimal format.

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parity error

6.2.3 SET_MAX_ON_DURATION command

Command role

This is a Short Command with argument.

This command defines the Max On-Duration parameter. This is the maximum duration in seconds a key can be considered Active. This setting is applied to all keys.

Master to Slave request

Table 14. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	00010b					1	0
1	MaxOnDuration							
2	8-bit checksum							

MaxOnDuration

The MaxOnDuration value must be between 1 to 255 seconds, in hexadecimal format. If 0x00, it is considered as infinite.

Slave to Master ACK response

In case of success, the Slave returns a ACK response packet (*Table 4*).

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parameter not supported
- Parity error
- Checksum error

6.2.4 SET_LOW_POWER_MODE command

Command role

This is a Short Command with argument.

This command defines the low power mode of the QST (Slave) device.

Master to Slave request

Table 15. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	00100b					1	0
1	Device Frequency	Free Run in Detect	Sleep Duration Factor					
2	8-bit checksum							

Device Frequency

Defines the QST device operating frequency.

0: Device is running at reduced frequency (default setting).
1: Device is running at maximum frequency (refer to QST device datasheet for further information).

Free Run in Detect

Defines how the QST device will act when a low power mode is enabled and if a touch is detected.

0: Low power mode is suspended when detection is on-going.
1: Low power mode is authorized.

Sleep Duration Factor

This value is between 1 and 62, in hexadecimal format. The sleep mode duration is equal to 'Sleep Duration Factor' x 20 milliseconds.

0x00: Low power mode is disabled.
0x3F: Sleep is entered immediately with an infinite duration (deep sleep). The QST device is woken up at the next communication from the Master device. Please refer to QST device datasheet for further information.

Slave to Master ACK response

In case of success, the Slave returns a ACK response packet (*Table 4*).

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parameter not supported
- Parity error
- Checksum error

6.2.5 SET_KEY_ACTIVATION command

Command role

This is a Short Command with argument.

This command enables a specific key or all keys.

Master to Slave request

Table 16. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	00101b					1	1
1	Enable	Key Identifier						
2	8-bit checksum							

Key Identifier

Unique identifier for a single- or multi-channel key.

0000000: All keys
0000001: Key 1
0000010: Key 2
0000011: Key 3
...
1111111: Key 127

Enable

Enables selected key(s).

0: Key(s) disabled
1: Key(s) enabled

Slave to Master ACK response

In case of success, the Slave returns a ACK response packet (*Table 4*).

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parameter not supported
- Parity error
- Checksum error

6.2.6 CALIBRATE_KEY command

Command role

This is a Short Command with or without an argument.

This command launches the calibration process for all keys or a specific key.

Master to Slave request

Table 17. Master to Slave request format without argument

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	00110b					0	0

Or:

Table 18. Master to Slave request format with argument

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	00110b					1	1
1	Reserved (0)	Key Identifier						
2	8-bit checksum							

Key Identifier

Unique identifier for a single- or multi-channel key.

0000000: All keys
0000001: Key 1
0000010: Key 2
0000011: Key 3
...
1111111: Key 127

Slave to Master ACK response

In case of success, the Slave returns a ACK response packet (*Table 4*).

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parameter not supported
- Parity error
- Checksum error

6.2.7 SET_GPIO_MODE command

Command role

This is a Short Command with an argument.

This command configures the general-purpose inputs/outputs.

Master to Slave request

Table 19. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	00111b					1	0
1	Control	Direction	Config	GPIO Identifier				
2	8-bit checksum							

GPIO Identifier

Unique identifier for a GPIO.

00000: All GPIOs
00001: GPIO 1
00010: GPIO 2
00011: GPIO 3
...
11111: GPIO 31

Control, **Direction** and **Config**

These bits define the output mode of the selected GPIO(s) as shown in *Table 20*.

Table 20. GPIO output mode selection

Configuration			Output mode description
Control	Direction	Config	
0	x	x	Automatic mode, GPIO configuration is defined by the QST device (refer to QST device datasheet)
1	0	0	Controlled mode, Input floating
1	0	1	Controlled mode, Input interrupt with pull-up
1	1	0	Controlled mode, Output Open drain
1	1	1	Controlled mode, Output Push-Pull

Slave to Master ACK response

In case of success, the Slave returns a ACK response packet (*Table 4*).

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parameter not supported
- Parity error
- Checksum error

6.2.8 GET_KEY_STATE command

Command role

This is a Short Command without an argument.

This command returns the state of the complete system.

Master to Slave request

Table 21. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	10000b					0	1

Slave to Master ACK response

In case of success, the Slave returns the packet described in *Table 22*. The structure of this packet depends on the number of single- and multi-channel keys implemented in the QST device.

The description of the single-channel keys comes first and then the multi-channel keys. All multi-channel keys are described in 2 steps: first the state and then the absolute position.

Table 22. Slave to Master response format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	Length = N						Parity bit
1	SCK 8 state	SCK 7 state	SCK6 state	SCK 5 state	SCK 4 state	SCK 3 state	SCK 2 state	SCK 1 state
2	SCK 16 state	SCK 15 state	SCK 14 state	SCK 13 state	SCK 12 state	SCK 11 state	SCK 10 state	SCK 9 state
X	0	0	0	MCK3 state	MCK 2 state	MCK 1 state	SCK 18 state	SCK 17 state
X + 1	Multi-channel key 1 position							
X + 2	Multi-channel key 2 position							
N	Reserved	Key error code						
N+1	8-bit checksum							

SCKx or MCKx state

The state of the selected single- or multi-channel key. Note that the total number of single- or multi-channel keys can be obtained using the GET_DEVICE_INFO command.

0: Key is “untouched”
1: Key is “touched”

Multi-channel key x position

This is an 8-bit value representing the position of the slider/wheel (multi-channel key). Possible values are 0 to 255, in hexadecimal format, depending on the selected resolution. For more information, see *Section 6.3.3: SET_MCKEY_PARAMETERS command on page 29*.

Key error code

Key error code describes the errors in the system on all keys. It is a cumulative description.

Bit 0: Calibration in progress
Bit 1: Maximum count reached
Bit 2: Minimum count not reached
Bits 3 to 6: Reserved (0)

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parity error

6.2.9 GET_KEY_ERROR command

Command role

This is a Short Command with or without an argument.

This command returns the error state of the complete system or the error state of a specific key.

Master to Slave request

Table 23. Master to Slave request format without argument

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	10001b					0	0

Or:

Table 24. Master to Slave request format with argument

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	10001b					1	1
1	Reserved (0)	Key Identifier						
2	8-bit checksum							

Key Identifier

Unique identifier for a single- or multi-channel key.

0000000: All keys
0000001: Key 1
0000010: Key 2
0000011: Key 3
...
1111111: Key 127

Slave to Master ACK response

In case of success, the Slave returns the packet described in *Table 25* for a command without an argument or in *Table 26* for a command with an argument (specific key status request). The structure of the first packet depends on the number of single- and multi-channel keys implemented in the QST device.

The description of the single-channel key states and errors comes first and then the multi-channel key states and errors.

Table 25. Slave to Master response format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	Length = N						Parity bit
1	SCKey 1 State	SCKey 1 Error code						
2	SCKey 2 State	SCKey 2 Error code						

Table 25. Slave to Master response format (continued)

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
x	MCKey 1 State	MCKey 1 Error code						
N + 1	8-bit checksum							

Or:

Table 26. Slave to Master response format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	000001b						0
1	yCKey x State	yCKey x Error code						
2	8-bit checksum							

SCKey x or MCKey x State

State of the selected key.

0: Key is inactive.
1: Key is active.

SCKey x or MCKey x Error code

Key error code describes the errors of the selected key.

Bit 0: Calibration in progress
Bit 1: Maximum count reached
Bit 2: Minimum count not reached
Bits 3 to 6: Reserved (0)

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parameter not supported
- Parity error
- Checksum error

6.2.10 GET_GPIO_STATE command

Command role

This is a Short Command without an argument.

This command returns the state of the general-purpose inputs/outputs.

Master to Slave request

Table 27. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	10010b					0	0

Slave to Master ACK response

In case of success, the Slave returns the packet described in *Table 28*. The structure of this packet depends on the number of general-purpose inputs/outputs implemented in the QST device. As a consequence, rows 2 to 4 are optional.

Table 28. Slave to Master response format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	N						Parity bit
1	GPIO 8 state	GPIO 7 state	GPIO 6 state	GPIO 5 state	GPIO 4 state	GPIO 3 state	GPIO 2 state	GPIO 1 state
2	GPIO 16 state	GPIO 15 state	GPIO 14 state	GPIO 13 state	GPIO 12 state	GPIO 11 state	GPIO 10 state	GPIO 9 state
3	GPIO 24 state	GPIO 23 state	GPIO 22 state	GPIO 21 state	GPIO 20 state	GPIO 19 state	GPIO 18 state	GPIO 17 state
4	GPIO 32 state	GPIO 31 state	GPIO 30 state	GPIO 29 state	GPIO 28 state	GPIO 27 state	GPIO 26 state	GPIO 25 state
5	8-bit checksum							

GPIO x

Returns the GPIO x state.

0: GPIO state ‘0’
1: GPIO state ‘1’

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parity error

6.2.11 GET_DEBUG_INFO command

Command role

This is a Short Command with or without an argument.

This command returns the debug information for all keys or a specific key. This information can be used to analyze the QST capacitive sensing engine.

Master to Slave request

Table 29. Master to Slave request format without argument

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	11101b					0	0

Or:

Table 30. Master to Slave request format with argument

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	11101b					1	1
1	Reserved (0)	Key Identifier						
2	8-bit checksum							

Key Identifier

Unique identifier for a single- or multi-channel key.

0000000: All keys
0000001: Key 1
0000010: Key 2
0000011: Key 3
...
1111111: Key 127

Slave to Master ACK response

Note: If the debug information is larger than the maximum packet size, the information is truncated to this maximum size. For further information, please refer to QST device datasheet.

For a single-channel key, in case of success, the Slave returns the packet described in *Table 31*.

Table 31. Slave to Master response format for single-channel key

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	Length = 000101b						1
1	SCkey x debug state							
2	SCKey x Reference MSB							
3	SCKey x Reference LSB							
4	SCKey x Burst Count MSB							
5	SCKey x Burst Count LSB							
6	8-bit checksum							

Or:

For a multi-channel key, in case of success, the Slave returns the packet described in *Table 32*.

Table 32. Slave to Master response format for Multi-channel key

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	Length = 001110b						0
1	MCKey x debug state							
2	MCKey x 8-bit resolution position							
3	MCKey x Reference A MSB							
4	MCKey x Reference A LSB							
5	MCKey x Burst Count A MSB							
6	MCKey x Burst Count A LSB							
7	MCKey x Reference B MSB							
8	MCKey x Reference B LSB							
9	MCKey x Burst Count B MSB							
10	MCKey x Burst Count B LSB							
11	MCKey x Reference C MSB							
12	MCKey x Reference C LSB							
13	MCKey x Burst Count C MSB							
14	MCKey x Burst Count C LSB							
15	8-bit checksum							

Or:

If no argument command is used or if the argument is 0x00, the Slave returns a packet containing the individual information beginning with single-channel keys and finishing with multi-channel keys (see *Table 33*). The structure of this packet depends on the number of single- and multi-channel keys implemented in the QST (Slave) device. If the numbers of keys is too high, the report is shortened depending on the QST device.

Table 33. Slave to Master response format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	Length = N						Parity bit
1	SCkey 1 debug state							
2	SCKey 1 Reference MSB							
3	SCKey 1 Reference LSB							
4	SCKey 1 Burst Count MSB							
5	SCKey 1 Burst Count LSB							
6	SCkey 2 debug state							
7	SCKey 2 Reference MSB							
8	SCKey 2 Reference LSB							
M	MCKey 1 debug state							

Table 33. Slave to Master response format (continued)

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
M + 1	MCKey 1 8-bit resolution position							
M + 2	MCKey 1 Reference A MSB							
M + 3	MCKey 1 Reference A LSB							
M + 4	MCKey 1 Burst Count A MSB							
M + 5	MCKey 1 Burst Count A LSB							
M + 6	MCKey 1 Reference B MSB							
M + 7	MCKey 1 Reference B LSB							
M + 8	MCKey 1 Burst Count B MSB							
M + 9	MCKey 1 Burst Count B LSB							
M + 10	MCKey 1 Reference C MSB							
M + 11	MCKey 1 Reference C LSB							
M + 12	MCKey 1 Burst Count C MSB							
M + 13	MCKey 1 Burst Count C LSB							
N + 1	8-bit checksum							

SCKey x or MCKey x debug state

Provides the state of the capacitive sensing engine for the selected single- or multi-channel key. For more information, refer to the QST device datasheet.

SCKey x or MCKey x Reference

This is a 16-bit value for the reference value of the selected key after calibration (3 different values for the 3 electrodes in the wheel/slider structure).

SCKey x or MCKey x Burst Count (BC)

This is a 16-bit value for the most recent Burst Count executed (3 different values for the 3 electrodes in the wheel/slider structure).

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parameter not supported
- Parity error
- Checksum error

6.2.12 RESET_DEVICE command

Command role

This is a Short Command without an argument.

This command resets the QST (Slave) device after the response has been sent.

Master to Slave request

Table 34. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	11111b					0	1

Slave to Master ACK response

In case of success, the Slave returns a ACK response packet (*Table 4*). The reset is generated after the response packet has been sent.

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parity error

6.3 Extended Command set description

6.3.1 SET_KEY_GROUP command

Command role

This command defines the AKS strategy on the system. It defines for each key the Group ID to which this key is assigned and also how the Group will behave.

Master to Slave request

The structure of this packet depends on the number of single- and multi-channel keys implemented in the QST device. The description of the single-channel keys comes first and then the multi-channel keys.

Table 35. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0x00						
1	Length = N							
2	G8 Mode	G7 Mode	G6 Mode	G5 Mode	G4 Mode	G3 Mode	G2 Mode	G1 Mode
3	G8 for SCK1	G7 for SCK 1	G6 for SCK 1	G5 for SCK 1	G4 for SCK 1	G3 for SCK 1	G2 for SCK 1	G1 for SCK 1
4	G8 for SCK 2	G7 for SCK 2	G6 for SCK 2	G5 for SCK 2	G4 for SCK 2	G3 for SCK 2	G2 for SCK 2	G1 for SCK 2
M	G8 for MCK1	G7 for MCK1	G6 for MCK1	G5 for MCK1	G4 for MCK1	G3 for MCK1	G2 for MCK1	G1 for MCK1
N + 2	8-bit checksum							

Gx Mode

Defines the group x AKS operating mode.

0: Locking AKS.
1: Unlocking AKS.

Gx for SCKy or MCKy

Assigns the selected single-channel key to the selected group.

0: No Group is selected and the current Key does not follow AKS.
1: Single- or multi-channel key (SCKy or MCKy) is part of Group Gx. In this case, the key detection is mutually exclusive with other keys of Group Gx.

Slave to Master ACK response

In case of success, the Slave returns a ACK response packet (*Table 4*).

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parameter not supported
- Checksum error

6.3.2 SET_SCKEY_PARAMETERS command

Command role

This command defines the threshold and hysteresis values used for single-channel key activation detection. The new setting is valid either for a specific key or for all keys.

Master to Slave request

Table 36. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0x01						
1	Length = 0x04							
2	Relative Values	Key Identifier						
3	Detection Threshold							
4	End of Detection Threshold							
5	Positive Recalibration Threshold							
6	8-bit checksum							

Key Identifier

Unique identifier for a single-channel key.

0000000: All keys
0000001: Key 1
0000010: Key 2
0000011: Key 3
...
1111111: Key 127

Relative Values

Defines how the argument values are expressed.

0: Argument values are expressed in absolute number.
1: Argument values are expressed in percentage of the Key's Reference Parameter = (0,1 x 'Reference' x 'Argument value')%.

Detection Threshold

The Detection Threshold is the difference between the 'Reference' and 'Burst Count' values used to declare detection. This value is signed and must be between –1 and –128.

End of Detection Threshold

The End of Detection Threshold is the difference between the 'Reference' and 'Burst Count' values used to declare the end of the detection condition. This value is signed and must be between –1 and –128.

Positive Recalibration Threshold

The Positive Recalibration Threshold is the difference between the 'Reference' and 'Burst Count' values used to declare an error needing a recalibration. This value is signed and must be between 1 and 128.

Slave to Master ACK response

In case of success, the Slave returns a ACK response packet (*Table 4*).

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parameter not supported
- Checksum error

6.3.3 SET_MCKEY_PARAMETERS command

Command role

This command defines the threshold, hysteresis and resolution values used for Multi-Channel Key activation detection. The new setting is valid either for a specific key or for all keys.

Master to Slave request

Table 37. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0x02						
1	Length = 0x07							
2	Relative Values	Key Identifier						
3	Detection Threshold							

Table 37. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
4	End of Detection Threshold							
5	Positive Recalibration Threshold							
6	Resolution							
7	Direction Change Integrator							
8	Direction Change Threshold							
9	8-bit checksum							

Key Identifier

Unique identifier for a multi-channel key.

0000000: All keys
0000001: Key 1
0000010: Key 2
0000011: Key 3
...
1111111: Key 127

Relative Values

Defines how the argument values are expressed.

0: Argument values are expressed in absolute number.
1: Argument values are expressed in percentage of the Key's Reference Parameter = (0,1 x 'Reference' x 'Argument value')%.

Detection Threshold

The Detection Threshold is the difference between the 'Reference' and 'Burst Count' values used to declare detection. This value is signed and must be between –1 and –128.

End of Detection Threshold

The End of Detection Threshold is the difference between the 'Reference' and 'Burst Count' values used to declare the end of the detection condition. This value is signed and must be between –1 and –128.

Positive Recalibration Threshold

The Positive Recalibration Threshold is the difference between the 'Reference' and 'Burst Count' values used to declare an error needing a recalibration. This value is signed and must be between 1 and 128.

Resolution

The Resolution is the number of bits used to encode the absolute position value (slider/wheel) returned for a multi-channel key. This value must be between 1 to 16, in hexadecimal format.

Direction Change Integrator

The Direction Change Integrator is the number of acquisitions needed to validate a change in the direction of the variation of the MCKey position. This value must be between 0 and 255.

Direction Change Threshold

The Direction Change Threshold is the minimum number of steps of the MCKey position to accept a change in the direction of the variation of this MCKey position. This value must be between 0 and 255.

Slave to Master ACK response

In case of success, the Slave returns a ACK response packet (*Table 4*).

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parameter not supported
- Checksum error

6.3.4 SET_DETECT_INTEGRATORS command

Command role

This command defines the Detection Integrator, End of Detection Integrator and Positive Recalibration Integrator parameters. The new setting is valid either for all keys or a specific key.

Master to Slave request

Table 38. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0x03						
1	Length = 0x04							
2	Reserved (0)	Key Identifier						
3	Detection Integrator							
4	End of Detection Integrator							
5	Positive Recalibration Integrator							
6	8-bit checksum							

Key Identifier

Unique identifier for a single- or multi-channel key.

0000000: All keys
0000001: Key 1
0000010: Key 2
0000011: Key 3
...
1111111: Key 127

Detection Integrator (DI)

The Detection Integrator is the number of acquisitions needed to confirm a detection change in the Key state. This value must be between 1 to 255, in hexadecimal format.

End of Detection Integrator (EDI)

The End of Detection Integrator is the number of acquisitions needed to confirm a end of detection change in the Key state. This value must be between 1 to 255, in hexadecimal format.

Positive Recalibration Integrator

The Positive Recalibration Integrator is the number of acquisitions needed to confirm a calibration of a key. This value must be between 1 to 255, in hexadecimal format.

Slave to Master ACK response

In case of success, the Slave returns a ACK response packet (*Table 4*).

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parameter not supported
- Checksum error

6.3.5 SET_DRIFT_COMPENSATION command

Command role

This command defines the Drift Compensation parameters. The new setting is valid either for a specific key or for all keys.

Master to Slave request

Table 39. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0x04						
1	Length = 0x05							
2	Reserved (0)	Key Identifier						
3	Positive Drift Integrator							
4	Negative Drift Integrator							
5	Common Time Step Factor							
6	Differential Time Step Factor							
7	8-bit checksum							

Key Identifier

Unique identifier for a single- or multi-channel key.

0000000: All keys
0000001: Key 1
0000010: Key 2
0000011: Key 3
...
1111111: Key 127

Positive Drift Integrator

This is the number of acquisitions with a count higher than the ‘Reference’ value to consider drifting. This value must be between 1 to 255, in hexadecimal format.

Negative Drift Integrator

This is the number of acquisitions with a count lower than the ‘Reference’ value to consider drifting. This value must be between 1 to 255, in hexadecimal format.

Common Time Step Factor

Time interval between two Common Drift verifications. This value should be high (fast). Time = ‘Common Time Step Factor’ x 10 milliseconds. This value must be between 0 and 255, in hexadecimal format. If 0x00, the common drift is disabled.

Differential Time Step Factor

Time interval between two Differential Drift verifications. This value should be low (slow). Time = ‘Differential Time Step Factor’ x 10 milliseconds. This value must be between 0 and 255, in hexadecimal format. If 0x00, the common drift is disabled.

Slave to Master ACK response

In case of success, the Slave returns a ACK response packet (*Table 4*).

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parameter not supported
- Parity error
- Checksum error

6.3.6 SET_GPIO_STATE command

Command role

This command sets the GPIO lines in the appropriate state. It only acts on the GPIOs configured in output mode.

Master to Slave request

The structure of this packet depends on the number of general-purpose inputs/outputs implemented in the QST device. As a consequence, rows 3 to 5 are optional.

Table 40. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0x08						
1	Length = N							
2	GPIO 8 state	GPIO 7 state	GPIO 6 state	GPIO 5 state	GPIO 4 state	GPIO 3 state	GPIO 2 state	GPIO 1 state
3	GPIO 16 state	GPIO 15 state	GPIO 14 state	GPIO 13 state	GPIO 12 state	GPIO 11 state	GPIO 10 state	GPIO 9 state
4	GPIO 24 state	GPIO 23 state	GPIO 22 state	GPIO 21 state	GPIO 20 state	GPIO 19 state	GPIO 18 state	GPIO 17 state

Table 40. Master to Slave request format (continued)

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
5	GPIO 32 state	GPIO 31 state	GPIO 30 state	GPIO 29 state	GPIO 28 state	GPIO 27 state	GPIO 26 state	GPIO 25 state
6	8-bit checksum							

GPIO x

Sets the GPIO x output state.

0: GPIO output state '0'
1: GPIO output state '1'

Slave to Master ACK response

In case of success, the Slave returns a ACK response packet (*Table 4*).

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parameter not supported
- Checksum error

6.3.7 SET_PWM_MODE command

Command role

This command configures the PWM output.

Master to Slave request

Table 41. Master to Slave request format

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0x09						
1	Length = 0x05							
2	Enable	Mode	Reserved (0)	GPIO Identifier				
3	PWM Frequency Factor							
4	PWM Duty Cycle							
5	PWM Duration factor							
6	PWM Step for Multi-Channel Key							
7	8-bit checksum							

GPIO Identifier

Unique identifier for a GPIO.

00000: All GPIOs
00001: GPIO 1
00010: GPIO 2
00011: GPIO 3
...
11111: GPIO 31

Enable

Enable the selected GPIO(s) PWM output.

0: GPIO(s) PWM output disabled.
1: GPIO(s) PWM output enabled.

Mode

Defines the PWM output mode of the selected GPIO.

0: Automatic (please refer to QST device datasheet for further information on the automatic mode)
1: Controlled

PWM Frequency Factor

Defines the PWM output frequency. If 0x00, the PWM signal is continuously generated. Other values follow a logarithm law: $f_{PWM} = 10^{(Frequency\ Factor-1)/64}$

This calculation gives possible values between 1 Hz to 9.3 kHz. The implementation in the QST device can be limited to certain values.

PWM Duty Cycle

Defines the PWM output duty cycle. This value must be between 0 to 100 and is expressed in percentage.

PWM Duration Factor

In Automatic mode, this is the duration of the PWM output activation before coming back to Idle state. PWM Duration = 'Duration Factor' x 10 ms. This value must be between 1 and 255.

PWM Step for Multi-Channel key

In Automatic mode, this is the stepping variation to activate the PWM output for the PWM duration.

Slave to Master ACK response

In case of success, the Slave returns a ACK response packet (*Table 4*).

Slave to Master STALL response

If an error is detected by the Slave, it returns a STALL response packet (*Table 6*). The possible error codes are:

- Command not supported
- Parameter not supported
- Checksum error

Appendix A Glossary

Adjacent Key Suppression (AKS): This is the algorithm used to prevent several keys from being active at the same time.

'Burst Count' Level (BC): This is a 16-bit value representing the number of pulses generated during the last acquisition (burst sequence).

'Delta' Level: This is a 16-bit value based on the difference between the 'Reference' and the 'Burst Count' levels. It is used to determine the state of a key by comparing it to some defined thresholds.

Detection Threshold: Difference between number of pulses used as reference for a key and the current measurement of number of pulses on this key to confirm key touch detection. Note that this value is negative as the reference is always higher than a measurement during activation.

Detection Integrator (DI): It is the number of acquisitions (Burst sequences) needed to confirm key touch detection.

Duration Factor: Integer, Number of predetermined period of time during which the corresponding Output is active.

End of Detection Integrator (EDI): It represents the number of detection sequences (Burst sequences) needed to confirm that the key has been inactivated (released).

End of Detection Threshold: Same as Detection Threshold for inactivation detection. The difference between Detection Threshold and End of Detection Threshold gives an hysteresis ensuring the system stability.

Frequency Factor: Integer used to set the PWM frequency.

GPIO ID: GPIO Identifier. This is a unique integer from 1 to 32 which identifies a General Purpose Input/Output.

Key ID: Key Identifier. This is a unique integer from 1 to 127 which identifies a key. SCKey and MCKey must have different KeyID.

Key Group: It defines a group of keys (represented by their KeyID) to which the AKS is applied.

Locking AKS: Once one key touch is detected, all other keys are locked in the "untouched" state until the touch is removed (key becomes "untouched").

MaxOnDuration: Maximum amount of time during which a key can be considered Active. After this duration, if a key is still active, it is recalibrated.

MCKey: Multi-Channel Key. This is a key which uses several channels. It can be QWheel, QSlide or others.

Negative Drift Integrator: It is the number of acquisitions (Burst sequences) needed to confirm that the reference of the key must be decreased.

Positive Drift Integrator: It is the number of acquisitions (Burst sequences) needed to confirm that the reference of the key must be increased.

Positive Recalibration Integrator: It is the number of acquisitions (Burst sequences) needed to confirm that a new calibration must be launched.

Positive Recalibration Threshold: Difference between number of pulses used as reference for a Key and the current measurement of number of pulses on this key to confirm that a

new calibration must be launched. Note that this value is positive as the reference is always lower than the measurement when recalibration is needed.

‘Reference’ Level: This is a 16-bit value representing the number of pulses generated during the calibration phase.

Resolution: This value is relative to MCKeys only. It gives the absolute position of a wheel or slider structure.

SCKey: Single-Channel Key. This is a key which uses 1 channel only, typically QTouch or QMatrix.

Step for Multi-Channel Key: Difference between previous position and current position of a MCKey needed to activate the PWM signal.

Time Step Factor: Integer, Number of predetermined period of time between two consecutive Drift condition verifications.

Unlocking AKS: On each acquisition, the signal strengths from each key are compared and this is the one with the highest signal level which is declared as active one.

Revision history

Table 42. Document revision history

Date	Revision	Changes
26-Sep-2007	1	Initial release.
19-Nov-2007	2	Updated Length values in *Table 31* in *Section 6.2.11: GET_DEBUG_INFO command on page 23* and in *Table 39* in *Section 6.3.5: SET_DRIFT_COMPENSATION command on page 32*. Updated *SET_DETECT_INTEGRATORS command* name. Updated *SET_MCKEY_PARAMETERS command* parameters. Updated *Table 37* in *Section 6.3.5: SET_DRIFT_COMPENSATION command on page 32*.

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