AZD088 IQS263 Communications Interface Guideline

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1. Introduction

1.1 Abstract

The IQS263 is a 3-channel I²C compatible device with multiple configuration options via a memory map.

The purpose of this document is:

1. To understand the I²C compatible interface
2. To support the example code provided for evaluation and driver development

Please note that a full description of features can be found in the IQS263 datasheet.

1.2 Connection description

The diagram below describes the hardware requirement for communicating with the IQS263.

**Please note the importance of using the RDY line and not only the SDA and SCL connections. See section 1.3 for more details.

![IQS263 hardware connection diagram](image-url)

Figure 1.1 IQS263 hardware connection diagram
1.3 Communication window description

<table>
<thead>
<tr>
<th>Streaming mode (polling at various times – example only)</th>
<th>Event mode (comms window only during event)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IQS263 will only allow for communication within a certain time-slot. Outside of this “slot” the device will give preference to capacitive conversions, calculations or sleep. With the specific implementation on the IQS263, the master device must:</td>
<td></td>
</tr>
<tr>
<td>1. read the bidirectional “RDY” I/O from the IQS263</td>
<td></td>
</tr>
<tr>
<td>2. only poll the device during the RDY = low period</td>
<td></td>
</tr>
<tr>
<td>3. create a communication window (useful in event mode) by writing the “RDY” low and poll the slave until ACK is received</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1.2 IQS263 Master-Slave interface options description
2. I2C communication protocol

The IQS263 slave device interfaces to a master controller via a 3-wire (SDA, SCL and RDY) serial interface bus and is I2C™ compatible, with a maximum communication speed of 400kbit/s.

Compatibility with various I2C libraries must be ensured by following the guidelines in this document.

The IQS263 can be used in 3 different modes:

<table>
<thead>
<tr>
<th>Mode</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streaming mode</td>
<td>recommended for initialization periods</td>
</tr>
<tr>
<td></td>
<td>Switch to event mode after initialization</td>
</tr>
<tr>
<td>Event mode</td>
<td>recommended for keeping power consumption minimal</td>
</tr>
<tr>
<td></td>
<td>recommended for minimizing bus communications and processor load</td>
</tr>
<tr>
<td>Force communication (polling)</td>
<td>recommended for event mode systems</td>
</tr>
<tr>
<td></td>
<td>Implement for case where communications are required, but no events are present</td>
</tr>
<tr>
<td></td>
<td>force open a communication window</td>
</tr>
</tbody>
</table>

2.1 RDY line description

RDY line (bi-directional)

- Indicator for master device (MCU)
- Indicator for when sensing is paused
- MCU output to force communications

VDDHI

IQS263

0V

RDY = LOW

- Communication window open
- Capacitive sensing paused
2.2 RDY line – known issues and workarounds

**t_A constraint:**
- Do not send I2C start command during \( t_A \)
- Result: Bus changes clocked into IQS263 buffer will cause CLK = LOW until next communication window where a NACK will be sent to master
  - \( t_{A,\text{min}} = 70\,\text{us} \) (2 MHz main clock)
  - Do reseed command +70us
  - Redo ATI command +112us
  - Force Sleep command +25us
  - Therefore: \( t_{A,\text{max}} = 182\,\text{us} \) (2MHz)
  - \( t_{A,\text{min}} = 35\,\text{us} \) (4 MHz)
  - \( t_{A,\text{max}} = 91\,\text{us} \) (4 MHz)
Workaround for issues relating to $t_A$:
- Ensure communications are effectively done after RDY changes to LOW
- Ensure communications are not initiated (first $I^2C$ start) only close to $I^2C$ timeout (Reg 0x0A:byte7 – default 5ms)

Workaround for issues relating to $t_B$:
- Do not re-initiate communications with next device or same device within the specified time.

Further details of fault condition when $t_A$ or $t_B$ are not adhered to:
- As mentioned above, the IQS263 will take control of the $I^2C$ bus CLK line by an extended clock stretching event.
- Any address polling at the next communication window will receive a NACK from the IQS263 $I^2C$ module and the condition will be reset.
- In the case of event mode with no expected events on the RDY line following, the watchdog timer ($t_{WDT}$, see Table 4.1) will reset the condition.
3. How to address the IQS263 via \textit{I}^2\textit{C}

![I2C Start, stop and repeat-start definitions](image)

![Control byte specification](image)

![Multiple data write sequence](image)

![Register read sequence with “repeat-start” after address setup](image)
Figure 3.5  Bus state change specifications

Figure 3.6  Dummy status register read setup
4. Streaming mode specification

4.1 Streaming and sampling times

Table 4.1 Sample and ready timing description

<table>
<thead>
<tr>
<th>Settings</th>
<th>CH0-CH3</th>
<th>Sensing Conversions</th>
<th>RDY</th>
<th>t\textsubscript{sample}</th>
<th>t\textsubscript{RDY}</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 MHz osc (40Hz sampling)</td>
<td></td>
<td></td>
<td></td>
<td>\approx 25ms</td>
<td>\approx 12ms</td>
</tr>
<tr>
<td>(Reg 0x09:byte0:bit1 = 0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 MHz osc (80Hz sampling)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Reg 0x09:byte0:bit1 = 1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbo Mode Enabled</td>
<td></td>
<td></td>
<td></td>
<td>&lt;25ms (2MHz) &lt;12ms (4MHz)</td>
<td></td>
</tr>
<tr>
<td>(Reg 0x09:byte3:bit2 = 0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Example Case</td>
<td>Default (no comms)</td>
<td>Typical (with comms)</td>
<td>WDT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Reg 0x0A:byte7 = 0x04)</td>
<td>(Read 3 registers @ 400kHz)</td>
<td>(Start condition, no stop condition)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t\textsubscript{RDY}</td>
<td>\approx 5ms</td>
<td>TBD</td>
<td>260ms (2MHz) 130ms (4MHz)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 4.2 ATI time (with streaming during ATI disabled)

<table>
<thead>
<tr>
<th>CH0-CH3</th>
<th>Sensing Conversions</th>
<th>RDY</th>
<th>t\textsubscript{ATI}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical</td>
<td>Max</td>
<td></td>
<td></td>
</tr>
<tr>
<td>400ms</td>
<td>850ms</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

See datasheet for full description of ATI time variations.
5. Event mode specification

- Event mode is recommended for most applications
- Default streaming mode is intended for initialization periods and applications that utilize reading raw sample data

5.1 Idle state

- In the idle state (RDY high) the device will not act on any communications on the SDA and SCL lines
- The device will do sampling and calculations while communication procedures are idle

5.2 Event flagged description

- Events are flagged in the IQS263 until read by the master device.
- Newer events will overwrite the older.
- The following is an example of event accumulation and overwriting:

<table>
<thead>
<tr>
<th>Events occurred:</th>
<th>Event flags read:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• ATI complete</td>
<td>• ATI complete,</td>
</tr>
<tr>
<td>• RDY toggle,</td>
<td>• movement,</td>
</tr>
<tr>
<td>• movement,</td>
<td>• proximity</td>
</tr>
<tr>
<td>• RDY toggle,</td>
<td></td>
</tr>
<tr>
<td>• proximity,</td>
<td></td>
</tr>
<tr>
<td>• RDY toggle,</td>
<td></td>
</tr>
<tr>
<td>• touch,</td>
<td></td>
</tr>
<tr>
<td>• RDY toggle,</td>
<td></td>
</tr>
<tr>
<td>• no touch, RDY low, poll IQS263, read flags</td>
<td></td>
</tr>
</tbody>
</table>

- Figure 5.1 shows the behaviour of RDY when missing RDY signal indicators in event mode:

Figure 5.1 Proximity / Touch / Movement Event (When the host reads out registers at the fourth RDY)
Figure 5.2 Proximity / Touch / Movement Event (When the host reads out registers at the first RDY)

Figure 5.3 ATI Event (When the host reads out registers at the fourth RDY.)
5.3 Event mode force communications

When using the IQS263 in event mode it will be required to implement a force communications procedure in the driver. The force communication is to be used as follows:

- **Failsafe**: using the device in event mode, a failsafe “check” will be required to ensure the IC is still in good working order while not generating any events.

- **Reseed**: When no movement is detected for a time period determined by the master MCU, a “reseed” command will clear such non-moving activation. This event will require forced communications.

- **ATI-error**: When ATI is somehow disrupted while being executed, an ATI-error may result. In this case, the MCU is responsible to call a redo-ATI in order to repeat a calibration attempt. Instead of engaging in multiple rapid retries, the master can schedule the retry according to application requirements by forcing communications when suited.

The handshake method previously recommended has a limited response rate and is not recommended for use.

The force communications technique is the fastest method of “catching” the IQS263 communications window. The following method is recommended:

- **Master (MCU) write RDY = LOW**
- Master initiates I^2^C repeated polling until ACK is received from IQS263 (if NACK is detected then master must continue polling)
- When ACK is received, master should release the RDY line by making the I/O an input
- When the ACK is received the communications window is open until a STOP-command is sent
- Background: when IQS263 is in sleep mode in between sensing cycles, the device will initiate wake-up procedure with the RDY pin change.
- Background: The wake-up procedure always starts with sensing procedure on one of the channels. After the sensing and calculations the communications window will allow for a response on address polling.
**t_C specification:**
- After forcing the RDY low, the IQS263 will initiate a wake-up procedure.
- $t_C = 4\text{ms}$ (typical)
- $t_C < 5\text{ms}$

**t_D specification:**
- One channel sensing data is gathered before allowing time for communications
- Channel sensing time is dependent on target setting and sensing frequency
- $t_D = 3\text{ms}$ (typical)

**t_E specification:**
- Time from IQS263 ready to respond to polling requests.
- Addressing the device in this window should result in an expected response (acknowledge)
- $t_E = 5\text{ms}$ (default)
- $t_E = \text{Reg 0x0A:byte7}$
- Reg 0x0A:byte7 time-out value is cancelled after successful polling
### Polling option: Brute force
- Recommended polling interval: 1ms

- ADDRESS POLLING
- NO POLLING
- ACK (when polling)
- NACK (when polling)

### Polling option: Time delay
- Recommended:
  - $t_{poll\_delay} > 8$ms
- Change the I2C time-out to match the chosen polling delay

- ADDRESS POLLING
- NO POLLING
- ACK (when polling)
- NACK (when polling)
6. Recommended master implementations

Please see the IQS263 datasheet for a full specification of options that are typically fixed during run-time of the IQS263.

Most popular initialization options are as follows:

<table>
<thead>
<tr>
<th>Category</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel setup</td>
<td>CH0 (distributed), CH1, CH2, CH3</td>
</tr>
<tr>
<td></td>
<td>CH0 cannot be disabled</td>
</tr>
<tr>
<td>Sensing specification</td>
<td>Sensing frequency and sample rate selection</td>
</tr>
<tr>
<td>Threshold adjustment</td>
<td>Filter halt</td>
</tr>
<tr>
<td></td>
<td>Proximity threshold (CH0)</td>
</tr>
<tr>
<td></td>
<td>Touch thresholds (CH1, CH2, CH3)</td>
</tr>
<tr>
<td></td>
<td>Movement threshold (CH0 or CH3)</td>
</tr>
<tr>
<td>Sensitivity adjustment</td>
<td>Target value (higher target – more sensitivity)</td>
</tr>
<tr>
<td></td>
<td>Base value (lower base – more sensitivity)</td>
</tr>
<tr>
<td>Communication specification</td>
<td>Streaming, Event mode</td>
</tr>
<tr>
<td></td>
<td>Streaming disabled during ATI option</td>
</tr>
<tr>
<td></td>
<td>I2C timeout</td>
</tr>
<tr>
<td>Filter options</td>
<td>LTA beta</td>
</tr>
<tr>
<td></td>
<td>Filtered touches</td>
</tr>
<tr>
<td></td>
<td>Touch debounce</td>
</tr>
<tr>
<td>UI options</td>
<td>Slider, swipe, wheel etc.</td>
</tr>
</tbody>
</table>
6.1 Default recommended master implementation

Default streaming mode
Clear "show reset"

POR

init_iqs263

Event mode & Redo-ATI

ATI event 1
Dummy read
ATI_busy = 1

ATI event 2
ATI_busy = 0
ATI_error = 1

ATI error

Command: Redo-ATI

x sec time-out

Force comms

Show reset = 1

No event state change

Idle

RDY low detect

Rapid state events

Event state cleared

Event state change
Prox / Touch / Slide

Event handler

RDY low detect

Flick / Tap / Movement / Reset

Prox / Touch / Slide

Event state
6.2 Alternate recommended master implementation

Default streaming mode
Clear "show reset"

POR
init_iqs263

Streaming mode & no streaming during ATI & Redo-ATI

ATI error
RDY = low
ATI_busy = 0
ATI_error = 1

x sec time-out
ignore RDY for x sec

RDY = low
Command:
Redo-ATI

RDY = low
ATI_busy = 0
ATI_error = 0
Set to "Event mode"

Show reset = 1

No event state change

Idle

Event state change
Prox / Touch / Slide

Event handler
RDY low detect

Prox / Touch / Slide

Rapid state events
Event state change
Prox / Touch / Slide

RDY low detect
Event state cleared

Rapid state events

Flick / Tap / Movement / Reset

Event handler

RDY low detect
Event state cleared

RDY low detect
Event state cleared
7. ATI (calibration) state

7.1 Event mode ATI events active

- After calling a redo-ATI, a dummy event is created to indicate the ATI start
- Read this dummy event in order to prevent repeated dummy events.
- Repeated ATI events (or streaming during ATI) causes a significant decrease in calibration speed
- By reading the dummy ATI event, the conversions required for calibration can rapidly execute without being slowed down by communication windows.
- Be sure to read events as soon as possible to prevent reoccurring events.

- IQS263 generates dummy ATI event after redo-ATI
- This must be read to clear the event, otherwise the RDY will toggle continuously while doing ATI (slows ATI considerably)
- Recommended: disable ATI events (mask), read ATI_busy 1second after redo-ATI command – check ATI-error.
8. Reseed case

8.1 Event mode reseed

- Usually RESEED is done automatically and the master device does not need to be aware of the event.
- The master may force a reseed in the case of an unwanted latched condition.
- Force communications and calling a reseed may have two outputs:
  1. Reseed only (LTA = counts)
  2. Redo-ATI (LTA=counts & maintain correct target)

- IQS263 does Reseed and ATI
  - Does force communications procedure
  - Sends reseed command to IQS263
  - Sends stop command
  - Waits for RDY=L
  - Reads the ATI Busy
  - Waits for RDY=L
  - Set RDY=L time-out (100ms)
  - If RDY = L then Read the ATI Busy & ATI Error bits to confirm ATI

- IQS263 does Reseed but not ATI
  - Does force communications procedure
  - Sends reseed command to IQS263
  - Sends stop command
  - Waits for RDY=L
  - Set RDY=L time-out (100ms)
  - If RDY ≠L then no ATI, only reseed was done
## Appendix A

### Contact Information

<table>
<thead>
<tr>
<th>USA</th>
<th>Asia</th>
<th>South Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical Address</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6507 Jester Blvd</td>
<td>Rm2125, Glittery City</td>
<td>109 Main Street</td>
</tr>
<tr>
<td>Bldg 5, suite 510G</td>
<td>Shennan Rd</td>
<td>Paarl</td>
</tr>
<tr>
<td>Austin</td>
<td>Futian District</td>
<td>7646</td>
</tr>
<tr>
<td>TX 78750</td>
<td>Shenzhen, 518033</td>
<td>South Africa</td>
</tr>
<tr>
<td>USA</td>
<td>China</td>
<td></td>
</tr>
<tr>
<td><strong>Postal Address</strong></td>
<td></td>
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<tr>
<td>6507 Jester Blvd</td>
<td>Rm2125, Glittery City</td>
<td>PO Box 3534</td>
</tr>
<tr>
<td>Bldg 5, suite 510G</td>
<td>Shennan Rd</td>
<td>Paarl</td>
</tr>
<tr>
<td>Austin</td>
<td>Futian District</td>
<td>7620</td>
</tr>
<tr>
<td>TX 78750</td>
<td>Shenzhen, 518033</td>
<td>South Africa</td>
</tr>
<tr>
<td>USA</td>
<td>China</td>
<td></td>
</tr>
<tr>
<td><strong>Tel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+1 512 538 1995</td>
<td>+86 755 8303 5294 ext 808</td>
<td>+27 21 863 0033</td>
</tr>
<tr>
<td><strong>Fax</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+1 512 672 8442</td>
<td></td>
<td>+27 21 863 1512</td>
</tr>
<tr>
<td><strong>Email</strong></td>
<td><a href="mailto:info@azoteq.com">info@azoteq.com</a></td>
<td><a href="mailto:linayu@azoteq.com.cn">linayu@azoteq.com.cn</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="mailto:info@azoteq.com">info@azoteq.com</a></td>
</tr>
</tbody>
</table>

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