IQS620 Datasheet

Combination sensor with dual channel capacitive proximity/touch, Hall-effect sensor and inductive sensing

The IQS620 ProxFusion™ IC is a multifunctional capacitive, Hall-effect & inductive sensor designed for applications where any or all of the technologies may be required. The IQS620 is an ultra-low power solution designed for short or long term activations through any of the sensing channels. The IQS620 is fully I²C compatible and can be configured to output main trigger events on GPIOs.

Features

- **Unique combination of sensing technologies:**
  - Capacitive sensing
  - Hall-effect sensing
  - Inductive sensing
- **Capacitive sensing**
  - 2pF to 200pF external capacitive load capability
  - Fully adjustable sensing options
- **Hall-effect sensing**
  - No external components required
  - Dual direction Hall switch sensor
  - 2 level detection (widely variable)
  - Detection range 1mT – 100mT
- **Inductive sensing**
  - Metal sensing UI with 2 level detection and hysteresis
  - Only external sense coil required (PCB trace)
- **Low power consumption:** 300uA (50 Hz response, all technologies in use)**, 2.5**uA (low power mode, zoom to scanning mode with wake-up)
- **Multiple integrated UI** options based on years of experience in sensing on fixed and mobile platforms:
  - Proximity / Touch
  - Proximity wake-up
  - SAR with movement and quick release



DFN10

Representations only, not actual markings

- **A**utomatic **T**uning **I**mplementation (**ATI**) – performance enhancement (10bit)
- Minimal external components
- Standard **I²C** interface (polling with sub 1ms clock stretching)
- Optional **RDY indication** for event mode operation
- **Event or Streaming mode**
- **Supply voltage: 1.8V to 3.3V**
- **Low profile DFN(3x3) – 10 pin package**

Applications

- Mobile electronics (phones/tablets)
- SAR safety requirements for laptops, tablets and phones
- Wearable devices
- White goods and appliances
- Human Interface Devices
- Proximity activated backlighting
- Applications with long-term activation
- Aftermarket automotive[1]

Available Packages	
T_A	DFN(3x3) - 10
-40°C to 85°C	IQS620

[1] The part is not automotive qualified.

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List of abbreviations

ATI – Automatic Tuning Implementation

LTA – Long term average

SAR – Specific absorption rate

UI – User interface

AC – Alternating current

DSP – Digital signal processing

RX – Receiving electrode

LTX – Inductive transmitting electrode

CS – Sampling capacitor

NP – Normal power

LP – Low power

ULP – Ultra low power

ACK – I^2C Acknowledge condition

NACK – I^2C Not Acknowledge condition

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1 Introduction

1.1 ProxFusion™

The ProxFusion™ sensor series provides all of the proven ProxSense® engine capabilities with additional sensors types. A combined sensor solution is available within a single platform.

1.2 Packaging and Pin-Out

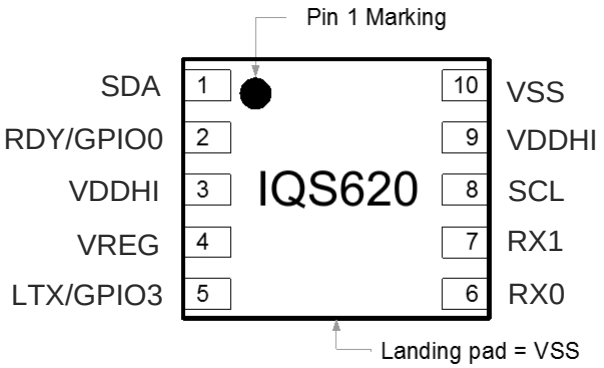


Figure 1.1 IQS620 pin-out (DFN10 package; device markings may differ)

Table 1.1 Pin-out description

IQS620 in DFN10			
Pin	**Name**	**Type**	**Function**
1	SDA	Digital input / output	**SDA** (I^2C Data signal)
2	GPIO0 / RDY	Configurable digital output Open drain active low logic	SAR activation output (higher priority) **RDY** (I^2C Ready interrupt signal; lower priority)
3	VDDHI	Supply input	Supply: 1.8V – 3.3V
4	VREG	Regulator output	Regulates the system's internal voltage Requires external capacitors to ground
5	GPIO3 / LTX	Configurable digital output PWM output / Transmitter electrode	PWM signal output (higher priority) / Connect to inductive sensor's transmitting coil (lower priority)
6	RX0	Receiving electrode	Connect to conductive area intended for sensor receiving
7	RX1	Receiving electrode	Connect to conductive area intended for sensor receiving
8	SCL	Digital input / output	**SCL** (I^2C Clock signal)
9	VDDHI	Supply input	Supply: 1.8V – 3.3V
10	VSS	Signal GND	Common ground reference

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1.3 Reference schematic

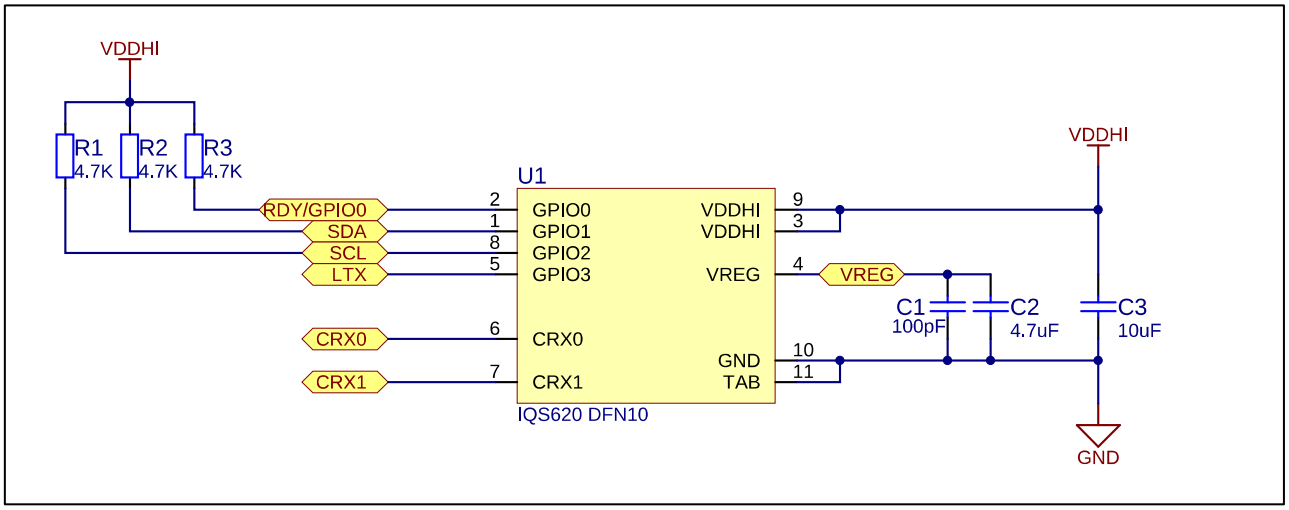


Figure 1.2 IQS620 reference schematic

1.4 Sensor channel combinations

The table below summarizes the IQS620's sensor and channel associations.

Table 1.2 Sensor - channel allocation

	Sensor / UI type	CH0	CH1	CH2	CH3	CH4	CH5
Capacitive	Self capacitive	○	○	○			
	SAR UI self	● Main	● Movement	○			
Hall-effect	Hall-effect switch UI					● Positive	● Negative
Inductive	Mutual inductive	○	○	●			
Temperature	Temperature trip and sensing				●		

Key:

○ - Optional implementation

● - Fixed use for UI

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2 Capacitive sensing

2.1 Introduction to ProxSense®

Building on the previous successes from the ProxSense® range of capacitive sensors, the same fundamental sensor engine have been implemented in the ProxFusion™ series.

The capacitive sensing capabilities of the IQS620 include:

- Self-capacitive sensing.
- Maximum of 3 capacitive channels to be individually configured.
  - Prox and touch adjustable thresholds
  - Individual sensitivity setups
  - Alternative ATI modes
- Enhanced SAR user interface:
  - For passing the SAR qualification
  - Movement sensing to distinguish between stationary in-contact objects and human interference
  - Quick release detection feature (fully configurable)
  - GPIO output of SAR activation (on pin2: GPIO0) for MCU interrupt capability
- Discreet button UI:
  - Fully configurable 2 level threshold setup – Traditional Prox & Touch activation levels.
  - Customizable filter halt time

2.2 Channel specifications

The IQS620 provides a maximum of 3 channels available to be configured for capacitive sensing. Each channel can be setup separately according to the channel's associated settings registers.

There are two distinct capacitive user interfaces available to be used.

a) Self capacitive proximity/touch UI (always enabled)

b) SAR UI

When the SAR UI is activated (ProxFusion Settings4: bit7):

- Channel 0 is used for as the main capacitive sensing channel for SAR detection.
- Channel 1 is used for capacitive movement detection. This is used to improve the SAR detection such as quick release detection.

Table 2.1 Capacitive sensing - channel allocation

Mode	CH0	CH1	CH2	CH3	CH4	CH5
Self capacitive	○	○	○			
SAR UI self	● Main	● Movement	○			

Key:

○ - Optional implementation

● - Fixed use for UI

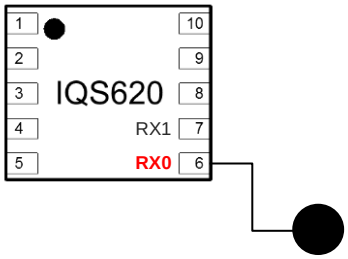
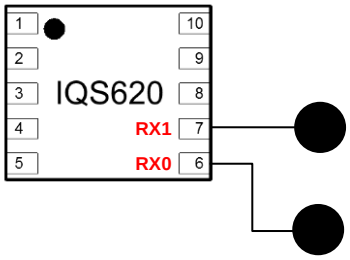
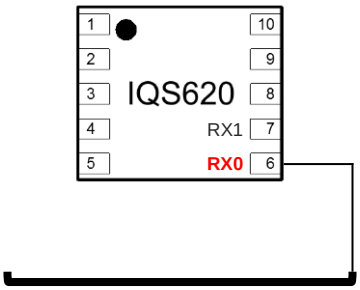
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2.3 Hardware configuration

In the table below are multiple options of configuring sensing (Rx) electrodes to realize different implementations (combinations not shown).

Table 2.2 Capacitive sensing - hardware description

	Self capacitive configuration
1 button	
2 buttons	
SAR antenna	

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2.4 Software configuration

To be completed.

2.5 Sensor data output and flags

The following registers should be monitored by the master to detect capacitive sensor output and SAR activations.

a) The **Global events register (0x11)** will show the IQS620's main events. Bit0 is dedicated to the ProxSense activations and two other bits (bit7 & bit1) is provided to show the state of the SAR UI. SAR_ACTIVE (bit7) will be constantly active during SAR detection. SAR event (bit1) will toggle upon each SAR qualified event or change of SAR status.

Global Events (0x11)								
Bit Number	**7**	6	5	4	3	2	**1**	**0**
Data Access	**R**	R	R	R	R	R	**R**	**R**
Name	**SAR ACTIVE**	PMU EVENT	SYS EVENT	TEMP EVENT	METAL DETECT	HALL EVENT	**SAR EVENT**	**PROX SENSE EVENT**

b) The **ProxFusion UI flags (0x12)** and **SAR UI flags (0x13)** provide more detail regarding the outputs. A prox and touch output bit for each channel 0 to 3 is provided in the ProxFusion UI flags register.

c) The **SAR UI Flags (0x13)** register will show detail regarding the state of the SAR output as well as Quick release toggles, movement activations and the state of the filter (halted or not).

ProxFusion UI flags (0x12)								
Bit Number	7	**6**	**5**	**4**	3	**2**	**1**	**0**
Data Access	-	**R**	**R**	**R**	-	**R**	**R**	**R**
Name	-	**CH2_T**	**CH1_T**	**CH0_T**	-	**CH2_P**	**CH1_P**	**CH0_P**
SAR UI flags (0x13)								
Bit Number	7	6	5	**4**	3	**2**	**1**	**0**
Data Access	-	-	-	**R**	-	**R**	**R**	**R**
Name	-	-	-	**SAR ACTIVE**		**QUICK RELEASE**	**MOVE-MENT**	**FHALT**

The SAR UI can also be used with the inductive sensing capabilities and is explained in section 4.Inductive sensing as well.

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3 Hall-effect sensing

3.1 Introduction to Hall-effect sensing

The IQS620 has two internal Hall-effect sensing plates (on chip). No external sensing hardware is required for Hall-effect sensing.

The Hall-effect measurement is essentially a current measurement of the induced current through the Hall-effect-sensor plates produced by the magnetic field passing perpendicular through each plate.

Advanced digital signal processing are performed to provide sensible output data.

- Two threshold levels are provided (prox & touch).
- Hall-effect output is linearized by inverting signals.
- North/South field direction indication provided.
- Differential Hall-Effect sensing:
  - Removes common mode disturbances
  - North-South field indication

3.2 Channel specifications

Channels 4 and 5 are dedicated to Hall-effect sensing. Channel 4 performs the positive direction measurements and channel 5 will handle all measurements in the negative direction. These two channels are used in conjunction to acquire differential Hall-effect data and will always be used as input data to the Hall-effect UI's.

There are two distinct Hall-effect user interfaces available:

a) General Hall-effect sensing

b) Hall-effect switch UI

Table 3.1 Hall-effect sensor – channel allocation

Mode	CH0	CH1	CH2	CH3	CH4	CH5
Hall-effect switch UI						
Smart cover					● Positive	● Negative
Slide switch						

Key:

○ - Optional implementation

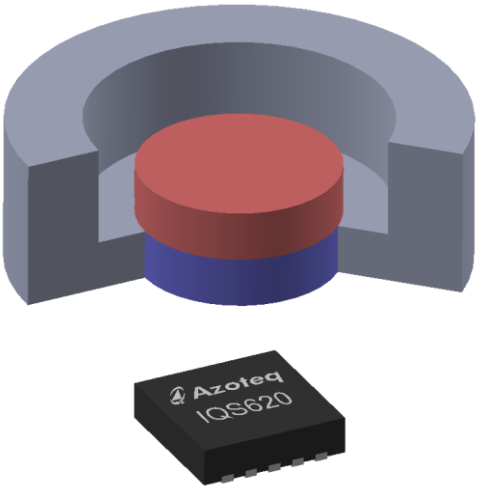
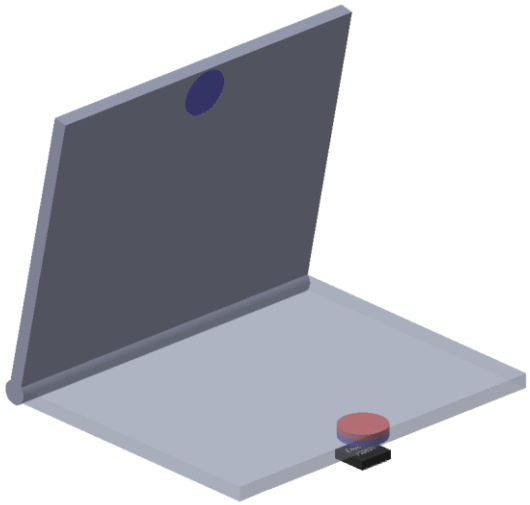
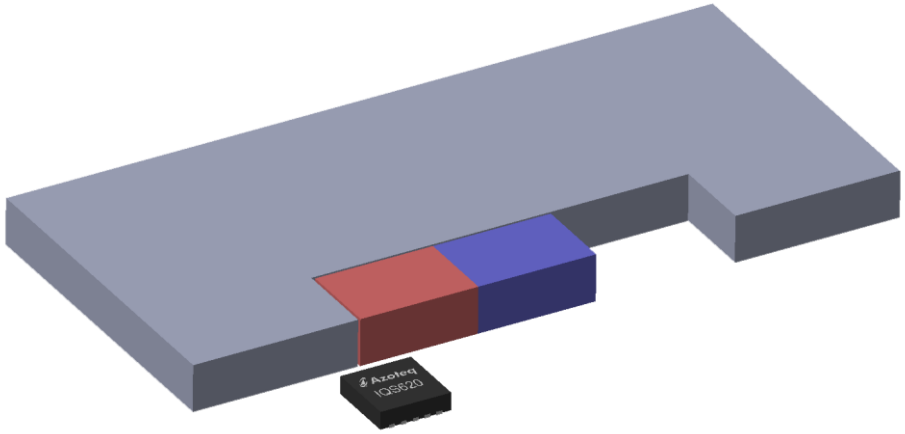
● - Fixed use for UI

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3.3 Hardware configuration

Rudimentary hardware configurations

	Axially polarized magnet (linear movement or magnet presence detection)
Hall-effect push switch	
Smart cover	
	Bar magnet (linear movement and magnet field detection)
Slide switch	

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3.4 Software configuration

To be completed.

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3.5 Sensor data output and flags

The following registers can be monitored by the master to detect Hall-effect related events.

a) Two bits in the **Global events (0x11)** register are dedicated to Hall-effect related output. **HALL_COVER_CLOSED (bit7)** will provide the status of a Hall-effect cover implementation (cover closed = 1 or cover open = 0). Bit2 will be toggled during any Hall-effect proximity detection.

Global events (0x11)								
Bit Number	7	6	5	4	3	**2**	1	0
Data Access	R	R	R	R	R	**R**	R	R
Name	SAR ACTIVE	PMU EVENT	SYS EVENT	TEMP EVENT	METAL DETECT EVENT	**HALL EVENT**	SAR EVENT	PROX SENSE EVENT

b) The **Hall-effect UI flags (0x16)** register provides the standard two level activation output (prox = **HALL_POUT** & touch = **HALL_TOUT**) as well as a **HALL_N/S** bit to indicate the magnet polarity orientation.

Hall-effect UI flags (0x16)								
Bit Number	7	6	5	4	3	**2**	**1**	**0**
Data Access	-	-	-	-	-	**R**	**R**	**R**
Name	-	-	-	-	-	**HALL TOUT**	**HALL POUT**	**HALL N/S**

c) The **Hall-effect UI output (0x17 & 0x18)** registers provide a 16 bit value of the Hall-effect amplitude detected by the sensor.

Hall-effect UI Output (0x17 - 0x18)								
Bit Number	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Data Access	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Name	**Hall-effect UI output low byte**							
Bit Number	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**
Data Access	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Name	**Hall-effect UI output high byte**							

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4 Inductive sensing

4.1 Introduction to inductive sensing

The IQS620 provides inductive sensing capabilities in order to detect the presence of metal/metal-type objects. Prox and touch thresholds are widely adjustable and individual hysteresis settings are definable for each.

4.2 Channel specifications

The IQS620 requires 3 sensing pins for mutual inductive sensing. The metal detect UI will be executed using channel 2.

The mutual inductive user interface is available on channel 2.

a) Metal detect UI (Dedicated to CH2)

Table 4.1 Inductive sensor – channel allocation

Mode	CH0	CH1	CH2	CH3	CH4	CH5
Mutual inductive	○	○	●			

Key:

○ - Optional implementation

● - Fixed use for UI

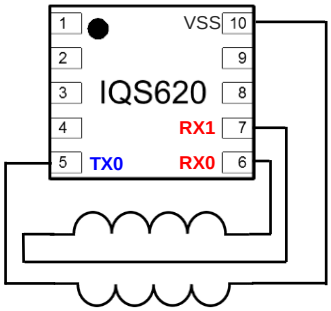
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4.3 Hardware configuration

Rudimentary hardware configurations (to be completed).

Table 4.2 Inductive hardware description

Mutual inductive


4.4 Software configuration

To be completed.

4.5 Sensor data output and flags

The following registers can be monitored by the master to detect inductive sensor related events.

a) **Global events (0x11)** to prompt for inductive sensor activation. Bit3 denoted as METAL_DETECT_EVENT will indicate the detection of a metal object using the inductive sensing.

Global events (0x11)								
Bit Number	7	6	5	4	**3**	2	1	0
Data Access	R	R	R	R	**R**	R	R	R
Name	SAR ACTIVE	PMU EVENT	SYS EVENT	TEMP EVENT	**METAL DETECT EVENT**	HALL EVENT	SAR EVENT	PROX SENSE EVENT

b) The **Metal detect UI flags (0x13)** register provides the classic prox/touch two level activation outputs as well as a bit to distinguish whether the current counts are above or below the LTA.

Metal detect UI flags (0x13)								
Bit Number	**7**	**6**	**5**	4	3	2	1	0
Data Access	**R**	**R**	**R**	-	-	-	-	-
Name	**Signed output**	**TOUCH**	**PROX**	-	-	-	-	-

c) **Metal detect UI output (0x14 & 0x15)** registers will provide a combined 16-bit value to acquire the magnitude of the inductive sensed object.

Metal detect UI output (0x14 - 0x15)								
Bit Number	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Data Access	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Name	**Metal detect UI output low byte**							
Bit Number	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**
Data Access	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Name	**Metal detect UI output high byte**							

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5 Temperature sensing

5.1 Introduction to temperature sensing

The IQS620 provides temperature sensing capabilities which can be used for temperature change monitoring or as an absolute temperature sensor (requires individual calibration). The use of the temperature sensor is primarily to reseed other sensor channels to account for sudden changes in environmental conditions.

The IQS620 uses a linearly proportional to absolute temperature sensor for temperature measurement. The temperature output is given by,

$$T = \frac{a}{b.CH_3} + c$$

Where $a, b\ and\ c$ are constants that are calculated during calibration. Additionally, the channel setup must be calculated during testing.

5.2 Channel specifications

The IQS620 requires only external passive components to do temperature sensing (no additional circuitry/components required). The temperature UI will be executed using data from channel 3 if correctly setup for temperature sensing.

Table 5.1 Temperature sensor – channel allocation

Mode	CH0	CH1	CH2	CH3	CH4	CH5
Temperature trip and sensing				•		

Key:

○ - Optional implementation

● - Fixed use for UI

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5.3 Hardware configuration

No additional hardware required. Temperature sensing realized on-chip

5.4 Software configuration

To be completed.

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5.5 Sensor data output and flags

The following registers can be monitored by the master to detect temperature sensor related events.

d) **Global events (0x11)** to prompt for temperature trip activation. Bit4 denoted as TEMP_EVENT will indicate the detection of a temperature event.

Global events (0x11)								
Bit Number	7	6	5	**4**	3	2	1	0
Data Access	R	R	R	**R**	R	R	R	R
Name	SAR ACTIVE	PMU EVENT	SYS EVENT	**TEMP EVENT**	METAL DETECT EVENT	HALL EVENT	SAR EVENT	PROX SENSE EVENT

e) The **Temperature UI flags (0x19)** register provides a temperature trip activation output bit if the condition of a temperature reseed threshold is tripped.

Temperature UI flags (0x19)								
Bit Number	**7**	**6**	**5**	4	3	2	1	0
Data Access	**R**	-	-	-	-	-	-	-
Name	**Temp trip**	-	-	-	-	-	-	-

f) **Temperature UI output (0x1A & 0x1B)** registers will provide a combined 16-bit value to provide the absolute temperature measured in units of Kelvin (K).

Temperature UI output (0x1A – 0x1B)								
Bit Number	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Data Access	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Name	**Temperature output low byte**							
Bit Number	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**
Data Access	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Name	**Temperature output high byte**							

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6 Device clock, power management and mode operation

6.1 Device main oscillator

The IQS620 has a **16MHz** main oscillator (default enabled) to clock all system functionality.

An option exists to reduce the main oscillator to 4MHz. This will result in all system timings, charge transfers and sample rates to be slower by half of the default implementations.

To set this option this:

- As a software setting – Set the System_Settings: bit4 = 1, via an I^2C command.
- As a permanent setting – Set the OTP option in FG Bank 0: bit2 = 1, using Azoteq USBProg program.

6.2 Device modes

The IQS620 supports the following modes of operation;

- **Normal mode** (Fixed report rate)
- **Low power mode** (Reduced report rate)
- **Ultra-low power mode** (Only channel 0 is sensed for a prox)
- **Halt mode** (Suspended/disabled)
  Note: Auto modes must be disabled to enter or exit halt mode.

The device will automatically switch between the different operating modes by default. However this Auto mode feature may be disabled by setting the DSBL_AUTO_MODE bit (Power_mode_settings 0xD2: bit5) to confine device operation to a specific power mode. The POWER_MODE bits (Power_mode_settings 0xD2: bit4-3) can then be used to specify the desired mode of operation.

6.2.1 Normal mode

Normal mode is the fully active sensing mode to function at a fixed report rate specified in the Normal Mode report Rate (0xD3) register. This 8-bit value is adjustable from 0ms – 255ms in intervals of 1ms.

Note: The device's low power oscillator have an accuracy as specified in section 9.

6.2.2 Low power mode

Low power mode is a reduced sensing mode where all channels are sensed but at a reduced sample rate. The sample rate can be specified in the Low Power Mode report Rate (0xD4) register. The 8-bit value is adjustable from 0ms – 255ms in intervals of 1ms. Reduced report rates also reduce the current consumed by the sensor.

Note: The device's low power oscillator have an accuracy as specified in section 9.

6.2.3 Ultra-low power mode

Ultra-low power mode is a reduced sensing mode where only channel 0 is sensed and no other channels or UI code are executed. Set the EN_ULP_MDE bit (Power_mode_settings: bit6) to enable use of the ultra-low power mode. The sample rate can be specified in the Low Power Mode report Rate (0xD5) register. The 8-bit value is adjustable from 0ms – 4sec in intervals of 16ms.

Wake up will occur on prox detection on channel 0.

6.2.4 Halt mode

Halt mode will suspend all sensing and will place the device in a dormant or sleep state. The device requires an I^2C command from a master to explicitly change the power mode out of the halt state before any sensor functionality can continue.

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6.2.5 Mode time

The mode time is specified in the Auto Mode Timer (0xD6) register. The 8-bit value is adjustable from 0ms – 2 min in intervals of 500ms.

6.3 Report rates

6.3.1 Calculation of each mode's report rate

Normal power segment rate

To be completed.

Auto modes change rates

To be completed.

Streaming/event mode rates

To be completed.

6.4 System reset

The IQS620 device monitor's system resets and events.

a) Every device power-on and reset event will set the Show Reset bit (System flags 0x10: bit7) and the master should explicitly clear this bit by setting the ACK_RESET (bit6) in System Settings.

b) The system events will also be indicated with the Global events register's SYS_EVENT bit (Global events 0x11: bit5) if any system event occur such as a reset. This event will continuously trigger until the reset has been acknowledged.

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7 Communication

7.1 I²C module specification

The device supports a standard two wire I²C interface with the addition of an RDY (ready interrupt) line. The communications interface of the IQS620 supports the following:

- Streaming data as well as event mode.
- The master may address the device at any time. If the IQS620 is not in a communication window, the device will return an ACK after which clock stretching may be induced until a communication window is entered. Additional communication checks are included in the main loop in order to reduce the average clock stretching time.
- The provided interrupt line (RDY) is an open-drain active low implementation and indicates a communication window.

7.2 Device address and sub-addresses

The default device address is **0x44 = DEFAULT_ADDR**.

Alternative sub-address options are definable in the following one-time programmable bits: **OTP Bank0 (bit3; 0; bit1; bit0) = SUB_ADDR_0** to **SUB_ADDR_7**

a) Default address: **0x44** = **DEFAULT_ADDR** OR **SUB_ADDR_0**
b) Sub-address: **0x45** = **DEFAULT_ADDR** OR **SUB_ADDR_1**
c) Sub-address: **0x46** = **DEFAULT_ADDR** OR **SUB_ADDR_2**
d) Sub-address: **0x47** = **DEFAULT_ADDR** OR **SUB_ADDR_3**
e) Sub-address: **0x4C** = **DEFAULT_ADDR** OR **SUB_ADDR_4**
f) Sub-address: **0x4D** = **DEFAULT_ADDR** OR **SUB_ADDR_5**
g) Sub-address: **0x4E** = **DEFAULT_ADDR** OR **SUB_ADDR_6**
h) Sub-address: **0x4F** = **DEFAULT_ADDR** OR **SUB_ADDR_7**

7.3 Additional OTP options

All one-time-programmable device options are located in OTP bank0.

OTP bank0								
Bit Number	7	6	5	4	3	2	1	0
Name	Internal use	COMMS ATI	-	-	SUB ADDRESS (bit3)	4MHz	SUB ADDRESS (bit1-0)	

Bit definitions:

- Bit 7: Internal use
  - Do not set. Leave bit cleared.
- Bit 6: : Communication mode during ATI
  - 0: No streaming events are generated during ATI
  - 1: Communication continue as setup regardless of ATI state.
- Bit 2: Main Clock frequency selection
  - 0: Run FOSC at 16MHz
  - 1: Run FOSC at 4MHz
- Bit 3,1,0: I2C sub-address
  - I2C address = 0x44 OR SUB_ADDR

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7.4 Recommended communication and runtime flow diagram

The following is a basic master program flow diagram to communicate and handle the device. It addresses possible device events such as output events, ATI and system events (resets).

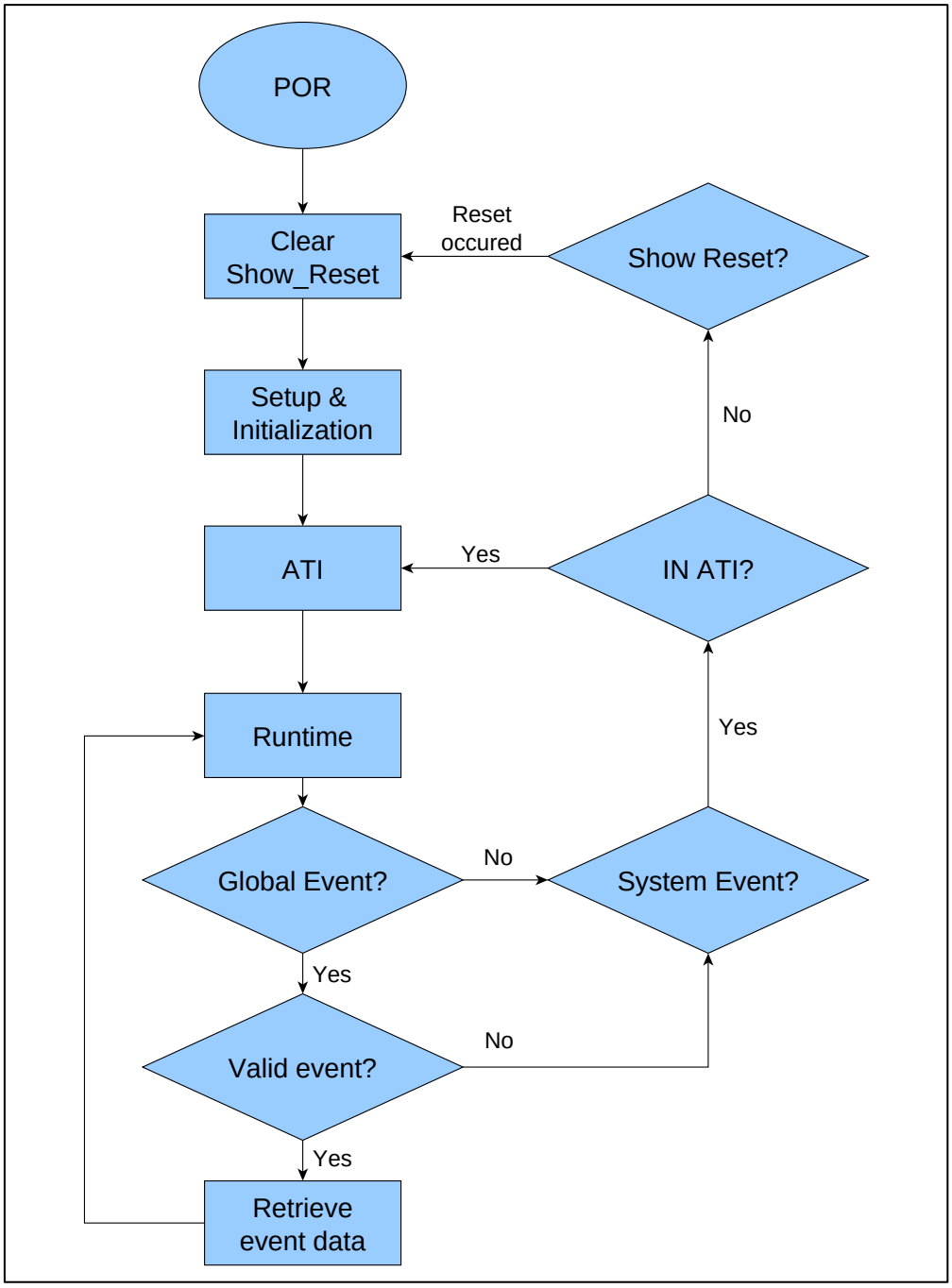


Figure 7.1 Master command structure and runtime event handling flow diagram

It is recommended that the master verifies the status of the System_Flags0 bits to identify events and resets. Detecting either one of these should prompt the master to the next steps of handling the IQS620.

Streaming mode communication is used for detail sensor evaluation during prototyping and/or development phases.

Event mode communication is recommended for runtime use of the IQS620. This reduce the communication on the I^2C bus and report only triggered events.

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8 Memory map

The full memory map is summarized below. Register groups are explained in the latter subsections.

Table 8.1 IQS620 Memory map index

Full Address	Group Name	Item Name	Data Access
0x00	Device information data	Product number	Read-Only
0x01		Software number	Read-Only
0x02		Hardware number	Read-Only
0x10	Flags and user interface data	System flags	Read-Only
0x11		Global events	Read-Only
0x12		ProxFusion UI flags	Read-Only
0x13		SAR and metal UI flags	Read-Only
0x14		Metal detect UI output 0	Read-Only
0x15		Metal detect UI output 1	Read-Only
0x16		Hall-effect UI flags	Read-Only
0x17		Hall-effect UI output 0	Read-Only
0x18		Hall-effect UI output 1	Read-Only
0x19		Temperature UI flags	Read-Only
0x1A		Temperature UI output 0	Read-Only
0x1B		Temperature UI output 1	Read-Only
0x20	Channel counts (raw data)	Channel 0 counts low	Read-Only
0x21		Channel 0 counts high	Read-Only
0x22		Channel 1 counts low	Read-Only
0x23		Channel 1 counts high	Read-Only
0x24		Channel 2 counts low	Read-Only
0x25		Channel 2 counts high	Read-Only
0x26		Channel 3 counts low	Read-Only
0x27		Channel 3 counts high	Read-Only
0x28		Channel 4 counts low	Read-Only
0x29		Channel 4 counts high	Read-Only
0x2A		Channel 5 counts low	Read-Only
0x2B		Channel 5 counts high	Read-Only
0x30	LTA values (filtered data)	Channel 0 LTA low	Read-Only
0x31		Channel 0 LTA high	Read-Only
0x32		Channel 1 LTA low	Read-Only
0x33		Channel 1 LTA high	Read-Only
0x34		Channel 2 LTA low	Read-Only
0x35		Channel 2 LTA high	Read-Only
0x40	ProxFusion sensor settings block 0	ProxFusion settings 0_0	Read-Write
0x41		ProxFusion settings 0_1	Read-Write
0x42		ProxFusion settings 0_2	Read-Write
0x43		ProxFusion settings 1_0	Read-Write
0x44		ProxFusion settings 1_1	Read-Write
0x45		ProxFusion settings 1_2	Read-Write
0x46		ProxFusion settings 2_0	Read-Write
0x47		ProxFusion settings 2_1	Read-Write
0x48		ProxFusion settings 2_2	Read-Write
0x49		ProxFusion settings 3_0	Read-Write
0x4A		ProxFusion settings 3_1	Read-Write
0x4B		ProxFusion settings 3_2	Read-Write

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0x50	ProxFusion sensor settings block 1	ProxFusion settings 4	Read-Write
0x51		ProxFusion settings 5	Read-Write
0x52		Compensation Ch0	Read-Write
0x53		Compensation Ch1	Read-Write
0x54		Compensation Ch2	Read-Write
0x55		Multipliers Ch0	Read-Write
0x56		Multipliers Ch1	Read-Write
0x57		Multipliers Ch2	Read-Write
0x60	ProxFusion UI settings	Prox threshold Ch0	Read-Write
0x61		Touch threshold Ch0	Read-Write
0x62		Prox threshold Ch1	Read-Write
0x63		Touch threshold Ch1	Read-Write
0x64		Prox threshold Ch2	Read-Write
0x65		Touch threshold Ch2	Read-Write
0x66		ProxFusion discrete UI halt time	Read-Write
0x70	SAR UI settings	SAR UI settings 0	Read-Write
0x71		SAR UI settings 1	Read-Write
0x72		QRD threshold Ch0	Read-Write
0x73		Filter halt threshold Ch0	Read-Write
0x74		Prox threshold Ch0	Read-Write
0x75		Quick release detection halt time	Read-Write
0x80	Metal detect UI settings	Metal detect UI settings	Read-Write
0x81		Metal detect UI filter halt threshold	Read-Write
0x82		Metal detect UI prox threshold	Read-Write
0x83		Metal detect UI touch threshold	Read-Write
0x90	Hall-effect sensor settings	Hall-effect settings 0	Read-Write
0x91		Hall-effect settings 1	Read-Write
0x92		Compensation Ch4 and Ch5	Read-Write
0x93		Multipliers Ch4 and Ch5	Read-Write
0xA0	Hall-effect switch UI settings	Hall-effect switch UI settings	Read-Write
0xA1		Hall-effect switch UI prox threshold	Read-Write
0xA2		Hall-effect switch UI touch threshold	Read-Write
0xC0	Temperature UI settings	Temperature UI settings	Read-Write
0xC1		Multipliers Ch3	Read-Write
0xC2		Temperature calibration data0	Read-Write
0xC3		Temperature calibration data1	Read-Write
0xD0	Device and power mode settings	System settings	Read-Write
0xD1		Active channels	Read-Write
0xD2		Power mode settings	Read-Write
0xD3		Normal mode report rate	Read-Write
0xD4		Low power mode report rate	Read-Write
0xD5		Ultra-low power mode report rate	Read-Write
0xD6		Auto mode time	Read-Write
0xD7		Global event mask	Read-Write
0xD8		PWM control	Read-Write

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8.2 Device Information Data

8.2.1 Product number

Product number (0x00)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R	R	R	R	R	R	R	R
Name	Device Product Number							

Bit definitions:

- Bit 7-0: Device Product Number = D’65’

8.2.2 Software number

Software number (0x01)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R	R	R	R	R	R	R	R
Name	Device Software Number							

Bit definitions:

- Bit 7-0: Device Software Number = D’04’

8.2.3 Hardware number

Hardware number (0x02)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R	R	R	R	R	R	R	R
Name	Device Hardware Number							

Bit definitions:

- Bit 7-0: Device Hardware Number = D’130’

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8.3 Flags and user interface data

8.3.1 System flags

System flags (0x10)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R	-	-	R	R	R	R	R
Name	SHOW RESET	-	-	POWER MODE		IN ATI	EVENT	NP SEG ACTIVE

Bit definitions:

- Bit 7: Reset Indicator
  - 0: No reset event
  - 1: A device reset has occurred and needs to be acknowledged.
- Bit 4-3: Active power-mode indicator
  - 00: Normal Mode
  - 01: Low Power Mode
  - 10: Ultra-Low Power Mode
  - 11: Halt Mode
- Bit 2: ATI busy indicator
  - 0: No channels are in ATI
  - 1: One or more channels are in ATI
- Bit 1: Global Event Indicator
  - 0: No new event to service
  - 1: An event has occurred and should be serviced
- Bit 0: Normal power segment indicator
  - 0: Not performing a normal power update
  - 1: Busy performing a normal power update

8.3.2 Global events

Global events (0x11)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R	R	R	R	R	R	R	R
Name	SAR ACTIVE	PMU EVENT	SYS EVENT	TEMP EVENT	METAL DETECT	HALL EVENT	SAR EVENT	PROX SENSE EVENT

Bit definitions:

- Bit 7: SAR activation state
  - 0: SAR output inactive
  - 1: SAR output active
- Bit 6: Power management unit event flag
  - 0: No event to report
  - 1: A power management event occurred
- Bit 5: System event flag
  - 0: No event to report

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- 1: A system event has occurred and should be handled

- Bit 4: Temperature event flag
  - 0: No event to report
  - 1: A temperature event has occurred and should be handled
- Bit 4: Metal detect event flag
  - 0: No event to report
  - 1: A metal detect event has occurred and should be handled
- Bit 2: Hall-effect event flag
  - 0: No event to report
  - 1: A Hall-effect event has occurred and should be handled
- Bit 1: SAR event flag
  - 0: No event to report
  - 1: A SAR event has occurred and should be handled
- Bit 0: ProxSense event flag
  - 0: No event to report
  - 1: A capacitive key event has occurred and should be handled

8.3.3 ProxFusion UI flags

ProxFusion UI flags (0x12)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	-	R	R	R	-	R	R	R
Name	-	CH2_T	CH1_T	CH0_T	-	CH2_P	CH1_P	CH0_P

Bit definitions:

- Bit 6: Ch2 touch indicator
  - 0: Delta below touch level
  - 1: Delta above touch level
- Bit 5: Ch1 touch indicator
  - 0: Delta below touch level
  - 1: Delta above touch level
- Bit 4: Ch0 touch indicator
  - 0: Delta below touch level
  - 1: Delta above touch level
- Bit 2: Ch2 proximity indicator
  - 0: Delta below proximity level
  - 1: Delta above proximity level
- Bit 1: Ch1 proximity indicator
  - 0: Delta below proximity level
  - 1: Delta above proximity level
- Bit 0: Ch0 proximity indicator
  - 0: Delta below proximity level
  - 1: Delta above proximity level

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8.3.4 SAR UI flags

SAR UI flags (0x13)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	-	-	-	R	-	R	R	R
Name	-	-	-	SAR ACTIVE		QRD	MOVE-MENT	FHALT

Bit definitions:

- Bit 4: SAR Standoff Active
  - 0: Delta below SAR threshold level
  - 1: Delta above SAR threshold level
- Bit 2: Quick Release Detection (QRD) indicator
  - 0: Quick release not detected
  - 1: Quick release detected
- Bit 1: Movement indicator
  - 0: Movement not detected
  - 1: Movement detected
- Bit 0: Filter Halt indicator
  - 0: Delta below filter halt level
  - 1: Delta above filter halt level

8.3.5 Metal detect UI flags

Metal detect UI flags (0x13)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R	R	R	-	-	-	-	-
Name	Signed output	TOUCH	PROX	-	-	-	-	-

Bit definitions:

- Bit 7: Delta directional signed output
  - 0: Counts rise above the LTA
  - 1: Counts fall below the LTA
- Bit 6: Metal detect touch indicator
  - 0: Delta below touch level
  - 1: Delta above touch level
- Bit 5: Metal detect proximity indicator
  - 0: Delta below proximity level
  - 1: Delta above proximity level

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8.3.6 Metal detect UI output

Metal detect UI output (0x14 - 0x15)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R	R	R	R	R	R	R	R
Name	Metal Detect UI Output Low Byte							
Bit Number	15	14	13	12	11	10	9	8
Data Access	R	R	R	R	R	R	R	R
Name	Metal Detect UI Output High Byte							

Bit definitions:

- Bit 15-0: Metal Detect UI output value

8.3.7 Hall-effect UI flags

Hall-effect UI flags (0x16)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	-	-	-	-	-	R	R	R
Name	-	-	-	-	-	TOUCH	PROX	HALL N/S

Bit definitions:

- Bit 2: Hall-effect touch indicator
  - 0: Field strength below touch level
  - 1: Field strength above touch level
- Bit 1: Hall-effect proximity indicator
  - 0: Field strength below proximity level
  - 1: Field strength above proximity level
- Bit 0: Hall-effect North South Field indication
  - 0: North field present
  - 1: South field present

8.3.8 Hall-effect UI output

Hall-effect UI output (0x17/0x18)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R	R	R	R	R	R	R	R
Name	Hall-effect UI Output Low Byte							
Bit Number	15	14	13	12	11	10	9	8
Data Access	R	R	R	R	R	R	R	R
Name	Hall-effect UI Output High Byte							

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Bit definitions:

- Bit 15-0: Hall-effect UI output
  - 0 – 8 000: Hall-effect UI output value

8.3.9 Temperature UI flags

Temperature UI flags (0x19)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R	-	-	-	-	-	-	-
Name	Temp trip	-	-	-	-	-	-	-

Bit definitions:

- Bit 7: Temperature trip indicator
  - 0: No event to report
  - 1: Temperature reseed event occurred

8.3.10 Temperature UI output

Temperature UI output (0x1A – 0x1B)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R	R	R	R	R	R	R	R
Name	Temperature output low byte							
Bit Number	15	14	13	12	11	10	9	8
Data Access	R	R	R	R	R	R	R	R
Name	Temperature output high byte							

Bit definitions:

- Bit 15-0: Temperature UI output
  - Integer value: Temperature output value in units of Kelvin (K)

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8.4 Channel counts (raw data)

Channel counts Ch0/1/2/3 (0x20/0x21 - 0x26/0x27)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R	R	R	R	R	R	R	R
Name	Channel Data Low Byte							
Bit Number	15	14	13	12	11	10	9	8
Data Access	R	R	R	R	R	R	R	R
Name	Channel Data High Byte							

Bit definitions:

- Bit 0-15: AC filtered or raw value counts

Channel counts Ch4/5 (0x28/0x29 - 0x2A/0x2B)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R	R	R	R	R	R	R	R
Name	Channel Data Low Byte							
Bit Number	15	14	13	12	11	10	9	8
Data Access	R	R	R	R	R	R	R	R
Name	Channel Data High Byte							

Bit definitions:

- Bit 0-15: AC filtered or raw value counts of Hall-effect sensors channels

8.5 LTA values (filtered data)

LTA Ch0/1/2 (0x30/0x31 - 0x34/0x35)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R	R	R	R	R	R	R	R
Name	LTA Low Byte							
Bit Number	15	14	13	12	11	10	9	8
Data Access	R	R	R	R	R	R	R	R
Name	LTA High Byte							

Bit definitions:

- Bit 0-15: LTA filter value output

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8.6 ProxFusion sensor settings block 0

8.6.1 ProxFusion settings 0

8.6.1.1 Capacitive sensing

ProxFusion settings 0_0/1/2 (0x40-0x42)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	-	-	-	-	R/W	R/W
Name	Capacitive sensor mode		Internal use	Internal use	-		RX Select	
Fixed value	0	0			-			

Bit definitions:

- Bit 7-6: Sensor Mode
  - 00: Capacitive sensing mode
- Bit 1-0: RX Select
  - 00: RX 0 and RX is disabled
  - 01: RX 0 is enabled
  - 10: RX 1 is enabled
  - 11: RX 0 and RX 1 is enabled

8.6.1.2 Inductive sensing

ProxFusion settings 0_0/1/2 (0x40-0x42)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	-	R/W	-	-	R/W	R/W
Name	Inductive sensor mode		Internal use	Multiplier range	-		RX Select	
Fixed value	1	0			-		1	1

Bit definitions:

- Bit 7-6: Sensor Mode
  - 10: Inductive sensor mode
- Bit 4: Multiplier range
  - 0: Small
  - 1: Large
- Bit 1-0: RX Select
  - 11: RX 0 and RX 1 is enabled

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8.6.2 ProxFusion settings 1

8.6.2.1 Capacitive sensing

ProxFusion settings 1_0/1/2 (0x43 - 0x45)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	-	R/W	R/W	R/W	-	-	R/W	R/W
Name	-	CSz	CHARGE FREQ		-		AUTO ATI MODE	

Bit definitions:

- Bit 6: CS size
  - 0: CS capacitor size is 15 pF
  - 1: CS capacitor size is 60 pF
- Bit 5-4: Charge frequency divider
  - 00: 1/2
  - 01: 1/4
  - 10: 1/8
  - 11: 1/16
- Bit 1-0: Auto ATI Mode
  - 00: ATI disabled
  - 01: Partial ATI (all multipliers are fixed)
  - 10: Semi-Partial ATI (only coarse multipliers are fixed)
  - 11: Full-ATI

8.6.2.2 Inductive sensing

ProxFusion settings 1_0/1/2 (0x43 - 0x45)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	-	R/W	R/W	R/W	-	-	R/W	R/W
Name	-	CSz	CHARGE FREQ		-		AUTO ATI MODE	

Bit definitions:

- Bit 6: CS size
  - 0: CS capacitor size is 15 pF
  - 1: CS capacitor size is 60 pF
- Bit 5-4: Charge frequency divider
  - 00: 1/2
  - 01: 1/4
  - 10: 1/8
  - 11: 1/16
- Bit 1-0: Auto ATI Mode
  - 00: ATI disabled
  - 01: Partial ATI (all multipliers are fixed)
  - 10: Semi-Partial ATI (only coarse multipliers are fixed)
  - 11: Full-ATI

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8.6.3 ProxFusion settings 2

8.6.3.1 Capacitive sensing

ProxFusion settings 2_0/1/2 (0x46 - 0x48)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	ATI_BASE		ATI_TARGET (x32)					

Bit definitions:

- Bit 7-6: Auto ATI base value
  - 00: 75
  - 01: 100
  - 10: 150
  - 11: 200
- Bit 5-0: Auto ATI Target
  - ATI Target is 6-bit value x 32

8.6.3.2 Inductive sensing

ProxFusion settings 2_0/1/2 (0x46 - 0x48)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	ATI_BASE		ATI_TARGET (x32)					

Bit definitions:

- Bit 7-6: Auto ATI base value
  - 00: 75
  - 01: 100
  - 10: 150
  - 11: 200
- Bit 5-0: Auto ATI Target
  - ATI Target is 6-bit value x 32

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8.6.4 ProxFusion settings 3

8.6.4.1 Capacitive sensing

ProxFusion settings 3_0/1/2 (0x49 - 0x4B)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	-	R/W	R/W	R/W	-
Name	UP_LENGTH		CS DIV	Internal use	UP LEN EN	PASS_LENGTH		-

Bit definitions:

- Bit 7-6: Up length select (requires **UP_LENGTH_EN = 1** for use)
  - 00: Up length = 0010
  - 01: Up length = 0110
  - 10: Up length = 1010
  - 11: Up length = 1110
- Bit 5: CS divider
  - 0: Normal CS cap size
  - 1: CS cap size 5 times smaller
- Bit 3: Up length select enable
  - 0: Up length select is disabled
  - 1: Up length select is enabled (value in bit 7-6 is used)
- Bit 2-1: Pass length select
  - 00: Pass length = 001
  - 01: Pass length = 011
  - 10: Pass length = 101
  - 11: Pass length = 111

8.6.4.2 Inductive sensing

ProxFusion settings 3_0/1/2 (0x49 - 0x4B)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	-	-	R/W	-	R/W	-	-	-
Name	-		CS DIV	Internal use	UP LEN EN	-		-

Bit definitions:

- Bit 5: CS divider
  - 0: Normal CS cap size
  - 1: CS cap size 3 times smaller

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8.7 ProxFusion sensor settings block 1

8.7.1 ProxFusion settings 4

8.7.1.1 Capacitive sensing

ProxFusion settings 4 (0x50)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	SAR EN	Internal use	TWO SIDED EN	ACF DISABLE	LTA BETA		ACF BETA	

Bit definitions:

- Bit 7: SAR UI enable
  - 0: SAR UI is disabled
  - 1: SAR UI is enabled
- Bit 5: Two sided detection
  - 0: Bidirectional detection disabled
  - 1: Bidirectional detection enabled
- Bit 4: Disable AC filter
  - 0: AC filter enabled
  - 1: AC filter disabled
- Bit 3-2: Long term average beta value
  - 00: 7
  - 01: 8
  - 10: 9
  - 11: 10
- Bit 1-0: AC filter beta value
  - 00: 1
  - 01: 2
  - 10: 3
  - 11: 4

8.7.1.2 Inductive sensing

ProxFusion settings 4 (0x50)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	SAR EN	METAL DETECT EN	TWO SIDED EN	ACF DISABLE	LTA BETA		ACF BETA	

Bit definitions:

- Bit 7: SAR UI enable
  - 0: SAR UI is disabled
  - 1: SAR UI is enabled
- Bit 6: Metal detection UI enable

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- 0: Metal detection UI is disabled
- 1: Metal detection UI is enabled

- Bit 5: Two sided detection
  - 0: Bidirectional detection disabled
  - 1: Bidirectional detection enabled
- Bit 4: Disable AC filter
  - 0: AC filter enabled
  - 1: AC filter disabled
- Bit 3-2: Long term average beta value
  - 00: 7
  - 01: 8
  - 10: 9
  - 11: 10
- Bit 1-0: AC filter beta value
  - 00: 1
  - 01: 2
  - 10: 3
  - 11: 4

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8.7.2 ProxFusion settings 5

ProxFusion settings 5 (0x51)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	-	-	-	-	-	-	-
Name	Disable Ch1 auto	Internal use						

Bit definitions:

- Bit7: Disable Ch1 auto
  - 0: Ch1 is enabled when SAR UI is active
  - 1: Ch1 is disabled when SAR UI is active
- Bit 6-0: Internal use

8.7.3 Compensation

Compensation Ch0/1/2 (0x52 - 0x54)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Compensation (0-7)							

Bit definitions:

- Bit 7-0: Compensation (7-0)
  - 0-255: Lower 8-bits of the Compensation value.

8.7.4 Multipliers

Multipliers Ch0/1/2 (0x55-0x57)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Compensation (8-9)		Multiplier coarse		Multiplier fine			

Bit definitions:

- Bit 7-6: Compensation (8-9)
  - 0-3: Upper 2-bits of the Compensation value.
- Bit 5-4: Multiplier coarse
  - 0-3: Coarse multiplier selection
- Bit 3-0: Multiplier fine
  - 0-15: Fine multiplier selection

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8.8 ProxFusion UI settings

8.8.1 Prox threshold Ch0/1/2

Prox threshold Ch0/1/2 (0x60/0x62/0x64)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Proximity threshold value							

Bit definitions:

- Bit 7-0: Proximity threshold = Proximity threshold value

8.8.2 Touch threshold Ch0/1/2

Touch threshold Ch0/1/2 (0x61/0x63/0x65)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Touch threshold value							

Bit definitions:

- Bit 7-0: Touch threshold = Touch threshold value * LTA/ 256

8.8.3 ProxFusion discrete UI halt time

ProxFusion discrete UI halt time (0x66)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Halt Time							

Bit definitions:

- Bit 7-0: Halt time in 500ms increments (decimal value x 500ms)

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8.9 SAR UI settings

8.9.1 SAR UI settings 0

SAR UI settings 0 (0x70)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	-	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	-	QRD Beta			SAR To GPIO0	Movement Beta		

Bit definitions:

- Bit 6-4: Quick Release Detection Beta
  - 0-7: quick release filter beta value
- Bit 3: SAR Standoff State To GPIO0
  - 0: SAR standoff state to GPIO0 not active. RDY on GPIO0
  - 1: SAR standoff state to GPIO0 active. No RDY signal
- Bit 2-0: Movement Detection Filter Beta
  - 0-7: Movement filter beta value

8.9.2 SAR UI settings 1

SAR UI settings 1 (0x71)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	LTA Halt timeout in no Prox				Movement detection Threshold			

Bit definitions:

- Bit 7-4: LTA Halt timeout in no Prox
  - 0-15: LTA Halt timeout in no Prox in 500 ms ticks
- Bit 3-0: Movement Detection Threshold
  - 0-15: Movement Threshold = Movement Threshold Value

8.9.3 Quick release detection threshold

Quick release detection threshold (0x72)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	QRD Threshold value							

Bit definitions:

- Bit 7-0: Proximity Threshold = Proximity Threshold Value

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8.9.4 Filter halt threshold

Filter halt threshold (0x73)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Filter Halt Threshold value							

Bit definitions:

- Bit 7-0: Filter Halt Threshold = Filter Halt Threshold Value

8.9.5 Proximity threshold

Proximity threshold (0x74)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Proximity Threshold value							

Bit definitions:

- Bit 7-0: Proximity Threshold = Proximity Threshold Value

8.9.6 Quick release detection halt time

Quick release detection halt time (0x75)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	LTA halt timeout after a QRD (decimal value x 500ms)							

Bit definitions:

- Bit 7-0: LTA halt timeout after a Quick release detection with no movement afterwards (decimal value x 500 ms)

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8.10 Metal detection UI settings

8.10.1 Metal detect UI settings

Metal detect UI settings (0x80)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	-	-	R/W	R/W	-	-	R/W	R/W
Name	-	-	Hysteresis T		-	-	Hysteresis P	

Bit definitions:

- Bit 5-4: Touch hysteresis
  - 00: Disabled
  - 01: 1/4 of threshold
  - 10: 1/8 of threshold
  - 11: 1/16 of threshold
- Bit 1-0: Proximity hysteresis
  - 00: Disabled
  - 01: 1/4 of threshold
  - 10: 1/8 of threshold
  - 11: 1/16 of threshold

8.10.2 Metal detect UI filter halt threshold

Metal detect UI filter halt threshold (0x81)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Metal detect filter halt threshold value							

Bit definitions:

- Bit 7-0: Filter halt threshold = Filter halt threshold value

8.10.3 Metal detect UI proximity threshold

Metal detect UI proximity threshold (0x82)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Proximity threshold value							

Bit definitions:

- Bit 7-0: Proximity threshold = Proximity threshold value

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8.10.4 Metal detect UI touch threshold

Metal detect UI touch threshold (0x83)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Touch threshold value							

Bit definitions:

- Bit 7-0: Touch threshold = Touch threshold value * 4

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8.11 Hall-effect sensor settings

8.11.1 Hall-effect settings 0

Hall-effect settings 0 (0x90)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	-	-	R/W	R/W	-	-	R/W	R/W
Name	-	-	CHARGE FREQ		reserved		AUTO ATI MODE	

Bit definitions:

- Bit 5-4: Charge frequency divider
  - 00: 1/2
  - 01: 1/4
  - 10: 1/8
  - 11: 1/16
- Bit 1-0: Auto ATI Mode
  - 00: ATI disabled
  - 01: Partial ATI (all multipliers are fixed)
  - 10: Semi-Partial ATI (only coarse multipliers are fixed)
  - 11: Full-ATI

8.11.2 Hall-effect settings 1

Hall-effect settings 1 (0x91)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	ATI_BASE		ATI_TARGET (x32)					

Bit definitions:

- Bit 7-6: Auto ATI base value
  - 00: 75
  - 01: 100
  - 10: 150
  - 11: 200
- Bit 5-0: Auto ATI Target
  - ATI Target is 6-bit value x 32

8.11.3 Compensation Ch4/5

Compensation Ch4/5 (0x92)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Compensation (7-0)							

Bit definitions:

- Bit 7-0: Compensation (7-0)

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- 7-0: Lower 8-bits of the Compensation value.

8.11.4 Multipliers Ch4/5

Multipliers Ch4/5 (0x93)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Compensation (9-8)		Multipliers coarse		Multipliers fine			

Bit definitions:

- Bit 7-6: Compensation (9-8)
  - 0-3: Upper 2-bits of the Compensation value.
- Bit 5-4: Multipliers coarse
  - 0-3: Coarse multiplier selection
- Bit 3-0: Multipliers fine
  - 0-15: Fine multiplier selection

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8.12 Hall-effect switch UI settings

8.12.1 Hall-effect switch UI settings

Hall-effect switch UI settings (0xA0)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	-	R/W	R/W	R/W	-	R/W	R/W	R/W
Name	-	Lin Mode	Hysteresis T		-	Swap Dir	Hysteresis P	

Bit definitions:

- Bit 6: Linearize Output
  - 0: Disabled
  - 1: Enabled
- Bit 5-4: Touch Hysteresis
  - 00: Disabled
  - 01: 1/4 of threshold
  - 10: 1/8 of threshold
  - 11: 1/16 of threshold
- Bit 2: Swap field direction indication
  - 0: Disabled
  - 1: Enabled
- Bit 1-0: Proximity Hysteresis
  - 00: Disabled
  - 01: 1/4 of threshold
  - 10: 1/8 of threshold
  - 11: 1/16 of threshold

8.12.2 Hall-effect switch UI proximity threshold

Hall-effect switch UI proximity threshold (0xA1)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Proximity Threshold Value							

Bit definitions:

- Bit 7-0: Proximity Threshold = Proximity Threshold Value

8.12.3 Hall-effect switch UI touch threshold

Hall-effect switch UI touch threshold (0xA2)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Touch Threshold Value							

Bit definitions:

- Bit 7-0: Touch Threshold = Touch Threshold Value * 4

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8.13 Temperature UI settings

8.13.1 Temperature UI settings

Temperature UI settings (0xC0)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	-	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	-	Reseed in prox	Reseed enable	Reseed threshold				

Bit definitions:

- Bit 6: Reseed in prox
  - 0: Reseed will not occur during a prox
  - 1: Reseed will occur during a prox
- Bit 5: Reseed enable
  - 0: Disabled
  - 1: Enabled
- Bit 4-0: Reseed threshold
  - 0 - 32: Reseed threshold = Reseed threshold value

8.13.2 Ch3 Multipliers

Multipliers Ch3 (0xC1)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	-	-	R/W	R/W	R/W	R/W	R/W	R/W
Name	-	-	Multiplier coarse		Multiplier fine			

Bit definitions:

- Bit 5-4: Multiplier coarse
  - 0-3: Coarse multiplier selection
- Bit 3-0: Multiplier fine
  - 0-15: Fine multiplier selection

8.13.3 Temperature calibration data

Temperature calibration data0 (0xC2)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W				R/W			
Name	Temperature multiplier				Temperature divider			

Bit definitions:

- Bit 7-4: Temperature multiplier
  - 0 – 16: Temperature multiplier value
- Bit 3 – 0: Temperature divider
  - 0 – 16:Temeprature divider value

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Temperature calibration data1 (0xC3)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Temperature offset							

Bit definitions:

- Bit 7-0: Temperature offset
  - 0 – 255: Temperature offset value

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8.14 Device and power mode settings

8.14.1 System settings

System settings (0xD0)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	W=1	W=1	R/W	R/W	R/W	R/W	W=1	W=1
Name	SOFT RESET	ACK RESET	EVENT MODE	4MHz	COMMS ATI	ATI BAND	REDO ATI	RESEED

Bit definitions:

- Bit 7: Software Reset (***Set only, will clear when done***)
  - 1: Causes the device to perform a WDT reset
- Bit 6: ACK Reset (***Set only, will clear when done***)
  - 1: Acknowledge that a reset has occurred. This event will trigger until acknowledged.
- Bit 5: Event mode enable
  - 0: Event mode disabled. Default streaming mode communication.
  - 1: Event mode communication enabled.
- Bit 4: Main Clock frequency selection
  - 0: Run FOSC at 16MHz
  - 1: Run FOSC at 4MHz
- Bit 3: Communications during ATI
  - 0: No communications are generated during ATI
  - 1: Communication continue as setup regardless of ATI state.
- Bit 2: Re-ATI Band selection
  - 0: Re-ATI when outside 1/8 of ATI target
  - 1: Re-ATI when outside 1/16 of ATI target
- Bit 1: Redo ATI on all channels (***Set only, will clear when done***)
  - 1: Redo the ATI on all channels
- Bit 0: Reseed all Long-term filters (***Set only, will clear when done***)
  - 1: Reseed all channels

8.14.2 Active channels

Active channels (0xD1)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	-	-	R/W	R/W	R/W	R/W	R/W	R/W
Name	-	-	Ch5	Ch4	Ch3	Ch2	Ch1	Ch0

Bit definitions:

- Bit 5: Ch5 (***note: Ch4 and Ch5 must both be enabled for Hall-effect switch UI to be functional***)
  - 0: Channel is enabled
  - 1: Channel is disabled
- Bit 4: Ch4 (***note: Ch4 and Ch5 must both be enabled for Hall-effect switch UI to be functional***)

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- 0: Channel is enabled
- 1: Channel is disabled

- Bit 3: Ch3
  - 0: Channel is enabled
  - 1: Channel is disabled
- Bit 2: Ch2 (***note: Ch2 must be enabled for metal detect UI to be functional***)
  - 0: Channel is enabled
  - 1: Channel is disabled
- Bit 1: Ch1 (***note: Ch0 and Ch1 must both be enabled for SAR UI to be functional***)
  - 0: Channel is disabled
  - 1: Channel is enabled
- Bit 0: Ch0 (***note: Ch0 and Ch1 must both be enabled for SAR UI to be functional***)
  - 0: Channel is disabled
  - 1: Channel is enabled

8.14.3 Power mode settings

Power mode settings (0xD2)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	PWM OUT	EN ULP MODE	DSBL AUTO MODE	POWER MODE		NP SEG RATE		

Bit definitions:

- Bit 7: PWM output activation
  - 0: PWM output inactive
  - 1: PWM output active
- Bit 6: : Allow auto ultra-low power mode switching
  - 0: ULP is disabled during auto-mode switching
  - 1: ULP is enabled during auto-mode switching
- Bit 5: Disable auto mode switching
  - 0: Auto mode switching is enabled
  - 1: Auto mode switching is disabled
- Bit 4-3: Manually select power mode (***note: bit 5 must be set***)
  - 00: Normal Power mode. The device runs at the normal power rate, all enabled channels and UIs will execute.
  - 01: Low Power mode. The device runs at the low power rate, all enabled channels and UIs will execute.
  - 10: Ultra-Low Power mode. The device runs at the ultra-low power rate, Ch0 is run as wake-up channel. The other channels execute at the NP-segment rate.
  - 11: Halt Mode. No conversions are performed; the device must be removed from this mode using an I2C command.
- Bit 2-0: Normal power segment update rate
  - 000: ½ ULP rate
  - 001: ¼ ULP rate

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- 010: 1/8 ULP rate
- 011: 1/16 ULP rate
- 100: 1/32 ULP rate
- 101: 1/64 ULP rate
- 110: 1/128 ULP rate
- 111: 1/256 ULP rate

8.14.4 Normal power mode report rate

Normal power mode report rate (0xD3)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Normal power mode report rate in ms							

Bit definitions:

- Bit 7-0: Normal mode report rate in ms (***note: LPOSC timer has +- 4 ms accuracy***)

8.14.5 Low power mode report rate

Low power mode report rate (0xD4)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Low power mode report rate in ms							

Bit definitions:

- Bit 7-0: Low-power mode report rate in ms (***note: LPOSC timer has +- 4 ms accuracy***)

8.14.6 Ultra-low power mode report rate

Ultra-low power mode report rate (0xD5)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Ultra-low power mode report rate in 16 ms increments							

Bit definitions:

- Bit 7-0: Ultra-low power mode report rate in 16 ms increments (decimal value x 16ms)

8.14.7 Auto mode timer

Auto mode timer (0xD6)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	Auto mode timer in 500 ms increments							

Bit definitions:

- Bit 7-0: Auto modes switching time in 500 ms increments (decimal value x 500ms)

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8.14.8 Global event mask

Global event mask (0xD7)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	SAR ACTIVE	PMU EVENT	SYS EVENT	TEMP EVENT	METAL DETECT	HALL EVENT	SAR EVENT	PROX SENSE EVENT

Bit definitions:

- Bit 7: SAR activation state mask
  - 0: Event is allowed
  - 1: Event is masked
- Bit 6: Power management unit event mask
  - 0: Event is allowed
  - 1: Event is masked
- Bit 5: System event mask
  - 0: Event is allowed
  - 1: Event is masked
- Bit 4: Temperature event mask
  - 0: Event is allowed
  - 1: Event is masked
- Bit 4: Metal detect event mask
  - 0: Event is allowed
  - 1: Event is masked
- Bit 2: Hall-effect event mask
  - 0: Event is allowed
  - 1: Event is masked
- Bit 1: SAR event mask
  - 0: Event is allowed
  - 1: Event is masked
- Bit 0: ProxSense event mask
  - 0: Event is allowed
  - 1: Event is masked

8.14.9 PWM duty cycle

PWM duty cycle (0xD8)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Name	PWM duty cycle (%)							

Bit definitions:

- Bit 7-0: PWM duty cycle (%)
  - 0-100: PWM duty cycle of the fixed 1kHz PWM output available on GPIO3

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9 Electrical characteristics

9.1 Absolute Maximum Specifications

The following absolute maximum parameters are specified for the device:

Exceeding these maximum specifications may cause damage to the device.

Table 9.1 Absolute maximum specification

Parameter	Absolute maximum
Operating temperature	-40°C to 85°C
Supply Voltage (VDDHI – GND)	3.6V
Maximum pin voltage	VDDHI + 0.5V (may not exceed VDDHI max)
Maximum continuous current (for specific Pins)	10mA
Minimum pin voltage	GND - 0.5V
Minimum power-on slope	100V/s
ESD protection	±4kV (Human body model)

9.2 Power On-reset/Brown out

Table 9.2 Power on-reset and brown out detection specifications

DESCRIPTION	Conditions	PARAMETER	MIN	MAX	UNIT
Power On Reset	V_{DDHI} Slope ≥ 100V/s @25°C	POR	TBC	TBC	V
Brown Out Detect	V_{DDHI} Slope ≥ 100V/s @25°C	BOD	TBC	TBC	V

9.3 Digital input/output trigger levels

Table 9.3 Digital input/output trigger level specifications

DESCRIPTION	Conditions	PARAMETER	MIN	TYPICAL	MAX	UNIT
All digital inputs	VDD = 1.8V	Input low level voltage	TBC	TBC	TBC	V
All digital inputs	VDD = 1.8V	Input high level voltage	TBC	TBC	TBC	V
All digital inputs	VDD = 3.3V	Input low level voltage	TBC	TBC	TBC	V
All digital inputs	VDD = 3.3V	Input high level voltage	TBC	TBC	TBC	V

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9.4 Current consumptions

9.4.1 Capacitive sensing alone

Table 9.4 Capacitive sensing current consumption

Power mode	Supply voltage	ATI target (counts)	Report rate (ms)	MIN	TYPICAL	MAX	UNIT
NP mode	VDD = 1.8V		10	-	TBC	-	µA
	VDD = 3.3V	512	10	-	26.42	-	
			20	-	17.5	-	
			100	-	5.2	-	
LP mode	VDD = 1.8V			-	TBC	-	
	VDD = 3.3V			-	TBC	-	
ULP mode	VDD = 1.8V			-	TBC	-	
	VDD = 3.3V	512	128	-	3.15	-	
			240	-	3.05	-	
			800	-	TBC	-	
Halt mode	VDD = 1.8V			-	TBC	-	
	VDD = 3.3V			-	TBC	-	

9.4.2 Capacitive sensing with SAR UI active

Table 9.5 Capacitive sensing and SAR UI current consumption

Power mode	Supply voltage	ATI target (counts)	Report rate (ms)	MIN	TYPICAL	MAX	UNIT
NP mode	VDD = 1.8V		10	-	TBC	-	µA
	VDD = 3.3V	512	10	-	27.8	-	
			20	-	18.03	-	
			30	-	12.25	-	
			100	-	5.35	-	
LP mode	VDD = 1.8V			-	TBC	-	
	VDD = 3.3V			-	TBC	-	
ULP mode	VDD = 1.8V			-	TBC	-	
	VDD = 3.3V	512	128	-	3.15	-	
			240	-	3.05	-	
			800	-	TBC	-	
Halt mode	VDD = 1.8V			-	TBC	-	
	VDD = 3.3V			-	TBC	-	

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9.4.3 Hall-effect sensing alone

Table 9.6 Hall-effect current consumption

Power mode	Supply voltage	ATI target (counts)	Report rate	MIN	TYPICAL	MAX	UNIT
NP mode	VDD = 1.8V			-	TBC	-	µA
	VDD = 3.3V	512	10	-	64.13	-	
			20	-	40.51	-	
			100	-	10.02	-	
LP mode	VDD = 1.8V			-	TBC	-	
	VDD = 3.3V			-	TBC	-	
ULP mode	VDD = 1.8V			-	TBC	-	
	VDD = 3.3V	512	80	-	4.08	-	
			400	-	3.03	-	
			800	-	2.32	-	
Halt mode	VDD = 1.8V			-	TBC	-	
	VDD = 3.3V			-	TBC	-	

9.4.4 Inductive sensing alone

Table 9.7 Inductive sensing current consumption

Power mode	Supply voltage	ATI target (counts)	Report rate	MIN	TYPICAL	MAX	UNIT
NP mode	VDD = 1.8V			-	TBC	-	µA
	VDD = 3.3V	512	10	-	47.47	-	
			20	-	30.27	-	
			100	-	7.88	-	
LP mode	VDD = 1.8V			-	TBC	-	
	VDD = 3.3V			-	TBC	-	
ULP mode	VDD = 1.8V			-	TBC	-	
	VDD = 3.3V			-	TBC	-	
Halt mode	VDD = 1.8V			-	TBC	-	
	VDD = 3.3V			-	TBC	-	

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9.5 Capacitive loading limits

To be completed.

9.6 Hall-effect measurement limits

To be completed.

9.7 Inductive measurement limits

To be completed.

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10 Package information

10.1 DFN10 package and footprint specifications

Table 10.1 DFN-10 Package dimensions (bottom)

Dimension	[mm]
A	3 ±0.1
B	0.5
C	0.25
D	n/a
F	3 ±0.1
L	0.4
P	2.4
Q	1.65

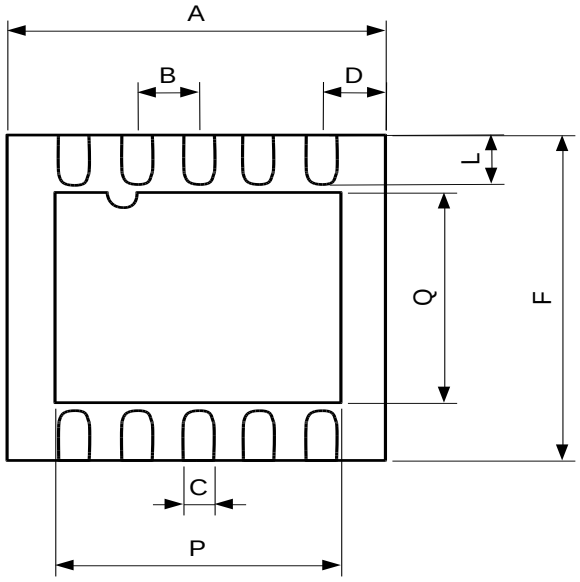


Figure 10.1 DFN-10 Package dimensions (bottom view). Note that the saddle needs to be connected to common GND on the PCB.

Table 10.2 DFN-10 Package dimensions (side)

Dimension	[mm]
G	0.05
H	0.65
I	0.7-0.8

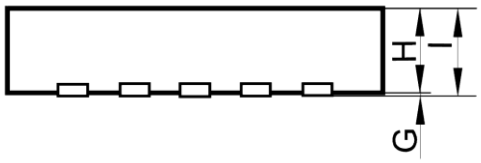


Figure 10.2 DFN-10 Package dimensions (side view)

Table 10.3 DFN-10 Landing dimensions

Dimension	[mm]
A	2.4
B	1.65
C	0.8
D	0.5
E	0.3
F	3.2

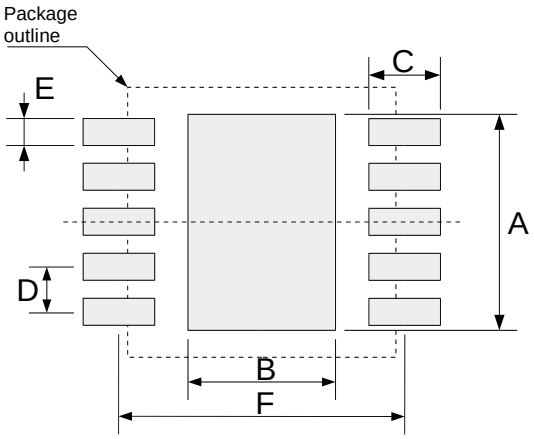


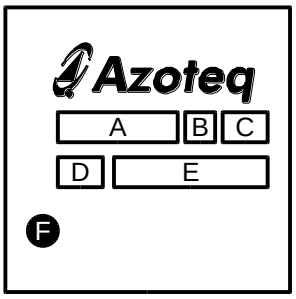
Figure 10.3 DFN-10 Landing pad dimensions (top view)

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10.2 Device marking (subjected to change for production)

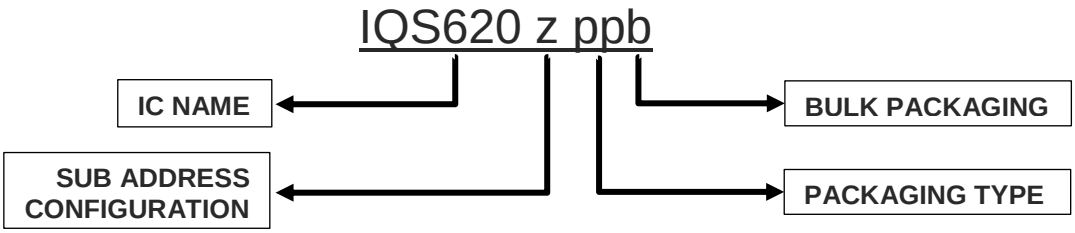
10.2.1 Top Marking



DEVICE NAME	**A**	=	IQS620
REVISION	**B**	=	x (IC Revision Number)
TEMPERATURE RANGE	**C**	=	t (i = Industrial, -40°C to 85°C)
DATE CODE	**D**	=	P (Internal use)
	E	=	WWYY (Batch number)
PIN 1 MARKING	**F**	=	Dot to indicate pin 1

10.3 Ordering Information

Order quantities will be subject to multiples of a full reel. Contact the official distributor for sample quantities. A list of the distributors can be found under the “Distributors” section of www.azoteq.com.

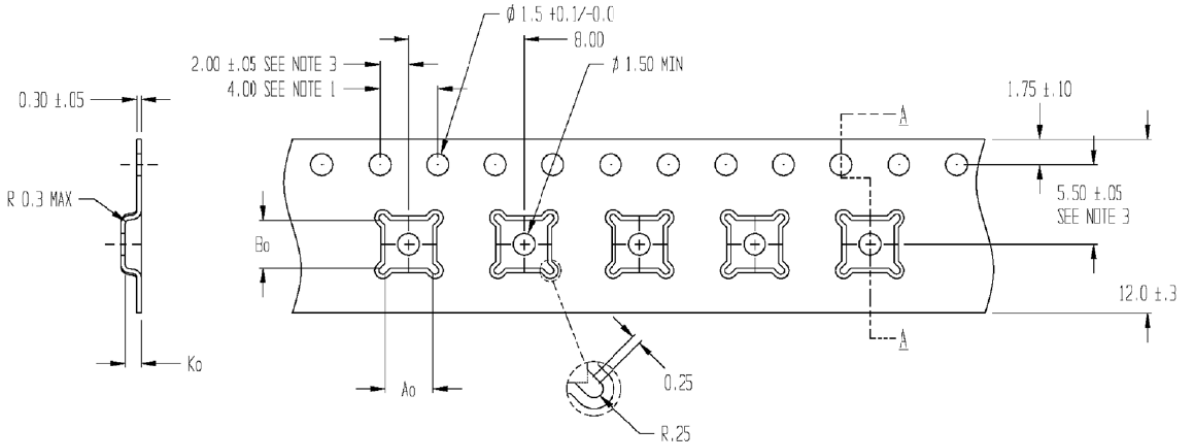


IC NAME	IQS620	=	IQS620
CONFIGURATION	z	=	Sub Address Configuration (hexadecimal) 0 = 44H 1 = 45H 2 = 46H 3 = 47H 4 = 4CH 5 = 4DH 6 = 4EH 7 = 4FH
PACKAGE TYPE	DN	=	DFN10 (3x3)
BULK PACKAGING	R	=	Reel DNF10 (3x3) – 3000pcs/reel

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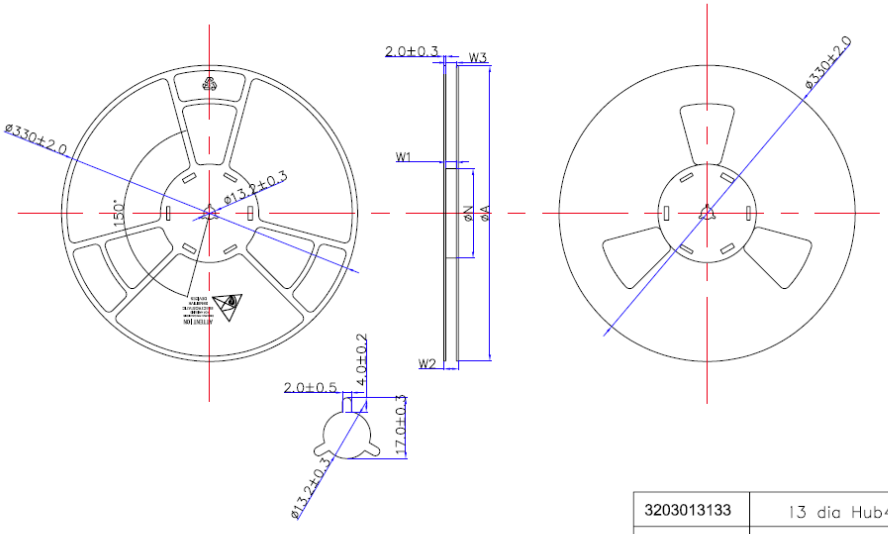
10.4 Tape and reel specification



SECTION A - A

A0=3.30
B0=3.30
K0=1.10

NOTES:
1、10 SPROCKET HOLE PITCH CUMULATIVE TOLERANCE ±0.2
2、CAMBER IN COMPLIANCE WITH EIA 481
3、POCKET POSITION RELATIVE TO SPROCKET HOLE
MEASURED AS TRUE POSITION OF POCKET, NOT POCKET HOLE



PRODUCT SPECIFICATIONS					
TYPE WIDTH	øA	øN	W1 (Min)	W2 (Max)	W3 (Max)
12MM	330±2.0	100±1.0	12.4	18.4	15.4
16mm	330±2.0	100±1.0	16.4	22.4	19.4
24MM	330±2.0	100±1.0	24.4	30.4	27.4

3203013133	13 dia Hub4 12mm width PS B
3203013213	13 dia Hub4 16mm width PS B
3203013253	13 dia Hub4 24mm width PS B

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10.5 MSL Level

Moisture Sensitivity Level (MSL) relates to the packaging and handling precautions for some semiconductors. The MSL is an electronic standard for the time period in which a moisture sensitive device can be exposed to ambient room conditions (approximately 30°C / 85%RH see J-STD033C for more info) before reflow occur.

Package	Level (duration)
DFN10	MSL 1 (Unlimited at ≤30°C / 85% RH) Reflow profile peak temperature < 260°C for < 30 seconds

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11 Datasheet revisions

11.1 Revision history

v1.0 – First release version

11.2 Errata

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Appendix A. Contact information

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Physical Address	6507 Jester Blvd Bldg 5, suite 510G Austin TX 78750 USA	Rm2125, Glittery City Shennan Rd Futian District Shenzhen, 518033 China	109 Main Street Paarl 7646 South Africa
Postal Address	6507 Jester Blvd Bldg 5, suite 510G Austin TX 78750 USA	Rm2125, Glittery City Shennan Rd Futian District Shenzhen, 518033 China	PO Box 3534 Paarl 7620 South Africa
Tel	+1 512 538 1995	+86 755 8303 5294 ext 808	+27 21 863 0033
Fax	+1 512 672 8442		+27 21 863 1512
Email	info@azoteq.com	info@azoteq.com	info@azoteq.com

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The following patents relate to the device or usage of the device: US 6,249,089; US 6,952,084; US 6,984,900; US 7,084,526; US 7,084,531; US 8,395,395; US 8,531,120; US 8,659,306; US 8,823,273; US 9,209,803; US 9,360,510; EP 2,351,220; EP 2,559,164; EP 2,656,189; HK 1,156,120; HK 1,157,080; SA 2001/2151; SA 2006/05363; SA 2014/01541; SA 2015/023634

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