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1 Introduction

This document specifies standard IQRF sensor device DPA commands and FRC commands.

ID of this standard is 0x5E.

The standard is implemented using one DPA peripheral and three DPA commands. It is intended for various sensor combinations; regardless it is a device containing:

a) only one sensor (mono-sensor),
b) more sensors of the same type (poly-sensor) and/or a combination of
c) more sensors of different types (multi-sensor).

The device supporting this standard can contain up to 32 sensors of any of the predefined types (quantities). Each sensor type defines a quantity, a unit, and a resolution when returning sensor data at DPA response caused by DPA request or returned by FRC. The sensors implemented by the device are addressed (indexed) consecutively using the index starting from index 0 up to 31. No index "gaps" are allowed.

An example of the device implementing 4 sensors:

1. The 1st sensor at index 0: temperature sensor,
2. The 2nd sensor at index 1: temperature sensor,
3. The 3rd sensor at index 2: CO_2 sensor and
4. The 4th sensor at index 3: humidity sensor.

The following chapters describe the standard in more detail. Also, see provided Custom DPA Handler source code examples for the best practice implementation details.

2 DPA Commands

The standard uses peripheral PNUM = 0x**5E** (stands for **SE**nsor)

2.1 Read Sensors

PCMD = 0x00

Reads data from the selected sensor(s). Optionally a proprietary data can be written to the sensor(s) too. Up to 32 sensors are supported.

Request

NADR	PNUM	PCMD	HWPID	0 … 3	4 … 3 + n * 5
NADR	0x5E	0x00	0xXXXX or 0xFFFF	Bitmap	WrittenData

Bitmap A 32-bit bitmap (4 bytes) specifying sensors to read data from.
There are 3 options how the Bitmap is used. Corresponding details and expected response to the request are discussed later in the Response section.

1. Read 1st sensor: the bitmap is not provided at all (i.e. the Request actually contains no data). In this case, WrittenData field cannot be present.
2. Read sensor(s): other bitmap values. If an unimplemented sensor is selected in the bitmap, there is, of course, no return value and also no error is reported. Thus the full bitmap 0xFF.FF.FF.FF indexing all theoretical 32 sensors will cause reading all actually implemented sensors without previous knowledge of their real count.

WrittenData Optional data to write to the sensors. The WrittenData data block consists of a list of a group of 5 bytes for one sensor. Bitmap field does not specify which sensor(s) data is written to. The 1st byte of the group is the sensor index; next 4 bytes are the actual data to write to the sensor. The meaning of the written data is proprietary and not standardized. If any of the specified sensors does not implement writing data then ERROR_DATA_LEN is returned. If the content of the written data is not valid ERROR_DATA is returned.

Response

NADR	PNUM	PCMD	HWPID	ErrN	DpaValue	0 … n
NADR	0x5E	0x80	0xXXXX	0	?	Data

Data The content depends on the request Bitmap format:

1. *Read 1st sensor:*

Same as option No 2 with Bitmap=0x00.00.00.01 (bitmap bytes 0x01, 0x00, 0x00, 0x00), i.e. 1st sensor (index 0) is selected. See below.

2. *Read sensor(s):*

Data contains list of sensor values for all selected sensors:

Data = [1st selected sensor value], [2nd selected sensor value], …, [last selected sensor value].

Length and format of each sensor value depend on the actual sensor type. See examples. If data from all selected sensors do not fit into reserved Data array (56 bytes at DPA 3.00) then the response is ERROR_FAIL.

2.2 Read Sensors with Types

PCMD = 0x01

This command reads not only the sensor values but also sensor types. The command is actually same as previously described Read Sensors command except that in the case when sensor values are returned at the response the values are always prefixed by 1 byte containing the sensor type. See examples.

2.3 Enumerate Sensors

PCMD = 0x3E

This command enumerates all implemented sensors.

Request

NADR	PNUM	PCMD	HWPID
NADR	0x5E	0x3E	0xXXXX or 0xFFFF

Response

NADR	PNUM	PCMD	HWPID	ErrN	DpaValue	0 … n
NADR	0x5E	0xBE	0xXXXX	0	?	Sensors

Sensors *n* equals the number of implemented sensors. Each returned byte specifies the type (quantity) of each sensor, starting from the index 0 to the last sensor. Standard sensor types are described in the dedicated chapters.

3 FRC Commands

Implemented three FRC commands return 2-bits, 1-byte or 2-bytes sensor values respectively depending on the sensor type. Also, optional “sleep after FRC” feature for the low-power (battery operated) devices is implemented.

FRC user-data has the same format for all implemented FRC commands:

UserData[0] 0x5E (equals to the PNUM).
UserData[1] Sensor type. 0x00 means any sensor type.
UserData[2] Sensor index [eeei.iiii]
bit:0…4 Sensor index (from 0 to 31) of the specified type or any type (see UserData[1]).
bit:5…7 Extended data used by some sensor types.

UserData[3] Options [xxxx.xxxs]
bit:0 When this bit is set then optional sleep parameters at UserData[4..6] are present. See below.
bit:1…7 Reserved.

UserData[4…6] Optional “sleep after FRC” parameters of the same format as CMD_OS_SLEEP, i.e. [4…5]=Time, [6]=Control

3.1 2-bits sensor value - 0x10

Returns 2-bits sensor data of the supporting sensor types.

3.2 1-byte sensor value - 0x90

Returns 1-byte wide sensor data of the supporting sensor types.

3.3 2-bytes sensor value - 0xE0

Returns 2-bytes wide sensor data of the supporting sensor types.

3.4 Predefined FRC values

FRC type			Meaning
2-bits	1-byte	2-bytes	
0b00	0x00	0x0000	No FRC response (device is not responding)
0b01	0x01	0x0001	FRC not implemented
	0x02	0x0002	Sensor error or Out of FRC range
	0x03	0x0003	Reserved

4 Sensor Types

Sensor type is a one byte value that specifies the type (quantity) of the sensor as well as the size of the sensor data in case of Read Sensors command and FRC. The sensor type (byte) uses the following format to encode data width and actual sensor type (bits x):

[0000.0000] *undefined*
[0xxx.xxxx] => 2 bytes of data (127 options)
[100x.xxxx] => 1 byte of data (32 options)
[101x.xxxx] => 4 bytes of data (32 options)
[11xx.xxxx] => variable number of bytes (64 options), the 1st data byte specifies number of remaining data bytes (e.g. 5, 0xAA, 0xBB, 0xCC, 0xDD, 0xEE)

4.1 [0x01] Temperature

- **The return value** is 2-bytes wide signed (two's complement) value, the unit is 1°C, the resolution is 1/16 °C = 0.0625 °C, and theoretical range is ±2,047.9375 °C. Value 0x8000 (i.e. -2,048 °C) specifies a sensor error.

[siii.iiii.iiii.ffff]
bit: 0…3 Fractional part (unit 1/16 °C).
bit: 4…14 Integer part (unit 1 °C).
bit: 15 Sign.

- **FRC 1-byte:** uses ½ °C resolution. Return value F = (T + 22) * 2 so T = F / 2 - 22 (i.e. 4 is -20.0 °C, 44 is 0.0 °C, 255 is 105.5 °C). Range is from -20.0 to 105.5 °C. When the value is out of this range, FRC error value is returned.
- **FRC 2-byte:** value is 2-byte return value +0x8000 that actually causes inverting of the most significant sign bit (i.e. 0x8000 is 0.0 °C, 0x8640 is 100.0 °C, 0x79C0 is -100.0 °C).

4.2 [0x02] CO^2

- **The return value** is 2-bytes wide unsigned CO^2 concentration value, the unit is 1 ppm, the resolution is 1 ppm, and theoretical range from 0 to 32,767 ppm. Value 0x8000 (i.e. 32,768 ppm) specifies a sensor error. Greater values are not used.

- **FRC 1-byte:** return value uses 16 ppm resolution. Return value F = (CO^2 / 16) + 4 so CO^2 = (F - 4) * 16 (i.e. 4 is 0 ppm, 255 is 4016 ppm). Range is from 0 to 4016 ppm. When the value is above this range, FRC error value is returned.
- **FRC 2-byte:** return value is CO^2 value +4 (i.e. 0x03EC=1,004 is 1,000 ppm).

4.3 [0x03] VOC (volatile organic compounds)

- **The return value** is 2-bytes wide unsigned VOC concentration value, the unit is 1 ppm, the resolution is 1 ppm, and theoretical range from 0 to 32,767 ppm. Value 0x8000 (i.e. 32,768 ppm) specifies a sensor error. Greater values are not used.

- **FRC 1-byte:** return value uses 16 ppm resolution. Return value F = (VOC / 16) + 4 so VOC = (F - 4) * 16 (i.e. 4 is 0 ppm, 255 is 4016 ppm). Range is from 0 to 4016 ppm. When the value is above this range, FRC error value is returned.
- **FRC 2-byte:** return value is VOC value +4 (i.e. 0x1160=4,448 is 4,444 ppm).

4.4 [0x04] Extra-low Voltage

- **The return value** is 2-bytes wide signed (two's complement) value, the unit is 1 V, the resolution is 1 mV, the range is ±32.767 V. Value 0x8000 (i.e. -32.768 V) specifies a sensor error.

- **FRC 2-byte:** return value is voltage value +0x8000 that actually causes inverting of the most significant sign (i.e. 0xB039=45,113 is 12.345 V). Because of FRC predefined values the raw values from 0x8000 to 0x8003 (i.e. -32.767 V to -32.755 V) cannot be passed.

4.5 [0x05] Earth's Magnetic Field

- **The return value** is 2-bytes wide signed (two's complement) value, the unit is 1 T (Tesla), the resolution is 0.1 μT, the range is ±3.2767 mT. Value 0x8000 (i.e. -3.2768 mT) specifies a sensor error.

- **FRC 2-byte:** return value is the magnetic field value +0x8000 that actually causes inverting of the most significant sign (i.e. 0xB039=45,113 is 1.2345 mT). Because of FRC predefined values the raw values from 0x8000 to 0x8003 (i.e. -3.2767 V to -3.2755 V) cannot be passed.

4.6 [0x06] Low Voltage

- **The return value** is 2-bytes wide signed (two's complement) value, the unit is 1 V, the resolution is 1/16 V = 0.0625 V, and the range is ±2,047.9375 V. Value 0x8000 (i.e. -2,048 V) specifies a sensor error.

`[siii.iiii.iiii.ffff]`
bit: 0…3 Fractional part (unit 1/16 V).
bit: 4…14 Integer part (unit 1 V).
bit: 15 Sign.

- **FRC 2-byte:** value is 2-byte return value +0x8000 that actually causes inverting of the most significant sign bit (i.e. 0x8000 is 0.0 V, 0x8E60 is 230.0 V, 0x7F40 is -12.0 V). Because of FRC predefined values the raw values from 0x8000 to 0x8003 (i.e. -2047.8125 V to -2047.9375 V) cannot be passed.

4.7 [0x07] Current

- **The return value** is 2-bytes wide signed (two's complement) value, the unit is 1 A, the resolution is 1 mA, the range is ±32.767 A. Value 0x8000 (i.e. -32.768 A) specifies a sensor error.
- **FRC 2-byte:** return value is 2-byte return value +0x8000 that actually causes inverting of the most significant sign (i.e. 0x84D2=34,002 is 1.234 A). Because of FRC predefined values the raw values from 0x8000 to 0x8003 (i.e. -32.767 A to -32.765 A) cannot be passed.

4.8 [0x08] Power

- **The return value** is unsigned and 2-bytes wide value, the unit is 1 W, the resolution is 1/4 W = 0.25 W, and the range is from 0.00 W to 16,383.50 W. Value 0xFFFF (i.e. 16,383.75 W) specifies a sensor error.

`[iiii.iiii.iiii.iiff]`
bit: 0…1 Fractional part (unit 1/4 W).
bit: 2…15 Integer part (unit 1 W).

- **FRC 2-byte: FRC 2-byte:** return value is power value +4 (i.e. 0x0FA4=4,004 is 1,000.00 W). Because of FRC predefined values the raw values from 0xFFFC to 0xFFFF (i.e. 16,383.00 W to 16,383.50 W) cannot be passed.

4.9 [0x09] Mains Frequency

- **The return value** is unsigned and 2-bytes wide value, the unit is 1 Hz, the resolution is 1 mHz, and the range is from 0.000 Hz to 65.534 Hz. Value 0xFFFF (i.e. 65.535 Hz) specifies a sensor error.

- **FRC 2-byte: FRC 2-byte:** return value is mains frequency value +4 (i.e. 0xC354=50,004 is 50.000 Hz). Because of FRC predefined values the raw values from 0xFFFC to 0xFFFF (i.e. 65.532 Hz to 65.535 Hz) cannot be passed.

4.10 [0x80] Humidity

- **The return value** is unsigned and 1-byte wide, the unit is 1 %, the resolution is 0.5 %, practical range is from 0.0 to 100.0 %. Value 0xEE (i.e. 119.0 %) specifies a sensor error. Other values are undefined.

```
[iiii.iiif]
```
bit: 0 Fractional part (unit ½ %).
bit: 1…7 Integer part.

- **FRC 1-byte:** return value is the return value (with 0.5 % resolution) +4 (i.e. 4 is 0.0 %, 204 is 100.0 %).

4.11 [0x81] Binary Data7

- **The return value** is 7 bits of data of the unspecified meaning. It can be proprietary used by the sensor for returning error states, binary inputs, counters, etc.

```
[ebbb.bbbb]
```
bit: 0…6 Binary data.
bit: 7 Specifies a sensor error. If this bit set then binary data is not valid. Binary data bits 0-6 must be zeroed.

- **FRC 2-bits:** return bit is a bit value of the binary data7 value at the bit position specified by the 3 extended data bits at UserData[2]. If the bit is set, then 0b11 otherwise 0b10 is returned. For instance, 0x41 returns value of the bit #2 of the binary data7 sensor with index 1.
- **FRC 1-byte:** return value is the return value +4 (i.e. 4 is 0=0x00, 131=0x83 is 127=0x7F).

4.11.1 Car Presence Status

Parking detectors use Binary data7 type to indicate the presence of the car on a parking slot. In reality bit 0 indicates whether the car is present.

4.12 [0x82] Power Factor

- **The return value** is unsigned and 1-byte wide, the unit is 1, the resolution is 0.005, the practical range is from 0.000 to 1.000. Value 0xEE (i.e. 1.190) specifies a sensor error. Other values are undefined.

- **FRC 1-byte:** return value is the return value (with 0.005 resolution) +4 (i.e. 4 is 0.000, 204 is 1.000).

4.13 [0xA0] Binary Data30

- **The return value** is 30 bits of data of the unspecified meaning. It can be proprietary used by the sensor for returning error states, binary inputs, counters, etc.

```
[e.x.bb.bbbb.bbbb.bbbb.bbbb.bbbb.bbbb.bbbb]
```
bit: 0…29 Binary data.
bit: 30 Reserved. Must be 0.
bit: 31 Specifies a sensor error. If this bit set then binary data is not valid. All other bits 0-30 must be zeroed.

- **FRC 2-byte:** return value is one of the specified halves of the binary data30 value. If bit 5 at extended data bits at UserData[2] is 0, then bit: 0…14 plus +4 is returned. If the bit is 1 then bit: 15…29 plus +4 is returned.

4.13.1 Vehicle Counter

Parking detectors use Binary data30 type to return a number of detected vehicles. The range is from 0 to 1,073,741,824.

4.13.2 Energy

The unit is 1 Wh, the resolution is also 1 Wh. The range is from 0 Wh to 1,073,741,824 Wh.

4.14 [0xA1] Consumption

- **The return value** is unsigned and 4-bytes wide value, the unit is 1 Wh, the resolution is 1 Wh, and the range is from 0 Wh to 4,294,967,295 Wh = ~4.3 GWh. Value 0xFFFFFFFF (i.e. 4,294,967,296 Wh) specifies a sensor error.

4.15 [0xA2] Datetime

- **The return value** is unsigned and 4-bytes wide value, the unit is 1 s, the resolution is 1 s. The value is a widely used Unix time i.e. "*number of seconds that have elapsed since 00:00:00 Coordinated Universal Time (UTC), 1 January 1970, minus the number of leap seconds that have taken place since then*". The range is from *1 January 1970 to* 19 January 2038 03:14:07 GMT. Value 0xFFFFFFFF (i.e. 19 January, 2038 03:14:08 GMT) specifies a sensor error.

5 Examples

Note: if not specified then PNUM=0x5E and always the same device.

Enumerate sensor types:

- Request

PCMD=0x3E Enumerate sensors

- Response

PCMD=0xBE, PData=[0x01 Temperature, 0x01 Temperature, 0x02 CO2, 0x80 Humidity] => 1st and 2nd sensors are temperature sensors, 3rd is CO_2 and 4th is humidity sensor.

Read values from sensors of indexes 0 and 3. Write 0x11, 0x22, 0x44, 0x55 to the 3rd sensor.

- Request

PCMD=0x00 Read sensors, PData=[0x09 1st and 4th sensor, 0x00, 0x00, 0x00][0x02 3rd sensor, 0x11, 0x22, 0x44, 0x55]

- Response

PCMD=0x80, PData=[0x40 Temperature value lower byte,0x01 Temperature value higher byte,0xA0 Humidity value] => 1st temperature sensor returns 20.0 °C, 4th humidity sensor returns 80.0 %.

Read values of indexes 0 and 3 from sensors including their types:

- Request

PCMD=0x01 Read sensors with types, PData=[0x09 1st and 4th sensor,0x00,0x00,0x00]

- Response

PCMD=0x81, PData=[0x01 Temperature, 0x40 Temperature value lower byte, 0x01 Temperature value higher byte, 0x80 Humidity, 0xA0 Humidity value] => 1st sensor is temperature sensor and it returns 20.0 °C, 4th sensor is humidity sensor and it returns 80.0 %.

Read value and type of the 1st sensor

- Request

PCMD=0x01 Read sensors with types, PData=*none* 1st sensor only

- Response

PCMD=0x81, PData=[0x01 Temperature, 0x40 Temperature value lower byte, 0x01 Temperature value higher byte] => 1st sensor is temperature sensor and it returns 20.0 °C.

Read FRC byte temperature value from the 2nd temperature sensor from all nodes. Nodes supporting this temperature FRC then deep-sleep for 5 minutes.

- Request

PNUM=0x0D FRC peripheral, PCMD=0x00 FRC Send, PData=[0x90 1-byte FRC][0x5E, 0x01 Temperature, 0x01 2nd sensor][0x01 Sleep used][0x8F Sleep time lower byte, 0x00 Sleep time higher byte, 0x20 Sleep control byte]

- Response

PNUM=0x0D, PCMD=0x80, PData=[0x?? FRC status][0x?? unused][0x40 Node#1, 0x59 Node#2, 0xF4 Node#3, 0x00, …, 0x00] => Nodes from addresses 1 to 3 returned temperatures 10.0 °C, 22.5 °C, 100.0 °C respectively.

6 ToDo

- Par1 and Par2 usage at peripheral enumeration