FIFO buffers embedded in ST MEMS sensors

Version 1.5

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Agenda

Educational part: What is FIFO? How it works? Watermark etc.

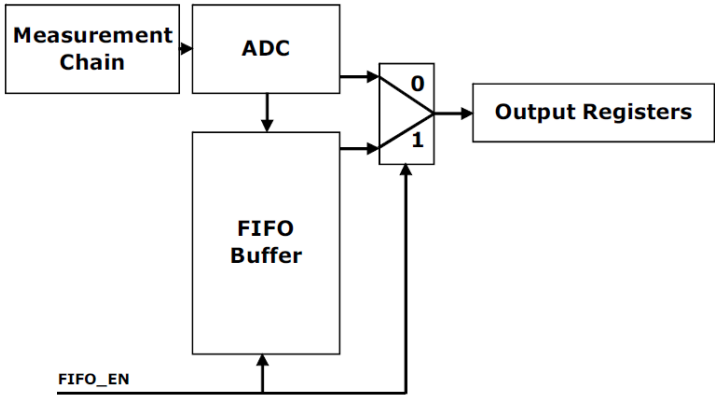
LIS3DH, L3GD20 and LIS3DSH FIFO features / modes

FIFO: Typical use cases: storing history of event, lowering MCU workload etc.

Why FIFO? How it works?

- FIFO allows to decrease the host MCU interaction with the sensor and therefore allows system power savings
- FIFO buffer can work in several different modes for application flexibility reasons
  - Bypass, FIFO, Stream, Stream to FIFO, …
- FIFO programmable watermark level, FIFO overrun and FIFO empty events can be enabled to generate interrupts

FIFO connection block diagram



FIFO in-sight view

Output registers	0x28h	0x29h	0x2Ah	0x2Bh	0x2Ch	0x2Dh
	XI(1)	Xh(1)	YI(1)	Yh(1)	ZI(1)	Zh(1)
FIFO index	Sample set					
FIFO(0)	XI(1)	Xh(1)	YI(1)	Yh(1)	ZI(1)	Zh(1)
FIFO(1)	XI(2)	Xh(2)	YI(2)	Yh(2)	ZI(2)	Zh(2)
FIFO(2)	XI(3)	Xh(3)	YI(3)	Yh(3)	ZI(3)	Zh(3)
FIFO(3)	XI(4)	Xh(4)	YI(4)	Yh(4)	ZI(4)	Zh(4)
…	…	…	…	…	…	…
…	…	…	…	…	…	…
FIFO(30)	XI(31)	Xh(31)	YI(31)	Yh(31)	ZI(31)	Zh(31)
FIFO(31)	XI(32)	Xh(32)	YI(32)	Yh(32)	ZI(32)	Zh(32)

32nd sample
33rd sample

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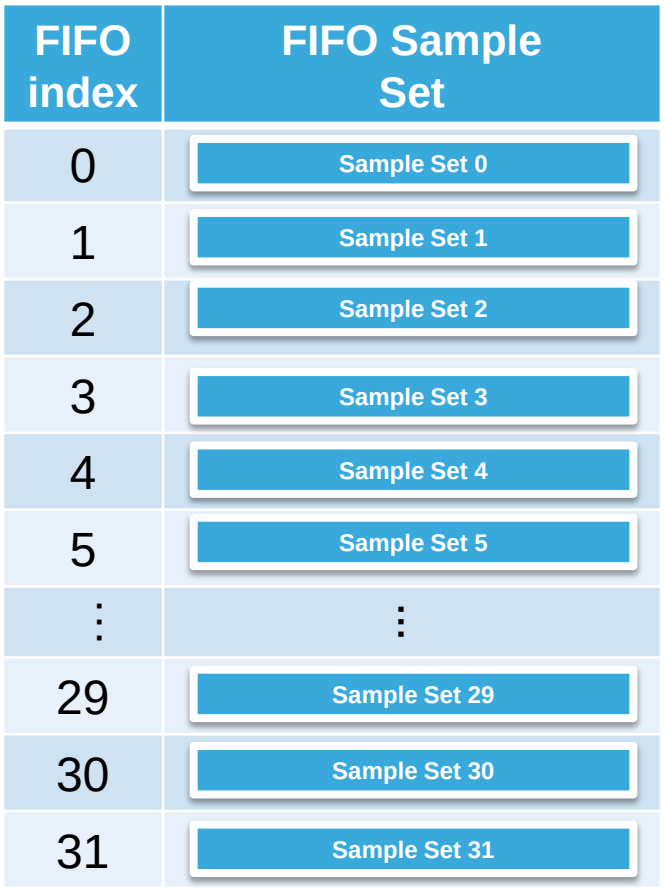
Watermark, Empty and Full/OVRN events



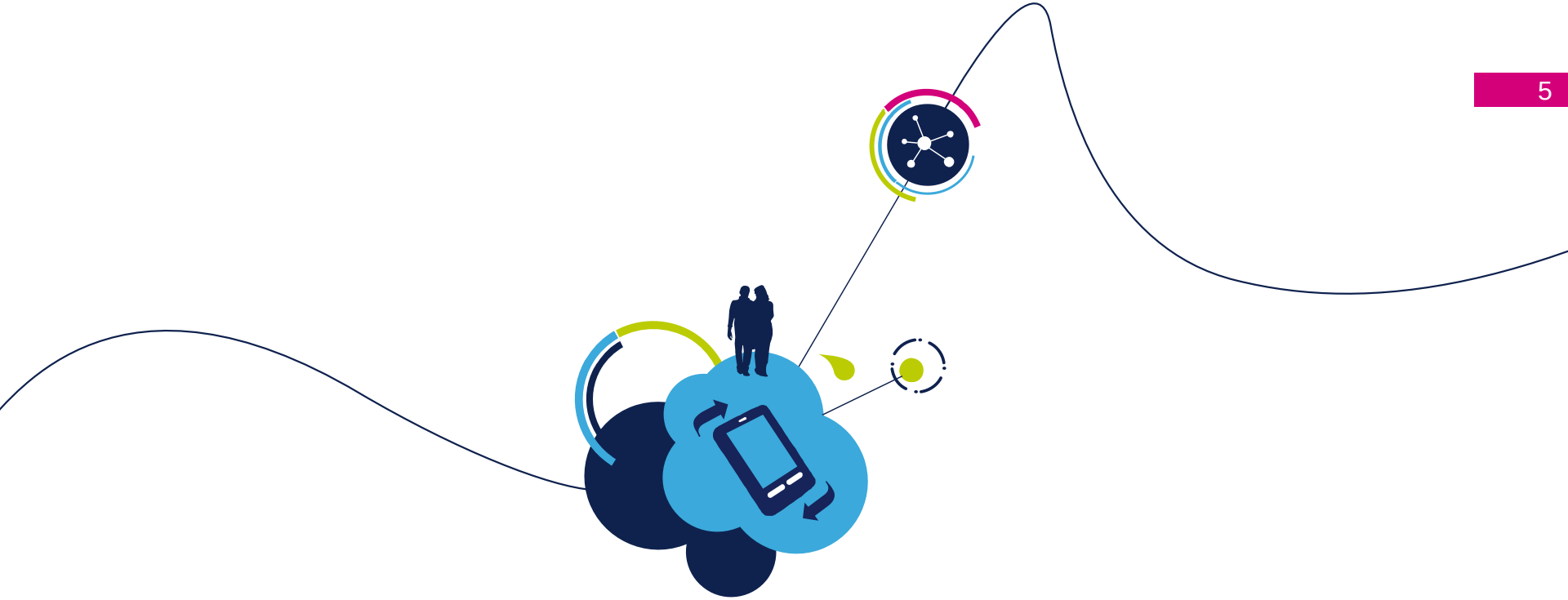
EMPTY flag is set high when all FIFO samples have been read and FIFO is empty

Watermark level (User selectable from 0 to 31) flag is set when the number of FIFO sample sets recorded exceeds this value

Full / OVRN flag is set high when FIFO buffer is full; this means that the FIFO buffer contains 32 unread samples. The OVRN bit is reset when the first sample data has been read

Watermark level set to 2

Dedicated register always contains the current number of unread samples in FIFO



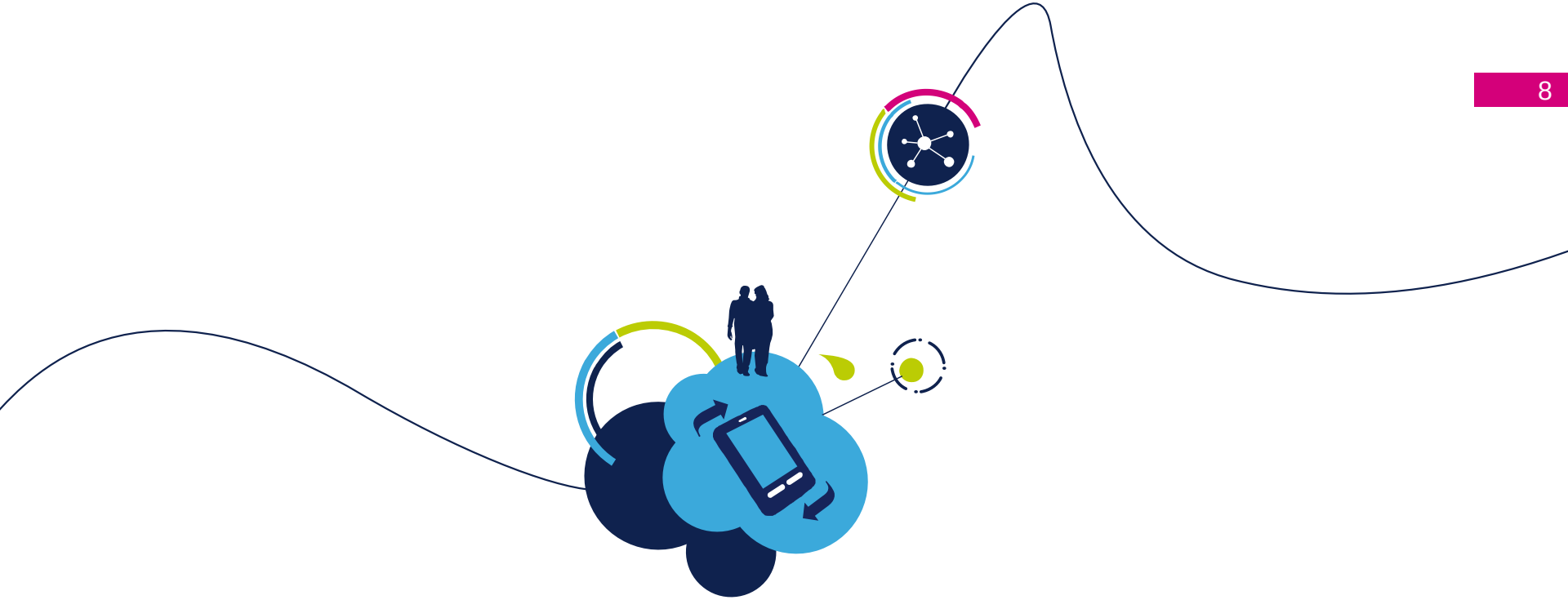
LIS3DH accelerometer FIFO

LIS3DH FIFO Parameters

- First in, first out buffer
  - Able to store up to **32 sample sets**
  - When FIFO is used - there is **10 bit** data resolution in normal mode; **8 bit** data resolution in low power mode (compared to 12 bit data resolution when FIFO is not used)
  - Each sample set is composed of **complete data from 3 axis**
- Sample sets are released from sensor to FIFO at selected output data rate (ODR)
- Flags
  - Full / Empty flags
  - Watermark flag – set when selectable number of sample sets has been stored
- Interrupts based on Full and Watermark (not on Empty) flags can be generated
- 4 modes of operation

LIS3DH FIFO Modes of operation

- FIFO
  - FIFO continues filling until it is full (32 sample sets stored) and then stops collecting data.
  - In order to restart FIFO mode it is mandatory to transit on Bypass mode.
- Stream
  - FIFO continues filling, when buffer is full, the older data is replaced by the actual one.
  - Bypass mode is used to stop this mode
- Stream to FIFO
  - FIFO continues filling, when buffer is full older data is replaced by the actual one.
  - When Trigger (user selectable event on INT1 or INT2) occurs:
    - if FIFO is already full it stops collecting data at the first sample after trigger (#30 samples before trigger + trigger sample + #1 sample after trigger)
    - If FIFO isn't full it continues filling till it will be full and then, if trigger is still present, it stops collecting data
- Bypass
  - FIFO buffer is not operational and it remains empty.
  - This mode can be used in order to reset FIFO when different mode is operating.



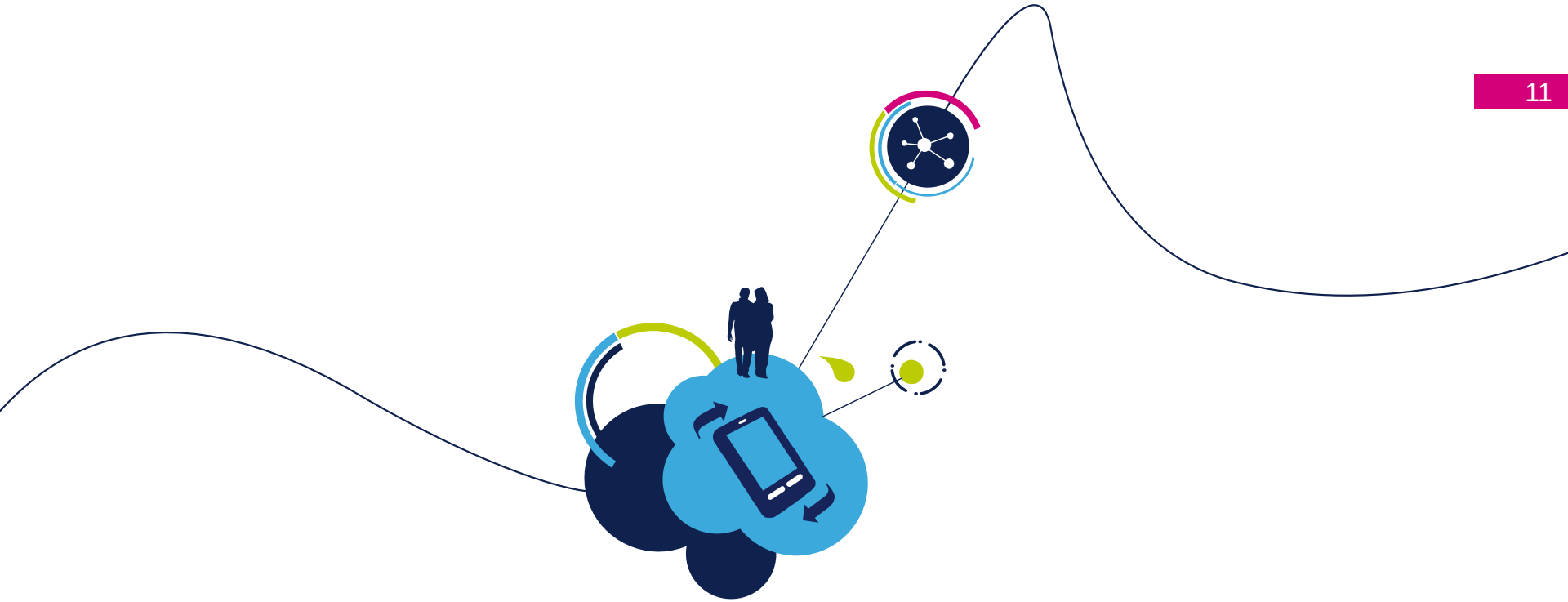
L3GD20 gyroscope FIFO

Differences L3GD20 vs. LIS3DH FIFO

- **16 bit** data resolution
- 1 new mode of operation : Bypass-to-Stream (5 modes in total)
- Interrupts based on all flags Full, Watermark and Empty can be generated
- Trigger event from INT1 (INT2 does not exists in L3GD20)

L3GD20 FIFO Modes of operation

- FIFO (Same as for LIS3DH)
  - FIFO continues filling until it is full (32 sample sets stored) and then stops collecting data.
  - In order to restart FIFO mode it is mandatory to transit on Bypass mode.
- Stream (Same as for LIS3DH)
  - FIFO continues filling, when buffer is full, the older data is replaced by the actual one.
  - Bypass mode is used to stop this mode
- Stream to FIFO (Same as for LIS3DH)
  - FIFO continues filling, when buffer is full older data is replaced by the actual one.
  - When Trigger (user selectable event) occurs:
    - if FIFO is already full it stops collecting data at the first sample after trigger (#30 samples before trigger + trigger sample + #1 sample after trigger)
    - If FIFO isn't full it continues filling till it will be full and then, if trigger is still present, it stops collecting data
- Bypass (Same as for LIS3DH)
  - FIFO buffer is not operational and it remains empty.
  - This mode can be used in order to reset FIFO when different mode is operating.
- Bypass-to-Stream (New compared to LIS3DH)
  - FIFO begins operating in Bypass mode
  - Once a trigger event occurs, the FIFO starts operating in Stream mode



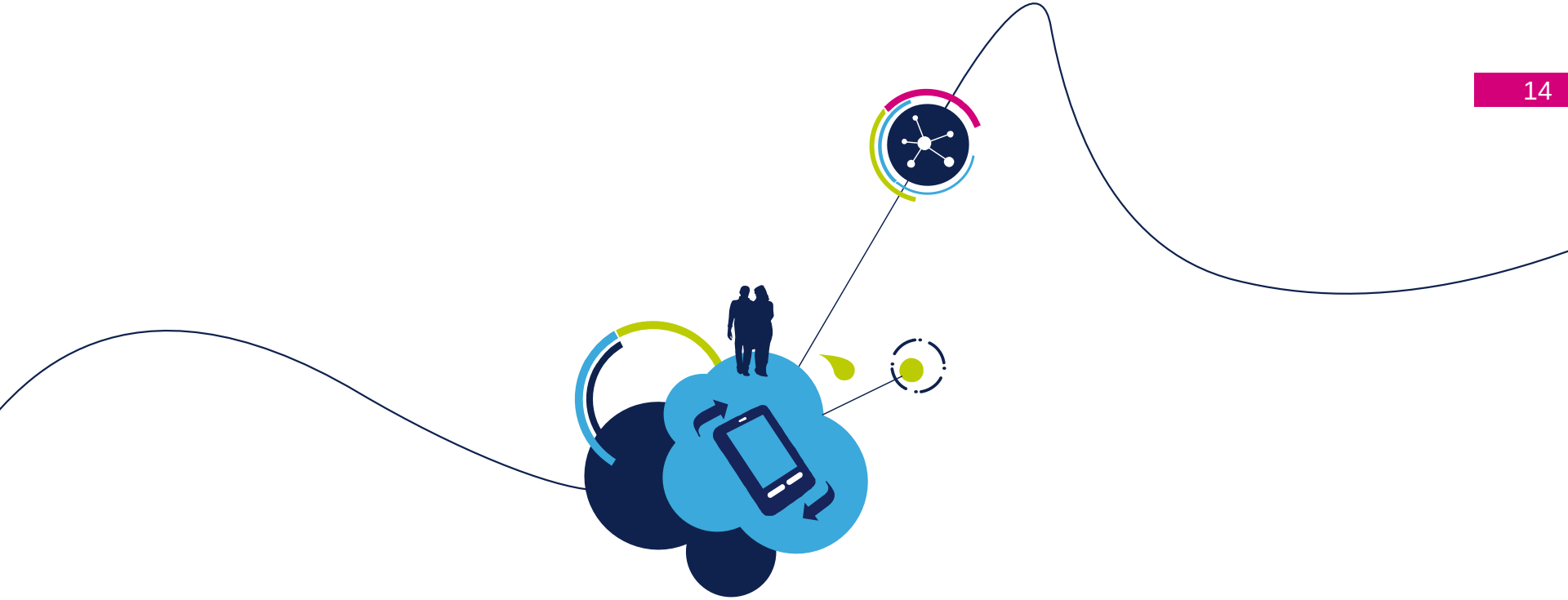
LIS3DSH accelerometer FIFO

Differences LIS3DSH vs. L3GD20 FIFO

- **14 bit** data resolution
- 1 new mode of operation: Bypass-to-FIFO (6 modes in total)
- Interrupts based on Watermark, Overrun (full) and Empty flags can be generated
- Trigger event from INT_SM2 (2nd state machine)

LIS3DSH FIFO Modes of operation

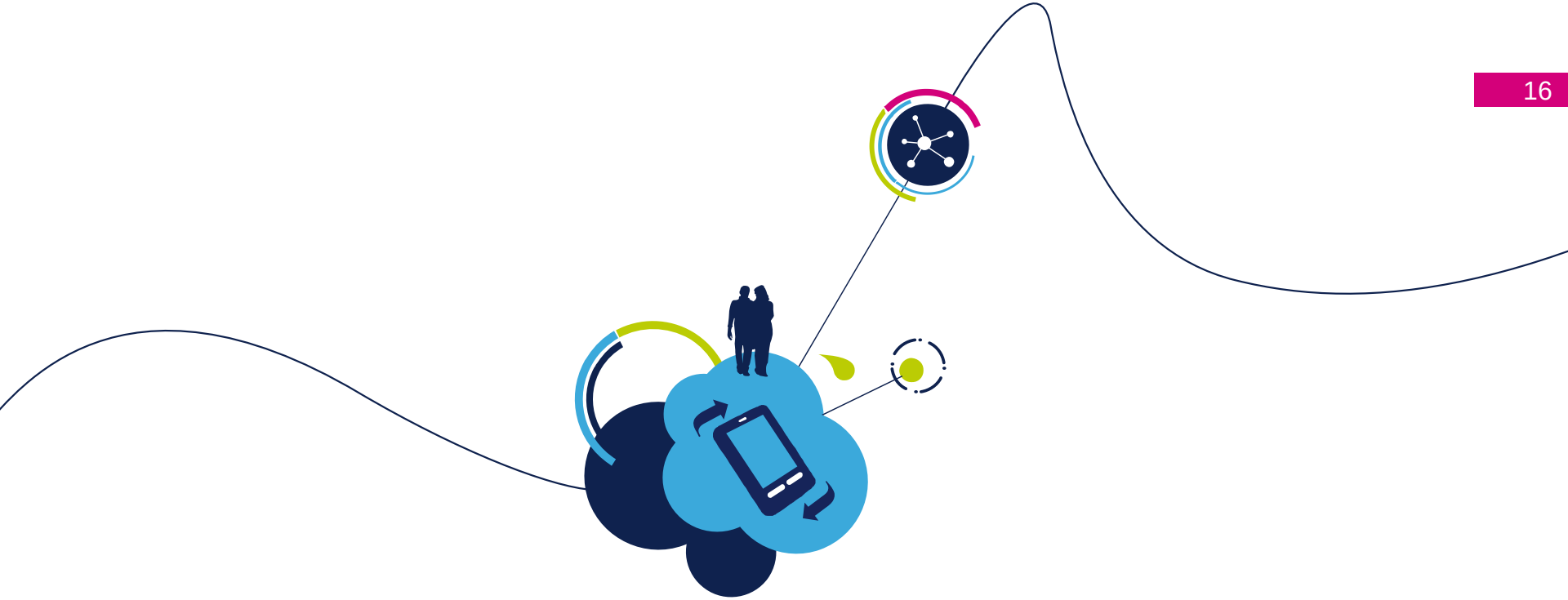
- FIFO (Same as for LIS3DH)
- Stream (Same as for LIS3DH)
- Stream to FIFO (Same as for LIS3DH)
  - FIFO continues filling, when buffer is full older data is replaced by the actual one.
  - When Trigger (user selectable event) occurs:
    - if FIFO is already full it stops collecting data at the first sample after trigger (#30 samples before trigger + trigger sample + #1 sample after trigger)
    - If FIFO isn't full it continues filling till it will be full and then, if trigger is still present, it stops collecting data
- Bypass (Same as for LIS3DH)
- Bypass-to-Stream (Same as for L3GD20)
  - FIFO begins operating in Bypass mode
  - Once a trigger event occurs, the FIFO starts operating in Stream mode
- Bypass-to-FIFO (New compared to L3GD20)
  - FIFO begins operating in Bypass mode
  - Once a trigger event occurs, the FIFO starts operating in FIFO mode (32 sample sets stored) and then stops collecting data



Other devices

Other ST MEMS sensors

Device	FIFO
L3G4200D Gyroscope	Same FIFO as L3GD20
LSM330D Accelerometer	Same FIFO as LIS3DH
LSM330D Gyroscope	Same FIFO as L3GD20
LSM330DLC Accelerometer	Same FIFO as LIS3DH
LSM330DLC Gyroscope	Same FIFO as L3GD20
LSM303DLHC Accelerometer	Same FIFO as LIS3DH
LSM303DLHC Magnetometer	No FIFO
LSM303D Accelerometer	5 modes Bypass, FIFO, Stream, Stream-to-FIFO, Bypass-to-Stream
LSM303D Magnetometer	No FIFO

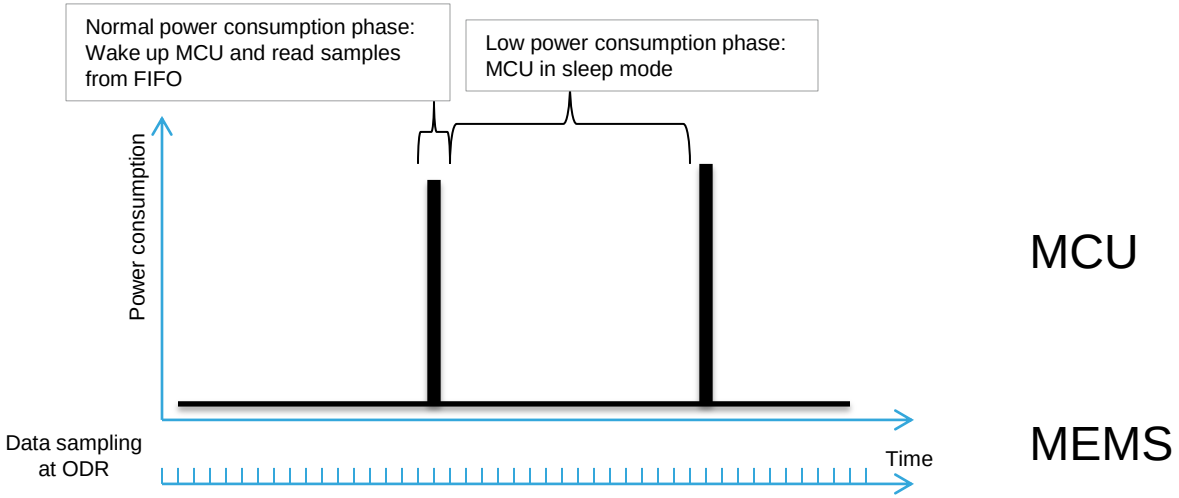


Why is FIFO so beneficial for a MEMS sensor?

Typical use cases

1. Lowering MCU power consumption – Achieving higher ODR
2. Saving history of an event
3. Avoiding data loss – Smooth data capture
4. Easy data acquisition for filtering or oversampling
5. Start data buffering when needed (otherwise FIFO not used)
6. Buffer and store data after an event occurs

1. Lowering power consumption – Achieving higher ODR



MCU can be put to sleep mode for much longer period of time.
MCU does not need to poll for new data frequently.
The same ODR can be achieved with lower power consumption.
or
Higher ODR can be achieved with the same power consumption.

- Way of Operation:
  - Acceleration data is stored in the FIFO without MCU intervention.
  - Once FIFO is full, MCU is waken up by interrupt signal coming from sensor.
  - Data is read in a single read sequence using address auto-increment.
  - **FIFO mode used: FIFO**

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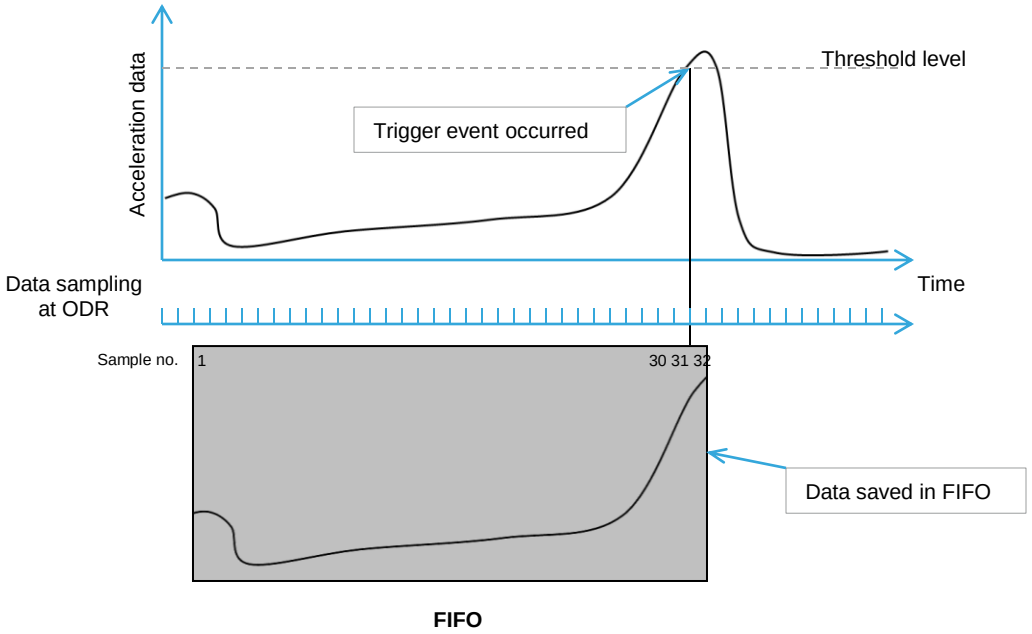
2. Saving history of an event

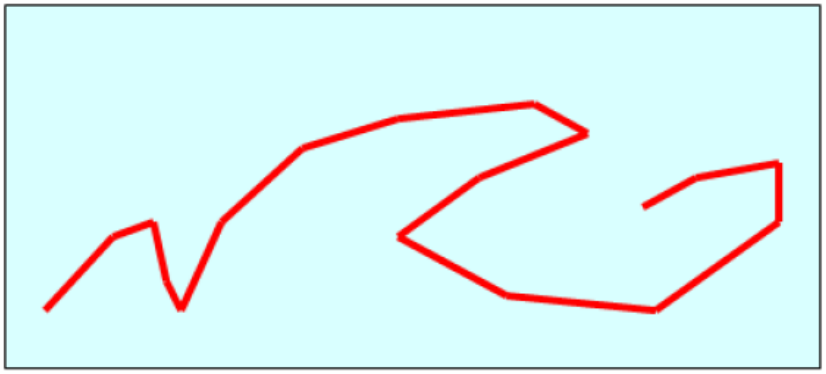


History of the event trigger can be read from the FIFO at any time.

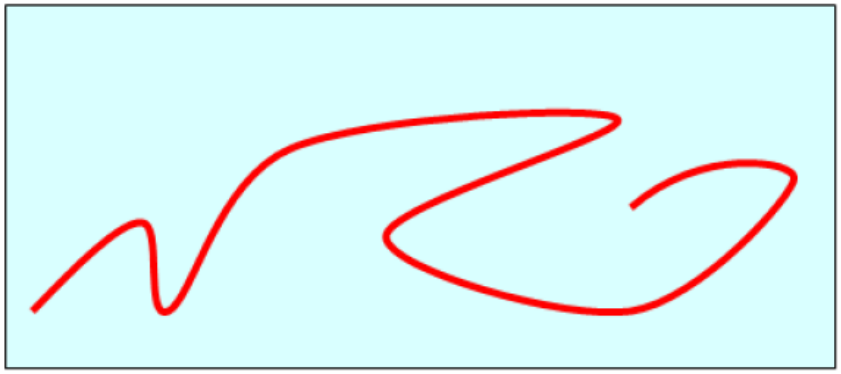
(30 samples before trigger + trigger sample + 1 sample after trigger)

- Way of operation
  - Data is being continuously stored in FIFO
  - When pre-selected trigger occurs, FIFO stops storing new data.
  - **FIFO mode used: Stream-to-FIFO mode**

3. Avoiding data loss – Smooth data capture



Without FIFO

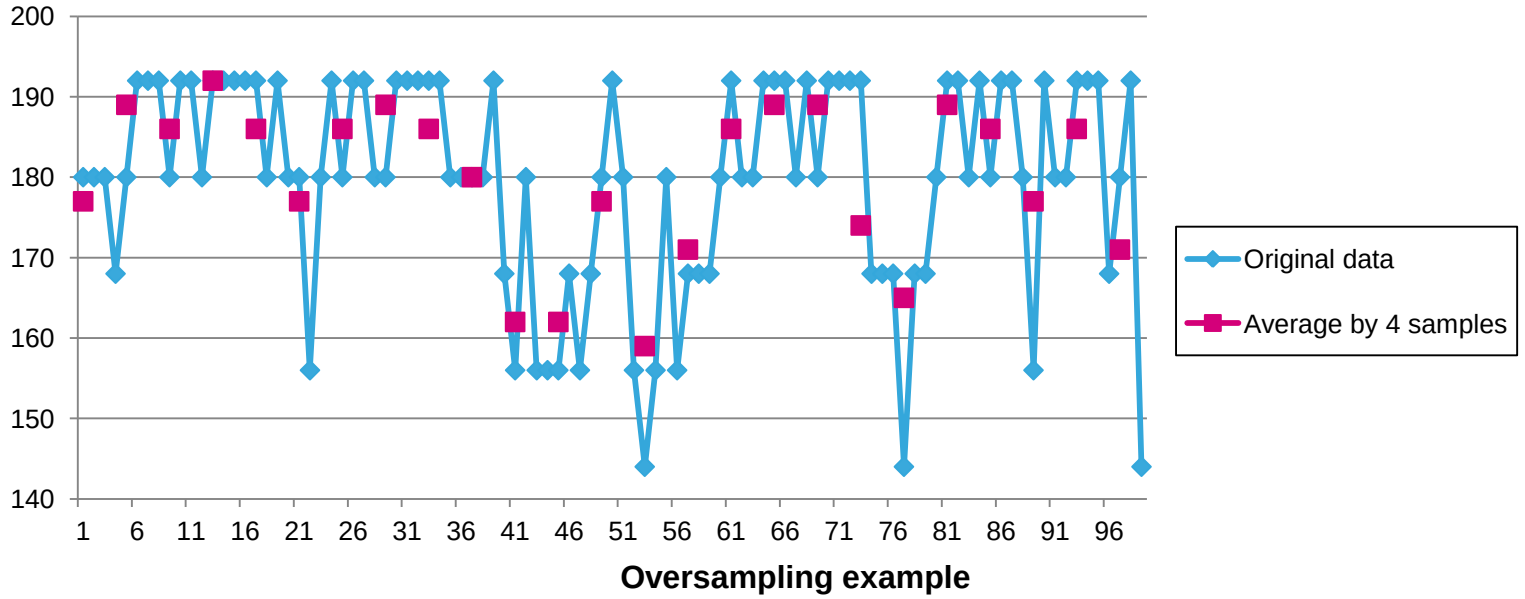


With FIFO

No data loss – smooth data capture.

- Way of operation
  - When MCU cannot read data at given ODR. (MCU would lose data because of other operation)
  - FIFO stores data at ODR and instructs MCU to read data only when FIFO is full or when user-selected watermark level (number of samples) is reached
  - **FIFO mode used: Stream or FIFO mode**

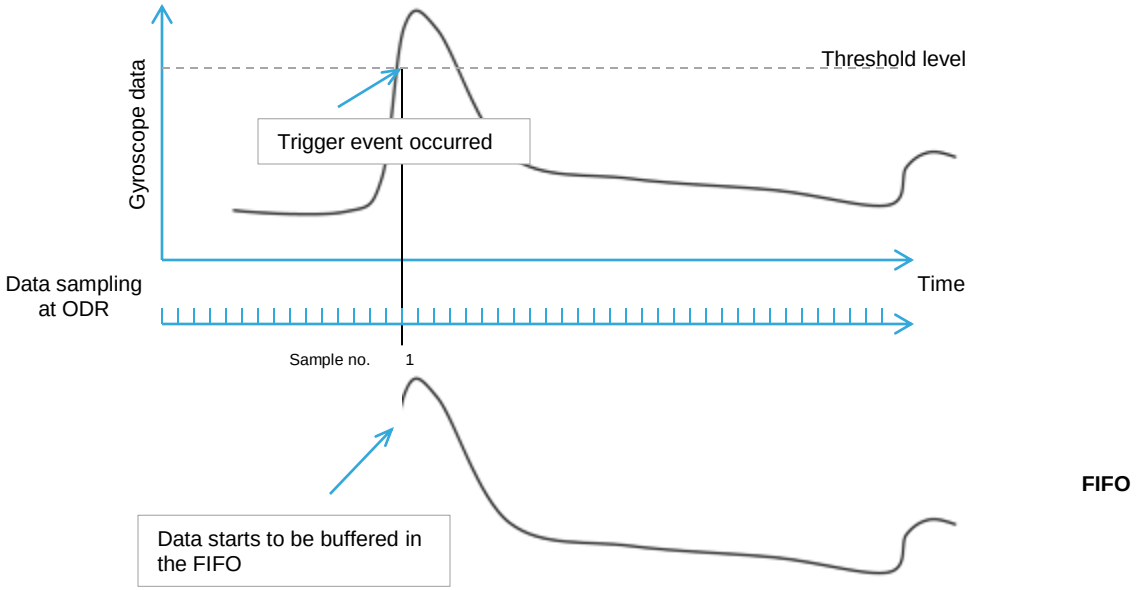
4. Easy data acquisition for filtering or oversampling



Easy digital data processing

- Way of operation
  - FIFO filled until required number of samples is reached and then read in one shot by MCU
  - E.g. oversampling for averaging filter: 2^{2n} samples is required to gain n extra bits in resolution
  - **FIFO mode used: FIFO mode (Watermark)**

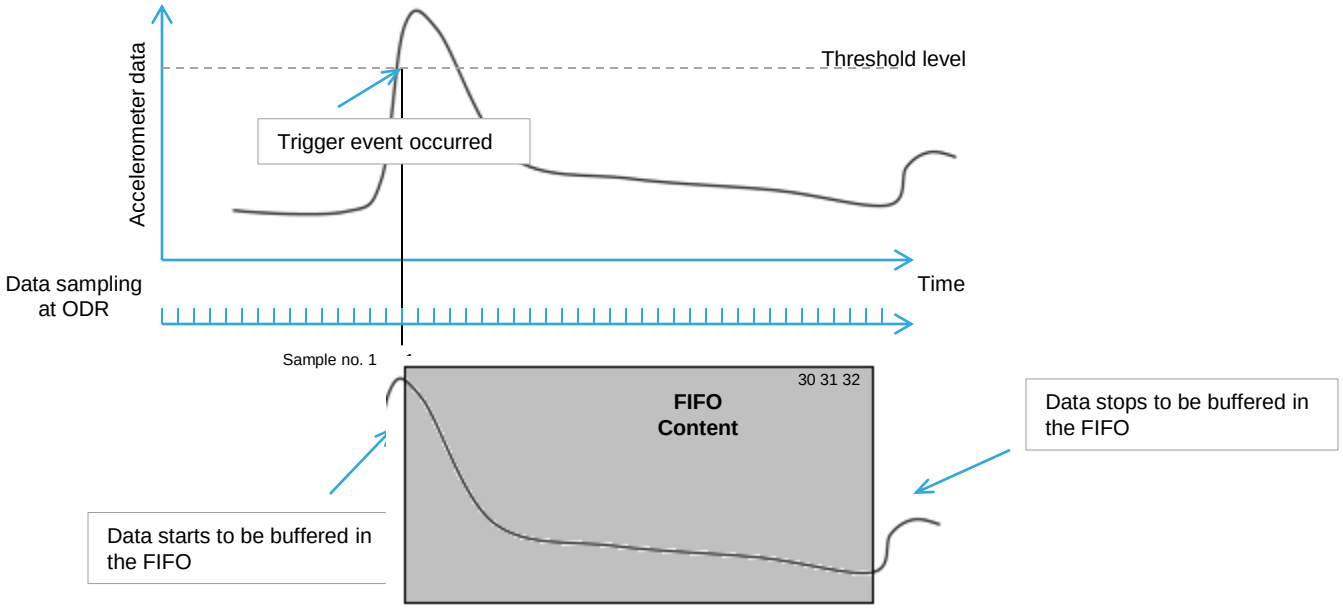
5. Start data buffering when needed



- Buffering the sensor data after the occurrence of the trigger event

- Way of operation
  - FIFO starts to work in the bypass mode (FIFO is not operational)
  - FIFO switches to stream mode when the selected interrupt event occurs (INT1_CFG)
  - Bypass-to-stream can be used in order to start the FIFO buffering when the configured interrupt is generated
  - When the FIFO is full, the next samples overwrite the oldest
  - **FIFO mode used: Bypass-to-Stream**

6. Buffer and store data after an event



- Buffering and storing the sensor (LIS3DSH) data (32 samples) after the occurrence of the trigger event

- Way of operation
  - FIFO starts to work in the bypass mode (FIFO buffering is not operational)
  - FIFO operation switches to FIFO mode when the selected interrupt event occurs
  - Bypass-to-stream can be used in order to start the FIFO buffering when the configured interrupt is generated
  - When the FIFO is full (32 samples), capturing of samples is stopped
  - **FIFO mode used: Bypass-to-FIFO**

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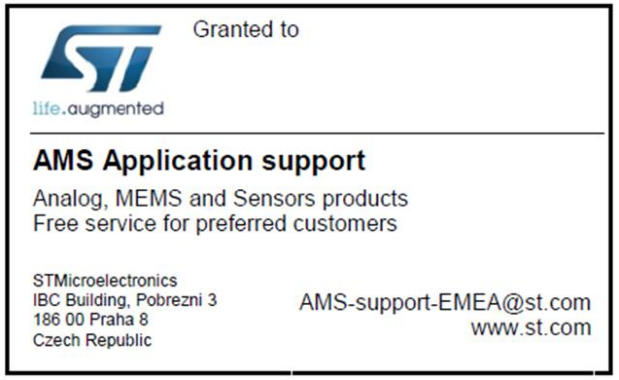
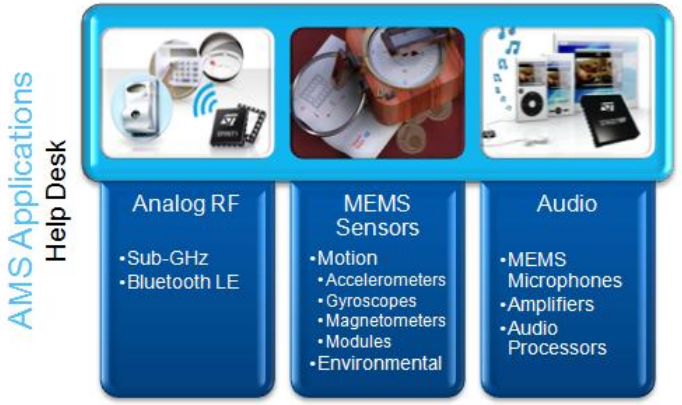
- Solving
  - Product and Application problems – answering detailed technical questions
- Providing
  - Design consulting (Schematic, PCB and Software)
  - Technical Trainings

Application Support Service Card

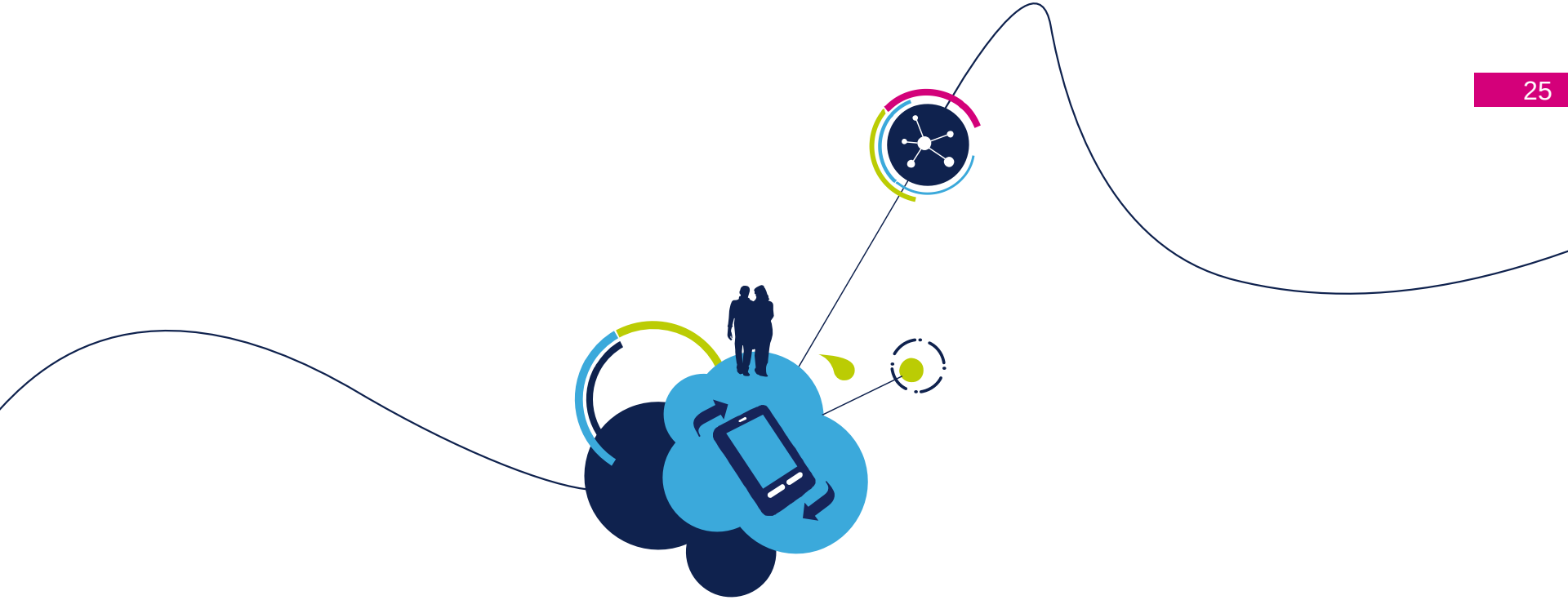


Application Support Team Focus



… and RF IPD/IPAD RF Baluns

Contact email: AMS-support-EMEA@st.com



Thank you !