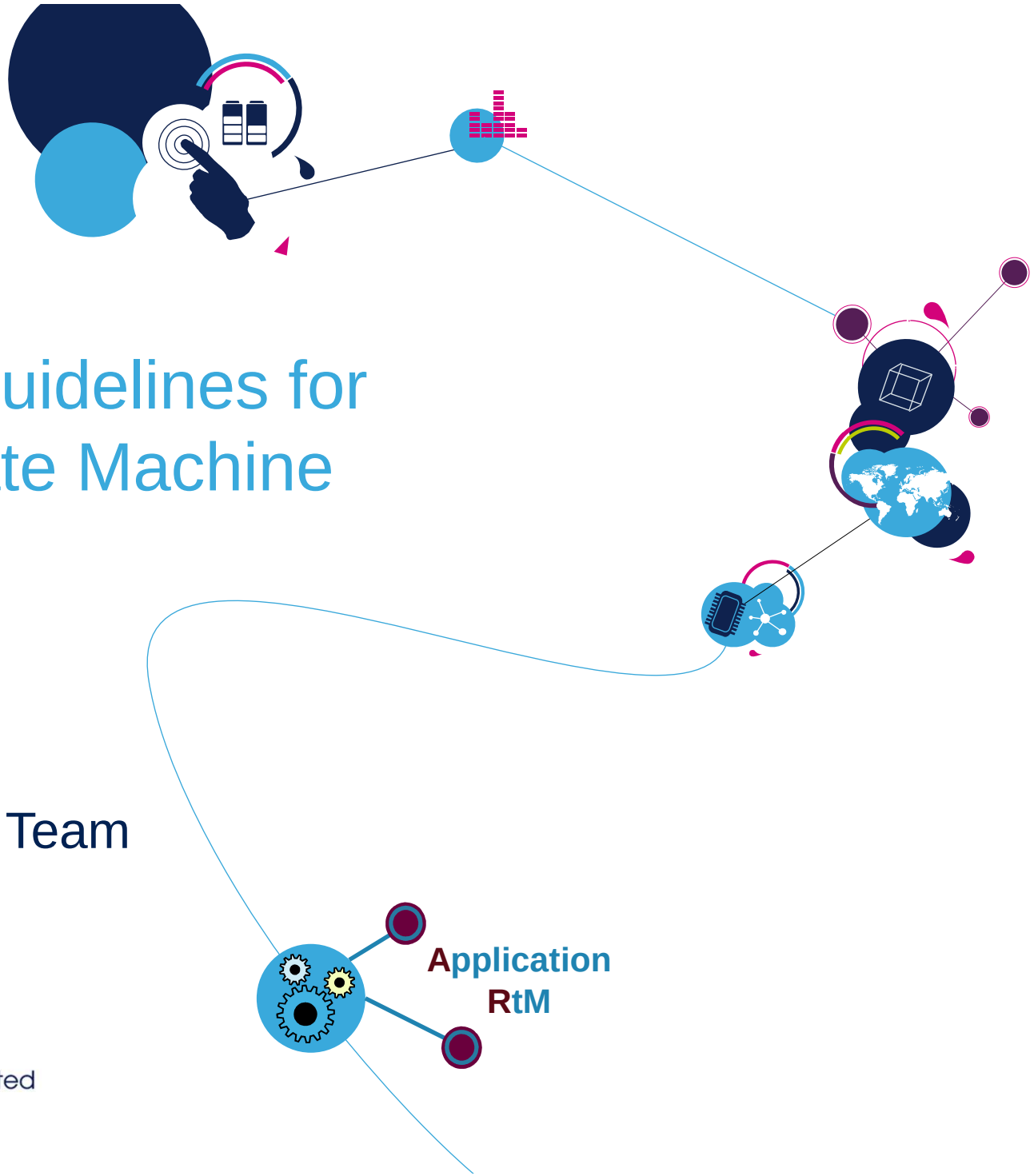

# Application Guidelines for LIS3DSH State Machine

June 24 2013

AMS Application Team

Application RtM

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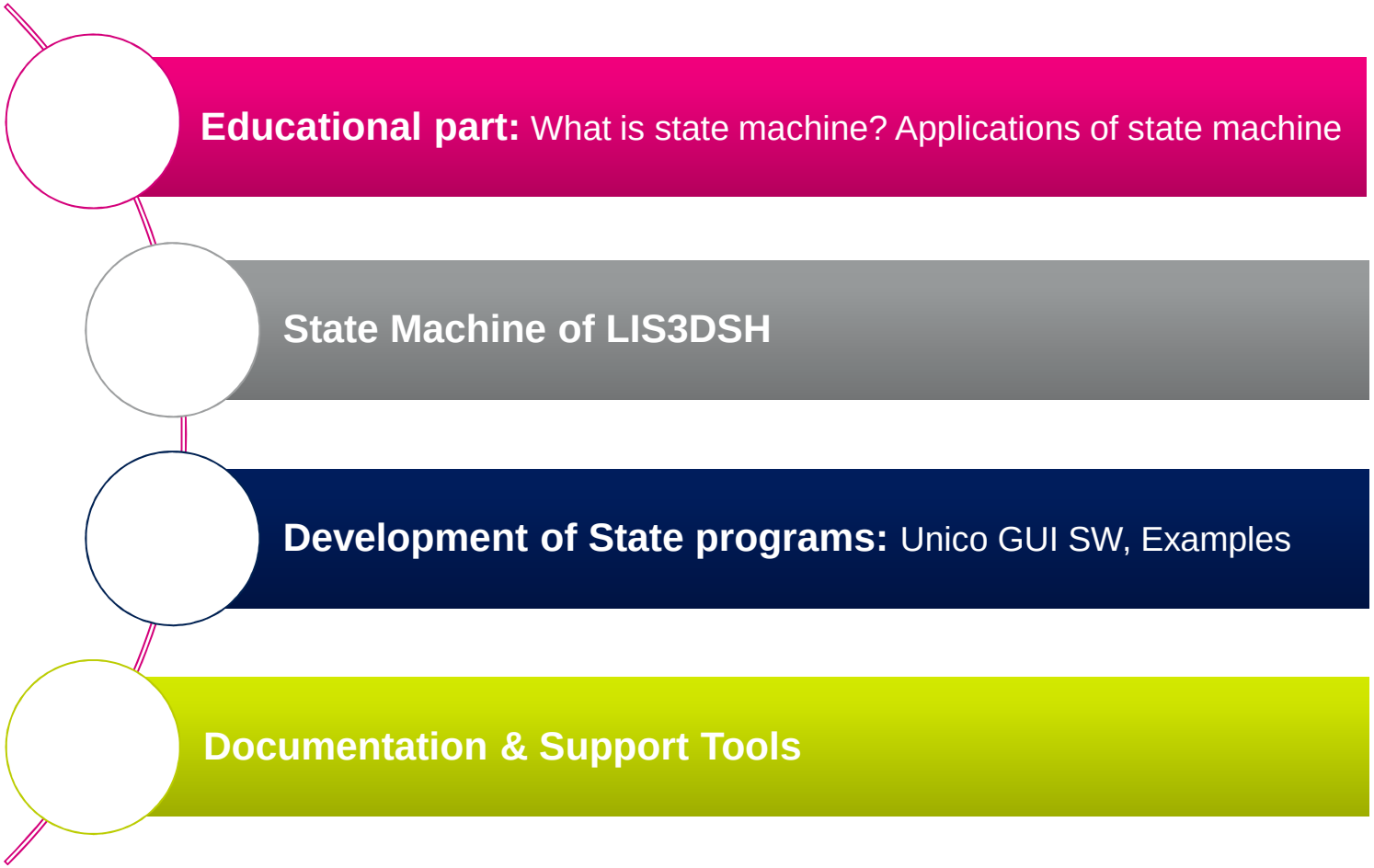
# Agenda

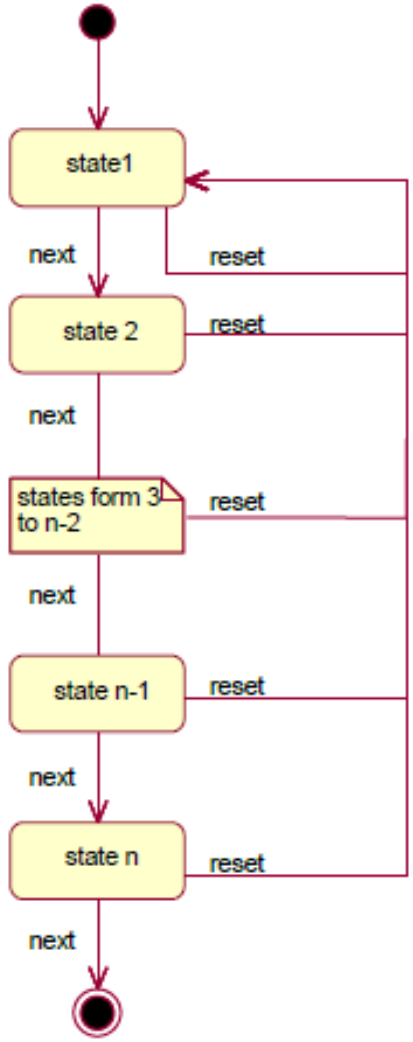




# What is state machine



- State Machine (SM) is a set of defined states, with inputs, outputs and transitions between states.
- The machine is in only one state at a time; the state it is in at any given time is called the current state.
- It can change from one state to another when a triggering event or condition occurs, this is called a transition.



# Applications of State Machine



- State Machine replaces functionalities of current devices
  - Wake up/Free fall
  - 6D orientations
  - Tap/Double Tap (similar to click and double-click action with mouse)
- Thanks to its flexibility many new applications can be addressed
  - Motion controlled user interface
  - Gaming and virtual reality
  - Pedometer
  - Intelligent power saving for handheld devices
  - Impact recognition and logging
  - Vibration monitoring and compensation

# LIS3DSH

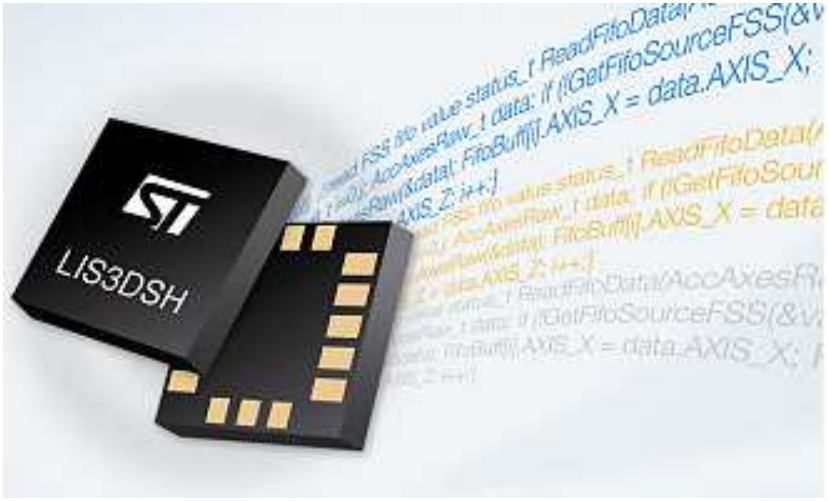


- 3-Axis Digital SPI/I2C Accelerometer
- 5 selectable Full Scales: ±2, 4, 6, 8, 16g
- 2 programmable embedded **finite-state machines** for interrupt generation
- Very High Resolution (up to **14 bit**) and low noise (**150µg/sqrt(Hz)**)
- Low power consumption: 11µA in Active mode (3.1Hz) and 2µA in Power down mode
- Anti-aliasing filter
- P2Pcompatible with LIS3DH


Pricing: 0.93usd for 10K

# LIS3DSH – 3-axis Accelerometer with State Machine






## LIS3DSH Features

- **3- Axis Digital** Output (I2C/SPI)
- Full Scales from ±2g up to ±16g
- Very low noise (150 µg/√Hz, 14-bit accuracy)
- 2 independent Smart **State machines**

## Key Advantages

- **Low current consumption** system due to state machine: gesture detection is managed by LIS3DSH while MCU stays in sleep mode
- Flexibility to run different **gesture detection algorithms**

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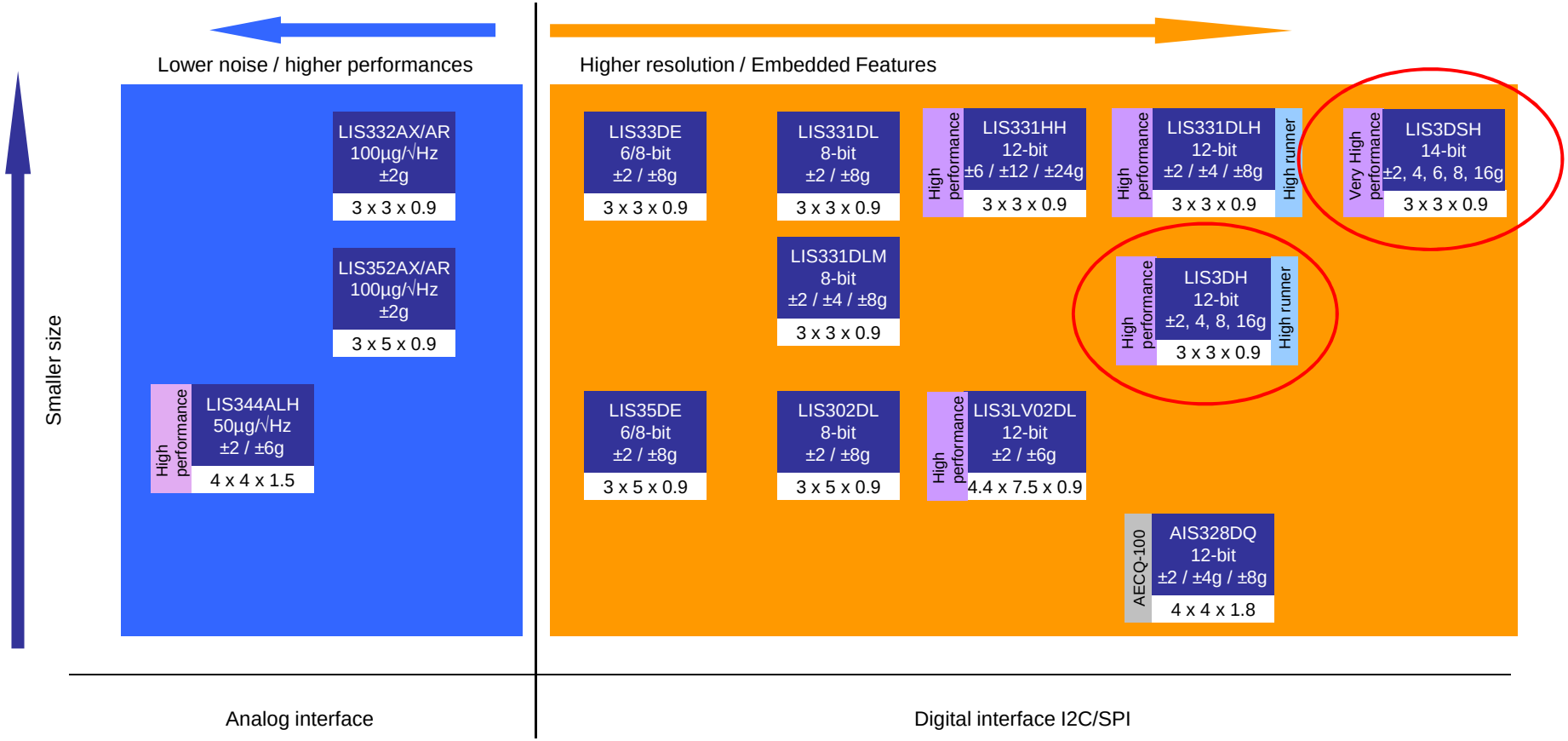
# Accelerometers - Portfolio



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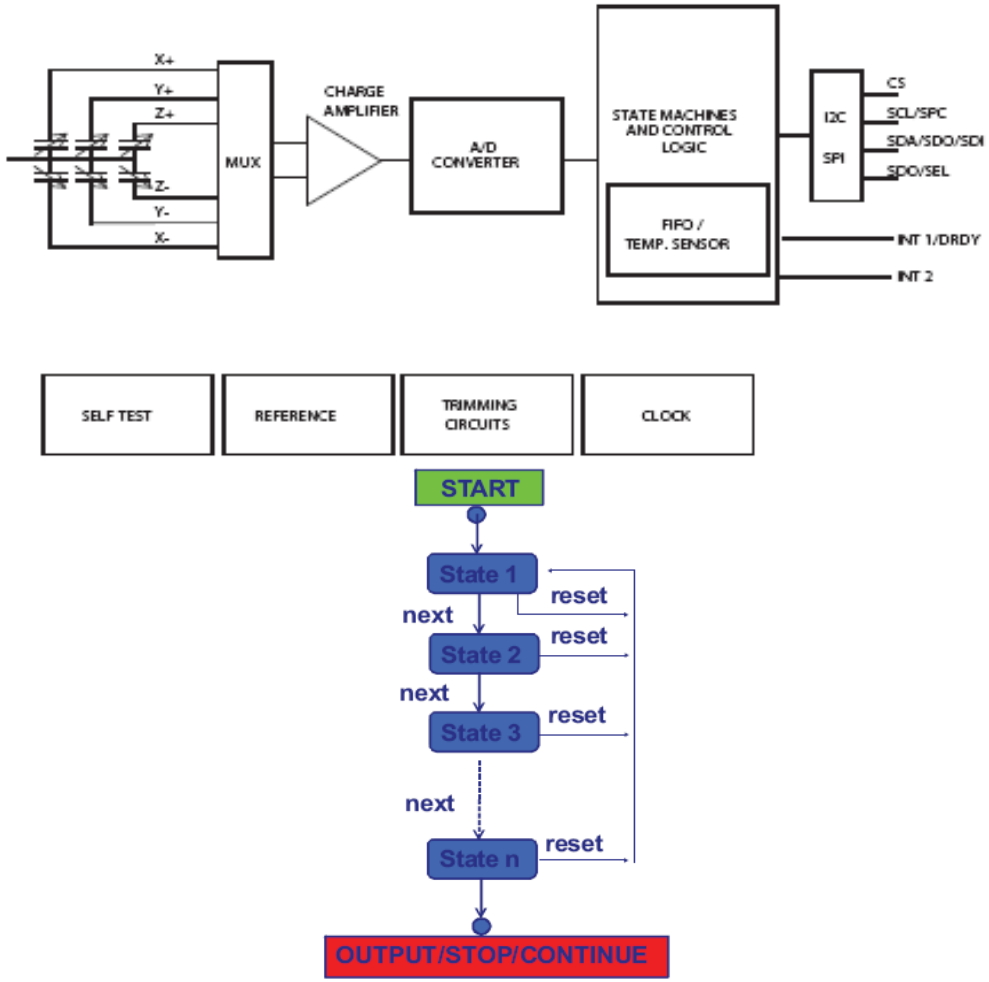
# LIS3DSH - 3-Axis Digital Accelerometer with Smart State Machine:

## Detailed Summary




### APPLICATION

- Accelerometer with Smart State Machine to run dedicated motion detection patterns
- Motion controlled user interface
- Mobile platform power consumption reduction

### KEY FEATURES

- Wide supply voltage, 1.7V to 3.6V
- Independent IOs supply (1.8 V) and supply voltage compatible
- Ultra low-power consumption down to 11 µA
- ±2g/±4g/±6g//±8g//±16g selectable full scale
- Low noise 150 ug/√Hz, 14bit resolution
- 16-bit data output, embedded FIFO
- 2 Programmable Embedded State Machine to run selectable motion detection patterns, Free-fall detection, Motion detection, Tap&Double-tap detection etc
- 2 independent programmable interrupts
- Ultra high stability over temperature
- I2C/SPI digital output interface
- Embedded self-test
- Package : LGA 3x3x1mm (same as LIS3DH)

### PRODUCT STATUS

- In production
- Samples: available
- Evaluation board: available

For latest updates pleas visit our website : www.st.com/

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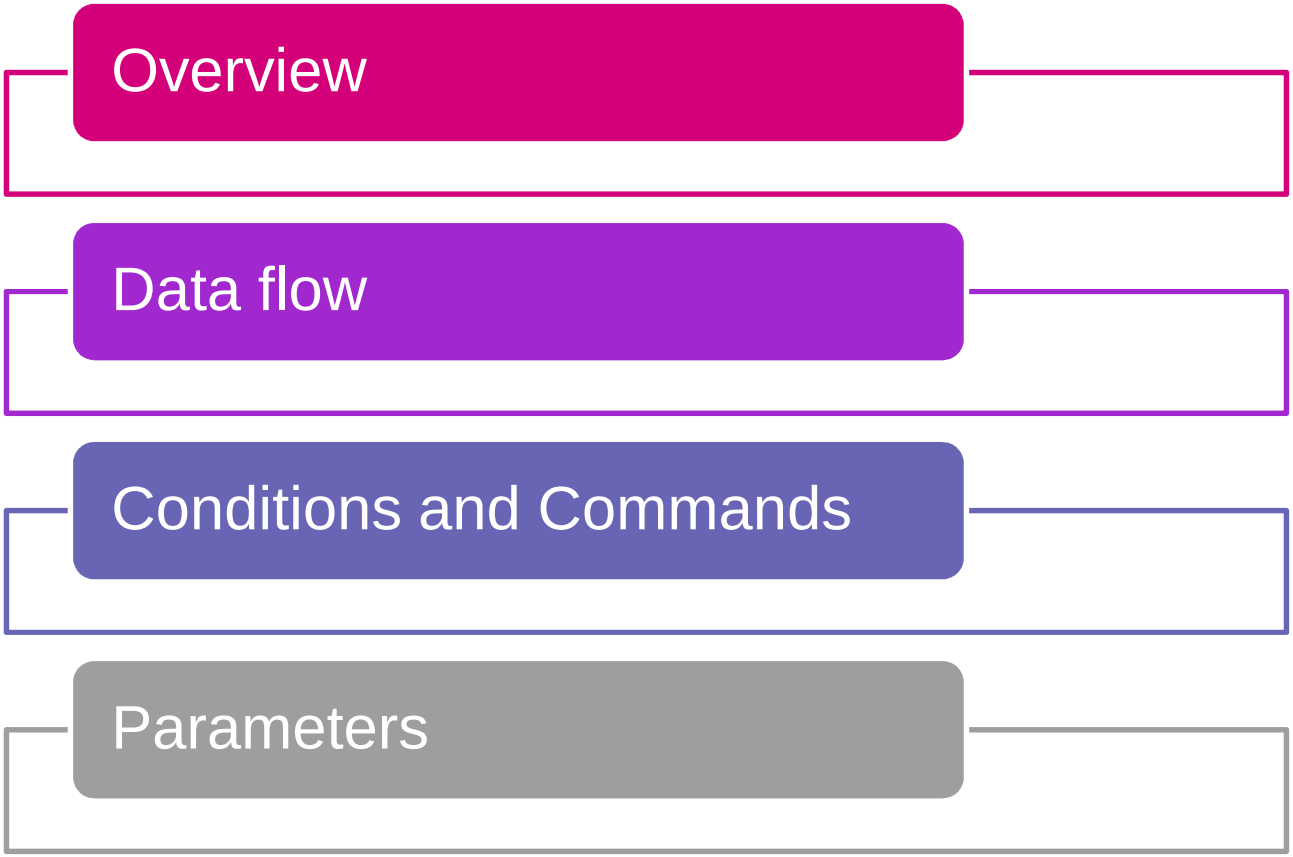
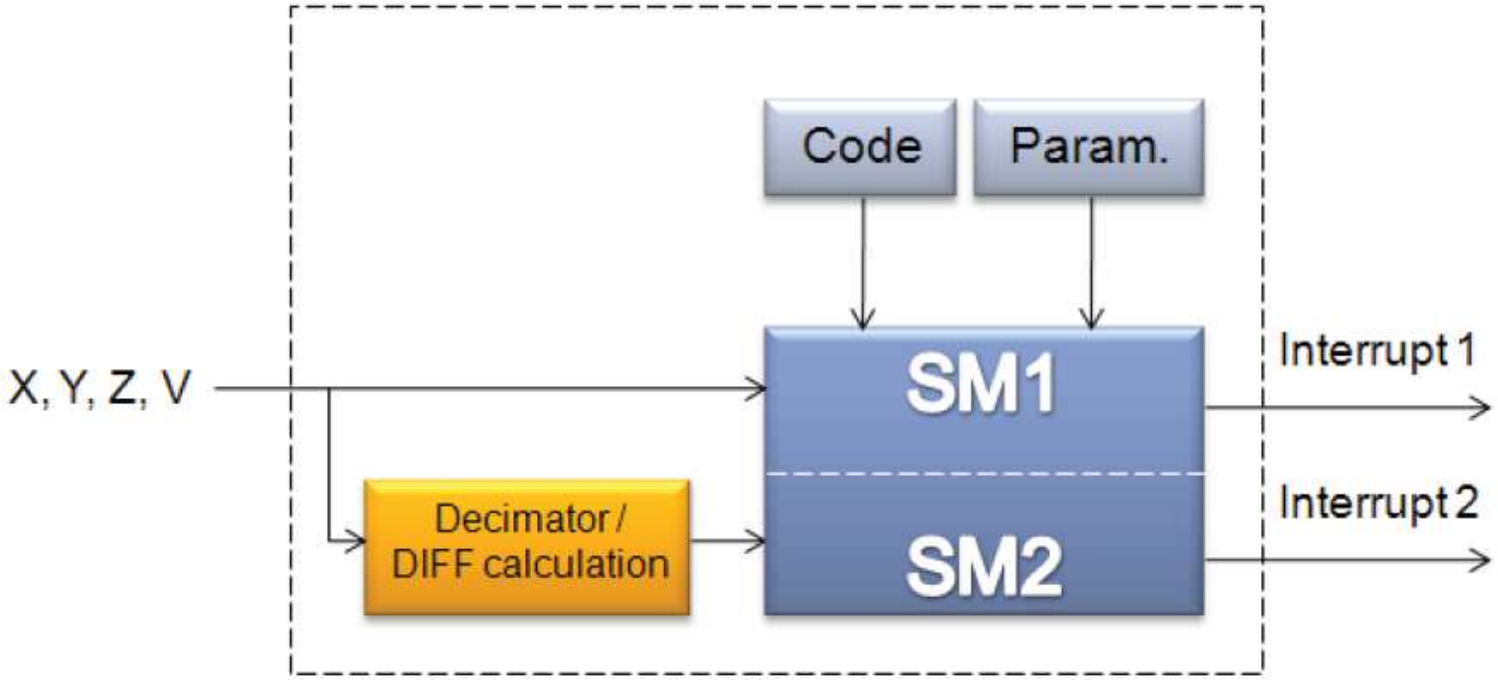
# State Machine of LIS3DSH





# State Machines of LIS3DSH






State-machines are identical with some exceptions:

- State Program #2 has decimator functionality
- State Program #2 has DIFF functionality

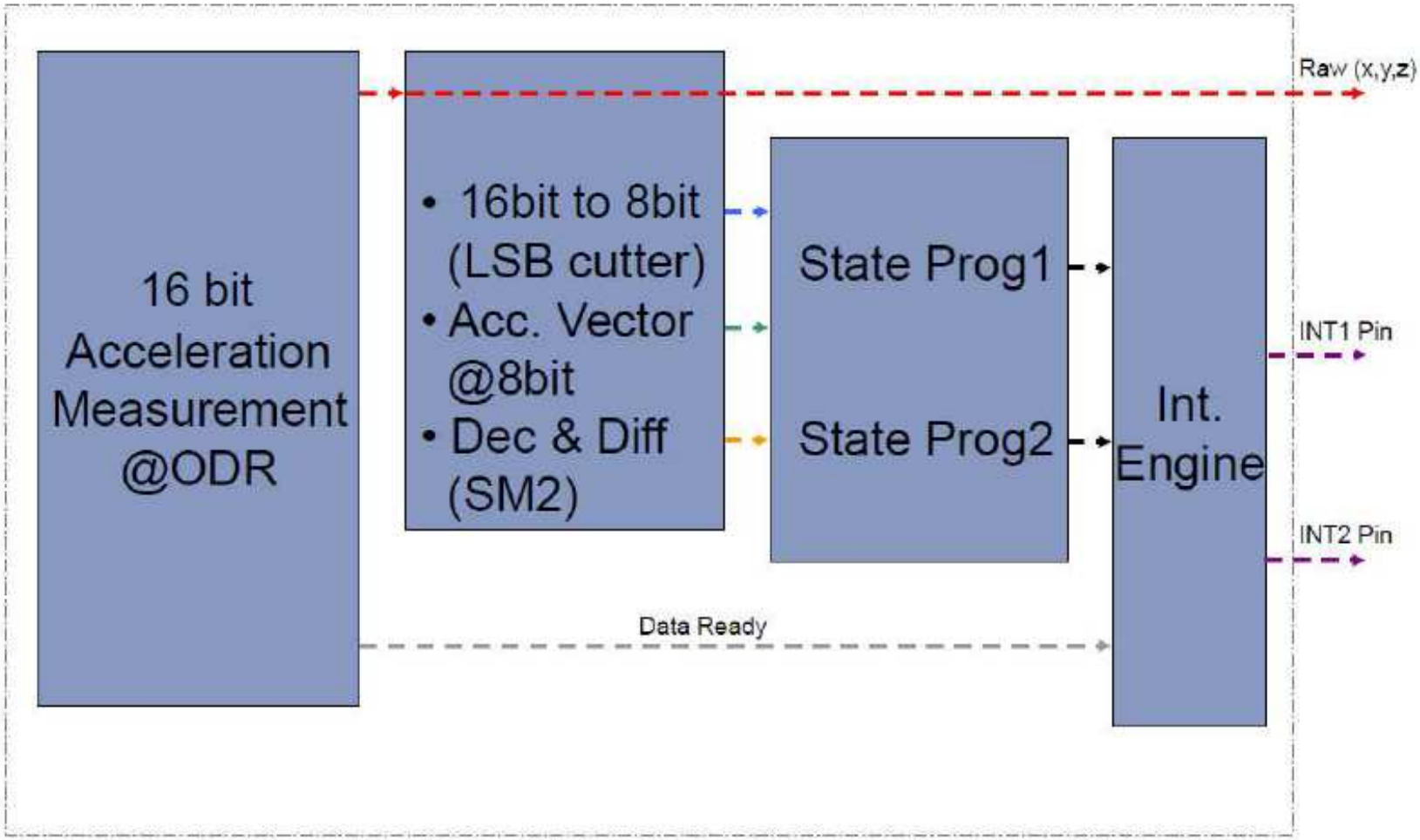
# State Machines Overview



- LIS3DSH has **two** independently configurable State Machines (SM)
- Each SM has up to 16 states
- SM can run once or can be continuously running (looping)
- **SM1 and SM2** can run **independently or synchronized** but with **same input** data
- SM1 is performed first
- Input data are 8-bit wide

# Data Flow





# Data processing blocks of State Machine



- **LSB cutter** - 8-bit input data to State Machine are generated by dividing sensor output data by 256:

  8 bit data = 16 bit data / 256.

- **Decimator** - reduces the sample rate of the data going to SM 2

  ODR_SM2 = ODR / (DES + 1)

  where DES is user-programmable register

- **DIFF calculation** - can be applied on input data of SM 2, there are two options:

  1. diff2 - difference between current data (X, Y, Z) and previous data.
  2. cs - difference between current data (X, Y, Z) and Constant Shift registers CS_X, CS_Y and CS_Z.

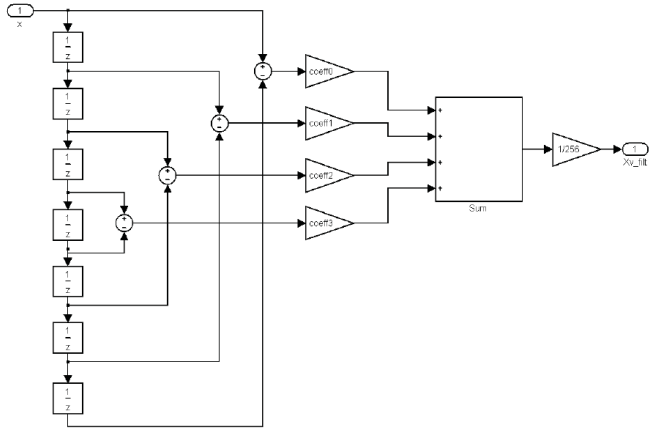
# Vector



- Vector (v) is 8-bit number which represents **amplitude of acceleration** applied on the sensor.
- It is **8-bit signed number** calculated by State Machine by an approximation formula.
- Acceleration vector amplitude is only available inside the two State Machines, but cannot be read outside.
- Vector can be filtered by 7$^{th}$ order **anti-symetric FIR filter**

$$Xv\_filt = (x0- x7)\ coeff0 + (x1-x6)\ coeff1 + (x2-x5)\ coeff2 + (x3-x4)\ coeff3$$

- Coefficients coeff0 to coeff3 are user-programmable.



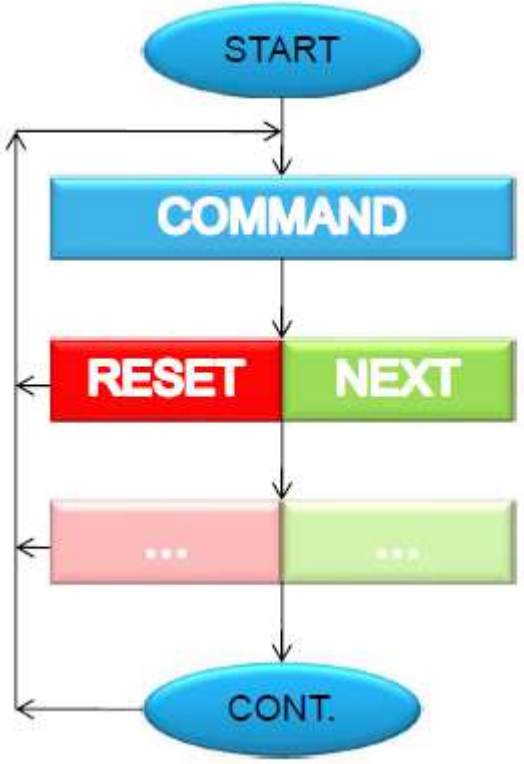
# State Machine Process



- Each state is configured through the Operation Codes (OPCODE). OPCODES can be divided in two groups:

- **NEXT/RESET Conditions**
  - NEXT/RESET conditions control operation flow of the state machine
  - RESET condition is in MSB part and NEXT condition is in LSB part of the OPCODE

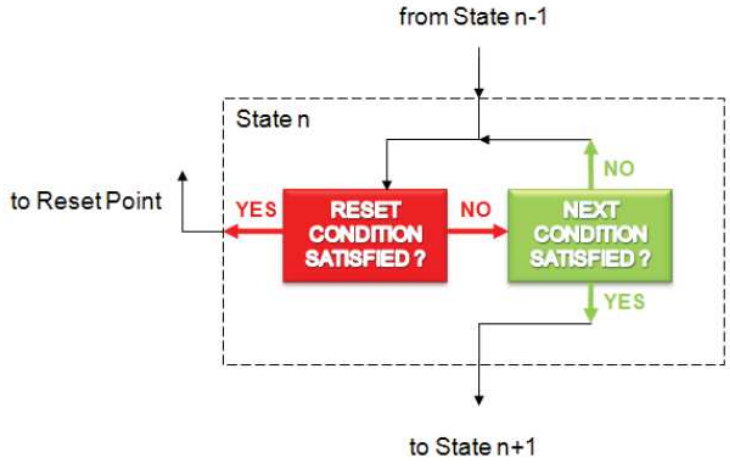
- **COMMANDS**
  - Commands have special tasks for flow control, output and synchronization
  - Commands and their parameters are executed as one step command.



# NEXT/RESET Conditions



- **RESET** condition is evaluated first, **NEXT** condition is evaluated only if **RESET** was not valid
- Transition to next state happens when "**NEXT** condition" is valid
- Transition to reset point happens when "**RESET** condition" is valid
- If both conditions are not valid, the same conditions are applied to the next sample
- Examples of conditions
  - TI1 - Timer 1 (16-bit value) valid
  - GNTH1 - Any/triggered axis greater than THRS1
  - LLTH2 - All axis less than or equal to THRS2
  - NZERO - Any axis zero crossed



# COMMANDS



- COMMANDS have special tasks for flow control, output and synchronization
- There are three types of COMMANDS, depending on execution timing:
  - Immediately executed: commands executed without waiting for a new sample
  - Executed after trigger: wait for an internal (a new sample) or external trigger (reading of the OUTSx - SMx status register) to proceed
  - Special commands (JMP commands): special conditions comparison for conditional jump commands.
- Examples of COMMANDS
  - CONT - Continues execution from RESET POINT, also generates interrupt
  - SETS1 – sets content of SETT1 register – SM1 control register
  - STHR2 – sets new value of Threshold 2 register
  - SRADI1 – enables DIFF calculation of SM2

# State Machines Synchronization

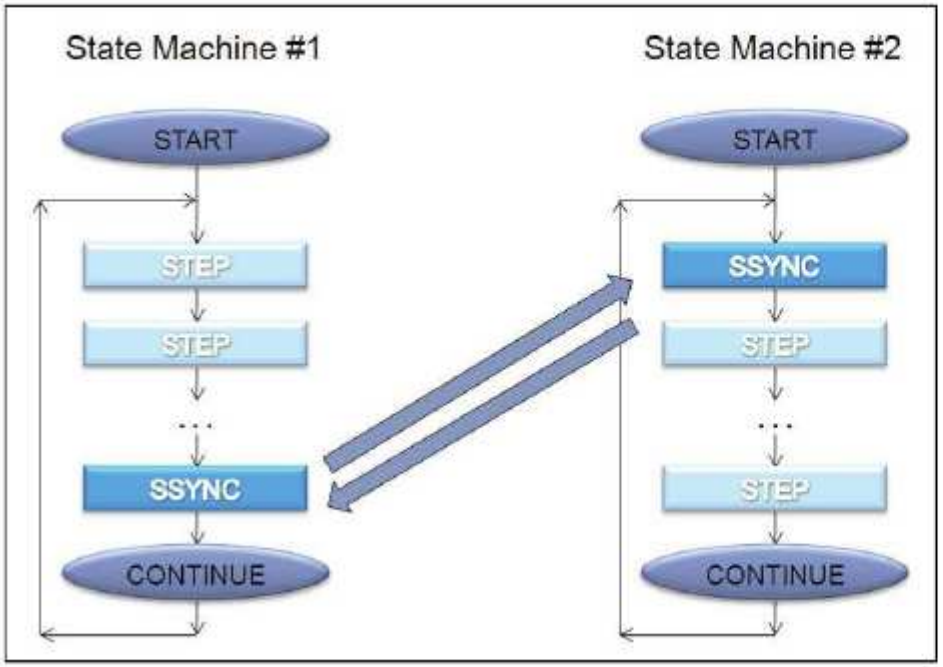


- Sequential synchronization is possible using **SSYNC** command
  - Each state machine has 16 states that can be combined up to 32 sequential states
  - State machine B can act as sub-function for State machine A (parameters can be totally different than main program)
  - State Program A can toggle execution to State Program B and vice versa
- Host can change inactive State Program when other State Program is running

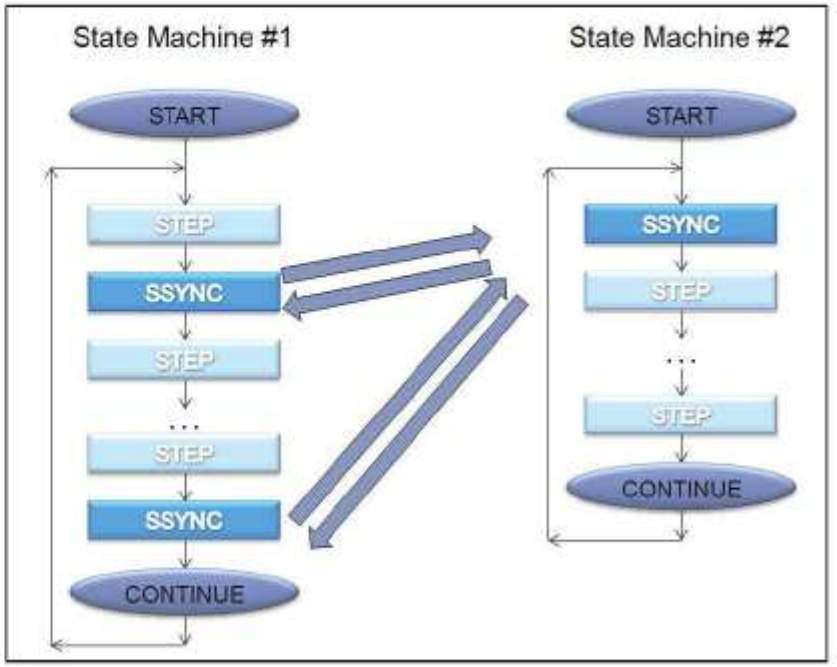
# State Machine Overview



- **SSYNC: SM1 + SM2 for 32 states SM**




- **SSYNC: SM2 as sub-routine of SM1**



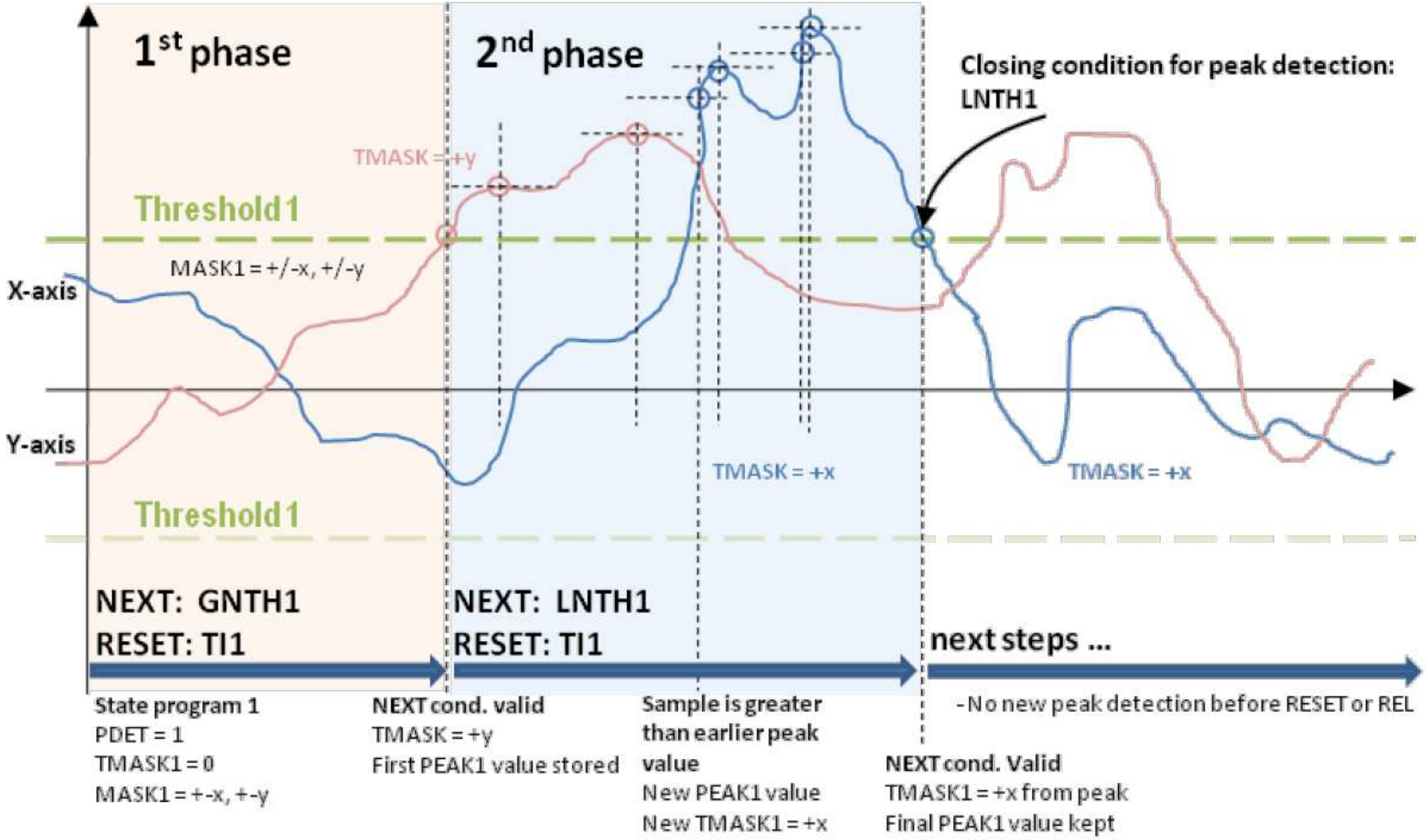
# State Machine Parameters



- 4 independent **Timers**
- 2 independent **Masks** (x, y, z, v)
- 3 independent acceleration **Thresholds** @8bit (Signed, Unsigned)
- **Peak Detection** function
  - Detects and stores the **highest peak** value during peak detection phase
  - Peak detection uses always “Greater than” condition and measured value is converted to absolute
  - This function allow to follow the axes that reach the absolute maximum value and not only first axis that trigger initial condition

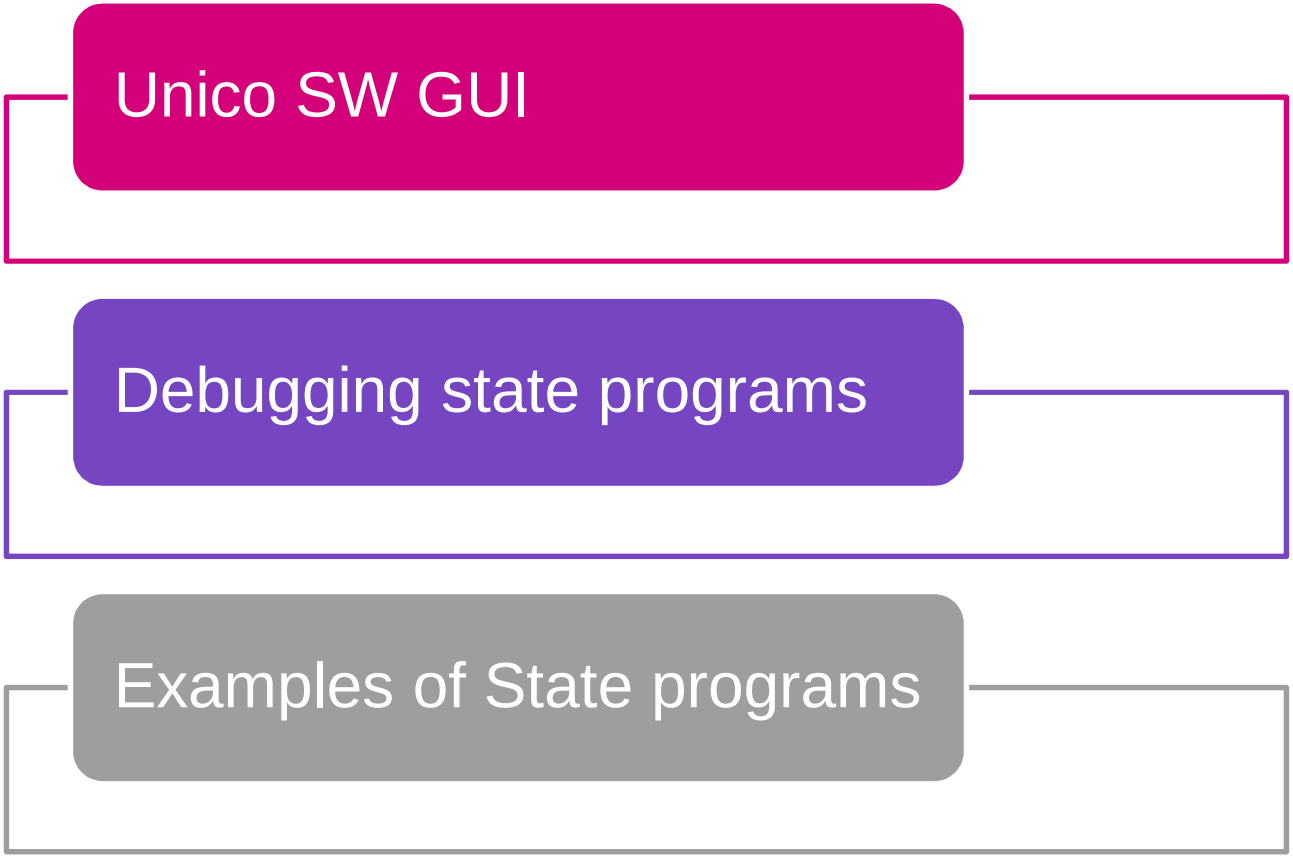
# Peak Detection Example





# Development of State programs





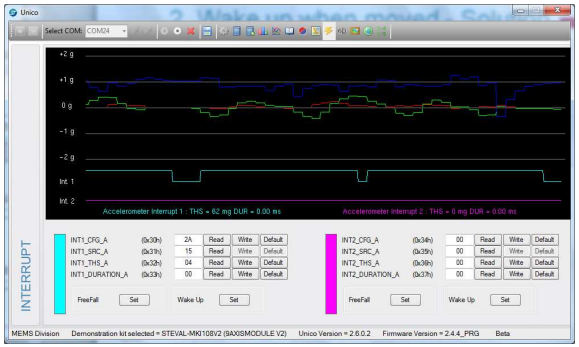
# Unico



- **GUI application** for Windows which allows to evaluate ST MEMS sensors

- Features
  - User friedly and fast getting started with MEMS sensors
  - Common interface to all kinds of ST MEMS sensors
    - accelerometers, gyroscopes, magnetic sensors and pressure sensors
    - Compatible with new sensors from ST
  - MEMS data displayed in several views
  - Access to all settings of each sensor
  - Examples of usaging ST sensors
  - Data from sensors can be stored on hard drive for further analysis

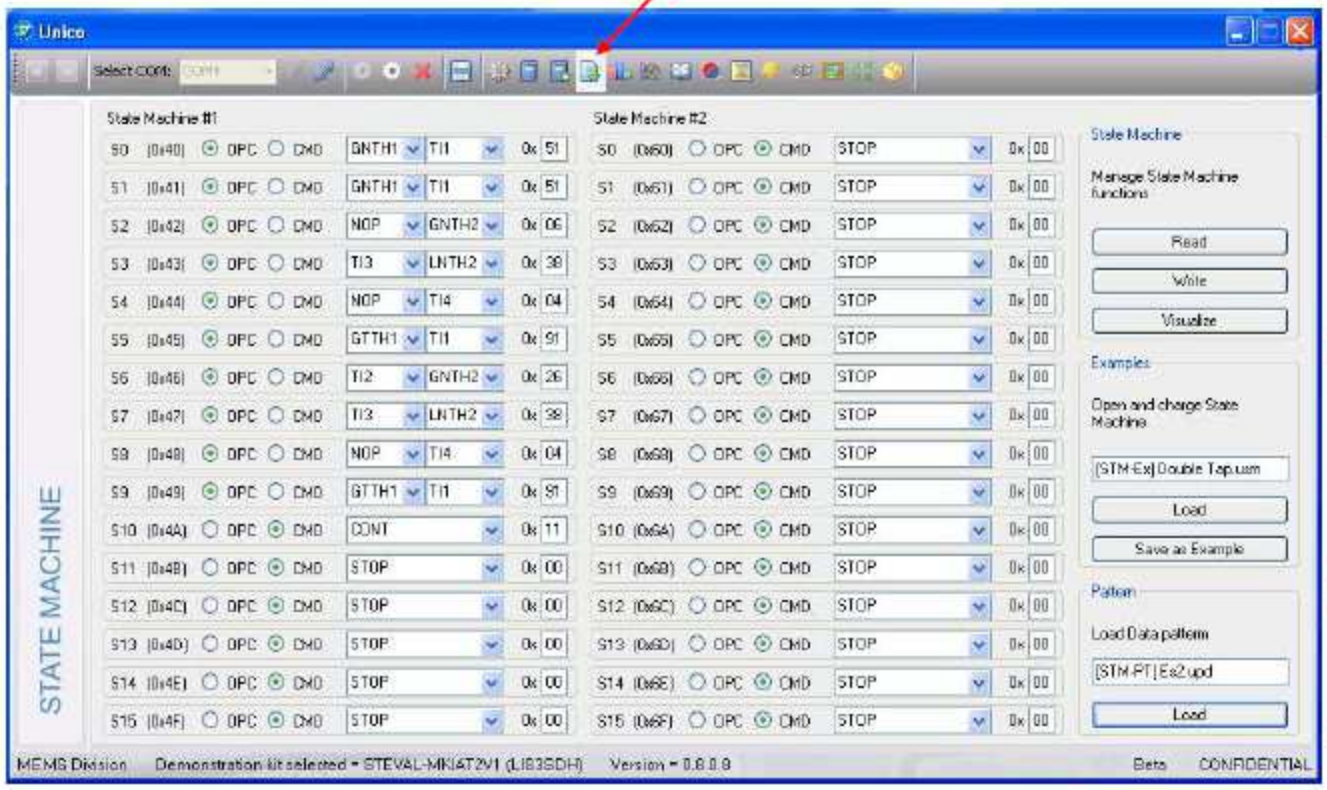




# State Machine in Unico



State Machine **button**




**Read**, **Write** and **Visualize** the current state machine

Load or Save **State Machine Configuration**

Load **Data Pattern** to test the State Machine

Each state can be programmed selecting either the code or through the interface

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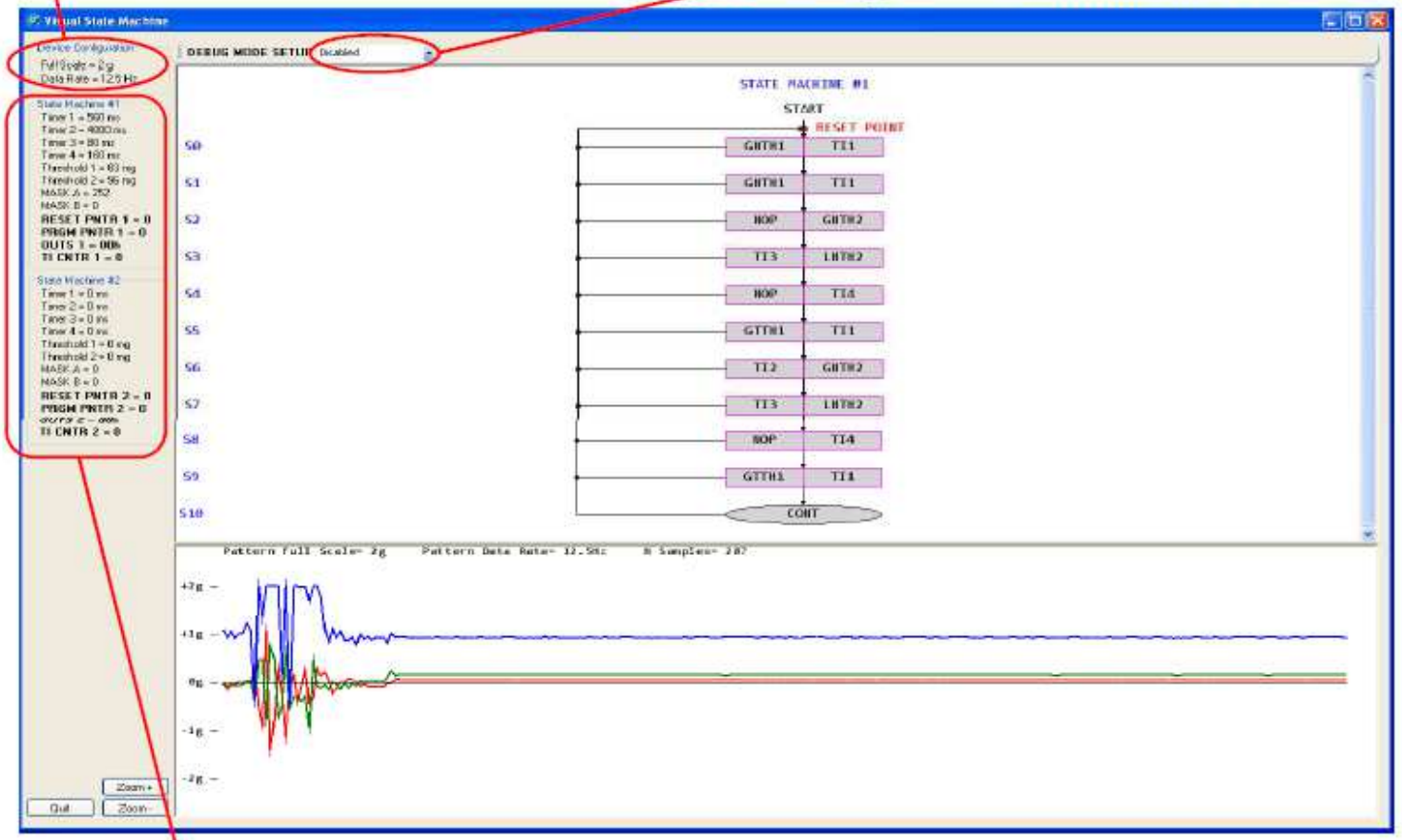
# Unico – Debug mode DISABLED



Actual device's configuration (FS, ODR)

Debug MODE **Enable/Disable** command



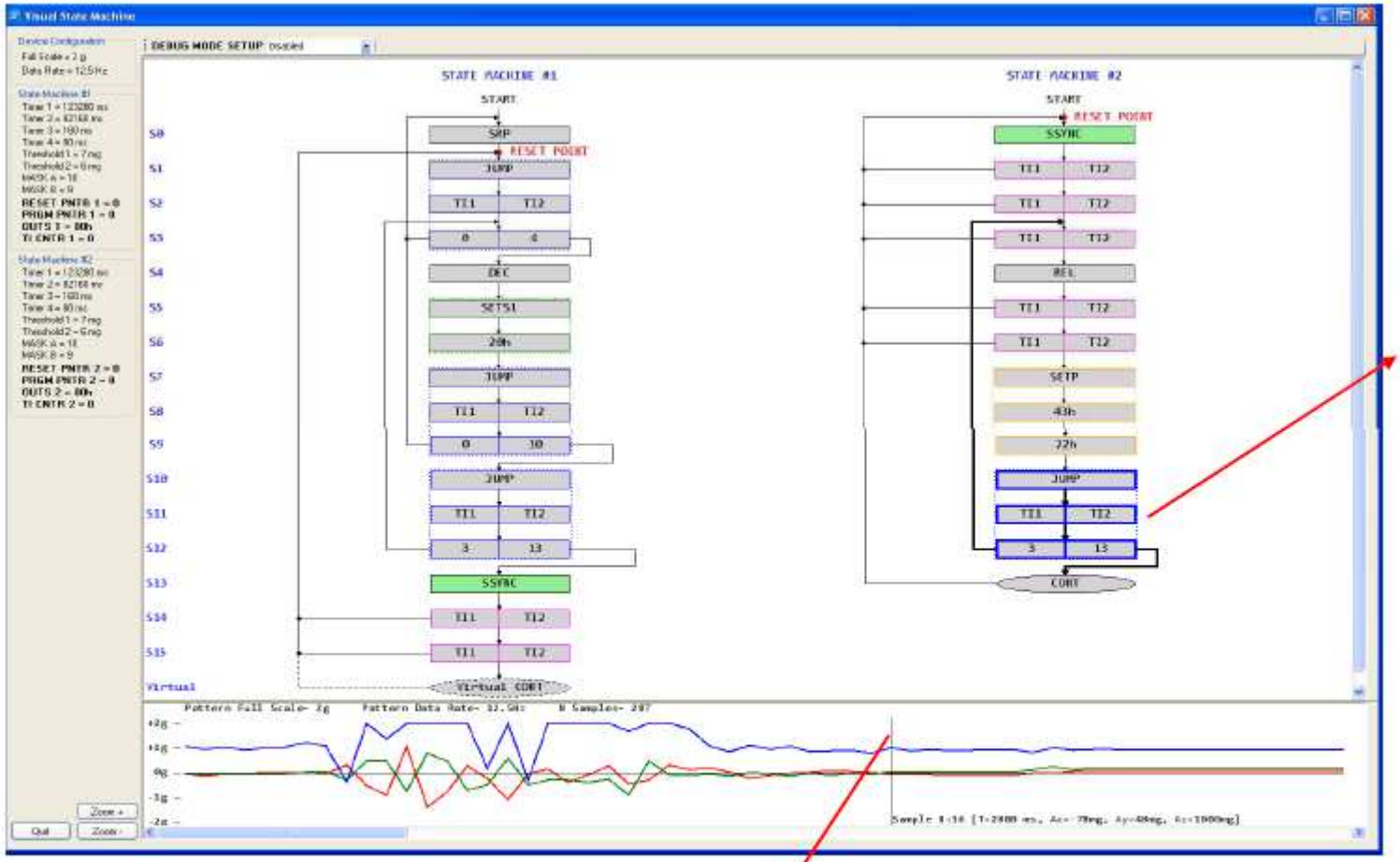

State Machine **Flow**

Loaded Data Pattern **Waveform /Info**

**NOTE:** State machines parameters are reported with Unit of Measurement indicated: their values are related to both corresponding registers value and device's FS/ODR in use.

# Unico – Debug mode DISABLED






When Debug is disabled it's possible to highlight a command and its arrows just clicking on it

When Debug is disabled it's possible to visualize the info of each sample just clicking on it

# Unico – Debug mode ENABLED




Current **state** (according to Program pointer value) is highlighted.

**Reset point** moves according to Reset pointer value.

Last **Loaded Sample info** [in LSB]

**State machines & INTERRUPT evolution**

**NOTE 1:** Units of Measurement are meaningless when Debug mode is Enabled; State machines parameters are related only to registers' values.

**NOTE 2: Boldfaced** parameters are REAL TIME updated.

# Examples

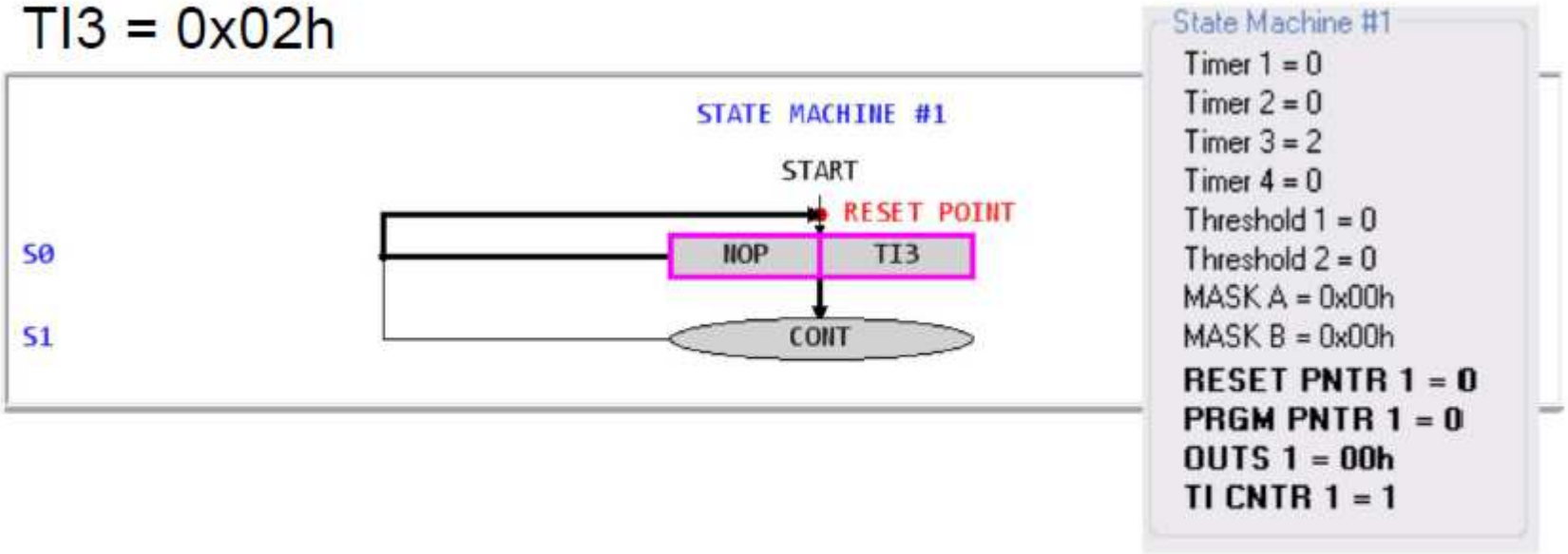


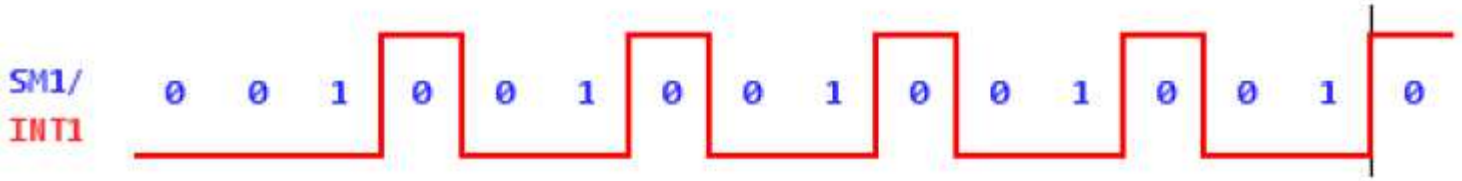
## State Machine Programs

1. Toggle
2. Wake Up
3. Free Fall
4. Double Tap
5. SSYNC

# Toggle

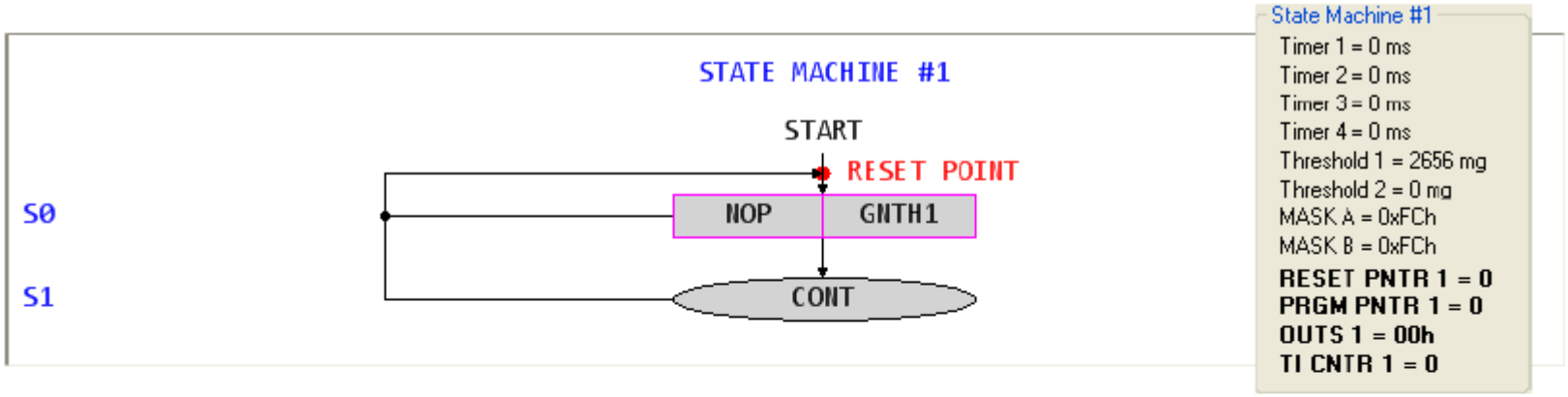


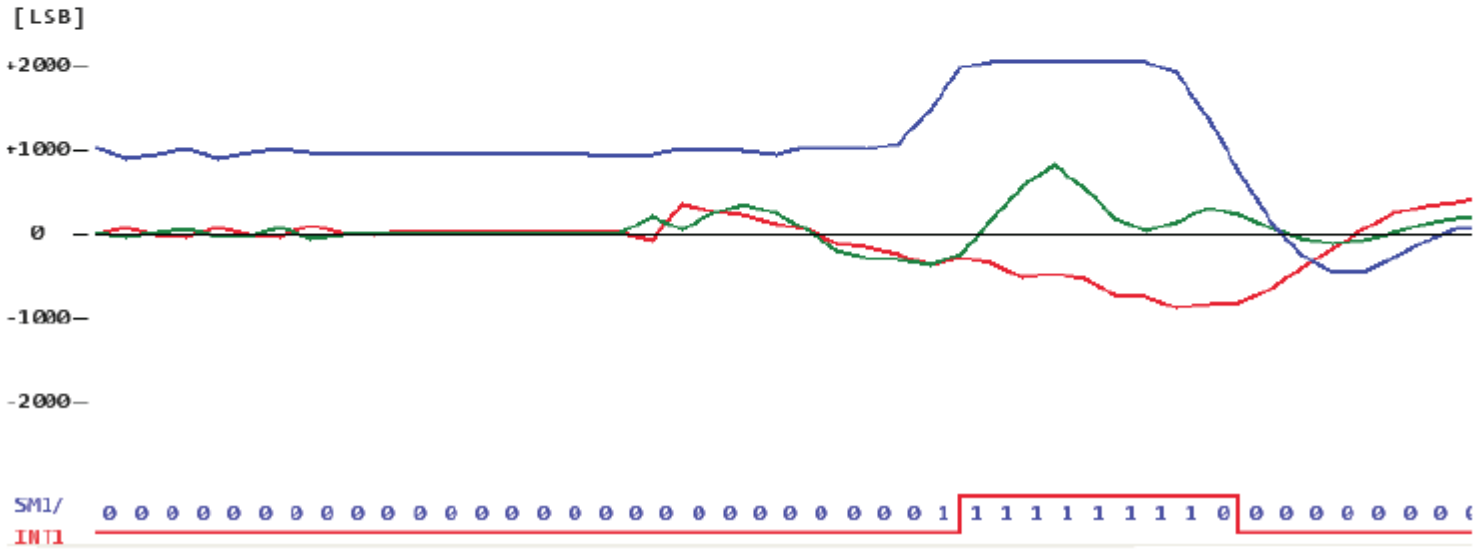


# Wake up

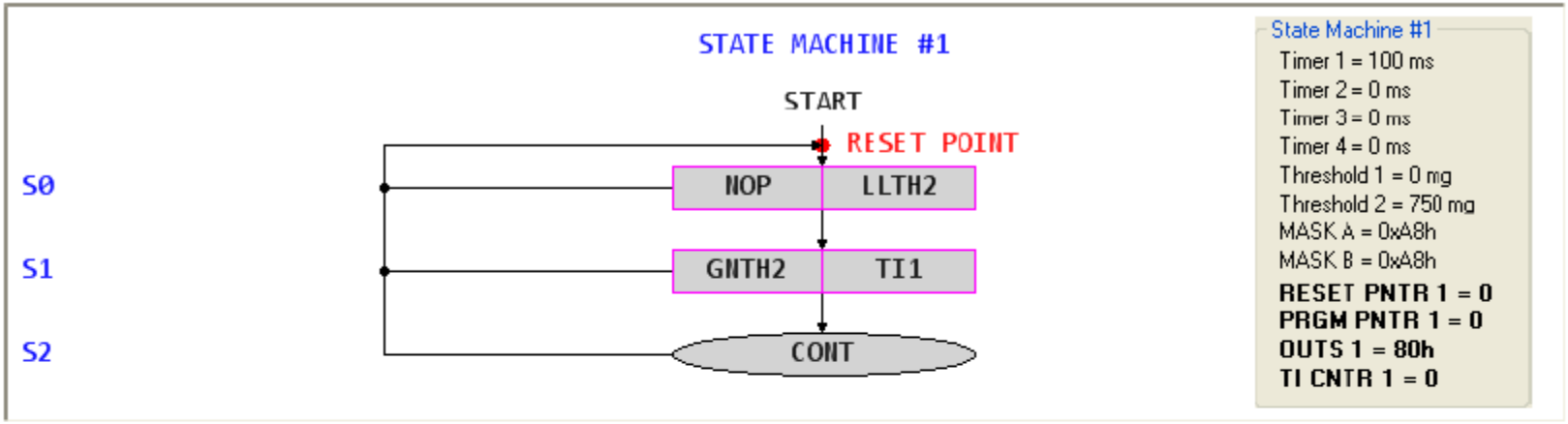


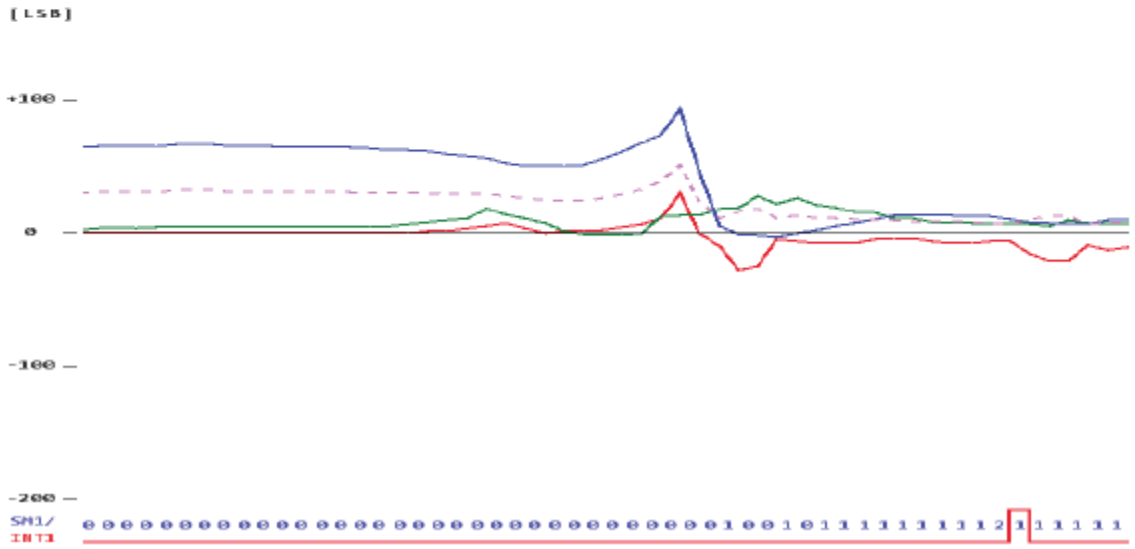


# Free Fall

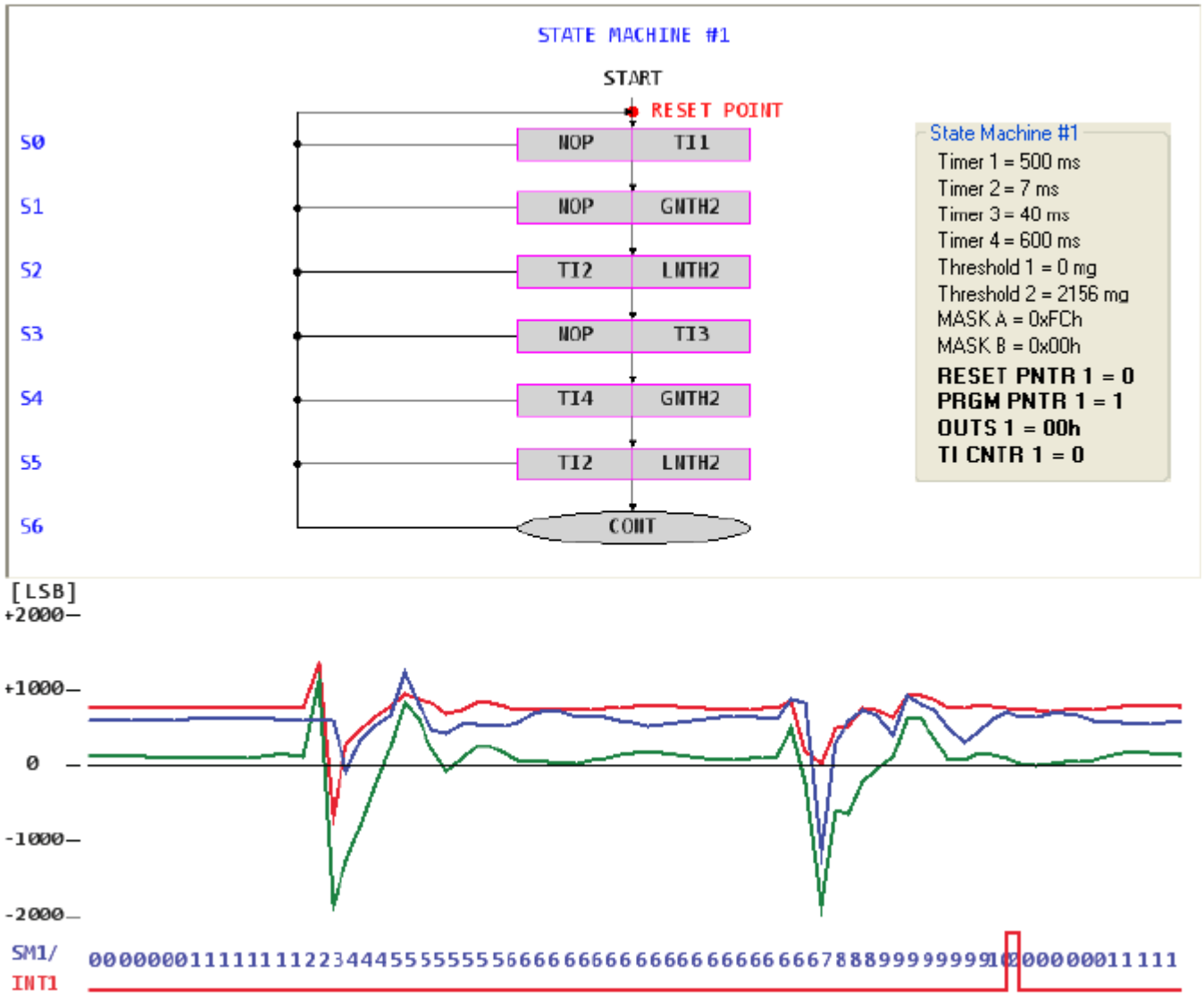




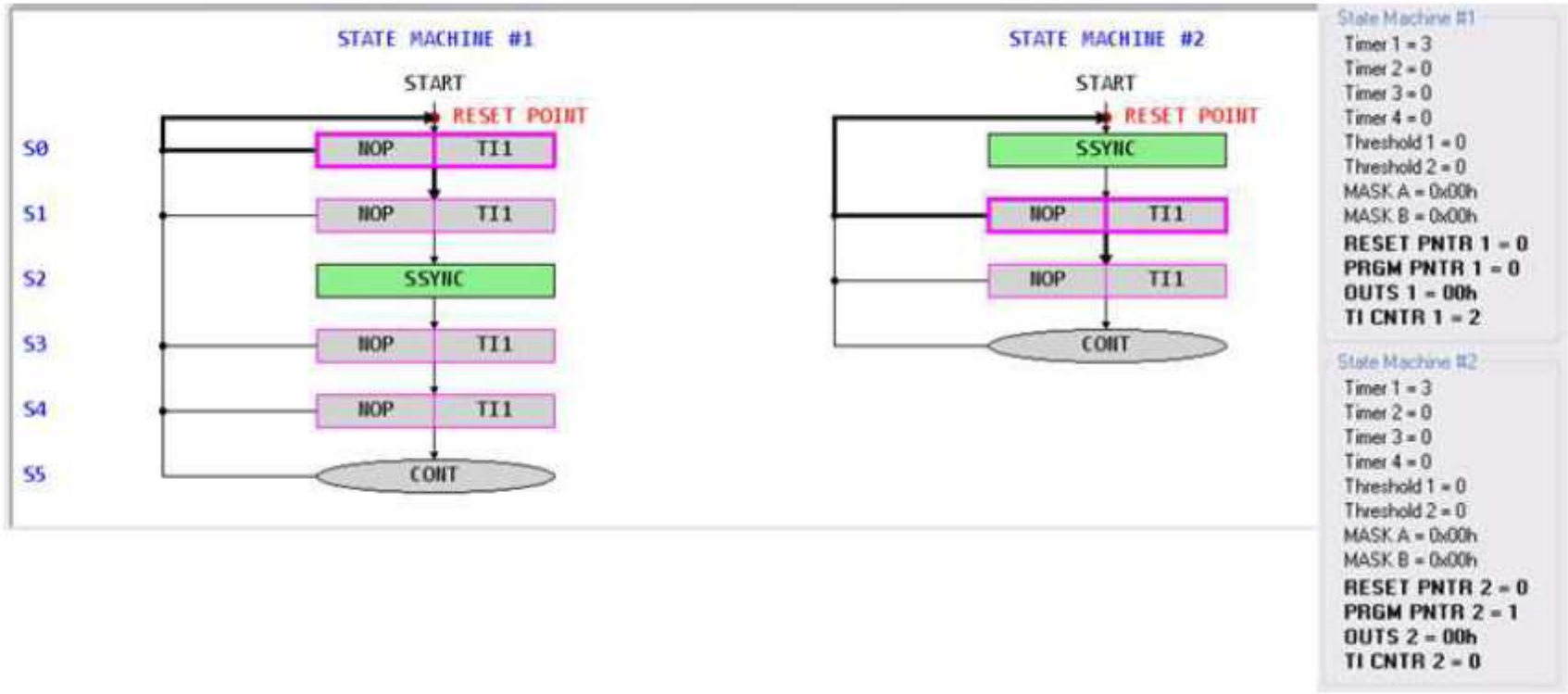
# Double Tap

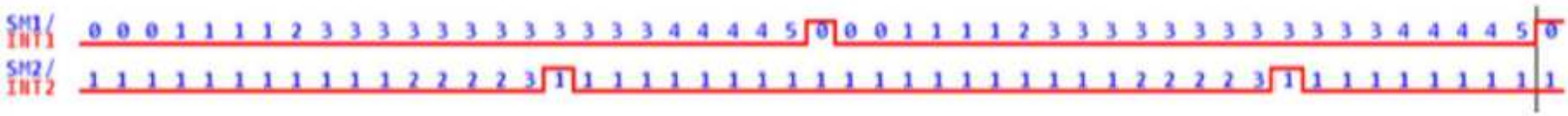




# SSYNC

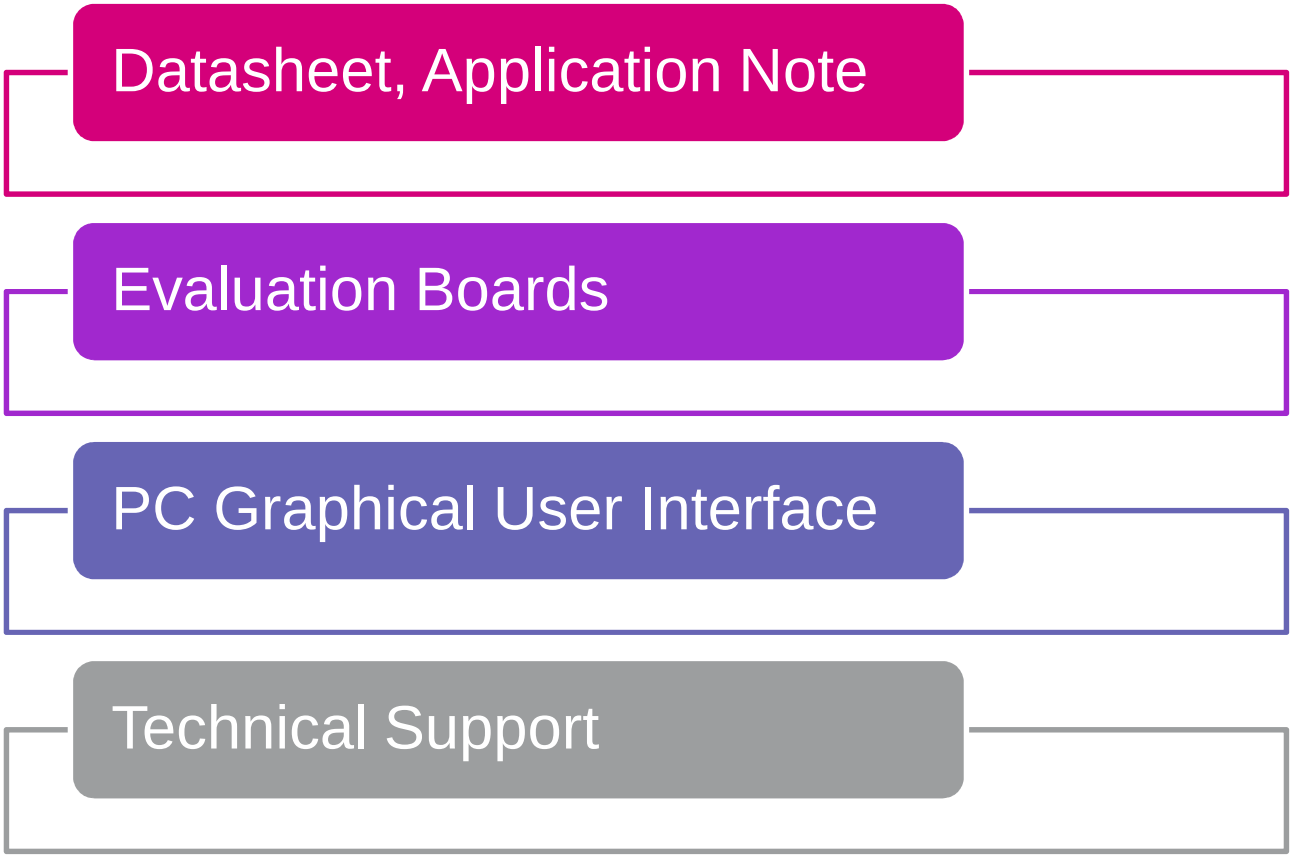




# Documentation & Support Tools





# Documentation



- ST MEMS products website
- LIS3DSH datasheet
- Application Note AN3393 LIS3DSH: 3-axis digital output accelerometer

**AN3393**
**Application note**

LIS3DSH: 3-axis digital output accelerometer

### Introduction

This document is intended to provide information on the use of and application hints related to ST's LIS3DSH 3-axial digital accelerometer.

The LIS3DSH is an ultra low-power high performance 3-axis linear accelerometer belonging to the "nano" family.

It has dynamically user selectable full scales of ±2*g*/±4*g*/±6*g*/±8*g*/±16*g* and is capable of measuring accelerations with output data rates from 3.125 Hz to 1.6 kHz.

The self-test capability allows the user to check the functioning of the sensor in the final application.

The LIS3DSH has an integrated first in, first out (FIFO) buffer allowing the user to store data for host processor intervention reduction.

The device can be configured to generate interrupt signals activated by user defined motion patterns. To do this, two embedded Finite State Machines can be programmed independently for motion detection. Each State Machine has 16 states.

The LIS3DSH is available in small thin plastic land grid array package (LGA), and it is guaranteed to operate over an extended temperature range from -40 °C to +85 °C.

**LIS3DSH**

MEMS digital output motion sensor
ultra low-power high performance three-axis "nano" accelerometer

Preliminary data

### Features

- Wide supply voltage, 1.71 V to 3.6 V
- Independent IOs supply (1.8 V) and supply voltage compatible
- Ultra low-power consumption
- ±2*g*/±4*g*/±6*g*/±8*g*/±16*g* dynamically selectable full-scale
- I²C/SPI digital output interface
- 16-bit data output
- Programmable embedded state machines
- Embedded temperature sensor
- Embedded self-test
- Embedded FIFO
- 10000 *g* high shock survivability
- ECOPACK® RoHS and "Green" compliant

### Applications

- Motion controlled user interface
- Gaming and virtual reality
- Pedometer
- Intelligent power saving for handheld devices
- Display orientation
- Click/double click recognition
- Impact recognition and logging
- Vibration monitoring and compensation

LGA-16 (3x3x1 mm)

of measuring accelerations with output data rates from 3.125 Hz to 1.6 kHz.

The self-test capability allows the user to check the functioning of the sensor in the final application.

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The LIS3DSH is available in a small thin plastic land grid array package (LGA) and it is guaranteed to operate over an extended temperature range from -40 °C to +85 °C.

**Table 1. Device summary**

| Order codes | Temperature range [° C] | Package | Packaging |
|---|---|---|---|
| LIS3DSH | -40 to +85 | LGA-16 | Tray |
| LIS3DSHTR | -40 to +85 | LGA-16 | Tape and reel |

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# Pedometer Based on State Machine



- Embedded 15bit step counter
- No pedometer firmware on Microcontroller
- Microcontroller can read pedometer in polling
- Automatic interrupt generation on stop walking sequence
- Automatic interrupt generation on every step
- Ultra Low Power consumption
- Strong anti-false detection

Available upon request


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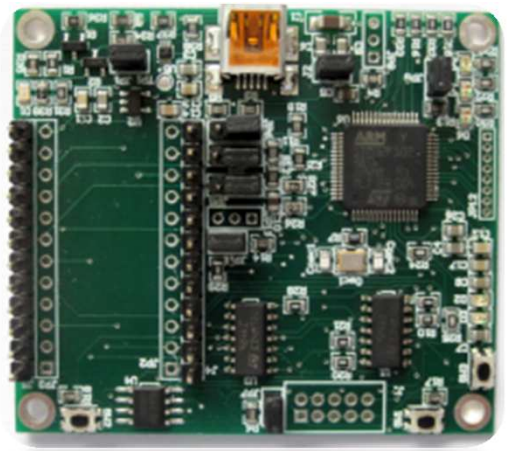
# Evaluation boards



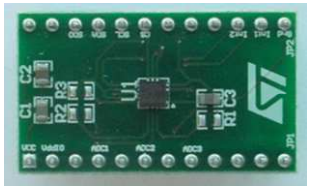
## STEVAL-MKI109V2



STM32-based MEMS motherboard compatible with ST MEMS adapters

- Firmware upgrades are possible via DFU
- Source codes available including low level drivers for STM32

Daughter board available:



**LIS3DSH**
STEVAL-MKI134V1

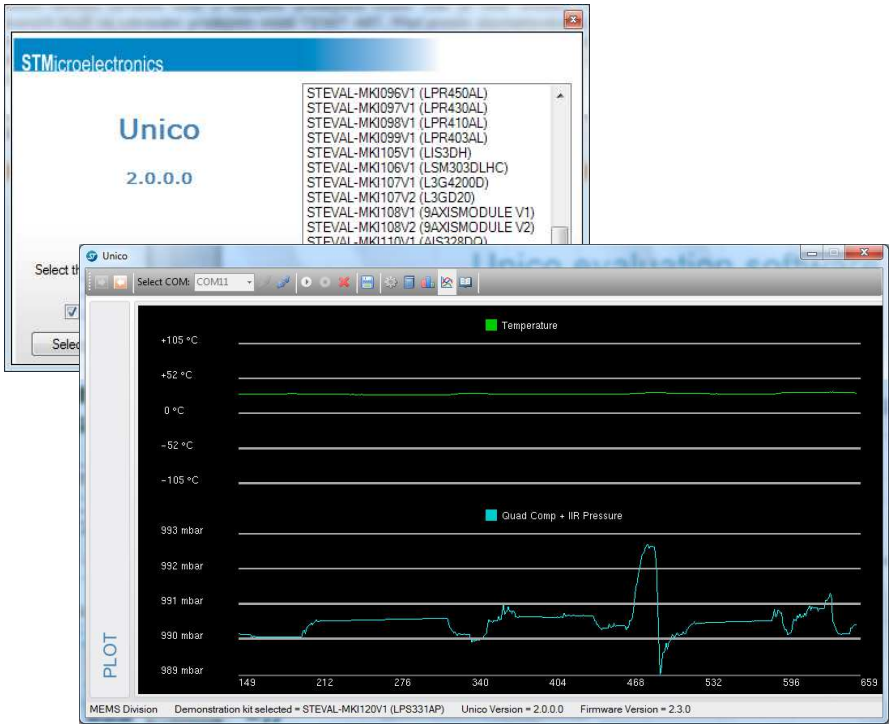
Note: **Schematics** and **Gerber** files are available under evaluation boards webpages in internet

# Unico Evaluation Software



- **Unico** is Graphical User Interface (GUI) **for PC** (Windows based)
- Designated to be used with STEVAL-MKI109V2 and any MEMS adapter board
- Connection
  - USB
  - Bluetooth – with STEVAL-MKI132V1

SOFTWARE PACKAGE
Click to download



# Analog, MEMS & Sensors (AMS) Application Support Team

… is providing technical application support for customers, designing in ST Analog, MEMS & Sensors products, in projects agreed with local EMEA ST sales office / Technical marketing team

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

## Application Support Service Card

Granted to

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Czech Republic

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## Application Support Team Focus


**… and RF IPD/IPAD RF Baluns**

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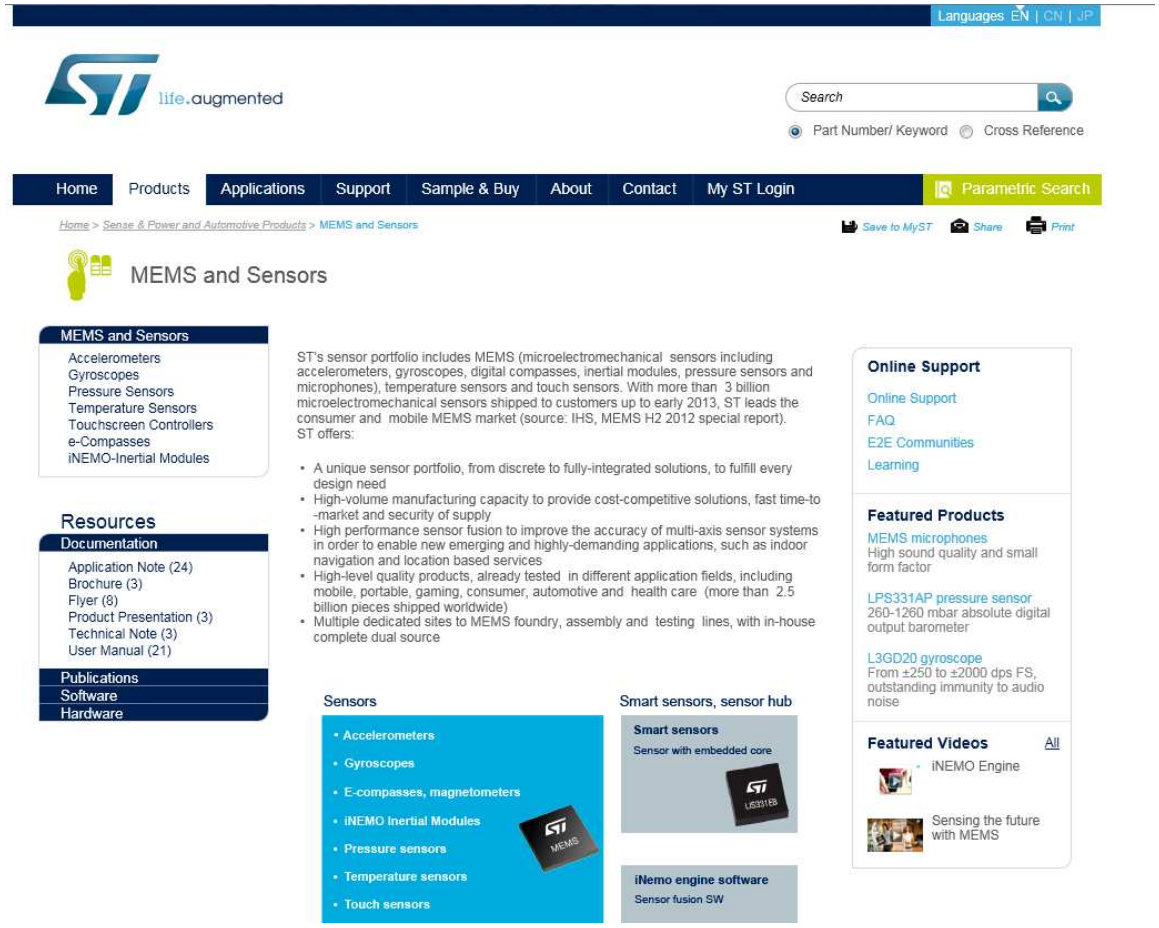
# For more information



- Web site: **www.st.com/mems**

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