Application Guidelines for LIS3DSH State Machine

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AMS Application Team
Agenda

Educational part: What is state machine? Applications of state machine

State Machine of LIS3DSH

Development of State programs: Unico GUI SW, Examples

Documentation & Support Tools
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
• 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

• P2P compatible 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**
Accelerometers - Portfolio

LIS33DE
6/8-bit
±2 / ±8g
3 x 3 x 0.9

LIS331DL
8-bit
±2 / ±8g
3 x 3 x 0.9

LIS35DE
6/8-bit
±2 / ±8g
3 x 5 x 0.9

LIS302DL
8-bit
±2 / ±8g
3 x 5 x 0.9

LIS344ALH
50µg/√Hz
±2 / ±8g
4 x 4 x 1.5

LIS332AX/AR
100µg/√Hz
±2g
3 x 3 x 0.9

LIS352AX/AR
100µg/√Hz
±2g
3 x 3 x 0.9

LIS331DLH
12-bit
±2 / ±4 / ±8g
3 x 3 x 0.9

LIS331HH
12-bit
±6 / ±12 / ±24g
3 x 3 x 0.9

LIS331DLM
8-bit
±2 / ±4 / ±8g
3 x 3 x 0.9

LIS331DLM
8-bit
±2 / ±4 / ±8g
3 x 3 x 0.9

LIS3LV02DL
12-bit
±2 / ±6g
4.4 x 7.5 x 0.9

LIS3LV02DL
12-bit
±2 / ±6g
4.4 x 7.5 x 0.9

LIS3DH
12-bit
±2, 4, 8, 16g
3 x 3 x 0.9

AIS328DQ
12-bit
±2, 4, 8, 16g
3 x 3 x 0.9

AIS328DQ
12-bit
±2, 4, 8, 16g
3 x 3 x 0.9

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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 µg/√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 please visit our website : www.st.com/
State Machine of LIS3DSH

Overview

Data flow

Conditions and Commands

Parameters
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 processing blocks of State Machine

- **LSB cutter** - 8-bit input data to State Machine are generated by dividing sensor output data by 256:
  
  $$8 \text{ bit data} = \frac{16 \text{ bit data}}{256}.$$

- **Decimator** - reduces the sample rate of the data going to SM 2
  
  $$\text{ODR}_{\text{SM2}} = \frac{\text{ODR}}{(\text{DES} + 1)}$$

  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-symmetric FIR filter**

\[
X_{v\_filt} = (x_0 - x_7) \text{ coeff}0 + (x_1 - x_6) \text{ coeff}1 + (x_2 - x_5) \text{ coeff}2 + (x_3 - x_4) \text{ coeff}3
\]

- Coefficients coeff0 to coeff3 are user-programmable.
State Machine Process

- Each state is configured through the Operation Codes (OPCODE). OPCODES can be divided into 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 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
• **SSYNC: SM1 + SM2 for 32 states SM**

State Machine #1

- START
- STEP
- STEP
- ...
- SSYNC
- CONTINUE

State Machine #2

- START
- STEP
- ...
- SSYNC
- CONTINUE

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

State Machine #1

- START
- STEP
- ...
- SSYNC
- CONTINUE

State Machine #2

- START
- SSYNC
- STEP
- ...
- SSYNC
- CONTINUE
- CONTINUE
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

1st phase
 Threshold 1
 X-axis
 Y-axis

2nd phase

Closing condition for peak detection:
LNTH1

Threshold 1

NEXT: GNTH1
RESET: TI1

NEXT cond. valid
TMASK = +y
First PEAK1 value stored

NEXT cond. Valid
TMASK1 = +x from peak
Final PEAK1 value kept

State program 1
PDET = 1
TMASK1 = 0
MASK1 = +/−x, +/−y

NEXT cond. valid
TMASK = +y
First PEAK1 value stored

Sample is greater than earlier peak value
New PEAK1 value
New TMASK1 = +x

next steps ...

-No new peak detection before RESET or REL
Development of State programs

- Unico SW GUI
- Debugging state programs
- Examples of State programs
• **GUI application** for Windows which allows to evaluate ST MEMS sensors

• **Features**
  • User friendly 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 using 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
Unico – Debug mode DISABLED

Actual device’s configuration (FS, ODR)

Debug MODE Enable/Disable command

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.
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.
State Machine Programs

1. Toggle
2. Wake Up
3. Free Fall
4. Double Tap
5. SSYNC
TI3 = 0x02h
Free Fall

STATE MACHINE #1

START

RESET POINT

S0

NOP  LLTH2

S1

GNTH2  TI1

S2

CONT

State Machine #1
Timer 1 = 100 ms
Timer 2 = 0 ms
Timer 3 = 0 ms
Timer 4 = 0 ms
Threshold 1 = 0 mg
Threshold 2 = 750 mg
MASK A = 0xA0h
MASK B = 0xB0h
RESET PNTR 1 = 0
PRGM PNTR 1 = 0
OUTS 1 = 80h
TI CNTR 1 = 0
Documentation & Support Tools

- Datasheet, Application Note
- Evaluation Boards
- PC Graphical User Interface
- Technical Support
• **ST MEMS products website**

• **LIS3DSH datasheet**

• **Application Note AN3393 LIS3DSH: 3-axis digital output accelerometer**

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**AN3393 Application note**

**LIS3DSH: 3-axis digital output accelerometer**

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**Introduction**

This document is intended to provide information on the use of and application hints related to ST’s LIS3DSH 3-axis 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 ±2g/±4g/±6g/±8g/±16g 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 has a full temperature range from -40 °C to +85 °C.
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
Evaluation boards

Daughter board available:

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

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

LIS3DSH
STEVAL-MKI134V1

www.emcu.it
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]
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