EECE-4710 "IoT and TinyML"

Tiny ML Kit - Testing the Sensors

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BE THE DIFFERENCE.

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Hardware Overview

Microcontroller	nRF52840 (datasheet)
Operating Voltage	3.3V
Input Voltage (limit)	21V
DC Current per I/O Pin	15mA
Clock Speed	64MHz
CPU Flash Memory	1MB (nRF52840)
SRAM	256KB (nRF52840)
EEPROM	none
Digital Input / Output Pins	14
PWM Pins	all digital pins
UART	1
SPI	1
I2C	1

Analog Input Pins	8 (ADC 12 bit 200 ksamples)
Analog Output Pins	Only through PWM (no DAC)
External Interrupts	all digital pins
LED_BUILTIN	13
USB	Native in the nRF52840 Processor
IMU	LSM9DS1 (datasheet)
Microphone	MP34DT05 (datasheet)
Gesture, light, proximity	APDS9960 (datasheet)
Barometric pressure	LPS22HB (datasheet)
Temperature, humidity	HTS221 (datasheet)
Length	45 mm
Width	18 mm
Weight	5 gr (with headers)

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TinyML Kit Tests – Part 2

→ Inertial Module - LSM9DS1
→ Digital MEMs Microphone - MP34DTOS-A
→ Camera Module - OV7675

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IMU

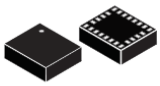
- LSM9DS1
  - System-in-package
  - 3D digital linear acceleration sensor
  - 3D digital angular rate sensor
  - 3D digital magnetic sensor
- Comm
  - **I2C** serial bus interface (standard and fast mode)
  - **SPI** serial standard interface

life.augmented

LSM9DS1

iNEMO inertial module:
3D accelerometer, 3D gyroscope, 3D magnetometer

Datasheet - production data



LGA-24L (3.5x3x1.0 mm)

Features

- 3 acceleration channels, 3 angular rate channels, 3 magnetic field channels
- ±2/±4/±8/±16 *g* linear acceleration full scale
- ±4/±8/±12/±16 gauss magnetic full scale
- ±245/±500/±2000 dps angular rate full scale
- 16-bit data output
- SPI / I^2C serial interfaces
- Analog supply voltage 1.9 V to 3.6 V
- "Always-on" eco power mode down to 1.9 mA
- Programmable interrupt generators
- Embedded temperature sensor
- Embedded FIFO
- Position and motion detection functions
- Click/double-click recognition
- Intelligent power saving for handheld devices
- ECOPACK®, RoHS and "Green" compliant

Applications

- Indoor navigation
- Smart user interfaces
- Advanced gesture recognition
- Gaming and virtual reality input devices
- Display/map orientation and browsing

Description

The LSM9DS1 is a system-in-package featuring a 3D digital linear acceleration sensor, a 3D digital angular rate sensor, and a 3D digital magnetic sensor.

The LSM9DS1 has a linear acceleration full scale of ±2*g*/±4*g*/±8/±16 *g*, a magnetic field full scale of ±4/±8/±12/±16 gauss and an angular rate of ±245/±500/±2000 dps.

The LSM9DS1 includes an I^2C serial bus interface supporting standard and fast mode (100 kHz and 400 kHz) and an SPI serial standard interface.

Magnetic, accelerometer and gyroscope sensing can be enabled or set in power-down mode separately for smart power management.

The LSM9DS1 is available in a plastic land grid array package (LGA) and it is guaranteed to operate over an extended temperature range from -40 °C to +85 °C.

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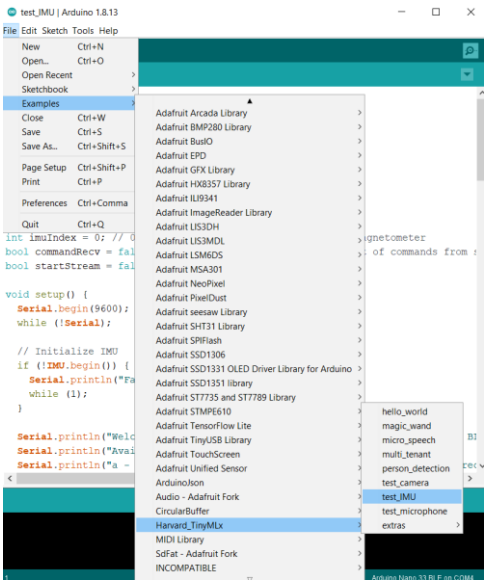
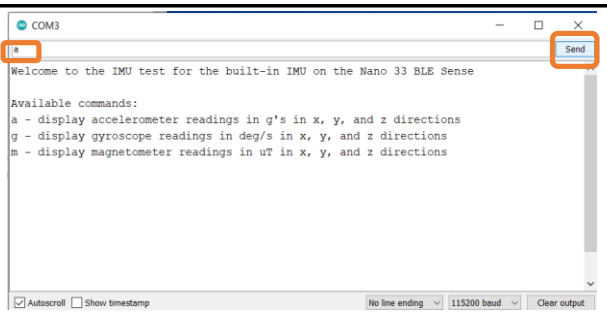
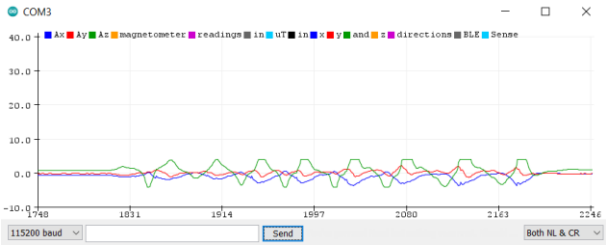
Testing IMU







Notes:

--Compiling & Uploading may take a few minutes

--Close the Serial Monitor before opening the Plotter

--Repeat test for 'g' and 'm'

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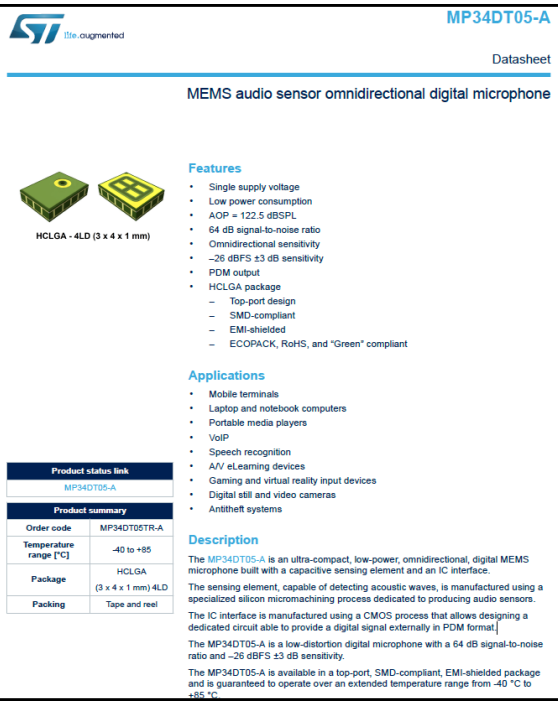
Microphone

- MP34DT05-A
  - Digital MEMS microphone built with a capacitive sensing element
  - Ultra-compact, low-power, omnidirectional
- Comm
  - IC interface manufactured using a CMOS process
  - Provides a digital signal externally in **PDM format**



MP34DT05-A

Datasheet

MEMS audio sensor omnidirectional digital microphone

HCLGA - 4LD (3 x 4 x 1 mm)

Features

- Single supply voltage
- Low power consumption
- AOP = 122.5 dBSPL
- 64 dB signal-to-noise ratio
- Omnidirectional sensitivity
- –26 dBFS ±3 dB sensitivity
- PDM output
- HCLGA package
  - Top-port design
  - SMD-compliant
  - EMI-shielded
  - ECOPACK, RoHS, and "Green" compliant

Applications

- Mobile terminals
- Laptop and notebook computers
- Portable media players
- VoIP
- Speech recognition
- A/V eLearning devices
- Gaming and virtual reality input devices
- Digital still and video cameras
- Antitheft systems

Product status link
MP34DT05-A

Product summary	
Order code	MP34DT05TR-A
Temperature range [°C]	-40 to +85
Package	HCLGA (3 x 4 x 1 mm) 4LD
Packing	Tape and reel

Description

The MP34DT05-A is an ultra-compact, low-power, omnidirectional, digital MEMS microphone built with a capacitive sensing element and an IC interface.

The sensing element, capable of detecting acoustic waves, is manufactured using a specialized silicon micromachining process dedicated to producing audio sensors.

The IC interface is manufactured using a CMOS process that allows designing a dedicated circuit able to provide a digital signal externally in PDM format.

The MP34DT05-A is a low-distortion digital microphone with a 64 dB signal-to-noise ratio and –26 dBFS ±3 dB sensitivity.

The MP34DT05-A is available in a top-port, SMD-compliant, EMI-shielded package and is guaranteed to operate over an extended temperature range from -40 °C to +85 °C.

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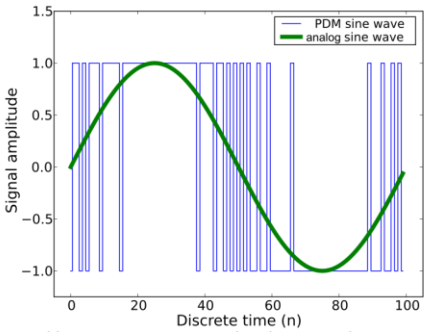
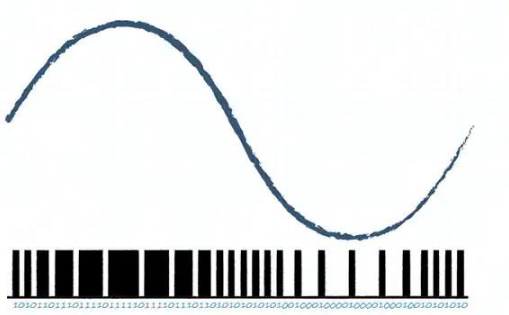
Pulse Density Modulation (PDM)

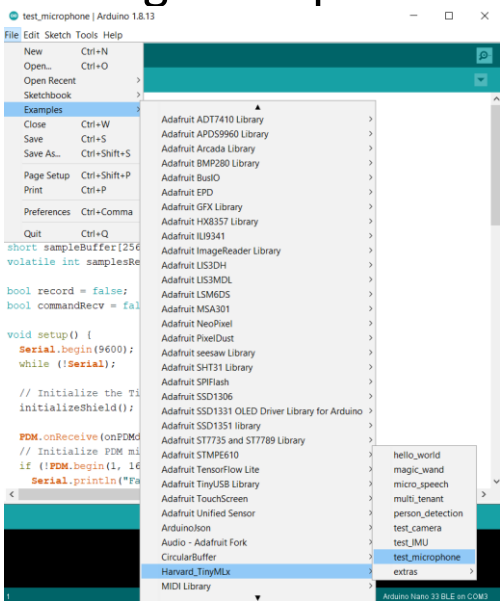
- A Pulse Density Modulation (PDM) microphone uses a Sigma-Delta modulator to oversample an acoustic signal at a high sampling rate. This digital PDM signal is output from the microphone as a 1-bit data word, where the density of ones and zeros in the data represents the amplitude of the audio signal.

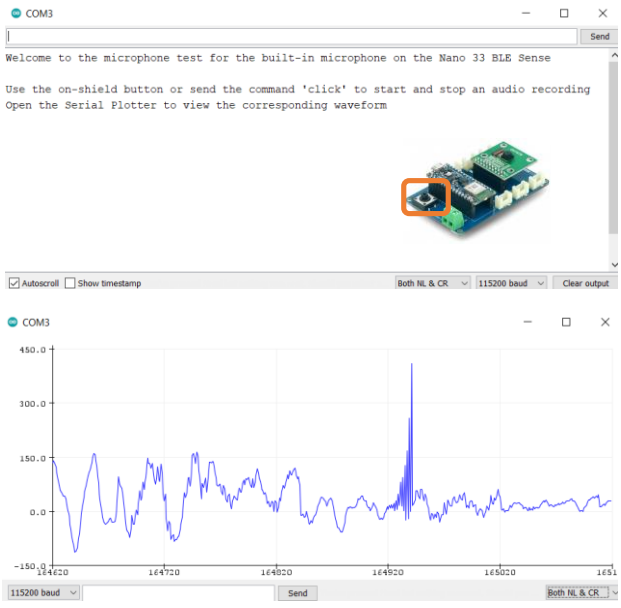




https://www.digikey.com/en/articles/a-comparison-of-digital-pdm-and-i2s-interfaces-in-mems-microphones
https://en.wikipedia.org/wiki/Pulse-density_modulation

Testing Microphone





Note: Close the Serial Monitor before opening the Plotter

OV7675 Camera Module

- **0.3 MP** CMOS image sensor
- active array size: **640×480**
- output formats: YUV422, Raw RGB, ITU656, RGB565
- input clock frequency: 1.5 ~ 27 MHz
- maximum image transfer rate: VGA 30fps, QVGA 60fps, QQVGA 240pfs
- pixel size: 2.5 µm x 2.5 µm
- image area: 1640 µm x 1220 µm

https://www.arducam.com/products/camera-breakout-board/0-3mp-ov7675/
https://github.com/ArduCAM/ArduCAM_USB_Camera_Shield
https://github.com/ArduCAM/Arduino

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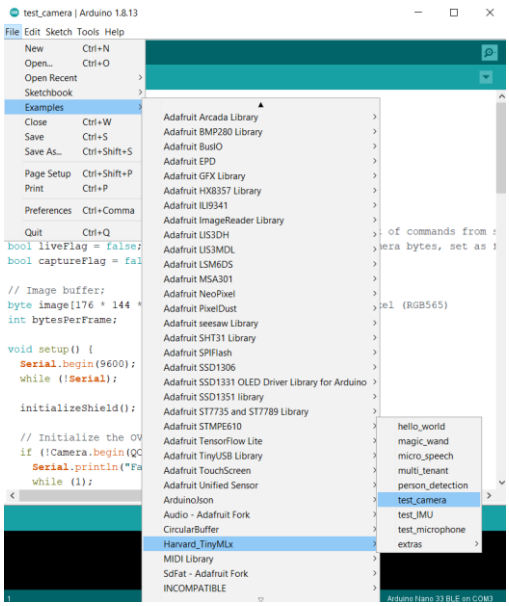
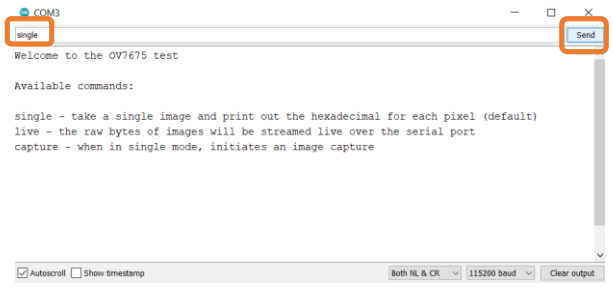
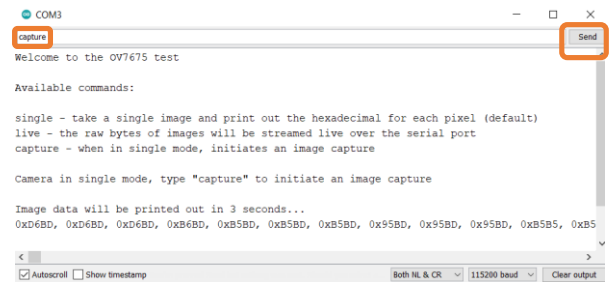
Testing Camera







Note: You can Press Button instead of sending 'capture'

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Testing Camera

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Credits

- A previous edition of this course was developed in collaboration with Dr. Susan C. Schneider of Marquette University.
- We are very grateful and thank all the following professors, researchers, and practitioners for jump-starting courses on TinyML and for sharing their teaching materials:

- Prof. Marcelo Rovai - TinyML - Machine Learning for Embedding Devices, UNIFEI
  - https://github.com/Mjrovai/UNIFEI-IESTI01-TinyML-2022.1
- Prof. Vijay Janapa Reddi - CS249r: Tiny Machine Learning, Applied Machine Learning on Embedded IoT Devices, Harvard
  - https://sites.google.com/g.harvard.edu/tinyml/home
- Prof. Rahul Mangharam – ESE3600: Tiny Machine Learning, Univ. of Pennsylvania
  - https://tinyml.seas.upenn.edu/#
- Prof. Brian Plancher - Harvard CS249r: Tiny Machine Learning (TinyML), Barnard College, Columbia University
  - https://a2r-lab.org/courses/cs249r_tinyml/

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References

- Additional references from where information and other teaching materials were gathered include:

- Applications & Deploy textbook: “TinyML” by Pete Warden, Daniel Situnayake
  - https://www.oreilly.com/library/view/tinyml/9781492052036/
- Deploy textbook “TinyML Cookbook” by Gian Marco Iodice
  - https://github.com/PacktPublishing/TinyML-Cookbook
- Jason Brownlee
  - https://machinelearningmastery.com/
- TinyMLedu
  - https://tinyml.seas.harvard.edu/
- Professional Certificate in Tiny Machine Learning (TinyML) – edX/Harvard
  - https://www.edx.org/professional-certificate/harvardx-tiny-machine-learning
- Introduction to Embedded Machine Learning - Coursera/Edge Impulse
  - https://www.coursera.org/learn/introduction-to-embedded-machine-learning
- Computer Vision with Embedded Machine Learning - Coursera/Edge Impulse
  - https://www.coursera.org/learn/computer-vision-with-embedded-machine-learning