EECE-4710 "IoT and TinyML"

Tiny ML Kit - Testing the Sensors

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BE THE DIFFERENCE.

1

TinyML Kit Tests – Part 3

→ Barometric Pressure & Temperature - LPS22HB

→ Humidity and Temperature - HTS221

2

Pressure + Temperature

- LPS22HB
  - Ultra-compact piezoresistive absolute pressure sensor
  - Functions as a digital output barometer
- Comm:
  - IC interface which communicates through **I2C or SPI**

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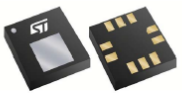
LPS22HB

MEMS nano pressure sensor: 260-1260 hPa absolute digital output barometer

Datasheet - production data



HLGA-10L
(2.0 x 2.0 x 0.76 mm)

Features

- 260 to 1260 hPa absolute pressure range
- Current consumption down to 3 µA
- High overpressure capability: 20x full-scale
- Embedded temperature compensation
- 24-bit pressure data output
- 16-bit temperature data output
- ODR from 1 Hz to 75 Hz
- SPI and I²C interfaces
- Embedded FIFO
- Interrupt functions: Data Ready, FIFO flags, pressure thresholds
- Supply voltage: 1.7 to 3.6 V
- High shock survivability: 22,000 *g*
- Small and thin package
- ECOPACK® lead-free compliant

Applications

- Altimeters and barometers for portable devices
- GPS applications
- Weather station equipment
- Sport watches

Description

The LPS22HB is an ultra-compact piezoresistive absolute pressure sensor which functions as a digital output barometer. The device comprises a sensing element and an IC interface which communicates through I²C or SPI from the sensing element to the application.

The sensing element, which detects absolute pressure, consists of a suspended membrane manufactured using a dedicated process developed by ST.

The LPS22HB is available in a full-mold, holed LGA package (HLGA). It is guaranteed to operate over a temperature range extending from -40 °C to +85 °C. The package is holed to allow external pressure to reach the sensing element.

3

Test: Barometric and Temperature Sensor – LPS22HB

- Review Arduino tutorial available at:
  - https://docs.arduino.cc/tutorials/nano-33-ble-sense/barometric-sensor/
- Install required library
  - Inside Arduino IDE: Tools -> Manage Libraries…
  - Search LPS22HB and then install Arduino_LPS22HB
- Run the tutorial sketch; make sure of correct operation
  - Sketch is included in files for this week as sketch_barometric/

4

4

Option #1:
Humidity + Temperature

- If your BLE 33 Sense board has this sensor only!
- HTS221
  - Capacitive digital sensor for relative humidity and temperature
  - Sensing element: polymer dielectric planar capacitor structure
  - Factory calibrated
- Comm:
  - **SPI and I2C** interfaces

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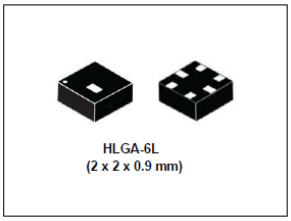
HTS221

Capacitive digital sensor for relative humidity and temperature

Datasheet - production data



HLGA-6L
(2 x 2 x 0.9 mm)

Applications

- Air conditioning, heating and ventilation
- Air humidifiers
- Refrigerators
- Wearable devices
- Smart home automation
- Industrial automation
- Respiratory equipment
- Asset and goods tracking

Features

- 0 to 100% relative humidity range
- Supply voltage: 1.7 to 3.6 V
- Low power consumption: 2 µA @ 1 Hz ODR
- Selectable ODR from 1 Hz to 12.5 Hz
- High rH sensitivity: 0.004% rH/LSB
- Humidity accuracy: ± 3.5% rH, 20 to +80% rH
- Temperature accuracy: ± 0.5 °C,15 to +40 °C
- Embedded 16-bit ADC
- 16-bit humidity and temperature output data
- SPI and I²C interfaces
- Factory calibrated
- Tiny 2 x 2 x 0.9 mm package
- ECOPACK® compliant

Description

The HTS221 is an ultra-compact sensor for relative humidity and temperature. It includes a sensing element and a mixed signal ASIC to provide the measurement information through digital serial interfaces.

The sensing element consists of a polymer dielectric planar capacitor structure capable of detecting relative humidity variations and is manufactured using a dedicated ST process.

The HTS221 is available in a small top-holed cap land grid array (HLGA) package guaranteed to operate over a temperature range from -40 °C to +120 °C.

5

Test: Humidity and Temperature Sensor – HTS221

- Review Arduino tutorial available at:
  - https://docs.arduino.cc/tutorials/nano-33-ble-sense/humidity-and-temperature-sensor
- Install required library
  - Inside Arduino IDE: Tools -> Manage Libraries…
  - Search HTS221 and then install Arduino_HTS221
- Run the tutorial sketch; make sure of correct operation
  - Sketch is included in files for this week as sketch_humidity/

6

6

Option #2:
Humidity + Temperature

- Workaround/alternative to Option #1
- Use discrete, separate DHT22 sensor for Humidity and Temperature
- DHT22
  - AM2303 output calibrated digital signal.
  - Single-bus data is used for communication, it costs 5mS for single time communication.
- Comm:
  - **Special 1-wire** interfaces, implemented by available libraries

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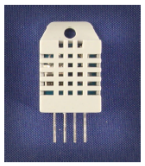
Digital-output relative humidity & temperature sensor/module

AM2303



Capacitive-type humidity and temperature module/sensor

1. Feature & Application:

* Full range temperature compensated * Relative humidity and temperature measurement
* Calibrated digital signal *Outstanding long-term stability *Extra components not needed
* Long transmission distance * Low power consumption *4 pins packaged and fully interchangeable

2. Description:

AM2303 output calibrated digital signal. It utilizes exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability.Its sensing elements is connected with 8-bit single-chip computer.

Every sensor of this model is temperature compensated and calibrated in accurate calibration chamber and the calibration-coefficient is saved in type of programme in OTP memory, when the sensor is detecting, it will cite coefficient from memory.
Small size & low consumption & long transmission distance(20m) enable AM2303 to be suited in all kinds of harsh application occasions.

7

Test: Humidity and Temperature Sensor – DHT22

- Read W7_Assignment document for details on wiring up the sensor to the BLE 33 Sense board
- Install required library
  - Inside Arduino IDE: Tools -> Manage Libraries…
  - Search “DHT sensor library” and then install DHT sensor library, if you do not have it already installed
- Compile the sketch; make sure of correct operation
  - Sketch is included in files for this week as sketch_dht22/

8

8

TinyML Kit Tests – Part 4 (Optional)

→ OPTIONAL Sensor Test
-- Gesture Detection - APDS-9960

→ OPTIONAL ML Tests
-- ML-1: Keyword Detection
-- ML-2: Person Detection

Digital Proximity, Ambient Light, RGB and Gesture Sensor

- APDS-9960
  - Gesture detection, Proximity detection
  - Digital Ambient Light Sense (ALS)
  - Color Sense (RGBC)
- Comm
  - I2C-bus Fast Mode Compatible Interface

APDS-9960
Digital Proximity, Ambient Light, RGB and Gesture Sensor

AVAGO TECHNOLOGIES

Data Sheet

Lead (Pb) Free
RoHS 6 fully compliant

Description

The APDS-9960 device features advanced Gesture detection, Proximity detection, Digital Ambient Light Sense (ALS) and Color Sense (RGBC). The slim modular package, L 3.94 × W 2.36 × H 1.35 mm, incorporates an IR LED and factory calibrated LED driver for drop-in compatibility with existing footprints.

Gesture detection

Gesture detection utilizes four directional photodiodes to sense reflected IR energy (sourced by the integrated LED) to convert physical motion information (i.e. velocity, direction and distance) to a digital information. The architecture of the gesture engine features automatic activation (based on Proximity engine results), ambient light subtraction, cross-talk cancelation, dual 8-bit data converters, power saving inter-conversion delay, 32-dataset FIFO, and interrupt-driven I²C-bus communication. The gesture engine accommodates a wide range of mobile device gesturing requirements: simple UP-DOWN-RIGHT-LEFT gestures or more complex gestures can be accurately sensed. Power consumption and noise are minimized with adjustable IR LED timing.

Description continued on next page...

Applications

- Gesture Detection
- Color Sense
- Ambient Light Sensing
- Cell Phone Touch Screen Disable
- Mechanical Switch Replacement

Features

- Ambient Light and RGB Color Sensing, Proximity Sensing, and Gesture Detection in an Optical Module
- Ambient Light and RGB Color Sensing
  - UV and IR blocking filters
  - Programmable gain and integration time
  - Very high sensitivity – Ideally suited for operation behind dark glass
- Proximity Sensing
  - Trimmed to provide consistent reading
  - Ambient light rejection
  - Offset compensation
  - Programmable driver for IR LED current
  - Saturation indicator bit
- Complex Gesture Sensing
  - Four separate diodes sensitive to different directions
  - Ambient light rejection
  - Offset compensation
  - Programmable driver for IR LED current
  - 32 dataset storage FIFO
  - Interrupt driven I²C-bus communication
- I²C-bus Fast Mode Compatible Interface
  - Data Rates up to 400 kHz
  - Dedicated Interrupt Pin
- Small Package L 3.94 × W 2.36 × H 1.35 mm

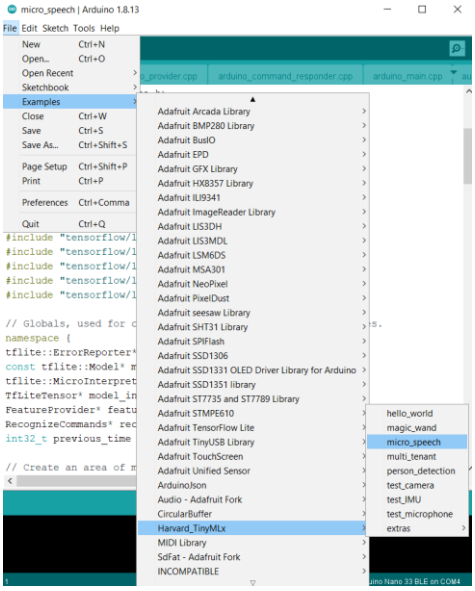
Test: Digital Proximity, Ambient Light, RGB and Gesture Sensor - APDS-9960

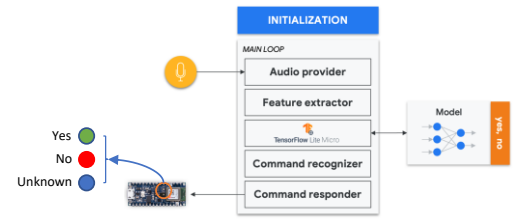
- Review Arduino tutorial available at:
  - https://docs.arduino.cc/tutorials/nano-33-ble-sense/gesture-sensor
- Run the tutorial

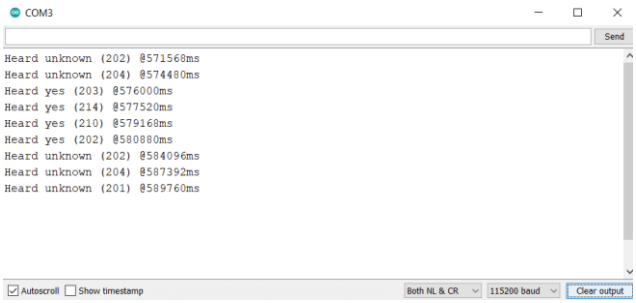
11

11

Optional Test: KeyWord Spotting

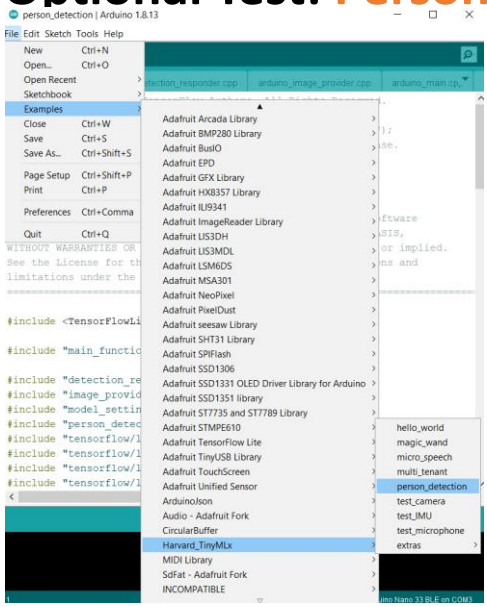


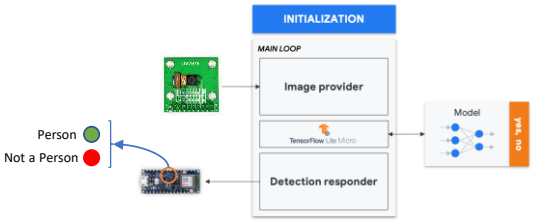


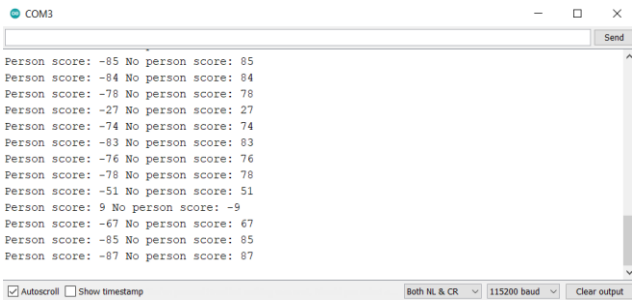


12

Optional Test: Person Detection







13

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/

14

14

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

15

15