To follow along

- Open the GitHub Repository
  - https://github.com/mathworks/Low-Cost-Hardware-with-MATLAB-Online
  - *It is recommended that Google Chrome be used*
- Download MATLAB Mobile on your smartphone:
  - https://www.mathworks.com/products/matlab-mobile.html

SCAN ME

Project-Based Learning with Low-Cost Hardware using MATLAB

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Education Application Engineer

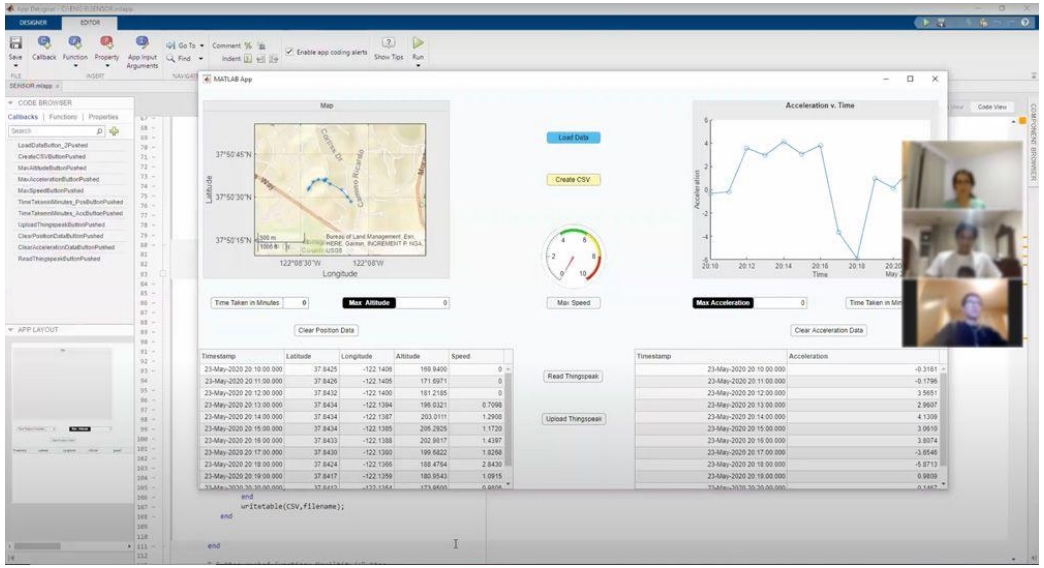
Siddharth Jawahar
Education Application Engineer

Agenda

- What is Project-Based Learning with MATLAB?
- Introduction to MATLAB Online and Live Editor
- Introduction to MATLAB Mobile
  - Activity: Collecting Sensor Data
- Using a Webcam with MATLAB Online
  - Activity: Taking a Selfie
- Using ThingSpeak with MATLAB Online
  - Activity: Plotting Traffic Data
- Third-Party Hardware for MATLAB
  - Raspberry Pi
  - Arduino
  - Demo: Controlling an LED with MATLAB
  - Demo: Controlling a Servo with Simulink

What is Project-Based Learning with MATLAB?

- Connect student work to the real world
- Create sophisticated, interactive applications that collect, exchange, and analyze real-world data
- Building students' self-confidence with MATLAB
- Keep students engaged when moving courses online
- Offer exposure to hardware in programming courses

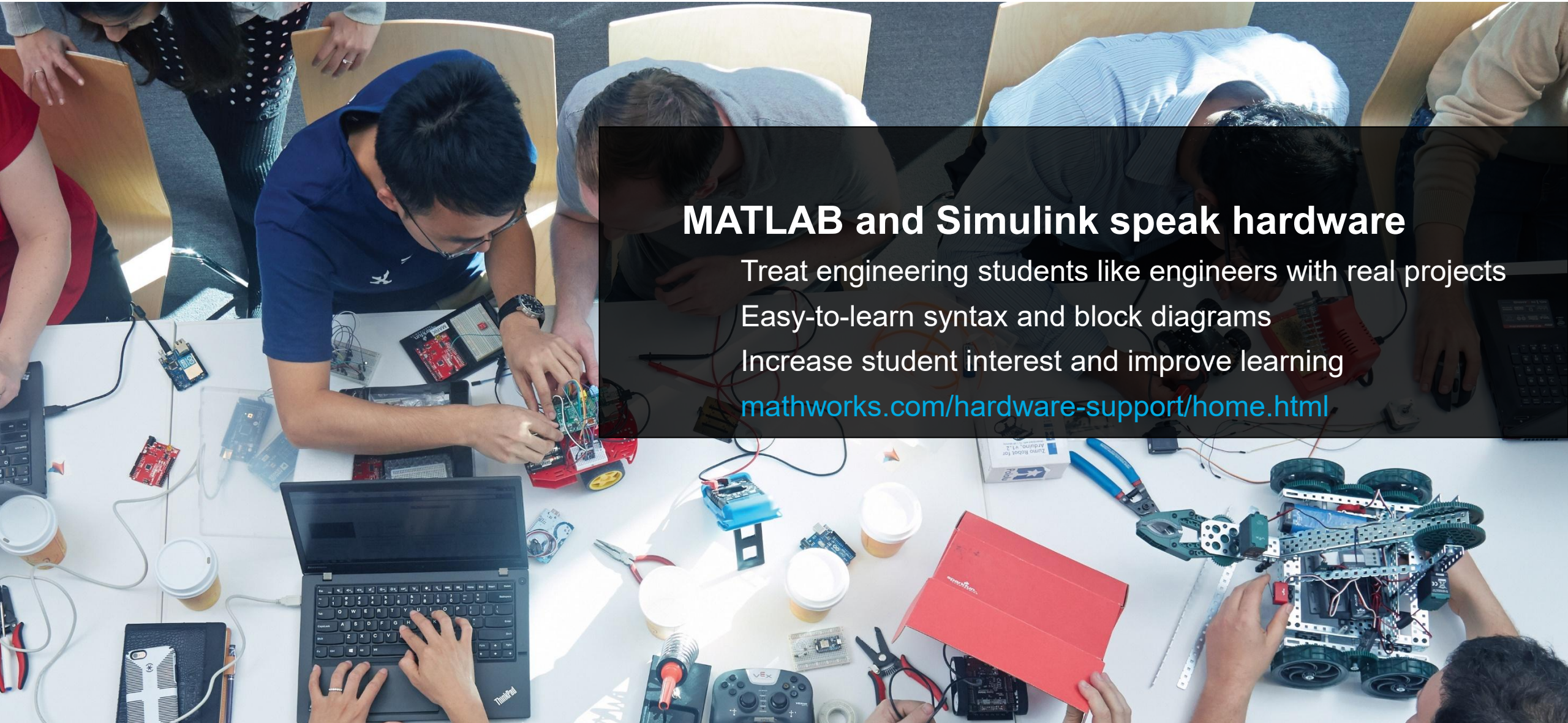


"The tools work well in classes with hundreds of students; since students can use the sensors in their own devices, we don't have to supply sensor hardware, and because these tools do not require any hardware setup, students can get started with data acquisition quickly."

-- Dr. André Knoesen, UC Davis

https://mathworks.com/company/technical-articles/engaging-students-in-project-based-learning-with-matlab-mobile-and-thingspeak.html

Project-Based Learning with Low-Cost Hardware



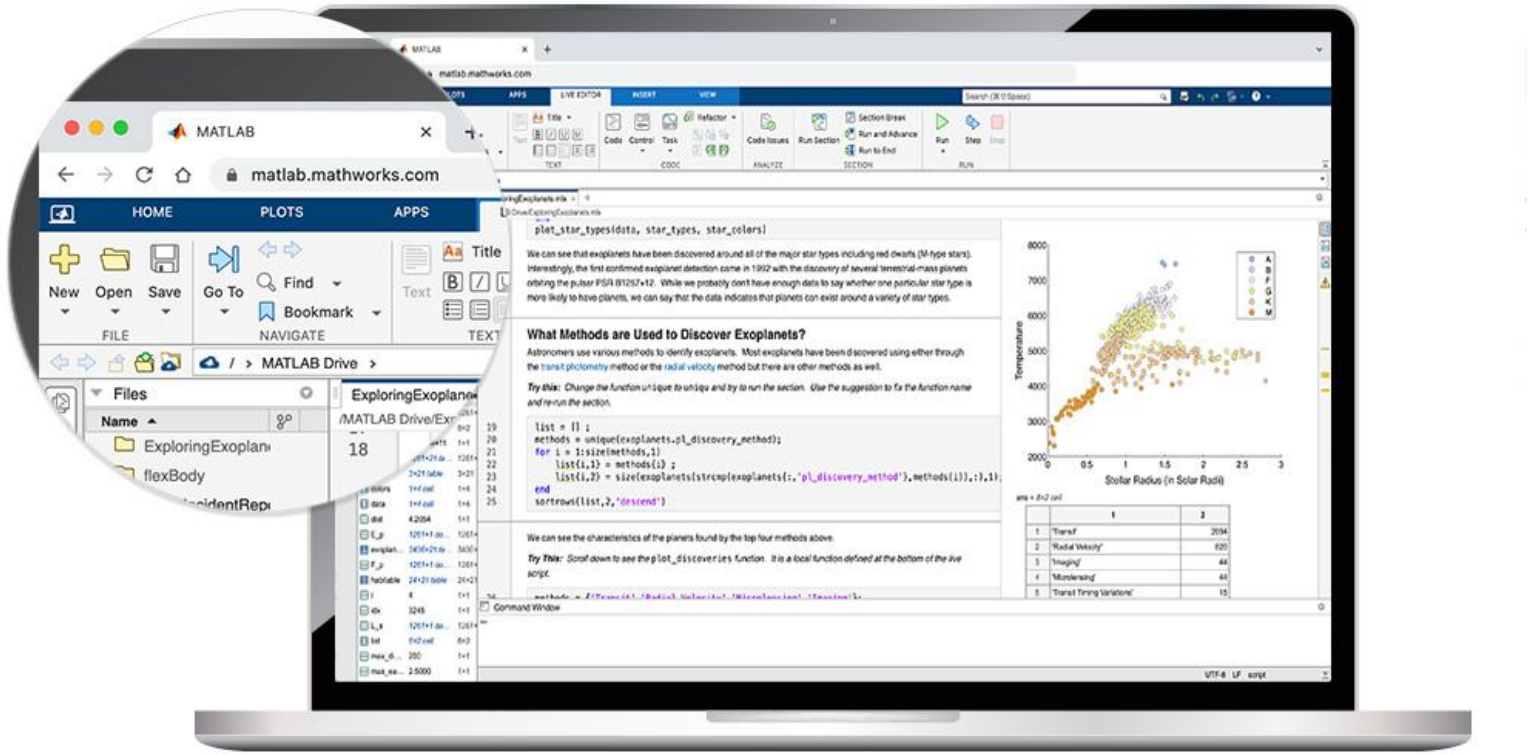
MATLAB and Simulink speak hardware

- Treat engineering students like engineers with real projects
- Easy-to-learn syntax and block diagrams
- Increase student interest and improve learning

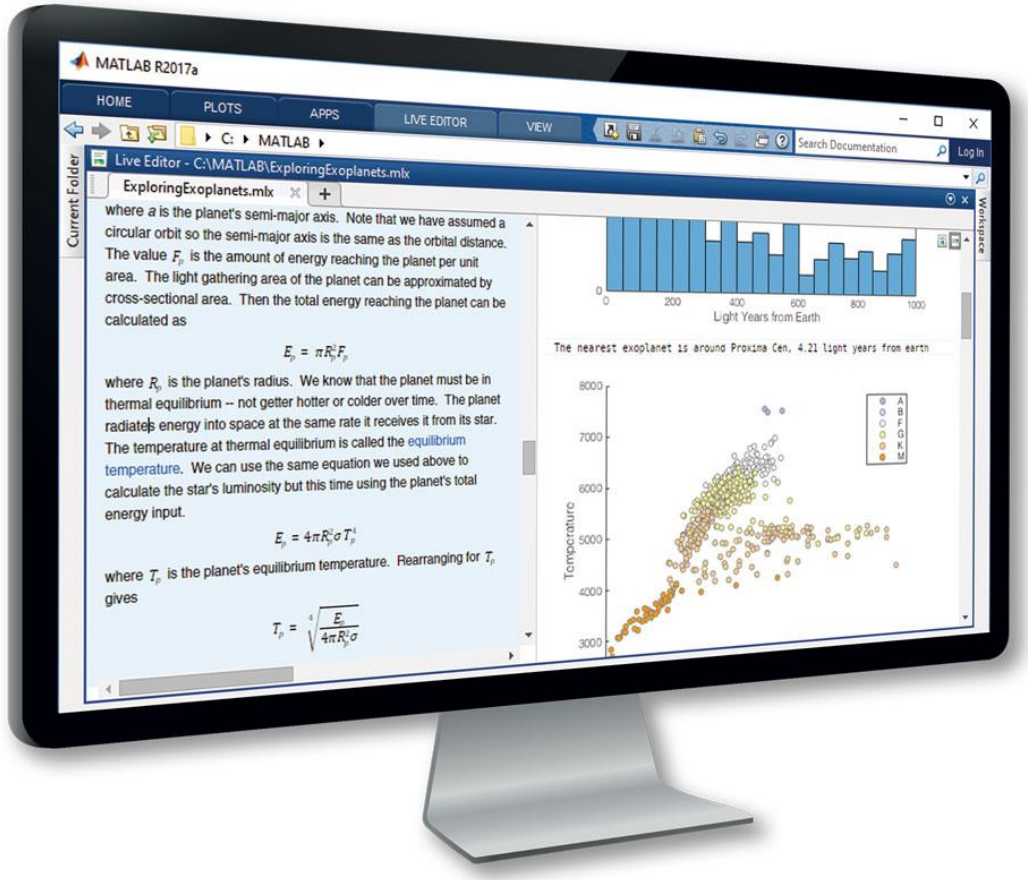
mathworks.com/hardware-support/home.html

What is MATLAB Online?

- Provides web-based access to the latest version of MATLAB
- Access your files, models, and data with MATLAB Drive
- Always running the latest version of MATLAB
- All the products on your license are pre-installed



Teach with MATLAB Live Editor



MATLAB in an Executable Notebook

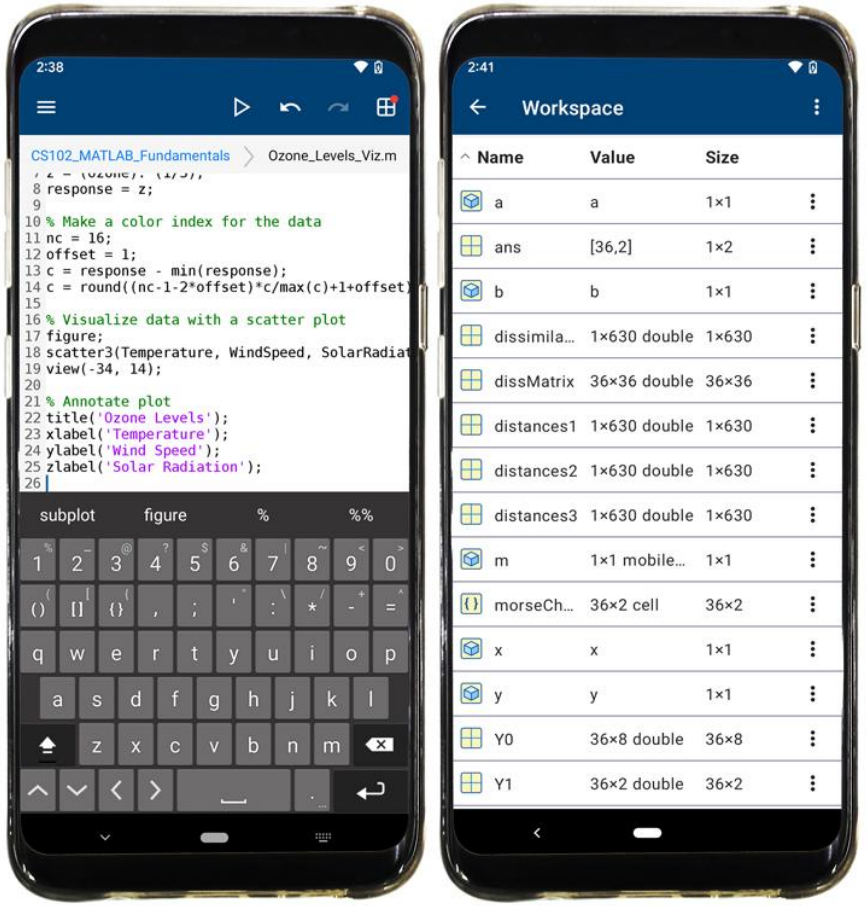
Use live scripts to create engaging lectures that combine explanatory text, mathematical equations, code, and results

Share live scripts directly with colleagues or students

Work in a single environment to eliminate context switching

What is MATLAB Mobile?

- Enables on-the-go access to MATLAB, allowing users to run scripts, visualize data, connect to cloud storage, and gather sensor data from mobile devices.
- Works natively on smartphones and tablets (iOS and Android). Connect a keyboard to your tablet for a better coding experience.
- Same access to MATLAB Drive, latest version of MATLAB, and all your products



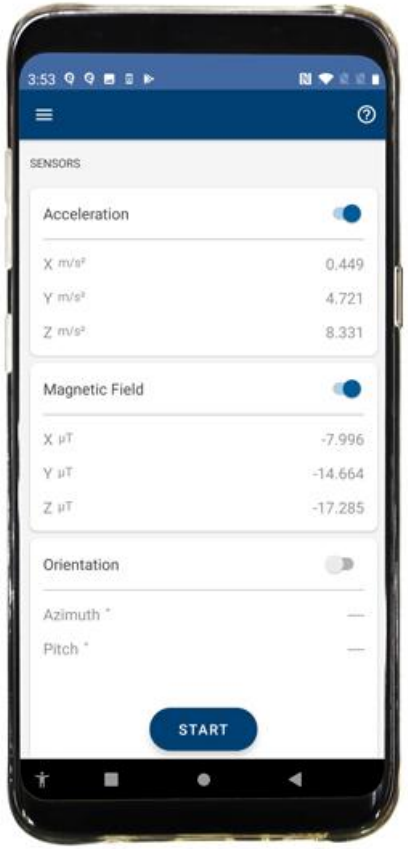
MATLAB Mobile allows you to…

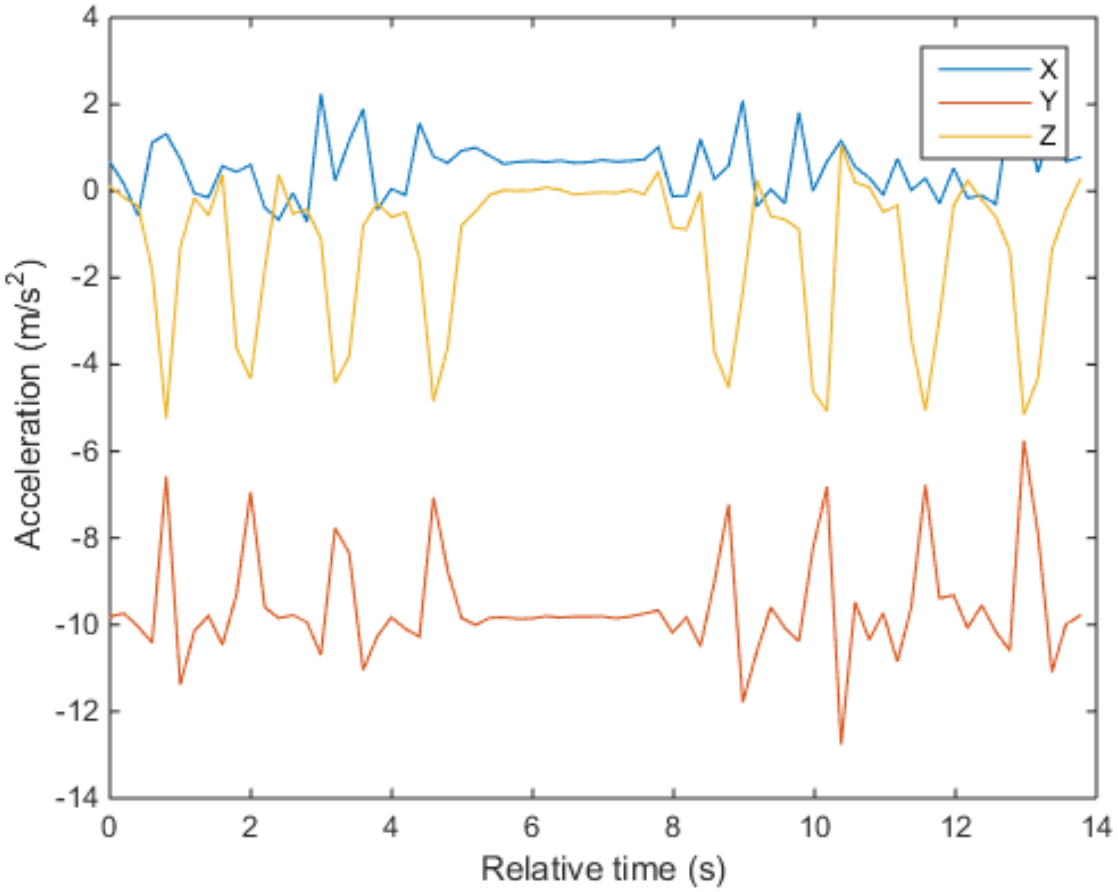
Acquire Sensor Data

Capture Images, Video, and Audio

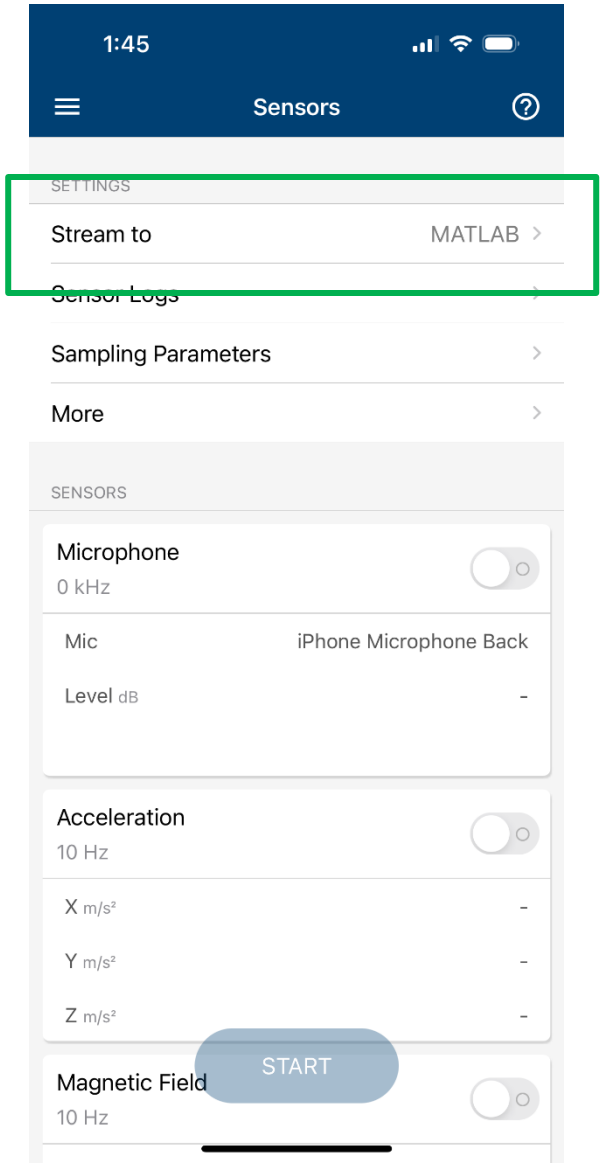
Connect to the MathWorks Cloud

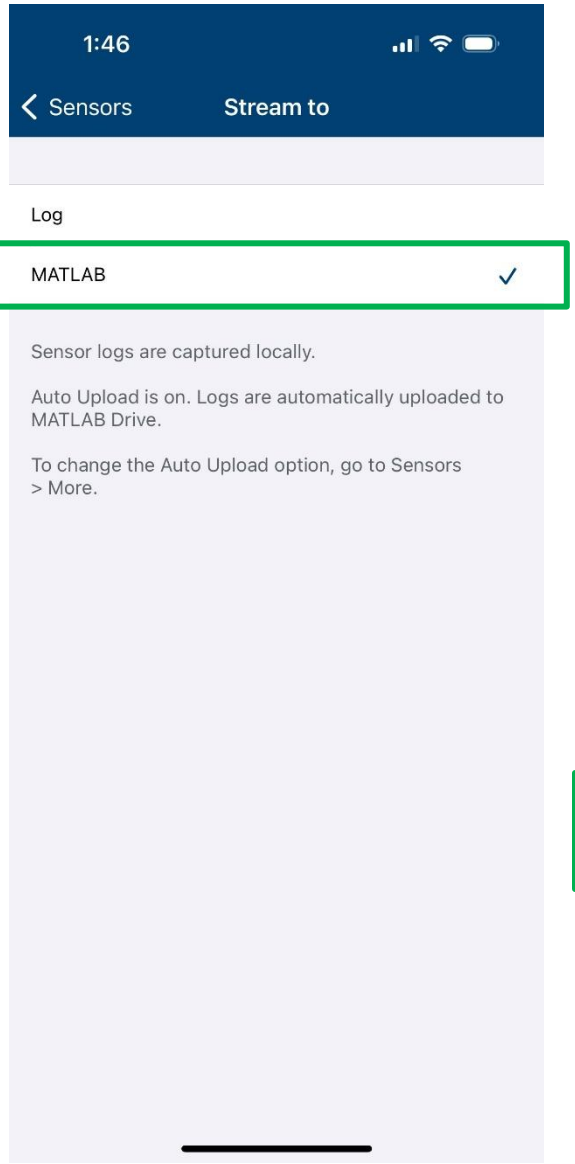
Activity: Collecting Smartphone Sensor Data

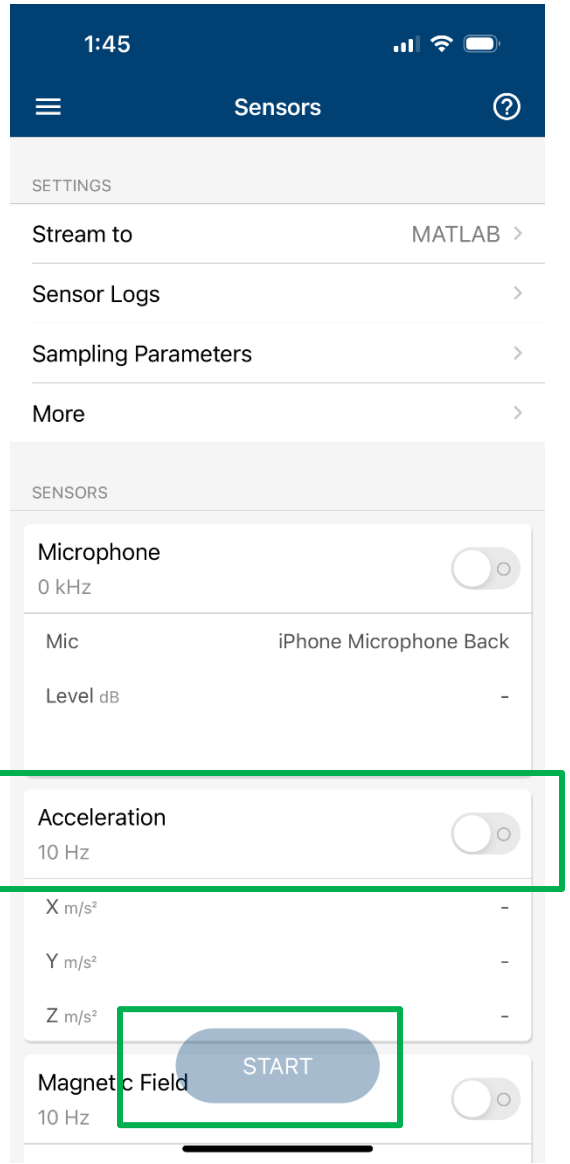




Follow along by clicking the demo title from the README in MATLAB Online or GitHub


1:45
Sensors
SETTINGS
Stream to
MATLAB
Sensor Logs
Sampling Parameters
More
SENSORS
Microphone
0 kHz
Mic
iPhone Microphone Back
Level dB
-
Acceleration
10 Hz
X m/s²
-
Y m/s²
-
Z m/s²
-
START
Magnetic Field
10 Hz


1:46
Sensors
Stream to
Log
MATLAB
Sensor logs are captured locally.
Auto Upload is on. Logs are automatically uploaded to MATLAB Drive.
To change the Auto Upload option, go to Sensors > More.


1:45
Sensors
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SENSORS
Microphone
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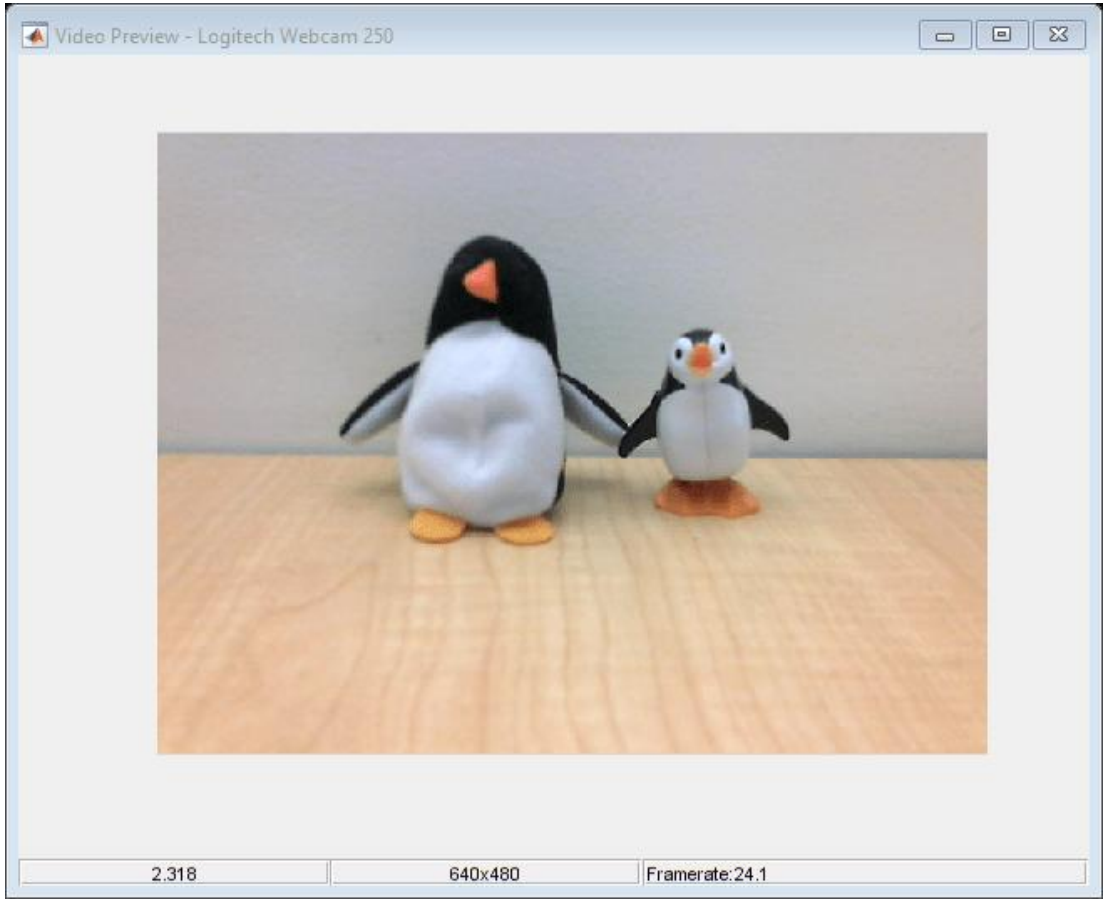
Mic
iPhone Microphone Back
Level dB
-
Acceleration
10 Hz
X m/s²
-
Y m/s²
-
Z m/s²
-
START
Magnetic Field
10 Hz

Activity: Collecting Smartphone Sensor Data

- **In this activity, we…**
  - Set MATLAB Mobile to log sensor data to MATLAB Drive
  - Activated smart device sensors to collect accelerometer info
  - Used MATLAB Online to view and plot this data from MATLAB Drive

- **This teaches students…**
  - Data collection using smart device sensors
  - How to use MATLAB Drive for file sharing
  - How to visualize data using MATLAB

Activity: Taking a Selfie using a Webcam



Follow along by clicking the activity title from the README in MATLAB Online or GitHub

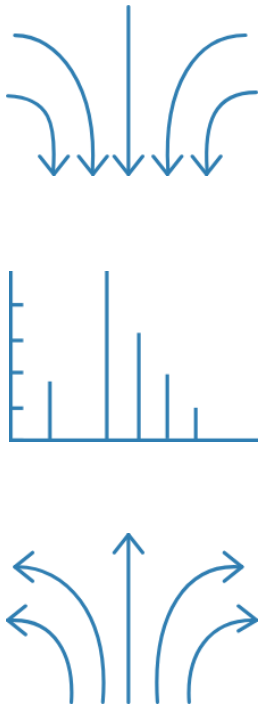
Activity: Taking a Selfie using a Webcam

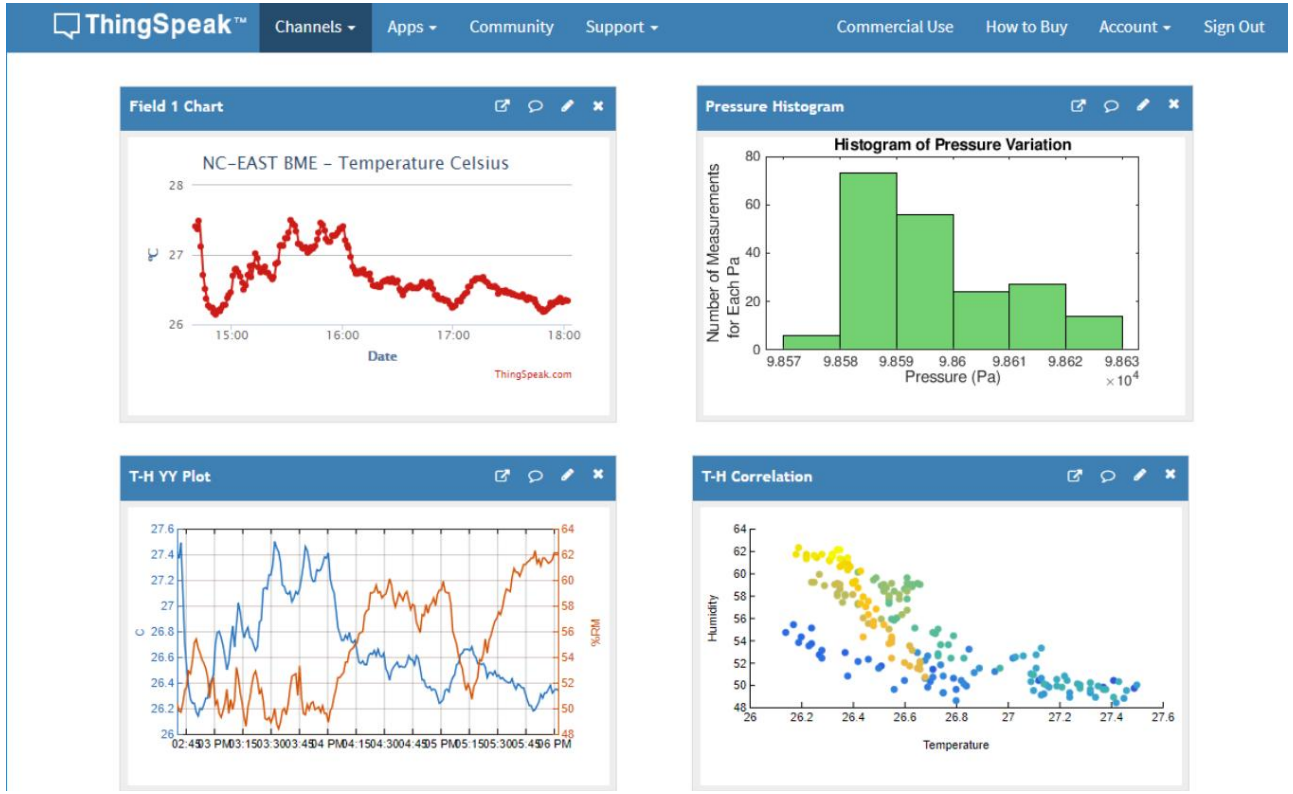
- **In this activity, we…**
  - Created a webcam object (**webcam**)
  - Took a photo of ourselves using our built-in or external webcams
  - Applied filters and effects to the image

- **This teaches students…**
  - How to connect to a webcam
  - How to use image filters and effects

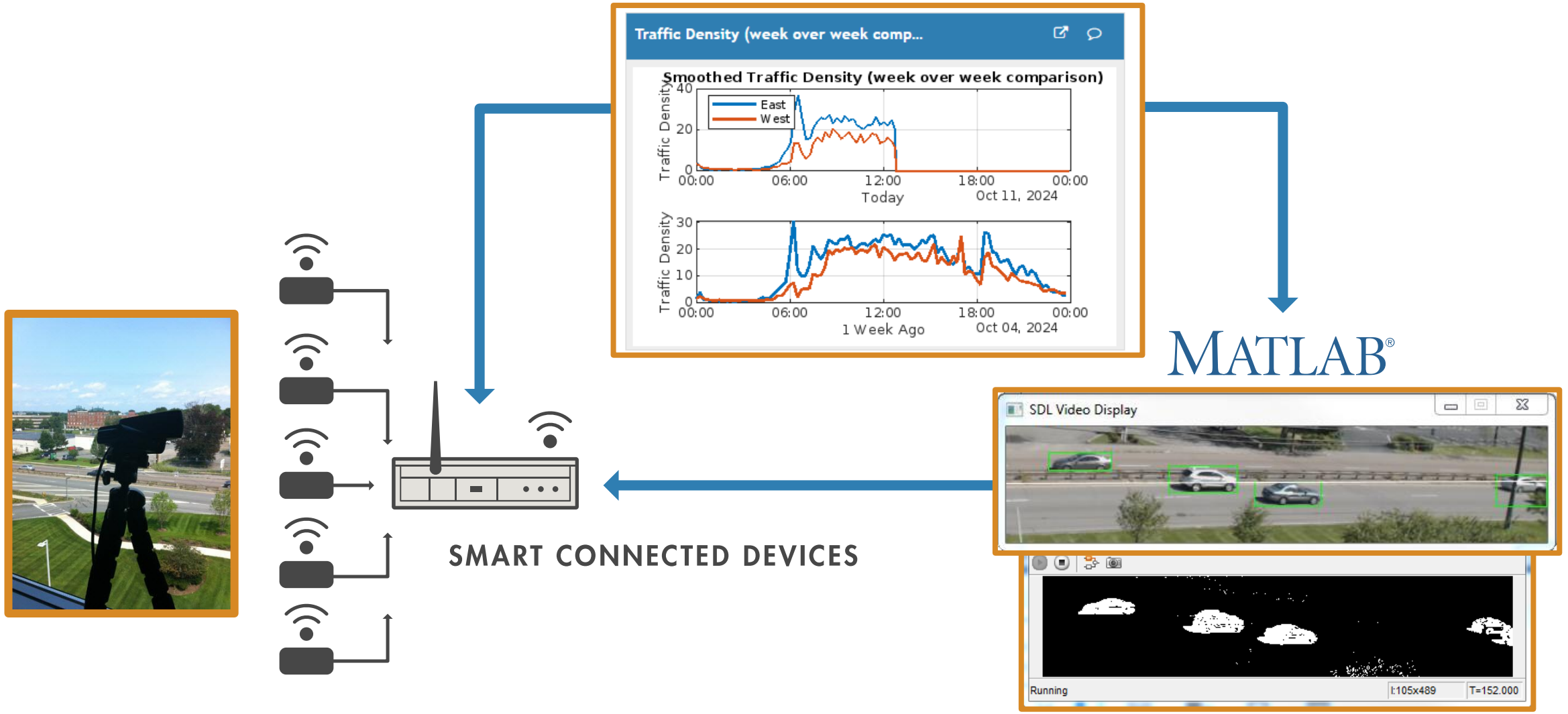
What is ThingSpeak?

- With ThingSpeak, you can read and write data from channels, act on this data, and interface with APIs and hardware

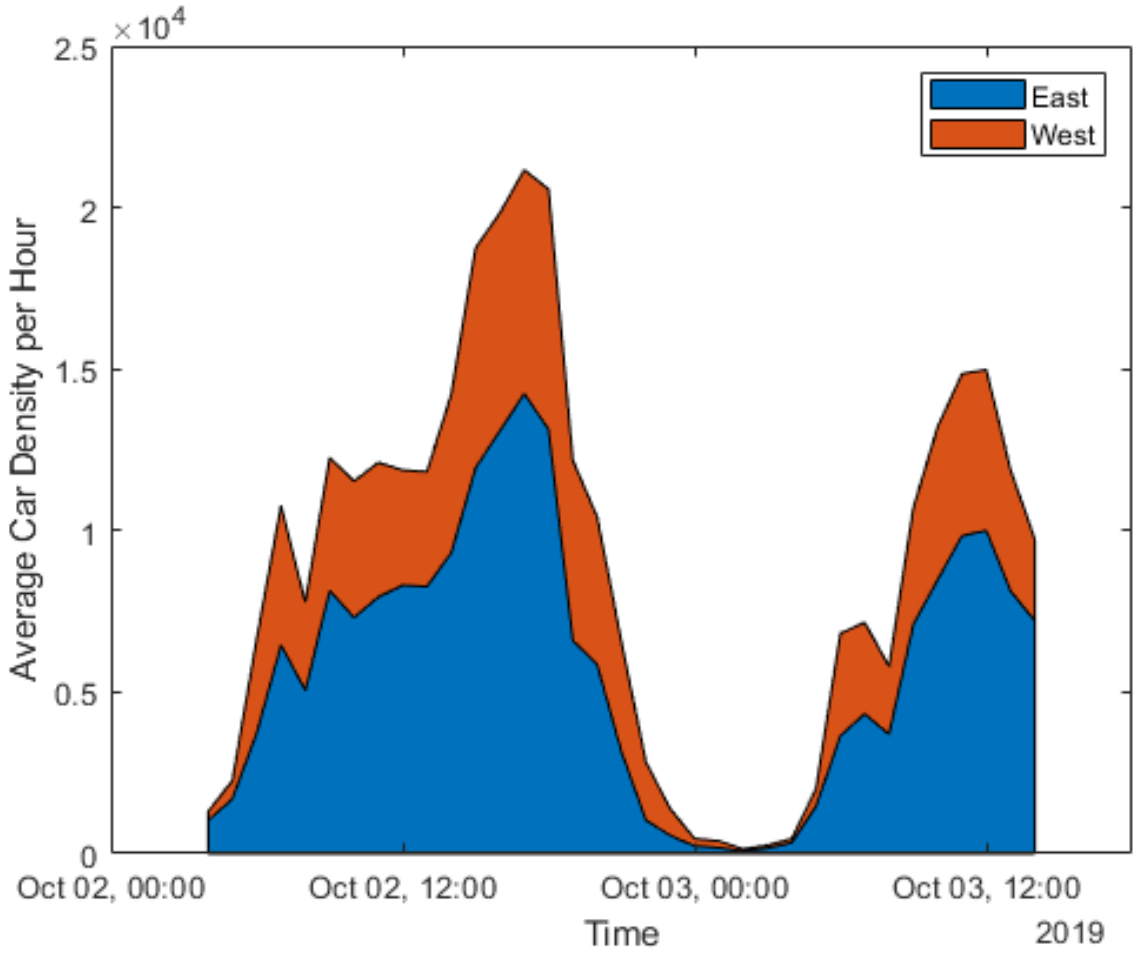




How does ThingSpeak work?



Activity: Plotting Traffic Data



Follow along by clicking the activity title from the README in MATLAB Online or GitHub

Activity: Plotting Traffic Data

- **In this activity, we…**
  - Viewed a public ThingSpeak channel
  - Create visualization code for MATLAB
  - Drew data from the public channel and produced a graph

- **This teaches students…**
  - How to draw information from ThingSpeak
  - How to plot data within MATLAB
  - How to gather information from hardware through the internet

What about external hardware?

Examples of MathWorks Supported Hardware

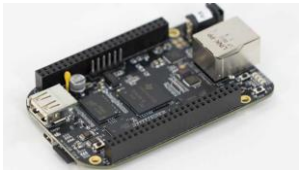
Arduino

Lego EV3

Raspberry Pi

Android/iOS Devices

Kinect for Windows



BeagleBone Black

Texas Instruments

STM Electronics

Freescale

Zynq SDR

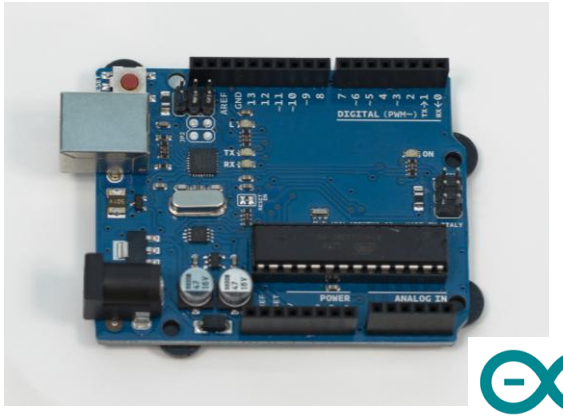
https://www.mathworks.com/hardware-support/home

Hardware you can leverage with MATLAB

- Low-cost microprocessor and microcontroller boards designed for students and makers
- Widely used to teach topics in electronic circuits, controls, and embedded systems
- Projects that can sense and interact with the physical world

Raspberry Pi

- I/O with GPIO Pins
- Image Processing



Arduino

- I/O with GPIO Pins
- Sensor Integration

Raspberry Pi

Supported Hardware

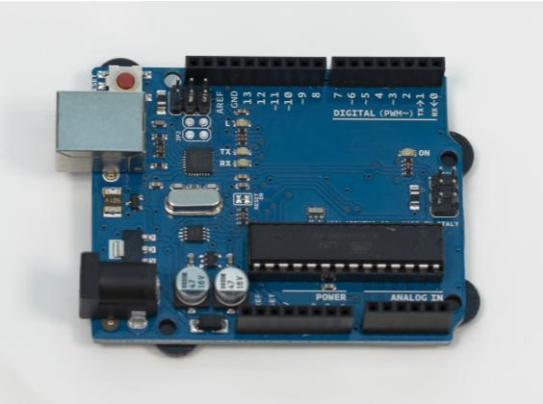
The following Raspberry Pi models are supported by the support package.

Raspberry Pi Model	MATLAB Releases Supported	Supported in MATLAB Online?
Raspberry Pi 1 Model B (discontinued)	R2014a - Current	No
Raspberry Pi 1 Model B+	R2014b - Current	No
Raspberry Pi 2 Model B	R2014b - Current	Yes
Raspberry Pi 3 Model B	R2016a - Current	Yes
Raspberry Pi Zero W	R2018a - Current	No
Raspberry Pi 3 Model B+	R2018b - Current	Yes
Raspberry Pi 4 Model B	R2020a - Current	Yes
Raspberry Pi Zero 2 W	R2023a - Current	Yes
Raspberry Pi Compute Module 4	R2023a - Current	Yes

Note: Raspberry Pi 1 Model A, Raspberry Pi 1 Model A+, and Raspberry Pi Zero are currently not supported.

Acquire sensor and image data from your connected Raspberry Pi using interactive communication and standalone execution modes

Arduino



Supported Hardware

Classic Boards

- Arduino Uno R3
- Arduino Mega 2560
- Arduino Leonardo
- Arduino Due
- Arduino Micro
- Arduino Mega-ADK
- Arduino motor control board

Nano Boards

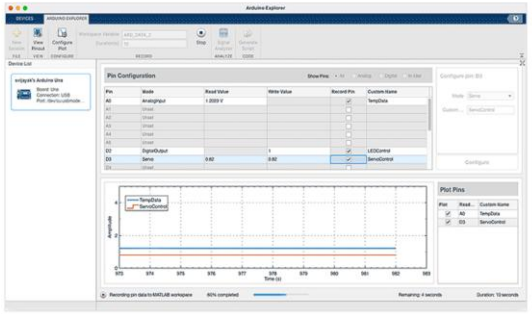
- Arduino Nano 3.0
- Arduino Nano 33 IoT
- Arduino Nano 33 BLE Sense

MKR Boards

- Arduino MKR1000
- Arduino MKR WIFI 1010
- Arduino MKR ZERO

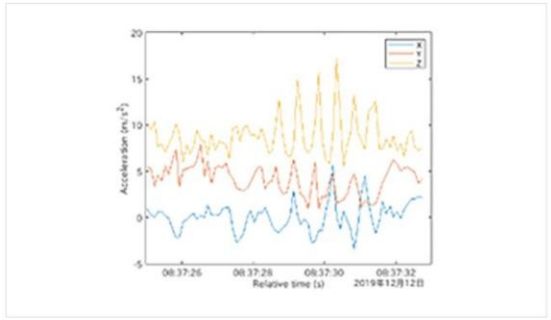
Other Boards and Kits

- ESP32 Wroom DevKit C
- ESP32 Wroom DevKit V1
- ESP32 WROVER
- Arduino Engineering Kit



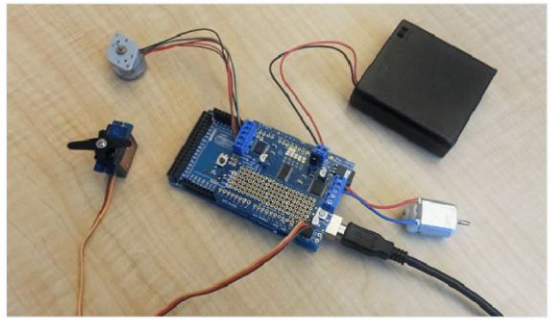
Arduino Explorer App

Setup an Arduino board; read, write, and analyze data from the board; and generate equivalent MATLAB code through an interactive UI.



Acquire Sensor Data

Communicate with a wide range of sensors, including IMU (Inertial Measurement Unit), environmental, and distance measurement sensors, right out of the box.



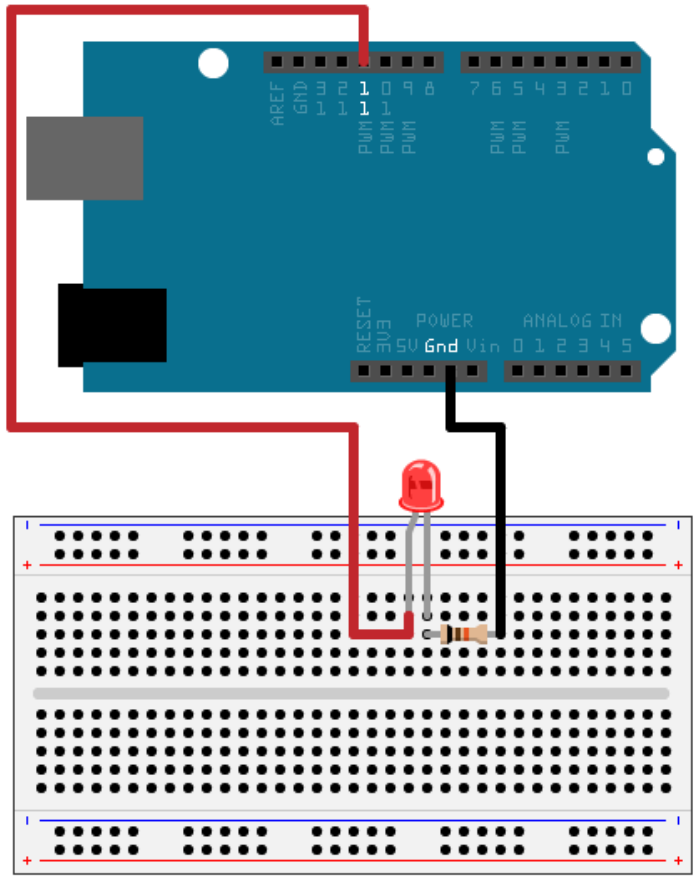
Control Other Devices

Communicate with an Arduino board over USB Cable or Wi-Fi to access peripheral devices and sensors connected over I2C, SPI, or CAN. Also drive DC, servo, and stepper motors.

Custom Add-Ons

Build custom add-ons to interface with additional hardware and software libraries.

Demo 3: Controlling an LED



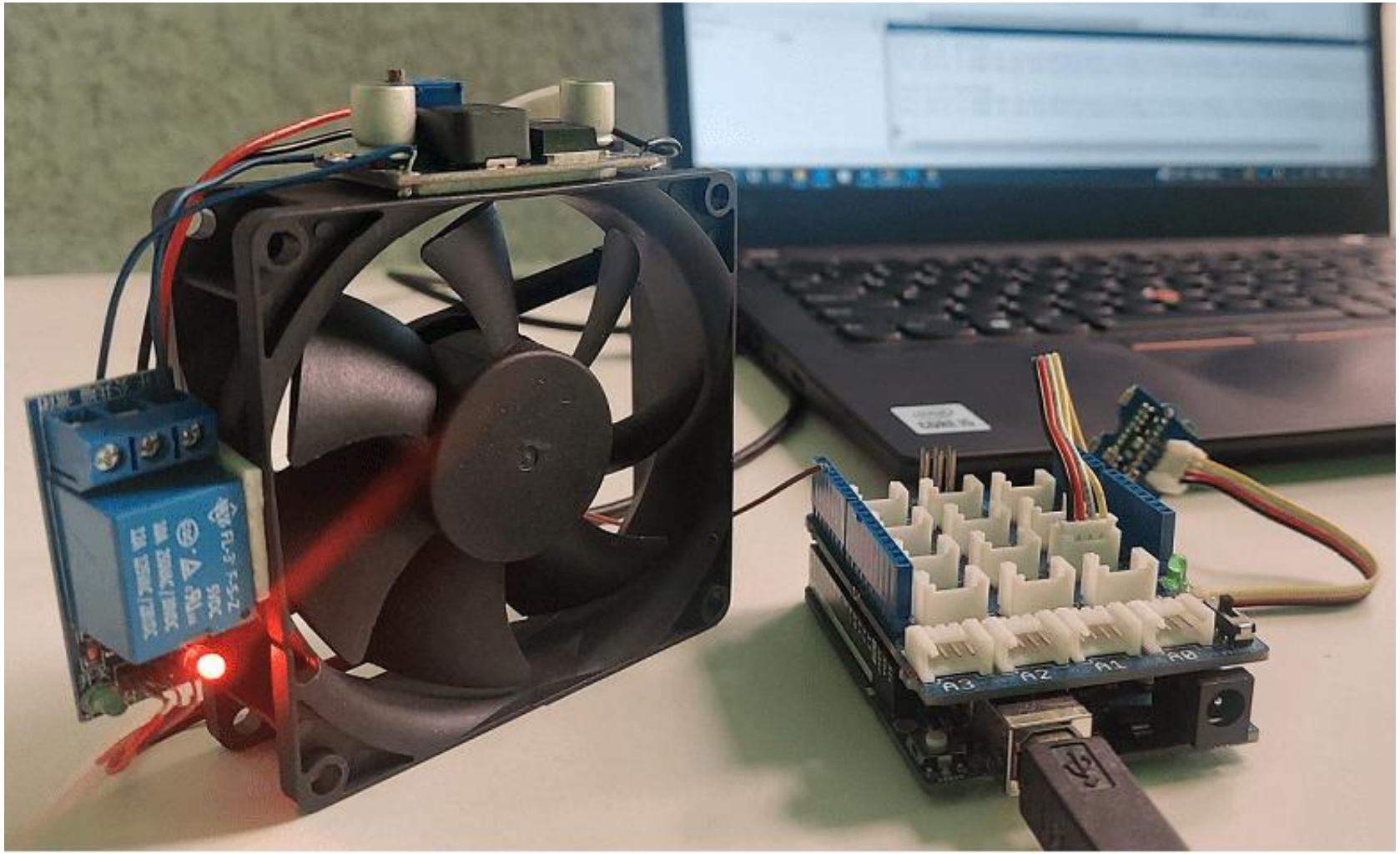
Follow along by downloading the file from GitHub and opening in MATLAB

Demo 3: Controlling an LED

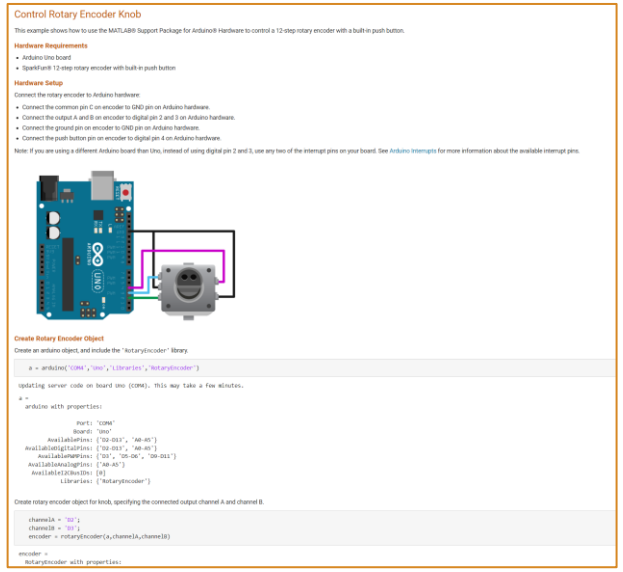
- **In this activity, we…**
  - Created an Arduino object to connect with our Arduino board
  - Used MATLAB to program an Arduino board to blink an LED

- **This teaches students…**
  - How to use an Arduino with MATLAB
  - How to construct a basic LED circuit
  - How hardware interacts with software in the real world

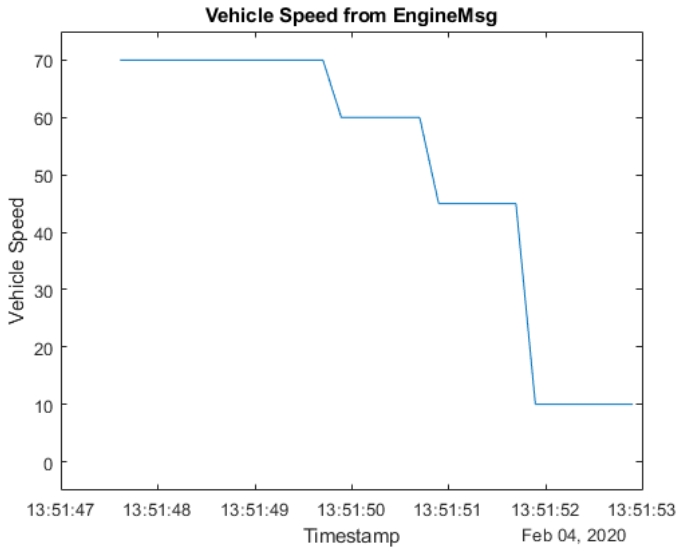
Advanced Workflow: Arduino Fan Control



Why MATLAB and Arduino together?



Integration with MATLAB material



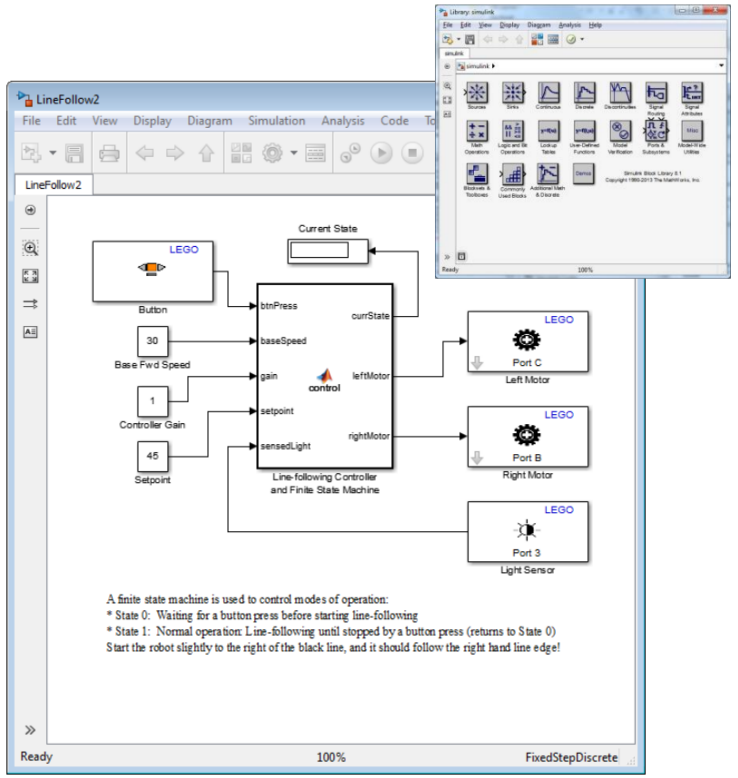
Data Visualization

Interactive Classroom Experience

What is Simulink?

The leading environment for modeling, simulating, and implementing dynamic and embedded systems

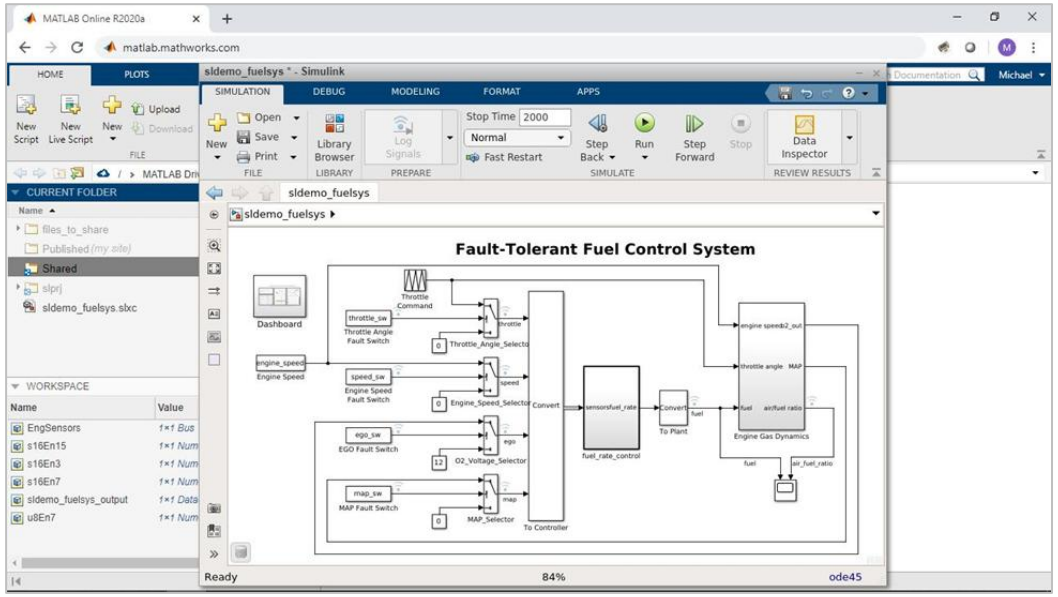
- **Block-diagram** environment
- Model, simulate and analyze **multi-domain** systems
- Accurately design, implement, and test:
  - Control systems
  - Signal & Image processing systems
  - Communications systems
  - And other **dynamic** systems

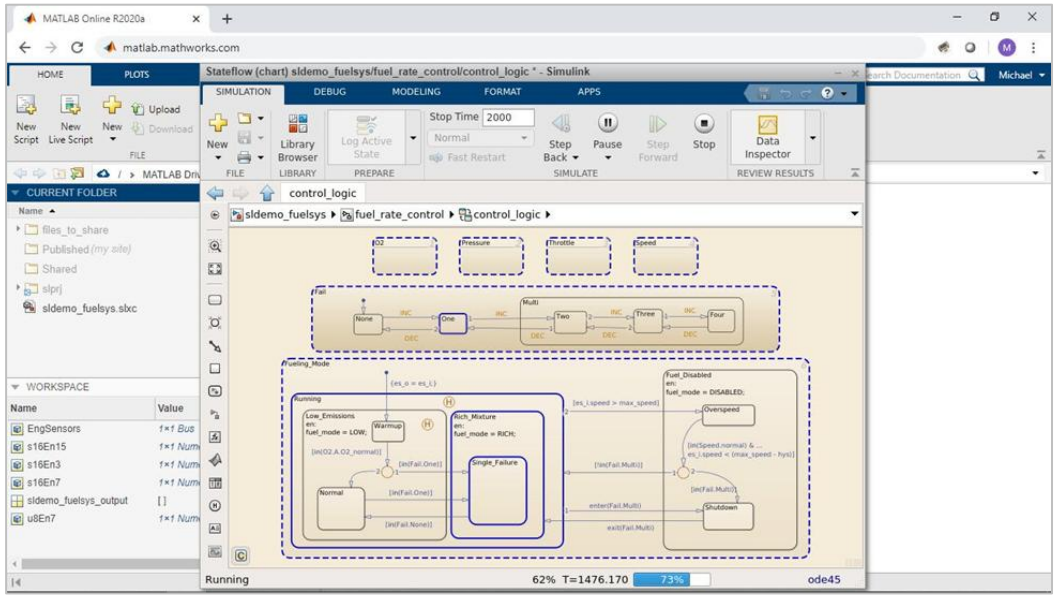


Simulink Online

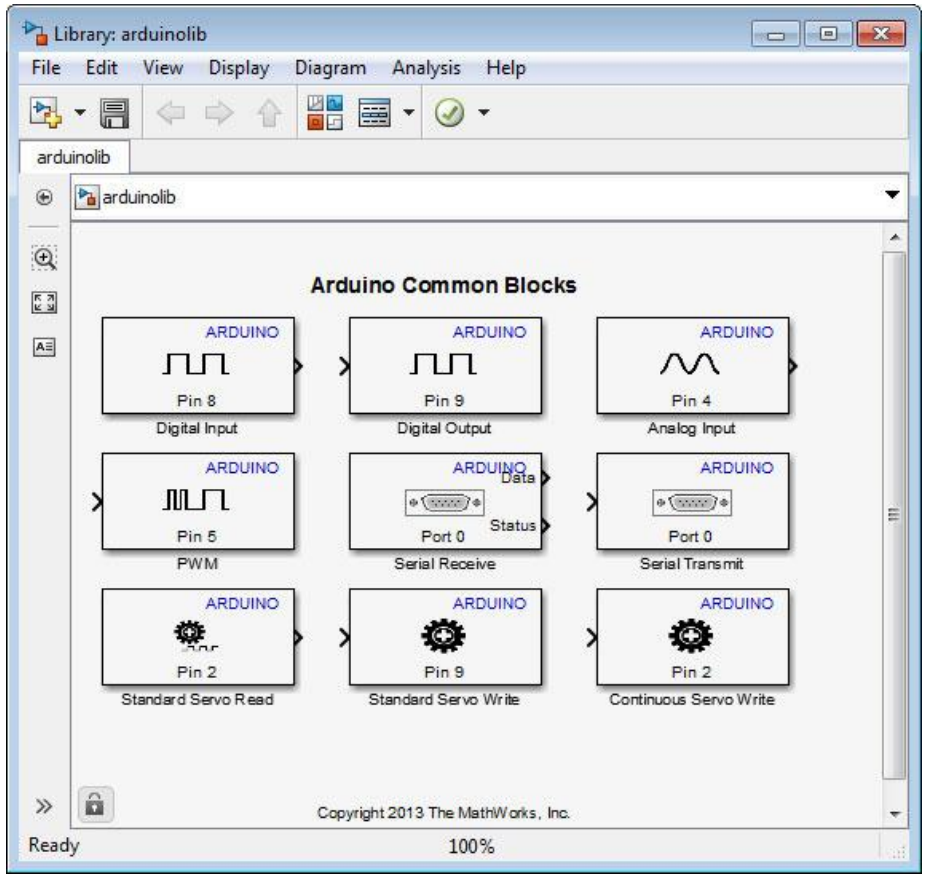
Use Simulink through your web browser

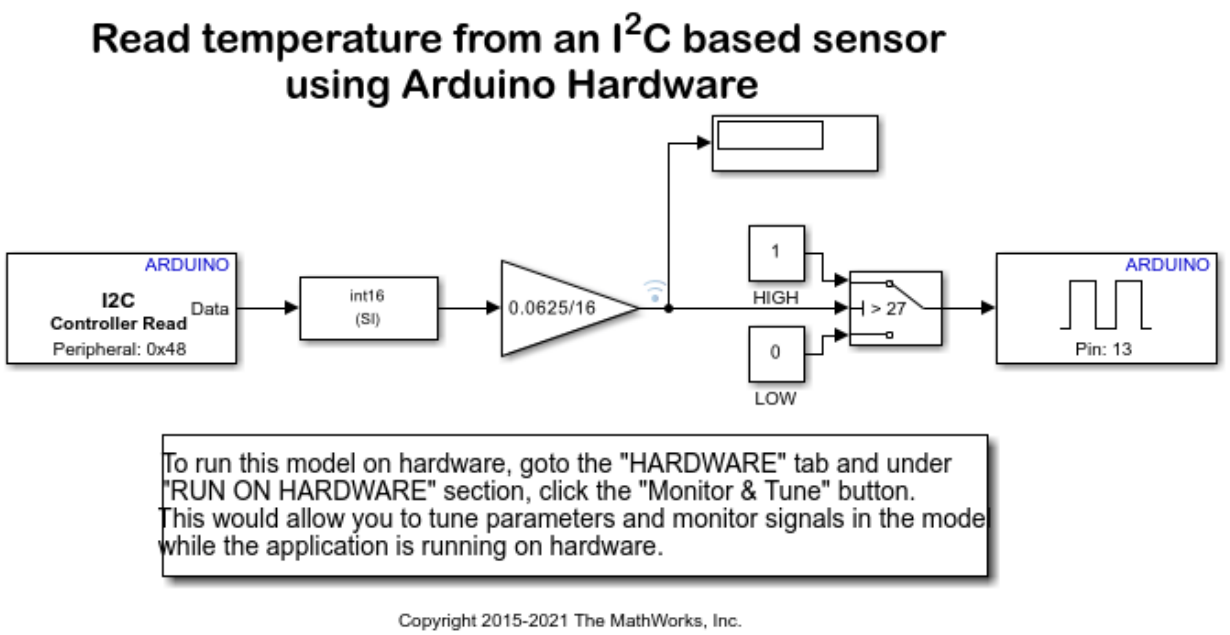
- No downloads or installations required
- Available to anyone with a Simulink license who is eligible to use MATLAB Online
  - Most EDU licenses and Individual
- Ideal for teaching, learning, and convenient, lightweight access



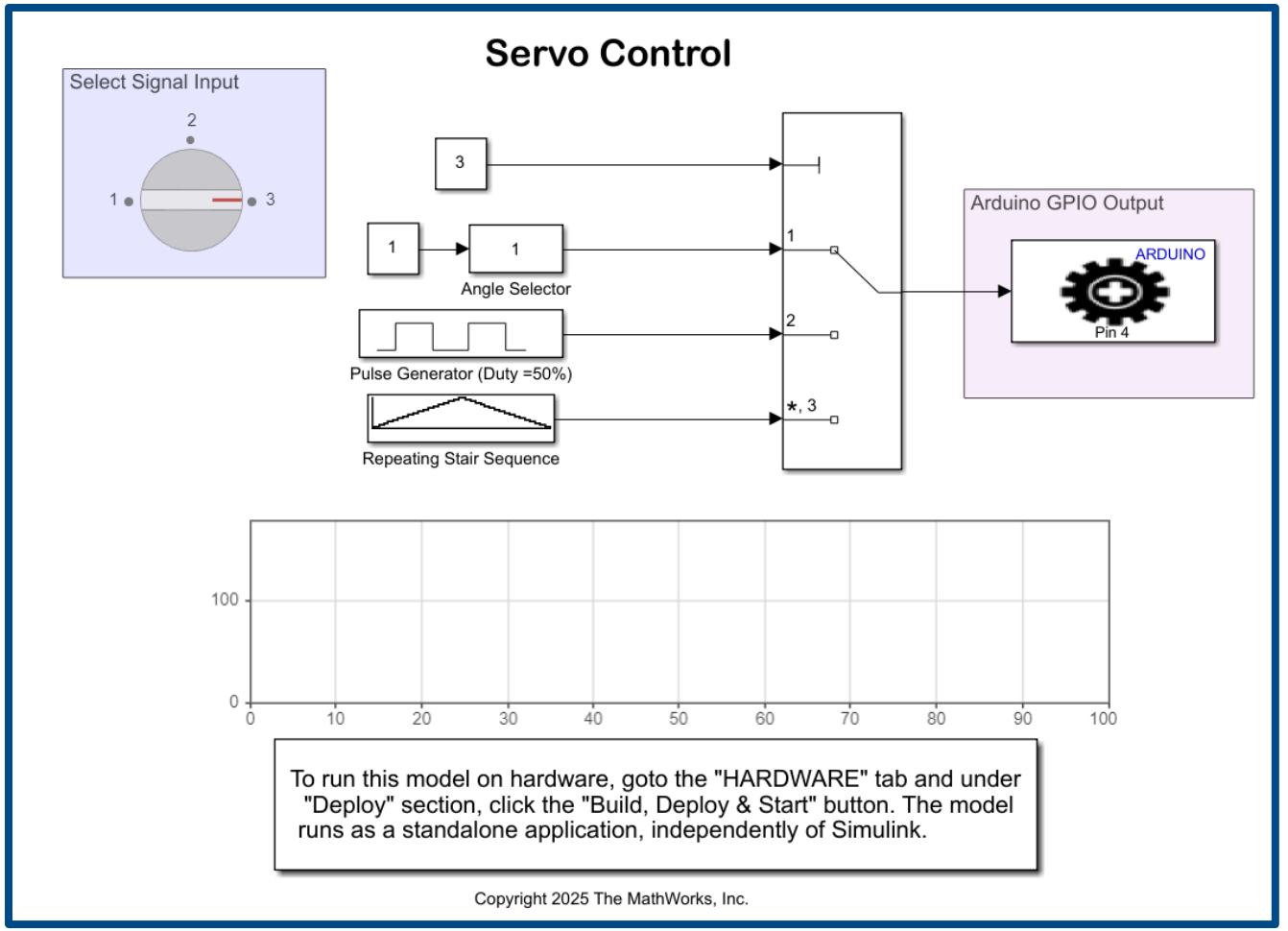


Interact with hardware using Simulink/Simulink Online



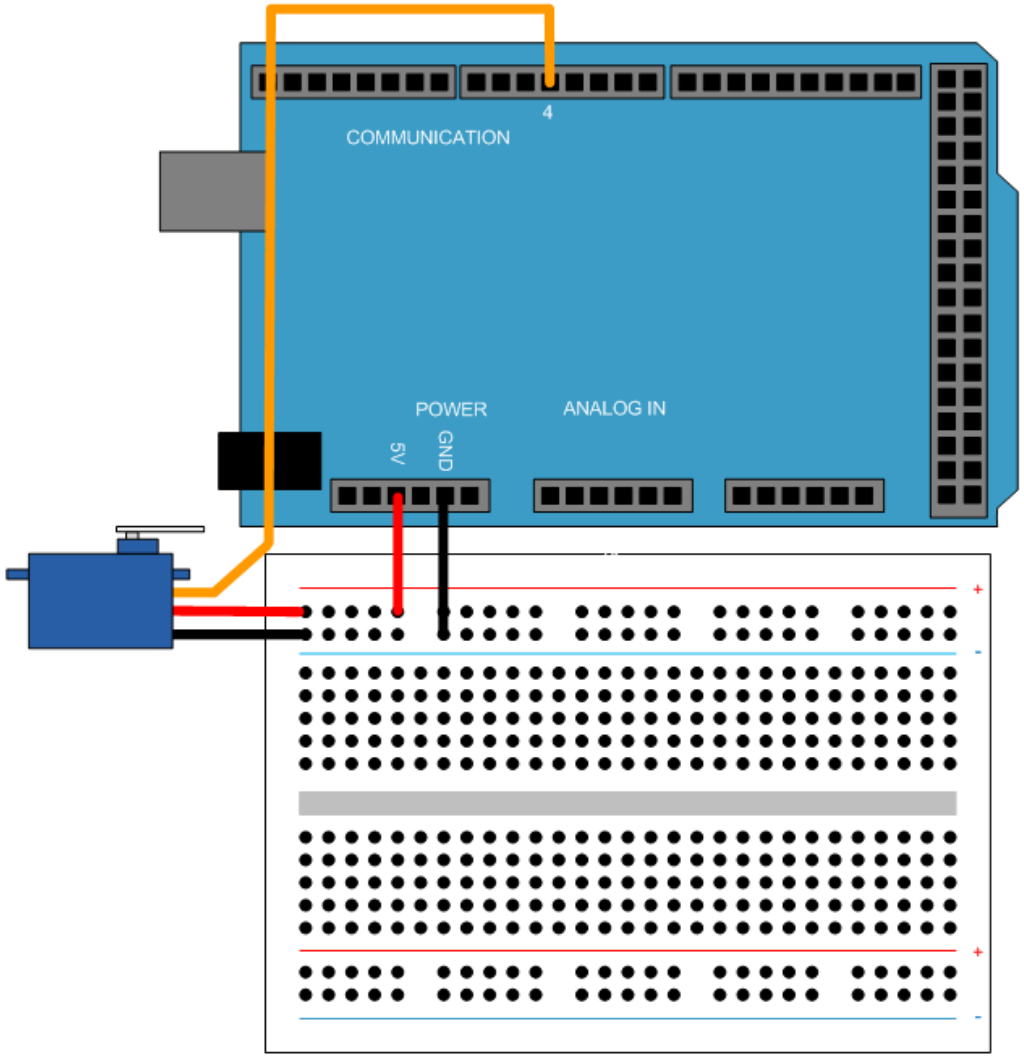


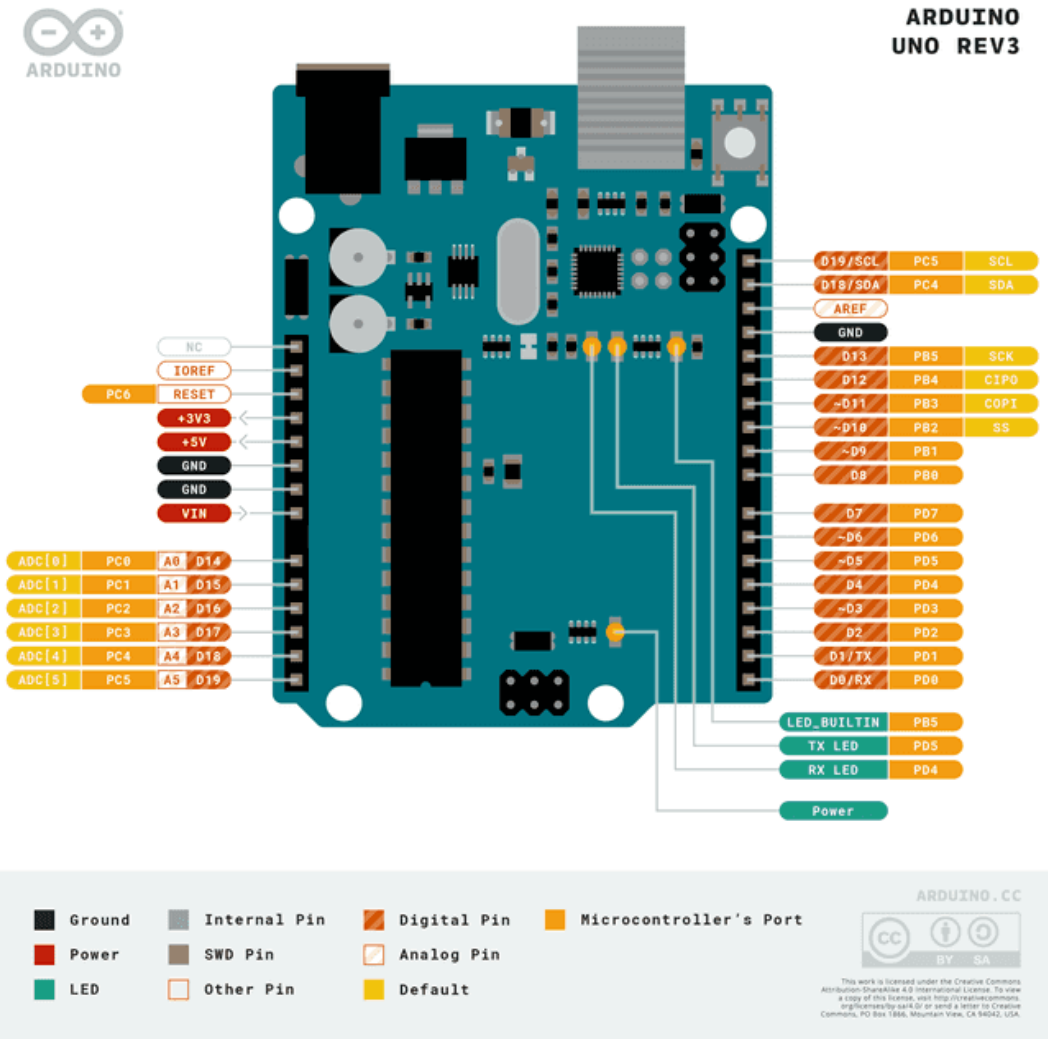
Demo: Control a Servo with Arduino and Simulink



Follow along by downloading the file from GitHub and opening in MATLAB

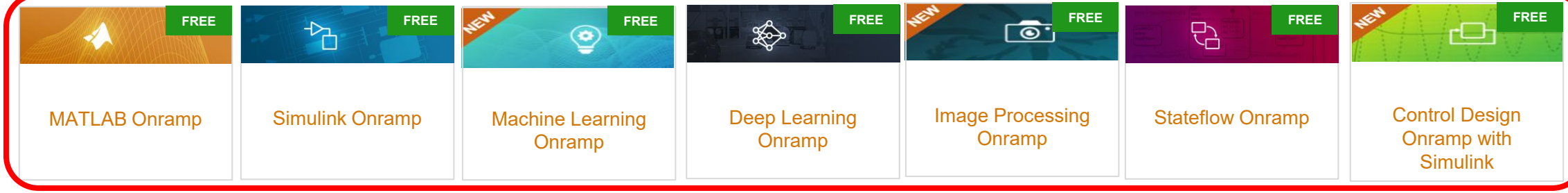
Demo: Control a Servo with Arduino and Simulink





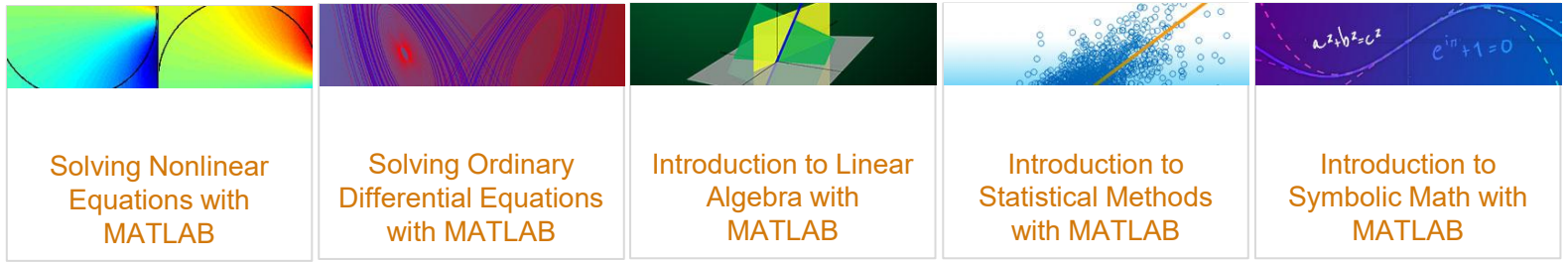
Self-Paced Courses

FREE "getting started" content – available for everyone



Computational Mathematics

*Available only to users at universities that offer campus-wide training access.



Other Resources:

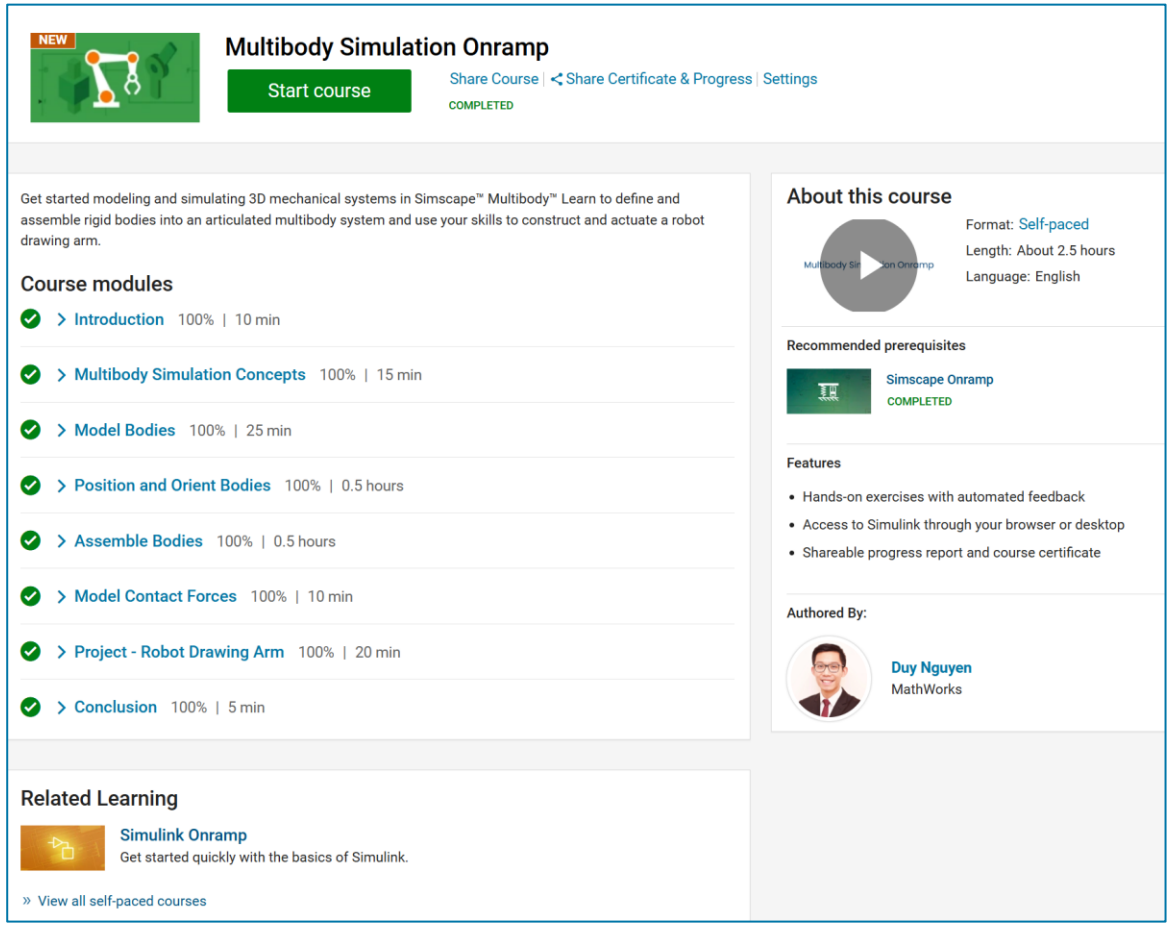
- Introduction to Model-Based Design with Simulink
- Physical Modeling with Simscape
- Simulink Control Design
- Robotics and Autonomous Systems
- (NEW) Multibody Simulation
- (NEW) Battery Systems

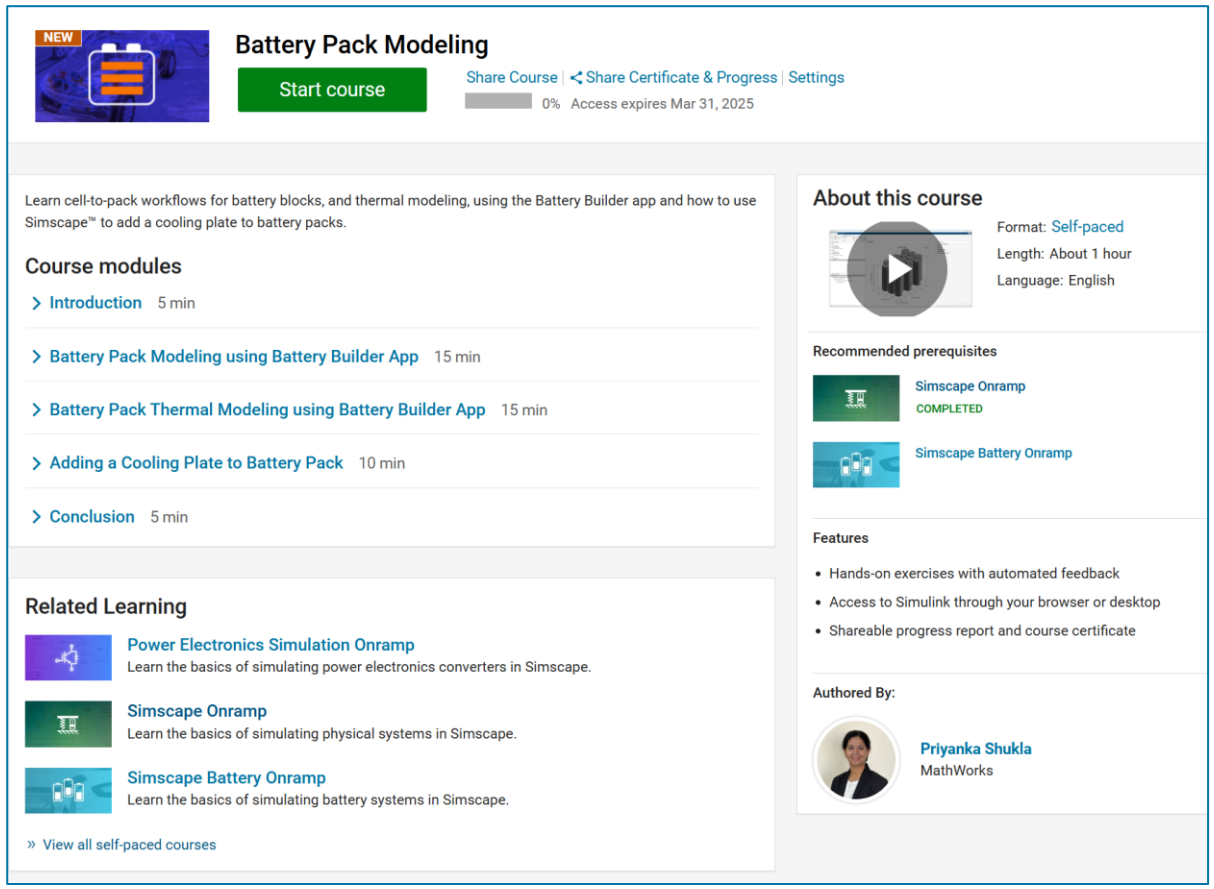
Core MATLAB

Data Science

Self-Paced Courses

FREE "getting started" content – available for everyone





Online Teaching Resources: Teaching resources created by MathWorks

Introduction to Engineering with Arduino

Version 1.0.0 (10.4 MB) by MathWorks Educator Content Development Team STAFF

An introduction to fundamental concepts of modern engineering using Arduino Hardware.
https://github.com/MathWorks-Teaching-Resources/Intro-To-Engineering

Follow

Overview | Functions | Models | Examples | Version History | Reviews (0) | Discussions (0)

Introduction to Engineering:

A Hands-On Exploration with Arduino

File Exchange or Open in MATLAB Online

Test Status R2024b | R2025a | R2025b

Curriculum Module

Created with R2024a. Compatible with R2024a and later releases.

Information

This curriculum module contains interactive MATLAB® live scripts introducing fundamental concepts of modern engineering using Arduino Hardware. The whole module is designed to explore these concepts using hardware using Arduino. You will explore the signals, data analysis, sensing, control and Internet of Things (IoT).

Background

You can use these live scripts as demonstrations in lectures, class activities, or interactive assignments outside class. This module covers the concepts of signals, control, and technical writing. It also includes examples of the Internet of Things and physical modeling.

The instructions inside the live scripts will guide you through the exercises and activities. Get started with each live script by running it one section at a time. To stop running the script or a section midway (for example, when an animation is in progress), use the Stop button in the **RUN** section of the **Live Editor** tab in the MATLAB Toolstrip.

Contact Us

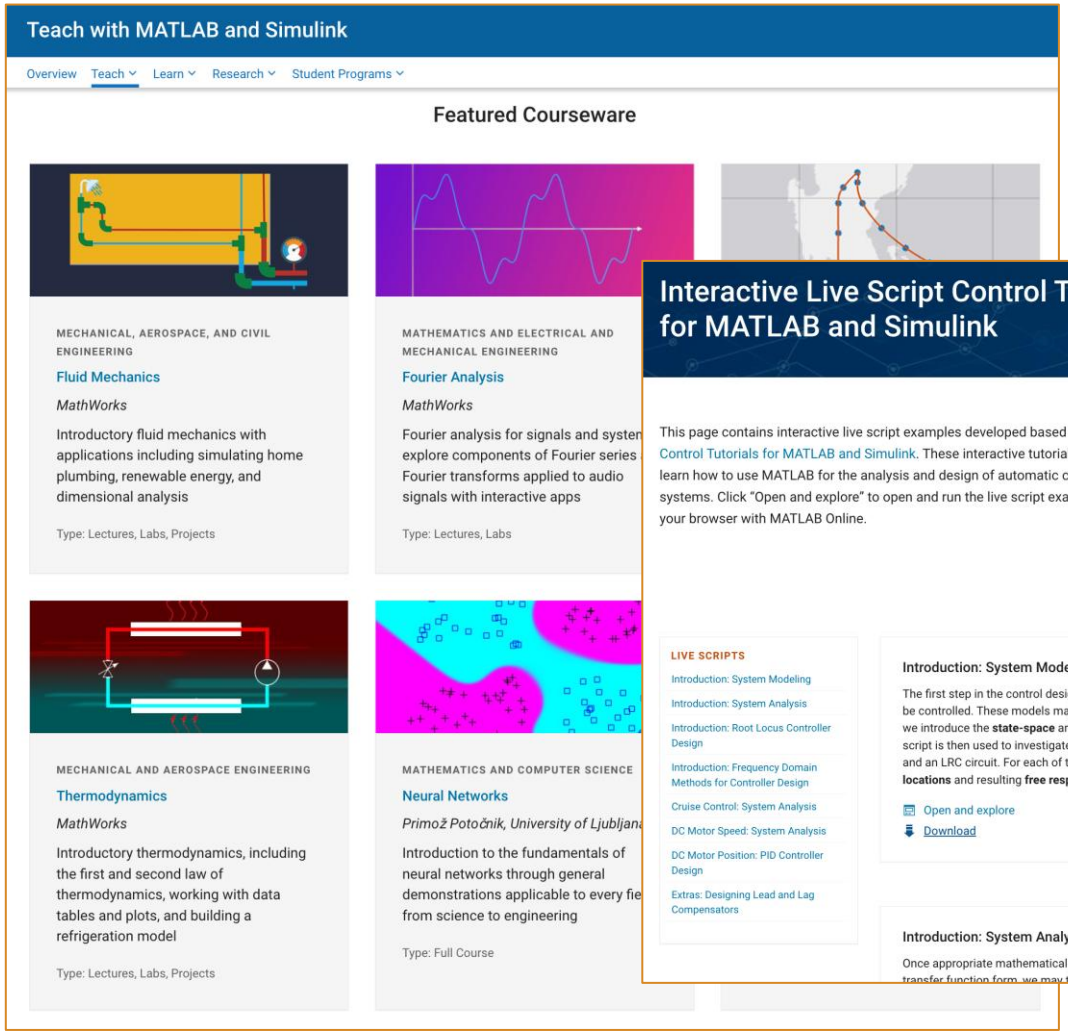
Solutions are available upon instructor request. Contact the MathWorks Educator Content Development Team if you would like to request solutions, provide feedback, or if you have a question.

Prerequisites

These scripts assume no prior knowledge of hardware programming and wiring. There is minimal MATLAB & Simulink knowledge required to complete the module. It is highly encouraged to follow online self-paced training to complete most of the activities:

- MATLAB Onramp
- Simulink Onramp

MATLAB Courseware:
Teaching resources created by your peers



Download:

Lecture Notes

Project Ideas

Accompanying Code

Additional Resources for Educators

- https://www.mathworks.com/academia.html
  - Access tools and resources for delivering great MATLAB based courses, including lectures, project-based learning, and assessments
  - Browse courseware and examples from MathWorks and educators

- https://www.mathworks.com/hardware-support/arduino.html
  - Get support for MATLAB, Simulink, and hardware support packages
  - Contact your Customer Success team for assistance with curriculum

- https://github.com/mathworks
- https://github.com/MathWorks-Teaching-Resources

MathWorks Education Application Engineers

consult with faculty and researchers to support them with their STEM initiatives,
including integrating computational or systems thinking into their curriculum and research

Questions?

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