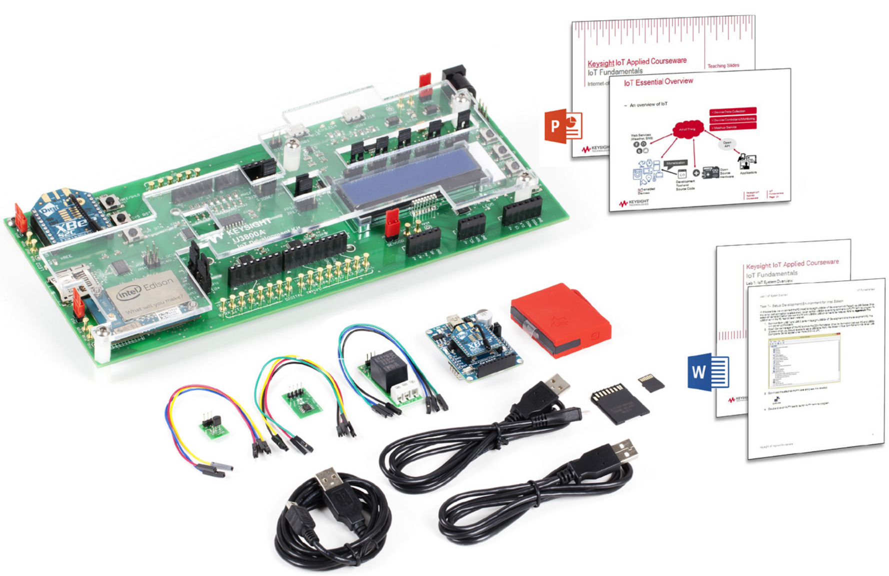
DATA SHEET

U3800 Series
IoT Applied Courseware



KEYSIGHT TECHNOLOGIES

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Introduction

The Internet of Things (IoT) is the next mega trend that will change the way we live and work, and it is predicted to touch almost every consumer and industrial application. The core technologies that enable the IoT are wireless communication and sensor developments, and ongoing advances in these technologies result in unique challenges. These challenges include new communications standards, increased sensor integrations and power consumption management. This puts heavy stress on an IoT device's design and validation cycle, and designers must constantly innovate to quickly and successfully develop and deploy IoT devices in the market.

The next generation of engineers will play a key role in the development of the IoT, and it is important that students graduate from an engineering program prepared for the electronic design, test and measurement challenges ahead of them. Educators must not only teach students the basics of designing and testing an IoT system; they must provide students with an understanding of the entire IoT ecosystem and relate these experiences to real-world applications.

With more than 75 years of test and measurement expertise, Keysight Technologies, Inc. can enable you to nurture the next generation of IoT-ready professionals. Keysight's ready-to-teach IoT applied courseware focuses on teaching practical design and test techniques and is designed to give students the opportunity to work with industry-grade test and measurement instruments in the lab – the same instruments that they would find in the industry.

Keysight's IoT applied courseware covers four major topics:

1. IoT Fundamentals – – Introduces the fundamentals of IoT. Students who complete this course will demonstrate the understanding of IoT's architecture, technologies, standards, wireless protocols, applications, and ecosystems.
2. IoT Systems Design – Students will learn how to design, develop, and evaluate an IoT-enabled embedded system using industry-standard tools.
3. IoT Wireless Communications – Students will learn how to develop typical IoT applications with various types of wireless connectivity. Students will also learn how to perform quick verification and design validation on these IoT applications.
4. IoT Sensors and Power Management – Teaches students how to characterize the power consumption of IoT devices onboard controllers, sensors and wireless modules. Students will understand the principles of power management and will be able to characterize micro-electro-mechanical systems (MEMS) devices.

Each courseware comes with a training kit and teaching slides. The training kit consists of a development kit and sensors, lab sheets, and problem-based assignments. Students can also use this kit to develop their projects once they have completed the course.

Comprehensive

- This courseware focuses on end-to-end learning of the IoT ecosystem, from the sensor node, gateway, cloud to end-user application/service. Topics such as different types of wireless technologies in a single training platform, including *Bluetooth*®, ZigBee, WLAN, and LoRa, are also included.
- Setting up a new course can be challenging and time-consuming. The courseware is designed for full-semester teaching, covering 2nd year – final year undergraduate program. Each full-semester of learning is comprised of teaching slides and a training kit with lab sheets and problem-based assignments. The teaching slides cover at least 36 hours of classroom sessions, and the training kit covers 18 hours of lab sessions. Educators can use this complete, out-of-the-box solution to accelerate the setup of a new IoT-focused course.

Real-world and industry-oriented

- Today, 51% of the companies are still having trouble in hiring qualified candidates to fill open engineering positions[1]. This courseware is designed to equip students with IoT engineering knowledge and skills that are most sought after by the industry. Students will gain practical experience in using leading-edge, industry-relevant tools and software to design and test IoT systems.

Up-to-date

- The IoT technology is constantly evolving. For that reason, Keysight will provide yearly content updates for three consecutive years at no additional cost. Both educators and students will keep pace with the evolving trends and technologies.

Expandable

- The training kit's modular design can be easily expanded to include other wireless connectivity and sensors. Add-on kits are also available to expand the teaching scope to include topics in the IoT, including wireless communications , sensors and power management. As a result, the educational institution's academic investment can be leveraged.

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U3801A/02A IoT Fundamentals Applied Courseware

Overview

The U3801A/02A IoT Fundamentals applied courseware is a ready-to-teach package focused on the fundamentals of the Internet of Things. It introduces students to the IoT's architecture, technologies, standards, wireless protocols, applications, and ecosystems. The courseware is designed as a resource for lecturers, and consists of teaching slides and a training kit.

- Targeted university subject: IoT systems, IoT fundamentals
- Targeted year of study: Second to final year undergraduates
- Prerequisites(s): Basic programming

Teaching slides	Training kit
Editable Microsoft PowerPoint slides	IoT development kit
Covers 36+ hours of classroom sessions	IoT sensor devices
	XBee ZigBee kit
	Lab sheets (Microsoft Word) and model answers
	Problem-based learning assignments
	Covers 18 hours of lab sessions

Learning outcomes

Students will be able to:

- Understand IoT concepts and the various building blocks, applications and ecosystems associated with the IoT
- Understand the architecture, standards and connectivity protocols in IoT
- Understand the workflow of hardware and software development in IoT from sensors to mobile devices
- Set up related software modules and connectivity from an IoT node, gateway, cloud or end-user client
- Understand high-level design and implement proof-of-concept for IoT applications with a focus in end-user applications

Key features and benefits

- Consists of teaching slides and a training kit for a full semester of teaching. A complete solution to accelerate the setup of a new IoT-focused course.
- Integrates hands-on industry-relevant experiences and real-world applications in IoT design and testing. Incorporates multiple wireless standards used in IoT-enabled embedded system applications.
- Yearly updates for three years at no additional cost, keeping pace with evolving IoT trends and technologies.
- Expandable training kit for lab assignments on wireless local area network (WLAN) 802.11, *Bluetooth* LE and ZigBee wireless connectivity and other wireless connectivity and sensors.
- Visible hardware building blocks on the training kit

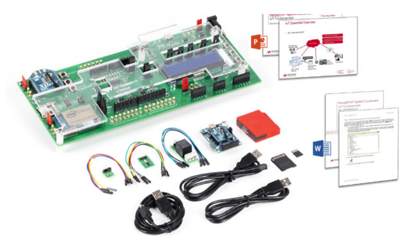

Figure 1. U3802A IoT Fundamentals applied courseware, with training kit and teaching slides

Courseware Contents

Teaching slides

The teaching slides are editable and cover 36+ hours of teaching for a full semester. The slides cover the following topics:

IoT essentials	Introduction to the essential elements of an IoT-enabled embedded system, IoT hardware platform (such as gateway and sensor node), IoT building blocks (such as sensors, connectivity and data), IoT applications and ecosystem.
Hardware for IoT	Introduction to different types of hardware used at an IoT sensor node, such as sensors, components, chips and boards.
Software for IoT	Introduction to the various programming languages (such as Python, Java and C) that can be used in IoT embedded system, cloud and end-user applications.
IoT connectivity protocols	Introduction to various wired and wireless connectivity protocols (such as SPI, I^2C, *Bluetooth* LE, WLAN 802.11, Z-wave, 6LoWPAN, NFC, etc.) as well as emerging standards (such as MQTT) used in the implementation of IoT-enabled embedded systems.
IoT application design essentials	Introduction to the concept of application programming interface for cloud computing and mobile devices (such as REST and JSON) for interoperability among IoT solutions. This topic includes security and identity management.
From IoT to data analytics	Introduction to the basics of data analytics and visualization using cloud computing technologies
Case studies	Case studies covering smart home and industrial/commercial automation applications.

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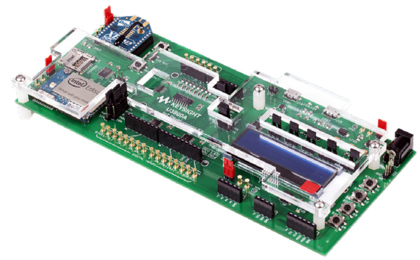
Training kit

IoT development kit

This hardware kit is a customizable embedded system development kit that can be configured as a gateway or a sensor device. It incorporates an Intel Edison compute module that is designed for expert makers, entrepreneurs, and industrial IoT applications. The system runs on Yocto Linux with open source software development, allowing students to compile C/C++ files or to run Python scripts. Samples of start projects are also available to enhance the learning process and allow a wide range of potential applications.



IoT development kit

This development kit can be utilized with all Keysight IoT applied coursewares.

Features:

- Open source software development environment
- High performance, dual-core CPU and single core micro-controller support complex data collection in a low power package
- Integrated WLAN 802.11, *Bluetooth* LE and ZigBee wireless connectivity support
- 1 GB DDR and 4 GB flash memory, simplifying configuration and increasing scalability
- Arduino UNO and XBee form factor interfaces support
- UARTs, I^{2}C, SPI, 40 GPIO, SD card connector and LCD
- Micro USB (UART), micro USB OTG
- Flexible power supply options: AC power adapter or USB host
- Various test points for verification
- Sensor connectors

IoT sensor device

The TI SensorTag kit includes ten low-power sensors: ambient light, digital microphone, magnetic sensor, humidity, pressure, accelerometer, gyroscope, magnetometer, object temperature, and ambient temperature.

IoT sensor device

XBee ZigBee kit

The XBee ZigBee starter kit is a compact platform that provides UART serial communication to an XBee ZigBee module. 5 V TTL logic interface offers a straightforward interface to microcontroller for embedded wireless development.

XBee ZigBee kit

Accessories

The following accessories are included with the hardware kit:

Item	Quantity
Micro USB cable, 1 m	2
Mini USB cable, 1.2 m	1
TI SensorTag kit	1
XBee ZigBee kit	1
Analog temperature sensor	1
Digital temperature sensor	1
Relay actuator	1
Micro SD card	1

Accessories

Lab Sheets

Lab Sheet	Topic	Description
1	Getting started in IoT: Acquiring, manipulating and displaying sensor data	IoT System Overview – Perform system setup, connection between host and target, test run a ready-made application using a sample application as the demonstration. Learn to build a simple IoT application to read data from sensors then display the results on an LCD.
2	Setting up your IoT gateway to broadcast sensor data to LAN/PAN via ZigBee® standard	Explore different connectivity protocols such as Bluetooth LE and ZigBee® standard, setting up your IoT Gateway to facilitate sensor to Gateway communication, and automate data collection using Python and C/C++.
3	Connecting your IoT devices to the cloud and leveraging cloud computing for data and services	Understand REST architecture by examining JSON, basic HTML and Java scripting. Explore the potential of web services provided by Google and Watson, learn to call and use these cloud services
4	Setting up your gateway for cloud and mobile device communications via MQTT	Understand MQTT messaging protocol. Learn about broker-client interaction and publish-subscribe activities. Further illustrate the broker-client relationship using U3800A-mobile device communication
5	Utilizing cloud data visualization and analytic tools to enhance your IoT applications	Modify a ready-made end user application with cloud using supported programming languages with different data analytics approaches
6	Demonstrating IoT end-to-end communication from sensors to mobile devices via cloud services	Cloud-enabled IoT Application demonstration which is based on a smart home IoT concept, the design deploy an IoT node onto cloud and visualize the results on an end-user client device

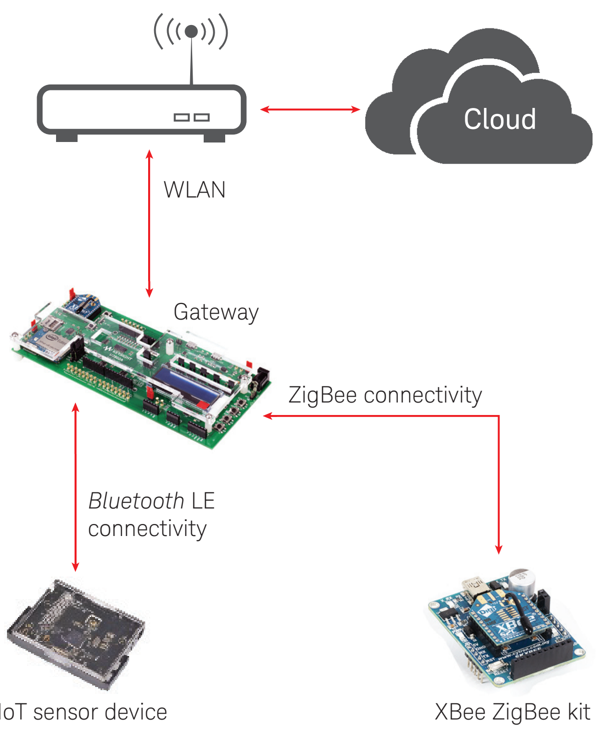


Figure 2. Typical lab setup.

Problem-based assignments

The problem-based assignments below allow students to enhance their problem-solving skills.

Smart home automation	Develop a smart thermostat using the available sensors and actuators to control electrical appliances
Industrial 4.0 automation	Develop a sensor-based factory automation application such as vibration and temperature monitoring

U3803A/04A IoT Systems Design Applied Courseware

Overview

The U3803A/04A IoT Systems Design applied courseware is a ready-to-teach package on the subject of the IoT, with the goal of providing students the ability to develop and embedded system with IoT capabilities. This courseware is designed as a resource for lecturers, and consists of teaching slides and a training kit.

- Targeted university subject: IoT systems, embedded systems
- Targeted year of study: Second to final year undergraduates
- Prerequisites(s): Basic programming

Teaching slides	Training kit
Editable Microsoft PowerPoint slides	IoT development kit
Covers 36+ hours of classroom sessions	IoT sensor devices
	XBee ZigBee kit
	Lab sheets (Microsoft Word) and model answers
	Problem-based learning assignments
	Covers 18 hours of lab sessions

Learning outcomes

Students will be able to:
- Design an embedded IoT gateway and IoT devices
- Configure IoT end-to-end systems from IoT devices to the cloud
- Create the operations of various I/O devices
- Set up wireless local area network (WLAN) 802.11, *Bluetooth* LE and ZigBee wireless connectivity.
- Apply industry standard software tools in IoT development
- Evaluate I/O signals and troubleshoot IoT systems using industry-grade test and measurement instruments

Key features and benefits

- Consists of teaching slides and a training kit for a full semester of teaching. A complete solution to accelerate the setup of a new IoT-focused course.
- Integrates hands-on industry-relevant experiences and real-world applications in IoT design and testing. Incorporates multiple wireless standards used in IoT-enabled embedded system applications and usage of industry-grade tools, such as digital multimeter (DMM) and oscilloscope.
- Yearly updates for three years at no additional cost, keeping pace with evolving IoT trends and technologies.
- Expandable training kit for lab assignments on wireless local area network (WLAN) 802.11, *Bluetooth* LE and ZigBee wireless connectivity and other wireless connectivity and sensors.
- Visible hardware building blocks on the training kit

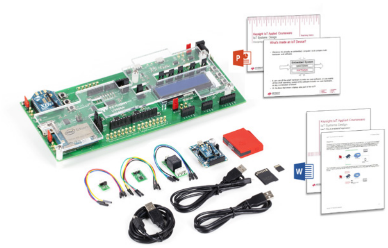


Figure 3. U3804A System Design Applied Courseware, with training kit and teaching slides

Courseware Contents

Teaching slides

The teaching slides are editable and cover 36+ hours of teaching for one full semester. The slides cover the following topics:

Essential elements of IoT systems	Introduction to an IoT-enabled embedded system, IoT building blocks, the past, present and future of IoT systems, and how IoT devices work.
Enabling technologies for IoT systems	Introduction to low-power embedded systems, Intel Atom and ARM-based CPUs, HDD and SDD, boot process, BIOS, GPU co-processors, and the challenges involved with IoT systems design.
Fundamentals of embedded systems for IoT	Introduction to embedded systems for IoT, including programming models and languages, shell programming, embedded operating systems and RTOS.
Connectivity for IoT	Introduction to various key wired and wireless technologies used in the implementation of IoT systems.
Designing IoT applica-tions using embedded systems	Introduction to what a toolchain is, and how to compile and test Linux programs, communicate between programs, and multitask inside a program.
Introduction to cloud computing	Introduction to Internetworking, cloud computing and web services, and security and identity management
Case studies	Case studies covering smart automobile and disaster management applications.

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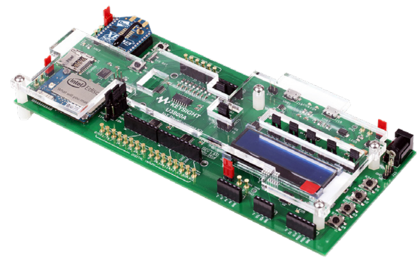
Training kit

IoT development kit

This hardware kit is a customizable embedded system development kit that can be configured as a gateway or a sensor device. It incorporates an Intel Edison compute module that is designed for expert makers, entrepreneurs, and industrial IoT applications.

The system runs on Yocto Linux with open source software development, allowing students to compile C/C++ files or to run Python scripts. Samples of start projects are also available to enhance the learning process and allow a wide range of potential applications.

This development kit can be utilized with all Keysight IoT applied coursewares.



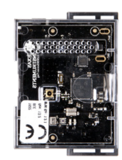
IoT development kit

Features:

- Open source software development environment
- High performance, dual-core CPU and single core micro-controller support complex data collection in a low power package
- Integrated WLAN 802.11, *Bluetooth* LE and ZigBee wireless connectivity support
- 1 GB DDR and 4 GB flash memory, simplifying configuration and increasing scalability
- Arduino UNO and XBee form factor interfaces support
- UARTs, I^2C, SPI, 40 GPIO, SD card connector and LCD
- Micro USB (UART), micro USB OTG
- Flexible power supply options: AC power adapter or USB host
- Various test points for verification
- Sensor connectors

IoT sensor device

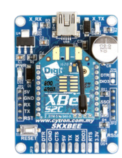
The TI SensorTag kit includes ten low-power sensors: ambient light, digital microphone, magnetic sensor, humidity, pressure, accelerometer, gyroscope, magnetometer, object temperature, and ambient temperature.



IoT sensor device

XBee ZigBee kit

The XBee ZigBee starter kit is a compact platform that provides UART serial communication to an XBee ZigBee module. 5 V TTL logic interface offers a straightforward interface to microcontroller for embedded wireless development.



XBee ZigBee kit

Accessories

The following accessories are included with the hardware kit:

Item	Quantity
Micro USB cable, 1 m	2
Mini USB cable, 1.2 m	1
TI SensorTag kit	1
XBee ZigBee kit	1
Analog temperature sensor	1
Digital temperature sensor	1
Relay actuator	1
Micro SD card	1

Accessories

Lab Sheets

Lab Sheet	Topic	Description	Required Instruments
1	Getting started in IoT: Acquiring, manipulating and displaying sensor data	IoT System Overview – Perform system setup, connection between host and target, test run a ready-made application using a sample application as the demonstration and build a simple IoT application to read data from sensors, and display the results on an LCD.	No
2	Programming your peripheral devices to interface on an IoT platform via GPIO and UART	Explore various functions of the IoT development kit, and develop programs to interface with push-button, LCD, external mass storage, UART, and GPIO.	No
3	Utilizing ZigBee® standard and gateway GPIOs for data acquisition and communication with analog IoT sensors	Set up the development kit to interface with external sensors and actuators. Learn to interface gateway to sensor devices and display the results on an LCD.	No
4	Setting up and deciphering I2C and SPI digital bus communications between the gateway and IoT sensors	Learn to write software applications with I2C and SPI communication protocols, this includes setup and configure digital sensors.	Yes, oscilloscope
5	Integrating wireless sensor networks to your IoT applications via Bluetooth LE and ZigBee® standard	Using wireless communication over Bluetooth® LE and ZigBee® standard, by developing IoT node devices that communicate with each other	Yes, DMM
6	Optimizing network usage for cloud and mobile device communications via REST and MQTT	Learn to call and use cloud services, use HTTP and MQTT protocols to connect to the cloud, set up, and test with mobile devices.	No
7	Building an IoT application that utilizes cloud data analysis and mobile device communication	Deploy and IoT sensor node onto cloud and visualize the results on an end user client device, such as a wearable device for activity monitoring	No

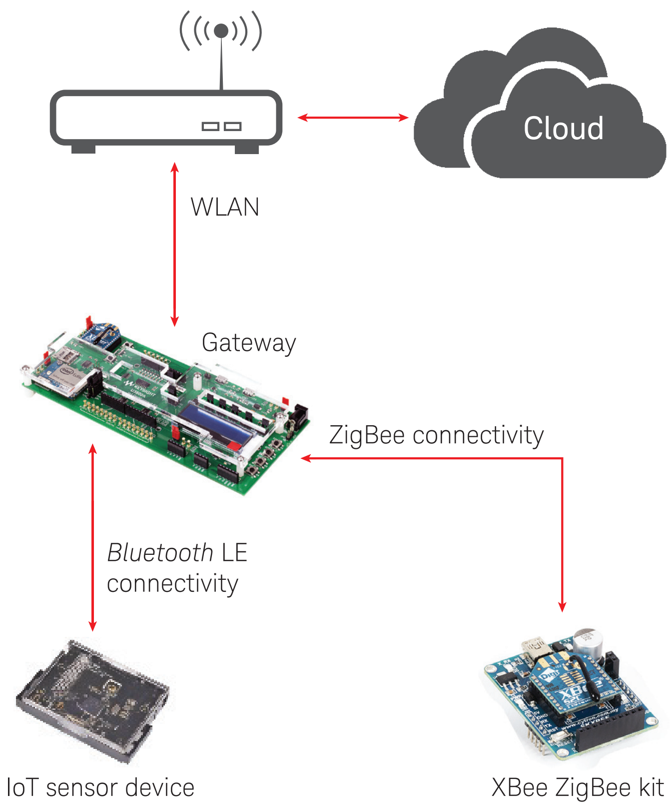


Figure 4. Typical lab setup.

Problem-based assignments

The problem-based assignments below allow students to enhance their problem-solving skills.

Smart street lamp	Develop a smart street lamp using the available sensors and actuators. The street lamp can be controlled over a network based on the light intensity of the surrounding environment.
Smart automobile	Develop a fitness tracker for cars using available sensors and logging the result in an SD card that can be retrieved with a smartphone for drivers to track the performance and safety of their cars.
Applied Industry 4.0	Develop an automated process flow that is also industry 4.0 subsystem to control tempering, molding and cooling process of a chocolate manufacturing plant.

U3805A/06A IoT Wireless Communications Applied Courseware

Overview

The IoT Wireless Communications applied courseware is a ready-to-teach package focused on the wireless connectivity of the Internet of Things, with the goal of providing students the ability to develop typical IoT applications with various types of wireless connectivity. Students will learn how to perform quick verification and design validation on IoT applications. The courseware is designed as a resource for lecturers and consists of teaching slides and a training kit.

- Targeted university subject: IoT wireless communications, advanced IoT
- Targeted year of study: Third to final year undergraduates
- Prerequisites(s): Basic electronics, C programming, signals and systems

Teaching slides	**Training kit**
Editable Microsoft PowerPoint slides	IoT development kit
Covers 36+ hours of classroom sessions	IoT sensor devices
	ZigBee and LoRa kits
	Lab sheets (Microsoft Word) and model answers
	Problem-based learning assignments
	Covers 24 hours of lab sessions

Key features and benefits

- Consists of teaching slides and a training kit for a full semester of teaching. A complete solution to accelerate the setup of a new IoT-focused course.
- Integrates hands-on industry-relevant experiences and real-world applications in IoT design and testing. Incorporates wireless standards used in IoT-enabled embedded system applications and usage of industry-grade tools, such as vector signal analyzers, to measure and evaluate the performance of the wireless technologies.
- Yearly updates for three years at no additional cost, keeping pace with evolving IoT trends and technologies.
- Expandable training kit for lab assignments on wireless local area network (WLAN) 802.11, *Bluetooth* LE and ZigBee wireless connectivity and other wireless connectivity and sensors.
- Visible hardware building blocks on the training kit

Learning outcomes

Students will be able to:
- Understand the main attributes of the major wireless technologies for IoT
- Understand and measure common impairments affecting radio performance
- Interpret radio specifications
- Compare and select suitable radio technology
- Evaluate wireless technologies using industrial-grade test and measurement instruments

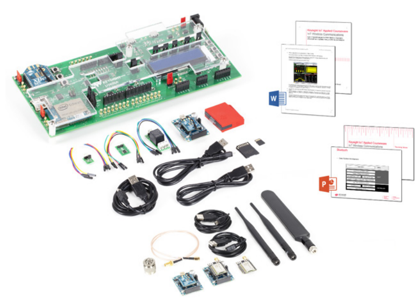


Figure 5:. U3806A IoT Wireless Communications applied courseware, with training kit and teaching slides

Courseware Contents

Teaching slides

The teaching slides are editable and cover 36+ hours of teaching for one full semester. The slides cover the following topics:

Overview of IoT connectivity	Technology revolution, wired and wireless connectivity, key enabling wireless technologies, working principles, communication models, applications in IoT
Principles of wireless communications	Radio propagation, path loss, digital modulation techniques, channel coding, transceiver architecture, radio specifications, unlicensed vs licensed bands, IoT system design challenges (integration of circuits and components, energy efficiency and battery life, signal integrity (SI) and power integrity (PI), heterogeneous mix of wireless technologies and multi-standard devices, interference, compliance and conformance, design tools (EEsof/ADS)
Wireless Standards for IoT	Cellular (2G, 3G, 4G), WLAN, ZigBee, *Bluetooth*, 6LoWPAN, NFC, NB-IoT, LoRa, Sigfox, future trend, technology selection considerations (range, data rate, cost, power consumption, frequency band, network topology, security)
Wireless Networking	Wireless networks and topologies, routing protocols, low power and lossy networks (LLNs), challenges for routing in LLNs
Test & Measurement for Wireless Connectivity	Industry practices in R&D/DVT and manufacturing test, wireless, regulatory and interference test challenges, multi-format wireless test, overview of wireless compliance, regulatory pre-compliance test, regulatory standards for IoT devices, industry certification (PTCRB/GCF), wireless modules certification
Case studies	Public safety (LTE/ WLAN), smart home (WLAN), energy management (ZigBee); healthcare (*Bluetooth*), smart city (6LoWPAN)

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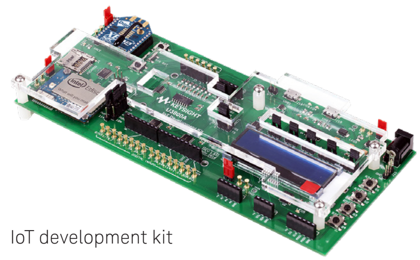
Training kit

IoT development kit

This hardware kit is a customizable embedded system development kit that can be configured as a gateway or a sensor device. It incorporates an Intel Edison compute module that is designed for expert makers, entrepreneurs, and industrial IoT applications. The system runs on Yocto Linux with open source software development, allowing students to compile C/C++ files or to run Python scripts. Samples of starter projects are also available to enhance the learning process and allow a wide range of potential applications.

This development kit can be utilized with all Keysight IoT applied coursewares.



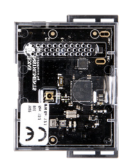
IoT development kit

Features:

- Open source software development environment
- High performance, dual-core CPU, and single core micro-controller support complex data collection in a low power package
- Integrated WLAN 802.11, *Bluetooth* LE and ZigBee wireless connectivity support
- 1 GB DDR and 4 GB flash memory, simplifying configuration and increasing scalability
- Arduino UNO and XBee form factor interfaces support
- UARTs, I2C, SPI, 40 GPIO, SD card connector and LCD
- Micro USB (UART), Micro USB OTG
- Flexible power supply options: AC power adapter or USB host
- Various test points for troubleshooting, current drain measurements, and sensor verification
- Sensor connectors

IoT sensor device

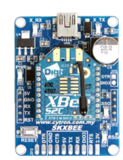
The TI SensorTag kit includes ten low-power sensors: ambient light, digital microphone, magnetic sensor, humidity, pressure, accelerometer, gyroscope, magnetometer, object temperature, and ambient temperature. This kit supports multi-standard wireless connectivity.



IoT sensor device

XBee ZigBee kit

The XBee starter kit is a compact platform that provides UART serial communication to an XBee ZigBee module. 5 V TTL logic interface offers a straightforward interface to the microcontroller for embedded wireless development.



XBee ZigBee kit

Accessories

The following accessories are included with the hardware kit:

Item	Quantity
Micro USB cable, 1 m	2
Mini USB cable, 1.2 m	1
TI SensorTag kit	1
XBee ZigBee kit	1
Analog temperature sensor	1
Digital temperature sensor	1
Relay actuator	1
Micro SD card	1

Accessories

Add-on item	Quantity
LoRa module (with antenna)	1
LoRa kit (LoRa module and XBee breakout board with USB cable)	1
Wideband antenna	1
SMA(m) to SMA(f) cable assembly, 1m	1
N-type(m) to SMA(f) adaptor	1

Accessories

The following accessories are not included and optional for lab activity:

Item	Quantity
ZigBee USB dongle (TI CC2531EMK)	1
Bluetooth LE USB dongle (TI CC2540EMK)	1

Lab sheets

Lab sheet topic	Required Instruments and Software Option 1: Basic Lab	Option 2: Advanced Lab
1. Setting Up IoT Sensor Network– Learn how to set up a typical IoT wireless sensor network	No	No
2. Analyzing *Bluetooth* Low Energy (LE) Protocol for Low Power IoT Devices – Learn how to set up and evaluate performance of wireless sensor network based on *Bluetooth* LE	No	No
3. Building Your ZigBee Mesh Network for Better Data Routing and Extended Range – Learn how to set up and evaluate performance (including interference simulation) of ZigBee based wireless sensor network	No	No
4. Evaluating the IoT Data Link Protocols for Short-Range Wireless Communications with Low Power Consumption (*Bluetooth* and ZigBee) - Learn how to set up and perform measurements for analysis of output power, modulation characteristics, initial carrier frequency tolerance (ICFT), carrier frequency drift, output spectrum bandwidth, and in-band spurious emission; receiver RSSI test	Yes, spectrum analyzer	Yes, signal analyzer
5. Evaluating and Improving Wireless Local Area Network (WLAN) Signal Performance - Learn how to set up and perform measurements for analysis of channel power, occupied bandwidth, and spectrum emission	Yes, spectrum analyzer	Yes, signal analyzer
6. Analyzing the Range and Coexistence of Low Power Long Range Communications (LoRa) - Range test; signal analysis	Yes, spectrum analyzer, PC installed VSA software	Yes, signal analyzer, installed with VSA software
7. Validating the WLAN Devices Design and High-Density WLAN Networks for Optimum Coverage – Learn how to set up and perform measurements for WLAN modulation analysis	Yes, spectrum analyzer, PC installed VSA software	Yes, signal analyzer, installed with VSA software
8. Validating and Comparing the *Bluetooth* LE and ZigBee Communications for Low Power Applications – Learn how to set up and perform measurements for *Bluetooth* LE and ZigBee modulation analysis	Yes, spectrum analyzer, PC installed VSA software	Yes, signal analyzer, installed with VSA software

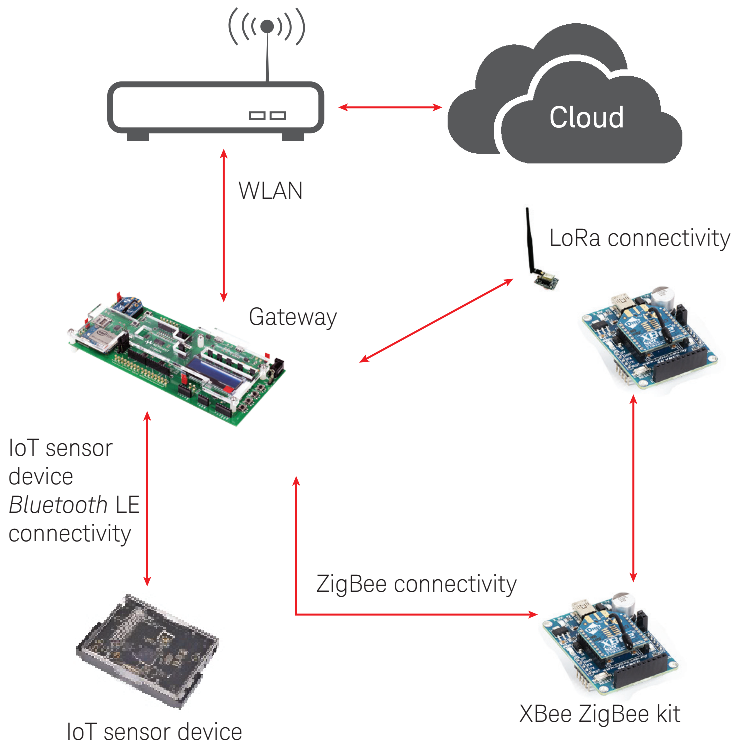


Figure 6. Typical lab setup.

A spectrum analyzer or a signal analyzer and Vector Signal Analysis (VSA) software are required. Refer to the Ordering Information section on page 28 for the recommended models

Problem-based assignments

The problem-based assignments below allow students to enhance their problem-solving skills.

Wireless Sensor Network for Home Automation	Develop a wireless sensor network with ZigBee Home Automation (ZHA) compliant protocol stack using the available sensor nodes for a smart home application such as light/temperature control.

U3807A/08A IoT Sensors and Power Management Applied Courseware

Overview

The IoT Sensors and Power Management applied courseware is a ready-to-teach package focused on the IoT device design, with the goal of teaching students how to characterize power consumption of IoT device onboard controller, sensors, and wireless modules. Students will understand the principles of power management and be able to characterize micro-electro-mechanical systems (MEMS) devices. The courseware is designed as a resource for lecturers and consists of teaching slides and a training kit.

- Targeted university subjects: IoT device power management, IoT sensors technologies, advanced IoT
- Targeted year of study: Third to final year undergraduates
- Prerequisites(s): Basic electronics, C programming, IoT fundamentals, feedback control systems

Teaching slides	Training kit
Editable Microsoft PowerPoint slides	IoT development kit
Covers 36+ hours of classroom sessions	IoT sensor devices
	MEMS pressure sensor
	Lab sheets (Microsoft Word) and model answers
	Problem-based learning assignments
	Covers 18 hours of lab sessions

Learning outcomes

Students will be able to:

- Explore the critical selection parameters of sensors for IoT applications
- Discover the principles of commonly used sensor technologies
- Evaluate performance of commonly used sensor modules
- Understand the design considerations in IoT applications (power management)
- Evaluate and validate power consumption of IoT devices and the sub-circuits using industrial-grade test and measurement instruments

Key features and benefits

- Comes with teaching slides and a training kit designed for a full semester of teaching. A complete solution to accelerate the setup of a new IoT-focused course.
- Integrates hands-on industry-relevant experiences and real-world applications in IoT design and testing. Incorporates power consumption characterization of the onboard subcircuits such as the processor, wireless connectivity module and sensors and usage of industry-grade tools, such as low-current measurement digital multimeter (DMM) and DC power analyzer.
- Yearly updates for three years at no additional cost, keeping pace with evolving IoT trends and technologies.
- Visible hardware building blocks on the training kit

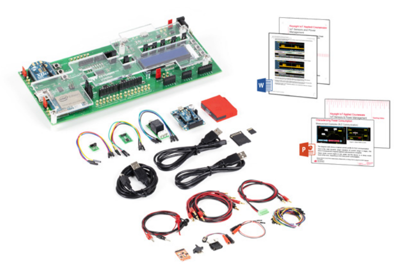


Figure 7. U3808A IoT Sensors and Power Management applied courseware, with training kit and teaching slides

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Courseware Contents

Teaching slides

The teaching slides are editable and cover 36+ hours of teaching for one full semester. The slides cover the following topics:

Overview of Internet-of-Things (IoT) System	Introduction to the architecture of an IoT system, applications of IoT and future trends, IoT building blocks and enabling technologies, industrial design challenges for IoT applications
Essentials of Power Circuits	Overview of commonly used power circuits in IoT embedded system, electronic devices used in power circuits, linear converter and regulator, DC-DC converters, feedback control in DC-DC converters, battery management circuits, power management integrated circuits (PMIC), voltage reference
Fundamentals of Power Measurement	DC power measurement techniques (shunt resistor, hall-effect sensor), dynamic power measurement, (idle, active, communication and sleep mode), battery rundown test, estimating battery lifetime: design considerations
Power Management Techniques	Low power circuit design in IoT embedded system, power management techniques (dynamic voltage and frequency scaling), dynamic power management (DPM): software – hardware co-design, energy harvesting for IoT sensor nodes: challenges and design considerations
Overview of Sensor Technology	Classification of sensor technologies, critical parameters in selecting the right sensor for applications, operating principles and performance evaluation of the sensors with specific focus on MEMS sensors
Sensor Measurement Techniques	Sensor data acquisition, excitation techniques, current sensing techniques, current sensors based on Ohm's law and Faraday's law, signal conditioning processes, analog-to-digital converter (ADC), test challenges for IoT smart sensors.
Sensor in Action	Introduction of inertial measurement unit (IMU), difference between gyroscope and accelerometer, gyroscope and accelerometer selection guide, gyroscope and accelerometer errors and their consequences, measuring tilt angle with gyroscope and accelerometer, advanced sensor fusion with Kalman filtering
Case Studies	Low power sensor node in home automation, design challenges of low-power weather monitoring system with energy harvesting technology, application of drones to smart agriculture, efficient data aggregation and processing for wearable sensors

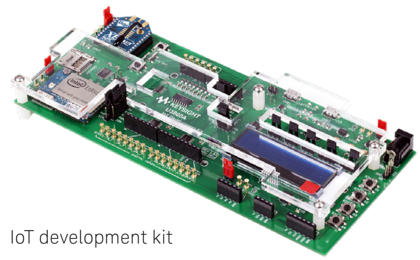
Training kit

IoT development kit

This hardware kit is a customizable embedded system development kit that can be configured as a gateway or a sensor device. It incorporates an Intel Edison compute module that is designed for expert makers, entrepreneurs, and industrial IoT applications.

The system runs on Yocto Linux with open source software development, allowing students to compile C/C++ files or to run Python scripts Samples of starter projects are also available to enhance the learning process and allow a wide range of potential applications.

This development kit can be utilized with all Keysight IoT applied coursewares



IoT development kit

Features:

- Open source software development environment
- High performance, dual-core CPU, and single core micro-controller support complex data collection in a low power package
- Integrated WLAN 802.11, *Bluetooth* LE and ZigBee wireless connectivity support
- 1 GB DDR and 4 GB flash memory, simplifying configuration and increasing scalability
- Arduino UNO and XBee form factor interfaces support
- UARTs, I2C, SPI, 40 GPIO, SD card connector and LCD
- Micro USB (UART), Micro USB OTG
- Flexible power supply options: AC power adapter or USB host
- Various test points for troubleshooting, current drain measurements, and sensor verification
- Sensor connectors

IoT sensor device

The TI SensorTag kit includes ten low-power sensors: ambient light, digital microphone, magnetic sensor, humidity, pressure, accelerometer, gyroscope, magnetometer, object temperature, and ambient temperature. This kit supports multi-standard wireless connectivity.

IoT sensor device

XBee ZigBee kit

The XBee starter kit is a compact platform that provides UART serial communication to an XBee ZigBee module. 5 V TTL logic interface offers a straightforward interface to the microcontroller for embedded wireless development.

XBee ZigBee kit

Accessories

The following accessories are included with the hardware kit:

Item	Quantity
Micro USB cable, 1 m	2
Mini USB cable, 1.2 m	1
TI SensorTag kit	1
XBee ZigBee kit	1
Analog temperature sensor	1
Digital temperature sensor	1
Relay actuator	1
Micro SD card	1

Accessories

Accessories

The following accessories are included with the hardware kit:

Add-on item	Quantity
Accelerometer and gyroscope sensor	1
MEMS pressure sensor	1
Croc clip to 4mm banana plug, 36 inches, 5A (red)	1
Croc clip to 4mm banana plug, 36 inches, 5A (black)	1
Phoenix (8-way) connector to banana plugs (one red, one black)	1
9V battery connector to banana jacks (one red, one black)	1
Test lead, 4mm banana plug to 4mm banana plug (black)	2
Test lead, 4mm banana plug to 4mm banana plug (red)	3
Jumper wires (female to male), 30cm, 10 per pack	1
Banana jack (female, red) to 1 pin female jumper connector	1
Banana jack (female, black) to 1 pin female jumper connector	1
Shunt resistor assembly	1


Accessories

The following accessories are not included and optional for lab activity:

Item	Quantity
9V rechargeable battery	2
Solar panel 5-10W, 12-18V (open circuit)	1

Lab sheets

Lab sheet topic	Required Instruments and Software	
	Option 1: Basic Lab	Option 2: Advanced Lab
1. Setting Up IoT Gateway and Connecting Sensor Network to the Cloud: From sensor nodes to cloud	No	No
2. Characterizing IoT Sensor Board (Device) Static and Dynamic Power Consumption	Yes, DMM	Yes, DMM, DC power analyzer
3. Evaluating the Impact of Dynamic Current Drain and Solar Energy Harvesting on IoT Battery Life	Yes, DMM	Yes, DMM, DC power analyzer
4. Optimizing Power Consumption and Efficiency Using Dynamic Power Management in Sensor Networks	Yes, DMM	Yes, DMM
5. Characterizing MEMS Accelerometer and Gyroscope Sensors, and their applications.	Yes, oscilloscope	Yes, oscilloscope
6. Characterizing MEMS Pressure and Temperature Sensors for Applications in Harsh Environment	Yes, oscilloscope	Yes, oscilloscope
7. Gesture Control using Inertial Measurement Unit (IMU)	No	No

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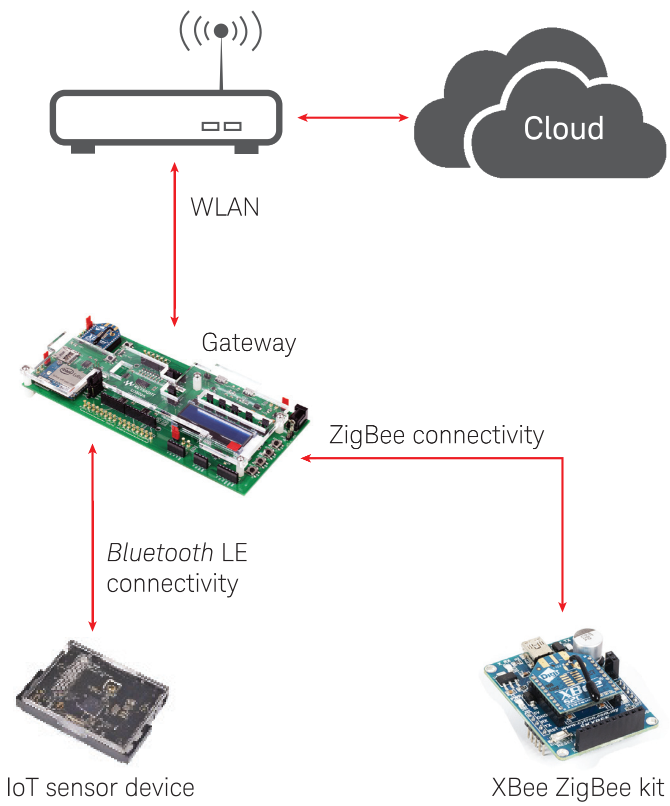


Figure 8. Typical lab setup.

A digital multimeter (DMM) with very low current measurement capabilities and a four-channel oscilloscope are required. Refer to the Ordering Information section on page 28 for the recommended models.

Problem-based assignments

The problem-based assignments below allow students to enhance their problem-solving skills.

Optimizing Power Consumption in IoT Sensor Nodes	Develop an IoT system to monitor the outdoor atmospheric pressure. Optimize the power consumption in IoT sensor nodes with various power management techniques. Discuss the trade-off involved in the optimization processes.

IoT Development Kit Characteristics

IoT development kit	
Dimensions	20 cm (w) x 8.5 cm (d) x 5 cm (h)
Compute module	Intel Edison (A dual-core, dual-threaded Intel Atom CPU at 500 MHz and a 32-bit Intel Quark microcontroller at 100 MHz)
RAM and flash storage	1 GB LPDDR3 PoP memory and 4 GB eMMC
Wireless communication	WLAN 802.11 a/b/g/n, *Bluetooth* LE (version 4.0) and ZigBee wireless connectivity
IoT development kit	
Supply voltage	6 to 12 V AC adapter (2 mm DC jack) USB port
Warranty	One year Three months for accessories

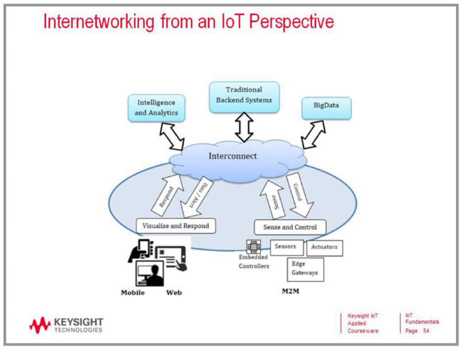
System and Installation Requirements

General	
PC operating system	Windows 7, 8 and 10 (64-bit)
Interface	USB (3 ports)

Preview IoT Applied Courseware Contents

Visit **www.keysight.com/find/TeachIoT** for more information about the contents of the IoT applied courseware and to view samples of the teaching slides and lab sheets.

IoT Fundamentals Applied Courseware



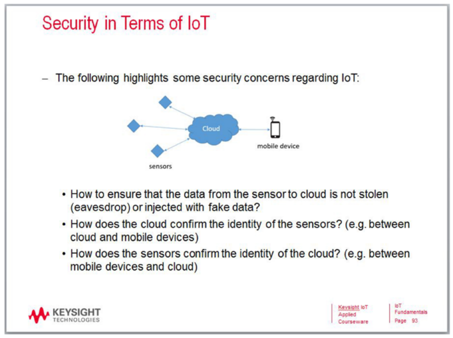
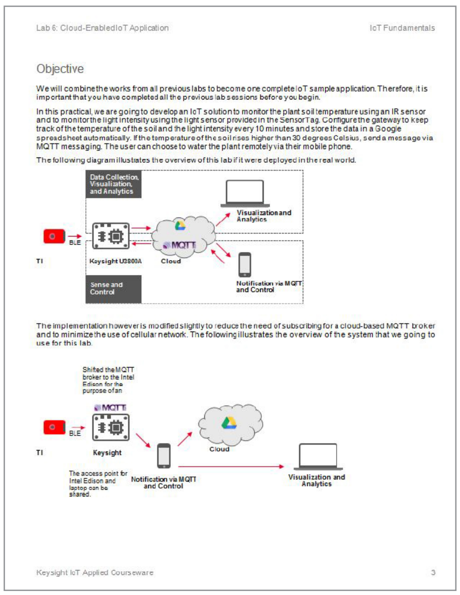


Figure 9. Samples of the teaching slides – Chapter 5, IoT Application Design Essentials. View more samples at the above link.



Lab 6: Cloud-Enabled IoT Application — IoT Fundamentals

Objective

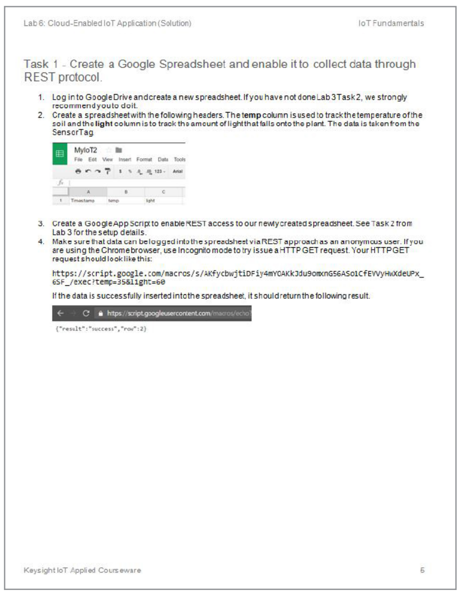
We will combine the works from all previous labs to become one complete IoT sample application. Therefore, it is important that you have completed all the previous lab sessions before you begin.

In this practical, we are going to develop an IoT solution to monitor the plant soil temperature using an IR sensor and to monitor the light intensity using the light sensor provided in the SensorTag. Configure the gateway to keep track of the temperature of the soil and the light intensity every 10 minutes and store the data in a Google spreadsheet automatically. If the temperature of the soil rises higher than 30 degrees Celsius, send a message via MQTT messaging. The user can choose to water the plant remotely via their mobile phone.

The following diagram illustrates the overview of this lab if it were deployed in the real world.

The implementation however is modified slightly to reduce the need of subscribing for a cloud-based MQTT broker and to minimize the use of cellular network. The following illustrates the overview of the system that we going to use for this lab.

Keysight IoT Applied Courseware — 3



Lab 6: Cloud-Enabled IoT Application (Solution) — IoT Fundamentals

Task 1 - Create a Google Spreadsheet and enable it to collect data through REST protocol.

1. Log in to Google Drive and create a new spreadsheet. If you have not done Lab 3 Task 2, we strongly recommend you to do it.
2. Create a spreadsheet with the following headers. The **temp** column is used to track the temperature of the soil and the **light** column is to track the amount of light that falls onto the plant. The data is taken from the SensorTag.

3. Create a Google App Script to enable REST access to our newly created spreadsheet. See Task 2 from Lab 3 for the setup details.
4. Make sure that data can be logged into the spreadsheet via REST approach as an anonymous user. If you are using the Chrome browser, use Incognito mode to try issue a HTTP GET request. Your HTTP GET request should look like this:

```
https://script.google.com/macros/s/AKfycbwjtiDFiy4mYOAKkJdu9omxnG56ASo1CfEVVyHwXdeUPx_6SF_/exec?temp=35&light=60
```

If the data is successfully inserted into the spreadsheet, it should return the following result.

{"result":"success","row":2}

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Figure 10. Samples of the lab sheets – Lab 6, Cloud-enabled IoT Application. View more samples at the above link.

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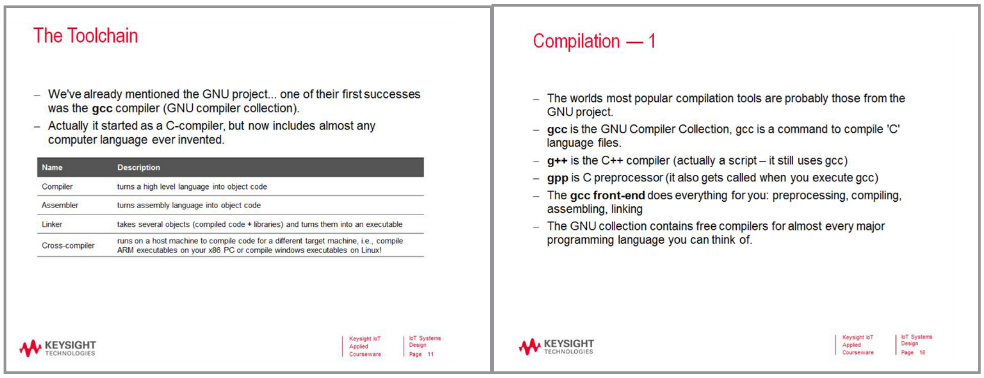
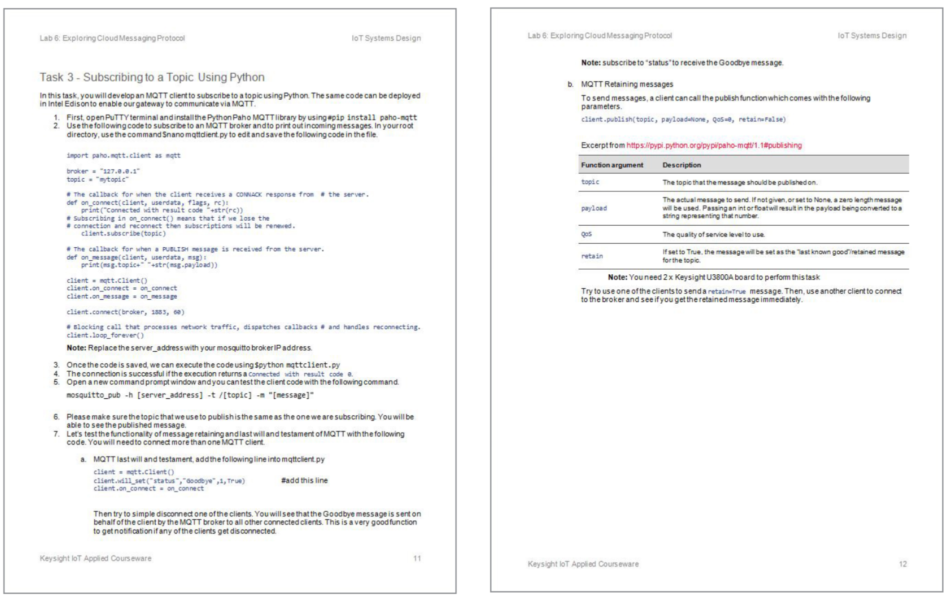


Figure 11. Samples of the teaching slides – Chapter 5, Designing IoT Applications Using Embedded Systems. View more samples at the above link.



Lab 6: Exploring Cloud Messaging Protocol   IoT Systems Design

Task 3 - Subscribing to a Topic Using Python

In this task, you will develop an MQTT client to subscribe to a topic using Python. The same code can be deployed in Intel Edison to enable our gateway to communicate via MQTT.

1. First, open PuTTY terminal and install the Python Paho MQTT library by using `#pip install paho-mqtt`
2. Use the following code to subscribe to an MQTT broker and to print out incoming messages. In your root directory, use the command $nano mqttclient.py to edit and save the following code in the file.

```
import paho.mqtt.client as mqtt

broker = "127.0.0.1"
topic = "mytopic"

# The callback for when the client receives a CONNACK response from  # the server.
def on_connect(client, userdata, flags, rc):
    print("Connected with result code "+str(rc))
# Subscribing in on_connect() means that if we lose the
# connection and reconnect then subscriptions will be renewed.
    client.subscribe(topic)

# The callback for when a PUBLISH message is received from the server.
def on_message(client, userdata, msg):
    print(msg.topic+" "+str(msg.payload))

client = mqtt.Client()
client.on_connect = on_connect
client.on_message = on_message

client.connect(broker, 1883, 60)

# Blocking call that processes network traffic, dispatches callbacks # and handles reconnecting.
client.loop_forever()
```

Note: Replace the server_address with your mosquitto broker IP address.

3. Once the code is saved, we can execute the code using `$python mqttclient.py`
4. The connection is successful if the execution returns a `Connected with result code 0`.
5. Open a new command prompt window and you can test the client code with the following command.

```
mosquitto_pub -h [server_address] -t /[topic] -m "[message]"
```

6. Please make sure the topic that we use to publish is the same as the one we are subscribing. You will be able to see the published message.
7. Let's test the functionality of message retaining and last will and testament of MQTT with the following code. You will need to connect more than one MQTT client.

   a. MQTT last will and testament, add the following line into mqttclient.py

```
client = mqtt.Client()
client.will_set("status","Goodbye",1,True)          #add this line
client.on_connect = on_connect
```

   Then try to simple disconnect one of the clients. You will see that the Goodbye message is sent on behalf of the client by the MQTT broker to all other connected clients. This is a very good function to get notification if any of the clients get disconnected.

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Lab 6: Exploring Cloud Messaging Protocol   IoT Systems Design

Note: subscribe to "status" to receive the Goodbye message.

b. MQTT Retaining messages

To send messages, a client can call the publish function which comes with the following parameters.

```
client.publish(topic, payload=None, QoS=0, retain=False)
```

Excerpt from https://pypi.python.org/pypi/paho-mqtt/1.1#publishing

Function argument	Description
topic	The topic that the message should be published on.
payload	The actual message to send. If not given, or set to None, a zero length message will be used. Passing an int or float will result in the payload being converted to a string representing that number.
QoS	The quality of service level to use.
retain	If set to True, the message will be set as the "last known good"/retained message for the topic.

Note: You need 2 x Keysight U3800A board to perform this task

Try to use one of the clients to send a `retain=True` message. Then, use another client to connect to the broker and see if you get the retained message immediately.

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Figure 12. Samples of the lab sheets – Lab 5, Exploring Cloud Messaging Protocol. View more samples at the above link.

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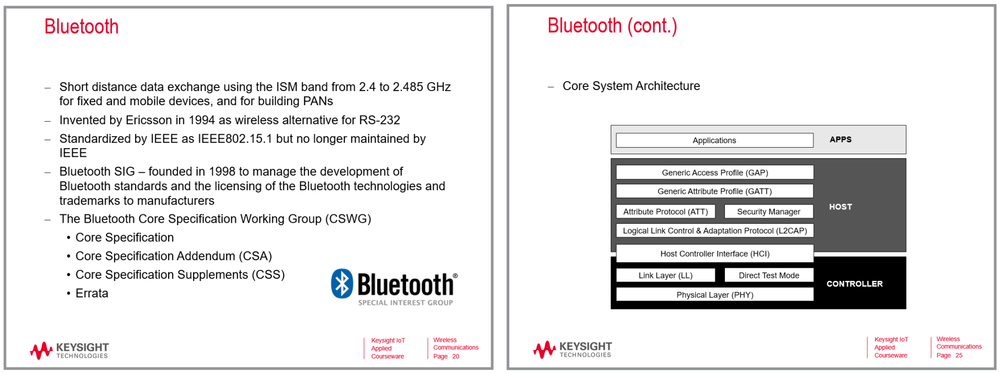
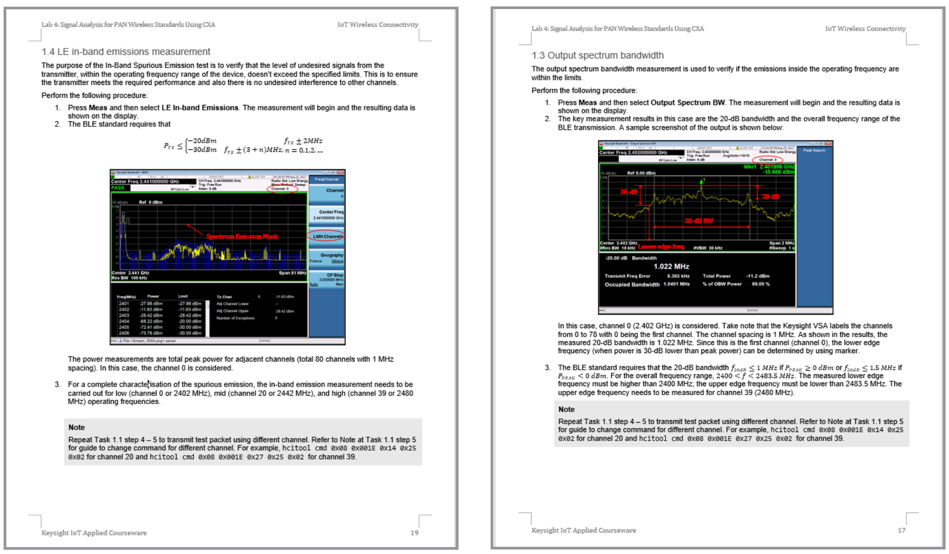


Figure 13. Samples of the teaching slides – Chapter 3, Wireless Standards for IoT. View more samples at the above link.



Lab 4: Signal Analysis for PAN Wireless Standards Using CXA — IoT Wireless Connectivity

1.4 LE in-band emissions measurement

The purpose of the In-Band Spurious Emission test is to verify that the level of undesired signals from the transmitter, within the operating frequency range of the device, doesn't exceed the specified limits. This is to ensure the transmitter meets the required performance and also there is no undesired interference to other channels.

Perform the following procedure:

1. Press **Meas** and then select **LE In-band Emissions**. The measurement will begin and the resulting data is shown on the display.
2. The BLE standard requires that

$$P_{TX} \leq \begin{cases} -20dBm & f_{TX} \pm 2MHz \\ -30dBm & f_{TX} \pm (3+n)MHz, n = 0,1,2,\ldots \end{cases}$$

The power measurements are total peak power for adjacent channels (total 80 channels with 1 MHz spacing). In this case, the channel 0 is considered.

3. For a complete characterisation of the spurious emission, the in-band emission measurement needs to be carried out for low (channel 0 or 2402 MHz), mid (channel 20 or 2442 MHz), and high (channel 39 or 2480 MHz) operating frequencies.

Note

Repeat Task 1.1 step 4 – 5 to transmit test packet using different channel. Refer to Note at Task 1.1 step 5 for guide to change command for different channel. For example, `hcitool cmd 0x08 0x001E 0x14 0x25 0x02` for channel 20 and `hcitool cmd 0x08 0x001E 0x27 0x25 0x02` for channel 39.

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Lab 4: Signal Analysis for PAN Wireless Standards Using CXA — IoT Wireless Connectivity

1.3 Output spectrum bandwidth

The output spectrum bandwidth measurement is used to verify if the emissions inside the operating frequency are within the limits.

Perform the following procedure:

1. Press **Meas** and then select **Output Spectrum BW**. The measurement will begin and the resulting data is shown on the display.
2. The key measurement results in this case are the 20-dB bandwidth and the overall frequency range of the BLE transmission. A sample screenshot of the output is shown below:

In this case, channel 0 (2.402 GHz) is considered. Take note that the Keysight VSA labels the channels from 0 to 78 with 0 being the first channel. The channel spacing is 1 MHz. As shown in the results, the measured 20-dB bandwidth is 1.022 MHz. Since this is the first channel (channel 0), the lower edge frequency (when power is 30-dB lower than peak power) can be determined by using marker.

3. The BLE standard requires that the 20-dB bandwidth $f_{20dB} \leq 1\,MHz$ if $P_{PEAK} \geq 0\,dBm$ or $f_{20dB} \leq 1.5\,MHz$ if $P_{PEAK} < 0\,dBm$. For the overall frequency range, $2400 < f < 2483.5\,MHz$. The measured lower edge frequency must be higher than 2400 MHz; the upper edge frequency must be lower than 2483.5 MHz. The upper edge frequency needs to be measured for channel 39 (2480 MHz).

Note

Repeat Task 1.1 step 4 – 5 to transmit test packet using different channel. Refer to Note at Task 1.1 step 5 for guide to change command for different channel. For example, `hcitool cmd 0x08 0x001E 0x14 0x25 0x02` for channel 20 and `hcitool cmd 0x08 0x001E 0x27 0x25 0x02` for channel 39.

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Figure 14. Samples of the lab sheets – Lab 4, Evaluating the IoT Data Link Protocols for Short Range Wireless Communications with Low Power Consumption. View more samples at the above link.

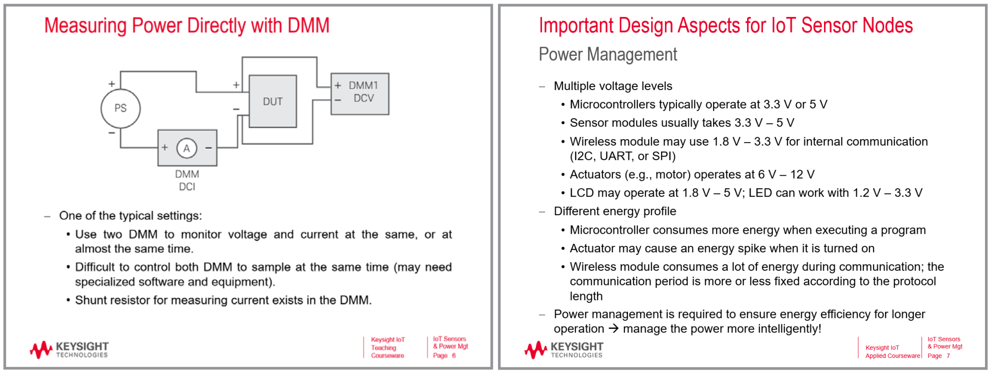
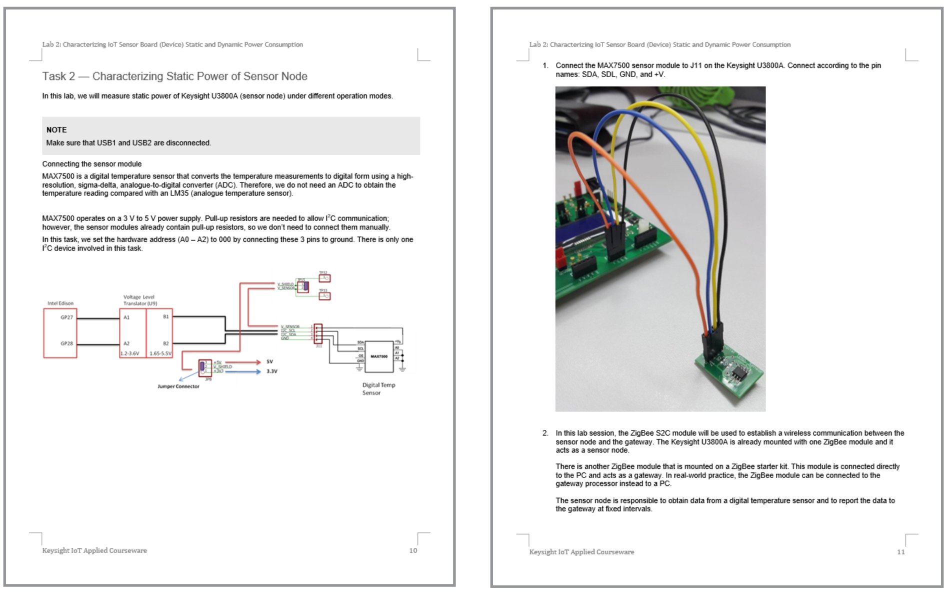


Figure 15. Samples of the teaching slides – Chapter 3, Fundamentals of Power Measurement. View more samples at the above link.


Lab 2: Characterizing IoT Sensor Board (Device) Static and Dynamic Power Consumption

Task 2 — Characterizing Static Power of Sensor Node

In this lab, we will measure static power of Keysight U3800A (sensor node) under different operation modes.

NOTE
Make sure that USB1 and USB2 are disconnected.

Connecting the sensor module

MAX7500 is a digital temperature sensor that converts the temperature measurements to digital form using a high-resolution, sigma-delta, analogue-to-digital converter (ADC). Therefore, we do not need an ADC to obtain the temperature reading compared with an LM35 (analogue temperature sensor).

MAX7500 operates on a 3 V to 5 V power supply. Pull-up resistors are needed to allow I^2C communication; however, the sensor modules already contain pull-up resistors, so we don't need to connect them manually.

In this task, we set the hardware address (A0 – A2) to 000 by connecting these 3 pins to ground. There is only one I^2C device involved in this task.

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Lab 2: Characterizing IoT Sensor Board (Device) Static and Dynamic Power Consumption

1. Connect the MAX7500 sensor module to J11 on the Keysight U3800A. Connect according to the pin names: SDA, SDL, GND, and +V.

2. In this lab session, the ZigBee S2C module will be used to establish a wireless communication between the sensor node and the gateway. The Keysight U3800A is already mounted with one ZigBee module and it acts as a sensor node.

   There is another ZigBee module that is mounted on a ZigBee starter kit. This module is connected directly to the PC and acts as a gateway. In real-world practice, the ZigBee module can be connected to the gateway processor instead to a PC.

   The sensor node is responsible to obtain data from a digital temperature sensor and to report the data to the gateway at fixed intervals.

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Figure 16. Samples of the lab sheets – Lab 2, Characterizing IoT Sensor Board (Device) Static and Dynamic Power Consumption. View more samples at the above link.

Watch a video overview or live demonstration

Visit the Keysight Educators playlist on the Keysight YouTube network at https://www.keysight.com/find/education-videos.

Watch an overview video to understand more about the IoT applied courseware, and take a look at how the training kit can be used in action within your teaching lab.

Ordering Information

Product number	Description
IoT Fundamentals Applied Courseware	
U3801A	IoT Fundamentals applied courseware, with training kit only
U3802A	IoT Fundamentals applied courseware, with training kit and teaching slides

Product number	Description
IoT Systems Design Applied Courseware	
U3803A	IoT Systems Design applied courseware, with training kit only
U3804A	IoT Systems Design applied courseware, with training kit and teaching slides
Recommended instruments	
34465A[1]	6½ digit, performance True*volt* digital multimeter
EDUX1002G	InfiniiVision 1000 X-Series education oscilloscope with waveform generator, 50 MHz, 1 GS/s, 2 analog channels

1. Other 34460 Series Truevolt DMMs models may be used, but 34465A is recommended as this model comes with a digitizing option for use with the IoT Sensors and Power Management applied courseware.

Product number	Description
IoT Wireless Communications Applied Courseware	
U3805A	IoT Wireless Communications applied courseware, with training kit only
U3806A	IoT Wireless Communications applied courseware, with training kit and teaching slides
Recommended Instruments and Software[1]	
For basic lab setup	
N9320B, or N9322C	RF Spectrum Analyzer (BSA), 9 kHz to 3 GHz Basic Spectrum Analyzer, 9 kHz to 7 GHz
For advance lab setup	
N9000B-503, N9000B-B25, N9077C-1FP N9081C-2FP	CXA Signal Analyzer, multi-touch, 9 kHz to 3 GHz Analysis bandwidth, 25 MHz WLAN 802.11a/b/g/j/p/n measurement application, fixed perpetual license *Bluetooth* measurement application, fixed perpetual license
For qualified education customers	
89600EDU-E01 89600EDU-E15	89600 VSA software, educational instructor license, transportable license 89600 VSA software, educational student license, 15 seats, floating license
For non-qualified education customers	
89601B-200, 89601B-AYA, 89601B-B7R, 89601B-BHJ	89600 VSA Software, transportable license Vector modulation analysis WLAN 802.11a/b/g modulation analysis WLAN 802.11n/ac modulation analysis

1. Refer to the Lab sheets section for instrument selection.

Product number	Description
IoT Sensors and Power Management Applied Courseware	
U3807A	IoT Sensors and Power Management applied courseware, with training kit only
U3808A	IoT Sensors and Power Management applied courseware, with training kit and teaching slides
Recommended Instruments[1]	
34465A-DIG, -MEM	6½ digit, performance Truevolt digital multimeter with high-speed digitizing and 2M memory
N6705C, N6781A	DC power analyzer 2-quadrant source/measure unit for battery drain analysis, 20 V, ±1 A or 6 V, ±3 A, 20 W
DSOX2004A	Oscilloscope: 70 MHz, 4 analog channels

Add-on options available for purchase for users of IoT Fundamentals, Systems Design, and Sensors and Power Management applied courseware. This is an accessory only.	
U3800WR1	Add Wireless Communications accessory kit for U3800 Series
U3800WR2	Add Wireless Communications accessory kit and teaching slides for U3800 Series
Add-on options available for purchase for users of IoT Fundamentals, Systems Design, and Sensors and Power Management applied courseware. This is an accessory only.	
U3800PW1	Add Sensors and Power Management accessory kit for U3800 Series
U3800PW2	Add Sensors and Power Management accessory kit and teaching slides for U3800 Series

1. Refer to the Lab sheets section for instrument selection.