Texas Instruments

Want to work for TI?

- Internships
- Rotation Programs
- Full-time positions

careers.ti.com

change the world, love your job.

TEXAS INSTRUMENTS

What does TI do?

What we've done for nearly 90 years…

We connect electronics customers to devices and technology that will help them build amazing products!

Reaching students and faculty
@ university.ti.com

The Texas Instruments University Program is dedicated to supporting engineering educators, researchers and students worldwide.

Teaching materials | Research labs | Design projects | Course Curricula | Teaching labs

Mark Easley

University Marketing Manager

Raleigh, NC

Software Engineer

Over 7 years at TI

Embedded Systems

& IoT experience

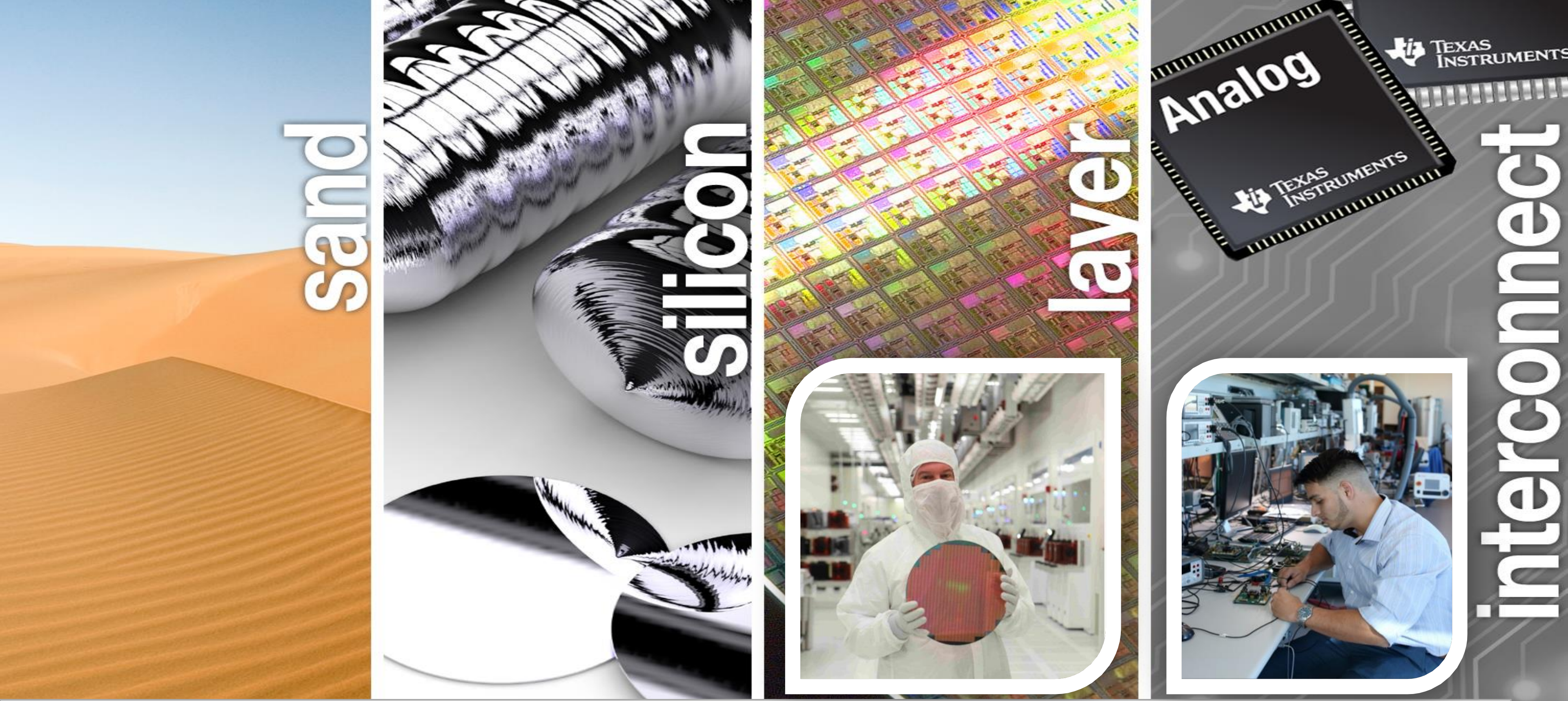
Today's agenda

- **IoT and Automation**
  - What? Why? How?
- TI-RSLK MAX Build & Test
  - Watch assembly video, build, use TI-RSLK Debug tool, customize appearance
- TI-RSLK MAX Programming
  - Setup Energia and robot library
  - Practice Line following and Finite State Machine
- TI-RSLK MAX Competition
  - Solve the maze time trial
  - Autonomous relay race

Quick Survey: Who is competing in a Robotics competition? Who is taking / has taken an embedded systems course? Freshman design course? Senior design course? Mechatronics or Robotics course?

Let’s take a quick look at how we manufacture products at TI

Semiconductor Industry

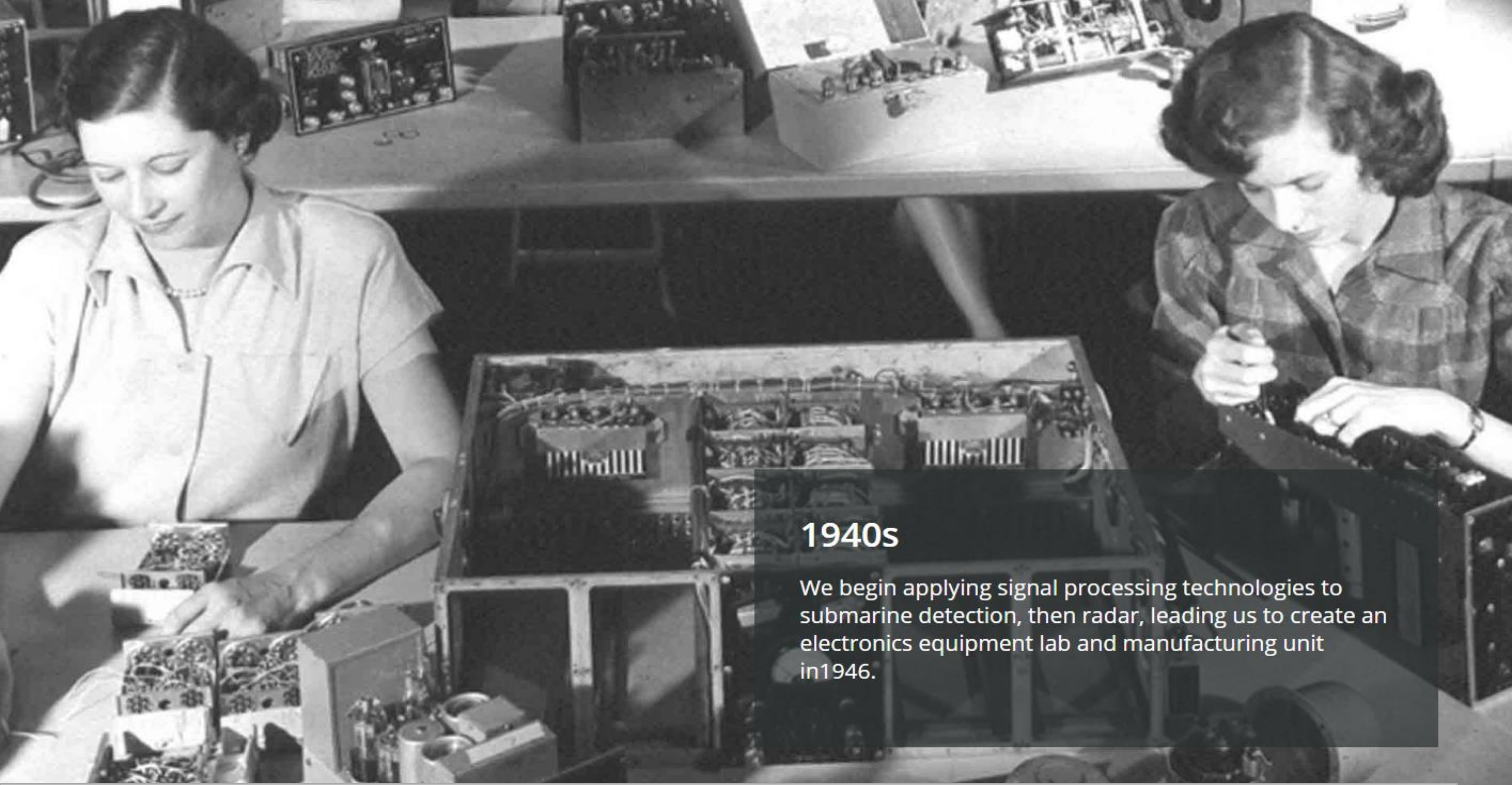


History of innovation

Over the last 85 years, we have re-engineered ourselves many times. Although today we are a global technology company, our spirit of innovation has been at the heart of who we are for decades, dating back to our founders and their vision for TI at its inception in 1930.

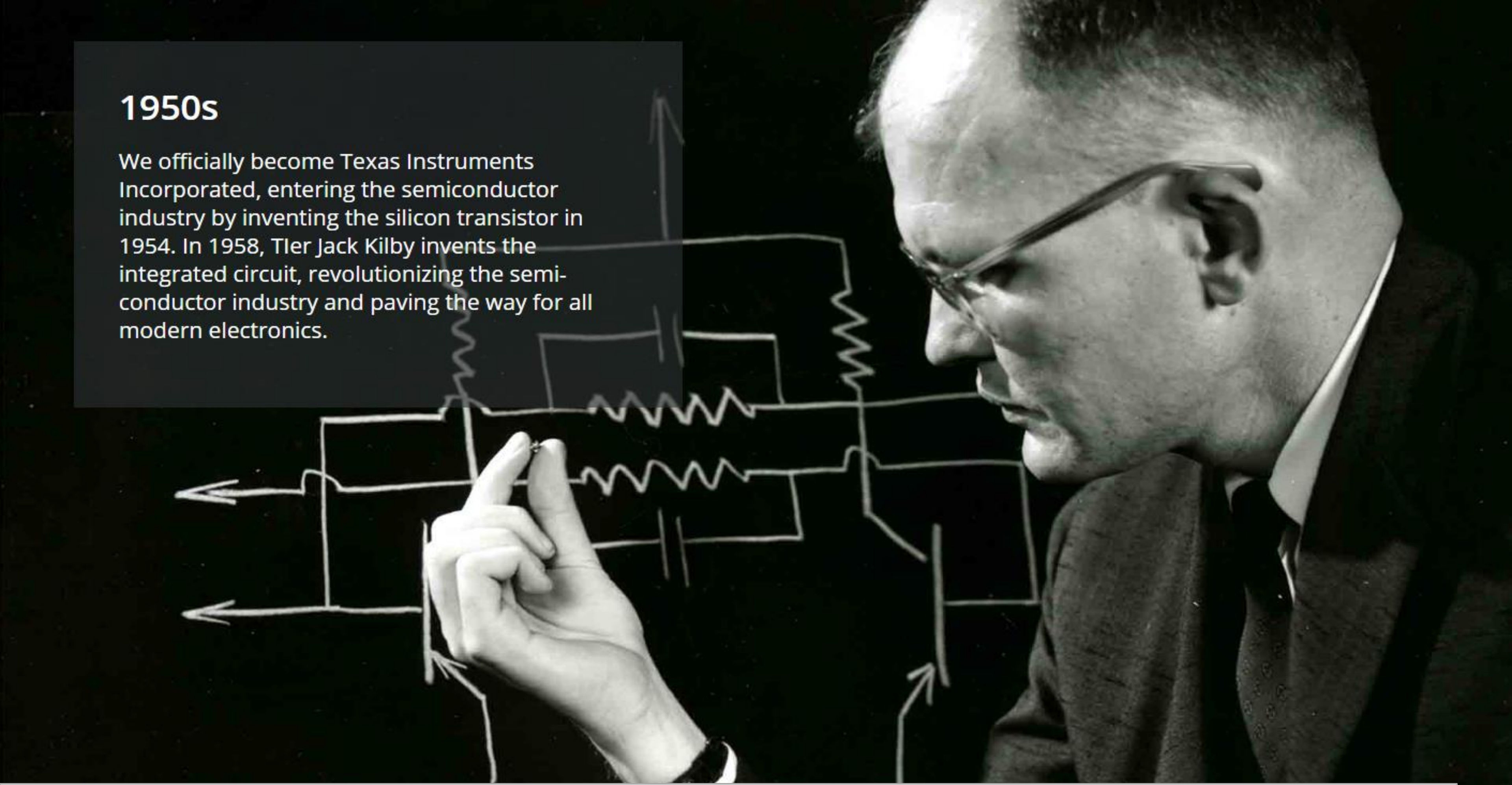
1930s

Geophysical Service Inc., a small oil and gas company, opens in 1930. The founders' entrepreneurial spirit, vision and innovation laid a solid foundation for today's Texas Instruments.



1940s

We begin applying signal processing technologies to submarine detection, then radar, leading us to create an electronics equipment lab and manufacturing unit in1946.



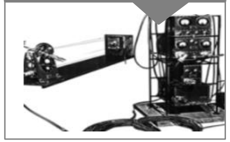
1950s

We officially become Texas Instruments Incorporated, entering the semiconductor industry by inventing the silicon transistor in 1954. In 1958, TIer Jack Kilby invents the integrated circuit, revolutionizing the semi-conductor industry and paving the way for all modern electronics.

Our history of reinvention

1930s
Oil exploration

1940s
Defense systems



1950s
Integrated circuit

1970s
Microprocessors

1980s
DSP, DLP®
Cinema

2000s
Analog and Embedded

2000s
Applied research –
Kilby Labs

Present day
Industrial and automotive technologies

Customers count on us to deliver great products, engineering expertise and support

PORTFOLIO

- Analog Power Products
- Analog Signal Chain
- Embedded Processing
- High Volume Analog & Logic
- DLP® Products

Key markets

- Industrial
- Automotive
- Personal electronics
- Communications equipment
- Enterprise systems

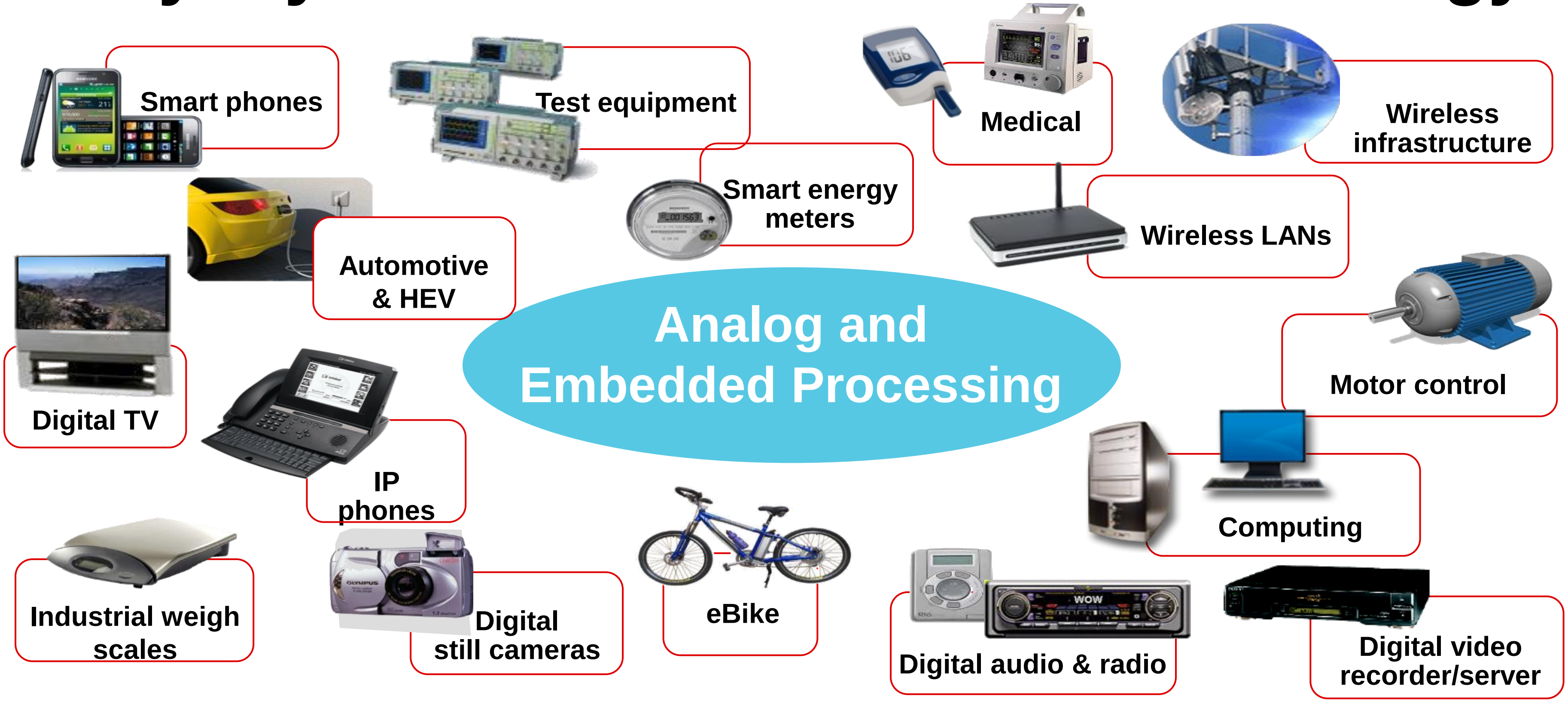
Manufacturing

- 200-mm
- 300-mm
- Quality and reliability
- Supply continuity
- Multi-sourcing
- On-time delivery

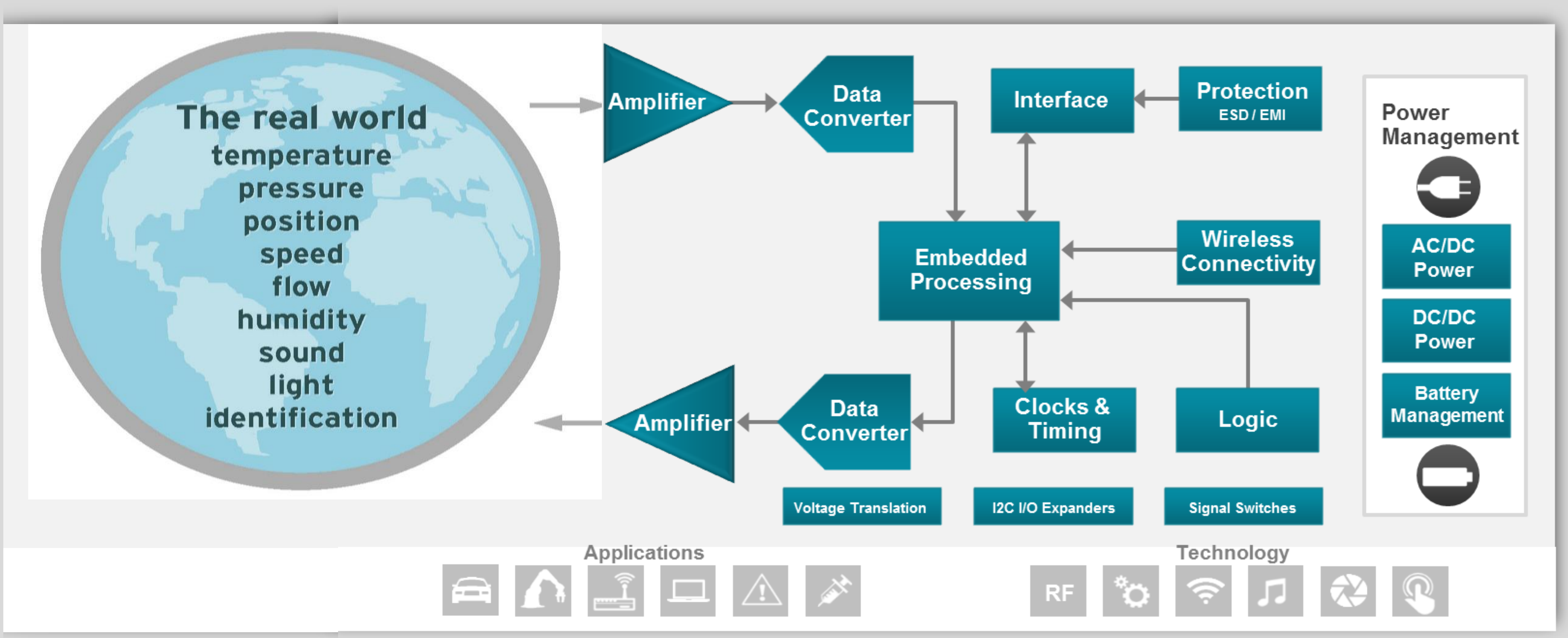
Support

- Easy part selection
- Reference designs
- Online support
- TI.com
- Training
- Technical sales and support
- TI store

Everyday electronics that use TI technology



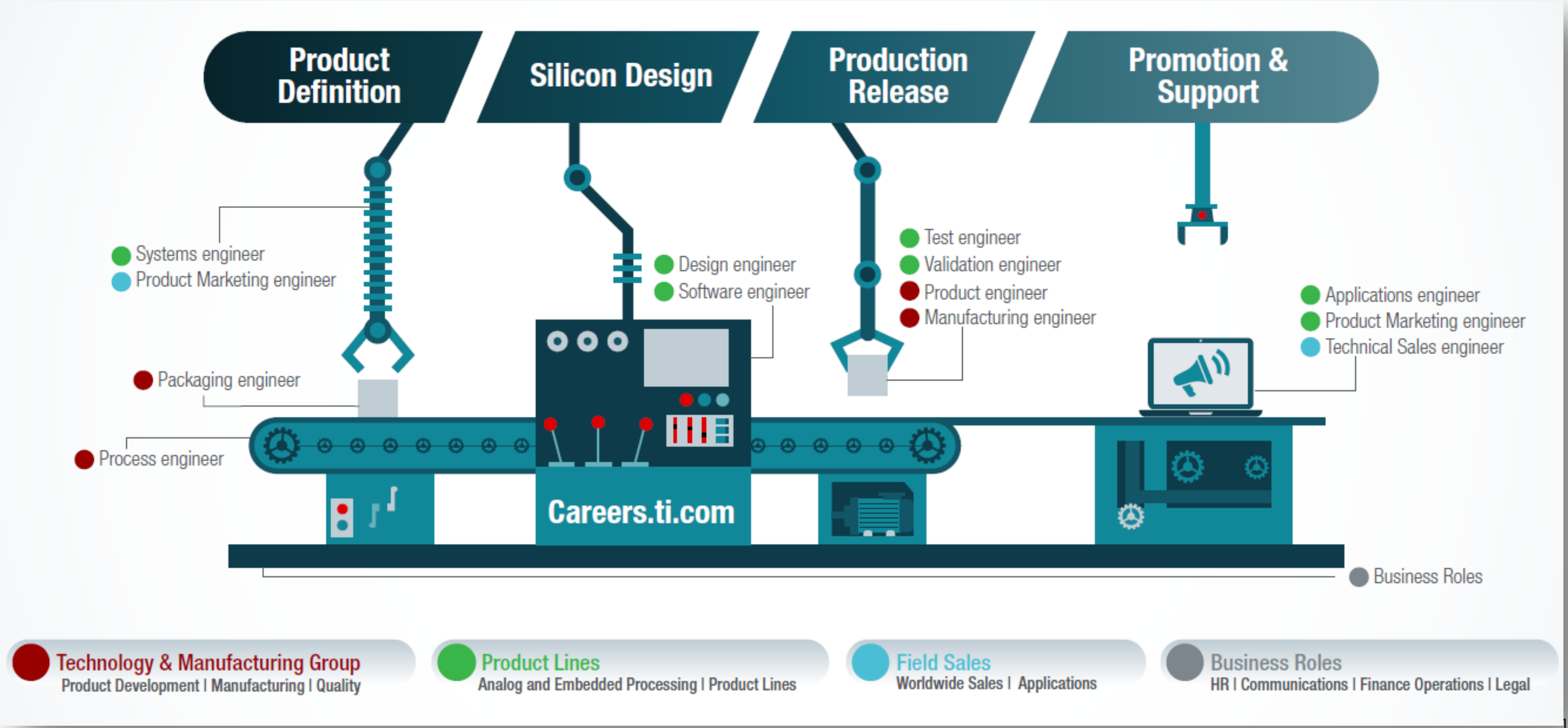
TI technologies at the heart of every system



Signal chain from the real world to the digital realm

Careers at TI

Engineering Positions at TI



We're looking for…

We're **changing** the **world,** one **chip** at a time. **Join us.**

- A top-performing student with a GPA of 3.0 or higher
- Pursuing undergraduate or graduate degree in:
  - **Electrical/Computer Engineering**
  - Computer Science
  - Chemical Engineering
  - Industrial Engineering
  - Mechanical Engineering
  - Materials Science
  - Finance/Accounting
  - Management Information Systems
  - Human Resources
  - Marketing/Communications

Engineering internship opportunities

- Applications Engineer
- Design Engineer
- Facilities
- IT
- Manufacturing Engineer
- Product Engineer
- Software Engineer
- Technical Sales
- Other engineering roles

Join a fun, collaborative environment, with flexible schedules and access to invaluable insight from TI leaders.

You dive into projects right away that **challenge** you to find creative solutions to complex problems.

Engineering New Grad Opportunities

Rotational Programs

Applications Engineer

Analog Design Engineer

Technology and Manufacturing

Embedded Processing Software Engineer

Information Technology

Product Engineer

Technical Sales Engineer

Product Marketing Engineer

Jumpstart your career!

TI's robust rotation programs provide you the opportunity to solve problems and invent solutions through a variety of hands-on, meaningful experiences from the very first day on the job. Receive personal mentorship from world-class experts, along with training and development opportunities to help you quickly make an impact at TI.

Job titles only cover a small portion of your work contributions…
Know your primary directives but expand and grow your role

Product Engineer

Design Engineer

Process Engineer

Test Engineer

Quality Engineer

SOFTWARE Engineer

Applications Engineer

Technical Sales Engineer

Systems Engineer

Validation Engineer

Product Marketing Engineer

Electronics and Semiconductor is a Global business

Chance to work in major cities across the nation and even the world!

Diverse and global workforce

More than
30,000
Employees in
35 countries

Embedded Systems create a world of possibilities that will continue to change everything

Electronics rapid prototyping with TI's broad portfolio of MCUs, analog & connectivity solutions

IoT + Automation

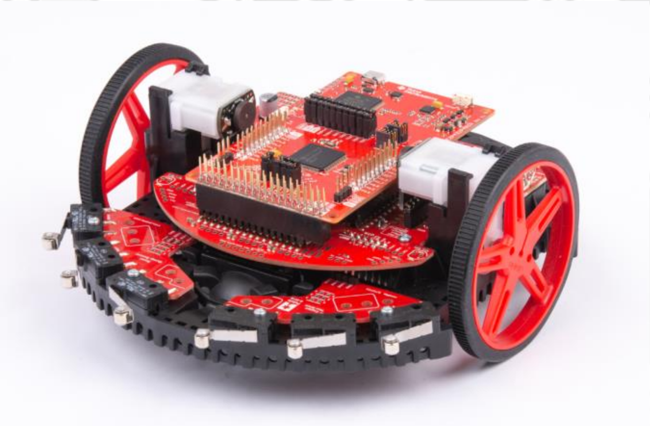
Texas Instruments

November 2019

Texas Instruments

TI-RSLK MAX

TI Robotics System Learning Kit



TI Information – Selective Disclosure

Innovate and accelerate with robotics systems learning

Robotics are everywhere!

Autonomous vehicles

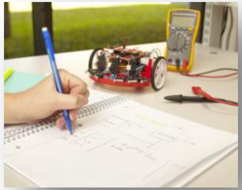
Factory automation

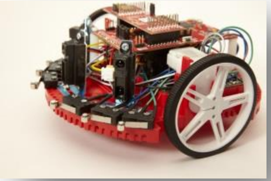
Security

Meet the TI-RSLK product family

The TI-RSLK (robotics system learning kit) product family includes a series of low-cost robotics kits and classroom curriculum that provide educators and students with hands-on, customizable options for learning electronic systems design.

The TI-RSLK includes:





Code Composer™ Studio

TI Training
training.ti.com

Curriculum	Hardware	Software	Projects	TI Resources

Introducing the TI-RSLK MAX

The newest addition to the TI-RSLK product family, the TI-RSLK MAX is simple to use, build and test.

With a solderless assembly process, students can have their own fully-functioning system built in under 15 minutes.

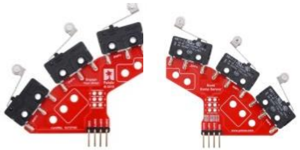
Hardware for TI-RSLK MAX (kit)

KIT CONTENTS

Cost: US$109 Teaches the foundations of an electronic system; robot can solve its way through a maze with line detection

SimpleLink™ MSP432P401R MCU LaunchPad™ Development Kit

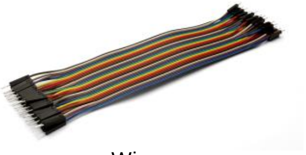
Line IR sensors



Bump switches

TI-RSLK Chassis Board

Chassis & Motor assembly with encoder



Wires

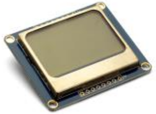
+ other mechanical & electronic components

OPTIONAL PURCHASES

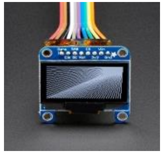
SimpleLink Bluetooth® low energy CC2650 module BoosterPack™ plug-in module

SimpleLink Wi-Fi® CC3100 wireless network processor BoosterPack plug-in module

Robot arm



LCD screen



OLED screen

Distance IR sensors

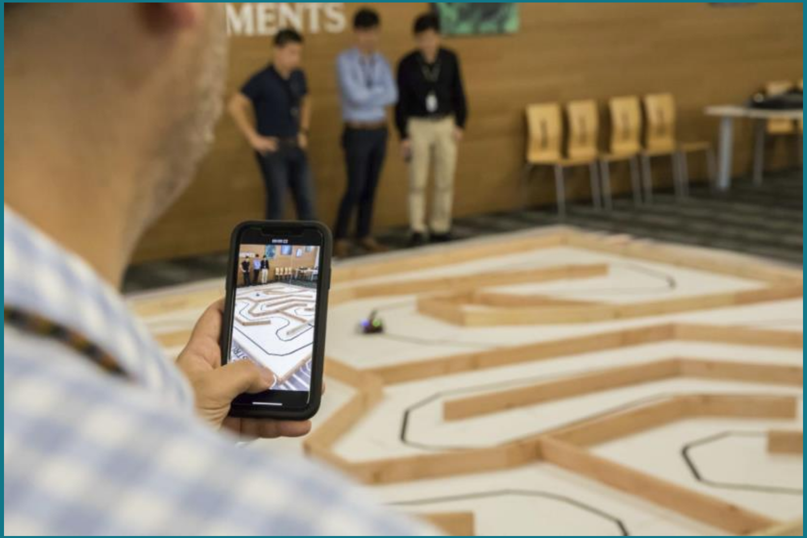
Designed with today's classroom in mind

- Low-cost makes it accessible for students to own or for classroom sets to be reused year-over-year

- Easily implemented into large classes and multiple course-types

- Works well for classrooms without access to soldering equipment.

Engage students with robotic challenges



The TI-RSLK series helps students physically grasp abstract concepts while having fun. The TI-RSLK MAX can solve a maze, line follow and avoid obstacles, and can also be designed to complete any challenge or task students dream up.

Preparing future engineers with TI-RSLK MAX

- The TI-RSLK MAX teaches systems-thinking through robotics, providing a foundation for future product design
- Provides a hands-on experience, which is proven to be more engaging and fun
- As early as freshmen year, students are seeing abstract concepts come to life in real ways
- Students prepare for their future by working as a team and using real-world engineering tools to solve problems

TI-RSLK MAX is available for purchase for $109 on the TI Store

The Rise of Electronics

From large desktop computers to tiny battery powered devices, EVERY innovation is all part of the same technology revolution

1800s-1900s

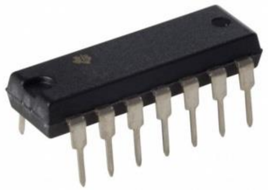
Edison & Tesla

- It pretty much always starts with the lightbulb, harnessing electricity for human applications, took lots of famous people to get to this point

1900s-1960s

Tubes, Transistors & Radio

- Electric computation and communication becomes possible and mainstream with the creation of the basic building blocks



1958

The Integrated Circuit

- Jack Kilby, a TI engineer, changed the world by inventing a practical way to shrink the size of electronics

The Rise of Electronics

From large desktop computers to tiny battery powered devices, EVERY innovation is all part of the same technology revolution

1970s-1990s

The PC Age

- Personal computers change business and productivity in every aspect of life worldwide

1990s-2010s

The Internet Age (& Mobile)

- Computers and electronics can talk to each other creating a whole new world of applications

2000s-2030s

The IoT Age

- Affordable connectivity and processing gives all electronics additional capabilities for new data driven and world changing behavior

This tech wave will have lasting effects on EVERY industry

Government Transportation Industrial Aviation

Agriculture Manufacturing Energy Retail / Ecommerce

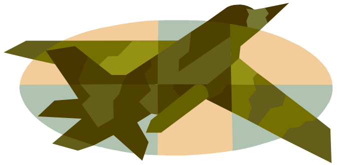
Medical Automotive Military Marine / Aquaculture

Food Real Estate Finance Construction

Opportunity to Disrupt

Definitions

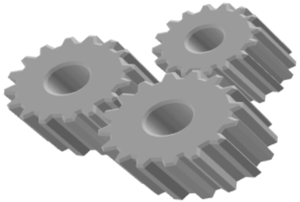
Clarity on where the fields of mechanical and electrical technical knowledge intersect



Aeronautics

Avionics

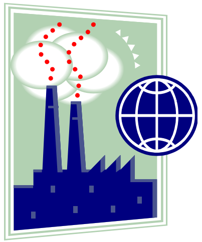
- Airplanes require many electromechanical subsystems to enable advanced flight such as lighting, communication, and safety systems



Robotics

Mechatronics

- Mobile robots that operate on land, sea, air can perform tasks too dangerous or difficult for humans or can scale beyond human capacity



Automation

Electromechanical Machines & Systems

- Application specific machines that perform repetitive mechanical tasks and are human interface driven

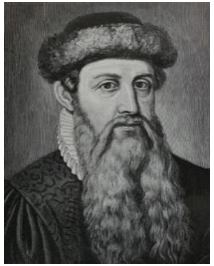
The Rise of Machines

Mechanics has been a field throughout human history and the ability to master it has built civilizations

1400s

Leonardo Da Vinci

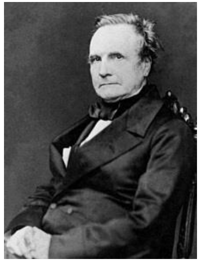
- Mechanical inventions that derive from study of the natural world and the dynamics and statics of motion and construction



1400s

Johannes Gutenberg

- The printing press is a classical machine that allowed humanity to spread ideas at a larger scale



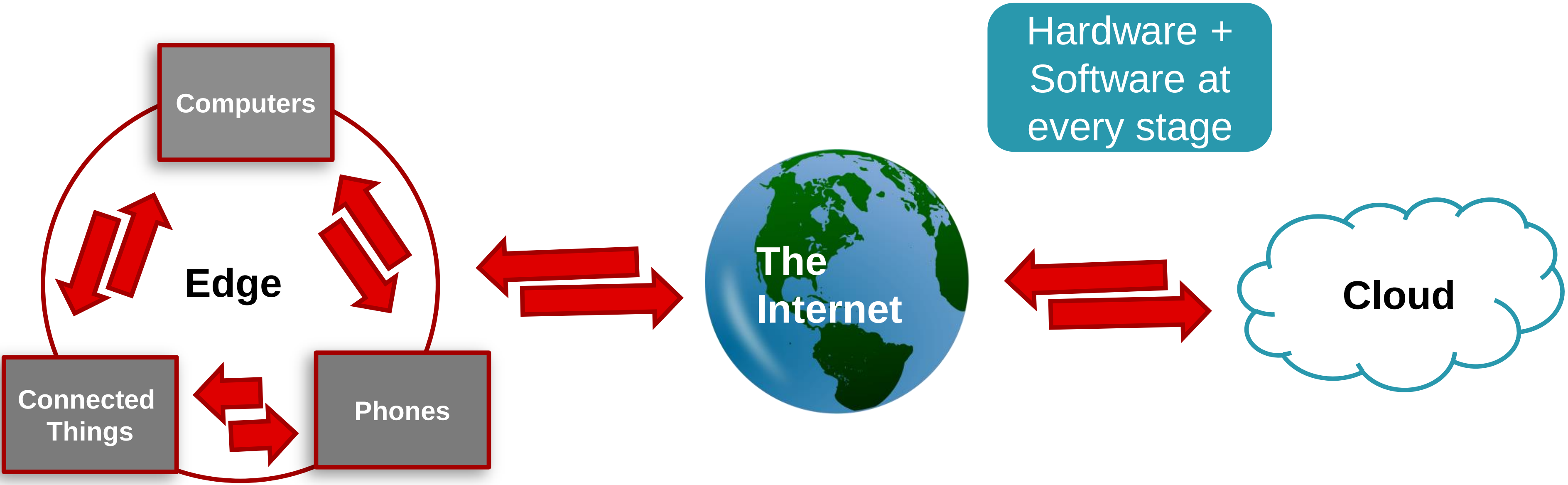
1800s

Charles Babbage

- Mechanical computer shows the concept of a programmable machine

Mechatronics + IoT
a birds eye view

IoT Data passes from physical hardware layers to software layers back and forth, connecting the real and digital worlds



Think products
- Anything that can talk to the internet or connect to something else that can talk to the internet

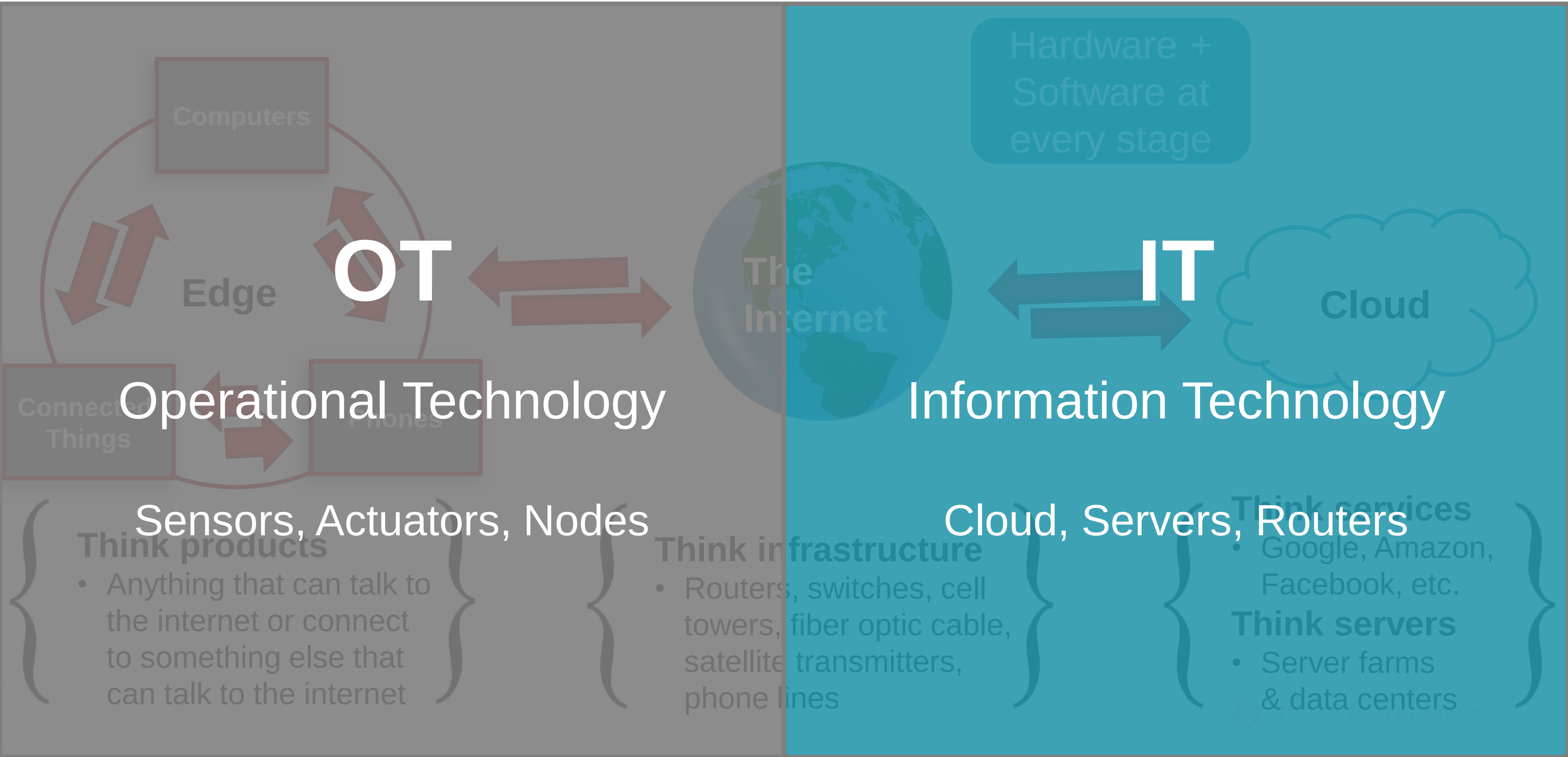
Think infrastructure
- Routers, switches, cell towers, fiber optic cable, satellite transmitters, phone lines

Think services
- Google, Amazon, Facebook, etc.

Think servers
- Server farms & data centers

The Internet of Things
a birds eye view

IoT Data passes from physical hardware layers to software layers back and forth, connecting the real and digital worlds



Product Development
a birds eye view

Hardware is hard, so you need to have a plan and understand the product development cycle

Summary from Maker.io

1 {Concept}

2 {Research}

3 {Evaluation}

4 {Design}

5 {Prototyping}

6 {Funding}

7 {Marketing}

8 {Production}

9 {Distribution}

10 {Support}

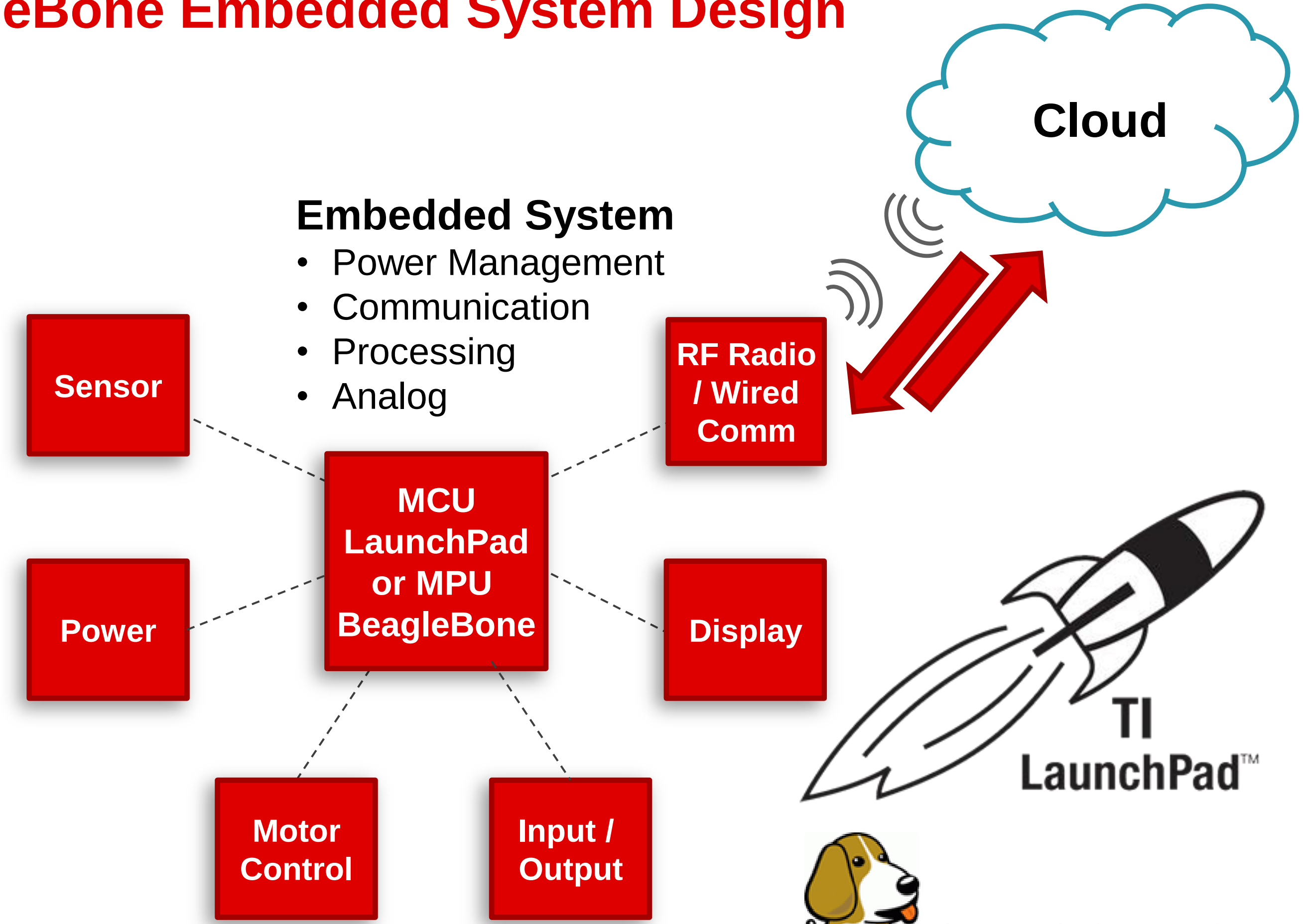
Product Development
a birds eye view

Two major tasks in design and engineering – both have value!

Optimize	Innovate
Make a process, product, or service incrementally better than previous iterations	Attempt a new process, product, or service to radically disrupt previous methods or solutions

TI LaunchPad & BeagleBone Embedded System Design
a bird's eye view

Embedded System
- Power Management
- Communication
- Processing
- Analog



Design Accessories
- Plug-in modules
- Through hole (breadboard) circuits
- Oscilloscope & logic analyzer & multimeter
- EDA / CAD tool (PCB and enclosure design)
- IDEs and SW Dev tools

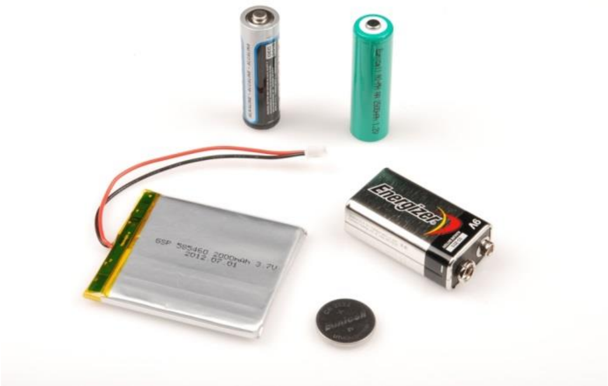
Power: Line Power vs Disposable Battery vs Rechargeable Battery
a comparison

What's the difference?

- Alkaline
- Li-Ion
- Li-Po or Li-Poly
- Lead Acid
- Nickel Metal Hydride
- Nickel Cadmium

Design Considerations

- Do I need continuous power?
- How convenient is it to recharge in the application?
- How mobile is the application?
- What is the form factor?
- What are the aesthetics and usability requirements?



Make use of tools like TI WEBENCH

Motors: Brushless vs Brushed vs Stepper
a comparison

Big portion of IoT is around intelligent movement

Make use of motor drivers and software libraries like TI MotorWare

What's the difference?

- Brushless
- Brushed
- Stepper
- AC / DC

Design Considerations

- Do I need accurate movement? (Stepper, encoders, hall effect sensors)
- Do I need high torque?
- Low complexity or high complexity control?
- Do I need high efficiency or long life?
- Do I need low cost?

Motors: Brushless vs Brushed vs Stepper
a comparison

Brushed DC

Advantages
- Cheapest and simplest motor
- Speed linear to applied voltage
- Simple Motor Control

Disadvantages
- High maintenance
- Low life-span (due to physical wear on brushes)

Brushless DC

Advantages
- High efficiency, long life
- Little to no maintenance
- High output power

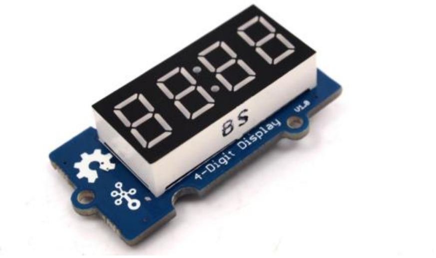
Disadvantages
- More complicated motor control
- More expensive

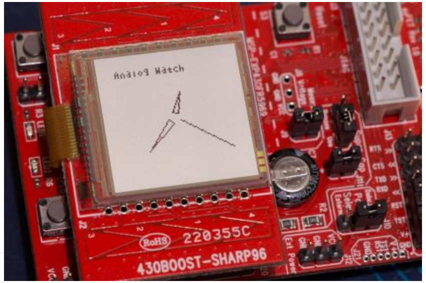
Stepper

Advantages
- Accurate position control
- Excellent low speed torque
- Long life

Disadvantages
- Low efficiency
- Prone to noise, ripple, and resonance
- Cannot accelerate loads rapidly

Displays: LCD vs OLED vs LED vs ePaper
a comparison





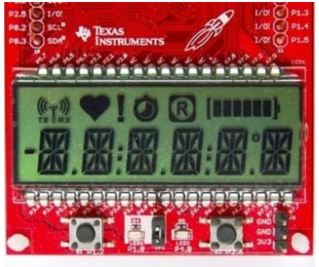
What's the difference?

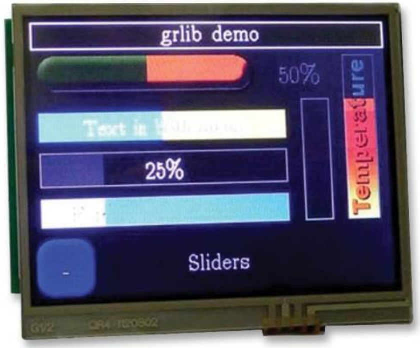
- LCD
- OLED
- LED Matrix
- LED Segment
- ePaper
- Cloud GUI, Web App, or Mobile App

Design Considerations

- Do I need color graphics?
- Does it require high refresh? Video?
- Do I need to display digits or alphanumeric?
- Does it need to be low power or battery free? Backlight?
- How will it mount in the enclosure?

Make use of display drivers and software libraries like TI Graphics Libraries





Easily add RF for wireless applications!

Which wireless?

Tradeoffs between range, bandwidth, cost, power usage, adoption

CONNECT MORE WITH TI

Wi Fi

- Ubiquitous
- High bandwidth
- Higher power usage

Bluetooth

- Common
- Small range
- Lower power
- Very low cost

(NFC / RFID)

- Super near range
- Low bandwidth
- Low power
- Low cost

SIGFOX (LPWAN)

One network A billion dreams

- Limited to certain cities
- Wider range
- Low bandwidth
- Higher cost

4G LTE (Cellular)

- Wide range
- High bandwidth
- Expensive – Data & HW

THREAD / 6LoWPAN

- Mesh networking
- Low power
- Very low cost
- IPV6 Addressable

ZigBee

- Mesh networking
- Low power
- Very low cost
- Not IP addressable

Infrared

- Line of Sight
- Low power
- Very low cost

Satellite

- Global range w/ Sat available
- Expensive – Data & HW

Proprietary

- Licensed and unlicensed spectrum with trade offs

Which wireless?

Tradeoffs between implementation effort

CONNECT MORE WITH TI

Wi-Fi

- Direct connect
- Access a wide variety of APIs directly
- Only requires domain expertise in internet and firmware
- High data rate
- Poor for mobile and rural use cases

Wi-Fi Primary Use Cases
- Smart Home
- Industrial/Commercial
- Fixed position connectivity
- Medical

BLE Primary Use Cases
- Wearable
- Phone accessory
- Streaming music
- Smart Home
- Medical

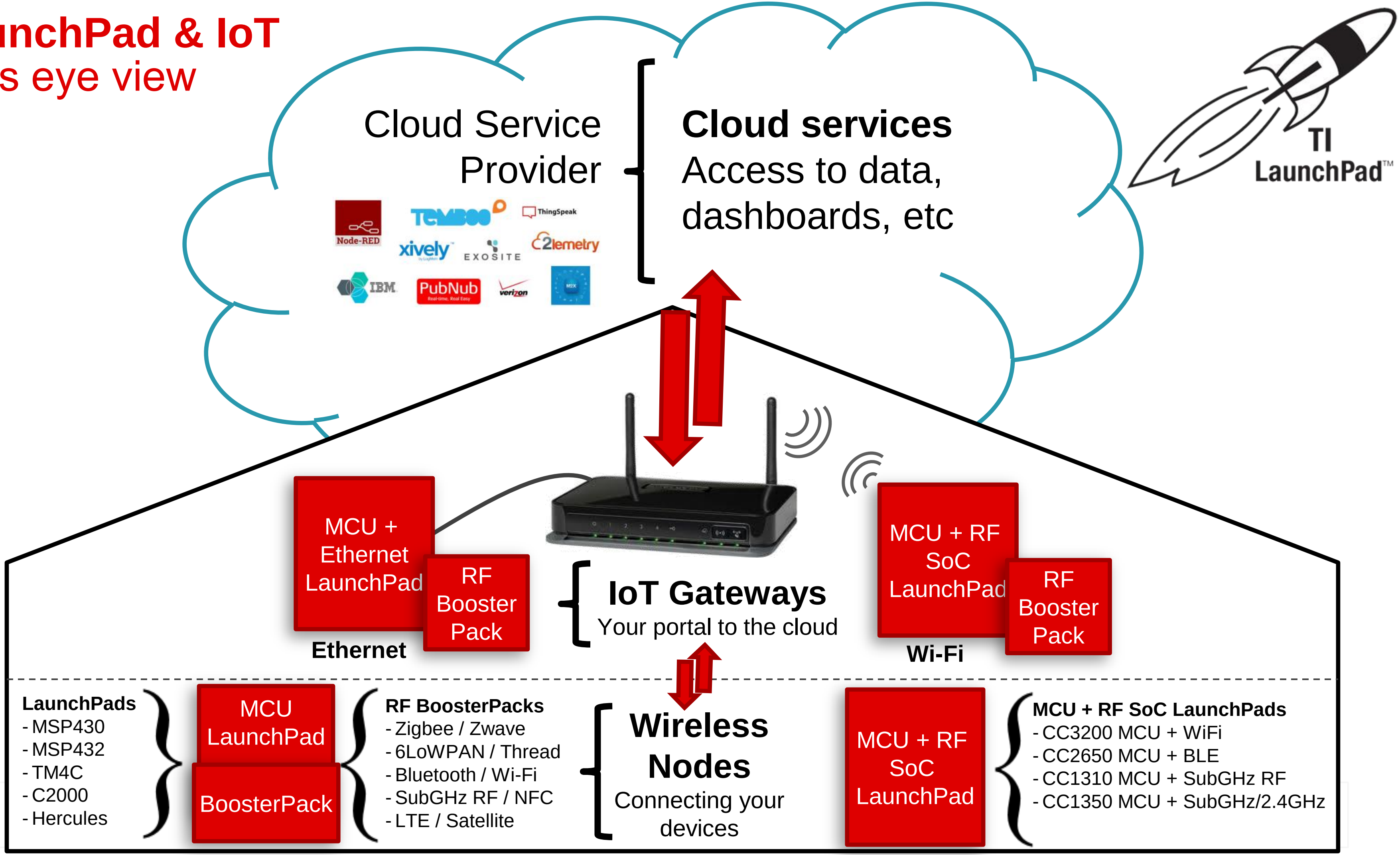
Bluetooth

- Requires a middleman gateway (Smartphone or embedded bridge)
- Everything is custom
- Need domain expertise in frontend and backend, UX, UI, firmware
- Low data rate
- Poor for crowded environment

TI LaunchPad and BeagleBone in the cloud

Cloud-connected TI Hardware is supported by various cloud partners & protocols via Wi-Fi, BLE, LTE, or Ethernet.

TI LaunchPad & IoT
a bird's eye view



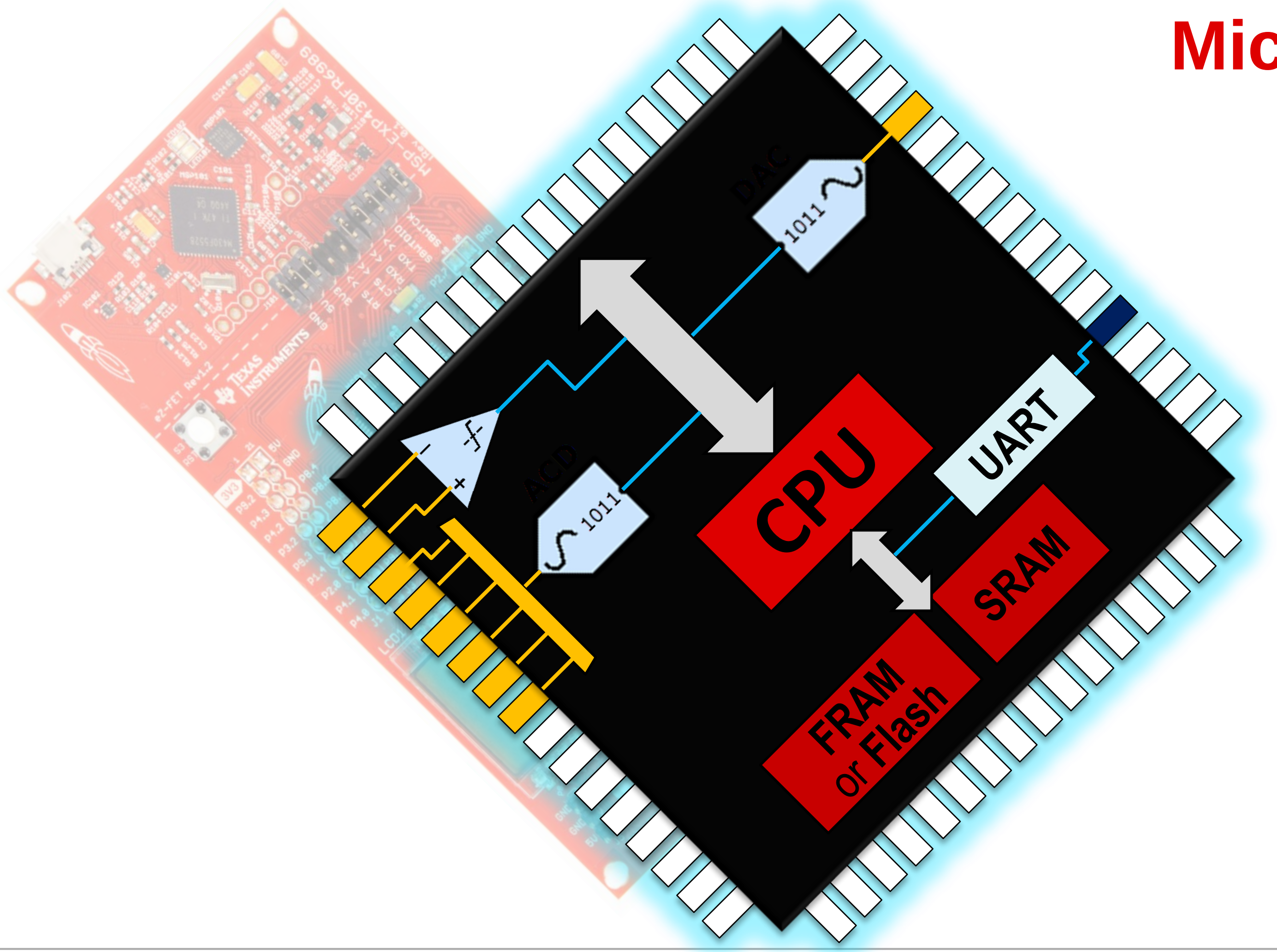
Microprocessors: Microcontrollers vs Single Board Computers
a comparison

What's the difference?
- TI LaunchPad
- BeagleBone
- Arduino
- RasPi

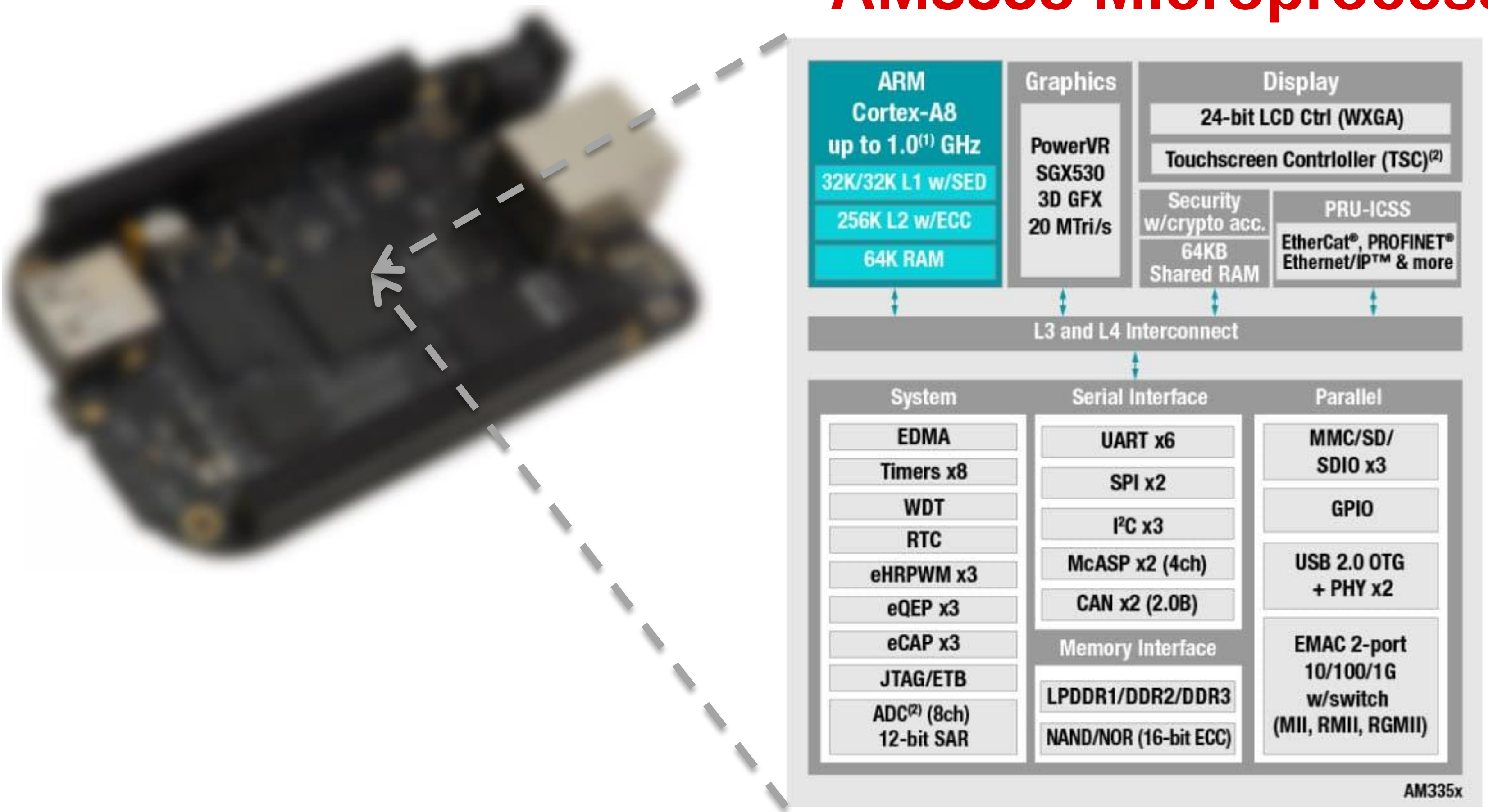
Design Considerations
- Do I need an operating system?
- Do I want it to be low cost?
- Can I program in C or do I need to use another language?
- Do I need real-time capability?

BeagleBone Black

Microcontroller



AM3358 Microprocessor



Microprocessors: Microcontrollers vs Single Board Computers
a comparison

TI LaunchPad™

Considerations:
- Power
- Integration
- Performance
- Cost

beagleboard.org

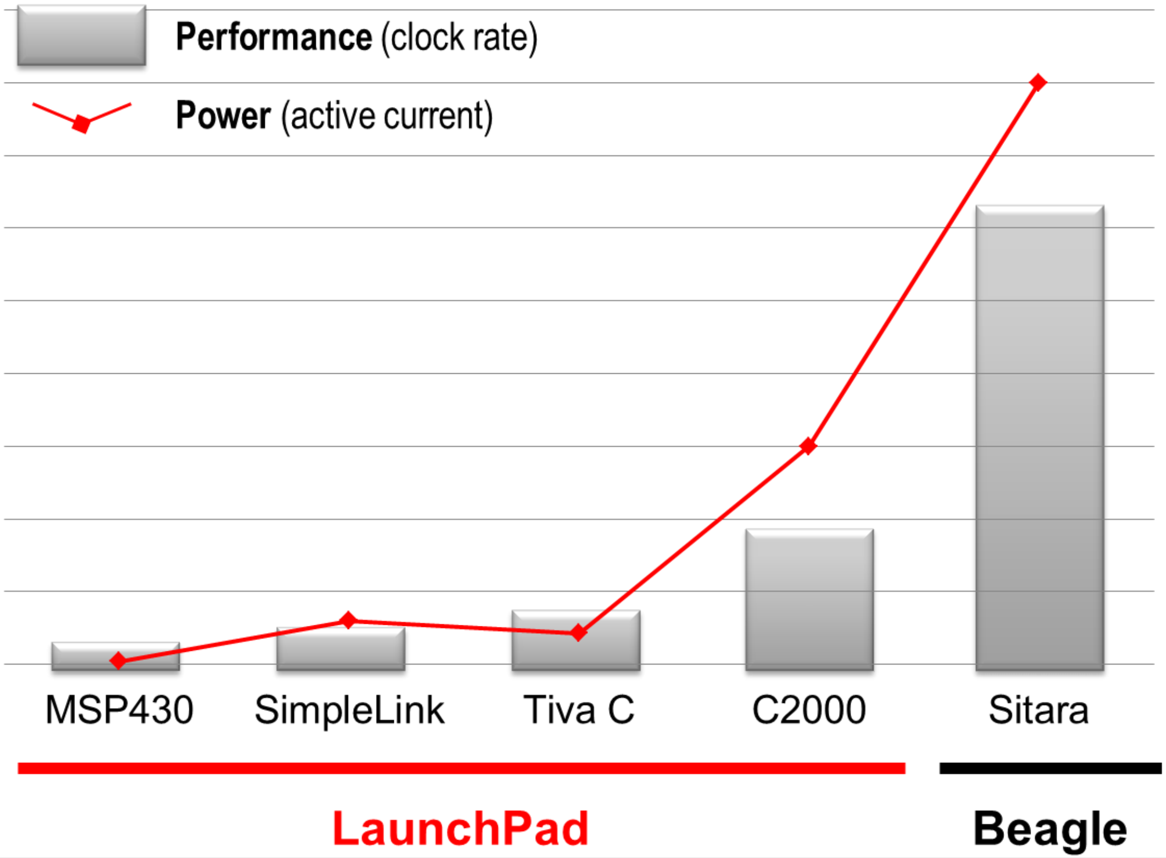
Advantages
- Overall less complex
- Overall less cost
- Overall lower power consumption
- Real-time capable

Disadvantages
- Less flexible software paths
- Less performance for computation intensive applications
- Only able to run RTOS but not full OS options

Advantages
- Overall higher performance
- Overall more peripheral capabilities
- More flexible software options and the ability to run Linux OS

Disadvantages
- More cost and complexity
- Managing Linux related updates
- Real-time capabilities often limited
- Higher power consumption

Performance vs Power



MSP430 is leading ultra-low power processor

MSP430 microcontroller running off three grapes.

It ran for almost two weeks before the grapes dried out too much.

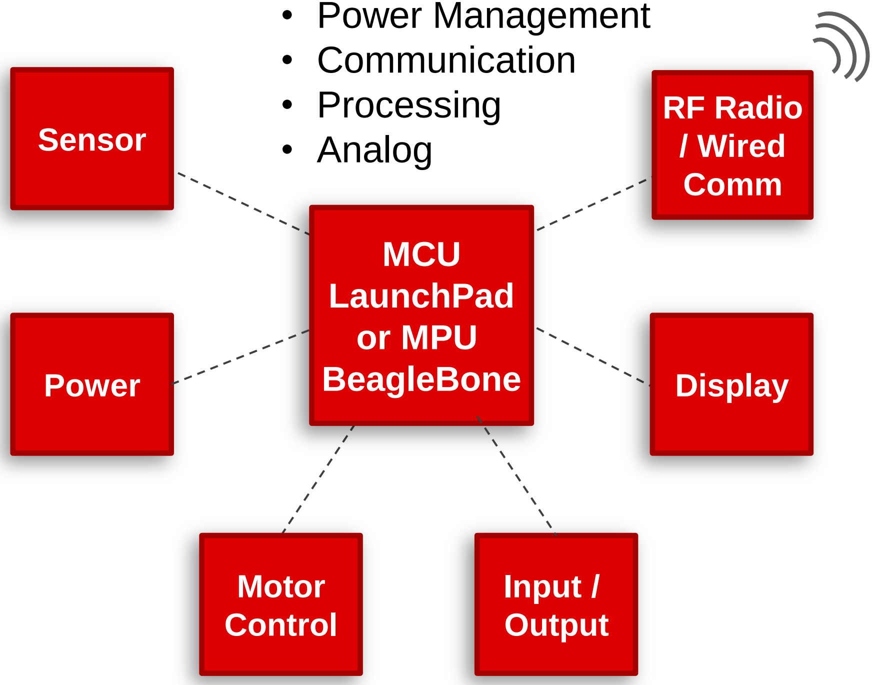
Is this how raisins are made?

TI LaunchPad & BeagleBone Embedded System Design

a bird's eye view

Embedded System

- Power Management
- Communication
- Processing
- Analog



Automation

What is it and who cares?

- **There are many reasons why automation is taking over**
  - **Efficiency and Safety**
  - **Cost savings**
  - **Technology availability and accessibility**

- This extends to all aspects
  - IoT gives us data that we can use for automation (proof it is worth the investment)
  - IoT enables automation to be scalable (can apply in many areas)

- Examples
  - Making stuff, driving stuff, delivering stuff, trading stuff, cooking stuff

Automation

Robots and Machines that learn

- **The big trend right now is in AI / ML but understand this is part of the larger theme of accelerating automation**
  - AI is not effective at real world manipulation
    - Software traditionally aids humans with work in the physical realm, but now humans are too expensive or are going beyond the limits of what is perceived as reasonable work
    - Robots and machines are an increasingly key part of the automation equation
  - Don’t forget the <u>human element</u> in any system!
    - Just because a human will do work based on various motivations doesn’t mean that is a “good” job (trucking, warehouse, industrial work, hazardous materials work, military/police)
    - Even though business demand is high, can’t overwork people and make unrealistic work-life balance

Automation

Engineering was hardware focused for centuries…

Software has seen a huge growth period over the last 20 years but now a swing back to hardware is occurring and skills in both arenas are very valuable!

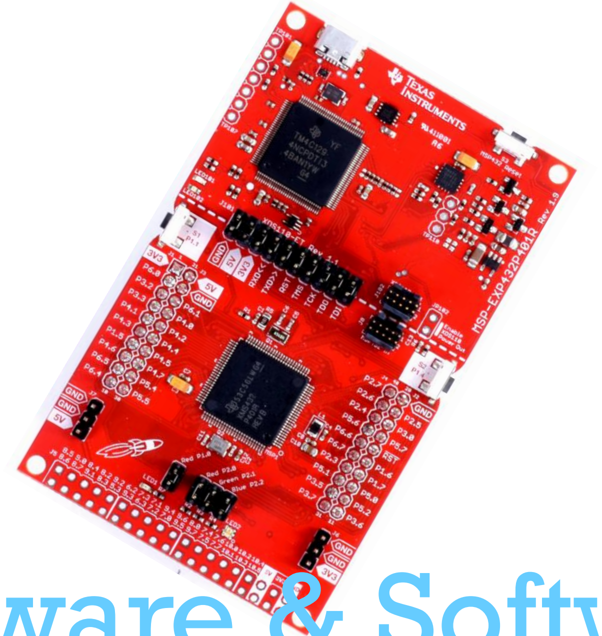
TI-RSLK MAX

TI **R**obotics **S**ystem **L**earning **K**it MAX

Making MADE simple

With the TI LaunchPad

TI LaunchPad™

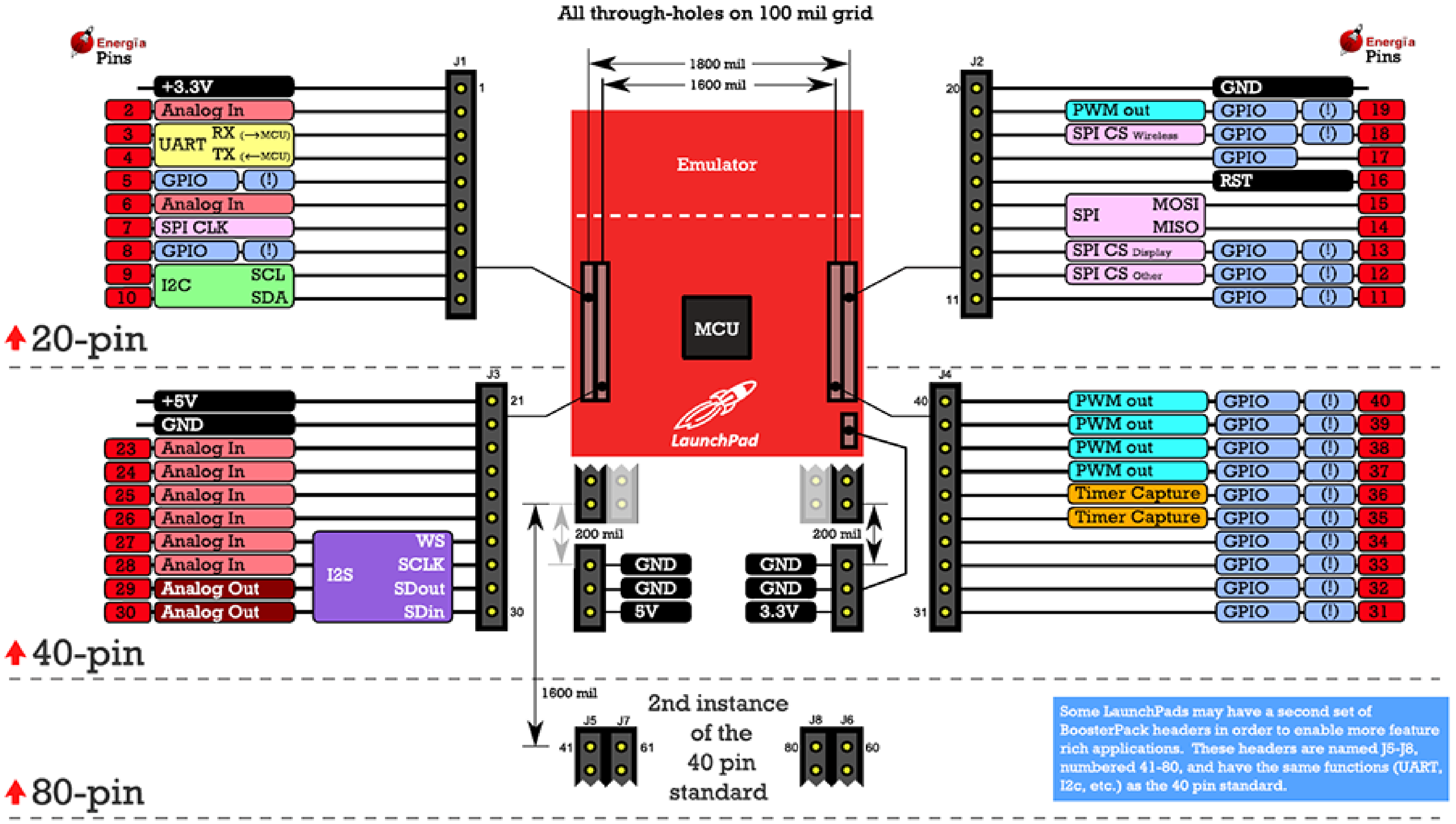
{  }

Hardware & Software

The LaunchPad Concept

Rapidly Prototype TI Solutions with Modular Hardware, Intuitive Software, & Community Support

BoosterPack pinout standard (ti.com/byob)



BoosterPack pinout standard (ti.com/byob)

The BoosterPack pinout standard enables:

- Cross-compatibility between LaunchPads & BoosterPacks
- BoosterPack stackability to create more complex solutions
- The same BoosterPack can work across multiple LaunchPads

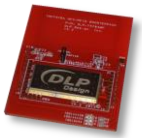
- **Learn more @ www.ti.com/byob**
- **Build your own BoosterPack (BYOB) with templates, resources & more!**

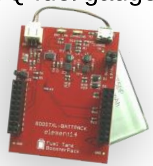
Quick demo recipes

Enable customers to experience TI differentiation

WiFi-enabled Meat Probe "iGrill". Send a tweet when temp exceeds threshold. = MSP430F5529 LaunchPad + WiFi CC3100 BoosterPack + Thermocouple BoosterPack (ADS1118)

Create a battery-powered WiFi-connected NFC/RFID tag reader = CC3200 Wi-Fi LaunchPad + NFC/RFID (TRF7970A) + LiPo Battery BoosterPack (BQ fuel gauge)





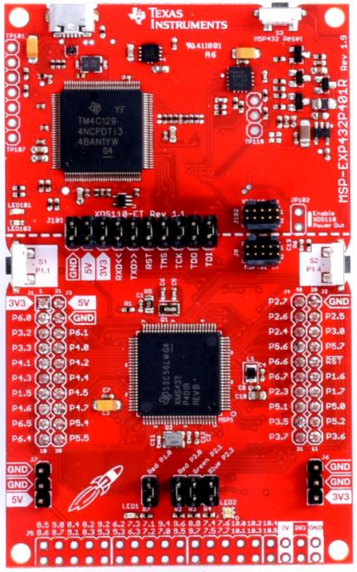
Create a multi-point SubGHz RF wireless temperature sensor network = MSP430G2553 LaunchPad + Sub-1GHz (CC110L) + MEMS Temp Sense BoosterPack (TMP006)

TI Microcontroller | *TI Wireless* | *TI Analog*

MSP432 LaunchPad

Introducing the SimpleLink MSP432P4 processor for Low Power + Performance

MSP-EXP432P401R



$19.99

Target MCU: MSP432P401R

BoosterPack Pinout: 40-pin

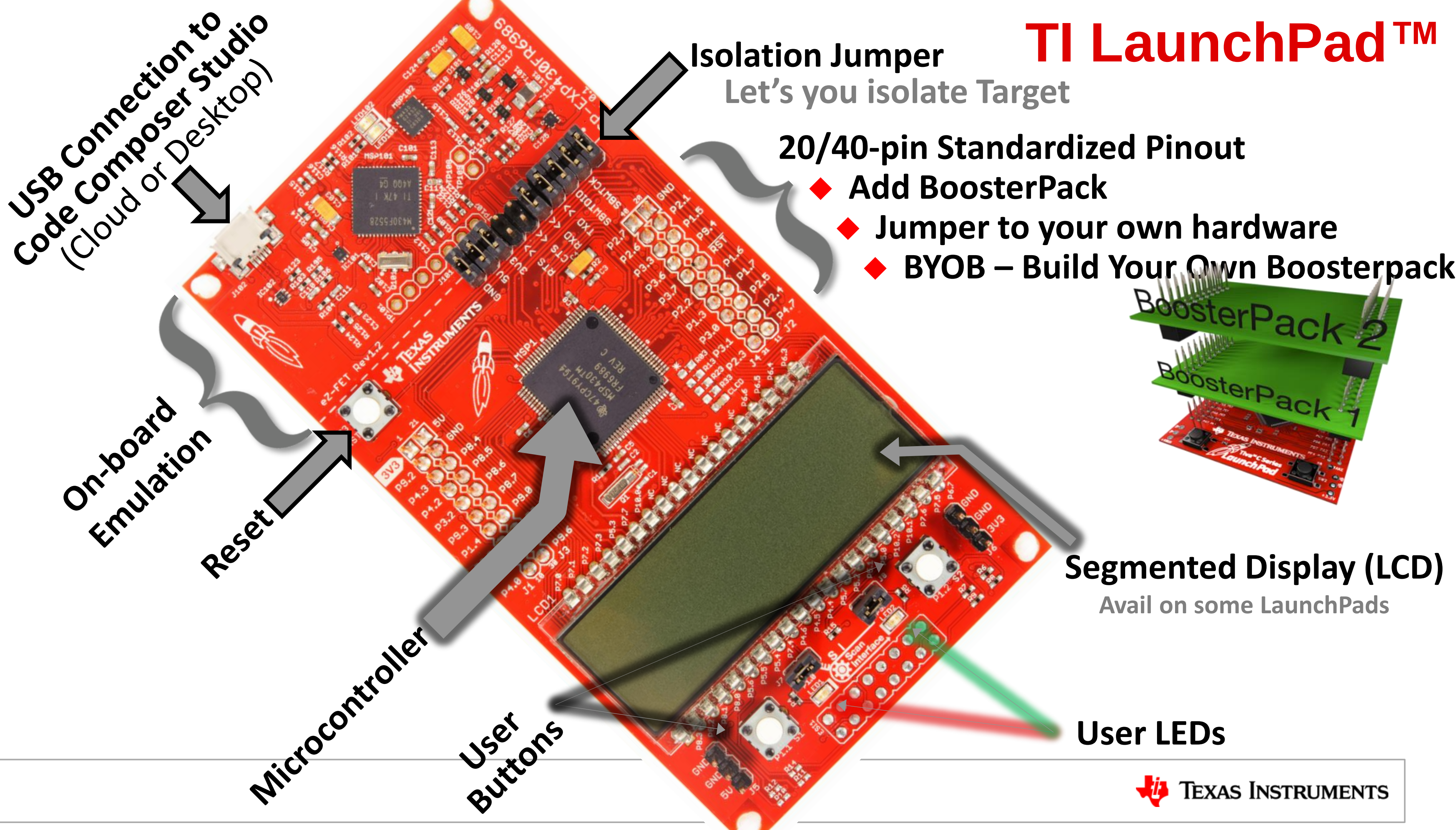
Specs:

- 48 MHz 32-bit ARM® Cortex™-M4F CPU
- 256 kB Flash / 64 kB RAM
- 14-bit 1MSPS SAR ADC, Timers, AES Accelerator, I2C, UART, SPI

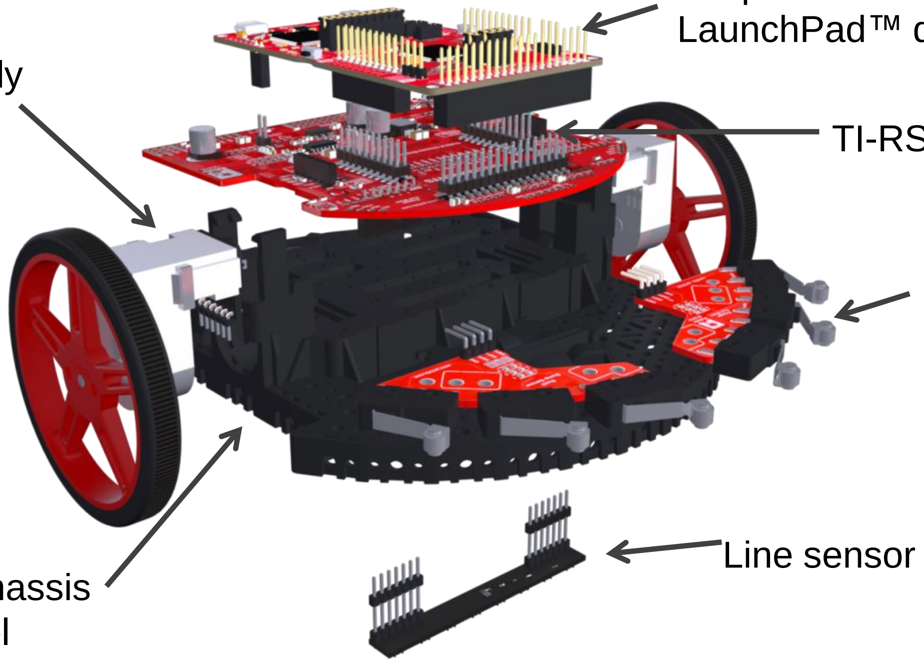
Why this LaunchPad?

- EnergyTrace+ to measure system current
- Good performance balance & great for general purpose applications

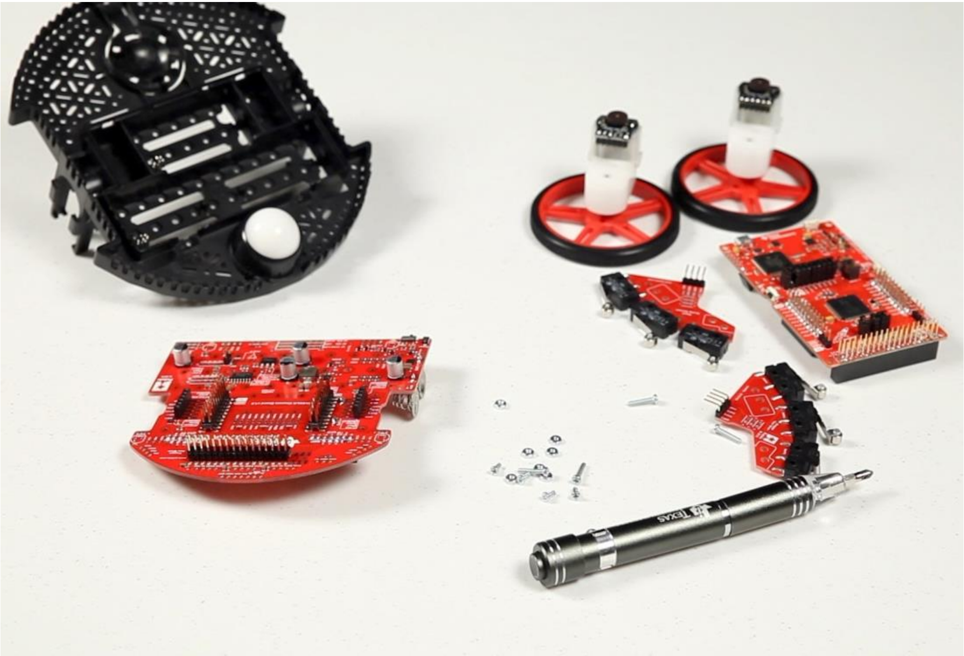
TI LaunchPad™

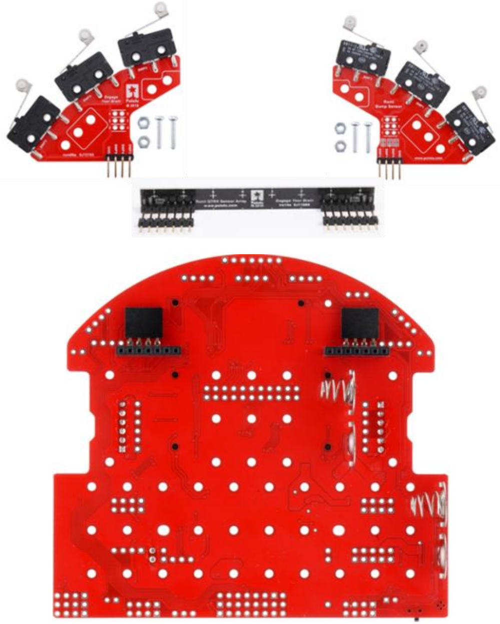


TI-RSLK MAX callouts

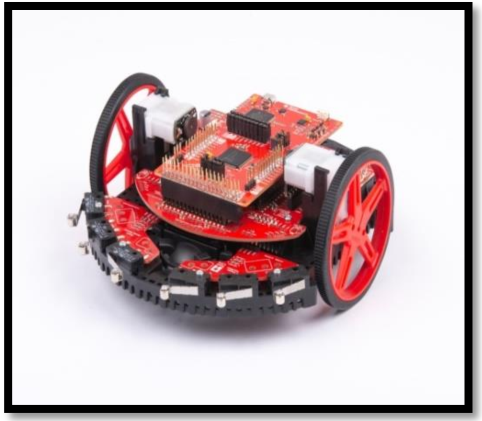


TI-RSLK MAX reusability





Using TI-RSLK MAX



<u>Programming</u>

Energia | C | DriverLib

TI-RTOS | Simplelink SDK

<u>Code Editors</u>

Code Composer Studio

CCS Cloud | Energia | IAR | Keil

Learn: Free tools to maximize hardware

- TExaS Display & GUI Debug Tool
  - Free Logic Analyzer and Oscilloscope tool available so no professional lab equipment is required
  - View the intro videos on Module 1.4 and 1.5 of the curriculum
  - GUI to visually sanity check the hardware during debugging

- Code Composer Studio
  - Industry grade Integrated Development Environment to expose students to a professional embedded software work flow
  - Local desktop (Mac, Windows, Linux) and cloud options available for maximum flexibility

- TI-RSLK Starter Code
  - Curriculum specific starter code to guide through the experience of modules

Learn: Expanded curriculum experiences

- Accessory Hardware for multiple year + multiple course investment
  - Attach new sensors, servo driven gripper arm, wireless modules, & analog circuits to keep the course fresh for students and instructors, preserve academic integrity
  - Evolve the hardware to serve breadth and depth to match introductory and advanced levels of course requirements

- Multiple Programming Possibilities
  - Teach low level C register programming, Driver Library functional programming, Arduino style abstraction programming with Energia, Real Time Operating Systems, Micropython, Rust, & more on the flexible MSP432 ARM Cortex-M4 architecture

- Flexibility for course customizations
  - Integrate course objectives around specific instrumentation or specialized topics

Module topics TI-RSLK MAX

Base | Supplemental

1 Code Composer Studio IDE	6 General Purpose Input Output Ports	11 Interfacing graphical displays	16 Tachometer
2 Voltage, Current, and Power	7 Finite State Machines	12 DC Motors	17 Control Systems
3 ARM Architecture (Assembly Program)	8 LEDs and Switches	13 PWM and Periodic interrupts	18 Serial Communications
4: Software Design using MSP432	9 SysTick Timer	14 I/O Triggered Interrupts	19 Bluetooth Low Energy - IOT
5: Build the robot	10 Debugging Real-time Systems	15 Data Acquisition	20 Wi-Fi

Learn: Inside each module

Introduction document with educational objectives, pre-requisites, references

Class Lecture slides and video

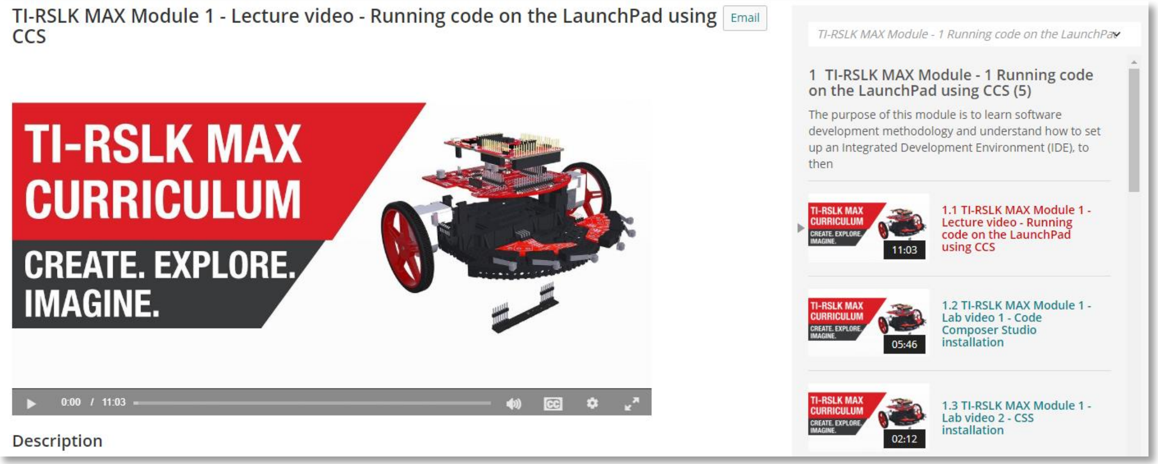
Lab document along with demo videos of completed lab

Quiz document for testing students

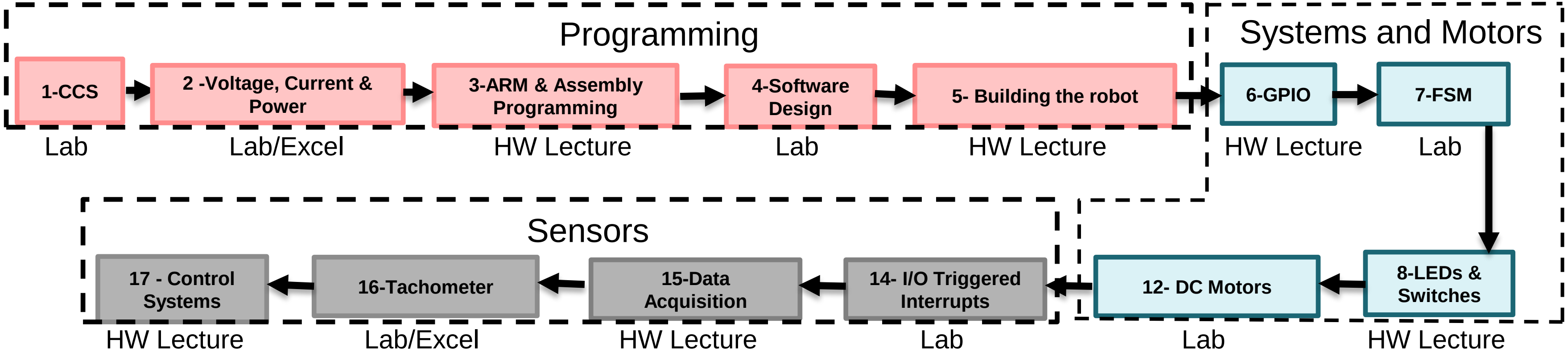
Class Activity document with homework exercises or practice problems

Learn: Video lectures

- Get personal instruction from Dr. Jonathan Valvano
- Walk through and preview lab exercises



Custom curriculum pathway



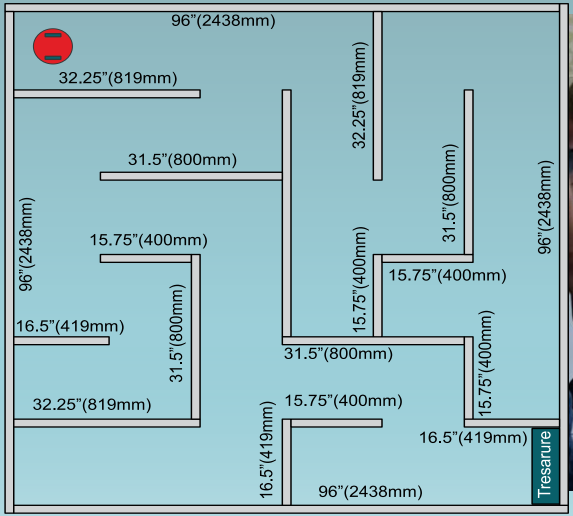
You will learn in this curriculum

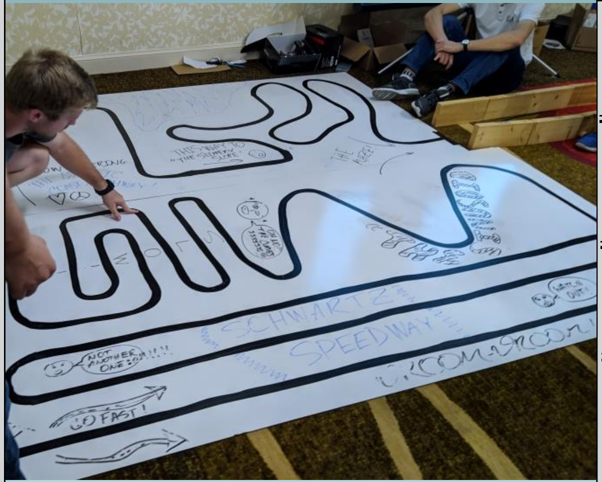
- Engineering Design Skills – Measurement, Data Acquisition, Excel data plotting, CAD Modeling, 3D Printing, soldering, wiring and documentation
- Electrical Engineering concepts – Voltage, current, power and energy
- Microcontroller C programming – PWM, ADC, GPIO and serial
- Software design and testing – Algorithms and Debugging
- Fundamental Theories- Nyquist, Central Limit, Little's
- Systems – State Machines, Controls and System Integration

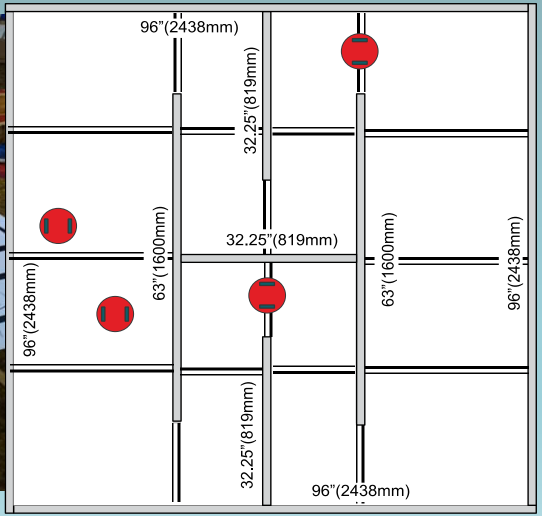
Notes

- Selected solutions could be provided to students
- Consider having some pre assembly and prep in summer to cut down on lab crowding and errors
- 3D modeling with Solidworks and printing exercises can be inserted
- MS Excel plotting can be done in lab 2 and 16

Compete: Engage students with challenges







- **Build system knowledge** from the modules in the core areas
- Create your maze or obstacle course, solve robotic challenges and compete

Department and campus wide competitions

- Create an opportunity for students to apply their engineering talent to a competition
  - Generate excitement within department or college
  - Buzzworthy content for campus news, magazine, and alum newsletters
  - Give students an outlet for creativity beyond the classroom

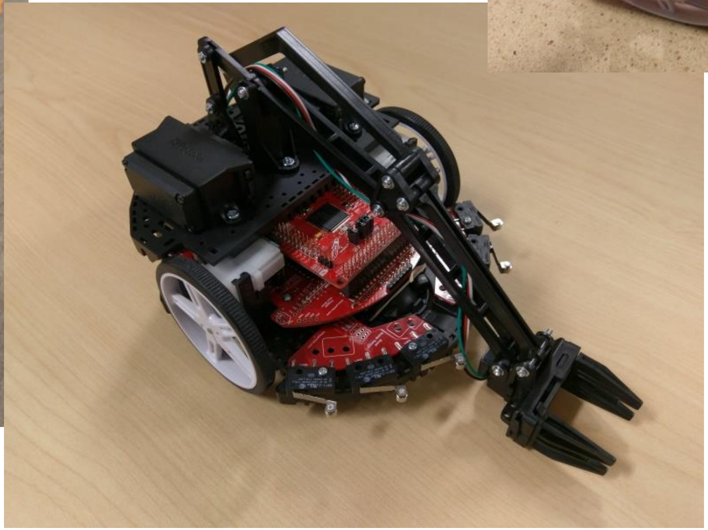
- Robot racing and time trials are easily put together at low cost and a standard platform with the TI-RSLK keeps the competition fair and accessible

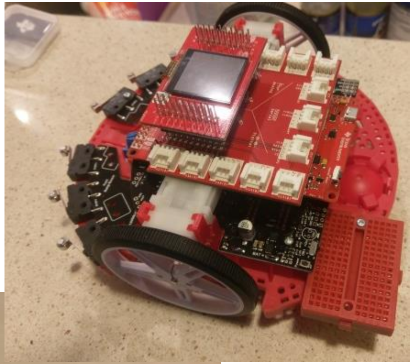
- TI can work with you around different logistics for hosting competitions

Compete: Beyond the maze!

- Obstacle Course (navigate different terrains and obstacles in confined area)
- Head to head competitions (racing, battle bots, balloon popping, team games)
- Aquatic (attach to flotation and propeller motors)
- Mobile Sensor (IoT robot measuring air quality)
- Mobile Security Platform (IoT robot measuring human detection)
- AI / Machine Learning
  - Transportation algorithms (simulate automotive traffic patterns or people movers)
  - Robotic Warehouse (swarm robotics to navigate crowded area efficiently)
  - Room traversal for cleaning tasks (robotic vacuum patterns)
- Cybersecurity and network integrity (real world cybersecurity practice)

Customize: Alternate Applications



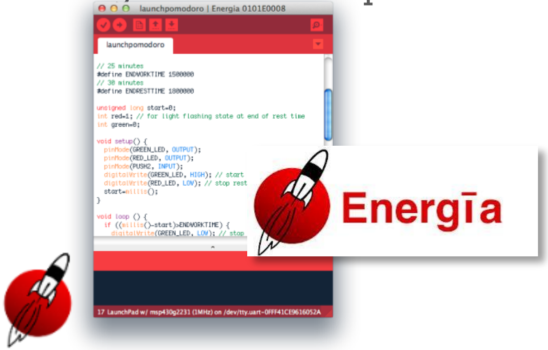


Intuitive & flexible software development paths speed up firmware creation for rapid prototyping

Rapid Prototyping

Energia

Light-weight, Community-driven, Wiring-based IDE for quick evaluation

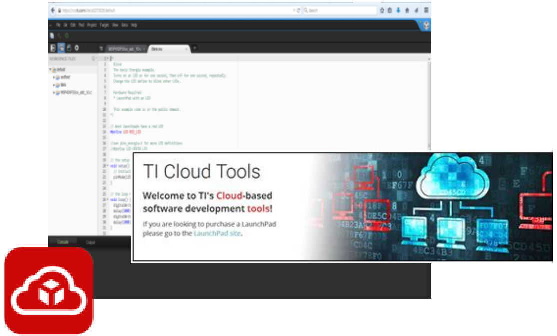


- **Intuitive coding environment**
- **Simplified interface**
- **Highly-abstracted API framework**
- **Open Source & Community-driven**

Evaluation

CCS Cloud

Browser-based code editor and Resource Explorer



- **Cross Platform**
- **Fast start & no installation**
- **Use Energia, TI-RTOS & more**
- **Resource Explorer integration**

Advanced

CCS & Pro Tools

Fully-capable dev environments from TI & third parties

- **Full debug capability & more**
- **Import Energia projects**
- **Access to third party compilers, features, and apps**

LaunchPad Software Tools - providing multiple points of entry

Energia Abstraction

Fly high above the bits & bytes

{ Boils it down to 1 line of code }

Energia

Highly-abstracted functional APIs

```
int sensorRead = analogRead(A0);  // Read analog channel A0
```

Peripheral Driver Library

Low level abstraction layer for populating peripheral registers

```
int analogRead(int  pin)
{
    ROM_SysCtlPeripheralEnable(SYSCTL_PERIPH_ADC0);
    ROM_GPIOPinTypeADC((uint32_t) portBASERegister(port),  digitalPinToBitMask(pin));
    ROM_ADCSequenceConfigure(ADC0_BASE, 3, ADC_TRIGGER_PROCESSOR, 0);
    ROM_ADCSequenceStepConfigure(ADC0_BASE, 3, 0, channel | ADC_CTL_IE | ADC_CTL_END);
    ROM_ADCSequenceEnable(ADC0_BASE, 3);
    ROM_ADCIntClear(ADC0_BASE, 3);
    ROM_ADCProcessorTrigger(ADC0_BASE, 3);
    while(!ROM_ADCIntStatus(ADC0_BASE, 3, false)) {
    }
    ROM_ADCIntClear(ADC0_BASE, 3);
    ROM_ADCSequenceDataGet(ADC0_BASE, 3, (unsigned long*) value);
    return value[0];
}
```

Low-level C Code

Each TI microcontroller peripheral is defined by a collection of registers

GPIO Registers:

- GPIODIR
- GPIOAFSEL
- GPIODR2R
- GPIOAMSEL

ADC Registers:

- ADCEMUX
- ADCSSPRI
- ADCSSMUX0
- ADCSSCTL0
- ADCSSOP0
- ADCACTSS
- ADCISC
- ADCPSSI
- ADCSSFSTAT0
- ADCSSFIFO0

0 1 1 0 1 0 1 0 | 0 1 1 0 1 0 1 0

0 1 1 0 1 0 1 0 | 0 1 1 0 1 0 1 0

TI Microcontroller

Control MCU hardware & peripherals

TI-RTOS and FreeRTOS

- The use of Real-Time Operating Systems (RTOS) is getting more common for IoT firmware deployment
- A simple operating system can schedule tasks and do a variety of functions
- RTOS helps with maximizing power efficiency, implementing security, managing wireless communication, and other complex functions
- Improves software quality and portability

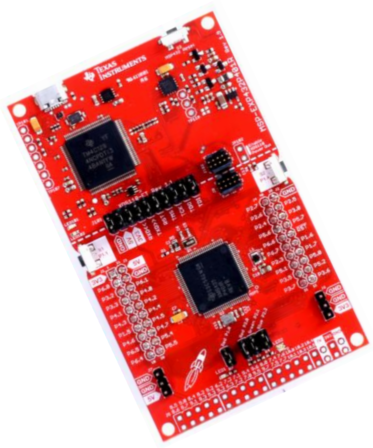
- Many free and open source options available today with TI RTOS and FreeRTOS recommended for TI devices

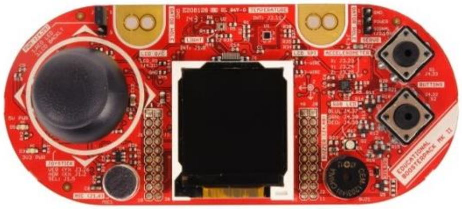
Download TI-RTOS at ti.com/tool/ti-rtos

RTOS & embedded: Getting started hardware

Complete take home lab experience!

- MSP432 LaunchPad™ (MSP-EXP432P401R)
- Educational BoosterPack MKII (BOOSTXL-EDUMKII)





The Community

Get support from TI & the online community!

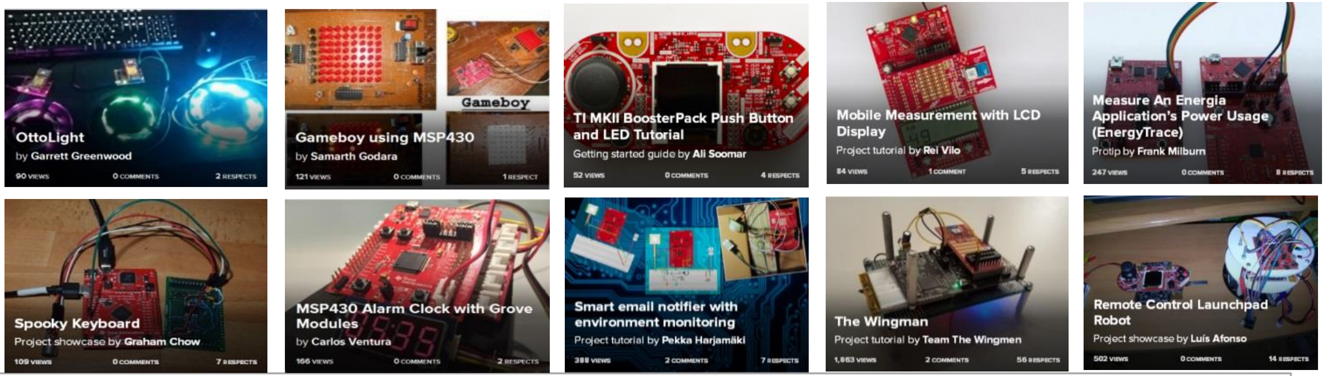
- http://e2e.ti.com
- Supported 24/7 by TI engineers!
- Over 1 million Q&As available on-demand
- Get support on TI's complete portfolio from microcontrollers to analog to connectivity

TI E2E™ Community

www.ti.com/diy
www.hackster.io/texasinstruments

- Share your electronics projects!

hackster.io



Thank you!

www.ti.com/rslk
www.ti.com/launchpad
(TIRSLK-EVM kits orderable from TI Store)

TI-RSLK MAX

Create, Explore, Imagine

Powered by LaunchPad

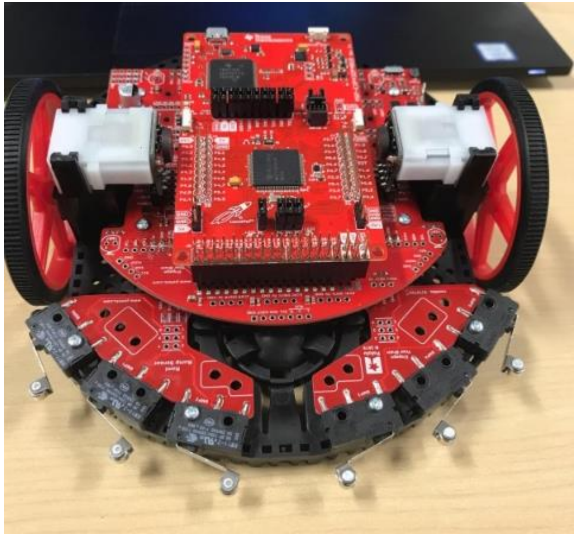
TEXAS INSTRUMENTS

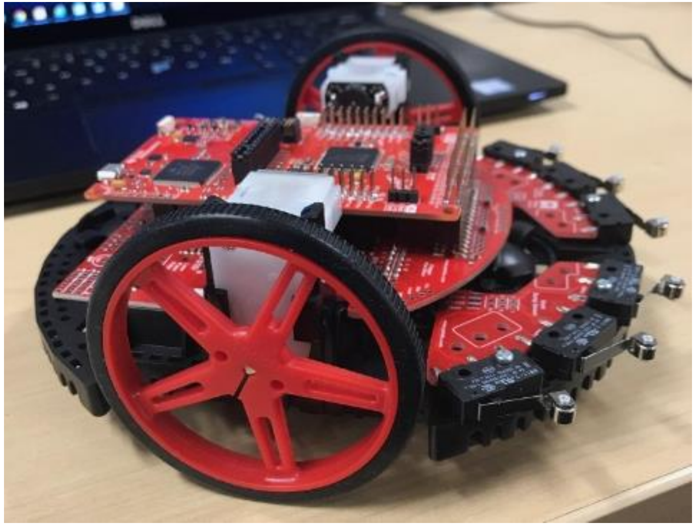
Today's agenda

- IoT and Automation
  - What? Why? How?
- **TI-RSLK MAX Build & Test**
  - Watch assembly video, build, use TI-RSLK Debug tool, customize appearance
- TI-RSLK MAX Programming
  - Setup Energia and robot library
  - Practice Line following and Finite State Machine
- TI-RSLK MAX Competition
  - Solve the maze time trial
  - Autonomous relay race

Workshop Materials

- TI-RSLK MAX





Human Machine Interaction

Does it feel responsive?
Does it feel like magic?

Active Control

- Human physically interacts with machine or system
  - Buttons
  - Touch screen
  - Wired or wireless Controller
- Has to be responsive
  - Quick reactions to input
  - Graphical indicators
  - Light, sound, or haptic indicators

Passive Control

- Machine or system automatically performs tasks
  - Requires minimal Human input
  - Leverages real world sensors or incoming data to make decisions
- Leads to poor user experience if interaction model is broken
  - E.g. Automatic door doesn’t open

Which philosophy is Amazon Echo? Xbox? Nest Thermostat?

Lab 1 Assemble TI-RSLK

Lab:
tinyurl.com/tihknworkshop2019

We will break here and get started with the hardware!

- Step 1: Watch the assembly video carefully
- Step 2: Follow build instructions at www.ti.com/rslk
- Step 3: Go to the RSLK debug tool in Chrome at www.ti.com/rslkdebugtool
- Step 3: Install the TI Cloud agent and browser extension
- Step 4: Test your robot for functionality
- Step 5: Customize the look of your robot

Today's agenda

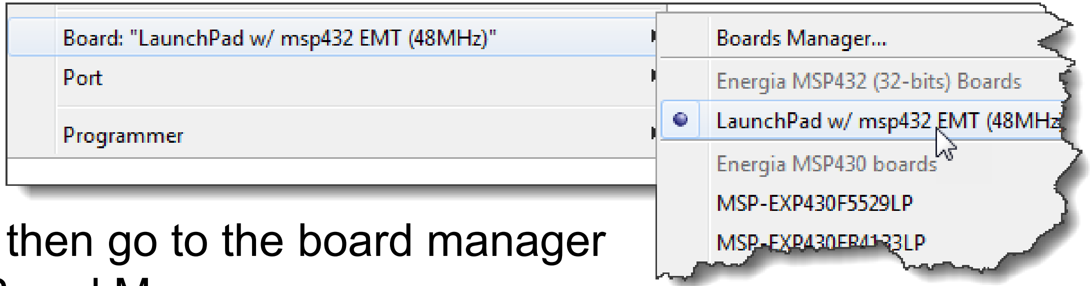
- IoT and Automation
  - What? Why? How?
- TI-RSLK MAX Build & Test
  - Watch assembly video, build, use TI-RSLK Debug tool, customize appearance
- **TI-RSLK MAX Programming**
  - Setup Energia and TI-RSLK MAX library
  - Practice Line following and Finite State Machine
- TI-RSLK MAX Competition
  - Solve the maze time trial
  - Autonomous relay race

Lab 2 Install Energia and library

Lab:
tinyurl.com/tihknworkshop2019

We will break here and get started with the hardware!

1. Download the Energia Installer and install
2. Start Energia and select your LaunchPad "LaunchPad w/ msp432 EMT (48MHz)" from *Tools* menu.



3. If LaunchPad isn't available, then go to the board manager to install – Tools > Board > Board Manager…
4. Create your free accounts at: [my.ti.com](my.ti.com)

Lab 2 Energia Introduction

Lab: **tinyurl.com/tihknworkshop2019**

- Step 1: Click the upload button and make sure your Red LED is blinking
  - If not or you get errors during compile, your system is not properly setup and you will not be able to proceed, so seek assistance from instructor or neighbors
  - If yes, then you can now test the integrated LCD screen
- Step 2: Open Dancing Robot example mentioned in the lab details
- Step 3: Click the upload button. You can use the pushbuttons and see results. Test it out!
- Examples are located in the IDE, click File > Examples > Robot Library

Lab 2 Energia Introduction

Lab: **tinyurl.com/tihknworkshop2019**

- Step 4: test the line following capability on the line following track
  - Calibrate your line sensor by running it on the line, it will go forward and then back, then click the button again to start it
- Step 5: test the state machine code on the wall track or use your kit boxes to create your own obstacles
- Step 6: Add additional logic to improve the line following speed and usability
- Step 7: combine the line following with the state machine to create a robot that can handle walls and lines

LaunchPad with MSP432P401R

Energia

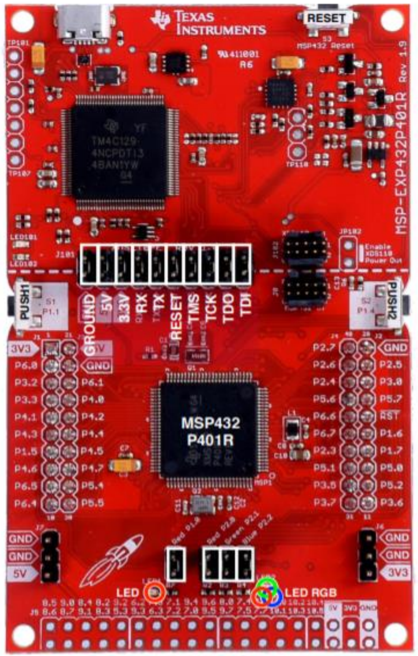
Revision 2.0

Flash	256	KB
SRAM	64	KB

Serial		hardware
ADC	14	bits
Use pins numbers only!		
Default I²C = (1)		
I²C (1) master only		

Hardware
Pin number
Other pin number
I²C
Serial UART
SPI
analogRead()
digitalRead() and digitalWrite()
digitalRead(), digitalWrite() and analogWrite()

RXD	
TXD	



J5	
41	56
57	72

Bumpers	CC2650	CC3100				J1	J3			Bumpers	Motors	Others	IR
	+3.3 V	+3.3 V		+3.3V		1	21		+5V				
	MRDY			A15	P6_0	2	22		GROUND				
	RX	RX		RX (1)	P3_2	3	23	P6_1	A14				DISTC
	TX	TX		TX (1)	P3_3	4	24	P4_0	A13	BMP0			
		nHIB		A12	P4_1	5	25	P4_2	A11	BMP1			
BMP2				A10	P4_3	6	26	P4_4	A9			Scope	
	SCK	SCK		SCK	P1_5	7	27	P4_5	A8	BMP3			
BMP4				A7	P4_6	8	28	P4_7	A6	BMP5			
			SCL (1)		P6_5	9	29	P5_4	A1		DIRL		
			SDA (1)		P6_4	10	30	P5_5	A0		DIRR		
									GROUND				
									GROUND				
									+5V				

CC2650	CC3100	Motors			J4	J2				Motors	CC3100	CC2650
		PWML		P2_7	40	20		GROUND			GROUND	GROUND
		PWMR		P2_6	39	19	P2_5				IRQ	SRDY
				P2_4	38	18	P3_0		CS		WiFi /CS	BLE /CS
	CTS			P5_6	37	17	P5_7					
	RTS			P6_6	36	16		RESET				LPRST
/RESET				P6_7	35	15	P1_6	SDA (0)	MOSI		MOSI	MOSI
	NWP TX			P2_3	34	14	P1_7	SCL (0)	MISO		MISO	MISO
	WLAN TX		A4	P5_1	33	13	P5_0	A5		ERB		
				P3_5	32	12	P5_2	A3		ELB		
		nSLPL		P3_7	31	11	P3_6			nSLPR		
			GROUND									
			GROUND									
			+3.3V									

Motors	PWMx	PWM signal
	DIRx	Direction
	nSLPx	/Sleep
Bumpers	BMPx	Bumper
Encoders	ELA	Encoder Left A
	ELB	Encoder Left B
	ERA	Encoder Rigth A
	ERB	Encoder Rigth B

73	P1_1	PUSH1
74	P1_4	PUSH2
75	P2_0	RED_LED
76	P2_1	GREEN_LED
77	P2_2	BLUE_LED
78	P1_0	YELLOW_LED

embeddedcomputing.weebly.com
Version 3.3 2018-11-14

Lab 3 Autonomous Mechatronics

We will break here to get to the heart of the competition portion!

- Step 1: Navigate to the lab details or refer to handout
- Step 2: Follow the instructions for setting up your robot chassis
- Step 3: Follow the lab details
- Step 4: Raise your hand if you need assistance

Lab: **tinyurl.com/tihknworkshop2019**

Competition

Maze Solving

- Traverse the line following and wall maze sections as quickly as possible
- Fastest time wins

Relay Race

- Race in a straight line, detect the wall, turn 180 and race back to the start line, detect the wall, turn 180 and race the final stretch
- Fastest time to complete three legs or furthest distance completed wins

Lab: **tinyurl.com/tihknworkshop2019**

Lab 4 Wi-Fi IoT Control (Optional)

We will break here to get to the bonus lab portion!

- Step 1: Navigate to the lab details or refer to handout
- Step 2: Follow the instructions for the Wi-Fi example
- Step 3: Follow the lab details
- Step 4: Raise your hand if you need assistance

Lab: **tinyurl.com/tihknworkshop2019**

SSID: **rslk1**

PASS: **rslkwifi**

Wi-Fi Connection for your LaunchPad, not your laptop, thanks!

Competition

Remote control race

- Race in a straight line, round the object, and race back to the start line
- Fastest time wins

Lab: **tinyurl.com/tihknworkshop2019**

RTOS kernel workshop

- https://training.ti.com/ti-rtos-workshop-series
- Covers getting started with TI-RTOS and guts of the OS
- How it interacts with the hardware

SimpleLink™ SDK training

- https://training.ti.com/introduction-simplelink-sdk
- Covers SimpleLink Software Development Kit basics
- How the SDK relies on RTOS to deliver its features

SimpleLink Academy training

- Covers tutorials on getting started with TI Hardware with numerous topics touching on RTOS

EdX course: Real-Time Bluetooth networks

- https://www.edx.org/course/real-time-bluetooth-networks-shape-the-world

- Taught by professors at University of Texas Austin
- Comprehensive, self paced, hands-on course on RTOS and IoT

MSP432 training

- https://training.ti.com/msp432-low-power-high-performance-mcus-training-series
- Covers MSP432 architecture and peripherals

- https://training.ti.com/msp430-workshop-series
- Online workshop compatible with MSP432P401R

MSP432 textbooks

- https://university.ti.com/en/faculty/teaching-materials-and-classroom-resources/embedded-learning-materials
- Many print resources available for the MSP43x chipset

Power and analog

Comprehensive supplemental learning!

- TI-PMLK www.ti.com/pmlk
- Power Design videos https://training.ti.com/introduction-power-topologies
- Power Supply Design Training https://training.ti.com/psds
- Power Supply Design Seminars http://www.ti.com/ww/en/power-training/login.shtml
- TI Precision Labs https://training.ti.com/ti-precision-labs-overview

DSP

Comprehensive supplemental learning!

- TI DSP Textbooks https://university.ti.com/en/faculty/teaching-materials-and-classroom-resources/embedded-learning-materials?category=digital-signal-processing
- Latest DSP Boards
  - OMAPL138 (TMDSLCDK138) + XDS200 FET Tool (TMDSEMU200-U)
  - C2000 LAUNCHXL-F28379D
- Lower performance DSP options
  - MSP432 and other ARM Cortex M devices
  - MSP430FR5994 with LEA