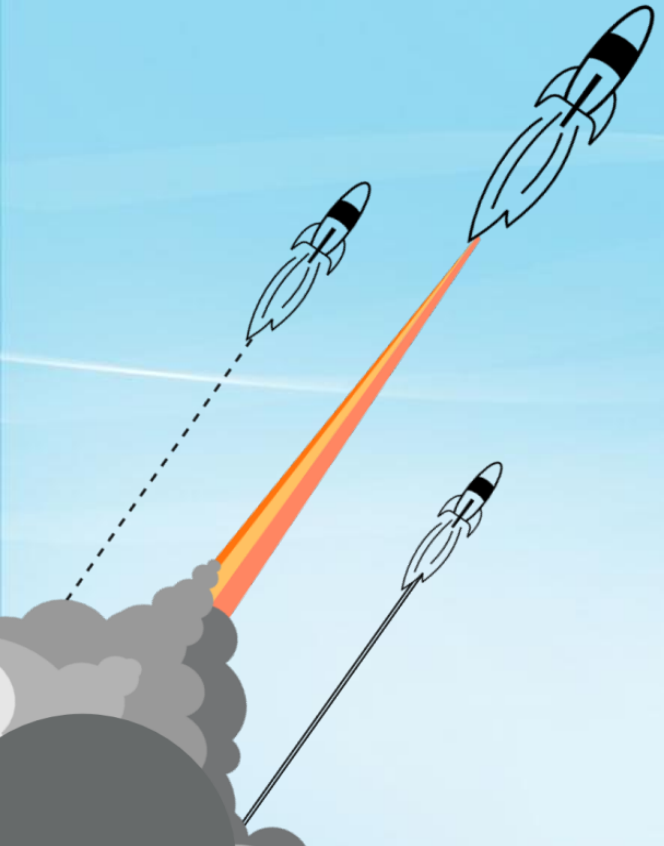


TI LaunchPad™ Ecosystem: Modular and affordable microcontroller development tools for rapid prototyping

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

Internet of Things Workshop

Texas Instruments

January 2018

Wi-Fi & BLE &

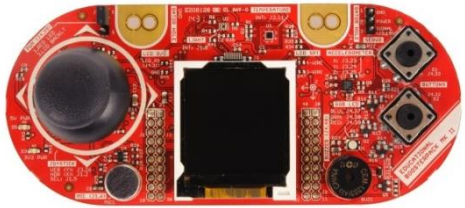
Sub-1GHz

Texas Instruments

For the greatest crash course on IoT and electronics you've ever done?

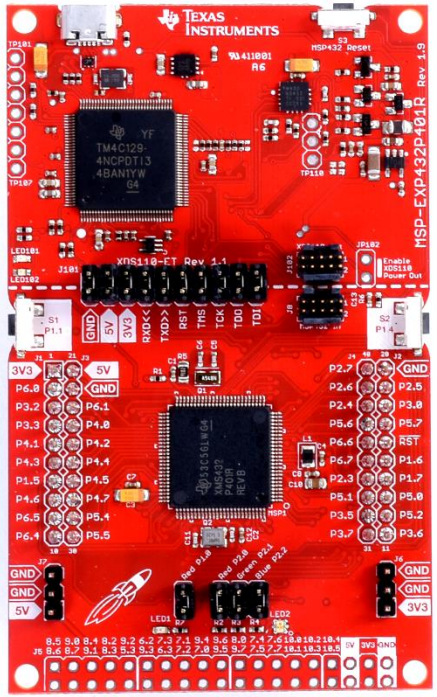
Wi-Fi Workshop Materials

- MSP432 LaunchPad (MSP-EXP432P401R)
  - Alternative: MSP-EXP430FR5994, MSP-EXP430F5529LP, EK-TM4C123GXL
- CC3100 Wi-Fi BoosterPack (CC3100BOOST, CC3100MODBOOST)
- Educational BoosterPack MK II (BOOSTXL-EDUMKII)



MSP432P401R LaunchPad

Introducing the SimpleLink MSP432 processor for Low Power + Performance



$12.99

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

MSP-EXP432P401R

SimpleLink™

MCU Platform

One environment.
Unlimited potential.

Texas Instruments

TI SimpleLink™ MCU Platform

We're building a cohesive developer ecosystem around our **ARM®-based SimpleLink microcontrollers (MCUs) and Network Processors**, revolving around a single SDK & powerful tool suite enabled by TI & partners.

Scalable Ultra-Low Power MCU Portfolio
of ARM-based MCUs & Network Processors.

Wireless solutions
Wireless SoCs, Stacks & certified solutions available

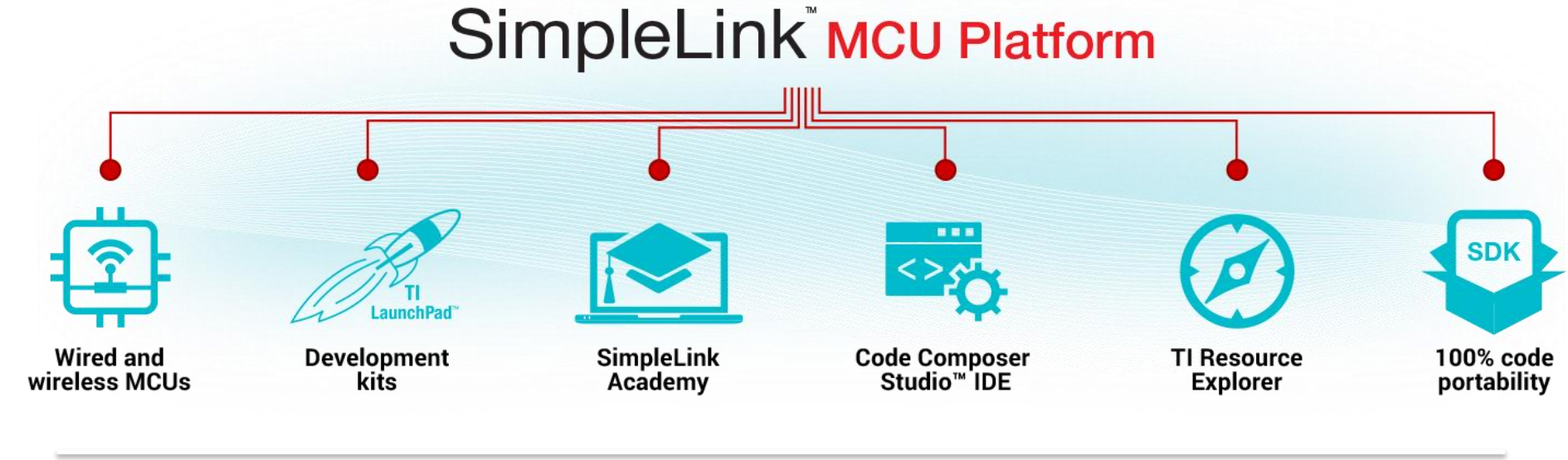
High precision analog integration
Best-in-class 14-bit 1Msps ADC w/ultra-low-power consumption

Comprehensive Tool Suite
TI & 3rd party IDEs, utilities & code generation tools

ONE SDK
Enabling 100% code re-use & portability.

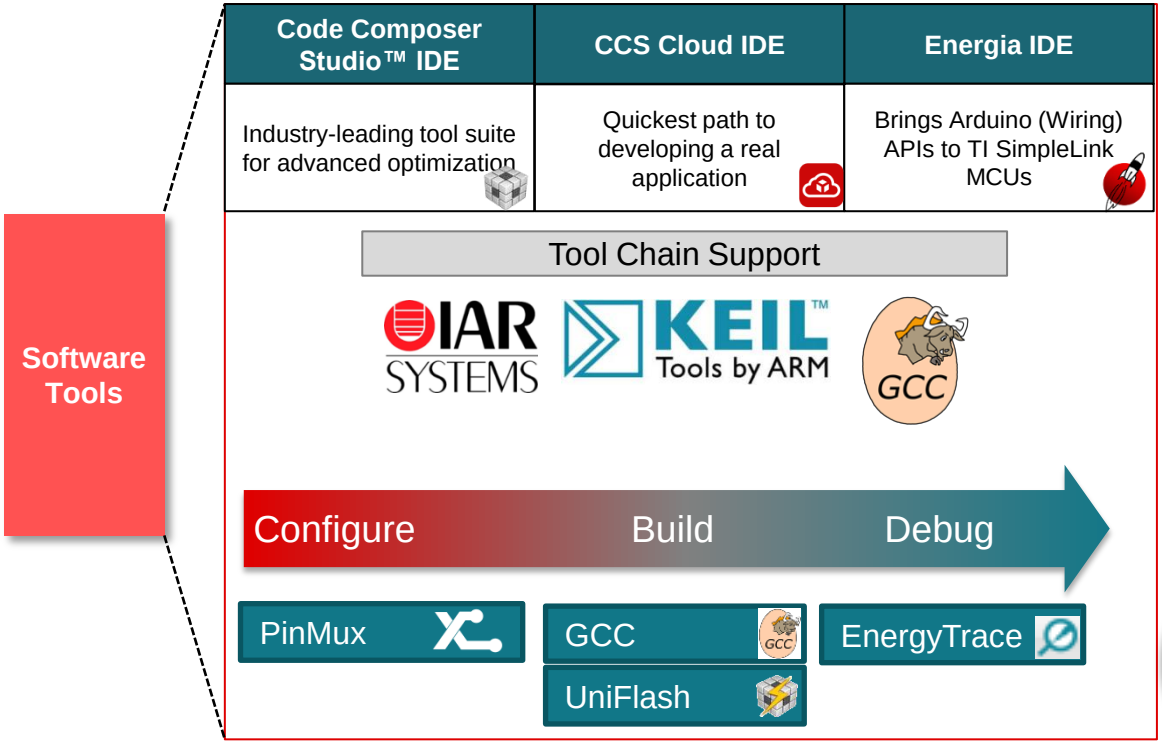
LaunchPad™ Kits
Low cost, modular hardware dev kits.

Everything you need is one click away with TI Resource Explorer
All of your development resources in one place.

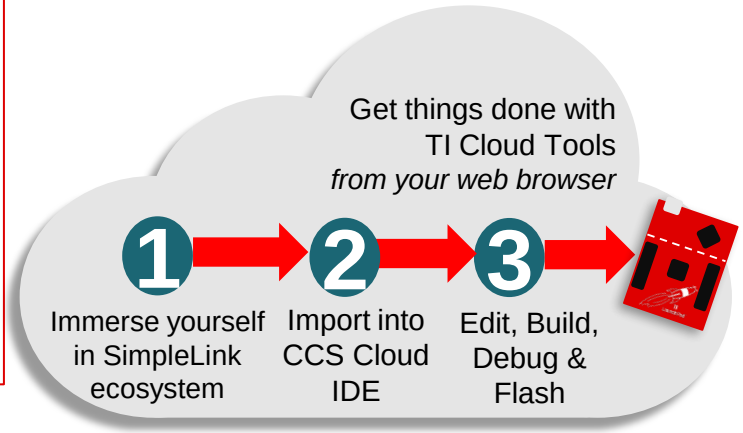


Unified experience to speed up customer time to market and manage IoT product life cycle

TI SimpleLink™ SDK Software Tools



- Multiple toolchain options to match your development needs
  - TI CCS, CCS Cloud, Energia
  - Local & Cloud-based access
  - Add'l toolchains supported: IAR, KEIL, GCC

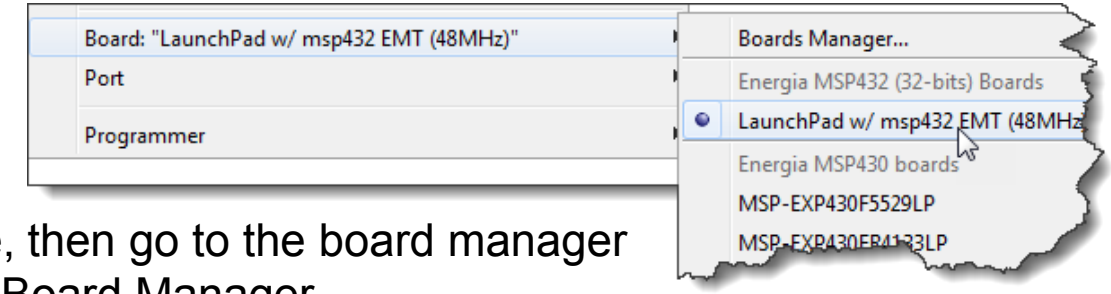


Wi-Fi Workshop Pre-work

Lab- https://goo.gl/**VbymuW**

We will break here and get started with the hardware!

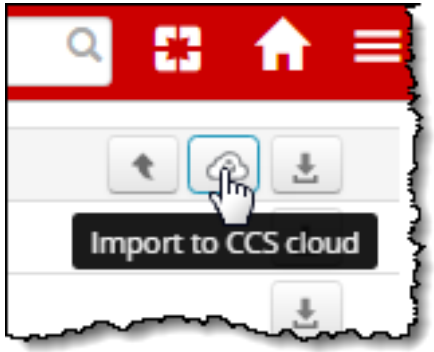
1. Download Energia from www.energia.nu
2. Unzip Energia to “install” it
3. Start Energia and select your LaunchPad “LaunchPad w/ msp432 EMT (48MHz)” from *Tools* menu.



4. If LaunchPad isn’t available, then go to the board manager to install – Tools > Board > Board Manager…
5. Create your free accounts at: my.ti.com and temboo.com

Lab 1 CCS Cloud & MSP432 LaunchPad Out of Box

1. Open TI Resource Explorer Cloud from dev.ti.com Lab- https://goo.gl/**VbymuW**
2. Find the *Out-of-Box Experience* (OOBE) for **MSP-EXP432P401R – Rev 2.x (Red)**
3. Import OOBE into CCS Cloud
   (You will need to log into
   my.ti.com to access the IDE)



4. Build the OOBE project (using hammer icon)
   and then click on “Run” to download the program to the LaunchPad (see LED blink)
5. Click back over to the TI Resource Explorer window and select:
   Out-of-Box Experience GUI
6. Connect the GUI to the LaunchPad (“Connect” button)

Lab 2 Energia Introduction with Blink and the EduBP

We will break here and get started with the hardware!

Lab:
https://goo.gl/**VbymuW**

- Step 1: Install Energia IDE from www.energia.nu
  - Alternative use the CCS Cloud IDE from dev.ti.com
- Step 2: Install any OS specific drivers associated with your TI LaunchPad
- Step 3: Plug in your TI LaunchPad board with the included USB cable
- Step 4: Open Energia IDE and adjust your preferences as necessary
- Step 5: Open basic test example - click File > Examples > Basics > Blink
- Step 6: Select your LaunchPad board or install board package – click Tools > Board
  - If LaunchPad is not MSP430 then go to the board manager to install – Tools > Board > Board Manager… and install your package from the menu. Select your specific LaunchPad from the list after installation.

Lab 2 Energia Introduction with Blink and the EduBP

- Step 7: 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 Educational BoosterPack
- Step 8: Open EDUBP example mentioned in the lab details
- Step 9: Click the upload button. You can use the joystick and see results on the LCD. Test it out!
- Step 10: There are additional examples for the BoosterPack that you can try if you have extra time, however we will be moving on quickly. They are documented at www.energia.nu/edumkii
- Examples are located in the IDE, click File > Examples > EducationalBP_MKII

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

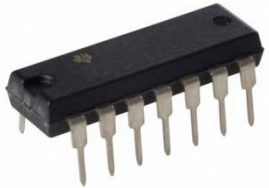
Edison & Tesla

- 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

Join the IoT revolution!

See the World!

Build a new industry!

IoT will change your life!

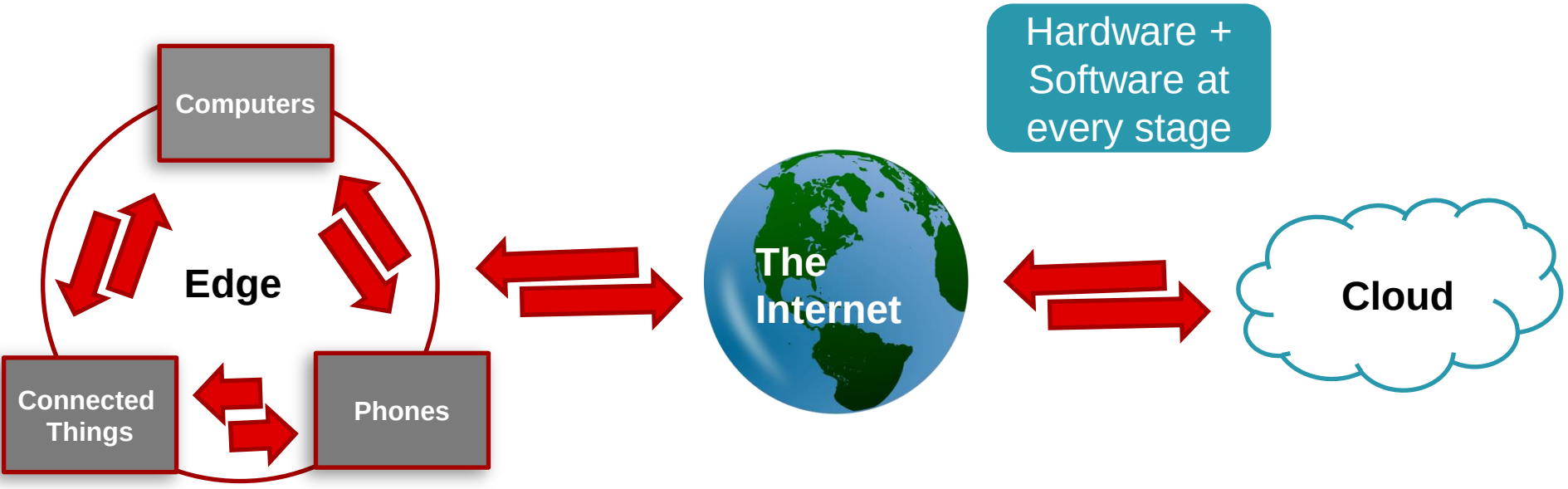
Can you make the next Great Product or Service?

WE WANT YOU!

Calling all Engineers, Makers, Entrepreneurs

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



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

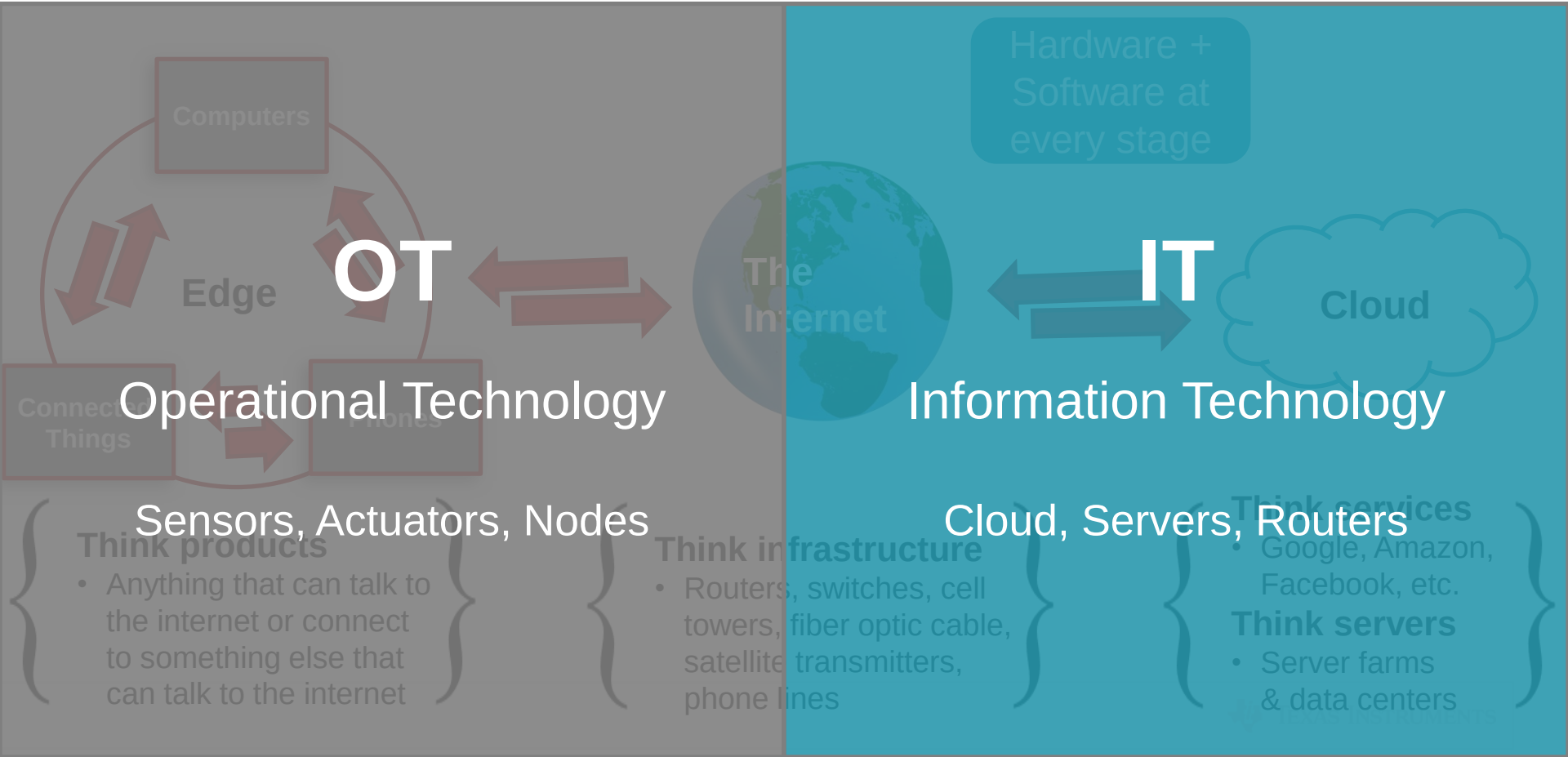
Think infrastructure
- Routers, switches, cell towers, fiber optic cable, satellite transmitters, phone lines

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



Edge Processing or Server Compute?
a comparison

Edge Processing (Hot Data Path)

You are processing heavy bits of data on the IoT device before delivery of simple packets

Advantages

- Keeps your data transmission smaller (bandwidth constrained radio transmission or expensive data rates)
- Distributed, less prone to security threats

Disadvantages

- More programmed logic on device side
- Harder to update
- Possibility of less uptime

Server Side Processing (Cold Data Path)

You are simply collecting and transmitting raw data or simplified converted data to the server for further processing

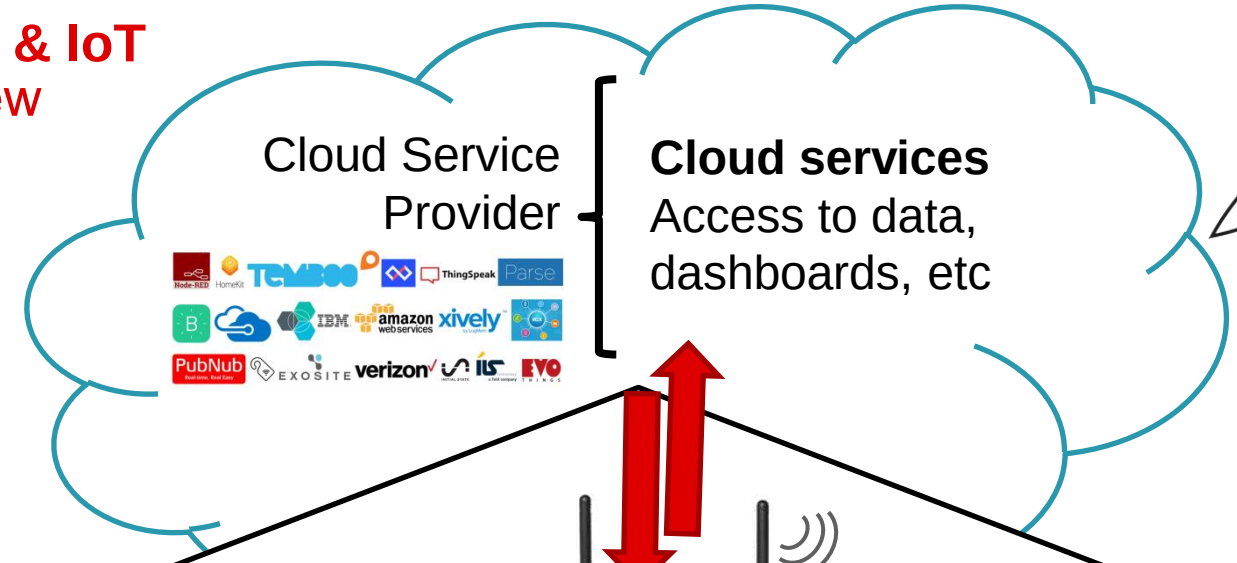
Advantages

- Common infrastructure and maintenance
- Take advantage of nearly unlimited compute power or magnitudes higher than an individual edge device
- Easy to update, low downtime

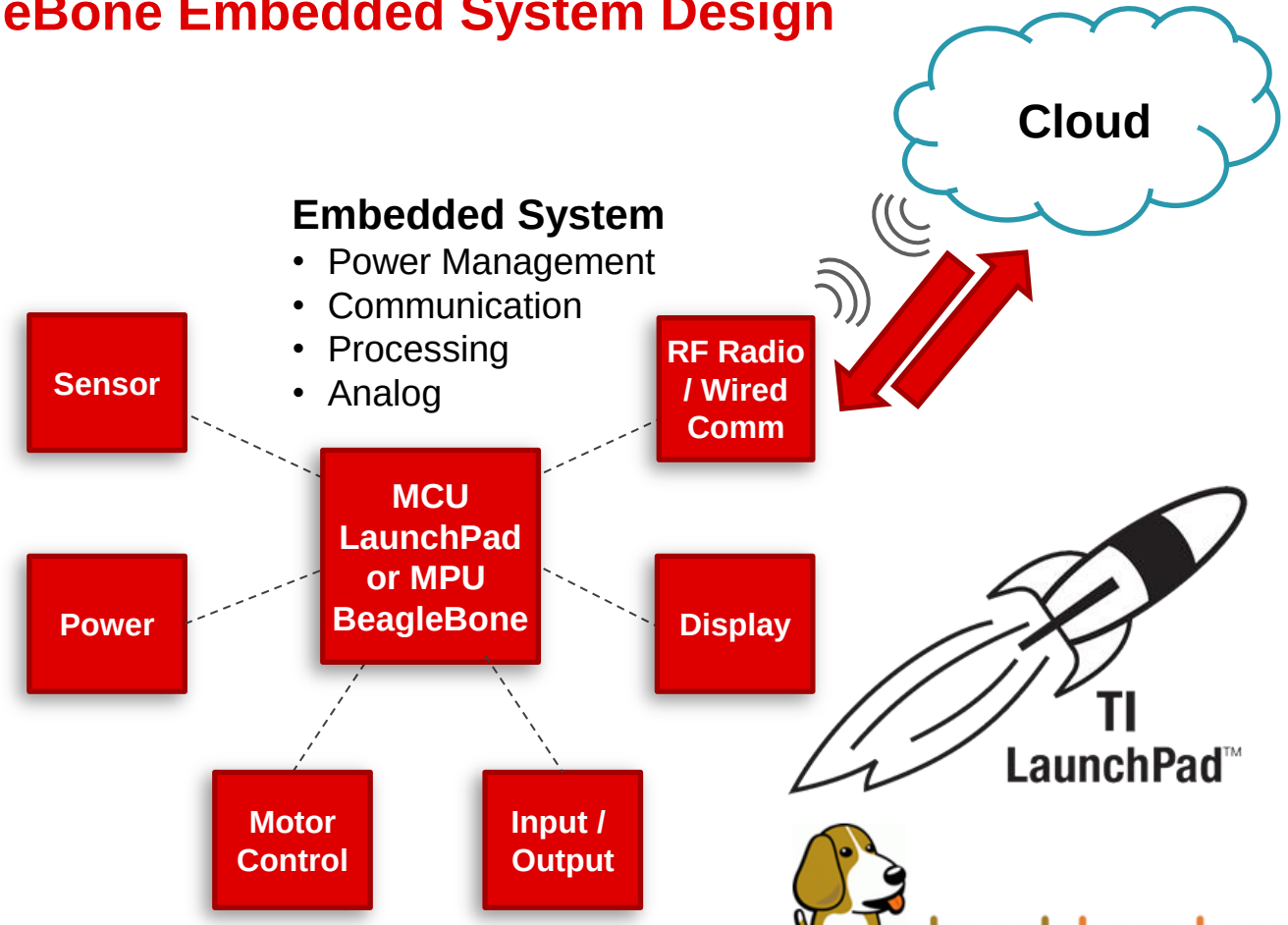
Disadvantages

- More frequent packets
- Database / data stream management
- Server downtime jeopardizes whole system

TI LaunchPad & IoT
a bird's eye view



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



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

Breakthrough Sensor Technology

www.ti.com/sensing

ULTRA SONIC SENSING

Inductive Sensing

Analog Temperature Sensors

CAPACITIVE Sensing

humidity

cap-to-dig (FDC)

Low Voltage, Low Power BUILDING BLOCKS

Sensor AFE

NANO Timer

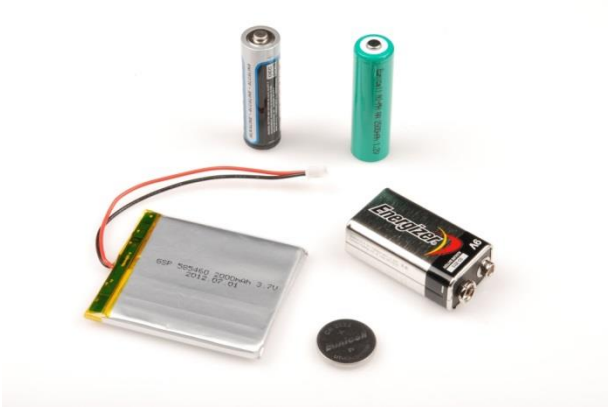
Sensing Innovation

Delivering better solutions today and new possibilities for tomorrow

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

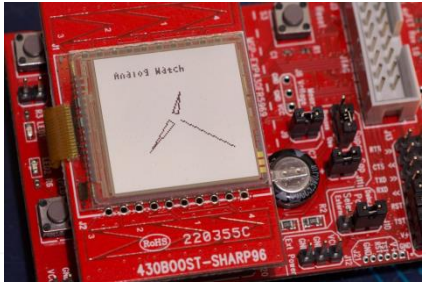
Advantages

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

Disadvantages

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

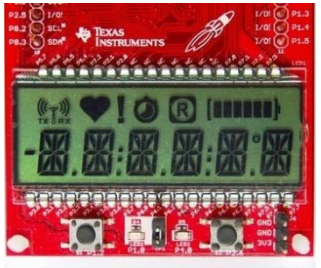
Displays: LCD vs OLED vs LED vs ePaper
a comparison

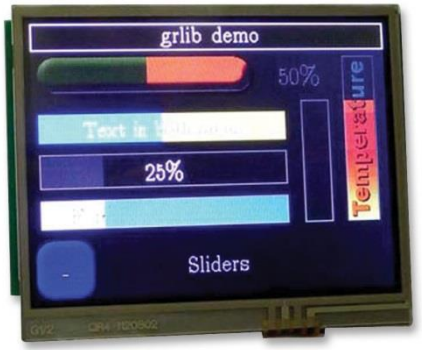


What's the difference?
- LCD
- OLED
- LED Matrix
- LED Segment
- ePaper
- Cloud GUI, Web App, or Mobile App

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 One network A billion dreams

(LPWAN)

- 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

- 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

- 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.

SaaS or IaaS or PaaS
a comparison

SaaS	IaaS	PaaS
Software Subscription	IT / Server Infrastructure	IT / Server Infrastructure + Software Application support
MS Office 365	Amazon Web Services	IBM Watson or MS Azure

Data to Cloud has a cost!

Protocol has a lot to do with packet size, security, ease of use, capability, scalability
Ethernet and Wi-Fi assumed data was “free” but mobile IoT now makes that not true

HTTP (Hypertext Transfer Protocol)

- Classic protocol that runs the traditional internet, request-response paradigm in client-server model
- Very heavy protocol with large packets and assuming that consuming large quantities of data is okay
- Highly reliable and easy to learn

MQTT (Message Queue Telemetry Transport)

- Bi-directional, Publish-Subscribe model
- Gaining more popularity for IoT as a lightweight alternative for HTTP
- Easy to learn but requires a Message Broker to be setup in your network or externally

AMQP (Advanced Message Queue Protocol)

- Emerging IoT protocol that addresses shortfalls of MQTT such as security and file transfers
- One to one (P2P) and one to many (Pub-Sub) communication

Software Effort: Custom vs. Packaged

Build your own or use existing tools?

IoT Software needs

Web application, servers, mobile app, device firmware

Types of existing tools

Open source, SaaS, PaaS, IaaS

DIY Advantages

- Highly customized
- Easier to maintain & less dependencies

Buy Advantages

- Less development work
- Outside support

DIY Disadvantages

- Lots of work, dedicated resources
- wide range of expertise required

Disadvantages

- Dependencies on the tools or services
- Tool or service limitations

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?

Rapid Prototyping or Embedded Design?

What is the distinction?

- **Prototyping** makes use of **pre-assembled, low cost hardware** and **open source software** solutions to quickly build out product concepts.
  - Open source SW libraries, Arduino shields, breakout modules, dev kits, 3D printing

- You first prototype to **prove your application**, test use cases, secure budget, find investors, define the market in a quick and dirty form factor where time and cash investments are huge limitations.
  - **Your prototype can be made pretty, but that doesn't make it a product!**

- **Embedded design** will mostly scrap what you did in the prototyping stage to **optimize for cost, scale, size, quality, manufacturability**. Everything will be custom from HW to SW.
  - Don't fall in love with your prototype, because it won't be what you release to market!

Time has a cost!

Cannot look at your BOM as the only measure of cost. There is design time and there is system level cost that should be accounted for

BOM and Manufacturing Costs and Fees

- Pure dollar amounts

Design time cost

- Bottle necks can be created depending on quality of evaluation tools, software experience, board layout complexity, testing, availability of reference design, vendor support

System level cost

- Do the parts work together efficiently as a system? System decisions might impact the customer experience (more battery life or reliability or flexibility)
- Is the supply chain strong? Poor inventory levels can result in huge costs

System Level Thinking
measure all design factors

Time has a cost!

Cannot look at your BOM as the only measure of cost. There is design time and there is system level cost that should be accounted for

A good designer can manage these things during a project

A **great** designer can anticipate these things **before** a project and plan around them

Look at the design at the subsystem level and system level and figure out how to best optimize

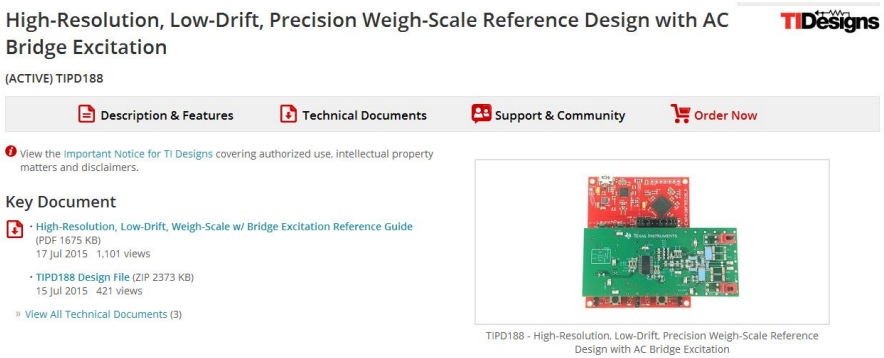
TIDesigns

www.ti.com/tidesigns

Reference Design Library

Jump start system design and speed time to market

- Comprehensive designs include schematics or block diagrams, BOMs, design files and test reports
- Created by experts with deep system and product knowledge
- Spans TI's portfolio of analog, embedded processor and connectivity products
- Supports a broad range of applications including industrial, automotive, consumer, medical and more



Microprocessors: Microcontrollers vs Single Board Computers
a comparison

TI LaunchPad™

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?

beagleboard.org

BeagleBone Black

Microprocessors: Microcontrollers vs Single Board Computers
a comparison

Considerations:
- Power
- Integration
- Performance
- Cost

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

Microprocessors: Selecting a Processor
tips & cautions

How to pick a processor

- Don’t always trust the vendor to guide you - they have many parts they are trying to sell! Define your spec and stick to it
- Look for **community,** educational resources, and **training**
- Look for well written **documentation**, clean getting started experiences, **accessible software**
- Look for **company support** (phone or email), distributor support, **pre-certifications** to speed time to market
- Beware of NDAs, complicated licenses, poor distribution, high obsolete rates

Microprocessors: SoC or SoM or SiP
a comparison

SoC (System on Chip)

Integrated processor chip with multiple cores and radios

Advantages

- Integrate key parts of a complex circuit to save space on a PCB circuit design

Disadvantages

- Slightly Expensive

Examples

- CC3220 Wi-Fi
- CC2640R2F BLE

SoM (System on Module)

Highly integrated compute module that is added to various embedded systems

Advantages

- Easily integrate a very complex piece of the PCB design into simpler PCB circuit designs
- Save space and design time

Disadvantages

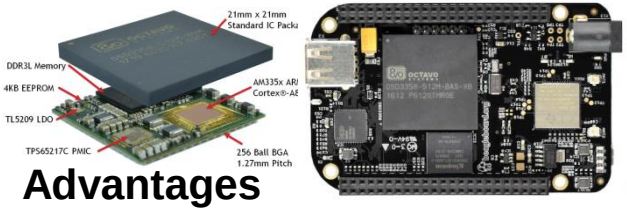
- Expensive

Examples

- BeagleCore
- CC2650MODA

SiP (System in Package)

Integrated processor chip and circuitry all in one



Advantages

- Very easily integrate a complex processor into a small space
- Save manufacturing cost and development time on board design

Disadvantages

- Expensive

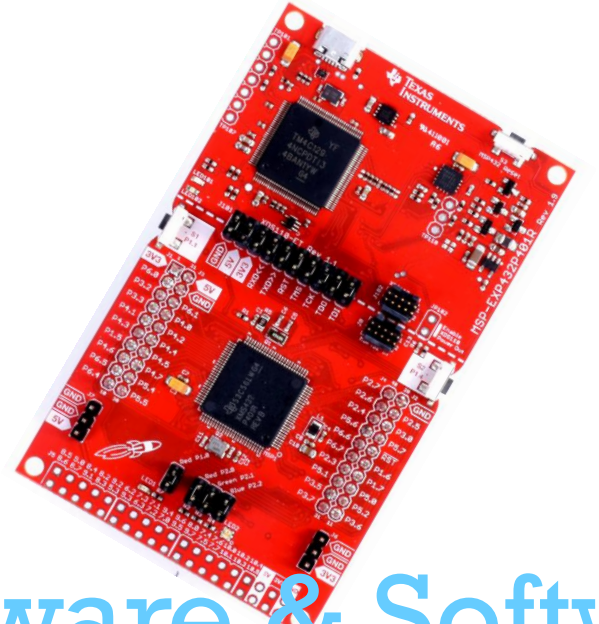
Examples

- Octavo OSD3358

Making MADE simple

With the TI LaunchPad

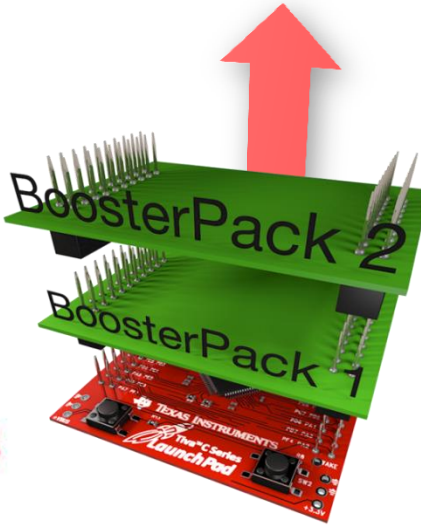
TI LaunchPad™



Hardware & Software

Rapid Prototyping

with TI LaunchPads & BoosterPacks



Why TI LaunchPad™ is better?

- Price $10-$30
- HW Debugger
- TI online resources
- Focus on Prototype to Production
- Performance and Variety
- Multiple supported SW paths

TI LaunchPad™

USB Connection to Code Composer Studio (Cloud or Desktop) & Energia

Isolation Jumper
Let's you isolate Target

20/40-pin Standardized Pinout
- Add BoosterPack
- Jumper to your own hardware
- BYOB – Build Your Own Boosterpack

On-board Emulation

Reset

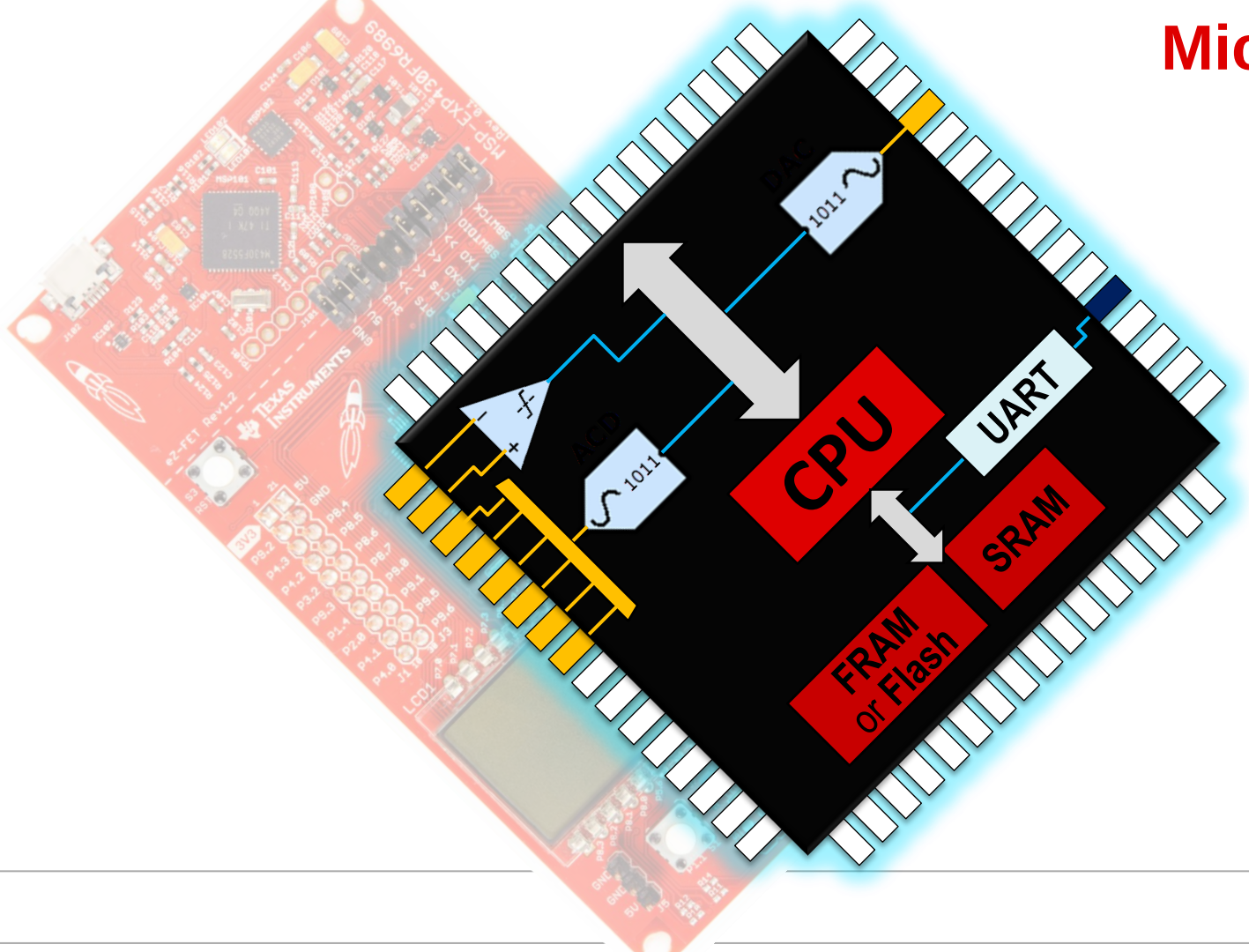
Microcontroller

User Buttons

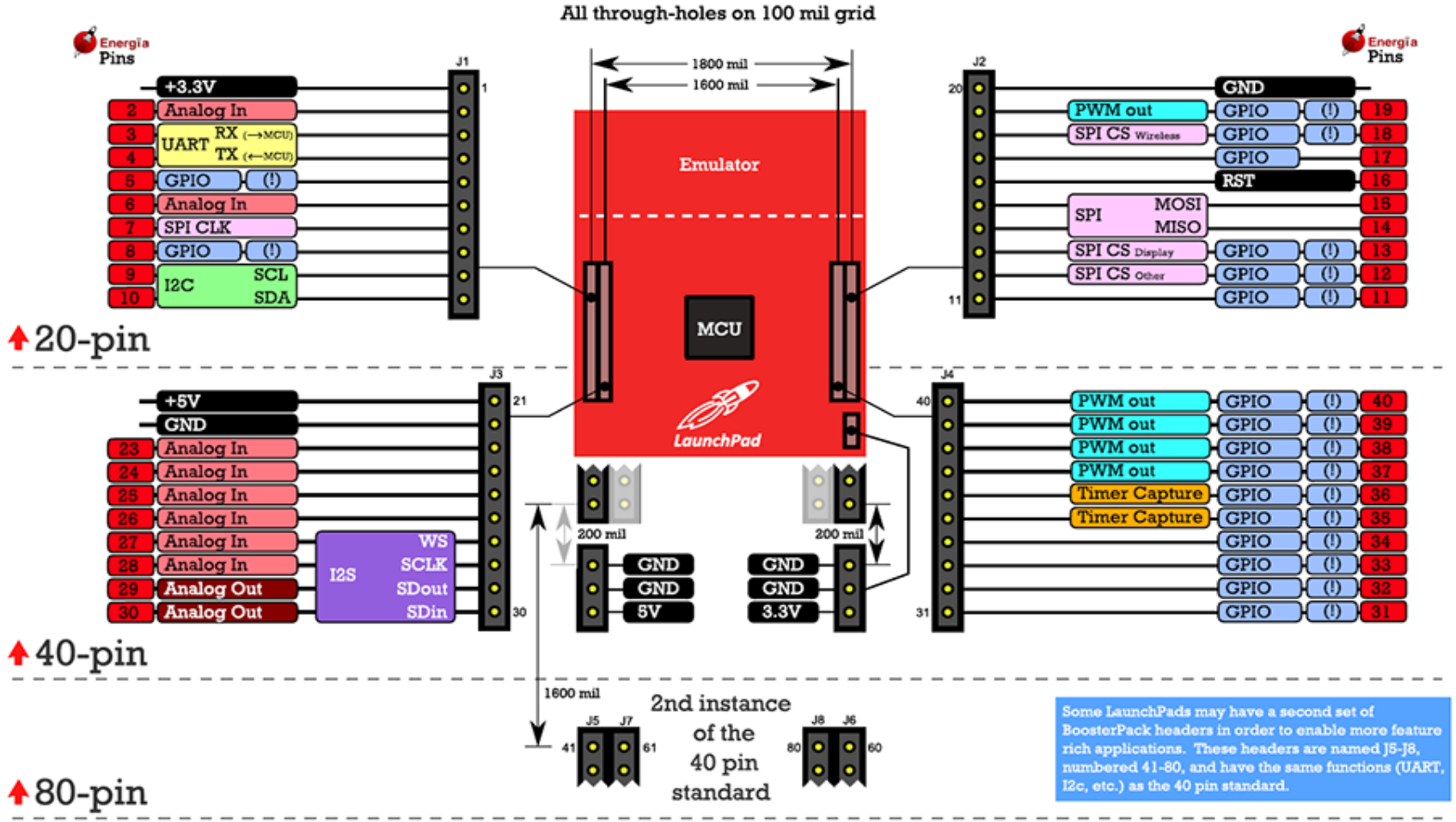
Segmented Display (LCD)
Available on some LaunchPads

User LEDs

Microcontroller



BoosterPack pinout standard (ti.com/byob)



BoosterPack pinout standard (ti.com/byob)

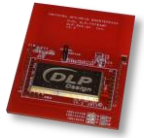
The BoosterPack pinout standard enables:

- 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*

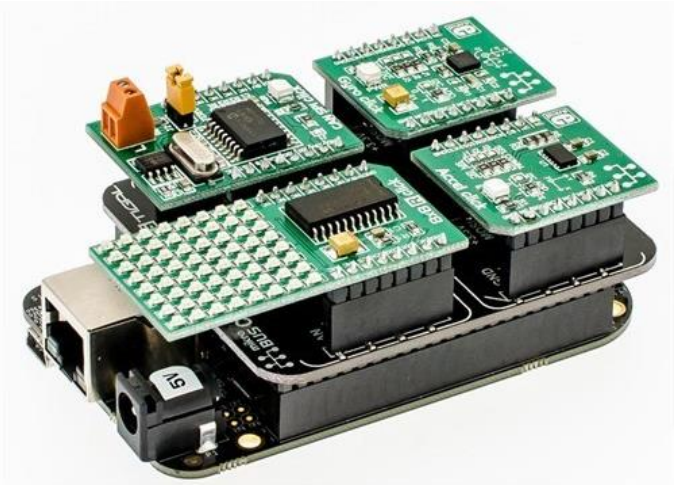
Making MADE simple

With the BeagleBone

Hardware & Software

Rapid Prototyping

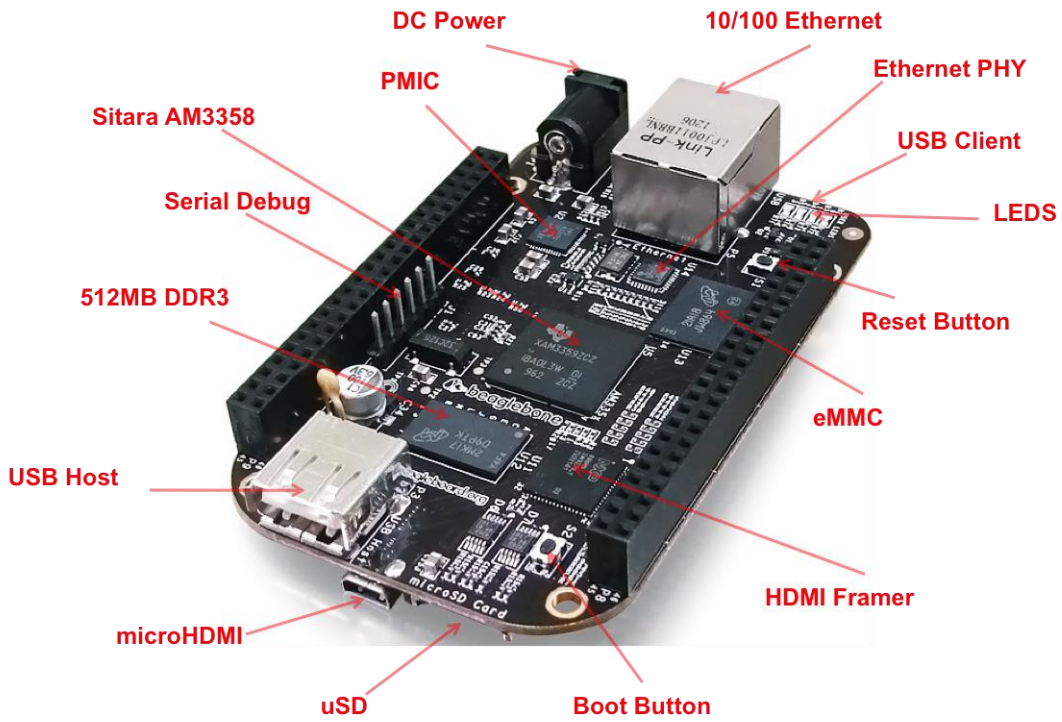
With BeagleBone Black and Capes



Why Beaglebone Black is great?

- **Price ~$45**
- **Large community**
- **Online resources from TI and Beagleboard.org**
- **Full Linux capable single board computer**
- **Multiple supported SW paths**
- **Completely open source for building your own derivative products!**

BeagleBone Black



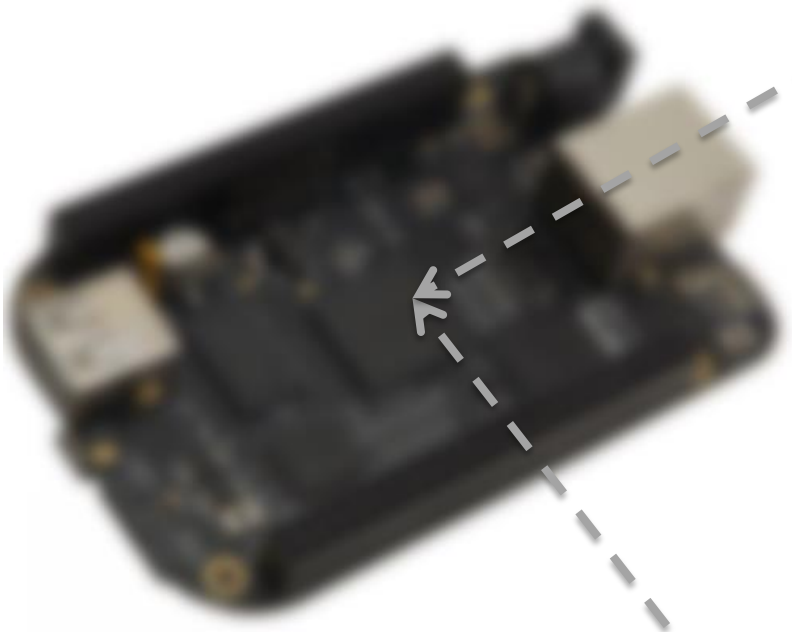
BeagleBone Black

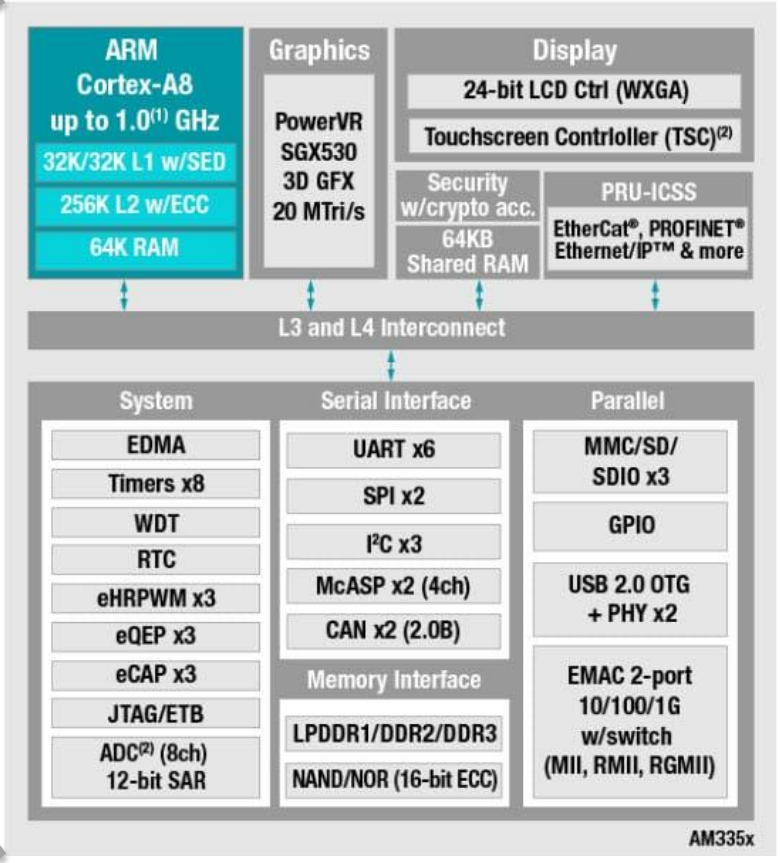
Processor: AM335x 1GHz ARM® Cortex-A8
- 512MB DDR3 RAM
- 4GB 8-bit eMMC on-board flash storage
- 3D graphics accelerator
- NEON floating-point accelerator
- 2x PRU 32-bit microcontrollers

Connectivity
- USB client for power & communications
- USB host
- Ethernet
- HDMI
- 2x 46 pin headers … Add a 'Cape'

Software Compatibility
- Debian
- Android
- Ubuntu
- Cloud9 IDE on Node.js w/ BoneScript lib
- plus much more

AM3358 Microprocessor





BeagleBone Capes

Pin access to external circuits or stackable modular hardware capes through dual 46 pin headers

Cape Expansion Headers

P9

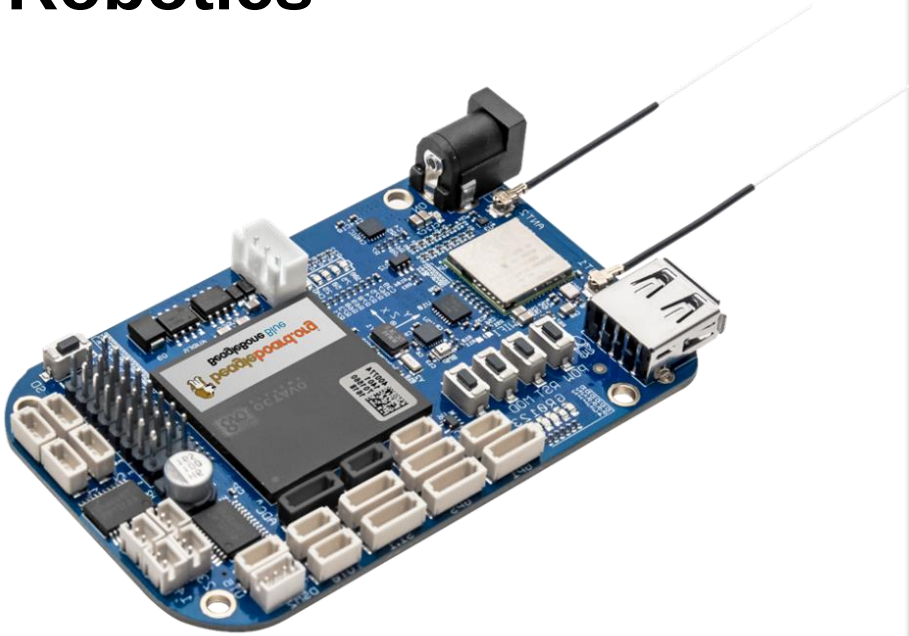
DGND	1	2	DGND
VDD_3V3	3	4	VDD_3V3
VDD_5V	5	6	VDD_5V
SYS_5V	7	8	SYS_5V
PWR_BUT	9	10	SYS_RESETN
UART4_RXD	11	12	GPIO_60
UART4_TXD	13	14	EHRPWM1A
GPIO_48	15	16	EHRPWM1B
SPI0_CS0	17	18	SPI0_D1
I2C2_SCL	19	20	I2C2_SDA
SPI0_D0	21	22	SPI0_SCLK
GPIO_49	23	24	UART1_TXD
GPIO_117	25	26	UART1_RXD
GPIO_115	27	28	SPI1_CS0
SPI1_D0	29	30	GPIO_112
SPI1_SCLK	31	32	VDD_ADC
AIN4	33	34	GNDA_ADC
AIN6	35	36	AIN5
AIN2	37	38	AIN3
AIN0	39	40	AIN1
GPIO_20	41	42	ECAPPWM0
DGND	43	44	DGND
DGND	45	46	DGND

LEGEND
Power/Ground/Reset
Available Digital
Available PWM
Shared I2C Bus
Reconfigurable Digital
Analog Inputs (1.8V)

P8

DGND	1	2	DGND
MMC1_DAT6	3	4	MMC1_DAT7
MMC1_DAT2	5	6	MMC1_DAT3
GPIO_66	7	8	GPIO_67
GPIO_69	9	10	GPIO_68
GPIO_45	11	12	GPIO_44
EHRPWM2B	13	14	GPIO_26
GPIO_47	15	16	GPIO_46
GPIO_27	17	18	GPIO_65
EHRPWM2A	19	20	MMC1_CMD
MMC1_CLK	21	22	MMC1_DAT5
MMC1_DAT4	23	24	MMC1_DAT1
MMC1_DAT0	25	26	GPIO_61
LCD_VSYNC	27	28	LCD_PCLK
LCD_HSYNC	29	30	LCD_AC_BIAS
LCD_DATA14	31	32	LCD_DATA15
LCD_DATA13	33	34	LCD_DATA11
LCD_DATA12	35	36	LCD_DATA10
LCD_DATA8	37	38	LCD_DATA9
LCD_DATA6	39	40	LCD_DATA7
LCD_DATA4	41	42	LCD_DATA5
LCD_DATA2	43	44	LCD_DATA3
LCD_DATA0	45	46	LCD_DATA1

BeagleBone Blue for Robotics



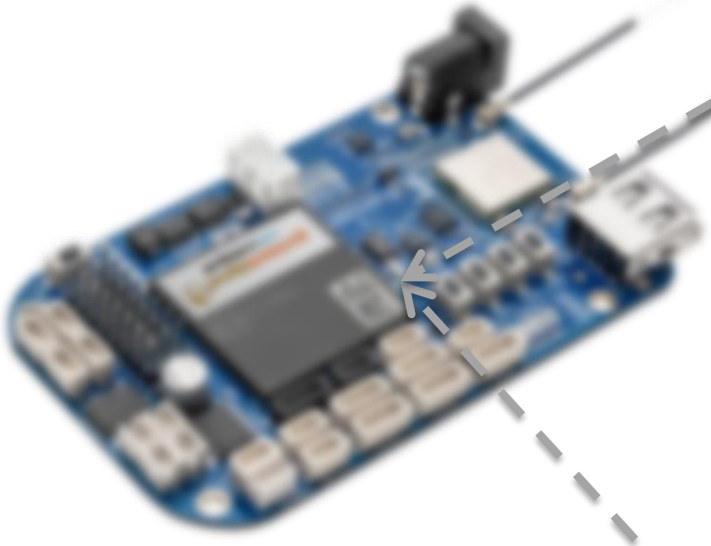
BeagleBone Blue

Processor: OSD335x 1GHz ARM® Cortex-A8
- 512MB DDR3 RAM
- 4GB 8-bit eMMC on-board flash storage
- 3D graphics accelerator
- NEON floating-point accelerator
- 2x PRU 32-bit microcontrollers

Connectivity
- Battery: 2-cell LiPo support with balancing, 9-18V charger input
- Wireless: 802.11bgn, Bluetooth 4.1 and BLE
- Motor control: 8 6V servo out, 4 DC motor out, 4 quadrature encoder in
- Sensors: 9 axis IMU, barometer
- Connectivity: HighSpeed USB 2.0 client and host
- User interface: 11 user programmable LEDs, 2 user programmable buttons
- Easy connect interfaces for adding additional sensors such as: GPS, DSM2 radio, UARTs, SPI, I2C, 1.8V analog, 3.3V GPIOs

Software Compatibility
- Debian, Android, Ubuntu, plus much more
- ROS, ArduPilot, LabVIEW
- Cloud9 IDE on Node.js w/ BoneScript lib

OSD3358 System-in-Package



400 Ball BGA

TPS65217C
Power In 5V:
- USB, Li-ion Battery

Power Out:
- 1.8V, 3.3V, SYS

TL5209
Power Out:
- 3.3V

Up To 1GB DDR3 main memory

Over 140 Passive Components

TI AM335x ARM® Cortex®-A8
- Up to 1 GHz clock
- 32KB L1 Icache and 32KB L1 Dcache
- 256KB L2 cache
- 64K shared L3 RAM

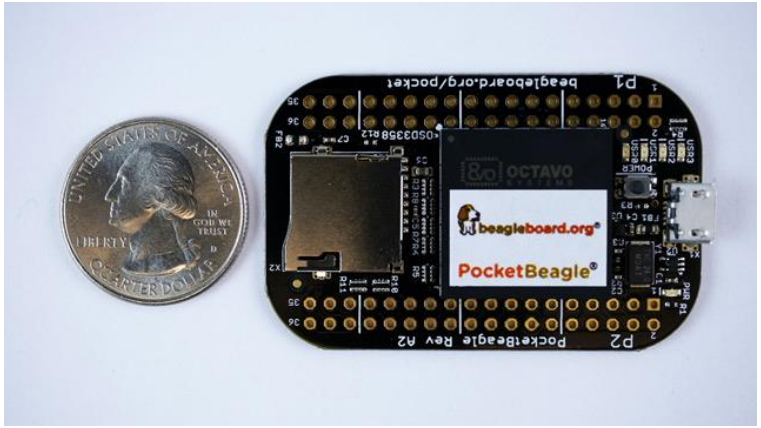
Parallel
- MMC, SD and SDIO x2
- GPIO x114

Serial
- UART x6
- SPI x2
- I2C x2
- Ethernet 10/100/1000 x 2
- USB 2.0 HS OTG + PHY x2

System
- 8 channel 12-bit SAR ADC
- JTAG
- 4 timer triggers
- 2 crystal oscillator inputs
- 2 eHARPWM of 16-bit time base counter

LCD Display
- Up to 24-bit color
- 3D Graphics Engine
- Character Display
- Active Matrix LCD
- Passive Matrix LCD

PocketBeagle
for Embedded Linux ($25)



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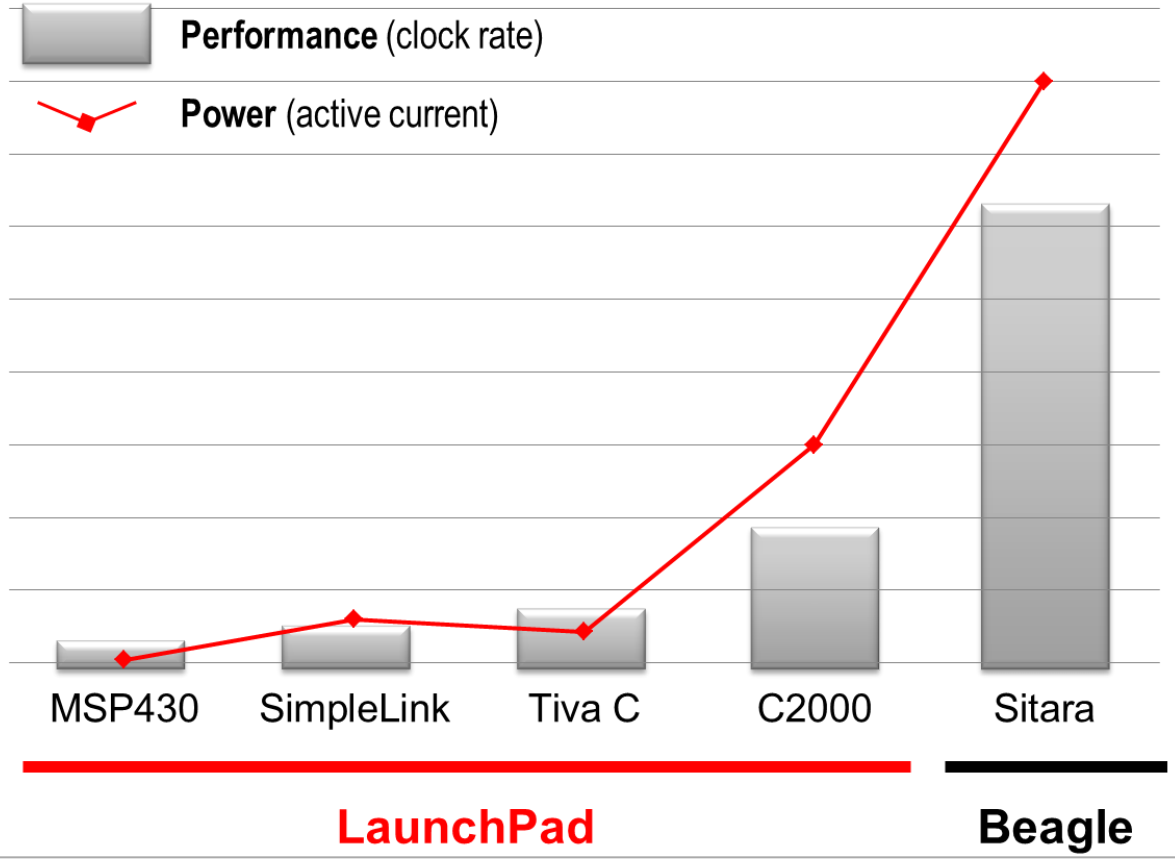
- 2x PRU 32-bit microcontrollers

Connectivity
- USB

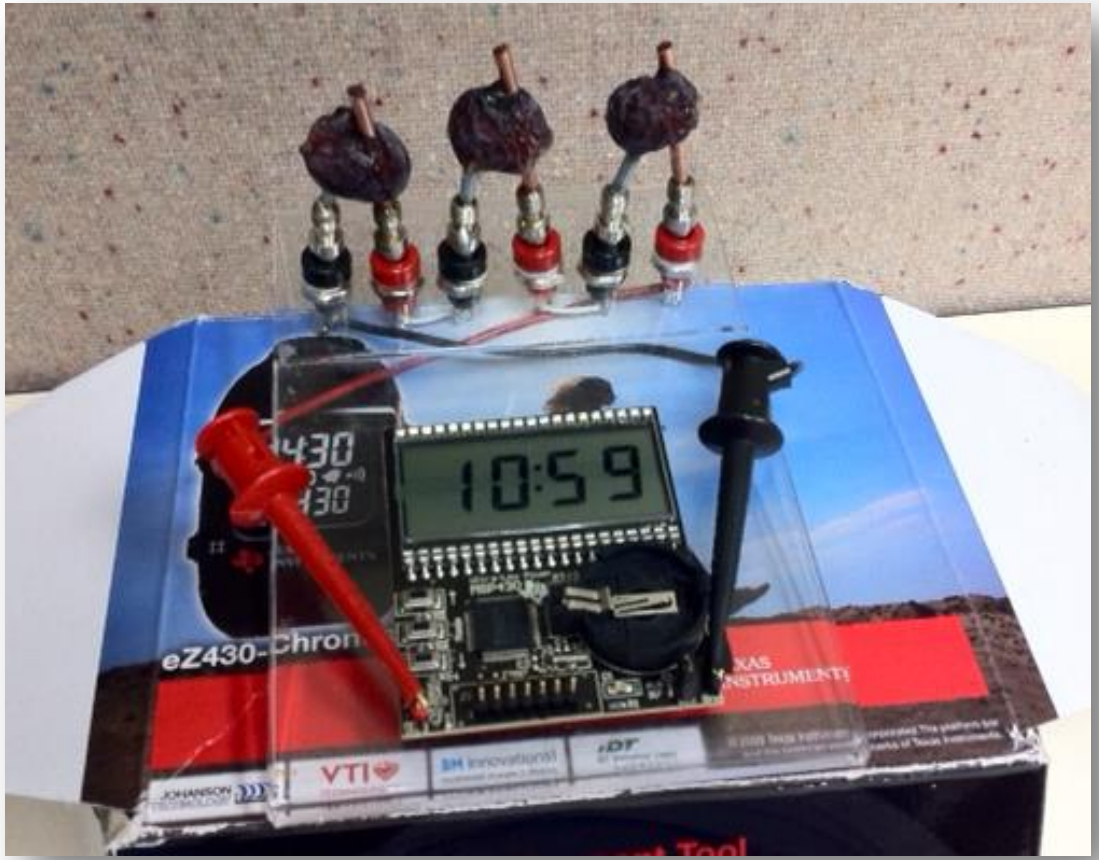
Software Compatibility
- Debian, Android, Ubuntu, plus much more
- ROS, ArduPilot, LabVIEW
- Cloud9 IDE on Node.js w/ BoneScript lib

PocketBeagle

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?

Microcontrollers (MCU)

Application (MPU)

MSP430	C2000	SimpleLink	Sitara	DSP	Keystone
16-bit/32-bit **Ultra Low Power & Cost**	32-bit **Real-time**	32-bit **Wireless and Connectivity**	32-bit **Linux Android**	16/32-bit **All-around DSP**	32-bit **Massive Performance**
• **MSP430 16-bit RISC** • **MSP432 32-bit ARM**	• **Real-time C28x MCU** • **ARM M3+C28**	**ARM Cortex-M3 Cortex-M4F**	**ARM Cortex-A8 Cortex-A9 Cortex-15**	**DSP C5000 C6000**	• **C66 + C66** • **A15 + C66** • **A8 + C64** • **ARM9 + C674**
• Low Pwr Mode ▪ 250nA (RTC) ▪ 770nA (LCD) • Smart Analog • EnergyTrace++	• Motor Control • Digital Power • Precision Timers/PWM	• M4 w/ WiFi • M3 w/ 2.4GHz • M3 w/ Sub-1GHz • M4 w/ Ethernet (MAC+PHY)	• $5 Linux CPU • 3D Graphics • PRU • Industrial I/O	• C5000 Low Power DSP • 32-bit fix/float C6000 DSP	• Fix or Float • Up to 12 cores 4 A15 + 8 C66x • DSP MMAC's: 352,000
Flash: 512K FRAM: 256K	512K Flash	256K to 2M Flash	L1: 32K x 2 L2: 256K	L1: 32K x 2 L2: 256K	L1: 32K x 2 L2: 1M + 4M
25 MHz	300 MHz	120 MHz	1.35 GHz	800 MHz	1.4 GHz

Rapid Prototype with TI LaunchPad Ecosystem

Get Started with BeagleBoards and TI EVMs

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

Want to work for TI?

- Internships
- Rotation Programs
- Full-time positions

careers.ti.com

change the world, love your job.

What does TI do?

What we've done for over 85 years…

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

TEXAS INSTRUMENTS

sand

silicon

layer

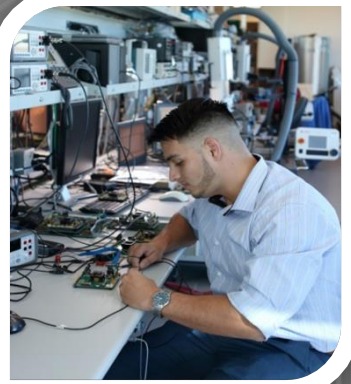
Embedded Processing

Texas Instruments

Analog

Texas Instruments

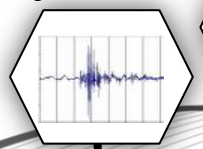
interconnect



Texas Instruments

Nearly Nine Decades of InnovaTIon

1930s
Revolutionizes oil exploration by measuring reflected signals



1940s
Applies signal measurement to magnetic anomaly detection

1950s
Invents the integrated circuit

1960s
Invents the handheld calculator

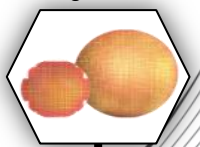
1970s
Applies signal processing to consumer products

1980s
Introduces single-chip digital signal processor

1990s
Creates first apps processor for multi-media cell phones

2000s
Introduces world's fastest analog-to-digital converter and lowest-power DC-DC converter

2010s
Industry's first 300mm analog wafer fab



Everyday electronics that use TI technology

Smart phones

Test equipment

Medical

Wireless infrastructure

Smart energy meters

Wireless LANs

Automotive & HEV

Digital TV

Motor control

Analog and Embedded Processing

IP phones

Computing

Industrial weigh scales

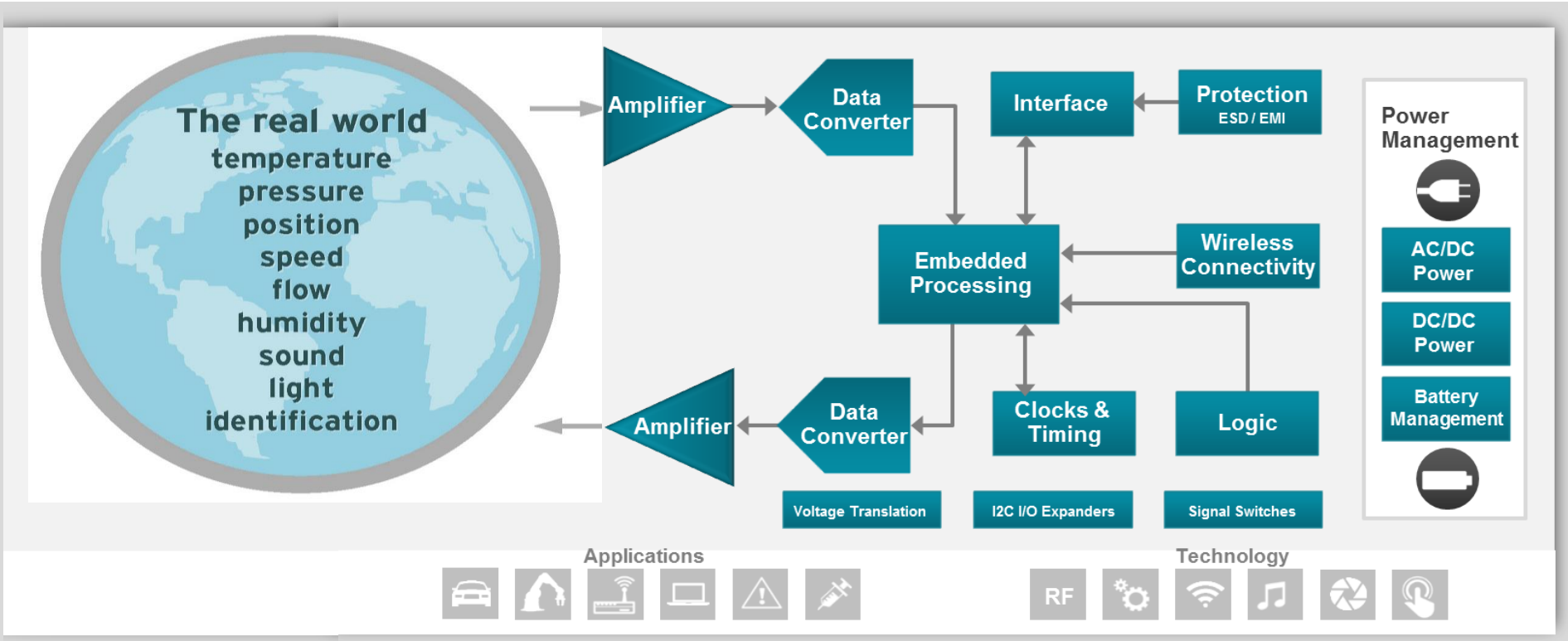
Digital still cameras

eBike

Digital audio & radio

Digital video recorder/server

TI technologies at the heart of every system



Signal chain from the real world to the digital realm

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

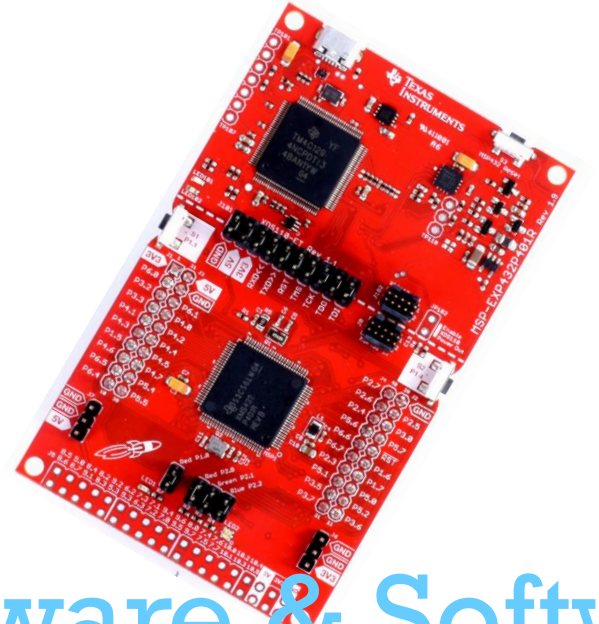




Making MADE simple

With the TI LaunchPad

TI LaunchPad™



Hardware & Software

The LaunchPad Concept

Rapidly Prototype

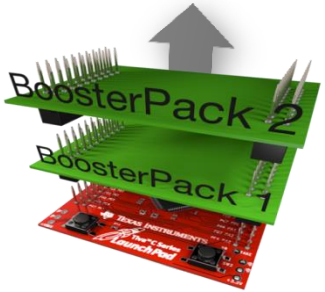
TI Solutions with

Modular Hardware,

Intuitive Software,

& Community Support

This overview shows why TI LaunchPad™ is the highest value microcontroller development tool on the market



Modular & Affordable

Hardware

Energia | IAR SYSTEMS | KEIL Tools by ARM

Intuitive & Flexible

Software

TI E2E™ Community | 43oh.com | hackster.io

Accessible & Engaged

Community Support

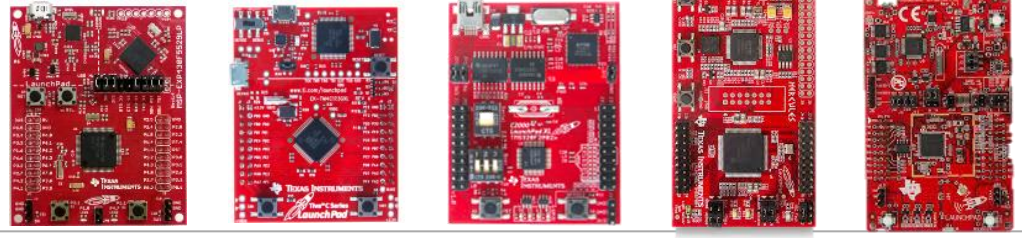
LaunchPad is TI's Common Denominator

Modular hardware enables developers to explore new ideas quickly

TI Wireless: Sub-1GHz, NFC/RFID, Wi-Fi, ZigBee, BLE, Bluetooth

Analog, sensors, displays & more from TI, 3rd parties & Maker community

LaunchPads featuring TI MCUs & BoosterPack interface



MSP430	MSP432 / TM4C	C2000	Hercules	SimpleLink
(Ultra-Low Power)	(ARM Cortex M4F)	(Real-time Control)	(Safety)	(MCU + Connectivity)

Texas Instruments

The LaunchPad Ecosystem

Everything you need to start microcontroller development

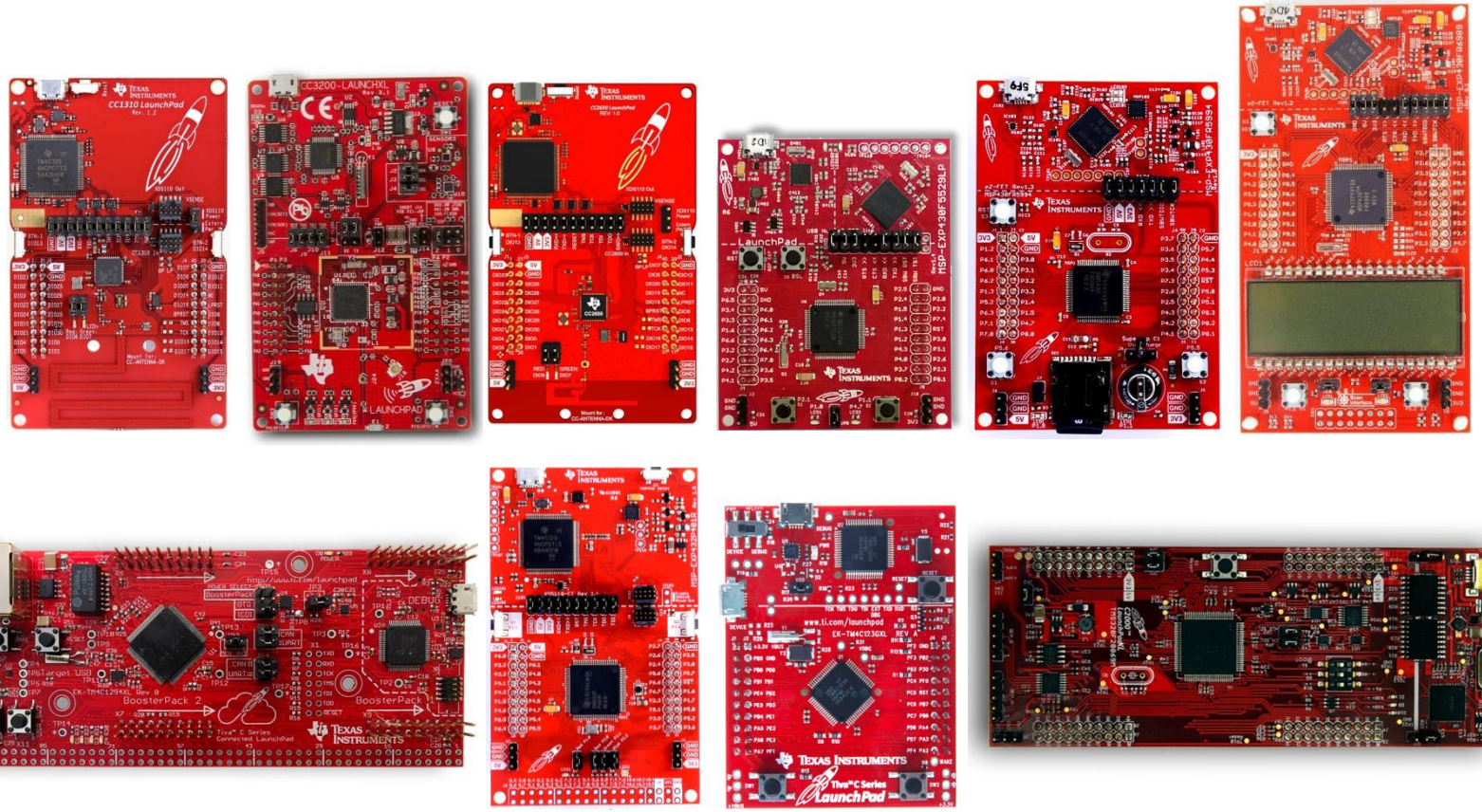
Hardware + Software + Community

Over 20 types of LaunchPads for different application needs!

Open Source Hardware

Works with TI LaunchPad™

The LaunchPad Ecosystem



General & Special Purpose MCUs

Full specs at www.ti.com/launchpad

Texas Instruments

The FRAM Advantage: At a Glance

www.ti.com/fram

Write More

Collect more data over time with 100x faster writes than Flash

Extend product life and ditch the EEPROM with infinite endurance

Decrease Power

Extend battery life with 250x lower energy writes vs Flash

Minimize wireless system power by shortening memory update times

Unified Memory

Simple to use with unmatched flexibility

Migration guides, code examples and application notes available!

The LaunchPad Ecosystem

Everything you need to start microcontroller development

Hardware + Software + Community

Many orderable BoosterPacks and open source designs available!

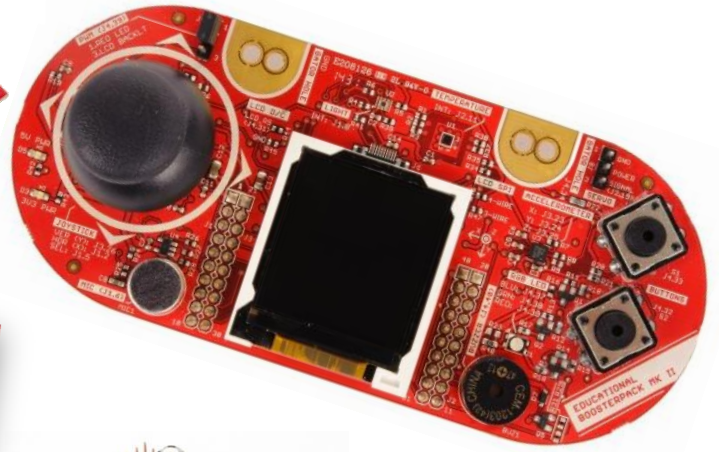
Open Source Hardware

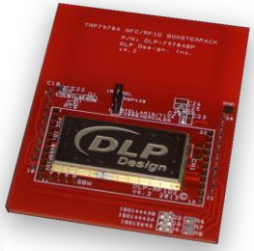
Works with TI LaunchPad™

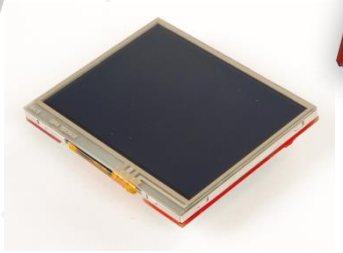
The LaunchPad Ecosystem

Everything you need to start microcontroller development

Hardware + Software + Community







Works with TI LaunchPad™

Open Source Hardware

Texas Instruments

Sidekick Basic Kit for TI LaunchPad™

Manufactured by Seeedstudio

Part List

1x Breadboard
1x Breadboard Adapter BoosterPack
5x Green LED
5x Red LED
1x RGB Common Anode LED
10x Ceramic Capacitor 10nF
10x Ceramic Capacitor 100nF
5x Aluminum Capacitor 100uF
10x Resistor 330 ohm
10x Resistor 1K ohm
10x Resistor 10K ohm
1x Tilt Switch
1x Thermistor
1x Photoresistor (photocell)
1x Diode
1x Piezo Buzzer
5x Button
5x Switch
2x Potentiometer with knob
1x Small DC Motor
1x 7 Segment Single Digit Display
1x 8-bit Shift Register (SN74HC595N)
2x NPN Transistor (2N2222)
1x Analog Temperature Sensor (LM19CIZ/NOPB)
5x Jumper Wire Long
20x Jumper Wire Short
1x Sidekick Manual

Learning Over 100+ electronic components to build basic and complex circuits

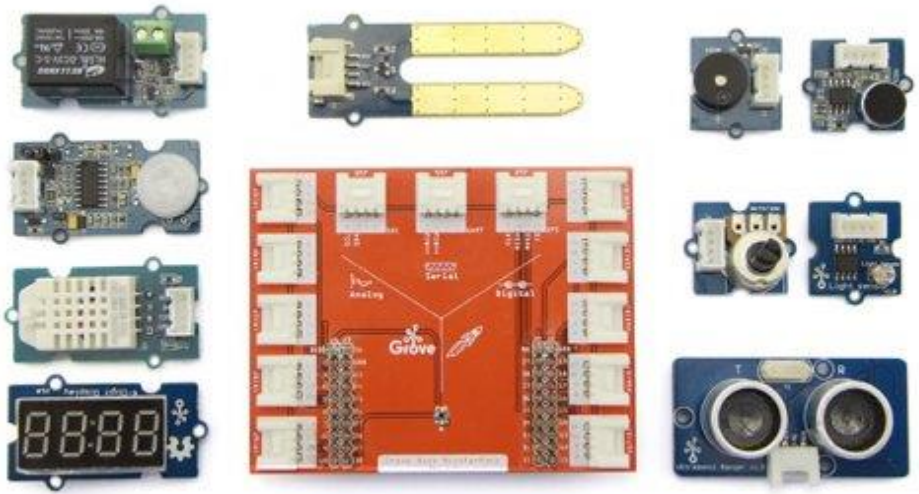
Compatibility Useful with any TI LaunchPad or other digital / analog development kit

Completeness All the popular accessories for beginners to develop with microcontrollers

Learn more @ www.energia.nu/sidekick

Grove Starter Kit for TI LaunchPad™

Manufactured by Seeedstudio



Part List

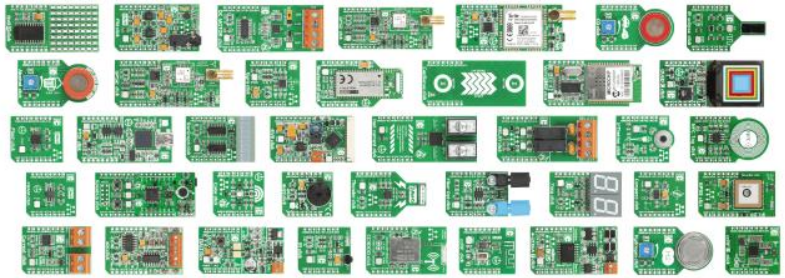
1x Grove Base BoosterPack
1x Grove Buzzer (Digital)
1x Grove Relay (Digital)
1x Grove 4-Digit-Display (Digital)
1x Grove Ultrasonic Range Sensor (Digital)
1x Grove PIR Motion Sensor (Digital)
1x Grove Light Sensor (Analog)
1x Grove Sound Sensor (Analog)
1x Grove Moisture Sensor (Analog)
1x Grove Temperature Humidity Sensor (Analog)
1x Grove Rotary Angle Sensor (Analog)
Grove Cables
Starter Guide Manual

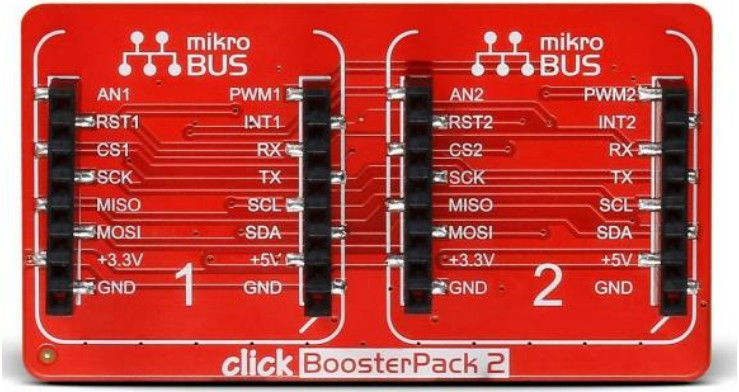
Learning 10 different grove modules to build basic and complex systems
Compatibility Useful with any TI LaunchPad or other digital / analog development kit
Completeness All the popular accessories for beginners to develop with microcontrollers

Learn more @ www.energia.nu/grovekit

Click BoosterPack 2

Manufactured by MikroElektronika





Click BoosterPack 2 has two mikroBUS sockets onboard, for simple and easy integration of MikroElektronika click boards with a TI LaunchPad™.

Add new functionality to your LaunchPad within minutes. More than 250 click boards available from audio and voice to power management and wireless connectivity clicks.

All MikroElektronika compilers come with code examples, so you'll have a great base to start with.

Learning Click boards to build basic and complex systems
Compatibility Useful with any TI LaunchPad or other digital / analog development kit
Completeness All the popular accessories for beginners to develop with microcontrollers

Learn more @ www.energia.nu/click

Texas Instruments

We all can CODE!

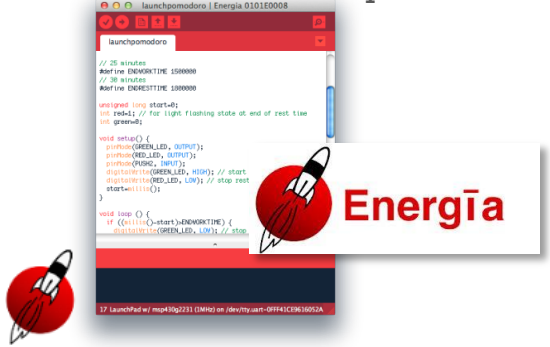
For FREE!

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

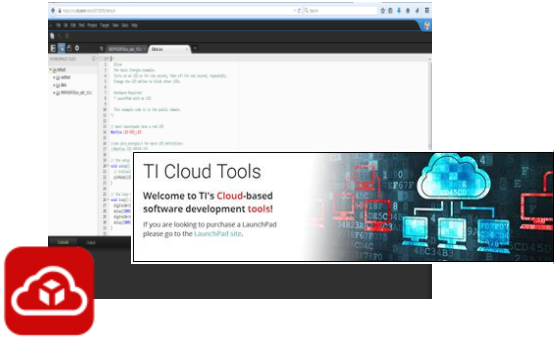


- **Intuitive coding environment**
- **Simplified interface**
- **Highly-abstracted API framework**
- **Open Source & Community-driven**

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

Texas Instruments

Energia Abstraction

Fly high above the bits & bytes

{ Boils it down to **1** line of code }

Abstraction

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

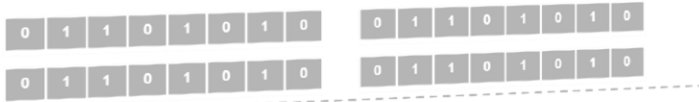
Each TI microcontroller peripheral is defined by a collection of registers

GPIO Registers:

- GPIODIR
- GPIOAFSEL
- GPIODR2R
- GPIOAMSEL

ADC Registers:

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

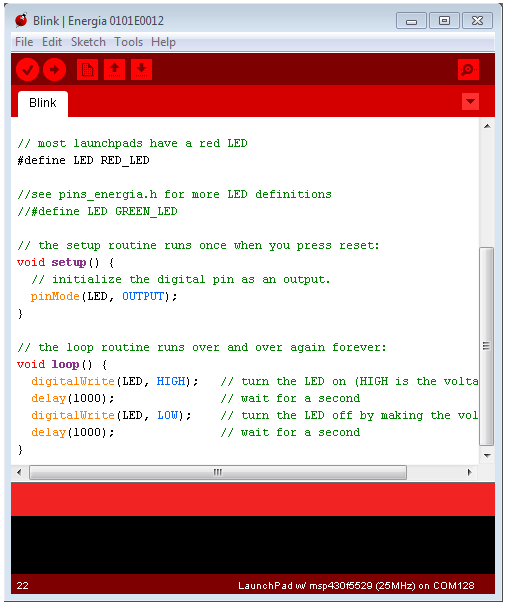


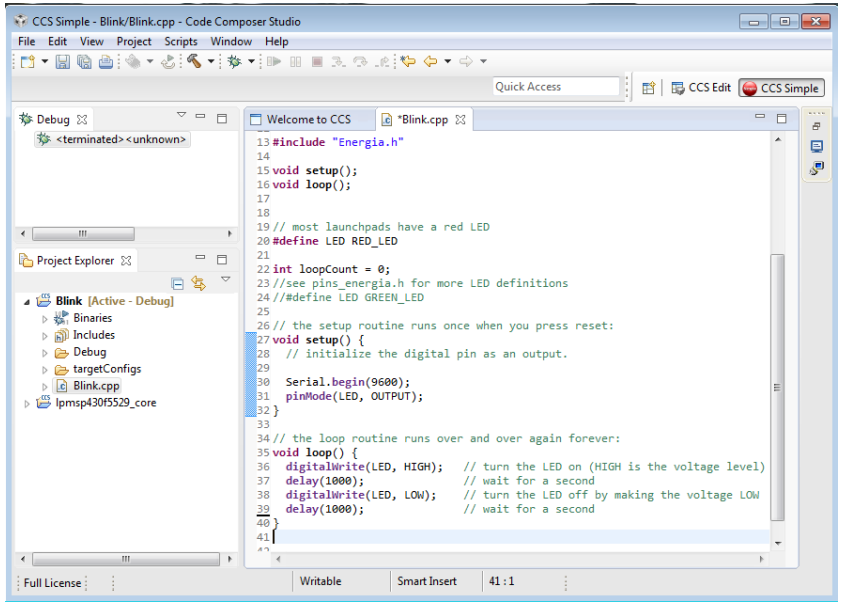
TI Microcontroller

Control MCU hardware & peripherals

Energia Import in CCSv6+ and CCS Cloud

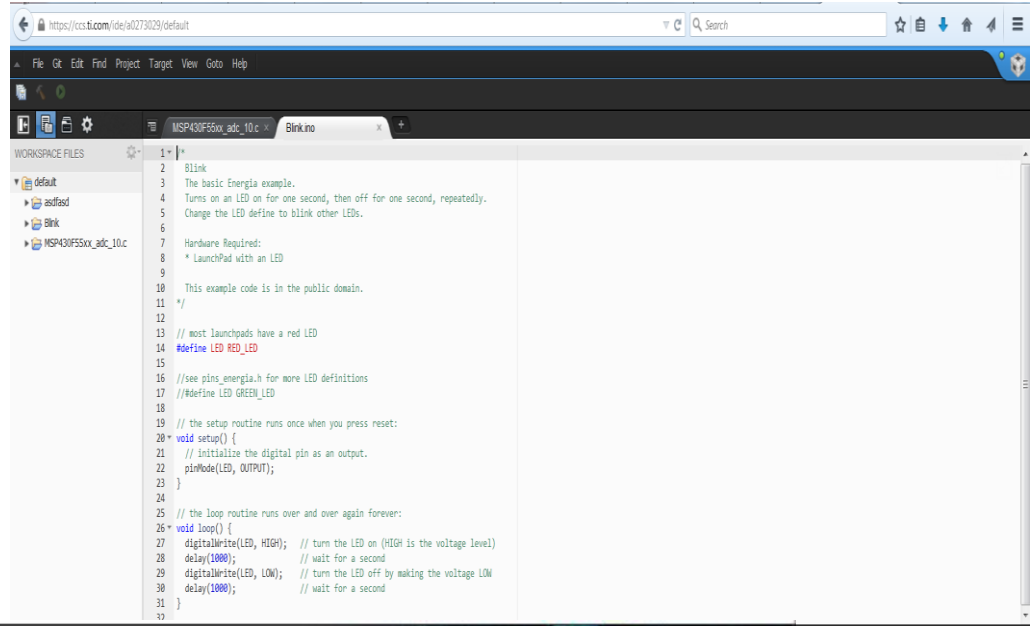
- Import an Energia sketch into Code Composer Studio v6 or v7 & pick up right where you left off.
- CCS introduces full debug capability & other professional features to further optimize your design.
- Modularize your code & leverage Energia APIs & libraries within CCS
- Enable “hybrid” projects that leverage low-level C, assembly & even abstracted Energia APIs enabling a developer maximum flexibility during code development.





Code Composer Studio Cloud

- **Browser based code editing tool to get your started quickly**
- **Access Resource Explorer to get the latest code examples, design files, and more.**
- **Cross Platform and allows you to upload firmware using TI Cloud Agent + Browser Extension**
- **Extended Debugging capability**

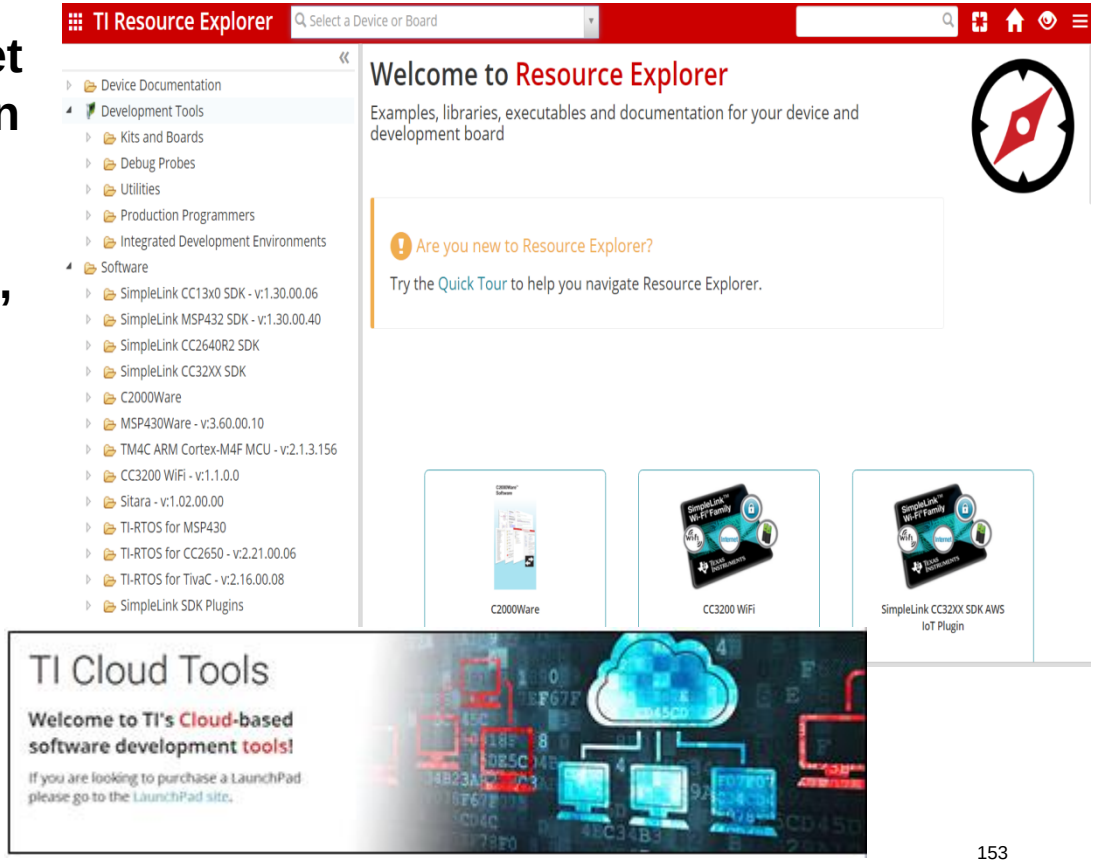


http://dev.ti.com

Resource Explorer

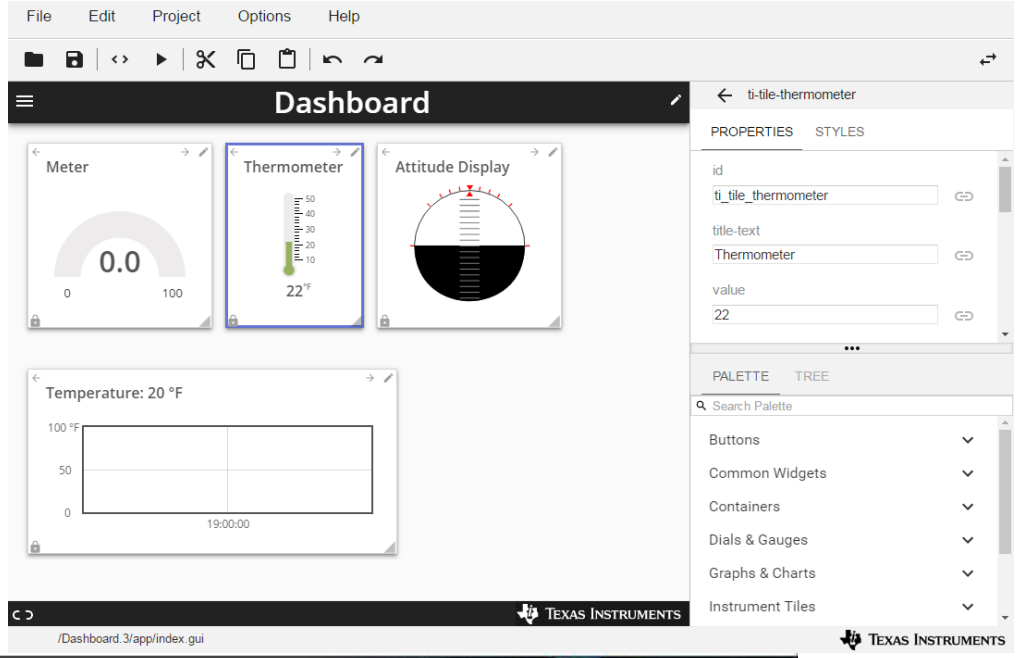
- **Access Resource Explorer to get the latest code examples, design files, and more.**
- **Support for TI-RTOS, FreeRTOS, and non-RTOS based code examples**
- **Materials for all TI processors searchable by part number and EVM**

http://dev.ti.com



GUI Composer

- **Create an interface to your application using user interface tool from TI**
- **Make use of streaming data, graphing tools, and widgets**
- **Share the GUI through the web or export to a local PC application**



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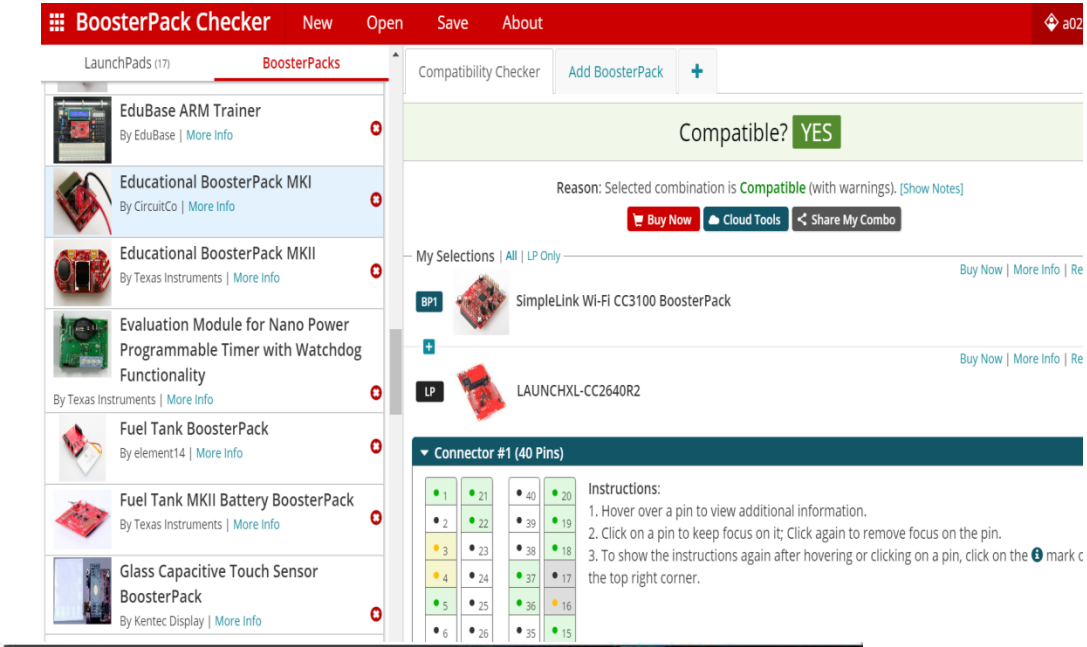
BoosterPack Checker

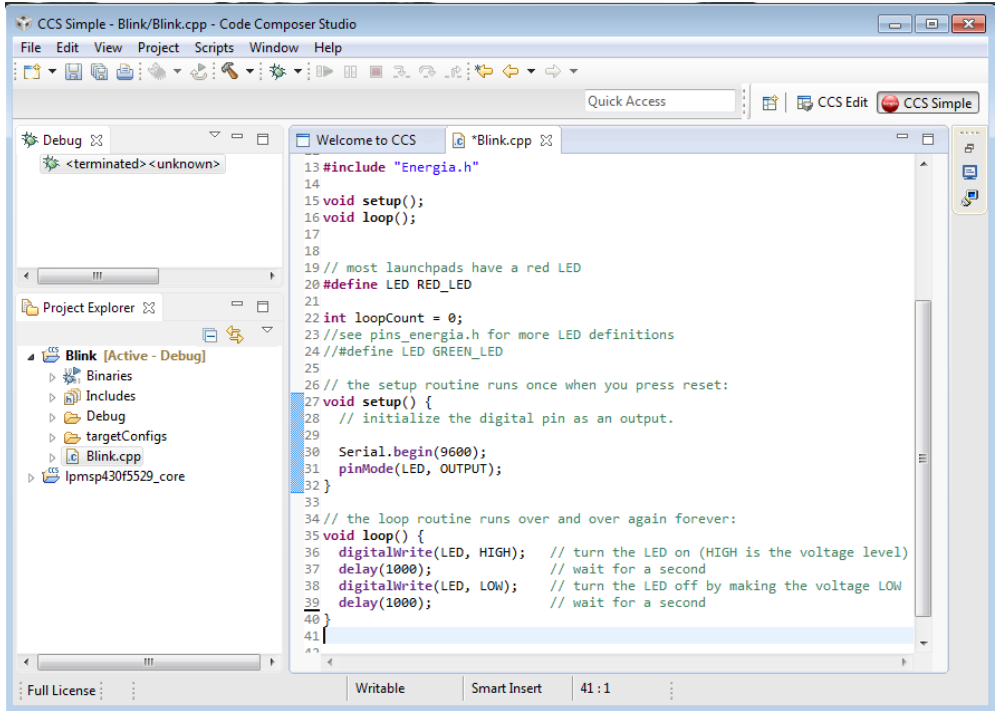
- **Check compatibility with different LaunchPad and BoosterPack combinations**



http://dev.ti.com

Code Composer Studio 7

- **Eclipse-based IDE for professional firmware developers that supports all TI processors**
- **CCS App Center allows you to stay current with the latest plugins and updates**
- **Use tools such as Energy Trace, GRACE, and more to optimize your workflow and application**
- **Resource Explorer exposes thousands of code examples and technical materials**



Download CCS Desktop at ti.com/ccstudio

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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

MSP Software Development

Pick a Coding Style…

Energia

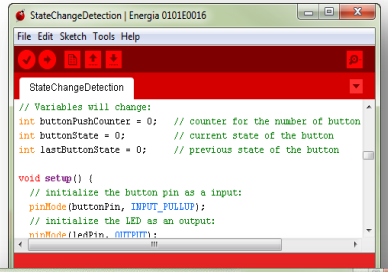
Driver Library
C coding / RTOS

Register-Based
C coding

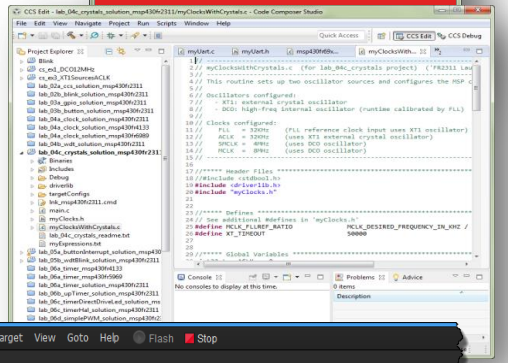
Low-Level
Hex programming

Choose a Tool…

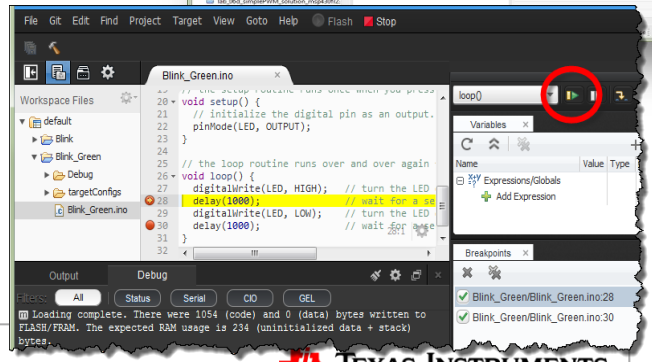
Energia IDE



CCS Desktop



CCS Cloud



Accessible & engaged community support gives new and experienced developers information to solve issues quickly

www.43oh.com

TI E2E™ Community

e2e.ti.com

hackster.io

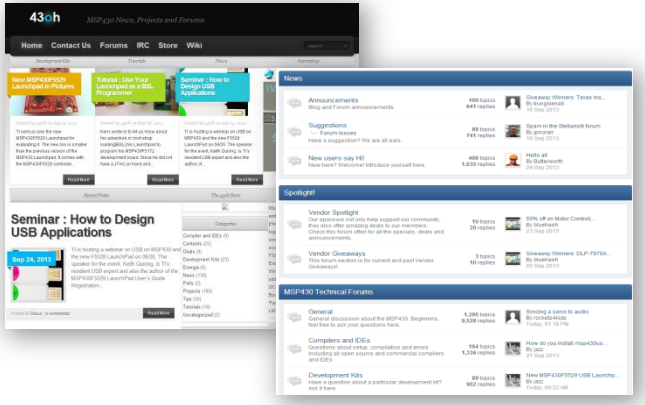
www.hackster.io/ti-launchpad

ti.com/lyd

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

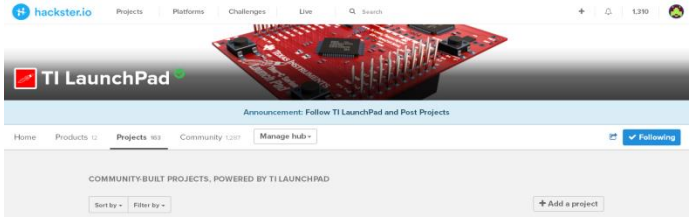


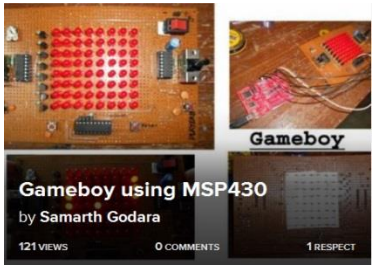
- www.43oh.com
- ~20,000 active members
- ~60 forum users online at any given time!
- Active & friendly online community & blog for the LaunchPad ecosystem!
- Home to much of the Energia community

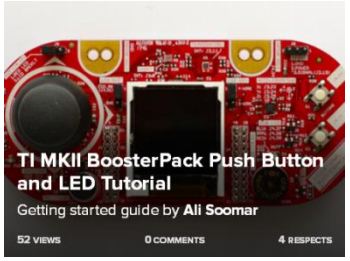
hackster.io - Share your electronics projects!

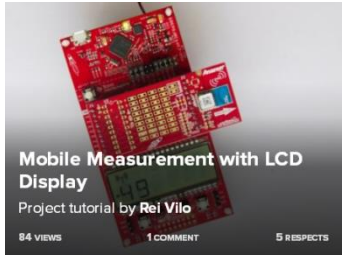
www.hackster.io/ti-launchpad

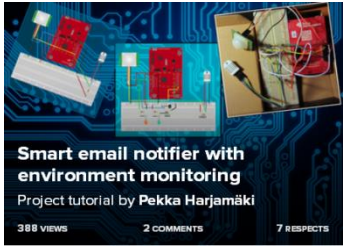
www.hackster.io/texasinstruments

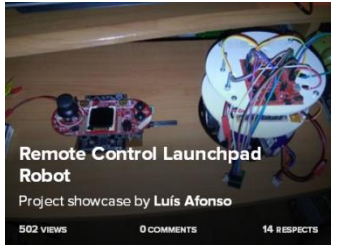






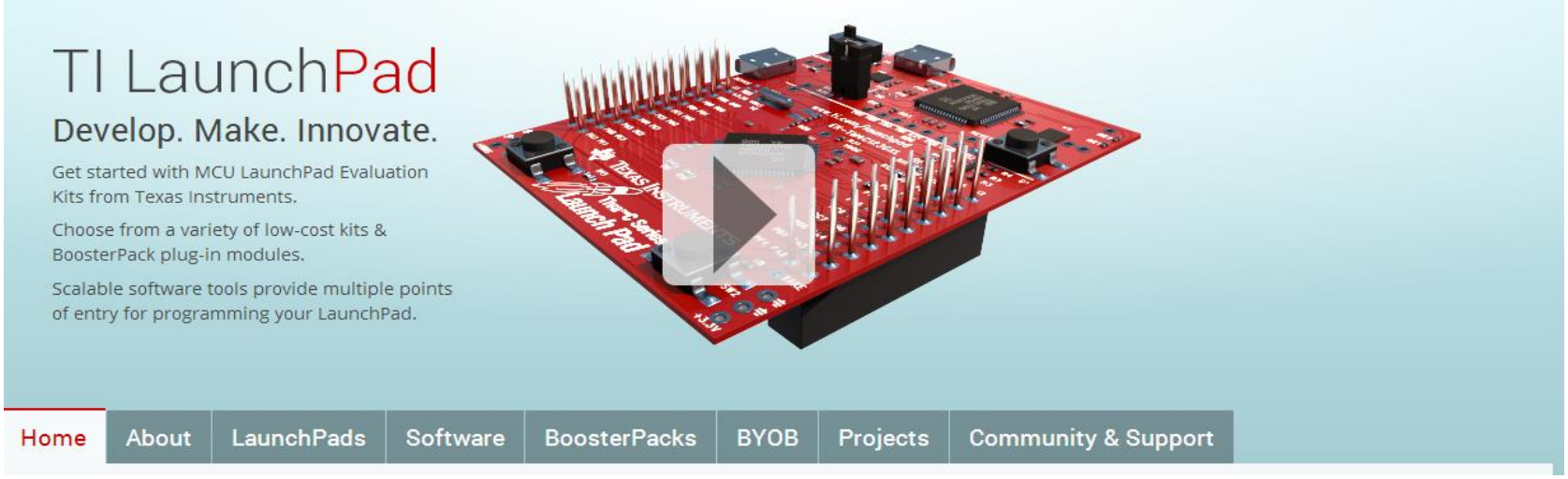






Where to go next: www.ti.com/launchpad

TI's official LaunchPad portal



Get specs, order hardware, find software tools, and download datasheets and design files

TI E2E™ Community

Sign up for a myTI account!

myTI

TI LaunchPad™ provides an ecosystem of hardware and software products, and community online resources that provides incredible value for rapid prototyping

Making MADE simple

With the TI LaunchPad

Questions?

www.ti.com/launchpad

Texas Instruments

Lab 3 Wi-Fi IoT with Temboo and Twitter

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

- Step 1: Navigate to the lab details or refer to handout
- Step 2: Create an account on www.temboo.com
- Step 3: Follow the lab details, no rude twitter shenanigans please
- Step 4: Raise your hand if you need assistance

Lab: https://goo.gl/**VbymuW**

SSID: **TEXINS3**

PASS: **launchpad**

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

Lab 4 GUI Composer

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 lab details
- Step 3: Raise your hand if you need assistance

Lab: https://goo.gl/**VbymuW**

SSID: **TEXINS3**

PASS: **launchpad**

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

Lab 5 More Wi-Fi IoT with Temboo

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 lab details
- Step 3: Raise your hand if you need assistance

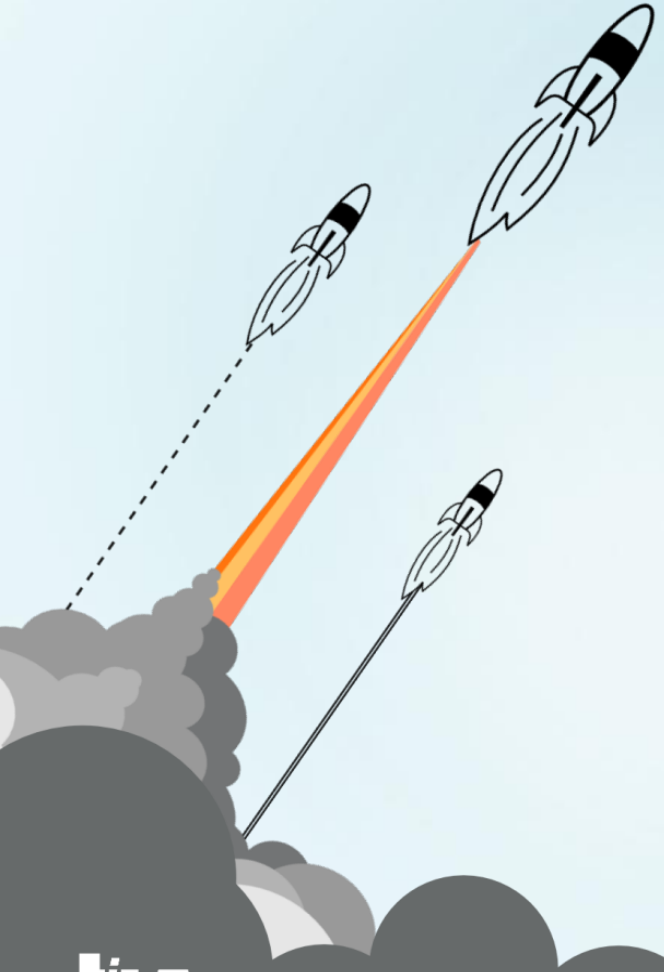
Lab: https://goo.gl/**VbymuW**

SSID: **TEXINS3**
PASS: **launchpad**

Local Wi-Fi Connection for your computer

SSID: **TEXINS3**
PASS: **launchpad**

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



Thank you!

www.ti.com/launchpad

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