Preparation for design students tackling electronics projects

Mark Easley
Texas Instruments University Program
Workshop overview

We will cover

• IoT topics and relevance to majority of student projects
• Scoping manageable automation and robotics projects
• Picking a processor that is appropriate for the design
• Working smart, simplify complex circuit design with tools
• Leverage reference designs to speed development
• Accessing professional help
• Advice on capstone resources
• Q&A on technologies accessible for student projects
Mark Easley (measley@ti.com)
University Marketing Manager
Raleigh, NC

Software Engineer
Over 9 years at TI
Embedded Systems & IoT experience
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

Experience matters with over 90 years of innovation
The Texas Instruments University Program is dedicated to supporting engineering educators, researchers and students worldwide.

Reaching students and faculty @ university.ti.com
Disclaimer: Electronics are unique

The following materials will be from the perspective of an ECE project or any project involving hardware design. Electrical Engineering, Computer Engineering, and Multi-disciplinary project with electronics.

Electronics projects require:

- Software… a processor is involved more times than not
- Prototyping… hardware starting with off the shelf components, wiring and breadboarding
- PCB design… CAD software available as open source, free license, paid license
- Debugging… scopes, test & measurement, power supplies, DMM
- System integration… putting the parts together can be more challenging than designing
Electronics project

Define, Design, Prototype, Customize
- What application are we solving for?
- What technologies exist today that have relevance for the application?

Stages
- Research the problem and end user
- Identify a technical solution thesis
- Design a prototype for proof of concept
- Iterate on design to customize for the application use cases
- Optimize design for manufacturability, usability, quality, reliability, cost
- Test design under stress and adverse conditions
- Release design
Electronics project

Embedded systems
- Processor
- Power Supply
- Sensors
- Actuators
- Connectivity

Keep it standard when possible
- Students will gravitate toward what they learned from the curriculum
- Provide microcontrollers that are commonly used at your school
- Have some easily sourced “go-to” parts or coordinate with lab staff

Pure analog projects without device programming are rare,
Need to have team comfortable with programming
Electronics project

PCB design using CAD tools
  - Schematic
  - Board layout
  - Design Rules Check
  - Auto routing (not recommended)
  - Symbols and footprints

Keep it standard when possible
  - Kicad or Autodesk EAGLE are popular tools because free license
  - Altium is used heavily in industry but it is a paid license
  - Students will want to work on their own computers, so self setup is best
  - Have students ramp up on these CAD tools over several weeks using tutorials
Questions?

Pause for Questions
Electronics project

PCB manufacturing and components
- BOM
- Board files or Gerbers
- PCB Contract Manufacturer (board house)
- Component distributor (Digi-key, Mouser, Newark, Adafruit, Sparkfun)
- Assembly (hand assemble or use a service)

Keep it standard when possible
- Find a reliable PCB manufacturer that students can use (Advanced Circuits, OSHpark, etc)
- Have ordering setup from common distributors either through online self service or Purchase Order system
- Have a BOM template that students can use
- Recommend package sizes for hand assembly
Electronics project

PCB Testing and Debugging
- Soldering, trace cutting, blue wiring
- Continuity testing
- Power Supply

Keep it standard when possible
- Have access to Digital Multimeter or USB oscilloscope for continuity and other basic tests
- Standalone power supply can be useful but most projects use standard voltages (5V, 9V, 12V)
- Access to benchtop equipment like an oscilloscope and logic analyzer can also
- Power supply design can be done easily with TI WEBENCH or with use of standard DC wall wart supplies available online
Electronics project

Accessing professional help
- Company forums, email, help lines
- Personal contacts

Use of reference designs
- Encourage students to search reference designs posted online for customer use
- Saves a lot of time and design effort
Questions?

Pause for Questions
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
July 2021
Mechatronics
a history

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

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

Robotics
- 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
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
Product Development
a birds eye view

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

1. Concept
2. Research
3. Evaluation
4. Design
5. Prototyping
6. Funding
7. Marketing
8. Production
9. Distribution
10. Support

Summary from Maker.io
Product Development
a birds eye view

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

Optimize
Make a process, product, or service incrementally better than previous iterations

Innovate
Attempt a new process, product, or service to radically disrupt previous methods or solutions

Summary from Maker.io
The typical block diagram

- Each project, while unique, follows a pretty standard formula
TI LaunchPad & BeagleBone Embedded System Design

a bird’s eye view

 Embedded System
• Power Management
• Communication
• Processing
• Analog

MCU LaunchPad or MPU BeagleBone

Sensor
Power
Motor Control
Input / Output
Display
RF Radio / Wired Comm

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
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
Stick with what works

- Get a standard list of development tools that are low cost and have good supply of devices for custom PCBs
- Boards the have used in curriculum and popular high utility boards like Arduino and RasPi
- Focus students on these tools to make life easier
Motors: Brushless vs Brushed vs Stepper
a comparison

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?

Big portion of IoT is around intelligent movement

Make use of motor drivers and software libraries like TI MotorWare
Motors: Brushless vs Brushed vs Stepper
a comparison

**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)

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

**Disadvantages**
- More complicated motor control
- More expensive

**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

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

- **4G LTE (Cellular)**
  - Wide range
  - High bandwidth
  - Expensive – Data & HW

- **Thread**
  - 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

**WiFi**
- 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

**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

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

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

Pause for Questions
TI LaunchPad & IoT
a bird’s eye view

Cloud Service Provider

Cloud services
Access to data, dashboards, etc

IoT Gateways
Your portal to the cloud

Ethernet

MCU + Ethernet LaunchPad
RF Booster Pack

Wi-Fi

MCU + RF SoC LaunchPad
RF Booster Pack

Wireless Nodes
Connecting your devices

LaunchPads
- MSP430
- MSP432
- TM4C
- C2000
- Hercules

MCU LaunchPad
BoosterPack

RF Booster Packs
- Zigbee / Zwave
- 6LoWPAN / Thread
- Bluetooth / Wi-Fi
- SubGHz RF / NFC
- LTE / Satellite

MCU + RF SoC LaunchPads
- CC3200 MCU + WiFi
- CC2650 MCU + BLE
- CC1310 MCU + SubGHz RF
- CC1350 MCU + SubGHz/2.4GHz

Cloud services
Access to data, dashboards, etc

MCU + RF SoC LaunchPads
- CC3200 MCU + WiFi
- CC2650 MCU + BLE
- CC1310 MCU + SubGHz RF
- CC1350 MCU + SubGHz/2.4GHz

LaunchPads
- MSP430
- MSP432
- TM4C
- C2000
- Hercules

MCU LaunchPad
BoosterPack

RF Booster Packs
- Zigbee / Zwave
- 6LoWPAN / Thread
- Bluetooth / Wi-Fi
- SubGHz RF / NFC
- LTE / Satellite
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?
Microcontroller
Making MADE simple
With the BeagleBone

Hardware & Software
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

**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
BeagleBone Capes

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

Cape Expansion Headers

**P9**
- DGND: 1, 2
- VDD_3V3: 3, 4
- VDD_5V: 5, 6
- SYS_5V: 7, 8
- PWR_BUT: 9, 10
- UART4_RXD: 11, 12
- UART4_TXD: 13, 14
- GPIO_48: 15, 16
- SPI0_CS0: 17, 18
- I2C2_SCL: 19, 20
- SPI0_D0: 21, 22
- GPIO_49: 23, 24
- GPIO_117: 25, 26
- GPIO_115: 27, 28
- SPI1_D0: 29, 30
- SPI1_SCLK: 31, 32
- AIN2: 33, 34
- AIN0: 35, 36
- AIN5: 37, 38
- AIN1: 39, 40
- GPIO_20: 41, 42
- DGND: 43, 44
- DGND: 45, 46

**P8**
- DGND: 1, 2
- MMC1_DAT6: 3, 4
- MMC1_DAT2: 5, 6
- GPIO_66: 7, 8
- GPIO_69: 9, 10
- GPIO_45: 11, 12
- EHRPWM2B: 13, 14
- GPIO_47: 15, 16
- GPIO_27: 17, 18
- EHRPWM2A: 19, 20
- MMC1_CLK: 21, 22
- MMC1_DAT0: 23, 24
- MMC1_CLK: 25, 26
- LCD_VSYNC: 27, 28
- LCD_HSYNC: 29, 30
- LCD_DATA14: 31, 32
- LCD_DATA13: 33, 34
- LCD_DATA12: 35, 36
- LCD_DATA9: 37, 38
- LCD_DATA8: 39, 40
- LCD_DATA7: 41, 42
- LCD_DATA6: 43, 44
- LCD_DATA5: 45, 46

**LEGEND**
- POWER/GROUND/RESET
- AVAILABLE DIGITAL
- AVAILABLE PWM
- SHARED I2C BUS
- RECONFIGURABLE DIGITAL
- ANALOG INPUTS (1.6V)
Microprocessors: Microcontrollers vs Single Board Computers
a comparison

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

Considerations:
◆ Power
◆ Integration
◆ Performance
◆ Cost
# 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
PocketBeagle for Embedded Linux ($25)

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
- USB

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

- **Performance** (clock rate)
- **Power** (active current)

LaunchPad

- MSP430
- SimpleLink
- Tiva C
- Beagle

C2000

Sitara
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?
Questions?

Pause for Questions
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

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!
Robotics project

Application and Chassis
- Mobile robotics
- Robotic arm or leg
- Prosthetics

Keep it standard when possible
- Use an existing chassis kit, custom design from scratch is complicated
Robotics project

Motor Drive
- Motor control programming
- Motor selection

Keep it standard when possible
- Use a reference design
TI Robotics System Learning Kit
One kit, many possibilities

Tackle many fundamental and trending topics in engineering with robotics

The TI-RSLK MAX has the flexibility to teach students:

• Intro to Engineering Design & Robotics
  • Embedded Systems
  • Internet of Things
• Sensors & Sensor Fusion
  • AI / ML
  • Controls
• Mechatronics
But, Why?
Innovate & accelerate with robotics system learning

Robotics is everywhere!

Autonomous vehicles  Factory automation  Security & safety

Multidisciplinary systems thinking is required to create these current and future applications

TI Information – Selective Disclosure
The Internet of Things is accelerating

Sensors and wireless electronics are everywhere!

Autonomous vehicles & electrification of transportation  
Industrial sensing in the smart factory  
Home automation & consumer electronics

Engineers need to know how to design data streams into their work

TI Information – Selective Disclosure
Meet the **TI-RSLK product family**

The TI robotics system learning kit (TI-RSLK) 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:

<table>
<thead>
<tr>
<th>Curriculum</th>
<th>Hardware</th>
<th>Software</th>
<th>Projects</th>
<th>TI Resources</th>
</tr>
</thead>
</table>

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TI Information – Selective Disclosure
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.
TI-RSLK MAX callouts

- Gear motor and encoder assembly
- SimpleLink™ MSP432P401R MCU LaunchPad™ development Kit
- TI-RSLK chassis board
- Bumper switch assembly
- Black robot chassis with red-wheel assembly
- Line sensor array
MSP432 LaunchPad
Introducing the SimpleLink MSP432P4 processor for Low Power + Performance

**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

$19.99
DRV5013 Hall Effect Sensor

1. Features
   - Digital Bipolar-Latch Hall Sensor
   - Superior Temperature Stability
     - \( B_{OP} \pm 10\% \) Over Temperature
   - Multiple Sensitivity Options (\( B_{OP} / B_{LP} \))
     - 1.2 / -1.2 mT (PA, see Device Nomenclature)
     - 2.7 / -2.7 mT (AD, see Device Nomenclature)
     - 6 / -6 mT (AG, see Device Nomenclature)
     - 12 / -12 mT (BC, see Device Nomenclature)
   - Supports a Wide Voltage Range
     - 2.5 to 36 V
   - No External Regulator Required
   - Wide Operating Temperature Range
     - \( T_{OP} = -40 \) to 125°C (Q, see Device Nomenclature)
   - Open-Drain Output (30-mA Sink)
   - Fast 35-\( \mu \)s Power-On Time
   - Small Package and Footprint
     - Surface Mount 3-Pin SC73-23 (DBZ)
     - 2.92 mm x 2.37 mm
     - Through-Hole 3-Pin TO-92 (LPG)
     - 4.00 mm x 3.15 mm
   - Protection Features
     - Reverse Supply Protection (up to -22 V)
     - Supports up to 40-V Lead Dump
     - Output Short-Circuit Protection
     - Output Current Limitation

2. Applications
   - Power Tools
   - Flow Meters
   - Valve and Solenoid Status
   - Brushless DC Motors
   - Proximity Sensing
   - Tachometers

3. Description
   The DRV5013 device is a chopper-stabilized Hall Effect Sensor that offers a magnetic sensing solution with superior sensitivity stability over temperature and integrated protection features.

   The magnetic field is indicated via a digital bipolar latch output. The IC has an open-drain output stage with 30-mA current sink capability. A wide operating voltage range from 2.5 to 36 V with reverse polarity protection up to -22 V makes the device suitable for a wide range of industrial applications.

   Internal protection functions are provided for reverse supply conditions, lead dump, and output short circuit of over current.

Device Information

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PACKAGE</th>
<th>BODY SIZE (MM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRV5013</td>
<td>SC73-23 (2)</td>
<td>2.92 mm x 1.35 mm</td>
</tr>
<tr>
<td></td>
<td>TO-92 (3)</td>
<td>4.00 mm x 3.15 mm</td>
</tr>
</tbody>
</table>

(1) For all available packages, see the package option addendum at the end of the data sheet.

TI Information – Selective Disclosure
**DRV8838 Motor Driver**

**DRV883x Low-Voltage H-Bridge Driver**

### 1 Features
- H-Bridge Motor Driver
  - Drives a DC Motor or Other Loads
  - Low MOSFET On-resistance: HS + LS 280 mΩ
- 1.8-A Maximum Drive Current
- Separate Motor and Logic Supply Pins:
  - Motor VM: 0 to 11 V
  - Logic VCC: 1.8 to 7 V
- PWM or PH/EN Interface
  - DRV8837: PWM, IN1/IN2
  - DRV8838: PH/EN
- Low-power Sleep Mode With 120-nA Maximum Sleep Current
  - nSLEEP pin
- Small Package and Footprint
  - 8 WSON (PowerPAD™)
  - 2.0 x 2.0 mm
- Protection Features
  - VCC Undervoltage Lockout (UVLO)
  - Overcurrent Protection (OCP)
  - Thermal Shutdown (TSD)

### 3 Description
The DRV883x provides an integrated motor driver solution for cameras, consumer products, toys, and other low-voltage or battery-powered motion control applications. The device can drive one DC motor or other devices like solenoids. The output driver block consists of N-channel power MOSFETs configured as an H-bridge to drive the motor winding. An internal charge pump generates needed gate drive voltages.

The DRV883x can supply up to 1.8 A of output current. It operates on a motor power supply voltage from 0 to 11 V, and a device power supply voltage of 1.8 V to 7.0 V.

The DRV8837 has a PWM (IN/IN) input interface; the DRV8838 has a PH/EN input interface. Both interfaces are compatible with industry-standard devices.

Internal shutdown functions are provided for overcurrent protection, short circuit protection, undervoltage lockout, and overtemperature.

### Device Information

<table>
<thead>
<tr>
<th>ORDER NUMBER</th>
<th>PACKAGE</th>
<th>BODY SIZE</th>
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</thead>
<tbody>
<tr>
<td>DRV8837DSGR</td>
<td>WSON (8)</td>
<td>2.0 x 2.0 mm</td>
</tr>
<tr>
<td>DRV8888DSGR</td>
<td>WSON (8)</td>
<td>2.0 x 2.0 mm</td>
</tr>
</tbody>
</table>

**Figure 5. DRV8838 Functional Block Diagram**
Gearmotor and Encoders

- **Motors**
  - 120:1 gear ratio
  - 120 rotations of small shaft/disc = 1 rotation of wheel
  - TI-RSLK powers these motors at battery voltage
    - 6 AA batteries x 1.5V max each = 9V max

- **Encoders**
  - Disc has 3 PN magnets = 6 poles
    - 2 magnetic field Hall Effect sensors per board
    - Provides 12 states/counts per rotation (vs 6 w/ just 1)

- 120 gear ratio x 12 counts per rotation = 1440 counts per rotation!
TPS568230/330 Switching Regulator = 5V, up to 8A

- Generate 5V
  - Feeds 3.3V
  - Future “Extras”
    - LCD/OLED display
    - Distance Sensors
    - Other sensors
TLV1117LV Linear Regulator = 3.3V, up to 1A

• 3.3V output for MSP432 LaunchPad

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**TLV1117LV 1-A, Positive Fixed-Voltage, Low-Dropout Regulator**

<table>
<thead>
<tr>
<th>Features</th>
</tr>
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<tbody>
<tr>
<td>1.5% Typical Accuracy</td>
</tr>
<tr>
<td>Low $I_{OQ}$: 100 µA (Maximum)</td>
</tr>
<tr>
<td>– 500 Times Lower Than Standard 1117 Devices</td>
</tr>
<tr>
<td>$V_{IN}$: 2 V to 5.5 V</td>
</tr>
<tr>
<td>– Absolute Maximum $V_{IN} = 6$ V</td>
</tr>
<tr>
<td>Stable With 0-mA Output Current</td>
</tr>
<tr>
<td>Low Dropout: 455 mV at 1 A for $V_{OUT} = 3.3$ V</td>
</tr>
<tr>
<td>High PSRR: 65 dB at 1 kHz</td>
</tr>
<tr>
<td>Minimum Ensured Current Limit: 1.1 A</td>
</tr>
<tr>
<td>Stable With Cost-Effective Ceramic Capacitors:</td>
</tr>
<tr>
<td>– With 0-Ω ESR</td>
</tr>
<tr>
<td>Temperature Range: −40°C to 125°C</td>
</tr>
<tr>
<td>Thermal Shutdown and Overcurrent Protection</td>
</tr>
<tr>
<td>Available in SOT-223 Package</td>
</tr>
</tbody>
</table>

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**Description**

The TLV1117LV series of low-dropout (LDO) linear regulators is a low input voltage version of the popular TLV1117 voltage regulator.

The TLV1117LV is an extremely low-power device that consumes 500 times lower quiescent current than traditional 1117 voltage regulators, making the device suitable for applications that mandate very low standby current. The TLV1117LV family of LDOs is also stable with 0 mA of load current; there is no minimum load requirement, making the device an ideal choice for applications where the regulator must power very small loads during standby in addition to large currents on the order of 1 A during normal operation. The TLV1117LV offers excellent line and load transient performance, resulting in very small magnitude undershoots and overshoots of output voltage when the load current requirement changes from less than 1 mA to more than 500 mA.
**TLV9004 4-channel Operational Amplifier**

- For Distance Sensors (or other)
## Hardware for TI-RSLK MAX (TIRSLK-EVM)

<table>
<thead>
<tr>
<th>KIT CONTENTS</th>
<th>OPTIONAL PURCHASES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaches the foundations of an electronic system; robot can solve its way through a maze with line and collision detection</td>
<td>Expand the capabilities and complexity of the system with additional accessories like sensors, connectivity, and actuators</td>
</tr>
<tr>
<td>SimpleLink™ MSP432P401R MCU LaunchPad™ Development Kit</td>
<td>SimpleLink Bluetooth® low energy CC2650 module BoosterPack™ plug-in module</td>
</tr>
<tr>
<td>Line IR sensors</td>
<td>SimpleLink Wi-Fi® CC3100 wireless network processor BoosterPack™ plug-in module</td>
</tr>
<tr>
<td>Bump switches</td>
<td>Robot arm</td>
</tr>
<tr>
<td>Chassis &amp; Motor assembly with encoder</td>
<td>Sensors BoosterPack™ plug-in module</td>
</tr>
<tr>
<td>Wires</td>
<td>OPT3101 Distance Sensor</td>
</tr>
<tr>
<td>Breadboard</td>
<td>Audio BoosterPack™ plug-in module</td>
</tr>
<tr>
<td>+ other mechanical &amp; electronic components</td>
<td>Sidekick Kit for TI LaunchPad</td>
</tr>
<tr>
<td>TI-RSLK Chassis Board</td>
<td>+ additional BoosterPack plug-in modules &amp; electronic components</td>
</tr>
</tbody>
</table>

**KIT CONTENTS**
- Line IR sensors
- Bump switches
- Chassis & Motor assembly with encoder
- Wires
- Breadboard
- + 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
- Sensors BoosterPack™ plug-in module
- OPT3101 Distance Sensor
- Audio BoosterPack™ plug-in module
- Sidekick Kit for TI LaunchPad
- + additional BoosterPack plug-in modules & electronic components
Customize: Alternate applications
TI-RSLK MAX reusability
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 virtual distance learning, flipped classrooms and classrooms without access to soldering equipment or lab benches
Expanded curriculum experiences

• Accessory hardware for multiple year + multiple course investment
  – Attach new sensors, servo driven gripper arm, wireless modules, and 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

• Flexibility for course customizations
  – Integrate course objectives around specific instrumentation or specialized topics
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. Your robot can also be customized to complete any challenge or task students dream up.
Engage students with robotic challenges

The TI-RSLK website provides community resources for making DIY challenges easy to set up for department or campus competitions. Generate excitement within department or college and buzzworthy content for campus publications and alumni newsletters. 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.
Compete: Beyond the maze!

- Obstacle course (navigate different terrains and obstacles in confined area)
- Head-to-head competitions (racing, battle bots, balloon popping and team games)
- 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)
Using TI-RSLK MAX

Programming

Code Editors
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 at TI.com and available for purchase through authorized distributors
Free tools to maximize hardware

- TExaS display & GUI debug tool, Code Composer Studio & TI-RSLK starter code
Learn: Video lectures

- Get personal instruction from Dr. Jonathan Valvano
- Walk through and preview lab exercises
Learn: Inside each module

- Introduction document with educational objectives, pre-requisites and 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
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
Learn: Ample academic resources

• Textbook resources and technical references on MSP432
  – Deep dive into the microcontroller with textbook references from university educators and technical manuals published by TI
  – Many print resources available for the MSP43x chipset

• Additional online courses and tutorials
  – Make use of tutorial content from popular online classes and websites
  – Online workshops compatible with MSP432P401R and MSP432 architecture and peripherals
    • https://training.ti.com/msp432-low-power-high-performance-mcus-training-series
    • https://training.ti.com/msp430-workshop-series
edX course: Fundamentals of Mechatronics MOOC

• High impact, first of it’s kind online course offering for Mechatronics
  – Deep dive for students, hobbyists, and professionals
  – Trends toward automation is boosting demand for mechatronics educational content
  – On-demand content on the popular EdX platform, free to audit & paid certificates are offered
  – Featuring TI-RSLK MAX and MSP432 LaunchPad, highly tied to TI-RSLK concepts and covering supplemental topics

Dr. Jonathan Rogers brings years of experience teaching mechatronics at Georgia Tech and as the Director of Aerial Robotics and Experimental Autonomy Lab

TI Information – Selective Disclosure
**edX course: Real-Time Bluetooth networks**

- [https://www.edx.org/course/real-time-bluetooth-networks-shape-the-world](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 & IoT

**edX course: Embedded Systems - Shape The World**

- [https://www.edx.org/course/embedded-systems-shape-the-world-microcontroller-i](https://www.edx.org/course/embedded-systems-shape-the-world-microcontroller-i)
- Taught by professors at University of Texas Austin
- Comprehensive, self paced, hands-on course on embedded systems
TI-RSLK MAX

TI Robotics System Learning Kit MAX
Questions?

Pause for Questions
Developing IoT Products

- Create Block diagram
- Prototype using evaluation modules provided by vendors
- Design PCB
- Write Firmware
- Develop cloud software using APIs
Sensor IoT

• Typical Characteristics
  – Long Range (deployed far from gateway)
  – High Density (in some cases)
  – Low Power (battery powered)
  – Low Bandwidth (small data packets)

• \( \text{I}^2\text{C} \) protocol is commonly used peripheral for sensors

• RF protocols range from mesh to star topology networks
  – Proprietary stack (provides lowest latency)
  – Zigbee, Xbee, TI 15.4
  – OpenThread, 6LoWPAN
Create multi-band sensor networks with the **LaunchPad™ SensorTag Kit (LPSTK)**.
SimpleLink™ CC1310 Wireless MCU LaunchPads
ARM® Cortex™ M3 based SoC with integrated Sub-1GHz, 6LoWPAN connectivity

Target MCU: CC1310
BoosterPack Pinout: 40-pin
Specs:
• 48MHz ARM® Cortex™-M3 CPU
• 128kB Flash / 20 kB RAM
• 12-bit ADC, I²C, I²S, UART, SPI, Ultra-low Power Sensor Controller
• Supports OTA upgrades & up to 8 capacitive sense buttons

Why this LaunchPad?
- Great starting point for IoT Applications
- All in one solution for 6LoWPAN or proprietary Sub-1GHz radio

$29.00

LAUNCHXL-CC1310
SimpleLink™ CC1352R1 LaunchPad SensorTag

ARM® Cortex™ M4 based SoC with integrated Sub-1GHz, 6LoWPAN connectivity

Target MCU: CC1352R1
BoosterPack Pinout: 40-pin
Specs:
- 48MHz ARM® Cortex™-M4 CPU
- 352kB Flash / 80 kB RAM
- 12-bit ADC, I²C, I²S, UART, SPI, Ultra-low Power Sensor Controller
- Supports OTA upgrades & up to 8 capacitive sense buttons

Why this LaunchPad?
- Great starting point for IoT Applications
- All in one solution for BLE & Sub-1GHz radio

$30.00

LPSTK-CC1352R
Meet the LPSTK *(LaunchPad SensorTag Kit)*

- Remove-able enclosure for easy access to PCB
- Lanyard loop
- Sub-1GHz SMA swivel antenna (Sub-1GHz (TI-15.4 or proprietary stacks))
- 2.4GHz PCB antenna
- Power switch, 2 user buttons & RGB LED
- Various on-board sensors: Temp, Humidity, Light, Motion, Hall Effect
- Easy access to I/Os & BoosterPack-compatible
- 2x AAA battery-operation
- Featuring SimpleLink™ multi-band CC1352R wireless MCU Paired with Johanson Technology IPC
Meet the SimpleLink™ multi-band CC1352R wireless MCU.

Part of the SimpleLink Platform – the industry’s broadest portfolio of connected, low-power & secure MCUs

- 48-MHz arm Cortex-M4F MCU
- 352kB flash (user programmable)
- 256kB ROM (protocols & library functions)
- 8kB cache SRAM (also available as general purpose RAM)
- Integrated Sensor Controller
- Multi-band sub-1 GHz and 2.4 GHz RF transceiver
- Integrated digital & analog peripherals
- Full support of the SimpleLink SDK
SimpleLink™ MCU Platform
One environment. Unlimited potential.

Texas Instruments
Unified experience to speed up customer time to market and manage IoT product life cycle
SimpleLink MCU Platform

Wired Microcontrollers
- Host Ethernet MCU
  MSP430F4
- Host MCU
  MSP432P4

Wireless Microcontrollers
- Bluetooth low energy
  CC254x
- Multi-standard
  CC135x
- WiFi
  CC3220
- Thread
  CC1352
  CC3162

Wireless Network Processors
- WiFi
  CC3135
  CC3129

Broadest portfolio of wired and wireless MCUs

SDK

100% Code portability

Wired
Ethernet | CAN | USB

Wi-Fi
CERTIFIED

Bluetooth

Sub-1GHz

zigen

THREAD

Multi-standard

Texas INSTRUMENTS
SimpleLink MCUs | Connecting every market
Seamless multi-protocol & multi-band operation.
Unparalleled flexibility to connect your applications.

Easily create a multi-node star sensor network
Quickly evaluate a complete star topology, featuring low-power, long-range sensors using TI's TI-15.4 stack over Sub-1GHz. Over 1 mile of range possible.

Create a scalable mesh network with Thread or ZigBee
The LPSTK is based on the multi-protocol SimpleLink CC1352R MCU, which support ZigBee and Thread. Developers have multiple mesh options that support multi-hop & self-healing networks.
Hardware tools you need to innovate.

LaunchPad Development Kits are open-ended hardware development platforms. These kits offer developers unrestricted development access to SimpleLink MCUs & can be used as a blank slate for creating the next big thing.

LaunchPad SensorTag Kits are a fully-enclosed, battery-operated wireless prototyping platform, featuring ready-to-go hardware. Developers can jumpstart their development with out-of-the-box battery-operation & on-board sensors.

**LaunchPad Development Kits**
- On-board debugger with EnergyTrace™ capability
- USB-powered
- Available for all SimpleLink families
- User LEDs & pushbuttons
- Access to all MCU pins
- BoosterPack-compatible

**LaunchPad SensorTag Kits**
- Battery-operated with remove-able enclosure
- On-board sensors (Temp, humidity, light, hall effect, motion)
- Featuring SimpleLink CC1352R MCU
- User LEDs & pushbuttons
- Access to all MCU pins
- BoosterPack-compatible

Flexible hardware kits for prototyping & development
Hardware flexibility facilitates rapid prototyping.

Ready-to-go hardware with on-board sensors & AAA battery operation

- User switch 1
- User switch 2
- HDC2080 (temp)
- OPT3001 (ambient light)
- DRV5032 (hall effect)
- 2x AAA battery-operation
- 3-axis accelerometer
- RGB LED
- BoosterPack-compatible

- **TI DRV5032** | Industry-leading ultra-low-power hall effect sensor
  
  *Featured use-case: Door/window sensors*

- **TI HDC2080** | High-accuracy, interruptible temp & humidity sensor
  
  *Featured use-case: Environmental sensing for building & factory automation*

- **TI OPT3001** | Industry-leading “Eye-matching” light sensor with IR rejection
  
  *Featured use-case: Environmental sensing for building & factory automation*

- **3-axis accelerometer** | Paired with CC1352R integrated Sensor Controller
  
  *Featured use-case: Asset tracking, tilt-detection & motion tracking*

- **Add your own sensors** | Rapidly prototype your own connected sensor nodes
  
  *Leverage the BoosterPack ecosystem or interface your own components*
Rapid prototyping with BoosterPack extendibility to add external hardware (sensors, displays & more)

SHARP LCD BoosterPack

Seeed Studio Grove BoosterPack + soil moisture sensor
Visualize sensor data & re-program LPSTK over-the-air

The SimpleLink Starter app is available for iOS and Android mobile devices to interface with the LPSTK over Bluetooth. Stream & visualize sensor data, or re-program the LPSTK with over-the-air download (OAD).
Go beyond the demo & iterate towards production.

Full debug support when paired with a SimpleLink LaunchPad kit

Full debug support is available when the LPSTK is connected to a SimpleLink LaunchPad kit debugger. An ARM JTAG 10-pin ribbon cable is provided with the LPSTK to allow full debug when needed.

Simply customize your LPSTK software with SysConfig

The SimpleLink SDK is configurable with an intuitive graphical interface called SysConfig. Change stack parameters, pin out configurations, driver capabilities and more through an easy-to-use interface.
Thanks!

Q&A

Mark Easley (measley@ti.com)
Texas Instruments University Program