Low Power Connectivity

Long Range, Low Power, Ease of Use

Sub-1GHz

RF4CE

Bluetooth® SMART

6LoWPAN

ZigBee®

M-Bus wireless

SIGFOX
One network A billion dreams

802.15.4g

THREAD

Wireless Connectivity Portfolio

Proximity	Personal area networks		Local area networks			Neighborhood area networks
NFC **RFID**	***Bluetooth*®** ***Bluetooth* LE**	**Proprietary 2.4GHz**	**ZigBee & RF4CE**	**Wi-Fi®**	**6LoWPAN**	**Sub-1GHz** **(standards or proprietary)**
Identification	*Personal Connection*	*Customizable*	*Mesh/ P2P*	*Existing Infrastructure*	*IP Mesh*	*Customizable*
Key Differences						
Data Up to 848 Kbps No battery to coin cell	Data or Voice Up to 3 Mbps Coin cell to AAA	Data Up to 1 Mbps Coin cell	Data Up to 256 Kbps Energy harvesting to AAA	Voice or video Up to 100 Mbps AA battery	Data Up to 256 Kbps Energy harvesting to AAA	Data Up to 1 Mbps Coin cell
Key Attributes						
• Passive operation & data storage • Dedicated multi-tag read zone • In Portable devices	• Interoperable with other Bluetooth devices • Large install base • In mobile devices	• Customizable to application • Robust RF	• Standards based • Self-healing mesh • Low power • Large area coverage • Remote control	• Existing infrastructure • High throughput	• IPv6 stack • Ultra low power • IoT platform	• Longest range (20km) • Customizable to application • Robust RF

cm — Up to 100m — **Range** — km

LPC Low power, long-range IoT

Home automation

Lighting control
Door locks
White goods

Smart grid

Flow Meters
E-Meters
Heat cost allocators

Alarm & security

Security alarms
Smoke/CO2 alarms
Security sensors

Retail

ESL / Price Tags
Locationing
Cold chain mgmt

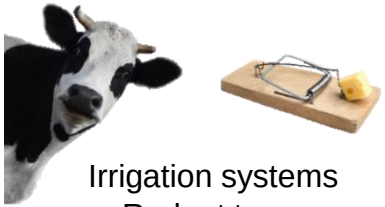
Logistics

Tollroad tags
Asset Tracking

Factory automation

Monitoring sensors
Cable replacement

Agriculture



Irrigation systems
Rodent traps
Animal tracking

Other

Rescue tracking
RC toys

Why Sub-1GHz?
It's Physics: Better Range, Power, Robustness

Range, Range, Range

- 100x more than Wi-Fi, BLE
- Full house coverage with a simple Star network
- Choice of long range modulations

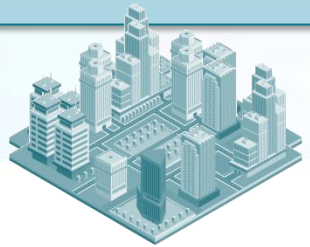
100 km Range Demo
CC1120 into space

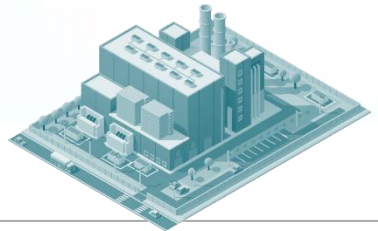
Lower Power

- 20 km on coin cell battery
- 10 years on coin cell battery
- Lower power vs. other technologies for the same range

Robustness

- Lower attenuation by walls and obstacles
- Avoid the crowded 2.4 GHz
- Narrow band provides better resilience to jammers



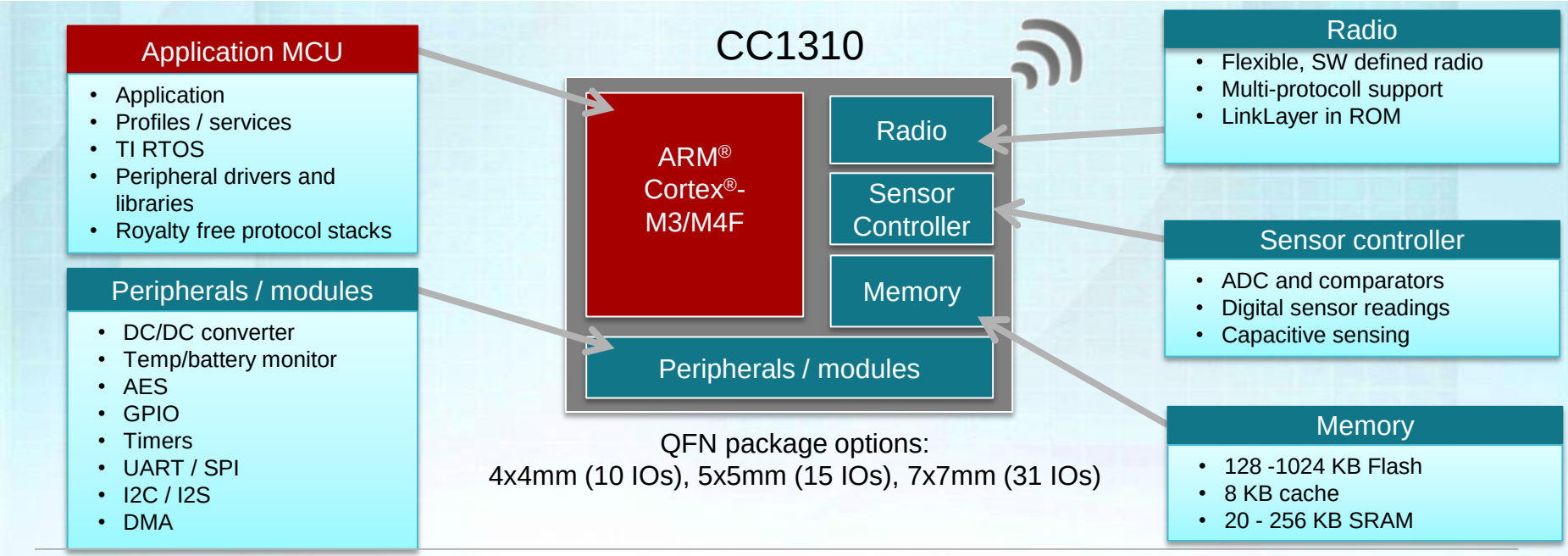


Texas Instruments

Low Power Connectivity

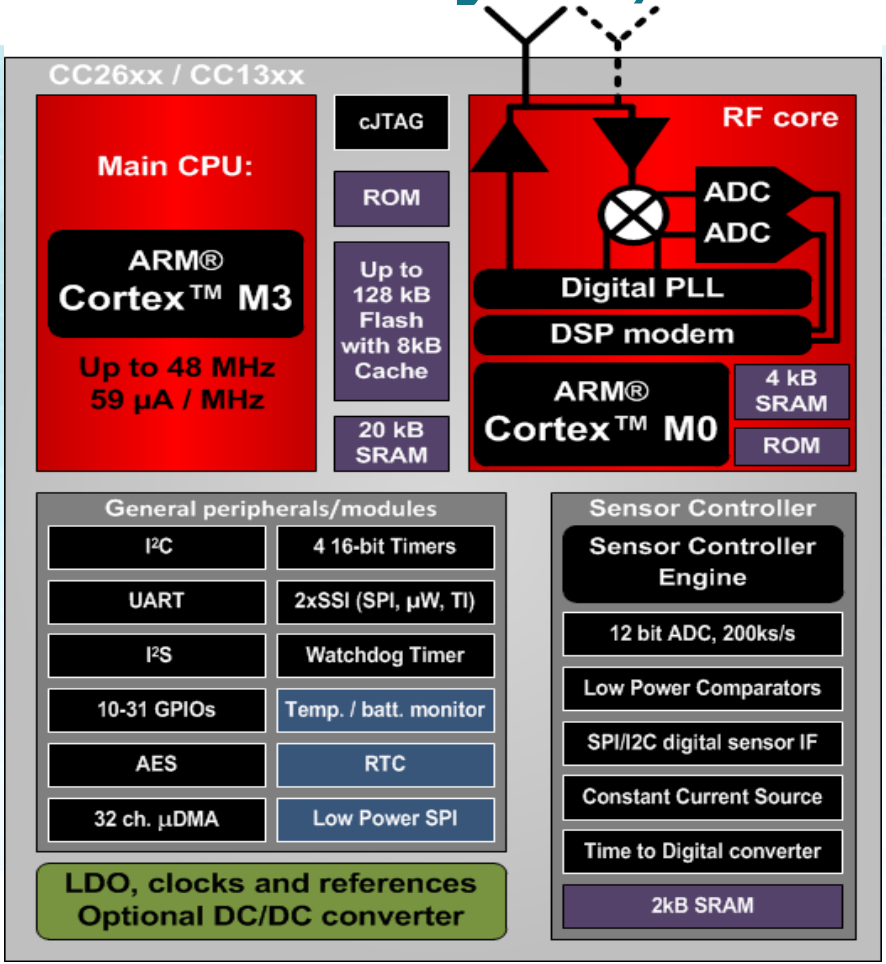
Product offering - HW

One architecture, several technologies



Sub-1GHz RF4CE Bluetooth SMART 6LoWPAN ZigBee M-Bus wireless SIGFOX One network A billion dreams 802.15.4g THREAD

CC1310 20 year, 20km on a coin cell



Quick Facts

Low Power
- 61 µA/MHz ARM Cortex M3
- 8.2 µA/MHz Sensor Controller
- 0.7 µA sleep with retention and RTC
- 5.5 mA RX (single-ended)
- 13 mA TX (single-ended) @10dBm

Long Range
- High sensitivity
  - -110 dBm @ 50 kbps
  - -124 dBm @ 0.625 kbps
- +14 dBm output power
- Strong co-existence - Up to 90 dB blocking

High Integration
- Up to 1.5Mbps
- 4x4, 5x5, 7x7 mm QFN
- 1.7 - 1.95 V or 1.8 – 3.8 V supply range
- 128 KB Flash + 8 KB Cache
- 20 KB RAM

Sensor to Cloud TI Design ™ system overview

TI Design sensor application

TI 15.4-Stack SDK

TI Design sensor application

TI 15.4-Stack SDK

TI Design sensor application

TI 15.4-Stack SDK

TI Design sensor application

TI 15.4-Stack SDK

Sub-1 GHz Network

TI Design Cloud IoT Agent

TI 15.4-Stack Linux SDK

Sitara AM335x Processor SDK

Sub-1 Ghz/Cloud Gateway

TI Design ™ : Beagle Bone Black+ CC1310 LaunchPAD

Cloud app

stackArmor

amazon web services

TI Design components

TI Product SDK

http://www.ti.com.cn/tool/cn/TIDEP0084

Sub-1 GHz Sensor to Cloud Industrial IoT Gateway

- Shows how a sub-1GHz based long range/low power sensor node can be connected to IoT cloud service providers (e.g AWS, Microsoft Azure, Google IoT)
- ***End to End*** reference***, built around*** BeagleBone Black and Sub-1GHz SensorTag™/Launchpad
- Software development based on TI-15.4MAC Sub-1GHz SDK, BBB SDK, AWS agent

Shorter time to market of new product

Ease of design and integration

- IoT agent integration
- Sub-1 GHz - IP Gateway proxy application
- TI-15.4MAC for Sub-1GHz out-of-the-box networking
- End-to-end system design

Rapid prototyping
Quick project spins
Easy-to-demo at end customers

Low cost and modular development platform

- CC13xx adaptor
- BeagleBone Black
- Sensor Tag
- Launchpad ecosystem

Seamless interface with any cloud provider

Flexibility and robustness

- Standard protocol cloud connectivity interface (e.g. MQTT)
- Local link control backup

Sub-1GHz Made Easy

Software

TI-15.4STACK

Standard 802.15.4g/e implementation

No need to build your own network protocol

Available now!

Certified SIGFOX solution

US: CC1120+CC1190
EMEA: CC1125
WW: CC1310TX

EVMs

CC1310 LaunchPad

Only $29!

CC1350 LaunchPad

Sub-1GHz+BLE solution

Only $29!

CC1350 Sensor Tag

First Sub-1GHz+BLE Dual-band demo kit

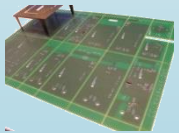
CC1120+CC1190 - US SIGFOX

CC1125 - EMEA SIGFOX

Tools/Resources

Sensor to Cloud

TI-Design for full Sub-1GHz based network gateway to cloud



- **Antenna Kit**
  Antenna design and selection kit
  Get coin cell design with CC1310

SimpleLink™

Sub-1GHz device: CC1310

硬件射频——从设计到成型

315 / 433 / 470 / 500 / 779 / 868 / 915 / 920 MHz

Speaker: TI engineer, Albin Zhang

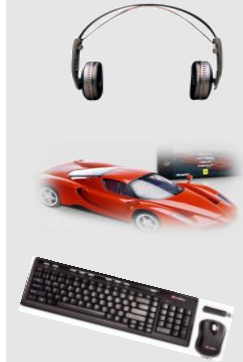
The industry's broadest wireless connectivity portfolio

Supported standards

134KHz /13.56MHz	Sub 1GHz	2.4GHz to 5GHz				Satellite
RFID NFC ISO14443A/B ISO15693	SimpliciTI 6LoWPAN W-MBus	SimpliciTI PurePath Wireless	ZigBee® 6LoWPAN RF4CE	*Bluetooth*® technology *Bluetooth*® low energy	Wi-Fi®	GNSS

Example applications













Product line up

TMS37157 TRF796x TRF7970	CC112X CC120X CC1180 **CC1310** **CC1350**	CC2500 CC2543/44/45 CC2590/91 CC8520/21 CC2530/31	CC2530 CC2530ZNP CC2531 CC2533 CC2520 CC2630	CC2560/4 CC2540/1 CC2570/1 CC2640 **CC1350** CC2650	WL127x WL18xx CC3000 CC31xx CC32xx CC3x20	WL18xx CC4000

CC1310

TI introduces the next generation Sub-1 GHz family

Improving the three key challenges for a *Sub-1 GHz Wireless MCU*:

Longest Range

- High sensitivity
  - -110 dBm @ 50 kbps
  - -124 dBm @ 625 bps
  - -119 dBm @ 5kbps
- Strong co-existence
  - Up to 80 dB blocking

Full-building to city-wide RF coverage

Lowest Power

- 5.5 mA Radio RX peak current
- 61 µA / MHz ARM Cortex M3
- 700 nA standby current w/RTC + full memory retention
- Sensor Controller Engine (SCE)

Up to 20 year battery life for sensor nodes and flow meters

Most Integrated

- 4x4, 5x5, 7x7 mm QFN
- On-Chip Flash
- Single Ended Output possible
- Integrated DCDC

Complete 315 / 433 / 470 / 500 / 868 / 915 / 920 MHz wireless MCU on a finger-tip size

CC13xx HW Training

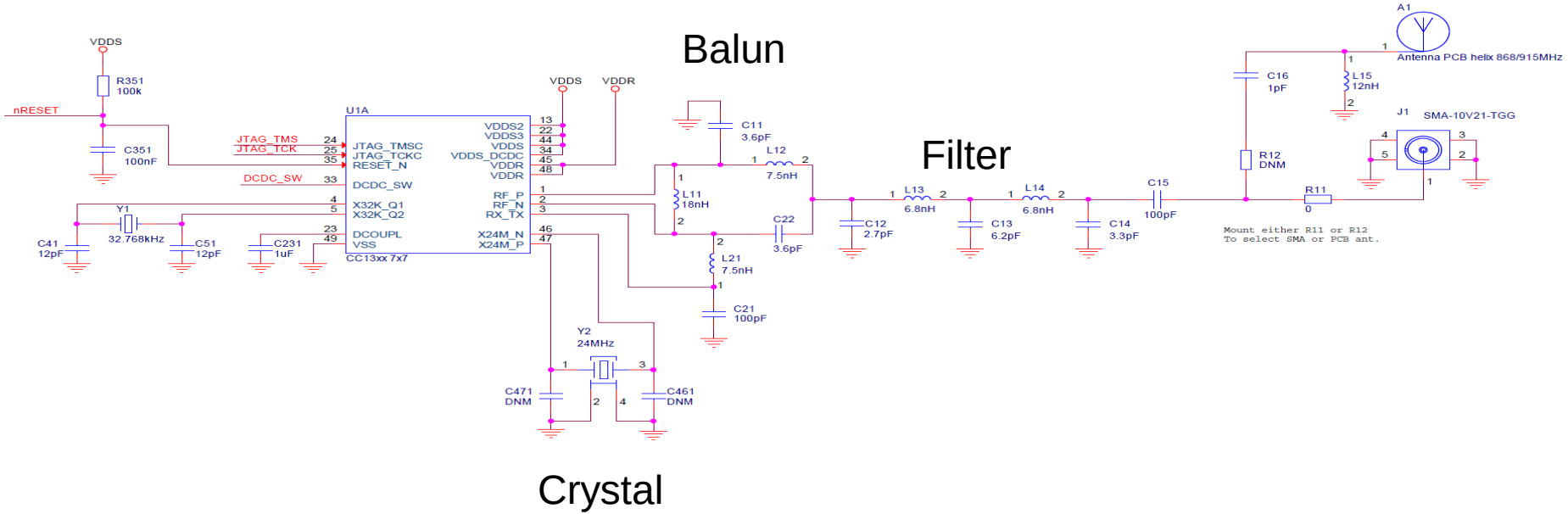
HW requirements and considerations for the CC13xx

Agenda

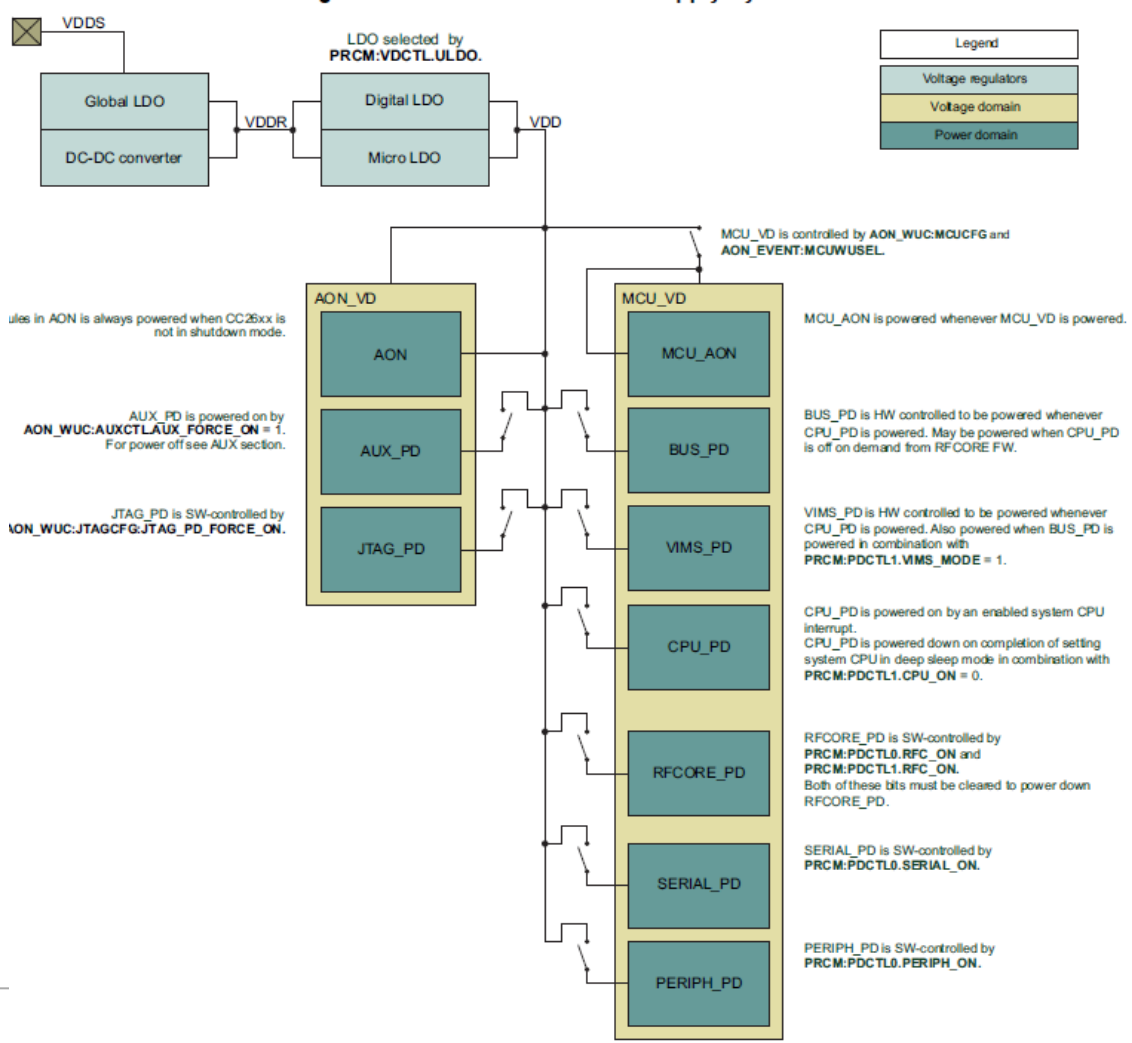
- Schematic overview
  - Walkthrough of external components
  - RF front end alternatives
- CC1310EM PCB designs with layout considerations
- Design process and testing briefing
- Antanna kits
- China Band supporting
- How to get your reference and support

Schematic overview

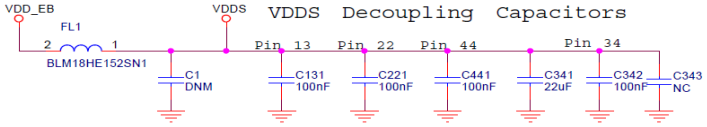
Reference Schematic

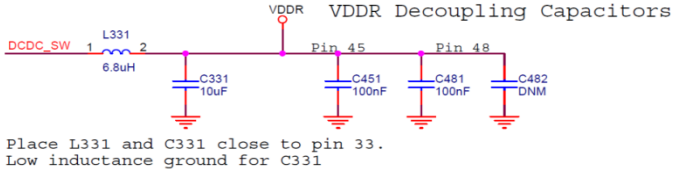


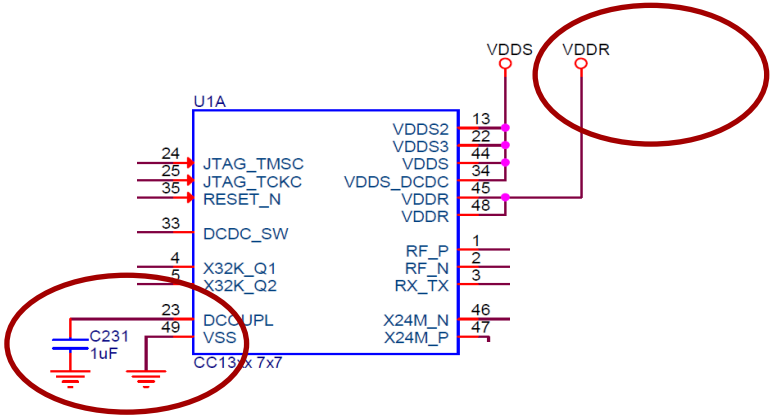
Power Supply - Overview



Power Supply - Decoupling







VDDS (pin 44):

- Main device supply pin, input voltage = 1.8 V – 3.8 V
- Decoupling: 100 nF

VDDS2 / VDDS3 (pin 13 / 22) (7x7 mm package only):

- Supply for a set of DIO pins.
- Decoupling: 100 nF (each)

VDDS_DCDC (pin 34):

- Input to internal DC/DC regulator
- Decoupling: 22 uF + 100 nF

DCDC_SW (pin 33):

- Output of internal DC/DC regulator
- Connect to 6.8 uH inductor and 10 uF capacitor
- Output is supply to the VDDR pins

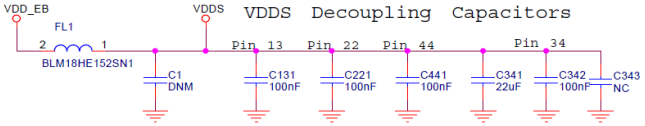
VDDR (pin 45 and 48):

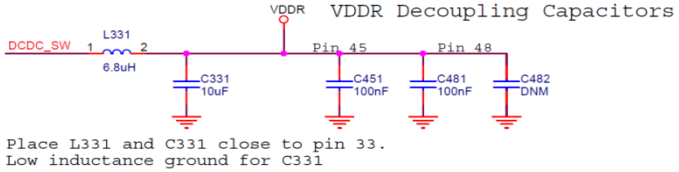
- Regulated supply pins, input voltage = 1.7 V – 1.95 V
- Decoupling: 100 nF (each)

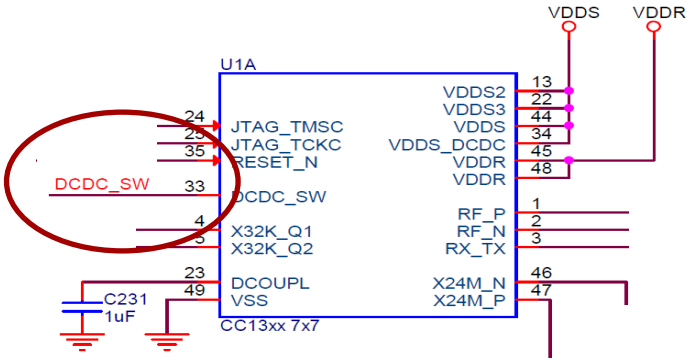
DCOUPL:

- Decoupling of internal LDO. Connect to 1 uF capacitor

Internal DCDC Regulator Mode

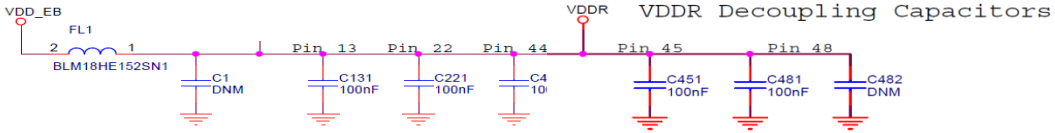


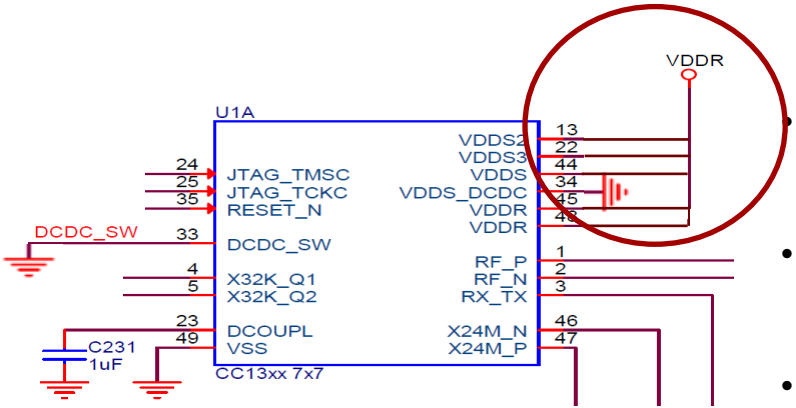




- Input voltage = 1.8 V – 3.8 V to all VDDS pins
- DCDC_SW connected to VDDR through 6.8 uH inductor (CC13xx)
- C331 is an important part of of the DCDC regulator and not a decoupling capacitor

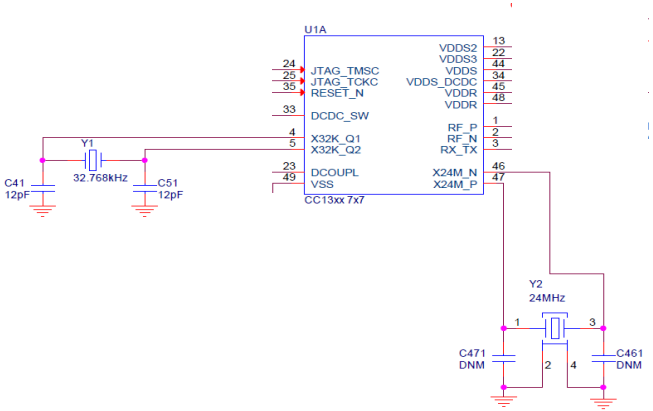
External Regulator Mode, 1.8 V supply





- Input voltage = 1.7 V – 1.95 V
- VDDS and VDDR pins tied together (except VDDS_DCDC)
- VDDS_DCDC and DCDC_SW must be connected to ground
- Typically used in applications with existing 1.8 V rail
- Recommended regulator: TPS62740

Reference Schematic - Oscillators



32 kHz RC Oscillator (internal):

- Can be calibrated automatically to have +/- 500 ppm tolerance and can thus be used for BLE (removing the requirement for 32 kHz crystal)
  - Calibration must be performed periodically while in a connection. Calibration periode is dependent on maximum temperature change

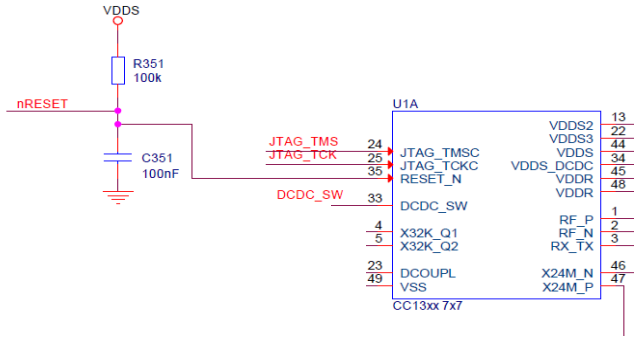
32 kHz XOSC:

- Will increase the sleep clock accuracy and thus reduce the power consumption for BLE (shorter RX windows around connection events)
- Connect to crystal and load capacitors. Lower CL will give lower power consumption
- Externally generated clock signal is supported. Input is through DIO-pin

24 MHz XOSC:

- 24 MHz, **+/- x ppm (determined by RF spec)**, CL = 5 – 9 pF, ESR_max<60 ohm
- Internal cap array (no need for external load caps)

Reference Schematic – JTAG / Reset



JTAG:

- Used for programming and debugging
- Default is cJTAG, 2-pin JTAG, using TCKC and TMSC
- 4-pin JTAG can be enabled, 2 of the DIOs are used for TDI and TDO (these are fixed pins, refer to the Technical Reference Manual)
- Supported debuggers:
  - XDS100 v3 (cJTAG)
  - XDS110 (cJTAG)
  - XDS200 (cJTAG)
  - IAR I-Jet (4-pin JTAG)
  - Segger J-Link (4-pin JTAG)

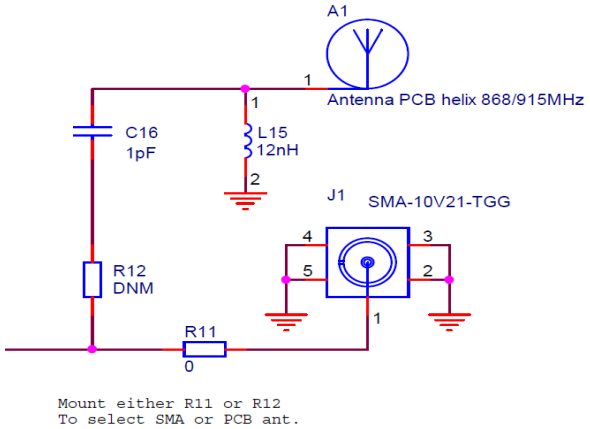
Reset Pin:

- Active low
- No internal pull-up
- Reset is a low power state

Recommended Debug Header:

- 10 pin 1.27 mm pitch header
- Official name: «Cortex Debug Connector»

Reference Schematic – Antenna / SMA



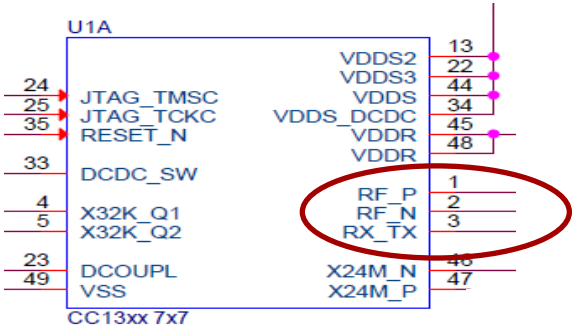
SMA connector:

- R11 and R12 are used to select SMA connector or PCB antenna
- Only one of R11 and R12 should be mounted
- Default in kits
  - CC13xx: SMA connector
  - CC26xx: PCB antenna

PCB antenna:

- CC1350EM-XD-7793. C16 and L15 are used for PCB antenna impedance matching

RF Pins



RF_P: RF positive output / input

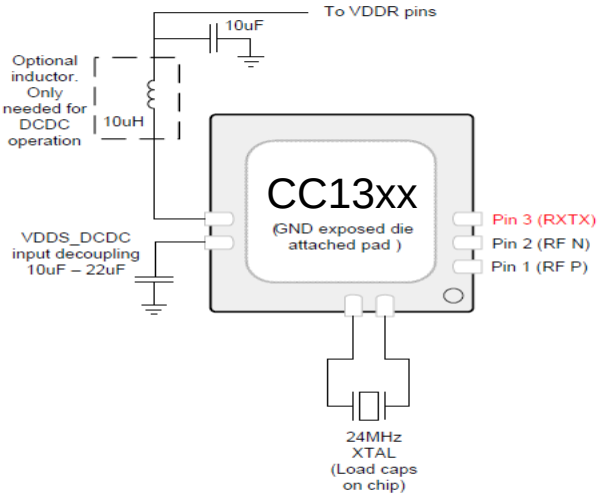
RF_N: RF negative output / input

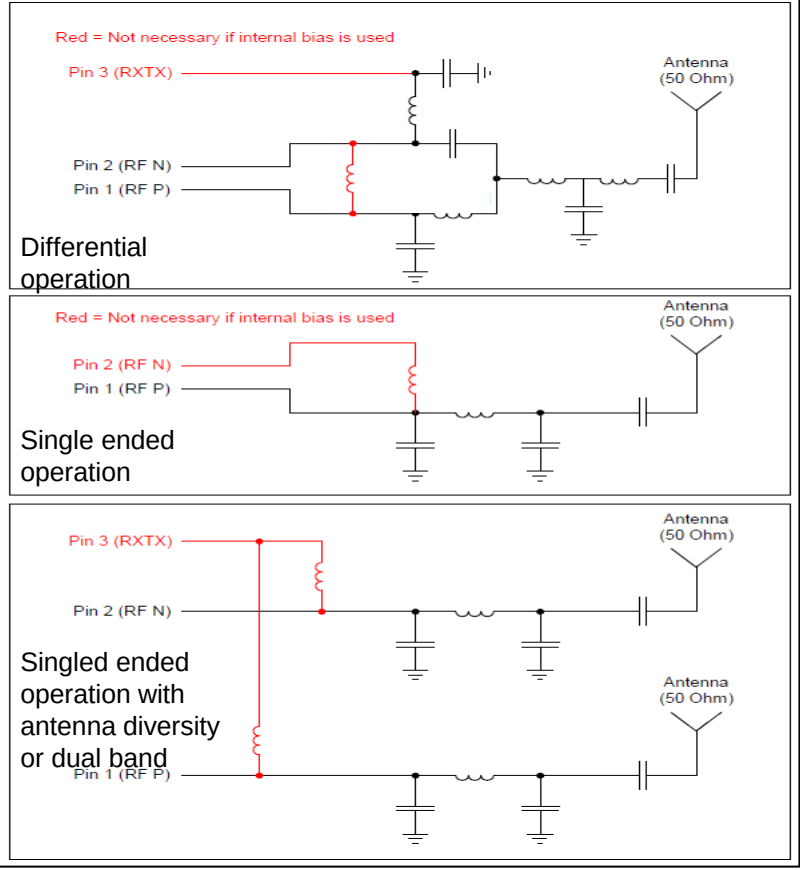
RX_TX: Optional RF bias pin

Several output configuration options:

- **Differential output:** Both RF pins are used and a balun + a pi-filter is required between the CC13xx and the antenna
- **Single ended output:** Only one of the RF pins is used for RF output. Only a pi-filter is required between the CC13xx and the antenna. Output power is reduced and sensitivity is degraded
- **External biasing** of the RF pins can be applied through the RX_TX pin. This will improve sensitivity, but requires an additional inductor.
- For single ended configuration, the unused RF pin may alternatively be used as bias pin
- RX_TX can be used for external control of for example an RF switch

CC13xx Front-End Options (1)





Differential vs Single ended:

- Approx. +1 dB sensitivity, +3 dB output power

External vs Internal bias:

- Approx. +2 dB

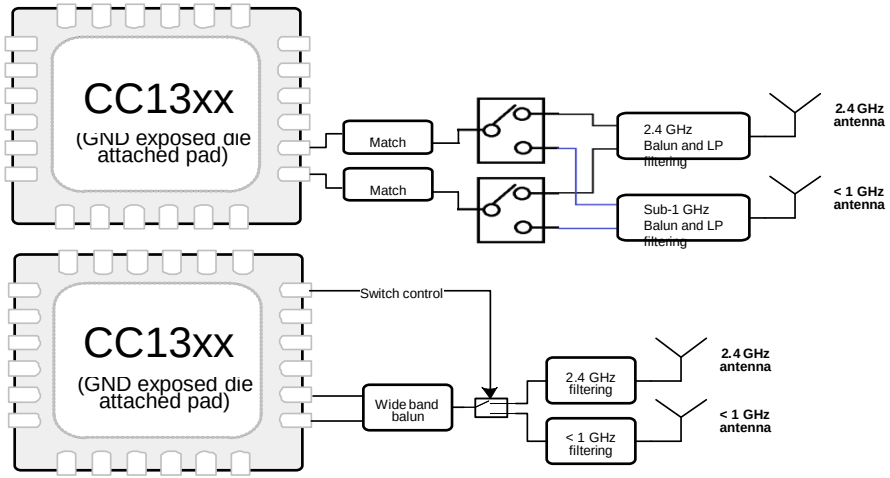
CC13xx Front-End Options (2)

	External bias	Internal bias
Differential	**Pros** • Best RX performance • Best TX performance **Cons** • Biggest footprint • Highest BOM cost	**Pros** • Slightly smaller footprint • Slightly lower BOM **Cons** • 2 dB lower sensitivity
Single-ended	**Pros** • Small footprint • Lower BOM cost **Cons** • 1 dB lower sensitivity • 3 dB lower output power	**Pros** • Smallest footprint • Lowest BOM cost **Cons** • 3 dB lower sensitivity • 3 dB lower output power

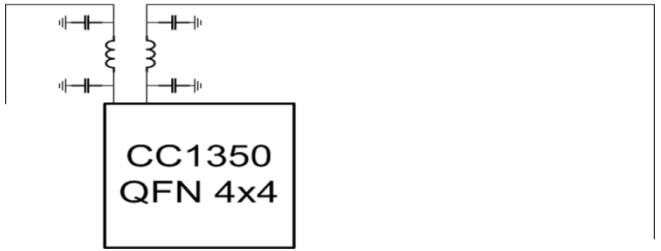
Dual Band: Sub-1 GHz and 2.4 GHz

CC1350 is the first device that handles both sub-1 GHz and 2.4 GHz frequency bands
CC1350 has a highly flexible RF interface, hence there are several ways to get a dual band design.

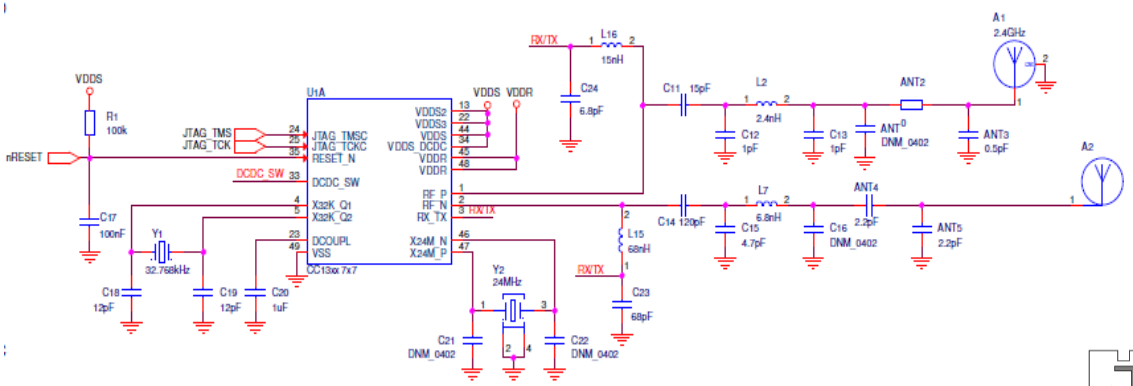
Differential:

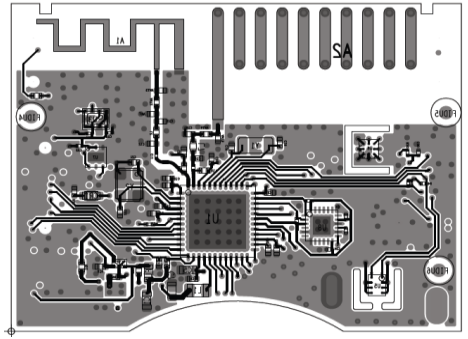


Single ended: *Lowest cost dual band solution*

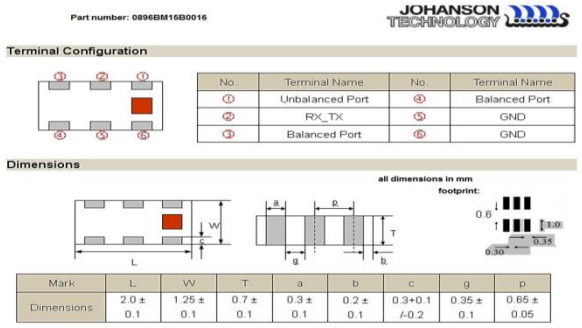


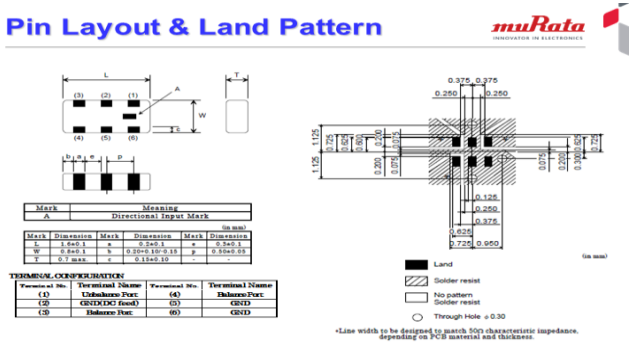
Dual Band HW





CC13xx – Integrated Balun

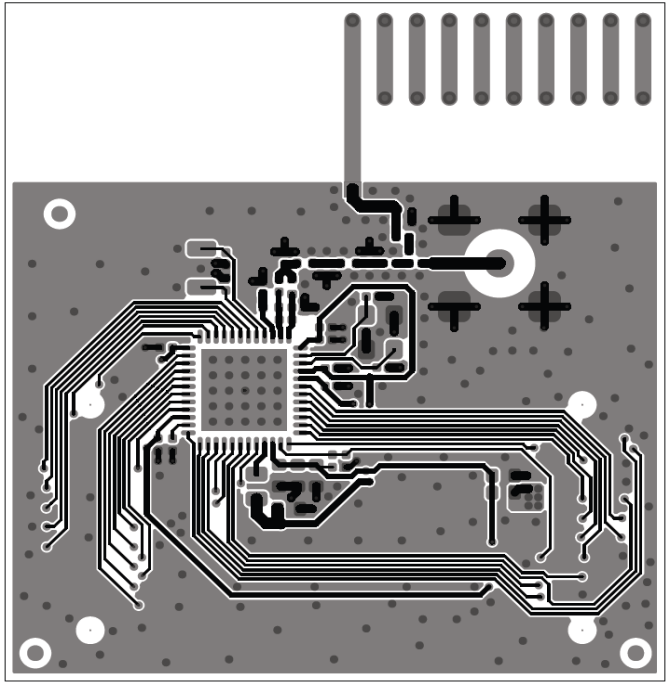




- Integrated Baluns will be available from Murata and Johanson
- Form factor: 6 pins 0603-package
- Murata will support external bias, Johanson will not
- Murata size for differential single frequency 868-915 MHz balun: 1.6 x 0.8 mm
- Johanson size for differential single frequency 868-915 MHz balun: 2.0 x 1.25 mm
- RF performance compared to discrete solution (may change):
  - 0.5 dB to 1 dB insertion loss
  - Improved surpression of harmonic emission

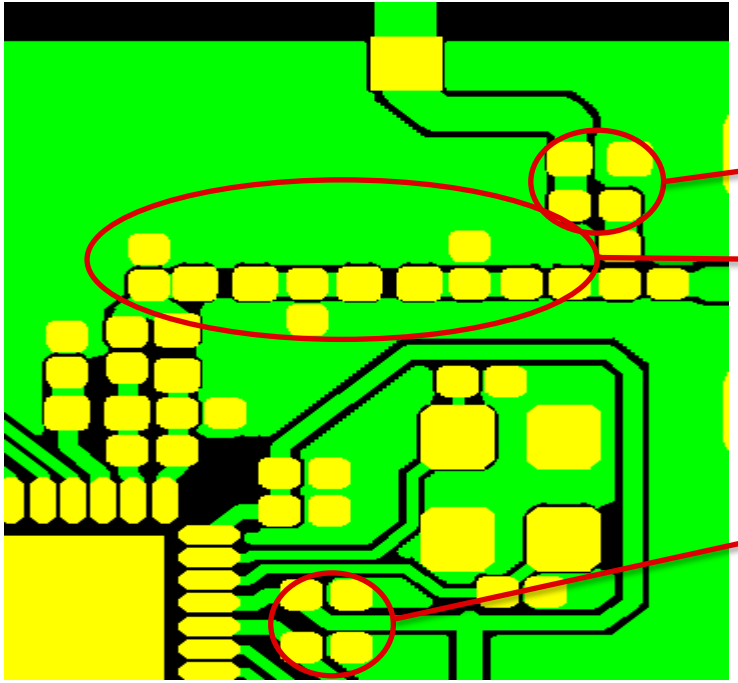
PCB design considerations

Reference Layout



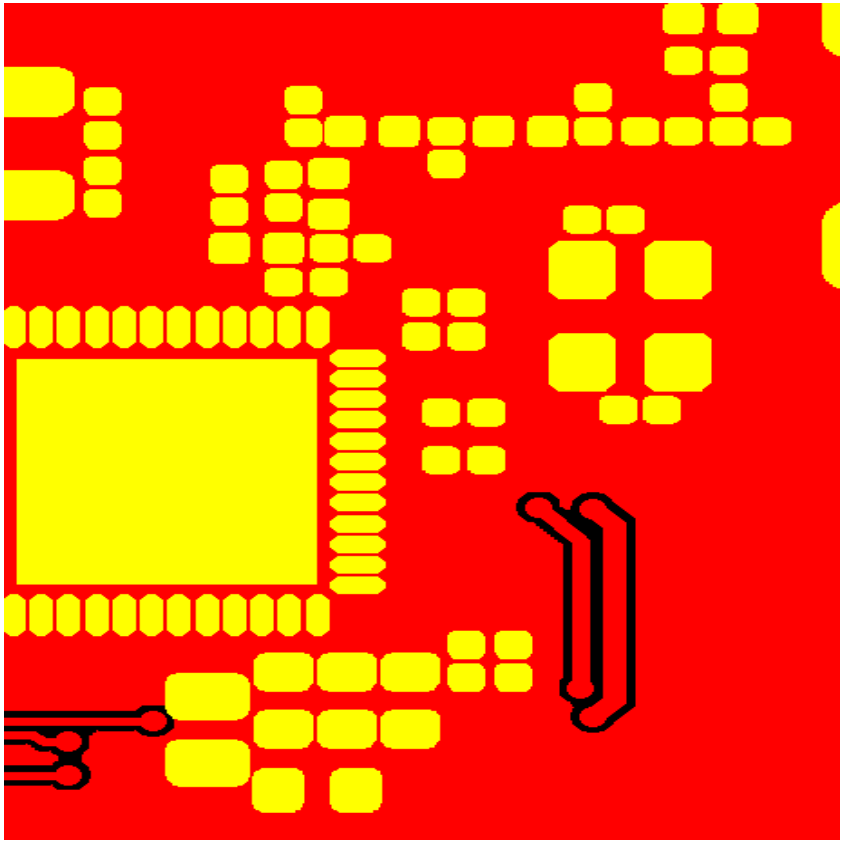
- Follow the reference layout! ☺
- 4-layer PCB for lowest harmonics at max power
  - 2- and 4-layer PCB design available
  - Board stack-up is in the reference design zip file
- Place the RF match close to the RF pins
  - Balun should be symmetrical wrt to RF ports for differential operation
- Solid ground plane
  - No signal traces underneath the RF path!
  - Keep as much signal- and power routing on the top layer as possible
- Place decoupling caps as close to the VDD pins as possible
  - Ground return paths between decoupling caps and CC13xx should be short and direct
- DC/DC-regulator must have a short and direct ground connection to CC13xx
- Balun should be symmetrical wrt to RF ports for differential operation

Reference Layout – Differential Output



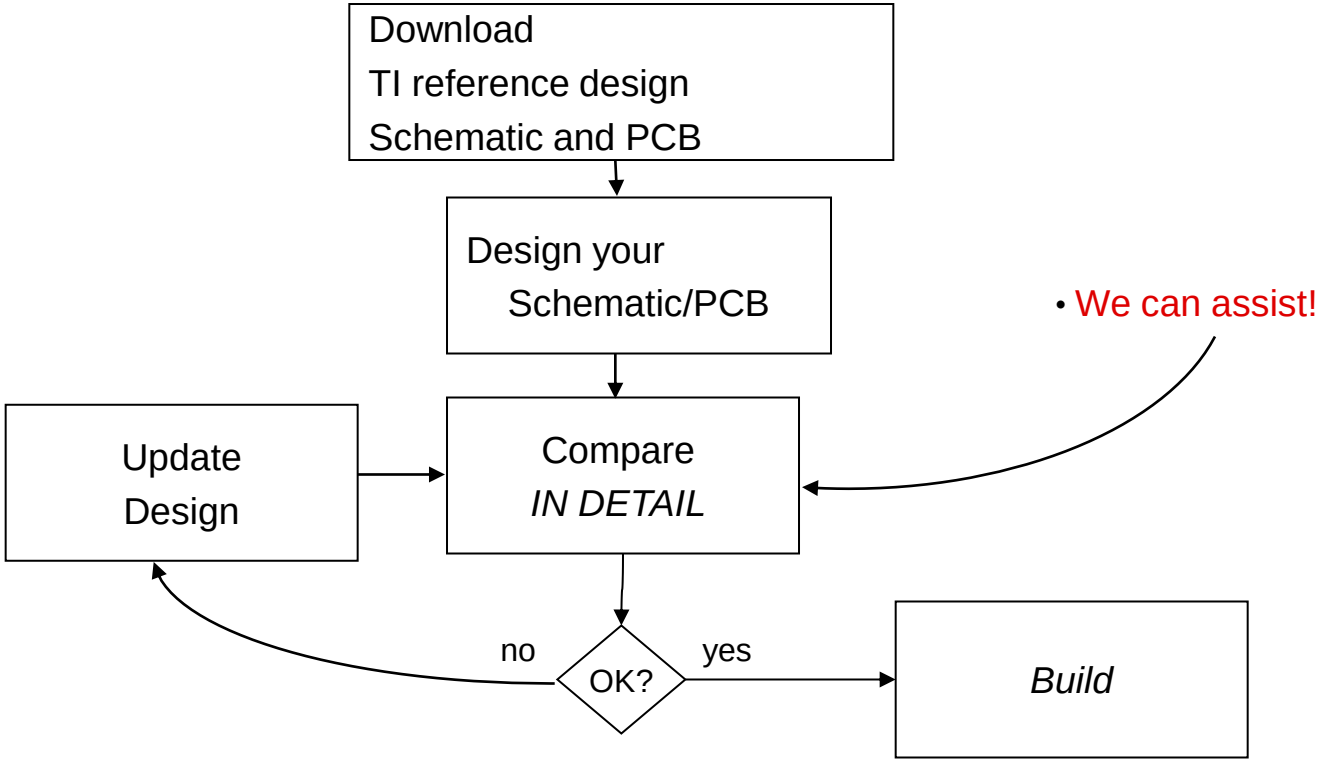
- Antenna match components
- Notice orientation of pi-filter layout
  - Shunt components oriented opposite way to avoid crosstalk
  - Notice symmetry in balun placement
- Notice placement of decoupling capacitors

Reference Layout – Differential Output



- No traces underneath the RF path
  - Failure to follow this may lead to reduced RF performance and spuriuos emission
- Make sure decoupling ground paths are short and direct (low impedance)
  - Failure to follow this may lead to reduced RF performance and spuriuos emission
- Make sure the DCDC switch ground path is short and direct (low impedance)
- Try to locate as much routing as possible on the top layer in 2-layer PCBs

Design Process

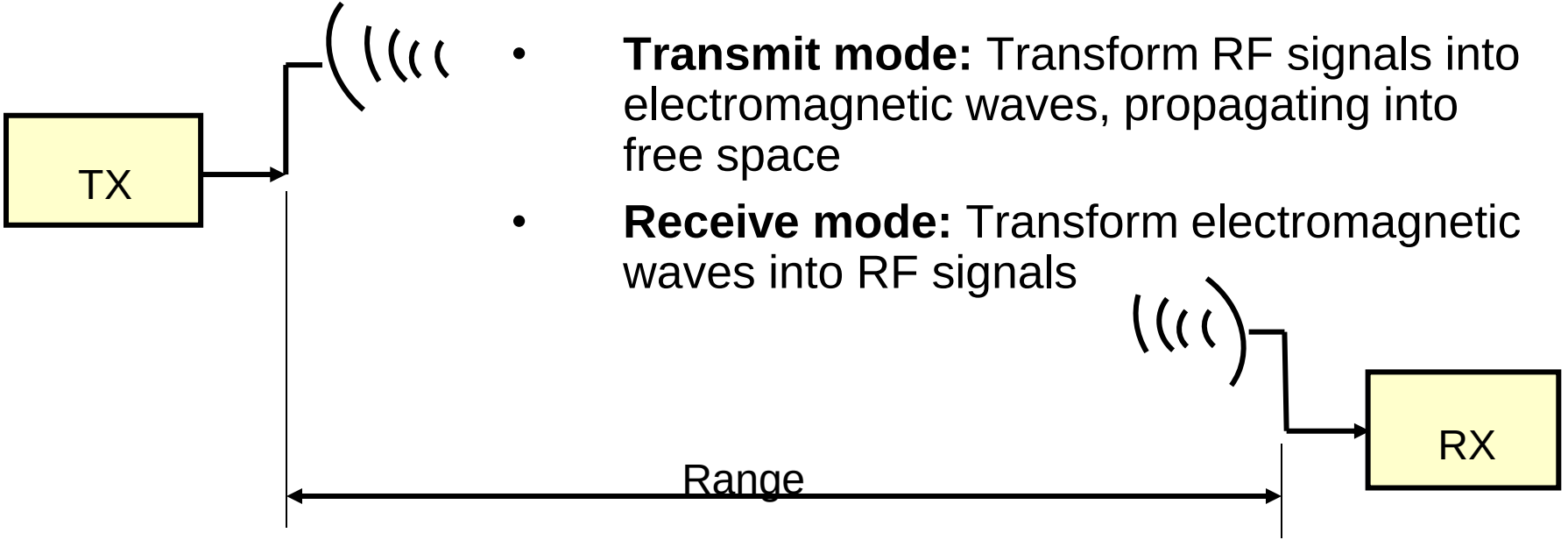


How and What to Test?

- Testing shall be divided up into separate parts, independent of each other
- Hardware, software, and antenna shall be tested separately
- Test the SW with well-known working HW.
  - E.g. evaluation modules
- Test the HW with well-known working SW.
  - E.g. SmartRF® Studio, SW examples from TI
- Test the antenna with a network analyzer

Antenna Design

Basic Function of an Antenna



- **Transmit mode:** Transform RF signals into electromagnetic waves, propagating into free space
- **Receive mode:** Transform electromagnetic waves into RF signals

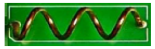
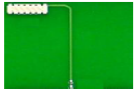
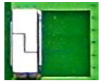
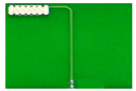
- The antenna is a key component for the successful design of a wireless communication system.

Antenna Selection Quick Guide

DN035

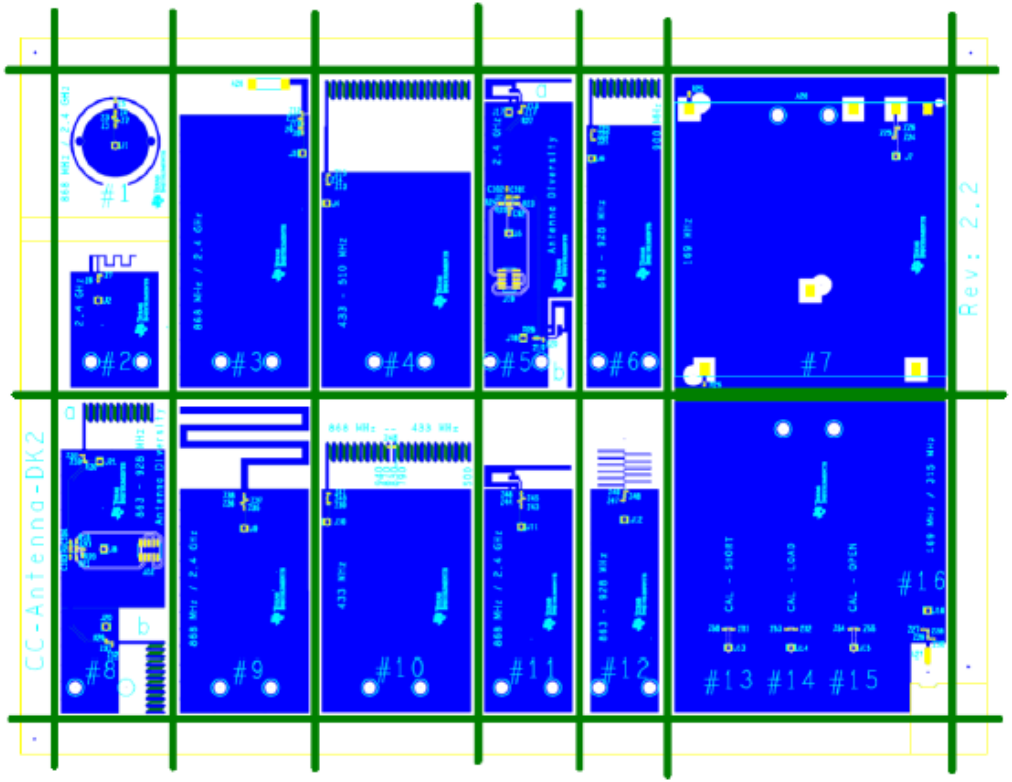
Antenna Selection Quick Guide

DN035

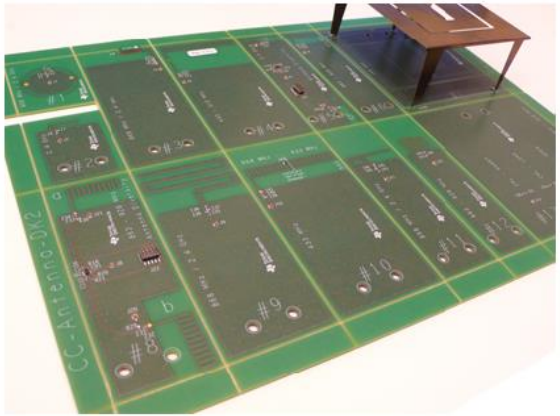
							
Design / Application Note	DN007 *1	AN043 *2	DN004	DNxxx	DN024	DN034	AN048
Frequency	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz
Typical Efficiency	80%(EB) 94%(SA)	68%(EB)	80%(EB)	65%(Zlight2)	76%(EB) 94%(SA)	72%(SA)	55%(USB)
Bandwidth@ VSWR 2:0	280 MHz	101 MHz	100 MHz	150 MHz	354 MHz (SA)	497 MHz	150 MHz
Dimensions (mm)	26 x 8	15 x 6	46 x 9	45 x 2.5	38 x 25	150 x 100	7 x 3
							
Design / Application Note	DN024 *1	DN023	DN031	DN031	DN033	DN031	DN038 *2
Frequency	868 / 915 / 920 MHz	868 / 915 / 920 MHz	868 / 915 / 920 MHz	868 / 915 / 920 MHz	868 / 915 / 920 MHz	868 / 915 / 920 MHz	868 / 915 / 920 MHz
Typical Efficiency	64%(EB) 98%(SA)	80%(SA)	69%(EB)	64%(EB)	48%(EB)	63%(EB)	66%(EB)
Bandwidth @ VSWR 2:0	88 MHz (SA)	40 MHz	62 MHz	56 MHz	56 MHz	6 MHz	40 MHz
Dimensions (mm)	38 x 25	43 x 20	10 x 28	48 x 8	15 x (5 to 29)	10 x 14	19 x 12
						Antenna Support Documentation Antenna Selection Comprehensive Guide AN058 Antenna Selection Quick Guide DN035 CC-Antenna-DK & Antenna Measurements Summary DN031 Range Measurements in an Open Field DN018 Antenna Reference Designs AN040, AN043, AN048, DN004, DN007, DN016, DN023, DN024, DN031, DN034, DN038, DNxxx OTA Measurement Reports DN0xx	
Design / Application Note	DN031	DN031 *1	DN031	DN031 *1	DN031 *1		
Frequency	433 MHz	433 MHz	433 MHz	315 MHz	136 - 240 MHz		
Typical Efficiency	20%(EB)	26%(EB)	15%(EB)	15%(EB)	7%(EB)		
Bandwidth @ VSWR 2:0	23 MHz	38 MHz	30 MHz	4 MHz	3 MHz		
Dimensions (mm)	37 x 9	42 x (10 to 29)	15 x (5 to 29)	37 x 9	42 x (22 to 29)		
EB: SmartRF Evaluation Board SA: Stand Alone	*1 First Choice Recommended Antenna	*2 Second Choice Recommended Antenna		SWRA351A	By Richard Wallace		

All the antenna documentation can be hyperlinked through DN035

Reference Designs – *CC-Antenna-DK2*



SWRA496



Antenna Performance

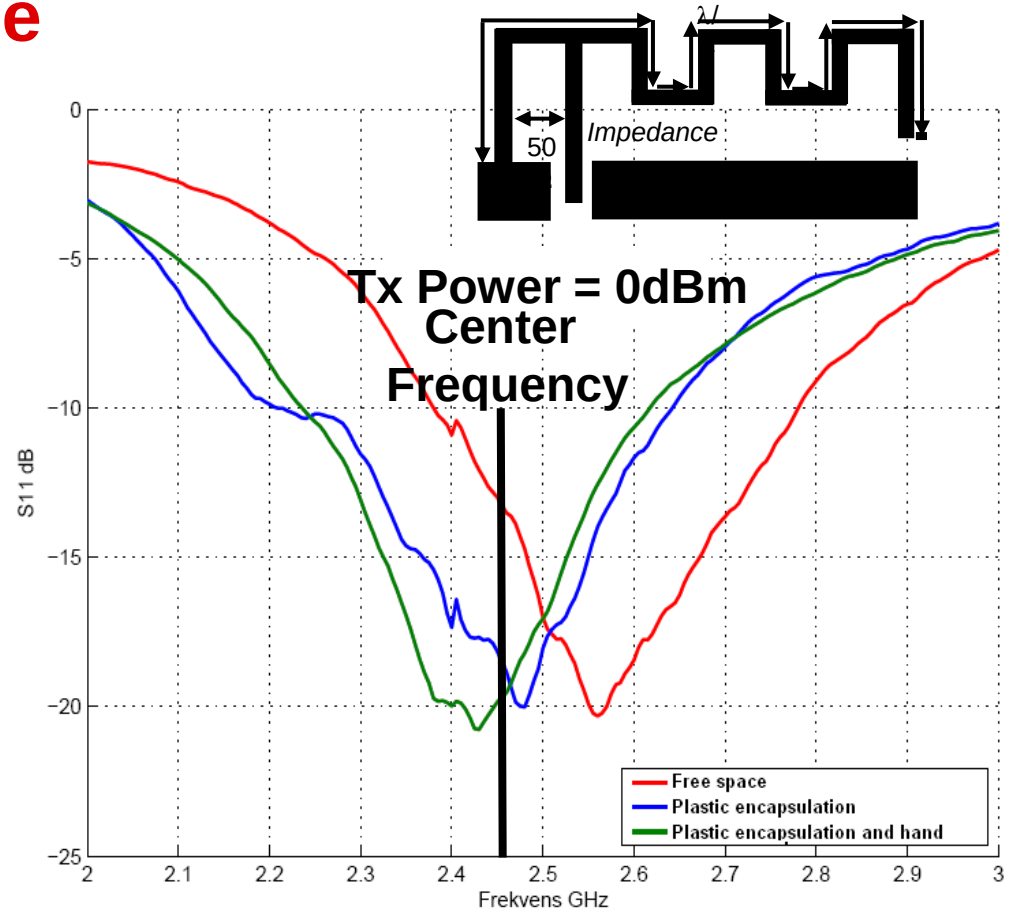
Tuning the antenna:

•Make sure the metals, plastics and human body close to the antenna are factored into the tuning

•The impedance and resonance frequency of the antenna get affected

•Need to re-tune in your realistic product in most of cases

•Strong recommend to involve the professional Antenna Manufacture for a serious product.



CC13xx with 433MHz, 470-510 MHz

Reference designs

http://www.deyisupport.com/question_answer/wireless_connectivity/f/45/t/124625.aspx

1)Standard 430-510 MHz reference design （14dBm，15dBm under boost mode）.

http://www.ti.com/lit/zip/swrc330 规格书里的所有指标都是在这块板子上测的。

2)High TX power (20dBm) reference design

a)Skyworks PA 433MHz

reference design: http://www.ti.com/lit/zip/swrc334

APN will publish soon.

b)Skyworks PA 470-510MHz

reference design: http://www.ti.com/lit/zip/swrc334

App Note: http://www.ti.com/lit/pdf/swra527

c)Discrete PA 470-510MHz.

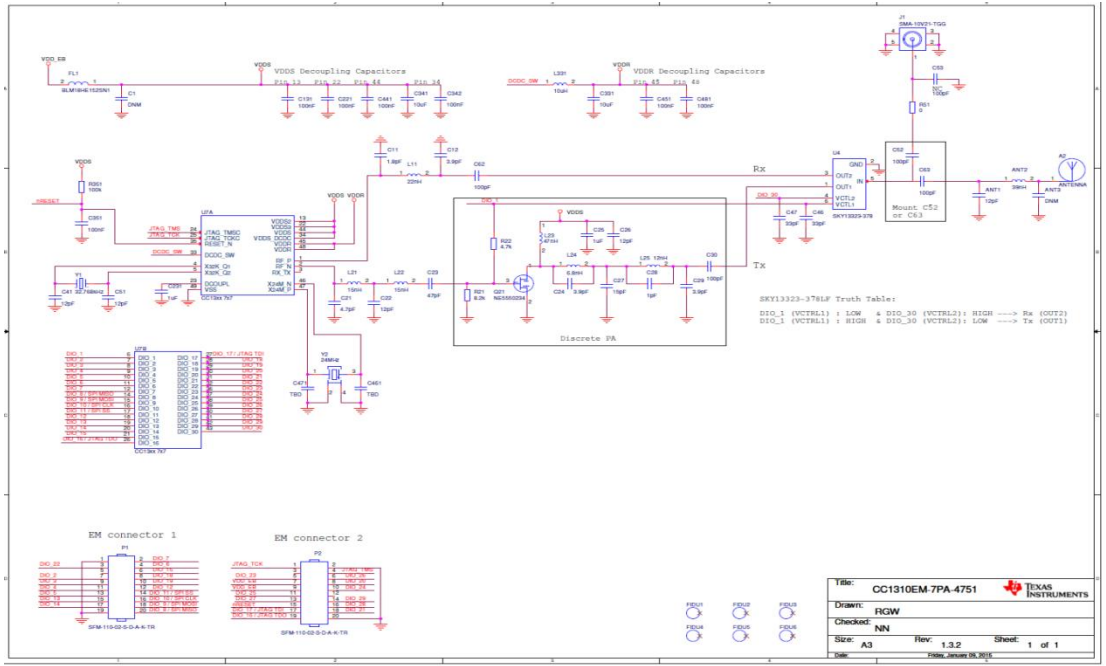
Reference design: http://www.ti.com/lit/zip/swrc311

App Notes: http://www.ti.com/lit/pdf/swra490

d)Dual Band reference design. 2.4GHz/433MHz with CC1350.

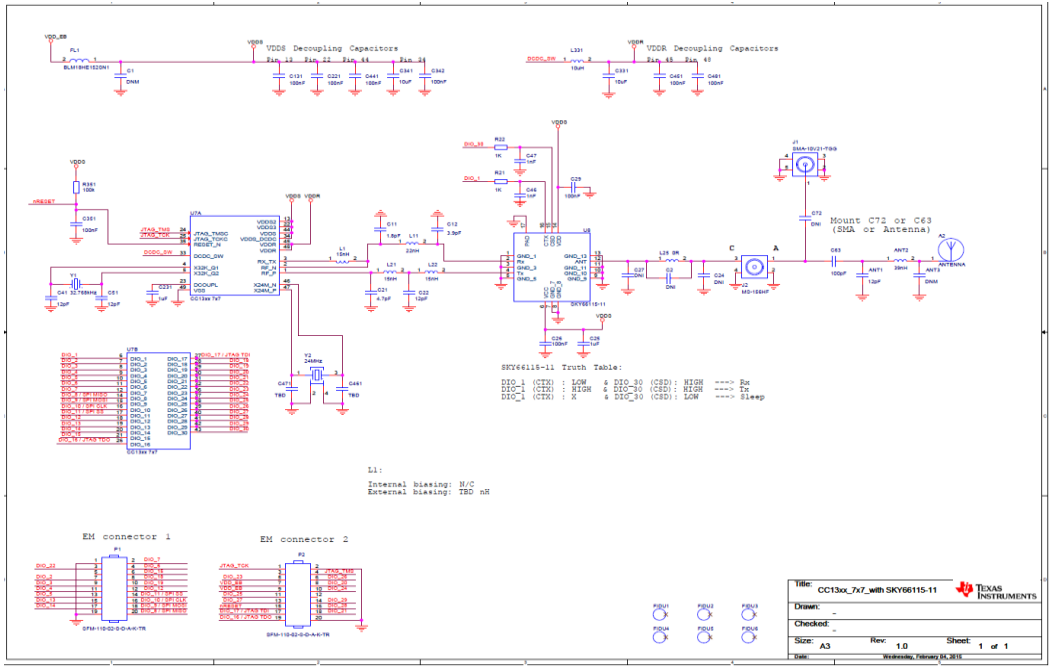
敬请期待。。。。。

CC13xx Discrete PA Ref Design



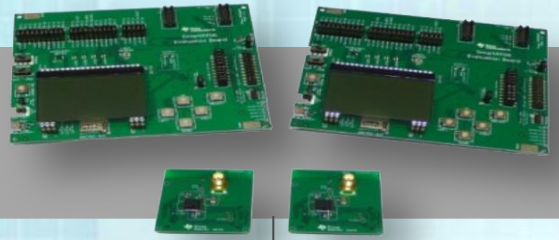
- RF_P set to Rx
- RF_N set to Tx
- Internal biasing
- Switch control: DIO1 & DIO30
- Skyworks SPDT:
  - SKY13323-378LF
- Power Transistor: Renesas NE5550234
- DIO1: Power Transistor Gate Control
- PA design can handle open/short circuits or extreme antenna mismatches.
- Tx: 20 dBm at 3.3V (80 mA)
- Rx: -105 dBm (50 kbps)
- Supported in SmartRF studio
- Integrated antenna

CC13xx Skyworks PA Ref Design



- Reduced component count
- External biasing
- RF_N set to Rx
- RF_P set to Tx
- Control: DIO1 & DIO30
- Skyworks FEM: SKY66115-11
- Tx: 20 dBm at 3.3V
- Rx: -106.5 dBm (50 kbps)
- Supported in SmartRF studio
- Integrated antenna

Get Started Fast: Development Kits



CC1310DK development kit

- Full-feature emulator for development and debugging
- For Evaluation of Sub-1GHz only for proprietary RF Networks
- $299 through the TI Store and distribution
- Additional EMK kits available for $99

CC1350 SensorTag kit

- Sensor-based DK for **IoT** and **Long Range** applications
- Get connected to the cloud in 3 minutes
- Easy programming and prototyping with add-on JTAG daughter card
- Free app for iOS & Android
- $29 through the TI Store and distribution

CC1310/CC1350 Launchpad

- Single Band: Sub-1GHz
- Dualband : Sub-1GHz + BLE
- Low-cost MCU evaluation kits and plug-in modules for quick development
- Leverages existing TI MCU ecosystem

Quick starter on-line!

Once you have your **myTI account**, you will get

On line resources:

HW and system documentations:

www.ti.com/CC1310

http://processors.wiki.ti.com/index.php/Category:Sub-1GHz

SW SDK and documentations:

http://www.ti.com/tool/simplelink-cc13x0-sdk

C:\ti\simplelink_cc13x0_sdk_1_00_00_13\docs

On line training:

Training in English: http://training.ti.com

Training in Chinese: http://www.TI.com.cn/training link to **21Dianyuan/21IC/eeWorld**

Academy: coming soon

Technical support forum:

E2E in English:

https://e2e.ti.com/support/wireless_connectivity/proprietary_sub_1_ghz_simpliciti/f/156

Deyisupport in Chinese:

http://www.deyisupport.com/question_answer/wireless_connectivity/f/45.aspx

CC13xx Software Development

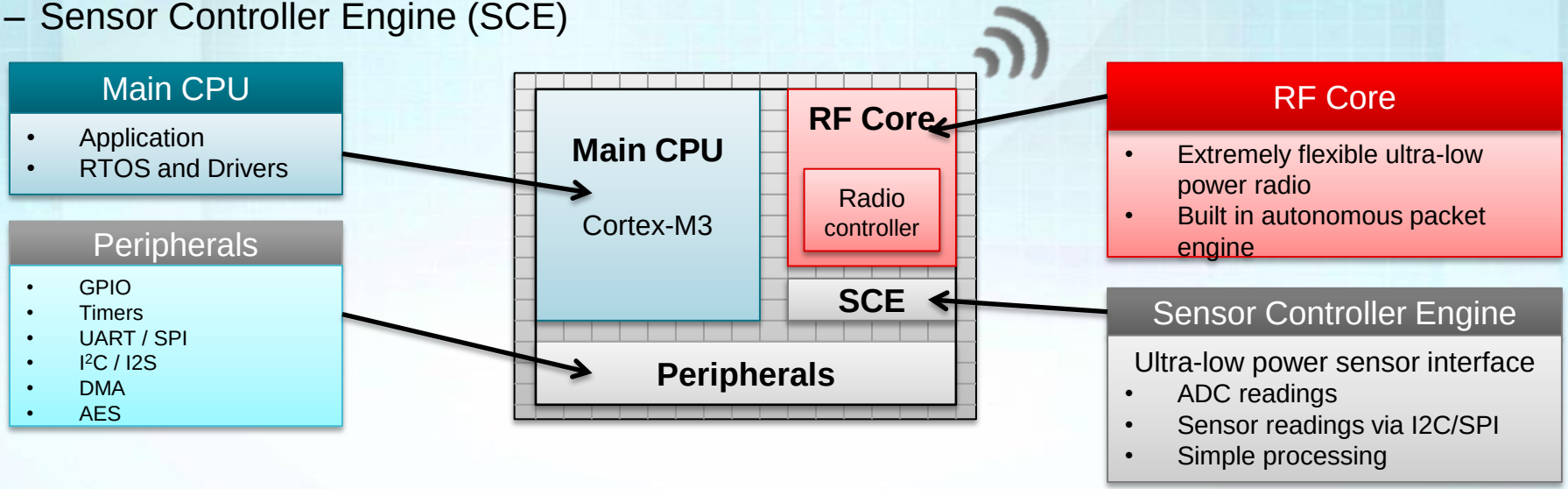
SimpleLink MCU

Mar, 2017

Barbara Wu

CC1310 Overview
ULP Wireless MCU

- Dedicated processors for dedicated tasks:
  - ARM Cortex-M3 Main Application CPU
  - RF Core Radio Controller
  - Sensor Controller Engine (SCE)

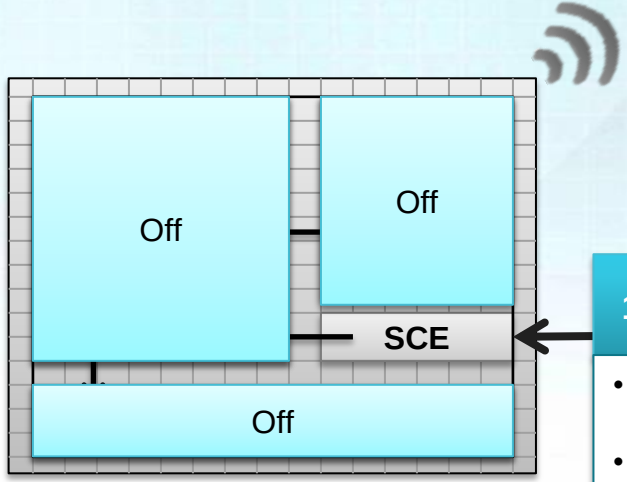


CC1310 How does it work?
Whole system example

- Requirement:
  - Sample value of external sensor once per second
  - Send encrypted radio alarm if the value is above the threshold

3. RF Core

- Configured by the **Main CPU**
- Automously creates and sends radio message
- Reports back when done



2. Main CPU

- Awoken by **SCE**
- Uses the AES in **Peripherals** for encryption
- Configure **RF Core** and start transmission

1. Sensor Controller Engine

- Wakes up once per second and reads sensor
- If above threshold, wake **Main CPU**

Average current consumption: ***1.6 µA*** *48 MHz, 3.3V, 1 packet per minute, 16 bytes payload, +12.5 dBm*

RF Core API *Background*

- Previous devices
  - Radio configured by writing directly to different registers.
  - Modes of operation (RX, TX, IDL, or SLEEP) have been entered by issuing strobe commands.

- CC1310
  - The RF Core is told what to do though an API (RX, TX, RX Sniff Mode) and the necessary registers are set internally based on the API command

Register Write vs. Command API

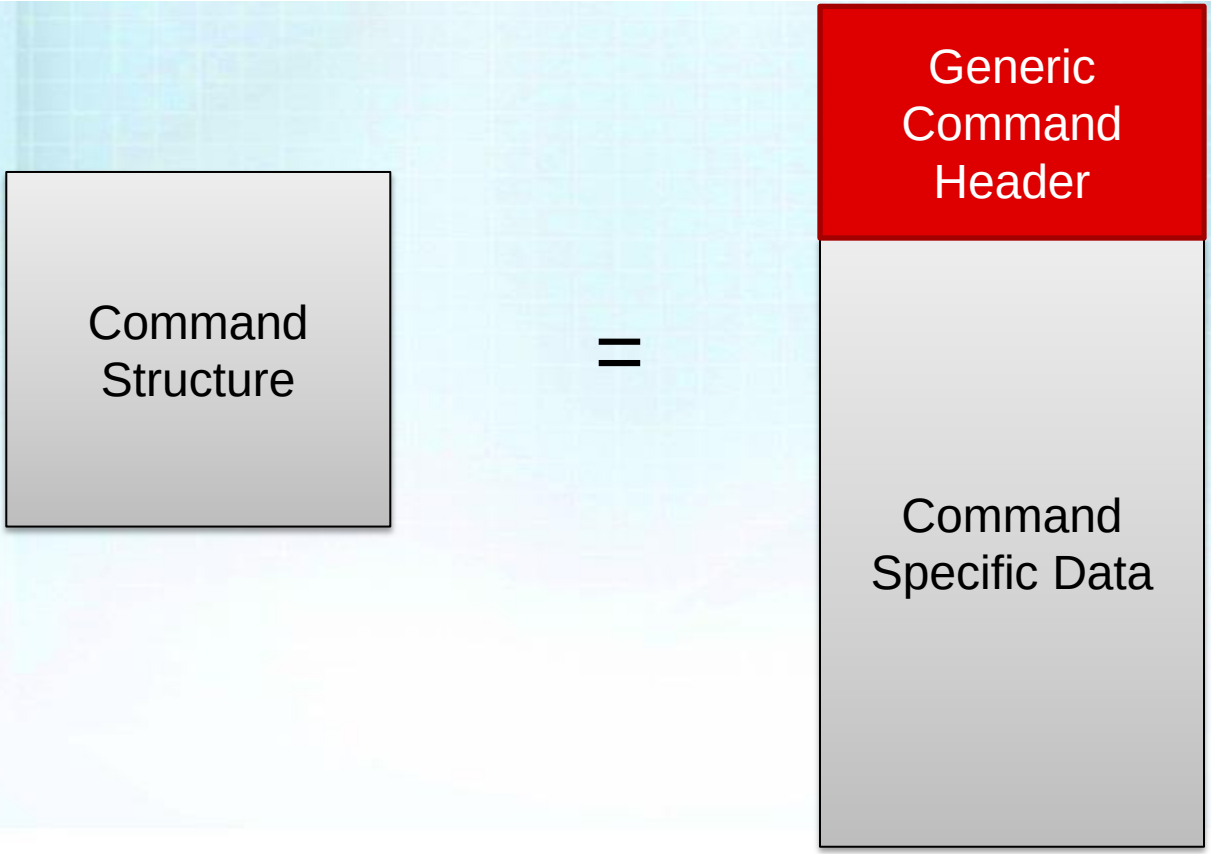
- CC1120
  - Registers associated with the Frequency Synthesizer:

FREQ2	SETTING_CFG	FS_DIG0	FS_CAL1	FS_DIVTWO	FS_DVC1	FS_PFD	FS_SPARE	FS_VCO2
FREQ1	FS_CFG	FS_CAL3	FS_CAL0	FS_DSM1	FS_DVC0	FS_PRE	FS_VCO4	FS_VCO1
FREQ0	FS_DIG1	FS_CAL2	FS_CHP	FS_DSM0	FS_LBI	FS_REG_DIV_CML	FS_VCO3	

- CC1310
  - **CMD_FS**

Byte Index	Field Name	Bit Index	Bitfield Name
14..15	frequency		
16..17	fractFreq		
18	synthConf	0	bTxMode
		1..5	refFreq
19	calibConf	0	bOverrideCalib
		1	bSkipTdcCalib
		2	bSkipCoarseCalib
		3	bSkipMidCalib
		4..7	coarsePrecal
20	midPrecal		
21	ktPrecal		
22..23	tdcPrecal		

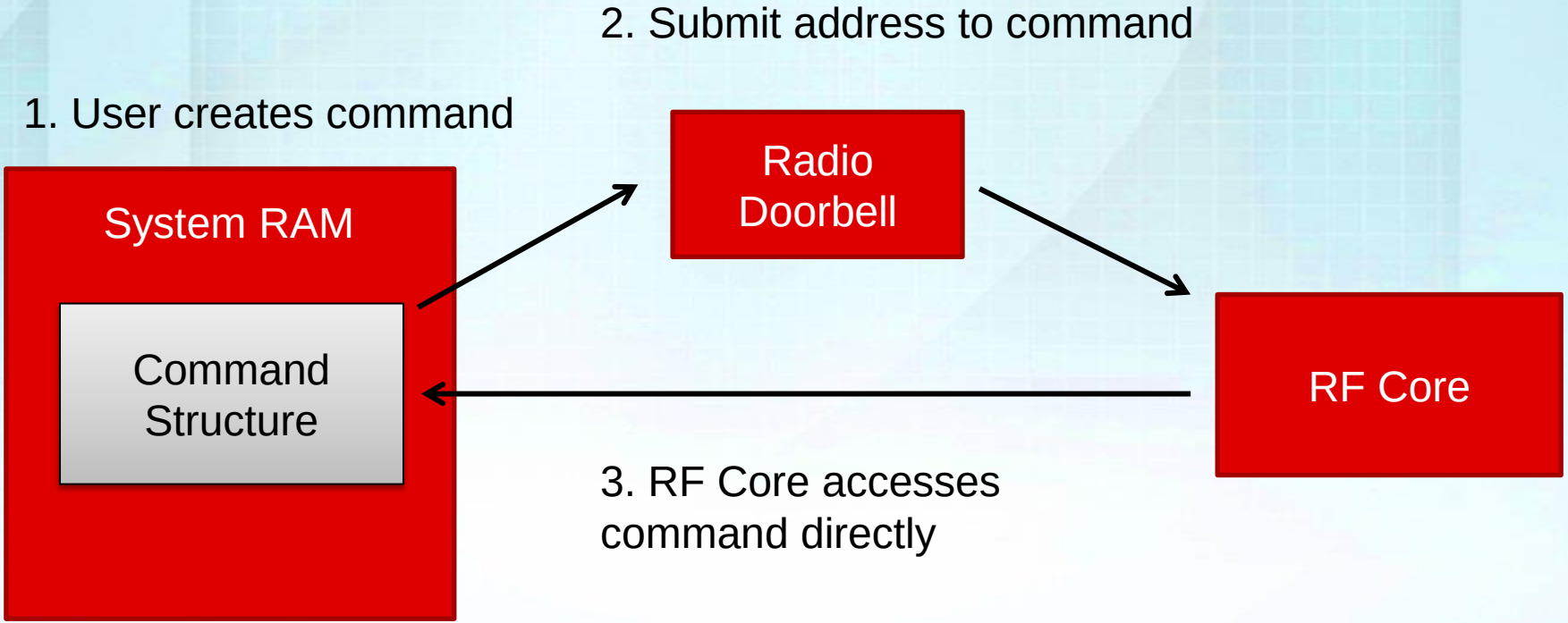
RF Core API *Radio Command*



RF Core API *Command Header*

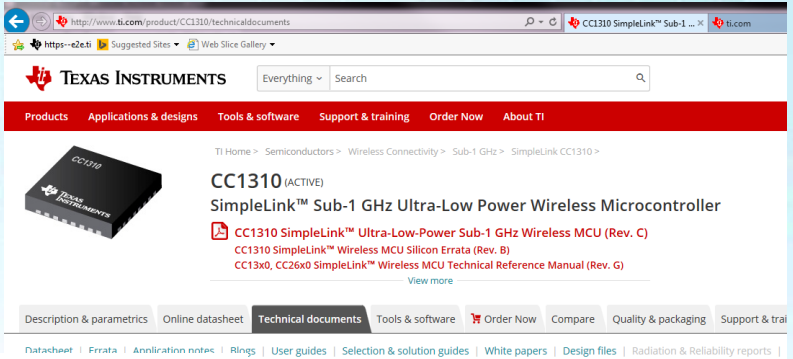
- commandNo - Command identifier (ID number)
- status - Current status of the command (can be read by the system CPU at any time)
- pNextOp - Pointer to the next operation to run
- startTime - Absolute or relative start time
- startTrigger - Identification of the trigger that starts the operation (TRIG_NOW, TRIG_NEVER, TRIG_ABSTIME, etc.)
- condition - Condition for running next operation (COND_ALWAYS, COND_NEVER, COND_STOP_ON_FALSE, etc.)

RF Core API *Submit Command (Simplified)*



Radio Command *Reference Document*

- CC13x0, CC26x0 SimpleLink Wireless MCU Technical Reference Manual



User guides (7)

Title	Type	Size (KB)	Date	Views
CC13x0, CC26x0 SimpleLink™ Wireless MCU Technical Reference Manual (Rev. G)	PDF	7696	21 Feb 2017	29,144
TI 15.4-Stack Linux® Gateway Example Application – Quick Start Guide (Rev. A)	PDF	4083	01 Dec 2016	1,946
TI 15.4-Stack CC1310 SimpleLink™ Embedded Example Applications – Quick Start (Rev. B)	PDF	735	01 Dec 2016	2,780
CC1310 SimpleLink™ TI-15.4 Stack 2.x.x Developer's Guide (Rev. A)	PDF	10653	01 Dec 2016	3,001

	Type	Size (KB)	Date	Views
1 GHz Wireless MCU (Rev. C)	PDF	1471	24 Oct 2016	

	Type	Size (KB)	Date	Views
:rrata (Rev. B)	PDF	36	05 Dec 2016	3,415

Title	Abstract	Type	Size (KB)	Date	Views
Using CC1190 Front End With CC13xx Under EN300220		PDF	238	09 Mar 2017	5

Sub1GHz Software Component

Sub- 1GHz

Wireless M-Bus

CC1120+CC1190
CC1310+CC1190

Contiki

6LoWPAN
IP/Mesh
Open source
CC1310/CC1350

SIGFOX

CC1120+CC1190
CC1125
Ultra Long Range

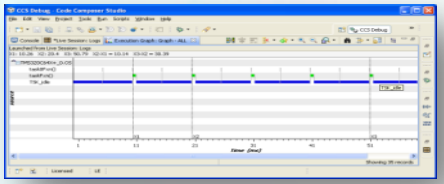
TI 15.4-Stack2.0
CC1310
802.15.4g/e star network

Connectivity Technology

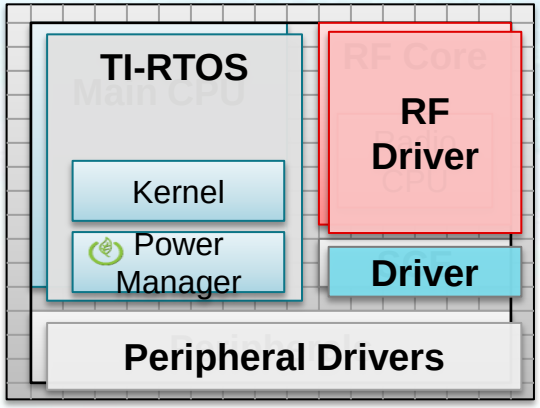
- Wireless Meter Bus
- Sub-1 GHz
- 6LoWPAN
- Sigfox

TI-RTOS Flexible Software Solution

- Real Time Operating System (RTOS)
  - Pre-emptive multi-threading
  - Deterministic scheduler
  - Tailored TI-RTOS Kernel
  - Completely integrated Power Manager
- Extensive toolbox
  - Semaphores
  - Mutexes
  - Mailboxes and more



Powerful RTOS tools



Whole system RTOS solution

- RF driver
  - Fully integrated with power module
- Peripheral Drivers
  - GPIO, I2C, SPI, UART, LCD

- Power Manager
  - Easy to get ultra-low power with no configuration
  - Fully integrated with drivers

What is TI 15.4-Stack ?

Star networking solution based on IEEE standard

Robust

- Supports sub-1 GHz band: avoid crowded 2.4GHz spectrum + Long Range
- Frequency Hopping
- Built-in acknowledgments and retries
- Secure operation: supports AES encryption and authentication

Uncompromised robustness

Easy

- Feature rich Out of the Box Example Applications
- Sensor to cloud solutions with IoT agent reference design
- Radio resource & network management
- Supports large network
- Compliant with regional regulations

Accelerate your time to market

Ultra-low power

- Best-in-class CC1310 platform
  - <6 mA peak current
  - 0.6 uA sleep current (RTC)
  - Autonomous sensor controller
- Protocol designed around sleepy devices with low overhead

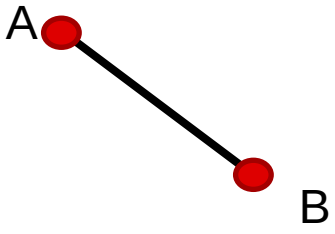
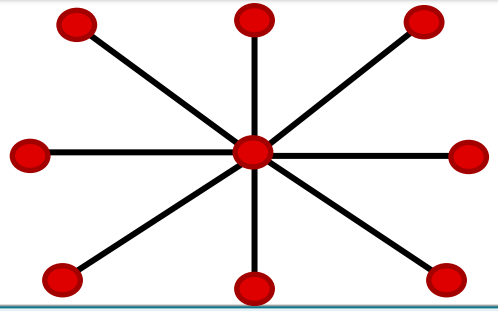
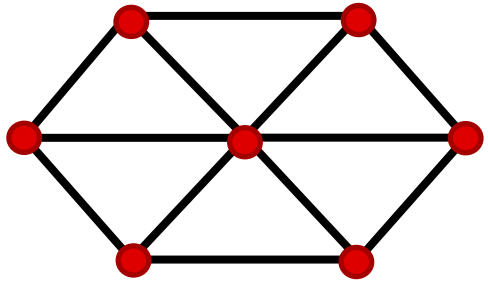
Very long battery life or energy harvesting

What is EasyLink ?

- Simple to use abstraction layer, abstract RF complexity away from user
  `EasyLink_init()`
  `EasyLink_transmit(), EasyLink_receive()`
- Distributed in SimpleLink™ CC13x0 SDK
- Support for different PHY settings, both sub-1GHz and 2.4GHz
  - IEEE802.15.4g (GFSK 50kbps), SimpleLink™ Long Range (5kbps) and Legacy Long Range Mode (LRM) 625bps
  - Custom settings exported from SmartRF Studio
- Muli purpose: 1) abstraction layer example/start 2) building block
- Platforms: CC1310/50LP, CC1350STK, CC2650
- CCS cloud & TI-RTOS based

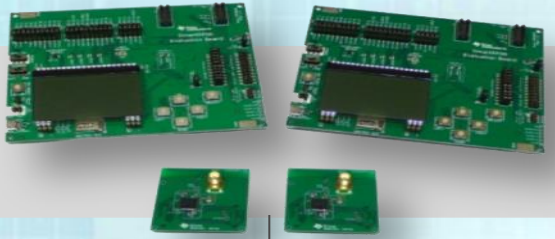
CC1310 What software should I use?

What does the end wireless network look like?

point-to-point	star	mesh
		
software protocol	software protocol	software protocol
TI-RTOS Range Test	Contiki-6LoWPAN wM-Bus (EMEA metering) TI-15.4, TI-RTOS	TI-RTOS Contiki-6LoWPAN
use cases	use cases	use cases
Long Range Test for RF Performance Measurements, Simple Point-to-Point Network	Home & Building Automation, Metering, WAN, Long Range Cloud Connections	Long Range Cloud Connections, Metering, Home & Building Automation

Get started fast: Development kit offering

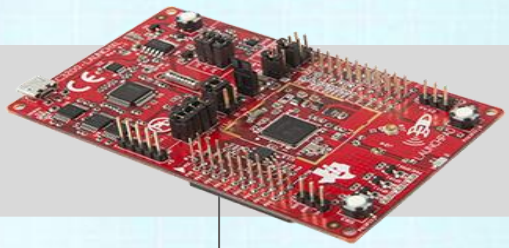
Available now!



CC1310 Development Kit

- Full-feature emulator for development and debugging
- For Evaluation of Sub-1 GHz RF Networks
- $299 through the TI Store and distribution
- Additional EMKs (with CCS license) available for $99

Available now!



CC1310, CC1350 Launchpad

- CC1310 Launchpad – Sub-1 GHz: Can be bundled with LCD screen boosterpack
- CC1350 Launchpad - Dualband : sub-1 GHz + 2.4GHz
- Low-cost MCU evaluation kits and plug-in modules for quick development
- Leverages existing TI MCU ecosystem

Available now!

CC1350 SensorTag kit

- Sensor-based DK for IoT and Long Range applications
- Get connected to the cloud in 3 minutes
- Easy programming and prototyping with add-on JTAG daughter card
- Free app for iOS & Android
- $29 through the TI Store and distribution

Getting Started *with CC1310 SW Development*

CCS Cloud + Example

- No software needed. Only a $29 Launchpad and a browser
- Click a button to flash device with Example project and follow instructions for your first guide
- Import project to CCS Cloud editor and develop / build / debug, or:
- Download all needed project files in one archive file for CCS Desktop development

SimpleLink Academy

- Training modules integrated with CCS
- Explanations and theory
- Interactive quizzes
- Tasks with step by step instructions
- Learn about:
  - TI-RTOS concepts (Task, Semaphore etc)
  - Proprietary RF Driver
  - Basic RX and TX
  - EasyLink Network Processor
  - Wireless Sensor Network
  - Sensor Controller Studio

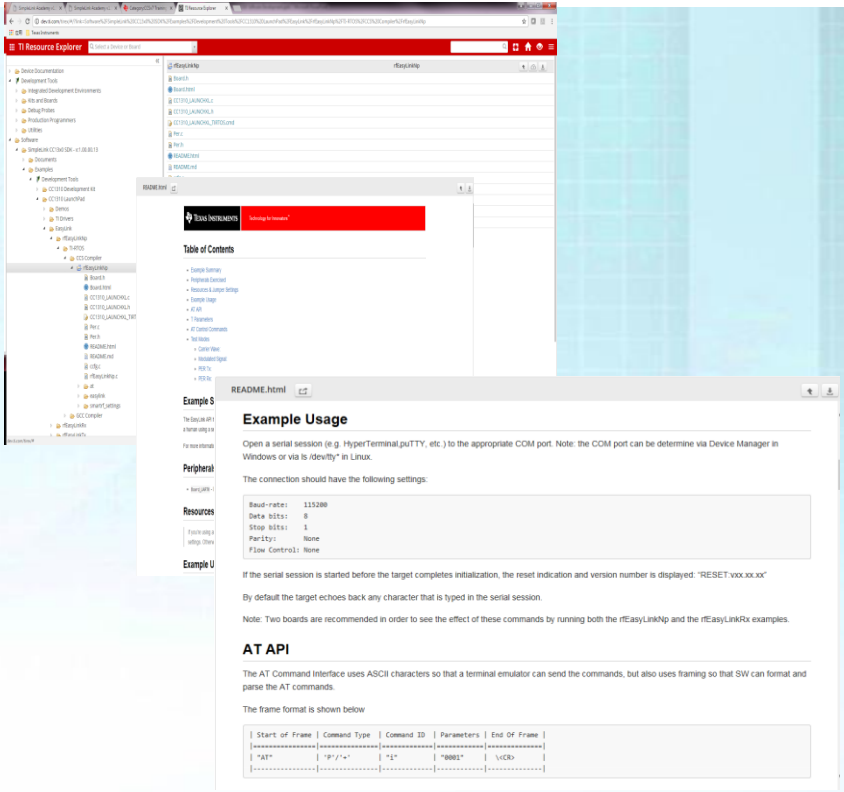
SimpleLink CC13x0 SDK

- TI-RTOS support for EasyLink and TI 15.4- Stack
  - Sensor and collector embedded application
  - Linux gateway example application
  - Sensor to cloud solution
  - Frequency hopping
  - Medium access with CSMA/CA and LBT
  - Network Management
  - Security – AES-128 encryption
  - FCC and ETSI compliant

Resource Explorer *EasyLink Network Processor*

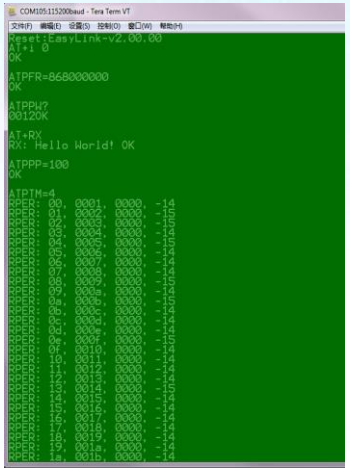
Visit dev.ti.com/tirex

- Get up and running in < 5 minutes with Launchpad as a terminal which use the Easylink serial AT command API to control the proprietary radio to send and receive data
  1. Locate rfEasyLinkNp in Resource Explorer
  2. Optionally download or import to CCS Cloud editor
  3. Build and download to the CC1310 LaunchPad
- EasyLink Network Processor also used in SimpleLink Academy

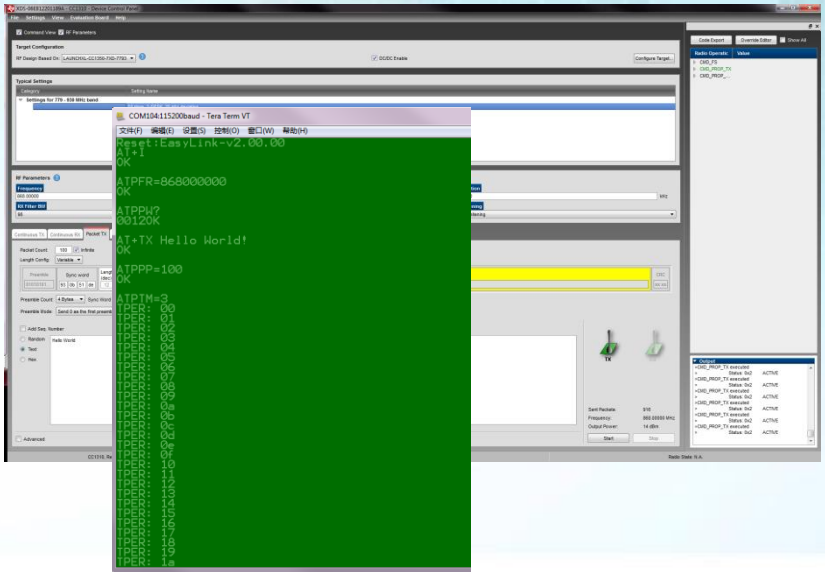


EasyLink Network Processor *Details*

- Two main features
- AT API
  - Start of Frame : AT
  - Two Command types :
    1. Pxx: Parameters
    2. +x: Control Commands
- Test Modes
  - Carrier Wave
  - Modulated Signal
  - PER Tx
  - PER Rx

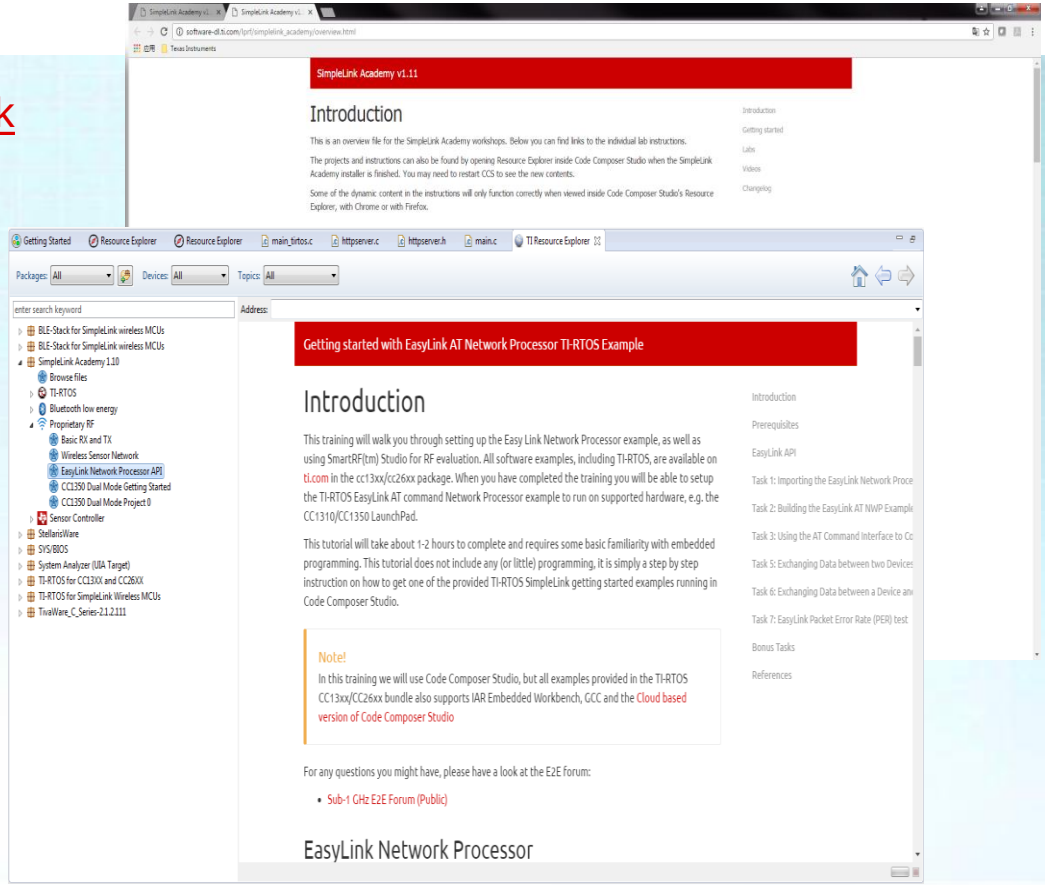


- Serial Session Connection
  - Input AT command to control
  - Output result/response



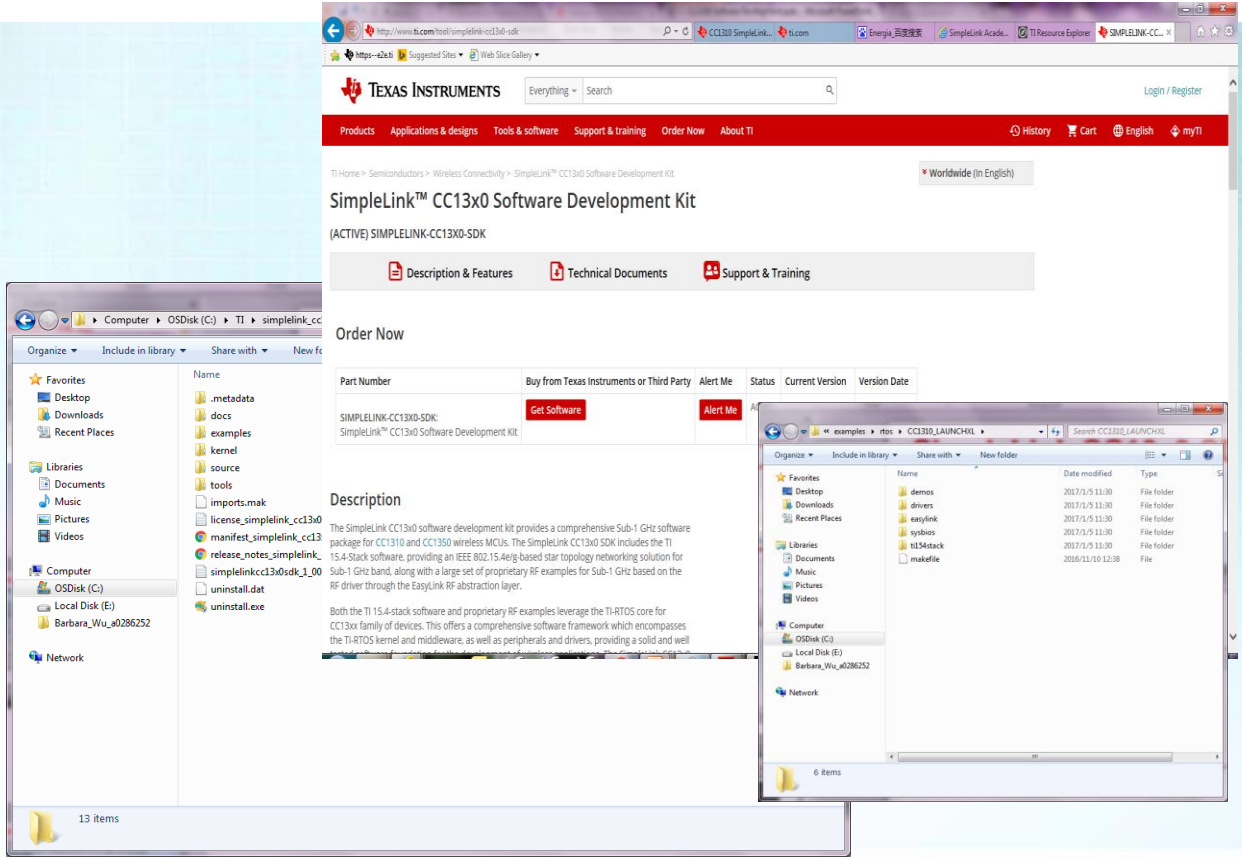
SimpleLink Academy

- Available at: SimpleLink Academy link
- Gets «anybody» up to speed on SW development for CC1310
- Integrated with CCS Desktop via separate installer
- Continuous roll-out of new labs and features.
- Richly formatted lab instructions
- Theory of operation
- Interactive quiz
- Learning by doing
- Quick links to further documentation



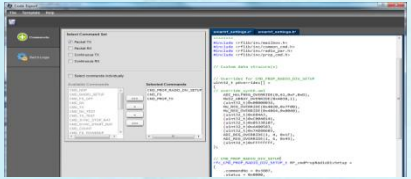
SimpleLink CC13x0 SDK

- Available at: www.ti.com
- Support IDE:
  - CCS
  - IAR
- Software components:
  - TI-RTOS
  - Peripheral drivers
  - TI 15.4-Stack
  - RF-Proprietary
- Documentation support
  - TI 15.4-Stack documentation
  - Proprietary RF documentation
  - CORE-SDK documentation
  - Drivers documentation
  - Kernel documentation
  - Additional online support

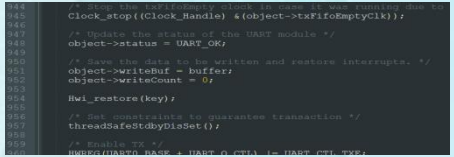


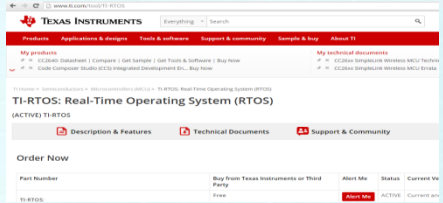
TI-RTOS – Proprietary tools example

SmartRF™ Studio 7



SimpleLink CC13x0 SDK





Radio Settings

RTOS

Drivers

Driver source Code

IDE & Compiler

CCS

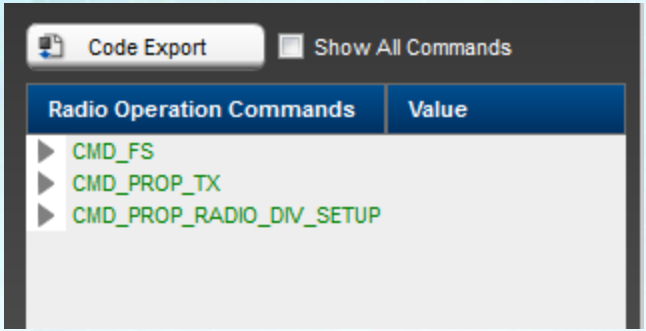
IAR SYSTEMS

Sensor Controller Studio

CC13x0 LaunchPad

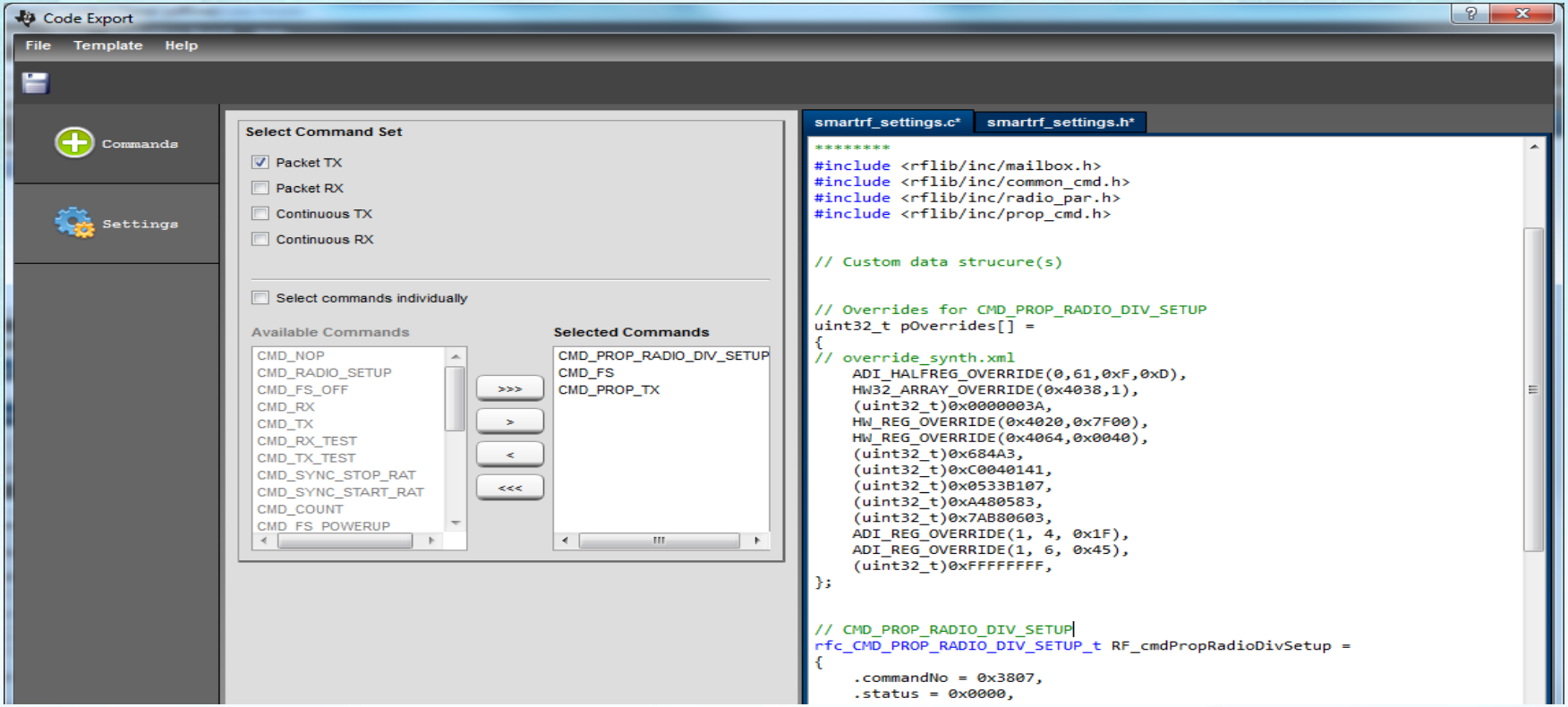
SmartRF™ Studio 7 (code export)

- Code export of radio operation commands



  - Generates a .c and a .h file (smartrf_settings.c and smartrf_settings.h) that should be included in the code

SmartRF™ Studio 7 (code export)



Sensor Controller Engine *(SCE)*

A proprietary low power CPU to offload the M3

Key features

- Handles sensor polling and performs simple processing
- Operates while the rest of the system is in powered down

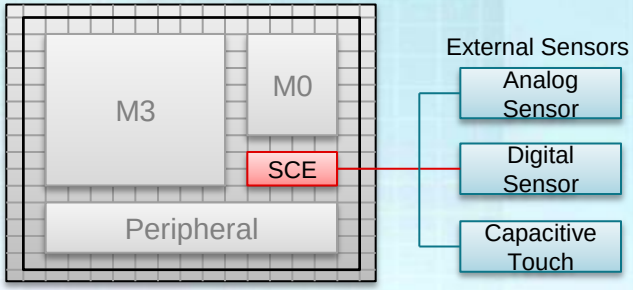
Examples of sensors that will greatly benefit from using the Sensor Controller:

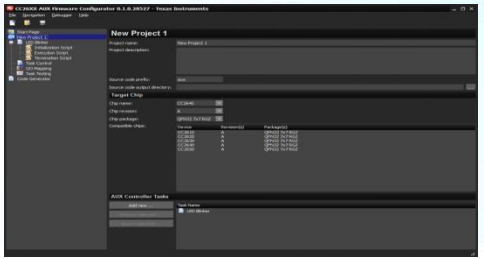
- PIR (motion detector)
- Capacitive touch keys
- Proximity sensors
- Accelerometers
- ADC measurements
- Pulse counting

- Use Sensor Controller Studio for configuration

Data Sheet – Key Features

- Autonomous 16-bit RISC CPU
- 2 KB SRAM (code + data)
- Clock Frequency:
  - 32kHz-24MHz





What is Sensor Controller Studio (SCS) ?

SCS is an Integrated Development Enviroment (IDE) with integrated compiler and debug capability. The tool has an intuitive GUI interface and the installer includes application examples.

1

Develop

- White C style code to initialize, execute and terminate tasks
- A task is a small program running from RAM in the SC
- Many examples exist to show how to control the various peripherals

2

Test

- Visualize output from tasks in the Task Testing pane
- Debug assembly code if neccessary

3

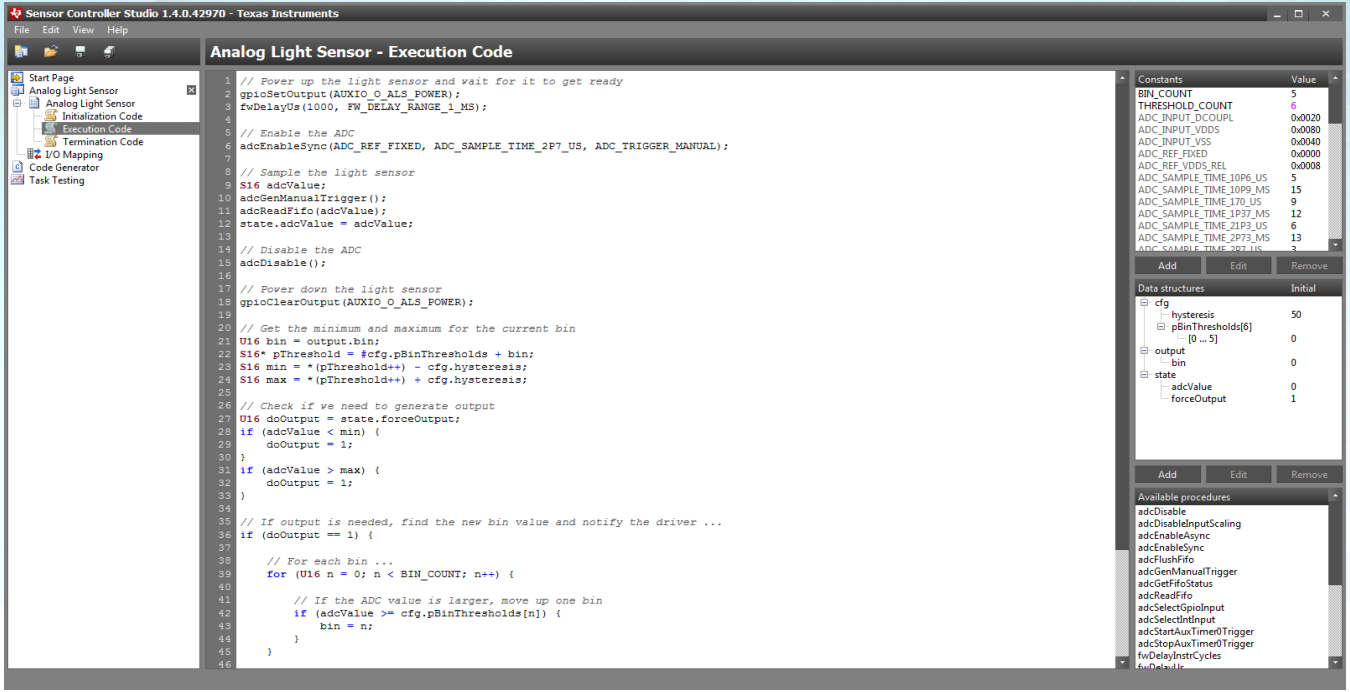
Export

- Generate driver and machine code.
- Export to main IDE for your software project

SCS 1 Develop code

Write C style code to initialize, execute and terminate tasks

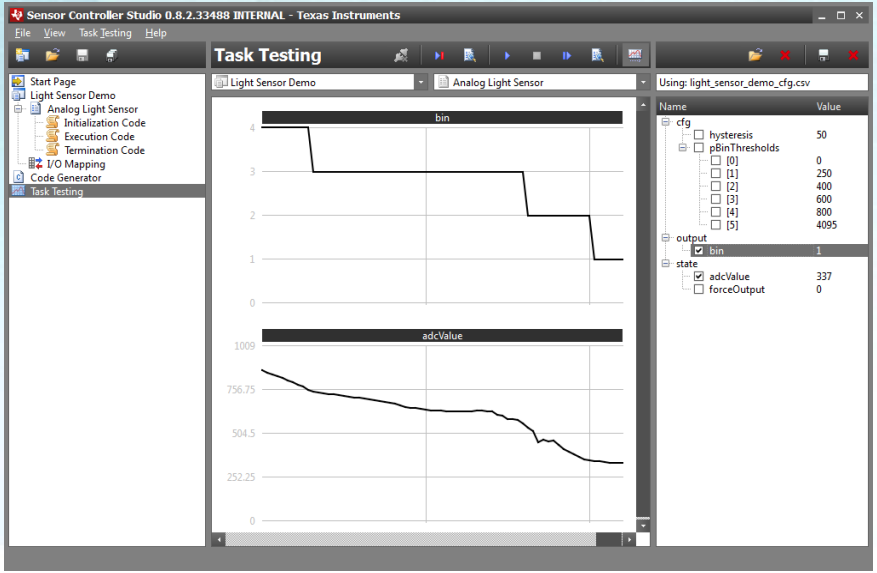
- A task is a small program running from RAM in the SC
- Many examples exist to show how to control the various peripherals
- Up to 8 tasks are possible to export from 1 project

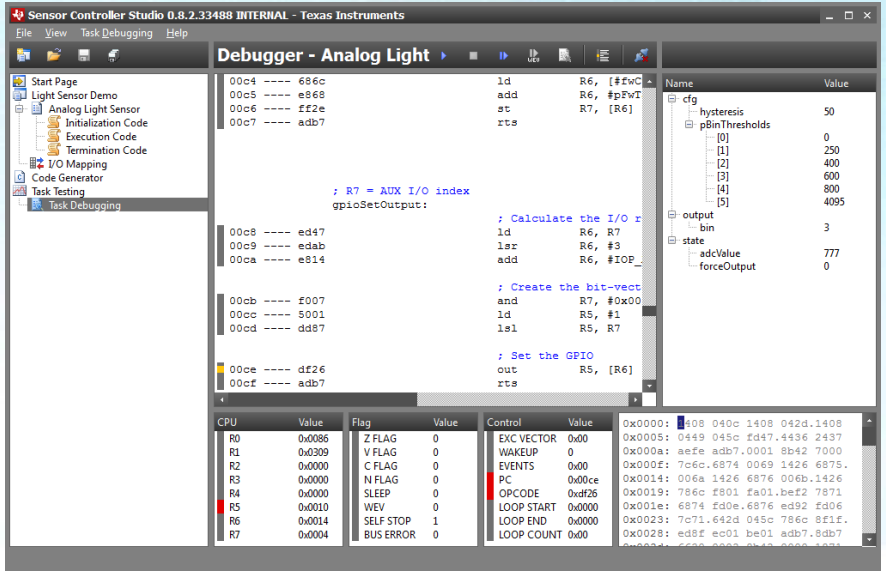


SCS 2 Test your task and debug

Visualize output from tasks in the Task Testing pane

- Debug assembly code if necessary
- Single step, set breakpoints etc
- A task is executed at a defined interval. If multiple tasks are defined, each tack is executed each n intervals (n can be defined for each task)



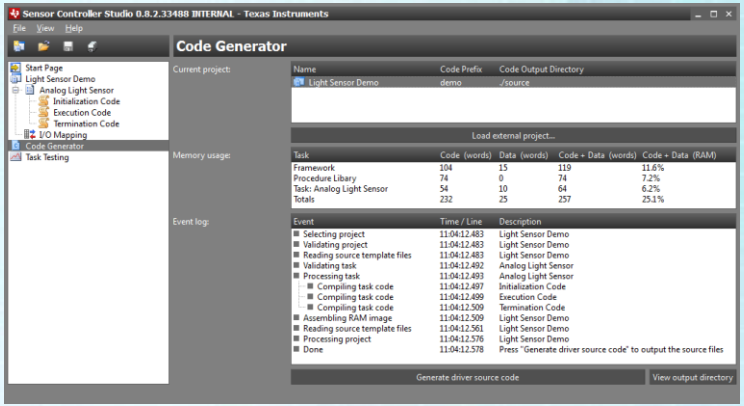


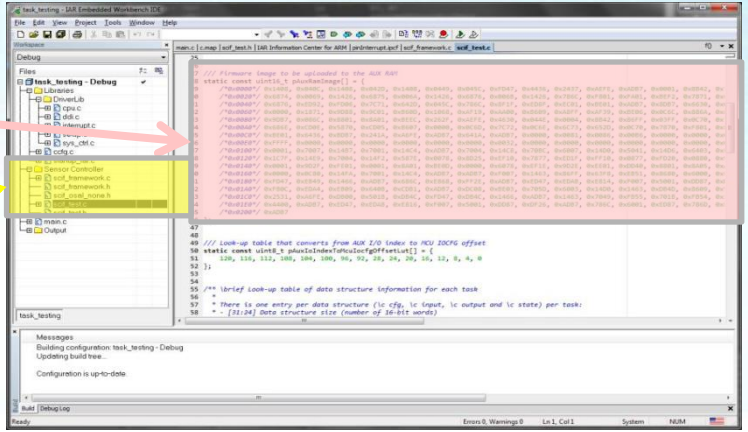
SCS 3 Code export

- Generate code and export to main IDE
- Support for IAR and CCS, with and without TI-RTOS

Image loaded to Sensor Controller RAM on startup

Project files exported from Sensor Controller Studio





SimpleLink™ Sub-1 GHz Support

Web Page:
http://www.ti.com/lsds/ti/wireless_connectivity/sub-1_ghz/overview.page
- Data Sheets
- Technical Reference Manual
- Application Notes
- Software & Tools Downloads and Updates
- Order Evaluation and Development Kits

Engineer 2 Engineer Support Forum:

http://e2e.ti.com/support/wireless_connectivity/f/156.aspx (English launguage)

http://www.deyisupport.com/question_answer/f/45.aspx (Chinese language)

- News and Announcements
- Useful Links
- Ask Technical Questions
- Search for Technical Content

Wiki:
http://processors.wiki.ti.com/index.php/Category:Sub-1GHz
- How to guides
- Intro Videos
- General Information

Thank you!

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