FTF 2016
TECHNOLOGY FORUM

LOW POWER MICROCONTROLLER APPLICATIONS

FTF-DES-N1969

ALLEN WILLSON
LPC PRODUCT APPLICATION ENGINEER

FTF-DES-N1969

18-MAY-2016

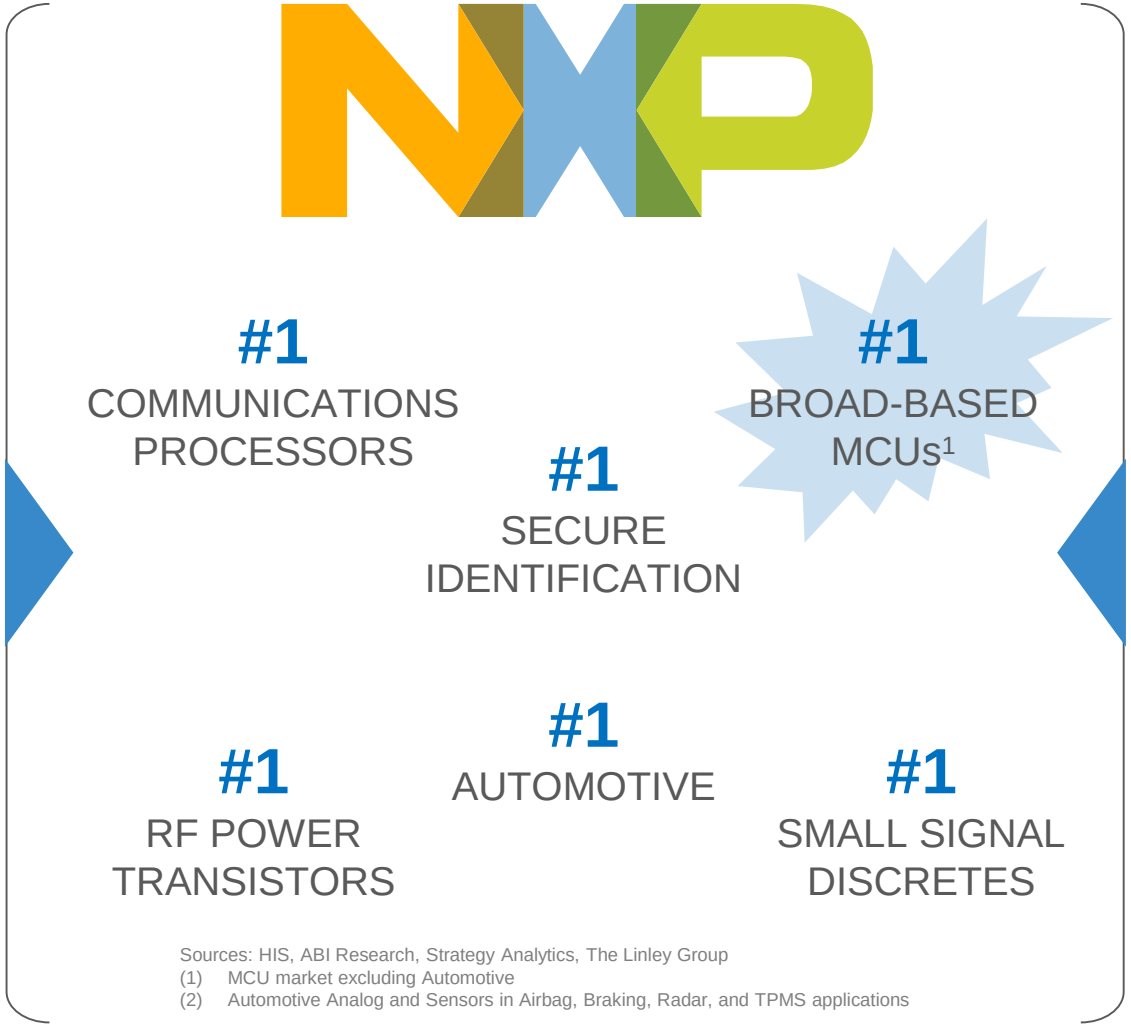
AGENDA

- NXP-FSL & Product Intro – Lecture
- Lab: PDM to PCM – Lecture
- Lab: PDM to PCM – Hands-on
- Lab: USB audio – Lecture
- Lab: USB audio – Hands-on
- Lab: Low Power – Lecture
- Lab: Low power – Hands-on
- VT Demos
- Summary & Closing

Expanded Solutions for Customers

freescale™

- **#1** Communications Processors
- **#1** RF Power Transistors
- **#1** Automotive Radar
- **#1** Automotive Safety[2]
- **#2** MCUs



Sources: HIS, ABI Research, Strategy Analytics, The Linley Group
(1) MCU market excluding Automotive
(2) Automotive Analog and Sensors in Airbag, Braking, Radar, and TPMS applications

NXP

- **#1** Secure Identification
- **#1** Car Entertainment
- **#1** In-Vehicle Networking
- **#1** Secure Car Access
- **#1** Smart Card MCUs
- **#1** Small Signal Discretes

Microcontrollers

Why Customers Choose Us

- Comprehensive portfolio supporting the diverse IoT landscape
- Consistently delivering new & innovative products
- Extensive software and development environment
- Industry leading customer support, quality, and longevity
- Broad ecosystem of partners enabling system solutions
- Ease of use solutions tailored for mass market

Products

LPC 32-bit ARM® Microcontrollers	Kinetis 32-bit ARM® Microcontrollers	i.MX ARM® Applications Processors

- Power efficient processing
- Integrated security & connectivity
- Scalable performance & integration
- Tailored application specific solutions; HW & SW
- Product Longevity

Applications

Wearable / Healthcare
- Health / Fitness & Wireless Healthcare
- Diabetes & Cardiac Care
- Diagnostics & therapy

Smart Home
- Smart meters & grid
- Integrated wireless connectivity solutions
- Home energy control

Smart Accessories
- Game controllers and consoles
- Wearable computing
- eReaders, tablets, portable navigation

Vehicle Networking & Information
- Infotainment, software define radio
- Navigation systems, E-call

Home Appliances
- Energy efficient refrigerators, dishwashers
- Human-machine interface
- Connected appliances

Factory Automation & Drives
- Machine-to-machine
- Motor control
- Industrial networking

Demand for Always-on, Sensor-based Features is Challenging Battery Life for End Applications

- **Always-on application and ARM Cortex-M4 performance?**
- **Need to maximize battery life of your application?**
- **Cost challenged?**
- **Next generation of user experience with integrated sound detection and voice recognition?**

- **Introducing LPC5411x Series Microcontrollers**
  - Redefining industry leading power efficiency for always on processing
  - Dedicated hardware for low-power voice input & processing

LPC5411x Family of MCUs

Expands Industry-Leading Power Efficiency for Always-on IoT Applications

Redefined, power-efficient MCUs, optimized for battery-operated applications that can sense the world around it through sound and voice detection

Extend Battery Life with Ultra-low power consumption

- Meeting the need for Cortex-M4 performance with aggressive active current consumption, now reaching **<85 µA/MHz** (from RAM at 48MHz)
- Low static currents, including **10 µA** for sensor listening in Deep Sleep mode (64KB RAM retained) and **19 µs** wake-up
- Flexible power mode options, including scalable RAM retention, to meet needs of specific application requirements
- Direct memory access (DMA), with various asynchronous peripherals to help reduce applications need for power

Added Flexibility & Power Efficiency with our Cortex-M0+ Co-processor

- Optional Cortex-M0+ co-processor, with single cycle multiplier for sensor interfacing, data aggregation, and system management low-bandwidth tasks
- Active current consumption, now reaching **<65 µA/MHz** (from RAM at 48MHz)
- Simplify design by eliminating need for second system-level microcontroller
- Preserve engineering investments across the LPC5411x family, with pin compatible versions - with and without our co-processor, to allow flexible scalability

Optimized integration for efficiency improvements and BOM cost reductions

- Ultra-low power, always-on voice and sound recognition with integrated features, including digital microphone interface (PDM to PCM) and frequency filtering (HW VAD)
- Eliminating need for external crystal or PLL with Crystal-less FS USB support
- Large RAM integration for complex algorithms, increased throughput and to perform sensor data batching while CPU is asleep
- Power-efficient 12-bit, 5 Msps ADC
- Save power and time through address match wake-up from I2C, SPI chip-selects and GPIO
- Ultimate in serial interface flexibility, providing with up to 8 instances of SPI, I2C, UART plus up to two I2S for audio output

NXP LPC Microcontroller Portfolio At-a-Glance

From entry level

Easy to use
Exceptional power efficiency
Lowest pin count

LPC800 Series

Low power, basic control and connectivity

- 30 MHz Cortex-M0+ core
- Basic serial connectivity
- Basic analog
- Low-pincount packages including TSSOP and HVQFN and XSON
- Ideal for 8-/16-bit transition

LPC1100 Series

Power efficient, broad selection, industry-standard connectivity

- 50 MHz Cortex-M0+ & M0 cores
- Serial connectivity: USB with PHY, CAN with transceiver
- Best-in-class analog
- Broad package selection
- Migration path to LPC1300 Series

LPC1200 Series

Noise immunity for industrial applications

- 45 MHz Cortex-M0 core
- High-immunity rating (IEC61697-1)
- 8 kV ESD protection
- Basic analog
- Real-time clock
- Fm I^2C with 10x bus-drive capability

to high performance & integration

Power efficiency
Advanced connectivity
Flexible peripherals

LPC1300 Series

Performance and basic connectivity

- Up to 72 MHz Cortex-M3 core
- Serial connectivity: USB, CAN
- Pin-compatible upgrade for most LPC1100 Series devices

LPC1500 Series

High-precision motion control

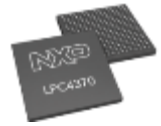
- Up to 72 MHz Cortex-M3 core
- Optimized for sensored & sensorless brushless motor control; free FOC firmware
- Serial connectivity: USB, CAN
- Advanced analog subsystem and SCTimer/PWM

LPC1700 Series LPC4000 Series

High performance with DSP options, multi-connectivity, advanced peripherals

- Up to 120 MHz Cortex-M3 core
- Advanced connectivity: USB, CAN, Ethernet
- Graphic LCD controller
- Pin-compatible migration path to LPC4000 Series and ARM7 LPC2x00 Series

- Up to 120 MHz Cortex-M4/M4F cores with DSP
- Advanced conn.: USB, CAN, Ethernet
- Graphic LCD controller
- Analog comparators
- Drop-in perf. upgrade for LPC1700 and LPC2x00 series



LPC1800 Series LPC4300 Series

Best performance with DSP and dual-core options, multi-high-speed connectivity, advanced peripherals

- Industry's highest-performing Cortex-M3 core, up to 180 MHz
- Advanced conn.: dual Hi-Speed USB, dual CAN, 10/100 Ethernet
- Advanced, flexible timers for event-driven timing and PWM applications
- Drop-in compatible with LPC4300 Series

- Up to 204 MHz Cortex-M4F core with DSP capabilities and Cortex-M0 coprocessor(s)
- Partition tasks across cores to optimize performance
- Advanced conn.: dual Hi-Speed USB, dual CAN, 10/100 Ethernet, configurable high-speed serial I/O
- Best-in-class analog, up to 80 Msps, 12-bit ADC

and redefined power-efficiency

Flexible peripherals
Smart integration

LPC54100 Series LPC54110 Series

Ultra-low-power for always-on sensor processing

- Up to 100 MHz single- & dual-core: Cortex-M4F & M0+ (opt.)
- Optimized for sensor listening, aggregation, fusion, and communication
- Ultra-low 'power down' mode, down to 3 µA for sensor listening
- Scalable power performance

- Up to 100 MHz single- & dual-core: Cortex-M4F & M0+ (opt.)
- Reduction in dynamic power
- Optimized for voice recognition and sound detection with integrated DMIC subsystem and HW VAD
- Scalable power performance

LPC5411x Block Diagram & Main Features

CPU

- **100MHz Cortex-M4F**
- **Optional Cortex-M0+ Co-processor**

Memory

- Up to 256 KB Flash, **192 KB RAM**

Peripherals

- Stereo DMIC subsystem
  - (PDM, decimator, HW VAD)
- **8 SPI, 8 I2C, 8 UART, 2 I²S channels.** Max 8 channels
- **Crystal-less FS USB**
- Power-efficient **5 Msps, 12-bit ADC**: full-spec performance (1.62 to 3.6V, -40 to 105 °C)

Clocks & timers

- **12/48/96 MHz FRO**, 100 kHz-1.5MHz WDOG OSC, 32 Xtal OSC, external clock input
- Basic & advanced timers including SCTimer/PWM
- Asynchronous peripheral bus

Packages

- LQFP64, WLCSP49

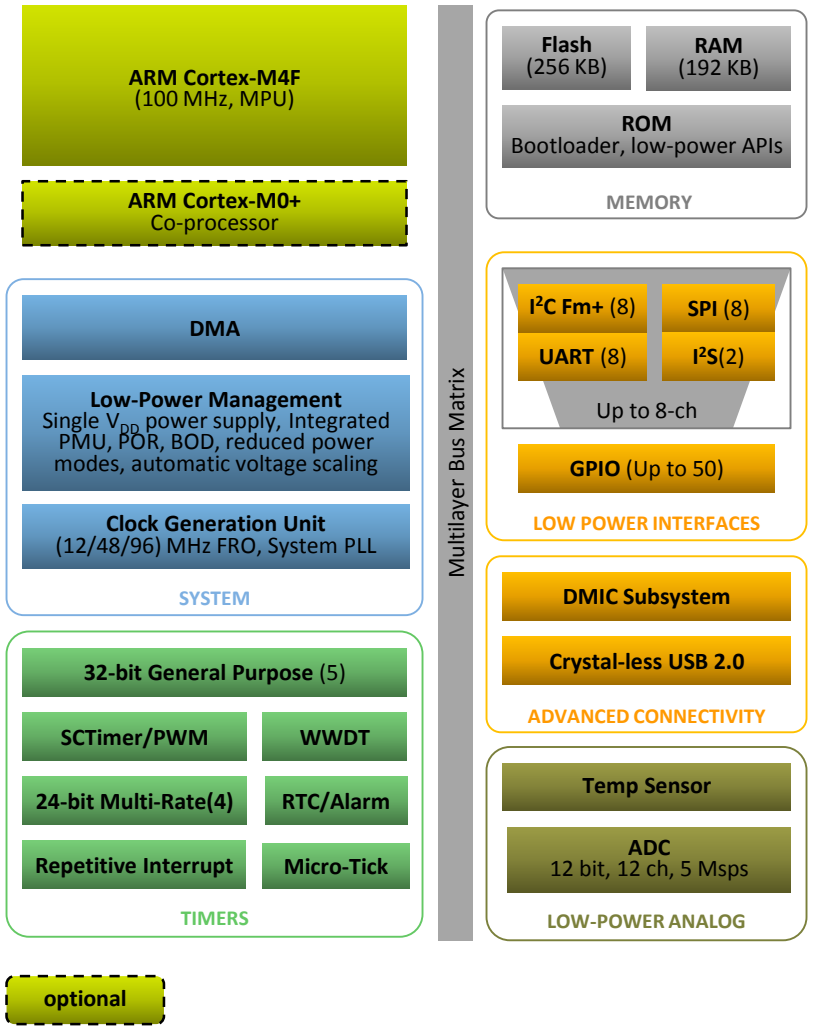
Other

- Operating voltage: 1.62 to 3.6V
- Temperature range: -40 to 105 °C

Availability

LPC5411x Silicon
LPCXpresso 54114 (OM13089)
LPC54114 Audio & Voice Recognition Kit (OM13090)

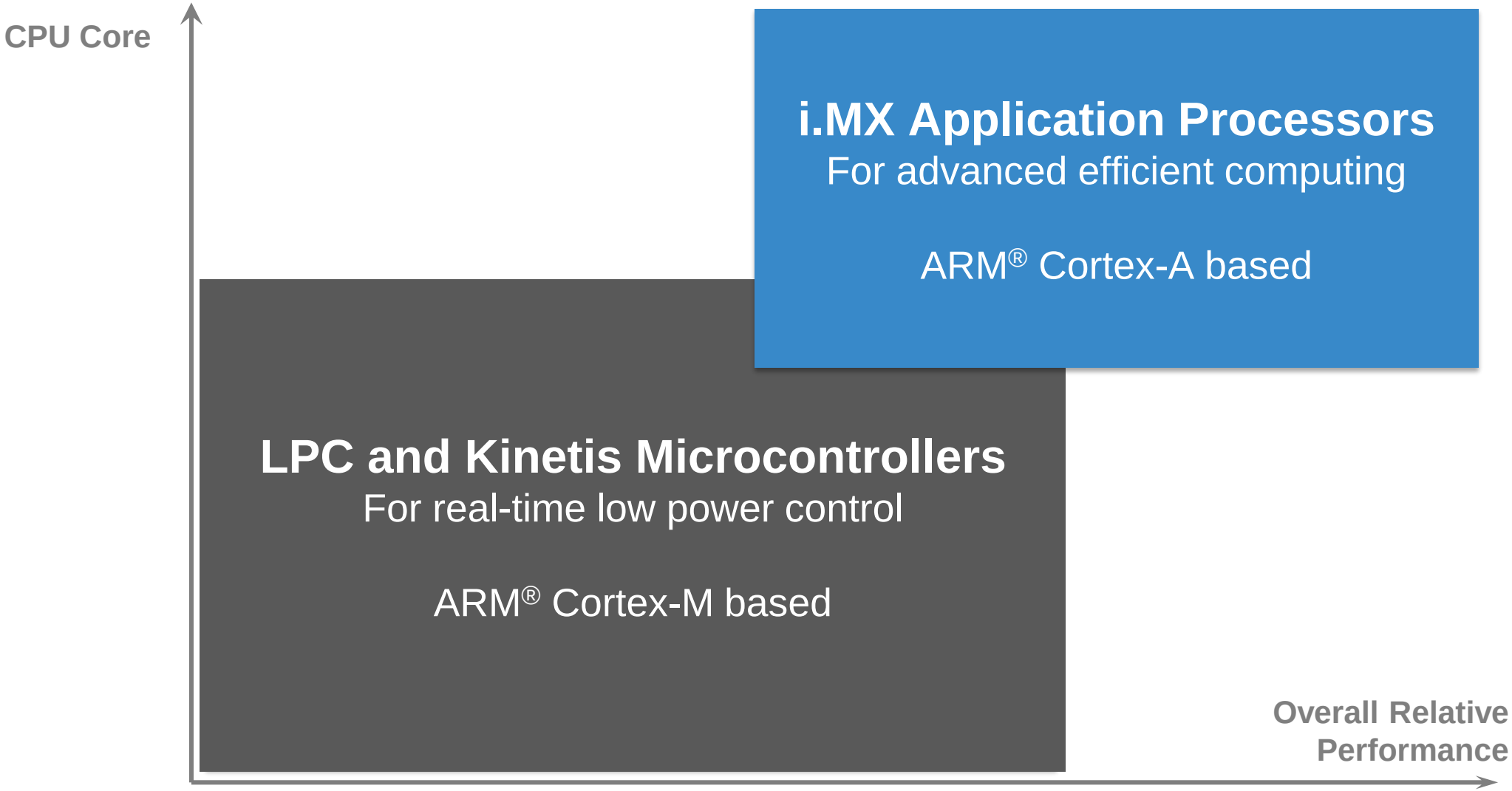
Limited Early Access Samples **NOW**
Market Announcement **Embedded World**
Full Market Launch **April-2016***
(WLCSP MP Jun-2016)



** Target Dates, Features, Specs Subject to Change*

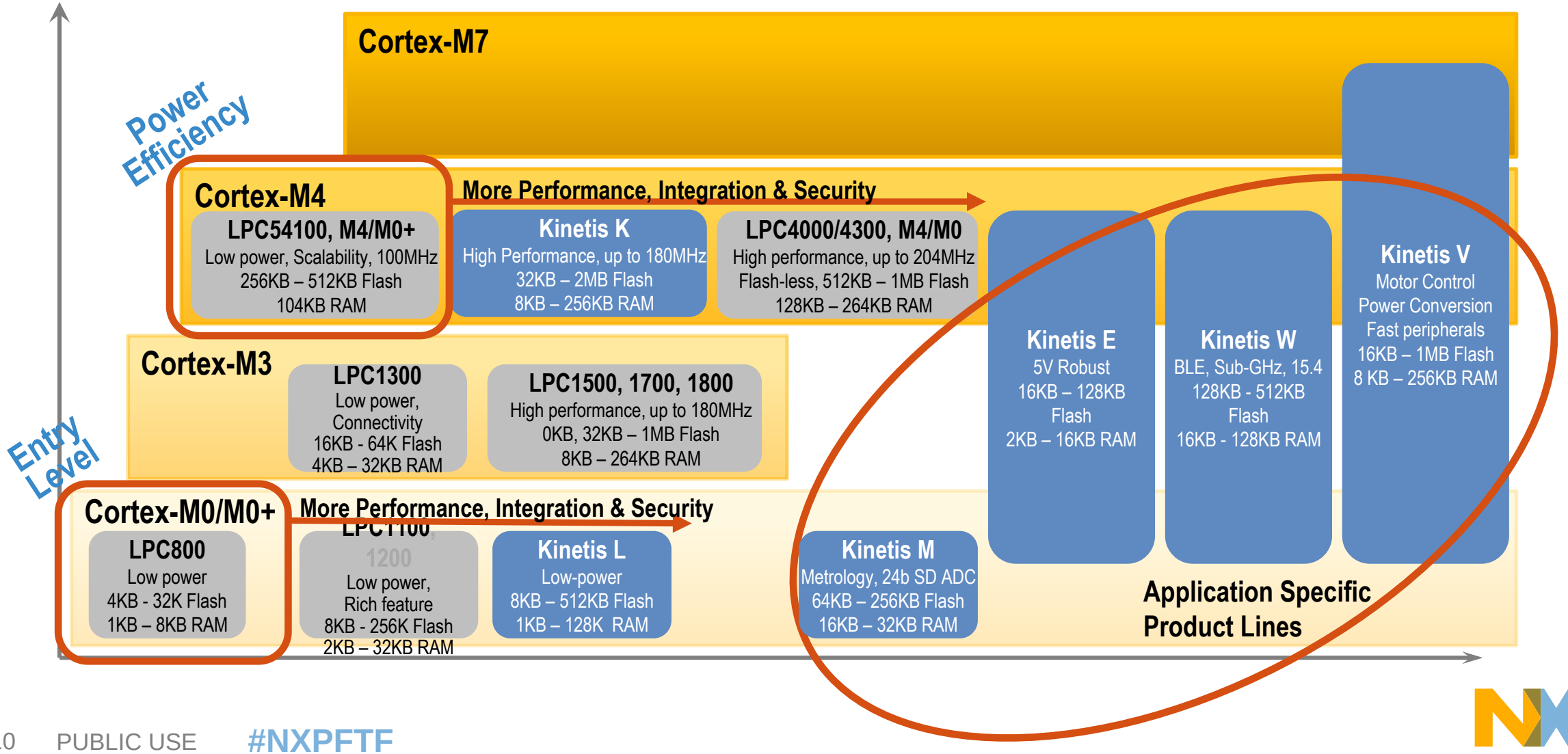
MICROCONTROLLER POSITIONING

Scalable ARM based Processors and Controllers



NXP's Breadth in Microcontrollers

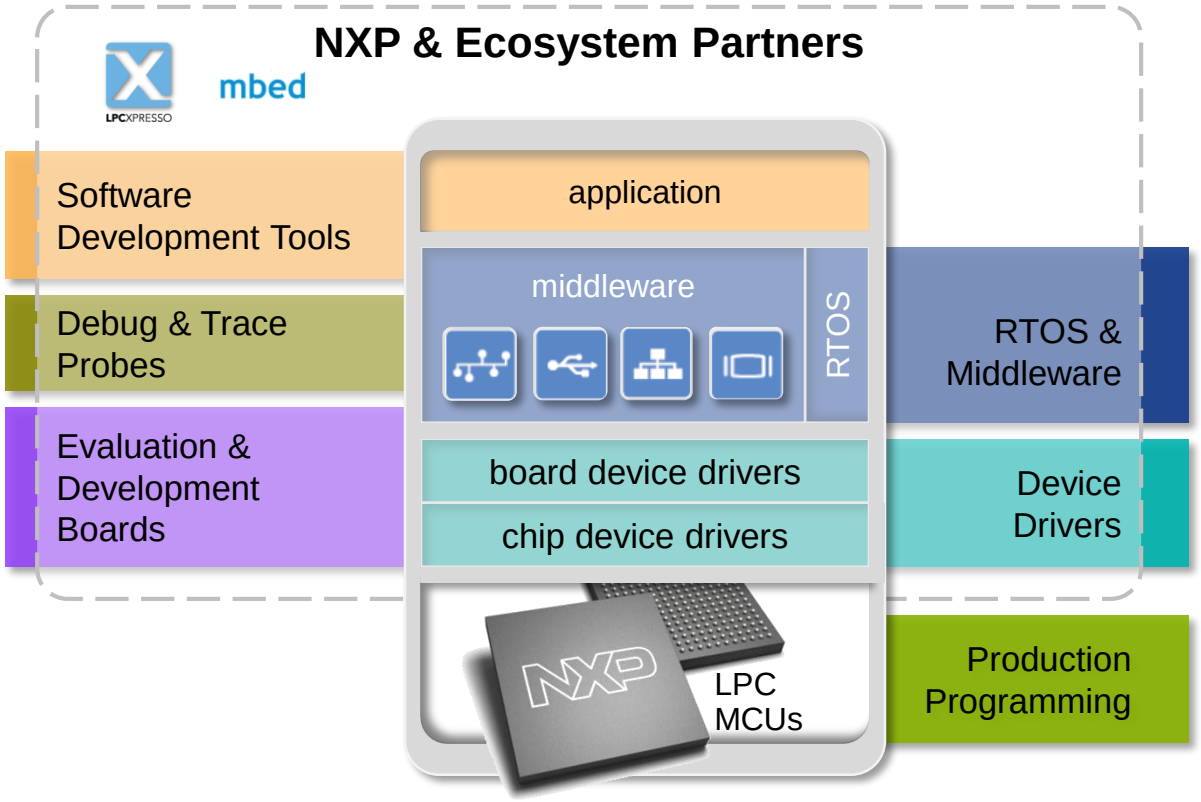
Kinetis + LPC = Broad Portfolio of Microcontroller Families



RECOMMENDED DEVELOPMENT BOARD

Start Developing in Minutes With the LPC Developers Ecosystem!

NXP brings together world-class development platforms, tools, boards, and software from NXP and partners to get you started developing on NXP LPC microcontrollers fast



LPCXpresso54114 Development Board

For Designing Low-power Applications Quickly

- Eclipse-based LPCXpresso IDE
  - GNU C/C++ toolchain, available in free and Pro versions
- Supported by Keil and IAR development tools
- Supported by the free drivers & firmware (LPCOpen)

Development Board	Board Description
LPCXpresso54114 **(**OM13089)	Rapid prototyping and evaluation board
LPC54114 Audio & Voice Recognition Kit **(**OM13090)	LPCXpresso54114 plus Audio / Display Shield Demos include USB/I2S audio demo, as well as voice recognition demos leveraging partner technology (Malaspina and Sensory)

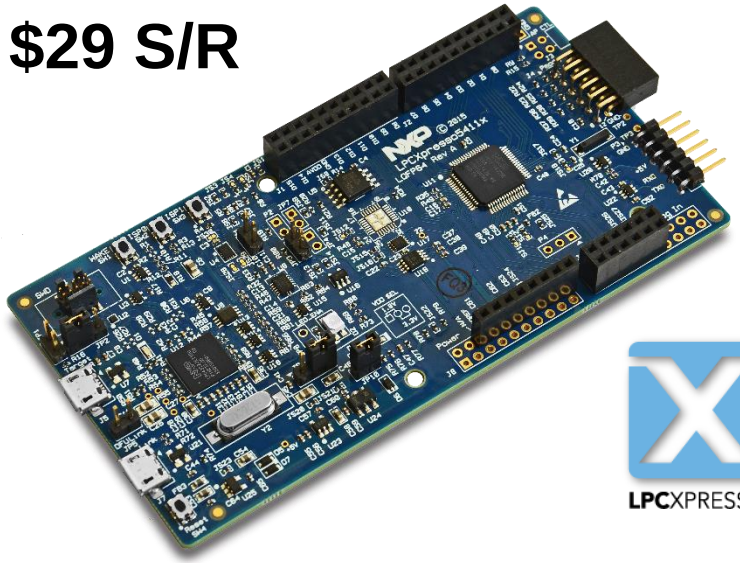
LPCXpresso54114 Development Board

For Designing Low-power Applications Quickly

LPCXpresso54114 Features

- LPC54114 dual-core (M4F and dual M0) MCU running at up to 100MHz
- On-board high-speed USB based debug probe with CMSIS-DAP and J-Link protocol support, can debug the on-board LPC54114 or an external target
- External debug probe option
- Tri-color LED, target Reset, ISP & interrupt/user buttons for easy testing of software functionality
- Expansion options based on Arduino UNO and Pmod™, plus additional expansion port pins
- On-board 1.8 V and 3.3 V regulators plus external power supply option
- 8Mb Macronix MX25R SPI flash
- Built-in MCU power consumption and supply voltage measurement
- UART, I²C and SPI port bridging from LPC54114 target to USB via the on-board debug probe
- FTDI UART connector

$29 S/R



LPCXPRESSO

SUCCESS IN LOW POWER APPLICATIONS

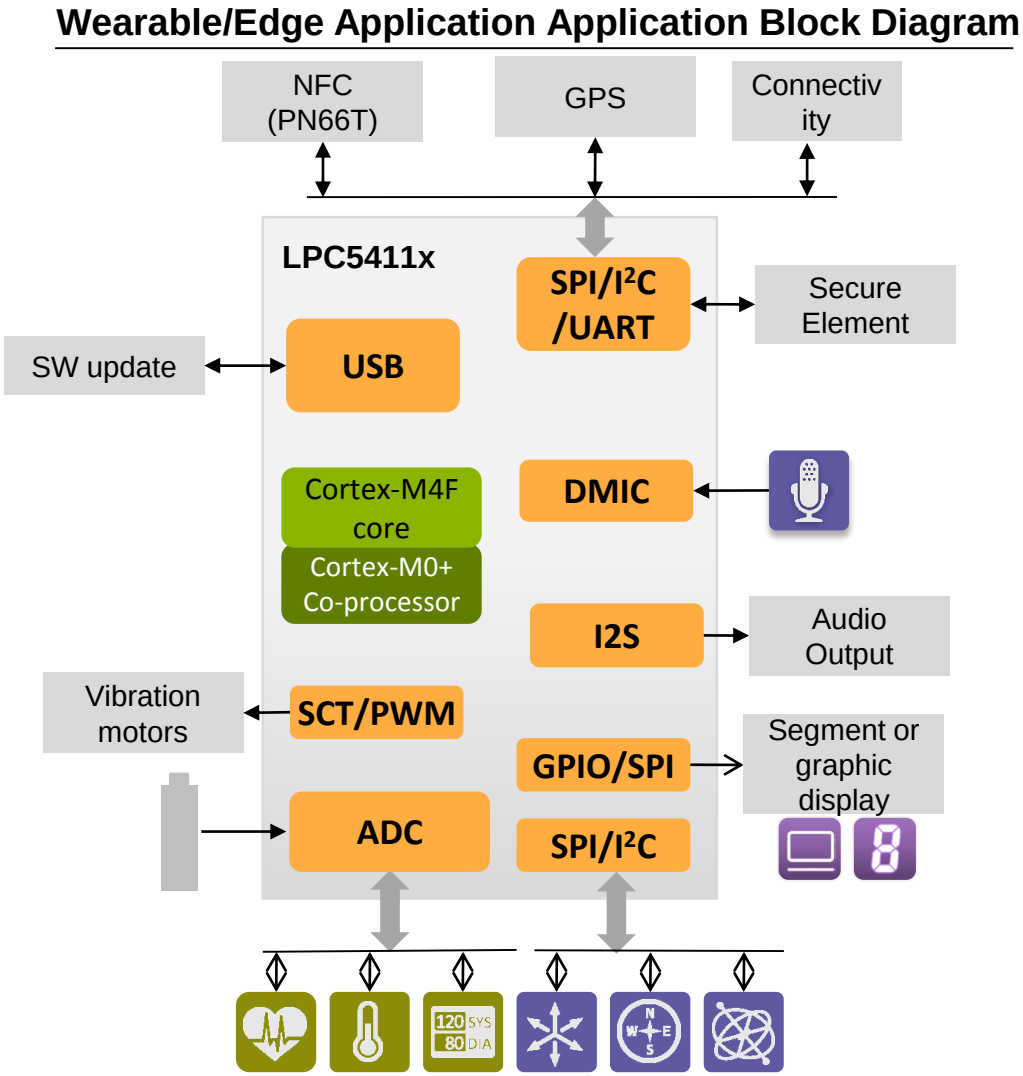
LPC5411x Family of MCUs

Target Applications

	Wearables	Gaming & Entertainment	Smart Home	Industrial
Key Features	• sensor processing • voice activation • health monitoring	• console orientation • user motion • voice activation	• Voice based UI • low power connectivity • sensor based environmental monitoring	• stability & balancing • sensor based environmental monitoring • dead reckoning
Types of Products	• smart watches • fitness bands • portable fitness • home health monitoring • clothing	• toys • air mouse / remote head-worn glasses / terminals	• thermostats • IoT sensor node • keyless entry & access • lighting control • fire, safety and security	• robotics & drones • fleet management • asset tracking • building automation

Optimized for Power Constrained Applications

- Low Active Currents for Always-On Processing
  - ARM® Cortex ® M4F <85 µA/MHz
  - Optional co-processor for sensor interfacing, data aggregation and system task management
  - ARM® Cortex ® M0+ <65 µA/MHz
- Optimized integration, including on-chip digital microphone (DMIC) subsystem
  - Maximize battery life through ultra-low power sound detection, voice recognition and activation
  - 12-bit, 5 Mbps ADC for high-precision analog sensor interface, full spec over voltage range: 1.62 to 3.6V
  - Accurate, Low-power FRO Supporting Crystal-less FS USB
- Optimal serial interfaces tailored for your application
  - Max eight channels from choice of 8 SPI,8 I2C, 8 UART, or two I2S



Always-on Voice Detection & Triggering

Clear Benefits Across Many Embedded Applications

- Sound and Voice to Trigger Application Functions … Numerous User Experience Benefits
  - More natural: no buttons to find/push, similar to regular conversation
  - More intuitive: commands based on native language
  - More convenient: hands-free, faster
  - Safer: hands-free, eyes-free / no need to look away from current task

Leaves eyes and hands free

More convenient

More intuitive

Call to Action

- LPC is alive and well …
- The LPC5411x Family is latest launch in an ongoing effort to improve energy efficiency, expect more in the LPC54000 Series
- Need your help becoming LPC product evangelists… share what you learn with others; speak up if support is needed
- Reach out to Justin Mortimer, LPC Product Marketing Manager for support prior to launch with early customer support
- Work together, develop opportunities, win sockets & increase market share

Documentation and Deliverables

Standard Deliverables	
Electrical Data Sheet	now
User Manual	now
LPCOpen	now
LPCXpresso v8.1	now
Keil uVision 5	patch
IAR EWARM 7	March

nxp.com
lpcware.com

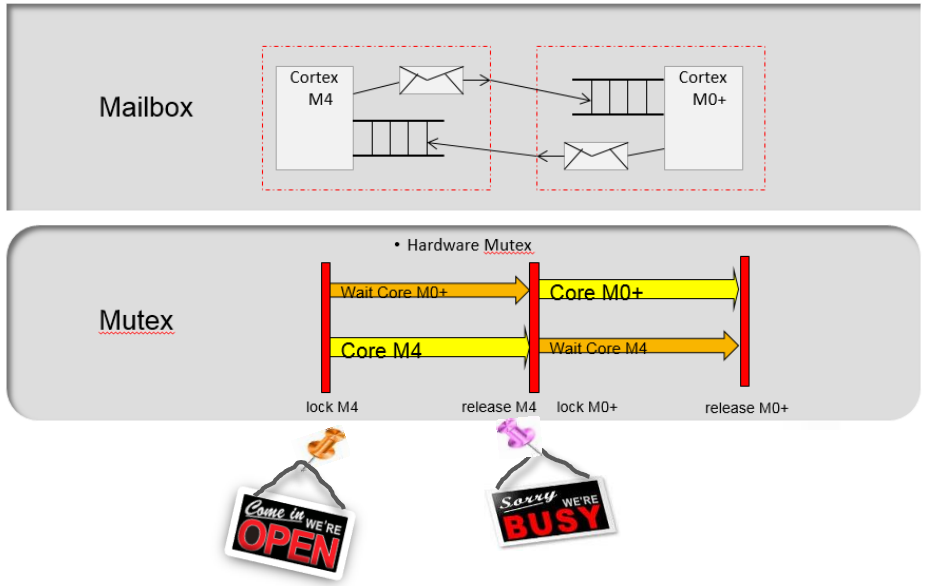
Application Notes and Demos	
CoreMark measurement guide	AN
Power modes and wake up times	AN
USB Compliance Checklist and Code	AN
USB Wakeup from low power modes	AN
In-Application Programming	reference
Solution Kit: Voice Trigger with Sensory library	AN
Solution Kit: Voice Trigger with Malaspina library	AN
SCT Cookbook: addition of LPC5411x	AN
Solution Kit: USB Audio Streaming	AN

DUAL CORE ARCHITECTURE

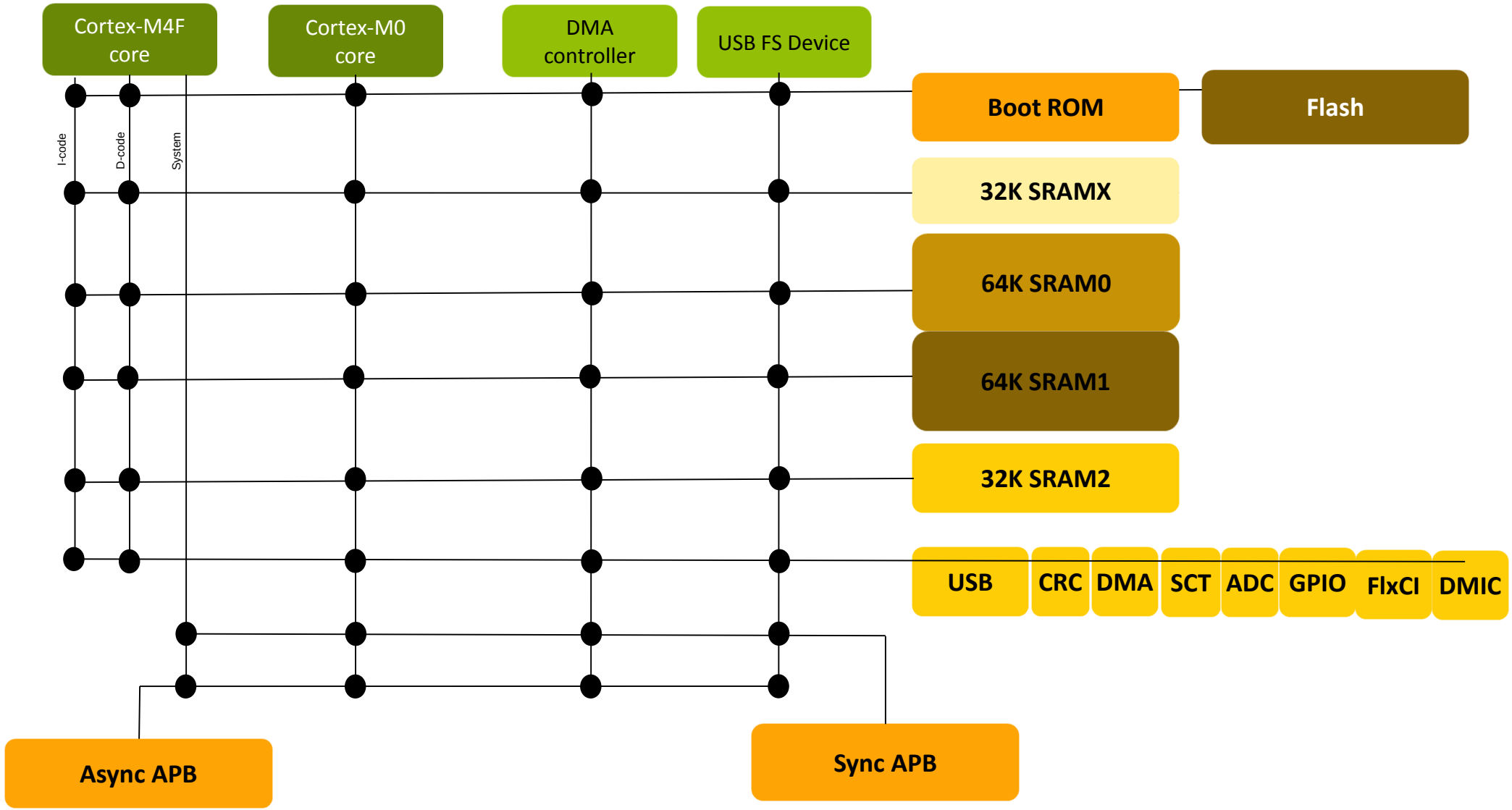
Cortex-M4/M0+ Implementation Overview

- Cortex-M4:
  - MPU
  - Single precision FPU
  - NVIC: VTOR + 8 priority levels
  - SysTick timer
  - SWD: 6 breakpoints, 4 watchpoints, SWO trace
- Cortex-M0+:
  - HW Multiply unit
  - NVIC: VTOR + 4 priority levels
  - SysTick timer
  - SWD with 4 breakpoints and 2 data watchpoints

- Mailbox available for each core
- 32-bit flag/interrupt register under user control
- Hardware mutex for shared resource management

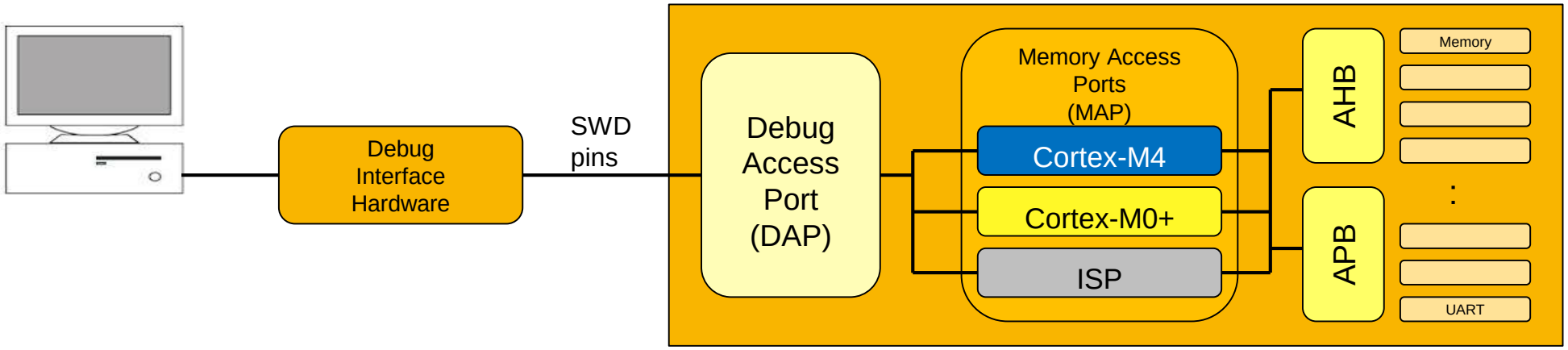


LPC541xx Simplified Architecture



Debug Access Port Structure (Simplified)

- The DAP can act as a bus master and can allow memory access to Advanced High-performance Bus (AHB) and Advanced Peripheral Bus (APB) even while the core is running.
- The busses are connected to Memory Access Ports (MEM-AP) of the DAP.



FLEXCOMM INTERFACE

Flexcomm Serial Communication Interface

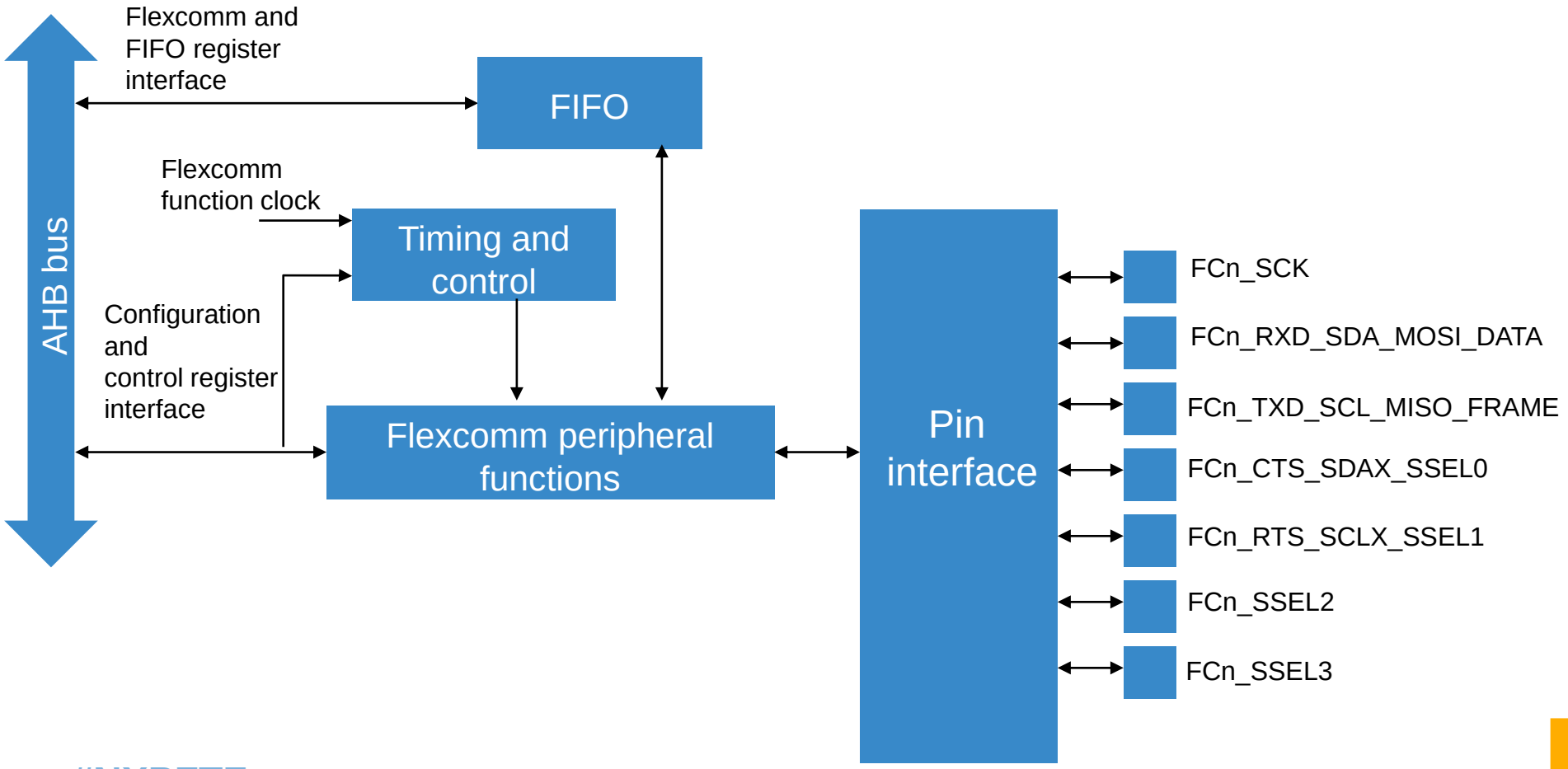
- 8 Flexcomm channels: Each channel provides a choice of serial peripherals, one of which can be selected by using the PSELID register

Flexcomm	Peripheral Function
Flexcomm 0 to Flexcomm 7	USART with asynchronous operation or synchronous master or slave operation.
	SPI master or slave, up to 4 SSEL per channel
	I^2C with separate master, slave and monitor functions.
Flexcomm 6 and Flexcomm 7	I^2S function with one to four I^2S channel pairs.

- Configuration examples:
  - 8 UARTS, 0 SPI, 0 I2C, 0 I2S
  - 4 UARTS, 1 SPI, 2 I2C, 1 I2S
  - …be cognizant of the pin configuration (initializer tool is available)
- True Open Drain pins: FC1 and FC4 have special I2C pins for FastMode+ support

FIFO and DMA Improve Throughput

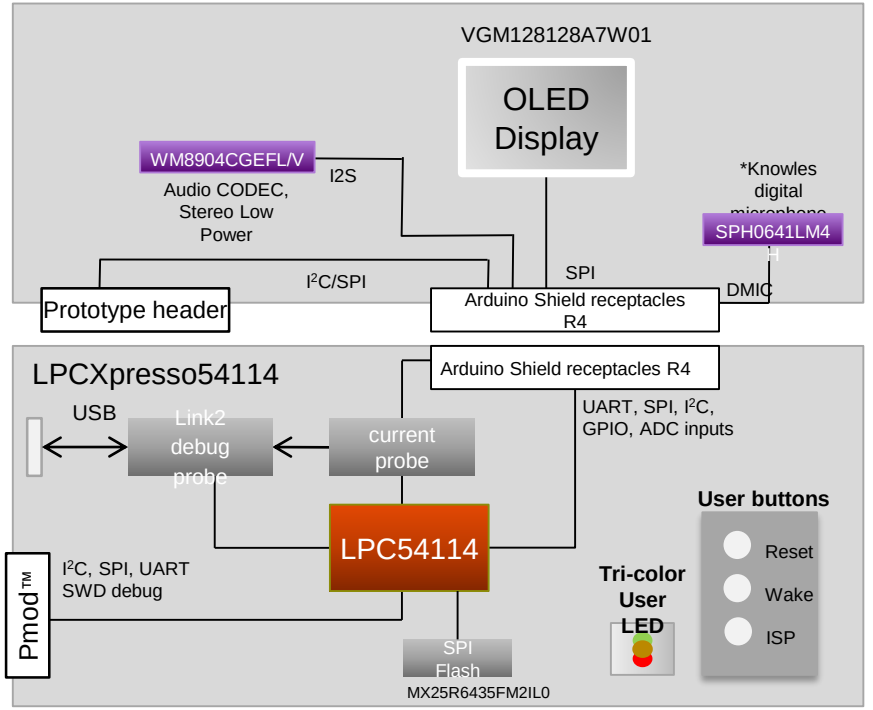
- Flexcomm FIFO buffers data for USART(16), SPI(8rx/8tx), and I2S(8)
- DMA requests are supported by each Flexcomm peripheral



AUDIO & VOICE RECOGNITION KIT OOBE

Audio & Voice Recognition Kit Anatomy

- Hardware
  - LPCXpresso54114
  - OLED display/DMIC/CODEC shield
- Demos/examples featuring:
  - Hardware DMIC Subsystem with VAD output
    - Knowles SPH0641LM4H digital microphone
    - Monochrome OLED display (160x160 pixels)
  - Audio I2S/USB demonstrator
    - Cirrus Logic (Wolfson) WM8904 audio codec with stereo line in/out sockets
    - USB/I2S audio demonstrator
  - Speaker independent phrase spotting library & demo from Sensory& Malaspina



OM13090 Link: www.nxp.com/OM13090

*Support other Digital Microphone besides Knowles

SETUP FOR LABS

Blinky Lab

- Goal
  - Verify that board and LPCXpresso IDE are setup correctly
- Duration: 15 mins
- Hardware:
  - LPCXpresso54114 board (1)
  - Micro USB cable (1)
- Software
  - LPCXpresso IDE v8.1 or later

LPCXpresso54114 Development Board for Designing Low-power Applications Quickly

- Features
  - LPC54114 MCU running at up to 100MHz
  - On-board high-speed USB based debug probe with CMSIS-DAP and J-Link protocol support
  - Can debug external target or use external debug probe (e.g. J-Link)
  - Tri-color LED, target Reset, ISP & interrupt/user buttons
  - Expansion options: Arduino UNO, Pmod™, plus extra connectors
  - On-board 1.8 V & 3.3 V regulators plus external power supply option
  - 8Mb Macronix MX25R SPI flash
  - Built-in MCU power consumption and supply voltage measurement
  - UART, I²C and SPI port bridging to USB via on-board debug probe
  - FTDI UART connector
- Free GCC/Eclipse-based LPCXpresso IDE
- Compatible with Keil and IAR development tools
- Supported by free drivers & firmware (LPCOpen)

Related links

LPCXpresso54114 (OM13089) ordering & downloads page
LPCXpresso IDE information and download
LPCOpen software libraries

Hardware Setup

J7 USB

To Debug

Confirm that Power LED (D3) is ON when the board is powered

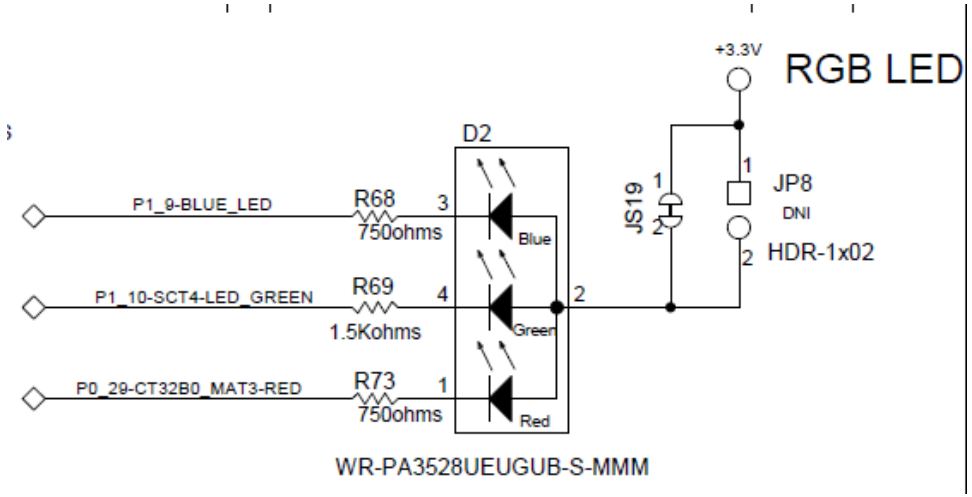
Blinky – Objective & High-level Steps

- Objectives
  - Build & run the ready-made project
  - Confirm that the LED D2 is blinking RED with code as is
  - Change the LED color to WHITE

- High-level Steps
  - Launch LPCXpresso IDE & select a workspace location of your choice
  - Import the lab archive
  - Build the “periph_blinky” project
  - Connect the board to PC using the debug USB port
  - Debug “periph_blinky” project
  - Wait for download to complete and then click “Resume”
  - Confirm that RED LED is blinking
  - Make necessary changes to blink WHITE color

- Reference - LPCX5411x Rev A1 Schematic

Blinky – Solution



- Source: LPCX5411x Rev A1 schematic
- To select WHITE color, Set & Toggle all Three LEDs
  - Board_LED_Toggle(0) // Toggle RED LED
  - Board_LED_Toggle(1) // Toggle GREEN LED
  - Board_LED_Toggle(2) // Toggle BLUE LED

LAB #1
DMIC SUBSYSTEM

DMIC Subsystem Lab

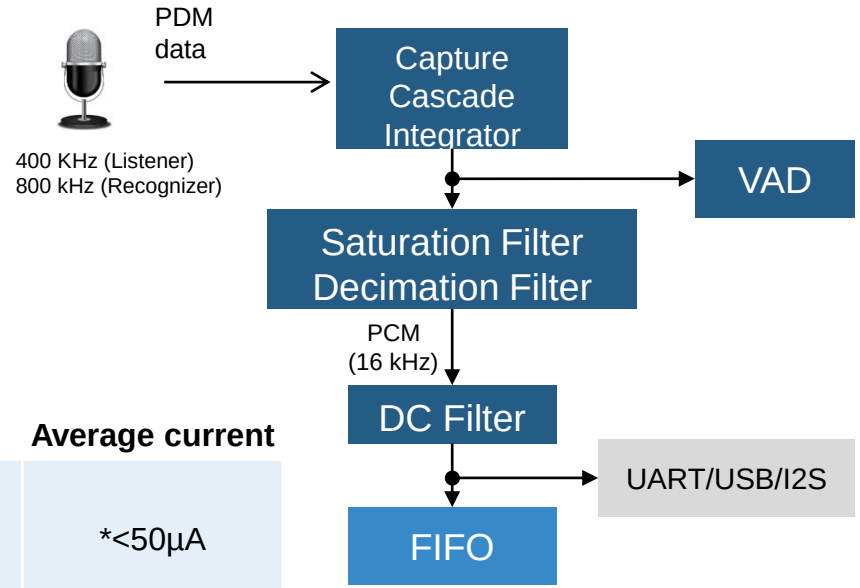
- Goal
  - Understand how the DMIC, HWVAD and I2S can be used to filter, analyze and route audio around the MCU
- Duration: 60 mins
- Hardware:
  - LPCXpresso54114 board (1)
  - Micro USB cable (1)
  - Earbuds
- Software
  - LPCXpresso IDE v8.1 or later
  - Lab workspace

LPCXPRESSO

DIGITAL MICROPHONE SUBSYSTEM

Digital Microphone Subsystem (DMIC) and Hardware Voice Activity Detector (VAD)

- Stereo Hardware PDM-PCM decimation, DC filtering, saturation
- H/W VAD Wave Envelope detector and noise floor detector
- Application example: while sleeping
  - DMIC wakes up the DMA
  - Batch data into audio FIFO
  - Copy data from FIFO, go back to sleep

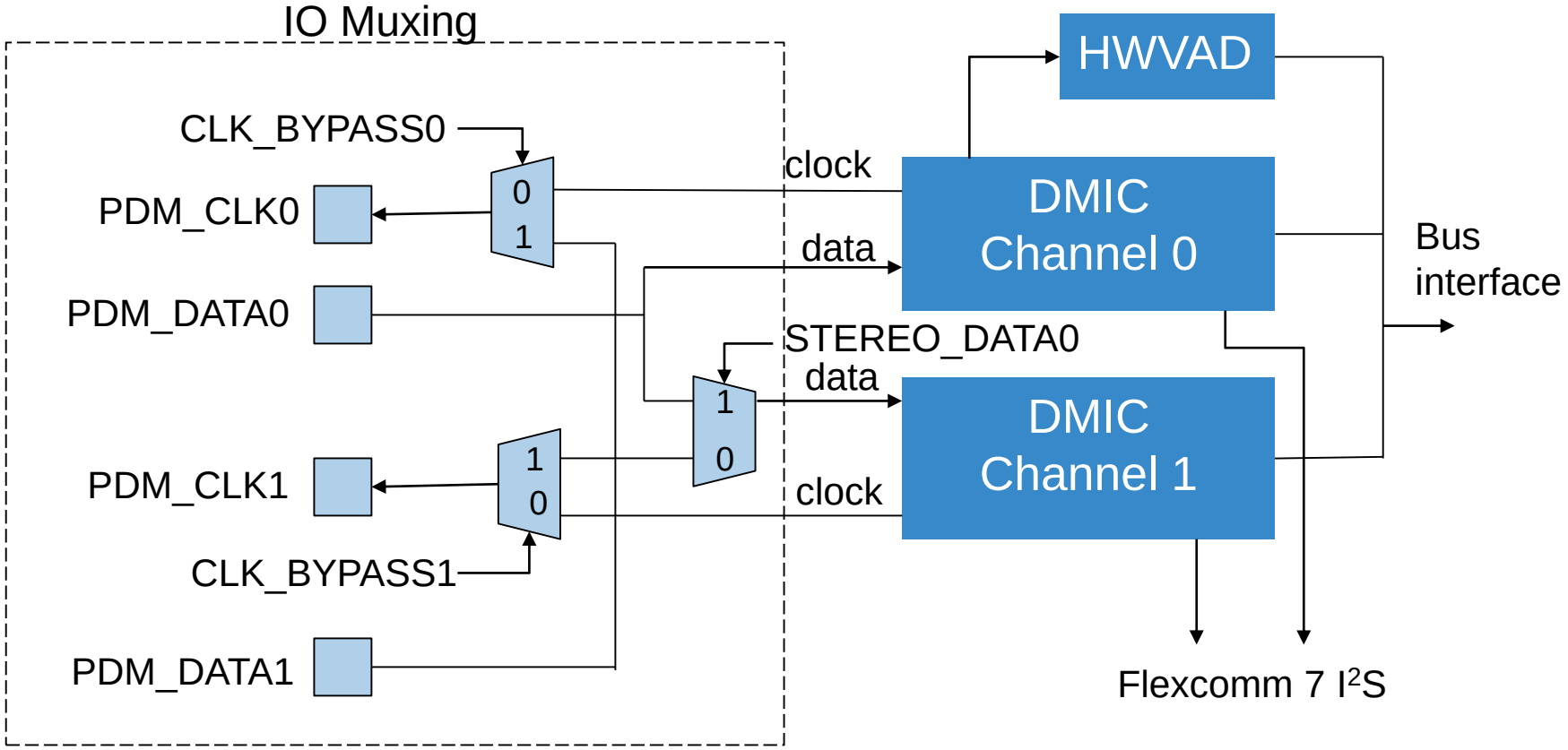


Voice Detection Stages		Uses	Average current
Stage 1	**Always on listening** • Detects audio envelope change • No audio batching • Runs only under quiet environment	• DMIC at lowest sample rate • VAD • WD osc (600 kHz)	*<50µA
Stage 2	**Detects possible speech** • Audio data batching • Speech envelope detection	• FRO (12 MHz) and nominal DMIC sample rate (800kHz) • M4 • DMA	*<300µA
Stage 3	**Recognizer** • Trigger command recognition	• FRO (84 MHz) • M4	*<1.5mA

(*)Preliminary Power numbers provided for a specific voice recognition application with a trigger phrase followed by command set

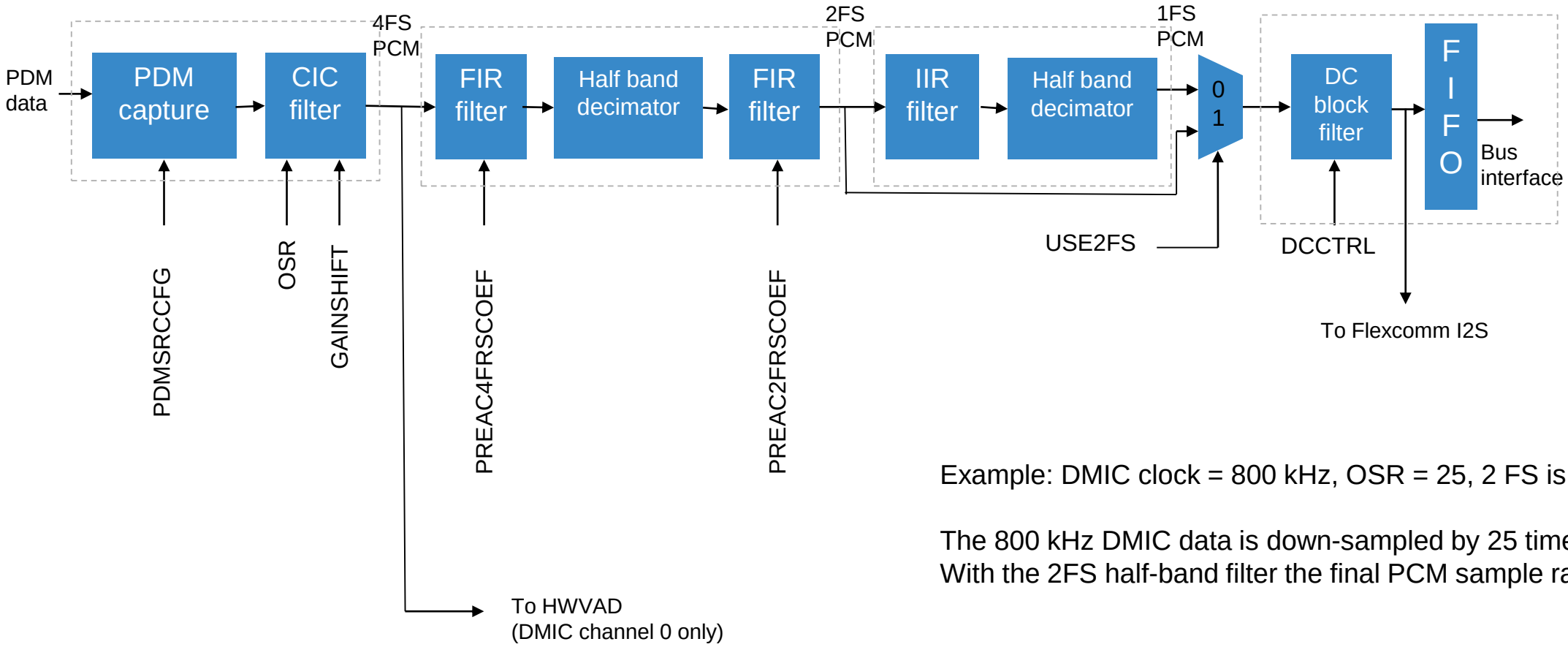
DMIC Subsystem

- PDM interface supports 2 single channel microphones or a single stereo microphone
- External codec supported by clock bypass



DMIC Subsystem

DMIC Channel Block Diagram

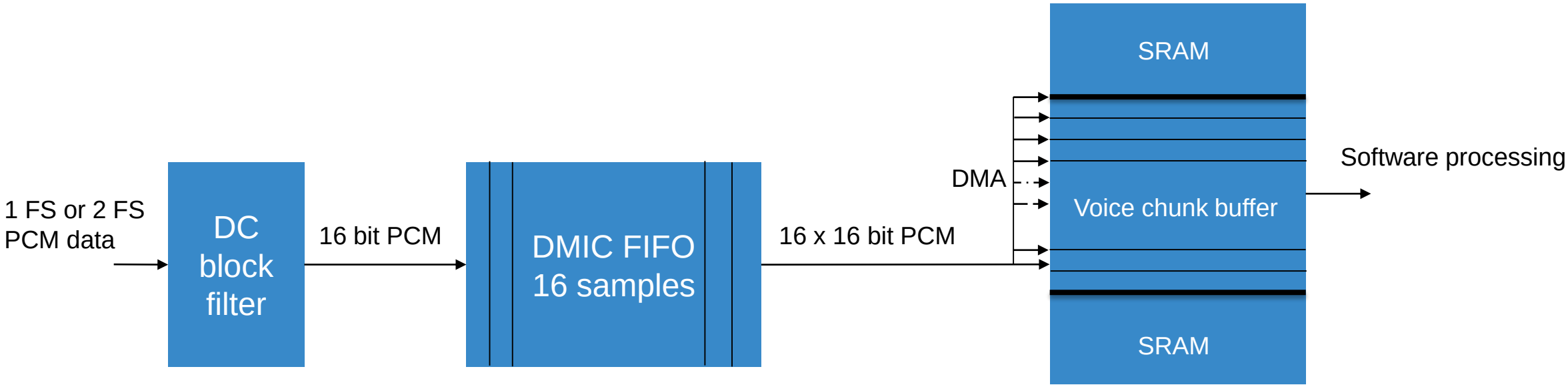


Example: DMIC clock = 800 kHz, OSR = 25, 2 FS is used:

The 800 kHz DMIC data is down-sampled by 25 times to 32 kHz.
With the 2FS half-band filter the final PCM sample rate is 16 kHz

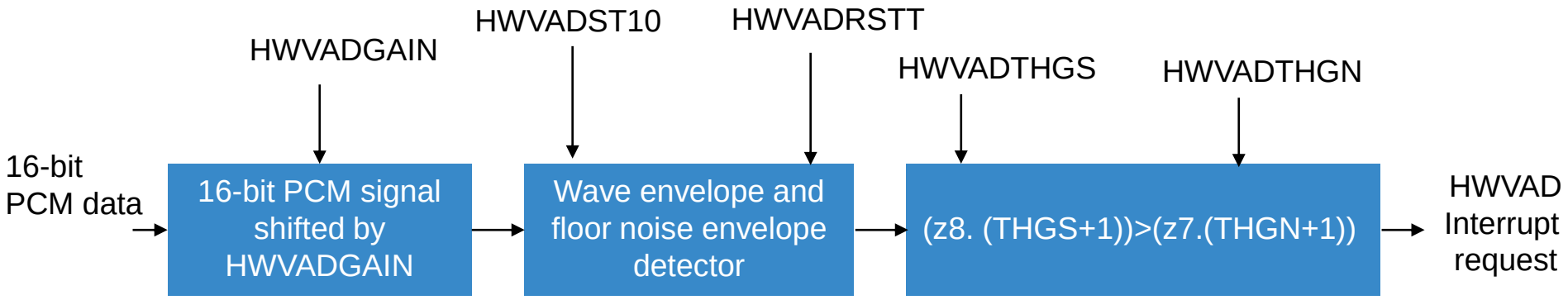
DMIC Subsystem

- 16 entry FIFO for each channel
- Data batching from FIFO into SRAM without intervention of ARM core
- DMA issues interrupt to ARM core for processing data



Hardware Voice Activity Detector (HWVAD)

- Implements Wave Envelope detector and a floor noise detector
- Analyzes PCM data from DMIC channel 0 by filter block
- Lowest Power operation compared to Software based voice detection
- Active during Deep-Sleep mode

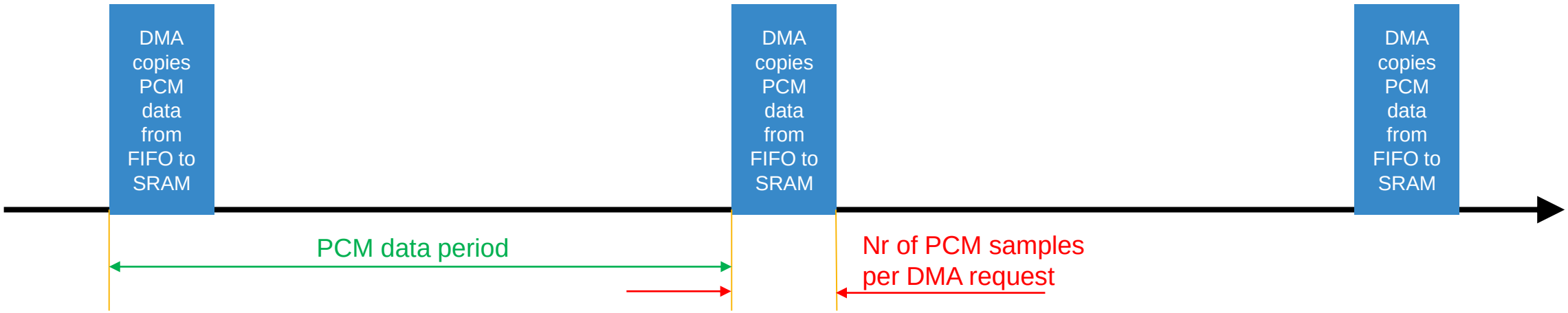


Summary: DMIC Subsystem

- LPC5411x contains a DMIC Subsystem that includes stereo Digital Microphone Interface (DMIC) and hardware voice activity detector(HWVAD)
- Full H/W decimation, PDM-PCM decimation, DC filtering, saturation
- Audio FIFO for batching audio data, 16 entries per each audio channel
- H/W VAD for audio envelope change detection, passive with no change to audio buffer
- Trigger audio batching while system clock is off
- Up to 192KB SRAM for audio buffers and general application support
- Fixed low power clock structure, no need for PLL to higher frequency

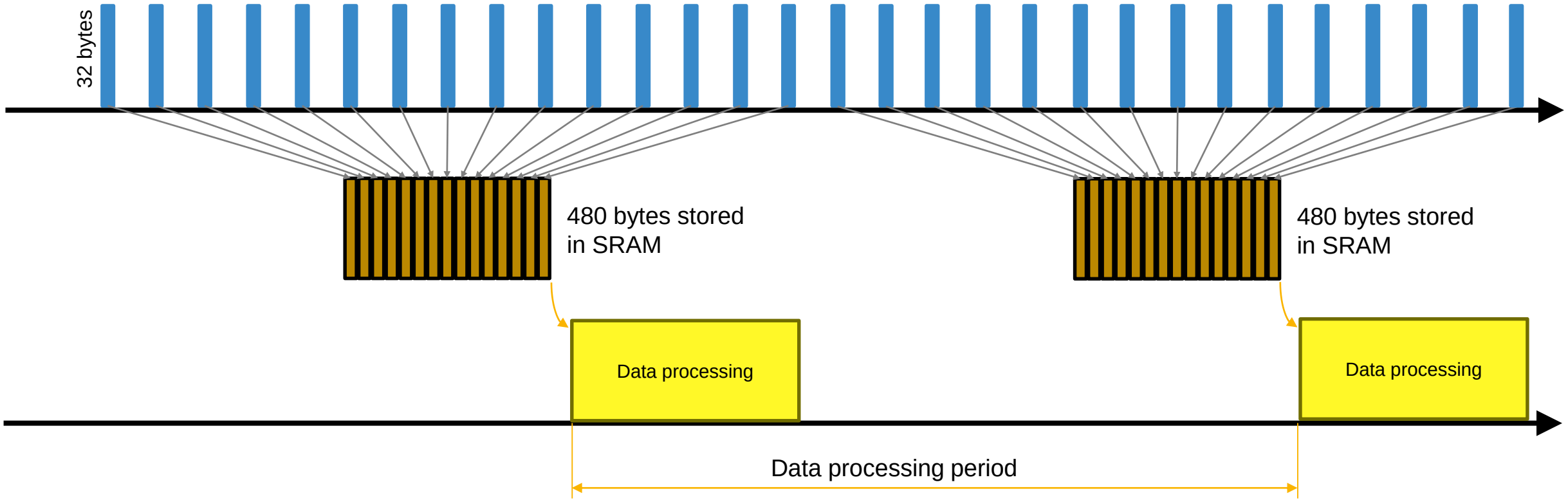
AUDIO HANDLING

DMIC Data Flow



- The PCM batching period depends on the DMIC sampling frequency, the chosen oversample rate and the size of the DMIC FIFO (the FIFO has 16 16-bit entries per channel)
- Example: 800kHz DMIC sampling, OSR = 25 plus one halfband filter results in DMA activity every 1ms (800kHz/50 = 16kHz, FIFO is full after 16 samples, 16 * 1/16kHz = 1ms)
- This DMA activity does not require the Cortex-M, the chip is in deep-sleep mode when receiving DMIC data

PCM Data Flow



- The data processing period depends on the amount of data the voice processing algorithm expects to get as a chunk.
- During speech detection or voice recognition this is a given period that determines the opportunity to be running in the Recognizer stage
- Example: 32 bytes per 1ms, 480 bytes per 15ms

Working With DMIC-HWVAD Projects

- Tasks for Workshop Attendees
- Hardware Setup
- Run the lpcopen “periph_i2s_dmic” example
- Modify the HWVAD noise/signal gain registers (#1)
- Modify the HWVAD noise/signal gain registers (#2)
- Analyze the noise floor output register

- Extra Credit: Merge some code from the “swim_oled” demo using the function of SW3 to write a text banner to the display.

Learn More About DMIC & HWVAD Subsystem

- Example
  - "periph_dmic" in LPCOpen example routes PCM data out the UART port (DMA streaming)

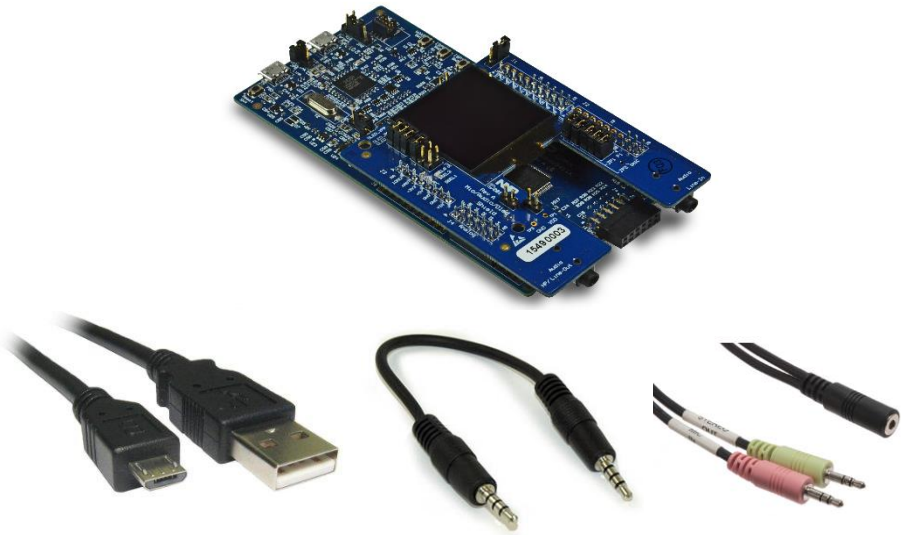
- Application Notes
  - Voice Trigger for Sensory and Malaspina

- User Manual
  - Chapter 25 "I2S interface"
  - Chapter 26 "DMIC Subsystem" (includes HWVAD)

LAB#2
LPC5411X CRYSTAL: LESS USB AUDIO

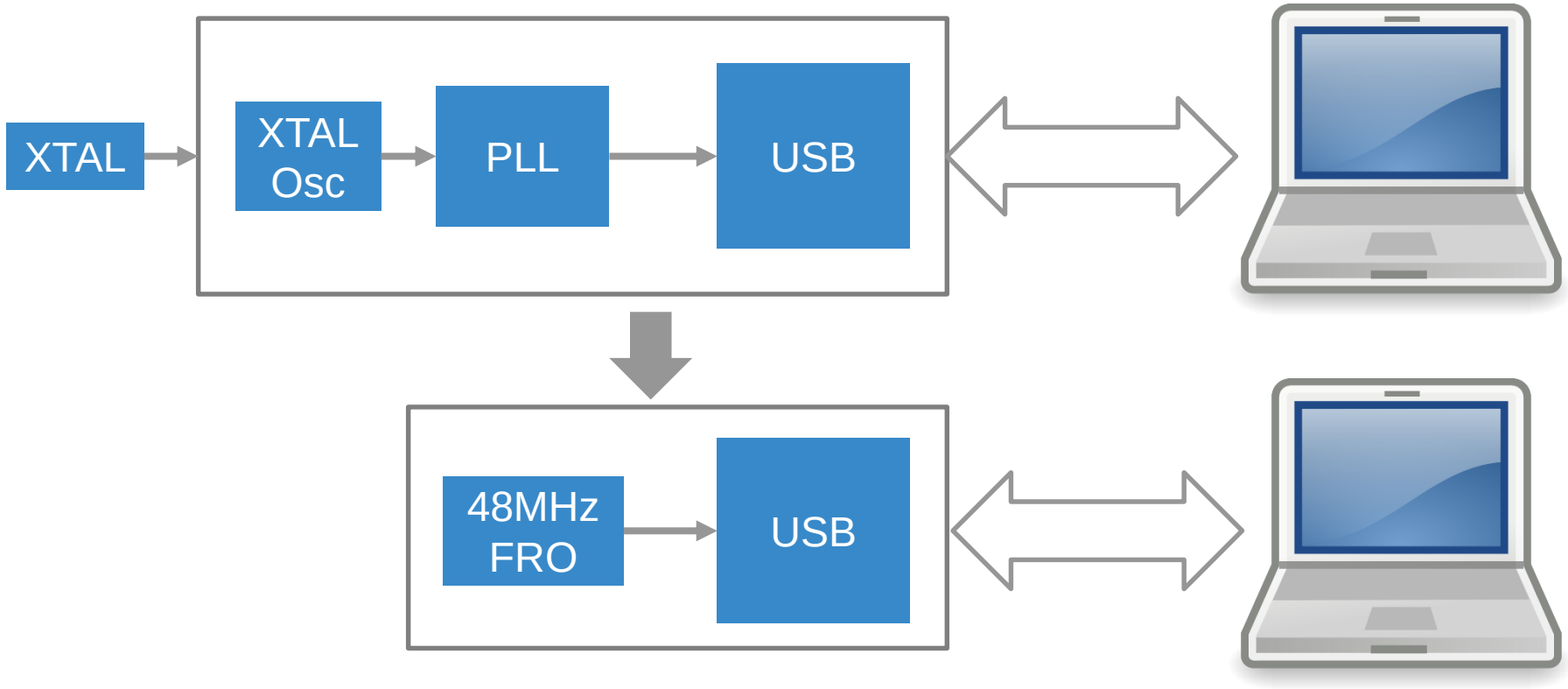
Crystal-less USB Audio Lab

- Goal
  - Learn more about LPC5411x crystal-less USB feature and how it can enable high-performance USB Audio applications
- Duration: 60 mins
- Hardware
  - LPC54114 Audio and Voice Recognition Kit (1)
  - Micro USB cable (1)
  - TRRS male audio cable (1)
  - TRRS audio breakout cable (1)
- Software
  - LPCXpresso IDE v8.1 or later
  - Audacity for recording and analyzing sounds



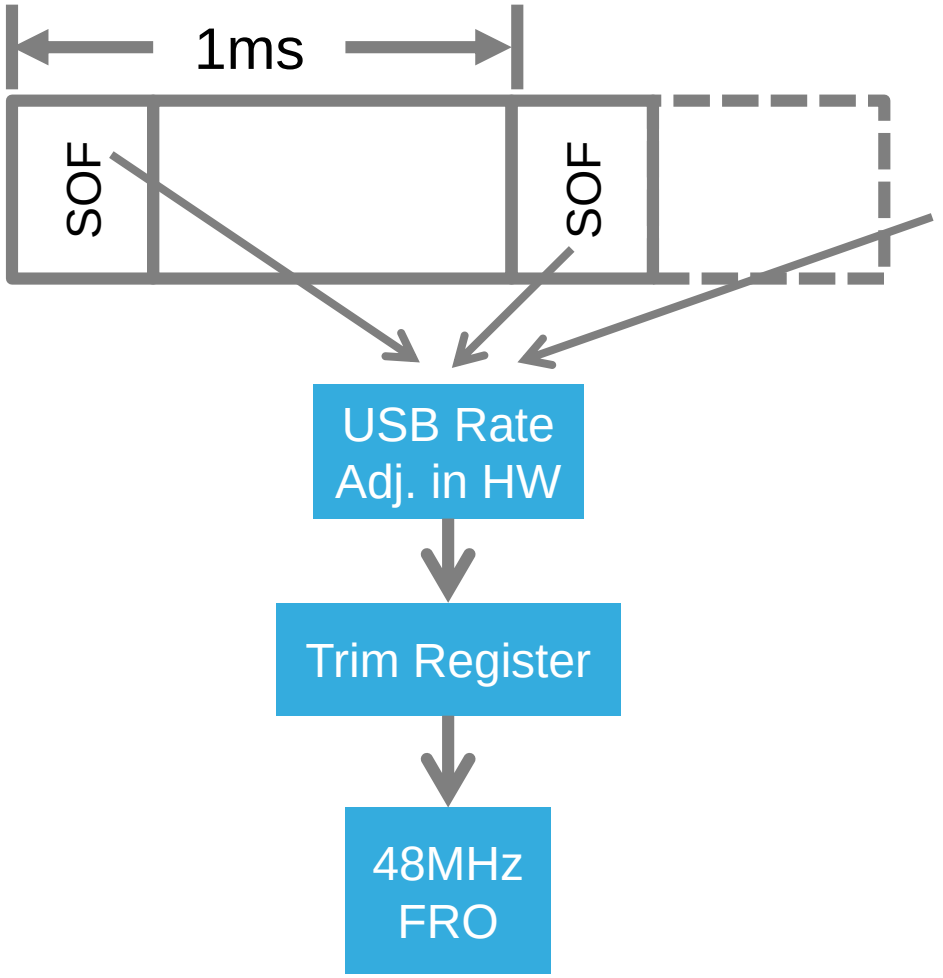
Crystal-less USB Device

Result: Lower Cost, Lower Power & Smaller Space



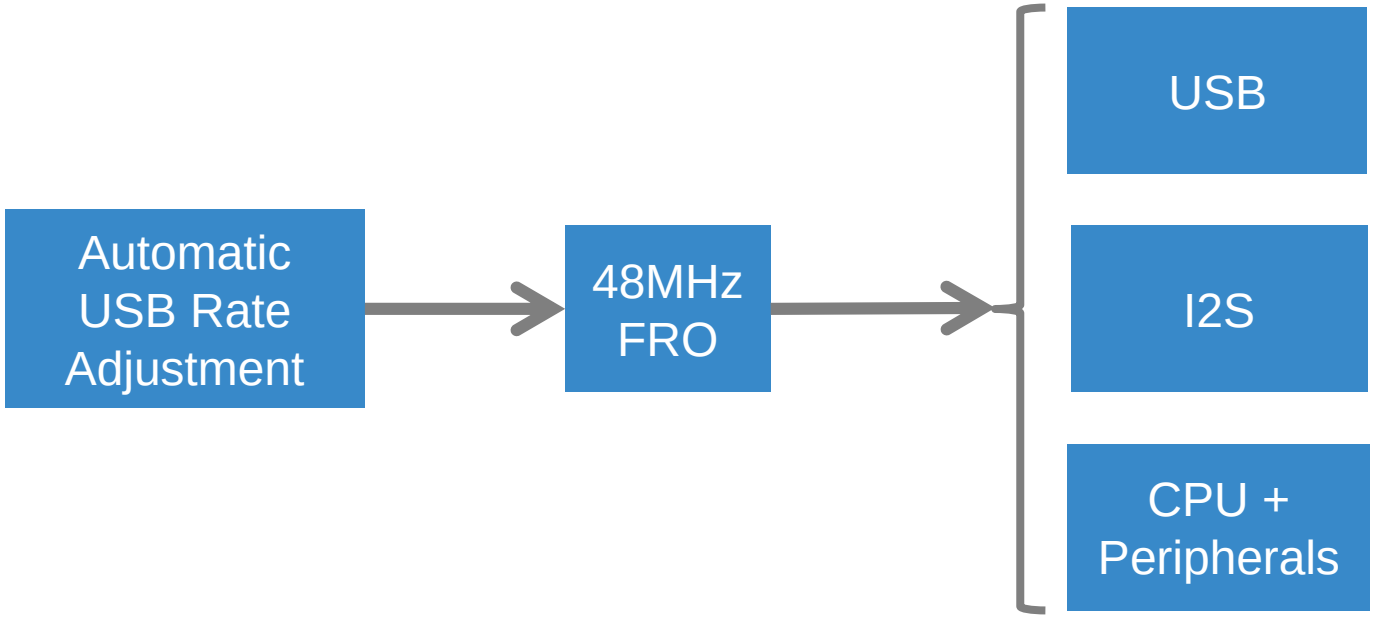
Generating +/- 0.25% Clock Without Crystal

- Automatic USB clock adjustment mode captures SOF event on USB bus
- HW counts several SOF events
- HW periodically generates new Trim values
- FRO periodically synchronizes to USB clock



Synchronizing I2S With USB

- Simplifies the audio buffer management



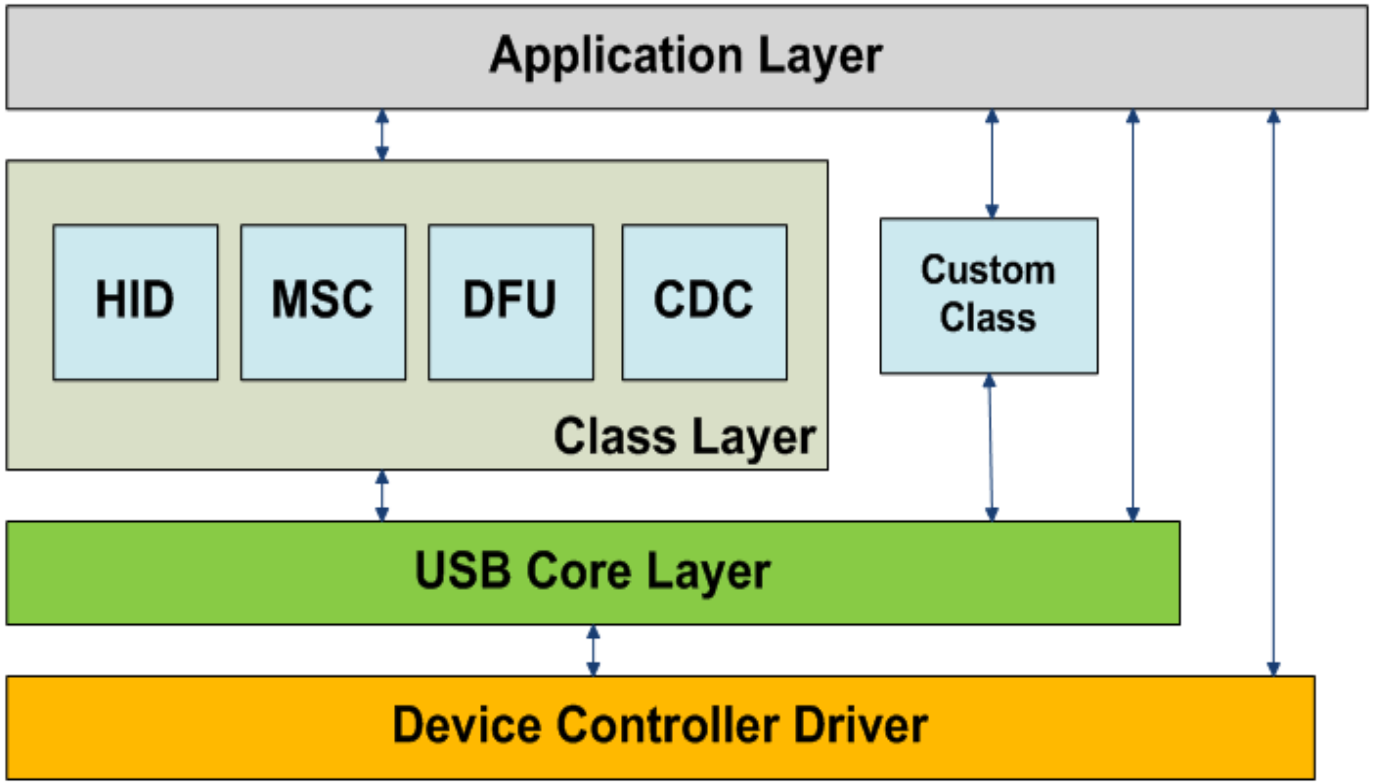
- I2S, USB and other peripherals automatically sync with USB when clocked by FRO

Free Running Oscillator (FRO)

- Low power internal Free-Running Oscillator (~100 uA, replaces former “IRC”)
- Provides two selectable outputs:
  - 48 MHz or 96 MHz (choose only one as the high frequency output)
  - 12 MHz output.
- Factory Trimmed for 48 MHz and 96 MHz
- +/- 1% accuracy over the full spec
- Some peripherals allow asynchronous operation from FRO while CPU operates from main clock
- FRO can be used as Main clock or PLL clock source
- Reduces dependency on System PLL
  - Benefit: fast restart after halting the CPU by sleep modes
  - Benefit: low power!
- Main Clock selects the 12 MHz FRO as the clock source on power-up or after reset

On-Chip USB (Device) ROM Drivers

- Low complexity means fast to market
- Reduces customer code complexity through built-in ROM drivers
  - HID, MSC, CDC, DFU
  - API driven approach
- Flash programming via MSC and built-in DFU driver
- Easy interface for adding new device classes (e.g. Audio)



Hardware Setup

USB

J7 to program
J5 to run

TRRS
M-M Cable

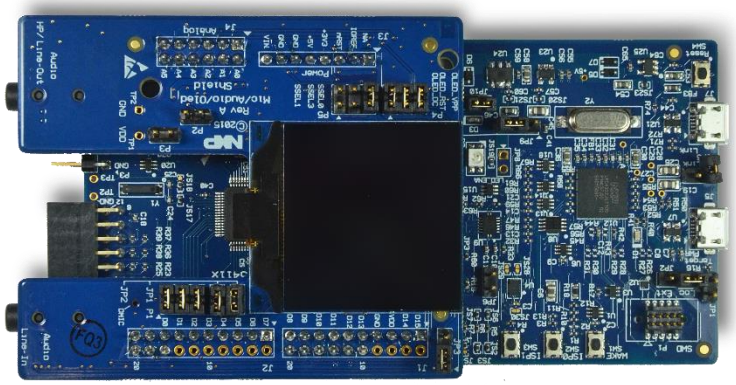
MIC-IN

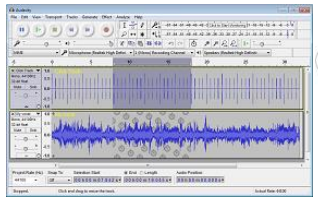
HP/Line-Out

STEREO-OUT

Line-In

LPC5411X Board with MAO Shield





Audacity or Mobile Apps
To play & record sounds

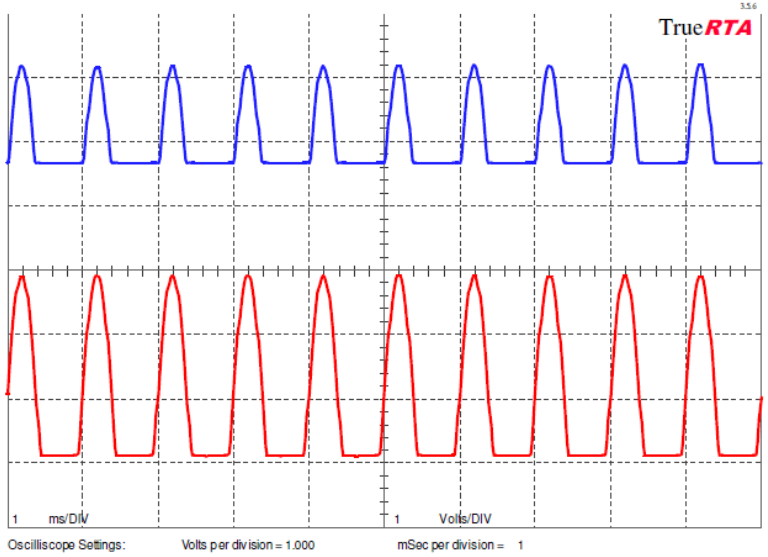
Crystal-less USB Audio – Objectives & High-level steps

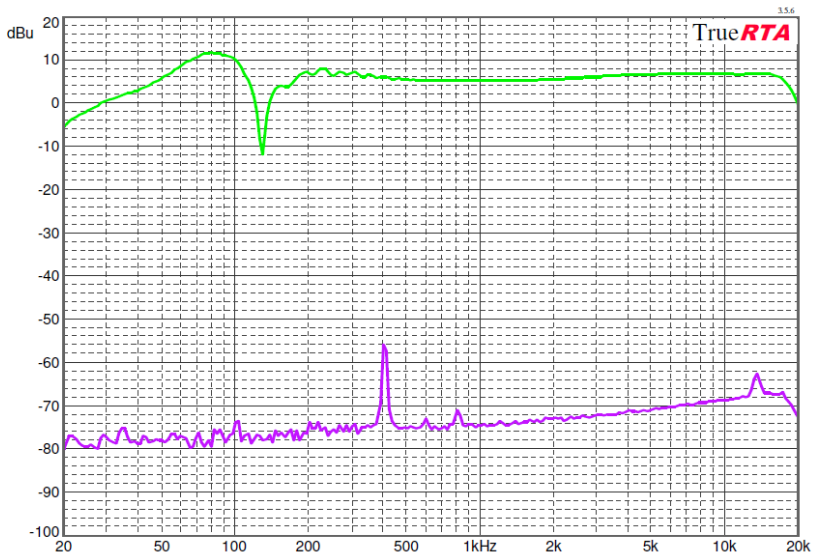
- Objectives
  - Learn how to run the crystal-less USB audio example
  - Learn how to demonstrate the playback and record performance of the LPC5411x

- High-level Steps
  - Build & download the “usbdrom_audio” project by connecting the USB to J7
  - Run the project by connecting the USB to J5
  - Verify the playback function by connecting headphone and TRRS breakout cable
  - Use Audacity/Smartphone to analyze the playback performance
  - Use Audacity/Smartphone to analyze the record performance

Few Notes About Audio Analysis

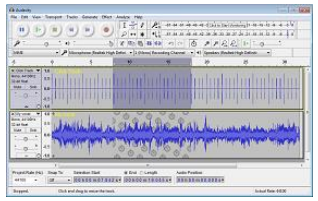
- Tone generator and recording devices are critical
  - Dell LATITUDE laptops are seen clipping sine wave tone & non-flat freq response





  - To eliminate generator/recording device issues, use iPhone/Mac (Android phones not tested)

Live Demonstration of Record Analysis Using iPhone



Recorder & Analyzer

Tone Generator

USB

J5 to run

TRRS
M-M Cable

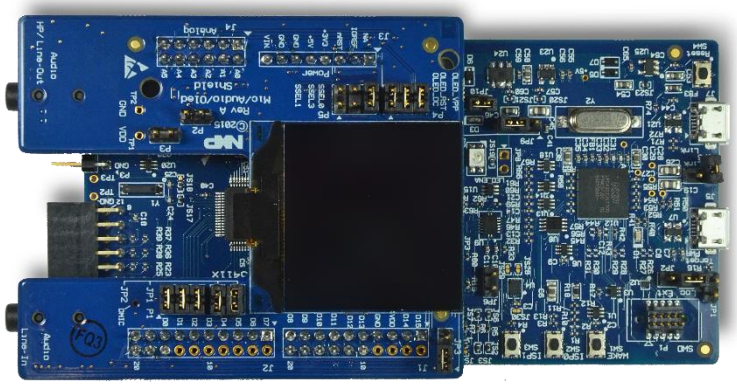
MIC-IN

HP/Line-Out

STEREO-OUT

Line-In

LPC5411X Board with MAO Shield



Crystal-less USB Audio Quiz

- LPC5411x always starts in 48MHz FRO mode. True or false?
- There is a PLL lock period when switching from 12MHz to 48 or 96MHz. True or False?
- HW-sync of USB with I2S eliminates the need for sample rate converter. True or False?
- The USB Audio example supports 96kHz sampling rate. True or False?

Learn More About Crystal-less USB and I2S

- Example
  - “usbdrom_audio” in LPCOpen for working example
- Application Notes
  - Solution kit: USB Audio Streaming
- User Manual
  - Chapter 4 “LPC5411x System configuration (SYSCON)”
  - Chapter 20 “LPC5411x USB 2.0 device controller”
  - Chapter 25 “LPC5411x I2S bus”

LAB #3
LPC5410X LOW POWER MODES

Power Modes Lab

- Goal
  - Learn about various power modes and their usage
- Duration: 60 mins
- Hardware:
  - LPCXpresso54114 board (1)
  - Micro USB cable (1)
  - Jumper shunt (1)
- Software
  - LPCXpresso IDE v8.1 or later

LPCXPRESSO

LPC5411x Low Power Modes

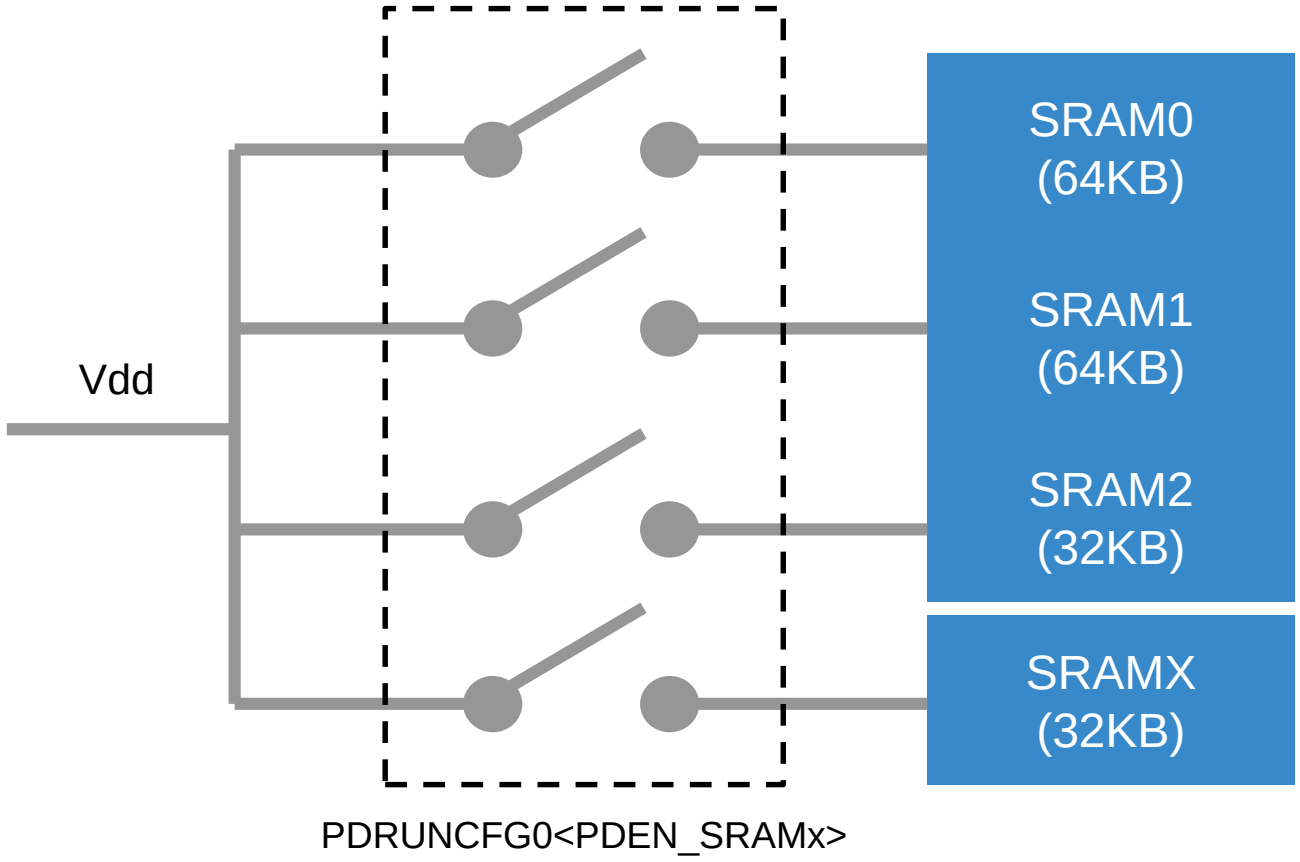
	CPU	SRAM	Peripherals	Flash	Oscillators	Wakeup Behavior
Run	Active	Configurable	Configurable	Active	Configurable	N/A
Sleep	Stopped(1)	Configurable	Configurable	Active	Configurable	Resume
Deep Sleep	Stopped(2)	Configurable	OFF	Standby	OFF	Resume
Deep Power Down	OFF(2)	OFF	OFF	OFF	OFF	Reset

Note 1: Only the core that executed Sleep is stopped, other is unaffected

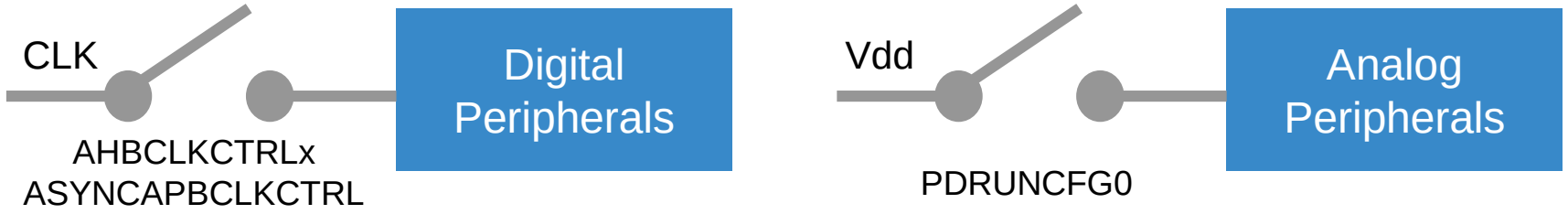
2 : Both cores are affected, regardless which core changed the mode

SRAM Power Control

Individual power down control for SRAM0, 1, 2 & X



Peripheral Power Control



	RTC	BOD, WDT, ADC	UART- , SPI-, I2C-slave	Others
Run	Configurable	Configurable	Configurable	Configurable
Sleep	Configurable	Configurable	Configurable	Configurable
Deep Sleep	Configurable	Configurable	Configurable	OFF
Deep Power Down	Configurable	OFF	OFF	OFF

I/O Pin Power Control

I/O pin states are retained in all modes except Deep Power Down

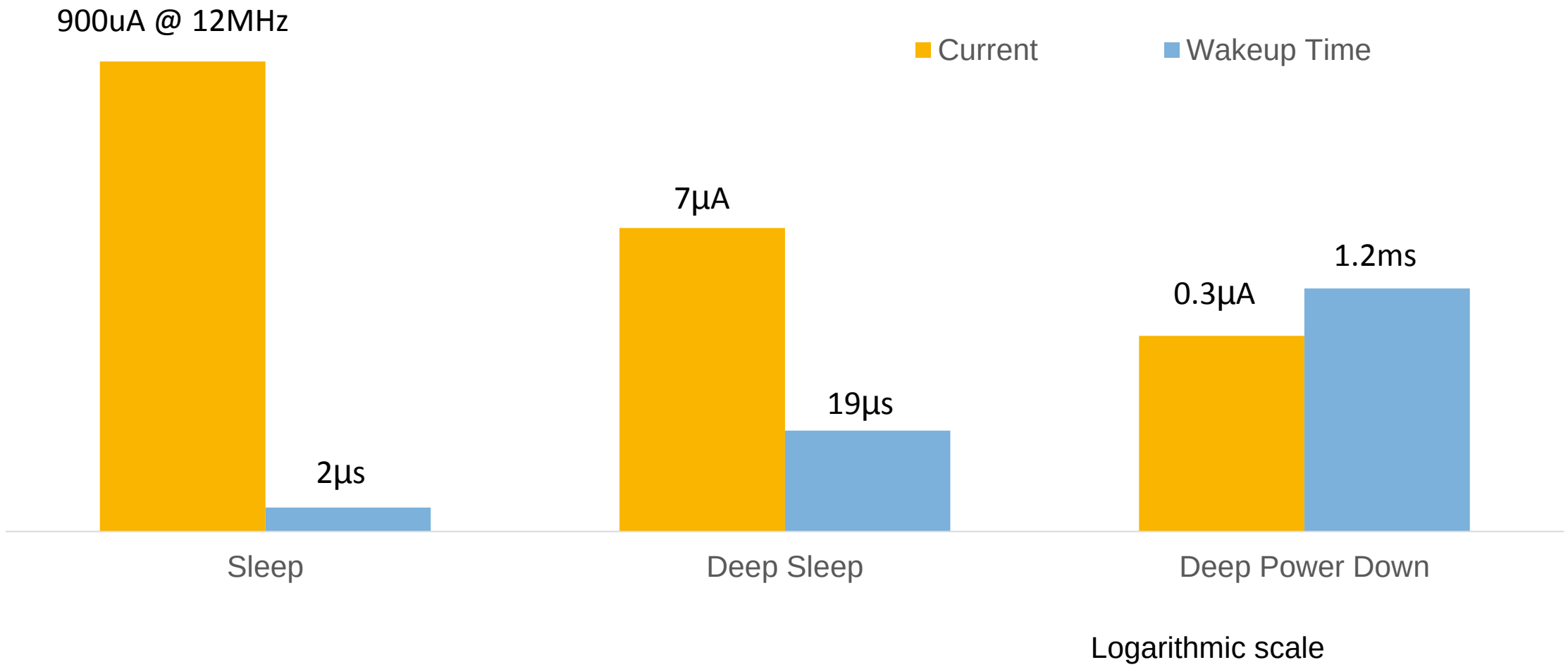
	Pin States
Run	Retained
Sleep	Retained
Deep Sleep	Retained
Deep Power Down	Tri-stated

Wakeup Triggers and Behaviors

	RTC	BOD, WDT, ADC	UART- , SPI-, I2C- slaves, DMIC, USB	Ext INT	Others
Run	Configurable	Configurable	Configurable	Configurable	Configurable
Sleep	Configurable	Configurable	Configurable	Configurable	Configurable
Deep Sleep	Configurable	Configurable	Configurable	Configurable	No
Deep Power Down	Configurable	No	No	No	No

	Wakeup Behavior
Sleep	Resume
Deep Sleep	Resume
Deep Power Down	RESET

LPC5411x Low Power Mode Consumptions



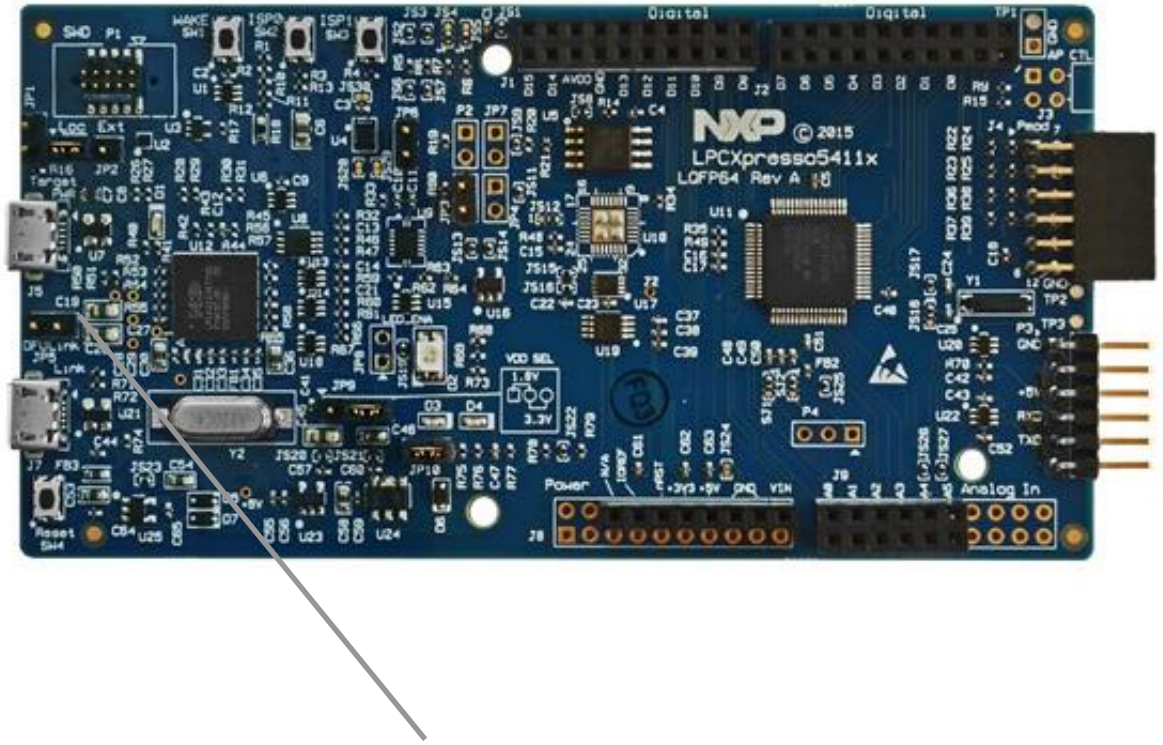
Power Consumption Reduction Tips

- Switch the main clock to the FRO and turn off the PLL before entering any low power mode
- Shut down IOCON clock when IO configuration is done
- Reduce leakage current from unused pins by enabling pull-down resistors or set the pins to output mode low
- Debug sessions do not stay active in any low power mode but Sleep mode

Hardware Setup

J7 USB

To Debug &
View UART output

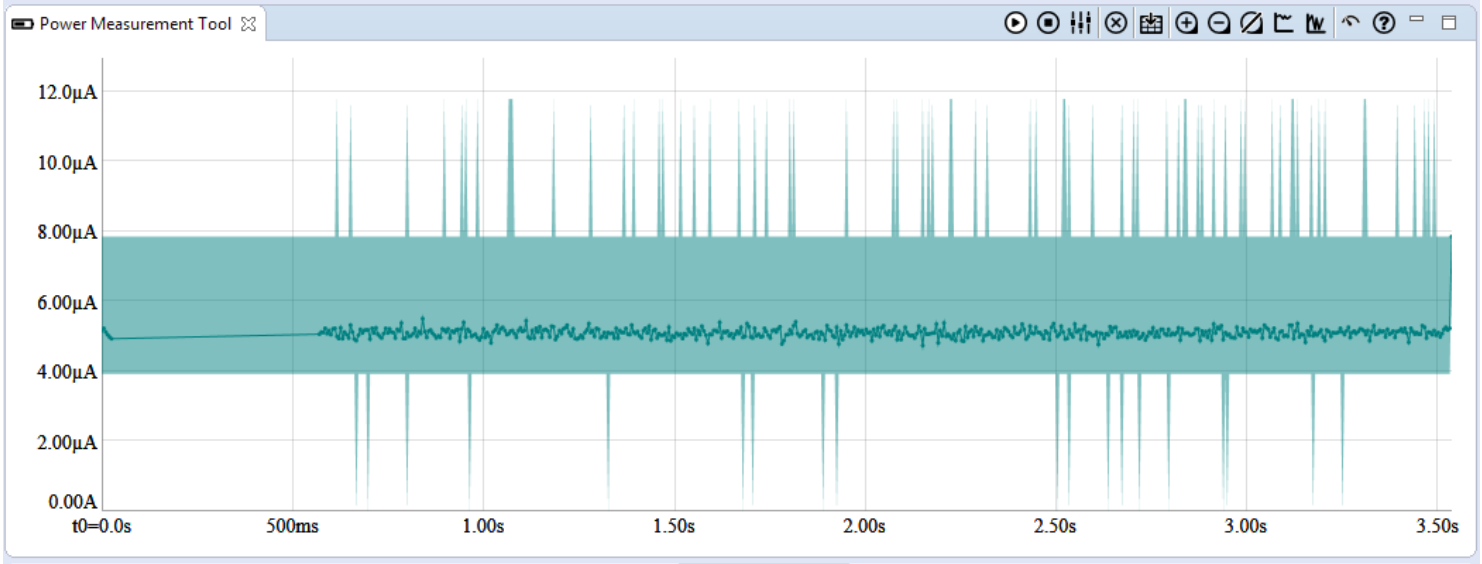


Power Measurement Tool

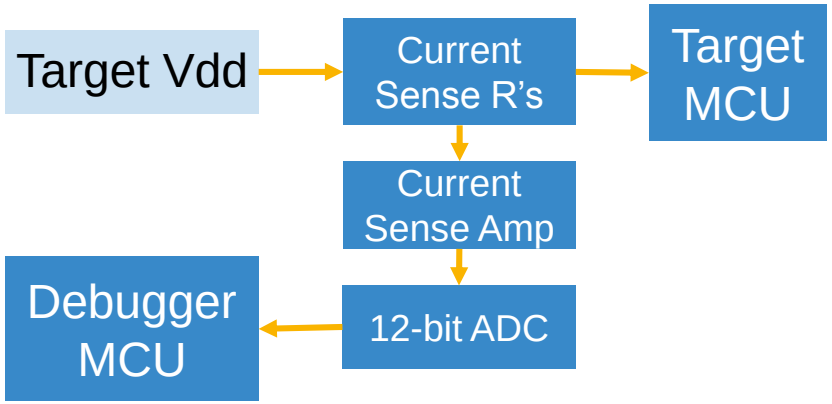
Shunt JP5 to force USB boot of on-board Link2 probe

Power Measurement Tool

- Built into LPCXpresso IDE
  - Uses USB debug connection
  - Displays Target or Shield consumption
  - Sample rate up to 200ksps
  - Programmable sample period
  - Auto and manual scale options
  - Export data to CSV
  - Available in 7.7.2 or later



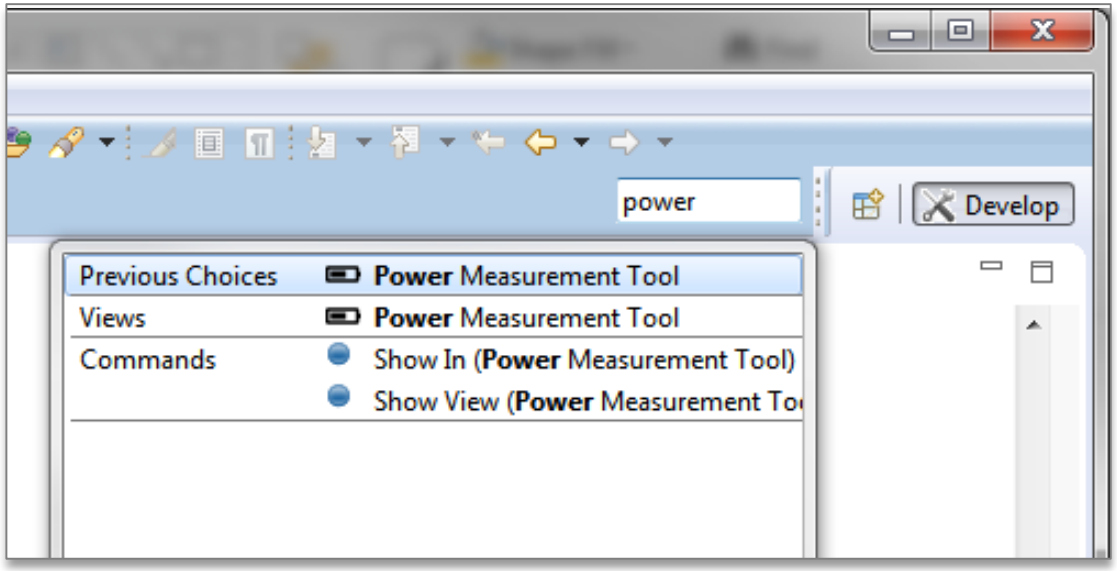
- Uses measurement HW on select LPCXpresso boards
  - 3.88uA/7.77uA to 16mA
  - 50k to 200ksps
  - Target Vdd = 3.3V or 1.8V



Using the Power Measurement Tool – I

- Close the DFULink jumper to download Power Measurement FW
- Connect the board via Link USB
- Open Power Measurement view by typing

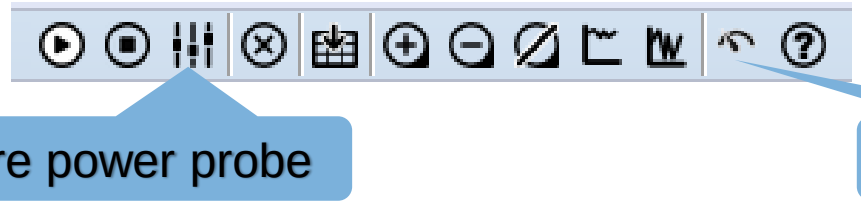
  “power” in Quick Access search box

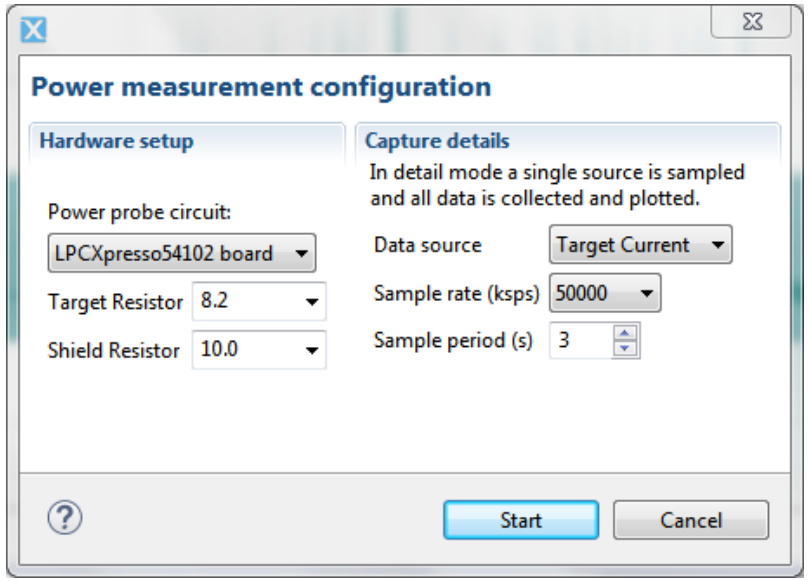


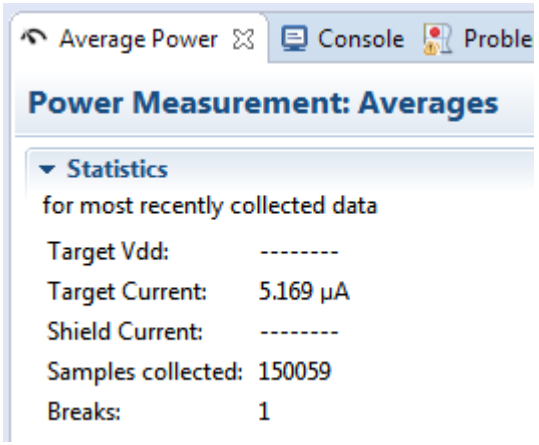
- Press Boot Debug Probe button to download the FW

Using the Power Measurement Tool – II

- Configure the power probe to sample at 50ksps
- Show View (Average Power) to view statistics







Power Modes – Objectives & High-level Steps

- Objectives
  - Exercise various power modes and observe their impact on current consumption
  - Analyze schematic and pin configuration to reduce current by more than 1uA in Deep Sleep mode
  - Bonus: Lower the startup clock frequency to reduce Sleep current consumption
- High-level Steps
  - Build & run the “periph_pmu” project
  - Use a serial terminal program of your choice to manipulate the power modes
  - Measure current during all Power modes
  - Find & change the configuration of one specific pin to reduce current by more than 1uA
  - Find the logic that configures the clock and change it to use 12MHz
- References
  - LPC5411x hands-on lab manual, Section 3 “Power Modes Lab”
  - LPCX5411x Rev A1 Schematic
  - LPC5411x UM Ch 7 “I/O pin configuration”
  - “src\pmu.c” source file

Power Mode Quiz

- A customer wants to achieve lowest possible power with LPC5411x. What are the key items you would want to know before providing your suggestion?

- A customer reports that his Deep Sleep mode current consumption goes up after few seconds/minutes. What might be causing it?

- A customer reports that the relays/switches on some I/O pins are switching erratically when he puts LPC5411x into a low power mode. What could be the issue?

Learn More About Power Modes

- Example
  - “periph_pmu” in LPCOpen for working example

- Application Notes
  - Power Modes and wakeup time
  - CoreMark Measurement

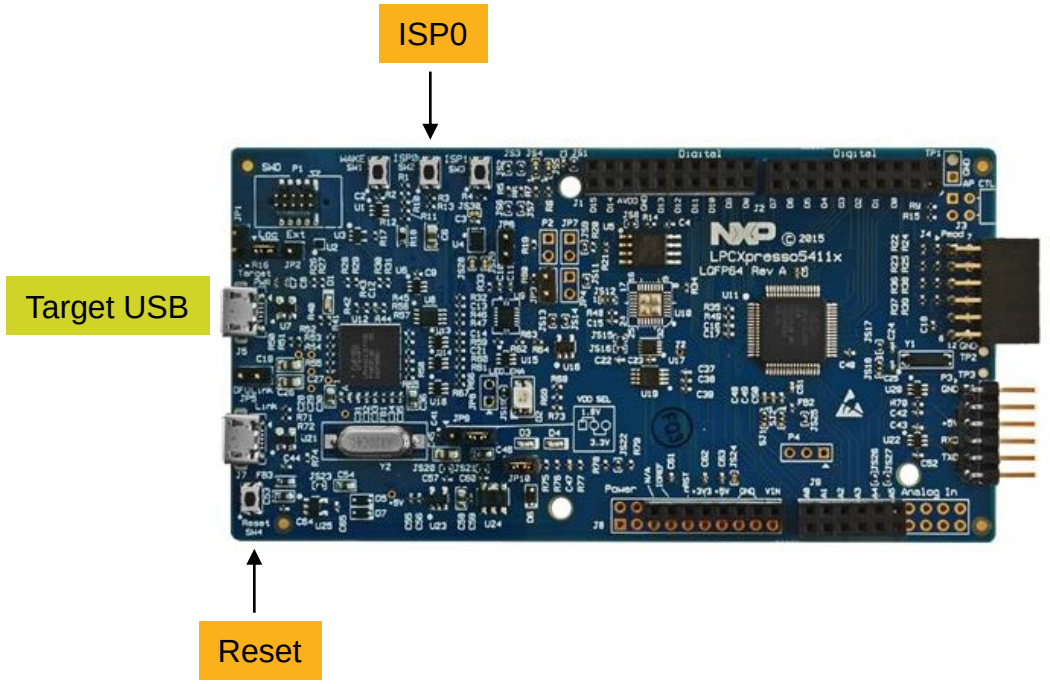
- User Manual
  - Chapter 4 “LPC5411x System configuration (SYSCON)” for clock management
  - Chapter 5 “LPC5411x Power management” for Power modes
  - Chapter 7 “LPC5411x I/O pin configuration (IOCON)” for I/O pin configuration
  - Chapter 31 “LPC5411x Power profiles/Power control API for ROM APIs

LAB #4
DEMONSTRATION

LPCXpresso54114 Development Board

Download firmware in USB MSC boot mode

- LPC5411x can be started in USB mass storage mode
- Firmware can be programmed Drag & Drop from a PC
- Enter USB mass storage mode:
  1) Connect a PC on the Target USB port
  2) Press and hold ISP0 button
  3) Make a reset with the Reset button
- You should see a MSC* device in your file manager,
  called CRP_DISABLD, with a size of 260kbyte.
- Delete any existing firmware.bin file on this drive
- Drag & drop any new firmware file to the drive.
  The file must have the name firmware.bin.



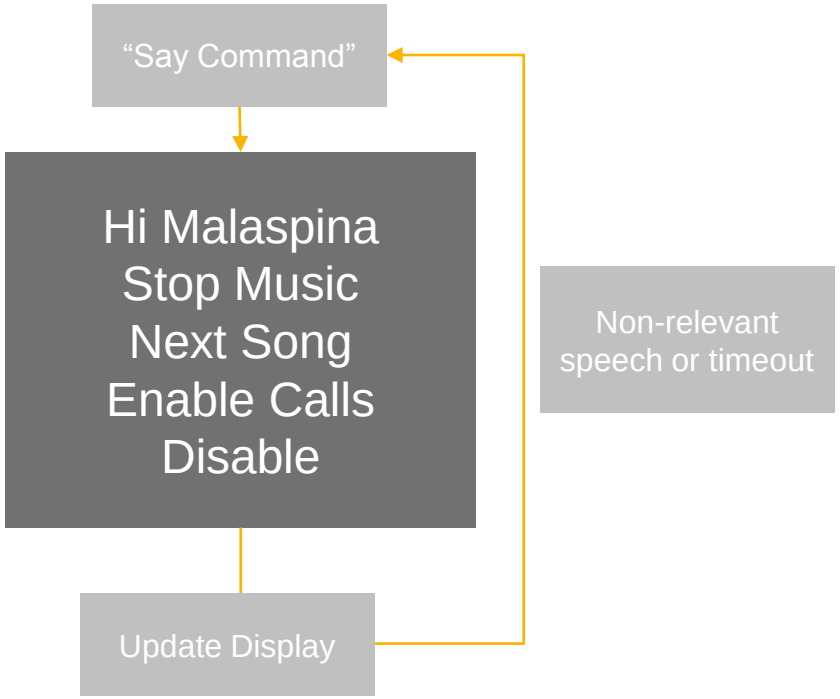
Voice Recognition Demos

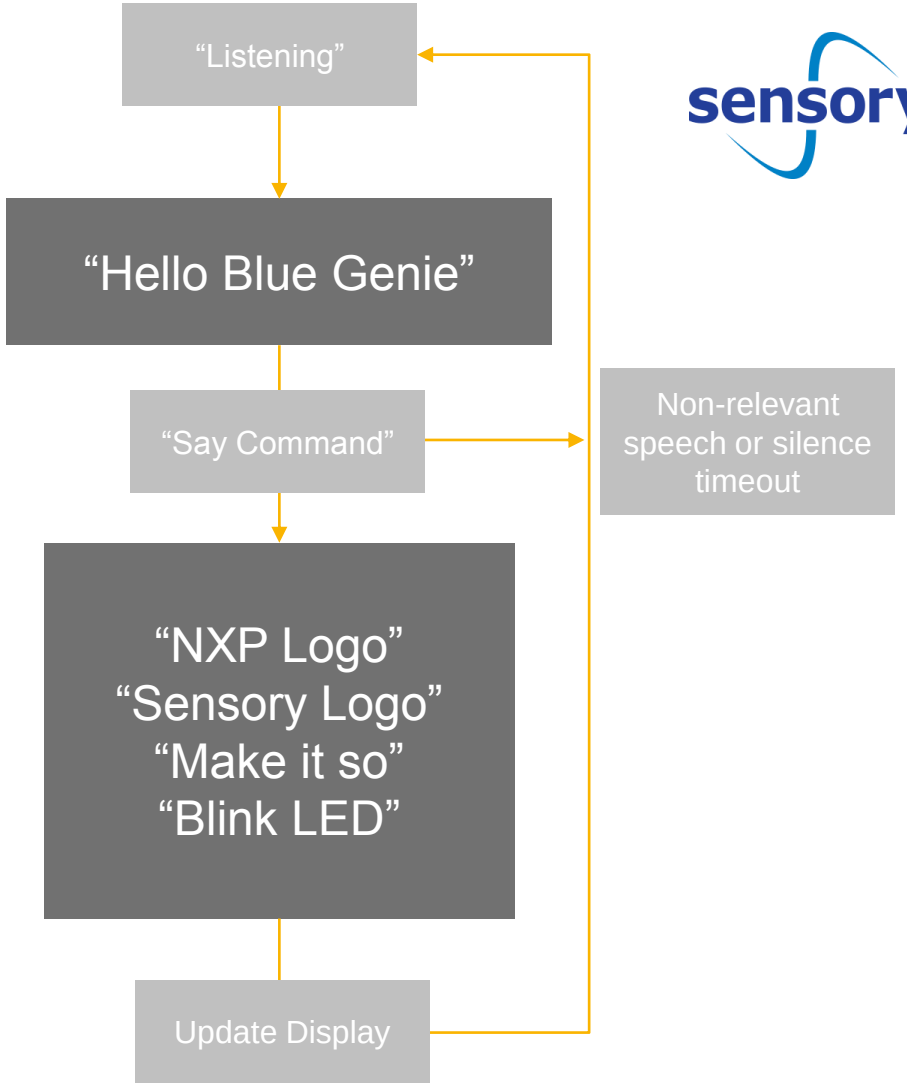
- Today: two key voice recognition partners: Sensory and Malaspina Labs
  - Both partners are providing demo applications

- These demos will be provided both as a binary and a build-able project
  - The binaries will be downloadable from the web, with drag n drop programming
  - Click-through evaluation license agreements with libraries to protected 3rd party IP
  - What happens after the recognition, is programmable by the user
    - UART message? I/O toggle? Etc…

- Sensory “Phrase Spotting” and Malaspina “SIVA”
  - Guidance and feedback are provided on the OLED display

Demo Flow


“Say Command”
Hi Malaspina
Stop Music
Next Song
Enable Calls
Disable
Update Display
Non-relevant
speech or timeout

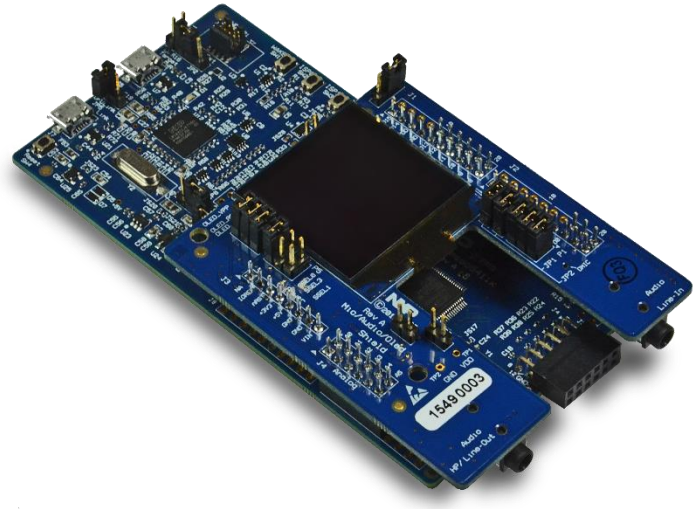

“Listening”
“Hello Blue Genie”
“Say Command”
“NXP Logo”
“Sensory Logo”
“Make it so”
“Blink LED”
Update Display
Non-relevant
speech or silence
timeout

Tips for a Successful Demonstration

- Recommendations for a successful demo
- Memorize the trigger and command vocabulary
- Train your speech pattern to trigger accurately
- Run the board from a rechargeable battery to make it portable
- Use natural speech flow without pausing between phrases
- Do not use rapid fire triggers and commands
- Add your customer’s company name to the LCD display

Example: Low Current Measurement with Voice Triggering

- Setup, using LPC54114 LPCXpresso board
- Short JP9 1-2 on LPC5411x CPU board to supply 1.8V to the MCU
- Remove all three P4 jumpers on OLED board to disconnect OLED signals
- Place current probe across JP4
- Power the board by connecting any USB cable to power source



- Steps
- Speak the trigger phrase: “Hello blue genie”
  - D2 LED will blink BLUE once to confirm that trigger command is detected
- Speak one of the following messages and observe D2 blink pattern change
  - “NXP logo”
  - “Sensory logo”
  - “Make it so”
  - “Blink LED”
  - “Flash display”

- Power consumption of the MCU Vdd only
  - Silent, waiting for command = ~200uA
  - During random speaking = ~4.7mA peak (some tuning can be done in software)

SUMMARY

LPC5411x Selling Points

- Run complex algorithms & save power with ultra low, scalable active current consumption
- Increase throughput and run complex algorithms using large RAM
- Save cost and board space using crystal-less USB
- Future-proof serial interface needs using FlexComm Interface
- Save power and increase throughput with up to 3.4Mbps in I2C slave interface to Application Processor
- Extend battery life using HW Voice Trigger in always listening applications

SECURE CONNECTIONS
FOR A SMARTER WORLD

ATTRIBUTION STATEMENT